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Manual Collection

SIMATIC

ET 200AL

ET 200AL distributed I/O system

This document contains a compilation of all manuals for the ET 200AL system family. Use the bookmarks on the left edge of the screen to navigate.

Edition

12/2019

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System manual

SIMATIC

ET 200AL

ET 200AL distributed I/O system

Edition

08/2019

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SIMATIC

ET 200AL Distributed I/O system

System Manual

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 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
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indicates that property damage can result if proper precautions are not taken.


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Preface

Purpose of the documentation

This documentation provides you with important information on how to configure, install, wire and commission the SIMATIC ET 200AL distributed I/O system.

Changes compared to previous version

This manual contains additions about the extension of the temperature range to -30 °C compared to the previous version:

Basic knowledge required

A basic knowledge of automation technology is required to understand the documentation.

Validity of the documentation

This documentation is valid for SIMATIC ET 200AL distributed I/O system.

Conventions

Please observe notes labeled as follows:

Note

A note contains important information on the product described in the documentation and on the handling of the product to which particular attention should be paid.

Recycling and disposal

For ecologically sustainable recycling and disposal of your old device, contact a certificated disposal service for electronic scrap and dispose of the device in accordance with the regulations in your country.

Additional support

- Information about Technical Support is available in section Siemens Industry Online Support (Page 5).
- The range of technical documentation for the individual SIMATIC products and systems can be found on the Internet (<http://www.siemens.com/simatic-tech-doku-portal>).
- Information about the online catalog and online order system is available in section Industry Mall (Page 5).

See also

Safety-related symbols for IP65/IP67 modules (Page 91)

Technical specifications (Page 81)

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- **Product support**

All the information and extensive know-how on your product, technical specifications, FAQs, certificates, downloads, and manuals.

- **Application examples**

Tools and examples to solve your automation tasks – as well as function blocks, performance information and videos.

- **Services**

Information about Industry Services, Field Services, Technical Support, spare parts and training offers.

- **Forums**

For answers and solutions concerning automation technology.

- **mySupport**

Your personal working area in Industry Online Support for messages, support queries, and configurable documents.

This information is provided by the Siemens Industry Online Support in the Internet (<http://www.siemens.com/automation/service&support>).

Industry Mall

The Industry Mall is the catalog and order system of Siemens AG for automation and drive solutions on the basis of Totally Integrated Automation (TIA) and Totally Integrated Power (TIP).

Catalogs for all the products in automation and drives are available on the Internet (<https://mall.industry.siemens.com>).

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System overview

1.1 What is the SIMATIC ET 200AL distributed I/O system?

SIMATIC ET 200AL

The SIMATIC ET 200AL distributed I/O system is a scalable and highly flexible, distributed I/O system for connecting process signals to a higher-level control system with a field bus.

Customer benefits of the system

Easy to use

- Easy wiring thanks to color-coded connectors
- CAx compliant labeling of all interfaces
- Fast, convenient configuration and commissioning with STEP 7 (TIA Portal)
- Configuration customizing for future extension through integrated configuration control

Energy efficiency

- PROFinergy as integrated function

Compact design

- High IO configuration limits for module widths of 30 mm or 45 mm and up to 32 modules for each ET 200AL
- High degree of protection IP65/IP67
- Adequate for temperatures from -30 °C/-25 °C to +55 °C and accelerations up to 10g

Flexible mounting

- Easy mounting in all mounting positions - even in small spaces
- Spatially separated mounting of the modules by means of a backplane bus designed as a cable (= ET connection)
- Flexible connection to PROFINET, PROFIBUS or integration in SIMATIC ET 200SP
- Integration of sensors and actuators through M8 and M12 connection technology



Communication standards

- PROFINET IO
- PROFIBUS DP
- IO-Link

Powerful technology

- Module with counting function

Figure 1-1 ET 200AL benefits

Area of application

The SIMATIC ET 200AL distributed I/O system is especially well suited for use in tight spaces, moving applications and for assembly and handling technology. Thanks to its scalable construction, you have the option to precisely customize its configuration to your on site needs.

The SIMATIC ET 200AL distributed I/O system features degree of protection IP65/IP67 and is suited to distributed use on a machine or assembly line.

Setup

The SIMATIC ET 200AL distributed I/O system is made up of the following components:

- Interface modules (PROFINET/PROFIBUS)
- Digital and analog I/O modules
- Communication module

After an interface module you can configure 2 lines (ET-Connection), each with 16 modules.

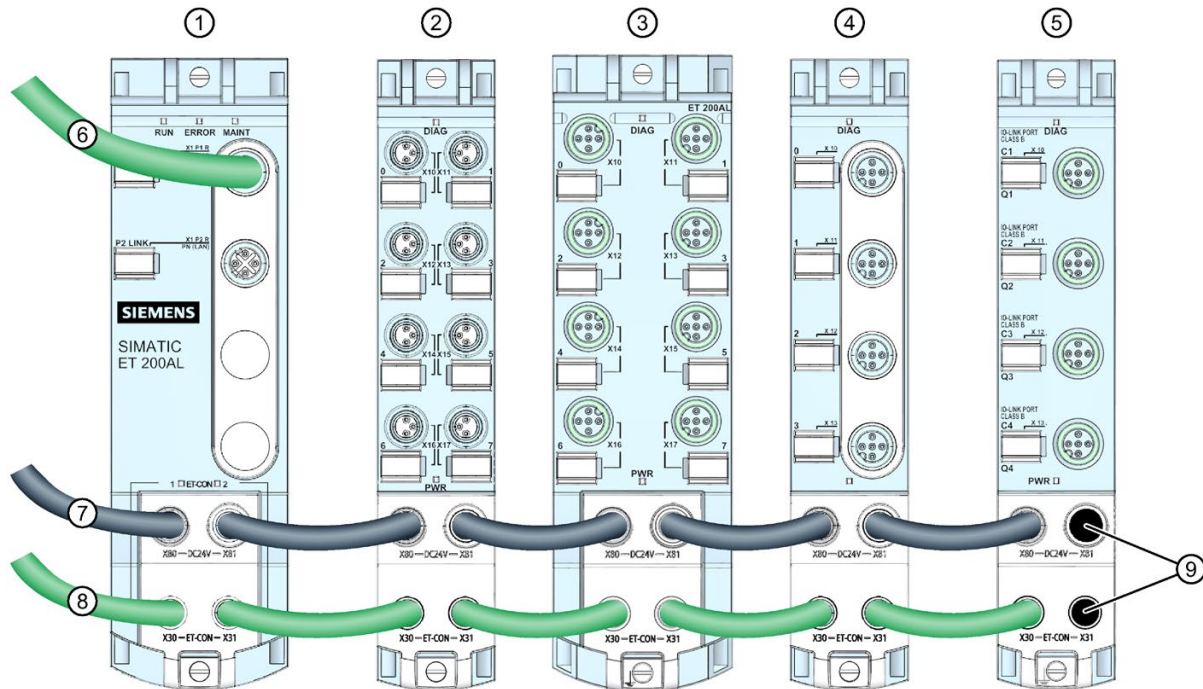
Alternatively, you can configure a line with 16 I/O modules on the SIMATIC ET 200SP distributed I/O system with BaseUnit BU-Send and the BusAdapter BA-Send 1xFC.

The ET-Connection backplane bus is designed as a cable. This allows you to create spatial distances of up to 15 m between the modules.

1.1 What is the SIMATIC ET 200AL distributed I/O system?

Configuration example

The figure below shows a configuration example of the SIMATIC ET 200AL distributed I/O system with a PROFINET interface module.



- ① Interface module (PROFINET)
- ② Digital input/Digital output module
- ③ Digital output module
- ④ Analog input module
- ⑤ Communication module
- ⑥ PROFINET cable
- ⑦ Power supply cable
- ⑧ ET-Connection cable
- ⑨ Sealing caps



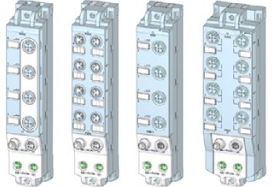




Figure 1-2 Configuration example of the ET 200AL

1.2 Components

Components of the ET 200AL distributed I/O system

The following table shows and explains the function of the most important components of the ET 200AL distributed I/O system.

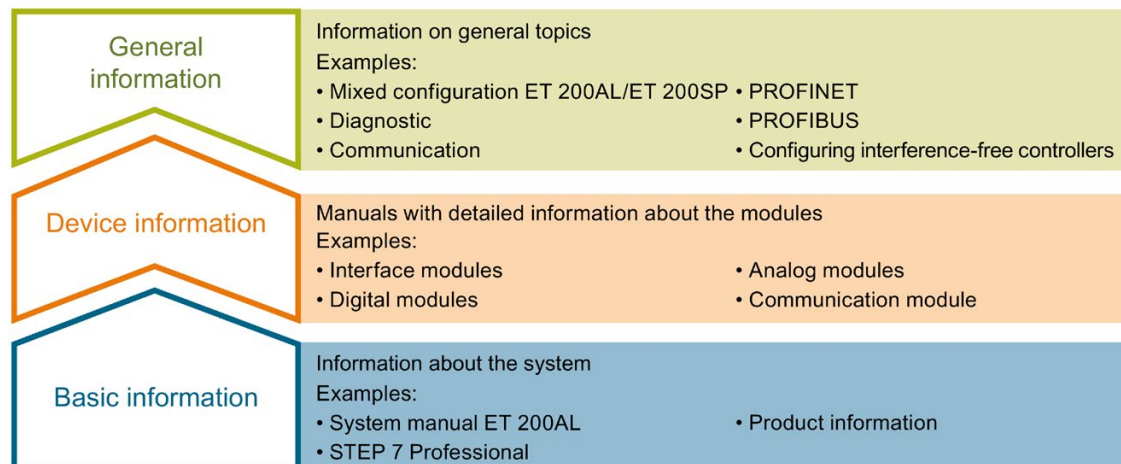
Table 1- 1 Components of the ET 200AL distributed I/O system

Components	Function	View
Interface module for PROFINET IO	<ul style="list-style-type: none"> The interface module connects the ET 200AL distributed I/O system with the IO controller Exchanges data with the I/O modules via ET-Connection 	
Interface module for PROFIBUS DP	<ul style="list-style-type: none"> The interface module connects the ET 200AL distributed I/O system with the DP master Exchanges data with the I/O modules via ET-Connection 	
I/O modules	<ul style="list-style-type: none"> The I/O modules form the interface to the process Recording and controlling the current process status via the connected sensors and actuators 	
Identification labels	<ul style="list-style-type: none"> The identification labels come with the module and can be machine printed Can be ordered separately 	
Bus cable and M8 connector for ET-Connection	<ul style="list-style-type: none"> The bus cable creates the bus connection between the modules 	
Power cable and M8 connector for power supply	<ul style="list-style-type: none"> The power cable provides power to the modules 	
Stripping tool ET-Connection	<ul style="list-style-type: none"> The stripping tool is used to strip the ET-Connection bus cable 	

Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742667>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<https://support.automation.siemens.com/WW/view/en/95242965>).

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You must register once to use the full functionality of "mySupport".

You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

Application planning

3.1 Hardware configuration

Mechanical maximum configuration

The following tables show the rules of the mechanical configuration. As soon as one of the following rules applies, the maximum configuration has been reached.

Table 3- 1 Maximum mechanical configuration - on ET 200AL interface module

Properties	Rule (max.)	
	Interface modules as of firmware version V1.0.0	Interface modules as of firmware version V1.0.1
Number of ET 200AL I/O modules in the configuration	32	
Number of ET-Connection outlets	2	
Number of I/O modules per ET-Connection outlet	16	
Spatial extension per ET-Connection line	160 m	240 m
Cable length between the modules	10 m	15 m

Table 3- 2 Maximum mechanical configuration - on ET 200SP with interface module

Properties	Rule (max.)	
	Interface modules as of firmware version V3.0.0	Interface modules as of firmware version V3.3.0
Number of ET 200AL I/O modules in the configuration	16	
Number of ET-Connection outlets	1	
Spatial extension ET-Connection line	160 m	240 m
Cable length between the modules	10 m	15 m

Table 3- 3 Maximum mechanical configuration - on ET 200SP with CPU

Properties	Rule (max.)
	CPUs with firmware version as of V2.0.0
Number of ET 200AL I/O modules in the configuration	16
Number of ET-Connection outlets	1
Spatial extension ET-Connection line	240 m
Cable length between the modules	15 m

Electrical maximum configuration

The number of usable I/O modules of a potential group is limited by the following points:

- Power requirements of the I/O modules
- Power requirements of the components supplied via these I/O modules

The maximum infeed current of the I/O modules is 4 A with 1L+ supply voltage (non-switched) and 2L+ load voltage (switched). When the maximum infeed current has been reached, you must open a new potential group.

Reference

You will find more information in the section Connecting cables for ET 200AL (Page 36).

3.2 Configuration variants with ET-Connection

3.2.1 ET 200AL with ET-Connection

Every ET 200AL interface module has 2 ET-Connection connections

From every ET-Connection, you have the option to set up a line with a maximum of 16 ET 200AL I/O modules.

ET-Connection1

The figure below shows a configuration in the IP65/IP67 environment with one ET-Connection line.

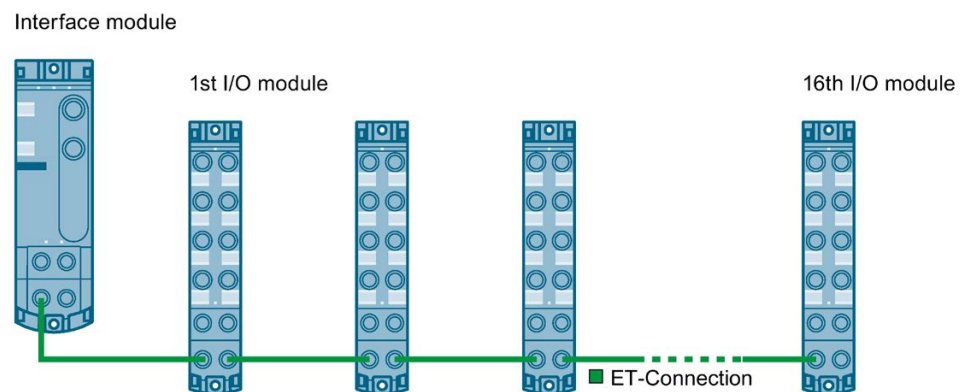


Figure 3-1 ET 200AL with ET-Connection1

ET-Connection1 and ET-Connection2

The figure below shows a configuration in the IP65/IP67 environment with two ET-Connection lines

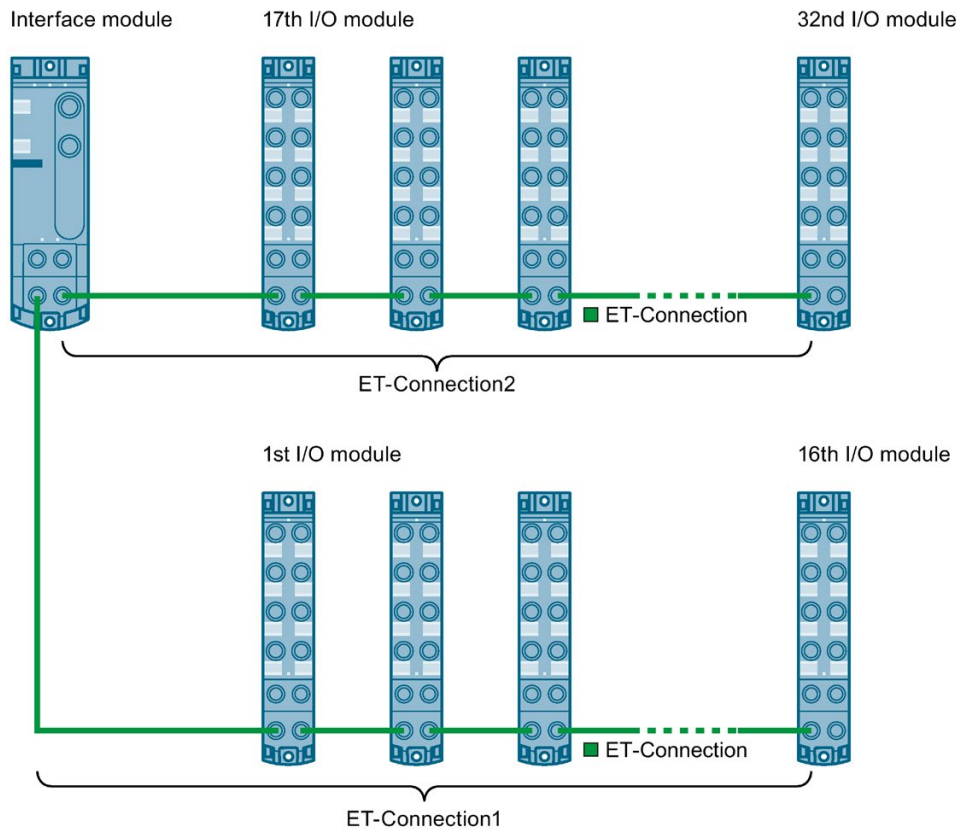


Figure 3-2 ET 200AL with ET-Connection1 and ET-Connection2

3.2.2 Hybrid configuration ET 200AL/ET 200SP with ET-Connection

Hybrid configuration ET 200AL and ET 200SP

You have the option to integrate the I/O modules of the ET 200AL distributed I/O system (IP65/IP67) in a configuration of the ET 200SP distributed I/O system (IP20).

The figure below shows a combination of the modules of the ET 200AL and ET 200SP distributed I/O systems.

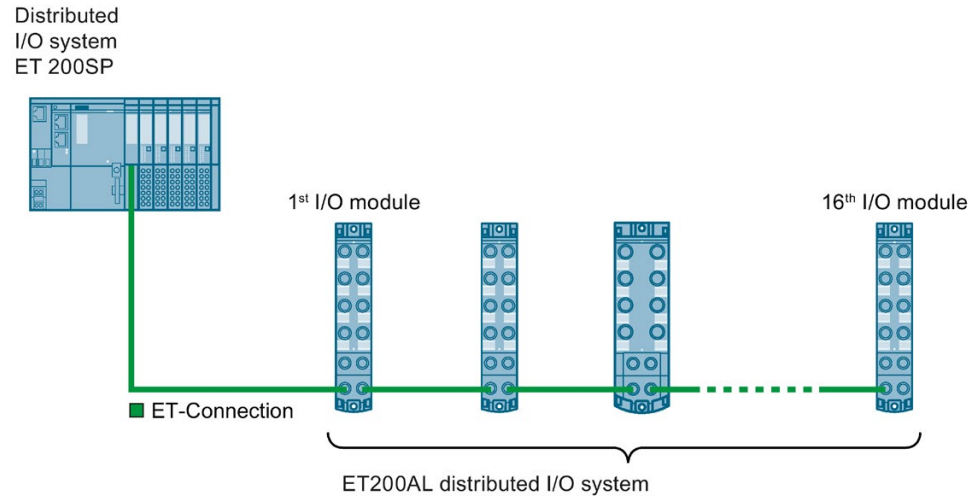


Figure 3-3 Hybrid configuration ET 200SP and ET 200AL with ET-Connection

Requirement

For a hybrid configuration, you need at least the following components:

- Interface module
 - IM 155-6 PN HF (V3.0 or higher)
 - IM 155-6 PN/2 HF (V4.2 or higher)
 - IM 155-6 PN/3 HF (V4.2 or higher)
 - IM 155-6 PN ST (V3.1 or higher)
 - IM 155-6 DP HF (V3.0 or higher)

Note

Using 15 m cable

Keep in mind that you can only use cables with a cable length of 15 m between the modules in combination with interface modules as of firmware version V3.3.0.

- CPU
 - 1510SP-1 PN (V2.0 or higher and STEP 7 (TIA Portal) V14 or higher)
 - 1512SP-1 PN (V2.0 or higher and STEP 7 (TIA Portal) V14 or higher)
 - 1510SP F-1 PN (V2.0 or higher and STEP 7 (TIA Portal) V14 or higher)
 - 1512SP F-1 PN (V2.0 or higher and STEP 7 (TIA Portal) V14 or higher)
- BaseUnit BU-Send with BusAdapter BA-Send 1xFC
- ET-Connection cable pre-assembled on one side
- Power cable pre-assembled on one side

Rules

When putting together a hybrid configuration, you must observe the following rules:

- The bus length of the ET 200SP distributed I/O system is a maximum of 1 m (excluding interface module/CPU, including BU-Send, BA-Send 1xFC and server module).
- A maximum of 16 ET 200AL I/O modules can be connected to ET-Connection.
- The maximum length of the bus cable for ET-Connection between two modules is 15 m.

Procedure

Watch video sequence (<https://support.industry.siemens.com/cs/ww/en/view/95886672>)

Proceed as follows to put together a multi-tier configuration:

1. Mount the BaseUnit BU-Send directly to the right of the ET 200SP interface module or the ET 200SP CPU.
2. Then install the other BaseUnits/I/O modules for the ET 200SP distributed I/O system and the server module.
3. Connect the bus cable for ET-Connection to the BusAdapter BA-Send 1×FC and install it on the BaseUnit BU-Send.
4. Fasten the BusAdapter BA-Send 1×FC with the BaseUnit BU-Send (1 screw with tightening torque of 0.2 Nm). Use a screwdriver with a 3 to 3.5 mm blade to do this.
5. Connect the other end of the bus cable for ET-Connection (with M8 connector) to the first ET 200AL I/O module (socket X30 ET-Connection IN).
6. Connect the supply voltage (24 V DC) to the ET 200AL I/O modules (X80 connector).

Mounting

4.1 Basics

Introduction

All the modules of the ET 200AL distributed I/O system are designed for the degree of protection IP65/IP67. This means that you can directly mount this system in your plant.

Installation position

You can mount the ET 200AL distributed I/O system in any position.

Minimum clearances

At ambient temperatures of 50 °C or higher, please ensure that the module is mounted at a distance of least 1 cm from an adjacent module or another device.

Mounting rules

When mounting the modules, you do not need to following any special rules.

Note

Mounting of the modules

Mount the ET 200AL distributed I/O system only with disconnected supply voltages.

4.2 Mounting modules

Introduction

The modules of the ET 200AL distributed I/O system are designed for installation on a level, firm surface.

Thanks to the axisymmetrical drill holes in the modules, you have the option to fasten the modules on an aluminum profile using tee nuts.

The following images shows the aluminum profile on which you can mount the modules.

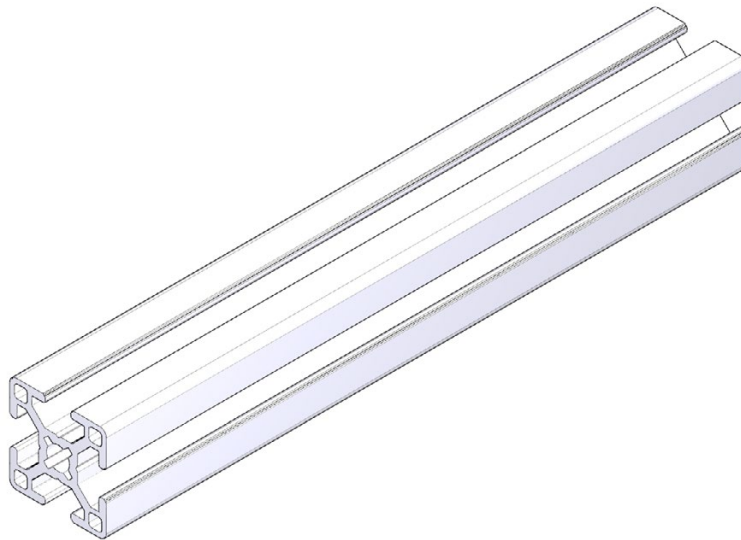


Figure 4-1 Aluminum profile

Required tools

For installation, you need a screwdriver or an Allen wrench.

Required screws

The following table shows and explains the screw types required to mount the modules.

Table 4- 1 Recommended screws

Screw type	Explanation
Socket head cap screw M4 according to DIN EN ISO 1207 / DIN EN ISO 1580	The screw length must be at least 30 mm. If you need washers, use DIN EN ISO 7089/DIN EN ISO 7090 washers.
Hexagon socket head cap screw M4 according to DIN EN ISO 4762	

Drill holes of the modules

All modules of the ET 200AL distributed I/O system feature a uniform drill pattern.

- All module housings are axisymmetrical.
- The distance between the top and bottom drill hole is identical for all modules.

Mounting interface module and 45 mm I/O modules (front)

Watch video sequence (<https://support.industry.siemens.com/cs/ww/en/view/95886672>)

The interface modules and the 45 mm I/O modules have an attachment point on top and on the bottom.

To mount an interface module or 45 mm I/O module, follow these steps:

1. Drill 2 fastening holes with 4.5 mm diameter at a distance of 149.6 mm.
2. Fasten the interface module or the 45 mm I/O module with the screws to both fastening points (tightening torque 1.2 Nm).

The figure below shows the dimensions for fastening the IM 157-1 PN interface module and the DQ 8x24VDC/2A 8xM12 45 mm I/O module.

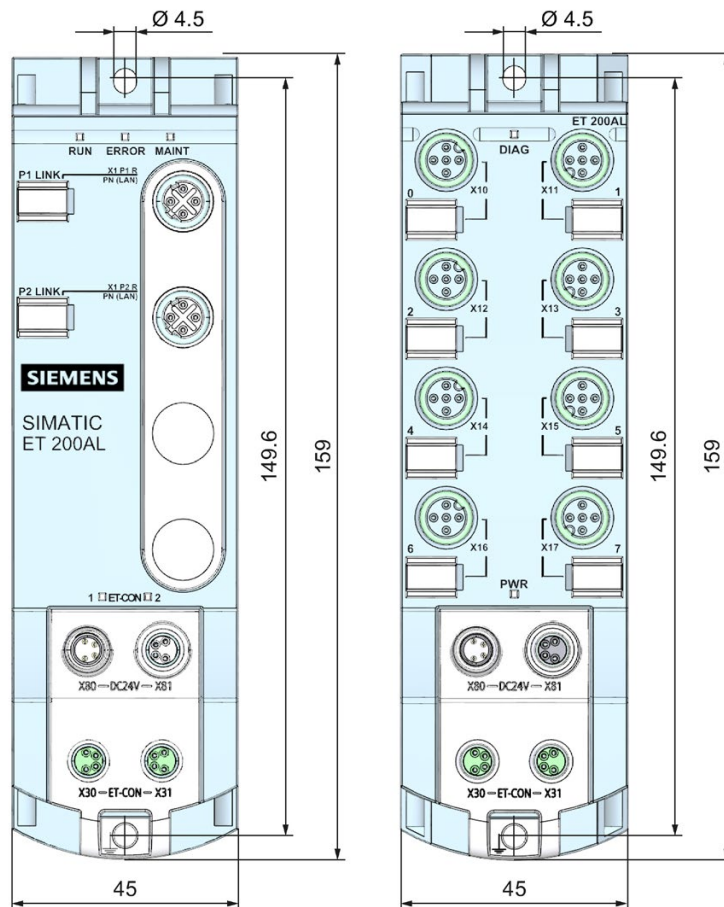


Figure 4-2 Dimensions for mounting interface modules and 45 mm I/O modules

Mounting 30 mm I/O modules (front or side)

Watch video sequence (<https://support.industry.siemens.com/cs/ww/en/view/95886672>)

The 30 mm I/O modules have an attachment point on top and on the bottom. You also have the option of fastening the 30 mm I/O modules at the side. When fastening them at the side, you must use the supplied spacers.

To mount a 30 mm I/O module, follow these steps:

1. Drill 2 fastening holes with 4.5 mm diameter at a distance of 149.6 mm.
2. Use the supplied spacers for side fastening of the I/O module on the top and bottom (on one side adjacent to the fastening surface).
3. Fasten the I/O module with the screws to both fastening points (tightening torque 1.2 Nm).

The figure below shows the dimensions for fastening the 30 mm I/O modules using the example of the DIQ 4+DQ 4x24VDC/0.5A 8xM8 I/O module.

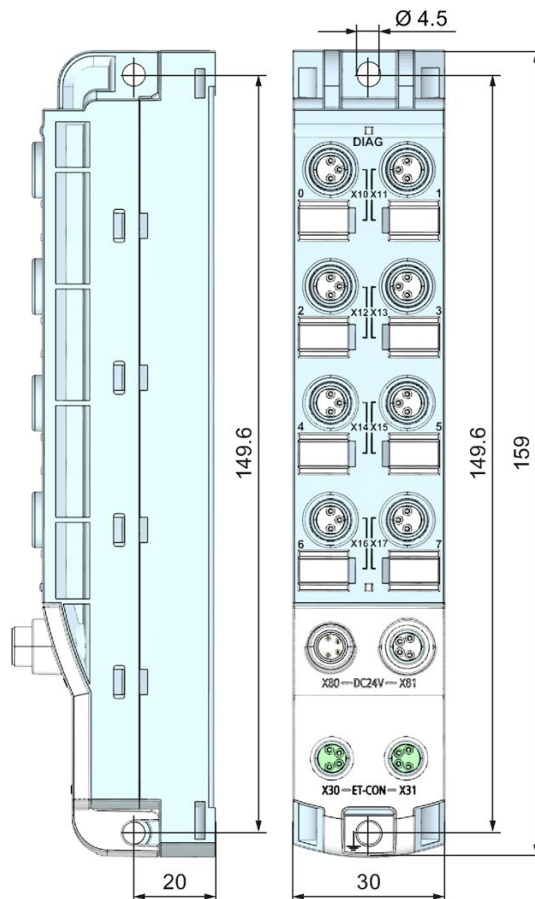


Figure 4-3 Dimensions for mounting 30 mm I/O modules

Fastening for cable ties

All module of the ET 200AL distributed I/O system have an integrated attachment point for cable ties. The attachment points are found on all four corners of the modules.

The figure below shows the top left attachment point for 2.5 mm wide cable ties for fastening the cables.

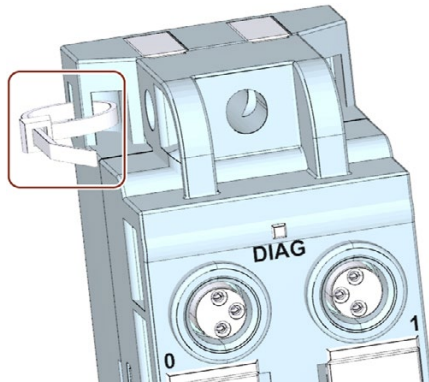


Figure 4-4 Top left attachment point for cable ties

Connecting

5.1 Rules and regulations for operation

Introduction

Depending on the area of application, the ET 200AL distributed I/O system, as a component of plants and systems, requires that special rules and specifications be followed.

This section gives an overview of the most important rules to be followed for integration of the ET 200AL distributed I/O system in a plant or in a system.

Specific application

Follow the safety and accident prevention regulations applicable to specific applications, e.g. the machinery directive.

EMERGENCY-STOP device

EMERGENCY-STOP devices according to IEC 60204 (corresponds to DIN VDE 113) must remain in effect in all operating modes of the plant or system.

Excluding hazardous system conditions

Hazardous operating states must not occur in the following situations:

- When the plant restarts after a voltage drop or power outage.
- When the ET 200AL distributed I/O system restarts after interruption of bus communication.

If necessary, EMERGENCY STOP must be forced!

An uncontrolled or undefined startup is not permitted after the "EMERGENCY STOP" is unlocked.

Cables and wires

Make sure that the cables used (incl. connectors) are approved for a continuous operating temperature of at least 70 °C.

Line voltage of the SELV/PELV power supply

The following section describes what you need to pay attention to with respect to the line voltage (you will find additional information in the section Information on insulation, protection class, degree of protection, and rated voltage (Page 90)):

- For stationary plants or systems without an all-pole line disconnecter, there must be a disconnecter unit (all-pole) fitted in the building installation.
- For load current supplies, the configured rated voltage range must correspond to the local line voltage.
- For all power circuits of the ET 200AL distributed I/O system, the fluctuation/deviation of the line voltage from the rated value must be within the permitted tolerance.

24 V DC supply

Below there is a description of what you need to pay attention to with 24 V DC supply:

- For buildings:
If there is a danger due to overvoltages, you must take lightning protection measures for external lightning protection (e.g. lightning protection elements).
- With 24 V DC supply lines and signal lines:
If there is a danger due to overvoltages, you must take lightning protection measures for internal lightning protection (e.g. lightning protection elements. You will find additional information in the Designing interference-free controllers (<https://support.industry.siemens.com/cs/ww/en/view/59193566>) function manual).
- For 24 V DC supply:
Ensure that there is a safe (electrical) separation of low voltage (SELV/PELV) according to IEC 61010-2-201 or IEC 60950-1.
You must secure all feeding supply voltages with a UL/IEC approved fuse 24 V DC/4 A (trigger characteristic type B or C).

Protection against outside electrical influences

Below is a description of what you must pay attention to in terms of protection against electrical impacts and/or faults:

- For all plants or systems in which the ET 200AL distributed I/O system is integrated, you must ensure that the equipment or system is functionally grounded to discharge electromagnetic interference.
- For supply, signal and bus cables, you must ensure that the cable routing and installation is correct.
- For signal and bus cables, you must ensure that a wire/cable breakage or a cross-wire does not lead to undefined states of the plant or system.

Reference

Additional information can be found in the function manual Designing interference-free controllers (<https://support.industry.siemens.com/cs/ww/en/view/59193566>).

5.2 Operation of the ET 200AL on grounded/non-grounded infeed

Introduction

Information is provided below on the overall configuration of an ET 200AL distributed I/O system on a grounded incoming supply (TN-S network). The specific subjects discussed are:

- Disconnecting devices, short-circuit and overload protection to IEC 60364 (corresponding to DIN VDE 0100) and IEC 60204 (corresponding to DIN VDE 0113)
- Load current supplies and load circuits
- Supply voltages of the ET 200AL distributed I/O system

Grounded infeed

In grounded incoming supplies, the neutral conductor of the supply system is grounded. A simple ground fault between a live conductor and ground or a grounded section of the plant causes the protective devices to trip.

Supply voltages

Two SELV/PELV supply voltages are available for the ET 200AL distributed I/O system.

- 1L+: Supply voltage (non-switched)
- 2L+: Load voltage (switched)

Secure electrical separation (SELV/PELV according to IEC 61010-2-201)

Mains devices/power supply modules with secure electrical separation are required for the operation of the ET 200AL distributed I/O system. This protection is designated as SELV (Safety Extra Low Voltage)/PELV (Protective Extra Low Voltage) according to IEC 60364-4-41.

Configuring ET 200AL with grounded reference potential

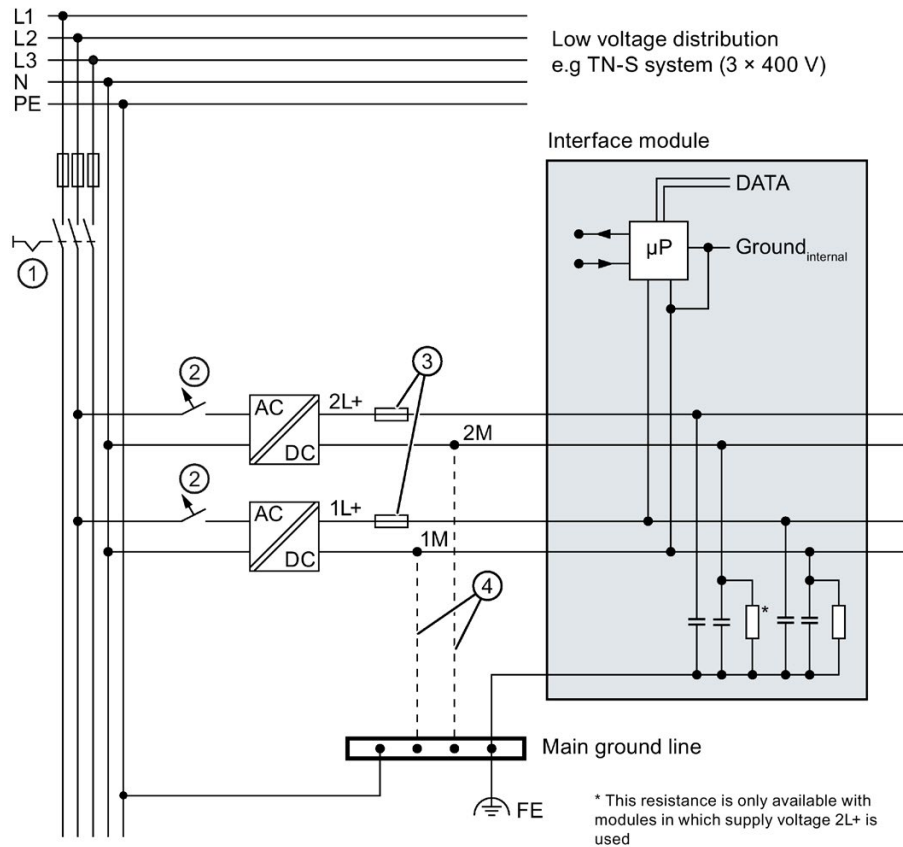
When configuring the ET 200AL distributed I/O system with grounded reference potential, occurring interference currents are discharged into functional earth. The connections must be externally connected (connection between 1M and FE).

Configuring ET 200AL with ungrounded reference potential

When configuring the ET 200AL distributed I/O system with non-grounded reference potential, occurring interference currents are discharged via an internal RC network to functional earth (no external connection between 1M and FE).

ET 200AL in the overall configuration

The figure below shows the ET 200AL distributed I/O system in the complete electrical configuration using the example of an interface module.



- ① Main switch
- ② Short-circuit and overvoltage protection
- ③ Fuses for cable protection (automatic circuit breaker for 4 A)
- ④ When configuring the ET 200AL distributed I/O system with non-grounded reference potential, no connection is made between 1M, 2M and FE.

Figure 5-1 Electrical configuration

Components and protective measures

Various components and protective measures are stipulated for setting up a complete plant. The types of components and the degree to which the protective measures are mandatory depend on the IEC regulation that applies to your plant setup.

The following table shows the components of the electrical configuration with reference to the previous figure and compares the IEC regulations.

Table 5- 1 Components of electrical configuration

	Reference to illustration	IEC 60364 (DIN VDE 0100)	IEC 60204 (DIN VDE 0113)
Disconnection element for controller, sensors, and actuators	①	Main switch	Disconnecter
Short-circuit / overload protection	②	Single-pole protection of circuits Secure all incoming supply cables with a circuit breaker (24 V DC/4 A).	Secure with one pole with a grounded secondary circuit
Cable protection	③	Protection of cables and wires against overcurrent	-

Insulation monitoring

In the following situations, you must provide insulation monitoring.

- When configuring the ET 200AL distributed I/O system with non-grounded reference potential
- When hazardous system conditions may occur due to errors

5.3 Electrical configuration of the ET 200AL

Electrical isolation

When electrically configuring the ET 200AL distributed I/O system, there is electrical isolation between:

- Load voltage 2L+ and all other switching parts
- Communication interfaces (PROFINET/PROFIBUS) of the interface modules and all other switching parts
- ET-Connection and all other switching parts

The following images show the potential conditions of the modules of the ET 200AL distributed I/O system.

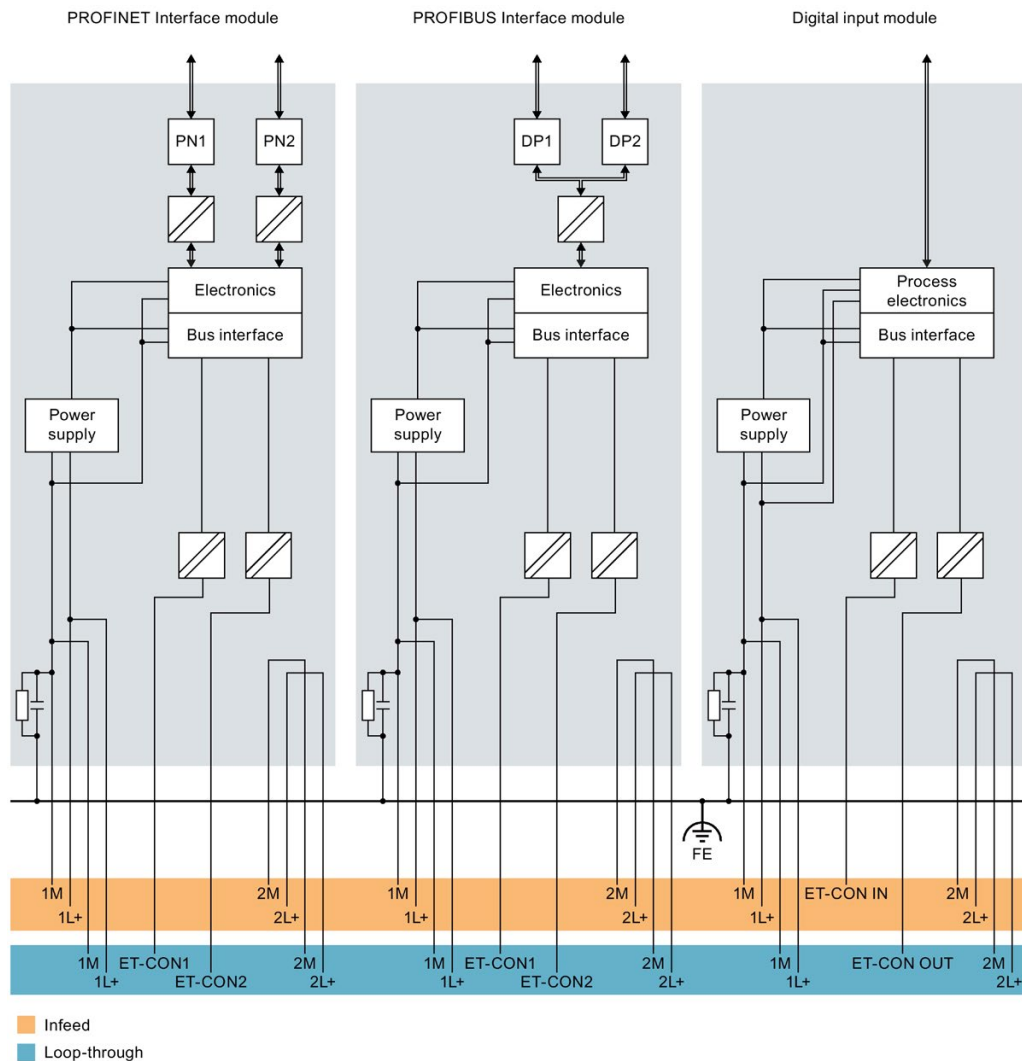


Figure 5-2 Potential conditions of the ET 200AL distributed I/O system (Part 1)

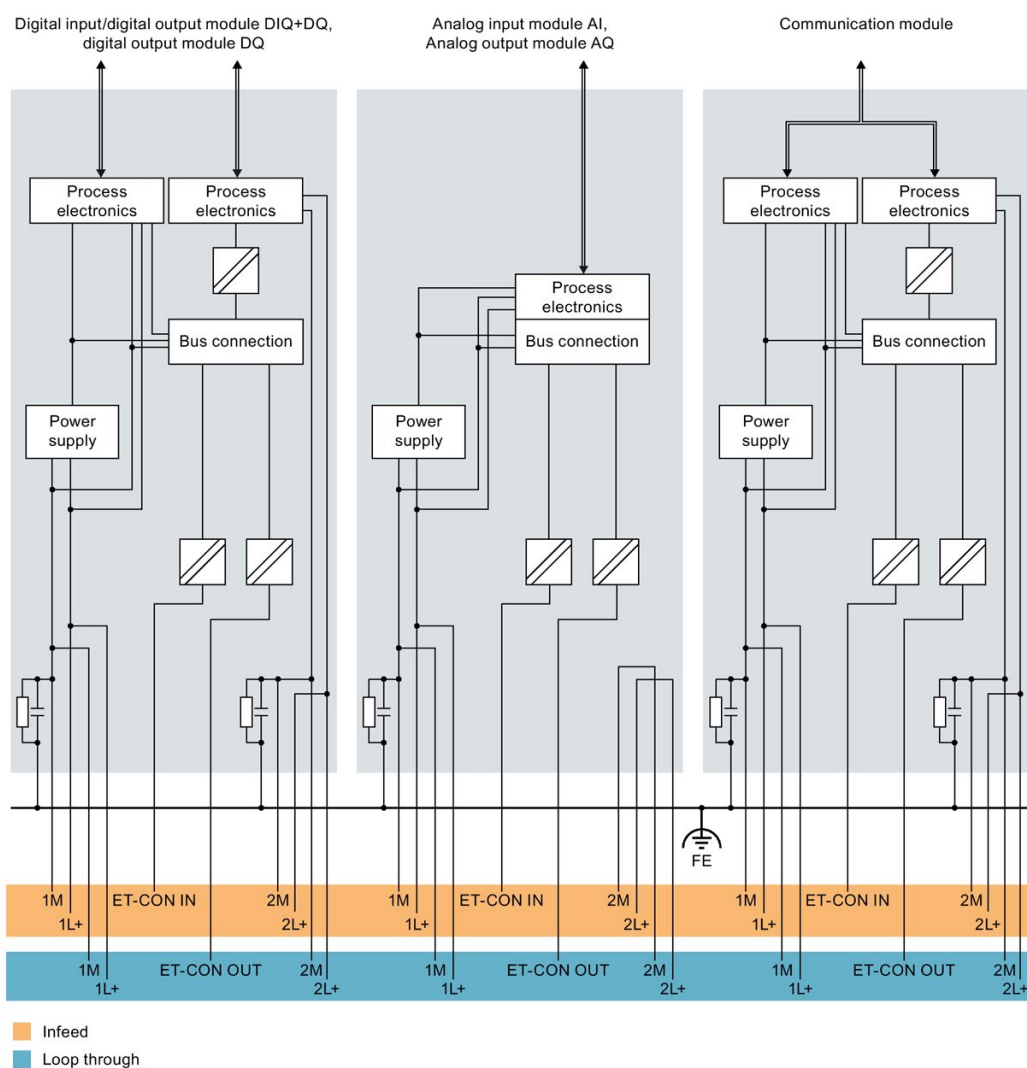


Figure 5-3 Potential conditions of the ET 200AL distributed I/O system (Part 2)

Connection of a digital output with a digital input

⚠ WARNING

Pay attention to the potential group

When a digital output is connected to a digital input, pay attention to the potential groups. Depending on the configuration, 1M and 2M may then be connected, resulting in elimination of the electrical isolation between 1L+ and 2L+. The possible compensating currents can destroy the digital module.

Cable protection

According to IEC 60364, cable protection is required, i.e. you must always secure the incoming lines externally.

You must secure all incoming supply voltages with a UL/IEC approved 24 V DC/4 A fuse (trigger characteristic type B or C).

Power supply of the configuration

Two voltage groups are available for the distributed I/O system ET 200AL: 1L+ (supply voltage) and 2L+ (load voltage)

A second infeed may be needed to supply all the modules of a configuration with the required voltage. Renewed voltage supply of 1L+ and 2L+ can be necessary to configure different potential groups or because the voltage is not sufficient for all modules due to the voltage drop. Create a power balance for the selection of the infeed point of the voltage.

Note

Turning 1L+ and 2L+ on and off

In contrast to the load voltage 2L+, the operational switching on and off of the supply voltage 1L+ results in a restart of the module.

The figure below shows a configuration with a new voltage infeed for the modules. The different potential groups have a gray background.

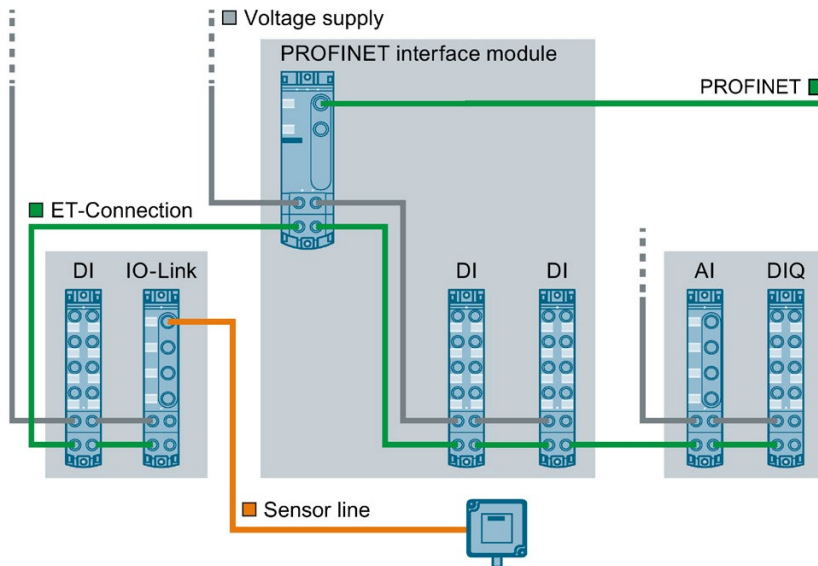


Figure 5-4 Wiring of the power supply

Reference

You will find additional information on electrical configuration and the voltage drop in the section Connecting cables for ET 200AL (Page 36).

5.4 Connecting ET 200AL to functional earth

Introduction

You must connect the distributed I/O system ET 200AL to functional earth (FE)

What is functional earth?

All ET 200AL modules feature a functional earth connection. This connection is used to suppress interference sensitivity, but not for protection purposes. With the functional earth connection, you create an electrical connection directly to a point of your system or shielding. This discharges the EMC interference directly into the earth. By discharging the EMC interference, the interference safety of the entire module is increased.

The figure below shows the symbol with which the functional earth connection is identified on the ET 200AL modules.

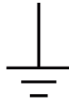


Figure 5-5 Functional earth

5.4.1 Mounting ET 200AL modules on conductive substrate

Requirement

Conductive substrate for mounting of the module

Required tools

To connect to functional earth, you need the following tools:

- Screwdriver

Required accessories:

To connect to functional earth, you need the following accessories:

- 2 x M4 fastening screws.

Mounting

To connect modules of the ET 200AL distributed I/O system to functional earth with a conductive mounting substrate, proceed as follows:

1. Drill two fastening holes.
2. Screw the module with the M4 fastening screws using a torque of 1.2 Nm.

Note

Earthing with conductive mounting substrate

When you fasten a module of the ET 200AL distributed I/O system on a conductive, grounded substrate, the bottom fastening screw provides a conductive connection to the ground potential.

Ensure that there is a low-impedance connection between the module and conductive underground as well as between the conductive underground and functional earth.

Reference

You will find more information on installing the modules in the section Mounting modules (Page 21).

5.4.2 Mounting ET 200AL modules on non-conductive substrate

Requirement

Conductive substrate for mounting of the module

Required tools

To connect to functional earth, you need the following tools:

- Screwdriver
- Stripping tool
- Crimp tool

Required accessories:

To connect to functional earth on a non-conductive fastening substrate, you need the following accessories:

- 2 x M4 fastening screws.
- Cable lug suitable for M4 screws
- Grounding cable (braided copper cable) with a minimum cross section of 4 mm²

Mounting

To connect modules of the ET 200AL distributed I/O system to functional earth, proceed as follows:

1. Drill two fastening holes.
2. Strip the grounding cable.
3. Fasten the cable lug to the grounding cable.
4. Screw the module and the cable lug with the M4 fastening screws using a torque of 1.2 Nm.

The figure below shows how to connect functional earth using the example of the IM 157-1 PN interface module.

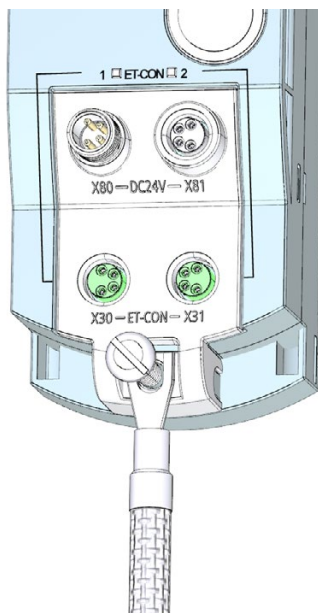


Figure 5-6 Connecting the functional earth

Note

Earthing with non-conductive mounting substrate

Make sure there is a low-impedance connection between the module and the functional earth.

Reference

You will find more information on installing the modules in the section Mounting modules (Page 21).

5.5 Connecting cables for ET 200AL

Impact of cable length on the supply voltage

When wiring your configuration, you must take into account the impact of the cable length on the supply voltage of the ET 200AL distributed I/O system.

⚠ CAUTION

Pay attention to maximum incoming currents

For each power supply (1L+, 2L+), you can feed in a maximum of 4A.

If you exceed the maximum incoming currents and do not comply with the required cable cross sections, an increased incoming current could lead to overheating of the cable insulation and the contacts. This could result in damage to the modules.

The figure below shows the voltage drop depending on the cable length for 4 current strengths, using the example of a copper cable with $\varnothing 0.5 \text{ mm}^2$.

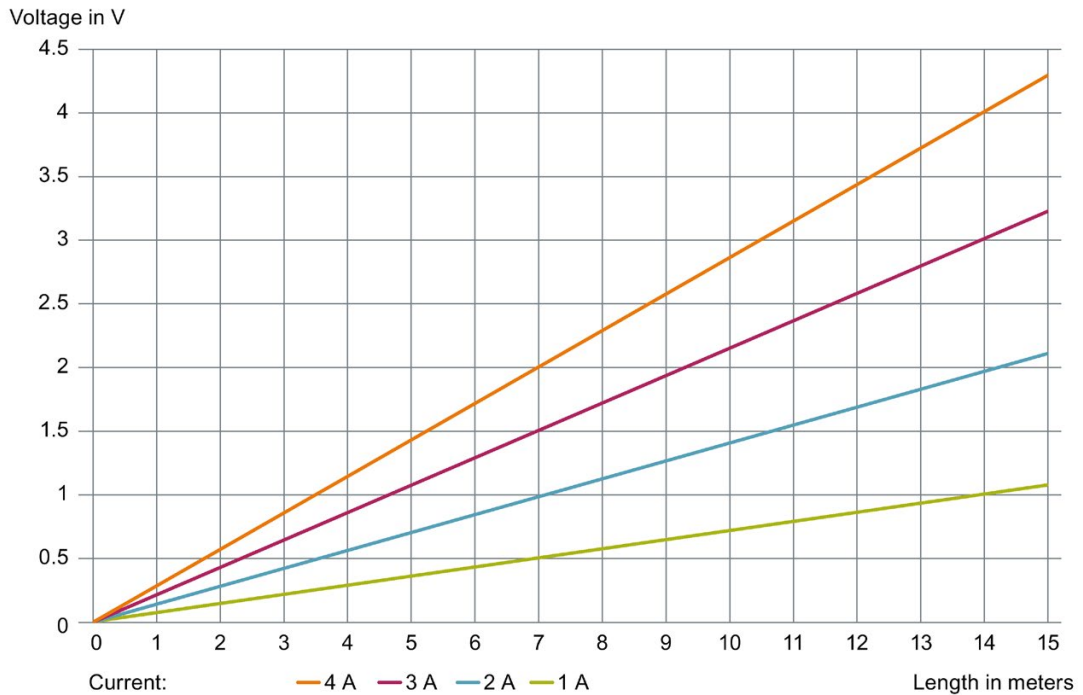


Figure 5-7 Voltage drop with a cable cross-section of 0.5 mm^2

To estimate the voltage drop in your ET 200AL distributed I/O system, you must add the voltage drops of the different cables. For every module used, you must add an additional voltage drop of around 0.1 V.

Example

If you have a 7 m power supply cable with $\varnothing 0.5 \text{ mm}^2$, the voltage drop is around 1.5 V with a load of 3 A.

5.6 Wiring

Connection

Connect all cables to the front side of the modules:

- Supply voltage and ET-Connection to the 4-pole M8 round sockets and M8 round connectors
- Signal lines to the 3-pole M8 or 4/5-pole M12 round sockets
- Fieldbus lines to the 4/5 pole M12 round sockets and M12 round connectors

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Requirement

Wire the modules with the supply voltage off.

Required tools

If you are not using pre-assembled cables, you need the following tools:

- Stripping tool
- Screwdriver to wire the connection plugs
- Stripping Tool for ET-Connection

Required accessories when connecting the supply voltage

You need the following accessories:

- Cables
 - pre-assembled power cable, M8, 4-pole, or
 - flexible 4-wire copper cable (wire cross section: 0.25 to 0.5 mm²)
- 4-pole M8 connection plug

Accessories required for the connection of ET-Connection

You need the following accessories:

- ET-Connection cables
- 4-pole M8 connection plug

Note

ET-Connection cables

When connecting ET-Connection **use only** the offered cables.

Connecting M8 connectors

To connect M8 connectors, proceed as follows:

1. Insert the connector in the appropriate round socket on the module.
Make sure that there is proper locking between the connector and socket.
2. Tighten the connector using the knurled screw with a torque of 0.4 Nm.

The figure below shows the connection of the M8 connectors, using the example of the DIQ 4+DQ 4x24VDC/0.5A 8xM8 digital input/digital output module.

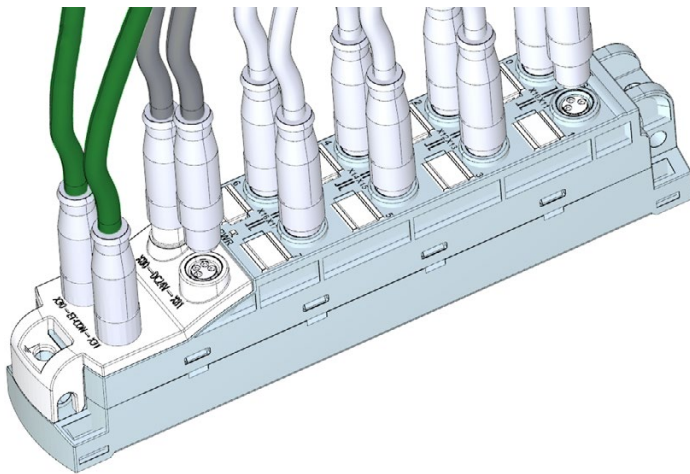


Figure 5-8 Connecting M8 connectors

Connecting M12 connectors

To connect M12 connectors, proceed as follows:

1. Insert the connector in the appropriate round socket on the module.
Make sure that there is proper locking between the connector and socket (nut and spring).
2. Tighten the connector using the knurled screw with a torque of 1 Nm.

The figure below shows the connection of the M12 connectors, using the example of the analog input module AI 4xU/I/RTD 4xM12.

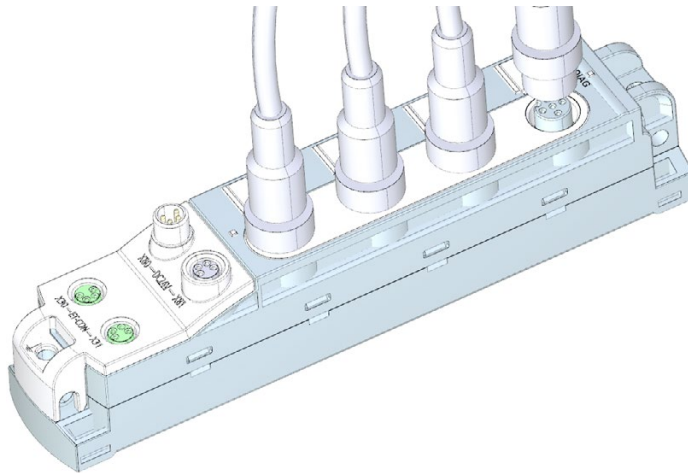


Figure 5-9 Connecting M12 connectors

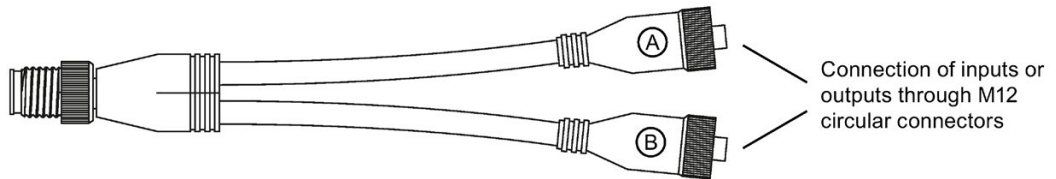
Pin assignment of the sockets

The pin assignment of the sockets can be found in the manuals for the interface modules (<https://support.industry.siemens.com/cs/ww/en/ps/14246/man>) and I/O modules (<https://support.industry.siemens.com/cs/ww/en/ps/14247/man>) in the section on pin assignment and on the side surface of the module.

Y-cable

The Y-cable allows you to connect two actuators or sensors to the inputs or outputs.

The use of a Y-cable is particularly recommended when two channels are occupied for each socket of an I/O device. The Y-cable distributes the channels to two circular connectors.



The figure below shows the wiring of the Y-cable.

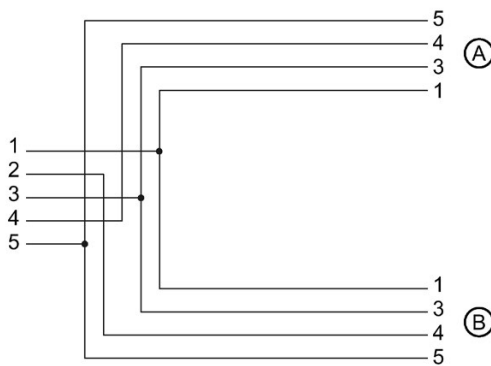


Figure 5-10 Wiring of the Y-cable

Sealing of unused sockets

To ensure IP65 or IP67 degree of protection, seal off all unused sockets with sealing caps.

Article numbers for accessories/spare parts.

You will find the article numbers in the Appendix in section Accessories/spare parts (Page 95).

5.7 ET 200AL marking

5.7.1 Factory markings

Introduction

For better orientation, the ET 200AL distributed I/O system is identified using various markings which will help you when configuring and connecting the modules.

Marking of the interfaces

The interfaces of the modules are factory-labeled.

The table below shows the labeling of the interfaces.

Table 5- 2 Interface labeling

interface	Labeling
PROFINET IO interfaces	X1 P1 R and X1 P2 R
PROFIBUS DP interfaces	X1 DP1 and X1 DP2
I/O input and output interfaces	X10 through X17
ET-Connection interfaces (interface modules)	X30 (ET-CON1) and X31 (ET-CON2)
ET-Connection interfaces (I/O modules)	X30 (ET-CON IN) and X31 (ET-CON OUT)
Power supply interfaces	X80 (IN) and X81 (OUT)

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

NOTICE

ET-Connection/supply voltage

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage. Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

Pin assignment

The pin assignments of the various interfaces are lasered at the factory, on the side of every module.

5.7.2 Optional markings

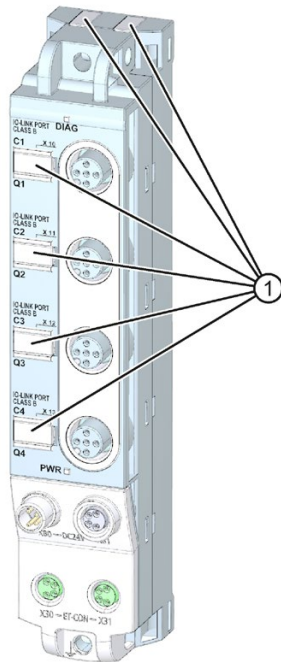
Introduction

In addition to the factory markings, there are also optional possibilities for labeling and/or identifying interfaces and modules on the ET 200AL distributed I/O system.

Identification label

The identification labels come with each module as strips and can be machine-printed. A strip has 10 identification labels measuring 10 x 5 mm in the color RAL9016. The identification labels can be inserted into every module at the points provided. The identification labels are used for channel, module and slot labeling.

The figure below shows all points where you can use the identification labels using the example of the IO-Link Master CM 4xIO-Link 4xM12 communication module.



① Identification labels

Figure 5-11 Optional marking

5.7.3 Mounting identification labels

Introduction

This section describes how to mount or remove identification labels.

Required tools

You need a screwdriver with 3 mm blade width (only to remove identification labels).

Mounting procedure

To mount an identification label, proceed as follows:

1. Print the identification label using commercially available marking systems.
2. Press the identification label out of its holder.
3. Stick the identification labels into the cutouts provided, as shown in the figure *Optional marking* (Page 42).

Mounting the identification labels is the same for all modules.

Removal procedure

To remove an identification label, proceed as follows:

1. Carefully use a screwdriver to pull out the identification label.

Removing identification labels is the same for all modules.

Configuring

Introduction

You configure and assign parameters for the ET 200AL distributed I/O system (interface modules and I/O modules) using STEP 7 or the configuration software of another manufacturer.

Requirements

Table 6- 1 Configuration software and requirements

Configuration software	Requirements	Installation information
STEP 7 (TIA Portal) as of V14 for modules: <ul style="list-style-type: none"> • DIQ 16x24VDC/0.5A 8xM12 • AQ 4XU/I, 4XM12 	<ul style="list-style-type: none"> • PROFINET IO, PROFIBUS DP: as of Support Package HSP 0194 	STEP 7 online help
STEP 7 (TIA Portal) V13 SP1 or higher for modules: <ul style="list-style-type: none"> • DI 8x24VDC 4xM12 • DI 16x24VDC 8xM12 	<ul style="list-style-type: none"> • PROFINET IO, PROFIBUS DP: as of Support Package HSP 0155 	
STEP 7 (TIA Portal) V13 SP1 or higher for modules: <ul style="list-style-type: none"> • DIQ 4+DQ 4x24VDC/0.5A 4xM12 • DQ 8x24VDC/2A 8xM12 	<ul style="list-style-type: none"> • PROFINET IO, PROFIBUS DP: as of Support Package HSP 0156 	
STEP 7 (TIA Portal) V13 SP1 or higher for modules: <ul style="list-style-type: none"> • IM 157-1 PN • IM 157-1 DP • DI 8x24VDC 8xM8 • DIQ 4+DQ 4x24VDC/0.5A 8xM8 • AI 4xU/I/RTD 4xM12 • CM 4xIO-Link 4xM12 	<ul style="list-style-type: none"> • none, integrated in STEP 7 	
STEP 7 as of V5.5 SP4 for modules: <ul style="list-style-type: none"> • IM 157-1 PN • IM 157-1 DP 	<ul style="list-style-type: none"> • PROFINET IO: as of Support Package HSP 0259 • PROFIBUS DP: as of Support Package HSP 0258 	

Configuration software	Requirements	Installation information
STEP 7 as of V5.5 SP4 for all IO modules	<ul style="list-style-type: none"> PROFINET IO, PROFIBUS DP: as of Support Package HSP 0260 	
STEP 7 (TIA Portal) as of V13 Update 3	<ul style="list-style-type: none"> PROFINET IO GSD file: GSDML-Vx.y-Siemens-ET200AL-"Date in format yyyyymmdd".xml (https://support.industry.siemens.com/cs/ww/en/view/92346477) for example: GSDML-V2.31-Siemens-ET200AL-20140507.xml PROFIBUS DP GSD file: siem81A9.gsg (https://support.industry.siemens.com/cs/ww/en/view/92346281) 	Manufacturer documentation
Software of third-party manufacturer		

Configuring the ET 200AL distributed I/O system

See the STEP 7 online help or the documentation of the manufacturer of the configuration software.

Configuration - PROFINET maximum configuration

Each of the connections for ET-Connection occupies a slot in the configuration. The slots for ET-Connection1 and ET-Connection2 are specified statically in the PROFINET GSD file. ET-Connection1 is permanently on slot 1 and ET-Connection2 on slot 18.

The fixed slot assignment of ET-Connection1 and ET-Connection2 offers you the following advantages:

- You can expand ET-Connection1 and ET-Connection2 without a high workload
- Transparency in configuration control
- Simplification of diagnostics alarms and troubleshooting

The figure below shows the maximum configuration with modules of the ET 200AL distributed I/O system.

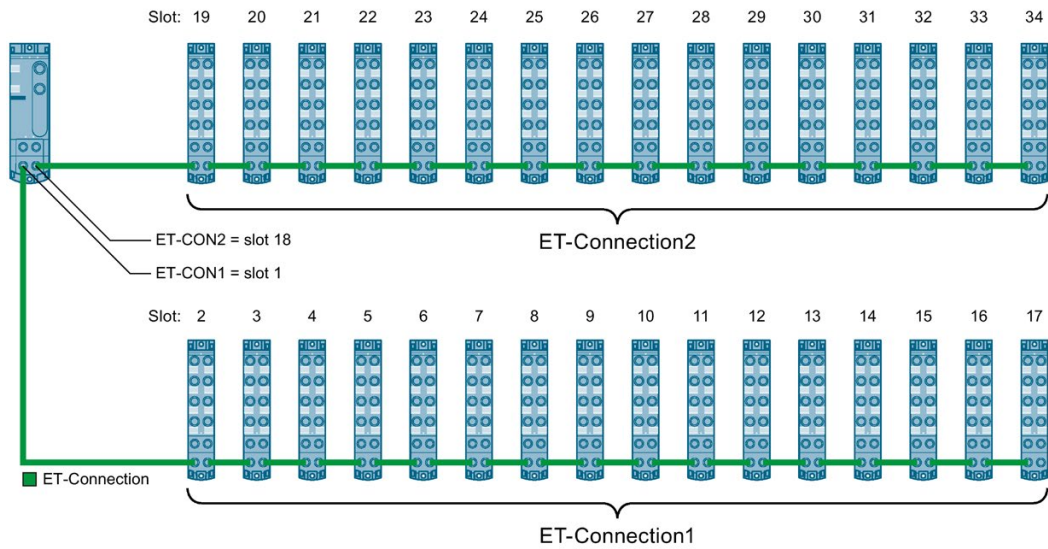


Figure 6-1 PROFINET maximum configuration

Reference

You can find additional information on this topic in section Configuration control (option handling) (Page 48).

Configuration - PROFIBUS maximum configuration

Each of the connections for ET-Connection occupies a slot in the configuration. The slot for ET-Connection1 is statically defined in the PROFIBUS GSD file. ET-Connection1 is always permanently installed in slot 1. Always place the topology module for ET-Connection2 on slot 18. You do not need to fill slots in the configuration for ET-Connection1 with dummy modules.

The fixed slot assignment of ET-Connection1 and ET-Connection2 offers you the following advantages:

- You can expand ET-Connection1 and ET-Connection2 without a high workload; for ET-Connection1 you need to remove the placeholder, the I/O module is placeable (no placeholders are needed for ET-Connection2)
- You cannot configure more modules on ET-Connection1 or ET-Connection2 than are allowed.
- Transparency in configuration control
- Simplification of diagnostics alarms and troubleshooting

The figure below shows the maximum configuration with modules of the ET 200AL distributed I/O system.

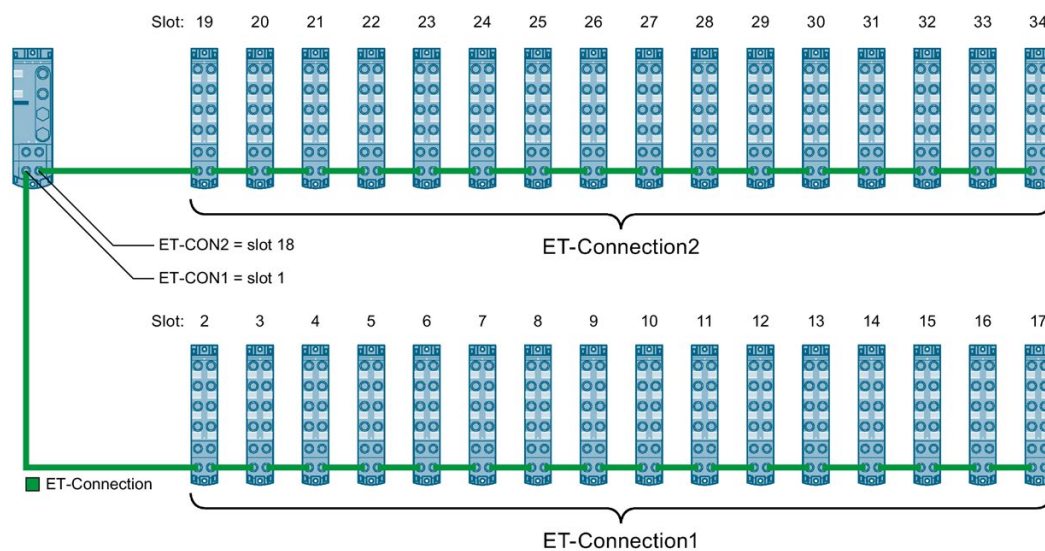


Figure 6-2 PROFIBUS maximum configuration

Reference

You can find additional information on this topic in section Configuration control (option handling) (Page 48).

Configuration control (option handling)

7.1 Configuration control

Introduction

With configuration control (option handling), you handle various standard machine configuration levels in one project without having to change the hardware configuration or user program.

Operating principle of configuration control

You can use configuration control to operate different standard machine configurations with a single configuration of the ET 200AL distributed I/O system.

- A station master (maximum configuration) is configured in a project. The station master comprises all modules needed for all possible equipment components of a modular standard machine.
- Provision is made in the user program of the project for various station options for the different configuration levels of the standard machine and for selection of a station option. A station option uses, for example, only some of the modules of the station master and these modules are not inserted in the configured order.
- Manufacturers of standard machines select a station option for a configuration level of the standard machine. They do not have change the project or download the modified configuration.

You use a control data record you have programmed to notify the CPU/interface module as to which modules are missing or located on different slots in a station option as compared to the station master. If a module with the configuration control is moved to another slot, it retains its parameter assignment.

The configuration control allows you to flexibly vary the centralized/distributed configuration. As a precondition for this, the station option must be able to be derived from the station master.

The following figure shows 3 configurations of a standard machine with the corresponding station options of the ET 200AL distributed I/O system.

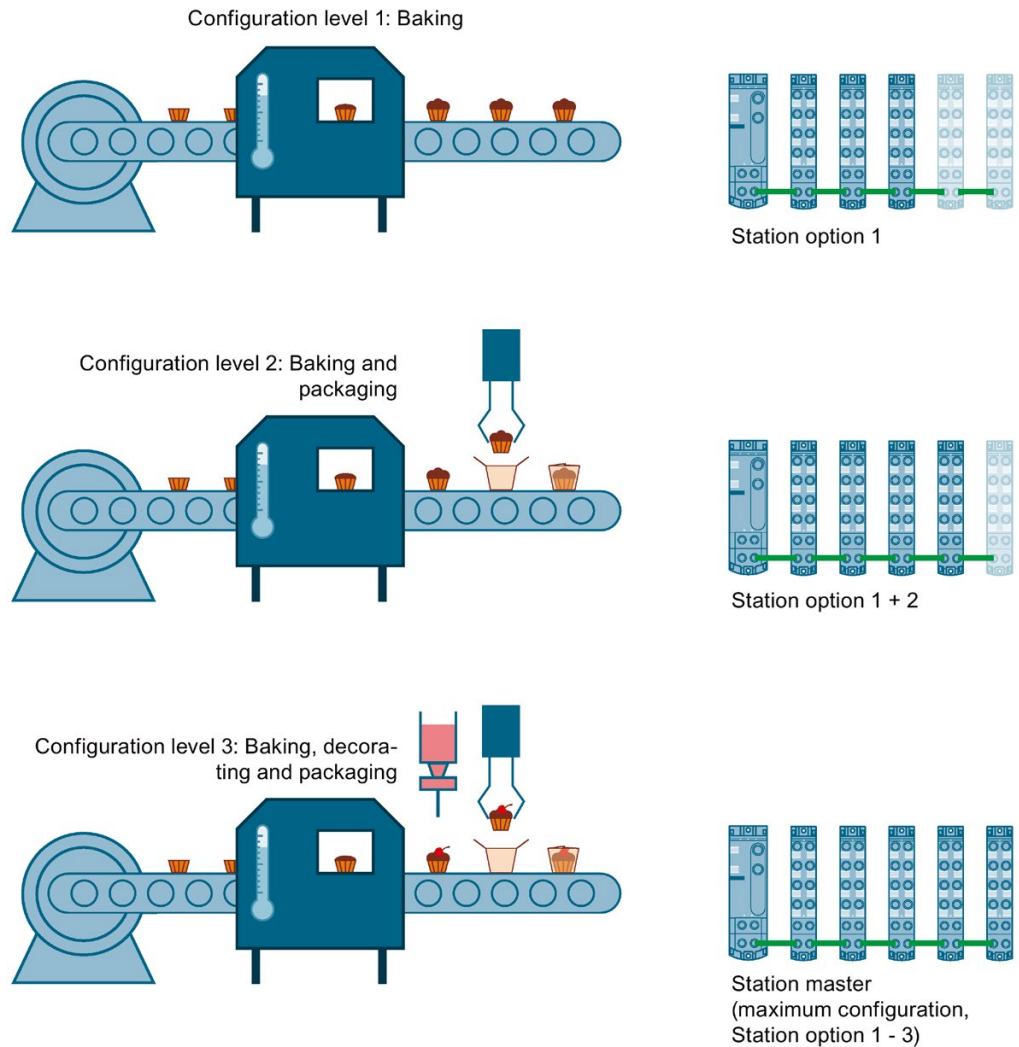


Figure 7-1 Various configuration levels of a standard machine with the corresponding station options of the ET 200AL distributed I/O system.

Benefits

- Easy project handling and commissioning through use of a single STEP 7 project for all station options.
- Easy handling during maintenance, versioning and upgrades.
- Hardware savings: Only the I/O modules needed for the current station option of the machine are installed.
- Potential savings when building, commissioning and creating documentation for standard machines.

Procedure

To set up the configuration control, follow these steps in the order given:

Step	Procedure	See...
1	Enable configuration control in STEP 7	Section Configuring (Page 51)
2	Create control data record	Section Creating the control data record (Page 53)
3	Transfer control data record	Section Transferring the control data record in the user program of the CPU (Page 62)

Library for configuration control

A library for configuration control is available for download (<https://support.industry.siemens.com/cs/ww/en/view/29430270>) on the internet. The library contains data types with the structure of the control data records for the ET 200AL distributed I/O system. You can implement your flexible automation solution economically with the help of these data types.

7.2 Configuring

Requirements

Via PROFINET IO:

- Configuration software, for example STEP 7 Professional as of V13
- IM 157-1 PN
- You have assigned the interface module to an IO controller in STEP 7

Via PROFIBUS DP:

- Configuration software, for example STEP 7 Professional as of V13
- IM 157-1 DP
- You have assigned the interface module to an DP master in STEP 7
- The parameter "Operation if preset configuration does not match actual configuration" is activated.
The parameter "Operation if preset configuration does not match actual configuration" is located in STEP 7 in the properties of the interface module under "Module parameters" > "Start-up".

Note

Disabled parameter "Startup if preset configuration does not match actual configuration"

If an I/O module is missing or an incorrect or additional I/O module is plugged in and the "Startup if preset configuration does not match actual configuration" parameter is disabled, the ET 200AL distributed I/O system does not start up.

The diagnostic "Slot x no module" or "Slot x wrong module" is generated.

If the IM 157-1 DP interface module does not start up in this status, the RUN and ERROR LEDs on the interface module flash red. The DIAG LEDs flash green on all I/O modules as well.

Required steps

Enable the "Allow to reconfigure the device via the user program" parameter when configuring the interface module.

- The parameter "Enable reconfiguration of device via user program" is located in the properties of the interface module under "Module parameters" > "Configuration control".

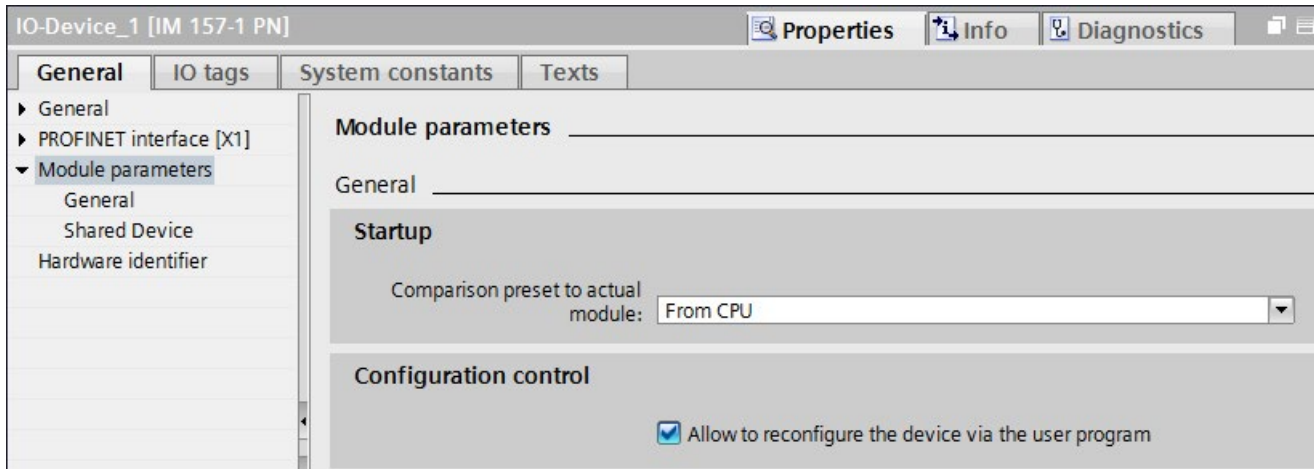


Figure 7-2 Enabling configuration control using the IM 157-1 PN as an example

7.3 Creating the control data record

7.3.1 Introduction

Required steps

The following description shows as an example how you can create a control data record for the configuration control in STEP 7 (TIA Portal).

To create a control data record for the configuration control, follow these steps:

1. Create a PLC data type that contains the structure of the control data record for an ET 200AL interface module.

You can find the structure of the control data record in section Control data record for the ET 200AL distributed I/O system (Page 55)

CTR_REC									
	Name	Data type	Default value	A...	W...	V...	S...	Comment	
1	Block_Lenght	USInt	76	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
2	Block_ID	USInt	196	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
3	Version	USInt	2	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
4	Subversion	USInt	1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
5	ET-Connection1	Struct		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	ET-Connection1 slots 2-17	
6	Topology module	USInt	1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	ET-Connection1 topology module	
7	Reserved 1	USInt	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
8	Slot 2	USInt	2	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	assigned "real" slot	
9	Reserved 2	USInt	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
10	Slot 3	USInt	3	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	assigned "real" slot	
11	Reserved 3	USInt	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
12	Slot 4	USInt	4	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	assigned "real" slot	
13	Reserved 4	USInt	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
14	Slot 5	USInt	5	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	assigned "real" slot	
15	Reserved 5	USInt	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
		USInt	6	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	assigned "real" slot	

Figure 7-3 Creating control data record 196

2. Create a global data block.

7.3 Creating the control data record

3. Create an array of the data type of the above created PLC data type in the data block.

The following figure shows a data block containing the control data records for an ET200AL interface module. In this example the data block contains three control data records.

ConfDB									
	Name	Data type	Start value	R...	A...	V...	S...	Comment	
1	Static			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
2	Option	Int	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Selection of record	
3	ConfigControl	Array[0..2] of "CTR_REC"		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
4	ConfigControl[0]	"CTR_REC"		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
5	ConfigControl[1]	"CTR_REC"		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
6	Block_Lenght	USInt	36	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	4+number of slots	

Figure 7-4 Data block for configuration control

4. In the "Start value" column of the control data records, enter which module is located at which slot.

ConfDB									
	Name	Data type	Start v...	R...	Comment	
1	Static			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
2	Option	Int	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Selection of record	
3	ConfigControl	Array[0..2] of "CTR_REC"		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
4	ConfigControl[0]	"CTR_REC"		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
5	Block_Lenght	USInt	76	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
6	Block_ID	USInt	196	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
7	Version	USInt	2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
8	Subversion	USInt	1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
9	ET-Connection1	Struct		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	ET-Connection1 slots 2-17	
10	Topology ...	USInt	1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	ET-Connection1 topology module	
11	Reserved 1	USInt	0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
12	Slot 2	USInt	0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	assigned "real" slot	
13	Reserved 2	USInt	0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
14	Slot 3	USInt	2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	assigned "real" slot	
15	Reserved 3	USInt	0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
16	Slot 4	USInt	3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	assigned "real" slot	

Figure 7-5 Assigning slots

Rules

Observe the following rules:

- Slot entries in the control data record outside the station master are ignored by the interface module.
- The control data record must contain the entries up to the last slot of the station option.
- Each slot of a station option may only be present once in the control data record.
- Each slot of a station option may only be assigned to one slot in the station master.
- The interface module (slot 0) is not an element of the configuration control, but instead controls this.
- The topology modules always have to exist in the data record:
 - The topology module ET-Connection 1 is always located on Slot 1.
 - The topology module ET-Connection 2 is always located on Slot 18.

7.3.2 Control data record for the ET 200AL distributed I/O system

Slot assignment

Note

Topology modules ET-Connection1 and ET-Connection2

Both topology modules ET-Connection1 and ET-Connection2 should be treated like real modules during configuration control.

Restriction: ET-Connection1 is always placed in Slot 1 and ET-Connection2 is always placed in Slot 18.

The following table shows the possible slots for the various modules for an ET 200AL interface module:

Table 7- 1 Slot assignment

Modules	Possible slots	Comment
Topology ET-Connection1	1	The topology module ET-Connection 1 is always located on Slot 1.
I/O modules ET-Connection1	2-17	-
Topology module ET-Connection2	18	The topology module ET-Connection2 is always located on Slot 18.
I/O modules ET-Connection2	19-34	-

Control data record

For configuration control of the ET 200AL distributed I/O system you define a control data record 196 V2.1, which contains a slot assignment for the modules. The table below shows the structure of a control data record with explanations of the individual elements.

Table 7- 2 Configuration control: Structure of control data record 196

Byte	Element	Code	Explanation
0	Block length	4 + (number of slots x 2)	Header
1	Block ID	196	
2	Version	2	
3	Subversion	1	
4	Slot topology module ET-Connection1	1 The topology module ET-Connection 1 is always located on Slot 1.	<p>Control element</p> <p>Contains information on which module is inserted in which slot.</p> <p>The following rule determines which value you must enter in the respective byte:</p> <ul style="list-style-type: none"> • If the module is included in the station option, enter the slot number of the module. • If the module does not exist in the station option, enter 0.
5	Reserved		
6	Slot 2 of the station master	Slot assignment in the station option	
7	Reserved		
:	:	:	
38	Slot topology module ET-Connection2	18 The topology module ET-Connection2 is always located on Slot 18	
39	Reserved		
40	Slot 19 of the station master	Slot assignment in the station option	
41	Reserved		
:	:	:	
4 + ((max. slot - 1) x 2))	Maximum slot of the station master	Slot assignment in the station option	
5 + ((max. slot - 1) x 2))	Reserved		

Combination of configuration control and shared device (for PROFINET)

The configuration control function in a shared device is therefore only for the I/O modules of the IO controller to which the interface module has subscribed. I/O modules that are assigned to no controller or a different controller behave like a station without activated configuration control.

In the control data record change the slots only for those modules that are assigned to the IO-Controller.

In the control data record do not move modules to slots that are assigned to a different IO controller or no IO controller. The interface module does not check whether a control data record 196 exists for these slots. The interface module assumes a 1-to-1 assignment for these slots.

Combination of configuration control and PROFlenergy (at PROFINET)

You can use configuration control together with PROFlenergy for the ET 200AL distributed I/O system.

Ensure that you use the slots of the used station option when creating Data record 3. Do not use the slots configured in the station master.

Example: You want to set up PROFlenergy for a DQ module of an IM 157-1 PN that works with configuration control. You have configured the DQ module to Slot 5 in the station master. You have moved the DQ module to Slot 2 in the station option. In order to set up PROFlenergy for this module use Slot 2 in Data record 3.

You can find more information about PROFlenergy in the Interface module IM 157-1 PN (<https://support.industry.siemens.com/cs/ww/en/view/89254863>) Equipment Manual.

7.3.3 Feedback data record at the ET200AL distributed I/O system

Operating principle

The feedback data record informs you about the accuracy of the module assignment and gives you the option of detecting assignment errors in the control data record. The feedback data record is mapped via a separate data record 197 V2.0.

Feedback data record

The feedback data record exists only when configuration control is configured and always refers to the maximum configuration limits **without interface module**, i.e., 34 slots. Partial reading of the feedback data record is possible.

Table 7- 3 Feedback data record

Byte	Element	Code	Explanation
0	Block length	66	Header
1	Block ID	197	
2	Version	2	
3		0	
4	Slot 1 status	0/1	Status = 1: <ul style="list-style-type: none"> • Module from station master is inserted in the station option • Slot is marked as not available in the control data record Status = 0: <ul style="list-style-type: none"> • Module pulled • Incorrect module inserted in the station option*
5	Reserved	0	
6	Status slot 2	0/1	
7	Reserved	0	
:	:	:	
70	Status Slot 34	0/1	
71	Reserved	0	

* Not possible if the slot is marked as not available.

Note

The data in the feedback data record is always mapped for all modules. In a Shared Device configuration, it is therefore irrelevant which IO controller the respective modules are assigned to.

As long as no control data record was sent, a one-to-one module assignment is assumed for the compilation of data record 197 (station master → station option).

Error messages

In the case of an error when reading the feedback data record, the RDREC instruction returns the following error messages via the STATUS block parameter:

Table 7- 4 Error messages

Error code	Meaning
80B1 _H	Invalid length; the length information in data record 197 is not correct.
80B5 _H	Configuration control not configured
80B8 _H	Parameter error The following events cause a parameter error: <ul style="list-style-type: none"> • Incorrect block ID in the header (not equal to 197) • Invalid version identifier in the header • A reserved bit was set • Multiple slots in the station master are assigned to the same slot in the station option

7.3.4 Example of a configuration control

Introduction

Several options/functional variations often exist for machines designed as series products. Or you have a plant that can operate in different modes. Combine the modules that are needed for a function. With configuration control (option handling), you have the option to switch these functions on and off or expand their configuration.

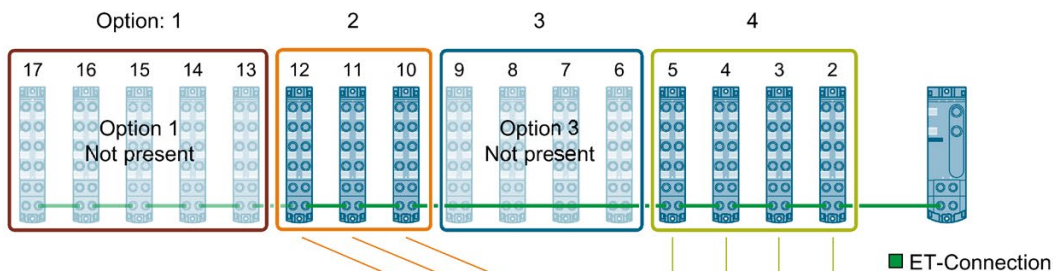
The following examples show how you can form the control data record for a station option. The station master consists of an interface module IM 157-1 PN and 15 I/O modules in this case.

Station option with associated control data record

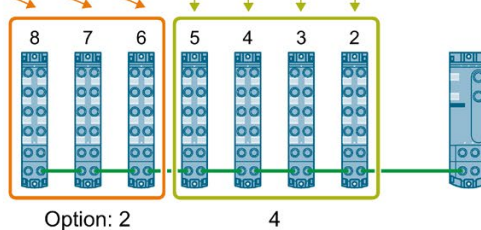
The configuration with the station options 2 and 4 differ from the station master as follows:

- The modules for options 1 and 3 do not exist.

Planned configuration / station master



Real configuration/
Station options



9	ET-Connection1	Struct		ET-Connection1 slots 2-17
10	Topology ...	USInt	1	ET-Connection1 topology module
11	Reserved 1	USInt	0	
12	Slot 2	USInt	2	assigned "real" slot
13	Reserved 2	USInt	0	
14	Slot 3	USInt	3	assigned "real" slot
15	Reserved 3	USInt	0	
16	Slot 4	USInt	4	assigned "real" slot
17	Reserved 4	USInt	0	
18	Slot 5	USInt	5	assigned "real" slot
19	Reserved 5	USInt	0	
20	Slot 6	USInt	0	assigned "real" slot
21	Reserved 6	USInt	0	
22	Slot 7	USInt	0	assigned "real" slot
23	Reserved 7	USInt	0	
24	Slot 8	USInt	0	assigned "real" slot
25	Reserved 8	USInt	0	
26	Slot 9	USInt	0	assigned "real" slot
27	Reserved 9	USInt	0	
28	Slot 10	USInt	6	assigned "real" slot
29	Reserved 10	USInt	0	
30	Slot 11	USInt	7	assigned "real" slot
31	Reserved 11	USInt	0	
32	Slot 12	USInt	8	assigned "real" slot
33	Reserved 12	USInt	0	
34	Slot 13	USInt	0	assigned "real" slot
35	Reserved 13	USInt	0	
36	Slot 14	USInt	0	assigned "real" slot
37	Reserved 14	USInt	0	
38	Slot 15	USInt	0	assigned "real" slot
39	Reserved 15	USInt	0	
40	Slot 16	USInt	0	assigned "real" slot
41	Reserved 16	USInt	0	
42	Slot 17	USInt	0	assigned "real" slot
43	Reserved 17	USInt	0	

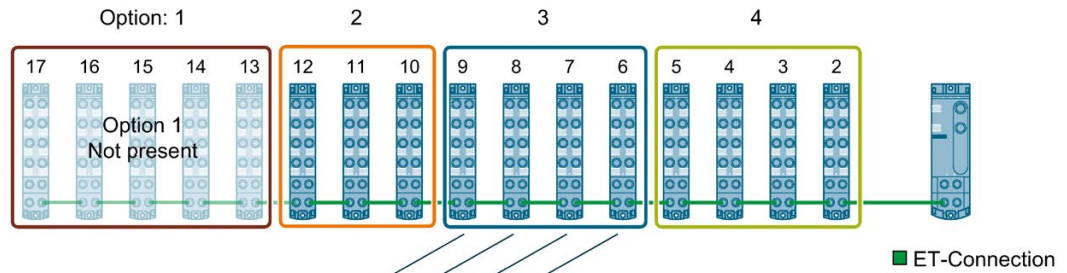
Figure 7-6 Example: Hardware configuration of Station option 2 and 4 with the associated control data record in STEP 7

Extension by a station option

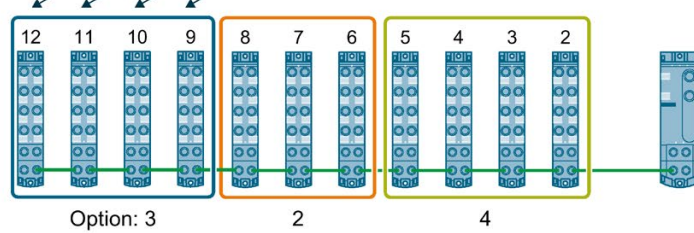
The following figure shows the configuration with the Station options 2 and 4 that has subsequently been extended by the Station option 3.

The modules of option 3 are added to the modules already existing.

Planned configuration / station master



Real configuration/
Station options



10	ET-Connection1	Struct		ET-Connection1 slots 2-17
11	Topology module	USInt	1	ET-Connection1 topology module
12	Reserved 1	USInt	0	
13	Slot 2	USInt	2	assigned "real" slot
14	Reserved 2	USInt	0	
15	Slot 3	USInt	3	assigned "real" slot
16	Reserved 3	USInt	0	
17	Slot 4	USInt	4	assigned "real" slot
18	Reserved 4	USInt	0	
19	Slot 5	USInt	5	assigned "real" slot
20	Reserved 5	USInt	0	
21	Slot 6	USInt	9	assigned "real" slot
22	Reserved 6	USInt	0	
23	Slot 7	USInt	10	assigned "real" slot
24	Reserved 7	USInt	0	
25	Slot 8	USInt	11	assigned "real" slot
26	Reserved 8	USInt	0	
27	Slot 9	USInt	12	assigned "real" slot
28	Reserved 9	USInt	0	
29	Slot 10	USInt	6	assigned "real" slot
30	Reserved 10	USInt	0	
31	Slot 11	USInt	7	assigned "real" slot
32	Reserved 11	USInt	0	
33	Slot 12	USInt	8	assigned "real" slot
34	Reserved 12	USInt	0	
35	Slot 13	USInt		assigned "real" slot

Figure 7-7 Example: Hardware configuration of station option 2 to 4 with the associated control data record in STEP 7

Detailed application example

You can find a detailed application example for the configuration control in S7-1500 in here under the keyword "Application example for ET 200SP (PROFINET) and S7-1500 based on the library" on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/29430270>).

7.4 Transferring the control data record in the user program of the CPU

Required steps

Transfer the created control data record 196 to the interface module using the WRREC (Write data record) instruction.

Parameters of the WRREC instruction

Below, you will find explanations of individual parameters of the WRREC instruction which you must supply with specific values in the configuration control context. You can find additional information on the WRREC instruction in the STEP 7 online help.

ID	HW identifier of the interface module. If you have selected the interface module in the network view or device view, the HW identifier is available in the System constants tab of the Inspector window. Use the value of the system constant "<Name_of_interface_module> Head".
INDEX	Data record number: 196 (decimal)
RECORD	Control data record to be transferred. You can find the structure of the control data record in section Control data record for the ET 200AL distributed I/O system (Page 55).

Selection of the station option in the user program

In order for the CPU to know which station option you want to operate, you must set up a possibility to select between the various control data records in the user program. You can implement the selection, for example, via an Int tag that references an array element. Note that the tag for selecting the control data record must be located in the retentive memory area. If the tag is not retentive, it will be initialized during startup of the CPU and will thus be unavailable for selection of the station option.

Special requirements relating to the transfer of the control data record to the interface module

- If you have enabled configuration control, the ET 200AL station is not ready for operation without a control data record. As long as no valid control data record has been transferred, the I/O modules are considered as failed by the CPU and exhibit substitute value behavior. The interface module continues to exchange data.
- The control data record is stored retentively in the interface module. Note:
 - If the configuration is unchanged, you do not have to rewrite the control data record 196 during restart.
 - If you write a control data record with modified configuration, this will result in a station failure in the distributed I/O system. The original data record 196 is deleted and the new data record 196 is saved retentively. The station will then restart with the modified configuration.

Error messages

In case of error, the WRREC instruction returns the following error messages via the STATUS block parameter:

Table 7- 5 Error messages

Error code	Meaning
80B1 _H	Invalid length; the length information in data record 196 is not correct.
80B2 _H	Invalid slot: The configured slot is not assigned
80B5 _H	Configuration control parameters not assigned.
80B8 _H	Parameter error Reasons for a parameter error are: <ul style="list-style-type: none"> • Incorrect block ID in the header (not equal to 196) • Invalid version identifier in the header • A reserved bit was set • A station master slot was assigned an invalid slot in the station option • Multiple slots in the station master are assigned to the same slot in the station option • For shared device on submodule level: violation of defined restrictions
80C5 _H	DP slave or module not available. Indicates that a data record has not been acknowledged due to the system.

If you receive the error code 80A2_H, 80B2_H or 80C5_H when writing to control data record 196, check whether the required configuration was accepted despite the error code.

7.5 Behavior during operation

Effect of discrepancy between station master and station option

For the online display and for the display in the diagnostics buffer (module OK or module faulty), the station master is always used and not the differing station option.

Example: A module outputs diagnostics data. This module is configured in slot 4 in the station master, but is inserted in slot 3 in the station option (missing module; see example in the next section). The online view (station master) shows an incorrect module in slot 4. In the real configuration, the module in slot 3 indicates an error via an LED display.

Response to modules that are not present

If modules are entered as not present in the control data record, the automation system behaves as follows:

- Modules designated as not present in the control data record do not supply diagnostics and their status is always OK. The value status is OK.
- Direct writing access to the outputs that are not present or writing access to the process image of outputs that are not present: Remains without effect; no access error is signaled.
- Direct reading access to the inputs that are not present or reading access to the process image of inputs that are not present: Value "0" is supplied; no access error is signaled.
- Write data record to module that is not present: Remains without effect; no error is signaled.
- Read data record from module that is not present: The output parameter STATUS of the instruction RDREC supplies the value 80A3_H "General CM error".

Commissioning

8.1 PROFINET IO

8.1.1 Commissioning ET 200AL on PROFINET IO

Introduction

The commissioning of your distributed I/O system depends on the system configuration. The following procedure describes the commissioning of the ET 200AL distributed I/O system on an IO controller.

Requirements for the ET 200AL distributed I/O system on the PROFINET IO

Note

Performing tests

You must ensure the safety of your plant. You therefore need to perform a complete functional test and the necessary safety checks before the final commissioning of a plant.

Also plan the tests to include any possible foreseeable errors. This will allow you to prevent people or plants from being placed in danger during operation.

Procedure

The following table shows the chapters/documents in which the required actions are described.

Table 8- 1 Requirements for the ET 200AL distributed I/O system on the PROFINET IO

Step	Procedure	See...
1	Mounting the ET 200AL interface module	Section Mounting (Page 20)
2	Wiring the ET 200AL interface module	Section Connecting (Page 25)
3	Configuring the ET 200AL interface module	Section Configuring (Page 44)
4	Turning on the supply voltage for the ET 200AL interface module	IM 157-1 PN interface module (https://support.industry.siemens.com/cs/ww/en/view/89254863) manual
5	ET 200AL interface module automatically switches to RUN mode	-

Reference

You can find additional information on assigning the PROFINET IO parameters in the PROFINET with STEP 7 V14

(<https://support.industry.siemens.com/cs/ww/en/view/49948856>) function manual.

8.1.2 Startup on PROFINET IO

Principle of operation

The figure below schematically shows the startup of the ET 200AL distributed I/O system on the PROFINET IO (= IO device) as a flow chart.

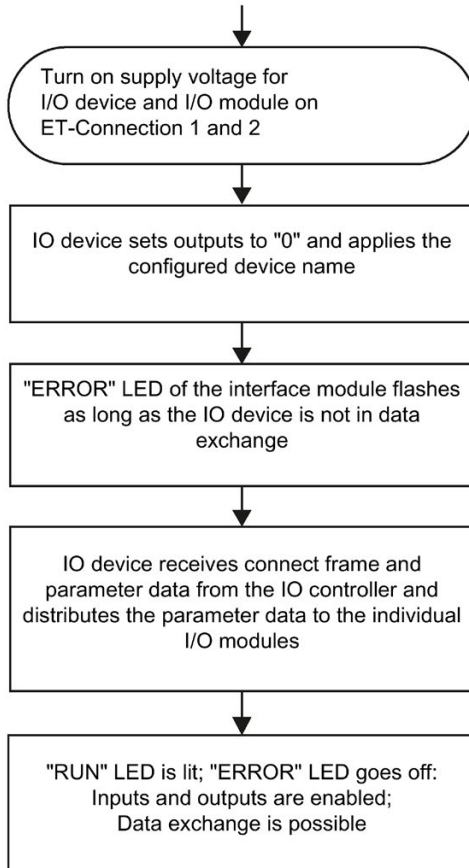


Figure 8-1 Startup of the ET 200AL distributed I/O system on the PROFINET IO

The figure below schematically shows the startup of an ET 200AL I/O module after an ET 200AL PROFINET interface module.

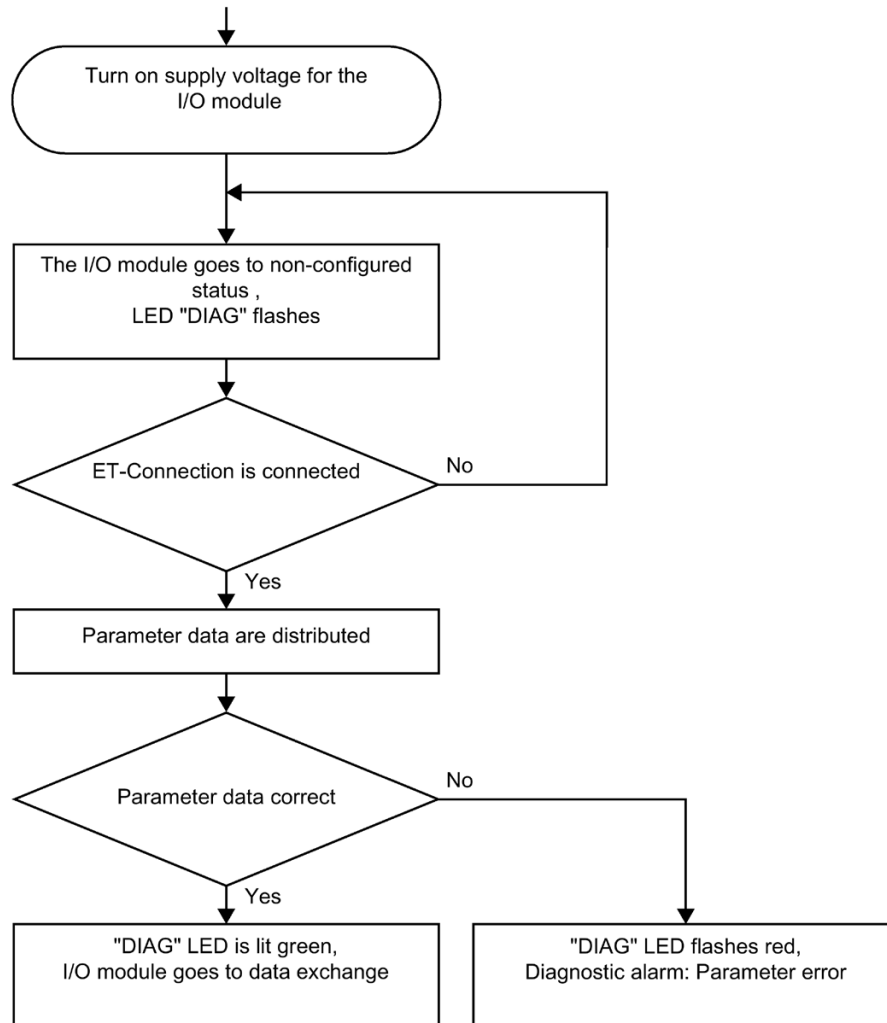


Figure 8-2 Startup of the ET 200AL I/O module

8.1.3 PROFIenergy

PROFIenergy (for PROFINET) makes it possible to reduce the energy consumption of the device using the PROFIenergy command during production downtime.

Additional information

You will find more information on the Internet (<http://www.profibus.com>) under Common Application Profile PROFIenergy; Technical Specification for PROFINET; as well as in the following documentation:

- IM 157-1 PN interface module
(<https://support.industry.siemens.com/cs/ww/en/view/89254863>) manual
- I/O modules (<https://support.industry.siemens.com/cs/ww/en/ps/14247/man>) manuals
- PROFINET System Description
(<https://support.industry.siemens.com/cs/ww/en/view/19292127>) system manual
- PROFINET with STEP 7 V14
(<https://support.industry.siemens.com/cs/ww/en/view/49948856>), function manual, Section: Saving energy with PROFIenergy
- Application guide for implementation of shutdown concepts with PROFIenergy.
(<https://support.industry.siemens.com/cs/ww/en/view/96837137>)
- Saving energy with SIMATIC S7 (STEP 7 as of V5.5)
(<https://support.industry.siemens.com/cs/ww/en/view/41986454>)
- Saving energy with SIMATIC S7 and SIMATIC HMI (TIA Portal)
(<https://support.industry.siemens.com/cs/ww/en/view/58235225>)
- SIMATIC S7 library for simple configuration of PROFIenergy.
(<https://support.industry.siemens.com/cs/ww/en/view/109478388>)
- You can find additional information on the PROFIenergy FBs ("PE_START_END" - FB 815, "PE_CMD" - FB 816) in the online help for STEP 7 V5.5 as of SP2, Help on system functions/function blocks.

8.2 PROFIBUS DP

8.2.1 Commissioning ET 200AL on PROFIBUS DP

Introduction

The commissioning of your distributed I/O system depends on the system configuration. The following procedure describes the commissioning of the ET 200AL distributed I/O system on a DP master.

Requirements for the ET 200AL distributed I/O system on a PROFIBUS DP

Note

Performing tests

You must ensure the safety of your plant. You therefore need to perform a complete functional test and the necessary safety checks before the final commissioning of a plant.

Also plan the tests to include any possible foreseeable errors. This helps to avoid endangering persons or equipment during operation.

Procedure

The following table shows the chapters/documents in which the required actions are described.

Table 8- 2 Requirements for the ET 200AL distributed I/O system on a PROFIBUS DP

Step	Procedure	See...
1	Mounting the ET 200AL interface module	Section Mounting (Page 20)
2	Setting the PROFIBUS DP address on the ET 200AL PROFIBUS interface module	IM 157-1 DP interface module (https://support.industry.siemens.com/cs/ww/en/view/89255073) manual, section Setting the PROFIBUS DP address and terminating resistor
3	Wiring the ET 200AL interface module	Section Connecting (Page 25)
4	Configuring the ET 200AL interface module	Section Configuring (Page 44)
5	Turning on the supply voltage for the ET 200AL interface module	IM 157-1 DP interface module (https://support.industry.siemens.com/cs/ww/en/view/89255073) manual
6	ET 200AL interface module automatically switches to RUN mode	-

8.2.2 Startup on PROFIBUS DP

Principle of operation

The figure below schematically shows the startup of the ET 200AL distributed I/O system on the PROFIBUS DP (= DP slave) as a flow chart.

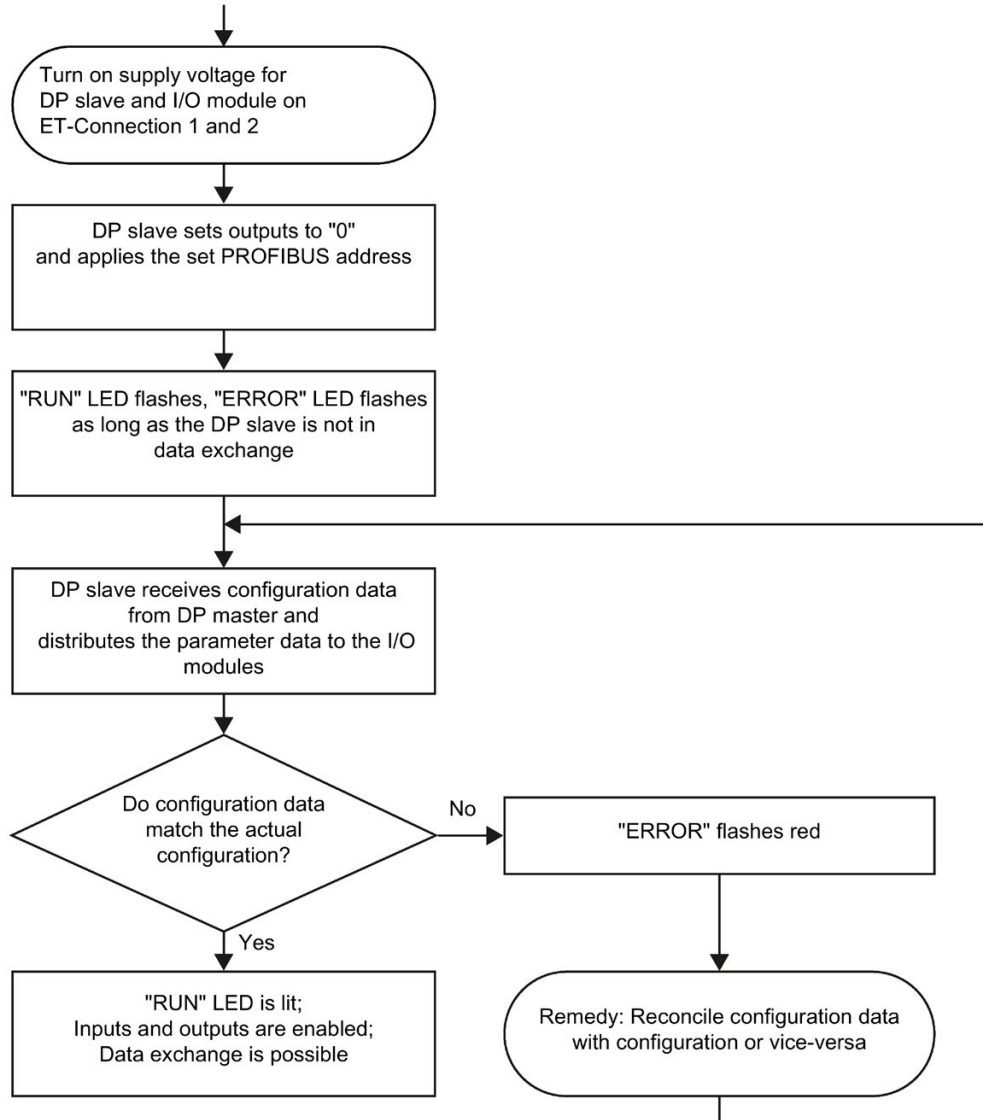


Figure 8-3 Startup of the ET 200AL distributed I/O system on PROFIBUS DP

The figure below schematically shows the startup of an ET 200AL I/O module after an ET 200AL PROFIBUS interface module as flow chart.

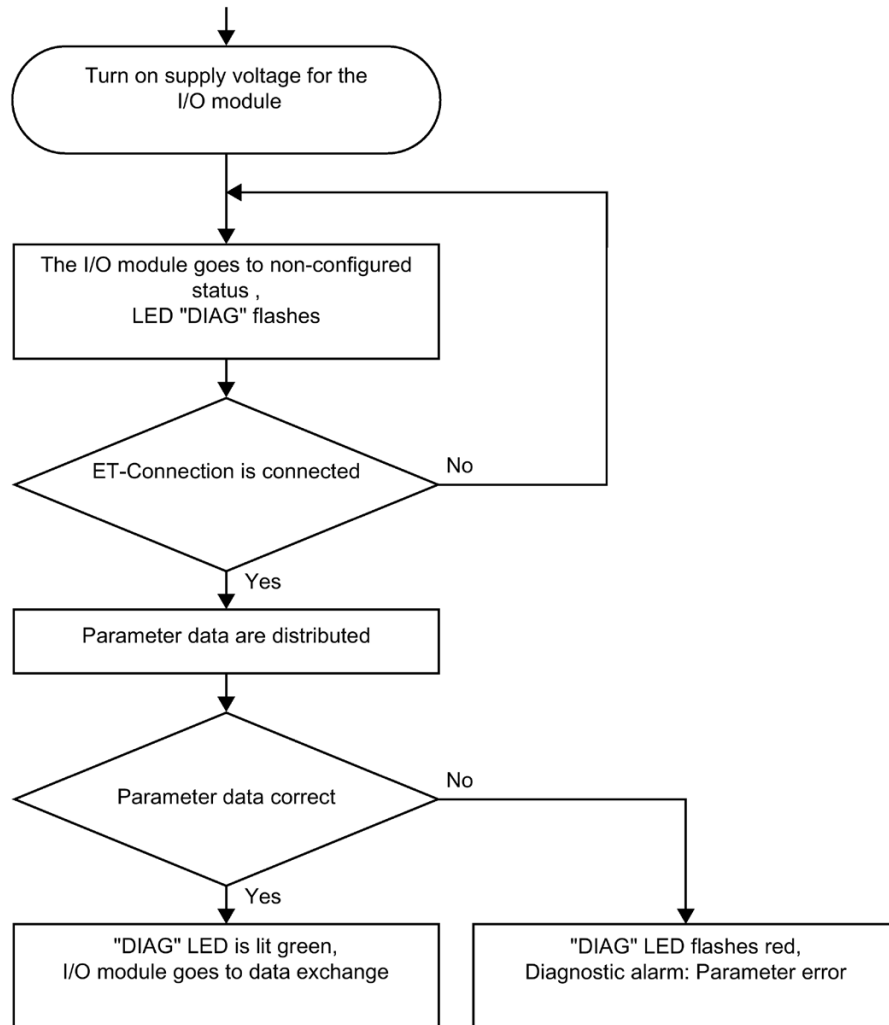


Figure 8-4 Startup of an ET 200AL I/O module

8.3 Identification and maintenance data

8.3.1 Reading out and entering I&M data

Introduction

Identification data I&M is information that is saved either as read-only (I data) or read/write (M data) on the interface module.

Identification data (I&M0): Manufacturer information on the module that is read-only and in some cases is also printed on the module housing, for example, article number, serial number and firmware version.

Maintenance data (I&M1, 2, 3): Plant-dependent information, e.g. installation location. Maintenance data is created during configuration and written to the module.

All modules of the ET 200AL distributed I/O system support identification data (I&M0 to I&M3).

The I&M identification data supports you in the following activities:

- Checking the plant configuration
- Locating hardware changes in a system
- Correcting errors in a system

With the I&M identification data, you have the option of clearly identifying modules online.

In STEP 7, the identification data is displayed in the "Module status - IM 157" and "Properties..." tabs (see STEP 7 online help).

Options for reading out I&M data

You have the following options for reading the I&M data:

- Via the user program
- Via STEP 7 or HMI devices

Procedure for reading I&M data by means of the user program

To read the I&M data of the interface module in the user program, use the instruction "RDREC".

Procedure for reading the I&M data using STEP 7

Requirement: There must be an online connection to the interface module.

1. In the project navigation, under "Distributed I/O", select the I/O device or the DP slave, e.g. "IM 157-1 PN".
2. Select: **IO device/DP slave > Online & Diagnostics > Identification & Maintenance.**

Procedure for input of maintenance data using STEP 7

The default module name is assigned by STEP 7. You have the option to enter the following data:

- Plant designation (I&M1)
- Location identifier (I&M1)
- Installation date (I&M2)
- Additional information (I&M3)
- Signature (I&M4), only for PROFINET

To enter the data, follow these steps:

1. In the device view of the STEP 7 hardware network editor, select the interface module, for example.
2. In the properties under "General", select the "Identification & Maintenance" area and enter the data.

During the loading of the hardware configuration, the I&M data are also loaded.

Reference

You can find additional information on I&M data of the ET 200SP (mixed configuration) in the ET 200SP distributed I/O system (<https://support.industry.siemens.com/cs/ww/en/view/58649293>) system manual.

8.3.2 Data record structure for I&M data

Reading I&M data records (distributed via PROFINET IO)

You can directly access specific identification data by selecting **Read data record** ("RDREC" instruction). You obtain the corresponding part of the identification data under the associated data record index.

The following table shows the principle behind the structure of data records.

Table 8- 3 Basic structure of data records with I&M identification data

Contents	Length (bytes)	Coding (hex)
Header information		
BlockType	2	I&M0: 0020 _H I&M1: 0021 _H I&M2: 0022 _H I&M3: 0023 _H I&M4: 0024 _H
BlockLength	2	I&M0: 0038 _H I&M1: 0038 _H I&M2: 0012 _H I&M3: 0038 _H I&M4: 0038 _H
BlockVersionHigh	1	01
BlockVersionLow	1	00
Identification data		
Identification data (see table below)	54	I&M0/Index AFF0 _H
	54	I&M1/Index AFF1 _H
	16	I&M2/Index AFF2 _H
	54	I&M3/Index AFF3 _H
	54	I&M4/Index AFF4 _H

The following table shows the structure of data records for I&M identification data.

Table 8- 4 Data record structure for I&M identification data

Identification data	Access	Default	Explanation
Identification data 0: (data record index AFF0 hex)			
VendorIDHigh	read (1 byte)	00H	This is where the name of the manufacturer is stored (42D = SIEMENS AG).
VendorIDLow	read (1 byte)	2AH	
Order_ID	read (20 bytes)	6ES7157-1AB00-0AB0	Order number of the module (e.g. of PROFINET interface module)
IM_SERIAL_NUMBER	read (16 bytes)	-	Serial number (device-specific)
IM_HARDWARE_REVISION	read (2 bytes)	1	Corresponding hardware version
IM_SOFTWARE_REVISION	read	Firmware version	Provides information about the firmware version of the module
• SWRevisionPrefix	(1 byte)	V	
• IM_SWRevision_Functional_Enhancement	(1 byte)	00 - FF _H	
• IM_SWRevision_Bug_Fix	(1 byte)	00 - FF _H	
• IM_SWRevision_Internal_Change	(1 byte)	00 - FF _H	
IM_REVISION_COUNTER	read (2 bytes)	0000 _H	provides information about configured changes on the module (not used)
IM_PROFILE_ID	read (2 bytes)	0000 _H	Generic device
IM_PROFILE_SPECIFIC_TYPE	read (2 bytes)	0005 _H	Interface modules
IM_VERSION	read	0101 _H	provides information about the version of the identification data (0101 _H = Version 1.1)
• IM_Version_Major	(1 byte)		
• IM_Version_Minor	(1 byte)		
IM_SUPPORTED	read (2 bytes)	001E _H	provides information about the existing identification data (I&M1 though I&M4)
Maintenance data 1: (data record index AFF1 hex)			
IM_TAG_FUNCTION	Read/write (32 bytes)	-	Enter an identifier for the module here, that is unique plant-wide.
IM_TAG_LOCATION	Read/write (22 bytes)	-	Enter the installation location of the module here.
Maintenance data 2: (data record index AFF2 hex)			
IM_DATE	Read/write (16 bytes)	YYYY-MM-DD HH:MM	Enter the installation date of the module here.
Maintenance data 3: (data record index AFF3 hex)			
IM_DESCRIPTOR	Read/write (54 bytes)	-	Enter a comment describing the module.

Reading I&M data records with data record 255 (distributed via PROFIBUS DP)

The modules support standardized access to identification data using DR 255 (index 65000 to 65003). For additional information on the DR 255 data structure, refer to the specifications of the Profile Guideline - Order No. 3.502.

Maintenance

9.1 Replacing modules

Replacing modules

Replacing a module is not permitted during ongoing operation.

 **WARNING**

Material damage can occur

If you remove/insert modules with the power connected, this can lead to undefined states in your system.

Material damage to the ET 200AL distributed I/O system may occur as a result.

Only remove or replace modules when the power is disconnected.

Always comply with the required standards and safety guidelines when configuring a system.

 **WARNING**

Mixing up ET-Connection1 and ET-Connection2

When connecting the modules, always ensure that they are properly connected.

If you mix up the lines for ET-Connection1 and ET-Connection2 when connecting the modules, this can lead to undefined states in your system.

Behavior of ET-Connection

During ongoing operation, a module replacement may be necessary, e.g. because the module is defective. If an I/O module fails in an ET-Connection line, the line remains active up to the failed I/O module. After replacing the I/O module, the ET-Connection line starts up by itself.

Procedure

To replace a module, proceed as follows:

1. Disconnect the supply voltage to the module to be replaced.
2. Completely remove all cables connected to the module.
3. Completely remove the fixing screws of the module

4. Replace the module.

Note

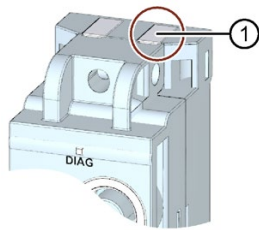
"New" module

The removed module may only be replaced by a module of the same type.

5. Fasten the module with a torque of 1.2 Nm.
6. Connect all cables.
7. Turn the supply voltage on.

<p>! WARNING</p> <p>Pay attention to the slot number of the module</p> <p>If you mix up the ET 200AL I/O modules when connecting them, this can cause personal injury and damage to the machine.</p> <p>The ET 200AL distributed I/O system cannot distinguish between modules of the same type during the actual/target comparison.</p> <p>We recommend that you clearly label the ET 200AL I/O modules with the slot number.</p>
--

The figure below shows a recommendation for labeling the ET 200AL I/O modules with the slot number.



- ① Recommendation for labeling the slot number

Figure 9-1 Slot number

Result

The disconnected I/O module and all downstream I/O modules start up again by themselves.

9.2 Firmware update

Introduction

During operation, it can become necessary to update the firmware (e.g. for function extensions).

Firmware updates are used to update the firmware of the interface module and I/O modules.

Note

Temporary bus interruption

When you perform a firmware update of an ET 200AL I/O module, then the ET-Connection is temporarily interrupted due to the restart of I/O module. All downstream ET 200AL I/O modules report a pull/plug interrupt.

Options for the firmware update

There are two ways to perform a firmware update:

- Online with STEP 7, V5.5 or higher
- Online with STEP 7, TIA Portal V13 or higher

Reference

You can find additional information on the procedure in the FAQs on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/88778936>) and in the online help for STEP 7.

9.3 Resetting interface module to factory settings (PROFINET)

Introduction

When you "Reset to factory settings", the interface module is reset to the delivery state settings. This means that all information that was saved internally on the interface module is deleted.

Result after resetting to factory settings

The following table shows an overview of the contents of the saved items after resetting to factory settings.

Table 9- 1 Result after resetting to factory settings

Memory object	Contents
IP address	Deleted (configurable when resetting: "Retain IP address"/ "Delete IP address")
Device name	Deleted
MAC address	Is not deleted
Identification data (I&M0)	Is not deleted
Maintenance data (I&M1, 2, 3, 4)	Are deleted (optional)
Firmware version	Is not deleted

Note

Failure of downstream stations is possible

Resetting an interface module to factory settings can lead to failure of downstream stations in a line.

Note

Substitute value behavior of I/O modules when resetting to factory settings

When "Resetting to factory settings", the I/O modules in the station take on the non-configured state, which means input data are not entered and output data are not output.

Reset options

There are two ways to reset an interface module to factory settings:

- Online with STEP 7 (TIA Portal)
- Online with STEP 7, V5.5 or higher

Requirement

You need an online connection to reset an interface module to factory settings.

Procedure with STEP 7 (TIA Portal)

Connect the PG/PC to the PROFINET IO interface of the ET 200AL distributed I/O system.

Make sure that there is an online connection to the interface module which is to be reset to factory settings.

1. Open the online and diagnostics view of the interface module.
2. In the "Functions" folder, select the "Reset to factory settings" group.
3. Select the "Retain IP address" option button if you want to retain the IP address, or the "Reset IP address" option button if you want to delete the IP address.
4. Click the "Reset" button.
5. Click "OK" in response to the confirmation prompts.

Result: The interface module performs the "Reset to factory settings" while the RUN LED flashes yellow. When the RUN LED is lit yellow, the interface module has been reset to factory settings and is in the STOP operating mode. The event "Reset to factory settings" is entered in the diagnostics buffer.

Procedure with STEP 7 V5.5 or higher

Connect the PG/PC to the PROFINET IO interface of the ET 200AL distributed I/O system.

Make sure that there is an online connection to the interface module which is to be reset to factory settings.

1. Open the SIMATIC Manager.
2. Select accessible devices.
3. Select the interface module.
4. Navigate through "Menu > Options > Edit Ethernet devices > Reset to factor settings > Reset".

Result: The interface module performs the "Reset to factory settings" while the RUN LED flashes yellow. When the RUN LED is lit yellow, the interface module has been reset to factory settings and is in the STOP operating mode. The event "Reset to factory settings" is entered in the diagnostics buffer.

Reference

You will find more information on the procedure in the STEP 7 online help.

9.4 Cleaning modules

When wired, ET 200AL modules comply with degree of protection IP65/IP67 and do not require any cleaning. If you do have to clean the modules, then use a dry or damp cloth. Please take care to comply with degree of protection IP65/67 when cleaning with liquids.

Technical specifications

Introduction

The technical specifications of the system are found in this section:

- The standards and test values that the ET 200AL distributed I/O system complies with and fulfills.
- The test criteria according to which the ET 200AL distributed I/O system was tested.

Technical specifications for the modules

The technical data of the individual modules can be found in the modules' manuals. If there are discrepancies between the statements in this document and the product manuals, the statements in the product manuals take priority.

Reference

The certificates for the markings and approvals can be found on the Internet (<https://support.industry.siemens.com>).

10.1 Standards and authorizations

Currently valid markings and authorizations

Note**Details on the components of the ET 200AL distributed I/O system**

The currently valid markings and approvals are printed on the components of the ET 200AL distributed I/O system.

CE mark



The ET 200AL distributed I/O system fulfills the requirements and protection targets of the following directives and complies with the harmonized European standards (ES) which have been promulgated for programmable logic controllers in the official gazettes of the European Community:

- 2014/30/EU "Electromagnetic Compatibility" (EMC directive)
- 2011/65/EU "Restriction of the use of certain hazardous substances in electrical and electronic equipment" (RoHS Directive)

The EC declarations of conformity are available to the responsible authorities at:

Siemens AG
Digital Factory

Factory Automation
DI FA AS SYS
Postfach 1963
D-92209 Amberg

These are also available for download on the Customer Support Internet pages, under the keyword "Declaration of Conformity".

UL approval



Underwriters Laboratories Inc. in accordance with

- UL 61010-2-201
- UL/CSA 61010-1 (Process Control Equipment)
- UL50/NEMA250 Enclosure Type 4X, Indoor use only, watertight

RCM Declaration of conformity for Australia/New Zealand



The ET 200AL distributed I/O system meets the requirements of EN 61000-6-4:2007 Generic standards – Emission standard for industrial environments.

Korea Certificate KCC-REM-S49-ET200



Please note that this device corresponds to limit class A with regard to the emission of radio interference. This device can be used in all areas, except residential areas.

이 기기는 업무용(A급) 전자파 적합기기로서 판매자 또는 사용자는 이 점을 주의하시기
바라며 가정 외의 지역에서 사용하는 것을 목적으로 합니다.

Marking for the Eurasian Customs Union



EAC (Eurasian Conformity)

Customs Union of Russia, Belarus and Kazakhstan

Declaration of conformity with the technical requirements of the Customs Union (TR CU)

IEC 61131-2

The ET 200AL distributed I/O system meets the requirements and criteria of standard IEC 61131-2, excluding the requirements mentioned in section 11 to 14 (programmable logic controllers, part 2: Equipment requirements and tests).

IEC 61010-2-201

The ET 200AL distributed I/O system fulfills the requirements and criteria of standard IEC 61010-2-201.

PROFINET standard

The interface module IM 157-1 PN based on standard IEC 61158 Type 10.

PROFIBUS standard

The interface module IM 157-1 DP based on standard IEC 61158 Type 3.

Marine approval

Classification societies:

- ABS (American Bureau of Shipping)
- BV (Bureau Veritas)
- DNV-GL (Det Norske Veritas - Germanischer Lloyd)
- LRS (Lloyds Register of Shipping)
- Class NK (Nippon Kaiji Kyokai)

IO-Link standard

The communication module CM 4xIO-Link 4xM12 based on standard IEC 61131-9.

Industrial use

The ET 200AL distributed I/O system is suitable for use in industrial environments. It meets the following standards for this type of use:

- Requirements on interference emission EN 61000-6-4: 2007 + A1: 2011
- Requirements on immunity EN 61000-6-2: 2005

Use in mixed areas

Under specific prerequisites you can use the ET 200AL distributed I/O system in a mixed area. A mixed area is used for residential purposes and for commercial operations that do not significantly impact the residential purpose.

If you want to use the ET 200AL distributed I/O system in mixed areas, you must ensure that its radio frequency interference emission complies with the limit classes of the EN 61000-6-3 generic standard. Suitable measures for observing these limits for use in a mixed area are, for example:

- Installation of the ET 200AL distributed I/O system in grounded control cabinets/control boxes
- Use of filters in supply cables

An additional individual acceptance test is also required.

Use in residential areas

Note

ET 200AL distributed I/O system not intended for use in residential areas

The ET 200AL distributed I/O system is not intended for use in residential areas. If you are using the ET 200AL distributed I/O system in residential areas, radio and TV reception may be affected.

Reference

The certificates for the markings and approvals can be found on the Internet under Service&Support (<http://www.siemens.com/automation/service&support>).

10.2 Electromagnetic compatibility

Definition

Electromagnetic compatibility is the ability of an electrical apparatus to function in a satisfactory manner in its electromagnetic environment without affecting this environment.

An I/O device of the ET 200AL distributed I/O system fulfills the requirements of the EMC law of the European Union. The requirement for this is that an I/O device of the ET 200AL distributed I/O system meets the specifications and guidelines for electrical configuration.

Pulse-shaped disturbance variables

The table below shows the electromagnetic compatibility of the distributed I/O systems compared to pulse-shaped disturbance variables.

Table 10- 1 Pulse-shaped disturbance variables

Pulse-shaped disturbance variable	Tested with	Corresponds to degree of severity
Electrostatic discharge according to IEC 61000-4-2.	Air discharge: ± 8 kV	3
	Contact discharge: ± 4 kV	2
Burst pulses (rapid transient disturbance values) according to IEC 61000-4-4.	± 2 kV (power supply cable)	3
	± 2 kV (PROFIBUS-/PROFINET line)	4
	± 1 kV (signal line <30 m)	3
	± 1 kV (ET-Connection)	3
High-energy surge according to IEC 61000-4-5.		
• Asymmetrical coupling	± 2 kV (24 V DC supply cable) with protective element	3
	± 0.5 kV (24 V DC supply cable) without protective element	1
	± 2 kV (PROFIBUS/PROFINET line) without protective element	3
• Symmetrical coupling	± 1 kV (24 V DC supply cable) with protective element	3
	± 0.5 kV (24 V DC supply cable) without protective element	2

Sinusoidal disturbance variables

The following tables show the electromagnetic compatibility of the distributed I/O systems to sinusoidal disturbance variables.

Table 10-2 RF radiation

RF radiation according to IEC 61000-4-3 Electromagnetic RF field, amplitude modulated		Corresponds to de- gree of severity
80 MHz to 1000 MHz	10 V/m	3
1.4 GHz to 6 GHz	3 V/m	2
80% AM (1 kHz)		

Table 10-3 RF coupling (signal and supply cables)

RF coupling according to IEC 61000-4-6.	Corresponds to de- gree of severity
0.15 MHz to 80 MHz	3
10 V _{rms} unmodulated	
80% AM (1 kHz)	
150 Ω source impedance	

Emission of radio frequency interference

The following table shows the interference emission of electromagnetic fields according to 55016: limit class A, group 1.

Table 10-4 Interference emission of electromagnetic fields

Frequency	Interference emission	Measuring distance
30 MHz to 230 MHz	<40 dB (μV/m) Q	10 m
230 MHz to 1000 MHz	<47 dB (μV/m) Q	10 m
1 GHz to 3 GHz	<76 dB (μV/m) P	3 m
3 GHz to 6 GHz	<80 dB (μV/m) P	3 m

24 V supply connection

The following table shows measurement ranges for low voltage according to EN 55016.

Table 10-5 Interference emission of electromagnetic fields

Frequency	Interference emission
0.15 MHz to 0.5 MHz	79 dB (μV) Q
	66 dB (μV) M
0.5 MHz to 30 MHz	73 dB (μV) Q
	60 dB (μV) M

10.3 Transport and storage conditions

Transport and storage conditions

The modules of the ET 200AL distributed I/O system exceed the specifications regarding transport and storage conditions pursuant to IEC 61131-2. The following table shows the conditions that apply to modules transported or stored in their original packaging.

Table 10- 6 Transport and storage conditions

Type of condition	Permissible range
Free fall	≤0.3 m
Temperature	-40 °C to +70 °C
Temperature variation	20 K/h
Barometric pressure	from 1140 hPa to 660 hPa (corresponds to a height of -1000 to 3500 m)
Relative humidity	from 5 to 95%

10.4 Mechanical and climatic ambient conditions

Operating conditions

The ET 200AL distributed I/O system is suitable for use in weather-proof, fixed locations. The conditions of use exceed the requirements pursuant to IEC 60721-3-3:

- Class 3M3 (mechanical requirements)
- Class 3K3 (climatic requirements)

Mechanical ambient conditions

The following table shows the mechanical ambient conditions, listed in sinusoid vibrations.

Table 10-7 Mechanical ambient conditions

Frequency band	Tested
5 Hz ≤ f ≤ 8 Hz	15 mm amplitude
8 Hz ≤ f ≤ 150 Hz	10g constant acceleration

Tests of mechanical ambient conditions

The following table shows the type and scope of the tests on mechanical ambient conditions.

Table 10-8 Tests of mechanical ambient conditions

Condition tested	Test standard	Values
Vibrations	Vibration test according to IEC 60068-2-6.	Type of oscillation: Frequency sweeps with a rate of change of 1 octave/minute. 5 Hz to 9.1 Hz, constant amplitude 15 mm 9.1 Hz to 150 Hz, constant acceleration 10g Duration of oscillation: 10 frequency sweeps per axis at each of three vertically aligned axes
Shock	Shock, tested according to IEC 60068-2-27	Type of shock: Half-sine Shock intensity: 30g peak value, 18 ms duration Direction of shock: 3 shocks each in ± direction in each of the 3 axes vertical to one another

Climatic ambient conditions

The following table shows the type and scope of the tests on climatic ambient conditions.

Table 10- 9 Climatic ambient conditions

Ambient conditions	Fields of application	Comments
Temperature	-25 °C to 55 °C	All installation positions
Temperature variation	10 K/h	-
Relative humidity	From 5 to 100%	With condensation
Barometric pressure	From 1140 hPa to 795 hPa	Corresponds to a height of - 1000 to 2000 m
Concentration of pollutants	ANSI/ISA-71.04 severity level G1; G2; G3	-

The following table shows the modules with functional versions which are permitted to - 30 °C.

Table 10- 10 Extended temperature range to -30 °C

Description	Article number	As of functional version
Interface modules ET 200AL		
IM 157-1 DP interface module	6ES7157-1AA00-0AB0	FS02
DI		
DI 8x24VDC, 8xM8	6ES7141-5BF00-0BA0	FS03
DI 8x24VDC, 4xM12	6ES7141-5AF00-0BA0	FS03
DI 16x24VDC, 8xM12	6ES7141-5AH00-0BA0	FS03
DQ		
DQ 8x24VDC/2A, 8xM12	6ES7142-5AF00-0BA0	FS03
DI/DQ		
DIQ 4+DQ 4x24VDC/0,5A, 8xM8	6ES7143-5BF00-0BA0	FS03
DIQ 4+DQ 4x24VDC/0,5A, 4xM12	6ES7143-5AF00-0BA0	FS03
DIQ 16x24VDC/0,5A, 8xM12	6ES7143-5AH00-0BA0	FS03
AI		
AI 4xU/I/RTD, 4xM12	6ES7144-5KD00-0BA0	FS04
AQ		
AQ 4xU/I, 4xM12	6ES7145-5ND00-0BA0	FS03
Communication modules		
CM 4xIO-LINK, 4xM12	6ES7147-5JD00-0BA0	FS05

10.5 Details on insulation, protection class, degree of protection and rated voltage

Insulation

The insulation is designed in compliance with the requirements of IEC 61010-2-201.

Note

Galvanic isolation with 707 V DC (Type Test) is tested for modules with 24 V DC supply voltage (SELV/PELV).

Pollution class according to IEC 61010-2-201

- Protection class III

Degree of protection IP65 and IP67

Degree of protection IP65 and IP67 according to IEC 60529 for all modules of the ET 200AL distributed I/O system:

- 1. Code number: Dust-proof and complete protection from contact
- 2. Code number: Protection from water
 - IP65: Protection from water jets from any angle (The water may not have any damaging effect)
 - IP67: Protection against temporary submersion (The water must not enter the enclosure in harmful quantities)

Rated voltage for operation










The following table shows the rated voltage and the corresponding tolerance with which the ET 200AL distributed I/O system operates.

Table 10- 11 Rated voltage for operation

Rated voltage (SELV/PELV)	Tolerance range
24 V DC	20.4 V to 28.8 V DC

10.6 Safety-related symbols for IP65/IP67 modules

The following table contains an explanation of the symbols located on your IP65/67 modules, their packaging or in the accompanying documentation.

Symbol	Meaning
	General warning sign Caution/Notice You must read the product documentation. The product documentation contains information about the type of potential hazard and enables you to recognize risks and implement countermeasures.
	The assigned safety symbols apply to devices with Ex approval . You must read the product documentation. The product documentation contains information about the type of potential hazard and enables you to recognize risks and implement countermeasures.
	Read the information provided by the product documentation. ISO 7010 M002
	Ensure the device is only installed by an electrically skilled person. IEC 60417 No. 6182
 CABLE SPEC.	Note that connected mains lines must be designed according to the expected minimum and maximum ambient temperature.
 EMC	Note that the device must be constructed and connected in accordance with EMC regulations.
 230V MODULES	Note that a 230 V device can be exposed to electrical voltages which can be dangerous. ANSI Z535.2
 24V MODULES	Note that a device of Protection Class III may only be supplied with a protective low voltage according to the standard SELV/PELV. IEC 60417-1-5180 "Class III equipment"
 INDOOR USE ONLY INDUSTRIAL USE ONLY	Be aware that the device is only approved for the industrial field and only for indoor use.

Safety-related shutdown of ET200AL standard modules



Introduction

The diagram below illustrates the fail-safe shutdown of ET 200AL standard modules.

In the configuration shown in the diagram below, all digital outputs that are operated with the 2L+ and 2M supply of the ET 200AL standard modules are switched to the safe OFF state. This step achieves the safety class SIL2/category 3/PLd.

Principle of operation

The higher-level safety relay (for example: 3SK1) disconnects the 2L+ and 2M supply. This switches all digital outputs operated with the 2L+ and 2M (switched) supply to the safe state. The digital outputs connected to the 1L+ and 1M (non-switched) supply are not intended for functional switching and therefore cannot be shut down safely.

There is no interaction between the outputs supplied by 1L+ and 2L+.

You can also integrate I/O modules that are operated solely at the supply 1L+ and 1M (non-switched) in the structure of your distributed I/O system. These I/O modules are not affected by a disconnection, they pass on the supply 2L+ and 2M (switched). The following figure shows the modules DI and AI as an example.

Block diagram

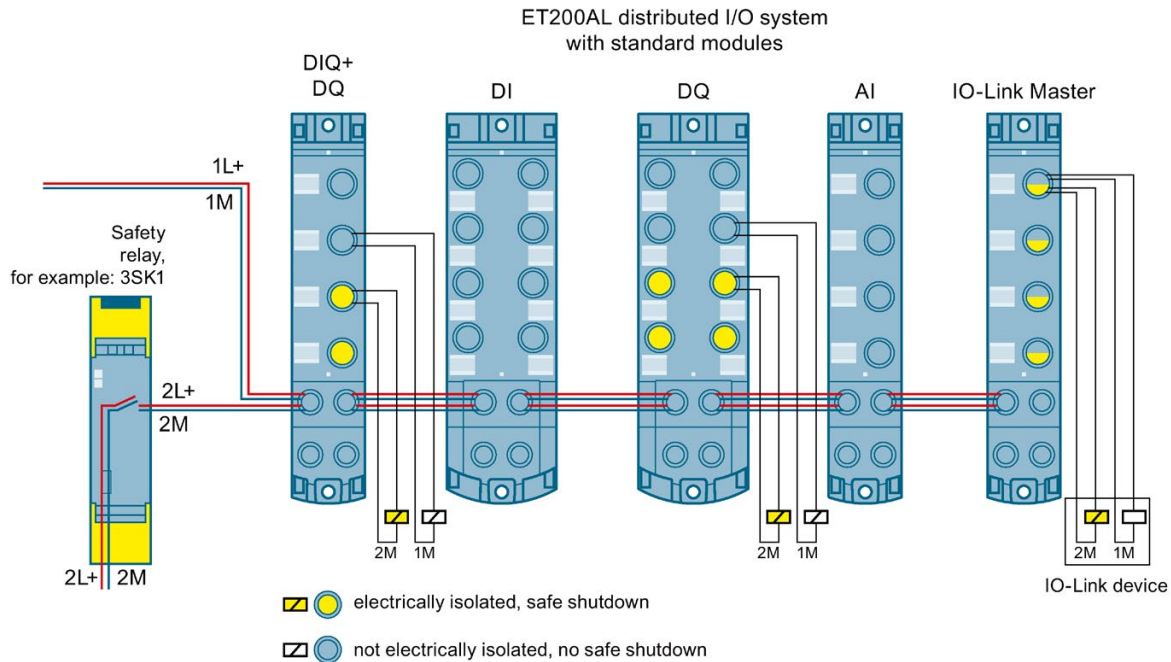


Figure A-1 Higher-level safety circuit with safety relay

Note

Usage of IO-Link devices

Please note that the IO-Link device must have corresponding safety characteristics in order to use safety-oriented tripping.

Requesting TÜV certificate (report no. SN89858T, Revision 1.1 of 10/11/2016)

You can request copies of the TÜV certificate and the accompanying report at the following address:

Siemens AG
 Digital Factory
 DI FA AS SYS
 Postfach 1963
 D-92209 Amberg

Reference

You can find additional information as well as an overview of the modules with safety-related shutdown on the Internet (<https://support.industry.siemens.com/cs/us/en/view/39198632>).

Dimension drawings

2 module widths are available with the distributed I/O system.

The figure below shows the height and width of the modules. The depth of the modules ranges from 40 mm to 46 mm. Detailed information on the dimensions of the individual modules can be found in the manuals for the Interface modules (<https://support.industry.siemens.com/cs/ww/en/ps/14246/man>) and I/O modules (<https://support.industry.siemens.com/cs/ww/en/ps/14247/man>) in the section "Dimension drawing".

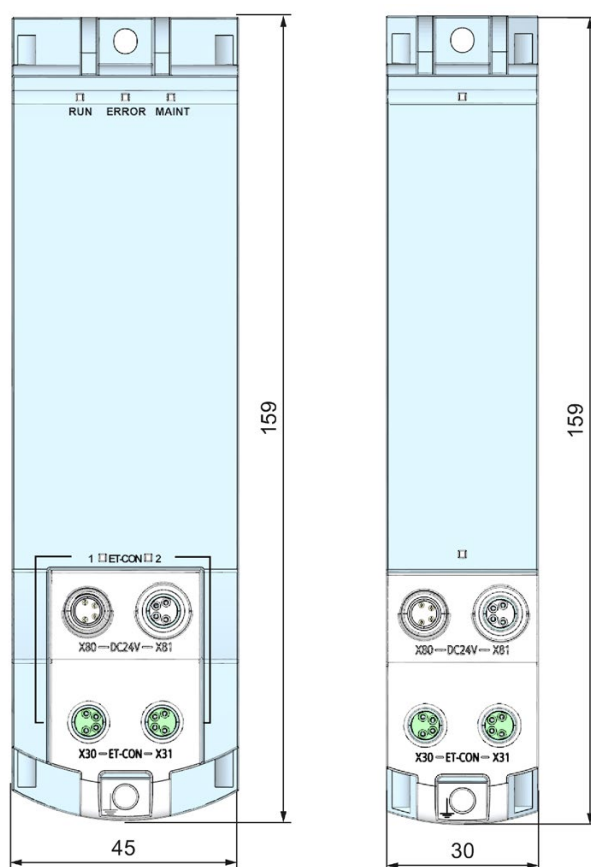


Figure B-1 Module dimension drawings (front view)

Accessories/spare parts

C.1 Accessories/spare parts

Accessories for the ET 200AL distributed I/O system

Table C- 1 Accessories for ET-Connection

Designation	Length	Article number	
		Standard	PUR
Cable			
Bus cable for ET-Connection M8, pre-assembled on both sides with 2 x M8 connectors, 4-pole, shielded	0.19 m	6ES7194-2LH02-0AA0	6ES7194-2MH02-0AA0
	0.3 m	6ES7194-2LH03-0AA0	6ES7194-2MH03-0AA0
	1.0 m	6ES7194-2LH10-0AA0	6ES7194-2MH10-0AA0
	2.0 m	6ES7194-2LH20-0AA0	6ES7194-2MH20-0AA0
	5.0 m	6ES7194-2LH50-0AA0	6ES7194-2MH50-0AA0
	10.0 m	6ES7194-2LN10-0AA0	6ES7194-2MN10-0AA0
	15.0 m	6ES7194-2LN15-0AA0	6ES7194-2MN15-0AA0
Bus cable for ET-Connection M8, pre-assembled on both sides with 2 x M8 connectors, angled, 4-pole, shielded	0.3 m	6ES7194-2LH03-0AB0	6ES7194-2MH03-0AB0
	1.0 m	6ES7194-2LH10-0AB0	6ES7194-2MH10-0AB0
	2.0 m	6ES7194-2LH20-0AB0	6ES7194-2MH20-0AB0
	5.0 m	6ES7194-2LH50-0AB0	6ES7194-2MH50-0AB0
	10.0 m	6ES7194-2LN10-0AB0	6ES7194-2MN10-0AB0
Bus cable for ET-Connection M8, pre-assembled on one side with 1 x M8 connector, 4-pole, shielded	2.0 m	6ES7194-2LH20-0AC0	6ES7194-2MH20-0AC0
	5.0 m	6ES7194-2LH50-0AC0	6ES7194-2MH50-0AC0
	10.0 m	6ES7194-2LN10-0AC0	6ES7194-2MN10-0AC0
	15.0 m	6ES7194-2LN15-0AC0	6ES7194-2MN15-0AC0
Connecting cable for bus cable ET-Connection M8, both ends assembled with 2x M8 socket, 4-pole, shielded	0.2 m	6ES7194-2LH02-0AD0	6ES7194-2MH02-0AD0
Connector			
M8 connector for ET-Connection, 4-pole, shielded		6ES7194-2AB00-0AA0	

Table C- 2 Accessories for power supply

Designation	Length	Article number	
		Standard	PUR
Cable			
Power cable M8, pre-assembled on both sides with M8 connector and M8 socket, 4-pole	0.19 m	6ES7194-2LH02-1AA0	6ES7194-2MH02-1AA0
	0.3 m	6ES7194-2LH03-1AA0	6ES7194-2MH03-1AA0
	1.0 m	6ES7194-2LH10-1AA0	6ES7194-2MH10-1AA0
	2.0 m	6ES7194-2LH20-1AA0	6ES7194-2MH20-1AA0
	5.0 m	6ES7194-2LH50-1AA0	6ES7194-2MH50-1AA0
	10.0 m	6ES7194-2LN10-1AA0	6ES7194-2MN10-1AA0
	15.0 m	6ES7194-2LN15-1AA0	6ES7194-2MN15-1AA0
Power cable M8, pre-assembled on both sides with angled M8 connector and angled M8 socket, 4-pole	0.3 m	6ES7194-2LH03-1AB0	6ES7194-2MH03-1AB0
	1.0 m	6ES7194-2LH10-1AB0	6ES7194-2MH10-1AB0
	2.0 m	6ES7194-2LH20-1AB0	6ES7194-2MH20-1AB0
	5.0 m	6ES7194-2LH50-1AB0	6ES7194-2MH50-1AB0
	10.0 m	6ES7194-2LN10-1AB0	6ES7194-2MN10-1AB0
	15.0 m	6ES7194-2LN15-1AB0	6ES7194-2MN15-1AB0
Power cable M8, pre-assembled on one side with M8 socket, 4-pole	2.0 m	6ES7194-2LH20-1AC0	6ES7194-2MH20-1AC0
	5.0 m	6ES7194-2LH50-1AC0	6ES7194-2MH50-1AC0
	10.0 m	6ES7194-2LN10-1AC0	6ES7194-2MN10-1AC0
	15.0 m	6ES7194-2LN15-1AC0	6ES7194-2MN15-1AC0
Connector			
M8 power connector, pin insert, 4-pole		6ES7194-2AA00-0AA0	
M8 power connector, socket insert, 4-pole		6ES7194-2AC00-0AA0	

Table C- 3 M12 connector

Designation		Article number
Non-preassembled connectors for X1 DP1 (pin)		
PROFIBUS M12 plug connector 180° with female insert		6GK1905-0EB00
PROFIBUS M12 plug connector FastConnect 180° with female insert		6GK1905-0EB10
PROFIBUS M12 plug connector, angled with female insert		3RK1902-1DA00
Non-preassembled connectors for X1 DP2 (socket)		
PROFIBUS M12 plug connector 180° with pin insert		6GK1905-0EA00
PROFIBUS M12 plug connector FastConnect 180° with pin insert		6GK1905-0EA10
PROFIBUS M12 plug connector angled with pin insert		3RK1902-1BA00
Non-preassembled connectors for X1 P1R PN (LAN) and X1 P2R PN (LAN) socket		
PROFINET M12 plug connector d-coded with FastConnect connection technology, 180	1 unit/ pack	6GK1901-0DB10-6AA0
	8 units/ pack	6GK1901-0DB10-6AA8
PROFINET M12 plug connector, D-coded with fast connect technology 180°	1 unit/ pack	6GK1901-0DB20-6AA0
	8 units/ pack	6GK1901-0DB20-6AA8
PROFINET M12 plug connector, D-coded, angled		3RK1902-2DA00

Table C- 4 Non-preassembled cable M12

Designation		Article number
Non-preassembled cable for X1 DP1 and X1 DP2		
PROFIBUS FC Cable		
FC Standard Cable		6XV1830-0EH10
FC Trailing Cable		6XV1830-3EH10
FC Food Cable (PE sheath)		6XV1830-0GH10
FC Robust Cable (PUR sheath)		6XV1830-0JH10
FC FRNC Cable (FRNC sheath)		6XV1830-0LH10
FC Underground Cable		6XV1830-3FH10
Festoon Cable GP (PVC sheath)		6XV1830-3GH10
FC Flexible Cable GP (PUR sheath)		6XV1831-2K
Non-preassembled connectors for X1 P1R PN (LAN) and X1 P2R PN (LAN)		
PROFIBUS FC Cable		
FC Standard Cable		6XV1840-2AH10
FC TP Trailing Cable		6XV1840-3AH10
FC TP Trailing Cable GP		6XV1870-2D
FC TP Marine Cable		6XV1840-4AH10
FC TP Torsion Cable		6XV1870-2F
FC TP Flexible Cable GP (PVC sheath)		6XV1870-2B
FC TP FRNC Cable (FRNC sheath)		6XV1871-2F
FC TP Food Cable (PE sheath)		6XV1871-2L
FC TP Festoon Cable GP (PVC sheath)		6XV1871-2S

Table C- 5 Pre-assembled cable M12

Designation	Article number	
Pre-assembled cable for X1 DP1 and X1 DP2		
PROFIBUS M12 connecting cable, trailing cable, pre-assembled on both sides with PROFIBUS M12 connectors, 180° (one end with socket, one end with pin)	0.3 m	6XV1830-3DE30
	0.5 m	6XV1830-3DE50
	1.0 m	6XV1830-3DH10
	1.5 m	6XV1830-3DH15
	2.0 m	6XV1830-3DH20
	3.0 m	6XV1830-3DH30
	5.0 m	6XV1830-3DH50
	10.0 m	6XV1830-3DN10
	15.0 m	6XV1830-3DN15
PROFIBUS M12 connecting cable, trailing cable, pre-assembled on both sides with PROFIBUS M12 connectors, angled (one end with socket, one end with pin)	1.5 m	6XV1830-3DH15-0SB0
	2.0 m	6XV1830-3DH20-0SB0
	3.0 m	3RK1902-1NB30
	5.0 m	3RK1902-1NB50
	10.0 m	3RK1902-1NC10
	15.0 m	6XV1830-3DN15-0SB0
Pre-assembled cable for X1 P1R PN (LAN) and X1 P2R PN (LAN)		
PROFINET M12 connecting cable, trailing cable, pre-assembled on both ends with M12 connectors 180° (pin)	0.3 m	6XV1870-8AE30
	0.5 m	6XV1870-8AE50
	1.0 m	6XV1870-8AH10
	1.5 m	6XV1870-8AH15
	2.0 m	6XV1870-8AH20
	3.0 m	6XV1870-8AH30
	5.0 m	6XV1870-8AH50
	10.0 m	6XV1870-8AN10
	15.0 m	6XV1870-8AN15
PROFINET M12 connecting cable, trailing cable, pre-assembled on both ends with M12 connectors, angled (pin)	0.3 m	6XV1870-8AE30-0SB0
	0.5 m	6XV1870-8AE50-0SB0
	1.0 m	6XV1870-8AH10-0SB0
	1.5 m	6XV1870-8AH15-0SB0
	2.0 m	6XV1870-8AH20-0SB0
	3.0 m	3RK1902-2NB30
	5.0 m	3RK1902-2NB50
	10.0 m	3RK1902-2NC10
	15.0 m	6XV1870-8AN15-0SB0
PROFINET M12 connecting cable, trailing cable, pre-assembled on both sides with PROFIBUS M12 connectors, angled (one end with pin, one end open)	3.0 m	3RK1902-2HB30
	5.0 m	3RK1902-2HB50
	10.0 m	3RK1902-2HC10
PROFINET M12 connecting cable, trailing cable, pre-assembled on one end with M12 connectors 180° (pin), other end with RJ45 plug 145°	2.0 m	6XV1871-5TH20
	3.0 m	6XV1871-5TH30
	5.0 m	6XV1871-5TH50
	10.0 m	6XV1871-5TN10
	15.0 m	6XV1871-5TN15

Table C- 6 Y cable

Description		Article number
SIMATIC DP, Y cable for distributed I/Os for double connection of I/Os using single cable, 5-pole, M12	0.2 m	6ES7194-6KA00-0XA0

Table C- 7 Additional accessories

Designation	Article number
Identification labels 10 x 5 mm RAL9016, composed of 200 labels on frames, per frame 40 labels	6ES7194-2BA00-0AA0
Sealing cap M8 for modules IP67	3RK1901-1PN00
Sealing cap M12 for modules IP67	3RX9802-0AA00
Bus connection plug PROFIBUS M12, pin insert, 5 units	6GK1905-0EC00
Stripping Tool for ET-Connection	6ES7194-2KA00-0AA0
Stripping Tool for PROFINET	6GK1901-1GA00
Stripping Tool for PROFIBUS	6GK1905-6AA00

Online catalog

Other article numbers for the ET 200AL distributed I/O system can be found on the Internet (<https://mall.industry.siemens.com>) in the online catalog and the online order system.

C.2 Cables

Cables for ET-Connection standard and PUR cable

The cables for ET-Connection are available in the following versions and lengths:

- Bus cable (4-wire), pre-assembled on both sides with 2 M8 connectors, 4-pole, shielded
 - available lengths: 0.19 m, 0.3 m, 1 m, 2 m, 5 m, 10 m, 15 m
- Bus cable (4-wire), pre-assembled on both sides with 2 M8 connectors, angled, 4-pole, shielded
 - available lengths: 0.3 m, 1 m, 2 m, 5 m, 10 m, 15 m
- Bus cable (4-wire), pre-assembled on one side 1x M8 connector, 4-pole, shielded
 - available lengths: 2 m, 5 m, 10 m, 15 m

The following table shows the technical properties of the bus cable ET-Connection standard.

Table C- 8 Cables for ET-Connection

General information	
Product type designation	BUS CABLE ET-CONNECTION
Function	To connect ET-CONNECTION devices with degree of protection IP65/IP67
Degree of protection and protection class	
IP65	Yes
IP67	Yes
Ambient conditions	
Ambient temperature during mounting	
minimum	-30 °C
maximum	80 °C
Storage/transport temperature	
Ambient temperature during transport and storage	
minimum	-40 °C
maximum	80 °C
Cables	
Cable designation	2Y(ST)CY 1x4x0.5/1.0-100-GN
Number of electrical wires	4
Design of shielding	Overlapped aluminum-lined sheet, coated with shielding made of tin plated copper wires
Outside diameter of the inner conductor	0.5 mm
Outside diameter of the wire insulation	1.0 mm
Outside diameter of the cable sheath	5 mm
Number of bending cycles	1000000; Trailing-chain suitable for 1 million bending cycles with a bending radius of 100 mm, a velocity of 4 m/s and an acceleration of 4 m/s ²
Permissible bending radius	
One time bending, min.	20 mm
Multiple bending, min.	40 mm
Constant bending	100 mm
Color of the cable sheath	Green
Color of the wire insulation of the data wires	White, yellow, blue, orange
Weight per length	34 kg/km
Mechanics/material	
Type of cable outlet	180° cable outlet 90° cable outlet (with angled connectors)
Number of connectors	1 or 2
Connector housing material	Metal
Wire insulation material	PE
Cable sheath material	PVC
Material property halogen free	No
Material property silicon free	Yes

* = Applies to cable lengths up to 10 meters.

The following table shows the technical properties of the bus cable ET-Connection, PUR cable.

Table C- 9 Cables for ET-Connection, PUR cable

General information	
Product type designation	BUS CABLE ET-CONNECTION, PUR CABLE
Function	To connect ET-CONNECTION devices with degree of protection IP65/IP67
Degree of protection and protection class	
IP65	Yes
IP67	Yes
Ambient conditions	
Ambient temperature during mounting	
minimum	-30 °C
maximum	80 °C
Storage/transport temperature	
Ambient temperature during transport and storage	
minimum	-40 °C
maximum	80 °C
Cables	
Cable designation	2Y(ST)C11Y 2x2x0.5/1.0-100-GN
Number of electrical wires	4
Design of shielding	Overlapped aluminum-lined sheet, coated with shielding made of tin plated copper wires
Outside diameter of the inner conductor	0.5 mm
Outside diameter of the wire insulation	1.0 mm
Outside diameter of the cable sheath	5 mm
Number of bending cycles	1000000*; trailing-chain suitable for 1 million bending cycles with a bending radius of 100 mm, a velocity of 4 m/s and an acceleration of 4 m/s ²
Permissible bending radius	
One time bending, min.	20 mm
Multiple bending, min.	40 mm
Constant bending	100 mm
Color of the cable sheath	Green
Color of the wire insulation of the data wires	White, yellow, blue, orange
Weight per length	34 kg/km
Mechanics/material	
Type of cable outlet	180° cable outlet 90° cable outlet (with angled connectors)
Number of connectors	1 or 2
Connector housing material	Metal
Wire insulation material	PE
Cable sheath material	PUR
Material property halogen free	Yes
Material property silicon free	Yes

* = Applies to cable lengths up to 10 meters.

Connecting cable for ET-Connection standard and PUR cable

You can use the connecting cable between two cables for ET-Connection.

Typical applications for using connecting cable for ET-Connection are:

- Combination of individual cable lengths by joining multiple pre-assembled cables for ET-Connection.
- Selective installation of disconnection points of cables for ET-Connection (for simple changing of cables and cable sections, e.g. with trailing-cable applications).

You can use a maximum of two connecting cables between the two modules.

The length of the cables for ET-Connection is limited to maximum 10 m when connecting cables are used.

The connecting cable for ET-Connection is available in the following design:

- Connecting cable for bus cable ET-Connection M8, both ends assembled with 2x M8 socket, 4-pole, shielded, length 0.2 m

The following table shows the technical properties of the connecting cable for ET-Connection standard.

Table C- 10 Connecting cables for ET-Connection

General information	
Product type designation	CONNECTING CABLE FOR BUS CABLE ET-CONNECTION, CABLE 0.2 M
Function	To connect two bus cables ET-CONNECTION
Degree of protection and protection class	
IP65	Yes
IP67	Yes
Ambient conditions	
Ambient temperature during mounting	
minimum	-30 °C
maximum	80 °C
Storage/transport temperature	
Ambient temperature during transport and storage	
minimum	-40 °C
maximum	80 °C
Cables	
Cable designation	2Y(ST)CY 1x4x0.5/1.0-100-GN
Number of electrical wires	4
Design of shielding	Overlapped aluminum-lined sheet, coated with shielding made of tin plated copper wires
Cable length	0.2 m
Outside diameter of the inner conductor	0.5 mm
Outside diameter of the wire insulation	1.0 mm
Outside diameter of the cable sheath	5 mm
Permissible bending radius	
One time bending, min.	20 mm
Multiple bending, min.	40 mm
Constant bending	100 mm
Color of the cable sheath	Green
Color of the wire insulation of the data wires	White, yellow, blue, orange
Weight per length	34 kg/km
Mechanics/material	
Type of cable outlet	180° cable outlet
Connector housing material	Metal
Wire insulation material	PE
Cable sheath material	PVC
Material property halogen free	No
Material property silicon free	Yes

The following table shows the technical properties of the connecting cable for ET-Connection, PUR cable.

Table C- 11 Connecting cables for ET-Connection, PUR cable

General information	
Product type designation	CONNECTING CABLE FOR BUS CABLE ET-CONNECTION, PUR CABLE 0.2 M
Function	To connect two bus cables ET-CONNECTION
Degree of protection and protection class	
IP65	Yes
IP67	Yes
Ambient conditions	
Ambient temperature during mounting	
minimum	-30 °C
maximum	80 °C
Storage/transport temperature	
Ambient temperature during transport and storage	
minimum	-40 °C
maximum	80 °C
Cables	
Cable designation	2Y(ST)C11Y 2x2x0.5/1.0-100-GN
Number of electrical wires	4
Design of shielding	Overlapped aluminum-lined sheet, coated with shielding made of tin plated copper wires
Cable length	0.2 m
Outside diameter of the inner conductor	0.5 mm
Outside diameter of the wire insulation	1.0 mm
Outside diameter of the cable sheath	5 mm
Permissible bending radius	
One time bending, min.	20 mm
Multiple bending, min.	40 mm
Constant bending	100 mm
Color of the cable sheath	Green
Color of the wire insulation of the data wires	White, yellow, blue, orange
Weight per length	34 kg/km
Mechanics/material	
Type of cable outlet	180° cable outlet
Connector housing material	Metal
Wire insulation material	PE
Cable sheath material	PUR
Material property halogen free	Yes
Material property silicon free	Yes

Cables of power supply standard and PUR cable

The cables for the power supply are available in the following versions and lengths:

- Power cable (4-wire), pre-assembled on both sides with a 4-pole M8 pin connector/socket connector
 - available lengths: 0.19 m, 0.3 m, 1 m, 2 m, 5 m, 10 m, 15 m
- Power cable (4-wire), pre-assembled on both sides with a 4-pole M8 pin connector/socket connector, angled
 - available lengths: 0.3 m, 1 m, 2 m, 5 m, 10 m, 15 m
- Power cable (4-wire), pre-assembled on one side with 1x M8 socket connector
 - available lengths: 2 m, 5 m, 10 m, 15 m

The following table shows the technical properties of the power supply cable, standard.

Table C- 12 Cables for power supply

General information	
Product type designation	POWER CABLE M8
Function	For connection of ET 200AL for 24 V DC power supply
Degree of protection and protection class	
IP65	Yes
IP67	Yes
Ambient conditions	
Ambient temperature during mounting	
minimum	-30 °C
maximum	80 °C
Storage/transport temperature	
Ambient temperature during transport and storage	
minimum	-40 °C
maximum	80 °C
Cables	
Cable designation	4 Li9Y 0.50 mm ² Y
Number of electrical wires	4
Outside diameter of the inner conductor	0.8 mm
Outside diameter of the wire insulation	1.46 mm
Outside diameter of the cable sheath	5.2 mm
Number of bending cycles	2500000; Trailing-chain suitable for 2.5 million bending cycles with a bending radius of 52 mm, a speed of 3 m/s ² and an acceleration of 10 m/s ²
Permissible bending radius	
One time bending, min.	26 mm
Multiple bending, min.	52 mm
Constant bending	52 mm
Color of the cable sheath	Gray

General information	
Color of the wire insulation of the power wires	White, brown, blue black
Weight per length	44 kg/km
Mechanics/material	
Type of cable outlet	180° cable outlet 90° cable outlet (with angled connectors)
Number of connectors	1 or 2
Connector housing material	Plastic
Wire insulation material	PP
Cable sheath material	PVC
Material property halogen free	No
Material property silicon free	Yes

The following table shows the technical properties of the power supply, PUR cable

Table C- 13 Cables for power supply, PUR cable

General information	
Product type designation	POWER CABLE M8, PUR CABLE
Function	For connection of ET 200AL for 24 V DC power supply
Degree of protection and protection class	
IP65	Yes
IP67	Yes
Ambient conditions	
Ambient temperature during mounting	
minimum	-30 °C
maximum	80 °C
Storage/transport temperature	
Ambient temperature during transport and storage	
minimum	-40 °C
maximum	80 °C
Cables	
Cable designation	LIF9Y11YFHF 4x0.50 mm ²
Number of electrical wires	4
Outside diameter of the inner conductor	1 mm
Outside diameter of the wire insulation	1.46 mm
Outside diameter of the cable sheath	5.1 mm
Number of bending cycles	2000000; trailing-chain suitable for 2 million bending cycles with a bending radius of 51 mm, a velocity of 5 m/s and an acceleration of 5 m/s ²
Permissible bending radius	
One time bending, min.	26 mm
Multiple bending, min.	51 mm
Constant bending	51 mm

General information	
Color of the cable sheath	Gray
Color of the wire insulation of the power wires	White, brown, blue black
Weight per length	44 kg/km
Mechanics/material	
Type of cable outlet	180° cable outlet 90° cable outlet (with angled connectors)
Number of connectors	1 or 2
Connector housing material	Plastic
Wire insulation material	PP
Cable sheath material	PE-PUR
Material property halogen free	Yes
Material property silicon free	Yes

C.3 Pin assignment and core color

Pin assignment of the sockets for ET-Connection

The tables below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

Table C- 14 Pin assignment for ET-Connection (interface modules)

Pin	Assignment		Assignment of the core color of the bus cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection1)	X31 socket (ET-Connection2)		X30	X31
1	RXP	RXP	yellow		
2	TXP	TXP	white		
3	TXN	TXN	blue		
4	RXN	RXN	orange		
Shielding	Functional earth FE		-		

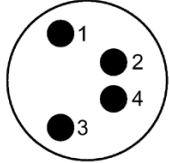
Table C- 15 Pin assignment for ET-Connection (I/O modules)

Pin	Assignment		Assignment of the core color of the bus cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	yellow		
2	RXP	TXP	white		
3	RXN	TXN	blue		
4	TXN	RXN	orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment for infeed of the supply voltage.

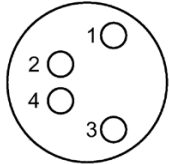
Table C- 16 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the core color of the power cable	Front view of the connector
	X80 connector (power input)		
1	Supply voltage 1L+ (non-switched)	brown	
2	Ground 2M (switched)	white	
3	Ground 1M (non-switched)	blue	
4	Load voltage 2L+ (switched)	black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment for loop-through of the supply voltage.

Table C- 17 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the core color of the power cable	Front view of the socket
	X81 Socket (power output)		
1	Supply voltage 1L+ (non-switched)	brown	
2	Ground 2M (switched)	white	
3	Ground 1M (non-switched)	blue	
4	Load voltage 2L+ (switched)	black	

Glossary

Bus

A common transfer route to which all devices are connected; it has two defined ends.

Configuration

Systematic arrangement of individual modules (design).

Connection plug

Physical connection between device and cable.

Device

Device that can send, receive or amplify data via the bus, e.g. IO device via PROFINET IO.

Diagnostics

Monitoring functions for the detection, localization, classification, display, and further evaluation of errors, faults, and alarms. They run automatically while the system is in operation. This increases the availability of systems by reducing commissioning times and downtimes.

Distributed I/O system

System with input and output modules that are configured on a distributed basis, far away from the CPU controlling them.

ET-Connection

Backplane bus through which a connection is made. This allows bus participants to be installed several meters from each other.

Firmware update

Upgrade of firmware for modules (interface modules, I/O modules etc.), e.g. after functional enhancements, to the newest firmware version (update).

Ground

Conductive earth whose electrical potential can be set equal to zero at any point.

All interconnected, inactive parts of a piece of equipment that cannot accept any dangerous contact voltage, even in the event of a fault.

Ground

Conductive earth whose electrical potential can be set equal to zero at any point.

All interconnected, inactive parts of a piece of equipment that cannot accept any dangerous contact voltage, even in the event of a fault.

GSD file

As a generic station description, this file in XML format has all the properties of a PROFINET or PROFIBUS device that are required for its configuration.

I/O modules

All modules that can be operated with a CPU or an interface module.

Identification data

Information that is saved in modules and that supports the user in checking the plant configuration and locating hardware changes.

Interface module

Module in the distributed I/O system. The interface module connects the distributed I/O system via a field bus with the CPU (I/O) controller and prepared the data for the/from the I/O modules.

Parameter assignment

Parameter assignment is the transfer of parameters from the IO controller to the IO device.

PELV

Protective **Extra Low Voltage** = protective extra-low voltage

PROFINET

PROcess Field NETwork, open Industrial Ethernet standard, which continues PROFIBUS and Industrial Ethernet. A cross-manufacturer communication, automation and engineering model, defined as an automation standard by PROFIBUS International e.V.

PROFINET IO controller

Device used to address connected I/O devices (e.g. distributed I/O systems). This means that: The IO controller exchanges input and output signals with assigned I/O devices. The IO controller often corresponds with the CPU in which the automation program is running.

PROFINET IO device

Distributed field device that can be assigned to one or more IO controllers (e.g. distributed I/O system, valve terminals, frequency converters, switches).

PROFINET IO

Communication concept for the realization of modular, distributed applications in the framework of PROFINET.

Reference potential

Potential from which the voltages of the circuits involved are observed and/or measured.

SELV

Safety Extra Low Voltage = Safety extra-low voltage

TIA Portal

Totally Integrated Automation Portal

The TIA Portal is the key to the full performance capability of Totally Integrated Automation. The software optimizes operating, machine and process sequences.

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SIEMENS

SIMATIC

ET 200SP

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Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

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Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Scope

This product information supplements the ET 200SP system manual documentation.

Security information

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security in the Internet (<http://www.siemens.com/industrialsecurity>).

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Application planning

Mixed configuration ET 200SP and ET 200AL with ET-Connection

You have the option of integrating the I/O modules of the ET 200AL distributed I/O system (IP65/IP67) in a configuration of the ET 200SP distributed I/O system (IP20).

The figure below shows a combination of the modules of the ET 200AL and ET 200SP distributed I/O system.

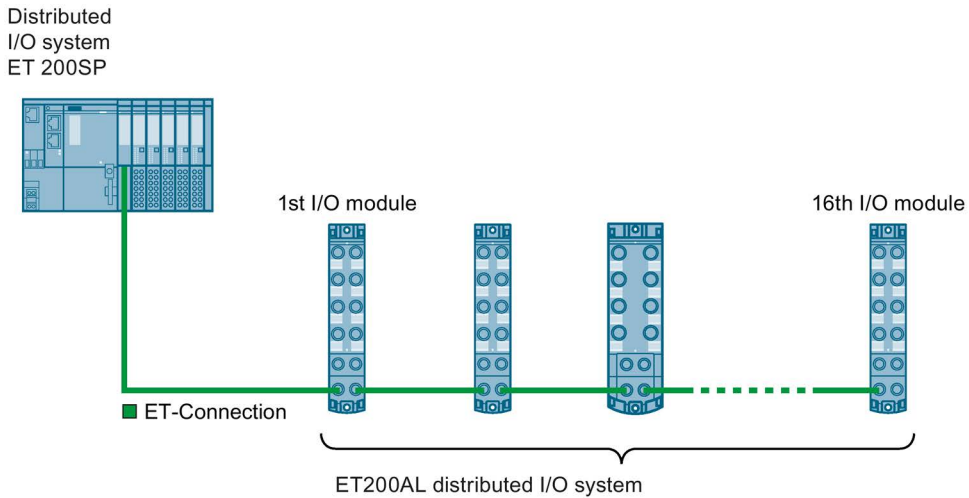


Image 1-1 Mixed configuration ET 200SP and ET 200AL with ET-Connection

Requirement

The following components support mixed configuration:

- Interface module
 - IM 155-6 PN HF (V3.0 or higher)
 - IM 155-6 PN ST (V3.1 or higher)
 - IM 155-6 DP HF (V3.0 or higher)
- CPU
 - CPU 1510SP-1 PN (V2.0 or higher)
 - CPU 1510SP F-1 PN (V2.0 or higher)
 - CPU 1512SP-1 PN (V2.0 or higher)
 - CPU 1512SP F-1 PN (V2.0 or higher)
- BaseUnit BU-Send with BusAdapter BA-Send 1xFC
- ET-Connection cable
- Power cable

Rules

You must observe the following rules when assembling a mixed configuration:

- The bus length of the ET 200SP distributed I/O system must not exceed 1 m (without interface module, including BU-Send/BA-Send 1xFC and server module)
- A maximum of 16 ET 200AL I/O modules can be connected to ET-Connection.
- The maximum length of the bus cable for ET-Connection between BA-Send and the first module or between two modules is 15 m.

The following table shows which firmware versions of your IM or CPU support which maximum bus cable length.

IM/CPU	2 m	5 m	10 m	15 m
IM 155-6 PN HF	V3.0 or higher	V3.0 or higher	V3.0 or higher	V3.3 or higher
IM 155-6 PN ST	V3.1 or higher	V3.1 or higher	V3.1 or higher	V3.3 or higher
IM 155-6 DP HF	V3.0 or higher	V3.0 or higher	V3.0 or higher	--
CPU 1510SP-1 PN	V2.0 or higher	V2.0 or higher	V2.0 or higher	V2.0 or higher
CPU 1510SP F-1 PN	V2.0 or higher	V2.0 or higher	V2.0 or higher	V2.0 or higher
CPU 1512SP-1 PN	V2.0 or higher	V2.0 or higher	V2.0 or higher	V2.0 or higher
CPU 1512SP F-1 PN	V2.0 or higher	V2.0 or higher	V2.0 or higher	V2.0 or higher

Procedure

To assemble a multi-tier configuration, follow these steps:

1. Install the BaseUnit BU-Send to the immediate right of the ET 200SP CPU/interface module.
When the BaseUnit BU-Send is used next to the ET 200SP CPU, a CM DP and an Ethernet CP or a maximum of 2 Ethernet CPs can be inserted between the CPU and BU-Send.
2. Then mount the additional BaseUnits / I/O modules for the ET 200SP distributed I/O system and the server module.
3. Connect the bus cable for ET-Connection to the BusAdapter BA-Send 1xFC and mount this on the BaseUnit BU-Send.
4. Screw the BusAdapter BA-Send 1xFC to the BaseUnit BU-Send (1 screw with 0.2 Nm tightening torque). To do this, use a screwdriver with a 3 to 3.5 mm blade.
5. Connect the other end of the bus cable for ET-Connection (with M8 connector) to the first ET 200AL I/O module (X30 socket ET-Connection IN).
6. Connect the supply voltage (24 V DC) to the ET 200AL I/O modules (X80 connector).

Note

Firmware update of an ET 200AL I/O module

When you run a firmware update of an ET 200AL I/O module, ET-Connection is briefly interrupted by the restart of the module. All downstream ET 200AL I/O modules report a pull/plug interrupt.

Mounting

Introduction

For the connection of the ET 200AL I/O module via ET-Connection to the ET 200SP, you require the BaseUnit BU-Send with the BusAdapter BA-Send 1xFC.

Requirement

- The mounting rail is mounted.
- The interface module is mounted.

Required tools

3 to 3.5 mm screwdriver (only for dismantling the BusAdapter)

Mounting BaseUnit BU-Send

To mount the BaseUnit BU-Send, follow these steps:

1. Mount the BU-Send to the right of the CPU/interface module.
2. Swivel the BU-Send back until you hear the mounting rail release click into place.
3. Move the BU-Send to the left until you hear it click into place on the CPU/interface module.

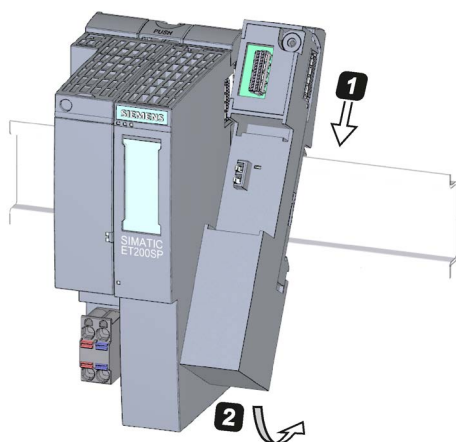


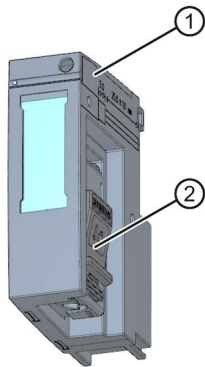
Image 2-1 Mounting BU-Send

4. Mount the BusAdapter BA-Send 1xFC only after you have connected the bus cable for ET-Connection (see section Connecting (Page 9)).

Connection

Introduction

You connect the ET 200AL I/O modules via the BusAdapter BA-Send 1×FC using ET-Connection.



- ① BusAdapter BA-Send 1×FC
- ② Connection element for ET-Connection bus cable

Image 3-1 BusAdapter BA-Send 1xFC

Required tools

Screwdriver with 3 to 3.5 mm blade

Required accessories

Use the bus cable for ET-Connection as connecting cable between the BusAdapter BA-Send 1xFC and the ET 200AL I/O modules.

We recommend using the stripping tool for ET-Connection (6ES7194-2KA00-0AA0) with blade cassette green (6GK1901-1B...). This guarantees fast and safe stripping.

The bus cable for ET-Connection M8, prefabricated on one side with 1 x M8 connector, 4-pole, shielded, is available in the following lengths:

- Length 2 m: 6ES7194-2LH20-0AC0
- Length 5 m: 6ES7194-2LH50-0AC0
- Length 10 m: 6ES7194-2LN10-0AC0
- Length 15 m: 6ES7194-2LN15-0AB0

Procedure

To connect the BusAdapter BA-Send 1xFC, follow these steps:

1. Strip the sheath of the bus cable at the open end as follows:

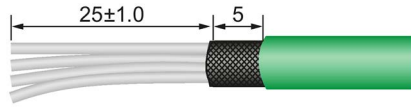
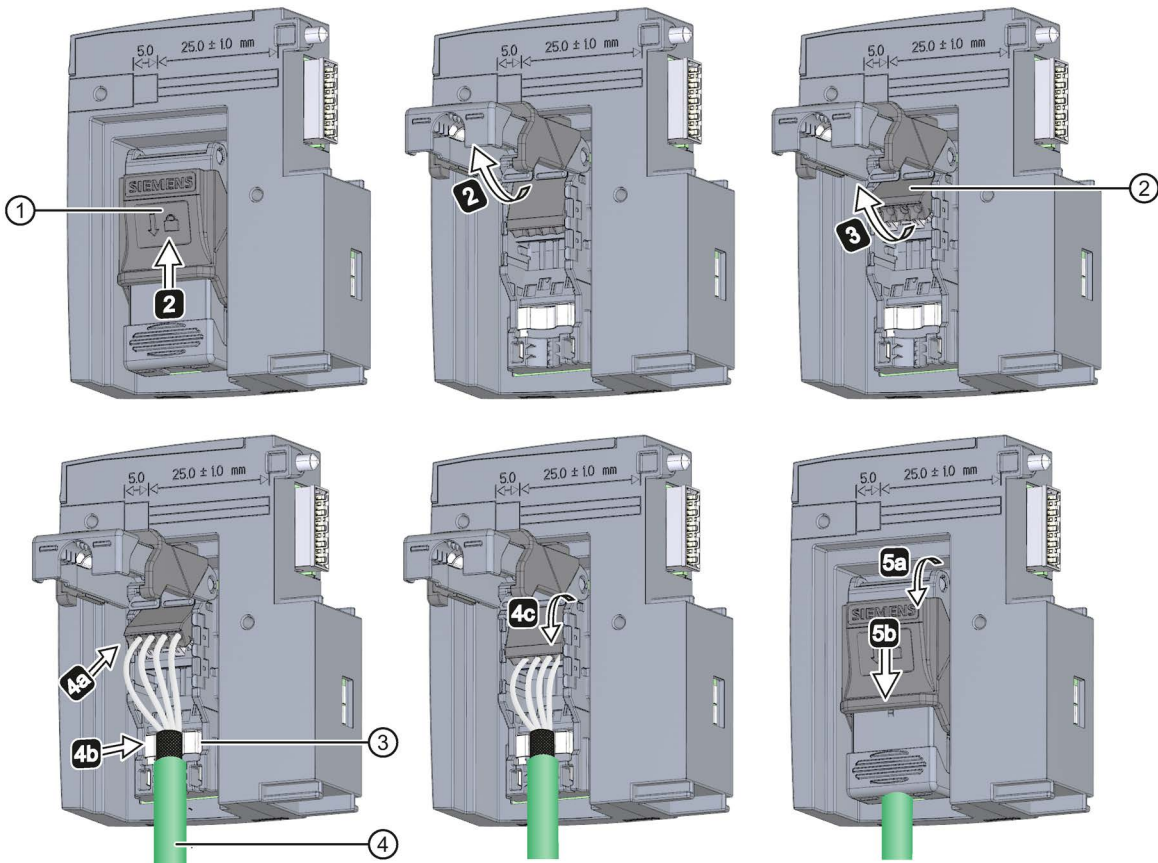


Image 3-2 Connecting cable

Use the stripping tool for ET-Connection to do this. The relevant settings are shown on the tool.

2. Pull back the locking slide of the BusAdapter BA-Send 1xFC and open the cover of the connection element.
3. Lift the cable routing up as far as it will go.
4. Insert the unstripped single cores of the bus cable (according to the imprinted color coding) into the cable routing as far as they will go and press the cable routing down as far as it will go.
5. Close the cover of the connection element and push the locking slide forward.

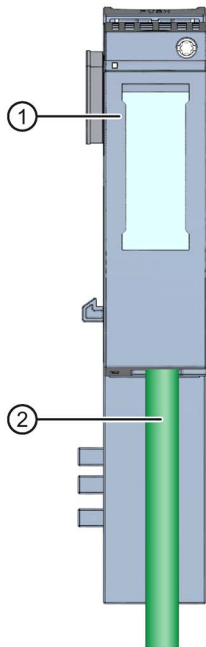
6. Connect and screw the BusAdapter BA-Send 1×FC to the BaseUnit BU-Send (1 screw with 0.2 Nm tightening torque.) To do this, use a screwdriver with a 3 to 3.5 mm blade.
7. Connect the M8 connector of the bus cable to the first ET 200AL I/O module (socket X30 ET-Connection IN). For more information about wiring the ET 200AL I/O module refer to the system manual of the ET 200AL distributed I/O system.



- | | | | |
|---|---------------|---|-----------------------------|
| ① | Locking slide | ③ | Shield contact |
| ② | Cable routing | ④ | Bus cable for ET-Connection |

Image 3-3 Connection of the BusAdapter BA-Send 1xFC

BusAdapter BA-Send 1×FC mounted



- ① BusAdapter BA-Send 1×FC
- ② Bus cable for ET-Connection

Image 3-4 BusAdapter BA-Send 1×FC mounted

Configuring

Introduction

The mixed configuration allows the connection of up to 16 ET 200AL I/O modules to the ET 200SP via ET-Connection. The figure below shows the configuration of the ET-Connection and the assignment of the slots.

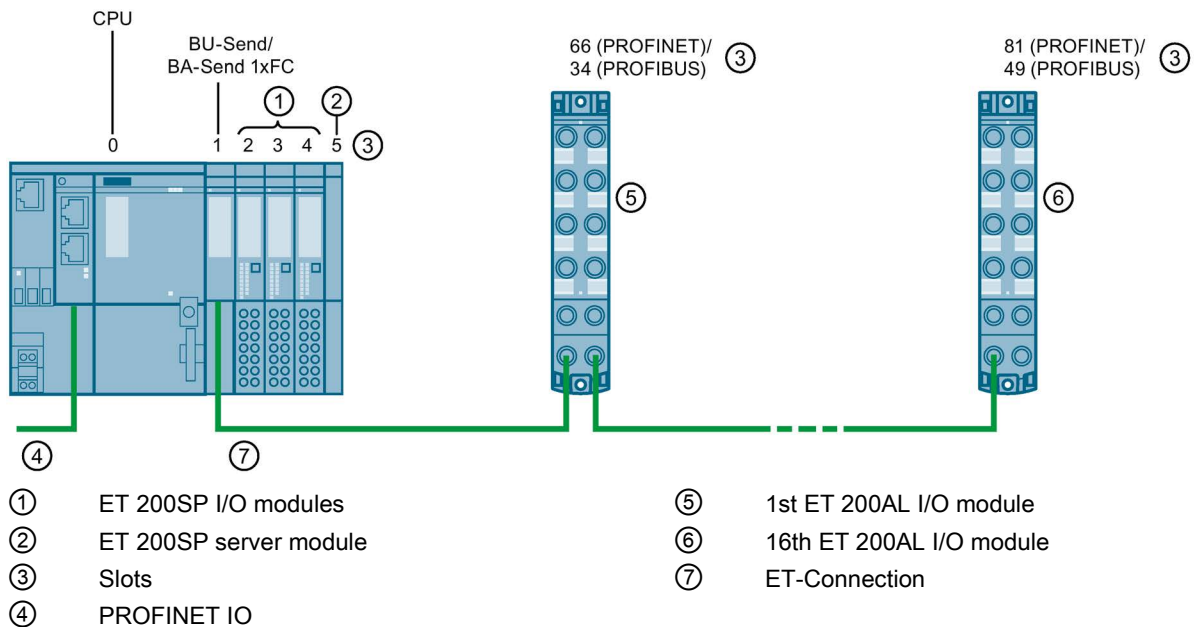


Image 4-1 Mixed configuration

For more information about connecting the ET-Connection, supply voltages, actuators and sensors, refer to the ET 200AL system manual.

Configuration with a CPU

In a configuration with a CPU, a maximum of 2 slots can be used immediately to the right of the CPU with CM DP module or Ethernet CP. Combinations are also possible, i.e. CM DP module and one Ethernet CP or two Ethernet CPs.

BU-Send and BA-Send should always be inserted to the immediate right of the CM/CP.

Rules

Observe the following rules when configuring:

- With mixed configurations, the following maximum configuration is possible:
 - 31 (IM 155-6 DP HF and IM 155-6 PN ST)/63 (IM 155-6 PN HF and CPUs) slots for ET 200SP modules
 - 16 slots for ET 200AL I/O modules
 - 1 slot for BU-Send/BA-Send 1xFC
 - 1 slot for server module.
- The mixed configuration may contain a maximum of 31 (IM 155-6 DP HF and IM 155-6 PN ST)/63 (IM 155-6 PN HF) ET 200SP I/O modules.
- The server module can also be mounted right next to the BU-Send/BA-Send 1xFC.
- Supported functions:

Function	Mixed configuration		
	ET 200SP		ET 200AL I/O modules on ET-Connection
	IM	CPU	
Isochronous mode	⑥	--	--
Configuration control	⑥	⑥	⑥
Shared device	⑥	⑥	⑥
PROFenergy	⑥	--	⑥
System redundancy S2	--	--	--

Configuring

Observe the following points when configuring:

- BU-Send/BA-Send 1xFC and server module must be configured. With BU-Send/BA-Send 1xFC, no parameters are available.
- Arrangement of the modules in the configuration:
 - Configure the BU-Send/BA-Send 1xFC downstream from the interface module in slot 1. Position the ET 200SP modules behind it.
 - Configure the ET 200AL I/O modules from slot 66 (PROFINET)/67 (CPU)/34 (PROFIBUS).
- The layout of the modules represents a preset configuration and is independent of the configuration control.
- The system redundancy S2 function is not available in a mixed configuration.

Configuration example

An example of a mixed configuration is shown below:

Hardware configuration

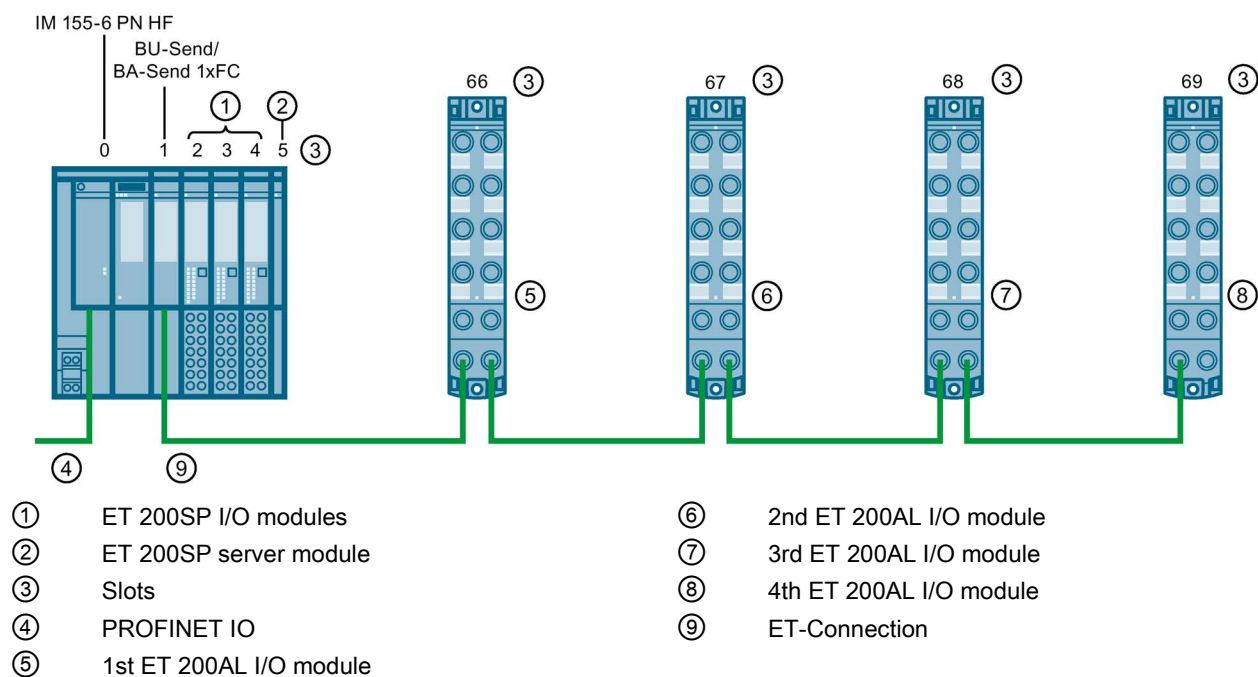


Image 4-2 Mixed configuration

Configuring configuration example

Table 4- 1 Overview

Mixed configuration	Module	Slot
ET 200SP	IM 155-6 PN HF	0
	BA-Send 1xFC	1
	DI 16×24VDC ST	2
	DI 16×24VDC ST	3
	DI 16×24VDC ST	4
	Server module	5
ET 200AL	DI 8x24VDC 8xM8	66
	DIQ 4+DQ 4x24VDC/0.5A 8xM8	67
	AI 4xU/I/RTD 4xM12	68
	CM 4xIO-Link 4xM12	69

Note

Configuration using PROFIBUS GSD file

When you use the PROFIBUS GSD file for the configuration, you must configure the gaps between the server module and the first ET 200AL I/O module with BU-Cover.

BaseUnit BU-Send

5.1 Product overview

Article number

6ES7193-6BN00-0NE0

View

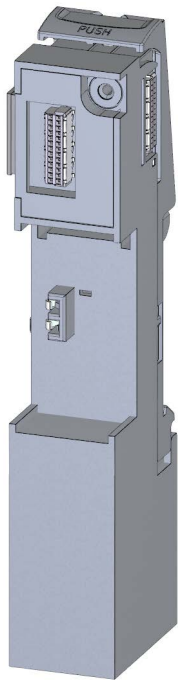


Image 5-1 BaseUnit BU-Send

Properties

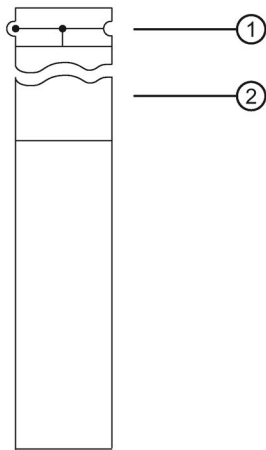
BaseUnit suitable for BusAdapter BA-Send 1xFC

5.2 Connection

Pin assignment

The BaseUnit BU-Send has only one slot for an expansion module. No other connections are available.

Schematic circuit diagram



- ① Backplane bus
- ② BA-Send 1xFC expansion module

Image 5-2 Schematic circuit diagram BU-Send

5.3 Technical specifications

Technical specifications of the BaseUnit BU-Send

	6ES7193-6BN00-0NE0
Product type designation	BaseUnit BU-Send
Installation type/mounting	
Rack mounting possible	Yes
Front installation possible	Yes
Rail mounting possible	Yes
Wall/direct mounting possible	No
Hardware configuration	
Slots	
Number of slots	1
Plug-in modules, other	Yes; BusAdapter BA-Send
Dimensions	
Width	20 mm
Height	117 mm
Depth	32 mm
Weights	
Weight, approx.	30 g

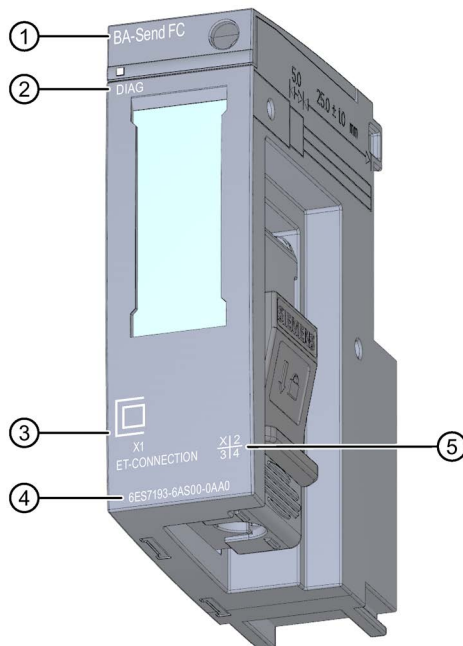
BusAdapter BA-Send 1xFC

6.1 Properties

Article number

6ES7193-6AS00-0AA0

View of the module



- ① Module type and name
- ② LED for diagnostics
- ③ ((Connection for ET-CONNECTION))
- ④ Article number
- ⑤ Functional version

Image 6-1 View of the BusAdapter BA-Send 1xFC

Properties

The module has the following technical properties:

- BusAdapter for the direct connection of ET-Connection
- Connects the interface module via ET-Connection with the ET 200AL I/O modules
- Supports all ET 200AL I/O modules

The module supports the following functions:

- Identification data I&M 0 to 3. See system manual ET 200SP Distributed I/O System (<http://support.automation.siemens.com/WW/view/en/58649293>).

Maximum configuration

- 16 ET 200AL I/O modules
- 15 m bus cable between BusAdapter BA Send and the first ET 200AL I/O module and between two ET 200AL I/O modules.
- Supported functions:

Function	Mixed configuration		
	ET 200SP		ET 200AL I/O modules on ET-Connection
	IM	CPU	
Isochronous mode	⑥	--	--
Configuration control	⑥	⑥	⑥
Shared device	⑥	⑥	⑥
PROFenergy	⑥	--	⑥
System redundancy S2	--	--	--

Accessories

The following components must be ordered separately:

- Labeling strips
- Reference identification label
- Stripping tool for ET-Connection
- Bus cables for ET-Connection

See also

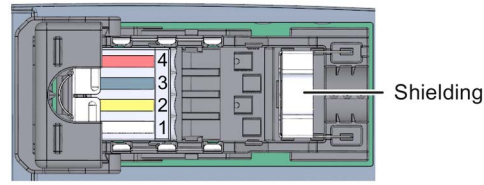
You can find more information on accessories and additional components in the Accessories/spare parts section of the ET 200AL distributed I/O system (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual.

6.2 Pin assignment

ET-Connection with BusAdapter BA-Send 1xFC

The following table shows the signal names and the designations for the pin assignment of the BusAdapter BA-Send 1xFC.

Table 6- 1 ET-Connection pin assignment with BusAdapter BA-Send 1xFC

View	Signal name	Description	
Port 1 	1	TD	Transmit data +
	2	RD	Receive data +
	3	TD_N	Transmit data -
	4	RD_N	Receive data -

6.3 Schematic circuit diagram

Schematic circuit diagram

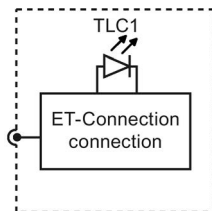
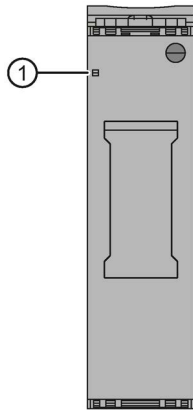


Image 6-2 Schematic circuit diagram for BusAdapter BA-Send 1xFC

6.4 Diagnostics by means of LED display

LED display

The figure below shows the LED display (status and fault display) of the BusAdapter BA-Send 1xFC.



① DIAG (green/red)




Image 6-3 LED display

Meaning of the LED display

The table below explains the meaning of the status and fault display.

DIAG LED

Table 6- 2 Status and fault display DIAG

DIAG LED	Meaning	Remedy
 Off	There is no connection between the ET-Connection interface of the BusAdapter BA-Send 1xFC and ET 200AL.	Check whether the bus cable is interrupted.
	The interface module does not support the BA-Send 1xFC.	Run a firmware update.
 On	There is a connection between the ET-Connection interface of the BusAdapter BA-Send 1xFC and ET 200AL.	---
 Flashes	There is (at least) one diagnostics alarm of an ET-Connection device. Group error for all ET-Connection bus nodes.	Check the ET-Connection device.
	Set configuration does not match the actual configuration on the ET-Connection.	Check the configuration of the ET-Connection to see whether a module is missing or defective, or whether a non-configured module is wired.

6.5 Technical specifications

Technical specifications of the BusAdapter BA-Send 1xFC

	6ES7193-6AS00-0AA0
Interfaces	
PROFINET IO	
Cable length	
<ul style="list-style-type: none"> Copper cables 	15 m; as of IM firmware V3.3: Bus nodes between BA-Send and the first ET-Connection as well as between all other bus nodes.
ET-Connection	
Number of interfaces ET-Connection	1
FC (FastConnect)	Yes
Ambient conditions	
Ambient temperature in operation	
Min.	0 °C
Max.	60 °C
Dimensions	
Width	20 mm
Weights	
Weight, approx.	44 g

SIEMENS



SIMATIC

ET 200AL

Interface module IM 157-1 DP (6ES7157-1AA00-0AB0)

Manual

Edition

12/2016

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SIMATIC

ET 200AL Interface module IM 157-1 DP (6ES7157-1AA00-0AB0)

Manual

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

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The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<https://support.industry.siemens.com/cs/ww/en/view/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions only form one element of such a concept.

Customer is responsible to prevent unauthorized access to its plants, systems, machines and networks. Systems, machines and components should only be connected to the enterprise network or the internet if and to the extent necessary and with appropriate security measures (e.g. use of firewalls and network segmentation) in place.

Additionally, Siemens' guidance on appropriate security measures should be taken into account. For more information about industrial security, please visit (<http://www.siemens.com/industrialsecurity>).

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends to apply product updates as soon as available and to always use the latest product versions. Use of product versions that are no longer supported, and failure to apply latest updates may increase customer's exposure to cyber threats.

To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed under (<http://www.siemens.com/industrialsecurity>).

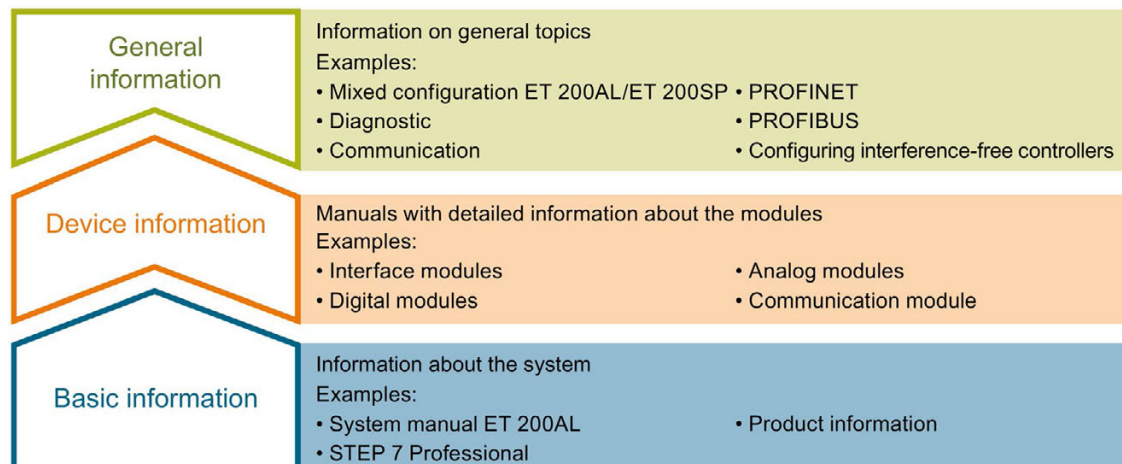
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Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742667>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

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In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.

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In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

Product overview

2.1 Properties

Article number

6ES7157-1AA00-0AB0

View of the module

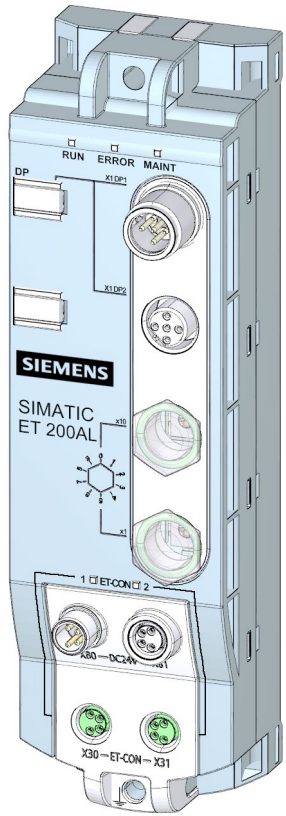


Figure 2-1 View of the IM 157-1 DP interface module

Properties

The module has the following technical properties:

- Connects the ET 200AL distributed I/O system with PROFIBUS DP
- 24 V DC supply voltage
- Operation as DP1 slave possible
- Direct data exchange (data exchange broadcast)
- Support for 2 ET-Connection lines
- Dimensions: 45 x 159 mm

The functions supported by the module are found in the chapter Functions (Page 12).

Maximum configuration

The module has the following maximum configuration:

- 244 bytes input data
- 244 bytes output data
- 32 I/O modules, up to 16 I/O modules can be connected for each ET-Connection line

Accessories

The following component is included with the module in the packaging:

- Identification labels

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

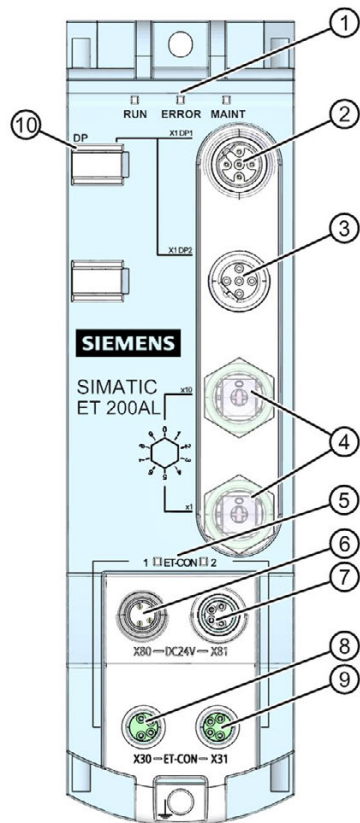
- Connectors
- Cables
- Stripping Tool for PROFIBUS
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

See also

You will find additional information on accessories and the other components in the Accessories/Spare parts section of the ET 200AL Distributed I/O System (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual.

2.2 Operator controls and display elements

The figure below shows the operator control and display elements of the interface module IM 157-1 DP.



- ① RUN, ERROR, MAINT: LED displays for the current operating status and diagnostics status
- ② X1 DP1: 1st PROFIBUS interface
- ③ X1 DP2: 2nd PROFIBUS interface
- ④ Rotary coding switch for setting the PROFIBUS address
- ⑤ ET-CON1, ET-CON2: LED displays for ET-Connection
- ⑥ X80: Connector for infeed of the supply voltage (POWER input)
- ⑦ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑧ X30: Socket for ET-Connection1
- ⑨ X31: Socket for ET-Connection2
- ⑩ DP: LED displays for the current operating status of the PROFIBUS interfaces

Figure 2-2 Operator controls and display elements

2.3 Functions

2.3.1 PROFIBUS DP

Introduction

The interface module supports the following PROFIBUS DP functions:

- Operation as DPV0 and DPV1 slave
- Identification data I&M0 to I&M3
- Firmware update
- Configuration control by means of the user program

PROFIBUS DP

The PROFIBUS DP interface is used for connection to CPUs. With PROFIBUS DP you can set up extended subnets.

PROFIBUS is the network for the cell and field area in the open, manufacturer-independent communication system SIMATIC NET. Physically, PROFIBUS is an electrical network based on a shielded two-wire cable or an optical network based on a fiber optic cable.

Data transmission via PROFIBUS DP features a standardized interface (EN 50170 Vol. 2) for the transmission of process input and process output data between SIMATIC S7 and field devices (DP slaves).

The transmission behavior via PROFIBUS DP is characterized by cyclical data exchange between the DP master and the DP slaves.

Reference

You will find more information on PROFIBUS DP in the STEP 7 online help and in the Function Manual PROFIBUS with STEP 7 V13 (<http://support.automation.siemens.com/WW/view/en/59193579>).

2.3.2 Configuration control (option handling)

Properties

Configuration control allows you to prepare your distributed I/O system for future extensions or options. Configuration control means that you can configure the planned maximum configuration of your distributed I/O system in advance and vary it later in a flexible manner by means of the user program.

Reference

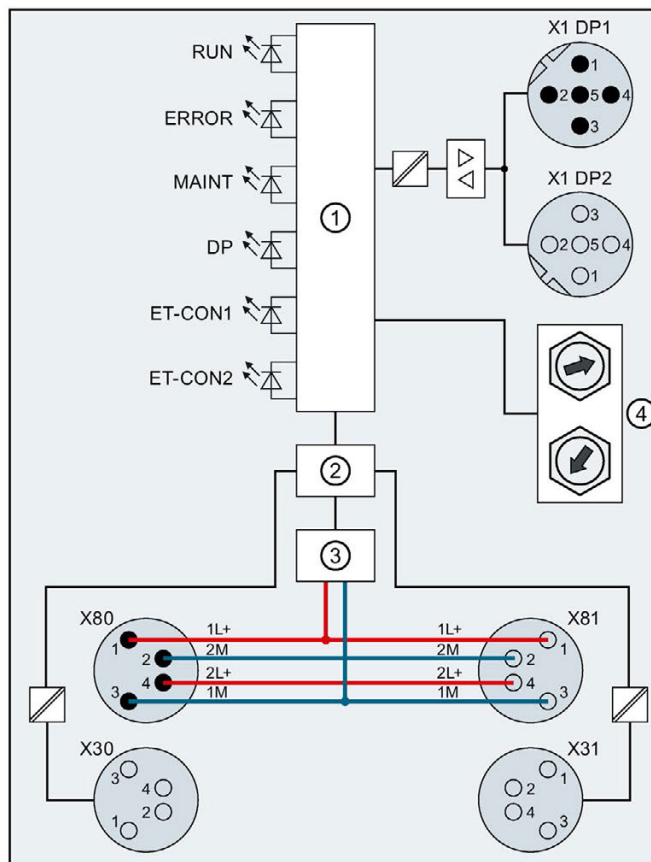
You can find more information on configuration control

- In the system manual ET 200AL Distributed I/O System (<https://support.industry.siemens.com/cs/ww/en/view/89254965>)
- On the Internet under the following link: Application collection (<https://support.industry.siemens.com/cs/ww/en/view/29430270>).
- In the STEP 7 online help.

Wiring

3.1 Terminal and block diagram

The image below shows the terminal and block diagram of the IM 157-1 DP interface module.



①	Electronics	1L+	Supply voltage 1L+ (non-switched)
②	ET-Connection interface	1M	Ground 1M (non-switched)
③	Internal supply voltage	2L+	Load voltage 2L+ (switched)
④	Rotary coding switch for PROFIBUS addresses	2M	Ground 2M (switched)
X1 DP1	1. PROFIBUS interface	RUN	LED operating state (green)
X1 DP2	2. PROFIBUS interface	ERROR	LED diagnostics status (red)
X80	Infeed of supply voltages	MAINT	LED diagnostics status (yellow)
X81	Loop-through of supply voltages	DP	PROFIBUS LED (green)
X30	Infeed of the ET-Connection	ET-CON1, ET-CON2	ET-Connection LEDs (green)
X31	Loop-through of the ET-Connection		

Figure 3-1 Terminal and block diagram

3.2 Pin assignment

Note

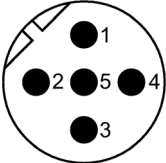
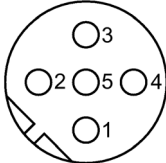
Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for PROFIBUS

The following table shows the pin assignment of the connectors and sockets for the connection of PROFIBUS.

Table 3- 1 Pin assignment for PROFIBUS

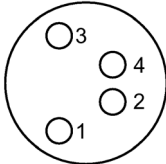
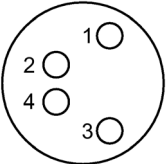
Pin	Assignment		Front view of the connector X1 DP1	Front view of the socket X1 DP2
	X1 DP1 connector (feed in)	X1 DP2 Socket (loop-through)		
1	-	Supply plus P5V*		
2	Data cable A			
3	Data reference potential M5*			
4	Data cable B			
5	Functional earth FE			
Shielding	Functional earth FE			

* The voltage may only be used for supplying the external terminating resistor. It is not permitted to loop-through the voltage by means of a cable to the next connector.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

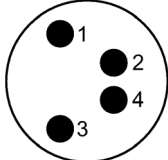
Table 3- 2 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection1)	X31 socket (ET-Connection2)		X30	X31
1	RXP	RXP	Yellow		
2	TXP	TXP	White		
3	TXN	TXN	Blue		
4	RXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The following table shows the pin assignment of the connector for infeed of the supply voltage.

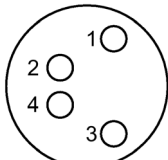
Table 3- 3 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the connector
	X80 connector (power input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3- 4 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the socket
	X81 Socket (power output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE
ET-Connection/supply voltage
Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage. Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

3.3 Configuring PROFIBUS DP address and terminating resistor

Properties

Use the PROFIBUS address to specify at which address the ET 200AL distributed I/O system is addressed on the PROFIBUS DP.

The PROFIBUS DP address is configured for the ET 200AL distributed I/O system with a rotary coding switch on the front of the housing.

Requirements

The following requirements apply:

- Each address is only assigned once on the PROFIBUS DP.
- The configured PROFIBUS DP address must match the PROFIBUS address defined in the configuration software.
- A change of the PROFIBUS DP address is only valid after POWER ON/POWER OFF on the IM 157-1 DP interface module.

Required tools

You need the following tools to configure the PROFIBUS DP address:

- 14 mm socket wrench
- 2.5 mm screwdriver

Setting the PROFIBUS DP address

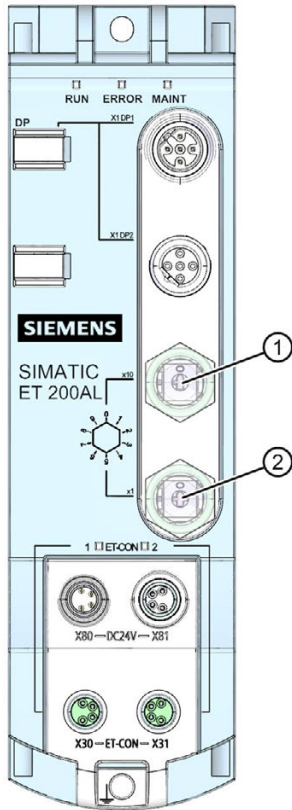
Configurable PROFIBUS DP addresses are 1 to 99.

Proceed as follows to configure the PROFIBUS DP address:

1. Remove the two M12 sealing caps from the rotary coding switches (use 14 mm socket wrench, if needed).
2. Configure the desired PROFIBUS DP address with a screwdriver on the rotary coding switches.
 - Top rotary coding switch: Tens digit
 - Bottom rotary coding switch: Ones digit
3. Screw the two M12 sealing caps back onto the thread to protect the rotary coding switches (torque: 0.5 to 0.8 Nm).
4. Switch the supply voltage off and on again (POWER OFF/POWER ON).

3.3 Configuring PROFIBUS DP address and terminating resistor

The figure below shows the rotary coding switches for configuring the PROFIBUS DP address.



- ① Rotary coding switch for PROFIBUS DP (tens digit)
- ② Rotary coding switch for PROFIBUS DP address (ones digit)

Figure 3-2 Setting the PROFIBUS address

The following table shows how to set PROFIBUS address 26 as an example.

Table 3-5 Setting of the PROFIBUS address

	Tens digit	Position 2
	Ones digit	Position 6

Connecting the terminating resistor for PROFIBUS DP

Terminate a PROFIBUS DP segment, on both of its ends, which means on the first and last device of the segment, with its characteristic impedance. There are two different terminating resistors available for this purpose, for sockets and for connectors.

The figure below shows typical use of a terminating resistor.

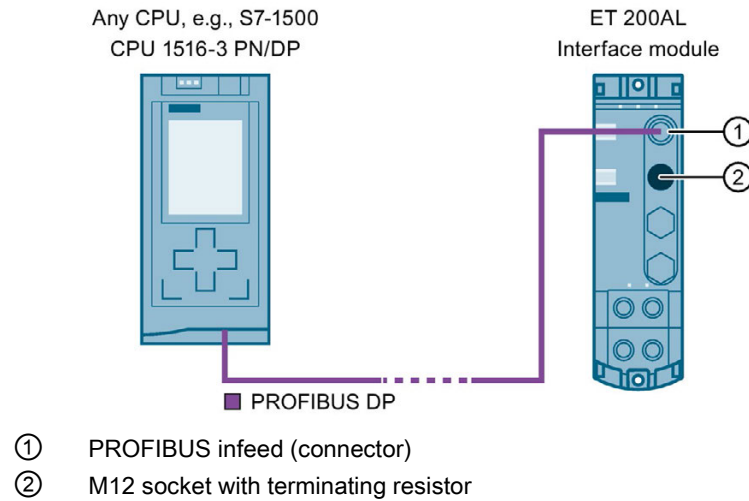


Figure 3-3 Terminating resistor

Parameters

4.1 Parameters

The following table shows the parameters for the IM 157-1 DP interface module.

Table 4- 1 Parameters

Parameters	Value range	Default ²	Efficiency range
Configuration control ¹	<ul style="list-style-type: none"> • Disable • Enable 	Disable	ET 200AL
Startup if preset configuration does not match actual configuration	<ul style="list-style-type: none"> • Disable • Enable 	Disable	ET 200AL
Diagnostics interrupt	<ul style="list-style-type: none"> • Disable • Enable 	Enable	ET 200AL
Hardware interrupt	<ul style="list-style-type: none"> • Disable • Enable 	Enable	ET 200AL
Pull/plug module interrupt	<ul style="list-style-type: none"> • Disable • Enable 	Enable	ET 200AL

¹ Note that the "Startup if preset configuration does not match actual configuration" parameter is always activated when you use configuration control.

² The defaults apply to the default startup. If no other parameters are specified by the DP master, the interface module IM 157-1 DP starts up with these parameters.

4.2 Explanation of the parameters

Configuration control

You can use this parameter to enable the configuration control function in the ET 200AL distributed I/O system.

Note**Configuration control**

The configuration control function can only be used if you set the "Startup if preset configuration does not match actual configuration" parameter to "YES".

Note**Configuring the enable**

If you configure the enable, the ET 200AL distributed I/O system requires a control data record 196 from the user program in order for the ET 200AL distributed I/O system to operate the I/O modules.

Additional information is available in the section Configuration control (option handling).

Startup if preset configuration does not match actual configuration

Enabled parameter

If the preset/actual configuration differ, a data exchange occurs between the DP master and the ET 200AL distributed I/O system.

Disabled parameter

If the preset/actual configuration differ, no data exchange occurs between the DP master and the ET 200AL distributed I/O system.

Note**More than 16 I/O modules in real configuration per ET-Connection line**

The preset/actual configuration do not match parameter is valid for 16 I/O modules per ET-Connection line.

Up to 16 I/O modules are recognized per line. Additional I/O modules are not recognized. A diagnostics alarm is not issued for these I/O modules. All I/O modules in the actual system after the 16th I/O module remain unconfigured (LED DIAG flashes green) and are not involved in the data exchange.

Diagnostics interrupt

You can use this parameter to enable or disable diagnostics interrupts.

Hardware interrupt

You can use this parameter to enable or disable hardware interrupts.

Pull/plug module interrupt

You can use this parameter to enable or disable pull/plug module interrupts.

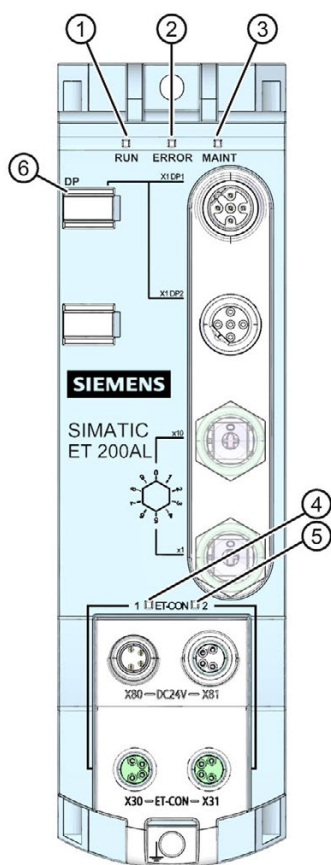
Interrupts, error messages, diagnostics and system alarms

5

5.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the IM 157-1 DP interface module.



- | | | |
|---|---------|----------|
| ① | RUN | (green) |
| ② | ERROR | (red) |
| ③ | MAINT | (yellow) |
| ④ | ET-CON1 | (green) |
| ⑤ | ET-CON2 | (green) |
| ⑥ | DP | (green) |

Figure 5-1 LED displays

















5.1 Status and error displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Corrective measures for diagnostics alarms can be found in the section Diagnostics alarms (Page 35).

LED RUN, LED ERROR, LED MAINT

Table 5- 1 Status and error displays of the LEDs RUN, ERROR, MAINT

LEDs			Meaning	Solution
RUN	ERROR	MAINT		
 Off	 Off	 Off	Supply voltage at interface module missing or too low	Check the supply voltage or switch it on on the interface module.
 On	 On	 On	Test of LEDs during startup: The three LEDs light up simultaneously for approximately 0.25 s.	-
 Flashes	 Off	 Off	Interface module is deactivated.	Activate the interface module with the configuration software or the user program.
			Interface module is not configured.	Configure the interface module with the configuration software.
			ET 200AL starts up.	-
			ET 200AL is being assigned parameters.	-
 On	Not relevant	Not relevant	ET 200AL is currently exchanging data with the DP master.	-
Not relevant	 Flashes	Not relevant	Group error and group error channels	Evaluate the diagnostics and eliminate the error.
			The preset configuration does not correspond to the actual configuration of the ET 200AL.	Check the configuration of the ET 200AL to see whether a module is missing, defective or if a module that is not configured is connected to ET-CON1 or ET-CON2.
			Parameter assignment error in the I/O module	Evaluate the display of the module status in STEP 7 or in STEP 7 (TIA portal) and correct the errors in the I/O module.
Not relevant	Not relevant	 On	Maintenance is demanded.	Execute maintenance
 Flashes	 Flashes	 Flashes	Hardware or firmware faulty. ¹	Replace the interface module.
 Flashes	Not relevant	Not relevant	Firmware is loading (all LEDs remain in their current state while the firmware update is being written)	---

¹ LED DP off

DP LED

Table 5-2 Status display of the DP LED

DP LED	Meaning	Solution
<p>□ Off</p>	There is no connection between the PROFIBUS interface of your PROFIBUS device and a communication partner (e.g. DP master).	Check whether the bus cable to the DP master is disconnected.
<p>■ On</p>	There is no connection between the PROFIBUS interface of your PROFIBUS device and a communication partner (e.g. DP master).	-

LED ET-CON1, LED ET-CON2

Table 5-3 Status displays of the LEDs ET-CON1 and ET-CON2

LEDs		Meaning	Solution
ET-CON1	ET-CON2		
<p>□ Off</p>		There are no I/O modules available at the respective ET-Connection or the modules do not have supply voltage.	Check the wiring for the ET-Connection or the supply voltage for the I/O module.
<p>■ On</p>		A communications connection to at least one IO module at the corresponding ET-Connection is available.	-

5.2 Interrupts

5.2.1 Evaluating interrupts

Introduction

With certain process statuses/errors, the DP slave in each case creates an interrupt block with the corresponding information in the diagnostics frame (DPV1 interrupt mechanism). Regardless of this, the diagnostic status of the DP slave is displayed in the identifier-related diagnostics, in the module status, and in the channel diagnostics.

Interrupts in DPV1 mode

The ET 200AL distributed I/O system supports the following interrupts:

- Diagnostics interrupts
- Hardware interrupts
- Pull/plug module interrupt

5.2.2 Trigger a diagnostics interrupt

For an incoming or outgoing event (for example, wire break on a channel of an I/O module), the interface module triggers a diagnostics interrupt if the I/O modules were configured accordingly and "Enable:diagnostics interrupt" is set.

The CPU interrupts user program execution and processes the diagnostics interrupt OB (OB 82). The event that triggered the interrupt is entered in the start information of the diagnostics interrupt OB.

5.2.3 Triggering a hardware interrupt

When a hardware interrupt occurs, the CPU interrupts execution of the user program and processes the hardware interrupt OB, for example OB 40. The event that triggered the interrupt is entered in the start information of the hardware interrupt OB.

Note

Diagnostics "Hardware interrupt lost" (from I/O module)

Do not use hardware interrupts for technological purposes (e.g., cyclical generation of hardware interrupts).

If the hardware interrupt load is too high, hardware interrupts can get lost depending on the number of I/O modules and the communication load.

5.2.4 Triggering an insert/remove module interrupt

When an insert/remove module interrupt occurs, the CPU interrupts execution of the user program and processes the insert/remove module interrupt OB (OB 83). The event that triggered the interrupt is entered in the start information of the insert/remove OB.

The pull/plug OB (OB 83) is also triggered for all subsequent I/O modules, because the ET-Connection and/or the power supply is interrupted.

5.2.5 Structure of data records

Definition

The interrupt section of the slave diagnostics indicates the interrupt type and the event that led to an interrupt being triggered. The interrupt section comprises 62 bytes including an interrupt header.

Position in the diagnostics frame

The interrupt section is located after the channel diagnostics.

Data records

The diagnostics data of a module are located in the data records 0 and 1:

- Data record 0 contains 4 bytes of diagnostics data that describe the current status of the distributed I/O system. Data record 0 is part of the header information of the OB 82 (local data bytes 8 to 11).
- Data record 1 contains 4 bytes of diagnostics data that are also available in data record 0.

The figure below shows the structure of data record 0.

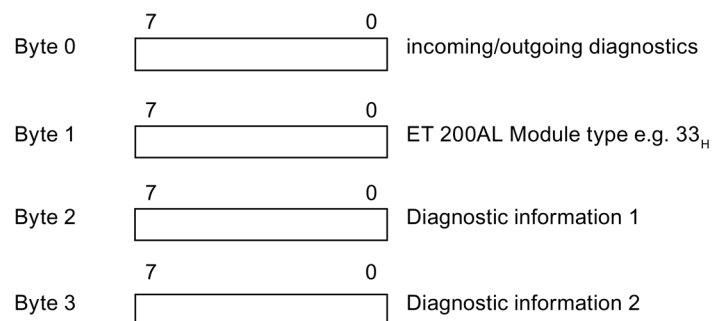


Figure 5-2 Structure of data record 0

5.2 Interrupts

The figure below shows the structure of data record 1.

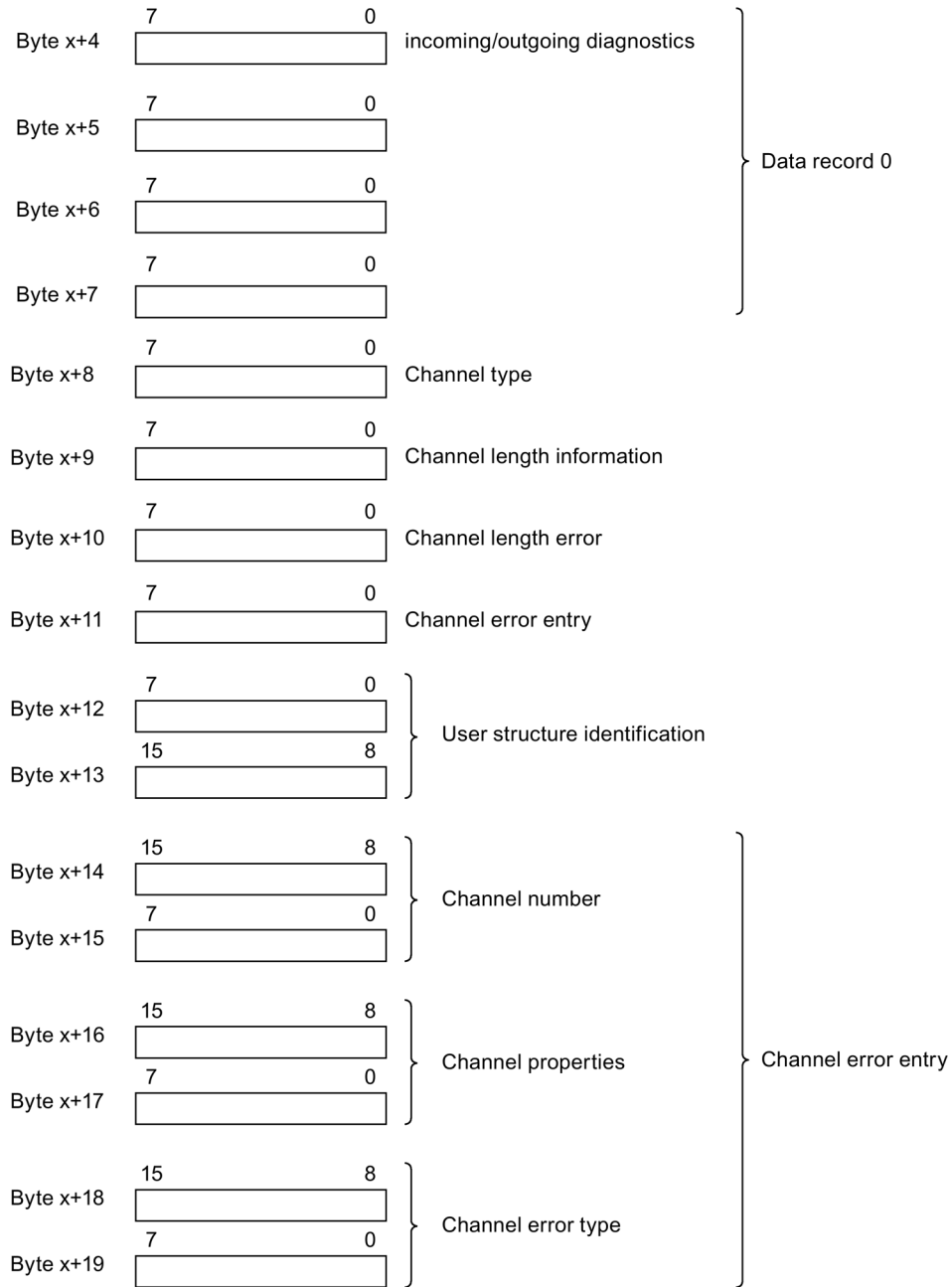


Figure 5-3 Structure of data record 1

Reading data records

You have the option to read out data records 0 and 1 via SFC 59 (RD_REC) or SFB 52 (RDREC). The data length of data record 1 is up to 240 bytes. In this case, data record 1 contains up to 38 channel fault entries.

Note the figures below in this section.

Contents

The contents of the interrupt information depend on the interrupt type:

- In the case of diagnostics interrupts, diagnostics data record 1 (up to 58 bytes) is sent as interrupt status information (starting from byte x+4).
- The length of the interrupt status information for hardware interrupts is 4 bytes.

Structure of interrupts

The figure below shows the structure of the interrupt section for the ET 200AL distributed I/O system.

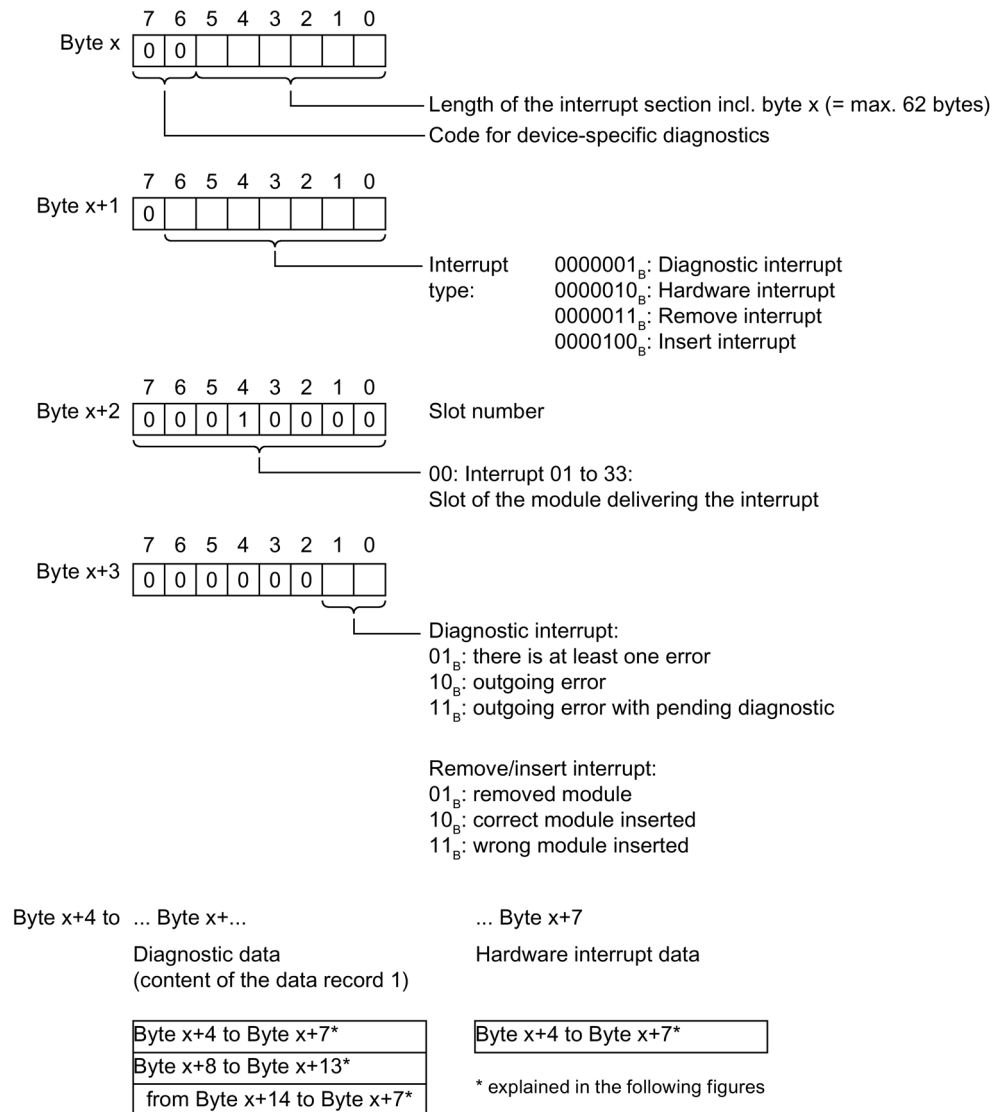


Figure 5-4 Structure of the interrupt status of the interrupt section

5.2 Interrupts

Diagnostics interrupt, byte x+4 to x+7

The figure below shows the structure of the diagnostics interrupt of byte x+4 to byte x+7.

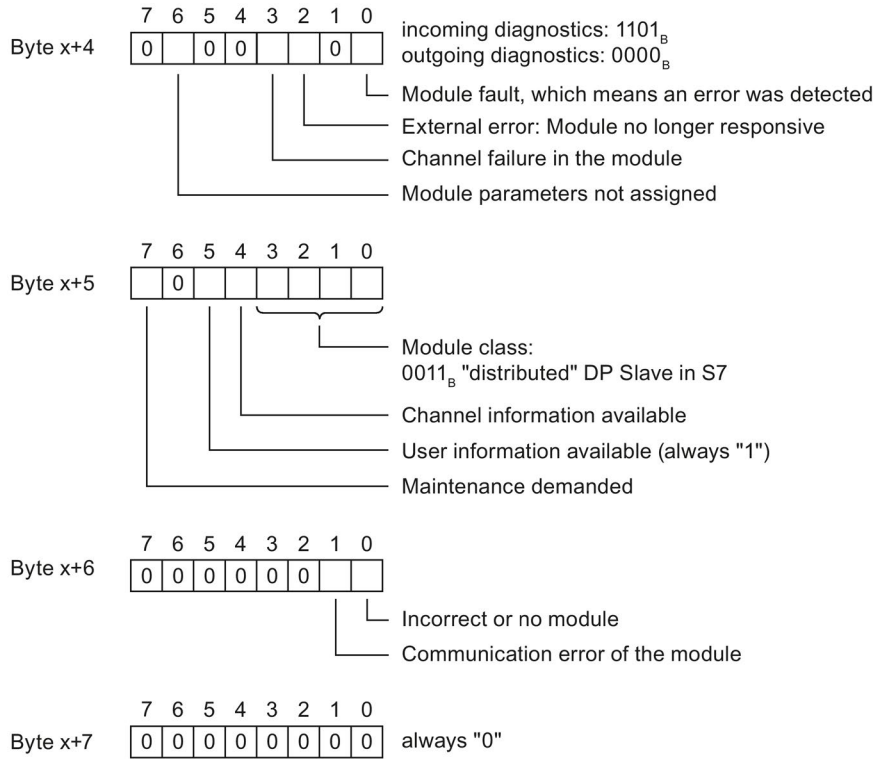


Figure 5-5 Structure of bytes x+4 to x+7 for diagnostics interrupt

Diagnostics interrupt, starting at byte x+8

The figure below shows the structure of the diagnostics interrupt starting at byte x+8.

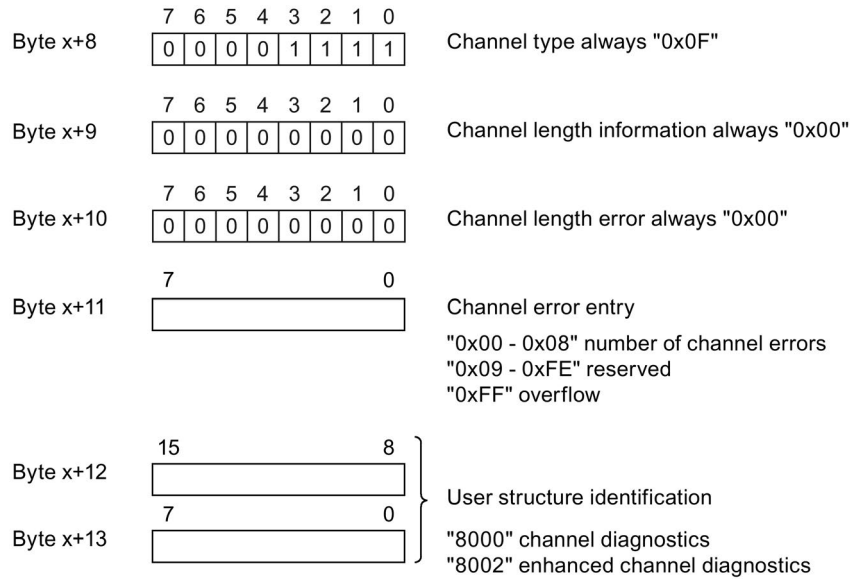


Figure 5-6 Structure starting at byte x+8

Diagnostics interrupt from the modules, starting at byte x+14

The channel error entries start from byte x+14. A channel fault entry is 6 bytes long and can follow 8 times starting at byte x+14.

If you read the channel faults with an SFB or SFC, then 38 channel diagnostics are possible.

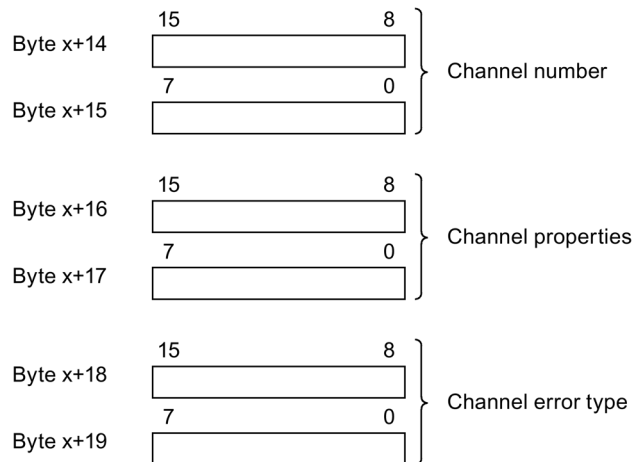


Figure 5-7 Structure starting from byte x+14

5.2 Interrupts

The following table is used to explain the channel error entries.

	Description	
Channel number	0 ... 63: Channel number for channel error 0x8000: Entire submodule	
Channel properties	Bits 0 to 7	00H: Free data type 01H: bit 02H: 2 bit 03H: 4 bit 04H: byte 05H: word 06H: double word 07H to FFH: Reserved
	Bit 8	0: Channel 1: Channel group
	Bit 9, 10	00H: Diagnostics 01H: Maintenance demanded 02H: Maintenance required 03H: Reserved
	Bit 11, 12	00H: Channel error-free 01H: Incoming diagnostics 02H: Outgoing diagnostics 03H: Outgoing diagnostics, but other diagnostics are also pending on this channel
	Bits 13 to 15	00H: Reserved 01H: Input channel 02H: Output channel 03H: Input/output channel
Channel error type	Explanations are available in the device manuals, in the section "Diagnostic alarms".	

Example of a diagnostics interrupt

The figure below shows an example of a diagnostics interrupt.

Example:

I/O module AI 4xU//RTD reports on channel 1 the diagnostic interrupt
"High limit exceeded"

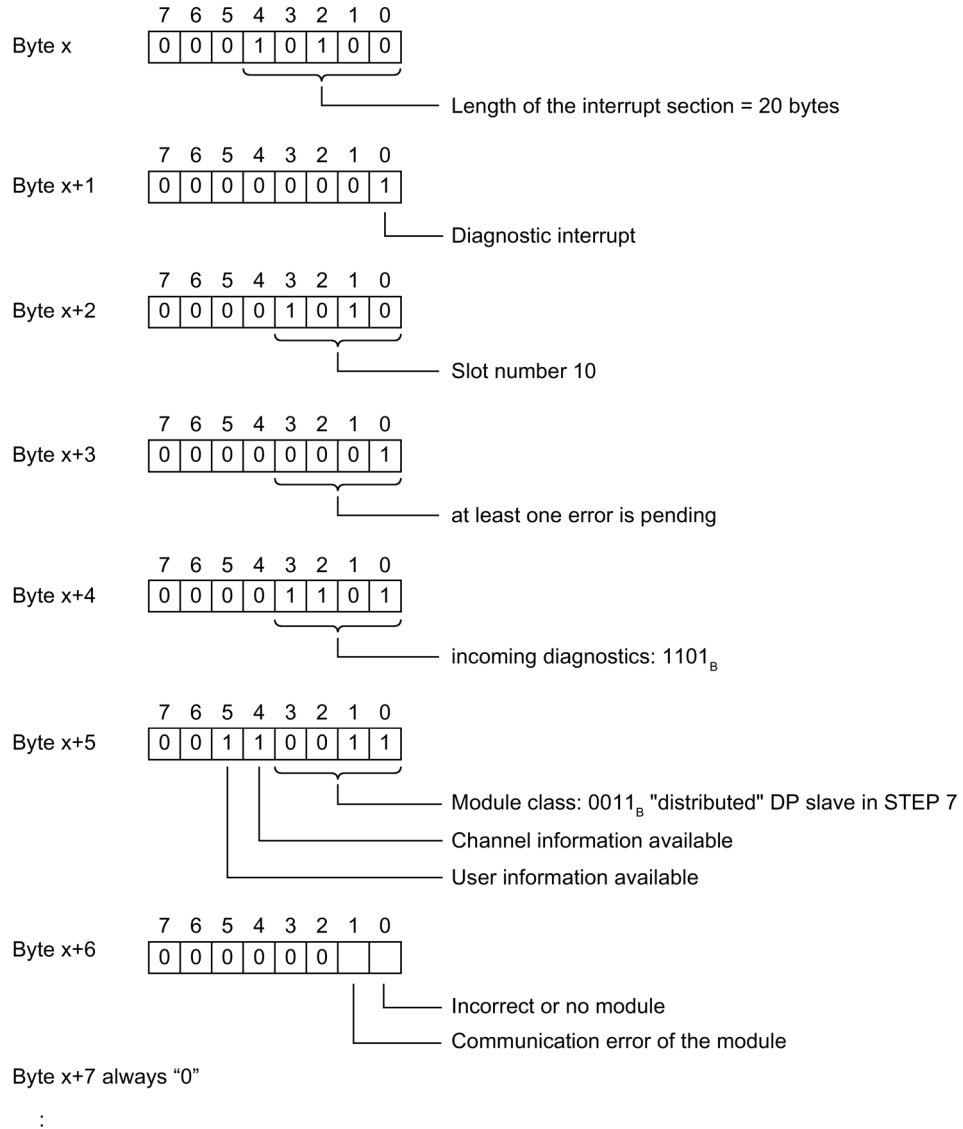


Figure 5-8 Example of a diagnostics interrupt (part 1)

5.2 Interrupts

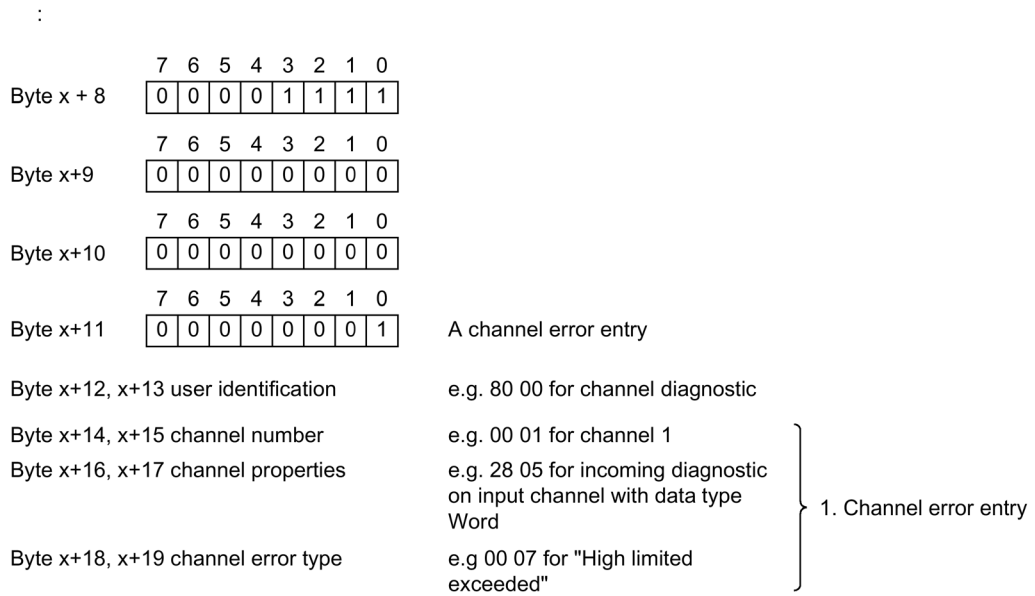


Figure 5-9 Example of a diagnostics interrupt (part 2)

Hardware interrupt of digital and analog input modules, bytes x+4 to x+7

The figure below shows the structure of a hardware interrupt.

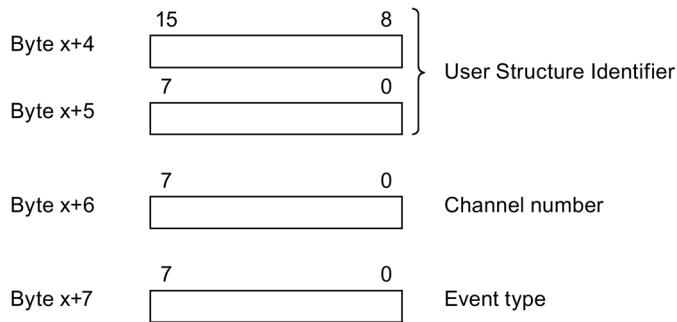


Figure 5-10 Structure as of Byte x+4 for hardware interrupt

Note

Byte x+4

You will find the event type in the device manual of the module that triggered the hardware interrupt.

5.3 Alarms

5.3.1 Diagnostics alarms

Actions after a diagnostics alarm in DPV1 mode

The error is entered in the channel diagnostics in the diagnostics frame:

- In DPV1 mode, diagnostics can be reported as diagnostics interrupts.
- After a diagnostics alarm, this is
 - entered in the diagnostics frame as a diagnostics interrupt block (always only one interrupt).
 - Stored in the diagnostics buffer of the CPU.
- The ERROR LED of the interface module flashes.
- OB 82 is called. If OB 82 is not available, the CPU goes into STOP mode.
- Acknowledgment of the diagnostics interrupt (a new interrupt is possible thereafter).

Length of the diagnostics frame

- The maximum frame length for the ET 200AL distributed I/O system with IM157-1 DP interface module (DPV1 mode) is 244 bytes.
- The minimum frame length is 6 bytes.

Reading out the diagnostics data

Table 5- 4 Reading the diagnostics with STEP 7

Automation system with DP master	Application	See...
SIMATIC S7/M7	Slave diagnostics in plain text in "DP Slave Diagnostics" tab on STEP 7 interface	"Hardware diagnostics" in STEP 7 online help
	"DP NRM_DG" instruction (SFC 13) Reading out slave diagnostics (store in the data area of the user program)	SFC: see STEP 7 online help
	"RD_REC" instruction (SFC 59) Reading out data records of the S7 diagnostics data (store in the data area of the user program)	See System and Standard Functions reference manual
	"RDREC" instruction (SFC 52) Reading data records from the DP slave	SFB: refer to STEP 7 online help (system functions/function blocks)
	"RALRM" instruction (SFC 54) Receiving interrupts from the interrupt OBs	SFB: refer to STEP 7 online help (system functions/function blocks)

5.3.2 Slave diagnostics

The figure below shows the structure of the slave diagnostics.

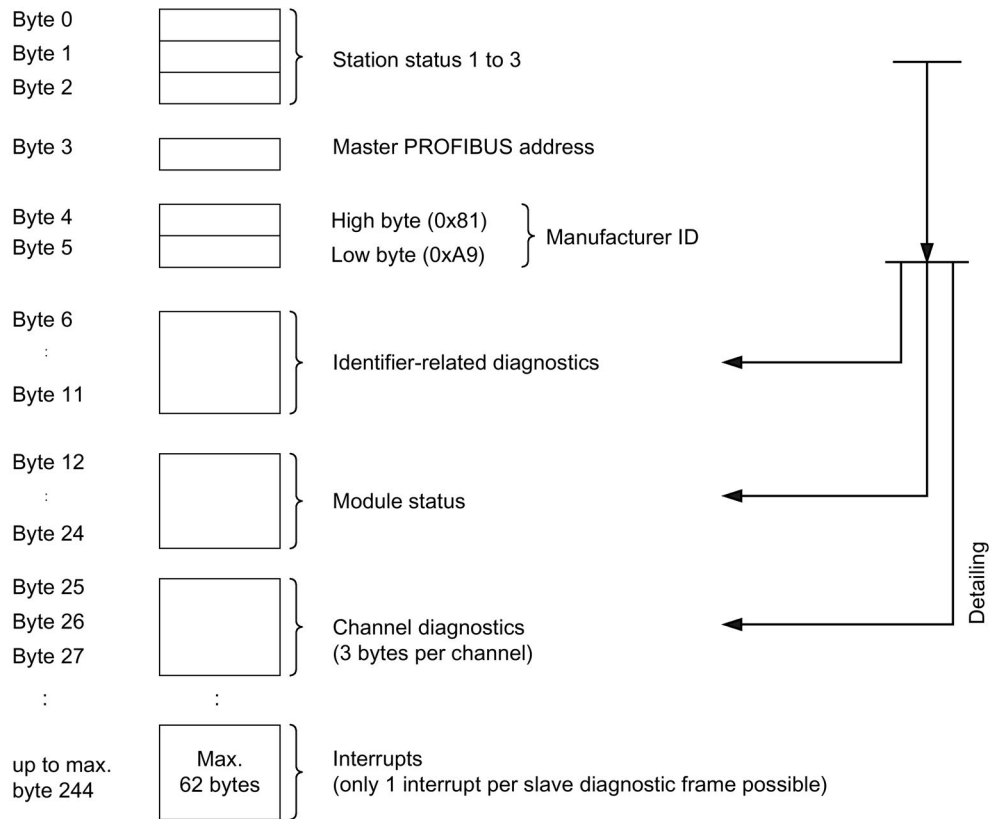


Figure 5-11 Structure of the slave diagnostics

Note

The length of the diagnostics frame varies with the IM 157-1 DP (depending on parameter assignment) between 6 and 244 bytes in DPV1 mode.

You can identify the length of the last received diagnostics frame in STEP 7 from the RET_VAL parameter in SFC 13.

5.3.3 Station statuses 1 to 3

The following tables show station status 1 to 3 and provide an overview of the status of a DP slave.

Structure of station status 1 (byte 0)

Table 5- 5 Structure of station status 1 (byte 0)

Bit	Meaning	Cause/Solution
0	1: The DP slave is not responding to the DP master.	<ul style="list-style-type: none"> • Correct PROFIBUS address set on the DP slave? • Bus connector connected? • Is the DP slave connected to the voltage supply? • RS485 repeater properly configured?
1	1: The DP slave is not yet ready to exchange data.	<ul style="list-style-type: none"> • Wait; the DP slave is currently starting up.
2	1: The configuration data transferred from the DP master to the DP slave does not match the DP slave configuration.	<ul style="list-style-type: none"> • Has the correct station type or the correct DP slave configuration been entered in the configuration software?
3	1: External diagnostics is available. (Group diagnostics display)	<ul style="list-style-type: none"> • Evaluate the ID-specific diagnostics, the module status, and/or the channel diagnostics. As soon as all errors have been eliminated, bit 3 is reset. The bit is set again when there is a new diagnostics alarm in the bytes of the aforementioned diagnostics.
4	1: The requested function is not supported by the DP slave (e.g. changing the PROFIBUS address using software).	<ul style="list-style-type: none"> • Check the configuration.
5	1: The DP master cannot interpret the response of the DP slave.	<ul style="list-style-type: none"> • Check the bus configuration.
6	1: The DP slave type does not match the software configuration.	<ul style="list-style-type: none"> • Has the correct station type been entered in the configuration software?
7	1: Parameters have been assigned to the DP slave by a different DP master (not the one that currently has access to the DP slave).	<ul style="list-style-type: none"> • The bit is always 1, for example, if you access the DP slave with the programming device or another DP master. • The PROFIBUS address of the DP master that assigned parameters to the DP slave is located in the "Master PROFIBUS address" diagnostics byte.

Structure of station status 2 (byte 1)

Table 5- 6 Structure of station status 2 (byte 1)

Bit	Meaning	
0	1:	The DP slave parameters need to be reassigned.
1	1:	A diagnostics alarm is pending. The DP slave will not operate until the problem is eliminated (static diagnostics alarm).
2	1:	The bit on the DP slave is always "1".
3	1:	The watchdog is activated for this DP slave.
4	1:	The DP slave has received the control command "FREEZE". ¹
5	1:	The DP slave has received the control command "SYNC". ¹
6	0:	Bit is always "0".
7	1:	The DP slave is disabled, that is, it has been removed from the processing in progress.
¹ The bit is updated only if another diagnostics alarm also changes.		

Structure of station status 3 (byte 2)

Table 5- 7 Structure of station status 3 (byte 2)

Bit	Meaning	
0 to 6	0:	Bits are always set to "0".
7	1:	<ul style="list-style-type: none"> • There are more diagnostic alarms pending than the DP slave is able to store. • The DP master cannot enter all the diagnostics alarms sent by the DP slave in its (channel) diagnostics buffer.

5.3.4 Master PROFIBUS address

The following is stored in the diagnostic byte Master PROFIBUS address:

- The PROFIBUS address of the DP master that assigned the parameters to the DP slave.
- The PROFIBUS address of the DP master that has read and write access to the DP slave.

The master PROFIBUS address is found in byte 3 of the slave diagnostics.

5.3.5 Manufacturer ID

The manufacturer ID contains a code specifying the type of the DP slave.

The following table shows the structure of the manufacturer ID (bytes 4, 5).

Table 5- 8 Description of the manufacturer ID

Byte 4	Byte 5	Manufacturer ID
81 _H	A9 _H	IM 157-1 DP interface module

5.3.6 Identifier-related diagnostics

The identifier-related diagnostics indicates whether modules of the ET 200AL distributed I/O system have errors or not. Identifier-related diagnostics starts at byte 6 and comprises 6 bytes.

The figure below shows how the identifier-related diagnostics for the ET 200AL distributed I/O system is structured with the IM 157-1 DP interface module.

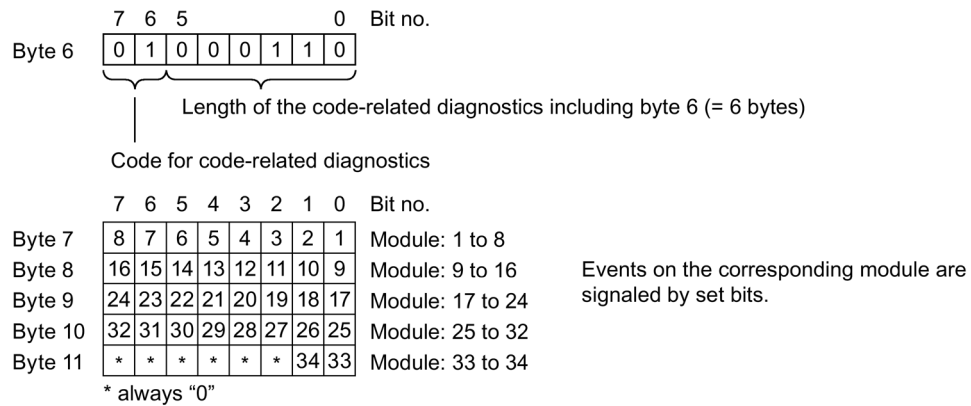


Figure 5-12 Structure of the identifier-related diagnostics

5.3.7 Module status

The module status indicates the status of the configured modules and provides more information on the identifier-related diagnostics with respect to the configuration. The module status begins after the identifier-related diagnostics and comprises 13 bytes.

The figure below shows how the module status for the ET 200AL distributed I/O system is structured with the IM 157-1 DP interface module.

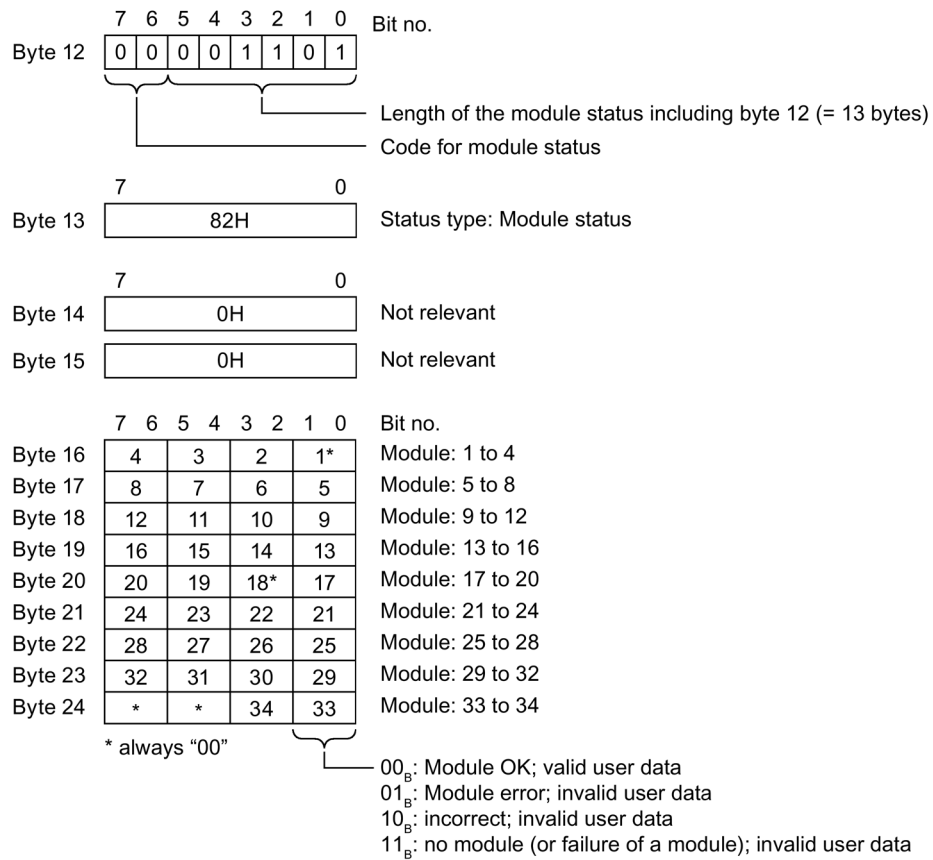


Figure 5-13 Module status structure

5.3.8 Channel diagnostics

Function

Channel diagnostics provides information about channel errors in modules and details of the identifier-related diagnostics. Channel diagnostics begins after the module status. Channel diagnostics does not affect the module status.

The figure below shows how the channel diagnostics for the ET 200AL distributed I/O system is structured with the IM 157-1 DP interface module.

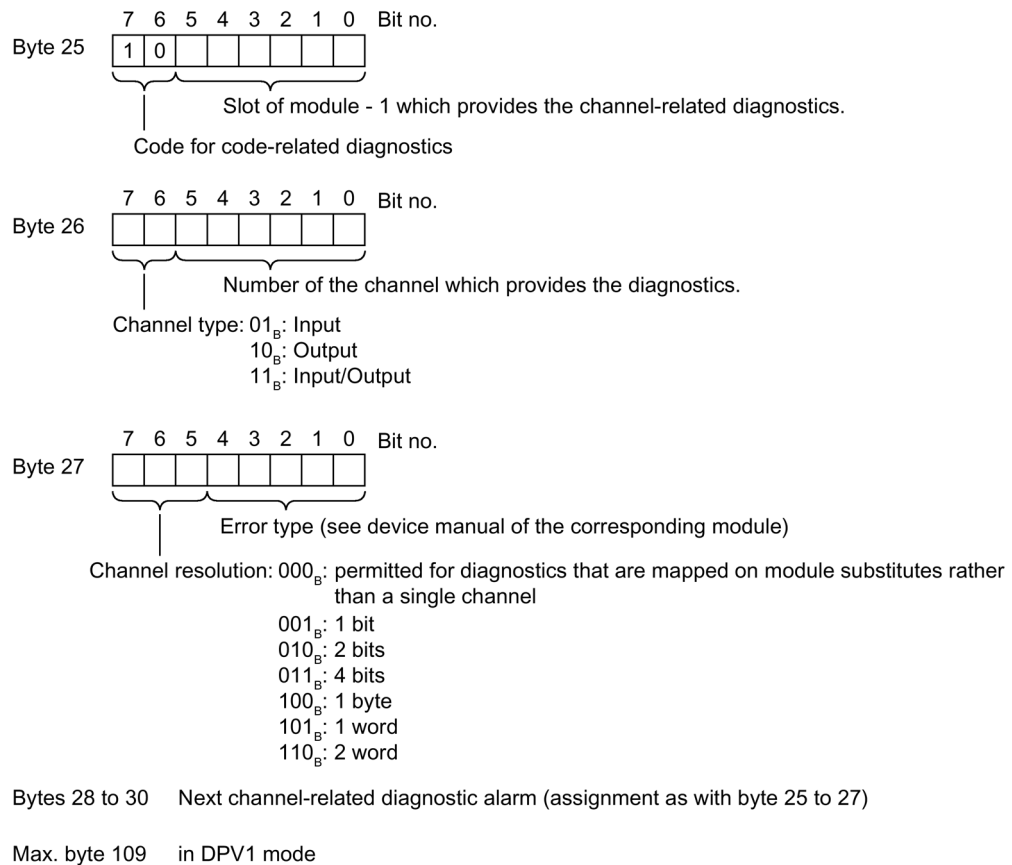


Figure 5-14 Structure of channel diagnostics

Technical specifications

Technical specifications of the interface module IM 157-1 DP

	6ES7157-1AA00-0AB0
General information	
Product type designation	IM 157-1 DP
Hardware functional status	E01
Firmware version	V1.0.x
Vendor identifier (VendorID)	81A9H
Product function	
I&M data	Yes; I&M0 to I&M3
Engineering with	
STEP 7 TIA Portal can be configured/integrated as of version	as of STEP 7 V13 SP1
STEP 7 can be configured/integrated as of version PROFIBUS as of GSD version/GSD revision	V5.5 SP4 Hotfix 3 or higher GSD as of revision 5
Configuration control	
Via data record	Yes
Supply voltage	
Load voltage 1L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction
Input current	
Current consumption (rated value)	50 mA
From load voltage 1L+ (unswitched current)	4 A; maximum value
From load voltage 2L+, max.	4 A; maximum value
Power loss	
Power loss, typ.	1.7 W
Address area	
Address space per station	
Address space per station, max.	244 bytes
Interfaces	
Number of PROFIBUS interfaces	1
1st interface	
Interface type	PROFIBUS DP

6ES7157-1AA00-0AB0	
Interface hardware	
RS 485	Yes
M12 port	Yes; 2x M12 b-coded
Protocols	
PROFIBUS DP slave	Yes
Interface hardware	
RS 485	
Transmission rate, max.	12 Mbps
Protocols	
PROFIBUS	
Services	
• SYNC capability	Yes
• FREEZE capability	Yes
• Direct data exchange (data exchange broadcast)	Yes
• DPV0	Yes
• DPV1	Yes
Interrupts/diagnostics/status information	
Interrupts	Yes
Diagnostics functions	Yes
Diagnostics indicator LED	
RUN LED	Yes; green LED
ERROR LED	Yes; red LED
MAINT LED	Yes; yellow LED
Connection display DP	Yes; green LED
Electrical isolation	
Between load voltages	Yes
between PROFIBUS DP and all other circuit components	Yes
Insulation	
Insulation tested with	707 V DC (type test)
Degree of protection and protection class	
Degree of protection according to EN 60529	
• IP65	Yes
• IP67	Yes
Ambient conditions	
Ambient temperature during operation	
Min.	-25 °C
Max.	55 °C

6ES7157-1AA00-0AB0	
Connection technology	
Power supply	M8, 4-pin
ET-Connection	
ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	45 mm
Height	159 mm
Depth	46 mm
Weights	
Weight, approx.	211 g

Dimension drawing

A

The figure below shows the dimension drawing of the IM 157-1 DP interface module in the front and side view.

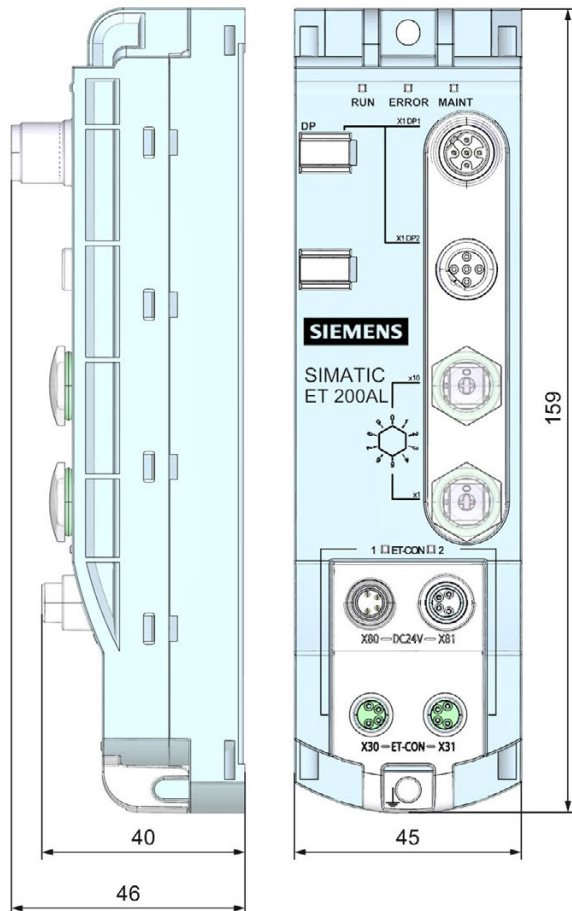


Figure A-1 Dimension drawing

Cycle times

B

The following figure shows the cycle times at ET-Connection based on the number of I/O modules.

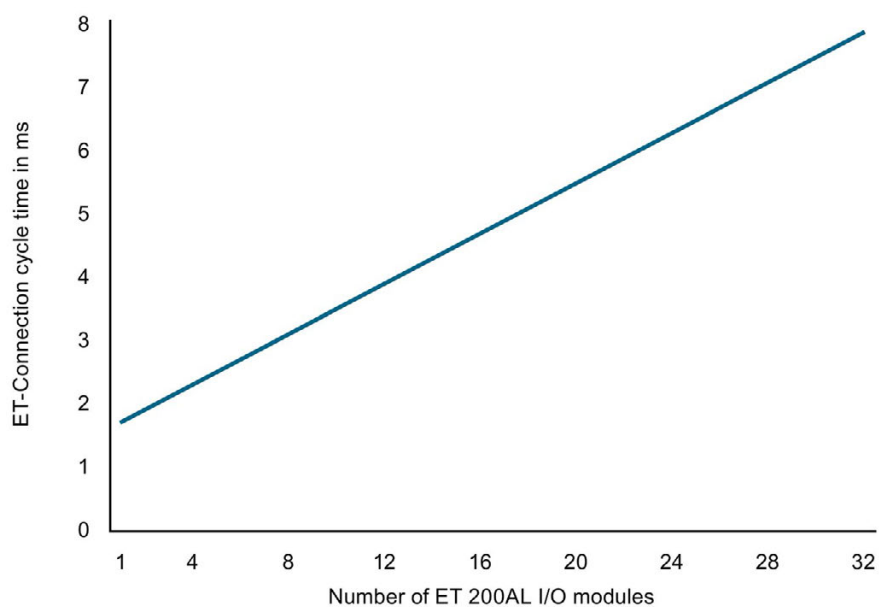


Figure B-1 Cycle times

The cycle time is independent of the PROFIBUS transmission rate.

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SIMATIC

ET 200AL

Interface module IM 157-1 PN (6ES7157-1AB00-0AB0)

Manual

Edition

12/2016

siemens.com

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SIMATIC

ET 200AL Interface module IM 157-1 PN (6ES7157-1AB00-0AB0)

Manual

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

⚠ DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
⚠ WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
⚠ CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.

If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

⚠ WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions only form one element of such a concept.

Customer is responsible to prevent unauthorized access to its plants, systems, machines and networks. Systems, machines and components should only be connected to the enterprise network or the internet if and to the extent necessary and with appropriate security measures (e.g. use of firewalls and network segmentation) in place.

Additionally, Siemens' guidance on appropriate security measures should be taken into account. For more information about industrial security, please visit (<http://www.siemens.com/industrialsecurity>).

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends to apply product updates as soon as available and to always use the latest product versions. Use of product versions that are no longer supported, and failure to apply latest updates may increase customer's exposure to cyber threats.

To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed under (<http://www.siemens.com/industrialsecurity>).

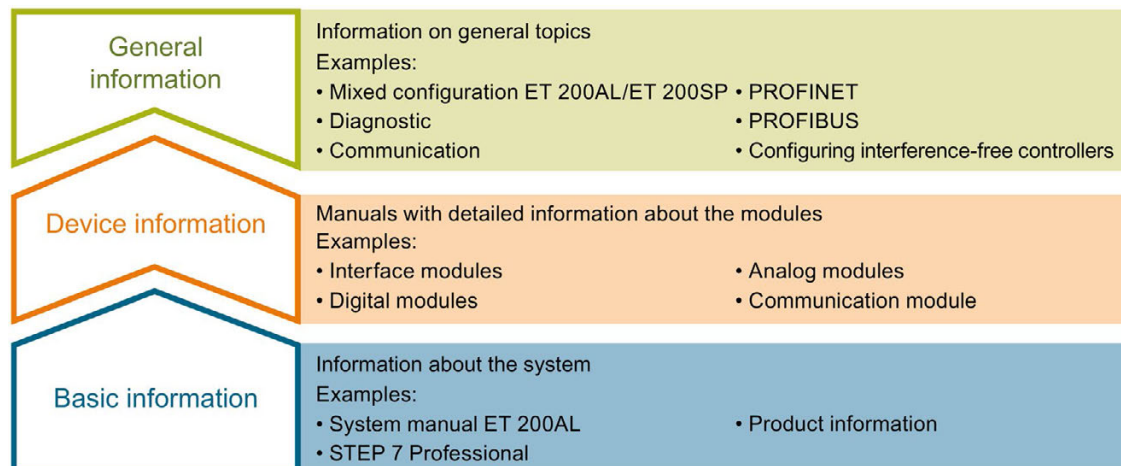
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Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742667>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

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You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<http://support.industry.siemens.com/My/ww/en/documentation>).

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You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet (<http://w3.siemens.com/mcmts/topics/en/simatic/tia-selection-tool>).

Product overview

2.1 Properties

Article number

6ES7157-1AB00-0AB0

View of the module

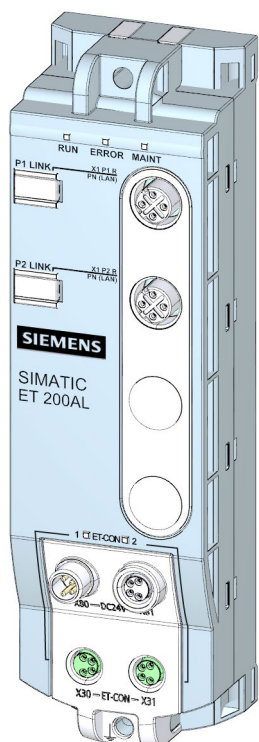


Figure 2-1 View of the IM 157-1 PN interface module

Properties

The module has the following technical properties:

- Connects the ET 200AL distributed I/O system with PROFINET IO
- 24 V DC supply voltage
- Support for 2 ET-Connection lines
- Dimensions: 45 x 159 mm

The functions supported by the module are found in the chapter Functions (Page 11).

Maximum configuration

The module has the following maximum configuration:

- 1430 bytes input data
- 1430 bytes output data
- 32 I/O modules, up to 16 I/O modules can be connected for each ET-Connection line

Note

- In the case of a shared device configuration, the sum of the I/O data of all controllers that share the device applies.
 - If more than two (max. four) controllers share the device, the maximum amount of I/O data including user data qualifier is limited to 360 bytes per controller.
-

Accessories

The following component is included with the module in the packaging:

- Identification labels

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

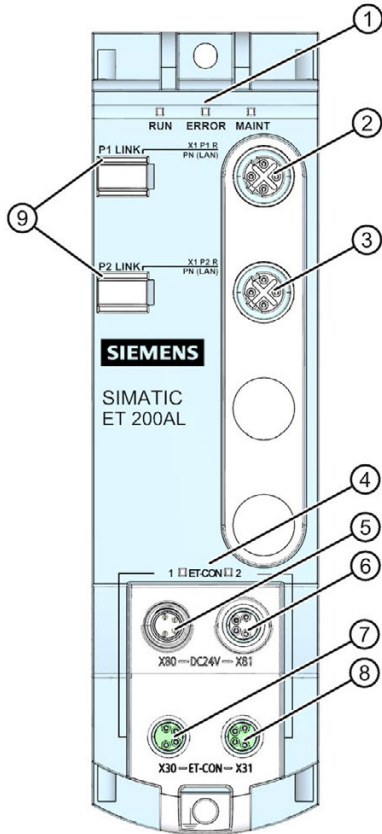
- Connectors
- Cables
- Stripping Tool for PROFINET
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

See also

You will find additional information on accessories and the other components in the Accessories/Spare parts section of the ET 200AL Distributed I/O System (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual.

2.2 Operator controls and display elements

The figure below shows the operator control and display elements of the interface module IM 157-1 PN.



- ① RUN, ERROR, MAINT: LED displays for the current operating status and diagnostics status
- ② X1 P1 R: 1st PROFINET interface
- ③ X1 P2 R: 2nd PROFINET interface
- ④ ET-CON1, ET-CON2: LED displays for ET-Connection
- ⑤ X80: Connector for infeed of the supply voltage (POWER input)
- ⑥ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑦ X30: Socket for ET-Connection1
- ⑧ X31: Socket for ET-Connection2
- ⑨ P1 LINK, P2 LINK: LED displays for the current operating status of the PROFINET interfaces

Figure 2-2 Operator controls and display elements

2.3 Functions

2.3.1 PROFINET IO

Introduction

The interface module supports the following PROFINET IO functions:

- Integrated switch with 2 ports
- Supported Ethernet services: ping, arp, network diagnostics (SNMP)/MIB-2, LLDP
- Port diagnostics
- Deactivating of ports
- Real-time communication
- Isochronous real-time communication
- Minimum update time 250 μ s
- Media redundancy (MRP)
- Media redundancy with planned duplication (MRPD)
- Device replacement with topological configuration
- Device replacement without topological configuration
- Shared Device
- Identification data I&M0 to I&M4
- Firmware update via PROFINET IO
- Reset to factory settings via PROFINET IO
- PROFIenergy
- Configuration control (option handling)
- Value status (of I/O modules)

Requirements

The following table shows the software requirements for the use of PROFINET IO functions with the IM 157-1 PN interface module.

Table 2- 1 Software requirements for PROFINET IO functions

PROFINET IO function	Configuration software	
	STEP 7 (TIA Portal) V13 or higher (with GSD file)	STEP 7 V5.5 SP4 or higher (with GSD file)/Software from third-party manufacturer ²
Real-time communication	X	X
Isochronous real-time communication	X	X
Device replacement without programming device	X	X
Media redundancy	X	X
Shared device	X ¹	X

¹ Use a S7-1500 CPU as a controller to use a shared device with STEP 7 (TIA Portal).

² Systems of third-party manufacturers: Depending on the range of functions of the third-party system

Real-time communication

A transmission method for PROFINET IO based on a cyclic data exchange with a provider-consumer model.

Isochronous real-time communication

Synchronized transmission method for cyclic exchange of IRT data between PROFINET devices. A reserved bandwidth within the send clock is available for IRT data. The reserved bandwidth ensures that IRT data can be transferred at reserved synchronized intervals, without being influenced by other higher network loads (e.g., TCP/IP communication, or additional real-time communication).

A topological configuration is required for IRT.

Note

IO controller as sync master with IRT communication

We recommend that you also operate the IO controller as a sync master when configuring IRT communication.

Otherwise IRT and RT configured IO devices may fail if the sync master fails.

Device replacement without programming device

IO devices with this function can easily be replaced. You do not have to assign the device name with the PG.

The replaced IO device is assigned the device name by the IO controller and not by the programming device. The IO controller uses the configured topology and the neighboring relationships determined by the IO devices for this purpose. To do this, all devices involved must support the LLDP protocol (Link Layer Discovery Protocol). The configured target topology must match the actual topology.

IO devices which were already used in another configuration must be reset to factory settings before being reused.

Media redundancy

Function for safeguarding communication and plant availability. Redundant transmission lines (ring topology) ensure that another communication path is made available in the event of a transmission section failure.

Shared device

A shared device is an IO device that provides its data to up to four IO controllers.

The "Shared device" function allows the modules or submodules of an IO device to be divided up among different IO controllers. Thus allowing flexible automation concepts. You have, for example, the possibility of combining I/O modules lying near other into an IO device.

When operating as a shared device, there might be temporary delays in the update of the IO data when establishing or terminating additional communications relationships to an IO controller.

You can find additional information in the STEP 7 online help and the manual and in the function manual PROFINET with STEP 7 V14

(<http://support.automation.siemens.com/WW/view/en/49948856>).

Cabling with fixed connection setting

If you configure a fixed connection setting for the port in STEP 7, you also have to disable "Autonegotiation/Autocrossover". By disabling "Autonegotiation/Autocrossover" you speed up establishment of the communication path.

Replacement of an IM 157-1 PN

If you replace an interface module with an interface module that has already been used, you must reset this IO device to the delivery state with "Reset to factory settings".

You will find more information on "Resetting to factory settings" in the ET 200AL Distributed I/O System (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual in the section "Resetting interface module (PROFINET) to factory settings".

Reference

You will find more information on the PROFINET IO functions in the PROFINET with STEP 7 V14 (<http://support.automation.siemens.com/WW/view/en/49948856>) Function Manual and in the STEP 7 online help.

2.3.2 PROFlenergy

2.3.2.1 What is PROFlenergy?

Introduction

PROFlenergy is a PROFINET-based data interface which makes it possible to switch off consumers in a coordinated and centrally controlled manner during break times regardless of the manufacturer or device. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFlenergy, this operating state is referred to as a "pause".

PROFINET devices are switched off with special commands in the user program of the PROFINET IO controller. Additional hardware is not needed: The PROFlenergy commands are interpreted by the PROFINET devices.

The device which provides PROFlenergy and supports the matching control data record owns the PE-Entity, the access point for these control data records. This PE-Entity represents I/O modules which do not have their own PE-Entity on the interface module. I/O modules that have their own PE-Entity are always addressed directly.

For the ET 200AL distributed I/O system, the PE-Entity is exclusively provided by the PROFINET interface module.

Procedure

To configure PROFlenergy, follow these steps:

1. Create the parameter data record, Index 3, in STEP 7.
2. Transfer the parameter data record to the interface module with the instruction "WRREC" - SFB 53.
3. Create the user program with the FBs to control the PROFlenergy commands ("PE_START_END" - FB 815, "PE_CMD" - FB 816).
4. Transfer the user program to the CPU.

Additional information

You will find more information on the Internet (<http://www.profibus.com>) under Common Application Profile PROFIenergy; Technical Specification for PROFINET; as well as in the following documentation:

- System manual ET 200AL Distributed I/O System
(<https://support.industry.siemens.com/cs/ww/en/view/89254965>)
- Device manuals I/O modules
(<https://support.industry.siemens.com/cs/ww/en/ps/14247/man>)
- System manual PROFINET System Description
(<https://support.industry.siemens.com/cs/ww/en/view/19292127>)
- PROFINET with STEP 7 V14
(<https://support.industry.siemens.com/cs/ww/en/view/49948856>), function manual, section: Saving energy with PROFIenergy
- Application guide for implementation of shutdown concepts with PROFIenergy.
(<https://support.industry.siemens.com/cs/ww/en/view/96837137>)
- Saving energy with SIMATIC S7 (STEP 7 as of V5.5)
(<https://support.industry.siemens.com/cs/ww/en/view/41986454>)
- Saving energy with SIMATIC S7 and SIMATIC HMI (TIA Portal)
(<https://support.industry.siemens.com/cs/ww/en/view/58235225>)
- SIMATIC S7 library for simple configuration of PROFIenergy.
(<https://support.industry.siemens.com/cs/ww/en/view/109478388>)
- You will find additional information on the PROFIenergy FBs ("PE_START_END" - FB 815, "PE_CMD" - FB 816) in the online help for STEP 7 V5.5 SP2 and higher on System functions/system function blocks.

2.3.2.2 Principle of operation

"Pause" control and "Pause" behavior

At the beginning/end of pauses, enable/disable the pause function on the system; the IO controller then sends the PROFIenergy command "Start_Pause" or "End_Pause" to the modules. The module then interprets the content of the PROFIenergy command and turns it off or on again. The ET 200AL interface module is the PE-Entity for the PROFIenergy-capable I/O modules of the ET 200AL distributed I/O system in this case.

Device information can be called up using additional PROFIenergy commands during the pauses. You can use these commands to transfer the "Start_Pause" / "End_Pause" command in good time.

Note

A complete PROFIenergy sequence consists of the commands "Start_Pause" and "End_Pause". Always observe this sequence during programming.

LED displays

PROFIenergy generally has no effect on the LED display. Exceptions can be found in the device manuals of the I/O modules.

Response to error detection

All channels whose pause mode is set to "PE_MODE_PROCEED" report errors as in productive operation.

The following rules apply to channels which switch to a pause mode other than "PE_MODE_PROCEED":

- All errors that are unrelated to the switch to "Pause" are reported.
- If error recognition is possible during "Pause", these errors continue to be reported.
- All error messages which are caused by the switch to "Pause" are suppressed.
- The following applies if error recognition is not possible during the "Pause":
 - The status of errors already pending before the "Pause" is retained.
 - Incoming and outgoing errors are reported once the "Pause" has been ended.

Note

Switching to "Pause" and out of "Pause" may cause an error to be reported.

Additional information

Additional information on diagnostics can be found in the I/O module device manuals.

Hardware interrupt

Ending a "Pause" causes hardware interrupts to be detected again.

"Pause" behavior under certain operating conditions

A "Pause" is ended in the following cases:

Table 2- 2 Ending a "Pause"

Ending a "Pause"	Explanation
The supply voltage 1L+ of the interface module module has failed.	The "pause" is exited and can be re-activated by re-sending the PROFlenergy parameter assignment followed by the "Start_Pause" command.
<ul style="list-style-type: none"> • Stop controller¹ • Controller failure (connection interrupted)¹ • Firmware update • Reset to factory settings • Deactivating the IO device¹ 	
The I/O module was pulled and plugged	
Station stop ¹ <ul style="list-style-type: none"> • Removing an I/O module 	The "pause" is exited , the PROFlenergy parameter assignment is still on the I/O module and the "pause" can be re-activated by the "Start_Pause" command.
The supply voltage 1L+ of the I/O module has failed	
The parameter settings of the I/O module were changed during operation using data record 128	

¹ The substitute value behavior was activated.

2.3.2.3 Parameter assignment

Parameter assignment

Keep the following points in mind when assigning parameters for PROFlenergy:

- Parameters for PROFlenergy are assigned with the parameter data record (version 2), index 3. The interface module distributes the PROFlenergy parameters to the I/O modules.
- The parameter assignment of an additional pause behavior is possible immediately after the start of the previous "Pause". The required state for the following pause is activated with a new "Start_Pause" command.
- You can write the parameter assignment as often as needed.
- The interface module checks the distribution of the parameters to the I/O modules and returns the result as a return value of the write job. In the case of a negative return value, there are one or more I/O modules that have not accepted the parameter data record. In this case, the I/O modules respond according to their last PROFlenergy parameter assignment in case of an incoming "Start_Pause" command. "Start_Pause"/"End_Pause" commands can be executed as planned with a positive return value.
- In case of a failure of an I/O module or station outage, you must repeat the parameter assignment using the parameter data record.
- The ET 200AL distributed I/O system supports configuration of the behavior of a "pause". If a different response is required for an additional "Pause", you will have to assign parameters again.

Note

Effect: The response (switch-off) of the I/O modules to PROFlenergy is related to the slot, which means all channels in the slot behave accordingly.

Parameter data record

You specify in the parameter data record for PROFIenergy which I/O modules (slots) are controlled with the PROFIenergy commands.

The following table shows the content of the parameter data record for PROFIenergy, index 3, which you create yourself and can transfer to the interface module.

Table 2- 3 Parameter data record for PROFIenergy (version 2), index 3

Byte	Element		Code	Explanation
0	Version		02 _D	Cannot be modified
1	Number of blocks		01 _D to 34 _D	Slots 1 to 34 depending on the configuration of the distributed I/O system ET 200AL
2	Block 1	Slot number	00 _D	Not assigned
			01 _D to 34 _D	I/O module slot with PROFIenergy
3		Mode	0 _D : PE_MODE_PROCEED, proceed at "Pause" 1 _D : PE_MODE_SHUTDOWN, shut down at "Pause" ¹ 3 _D : PE_MODE_LAST_VALUE, last output or measured value is retained 4 _D : PE_MODE_SUBST_VALUE, substitute value "0" ²	
:	:	:	:	
64	Block 32	Slot number	See Block 1	
65		Mode		

¹ The specific behavior depends on the used I/O module (with a digital input module, for example, the sensor supply is turned off or the outputs are without power supply and voltage supply with an analog output module)

² An analog output module (e. g. with the output range 0 mA to 20 mA, ± 20 mA) or a digital output module issues the value "0".

Error messages

The following table shows which error messages the feedback data record returns, if necessary:

Table 2- 4 Error messages

Error code	Meaning	
80B1 _H	Impermissible length	Check the length of the data record
80E0 _H	Error in header information	Check the data record header information
80E1 _H	Parameter error <ul style="list-style-type: none"> at least one I/O module does not support PROFIenergy A parameter value has been incorrectly encoded 	Check the content of the data record and correct the parameter assignment error before starting the "Pause". Parameter assignment errors which are not corrected can result in incorrect I/O module shutdown behavior.

2.3.2.4 PROFenergy control data records

PROFenergy control data records

The control data record for PROFenergy, Index 80A0H, supports the following services for the IM 157-1 PN interface module:

Table 2- 5 Control data records for PROFenergy

Service	Service ID	Meaning
Start pause ¹	01H	Assuming the configured Pause behavior, suppressing all associated diagnostics data
End Pause	02H	Leaving the pause
Query Modes	03H	Reads the supported modes <ul style="list-style-type: none"> • Request List Energy Saving Modes • Request Get Mode (Energy Saving Mode Data)
PEM status	04H	Reading the PROFenergy status
PE_Identify	05H	Reading the supported PROFenergy services

¹ The minimum (configurable) pause time for the ET 200AL distributed I/O system is 10 s.

2.3.3 Configuration control (option handling)

Properties

Configuration control allows you to prepare your distributed I/O system for future extensions or options. Configuration control means that you can configure the planned maximum configuration of your distributed I/O system in advance and vary it later in a flexible manner by means of the user program.

Reference

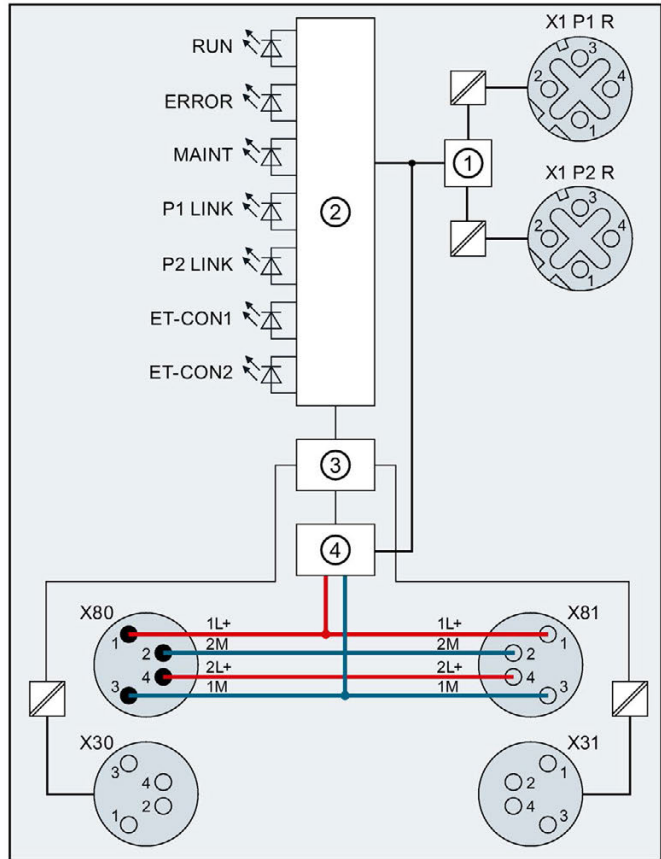
You can find more information on configuration control

- In the system manual ET 200AL Distributed I/O System (<https://support.industry.siemens.com/cs/ww/en/view/89254965>)
- On the Internet under the following link: Application collection (<https://support.industry.siemens.com/cs/ww/en/view/29430270>).
- In the STEP 7 online help.

Wiring

3.1 Terminal and block diagram

The image below shows the terminal and block diagram of the IM 157-1 PN interface module.



- | | | | |
|---------|-----------------------------------|------------------|-----------------------------------|
| ① | Switch | 1L+ | Supply voltage 1L+ (non-switched) |
| ② | Electronics | 1M | Ground 1M (non-switched) |
| ③ | ET-Connection interface | 2L+ | Load voltage 2L+ (switched) |
| ④ | Internal supply voltage | 2M | Ground 2M (switched) |
| X1 P1 R | 1. PROFINET interface | RUN | LED operating state (green) |
| X1 P2 R | 2. PROFINET interface | ERROR | LED diagnostics status (red) |
| X80 | Infeed of supply voltages | MAINT | LED diagnostics status (yellow) |
| X81 | Loop-through of supply voltages | P1 LINK, P2 LINK | PROFINET LEDs (green) |
| X30 | Infeed of the ET-Connection | ET-CON1, ET-CON2 | ET-Connection LEDs (green) |
| X31 | Loop-through of the ET-Connection | | |

Figure 3-1 Terminal and block diagram

3.2 Pin assignment

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for PROFINET

The following table shows the pin assignment of the two sockets for PROFINET.

Table 3- 1 Pin assignment of the PROFINET sockets

Pin	Assignment		Front view of the sockets	
	X1 P1 R Socket	X1 P2 R Socket	X1 P1 R	X1 P2 R
1	TXP	RXP		
2	RXP	TXP		
3	TXN	RXN		
4	RXN	TXN		
Shielding	Functional earth FE			

Note

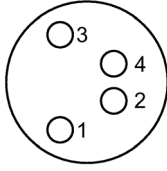
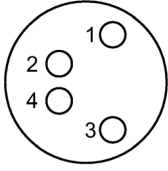
Pin assignments

If you disable "Autonegotiation" in STEP 7, you must pay attention to the different pin assignments of X1 P1 R and X1 P2 R.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

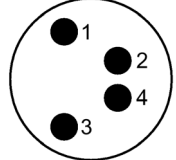
Table 3- 2 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection1)	X31 socket (ET-Connection2)		X30	X31
1	RXP	RXP	Yellow		
2	TXP	TXP	White		
3	TXN	TXN	Blue		
4	RXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The following table shows the pin assignment for infeed of the supply voltage.

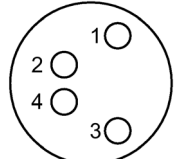
Table 3- 3 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the connector
	X80 connector (power input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The following table shows the pin assignment for loop-through of the supply voltage.

Table 3- 4 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the socket
	X81 Socket (power output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE

ET-Connection/supply voltage

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage.
Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

 **CAUTION**

PROFINET IO

Modules with PROFINET interfaces may only be operated under the following condition:
All connected devices must be equipped with SELV/PELV power supplies.

Parameters

4.1 Parameters

The following table shows the parameters for the IM 157-1 PN interface module.

Table 4- 1 Parameters (GSD file)

Parameters	Value range	Default	Efficiency range
Configuration control	<ul style="list-style-type: none"> • Disable • Enable 	Disable	ET 200AL

4.2 Explanation of the parameters

Configuration control

You can use this parameter to enable the configuration control function in the ET 200AL distributed I/O system.

Note

If you configure the enable, the ET 200AL distributed I/O system requires a control data record 196 from the user program in order for the ET 200AL distributed I/O system to operate the I/O modules.

Reference

You will find more information in the section Configuration control (option handling) and in the STEP 7 online help.

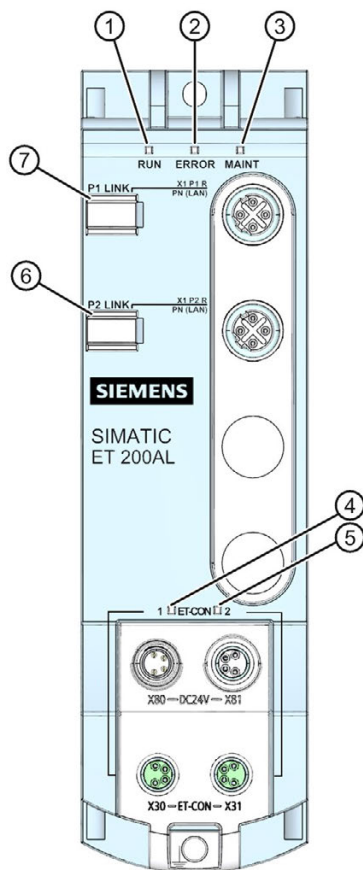
Interrupts, error messages, diagnostics and system alarms

5

5.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the interface module IM 157-1 PN.



- | | | |
|---|---------|----------|
| ① | RUN | (green) |
| ② | ERROR | (red) |
| ③ | MAINT | (yellow) |
| ④ | ET-CON1 | (green) |
| ⑤ | ET-CON2 | (green) |
| ⑥ | P2 LINK | (green) |
| ⑦ | P1 LINK | (green) |

















Figure 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Corrective measures for diagnostics alarms can be found in the section Diagnostics alarms (Page 30).

LED RUN, LED ERROR, LED MAINT




Table 5- 1 Status and error displays of the LEDs RUN, ERROR, MAINT

LEDs			Meaning	Solution
RUN	ERROR	MAINT		
 Off	 Off	 Off	Missing or insufficient supply voltage on interface module.	Check the supply voltage or switch it on on the interface module.
 On	 On	 On	Test of LEDs during startup: The three LEDs light up simultaneously for approximately 0.25 s.	---
 Flashes	 Off	 Off	Interface module is deactivated.	Activate the interface module with the configuration software or the user program.
			Interface module is not configured.	Configure the interface module with the configuration software.
			ET 200AL starts up.	---
			ET 200AL is being assigned parameters.	---
 On	Not relevant	Not relevant	ET 200AL is currently exchanging data with the IO controller.	---
Not relevant	 Flashes	Not relevant	Group error	Evaluate the diagnostics and eliminate the error.
			The preset configuration does not correspond to the actual configuration of the ET 200AL.	Check the configuration of the ET 200AL to see whether a module is missing, defective or if a module that is not configured is connected to ET-CON1 or ET-CON2 .
			Parameter assignment error in the I/O module	Evaluate the display of the module status in STEP 7 or in STEP 7 (TIA portal) and correct the errors in the I/O module.
Not relevant	Not relevant	 On	Maintenance	See section Maintenance events (Page 32)
 Flashes	 Flashes	 Flashes	The "Node flash test" is run (the LEDs P1 LINK and P2 LINK of the PROFINET interface also flash).	---
			Hardware or firmware defective (The LEDs P1 LINK and P2 LINK of the PROFINET interface do not flash).	Replace the interface module.
 Flashes	Not relevant	Not relevant	Firmware is loading (all LEDs remain in their current state while the firmware update is being written)	---

5.1 Status and error displays



LED P1 LINK, LED P2 LINK

Table 5- 2 Status displays of the LEDs P1 LINK and P2 LINK

LEDs		Meaning	Solution
P1 LINK	P2 LINK		
 Off		There is no connection between the PROFINET interface of your PROFINET device and a communication partner (e.g., IO controller).	Check whether the bus cable to the switch or IO controller is disconnected.
 On		There is no connection between the PROFINET interface of your PROFINET device and a communication partner (e.g., IO controller).	-
 Flashes		The "Node flash test" is run (the RUN, ERROR and MAINT LEDs also flash).	-

LED ET-CON1, LED ET-CON2

Table 5- 3 Status displays of the LEDs ET-CON1 and ET-CON2

LEDs		Meaning	Solution
ET-CON1	ET-CON2		
 Off		There are no I/O modules available at the respective ET-Connection or the modules do not have supply voltage.	Check the wiring for the ET-Connection or the supply voltage for the I/O module.
 On		A communications connection to at least one IO module at the corresponding ET-Connection is available.	-

5.2 Interrupts

5.2.1 Evaluating interrupts

Introduction

Interrupts are triggered by the IO device in case of errors. Interrupts are evaluated based on the I/O controller used.

Evaluating interrupts with I/O controllers

The ET 200AL distributed I/O system supports the following interrupts:

- Diagnostics interrupts
- Hardware interrupts
- Pull/plug module interrupt

In the event of an interrupt, interrupt OBs are automatically called in the CPU of the IO controller.

Information on the cause and class of the error is already available, based on the OB number and start information.

Detailed information on the error event can be obtained in the error OB using the instruction "RALRM" (read additional interrupt information).

System diagnostics

In STEP 7 (TIA Portal), the updated system diagnostic is available for the modules of the S7-1500 automation system (IO controller CPU S7-1500) and ET 200AL (IO device). Independent of the cyclic user program, messages are made available on the display of the CPU S7-1500, the CPU web server and the HMI device.

You will find more information on systemic diagnostics in the Function Manual Diagnostics (<http://support.automation.siemens.com/WW/view/en/59192926>).

5.2.2 Trigger a diagnostics interrupt

For an incoming or outgoing event (for example, wire break on a channel of an I/O module), the interface module triggers a diagnostics interrupt if the parameters were assigned accordingly.

The CPU interrupts the processing of the user program and processes the diagnostics interrupt OB (OB 82). The event that triggered the interrupt is entered in the start information of the diagnostics interrupt OB.

5.3 Alarms

5.2.3 Triggering a hardware interrupt

During a hardware interrupt, the CPU interrupts the processing of the user program and processes the hardware interrupt OB (e.g., OB 40). The event that triggered the interrupt is entered in the start information of the hardware interrupt OB.

Note

Diagnostics "Hardware interrupt lost" (from I/O module)

Avoid creating hardware interrupts cyclically.

If the hardware interrupt load is too high, hardware interrupts can get lost depending on the number of I/O modules and the communication load.

5.2.4 Triggering an insert/remove module interrupt

When an insert/remove module interrupt occurs, the CPU interrupts execution of the user program and processes the insert/remove module interrupt OB (OB 83). The event that triggered the interrupt is entered in the start information of the insert/remove OB.

The pull/plug OB (OB 83) is also triggered for all subsequent I/O modules, because the ET-Connection and/or the power supply is interrupted.

5.3 Alarms

5.3.1 Diagnostics alarms

Actions after a diagnostics alarm

There can be more than one diagnostic alarm at a given time. Actions initiated by diagnostics alarms:

- The ERROR LED of the interface module flashes.
- Diagnostic data is reported as diagnostics interrupts to the CPU of the IO controller and can be read via data records.
- Incoming diagnostics alarms are saved to the diagnostics buffer of the I/O controller.
- OB 82 is called. If OB 82 is not available, the I/O controller goes into STOP mode.

You can find more information on this topic in the STEP 7 online help.

Reading out the diagnostics data

Table 5- 4 Reading the diagnostics with STEP 7

Automation system with IO controller	Application	See...
SIMATIC S7	Diagnostics as plain text in STEP 7 in online and diagnostics view	STEP 7 online help <ul style="list-style-type: none"> STEP 7 V13 and higher Function Manual PROFINET with STEP 7 V13 (http://support.automation.siemens.com/WW/view/en/49948856) STEP 7 V5.5 and higher System Manual PROFINET System Description (http://support.automation.siemens.com/WW/view/en/19292127)
	"RDREC" instruction (SFB 52) Reading data records from the IO device	
	"RALRM" instruction (SFB 54) Receiving alarms from the IO device	

Additional information on the data records for PROFINET IO

The structure of the diagnostics data records and programming examples can be found in the Programming Manual From PROFIBUS DP to PROFINET IO (<http://support.automation.siemens.com/WW/view/en/19289930>) and in the Application example (<http://support.automation.siemens.com/WW/view/en/24000238>).

Causes of error and troubleshooting

Causes of errors and corrective measures of diagnostics alarms are described in the device manuals of the I/O modules (<http://support.automation.siemens.com/WW/view/en/89013554>) in the section Interrupt, Error and System Messages.

5.3.2 Maintenance events

Triggering of a maintenance event

The PROFINET IO interfaces of the interface module support the diagnostics concept and maintenance concept in PROFINET IO according to standard IEC 61158-6-10. The goal is the early recognition and correction of potential disruptions.

For the interface module, maintenance events signal to the user when a network component must be checked or replaced.

The CPU interrupts user program execution and processes the diagnostic block OB 82. The event that triggered the maintenance event is entered in the start information of the OB 82.


The interface module signals a maintenance event to the higher-level diagnostics system in the case of the following event:

Table 5- 5 Triggering of a maintenance event

Maintenance alarm	Event	Alarm/Meaning
Maintenance demanded LED MAINT is lit.	Synchronization loss	<ul style="list-style-type: none"> No synchronization frame received. No synchronization message frame was received by the sync master within the timeout period after parameter assignment or during operation. Successive synchronization frames are located outside permitted limits (jitter).

System alarms in STEP 7 (TIA Portal)

The maintenance information is generated in STEP 7 (TIA Portal) V12 SP1 and higher with the following system alarms:

- Maintenance demanded - indicated for each port by a yellow wrench icon  in the device view or in the hardware configuration.

You can find more information on this topic in the STEP 7 online help.

5.3.3 Channel diagnostics

Function

Channel-related diagnostics provides information about channel faults in modules.

Channel faults are mapped as channel diagnostics data in IO diagnostics data records.

The data record is read with the "RDREC" instruction (SFB 52).

Structure of the diagnostics data records

The data records supported by the ET 200AL distributed I/O system are based on the PROFINET IO standard - Application Layer Service definition V2.2.

You can download the standard on the Internet (<http://www.profibus.com>) from home page of the PROFIBUS user organization free of charge.

Structure of the manufacturer-specific diagnostics data records

The structure of the diagnostics data records is differentiated by the BlockVersion. The following BlockVersion applies to the IM 157-1 PN interface modules:

Table 5- 6 Structure of the manufacturer-specific diagnostics data records

IM 157-1 PN interface module	BlockVersion
6ES7157-1AB00-0AB0	W#16#0101

5.3.4 Invalid configuration states of ET 200AL on the PROFINET IO

Invalid configuration states

If the number of modules exceeds the maximum configuration limit, the extra modules are ignored by the system. No data exchange takes place.

5.3.5 STOP of the IO controller and recovery of the IO device

STOP of the SIMATIC IO controller

If diagnostics from the IO device are received by the IO controller in the STOP state, these diagnostics do not result in a start of the organization blocks after startup of the IO controller. You must read the data record E00C_H in OB 100 with the "RDREC" instruction.

Return of the SIMATIC IO device

If you want to read out the diagnostics of a station after the station return, you must read the data record E00C_H in OB 86 with the "RDREC" instruction.

Technical specifications

Technical specifications of the interface module IM 157-1 PN

	6ES7157-1AB00-0AB0
General information	
Product type designation	IM 157-1 PN
Hardware functional status	E01
Firmware version	V1.0.x
Vendor identifier (VendorID)	002AH
Product function	
I&M data	Yes; I&M0 to I&M4
Engineering with	
STEP 7 TIA Portal can be configured/integrated as of version	as of STEP 7 V13 SP1
STEP 7 can be configured/integrated as of version	V5.5 SP4 Hotfix 3 or higher
PROFINET as of GSD version/GSD revision	GSDML V2.3.1
Configuration control	
Via data record	Yes
Supply voltage	
Load voltage 1L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction
Input current	
Current consumption (rated value)	100 mA
From load voltage 1L+ (unswitched current)	4 A; maximum value
From load voltage 2L+, max.	4 A; maximum value
Power loss	
Power loss, typ.	2.9 W
Address area	
Address space per station	
Address space per station, max.	1430 bytes
Interfaces	
Number of PROFINET interfaces	1
1st interface	
Interface type	PROFINET
Interface hardware	
Integrated switch	Yes
M12 port	Yes; 2x M12 d-coded

6ES7157-1AB00-0AB0	
Protocols	
PROFINET IO device	Yes
Interface hardware	
M12 port	
10 Mbps	Yes; for Ethernet services
100 Mbps	Yes; PROFINET with 100 Mbps full duplex (100BASE-TX)
Transmission method	PROFINET with 100 Mbps full duplex (100BASE-TX)
Autonegotiation	Yes
Autocrossing	Yes
Protocols	
PROFINET IO device	
Services	
• Open IE communication	Yes
• IRT	Yes; 250 μ s, 500 μ s, 1 ms, 2 ms, 4 ms, 8 ms, 16 ms, 32 ms, 64 ms, 128 ms
• MRP	Yes
• MRPD	Yes
• PROFIenergy	Yes
• Shared Device	Yes
• Number of IO controllers with shared device, max.	4
Open IE communication	
TCP/IP	Yes
SNMP	Yes
LLDP	Yes
Interrupts/diagnostics/status information	
Interrupts	Yes
Diagnostics functions	Yes
Diagnostics indicator LED	
RUN LED	Yes; green LED
ERROR LED	Yes; red LED
MAINT LED	Yes; yellow LED
Connection display LINK TX/RX	Yes; 2x green LED
Electrical isolation	
Between load voltages	Yes
Between PROFINET and all other circuits	Yes
Insulation	
Insulation tested with	707 V DC (type test)

6ES7157-1AB00-0AB0	
Degree of protection and protection class	
Degree of protection according to EN 60529	
• IP65	Yes
• IP67	Yes
Ambient conditions	
Ambient temperature during operation	
Min.	-25 °C
Max.	55 °C
Connection technology	
Power supply	M8, 4-pin
ET-Connection	
ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	45 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	263 g

Dimension drawing

A

The figure below shows the dimension drawing of the IM 157-1 PN interface module in the front and side view.

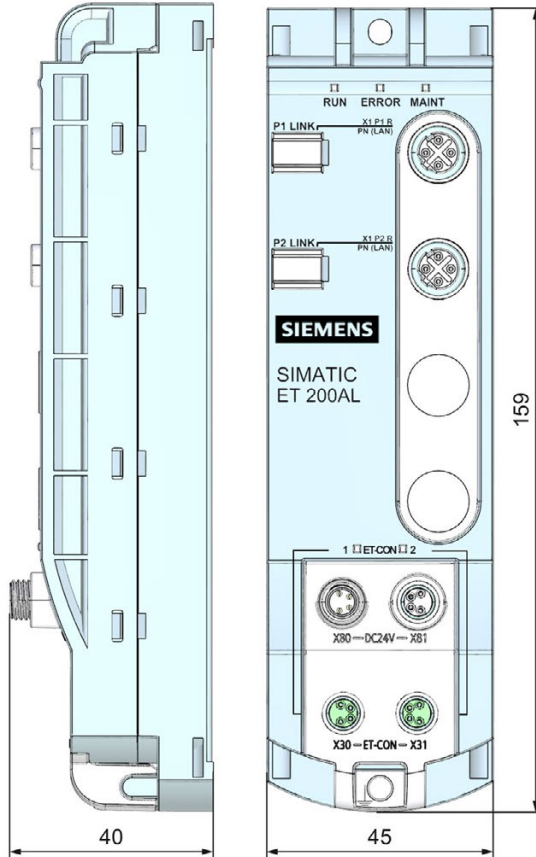


Figure A-1 Dimension drawing

Cycle times

The figure below shows the cycle times at ET-Connection based on the number of I/O modules with a Profinet send clock of 0.5ms.

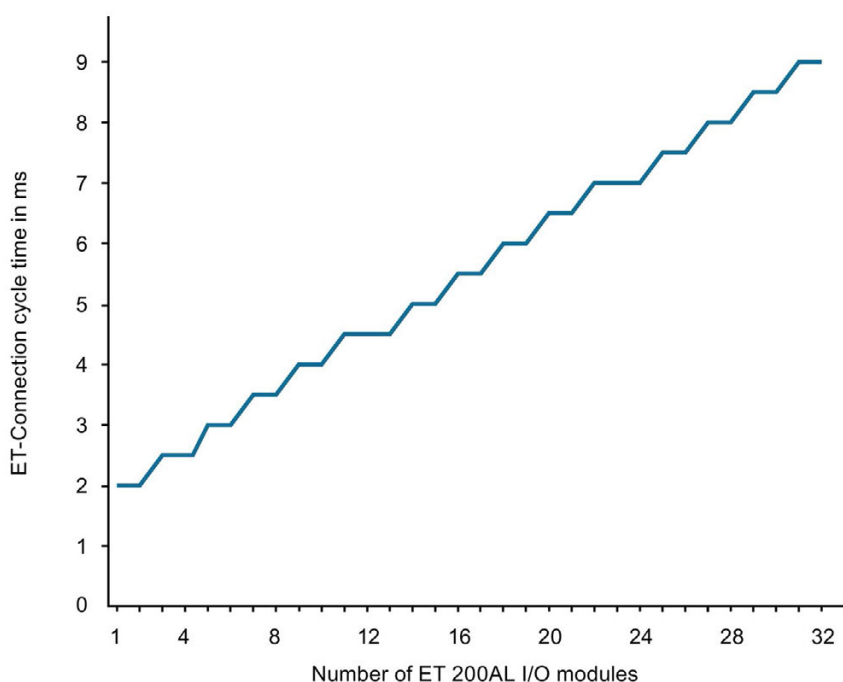
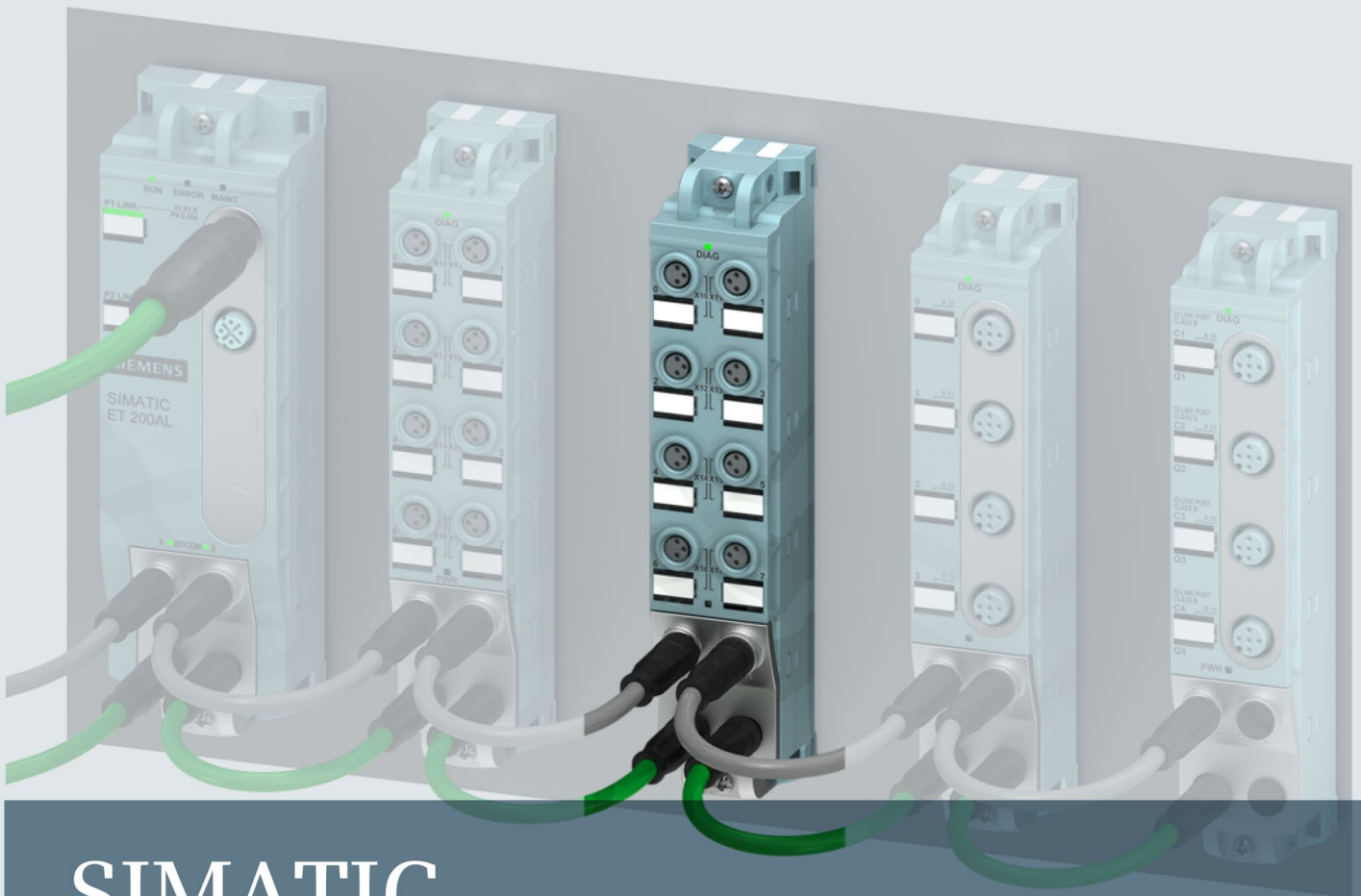


Figure B-1 Cycle times

The cycle time at ET-Connection is synchronized with the PROFINET send clock. This means that the input data of the I/O modules are transmitted via ET-Connection without further delay (wait time in the interface module) via PROFINET. The output data from PROFINET is also transmitted without further delay via ET-Connection to the I/O modules. Thus, the cycle time of the ET-Connection, based on the number of I/O modules, is always a multiple of the configured PROFINET send clock.

The chart shown above shows the trend for a send clock of 0.5 ms. With larger send clocks, the gradation of the trend changes according to the send clock.

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SIMATIC

ET 200AL

Digital input module DI 8x24VDC 8xM8 (6ES7141-5BF00-0BA0)

Manual

Edition

02/2016

Answers for industry.

SIEMENS

SIMATIC

ET 200AL
Digital input module
DI 8x24VDC 8xM8
(6ES7141-5BF00-0BA0)

Manual

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A

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (<http://www.siemens.com/industrialsecurity>).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (<http://support.automation.siemens.com>).

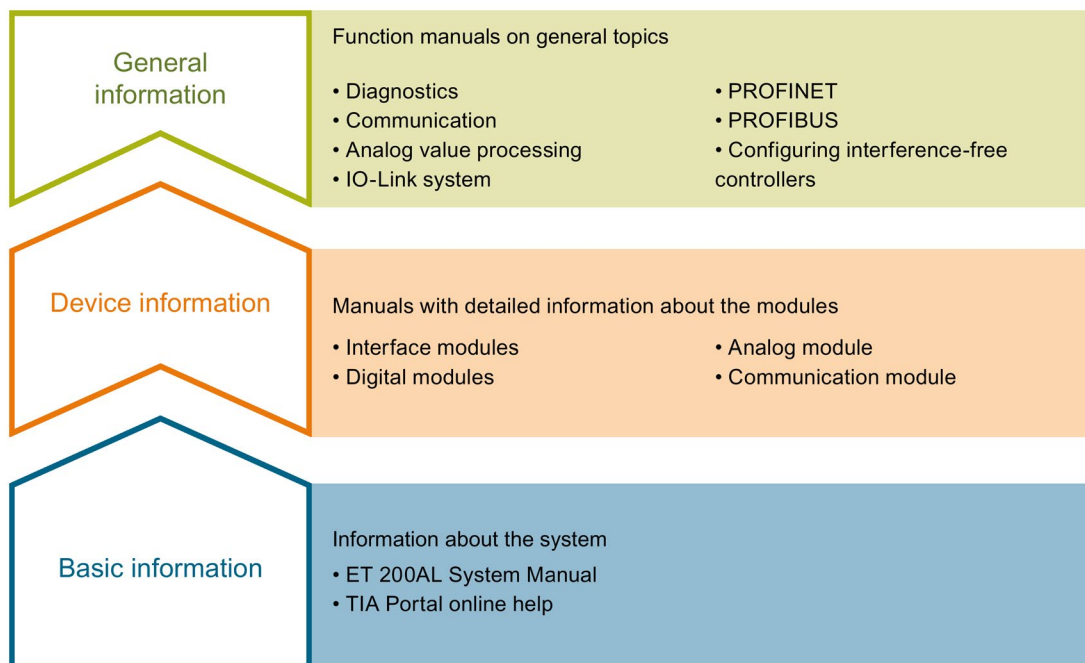
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Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<http://w3.siemens.com/mcms/industrial-automation-systems-simatic/en/manual-overview/tech-doc-et200/Pages/Default.aspx>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

"mySupport" - Documentation

In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.

You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<http://support.industry.siemens.com/My/ww/en/documentation>).

"mySupport" - CAx data

In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

Product overview

2.1 Properties

Article number

6ES7141-5BF00-0BA0

View of the module

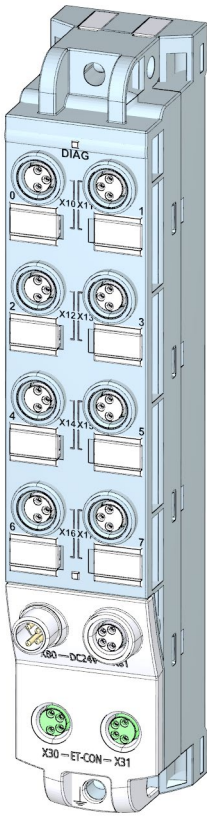


Image 2-1 View of the DI 8x24VDC 8xM8 digital input module

Properties

The module has the following technical properties:

- 8 digital inputs
- M8 sockets for connection of sensors
- 24 V DC supply voltage
- Configurable diagnostics can be set for each module
- Typical input delay of 3 ms
- Suitable for switches and proximity switches
- Dimensions 30 x 159 mm

The module supports the following functions:

- Firmware update
- Identification and maintenance data I&M0 to I&M3
- Value status (Quality Information)
- PROFIenergy

Accessories

The following components are included in the module package:

- Identification labels
- Spacers

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

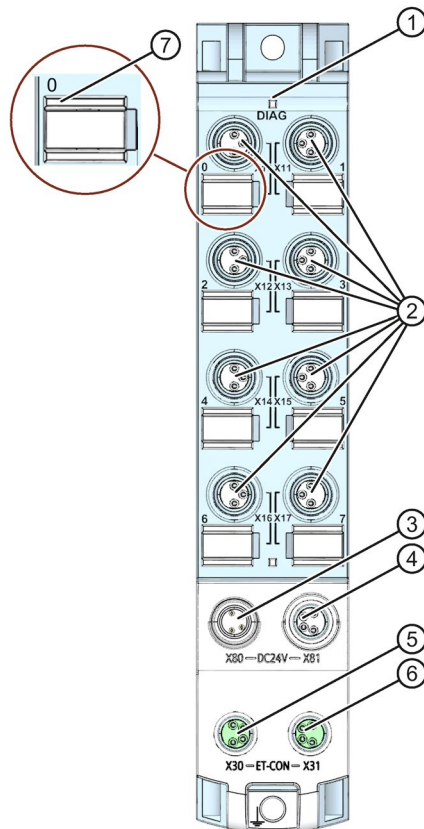
- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap

See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual.

2.2 Operator controls and display elements

The following figure shows the operator controls and display elements of the DI 8x24VDC 8xM8 digital input module.



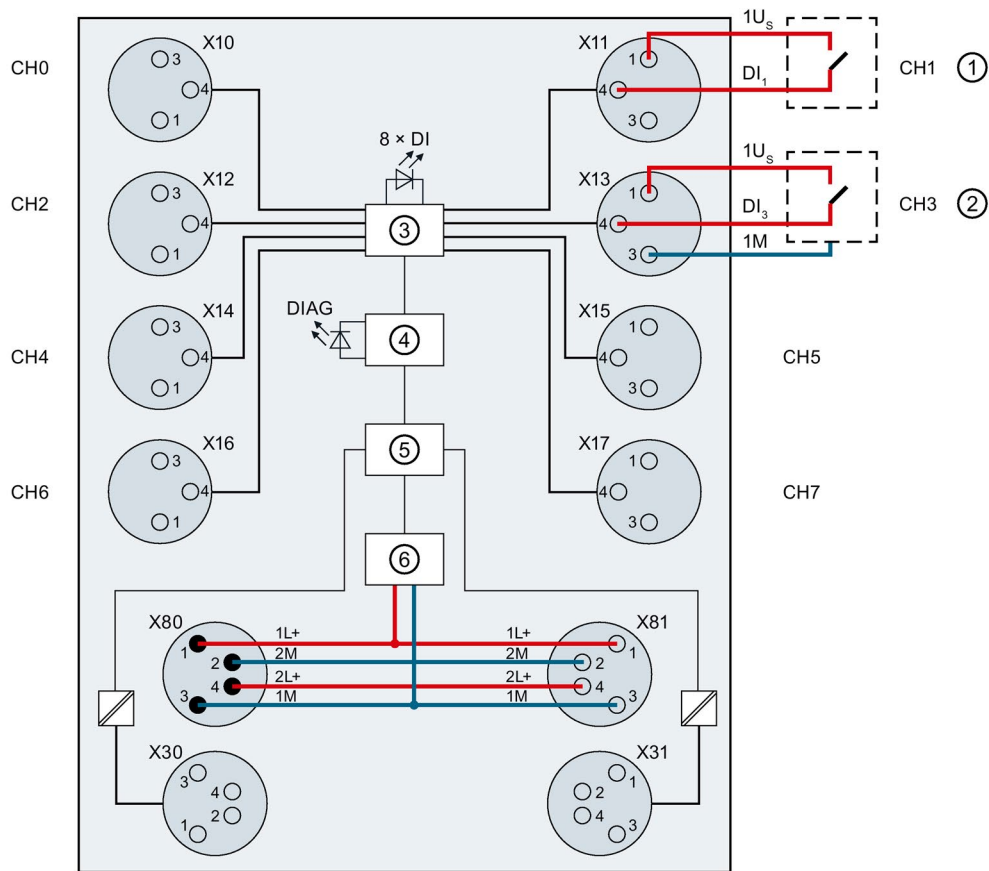
- ① DIAG: LED display for the diagnostic status
- ② X10 to X17: Sockets for the input signal
- ③ X80: Connector for infeed of the supply voltage (POWER input)
- ④ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑤ X30: Socket for ET-Connection IN
- ⑥ X31: Socket for ET-Connection OUT
- ⑦ LED displays 0 to 7 for the channel status

Image 2-2 Operator controls and display elements

Wiring

3.1 Terminal and block diagram

The following figure shows an example of the pin assignment of signal outputs with 2- and 3-wire connection.



①	2-wire connection	X30	Infeed of the ET-Connection
②	3-wire connection	X31	Loop-through of the ET-Connection
③	DI circuit	1L+	Supply voltage 1L+ (non-switched)
④	Microcontroller	1M	Ground 1M (non-switched)
⑤	ET-Connection interface	2L+	Load voltage 2L+ (switched)
⑥	Internal supply voltage	2M	Ground 2M (switched)
X10 to X17	Channels 0 to 7	1Us	24 V encoder supply
X80	Infeed of supply voltages	DI _n	Input signal
X81	Loop-through of supply voltages	DI	Channel status LEDs (0 to 7) (green)
		DIAG	LED diagnostic status (red/green)

Image 3-1 Terminal and block diagram

3.2 Pin assignment

Note

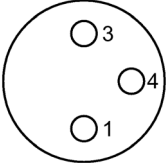
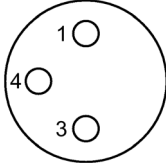
Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for digital inputs

The table below shows the pin assignment of the 8 sockets for the connection of digital inputs.

Table 3- 1 Pin assignment for digital inputs

Pin	Assignment	Front view of the sockets	
		X10, X12, X14, X16	X11, X13, X15, X17
1	24 V encoder supply 1Us (derived from 1L+ non-switched)		
3	Encoder supply ground 1M		
4	Input signal DI ₀ : Connector X10 Input signal DI ₁ : Connector X11 Input signal DI ₂ : Connector X12 Input signal DI ₃ : Connector X13 Input signal DI ₄ : Connector X14 Input signal DI ₅ : Connector X15 Input signal DI ₆ : Connector X16 Input signal DI ₇ : Connector X17		

NOTICE

24 V encoder supply 1Us

Use only the 24 V encoder supply 1Us provided by the digital input module to supply power to the encoder.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

Table 3-2 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

Table 3-3 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3-4 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE**ET-Connection/supply voltage**

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage.

Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

Parameters/address space

4.1 Parameters

The following table shows the parameters for the DI 8x24VDC 8xM8 digital input module.

Table 4- 1 Parameters

Parameters	Value range	Default	Scope
Diagnostics: Short-circuit to ground	<ul style="list-style-type: none"> Disable Enable 	Disable	Module

4.2 Explanation of the parameters

Diagnostics: Short-circuit to ground

Enabling of the diagnostics if a short-circuit of the encoder supply to ground occurs.

4.3 Address space

The figure below shows the assignment of the address space for the digital input module DI 8x24VDC 8xM8 with value status (Quality Information, QI). If you are using PROFINET and the value status was enabled, the addresses for the value status are available. The value status is not available for PROFIBUS.

Assignment in the process image input (PII)

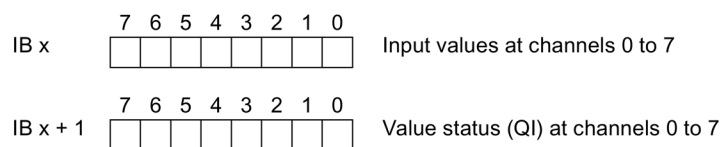


Image 4-1 Address space

Configuration options of the DI 8x24VDC 8xM8 digital input module

You have the following configuration options:

- Configuration 1: without value status
- Configuration 2: with value status

Evaluating the value status

An additional byte is occupied in the input address space if you enable the value status for the digital input module. Bits 0 to 7 in this byte are assigned to a channel and provide information on the validity of the digital input value.

Bit = 1: No error on channel.

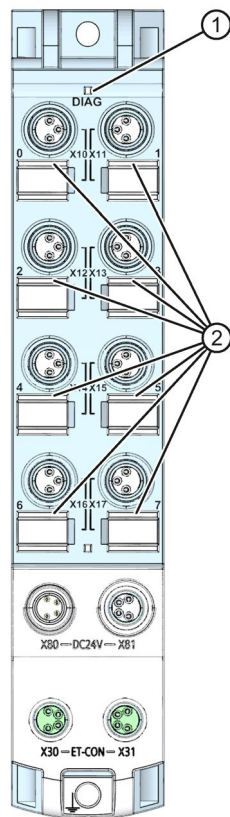
Bit = 0: Error on channel.

Interrupts/diagnostics alarms

5.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the DI 8x24VDC 8xM8 digital input module.



- ① Diagnostic status (DIAG) (red/green)
- ② Channel status (0 to 7) (green)





Image 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Corrective measures for diagnostics alarms can be found in the section Diagnostics alarms (Page 19).



DIAG LED

Table 5- 1 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> Module parameters not assigned Loading firmware (while the firmware update is being performed, all LEDs retain their current status)
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics

LED channel status

Table 5- 2 LED channel status display

LED channel status	Meaning
 Off	Process signal = 0
 On	Process signal = 1

5.2 Interrupts

The DI 8x24VDC 8xM8 digital input module supports diagnostic interrupts.

Diagnostic interrupt

The digital input module generates a diagnostic interrupt at the following events:

- Short-circuit of encoder supply to ground

5.3 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the DIAG LED flashes red on the digital input module. You can read out the diagnostics alarms, for example, in the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 5- 3 Diagnostics alarms, their meanings and corrective measures

Diagnostics alarm	Error code	Meaning	Remedy
Short-circuit	1H	Short-circuit encoder supply to ground	Eliminate the short-circuit

Technical specifications

Technical specifications of the DI 8x24VDC 8xM8 digital input module

	6ES7141-5BF00-0BA0
General information	
Product type designation	DI 8X24VDC, 8XM8
Hardware functional status	E01
Firmware version	V1.0.x
Product function	
I&M data	Yes; I&M0 to I&M3
Engineering with	
STEP 7 TIA Portal can be configured/integrated as of version	As of STEP 7 V13 SP1
STEP 7 can be configured/integrated as of version	V5.5 SP4 Hotfix 3 or higher
PROFIBUS as of GSD version/GSD revision	GSD as of revision 5
PROFINET as of GSD version/GSD revision	GSDML V2.3.1
Supply voltage	
Load voltage 1L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction; encoder supply outputs are connected with reverse polarity
Input current	
Current consumption (rated value)	25 mA; no load
From load voltage 1L+ (unswitched voltage)	4 A; maximum value
From load voltage 2L+, max.	4 A; maximum value
Encoder supply	
Number of outputs	8
24 V encoder supply	
Short-circuit protection	Yes; per module, electronic
Output current, max.	0.7 A; total current of all encoders
Power loss	
Power loss, typ.	1.9 W
Digital inputs	
Number of inputs	8
Input characteristic curve acc. to IEC 61131, type 3	Yes

6ES7141-5BF00-0BA0	
Number of inputs that can be controlled simultaneously	
All mounting positions	
<ul style="list-style-type: none"> up to 55 °C, max. 	8
Input voltage	
Type of input voltage	DC
Rated value (DC)	24 V
For signal "0"	-30 ... +5 V
For signal "1"	+11 ... +30 V
Input current	
For signal "1", typ.	3.2 mA
Input delay (for rated value of input voltage)	
For standard inputs	
<ul style="list-style-type: none"> at "0" to "1", min. 	1.2 ms
<ul style="list-style-type: none"> at "0" to "1", max. 	4.8 ms
<ul style="list-style-type: none"> at "1" to "0", min. 	1.2 ms
<ul style="list-style-type: none"> at "1" to "0", max. 	4.8 ms
Cable length	
Unshielded, max.	30 m
Encoders	
Connectable encoders	
2-wire sensor	Yes
<ul style="list-style-type: none"> Permissible quiescent current (2-wire sensor), max. 	1.5 mA
Interrupts/diagnostics/status information	
Interrupts	
Diagnostic interrupt	Yes; configurable
Diagnostics alarms	
Short-circuit	Yes; encoder supply to ground; module-based
Diagnostics indicator LED	
Channel status display	Yes; green LED
For module diagnostics	Yes; green/red LED
Electrical isolation	
Between load voltages	Yes
Electrical isolation of channels	
Between channels	No
Between the channels and backplane bus	Yes
Between the channels and power supply of the electronics	No
Insulation	
Insulation tested with	707 V DC (type test)

6ES7141-5BF00-0BA0	
Degree of protection and protection class	
Degree of protection according to EN 60529	
• IP65	Yes
• IP67	Yes
Ambient conditions	
Ambient temperature in operation	
Min.	-25 °C
Max.	55 °C
Connection technology	
Inputs/outputs	M8, 3-pin
Power supply	M8, 4-pin
ET-Connection	
ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	30 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	145 g

PROFenergy

7.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific behavior of the digital input module is explained in the following section.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<http://support.automation.siemens.com/WW/view/en/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V13 (<http://support.automation.siemens.com/WW/view/en/49948856>).

Application examples (<http://support.automation.siemens.com/WW/view/en/41986454>) are also available on the Internet.

7.2 Behavior of the digital input module

Requirement

You can use the PROFenergy function when you use the internal encoder supply.

Display

The channel status LEDs are directly influenced by the signal level at the socket. If the encoder supply is switched off, this causes the channel status LEDs to also switch off.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- Encoder supply switch-off upon the start of "pause" does not result in the "Short-circuit" alarms.
- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

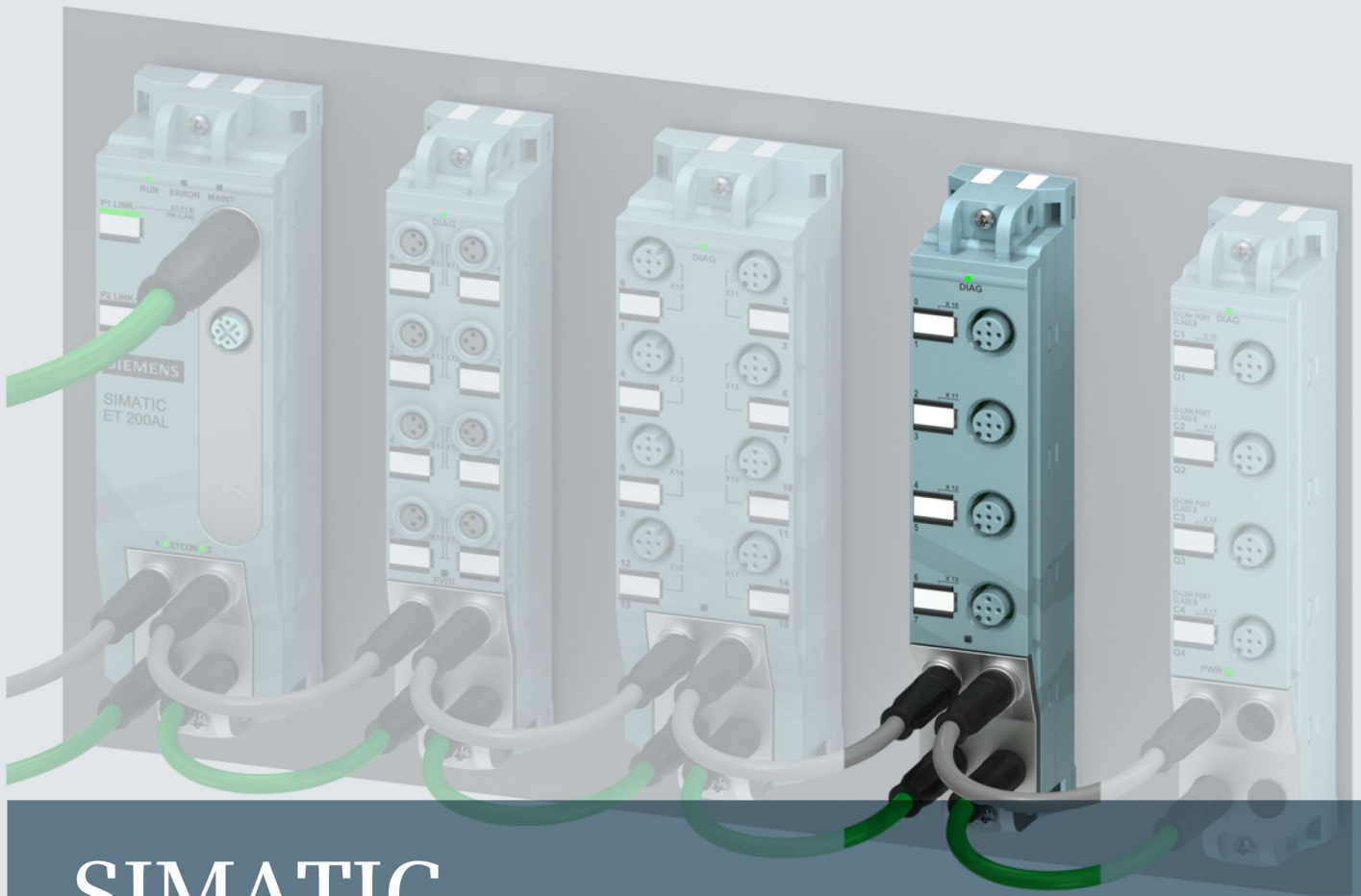
The following table shows the "Mode" parameter.

Table 7- 1 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" • Encoder supply U _S switched off ¹ • Pause substitute value: 0 _B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" • Encoder supply U _S switched off ¹ • Pause substitute value: Last input value • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" • Encoder supply U _S switched off ¹ • Pause substitute value: Configured pause substitute value • Value status "BAD"

¹ As there is only one encoder supply U_S for all channels, the supply can only be switched off at "pause" if no channel is configured in PE_MODE_PROCEED.

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SIMATIC

ET 200AL

Digital input module DI 8x24VDC 4xM12 (6ES7141-5AF00-0BA0)

Manual

Edition

02/2016

Answers for industry.

SIEMENS

SIMATIC

ET 200AL
Digital input module
DI 8x24VDC 4xM12
(6ES7141-5AF00-0BA0)

Manual

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PROFInergy

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Dimension drawing

A

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

Trademarks

All names identified by ® are registered trademarks of Siemens AG. The remaining trademarks in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owner.

Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (<http://www.siemens.com/industrialsecurity>).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (<http://support.automation.siemens.com>).

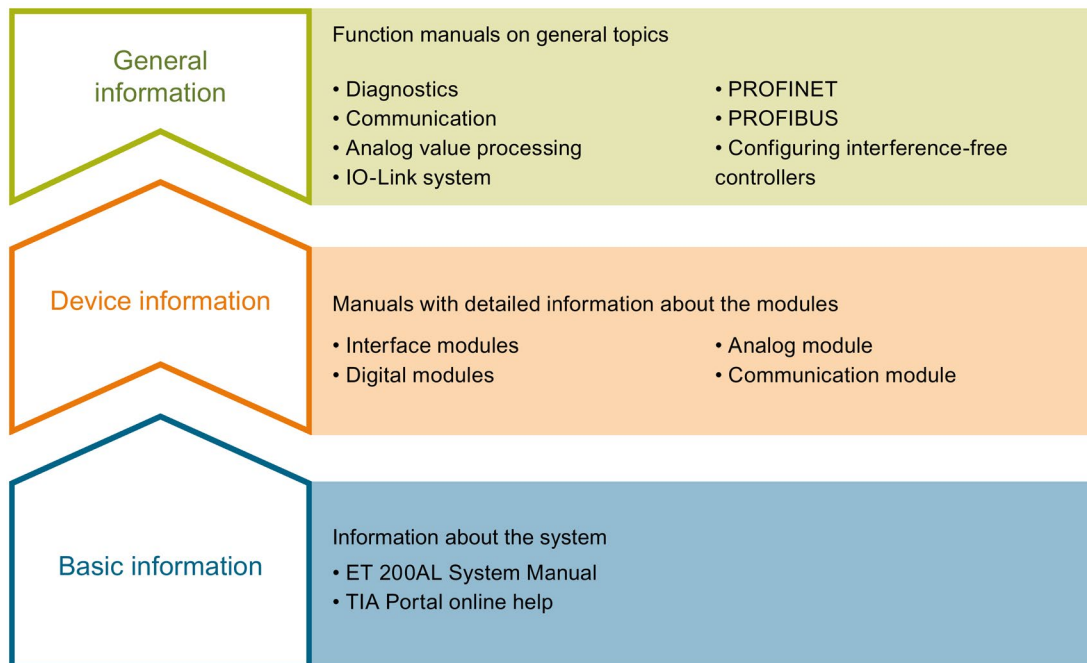
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Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<http://w3.siemens.com/mcms/industrial-automation-systems-simatic/en/manual-overview/tech-doc-et200/Pages/Default.aspx>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

"mySupport" - Documentation

In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.

You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<http://support.industry.siemens.com/My/ww/en/documentation>).

"mySupport" - CAx data

In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

Product overview

2.1 Properties

Article number

6ES7141-5AF00-0BA0

View of the module

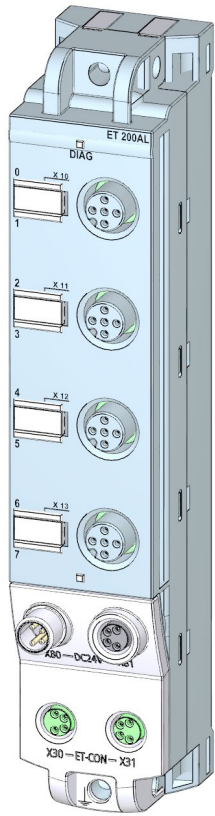


Image 2-1 View of the DI 8x24VDC 4xM12 digital input module

Properties

The module has the following technical properties:

- 8 digital inputs
- M12 sockets for connection of sensors
- 24 V DC supply voltage
- Configurable diagnostics can be set for each module
- Typical input delay of 3 ms
- Suitable for switches and proximity switches
- Dimensions 30 x 159 mm

The module supports the following functions:

- Firmware update
- Identification and maintenance data I&M0 to I&M3
- Value status (Quality Information)
- PROFIenergy

Accessories

The following components are included in the module package:

- Identification labels
- Spacers

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

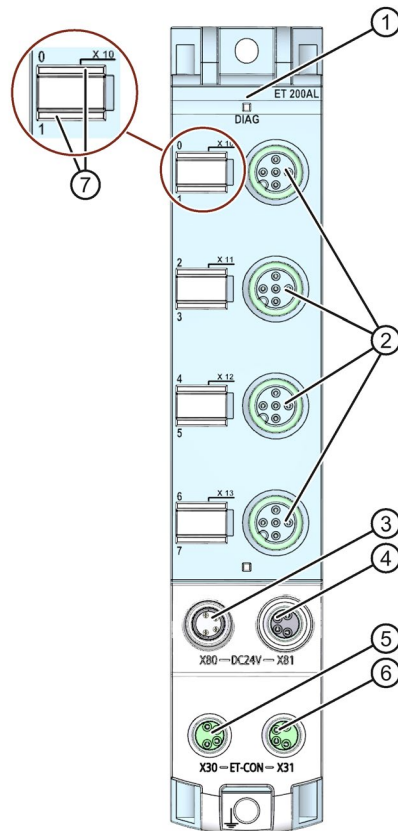
See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system

(<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual.

2.2 Operator controls and display elements

The figure below shows the operator controls and display elements of the DI 8x24VDC 4xM12 digital input module.



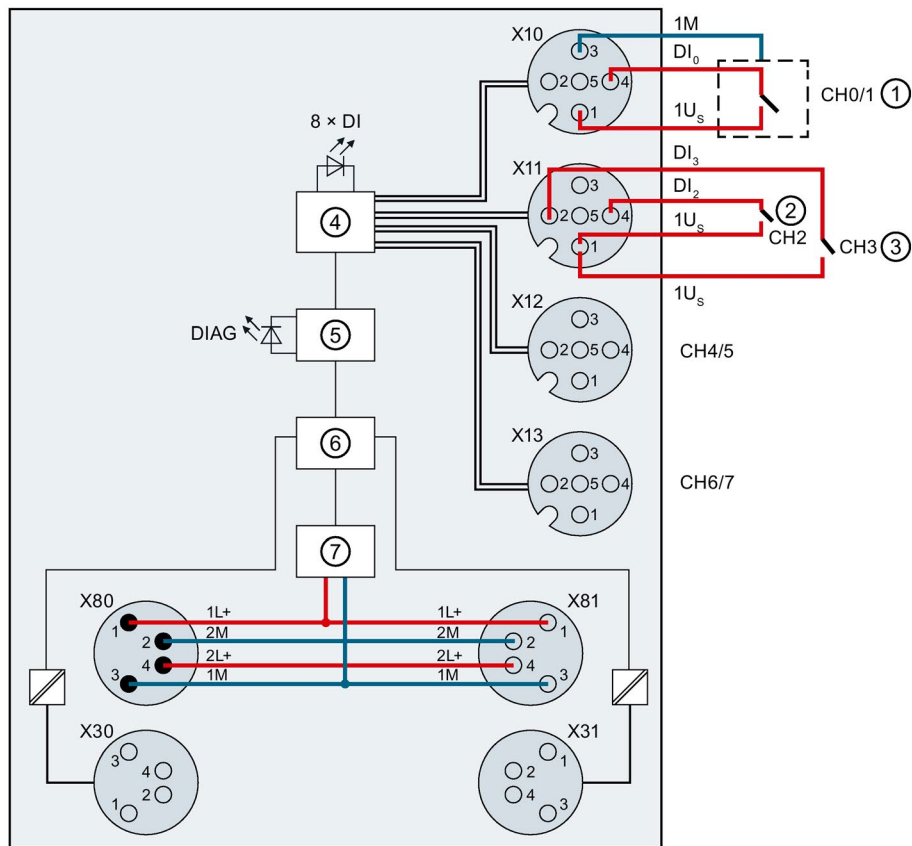
- ① DIAG: LED display for the diagnostic status
- ② X10 to X13: Sockets for the input signal
- ③ X80: Connector for infeed of the supply voltage (POWER input)
- ④ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑤ X30: Socket for ET-Connection IN
- ⑥ X31: Socket for ET-Connection OUT
- ⑦ LED displays 0 to 7 for the channel status

Image 2-2 Operator controls and display elements

Wiring

3.1 Terminal and block diagram

The figure below shows an example of the pin assignment of signal inputs with 2-wire and 3-wire connection.



①	3-wire connection	X30	Infeed of the ET-Connection
②	2-wire connection	X31	Loop-through of the ET-Connection
③	2-wire connection	1L+	Supply voltage 1L+ (non-switched)
④	DI circuit	1M	Ground 1M (non-switched)
⑤	Microcontroller	2L+	Load voltage 2L+ (switched)
⑥	ET-Connection interface	2M	Ground 2M (switched)
⑦	Internal supply voltage	1Us	24 V encoder supply
X10 to X13	Channels 0 to 7	DI _n	Input signal
X80	Infeed of supply voltages	DI	Channel status LEDs (0 to 7) (green)
X81	Loop-through of supply voltages	DIAG	LED diagnostic status (red/green)
Image 3-1	Terminal and block diagram		

3.2 Pin assignment

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for digital inputs

The table below shows the pin assignment of the 4 sockets for the connection of digital inputs.

Table 3- 1 Pin assignment for digital inputs

Pin	Assignment	Front view of the sockets
	X10 to X13 sockets for digital inputs	
1	24 V encoder supply 1Us (derived from 1L+ non-switched)	
2	Input signal DI ₁ : Connector X10 Input signal DI ₃ : Connector X11 Input signal DI ₅ : Connector X12 Input signal DI ₇ : Connector X13	
3	Encoder supply ground 1M	
4	Input signal DI ₀ : Connector X10 Input signal DI ₂ : Connector X11 Input signal DI ₄ : Connector X12 Input signal DI ₆ : Connector X13	
5	Functional earth FE	

NOTICE

24 V encoder supply 1Us

Use only the 24 V encoder supply 1Us provided by the digital input module to supply power to the encoder.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

Table 3-2 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

Table 3-3 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3-4 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE**ET-Connection/supply voltage**

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage.

Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

Parameters/address space

4.1 Parameters

The table below shows the parameters for the DI 8x24VDC 4xM12 digital input module.

Table 4- 1 Parameters

Parameters	Value range	Default	Scope
Diagnostics: Short-circuit to ground	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module

4.2 Explanation of the parameters

Diagnostics: Short-circuit to ground

Enabling of the diagnostics if a short-circuit of the encoder supply to ground occurs.

4.3 Address space

The figure below shows the assignment of the address space for the digital input module DI 8x24VDC 4xM12 with value status (Quality Information, QI).

The address space for the value status is allocated by the module, if the value status is configured using the PROFINET interface module.

Assignment in the process image input (PII)

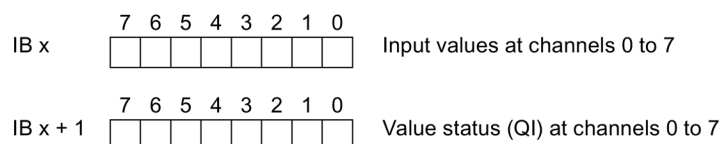


Image 4-1 Address space

Configuration options of the DI 8x24VDC 4xM12 digital input module

You have the following configuration options:

- Configuration 1: without value status
- Configuration 2: with value status

Evaluating the value status

An additional byte is occupied in the input address space if you enable the value status for the digital input module. Bits 0 to 7 in this byte are assigned to a channel and return information about the validity of the digital input value.

Bit = 1: No error on channel.

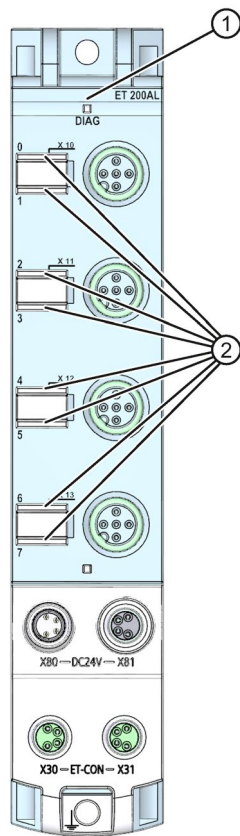
Bit = 0: Error on channel.

Interrupts/diagnostic alarms

5.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the DI 8x24VDC 4xM12 digital input module.



- ① Diagnostic status (DIAG) (red/green)
- ② Channel status (0 to 7) (green)





Image 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Remedial measures for diagnostic alarms can be found in section Diagnostics alarms (Page 19).



DIAG LED

Table 5- 1 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> Module parameters not assigned Loading firmware (while the firmware update is being performed, all LEDs retain their current status)
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics

LED channel status

Table 5- 2 LED channel status display

LED channel status	Meaning
 Off	Process signal = 0
 On	Process signal = 1

5.2 Interrupts

The DI 8x24VDC 4xM12 digital input module supports diagnostic interrupts.

Diagnostic interrupt

The digital input module generates a diagnostic interrupt at the following events:

- Short-circuit of encoder supply to ground

5.3 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the DIAG LED flashes red on the digital input module. You can read out the diagnostics alarms, for example, in the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 5- 3 Diagnostics alarms, their meanings and corrective measures

Diagnostics alarm	Error code	Meaning	Remedy
Short-circuit	1H	Short-circuit encoder supply to ground	Eliminate the short-circuit

Technical specifications

6.1 Technical specifications

Technical specifications of the DI 8x24VDC 4xM12 digital input module

	6ES7141-5AF00-0BA0
General information	
Product type designation	DI 8X24VDC, 4XM12
Hardware functional status	E01
Firmware version	V1.0.x
Product function	
I&M data	Yes; I&M0 to I&M3
Engineering with	
STEP 7 TIA Portal can be configured/integrated as of version	As of STEP 7 V13 SP1
STEP 7 can be configured/integrated as of version	V5.5 SP4 Hotfix 7 or higher
PROFIBUS as of GSD version/GSD revision	GSD as of revision 5
PROFINET as of GSD version/GSD revision	GSDML V2.3.1
Supply voltage	
Load voltage 1L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction; encoder supply outputs are connected with reverse polarity
Input current	
Current consumption (rated value)	25 mA; no load
From load voltage 1L+ (unswitched voltage)	4 A; maximum value
From load voltage 2L+, max.	4 A; maximum value
Encoder supply	
Number of outputs	4
24 V encoder supply	
Short-circuit protection	Yes; per module, electronic
Output current, max.	0.7 A; total current of all encoders
Power loss	
Power loss, typ.	1.9 W
Digital inputs	
Number of inputs	8
Input characteristic curve acc. to IEC 61131, type 3	Yes

	6ES7141-5AF00-0BA0
Number of inputs that can be controlled simultaneously	
All mounting positions	
<ul style="list-style-type: none"> up to 55 °C, max. 	8
Input voltage	
Type of input voltage	DC
Rated value (DC)	24 V
For signal "0"	-30 ... +5 V
For signal "1"	+11 ... +30 V
Input current	
For signal "1", typ.	3.2 mA
Input delay (for rated value of input voltage)	
For standard inputs	
<ul style="list-style-type: none"> at "0" to "1", min. 	1.2 ms
<ul style="list-style-type: none"> at "0" to "1", max. 	4.8 ms
<ul style="list-style-type: none"> at "1" to "0", min. 	1.2 ms
<ul style="list-style-type: none"> at "1" to "0", max. 	4.8 ms
Cable length	
Unshielded, max.	30 m
Encoders	
Connectable encoders	
2-wire sensor	Yes
<ul style="list-style-type: none"> Permissible quiescent current (2-wire sensor), max. 	1.5 mA
Interrupts/diagnostics/status information	
Interrupts	
Diagnostic interrupt	Yes; configurable
Diagnostics alarms	
Short-circuit	Yes; encoder supply to ground; module-based
Diagnostics indicator LED	
Channel status display	Yes; green LED
For module diagnostics	Yes; green/red LED
Electrical isolation	
Between load voltages	Yes
Electrical isolation of channels	
Between channels	No
Between the channels and backplane bus	Yes
Between the channels and power supply of the electronics	No
Insulation	
Insulation tested with	707 V DC (type test)

6ES7141-5AF00-0BA0	
Degree of protection and protection class	
Degree of protection according to EN 60529	
• IP65	Yes
• IP67	Yes
Ambient conditions	
Ambient temperature in operation	
Min.	-25 °C
Max.	55 °C
Connection technology	
Inputs/outputs	M12, 5-pin
Power supply	M8, 4-pin
ET-Connection	
ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	30 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	145 g

PROFenergy

7.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. The majority of the energy is saved by the process itself; the PROFINET device itself only contributes a few watts of saving potential. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific behavior of the digital input module is explained in the following section.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<https://support.industry.siemens.com/cs/ww/en/view/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V13 (<https://support.industry.siemens.com/cs/ww/en/view/49948856>).

Application examples (<https://support.industry.siemens.com/cs/ww/en/view/41986454>) are also available on the Internet.

7.2 Behavior of the digital input module

Display

The channel status LEDs are directly influenced by the signal level at the socket. If the encoder supply is switched off, this causes the channel status LEDs to also switch off.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- Encoder supply switch-off upon the start of "pause" does not result in the "Short-circuit" alarms.
- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 7- 1 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" • Encoder supply U _S switched off ¹ • Pause substitute value: 0 _B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" • Encoder supply U _S switched off ¹ • Pause substitute value: Last input value • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" • Encoder supply U _S switched off ¹ • Pause substitute value: Configured pause substitute value • Value status "BAD"

¹ As there is only one encoder supply U_S for all channels, the supply can only be switched off at "pause" if no channel is configured in PE_MODE_PROCEED.

Dimension drawing

The figure below shows the dimension drawing of the DI 8x24VDC 4xM12 digital input module in front and side view.

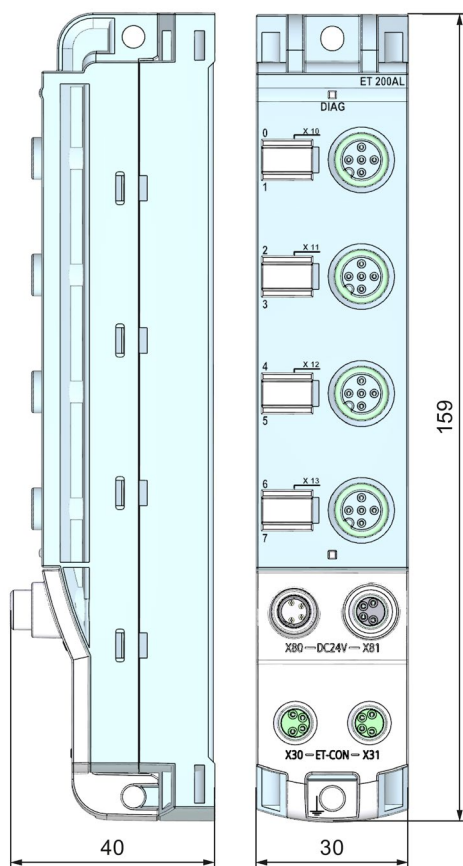
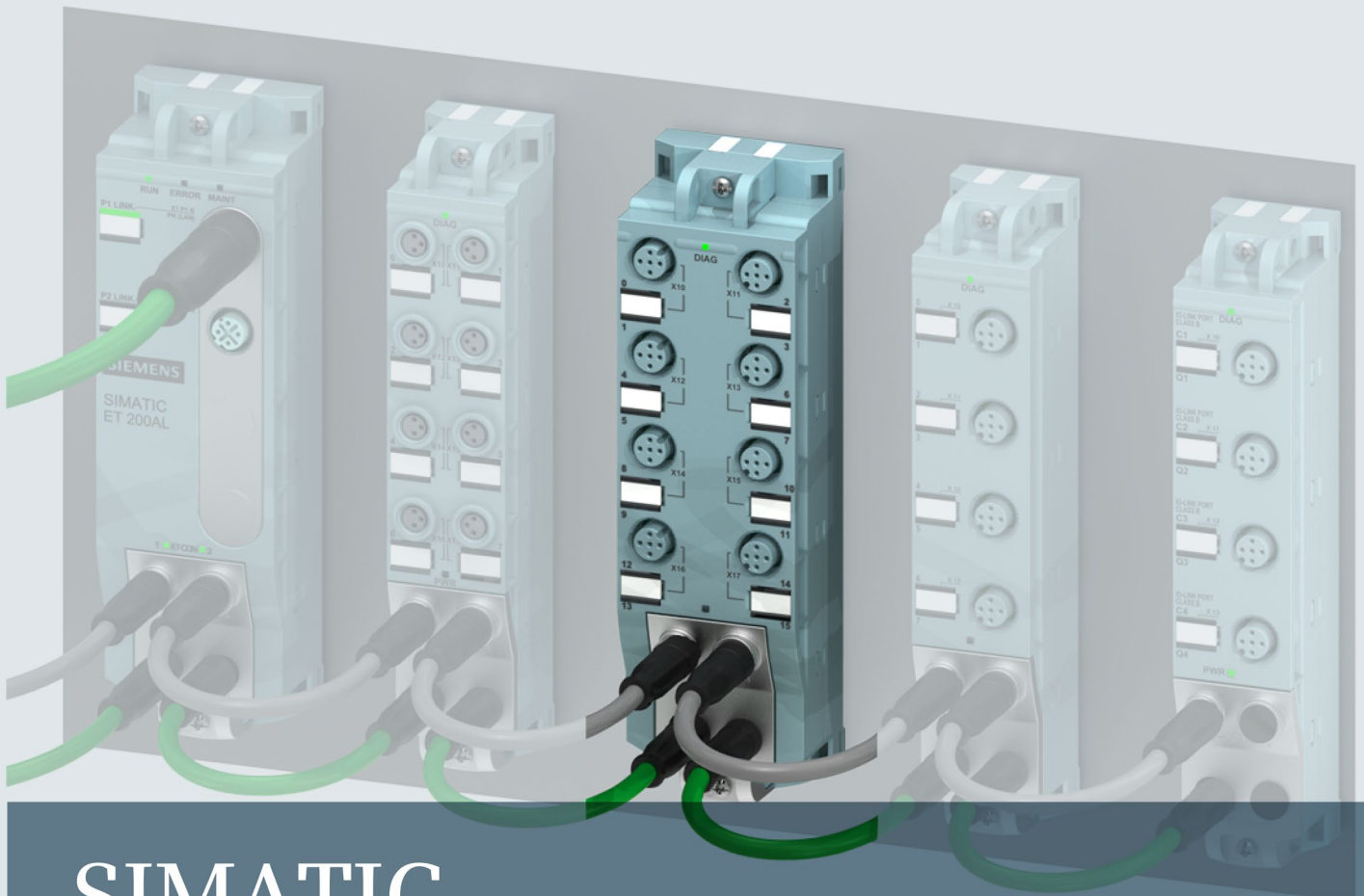


Image A-1 Dimension drawing

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SIMATIC

ET 200AL

Digital input module DI 16x24VDC 8xM12 (6ES7141-5AH00-0BA0)

Manual

Edition

02/2016

Answers for industry.

SIEMENS

SIMATIC

ET 200AL
Digital input module
DI 16x24VDC 8xM12
6ES7141-5AH00-0BA0)

Manual

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

Trademarks

All names identified by ® are registered trademarks of Siemens AG. The remaining trademarks in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owner.

Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (<http://www.siemens.com/industrialsecurity>).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (<http://support.automation.siemens.com>).

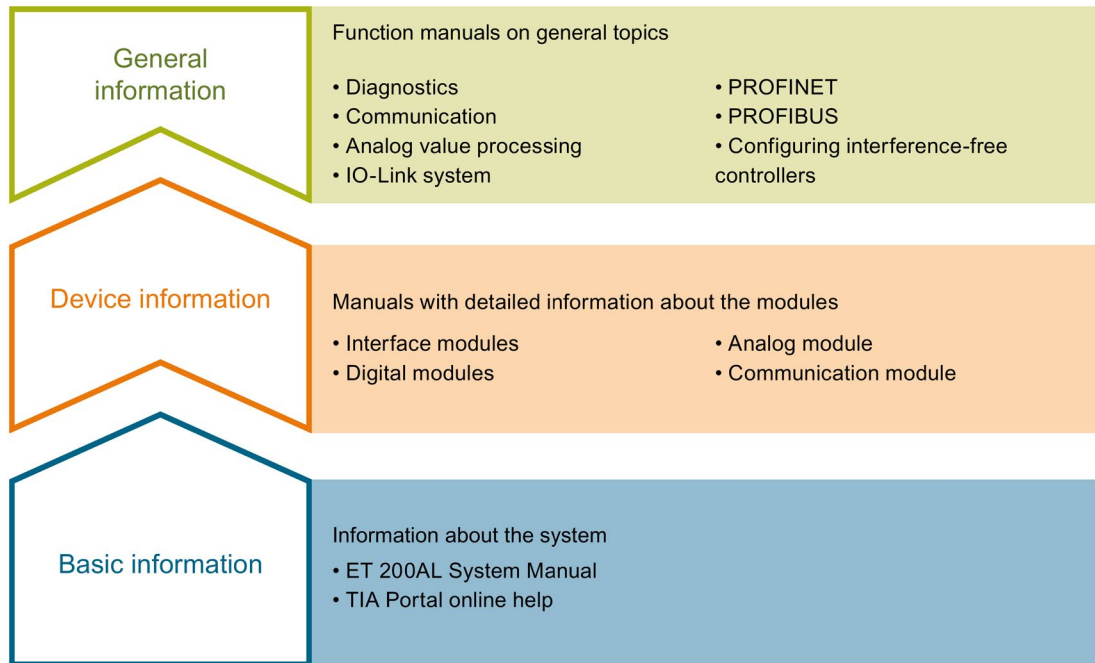
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Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<http://w3.siemens.com/mcms/industrial-automation-systems-simatic/en/manual-overview/tech-doc-et200/Pages/Default.aspx>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

"mySupport" - Documentation

In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.

You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<http://support.industry.siemens.com/My/ww/en/documentation>).

"mySupport" - CAx data

In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

Product overview

2.1 Properties

Article number

6ES7141-5AH00-0BA0

View of the module

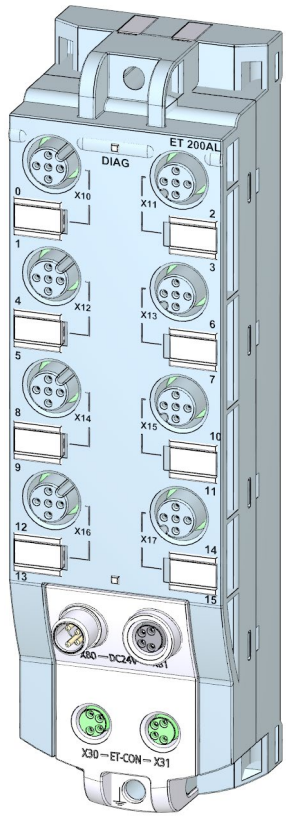


Image 2-1 View of the DI 16x24VDC 8xM12 digital input module

Properties

The module has the following technical properties:

- 16 digital inputs
- M12 sockets for connection of sensors
- 24 V DC supply voltage
- Configurable diagnostics can be set for each module
- Typical input delay of 3 ms
- Suitable for switches and proximity switches
- Dimensions 45 x 159 mm

The module supports the following functions:

- Firmware update
- Identification and maintenance data I&M0 to I&M3
- Value status (Quality Information)
- PROFIenergy

Accessories

The following components are included in the module package:

- Identification labels

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

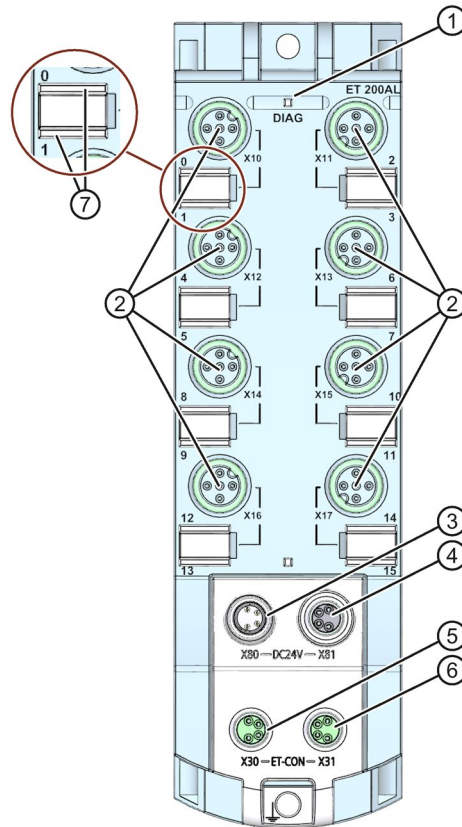
- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system (<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual.

2.2 Operator controls and display elements

The figure below shows the operator controls and display elements of the DI 16x24VDC 8xM12 digital input module.



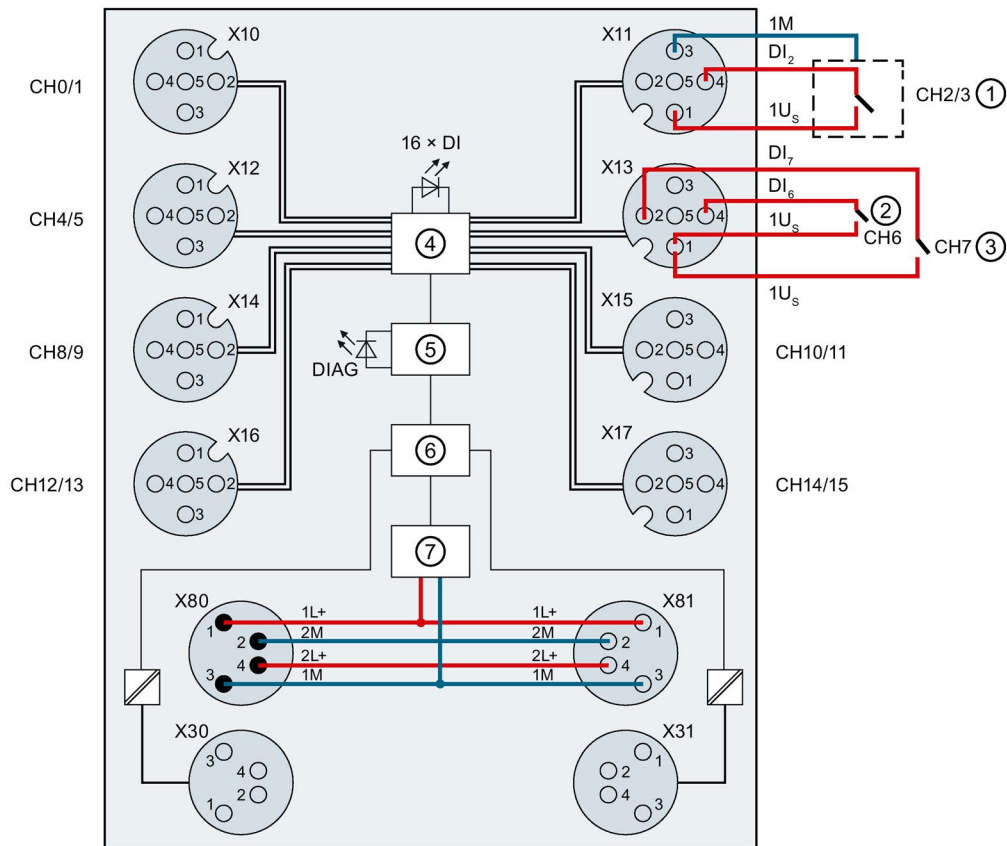
- ① DIAG: LED display for the diagnostic status
- ② X10 to X17: Sockets for the input signal
- ③ X80: Connector for infeed of the supply voltage (POWER input)
- ④ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑤ X30: Socket for ET-Connection IN
- ⑥ X31: Socket for ET-Connection OUT
- ⑦ LED displays 0 to 15 for the channel status

Image 2-2 Operator controls and display elements

Wiring

3.1 Terminal and block diagram

The figure below shows an example of the pin assignment of signal inputs with 2-wire and 3-wire connection.



①	3-wire connection	X30	Infeed of the ET-Connection
②	2-wire connection	X31	Loop-through of the ET-Connection
③	2-wire connection	1L+	Supply voltage 1L+ (non-switched)
④	DI circuit	1M	Ground 1M (non-switched)
⑤	Microcontroller	2L+	Load voltage 2L+ (switched)
⑥	ET-Connection interface	2M	Ground 2M (switched)
⑦	Internal supply voltage	1Us	24 V encoder supply
X10 to X17	Channels 0 to 7	DI _n	Input signal
X80	Infeed of supply voltages	DI	Channel status LEDs (0 to 15) (green)
X81	Loop-through of supply voltages	DIAG	LED diagnostic status (red/green)

Image 3-1 Terminal and block diagram

3.2 Pin assignment

Note

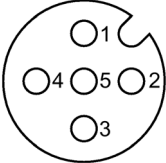
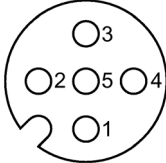
Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for digital inputs

The table below shows the pin assignment of the 8 sockets for the connection of digital inputs.

Table 3- 1 Pin assignment for digital inputs

Pin	Assignment	Front view of the sockets	
		X10, X12, X14, X16	X11, X13, X15, X17
1	24 V encoder supply 1Us (derived from 1L+ non-switched)		
2	Input signal DI ₁ : Connector X10 Input signal DI ₃ : Connector X11 Input signal DI ₅ : Connector X12 Input signal DI ₇ : Connector X13 Input signal DI ₉ : Connector X14 Input signal DI ₁₁ : Connector X15 Input signal DI ₁₃ : Connector X16 Input signal DI ₁₅ : Connector X17		
3	Encoder supply ground 1M		
4	Input signal DI ₀ : Connector X10 Input signal DI ₂ : Connector X11 Input signal DI ₄ : Connector X12 Input signal DI ₆ : Connector X13 Input signal DI ₈ : Connector X14 Input signal DI ₁₀ : Connector X15 Input signal DI ₁₂ : Connector X16 Input signal DI ₁₄ : Connector X17		
5	Functional earth FE		

NOTICE

24 V encoder supply 1Us

Use only the 24 V encoder supply 1Us provided by the digital input module to supply power to the encoder.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

Table 3-2 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

Table 3-3 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3-4 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE**ET-Connection/supply voltage**

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage.

Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

Parameters/address space

4.1 Parameters

The table below shows the parameters for the DI 16x24VDC 8xM12 digital input module.

Table 4- 1 Parameters

Parameters	Value range	Default	Scope
Diagnostics: Short-circuit to ground	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module

4.2 Explanation of the parameters

Diagnostics: Short-circuit to ground

Enabling of the diagnostics if a short-circuit of the encoder supply to ground occurs.

4.3 Address space

The figure below shows the assignment of the address space for the digital input module DI 16x24VDC 8xM12 with value status (Quality Information, QI).

The address space for the value status is allocated by the module, if the value status is configured using the PROFINET interface module.

Assignment in the process image input (PII)

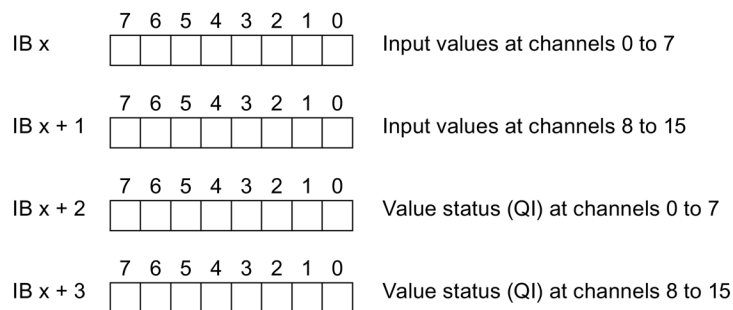


Image 4-1 Address space

Configuration options of the DI 16x24VDC 8xM12 digital input module

You have the following configuration options:

- Configuration 1: without value status
- Configuration 2: with value status

Evaluating the value status

An additional two bytes are occupied in the input address space if you enable the value status for the digital input module. Bits 0 to 7 in these bytes are assigned to a channel and return information about the validity of the digital input value.

Bit = 1: No error on channel.

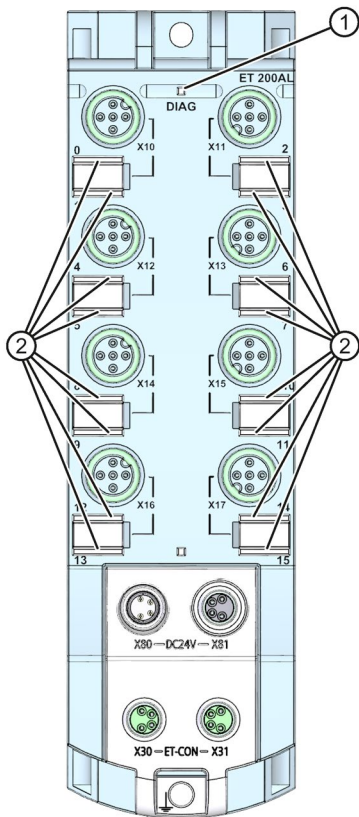
Bit = 0: Error on channel.

Interrupts/diagnostic alarms

5.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the DI 16x24VDC 8xM12 digital input module.



- ① Diagnostic status (DIAG) (red/green)
- ② Channel status (0 to 15) (green)

Image 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Remedial measures for diagnostic alarms can be found in section Diagnostics alarms (Page 20).

DIAG LED

Table 5- 1 Error display of the DIAG LED

DIAG LED	Meaning
□ Off	No supply voltage 1L+
⚡ Flashes	<ul style="list-style-type: none"> Module parameters not assigned Loading firmware (while the firmware update is being performed, all LEDs retain their current status)
■ On	Module parameters assigned and no module diagnostics
⚡ Flashes	Module parameters assigned and module diagnostics

LED channel status

Table 5- 2 LED channel status display

LED channel status	Meaning
□ Off	Process signal = 0
■ On	Process signal = 1

5.2 Interrupts

The DI 16x24VDC 8xM12 digital input module supports diagnostic interrupts.

Diagnostic interrupt

The digital input module generates a diagnostic interrupt at the following events:

- Short-circuit of encoder supply to ground

5.3 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the DIAG LED flashes red on the digital input module. You can read out the diagnostics alarms, for example, in the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 5- 3 Diagnostics alarms, their meanings and corrective measures

Diagnostics alarm	Error code	Meaning	Remedy
Short-circuit	1 _H	Short-circuit encoder supply to ground	Eliminate the short-circuit

Technical specifications

6.1 Technical specifications

Technical specifications of the DI 16x24VDC 8xM12 digital input module

	6ES7141-5AH00-0BA0
General information	
Product type designation	DI 16X24VDC, 8XM12
Hardware functional status	E01
Firmware version	V1.0.x
Product function	
I&M data	Yes; I&M0 to I&M3
Engineering with	
STEP 7 TIA Portal can be configured/integrated as of version	As of STEP 7 V13 SP1
STEP 7 can be configured/integrated as of version	V5.5 SP4 Hotfix 7 or higher
PROFIBUS as of GSD version/GSD revision	GSD as of revision 5
PROFINET as of GSD version/GSD revision	GSDML V2.3.1
Supply voltage	
Load voltage 1L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction; encoder supply outputs are connected with reverse polarity
Input current	
Current consumption (rated value)	30 mA; no load
From load voltage 1L+ (unswitched voltage)	4 A; maximum value
From load voltage 2L+, max.	4 A; maximum value
Encoder supply	
Number of outputs	8
24 V encoder supply	
Short-circuit protection	Yes; per module, electronic
Output current, max.	1.4 A; total current of all encoders
Power loss	
Power loss, typ.	2.7 W
Digital inputs	
Number of inputs	16
Input characteristic curve acc. to IEC 61131, type 3	Yes

6ES7141-5AH00-0BA0	
Number of inputs that can be controlled simultaneously	
All mounting positions	
<ul style="list-style-type: none"> up to 55 °C, max. 	16
Input voltage	
Type of input voltage	DC
Rated value (DC)	24 V
For signal "0"	-30 ... +5 V
For signal "1"	+11 ... +30 V
Input current	
For signal "1", typ.	3.2 mA
Input delay (for rated value of input voltage)	
For standard inputs	
<ul style="list-style-type: none"> at "0" to "1", min. 	1.2 ms
<ul style="list-style-type: none"> at "0" to "1", max. 	4.8 ms
<ul style="list-style-type: none"> at "1" to "0", min. 	1.2 ms
<ul style="list-style-type: none"> at "1" to "0", max. 	4.8 ms
Cable length	
Unshielded, max.	30 m
Encoders	
Connectable encoders	
2-wire sensor	Yes
<ul style="list-style-type: none"> Permissible quiescent current (2-wire sensor), max. 	1.5 mA
Interrupts/diagnostics/status information	
Interrupts	
Diagnostic interrupt	Yes; configurable
Diagnostics alarms	
Short-circuit	Yes; encoder supply to ground; module-based
Diagnostics indicator LED	
Channel status display	Yes; green LED
For module diagnostics	Yes; green/red LED
Electrical isolation	
Between load voltages	Yes
Electrical isolation of channels	
Between channels	No
Between the channels and backplane bus	Yes
Between the channels and power supply of the electronics	No
Insulation	
Insulation tested with	707 V DC (type test)

6ES7141-5AH00-0BA0	
Degree of protection and protection class	
Degree of protection according to EN 60529	
• IP65	Yes
• IP67	Yes
Ambient conditions	
Ambient temperature in operation	
Min.	-25 °C
Max.	55 °C
Connection technology	
Inputs/outputs	M12, 5-pin
Power supply	M8, 4-pin
ET-Connection	
ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	45 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	184 g

PROFenergy

7.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific behavior of the digital input module is explained in the following section.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<https://support.industry.siemens.com/cs/ww/en/view/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V13 (<https://support.industry.siemens.com/cs/ww/en/view/49948856>).

Application examples (<https://support.industry.siemens.com/cs/ww/en/view/41986454>) are also available on the Internet.

7.2 Behavior of the digital input module

Display

The channel status LEDs are directly influenced by the signal level at the socket. If the encoder supply is switched off, this causes the channel status LEDs to also switch off.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- Encoder supply switch-off upon the start of "pause" does not result in the "Short-circuit" alarms.
- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 7- 1 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> • Encoder supply U_S switched off ¹ • Pause substitute value: 0_B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> • Encoder supply U_S switched off ¹ • Pause substitute value: Last input value • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> • Encoder supply U_S switched off ¹ • Pause substitute value: Configured pause substitute value • Value status "BAD"

¹ As there is only one encoder supply U_S for all channels, the supply can only be switched off at "pause" if no channel is configured in PE_MODE_PROCEED.

Dimension drawing

The figure below shows the dimension drawing of the DI 16x24VDC 8xM12 digital input module in front and side view.

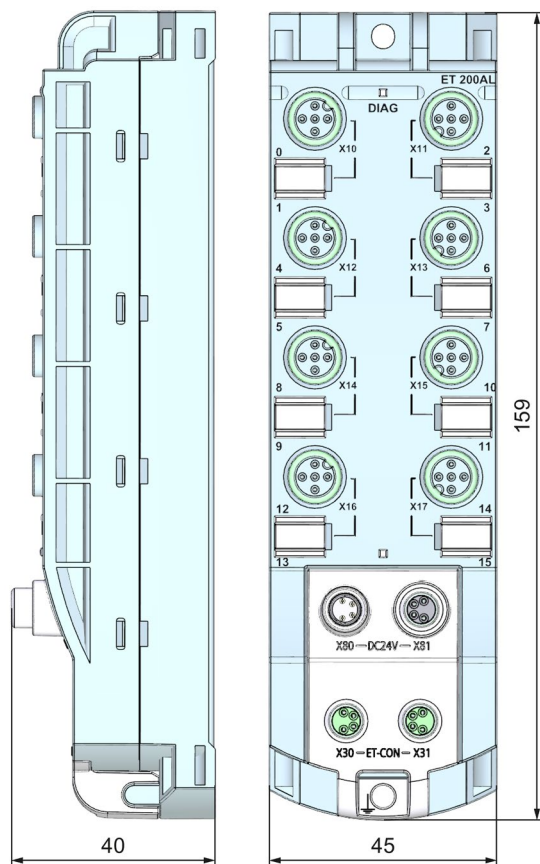
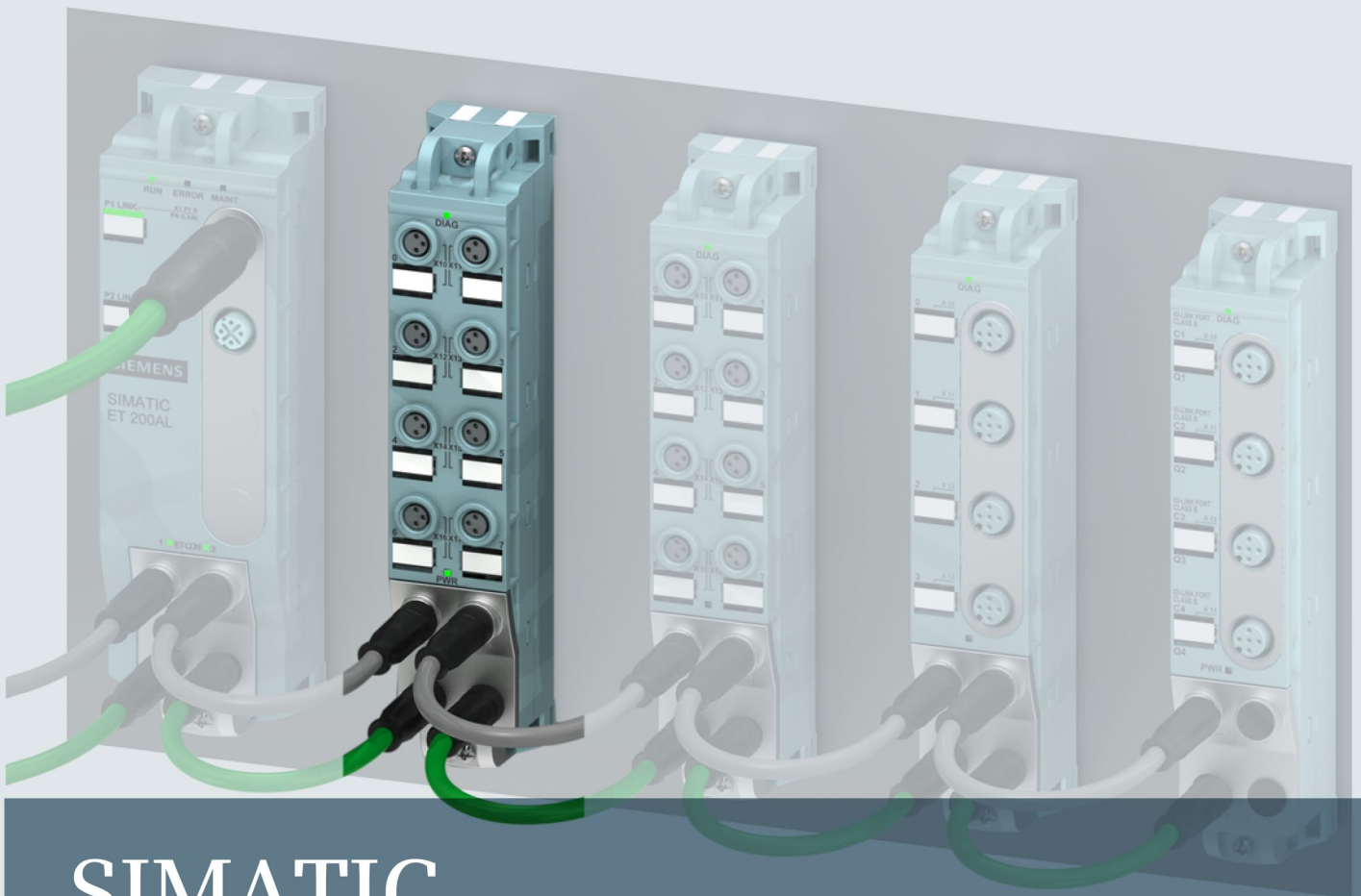


Image A-1 Dimension drawing

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ET 200AL

Digital input / output module DIQ 4+DQ 4x24VDC/0.5A 8xM8 (6ES7143-5BF00-0BA0)

Manual

Edition

02/2016

Answers for industry.

SIEMENS

SIMATIC

ET 200AL

Digital input/digital output module
DIQ 4+DQ 4x24VDC/0.5A 8xM8
(6ES7143-5BF00-0BA0)

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (<http://www.siemens.com/industrialsecurity>).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (<http://support.automation.siemens.com>).

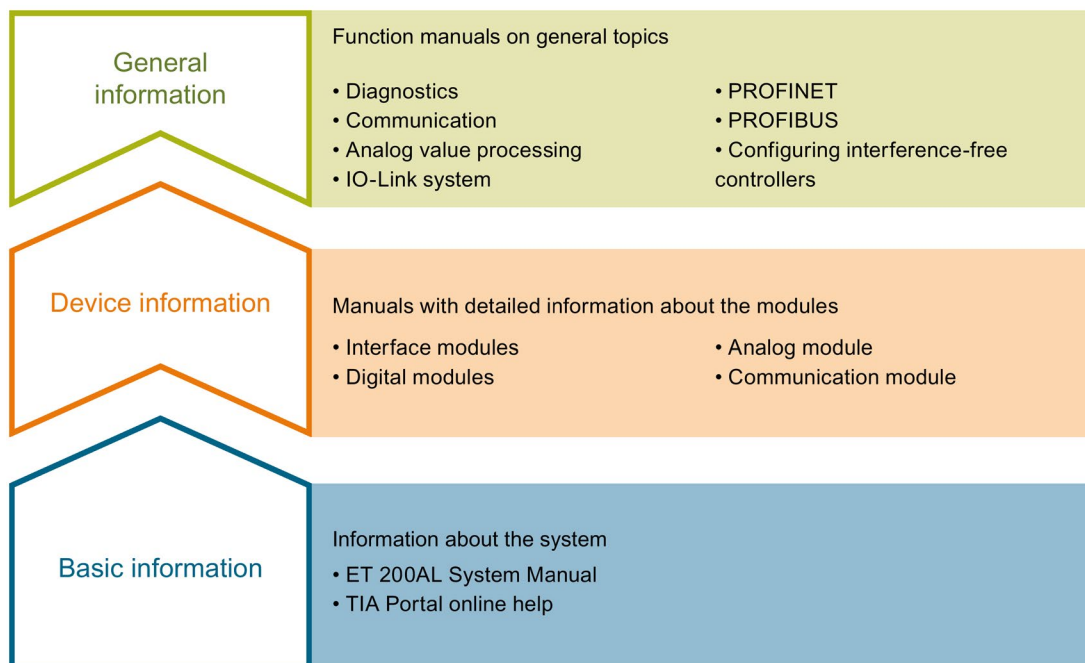
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Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<http://w3.siemens.com/mcms/industrial-automation-systems-simatic/en/manual-overview/tech-doc-et200/Pages/Default.aspx>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

"mySupport" - Documentation

In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.

You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<http://support.industry.siemens.com/My/ww/en/documentation>).

"mySupport" - CAx data

In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

Product overview

2.1 Properties

Article number

6ES7143-5BF00-0BA0

View of the module

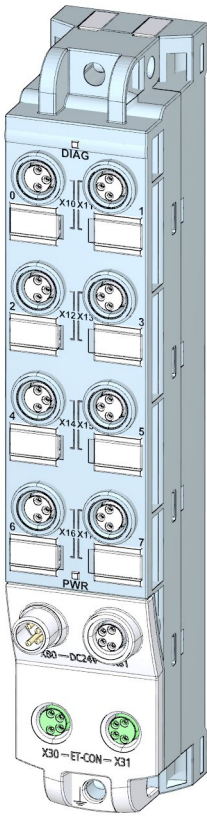


Image 2-1 View of the DIQ 4+DQ 4x24VDC/0,5A 8xM8 digital input/digital output module

Properties

The module has the following technical properties:

- 4 digital inputs or digital outputs and 4 digital outputs, depending on parameter assignment
 - DIQ signals connected to 1L+ (non-switched)
 - DQ signals connected to 2L+ (switched)
- M8 sockets for connection of sensors and actuators
- Digital inputs:
 - 24 V DC supply voltage
 - Configurable diagnostics can be set for each module
 - Typical input delay of 3 ms
 - Suitable for switches and proximity switches
- Digital outputs:
 - Rated load voltage 24 V DC
 - Suitable for solenoid valves, DC contactors, and indicator lights
 - Output current 0.5 A per output
 - Configurable diagnostics can be set for each module
- Dimensions 30 x 159 mm

The module supports the following functions:

- Firmware update
- Identification and maintenance data I&M0 to I&M3
- Value status (Quality Information)
- PROFIenergy

Accessories

The following components are included in the module package:

- Identification labels
- Spacers

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap

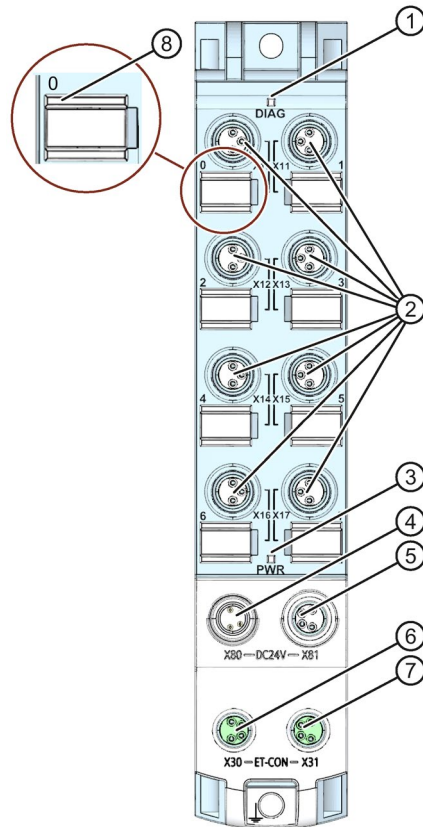
See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system

(<http://support.automation.siemens.com/WW/view/en/89254965>) system manual.

2.2 Operator controls and display elements

The following figure shows the operator controls and display elements of the DIQ 4+DQ 4x24VDC/0.5A 8xM8 digital input/digital output module.



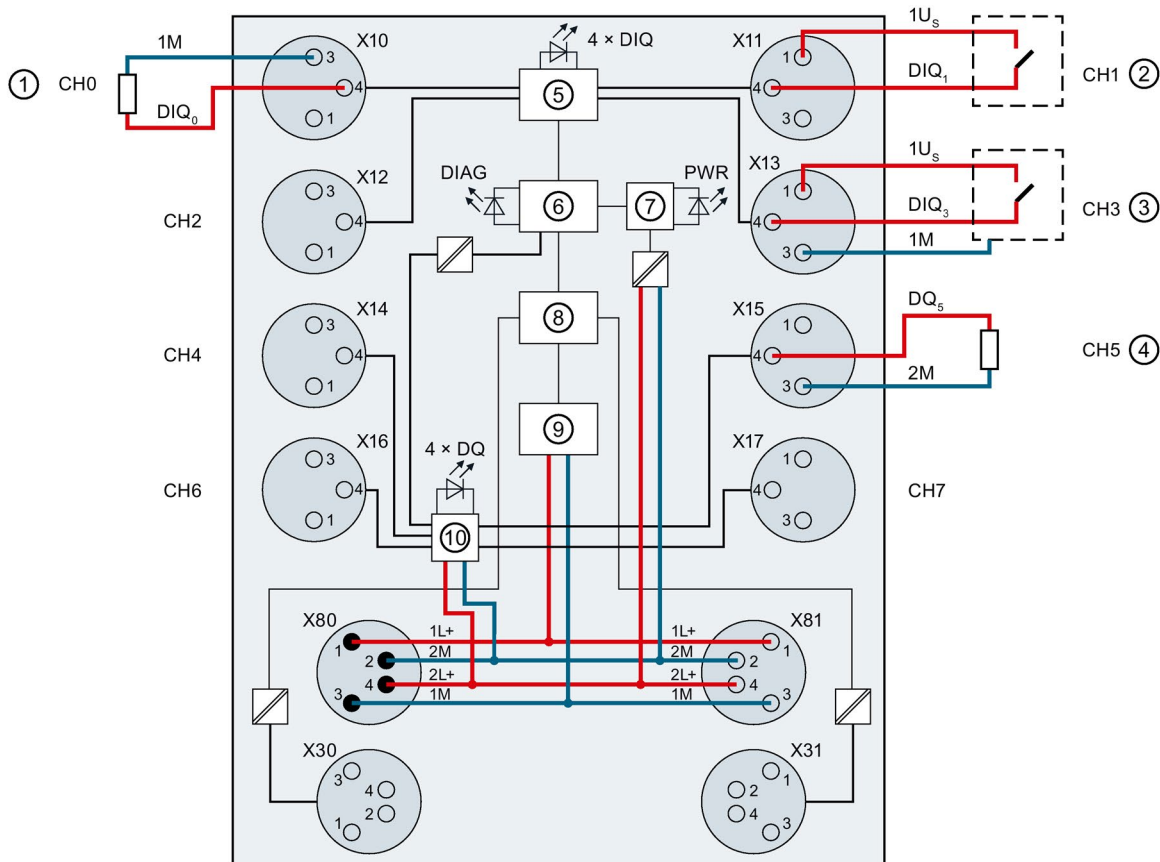
- ① DIAG: LED display for the diagnostic status
- ② X10 to X17: Sockets for the input/output signal
- ③ PWR: LED display for the load voltage 2L+
- ④ X80: Connector for infeed of the supply voltage (POWER input)
- ⑤ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑥ X30: Socket for ET-Connection IN
- ⑦ X31: Socket for ET-Connection OUT
- ⑧ LED displays 0 to 7 for the channel status

Image 2-2 Operator controls and display elements

Wiring

3.1 Terminal and block diagram

The following figure shows an example of the pin assignment of signal inputs with 2- and 3-wire connection as well as signal outputs.



- | | | | |
|------------|--|------------------|---|
| ① | Configured as output | X30 | Infeed of the ET-Connection |
| ② | Configured as input: 2-wire connection | X31 | Loop-through of the ET-Connection |
| ③ | Configured as input: 3-wire connection | 1L+ | Supply voltage 1L+ (non-switched) |
| ④ | Output | 1M | Ground 1M (non-switched) |
| ⑤ | DI/DQ circuit | 2L+ | Load voltage 2L+ (switched) |
| ⑥ | Microcontroller | 2M | Ground 2M (switched) |
| ⑦ | Monitoring | 1Us | 24 V encoder supply |
| ⑧ | ET-Connection interface | DIQ _n | Input/output signal |
| ⑨ | Internal supply voltage | DQ _n | Output signal |
| ⑩ | DQ circuit | DIQ | LEDs channel status (0, 1, 2 and 3) (green) |
| X10 to X17 | Channels 0 to 7 | DQ | LEDs channel status (4, 5, 6 and 7) (green) |
| X80 | Infeed of supply voltages | DIAG | LED diagnostic status (red/green) |
| X81 | Loop-through of supply voltages | PWR | LED supply voltage 2L+ (green) |

Image 3-1 Terminal and block diagram

3.2 Pin assignment

Note

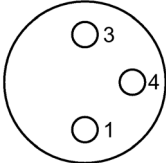
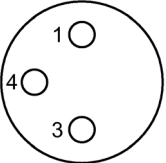
Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for digital inputs/digital outputs

The tables below show the pin assignments of the 8 sockets for connection of the digital inputs/digital outputs.

Table 3- 1 Pin assignment for digital inputs/digital outputs

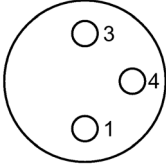
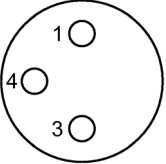
Pin	Assignment	Front view of the sockets	
		X10, X12	X11, X13
	X10 to X13 sockets for digital inputs/ digital outputs		
1	24 V encoder supply 1Us (derived from 1L+ non-switched)		
3	Encoder supply ground 1M		
4	Input/output signal DIQ ₀ : Connector X10 Input/output signal DIQ ₁ : Connector X11 Input/output signal DIQ ₂ : Connector X12 Input/output signal DIQ ₃ : Connector X13		

NOTICE

24 V encoder supply 1Us

Use only the 24 V encoder supply 1Us provided by the digital input/digital output module to supply power to the encoder.

Table 3- 2 Pin assignment for digital outputs

Pin	Assignment	Front view of the sockets	
		X14, X16	X15, X17
	X14 to X17 sockets for digital outputs		
1	Unassigned		
3	Ground 2M		
4	Output signal DQ ₄ : Connector X14 Output signal DQ ₅ : Connector X15 Output signal DQ ₆ : Connector X16 Output signal DQ ₇ : Connector X17		

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

Table 3- 3 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

Table 3- 4 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3- 5 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE**ET-Connection/supply voltage**

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage.

Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

Parameters/address space

4.1 Parameters

The following table shows the parameters for the DIQ 4+DQ 4x24VDC/0.5A 8xM8 digital input/digital output module.

Table 4- 1 Parameters

Parameters	Value range	Default	Scope
Diagnostics: Missing load voltage 2L+	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module
Diagnostics: Short-circuit to ground	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module (Short-circuit of encoder supply or of the output to ground)
Freely assignable channel 0 ... 3	<ul style="list-style-type: none"> • DI • DQ 	DI	Channel
Reaction to CPU/master STOP	<ul style="list-style-type: none"> • Shut down • Keep last value • Output substitute value 	Shut down	Module (digital outputs)
Substitute value channel 0 ... 7	<ul style="list-style-type: none"> • 0 • 1 	0	Channel (digital outputs)

4.2 Explanation of the parameters

Diagnostics: Missing load voltage 2L+

Enabling of the diagnostics for missing or insufficient load voltage 2L+.

Diagnostics: Short-circuit to ground

Enabling of the diagnostics for short-circuit of the encoder supply or output to ground.

Freely assignable channel n

With this parameter, you set whether the channel is to be operated as an input or output.

Reaction to CPU/master STOP

With this parameter, you set the reaction of the digital outputs of the digital input/digital output module after a CPU/master STOP:

- Shut down: The digital output is de-energized.
- Keep last value: The last value of the digital output remains activated.
- Output substitute value: The module outputs a configured substitute value.

Substitute value channel 0 ... 7

With this parameter, you set substitute values for the digital outputs.

4.3 Address space

The figure below shows the assignment of the address space for the digital input/digital output module DIQ 4+DQ 4x24VDC/0.5A 8xM8 with value status (Quality Information, QI).

The address space for the value status is allocated by the module, if the value status is configured using the PROFINET interface module.

Assignment in the process image input (PII)

	7	6	5	4	3	2	1	0	
IB x	0	0	0	0					Input values at channels 0 to 3

	7	6	5	4	3	2	1	0	
IB x + 1	0	0	0	0					Value status (QI) for inputs at channels 0 to 3

	7	6	5	4	3	2	1	0	
IB x + 2									Value status (QI) for outputs at channels 0 to 7

Assignment in the process image output (PIQ)

	7	6	5	4	3	2	1	0	
QB x									Output values at channels 0 to 7

Image 4-1 Address space DIQ 4+DQ 4x24VDC/0.5A 8x8M

Note

Parameter assignment of the channels

Parameters for the first four channels can be freely assigned.

For the channels 0 ... 3 that are configured as input, the corresponding values in the output data do not trigger any reaction.

For the channels 0 ... 3 that are configured as output, the input value in the process image is 0.

Configuration options of the digital input/digital output module DIQ 4+DQ 4x24VDC/0.5A 8xM8

You have the following configuration options:

- Configuration 1: without value status
- Configuration 2: with value status

Evaluating the value status

An additional two bytes are occupied in the input address space if you enable the value status for the digital input/digital output module. The value status of the inputs is assigned to bits 0 to 3 in input byte $x + 1$. The value status of the outputs is assigned to bits 0 to 7 in input byte $x + 2$. This additional information provides information regarding the validity of the digital values or channel status.

Bit = 1: No error on channel.

Bit = 0: Error on channel.

If the channel is configured as input, this means:

- Short-circuit to ground at sensor supply or
- Parameter error

If the channel is configured as output, this means:

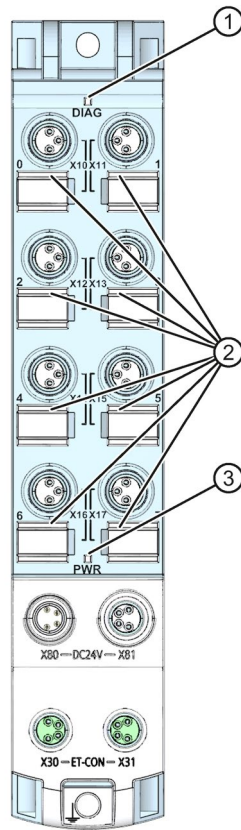
- Short-circuit of output to ground or
- Parameter error or
- For channels 4 ... 7: Missing load voltage 2L+

Interrupts/diagnostics alarms

5.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the digital input/digital output module DIQ 4+DQ 4x24VDC/0.5A 8xM8.



- | | | |
|---|--------------------------|-------------|
| ① | Diagnostic status (DIAG) | (red/green) |
| ② | Channel status (0 to 7) | (green) |
| ③ | Load voltage 2L+ (PWR) | (green) |





Image 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Corrective measures for diagnostics alarms can be found in the section Diagnostics alarms (Page 21).



DIAG LED

Table 5- 1 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> Module parameters not assigned Loading firmware (while the firmware update is being performed, all LEDs retain their current status)
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics



LED channel status

Table 5- 2 LED channel status display

LED channel status	Meaning
 Off	Process signal = 0
 On	Process signal = 1

PWR LED

Table 5- 3 Status display of the PWR LED

PWR LED	Meaning
 Off	Load voltage 2L+ is missing or too low
 On	Load voltage 2L+ present

5.2 Interrupts

The DIQ 4+DQ 4x24VDC/0.5A 8xM8 digital input/digital output module supports diagnostic interrupts.

Diagnostic interrupt

The digital input/digital output module generates a diagnostic interrupt at the following events:

- Short-circuit of encoder supply to ground
- Short-circuit of outputs to ground
- Load voltage 2L+ missing or too low

5.3 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the DIAG LED flashes red on the digital input/output module.

You can read out the diagnostics alarms, for example, from the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 5- 4 Diagnostics alarms, their meanings and corrective measures

Diagnosics alarm	Error code	Meaning	Remedy
Short-circuit*	1H	Short-circuit encoder supply to ground	<ul style="list-style-type: none"> • Eliminate the short-circuit
		Short-circuit of outputs to ground	
Load voltage 2L+ missing**	11H	Load voltage 2L+ missing or too low	<ul style="list-style-type: none"> • Check the supply voltage • Check the module
<p>* If a short-circuit of the encoder supply to ground is detected, the diagnostic alarm "Short-circuit" is always output. This alarm is output even if all channels are configured as outputs.</p> <p>** If you are using ET 200AL modules in connection with the ET 200SP distributed I/O system, the diagnostic alarm "Load voltage missing" is displayed.</p>			

Note

Channel type

The digital input/digital output module is always signaled as a mixed module (channel type "Input/Output") in the case of diagnostic events, even if you have configured the digital input/digital output module exclusively as an output module.

Technical specifications

Technical specifications of the DIQ 4+DQ 4x24VDC/0.5A 8xM8 digital input/digital output module

	6ES7143-5BF00-0BA0
General information	
Product type designation	DIQ 4+DQ 4X24VDC/0,5A, 8xM8
Hardware functional status	E01
Firmware version	V1.0.x
Product function	
I&M data	Yes; I&M0 to I&M3
Engineering with	
STEP 7 TIA Portal can be configured/integrated as of version	As of STEP 7 V13 SP1
STEP 7 can be configured/integrated as of version	V5.5 SP4 Hotfix 3 or higher
PROFIBUS as of GSD version/GSD revision	GSD as of revision 5
PROFINET as of GSD version/GSD revision	GSDML V2.3.1
Supply voltage	
Load voltage 1L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction; encoder supply outputs are connected with reverse polarity, loads will be activated
Load voltage 2L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction; loads will be activated
Input current	
Current consumption (rated value)	40 mA; no load
From load voltage 1L+ (unswitched voltage)	4 A; maximum value
From load voltage 2L+, max.	4 A; maximum value
Encoder supply	
Number of outputs	4
24 V encoder supply	
Short-circuit protection	Yes; per module, electronic
Output current, max.	0.7 A; total current of all encoders
Power loss	
Power loss, typ.	2.5 W

6ES7143-5BF00-0BA0	
Digital inputs	
Number of inputs	4; can be configured as DIQ
Input characteristic curve acc. to IEC 61131, type 3	Yes
Number of inputs that can be controlled simultaneously	
All mounting positions	
<ul style="list-style-type: none"> up to 55 °C, max. 	4
Input voltage	
Type of input voltage	DC
Rated value (DC)	24 V
For signal "0"	-3 ... +5 V
For signal "1"	+11 ... +30 V
Input current	
For signal "1", typ.	3.2 mA
Input delay (for rated value of input voltage)	
For standard inputs	
<ul style="list-style-type: none"> at "0" to "1", min. at "0" to "1", max. at "1" to "0", min. at "1" to "0", max. 	1.2 ms 4.8 ms 1.2 ms 4.8 ms
Cable length	
Unshielded, max.	30 m
Digital outputs	
Number of outputs	8; 4 DQ fixed, 4 DIQ can be assigned
<ul style="list-style-type: none"> In groups of 	4; 2 load groups for 4 outputs each
Short-circuit protection	Yes; per channel, electronic
<ul style="list-style-type: none"> Response threshold, typ. 	0.7 A
Limitation of inductive shutdown voltage to	2L+ (-47 V)
Switching capacity of outputs	
With lamp load, max.	5 W
Load resistance range	
Low limit	48 Ω
High limit	4 kΩ
Output voltage	
For signal "1", min.	L+ (-0.8 V)
Output current	
For signal "1" rated value	0.5 A
For signal "0" residual current, max.	0.5 mA

6ES7143-5BF00-0BA0	
Switching frequency	
With resistive load, max.	100 Hz
With inductive load, max.	0.5 Hz
With lamp load, max.	1 Hz
Total current of outputs	
Current per group, max.	2 A
Cable length	
Unshielded, max.	30 m
Encoders	
Connectable encoders	
2-wire sensor	Yes
<ul style="list-style-type: none"> Permissible quiescent current (2-wire sensor), max. 	1.5 mA
Interrupts/diagnostics/status information	
Substitute values can be applied	Yes; channel-based, configurable
Interrupts	
Diagnostic interrupt	Yes; configurable
Diagnostics alarms	
Short-circuit	Yes; outputs to ground; encoder supply to ground; module-based
Diagnostics indicator LED	
Channel status display	Yes; green LED
For module diagnostics	Yes; green/red LED
For load voltage monitoring	Yes; green LED
Electrical isolation	
Between load voltages	Yes
Electrical isolation of channels	
Between the channels, in groups of	4; DIQ channels are electrically isolated from DQ channels
Between the channels and backplane bus	Yes
Between the channels and power supply of the electronics	No; DIQ channels are non-isolated and DQ channels are isolated from supply voltage 1L+
Insulation	
Insulation tested with	707 V DC (type test)
Degree of protection and protection class	
Degree of protection according to EN 60529	
<ul style="list-style-type: none"> IP65 	Yes
<ul style="list-style-type: none"> IP67 	Yes
Ambient conditions	
Ambient temperature in operation	
Min.	-25 °C
Max.	55 °C

6ES7143-5BF00-0BA0	
Connection technology	
Inputs/outputs	M8, 3-pin
Power supply	M8, 4-pin
ET-Connection	
ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	30 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	145 g

PROFenergy

7.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific behavior of the digital input/digital output module is explained in the following sections.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<http://support.automation.siemens.com/WW/view/en/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V13 (<http://support.automation.siemens.com/WW/view/en/49948856>).

Application examples (<http://support.automation.siemens.com/WW/view/en/58235225>) are also available on the Internet.

7.2 DI operating mode

Display

The channel status LEDs are directly influenced by the signal level at the socket. If the encoder supply is switched off, this causes the channel status LEDs to also switch off.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- Encoder supply switch-off upon the start of "pause" does not result in the "Short-circuit" alarms.
- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 7- 1 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> • Supply voltage U_S switched off ¹ • Pause substitute value: 0_B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> • Supply voltage U_S switched off ¹ • Pause substitute value: Last input value • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> • Supply voltage U_S switched off ¹ • Pause substitute value: Configured pause substitute value • Value status "BAD"

¹ As there is only one encoder supply U_S for all channels, the supply can only be switched off at "pause" if all channels are configured to switch off.

7.3 DQ operating mode

Display

The channel status LEDs are directly affected by the signal level at the socket.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 7-2 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" • Pause substitute value: 0 _B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" • Pause substitute value: Last output value is maintained • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" • Pause substitute value: Configured pause substitute value is output • Value status "BAD"

Dimension drawing

A

The following figure shows the dimension drawing of the DIQ 4+DQ 4x24VDC/0.5A 8xM8 digital input/digital output module in front and side views.

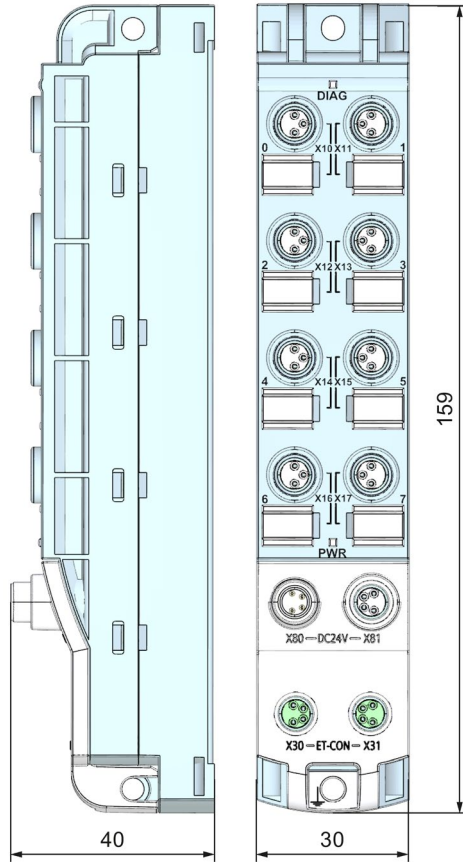
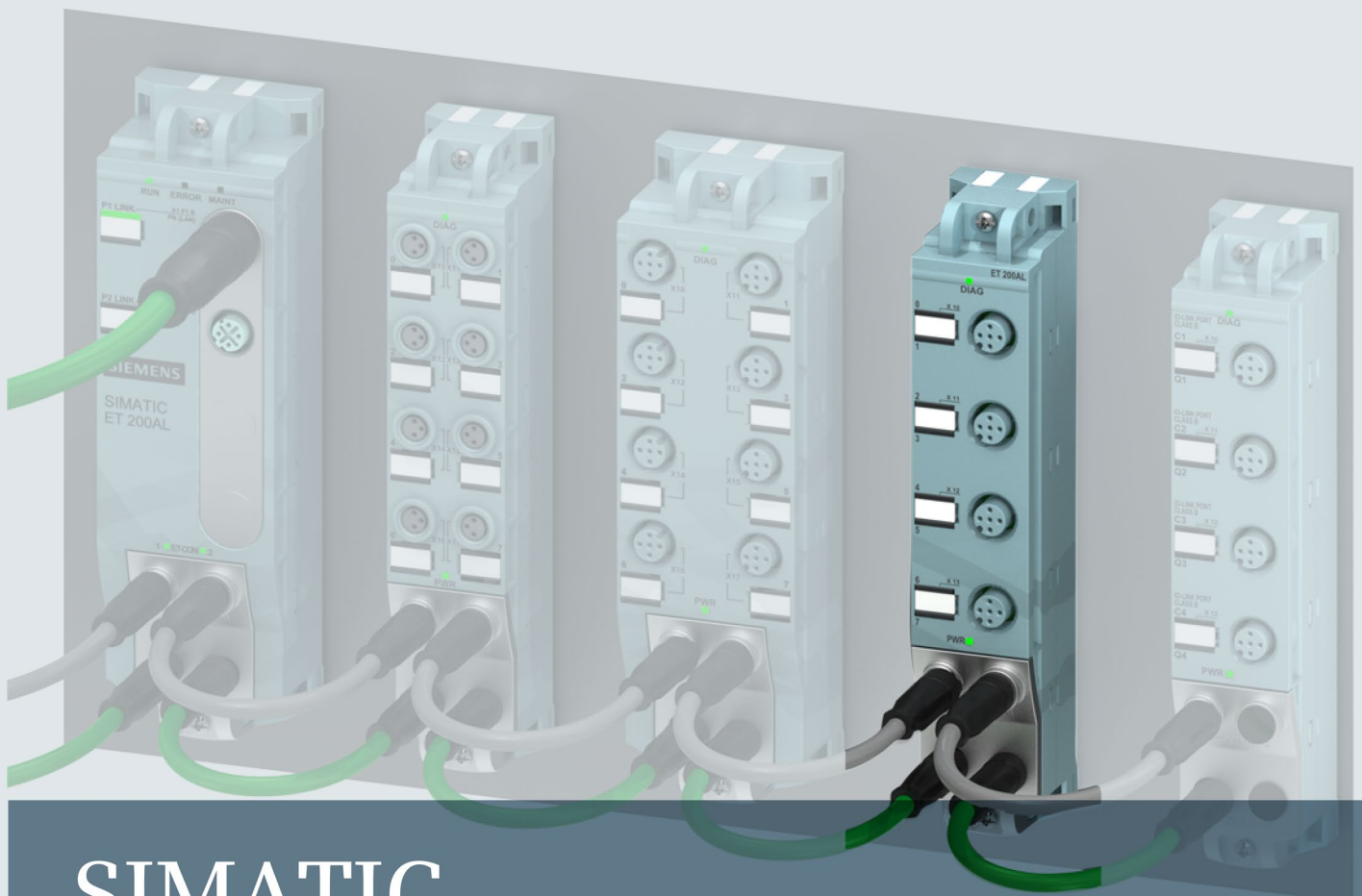


Image A-1 Dimension drawing

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SIMATIC

ET 200AL

Digital input / output module DIQ 4+DQ 4x24VDC/0.5A 4xM12 (6ES7143-5AF00-0BA0)

Manual

Edition

02/2016

Answers for industry.

SIEMENS

SIMATIC

ET 200AL

Digital input/digital output module
DIQ 4+DQ 4x24VDC/0.5A 4xM12
(6ES7143-5AF00-0BA0)

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Parameters/address space

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Interrupts/diagnostic alarms

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7

Dimension drawing

A

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

DANGER

indicates that death or severe personal injury **will** result if proper precautions are not taken.

WARNING

indicates that death or severe personal injury **may** result if proper precautions are not taken.

CAUTION

indicates that minor personal injury can result if proper precautions are not taken.

NOTICE

indicates that property damage can result if proper precautions are not taken.

If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

WARNING

Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

Trademarks

All names identified by ® are registered trademarks of Siemens AG. The remaining trademarks in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owner.

Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (<http://www.siemens.com/industrialsecurity>).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (<http://support.automation.siemens.com>).

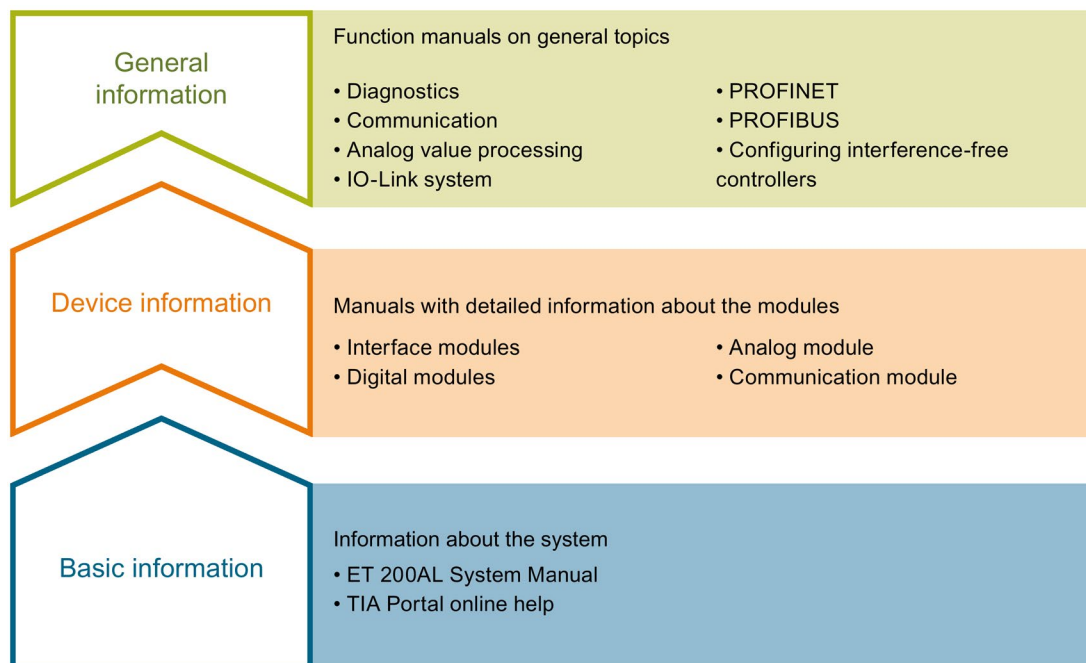
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Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<http://w3.siemens.com/mcms/industrial-automation-systems-simatic/en/manual-overview/tech-doc-et200/Pages/Default.aspx>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

"mySupport" - Documentation

In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.

You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<http://support.industry.siemens.com/My/ww/en/documentation>).

"mySupport" - CAx data

In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

Product overview

2.1 Properties

Article number

6ES7143-5AF00-0BA0

View of the module

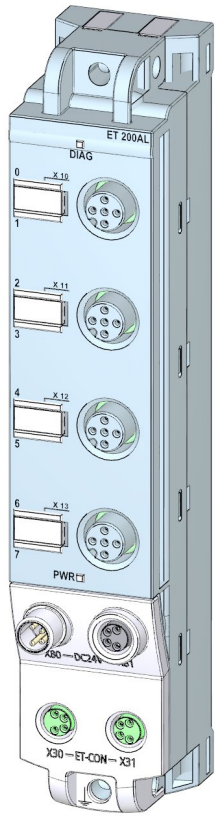


Image 2-1 View of the DIQ 4+DQ 4x24VDC/0.5A 4xM12 digital input/digital output module

Properties

The module has the following technical properties:

- 4 digital inputs or digital outputs and 4 digital outputs, depending on parameter assignment
 - DIQ signals connected to 1L+ (non-switched)
 - DQ signals connected to 2L+ (switched)
- M12 sockets for connection of sensors and actuators
- Digital inputs:
 - 24 V DC supply voltage
 - Configurable diagnostics can be set for each module
 - Typical input delay of 3 ms
 - Suitable for switches and proximity switches
- Digital outputs:
 - Rated load voltage 24 V DC
 - Suitable for solenoid valves, DC contactors, and indicator lights
 - Output current per output 0.5 A
 - Configurable diagnostics can be set for each module
- Dimensions 30 x 159 mm

The module supports the following functions:

- Firmware update
- Identification and maintenance data I&M0 to I&M3
- Value status (Quality Information)
- PROFIenergy

Accessories

The following components are included in the module package:

- Identification labels
- Spacers

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

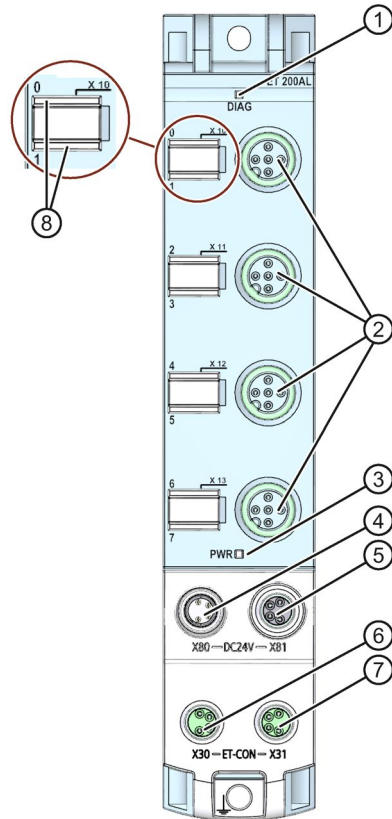
See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system

(<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual.

2.2 Operator controls and display elements

The figure below shows the operator controls and display elements of the DIQ 4+DQ 4x24VDC/0.5A 4xM12 digital input/digital output module.



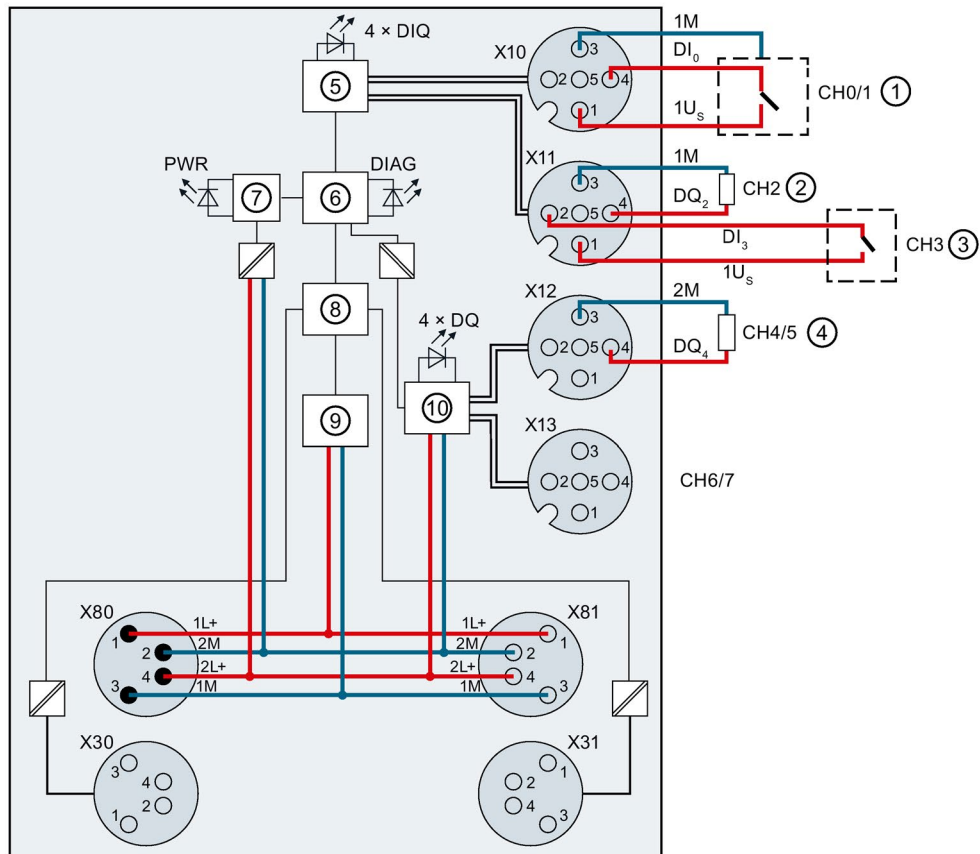
- ① DIAG: LED display for the diagnostic status
- ② X10 to X13: Sockets for the input/output signal
- ③ PWR: LED display for load voltage 2L+
- ④ X80: Connector for infeed of the supply voltage (POWER input)
- ⑤ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑥ X30: Socket for ET-Connection IN
- ⑦ X31: Socket for ET-Connection OUT
- ⑧ LED displays 0 to 7 for the channel status

Image 2-2 Operator controls and display elements

Wiring

3.1 Terminal and block diagram

The figure below shows an example of the pin assignment of signal inputs with 2-wire and 3-wire connection as well as signal outputs.



①	Configured as input: 3-wire connection	X30	Infeed of the ET-Connection
②	Configured as output	X31	Loop-through of the ET-Connection
③	Configured as input: 2-wire connection	1L+	Supply voltage 1L+ (non-switched)
④	Output	1M	Ground 1M (non-switched)
⑤	DI/DQ circuit	2L+	Load voltage 2L+ (switched)
⑥	Microcontroller	2M	Ground 2M (switched)
⑦	Monitoring	1Us	24 V encoder supply
⑧	ET-Connection interface	DIQ _n	Input/output signal
⑨	Internal supply voltage	DQ _n	Output signal
⑩	DQ circuit	DIQ	LEDs channel status (0, 1, 2 and 3) (green)
X10 to X13	Channels 0 to 7	DQ	LEDs channel status (4, 5, 6 and 7) (green)
X80	Infeed of supply voltages	DIAG	LED diagnostic status (red/green)
X81	Loop-through of supply voltages	PWR	LED supply voltage 2L+ (green)

Image 3-1 Terminal and block diagram

3.2 Pin assignment

Note

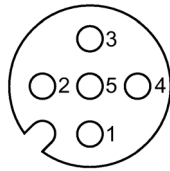
Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for digital inputs/digital outputs

The tables below show the pin assignments of the 4 sockets for connection of the digital inputs/digital outputs.

Table 3- 1 Pin assignment for digital inputs/digital outputs

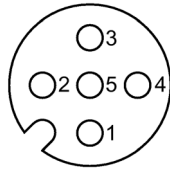
Pin	Assignment	Front view of the sockets
	X10 and X11 - sockets for digital inputs/digital outputs	
1	24 V encoder supply 1Us (derived from 1L+ non-switched)	
2	Input/output signal DIQ1: Connector X10 Input/output signal DIQ3: Connector X11	
3	Encoder supply ground 1M	
4	Input/output signal DIQ0: Connector X10 Input/output signal DIQ2: Connector X11	
5	Functional earth FE	

NOTICE

24 V encoder supply 1Us

Use only the 24 V encoder supply 1Us provided by the digital input/digital output module to supply power to the encoder.

Table 3- 2 Pin assignment for digital outputs

Pin	Assignment	Front view of the sockets
	X12 and X13 sockets for digital outputs	
1	Unassigned	
2	Output signal DQ5: Connector X12 Output signal DQ7: Connector X13	
3	Ground 2M	
4	Output signal DQ4: Connector X12 Output signal DQ6: Connector X13	
5	Functional earth FE	

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

Table 3- 3 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

Table 3- 4 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3- 5 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE**ET-Connection/supply voltage**

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage.

Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

Parameters/address space

4.1 Parameters

The table below shows the parameters for the DIQ 4+DQ 4x24VDC/0.5A 4xM12 digital input/digital output module.

Table 4- 1 Parameters

Parameters	Value range	Default	Scope
Diagnostics: Missing load voltage 2L+	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module
Diagnostics: Short-circuit to ground	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module (Short-circuit of encoder supply or of the output to ground)
Freely assignable channel 0 ... 3	<ul style="list-style-type: none"> • DI • DQ 	DI	Channel
Reaction to CPU/master STOP	<ul style="list-style-type: none"> • Shut down • Keep last value • Output substitute value 	Shut down	Module (digital outputs)
Substitute value channel 0 ... 7	<ul style="list-style-type: none"> • 0 • 1 	0	Channel (digital outputs)

4.2 Explanation of the parameters

Diagnostics: Missing load voltage 2L+

Enabling of the diagnostics for missing or insufficient load voltage 2L+.

Diagnostics: Short-circuit to ground

Enabling of the diagnostics for short-circuit of the encoder supply or output to ground.

Freely assignable channel n

With this parameter, you set whether the channel is to be operated as an input or output.

Reaction to CPU/master STOP

With this parameter, you set the reaction of the digital outputs of the digital input/digital output module after a CPU/master STOP:

- Shut down: The digital output is de-energized.
- Keep last value: The last value of the digital output remains activated.
- Output substitute value: The module outputs a configured substitute value.

Substitute value channel 0 ... 7

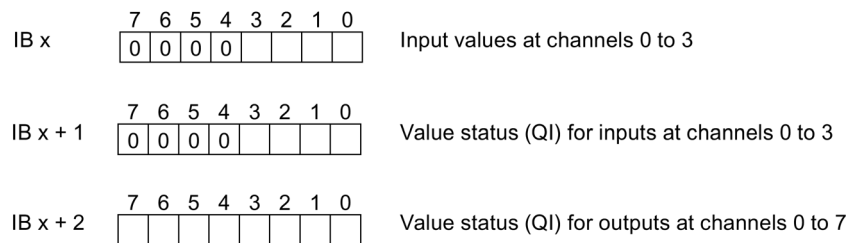
With this parameter, you set substitute values for the digital outputs.

4.3 Address space

The figure below shows the assignment of the address space for the digital input/digital output module DIQ 4+DQ 4x24VDC/0.5A 4xM12 with value status (Quality Information, QI).

The address space for the value status is allocated by the module, if the value status is configured using the PROFINET interface module.

Assignment in the process image input (PII)



Assignment in the process image output (PIQ)

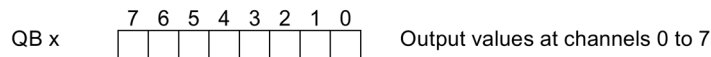


Image 4-1 Address space

Note

Parameter assignment of the channels

Parameters for the first four channels can be freely assigned.

For the channels 0 ... 3 that are configured as input, the corresponding values in the output data do not trigger any reaction.

For the channels 0 ... 3 that are configured as output, the input value in the process image is 0.

Configuration options of the digital input/digital output module DIQ 4+DQ 4x24VDC/0.5A 4xM12

You have the following configuration options:

- Configuration 1: without value status
- Configuration 2: with value status

Evaluating the value status

An additional two bytes are occupied in the input address space if you enable the value status for the digital input/digital output module. The value status of the inputs is assigned to bits 0 to 3 in input byte $x + 1$. The value status of the outputs is assigned to bits 0 to 7 in input byte $x + 2$. This additional information provides information regarding the validity of the digital values or channel status.

Bit = 1: No error on channel.

Bit = 0: Error on channel.

If the channel is configured as input, this means:

- Short-circuit to ground at sensor supply or
- Parameter error

If the channel is configured as output, this means:

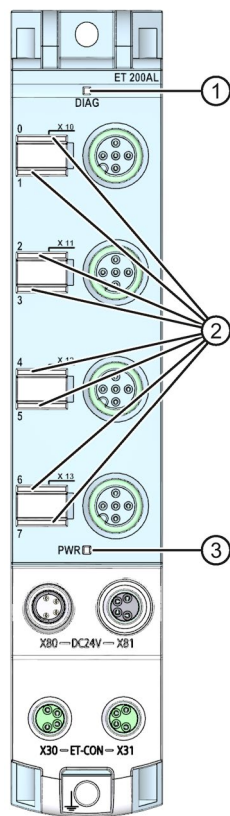
- Short-circuit of output to ground or
- Parameter error or
- For channels 4 ... 7: Missing load voltage 2L+

Interrupts/diagnostic alarms

5.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the digital input/digital output module DIQ 4+DQ 4x24VDC/0.5A 4xM12.



- ① Diagnostic status (DIAG) (red/green)
- ② Channel status (0 to 7) (green)
- ③ Load voltage 2L+ (PWR) (green)





Image 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Remedial measures for diagnostic alarms can be found in the section Diagnostics alarms (Page 21).



DIAG LED

Table 5- 1 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> Module parameters not assigned Loading firmware (while the firmware update is being performed, all LEDs retain their current status)
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics



LED channel status

Table 5- 2 LED channel status display

LED channel status	Meaning
 Off	Process signal = 0
 On	Process signal = 1

PWR LED

Table 5- 3 Status display of the PWR LED

PWR LED	Meaning
 Off	Load voltage 2L+ is missing or too low
 On	Load voltage 2L+ present

5.2 Interrupts

The DIQ 4+DQ 4x24VDC/0.5A 4xM12 digital input/digital output module supports diagnostic interrupts.

Diagnostic interrupt

The digital input/digital output module generates a diagnostic interrupt at the following events:

- Short-circuit of encoder supply to ground
- Short-circuit of outputs to ground
- Load voltage 2L+ missing or too low

5.3 Diagnostics alarms

A diagnostic alarm is output for each diagnostic event and the DIAG LED flashes red on the digital input/digital output module.

You can read out the diagnostics alarms, for example, from the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 5- 4 Diagnostics alarms, their meanings and corrective measures

Diagnosics alarm	Error code	Meaning	Remedy
Short-circuit*	1H	Short-circuit encoder supply to ground	<ul style="list-style-type: none"> • Eliminate the short-circuit
		Short-circuit of outputs to ground	
Load voltage 2L+ missing**	11H	Load voltage 2L+ missing or too low	<ul style="list-style-type: none"> • Check the supply voltage • Check the module
<p>* If a short-circuit of the encoder supply to ground is detected, the diagnostic alarm "Short-circuit" is always output. This alarm is output even if all channels are configured as outputs.</p> <p>** If you are using ET 200AL modules in connection with the ET 200SP distributed I/O system, the diagnostic alarm "Load voltage missing" is displayed.</p>			

Note

Channel type

The digital input/digital output module is always signaled as a mixed module (channel type "Input/Output") in the case of diagnostic events, even if you have configured the digital input/digital output module exclusively as an output module.

Technical specifications

6.1 Technical specifications

Technical specifications of the DIQ 4+DQ 4x24VDC/0.5A 4xM12 digital input/digital output module

	6ES7143-5AF00-0BA0
General information	
Product type designation	DIQ 4+DQ 4X24VDC/0,5A, 4XM12
Hardware functional status	E01
Firmware version	V1.0.x
Product function	
I&M data	Yes; I&M0 to I&M3
Engineering with	
STEP 7 TIA Portal can be configured/integrated as of version	As of STEP 7 V13 SP1
STEP 7 can be configured/integrated as of version	V5.5 SP4 Hotfix 7 or higher
PROFIBUS as of GSD version/GSD revision	GSD as of revision 5
PROFINET as of GSD version/GSD revision	GSDML V2.3.1
Supply voltage	
Load voltage 1L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction; encoder supply outputs are connected with reverse polarity, loads will be activated
Load voltage 2L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction; loads will be activated
Input current	
Current consumption (rated value)	40 mA; no load
From load voltage 1L+ (unswitched voltage)	4 A; maximum value
From load voltage 2L+, max.	4 A; maximum value
Encoder supply	
Number of outputs	4
24 V encoder supply	
Short-circuit protection	Yes; per module, electronic
Output current, max.	0.7 A; total current of all encoders

6ES7143-5AF00-0BA0	
Power loss	
Power loss, typ.	2.5 W
Digital inputs	
Number of inputs	4; can be configured as DIQ
Input characteristic curve acc. to IEC 61131, type 3	Yes
Number of inputs that can be controlled simultaneously	
All mounting positions	
<ul style="list-style-type: none"> up to 55 °C, max. 	4
Input voltage	
Type of input voltage	DC
Rated value (DC)	24 V
For signal "0"	-3 ... +5 V
For signal "1"	+11 ... +30 V
Input current	
For signal "1", typ.	3.2 mA
Input delay (for rated value of input voltage)	
For standard inputs	
<ul style="list-style-type: none"> at "0" to "1", min. at "0" to "1", max. at "1" to "0", min. at "1" to "0", max. 	1.2 ms 4.8 ms 1.2 ms 4.8 ms
Cable length	
Unshielded, max.	30 m
Digital outputs	
Number of outputs	8; 4 DQ fixed, 4 DIQ can be assigned
<ul style="list-style-type: none"> In groups of 	4; 2 load groups for 4 outputs each
Short-circuit protection	Yes; per channel, electronic
<ul style="list-style-type: none"> Response threshold, typ. 	0.7 A
Limitation of inductive shutdown voltage to	2L+ (-47 V)
Switching capacity of outputs	
With lamp load, max.	5 W
Load resistance range	
Low limit	48 Ω
High limit	4 kΩ
Output voltage	
For signal "1", min.	L+ (-0.8 V)
Output current	
For signal "1" rated value	0.5 A
For signal "0" residual current, max.	0.5 mA

6ES7143-5AF00-0BA0	
Switching frequency	
With resistive load, max.	100 Hz
With inductive load, max.	0.5 Hz
With lamp load, max.	1 Hz
Total current of outputs	
Current per group, max.	2 A
Cable length	
Unshielded, max.	30 m
Encoders	
Connectable encoders	
2-wire sensor	Yes
<ul style="list-style-type: none"> Permissible quiescent current (2-wire sensor), max. 	1.5 mA
Interrupts/diagnostics/status information	
Substitute values can be applied	Yes; channel-based, configurable
Interrupts	
Diagnostic interrupt	Yes; configurable
Diagnostics alarms	
Short-circuit	Yes; outputs to ground; encoder supply to ground; module-based
Diagnostics indicator LED	
Channel status display	Yes; green LED
For module diagnostics	Yes; green/red LED
For load voltage monitoring	Yes; green LED
Electrical isolation	
Between load voltages	Yes
Electrical isolation of channels	
Between the channels, in groups of	4; DIQ channels are electrically isolated from DQ channels
Between the channels and backplane bus	Yes
Between the channels and power supply of the electronics	No; DIQ channels are non-isolated and DQ channels are isolated from supply voltage 1L+
Insulation	
Insulation tested with	707 V DC (type test)
Degree of protection and protection class	
Degree of protection according to EN 60529	
<ul style="list-style-type: none"> IP65 	Yes
<ul style="list-style-type: none"> IP67 	Yes
Ambient conditions	
Ambient temperature in operation	
Min.	-25 °C
Max.	55 °C

6ES7143-5AF00-0BA0	
Connection technology	
Inputs/outputs	M12, 5-pin
Power supply	M8, 4-pin
ET-Connection	
ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	30 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	145 g

7.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific behavior of the digital input/digital output module is explained in the following sections.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<https://support.industry.siemens.com/cs/ww/en/view/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V13 (<https://support.industry.siemens.com/cs/ww/en/view/49948856>).

Application examples (<https://support.industry.siemens.com/cs/ww/en/view/41986454>) are also available on the Internet.

7.2 DI operating mode

Display

The channel status LEDs are directly influenced by the signal level at the socket. If the encoder supply is switched off, this causes the channel status LEDs to also switch off.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- Encoder supply switch-off upon the start of "pause" does not result in the "Short-circuit" alarms.
- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 7- 1 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> • Supply voltage U_S switched off ¹ • Pause substitute value: 0_B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> • Supply voltage U_S switched off ¹ • Pause substitute value: Last input value • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> • Supply voltage U_S switched off ¹ • Pause substitute value: Configured pause substitute value • Value status "BAD"

¹ As there is only one encoder supply U_S for all channels, the supply can only be switched off at "pause" if all channels are configured to switch off.

7.3 DQ operating mode

Display

The channel status LEDs are directly affected by the signal level at the socket.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 7-2 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> • Pause substitute value: 0_B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> • Pause substitute value: Last output value is maintained • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> • Pause substitute value: Configured pause substitute value is output • Value status "BAD"

Dimension drawing

The figure below shows the dimension drawing of the DIQ 4+DQ 4x24VDC/0.5A 4xM12 digital input/digital output module in front and side views.

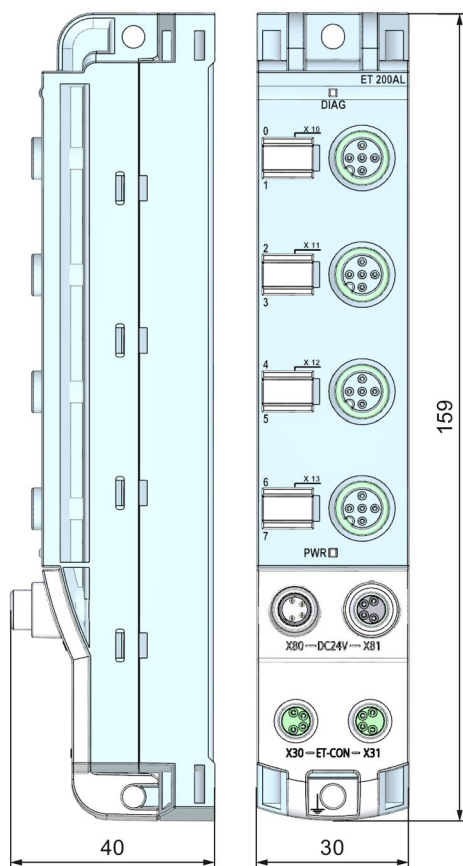
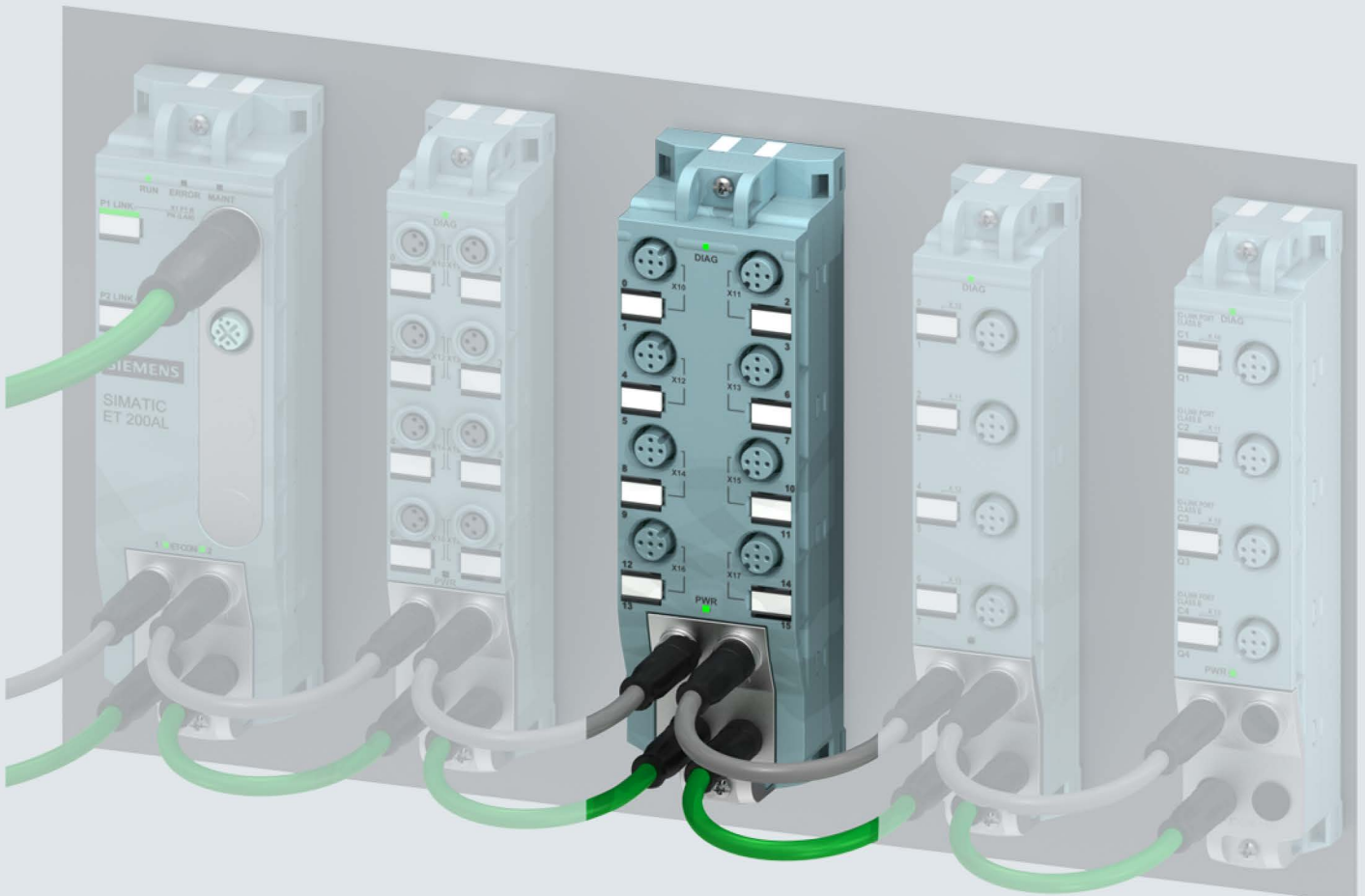


Image A-1 Dimension drawing

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Manual

SIMATIC

ET 200AL

Digital input / output module
DIQ 16x24VDC/0.5A 8xM12
(6ES7143-5AH00-0BA0)

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SIEMENS

SIMATIC

ET 200AL

Digital input/Digital output module DIQ 16x24VDC/0.5A 8xM12 (6ES7143-5AH00-0BA0)

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

⚠ DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
⚠ WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
⚠ CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.

If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

⚠ WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions constitute one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For additional information on industrial security measures that may be implemented, please visit (<http://www.siemens.com/industrialsecurity>).

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customers' exposure to cyber threats.

To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed under (<http://www.siemens.com/industrialsecurity>).

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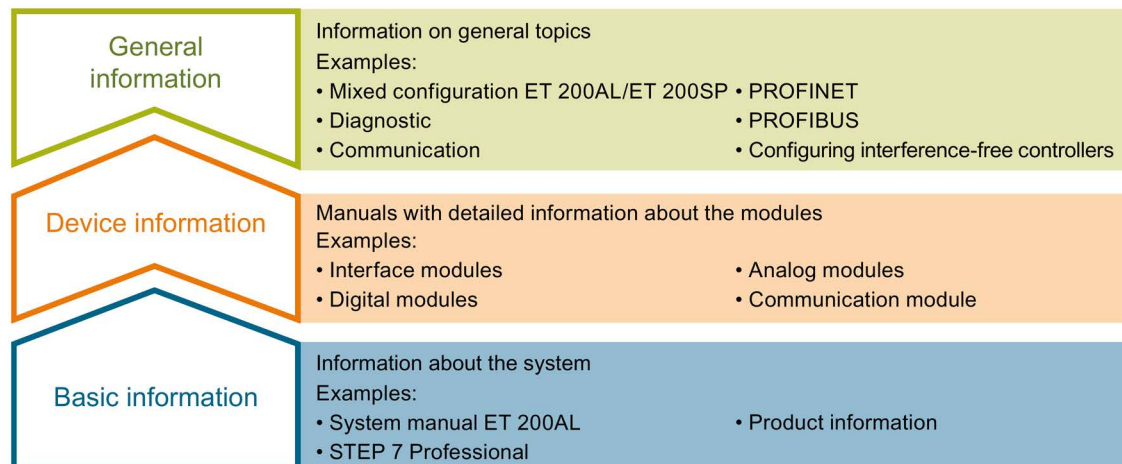
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Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742667>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

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In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.

You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<http://support.industry.siemens.com/My/ww/en/documentation>).

"mySupport" - CAx data

In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

SIMATIC Automation Tool

You can use the SIMATIC Automation Tool to perform commissioning and maintenance activities simultaneously on different SIMATIC S7 stations as a bulk operation, independently of the TIA Portal.

General function overview:

- Network browsing and creation of a table showing the accessible devices in the network
- Flashing of device LEDs or HMI display to locate a device
- Downloading of addresses (IP, subnet, gateway) to a device
- Downloading the PROFINET name (station name) to a device
- Placing a CPU in RUN or STOP mode
- Setting the time in a CPU to the current time of your PG/PC
- Downloading a new program to a CPU or an HMI device
- Downloading from CPU, downloading to CPU or deleting recipe data from a CPU
- Downloading from CPU or deleting data log data from a CPU
- Backup/restore of data from/to a backup file for CPUs and HMI devices
- Downloading service data from a CPU
- Reading the diagnostics buffer of a CPU
- Performing a CPU memory reset
- Resetting devices to factory settings
- Downloading a firmware update to a device

You can find the SIMATIC Automation Tool on the Internet

(<https://support.industry.siemens.com/cs/ww/en/view/98161300>).

PRONETA

With SIEMENS PRONETA (PROFINET network analysis), you analyze the system network during commissioning. PRONETA features two core functions:

- The topology overview independently scans the PROFINET network and all connected components.
- The IO check is a fast test of the wiring and the module configuration of a system.

You can find SIEMENS PRONETA on the Internet

(<https://support.industry.siemens.com/cs/ww/en/view/67460624>).

SINETPLAN

SINETPLAN, the Siemens Network Planner, supports you in planning automation systems and networks based on PROFINET. The tool facilitates professional and predictive dimensioning of your PROFINET installation as early as in the planning stage. In addition, SINETPLAN supports you during network optimization and helps you to exploit network resources optimally and to plan reserves. This helps to prevent problems in commissioning or failures during productive operation even in advance of a planned operation. This increases the availability of the production plant and helps improve operational safety.

The advantages at a glance

- Network optimization thanks to port-specific calculation of the network load
- Increased production availability thanks to online scan and verification of existing systems
- Transparency before commissioning through importing and simulation of existing STEP 7 projects
- Efficiency through securing existing investments in the long term and optimal exploitation of resources

You can find SINETPLAN on the Internet (<https://www.siemens.com/sinetplan>).

Product overview

2.1 Properties

Article number

6ES7143-5AH00-0BA0

View of the module

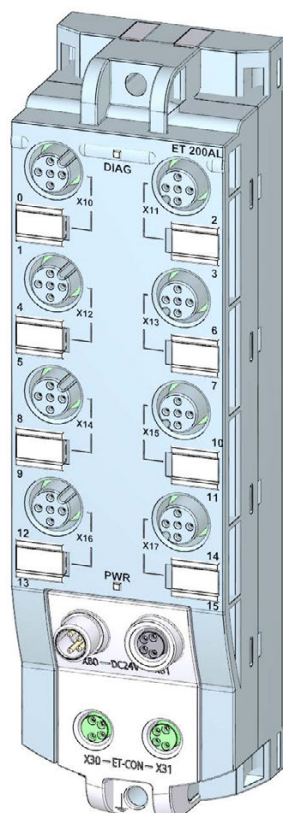


Figure 2-1 View of the digital input/digital output module DIQ 16x24VDC/0.5A 8xM12

Properties

The module has the following technical properties:

- 16 digital inputs or digital outputs, depending on configuration and parameter assignment
 - 8 DIQ signals connected to 1L+ (non-switched)
 - 8 DQ signals connected to 2L+ (switched)
- M12 sockets for connection of sensors and actuators
- Digital inputs:
 - 24 V DC supply voltage
 - Suitable for switches and proximity switches
 - Input delay configurable
 - Configurable diagnostics can be set for each module
- Digital outputs:
 - Rated load voltage 24 V DC
 - Suitable for solenoid valves, DC contactors, and indicator lights
 - Output current per output 0.5 A
 - Configurable diagnostics can be set for each module
- Counters:
 - Configuration method 2xCount or 4xCount with 2 or 4 counters
 - Counting frequency 2 kHz
 - Counting width 32 bits
 - Counting direction parameterizable or controllable via direction input
 - GATE function controllable via the control interface or via control input
 - Configurable diagnostics and hardware interrupts can be set for each module
 - Input delay configurable
- Dimensions 45 x 159 mm

The module supports the following functions:

- Firmware update
- Identification and maintenance data I&M0 to I&M3
- Value status (Quality Information)
- PROFIenergy

Accessories

The following components are included in the module package:

- Identification labels

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

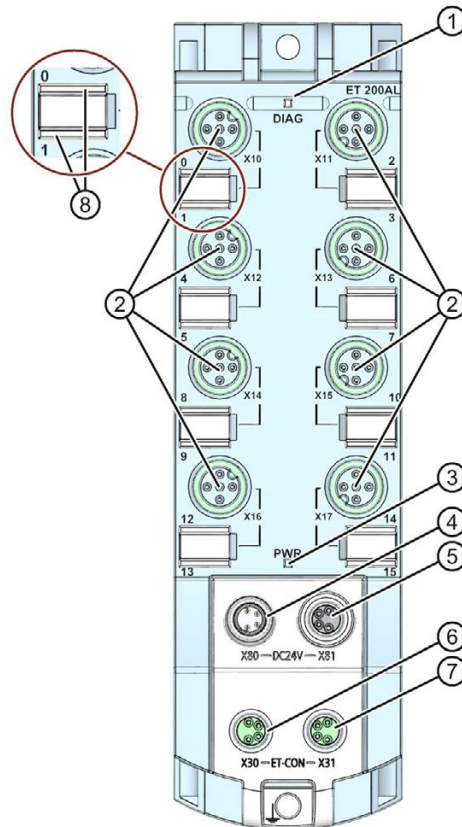
See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system

(<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual.

2.2 Operator controls and display elements

The following figure shows the operator controls and display elements of the digital input/digital output module DIQ 16x24VDC/0.5A 8xM12.



- ① DIAG: LED display for the diagnostic status
- ② X10 to X17: Sockets for the input/output signal
- ③ PWR: LED display for load voltage 2L+
- ④ X80: Connector for infeed of the supply voltage (POWER input)
- ⑤ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑥ X30: Socket for ET-Connection IN
- ⑦ X31: Socket for ET-Connection OUT
- ⑧ LED displays 0 to 15 for the channel status

Figure 2-2 Operator controls and display elements

Configuration modes for digital inputs/outputs

3.1 Overview

Introduction

With the configuration modes for digital inputs and outputs, you can configure each channel of the module as an input or output consistent with your application.

You use the available configuration modes to specify how the channels will be used:

- **DIQ:**
You can use each channel as an input or output through a corresponding parameter assignment.
- **DIQ with value status:**
You can use each channel as an input or output through a corresponding parameter assignment. Additionally, the value status gives you information about the validity of the digital values and the channel status.
- **DQ16:**
All channels (0..15) are configured as outputs.
- **DI8/DQ8:**
Channels 0..7 are configured as inputs, and channels 8..15 are configured as outputs.
- **DIQ MIX:**
The channels 0, 2, 4, 6, 8, 10, 12, 14 and 16 have a fixed configuration as outputs, the channels 1, 3, 5, 7, 9, 11, 13 and 15 have a fixed configuration as inputs.

Note

Project engineering configuration mode DIQ MIX

Note that you can only use the configuration mode DIQ MIX when configuring via GSD file and in connection with the interface modules IM 157-1 PN and IM 157-1 DP.

Benefits

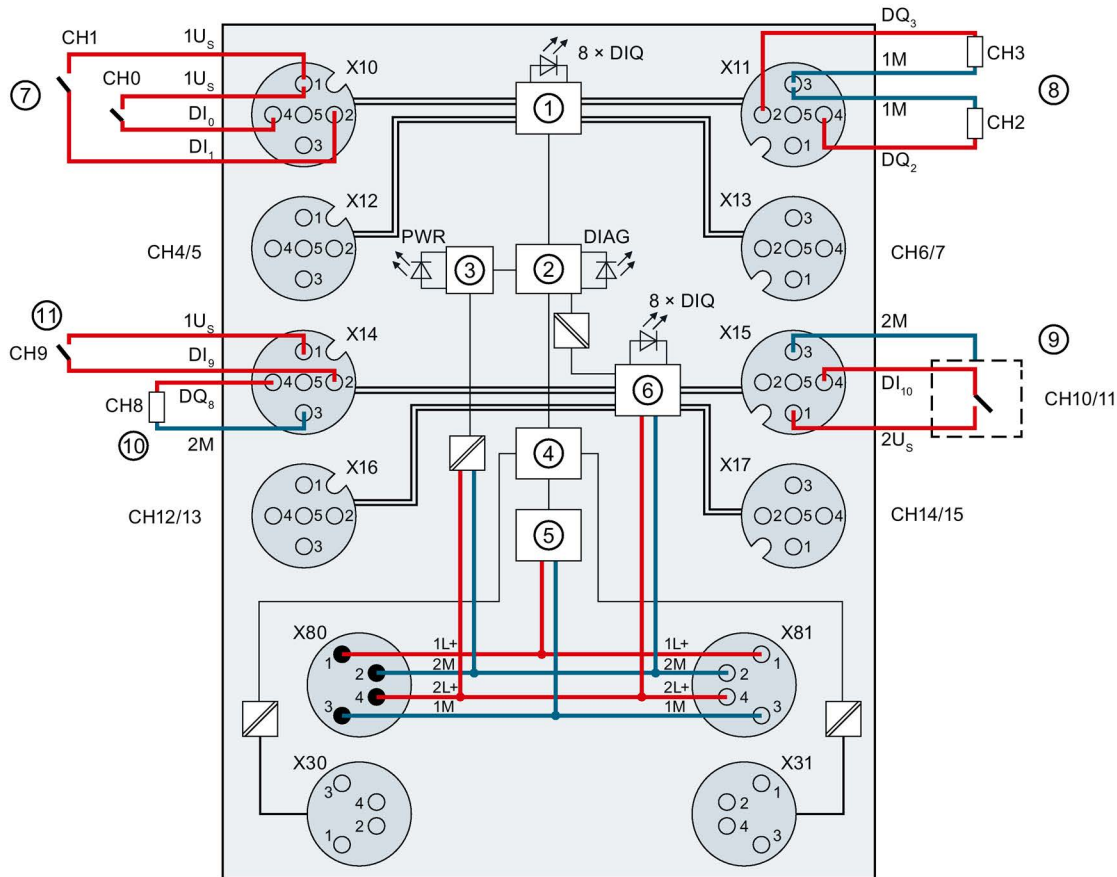
The address space occupied by the module is significantly reduced in the DQ16, DI8/DQ8 and DIQ MIX configuration modes compared with the DIQ configuration modes.

This reduction offers you advantages if you have already assigned the available address space of your plant for other processes.

3.2 Wiring

3.2.1 Terminal and block diagram

The figure below shows an example of the pin assignment of signal inputs with 2-wire and 3-wire connection and of signal outputs in the configuration modes for digital inputs and outputs.



- | | | | |
|------------|--|------------------|-------------------------------------|
| ① | DI/DQ circuit (1L+ non-switched) | X81 | Loop-through of supply voltages |
| ② | Microcontroller | X30 | Infeed of the ET-Connection |
| ③ | Monitoring | X31 | Loop-through of the ET-Connection |
| ④ | ET-Connection interface | 1L+ | Supply voltage 1L+ (non-switched) |
| ⑤ | Internal supply voltage | 1M | Ground 1M (non-switched) |
| ⑥ | DI/DQ circuit (2L+ switched) | 2L+ | Load voltage 2L+ (switched) |
| ⑦ | Parameterized as inputs: 2-wire connection | 2M | Ground 2M (switched) |
| ⑧ | Parameterized as outputs | 1Us | 24 V encoder supply |
| ⑨ | Configured as input: 3-wire connection | 2Us | 24 V encoder supply |
| ⑩ | Configured as output | DIQ _n | Input/output signal |
| ⑪ | Configured as input: 2-wire connection | DIQ | LEDs channel status (0..15) (green) |
| X10 to X17 | Channels 0 to 15 | DIAG | Diagnostic status LED (red/green) |
| X80 | Infeed of supply voltages | PWR | LED supply voltage 2L+ (green) |

Figure 3-1 Wiring and block diagram of configuration modes for digital inputs and outputs

3.2.2 Pin assignment

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

NOTICE

24 V encoder supply 1Us / 2Us

Use only the 24 V encoder supplies 1Us and 2Us provided by the digital input/digital output module to supply power to the encoder.

Pin assignment of the sockets for digital inputs/digital outputs in the configuration modes DIQ and DIQ with value status

The tables below show the pin assignments of the 8 sockets for connection of the digital inputs/digital outputs.

Table 3- 1 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X10, X12	X11, X13
1	24 V encoder supply 1Us (derived from 1L+ non-switched)		
2	Input/output signal DIQ ₁ : Connector X10 Input/output signal DIQ ₃ : Connector X11 Input/output signal DIQ ₅ : Connector X12 Input/output signal DIQ ₇ : Connector X13		
3	Ground 1M		
4	Input/output signal DIQ ₀ : Connector X10 Input/output signal DIQ ₂ : Connector X11 Input/output signal DIQ ₄ : Connector X12 Input/output signal DIQ ₆ : Connector X13		
5	Functional earth FE		

Table 3- 2 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X14, X16	X15, X17
1	24 V encoder supply 2Us (derived from 2L+ switched)		
2	Input/output signal DIQ ₉ : Connector X14 Input/output signal DIQ ₁₁ : Connector X15 Input/output signal DIQ ₁₃ : Connector X16 Input/output signal DIQ ₁₅ : Connector X17		
3	Ground 2M		
4	Input/output signal DIQ ₈ : Connector X14 Input/output signal DIQ ₁₀ : Connector X15 Input/output signal DIQ ₁₂ : Connector X16 Input/output signal DIQ ₁₄ : Connector X17		
5	Functional earth FE		

Pin assignment of the sockets for digital inputs/digital outputs in the configuration mode DQ16

The tables below show the pin assignments of the 8 sockets for connection of the digital inputs/digital outputs in the configuration mode DQ16.

In this configuration mode, socket pins 2 and 4 are always permanently assigned to output signals.

Table 3- 3 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X10, X12	X11, X13
1	24 V encoder supply 1Us (derived from 1L+ non-switched)		
2	Output signal DQ ₁ : Connector X10 Output signal DQ ₃ : Connector X11 Output signal DQ ₅ : Connector X12 Output signal DQ ₇ : Connector X13		
3	Ground 1M		
4	Output signal DQ ₀ : Connector X10 Output signal DQ ₂ : Connector X11 Output signal DQ ₄ : Connector X12 Output signal DQ ₆ : Connector X13		
5	Functional earth FE		

3.2 Wiring

Table 3- 4 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X14, X16	X15, X17
1	24 V encoder supply 2Us (derived from 2L+ switched)		
2	Output signal DQ ₉ : Connector X14 Output signal DQ ₁₁ : Connector X15 Output signal DQ ₁₃ : Connector X16 Output signal DQ ₁₅ : Connector X17		
3	Ground 2M		
4	Output signal DQ ₈ : Connector X14 Output signal DQ ₁₀ : Connector X15 Output signal DQ ₁₂ : Connector X16 Output signal DQ ₁₄ : Connector X17		
5	Functional earth FE		

Pin assignment of the sockets for digital inputs/digital outputs in the configuration mode DI8/DQ8

The tables below show the pin assignments of the 8 sockets for connection of the digital inputs/digital outputs in the configuration mode DI8/DQ8.

In this configuration mode, pins 2 and 4 for the sockets X10 to X13 are always permanently assigned to the input signals, pins 2 and 4 for the sockets X14 to X17 are always permanently assigned to the output signals.

Table 3- 5 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X10, X12	X11, X13
1	24 V encoder supply 1Us (derived from 1L+ non-switched)		
2	Input signal DI ₁ : Connector X10 Input signal DI ₃ : Connector X11 Input signal DI ₅ : Connector X12 Input signal DI ₇ : Connector X13		
3	Ground 1M		
4	Input signal DI ₀ : Connector X10 Input signal DI ₂ : Connector X11 Input signal DI ₄ : Connector X12 Input signal DI ₆ : Connector X13		
5	Functional earth FE		

Table 3- 6 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X14, X16	X15, X17
1	24 V encoder supply 2Us (derived from 2L+ switched)		
2	Output signal DQ ₉ : Connector X14 Output signal DQ ₁₁ : Connector X15 Output signal DQ ₁₃ : Connector X16 Output signal DQ ₁₅ : Connector X17		
3	Ground 2M		
4	Output signal DQ ₈ : Connector X14 Output signal DQ ₁₀ : Connector X15 Output signal DQ ₁₂ : Connector X16 Output signal DQ ₁₄ : Connector X17		
5	Functional earth FE		

Pin assignment of the sockets for digital inputs/digital outputs in the configuration mode DIQ MIX

The tables below show the pin assignments of the 8 sockets for connection of the digital inputs/digital outputs in the configuration mode DIQ MIX.

In this configuration mode, socket pin 2 is always permanently assigned to input signals, pin 4 is always permanently assigned to output signals.

Table 3- 7 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X10, X12	X11, X13
1	24 V encoder supply 1Us (derived from 1L+ non-switched)		
2	Input signal DI ₁ : Connector X10 Input signal DI ₃ : Connector X11 Input signal DI ₅ : Connector X12 Input signal DI ₇ : Connector X13		
3	Ground 1M		
4	Output signal DQ ₀ : Connector X10 Output signal DQ ₂ : Connector X11 Output signal DQ ₄ : Connector X12 Output signal DQ ₆ : Connector X13		
5	Functional earth FE		

3.2 Wiring

Table 3- 8 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X14, X16	X15, X17
1	24 V encoder supply 2Us (derived from 2L+ switched)		
2	Input signal DI ₉ : Connector X14 Input signal DI ₁₁ : Connector X15 Input signal DI ₁₃ : Connector X16 Input signal DI ₁₅ : Connector X17		
3	Ground 2M		
4	Output signal DQ ₈ : Connector X14 Output signal DQ ₁₀ : Connector X15 Output signal DQ ₁₂ : Connector X16 Output signal DQ ₁₄ : Connector X17		
5	Functional earth FE		

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

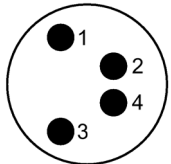
Table 3- 9 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

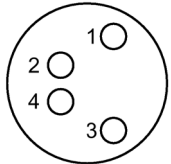
Table 3- 10 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the core color of the power cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3- 11 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the core color of the power cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE

ET-Connection/supply voltage

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage. Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

3.3 Parameters/address space

3.3.1 Parameters

The following table shows the parameters for the DIQ 16x24VDC/0.5A 8xM12 digital input / digital output module in the configuration modes for digital inputs and outputs.

Table 3- 12 Parameters

Parameters	Value range	Default	Scope
Diagnostics: Missing load voltage 2L+	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module
Diagnostics: Short-circuit to ground	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module (Short-circuit of encoder supply or of the output to ground)
Reaction to CPU/master STOP	<ul style="list-style-type: none"> • Shut down • Keep last value • Output substitute value 	Shut down	Module (digital outputs)
Freely configurable channel*	<ul style="list-style-type: none"> • DI • DQ 	DI	Channel
Substitute value channel	<ul style="list-style-type: none"> • 0 • 1 	0	Channel (digital outputs)
Input delay**	<ul style="list-style-type: none"> • 0.05 ms • 0.1 ms • 0.4 ms • 0.8 ms • 1.6 ms • 3.2 ms • 12.8 ms • 20 ms 	3.2 ms	Channel (Digital inputs)

* = Can only be set in DIQ or DIQ with value status configuration mode.

** = Not available in DQ16 mode. Only values starting from 1.6 ms can be configured for the input delay for channels 8..15.

3.3.2 Explanation of the parameters

Diagnostics: Missing load voltage 2L+

Enabling of the diagnostics for missing or insufficient load voltage 2L+.

Diagnostics: Short-circuit to ground

Enabling of the diagnostics, at short-circuit of an encoder supply or of an output to ground.

Freely assignable channel

With this parameter, you set whether the channel is to be operated as an input or output. You can only set this parameter in the DIQ and DIQ with value status configuration modes.

Reaction to CPU/master STOP

With this parameter, you set the reaction of the channels configured as output of the digital input/output module after a CPU/master STOP:

- Deactivate: The digital output is de-energized.
- Keep last value: The last value of the digital output remains activated.
- Output substitute value: The module outputs a configured substitute value.

Substitute value channel

With this parameter, you set substitute values for the digital outputs.

Input delay

This parameter can be used to avoid signal faults. Changes to the signal are only detected if they are present and stable for longer than the set input delay time. You cannot set this parameter in DQ16 mode.

3.3.3 Address space

The DIQ 16x24VDC/0.5A 8xM12 digital input/output module occupies a different number of bytes in the process image input (PII) or process image output (PIQ), depending on which configuration mode you selected.

The following figures show you the various assignments of the address spaces.

Note

Parameter assignment of the channels

In the configuration modes for digital inputs and outputs, either all channels are user configurable or all channels have a fixed configuration, depending on the configuration.

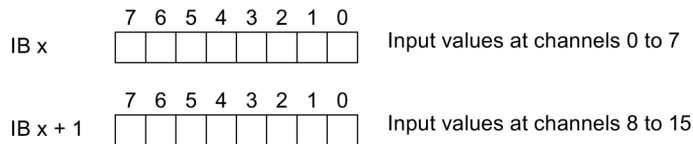
For the channels that are configured as an input, the corresponding values in the output data do not trigger any reaction.

For the channels that are configured as an output, the input value in the process image is 0.

Configuration mode DIQ without value status

The figure below shows the assignment of the address space for the DIQ 16x24VDC/0.5A 8xM12 digital input / digital output module in the DIQ without value status configuration mode (Quality Information, QI).

Assignment in the process image input (PII)



Assignment in the process image output (PIQ)

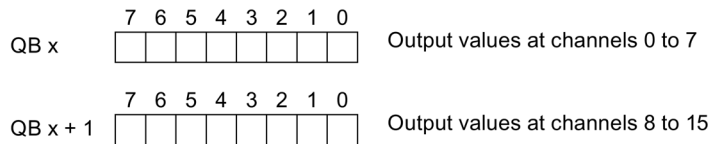


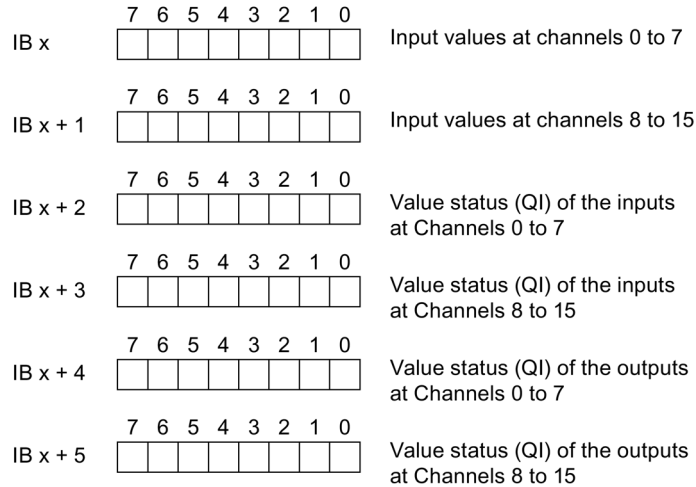
Figure 3-2 Address space in DIQ without value status configuration mode

Configuration mode DIQ with value status

The figure below shows the assignment of the address space for the digital input/digital output module DIQ 16x24VDC/0.5A 8xM12 with value status (Quality Information, QI) in the configuration method DIQ.

The address space for the value status is allocated by the module, if the value status is configured using the PROFINET interface module.

Assignment in the process image input (PII)



Assignment in the process image output (PIQ)

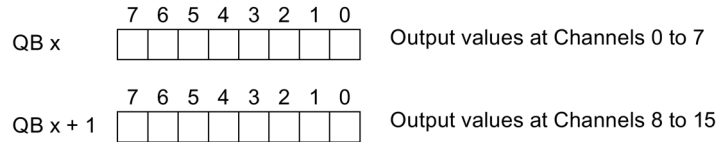


Figure 3-3 Address space in DIQ with value status configuration mode

Configuration mode DQ16

In DQ16 configuration mode, the address space is reduced by the fixed parameter assignment.

Assignment in the process image output (PIQ)

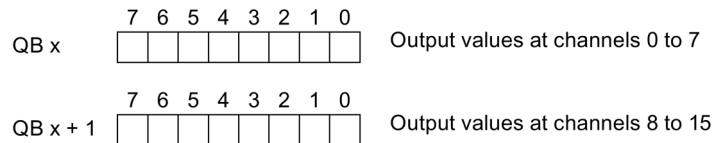


Figure 3-4 Address space in DQ16 configuration mode

3.3 Parameters/address space

Configuration mode DI8/DQ8

In DI8/DQ8 configuration mode, the address space is reduced by the fixed parameter assignment of the channels.

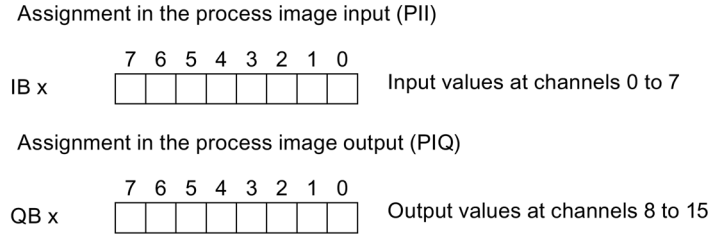


Figure 3-5 Address space in DI8/DQ8 configuration mode

Configuration mode DIQ MIX

In DIQ MIX configuration mode, the address space is reduced by the fixed parameter assignment of the channels.

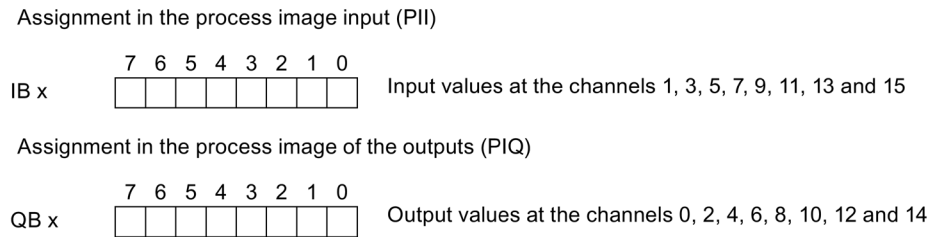


Figure 3-6 Address space in DIQ MIX configuration mode

Evaluating the value status

An additional four bytes are occupied in the input address space if you enable the value status for the digital input/digital output module. The value status of the inputs is assigned to the input bytes x + 2 and x + 3. The value status of the outputs is assigned to the input bytes x + 4 and x + 5. This additional information provides information regarding the validity of the digital values or channel status.

Bit = 1: No error on channel.

Bit = 0: Error on channel.

If the channel is configured as input, this means:

- Short-circuit of an encoder supply to ground, or
- Parameter error, or
- For channels 8 ... 15: Missing load voltage 2L+

If the channel is configured as output, this means:

- Short-circuit of the output to ground, or
- Parameter error, or
- For channels 8 ... 15: Missing load voltage 2L+

3.4 Interrupts/diagnostic alarms

3.4.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the digital input module / digital output module DIQ 16x24VDC/0.5A 8xM12.

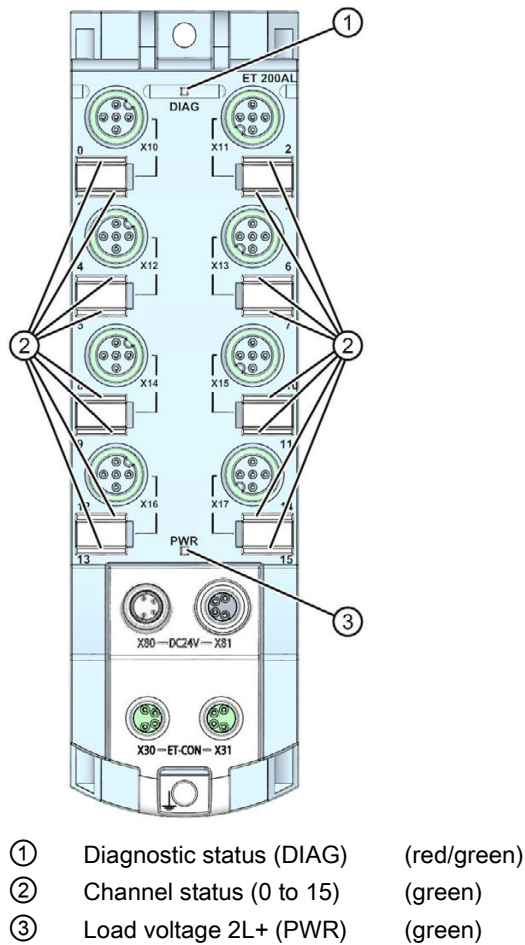






Figure 3-7 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Remedial measures for diagnostic reports can be found in chapter Diagnostics alarms (Page 29).



DIAG LED

Table 3- 13 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> Module parameters not assigned (after switching on the supply voltage 1L+) Loading firmware (while the firmware update is being performed, all LEDs retain their current status) No connection to the ET-Connection and/or the fieldbus
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics



LED channel status

Table 3- 14 LED channel status display

LED channel status	Meaning
 Off	Process signal = 0
 On	Process signal = 1

PWR LED

Table 3- 15 Status display of the PWR LED

PWR LED	Meaning
 Off	Load voltage 2L+ is missing or too low
 On	Load voltage 2L+ present

3.4.2 Interrupts

The digital input / digital output module DIQ 16x24VDC/0.5A 8xM12 in the configuration method DIQ supports diagnostic interrupts.

Diagnostic interrupt

The digital input/digital output module generates a diagnostic interrupt at the following events:

- Short-circuit of an encoder supply to ground, or
- Short-circuit of an output to ground
- Load voltage 2L+ missing or too low
- Parameter assignment error

3.4.3 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the LED DIAG flashes red on the digital input/digital output module.

You can read out the diagnostics alarms, for example, from the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 3- 16 Diagnostics alarms, their meanings and corrective measures

Diagnosics alarm	Error code	Meaning	Solution
Short circuit ¹	1H	Short-circuit of an encoder supply to ground	<ul style="list-style-type: none"> • Eliminate the short-circuit
		Short-circuit of an output to ground	
Parameter assignment error	10H	Module parameter assignment is faulty	Correction of the parameter assignment
Load voltage 2L+ missing ²	11H	Load voltage 2L+ missing or too low	<ul style="list-style-type: none"> • Check the supply voltage • Check the module
<p>¹ = If a short-circuit of an encoder supply to ground is detected, the diagnostic alarm "Short-circuit" is always output. This alarm is output even if all channels are configured as outputs.</p> <p>² = If you are using ET 200AL modules in connection with the ET 200SP distributed I/O system, the diagnostic alarm "Load voltage missing" is displayed.</p>			

Note

Channel type

The digital input/digital output module is always signaled as a mixed module (channel type "Input/Output") in the case of diagnostic events, even if you have configured the digital input/digital output module exclusively as an output or input module.

Counting

Counting function

Counting refers to the detection and summation of events. The respective counters of the module detect encoder signals and pulses and evaluate them accordingly, for example:

- For counting general piece goods up to a maximum limit
- For applications with recurring counting processes

You can control the counting processes with the digital inputs of the digital input / digital output module belonging to the counter. You can control the digital output belonging to the counter exactly to defined counter values via comparative results independently of the user program.

You can parameterize the behavior of the respective counter by means of the functions described below.

Counter limits

The counter values define the range of values of the counter value than can be used. The counter limits are configurable and can be modified during runtime using the user program. The maximum adjustable count limit amounts to 2147483647 ($2^{31}-1$). The maximum adjustable count limit amounts to -2147483648 (-2^{31}).

You can continue or stop counting (automatic gate stop) on violation of a counting limit. At an overflow or underflow of the count value one event bit is respectively set in the feedback interface. The count value jumps to the respective other counting limit.

Start value

You can configure a start value within the counter limits. The start value can be modified during runtime with the user program.

Load value

In addition to the parameterization you can influence the counting behavior additionally via the control interface by means of the load value. Depending on the bit sequence of the load request (LD_SLOT) contained in the control byte you can load the load value (SLOT) as a current count value, start value, comparative value or count limit.

If you re-parameterize the module, loaded values are overwritten automatically. Therefore, if necessary, carry out the adjustment of the values via the control interface again after a re-parameterization.

Comparison value

You specify a comparison value that controls the associated count output independently of the user program.

The comparison value can be parameterized and can be changed with the user program during runtime.

Gate control

Together with the hardware gate the software gate forms the internal gate. The module only counts when the internal gate is open.

You control the HW gate externally via the digital inputs DI₄ and DI₆. You control the SW gate via the user program. You can activate and use the hardware gate in the 2xCount configuration method by using parameterization.

Counting direction

The counting direction is specified either by the direction of the respective counter or via the parameter assignment of the counter.

You control the counting direction via the digital inputs DI₅ and DI₇. You can activate and use the direction inputs in the 2xCount configuration method by using parameterization.

Overview of configuration methods

The following table shows a list of the channel properties for the configuration methods 2xCount and 4xCount.

You can count with DI₀ and DI₂ (configuration method 2xCount) or respectively with DI₀, DI₂, DI₄ and DI₆ (configuration method 4xCount).

Table 4- 1 Configuration methods of the DIQ 16x24VDC/0.5A 8xM12

Property	Configuration method	
	2xCount (Page 32)	4xCount (Page 52)
Number of counters	2	4
Counter width, max. counting frequency	32 bits, 2 kHz	32 bits, 2 kHz
Counter inputs	Channels 0, 2	Channel 0, 2, 4, 6
Count outputs	Channel 1, 3	Channel 1, 3, 5, 7
Input for gate stop / start ¹	Channel 4, 6	-
Input for counting direction ¹	Channel 5, 7	-
Number of freely parameterizable channels	8	8
Parameterizable input delay ²	0.05 ms .. 20 ms	0.05 ms .. 20 ms
Process data length	Inputs	14 bytes
	Outputs	14 bytes
		26 bytes

¹ = Can also be used as default digital inputs via the parameter assignment as "Digital input without function".

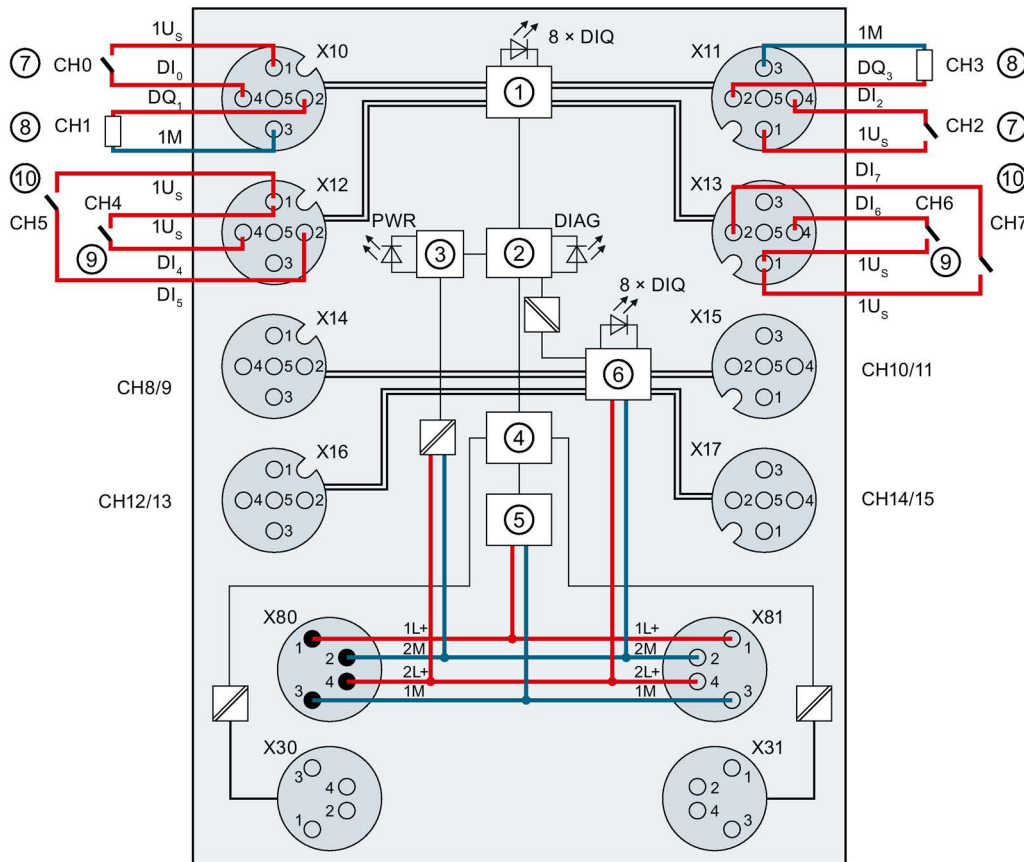
² = Only values as of 1.6 ms can be parameterized as the input delay for Channels 8..15.

4.1 Configuration method 2xCount

4.1.1 Wiring

4.1.1.1 Terminal and block diagram

The following figure shows as an example the pin assignment of the counters in the configuration method Count (2xCount). Connection examples for allocating the freely parameterizable channels 8..15 are available in the section Configuration method DIQ, subsection Terminal and block diagram (Page 15).



- | | | | |
|------------|--|------------------|---------------------------------------|
| ① | DI/DQ circuit (1L+ non-switched) | X81 | Loop-through of supply voltages |
| ② | Microcontroller | X30 | Infeed of the ET-Connection |
| ③ | Monitoring | X31 | Loop-through of the ET-Connection |
| ④ | ET-Connection interface | 1L+ | Supply voltage 1L+ (non-switched) |
| ⑤ | Internal supply voltage | 1M | Ground 1M (non-switched) |
| ⑥ | DI/DQ circuit (2L+ switched) | 2L+ | Load voltage 2L+ (switched) |
| ⑦ | Counting input counter | 2M | Ground 2M (switched) |
| ⑧ | DQ for counters | 1Us | 24 V encoder supply |
| ⑨ | Gate start/stop (level-controlled) or digital input without function | DIQ _n | Input/output signal |
| ⑩ | Counting direction or digital input without function | DIQ | Channel status LEDs (0 to 15) (green) |
| X10 to X17 | Channels 0 to 15 | DIAG | Diagnostic status LED (red/green) |
| X80 | Infeed of supply voltages | PWR | LED supply voltage 2L+ (green) |

Figure 4-1 Wiring and block diagram configuration method 2xCount

4.1.1.2 Pin assignment

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for counting channels and digital inputs / outputs

The table below shows the pin assignments of the 4 sockets for the connection of the counting channels.

Table 4- 2 Pin assignment for counting channels

Pin	Assignment	Front view of the sockets	
		X10, X12	X11, X13
1	24 V encoder supply 1Us (derived from 1L+ non-switched)		
2	Count output for Counter 0: Connector X10 Counting output for Counter 1: Connector X11 Counting direction of Counter 0 or Input signal DI ₅ : Connector X12 Counting direction of Counter 1 or Input signal DI ₇ : Connector X13		
3	Ground 1M		
4	Count input for Counter 0: Connector X10 Count input for Counter 1: Connector X11 Counting direction of Counter 0 or Input signal DI ₄ : Connector X12 Counting direction of Counter 1 or Input signal DI ₆ : Connector X13		
5	Functional earth FE		

NOTICE

24 V encoder supply 1Us

Use only the 24 V encoder supply 1Us provided by the digital input/digital output module to supply power to the encoder.

4.1 Configuration method 2xCount

The table below shows the pin assignments of the 4 sockets for the connection of the digital inputs / digital outputs.

Table 4- 3 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X14, X16	X15, X17
1	24 V encoder supply 2Us (derived from 2L+ switched)		
2	Input/output signal DIQ ₉ : Connector X14 Input/output signal DIQ ₁₁ : Connector X15 Input/output signal DIQ ₁₃ : Connector X16 Input/output signal DIQ ₁₅ : Connector X17		
3	Ground 2M		
4	Input/output signal DIQ ₈ : Connector X14 Input/output signal DIQ ₁₀ : Connector X15 Input/output signal DIQ ₁₂ : Connector X16 Input/output signal DIQ ₁₄ : Connector X17		
5	Functional earth FE		

NOTICE

24 V encoder supply 2Us

Use only the 24 V encoder supply 2Us provided by the digital input/digital output module to supply power to the encoder.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

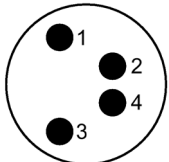
Table 4- 4 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

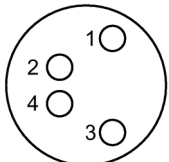
Table 4- 5 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the core color of the power cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 4- 6 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the core color of the power cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE

ET-Connection/supply voltage

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage.

Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

4.1.2 Parameters/address space

4.1.2.1 Parameters

In the configuration method 2xCount of the digital input / digital output module DIQ 16x24VDC/0.5A 8xM12 the Channels 0 to 7 are used by the counting function. The Channels 8 to 15 can be parameterized freely.

The following table shows the general parameter of the module.

Table 4- 7 General parameters

Parameters	Value range	Default	Scope
Diagnostics: Missing load voltage 2L+	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module
Diagnostics: Short-circuit to ground	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module (Short-circuit of encoder supply or of the output to ground)
Behavior at CPU/master STOP (8...15)	<ul style="list-style-type: none"> • Shut down • Keep last value • Output substitute value 	Shut down	Module (digital outputs)

The following table shows the parameters of Counter 0 and Counter 1.

Table 4- 8 Parameters of Counter 0 and Counter 1

Parameter	Value range	Default	Scope
Counting behavior Counter 0 (DI0), Counter 1 (DI2)			
Input delay DI	<ul style="list-style-type: none"> 0.05 ms 0.1 ms 0.4 ms 0.8 ms 1.6 ms 3.2 ms 12.8 ms 20 ms 	0.05 ms	Counter
Counting direction ¹	<ul style="list-style-type: none"> Forward Backward 	Forward	Counter
Edge selection	<ul style="list-style-type: none"> On a rising edge On a falling edge 	On a rising edge	Counter
Behavior when a counting limit is exceeded	<ul style="list-style-type: none"> Stop counting Continue counting 	Stop counting	Counter
Comparison value	-2147483648...2147483647	10	Counter
Start value ²	-2147483648...2147483647	0	Counter
High count limit	-2147483648...2147483647	2147483647	Counter
Counter low limit ²	-2147483648...2147483647	0	Counter
Behavior Counter 0 (DQ1), Counter 1 (DQ3)			
Behavior DQ	<ul style="list-style-type: none"> Count value between a comparison value and the high counting limit Count value between a comparison value and the low counting limit 	Count value between a comparison value and the high counting limit	Counter
Hardware interrupt DQ	<ul style="list-style-type: none"> Inactive Comparison event for DQ has occurred 	Inactive	Counter
Behavior at CPU/master STOP for DQ	<ul style="list-style-type: none"> Continue Output substitute value 	Continue	Counter
Substitute value DQ	<ul style="list-style-type: none"> 0 1 	0	Counter

4.1 Configuration method 2xCount

Parameter	Value range	Default	Scope
Behavior Counter 0 (DI4), Counter 1 (DI6)			
Behavior DI	<ul style="list-style-type: none"> Digital input without function Gate start/stop (level-controlled) 	Digital input without function	Counter
Behavior Counter 0 (DI5), Counter 1 (DI7)			
Behavior DI	<ul style="list-style-type: none"> Digital input without function Counting direction 	Digital input without function	Counter
Input delay DI	<ul style="list-style-type: none"> 0.05 ms 0.1 ms 0.4 ms 0.8 ms 1.6 ms 3.2 ms 12.8 ms 20 ms 	3.2 ms	Counter

¹ = Is ignored if DI5/DI7 is parameterized as the direction input.

² = Cannot be parameterized with GSD file

The table below shows the parameters of the freely assignable Channels 8...15.

Table 4- 9 Parameter freely assignable Channels 8..15

Parameter	Value range	Default	Scope
Freely assignable channel	<ul style="list-style-type: none"> DI DQ 	DI	Channel
Substitute value channel	<ul style="list-style-type: none"> 0 1 	0	Channel (digital outputs)
Input delay	<ul style="list-style-type: none"> 1.6 ms 3.2 ms 12.8 ms 20 ms 	3.2 ms	Channel (digital inputs)

See also

Pin assignment (Page 33)

4.1.2.2 Explanation of the parameters

General parameters

Diagnostics: Missing load voltage 2L+

Enabling of the diagnostics for missing or insufficient load voltage 2L+.

Diagnostics: Short circuit to ground

Enabling of the diagnostics, at short-circuit of an encoder supply or of an output to ground.

Behavior at CPU/master STOP (8...15)

With this parameter you set the reaction of the digital outputs of after a CPU/master STOP. Behavior DQ at freely assignable Channels 8...15:

- Deactivate: The digital output is de-energized.
- Keep last value: The last value of the digital output remains activated.
- Output substitute value: The digital output outputs a configured substitute value.

Parameter counting function

Input delay DI

This parameter can be used to suppress signal faults. Changes to the signal are only detected if they are constantly pending longer than the set input delay time.

Note**Influences the counting frequency**

When setting the input delay take into account that the counting frequency possible is automatically reduced at higher values.

In order to achieve the maximum counting frequency of 2 kHz select an input delay smaller than 0.4 ms.

Counting direction

Use this parameter to select the direction in which counting is carried out:

- Forward
- Backward.

Note

If you have parameterized DI₅ or DI₇ as the direction input in the respective counter, this parameter is ineffective.

Edge selection

Use this parameter to select the edge that is counted:

- At rising edge:
The respective counter counts all the rising edges at the counter input.
- At falling edge:
The respective counter counts all the falling edges at the counter input.

Note

If you have parameterized DI₅ or DI₇ as the direction input in the respective counter and the counting direction changes in the process, the count edge is adapted automatically (contrary edges).

Behavior when a counting limit is exceeded

With this parameter you select the behavior when the high counting limit is violated in the upward direction or the low counting limit is violated in the downward direction:

- Stop counting:
After a counting limit is violated, the internal gate is closed. This stops the counting process. The counter value is set to the opposite counting limit. To start the counting process again, you must close and reopen the SW gate.
- Continue counting:
After a counting limit is violated, the counter value is set to the opposite counting limit and counting continues.

Comparison value

With this parameter you specify the comparison value.
The following applies:

- Low counting limit \leq Comparison value \leq High counting limit

Start value

With this parameter you specify the start value.
The following applies:

- Low counting limit \leq Start value \leq High counting limit

High counting limit

With this parameter you specify the high counting limit.
The following applies:

- Low counting limit $<$ High counting limit \leq 2147483647 ($2^{31} - 1$)

Low counting limit

With this parameter you specify the low counting limit.
The following applies:

- High counting limit $>$ Low counting limit \geq -2147483648 (-2^{31})

Behavior DQ

With the "Behavior DQ" you select the counter values at which the count output is set. When the current count value fulfils the parameterized condition, the associated count output is set.

This means the signal state "1" is set at the count output when:

- Count value between a comparison value and the high counting limit:
Comparison value \leq Count value \leq High counting limit

or

- Count value between a comparison value and the low counting limit:
Low counting limit \leq Count value \leq Comparison value.

Hardware interrupt DQ

With this parameter you specify whether or not a hardware interrupt is generated by the event "Comparison event occurred for DQ".

Behavior at CPU/master STOP for DQ

With this parameter you set the reaction of the count output of a counter after a CPU/master STOP.

Behavior DQ:

- Continue: Signal state of the count output continues to be controlled by comparison conditions.
- Output substitute value: The count output outputs a configured substitute value.

Note**Count value at CPU/Master STOP**

Independently of the selected reaction of the count output, the count value continues to change during a CPU/Master STOP depending on the input edge, counting continues.

Substitute value DQ

With this parameter you set the substitute value of the digital output of a counter if the setting "Output substitute value" has been selected at the parameter "Behavior at CPU/master STOP for DQ".

Behavior DI (gate control)

With this parameter you select whether a counting function is assigned to the digital input or whether this functions like a standard digital input:

- Gate start/stop:
The digital input influences the internal gate of Counter 0 or Counter 1. Signal "1" at the digital input opens the HW gate for the counter. Signal "0" at the digital input closes the HW gate for the counter.
- Digital input without function:
No counting function is assigned to the digital input. It functions like a standard digital input.

Behavior DI (direction input)

With this parameter you select whether a counting function is assigned to the digital input or whether this functions like a standard digital input:

- Counting direction:
The digital input reverses the counting direction at Counter 0 or Counter 1, in order to adjust it to the process. With signal "0" at the digital input, the counter forwards. With signal "1" at the digital input, the counter counts backwards.
- Digital input without function:
No counting function is assigned to the digital input. It functions like a standard digital input.

Parameter freely assignable Channels 8..15

Freely assignable channel

With this parameter, you set whether the channel is to be operated as an input or output.

Input delay channel

This parameter can be used to suppress signal interference. Changes to the signal are only detected if they are constantly pending longer than the set input delay time.

Substitute value channel

With this parameter, you set substitute values for the digital outputs.

See also

Assignment of the feedback interface (Page 45)

4.1.2.3 Assignment of the control interface

The user program uses the control interface to influence the behavior of the counters and the channels 8...15 of the module parameterized as an output.

The figure below shows the address assignment of the module in the process image output in the configuration method 2xCount.

At Counter 0 x stands for the output byte QB 2 in this case, at Counter 1 you add 6 bytes to this output byte.

When you assign a different start address to the digital input/digital output module, the byte sequence changes correspondingly.

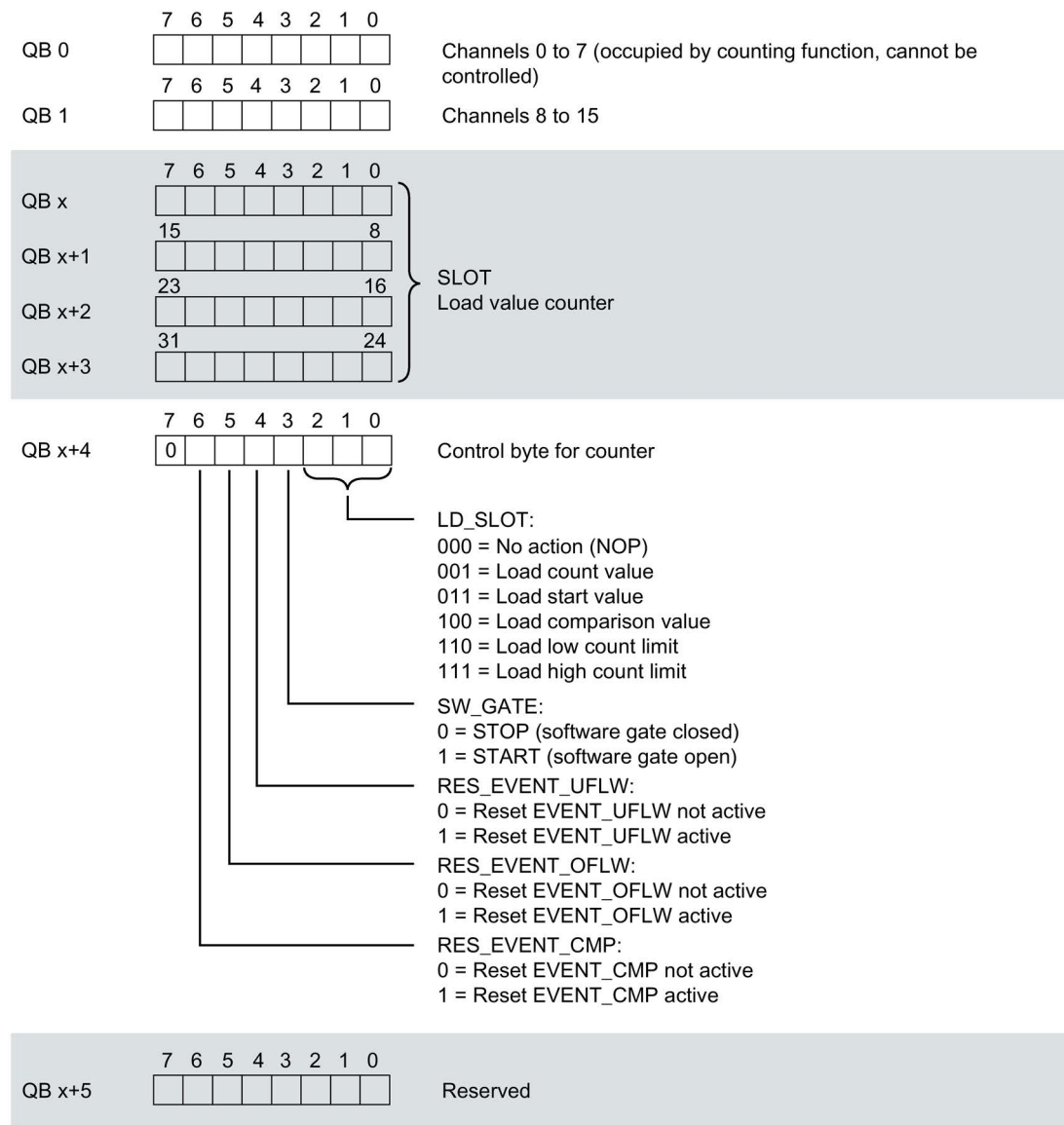


Figure 4-2 Address space control interface configuration method 2xCount

Note**Parameter assignment of the channels**

The corresponding values in the output data do not trigger any reaction for all the channels that are used as an input.

You cannot control the count outputs via the user program.

4.1.2.4 Explanations on the control interface

Table 4- 10 Explanations on the control bits

Control bit	Explanations
SLOT	You specify the load value for the respective counter in these bytes. Through the load request LD_SLOT you load the predefined value into the counter.
LD_SLOT	With this load request you control for which value of the counter the value specified in SLOT is to be loaded. The counter carries out the respective action as soon as LD_SLOT changes. If you have entered the load request LD_SLOT = 011 _B open the SW gate, every counting process begins with the value defined in the SLOT as the start value. If you have entered a different load request and open the SW gate, counting is continued with the current count value at every start of the counting process. Both cases also apply at a parameterized HW gate as long as and until the SW gate is closed.
SW_GATE	With this bit you open and close the SW gate of the respective counter. Together with the hardware gate the software gate forms the internal gate. The module only counts when the internal gate is open. 0 means: Software gate closed 1 means: Software gate open
RES_EVENT_UFLW	With this bit you trigger the resetting of the stored event in the feedback bit EVENT_UFLW for the respective counter.
RES_EVENT_OFLW	With this bit you trigger the resetting of the stored event in the feedback bit EVENT_OFLW for the respective counter.
RES_EVENT_CMP	With this bit you trigger the resetting of the stored event in the feedback bit EVENT_CMP for the respective counter.

4.1.2.5 Assignment of the feedback interface

Feedback interface

The user program receives current values and status information from the module via the feedback interface.

The figure below shows the address assignment of the module in the process image input in the configuration method 2xCount.

At Counter 0 x stands for the input byte IB 2 in this case, at Counter 1 you add 6 bytes to this output byte.

When you assign a different start address to the digital input/digital output module, the byte sequence changes correspondingly.

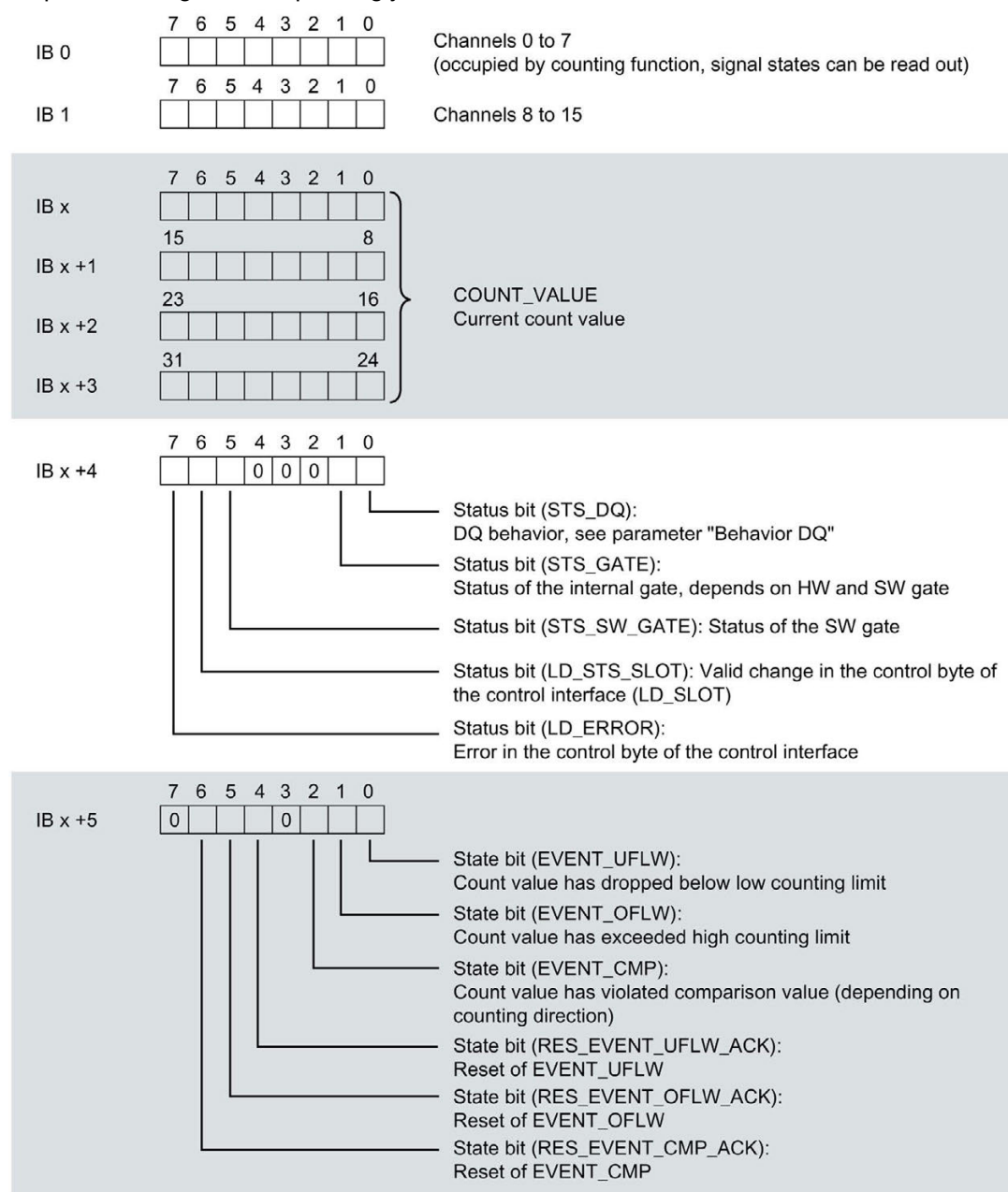


Figure 4-3 Address space feedback interface configuration method 2xCount

4.1.2.6 Explanations for the feedback interface

Table 4- 11 Explanations for the feedback bits

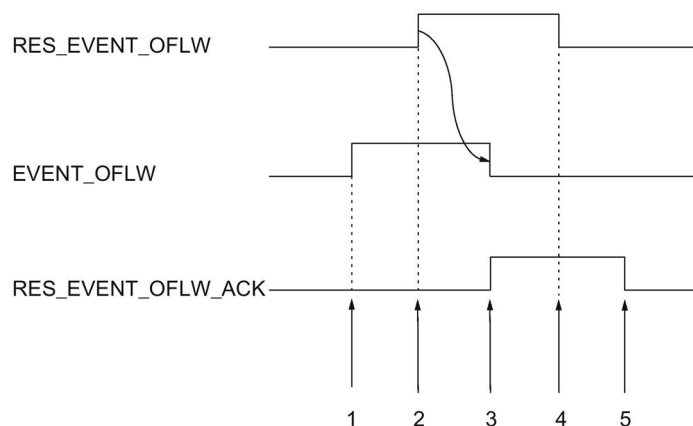
Feedback bit	Explanations
COUNT_VALUE	This value supplies the current count value for the respective counter.
STS_DQ	This bit returns the current signal state of the count output.
STS_GATE	<p>Together with the hardware gate the software gate forms the internal gate. This bit shows the state of the internal gate for the respective counter. The module only counts when the internal gate is open.</p> <p>0 means: Internal gate closed / counter does not count 1 means: internal Tor open / counter counts</p> <p>Note: After a POWER OFF / ON or a change in the parameterization, all the values of the changed counter are transferred again to the module. In the process the internal gate of the respective counter is closed and the count value is set to the start value. Close and open the respective SW gate to restart the counting process.</p> <p>Note: When the PROFIBUS interface model is used, the CPU/Master automatically generates the "rising edge" signal after disconnection/reconnection of the communications. This continues the counting process.</p>
STS_SW_GATE	<p>This bit shows the status of the software gate.</p> <p>0 means: Software gate closed 1 means: Software gate open</p>
LD_STS_SLOT	This bit indicates through a status change (toggling) for the respective counter that loading of the control interface has been carried out successfully.
LD_ERROR	<p>This bit indicates for the respective counter that an error has occurred during loading of the control interface.</p> <p>The load value was not accepted.</p> <p>One of the following conditions is fulfilled:</p> <ul style="list-style-type: none"> • Low counting limit > Count value • Low counting limit > Start value • Low counting limit > Comparison value • Count value > High counting limit • Start value > High counting limit • Comparison value > High counting limit • Low counting limit ≥ High counting limit • No valid load request in LD_SLOT
EVENT_UFLW	<p>This bit shows for the respective counter whether an underflow (value dropped below the low count limit) has occurred.</p> <p>You reset the state by acknowledging with RES_EVENT_UFLW.</p>
EVENT_OFLW	<p>This bit shows for the respective counter whether an overflow (value exceeded the high count limit) has occurred.</p> <p>You reset the state by acknowledging with RES_EVENT_OFLW.</p>
EVENT_CMP	<p>This bit shows for the respective counter whether a comparison event with the comparison value has occurred.</p> <p>You reset the state by acknowledging with RES_EVENT_CMP.</p> <p>The EVENT_CMP bit is not set if the count value is set to the start value.</p>

Feedback bit	Explanations
RES_EVENT_UFLW_ACK	This bit shows for the respective counter whether the resetting of the event bit EVENT_UFLW is active.
RES_EVENT_OFLW_ACK	This bit shows for the respective counter whether the resetting of the event bit EVENT_OFLW is active.
RES_EVENT_CMP_ACK	This bit shows for the respective counter whether the resetting of the event bit EVENT_CMP is active.

Complete acknowledgment principle

Storing bits are acknowledged in accordance with the complete acknowledgment principle.

The figure below shows an example for the course of the complete acknowledgment principle at an overflow:



- ① The feedback bit EVENT_OFLW is set as a storing event at an overflow bit.
- ② The set the control bit RES_EVENT_OFLW in order to initiate resetting of EVENT_OFLW.
- ③ The feedback bit RES_EVENT_OFLW_ACK is set when the resetting of EVENT_OFLW has been recognized.
- ④ You reset the control bit RES_EVENT_OFLW .
- ⑤ The feedback bit RES_EVENT_OFLW_ACK is reset.

Figure 4-4 Acknowledgment principle

Note

When you have initiated the resetting of an event bit, you have to wait for the respective feedback bit. You can initiate a further reset subsequently.

Note

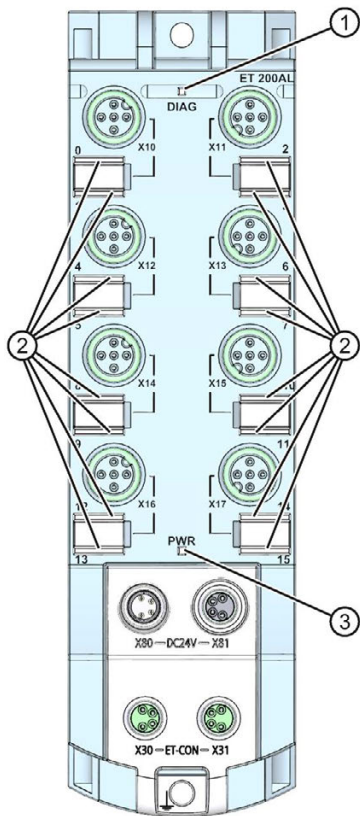
An opening of the SW gate or HW gate (0-1 transition) resets all event bits.

4.1.3 Interrupts/diagnostic alarms

4.1.3.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the digital input module / digital output module DIQ 16x24VDC/0.5A 8xM12.



- ① Diagnostic status (DIAG) (red/green)
- ② Channel status (0 to 15) (green)
- ③ Load voltage 2L+ (PWR) (green)





Figure 4-5 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Remedial measures for diagnostic reports can be found in chapter Diagnostics alarms (Page 51).



DIAG LED

Table 4- 12 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> Module parameters not assigned (after switching on the supply voltage 1L+) Loading firmware (while the firmware update is being performed, all LEDs retain their current status) No connection to the ET-Connection and/or the fieldbus
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics



LED channel status

Table 4- 13 LED channel status display

LED channel status	Meaning
 Off	Process signal = 0
 On	Process signal = 1

PWR LED

Table 4- 14 Status display of the PWR LED

PWR LED	Meaning
 Off	Load voltage 2L+ is missing or too low
 On	Load voltage 2L+ present

4.1.3.2 Interrupts

The digital input / digital output module DIQ 16x24VDC/0.5A 8xM12 in the configuration method 2xCount supports diagnostic and hardware interrupts.

Diagnostic interrupt

The digital input/digital output module generates a diagnostic interrupt at the following events:

- Short-circuit of an encoder supply to ground, or
- Short-circuit of an output to ground
- Load voltage 2L+ missing or too low
- Parameter assignment error

Hardware interrupt

The module generates a hardware interrupt at the following event:

- Comparison event occurred for DQ

For detailed information on the error event, refer to the hardware interrupt organization block with the "RALRM" instruction (read additional interrupt info) and to the STEP 7 online help.

The module channel that triggered the hardware interrupt is entered in the start information of the organization block. The figure below shows the assignment to the bits of the local data double word 8.

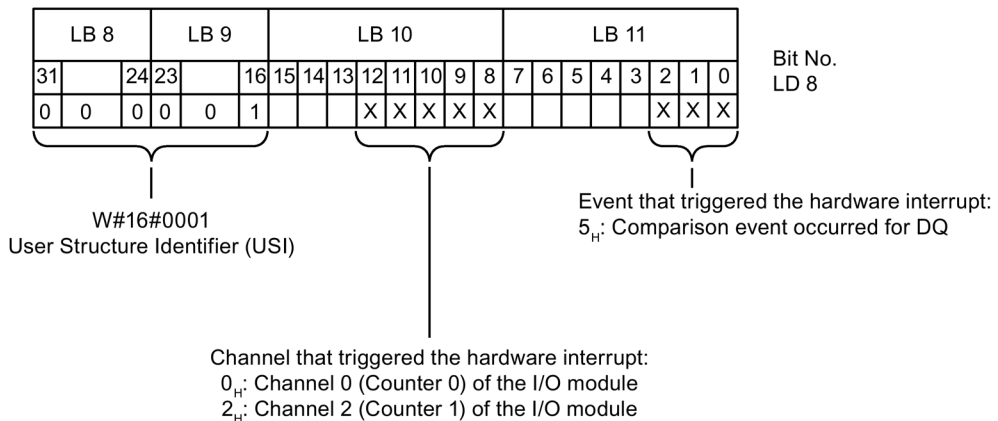


Figure 4-6 Start information of the organization block in the configuration method 2xCount

4.1.3.3 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the LED DIAG flashes red on the digital input/digital output module.

You can read out the diagnostics alarms, for example, from the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 4- 15 Diagnostics alarms, their meanings and corrective measures

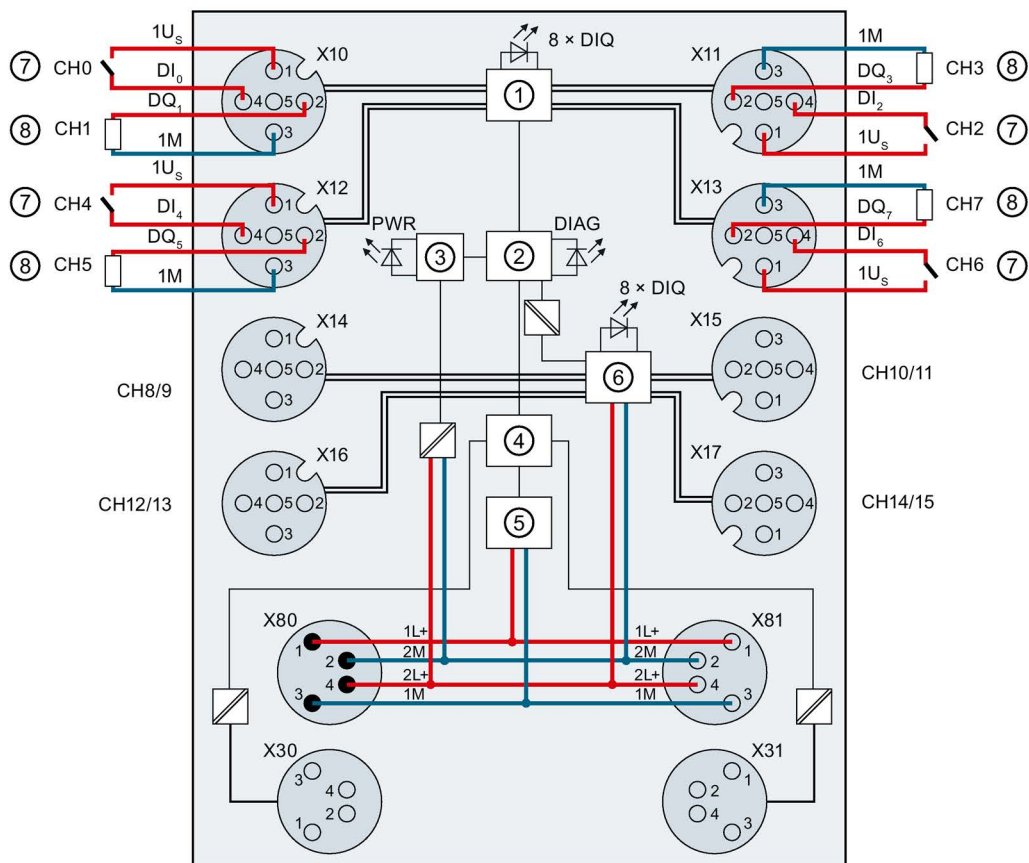
Diagnosics alarm	Error code	Meaning	Solution
Short circuit ¹	1H	Short-circuit of an encoder supply to ground	<ul style="list-style-type: none"> Eliminate the short-circuit
		Short-circuit of an output to ground	
Parameter assignment error	10H	Module parameter assignment is faulty	Correction of the parameter assignment
Load voltage 2L+ missing ²	11H	Load voltage 2L+ missing or too low	<ul style="list-style-type: none"> Check the supply voltage Check the module
Hardware interrupt lost	16H	At least one hardware interrupt could not be signaled because too many hardware interrupts are pending.	Correct the program or the process
<p>¹ If a short-circuit of the encoder supply to ground is detected, the diagnostic alarm "Short-circuit" is always output. This alarm is output even if all channels are configured as outputs.</p> <p>² If you are using ET 200AL modules in connection with the ET 200SP distributed I/O system, the diagnostic alarm "Load voltage missing" is displayed.</p>			

4.2 Configuration method 4xCount

4.2.1 Wiring

4.2.1.1 Terminal and block diagram

The following figure shows as an example the pin assignment of the counters in the configuration method Count (4xCount). Connection examples for allocating the freely parameterizable channels 8..15 are available in the section Configuration method DIQ, subsection Terminal and block diagram (Page 15).



- | | | | |
|------------|----------------------------------|------------------|---------------------------------------|
| ① | DI/DQ circuit (1L+ non-switched) | X30 | Infeed of the ET-Connection |
| ② | Microcontroller | X31 | Loop-through of the ET-Connection |
| ③ | Monitoring | 1L+ | Supply voltage 1L+ (non-switched) |
| ④ | ET-Connection interface | 1M | Ground 1M (non-switched) |
| ⑤ | Internal supply voltage | 2L+ | Load voltage 2L+ (switched) |
| ⑥ | DI/DQ circuit (2L+ switched) | 2M | Ground 2M (switched) |
| ⑦ | Counting input counter | 1Us | 24 V encoder supply |
| ⑧ | DQ for counters | DIQ _n | Input/output signal |
| X10 to X17 | Channels 0 to 15 | DIQ | Channel status LEDs (0 to 15) (green) |
| X80 | Infeed of supply voltages | DIAG | Diagnostic status LED (red/green) |
| X81 | Loop-through of supply voltages | PWR | LED supply voltage 2L+ (green) |

Figure 4-7 Wiring and block diagram configuration method 4xCount

4.2.1.2 Pin assignment

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for counting channels and digital inputs / outputs

The table below shows the pin assignments of the 4 sockets for the connection of the counting channels.

Table 4- 16 Pin assignment for counting channels

Pin	Assignment	Front view of the sockets	
		X10, X12	X11, X13
1	24 V encoder supply 1Us (derived from 1L+ non-switched)		
2	Count output for Counter 0: Connector X10 Counting output for Counter 1: Connector X11 Counting output for Counter 2: Connector X12 Counting output for Counter 3: Connector X13		
3	Ground 1M		
4	Count input for Counter 0: Connector X10 Count input for Counter 1: Connector X11 Count input for Counter 2: Connector X12 Count input for Counter 3: Connector X13		
5	Functional earth FE		

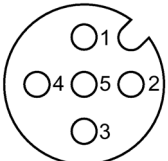
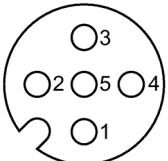
NOTICE

24 V encoder supply 1Us

Use only the 24 V encoder supply 1Us provided by the digital input/digital output module to supply power to the encoder.

The table below shows the pin assignments of the 4 sockets for the connection of the digital inputs / digital outputs.

Table 4- 17 Pin assignment for digital inputs/digital outputs

Pin	Assignment	Front view of the sockets	
		X14, X16	X15, X17
1	24 V encoder supply 2Us (derived from 2L+ switched)		
2	Input/output signal DIQ ₉ : Connector X14 Input/output signal DIQ ₁₁ : Connector X15 Input/output signal DIQ ₁₃ : Connector X16 Input/output signal DIQ ₁₅ : Connector X17		
3	Ground 2M		
4	Input/output signal DIQ ₈ : Connector X14 Input/output signal DIQ ₁₀ : Connector X15 Input/output signal DIQ ₁₂ : Connector X16 Input/output signal DIQ ₁₄ : Connector X17		
5	Functional earth FE		

NOTICE

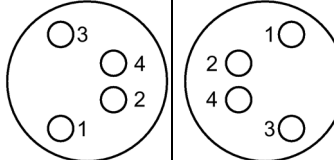
24 V encoder supply 2Us

Use only the 24 V encoder supplies 2Us provided by the digital input/digital output module to supply power to the encoder.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

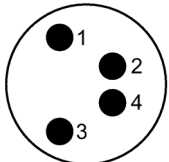
Table 4- 18 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

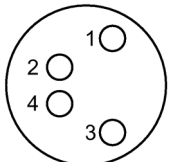
Table 4- 19 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the core color of the power cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 4- 20 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the core color of the power cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE

ET-Connection/supply voltage

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage.

Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

4.2.2 Parameters/address space

4.2.2.1 Parameters

In the configuration method 4xCount of the digital input / digital output module DIQ 16x24VDC/0.5A 8xM12 the Channels 0 to 7 are used by the counting function. The Channels 8 to 15 can be parameterized freely.

The following table shows the general parameter of the module.

Table 4- 21 General parameters

Parameters	Value range	Default	Scope
Diagnostics: Missing load voltage 2L+	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module
Diagnostics: Short-circuit to ground	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module (Short-circuit of the encoder supply or of the output to ground)
Behavior at CPU/master STOP (8...15)	<ul style="list-style-type: none"> • Shut down • Keep last value • Output substitute value 	Shut down	Module (digital outputs)

The table below shows the parameters of Counter 0 to Counter 3.

Table 4- 22 Parameters of Counter 0 to Counter 3

Parameter	Value range	Default	Scope
Counting behavior Counter 0 (DI0), Counter 1 (DI2), Counter 2 (DI4) and Counter 3 (DI6)			
Input delay DI	<ul style="list-style-type: none"> 0.05 ms 0.1 ms 0.4 ms 0.8 ms 1.6 ms 3.2 ms 12.8 ms 20 ms 	0.05 ms	Counter
Counting direction	<ul style="list-style-type: none"> Forward Backward 	Forward	Counter
Edge selection	<ul style="list-style-type: none"> On a rising edge On a falling edge 	On a rising edge	Counter
Behavior when a counting limit is exceeded	<ul style="list-style-type: none"> Stop counting Continue counting 	Stop counting	Counter
Comparison value	-2147483648...2147483647	10	Counter
Start value ¹	-2147483648...2147483647	0	Counter
High count limit	-2147483648...2147483647	2147483647	Counter
Low counting limit ¹	-2147483648...2147483647	0	Counter
Behavior Counter 0 (DQ1), Counter 1 (DQ3), Counter 2 (DQ5), Counter 3 (DQ7)			
Behavior DQ	<ul style="list-style-type: none"> Count value between a comparison value and the high counting limit Count value between a comparison value and the low counting limit 	Count value between a comparison value and the high counting limit	Counter
Hardware interrupt DQ	<ul style="list-style-type: none"> Inactive Comparison event for DQ has occurred 	Inactive	Counter
Behavior at CPU/master STOP for DQ	<ul style="list-style-type: none"> Continue Output substitute value 	Continue	Counter
Substitute value DQ	<ul style="list-style-type: none"> 0 1 	0	Counter

¹ = Cannot be parameterized with GSD file

The table below shows the parameters of the freely assignable Channels 8...15.

Table 4- 23 Parameter freely assignable Channels 8..15

Parameter	Value range	Default	Scope
Freely assignable channel	<ul style="list-style-type: none"> • DI • DQ 	DI	Channel
Substitute value channel	<ul style="list-style-type: none"> • 0 • 1 	0	Channel (digital outputs)
Input delay	<ul style="list-style-type: none"> • 1.6 ms • 3.2 ms • 12.8 ms • 20 ms 	3.2 ms	Channel (digital inputs)

See also

Pin assignment (Page 53)

4.2.2.2 Explanation of the parameters

General parameters

Diagnostics: Missing load voltage 2L+

Enabling of the diagnostics for missing or insufficient load voltage 2L+.

Diagnostics: Short circuit to ground

Enabling of the diagnostics, at short-circuit of an encoder supply or of an output to ground.

Behavior at CPU/master STOP (8...15)

With this parameter you set the reaction of the digital outputs of after a CPU/master STOP. Behavior DQ at freely assignable Channels 8...15:

- Deactivate: The digital output is de-energized.
- Keep last value: The last value of the digital output remains activated.
- Output substitute value: The digital output outputs a configured substitute value.

Parameter counting function

Input delay DI

This parameter can be used to suppress signal faults. Changes to the signal are only detected if they are constantly pending longer than the set input delay time.

Note

Influences the counting frequency

When setting the input delay take into account that the counting frequency possible is automatically reduced at higher values.

In order to achieve the maximum counting frequency of 2 kHz select an input delay smaller than 0.4 ms.

Counting direction

Use this parameter to select the direction in which counting is carried out:

- Forward
- Backward.

Edge selection

Use this parameter to select the edge that is counted:

- At rising edge:
The respective counter counts all the rising edges at the counter input.
- At falling edge:
The respective counter counts all the falling edges at the counter input.

Behavior when a counting limit is exceeded

With this parameter you select the behavior when the high counting limit is violated in the upward direction or the low counting limit is violated in the downward direction:

- Stop counting:
After a counting limit is violated, the internal gate is closed. This stops the counting process. The counter value is set to the opposite counting limit. To start the counting process again, you must close and reopen the SW gate.
- Continue counting:
After a counting limit is violated, the counter value is set to the opposite counting limit and counting continues.

Comparison value

With this parameter you specify the comparison value.

The following applies:

- Low counting limit \leq Comparison value \leq High counting limit

Start value

With this parameter you specify the start value.

The following applies:

- Low counting limit \leq Start value \leq High counting limit

High counting limit

With this parameter you specify the high counting limit.

The following applies:

- Low counting limit $<$ High counting limit \leq 2147483647 ($2^{31} - 1$)

Low counting limit

With this parameter you specify the low counting limit.

The following parameter applies:

- High counting limit > Low counting limit $\geq -2147483648 (-2^{31})$

Behavior DQ

With the "Behavior DQ" you select the counter values at which the count output is set.

When the current count value fulfils the parameterized condition, the associated count output is set.

This means the signal state "1" is set at the count output when:

- Count value between a comparison value and the high counting limit:
Comparison value \leq Count value \leq High counting limit

or

- Count value between a comparison value and the low counting limit:
Low counting limit \leq Count value \leq Comparison value.

Hardware interrupt DQ

With this parameter you specify whether or not a hardware interrupt is generated by the event "Comparison event occurred for DQ".

Behavior at CPU/master STOP for DQ

With this parameter you set the reaction of the count output of a counter after a CPU/master STOP.

Behavior DQ:

- Continue: Signal state of the count output continues to be controlled by comparison conditions.
- Output substitute value: The count output outputs a configured substitute value.

Note

Count value at CPU/Master STOP

Independently of the selected reaction of the count output, the count value continues to change during a CPU/Master STOP depending on the input edge, counting continues.

Substitute value DQ

With this parameter you set the substitute value of the digital output of a counter if the setting "Output substitute value" has been selected at the parameter "Behavior at CPU/master STOP for DQ".

Parameter freely assignable Channels 8..15

Freely assignable channel

With this parameter, you set whether the channel is to be operated as an input or output.

Input delay channel

This parameter can be used to suppress signal interference. Changes to the signal are only detected if they are constantly pending longer than the set input delay time.

Substitute value channel

With this parameter, you set substitute values for the digital outputs.

4.2.2.3 Assignment of the control interface

The user program uses the control interface to influence the behavior of the counters and the channels 8...15 of the module parameterized as an output.

The figure below shows the address assignment of the module in the process image output in the configuration method 4xCount.

At Counter 0 x stands for the output byte QB 2 in this case, at Counters 1 to 3 you add 6 bytes, 12 bytes and 18 bytes respectively to this output byte.

When you assign a different start address to the digital input/digital output module, the byte sequence changes correspondingly.

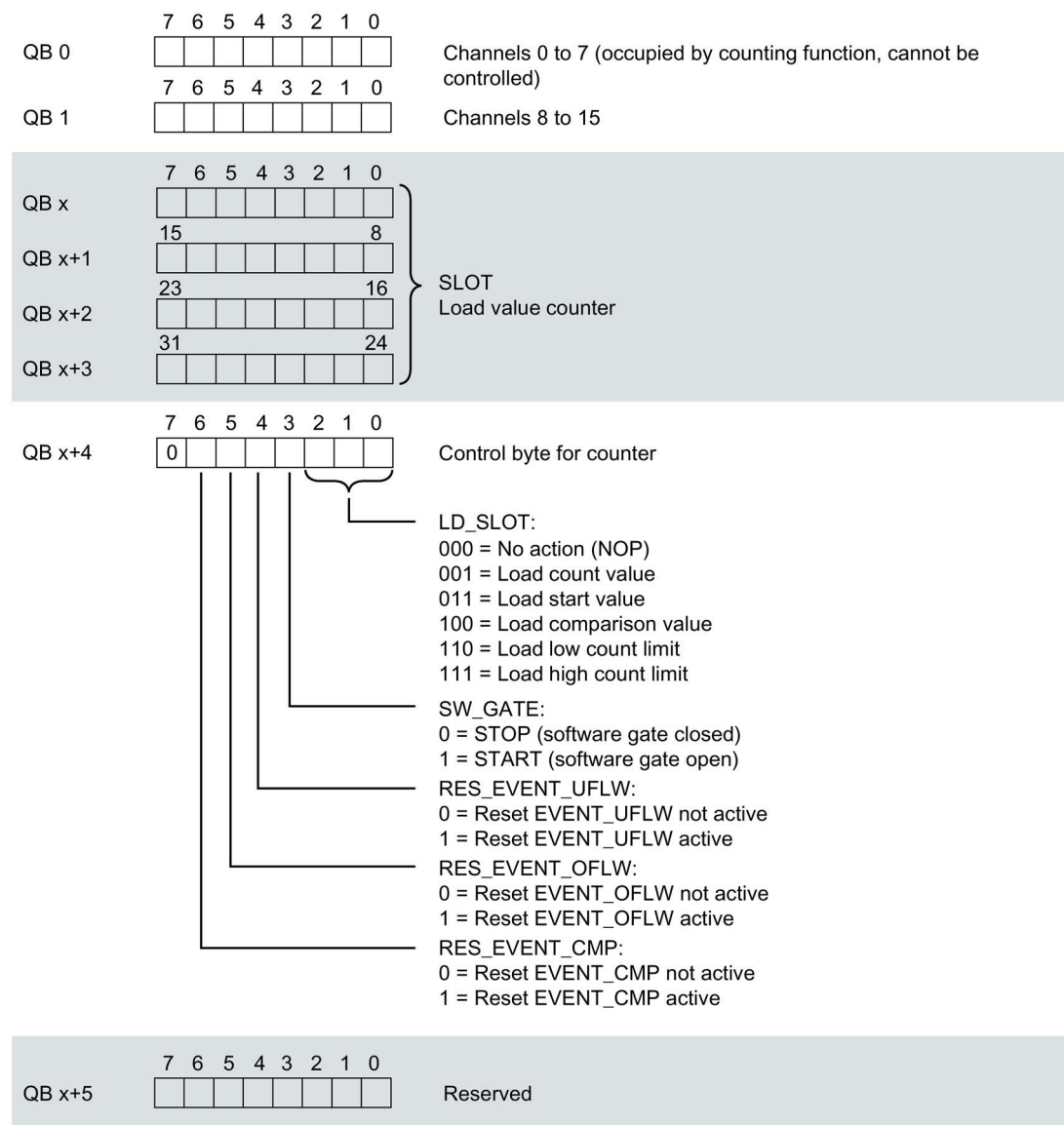


Figure 4-8 Address space control interface configuration method 4xCount

Note**Parameter assignment of the channels**

The corresponding values in the output data do not trigger any reaction for all the channels that are used as an input.

You cannot control the count outputs via the user program.

4.2.2.4 Explanations on the control interface

Table 4- 24 Explanations on the control bits

Control bit	Explanations
SLOT	You specify the load value for the respective counter in these bytes. Through the load request LD_SLOT you load the predefined value into the counter.
LD_SLOT	With this load request you control for which value of the counter the value specified in SLOT is to be loaded. The counter carries out the respective action as soon as LD_SLOT changes. If you have entered the load request LD_SLOT = 011 _B open the SW gate, every counting process begins with the value defined in the SLOT as the start value. If you have entered a different load request and open the SW gate, counting is continued with the current count value at every start of the counting process. Both cases apply as long as and until the SW gate is closed.
SW_GATE	With this bit you open and close the SW gate of the respective counter. The module only counts when the software gate is open. 0 means: Software gate closed 1 means: Software gate open
RES_EVENT_UFLW	With this bit you trigger the resetting of the stored event in the feedback bit EVENT_UFLW for the respective counter.
RES_EVENT_OFLW	With this bit you trigger the resetting of the stored event in the feedback bit EVENT_OFLW for the respective counter.
RES_EVENT_CMP	With this bit you trigger the resetting of the stored event in the feedback bit EVENT_CMP for the respective counter.

4.2.2.5 Assignment of the feedback interface

Feedback interface

The user program receives current values and status information from the module via the feedback interface.

The figure below shows the address assignment of the module in the process image input in the configuration method 4xCount.

At Counter 0 x stands for the input byte IB 2 in this case, at Counters 1 to 3 you add 6 bytes, 12 bytes and 18 bytes respectively to this input byte.

When you assign a different start address to the digital input/digital output module, the byte sequence changes correspondingly.

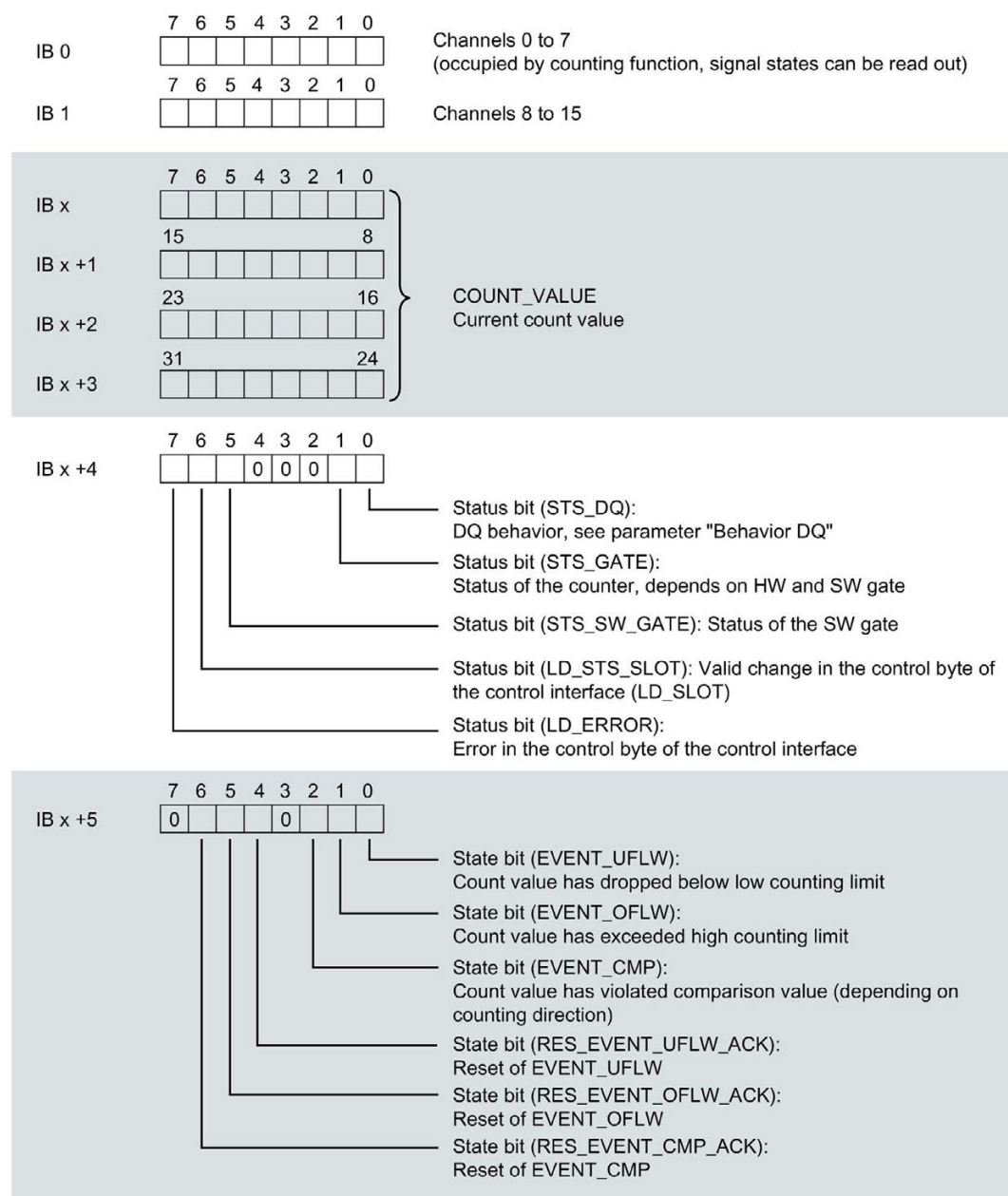


Figure 4-9 Address space feedback interface configuration method 4xCount

4.2.2.6 Explanations for the feedback interface

Table 4- 25 Explanations for the feedback bits

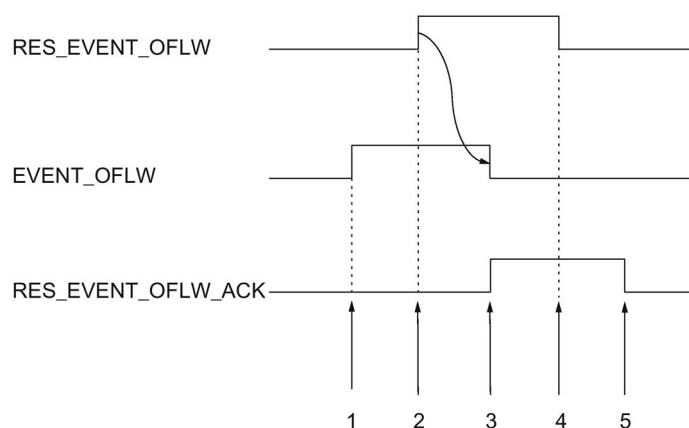
Feedback bit	Explanations
COUNT_VALUE	This value supplies the current count value for the respective counter.
STS_DQ	This bit returns the current signal state of the count output.
STS_GATE	<p>This bit shows the state of the internal gate for the respective counter. The module only counts when the internal gate is open.</p> <p>0 means: Internal gate closed / counter does not count 1 means: internal Tor open / counter counts</p> <p>Note: After a POWER OFF / ON or a change in the parameterization, all the values of the changed counter are transferred again to the module. In the process the internal gate of the respective counter is closed and the count value is set to the start value. Close and open the respective SW gate to restart the counting process.</p> <p>Note: When the PROFIBUS interface model is used, the CPU/Master automatically generates the "rising edge" signal after disconnection/reconnection of the communications. This continues the counting process.</p>
STS_SW_GATE	<p>This bit shows the status of the software gate.</p> <p>0 means: Software gate closed 1 means: Software gate open</p>
LD_STS_SLOT	This bit indicates through a status change (toggling) for the respective counter that loading of the control interface has been carried out successfully.
LD_ERROR	<p>This bit indicates for the respective counter that an error has occurred during loading of the control interface.</p> <p>The load value was not accepted.</p> <p>One of the following conditions is fulfilled:</p> <ul style="list-style-type: none"> • Low counting limit > Count value • Low counting limit > Start value • Low counting limit > Comparison value • Count value > High counting limit • Start value > High counting limit • Comparison value > High counting limit • Low counting limit ≥ High counting limit • No valid load request in LD_SLOT
EVENT_UFLW	<p>This bit shows for the respective counter whether an underflow (value dropped below the low count limit) has occurred.</p> <p>You reset the state by acknowledging with RES_EVENT_UFLW.</p>
EVENT_OFLW	<p>This bit shows for the respective counter whether an overflow (value exceeded the high count limit) has occurred.</p> <p>You reset the state by acknowledging with RES_EVENT_OFLW.</p>
EVENT_CMP	<p>This bit shows for the respective counter whether a comparison event with the comparison value has occurred.</p> <p>You reset the state by acknowledging with RES_EVENT_CMP.</p> <p>The EVENT_CMP bit is not set if the count value is set to the start value.</p>

Feedback bit	Explanations
RES_EVENT_UFLW_ACK	This bit shows for the respective counter whether the resetting of the event bit EVENT_UFLW is active.
RES_EVENT_OFLW_ACK	This bit shows for the respective counter whether the resetting of the event bit EVENT_OFLW is active.
RES_EVENT_CMP_ACK	This bit shows for the respective counter whether the resetting of the event bit EVENT_CMP is active.

Complete acknowledgment principle

Storing bits are acknowledged in accordance with the complete acknowledgment principle.

The figure below shows an example for the course of the complete acknowledgment principle at an overflow:



- ① The feedback bit EVENT_OFLW is set as a storing event at an overflow bit.
- ② The set the control bit RES_EVENT_OFLW in order to initiate resetting of EVENT_OFLW.
- ③ The feedback bit RES_EVENT_OFLW_ACK is set when the resetting of EVENT_OFLW has been recognized.
- ④ You reset the control bit RES_EVENT_OFLW .
- ⑤ The feedback bit RES_EVENT_OFLW_ACK is reset.

Figure 4-10 Acknowledgment principle

Note

When you have initiated the resetting of an event bit, you have to wait for the respective feedback bit. You can initiate a further reset subsequently.

Note

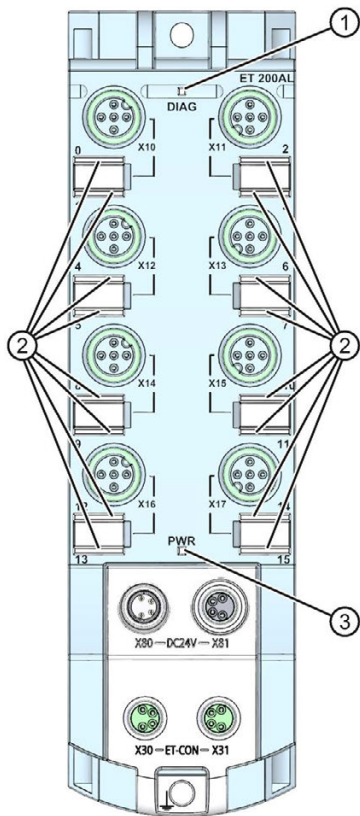
An opening of the SW gate or HW gate (0-1 transition) resets all event bits.

4.2.3 Interrupts/diagnostic alarms

4.2.3.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the digital input module / digital output module DIQ 16x24VDC/0.5A 8xM12.



- ① Diagnostic status (DIAG) (red/green)
- ② Channel status (0 to 15) (green)
- ③ Load voltage 2L+ (PWR) (green)





Figure 4-11 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Remedial measures for diagnostic reports can be found in chapter Diagnostics alarms (Page 69).



DIAG LED

Table 4- 26 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> Module parameters not assigned (after switching on the supply voltage 1L+) Loading firmware (while the firmware update is being performed, all LEDs retain their current status) No connection to the ET-Connection and/or the fieldbus
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics



LED channel status

Table 4- 27 LED channel status display

LED channel status	Meaning
 Off	Process signal = 0
 On	Process signal = 1

PWR LED

Table 4- 28 Status display of the PWR LED

PWR LED	Meaning
 Off	Load voltage 2L+ is missing or too low
 On	Load voltage 2L+ present

4.2.3.2 Interrupts

The digital input / digital output module DIQ 16x24VDC/0.5A 8xM12 in the configuration method 4xCount supports diagnostic and hardware interrupts.

Diagnostic interrupt

The digital input/digital output module generates a diagnostic interrupt at the following events:

- Short-circuit of an encoder supply to ground, or
- Short-circuit of an output to ground
- Load voltage 2L+ missing or too low
- Parameter assignment error

Hardware interrupt

The module generates a hardware interrupt at the following event:

- Comparison event occurred for DQ

For detailed information on the error event, refer to the hardware interrupt organization block with the "RALRM" instruction (read additional interrupt info) and to the STEP 7 online help.

The module channel that triggered the hardware interrupt is entered in the start information of the organization block. The figure below shows the assignment to the bits of the local data double word 8.

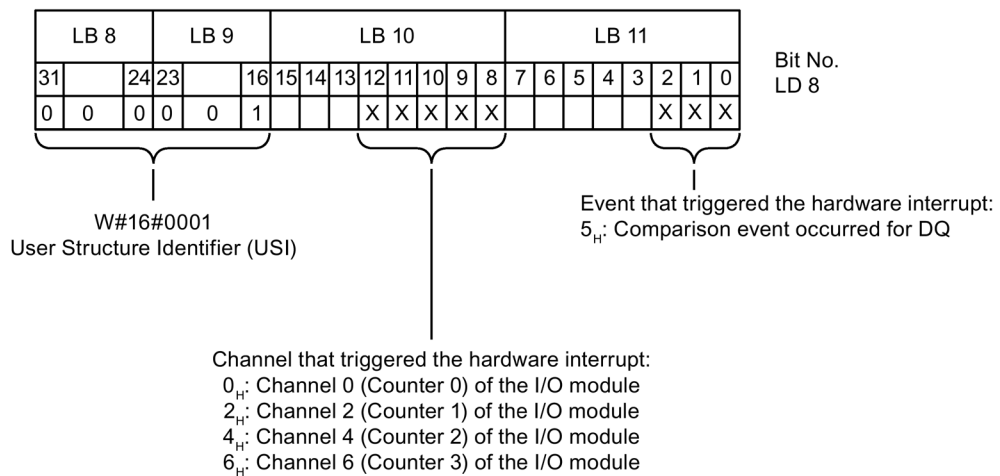


Figure 4-12 Start information of the organization block in the configuration method 4xCount

4.2.3.3 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the LED DIAG flashes red on the digital input/digital output module.

You can read out the diagnostics alarms, for example, from the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 4- 29 Diagnostics alarms, their meanings and corrective measures

Diagnosics alarm	Error code	Meaning	Solution
Short circuit ¹	1H	Short-circuit of an encoder supply to ground	<ul style="list-style-type: none"> Eliminate the short-circuit
		Short-circuit of an output to ground	
Parameter assignment error	10H	Module parameter assignment is faulty	Correction of the parameter assignment
Load voltage 2L+ missing ²	11H	Load voltage 2L+ missing or too low	<ul style="list-style-type: none"> Check the supply voltage Check the module
Hardware interrupt lost	16H	At least one hardware interrupt could not be signaled because too many hardware interrupts are pending.	Correct the program or the process
<p>¹ If a short-circuit of the encoder supply to ground is detected, the diagnostic alarm "Short-circuit" is always output. This alarm is output even if all channels are configured as outputs.</p> <p>² If you are using ET 200AL modules in connection with the ET 200SP distributed I/O system, the diagnostic alarm "Load voltage missing" is displayed.</p>			

4.3 Examples of counting

In this section, you will find examples of the behavior of the counter and how you can specify this behavior. You specify the properties of the counter in the parameter assignment.

The boundary conditions apply for the following examples:

- You set the bit SW_GATE to "1", the counting process starts.
- If you reset the bit SW_GATE before a count limit is reached, the counting process stops. Set the bit SW_GATE to restart the counting process. The value with which the counting process starts again depends on the content of the control interface.

These conditions only apply if you do not use a HW gate (configuration method 2xCount).

Behavior DQ - Count value between a comparison value and the high counting limit (counting direction forward)

The following section shows the behavior of the count output with the parameter assignment "Set output DQ: Count value between a comparison value and the high counting limit".

The count output is set to "1" if the current values lies between the comparison value and the high count limit.

You can optionally enable a hardware interrupt through the parameterization. This is generated with the rising edge of the count output.

The following figure shows an example of the signal state of the count output depending on the parameterization mentioned above.

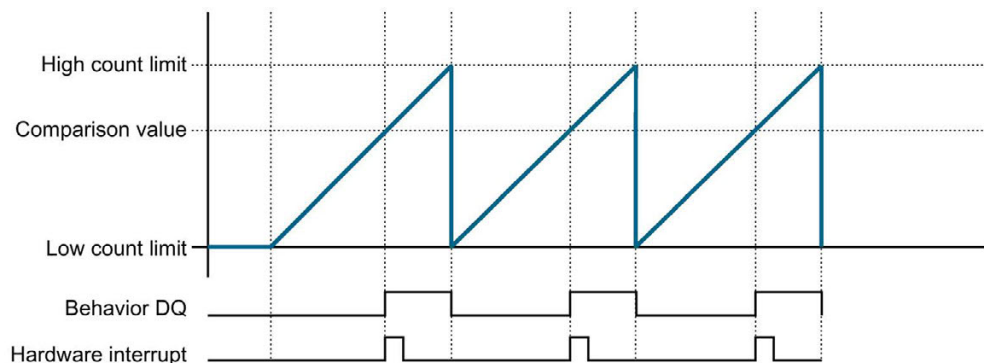


Figure 4-13 Behavior DQ and hardware interrupt

Behavior DQ - count value between a comparison value and the low counting limit (counting direction backward)

The following section shows the behavior of the count output with the parameter assignment "Set output DQ: Between a comparison value and the low counting limit".

The count output is set to "1" if the current values lies between the comparison value and the low count limit.

You can optionally enable a hardware interrupt through the parameterization. This is generated with the rising edge of the count output.

The following figure shows an example of the signal state of the count output depending on the parameterization mentioned above.

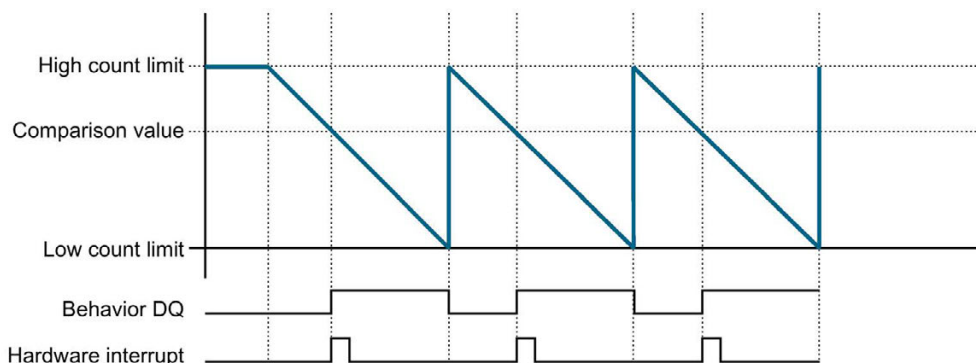


Figure 4-14 Behavior DQ and hardware interrupt

Start and stop the counting process via the gate control (counting direction forward, configuration method 2xCount)

The following section shows the behavior of the counter depending on the control input at the parameterization "Behavior DI: Gate control in combination with "Behavior when a counting limit is exceeded: Stop counting".

If you set the HW gate to "1" via the control input, the counting process is started. If you set the HW gate to "0", the counting process stops.

Note that the counting process also stops if you close the SW gate while the HW gate is opened.

HW gate and SW gate together form the internal gate. The module only counts when the internal gate is open.

The following figure shows an example of the behavior of the counter at gate control with the principle of stopping counting when a counting limit is exceeded.

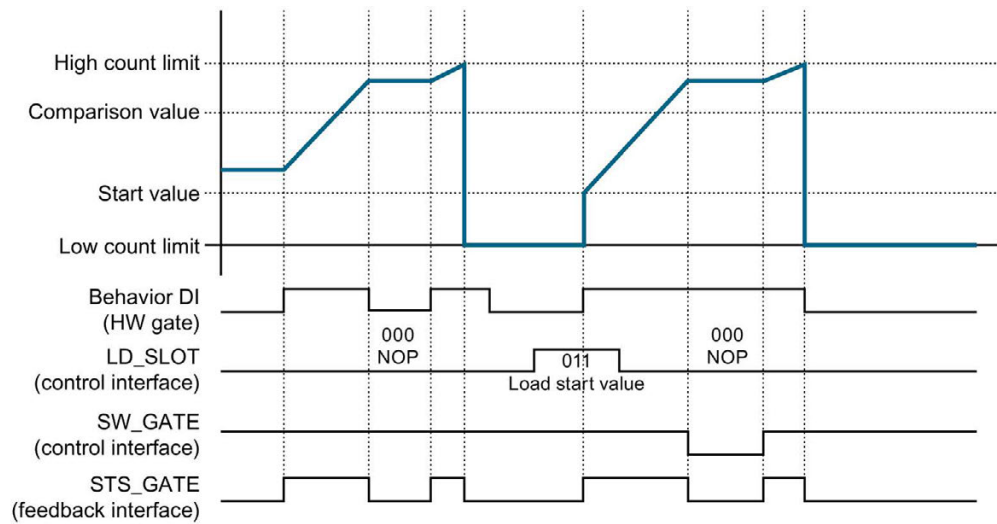


Figure 4-15 Gate control and principle: Stop counting

Change counting direction via count input and stop counting (configuration method 2xCount)

The following section shows the behavior of the counter depending on the direction input at the parameterization "Behavior DI: Counting direction" in combination with "Behavior when a counting limit is exceeded: Stop counting".

If you have parameterized the digital input of a counter as a direction input, you can change the counting direction via corresponding signals at this input.

Irrespective of the parameterization the counter always forward if the signal state "0" is set at direction input or, respectively backward if the signal state is "1".

If you change the counting direction via a signal change at the direction input, the edge detection (rising / falling edge) is also switched over.

The following figure shows an example of the behavior of the counter at a change in the counting direction with the principle of stopping counting when a counting limit is exceeded.

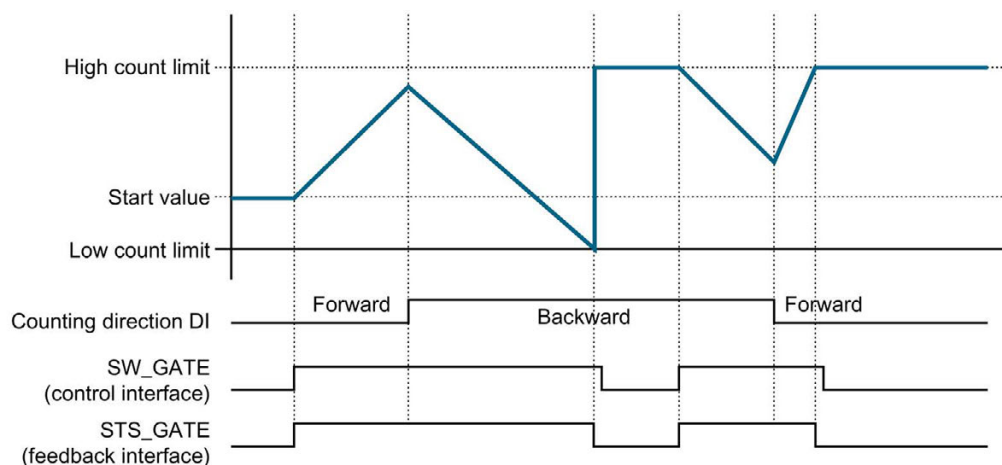


Figure 4-16 Changing the counting direction and principle: Stop counting

Behavior when a counting limit is exceeded - Stop counting (counting direction forward)

The following section describes the effects of the parameter "Behavior when a counting limit is exceeded: Stop counting" in the counting direction forward. To control the counter, the bits of the control byte of the control interface are used, see the configuration method 2xCount, section Assignment of the control interface (Page 43) and configuration method 4xCount, section Assignment of the control interface (Page 61).

You have entered the bit string 011 in the control byte of the control interface. This bit string loads the value defined in the load value (SLOT) as the start value of the counter via the load request (LD_SLOT).

After the high counting limit is violated, counting is aborted (counting stops) and the counted value jumps to the low counting limit.

The bit STS_GATE is reset in the feedback interface, the bit EVENT_OFLW is set.

The following figure shows an example of the principle of stopping counting when the high count limit is exceeded, counting direction forward.

The behavior "Behavior DQ" is set to "Count value between a comparison value and the high counting limit".

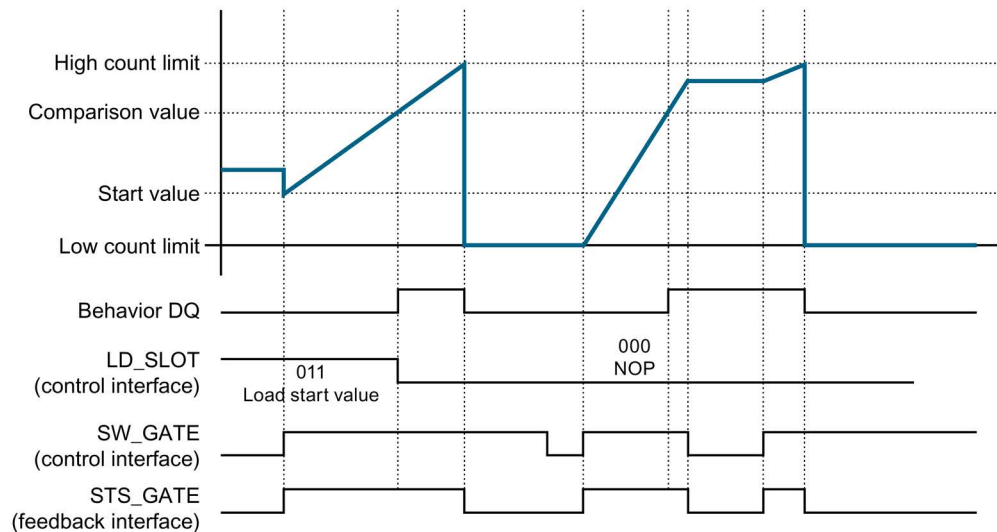


Figure 4-17 Principle: Stop counting (counting direction forward)

You can find additional information on the behavior of the counter at an overflow in the section Explanations for the feedback interface (Page 46).

Behavior when a counting limit is exceeded - Continue counting (counting direction backward)

The following section describes the effects of the parameter "Behavior when a counting limit is exceeded: Continue counting". To control the counter, the bits of the control byte of the control interface are used, see the configuration method 2xCount, section Assignment of the control interface (Page 43) and configuration method 4xCount, section Assignment of the control interface (Page 61).

After the low counting limit is underpassed, the counted value jumps to the high counting limit and counting is continued.

The bit STS_GATE is **not** reset when a count limit is exceeded.

The following figure shows an example of the principle of stopping counting when the low count limit is exceeded, counting direction backward.

The behavior "Behavior DQ" is set to "Count value between a comparison value and the high counting limit".

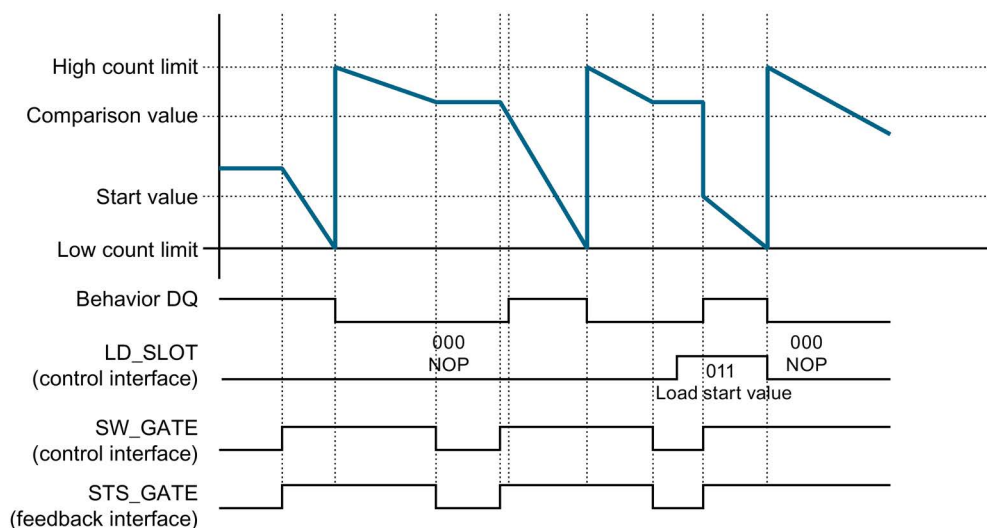


Figure 4-18 Principle: Continue counting (counting direction backward)

Reference

You will find general information on the counting function in the section Counting (Page 30).

Further information about the pin assignment, parameters, control and feedback interface, etc. is available in the sections Configuration method 2xCount (Page 32) and Configuration method 4xCount (Page 52).

Technical specifications

Technical specifications of the DIQ 16x24VDC/0.5A 8xM12 digital input/digital output module

Article number	6ES7143-5AH00-0BA0
General information	
Product type designation	DIQ 16x24VDC/0.5A
HW functional status	E01
Product function	
<ul style="list-style-type: none"> I&M data 	Yes; I&M0 to I&M3
Engineering with	
<ul style="list-style-type: none"> STEP 7 TIA Portal configurable/integrated as of version 	STEP 7 V14 or higher
<ul style="list-style-type: none"> STEP 7 configurable/integrated as of version 	V5.5 SP4 Hotfix 7 or higher
<ul style="list-style-type: none"> PROFIBUS as of GSD version/GSD revision 	GSD as of Revision 5
<ul style="list-style-type: none"> PROFINET as of GSD version/GSD revision 	GSDML V2.3.1
Operating mode	
<ul style="list-style-type: none"> DI 	Yes
<ul style="list-style-type: none"> Counter 	Yes
<ul style="list-style-type: none"> DQ 	Yes
Supply voltage	
Load voltage 1L+	
<ul style="list-style-type: none"> Rated value (DC) 	24 V
<ul style="list-style-type: none"> permissible range, lower limit (DC) 	20.4 V
<ul style="list-style-type: none"> permissible range, upper limit (DC) 	28.8 V
<ul style="list-style-type: none"> Reverse polarity protection 	Yes; Against destruction; encoder power supply outputs applied with reversed polarity, loads pick up
Load voltage 2L+	
<ul style="list-style-type: none"> Rated value (DC) 	24 V
<ul style="list-style-type: none"> permissible range, lower limit (DC) 	20.4 V
<ul style="list-style-type: none"> permissible range, upper limit (DC) 	28.8 V
<ul style="list-style-type: none"> Reverse polarity protection 	Yes; Against destruction; encoder power supply outputs applied with reversed polarity, loads pick up

Article number	6ES7143-5AH00-0BA0
Input current	
Current consumption (rated value)	75 mA; without load
from load voltage 1L+ (unswitched voltage)	4 A; Maximum value
from load voltage 2L+, max.	4 A; Maximum value
Encoder supply	
Number of outputs	8
24 V encoder supply	
<ul style="list-style-type: none"> Short-circuit protection 	Yes; Per load voltage, electronic
<ul style="list-style-type: none"> Output current, max. 	1.4 A; Total current of all encoders, max. 0.7 A per load voltage
Power loss	
Power loss, typ.	4 W
Digital inputs	
Number of digital inputs	16; Parameterizable as DIQ
Input characteristic curve in accordance with IEC 61131, type 3	Yes
Number of simultaneously controllable inputs all mounting positions	
– up to 55 °C, max.	16
Digital input functions, parameterizable	
<ul style="list-style-type: none"> Freely usable digital input 	Yes
<ul style="list-style-type: none"> Counter 	Yes
– Number, max.	4
– Counting frequency, max.	2 kHz
– Counting width	32 bit; Incl. sign
– Counting direction up/down	Yes
Input voltage	
<ul style="list-style-type: none"> Rated value (DC) 	24 V
<ul style="list-style-type: none"> for signal "0" 	-3 to +5V
<ul style="list-style-type: none"> for signal "1" 	+11 to +30V
Input current	
<ul style="list-style-type: none"> for signal "1", typ. 	3 mA
Input delay (for rated value of input voltage) for standard inputs	
– parameterizable	Yes
– at "0" to "1", min.	0.05 ms; 1.6 ms for channels 8 through 15
– at "0" to "1", max.	20 ms
– at "1" to "0", min.	0.05 ms; 1.6 ms for channels 8 through 15
– at "1" to "0", max.	20 ms

Article number	6ES7143-5AH00-0BA0
for technological functions	
– parameterizable	Yes
Cable length	
• unshielded, max.	30 m
Digital outputs	
Number of digital outputs	16; Parameterizable as DIQ
• in groups of	8; 2 load groups for 8 outputs each
Short-circuit protection	Yes; per channel, electronic
• Response threshold, typ.	0.7 A
Limitation of inductive shutdown voltage to	L+ (-53 V)
Digital output functions, parameterizable	
• Switching tripped by comparison values	Yes
• Freely usable digital output	Yes
Switching capacity of the outputs	
• on lamp load, max.	5 W
Load resistance range	
• lower limit	48 Ω
• upper limit	4 kΩ
Output voltage	
• for signal "1", min.	L+ (-0.8 V)
Output current	
• for signal "1" rated value	0.5 A
• for signal "0" residual current, max.	0.5 mA
Switching frequency	
• with resistive load, max.	100 Hz
• with inductive load, max.	0.5 Hz
• on lamp load, max.	1 Hz
Total current of the outputs	
• Current per group, max.	4 A
Cable length	
• unshielded, max.	30 m
Encoder	
Connectable encoders	
• 2-wire sensor	Yes
– permissible quiescent current (2-wire sensor), max.	1.5 mA

Article number	6ES7143-5AH00-0BA0
Interrupts/diagnostics/status information	
Substitute values connectable	Yes; channel by channel, parameterizable
Alarms	
• Diagnostic alarm	Yes; Parameterizable
Diagnostic messages	
• Short-circuit	Yes; Outputs to M; encoder supply to M; module by module
Diagnostics indication LED	
• Channel status display	Yes; Green LED
• for module diagnostics	Yes; Green/red LED
• For load voltage monitoring	Yes; Green LED
Potential separation	
between the load voltages	Yes
Potential separation channels	
• between the channels, in groups of	8
• between the channels and backplane bus	Yes
• between the channels and the power supply of the electronics	No; 8 channels are non-isolated and 8 channels are isolated from supply voltage 1L+
Isolation	
Isolation tested with	707 V DC (type test)
Degree and class of protection	
IP degree of protection	IP65/67
Ambient conditions	
Ambient temperature during operation	
• min.	-25 °C
• max.	55 °C
Connection method	
Design of electrical connection for the inputs and outputs	M12, 5-pole
Design of electrical connection for supply voltage	M8, 4-pole
ET-Connection	
• ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	45 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	195 g

PROFenergy

6.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific behavior of the digital input/digital output module with counting function is explained in the following sections.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<https://support.industry.siemens.com/cs/ww/en/view/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V14 (<https://support.industry.siemens.com/cs/ww/en/view/49948856>).

Application examples (<https://support.industry.siemens.com/cs/ww/en/view/41986454>) are also available on the Internet.

6.2 Behavior of the digital inputs

Display

The channel status LEDs are directly influenced by the signal level at the socket. If the encoder supply is switched off, this causes the channel status LEDs to also switch off.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- Encoder supply switch-off upon the start of "pause" does not result in the "Short-circuit" alarms.
- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 6- 1 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> • Encoder supply U_S switched off ¹ • Pause substitute value: 0_B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> • Encoder supply U_S switched off ¹ • Pause substitute value: Last input value • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> • Encoder supply U_S switched off ¹ • Pause substitute value: Configured pause substitute value • Value status "BAD"

¹ There are two encoder supplies, 1U_S for Channels 0 to 7 and 2U_S for Channels 8 to 15. At a "Pause" the supplies can only be switched off if no channel is configured in PE_MODE_PROCEED.

6.3 Behavior of the digital outputs

Display

The channel status LEDs are directly affected by the signal level at the socket.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 6-2 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" • Pause substitute value: 0 _B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" • Pause substitute value: Last output value is maintained • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" • Pause substitute value: Configured pause substitute value is output • Value status "BAD"

6.4 Behavior of the digital inputs of the counters

Display

The channel status LEDs are directly influenced by the signal level at the socket. If the encoder supply is switched off, this causes the channel status LEDs to also switch off.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- Encoder supply switch-off upon the start of "pause" does not result in the "Short-circuit" alarms.
- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Note

Channels of a counter

All the channels that belong to a counter must have the same PROFenergy behavior. If substitute value behavior is parameterized, this also has to be the same for all channels of a counter.

If the PROFenergy behavior is not the same for all the channels of a counter, the module rejects the PROFenergy parameterization.

Further information on the assignment of the counting channels for the configuration method 2xCount is available in the section Pin assignment (Page 33), for the configuration method 4xCount in the section Pin assignment (Page 53).

Mode parameter

The following table shows the "Mode" parameter.

Table 6-3 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	The counter functions as in the normal count mode. The count output depends on the count value.
	1 _D : PE_MODE_SHUTDOWN	The count value is no longer updated. The count output is set to 0.
	3 _D : PE_MODE_LAST_VALUE	The count value is no longer updated (the input does not supply any edges). The count output contains the last value, since the count is no longer updated.
	4 _D : PE_MODE_SUBST_VALUE	The count value is no longer updated (the input does not supply any edges). The count output is set to the parameterized substitute value, irrespective of the count value.

Dimension drawing

A

The figure below shows the dimension drawing of the DIQ 16x24VDC/0.5A 8xM12 digital input/digital output module in front and side views.

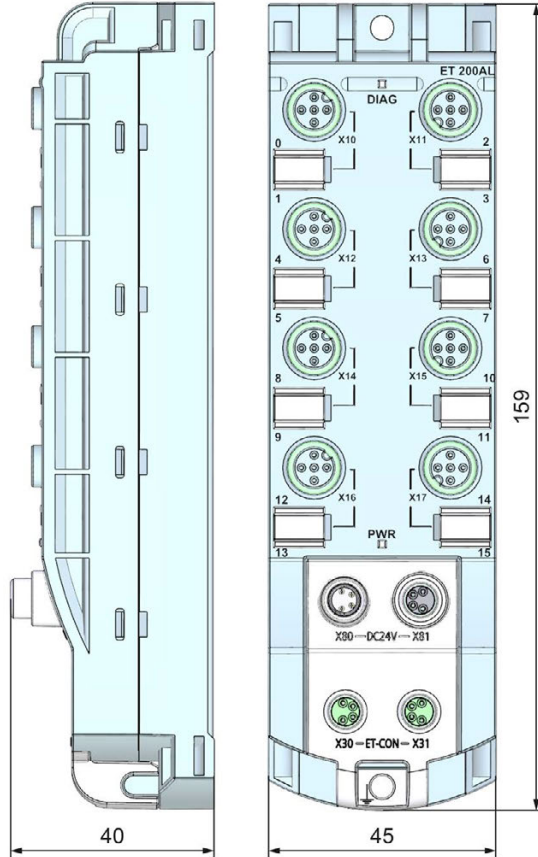
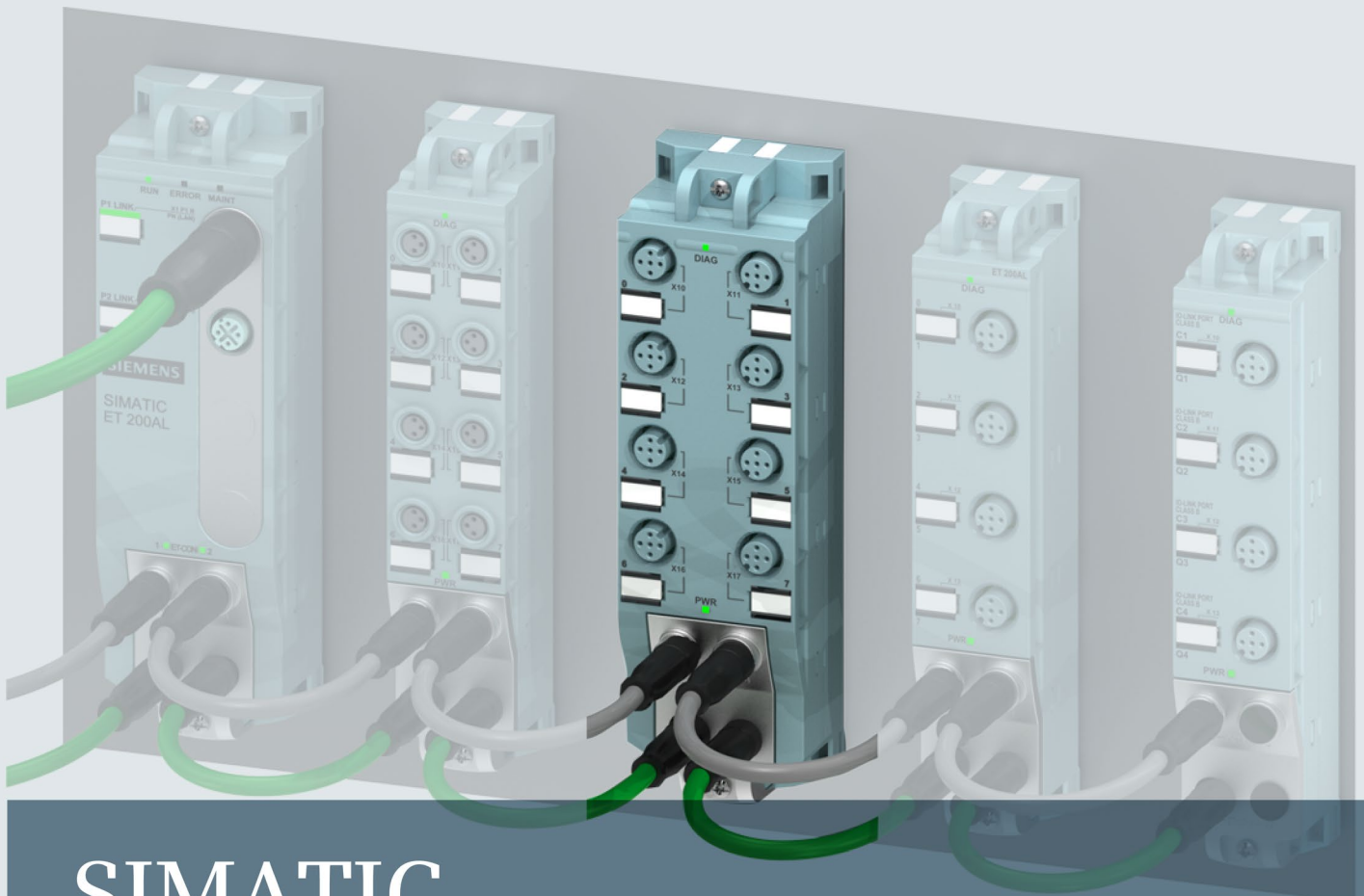


Figure A-1 Dimension drawing

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SIMATIC

ET 200AL

Digital output module DQ 8x24VDC/2A 8xM12 (6ES7142-5AF00-0AB0)

Manual

Edition

02/2016

Answers for industry.

SIEMENS

SIMATIC

ET 200AL
Digital output module
DQ 8x24VDC/2A 8xM12
(6ES7142-5AF00-0BA0)

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A

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (<http://www.siemens.com/industrialsecurity>).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (<http://support.automation.siemens.com>).

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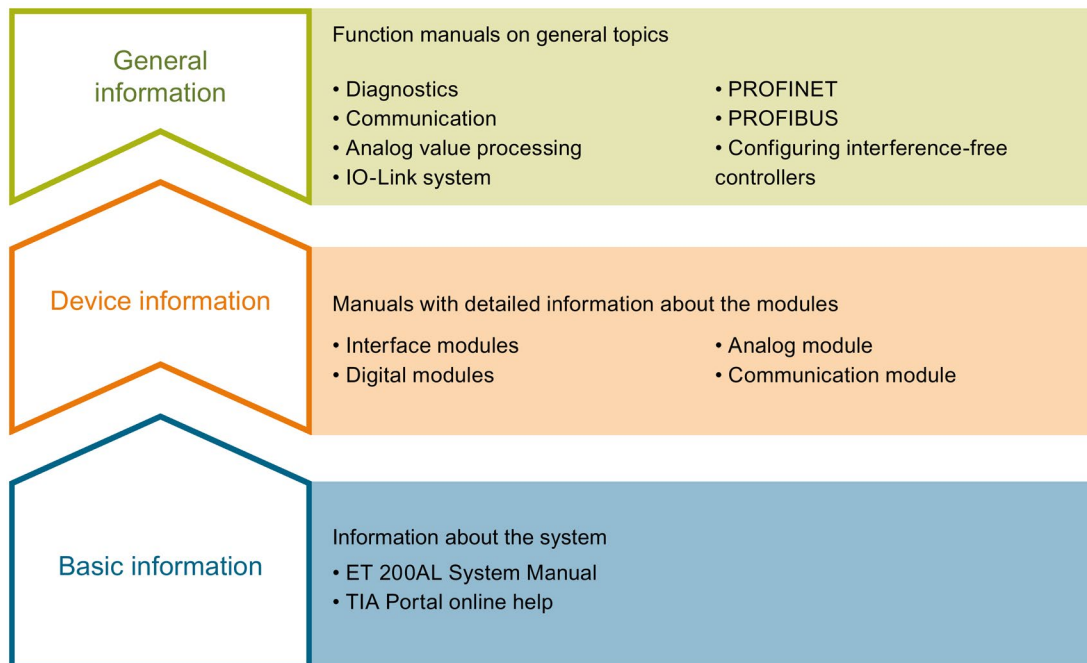
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Documentation guide

1

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<http://w3.siemens.com/mcms/industrial-automation-systems-simatic/en/manual-overview/tech-doc-et200/Pages/Default.aspx>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

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"mySupport" - Documentation

In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.

You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<http://support.industry.siemens.com/My/ww/en/documentation>).

"mySupport" - CAx data

In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

Product overview

2.1 Properties

Article number

6ES7142-5AF00-0BA0

View of the module

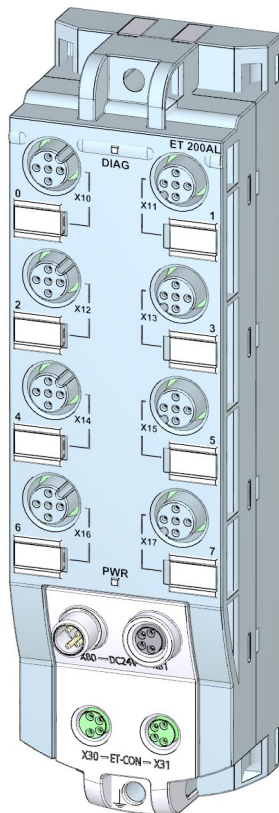


Image 2-1 View of the DQ 8x24VDC/2A 8xM12 digital output module

Properties

The module has the following technical properties:

- 8 digital outputs
 - Channels 0 to 3 connected to 1L+ (non-switched)
 - Channels 4 to 7 connected to 2L+ (switched)
- M12 sockets for connection of actuators
- Rated load voltage 24 V DC
- Suitable for solenoid valves, DC contactors, and indicator lights
- Output current per output 2 A
- Configurable diagnostics can be set for each module
- Dimensions 45 x 159 mm

The module supports the following functions:

- Firmware update
- Identification and maintenance data I&M0 to I&M3
- Value status (Quality Information)
- PROFIenergy

Accessories

The following components are included in the module package:

- Identification labels

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

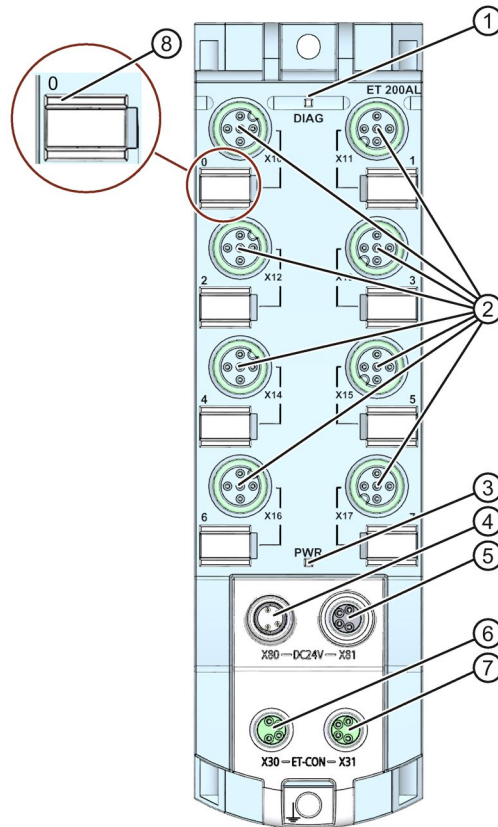
- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system (<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual.

2.2 Operator controls and display elements

The figure below shows the operator controls and display elements of the DQ 8x24VDC/2A 8xM12 digital output module.



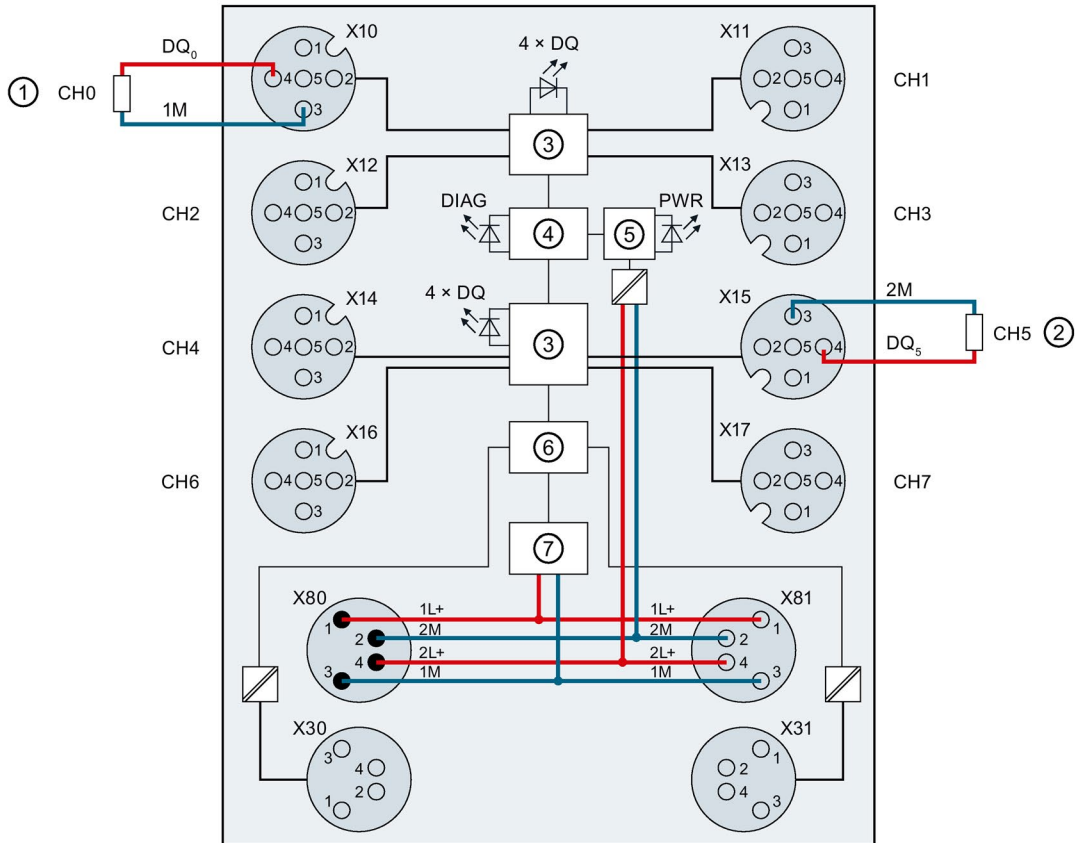
- ① DIAG: LED display for the diagnostic status
- ② X10 to X17: Sockets for the output signal
- ③ PWR: LED display for load voltage 2L+
- ④ X80: Connector for infeed of the supply voltage (POWER input)
- ⑤ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑥ X30: Socket for ET-Connection IN
- ⑦ X31: Socket for ET-Connection OUT
- ⑧ LED displays 0 to 7 for the channel status

Image 2-2 Operator controls and display elements

Wiring

3.1 Terminal and block diagram

The example in the figure below shows the pin assignment of signal outputs.



- | | | | |
|------------|---------------------------------|-----------------|--------------------------------------|
| ① | Output to 1L+ | X30 | Infeed of the ET-Connection |
| ② | Output to 2L+ | X31 | Loop-through of the ET-Connection |
| ③ | DQ circuit | 1L+ | Supply voltage 1L+ (non-switched) |
| ④ | Microcontroller | 1M | Ground 1M (non-switched) |
| ⑤ | Monitoring | 2L+ | Load voltage 2L+ (switched) |
| ⑥ | ET-Connection interface | 2M | Ground 2M (switched) |
| ⑦ | Internal supply voltage | 1Us | 24 V encoder supply |
| X10 to X17 | Channels 0 to 7 | DQ _n | Output signal |
| X80 | Infeed of supply voltages | DQ | Channel status LEDs (0 to 7) (green) |
| X81 | Loop-through of supply voltages | | |

Image 3-1 Terminal and block diagram

3.2 Pin assignment

Note

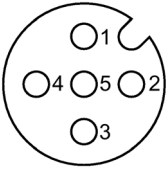
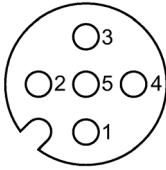
Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the sockets for digital outputs

The tables below show the pin assignments of the 8 sockets for connection of the digital outputs.

Table 3- 1 Pin assignment for digital outputs

Pin	Assignment	Front view of the sockets	
		X10, X12, X14, X16	X11, X13, X15, X17
1	Unassigned		
2	Unassigned		
3	X10 - X13: Ground 1M X14 - X17: Ground 2M		
4 *	Output signal DQ ₀ : Connector X10 Output signal DQ ₁ : Connector X11 Output signal DQ ₂ : Connector X12 Output signal DQ ₃ : Connector X13 Output signal DQ ₄ : Connector X14 Output signal DQ ₅ : Connector X15 Output signal DQ ₆ : Connector X16 Output signal DQ ₇ : Connector X17		
5	Functional earth FE		

* The outputs DQ₀ to DQ₃ are connected to 1L+; the outputs DQ₄ to DQ₇ are connected to 2L+.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

Table 3-2 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shielding	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

Table 3-3 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3-4 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE**ET-Connection/supply voltage**

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage.

Mixing up the ET-Connection connectors and the connectors for the supply voltage can destroy the module.

Parameters/address space

4.1 Parameters

The table below shows the parameters for the DQ 8x24VDC/2A 8xM12 digital output module.

Table 4- 1 Parameters

Parameters	Value range	Default	Scope
Diagnostics: Missing load voltage 2L+	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module
Diagnostics: Short-circuit to ground	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module (Short-circuit of the output to ground)
Reaction to CPU/master STOP	<ul style="list-style-type: none"> • Shut down • Keep last value • Output substitute value 	Shut down	Module
Substitute value channel 0 ... 7	<ul style="list-style-type: none"> • 0 • 1 	0	Channel

4.2 Explanation of the parameters

Diagnostics: Missing load voltage 2L+

Enabling of the diagnostics for missing or insufficient load voltage 2L+.

Diagnostics: Short-circuit to ground

Enabling of the diagnostics for short-circuit of the output to ground.

Reaction to CPU/master STOP

With this parameter, you set the reaction of the digital outputs of the module after a CPU/master STOP:

- Shut down: The digital output is de-energized.
- Keep last value: The last value of the digital output remains activated.
- Output substitute value: The module outputs a configured substitute value.

Substitute value channel 0 ... 7

With this parameter, you set substitute values for the digital outputs.

4.3 Address space

The figure below shows the assignment of the address space for the digital output module DQ 8x24VDC/2A 8xM12 with value status (Quality Information, QI).

The address space for the value status is allocated by the module, if the value status is configured using the PROFINET interface module.

Assignment in the process image input (PII)



Assignment in the process image output (PIQ)

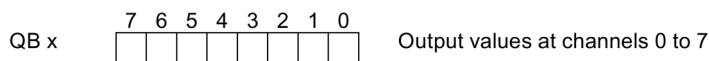


Image 4-1 Address space

Configuration options of the digital output module DQ 8x24VDC/2A 8xM12

You have the following configuration options:

- Configuration 1: without value status
- Configuration 2: with value status

Evaluating the value status

An additional byte is occupied in the input address space if you enable the value status for the digital output module. The value status of the outputs is assigned to bits 0 to 7 in input byte x. This additional information provides information regarding the validity of the digital values or channel status.

Bit = 1: No error on channel.

Bit = 0: Error on channel.

This means:

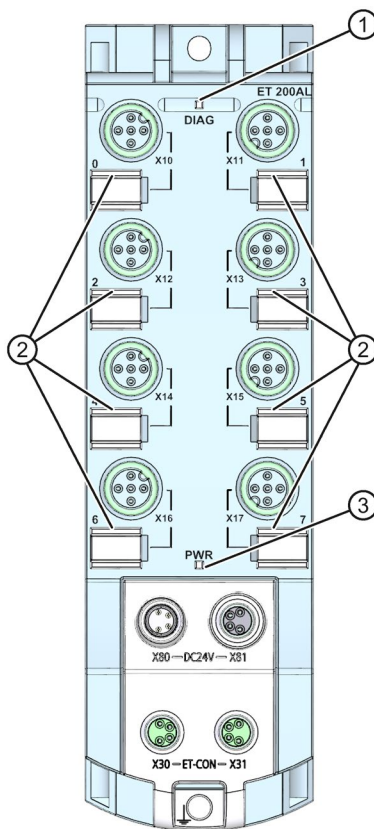
- Short-circuit of output to ground or
- Parameter error or
- For channels 4 ... 7: Missing load voltage 2L+

Interrupts/diagnostic alarms

5.1 Status and error displays

LED displays

The figure below shows the LED displays (status and error displays) of the digital output module DQ 8x24VDC/2A 8xM12.



- | | | |
|---|--------------------------|-------------|
| ① | Diagnostic status (DIAG) | (red/green) |
| ② | Channel status (0 to 7) | (green) |
| ③ | Load voltage 2L+ (PWR) | (green) |





Image 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Remedial measures for diagnostic alarms can be found in the section Diagnostics alarms (Page 20).



DIAG LED

Table 5- 1 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> Module parameters not assigned Loading firmware (while the firmware update is being performed, all LEDs retain their current status)
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics



LED channel status

Table 5- 2 LED channel status display

LED channel status	Meaning
 Off	Process signal = 0
 On	Process signal = 1

PWR LED

Table 5- 3 Status display of the PWR LED

PWR LED	Meaning
 Off	Load voltage 2L+ is missing or too low
 On	Load voltage 2L+ present

5.2 Interrupts

The digital output module DQ 8x24VDC/2A 8xM12 supports diagnostics interrupts.

Diagnostic interrupt

The digital output module generates a diagnostic interrupt at the following events:

- Short-circuit of outputs to ground
- Load voltage 2L+ missing or too low

5.3 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the DIAG LED flashes red on the digital output module. You can read out the diagnostics alarms, for example, from the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 5- 4 Diagnostics alarms, their meanings and corrective measures

Diagnosics alarm	Error code	Meaning	Remedy
Short-circuit	1H	Short-circuit of outputs to ground	<ul style="list-style-type: none">• Eliminate the short-circuit
Load voltage 2L+ missing*	11H	Load voltage 2L+ missing or too low	<ul style="list-style-type: none">• Check the supply voltage• Check the module
* If you are using ET 200AL modules in connection with the ET 200SP distributed I/O system, the diagnostics alarm "Load voltage missing" is displayed.			

Technical specifications

6.1 Technical specifications

Technical specifications of the DQ 8x24VDC/2A 8xM12 digital output module

	6ES7142-5AF00-0BA0
General information	
Product type designation	DQ 8X24VDC/2A, 8XM12
Hardware functional status	E01
Firmware version	V1.0.x
Product function	
I&M data	Yes; I&M0 to I&M3
Engineering with	
STEP 7 TIA Portal can be configured/integrated as of version	As of STEP 7 V13 SP1
STEP 7 can be configured/integrated as of version	V5.5 SP4 Hotfix 7 or higher
PROFIBUS as of GSD version/GSD revision	GSD as of revision 5
PROFINET as of GSD version/GSD revision	GSDML V2.3.1
Supply voltage	
Load voltage 1L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction; loads will be activated
Load voltage 2L+	
Rated value (DC)	24 V
Low limit of permitted range (DC)	20.4 V
High limit of permitted range (DC)	28.8 V
Reverse polarity protection	Yes; against destruction; loads will be activated
Input current	
Current consumption (rated value)	40 mA; no load
From load voltage 1L+ (unswitched voltage)	4 A; maximum value
From load voltage 2L+, max.	4 A; maximum value
Power loss	
Power loss, typ.	4 W
Digital outputs	
Number of outputs	8
• In groups of	4; 2 load groups for 4 outputs each
Short-circuit protection	Yes; per channel, electronic
• Response threshold, typ.	2.8 A
Limitation of inductive shutdown voltage to	2L+ (-47 V)

6ES7142-5AF00-0BA0	
Switching capacity of outputs	
With lamp load, max.	10 W
Load resistance range	
Low limit	12 Ω
High limit	4 kΩ
Output voltage	
For signal "1", min.	L+ (-0.8 V)
Output current	
For signal "1" rated value	2 A
For signal "1" permissible range, max.	2 A, with inductive load according to IEC 60947-5-1, DC13 / AC-15
For signal "0" residual current, max.	0.5 mA
Switching frequency	
With resistive load, max.	100 Hz
With inductive load, max.	0.1 Hz; 0.25 Hz at 25 °C
With lamp load, max.	1 Hz
Total current of outputs	
Current per group, max.	4 A; with inductive load, max. 2 channels per group
Cable length	
Unshielded, max.	30 m
Interrupts/diagnostics/status information	
Substitute values can be applied	Yes; channel-based, configurable
Interrupts	
Diagnostic interrupt	Yes; configurable
Diagnostics alarms	
Short-circuit	Yes; outputs to ground; module-based
Diagnostics indicator LED	
Channel status display	Yes; green LED
For module diagnostics	Yes; green/red LED
For load voltage monitoring	Yes; green LED
Electrical isolation	
Between load voltages	Yes
Electrical isolation of channels	
Between the channels, in groups of	4
Between the channels and backplane bus	Yes
Between the channels and power supply of the electronics	No; 4 channels are non-isolated and 4 channels are isolated from supply voltage 1L+
Insulation	
Insulation tested with	707 V DC (type test)

6ES7142-5AF00-0BA0	
Degree of protection and protection class	
Degree of protection according to EN 60529	
• IP65	Yes
• IP67	Yes
Ambient conditions	
Ambient temperature in operation	
Min.	-25 °C
Max.	55 °C
Connection technology	
Inputs/outputs	M12, 5-pin
Power supply	M8, 4-pin
ET-Connection	
ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	45 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	192 g

7.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific behavior of the digital output module is explained in the following sections.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<https://support.industry.siemens.com/cs/ww/en/view/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V13 (<https://support.industry.siemens.com/cs/ww/en/view/49948856>).

Application examples (<https://support.industry.siemens.com/cs/ww/en/view/41986454>) are also available on the Internet.

7.2 Behavior of the digital output module

Display

The channel status LEDs are directly affected by the signal level at the socket.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- During the "pause", error detection of "Short circuit" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 7- 1 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> • Pause substitute value: 0_B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> • Pause substitute value: Last output value is maintained • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> • Pause substitute value: Configured pause substitute value is output • Value status "BAD"

Dimension drawing

The figure below shows the dimension drawing of the DQ 8x24VDC/2A 8xM12 digital output module in front and side views.

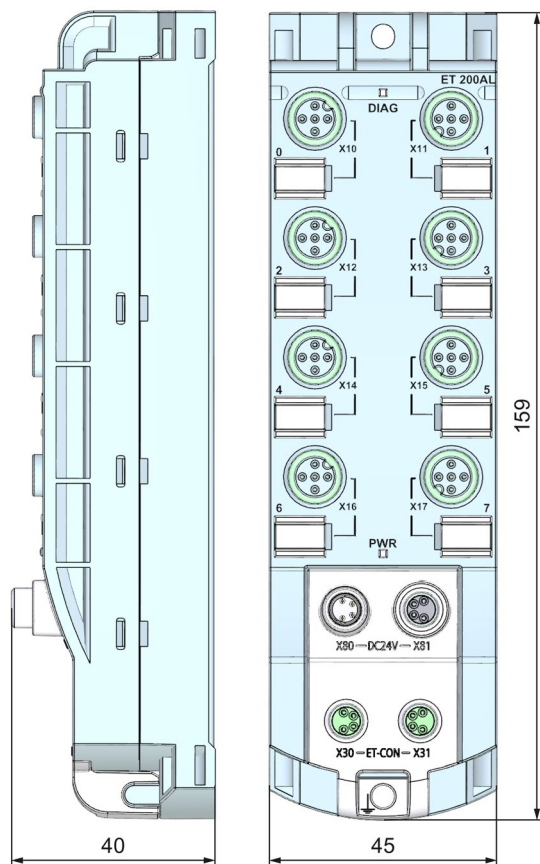
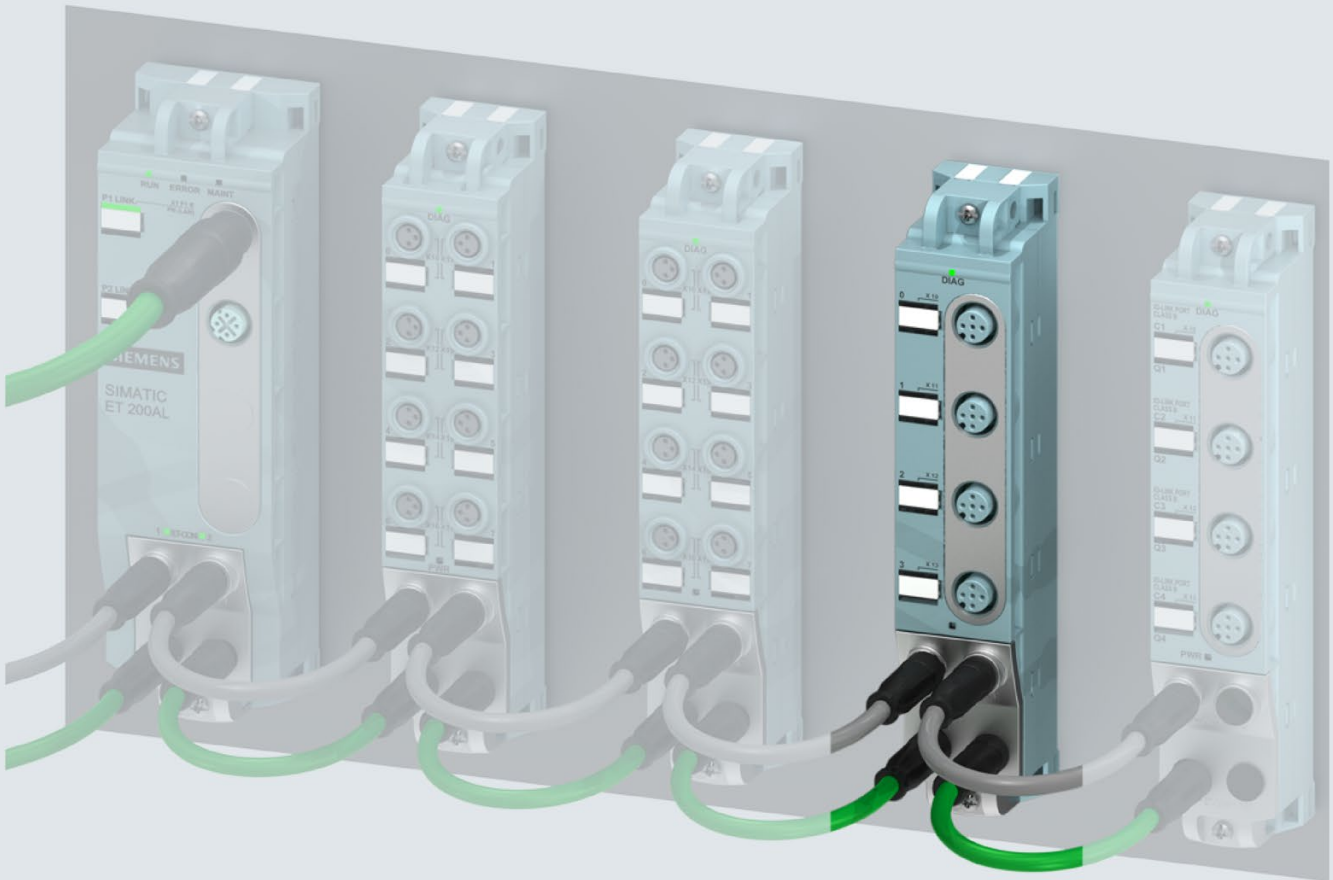


Image A-1 Dimension drawing

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Manual

SIMATIC

ET 200AL

Analog input module AI 4xU/I/RTD 4xM12
(6ES7144-5KD00-0BA0)

Edition

07/2019

support.industry.siemens.com

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SIMATIC

ET 200AL Analog input module AI 4xU/I/RTD 4xM12 (6ES7144-5KD00-0BA0) Manual

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Parameters/address space	4
Interrupts/diagnostics alarms	5
Technical specifications	6
PROFInergy	7
Dimension drawing	A
Representation of analog values	B

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

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⚠ WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
⚠ CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.

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We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Changes compared to previous version

Compared to the previous version, this manual contains the following adaptations in the section Technical specifications (Page 37).

Conventions

Also observe notes marked as follows:

Note

A note contains important information on the product described in the documentation and on the handling of the product to which particular attention should be paid.

See also

Terminal and block diagram (Page 12)

Parameters (Page 19)

ET 200AL Documentation Guide (Page 6)

Security information

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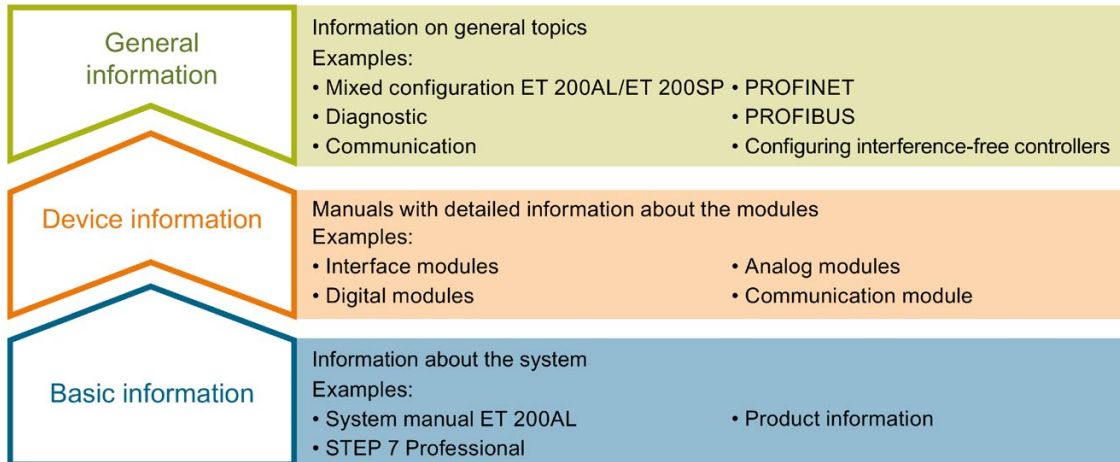
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ET 200AL Documentation Guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742667>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<https://support.automation.siemens.com/WW/view/en/95242965>).

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Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

Product overview

2.1 Properties

Article number

6ES7144-5KD00-0BA0

View of the module

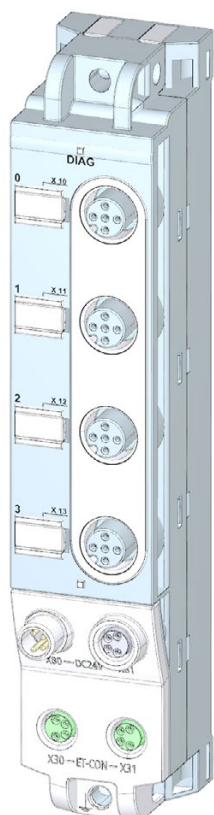


Figure 2-1 View of the analog input module AI 4xU/I/RTD 4xM12

Properties

The module has the following technical properties:

- 4 analog inputs
- M12 sockets for connection of sensors
- Measurement type can be set for each channel:
 - Voltage
 - Current (2-/4-wire transducers)
 - Resistance (2-/3-wire connection)
 - Resistance thermometer (RTD) (2-/3-wire connection)
- Resolution 16-bit
- Dimensions 30 x 159 mm
- Configurable diagnostics can be set for each channel
- Hardware interrupt on limit violation can be set per channel (two high and two low limits per channel)

The module supports the following functions:

- Firmware update
- Identification and maintenance data I&M0 to I&M3
- Value status (Quality Information)
- PROFIenergy

Note

Process values during startup

As long as no parameters have been received by the I/O module, the I/O module returns the process value 7FFF_H.

Accessories

The following components are included in the module package:

- Identification labels
- Spacers

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

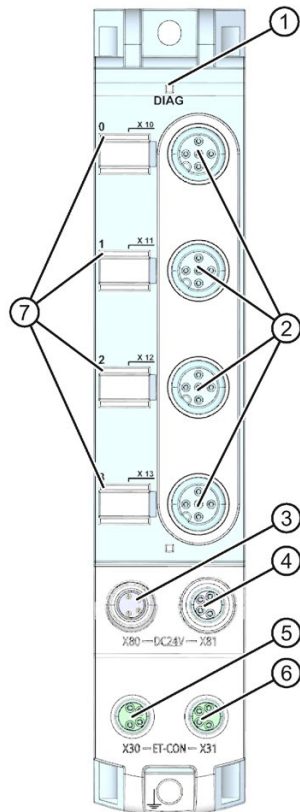
See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system

(<http://support.automation.siemens.com/WW/view/en/89254965>) system manual.

2.2 Operator controls and display elements

The figure below shows the operator controls and display elements of the analog input module AI 4xU/I/RTD 4xM12.



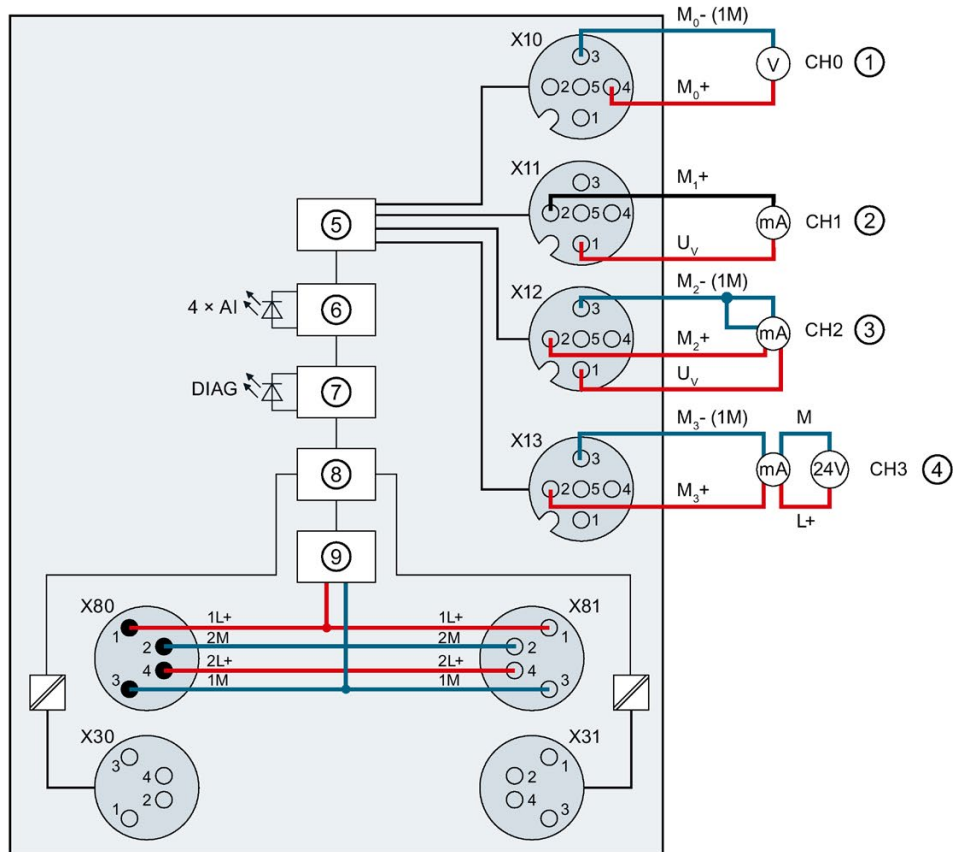
- ① DIAG: LED display for the diagnostic status
- ② X10 to X13: Sockets for the input signal
- ③ X80: Connector for infeed of the supply voltage (POWER input)
- ④ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑤ X30: Socket for ET-Connection IN
- ⑥ X31: Socket for ET-Connection OUT
- ⑦ LED displays 0 to 3 for the channel status

Figure 2-2 Operator controls and display elements

Wiring

3.1 Terminal and block diagram

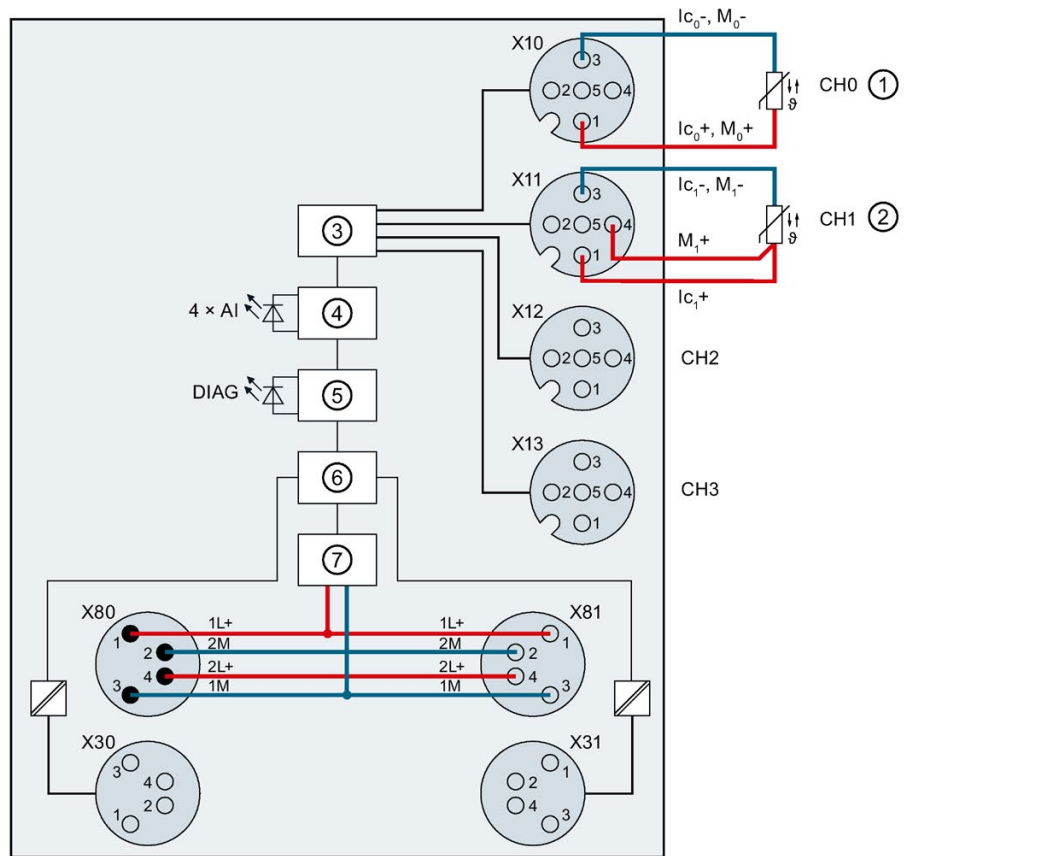
The figure below shows an example of the pin assignment for voltage measurement and current measurement.



①	Voltage measurement	X30	Infeed of the ET-Connection
②	Current measurement (2 DMU)	X31	Loop-through of the ET-Connection
③	Current measurement (4 DMU, with internal power supply)	1L+	Supply voltage 1L+ (non-switched)
④	Current measurement (4 DMU, with external power supply)	1M	Ground 1M (non-switched)
⑤	Multiplexer	2L+	Load voltage 2L+ (switched)
⑥	Analog-to-digital converter (ADC)	2M	Ground 2M (switched)
⑦	Microcontroller	M _n +	Measuring input positive, channel n
⑧	ET-Connection interface	M _n -	Measuring input negative, channel n
⑨	Internal supply voltage	U _v	24 V encoder supply
X10 to X13	Channels 0 to 3	AI	LEDs channel status (0, 1, 2 and 3) (green)
X80	Infeed of supply voltages	DIAG	LED diagnostic status (red/green)
X81	Loop-through of supply voltages		

Figure 3-1 Terminal and block diagram for voltage and current measurement

The example in the following figure shows the pin assignment for the resistance thermometer.



①	RTD/R 2-wire connection	X30	Infeed of the ET-Connection
②	RTD/R 3-wire connection	X31	Loop-through of the ET-Connection
③	Multiplexer	1L+	Supply voltage 1L+ (non-switched)
④	Analog-to-digital converter (ADC)	1M	Ground 1M (non-switched)
⑤	Microcontroller	2L+	Load voltage 2L+ (switched)
⑥	ET-Connection interface	2M	Ground 2M (switched)
⑦	Internal supply voltage	M _n +	Measuring input positive, channel n
X10 to X13	Channels 0 to 3	M _n -	Measuring input negative, channel n
X80	Infeed of supply voltages	I _{c_n} +	Current output, current feed, RTD/R channel n
X81	Loop-through of supply voltages	AI	LEDs channel status (0, 1, 2 and 3) (green)
		DIAG	LED diagnostic status (red/green)

Figure 3-2 Terminal and block diagram for resistance thermometer

3.2 Pin assignment

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

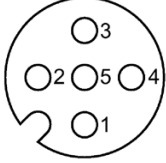
Pin assignment of the sockets for analog inputs

The tables below show the pin assignments of the four sockets for connection of the analog inputs.

Table 3- 1 Pin assignment of the sockets for analog inputs (voltage measurement)

Pin	Assignment	Front view of the sockets
	X10 to X13 - sockets for analog inputs (voltage measurement)	
1	24 V encoder supply 1Us (derived from 1L+ non-switched)	
2	Reserved	
3	Encoder supply ground 1M	
4	Measuring input M ₀ +: Connector X10 Measuring input M ₁ +: Connector X11 Measuring input M ₂ +: Connector X12 Measuring input M ₃ +: Connector X13	
5	Functional earth FE	
Shield	Functional earth FE	

Table 3- 2 Pin assignment of the sockets for analog inputs (current measurement)

Pin	Assignment	Front view of the sockets
	X10 to X13 sockets for analog inputs (current measurement)	
1	24 V encoder supply 1U _S (derived from 1L+ non-switched)	
2	Measuring input M ₀₊ : Connector X10 Measuring input M ₁₊ : Connector X11 Measuring input M ₂₊ : Connector X12 Measuring input M ₃₊ : Connector X13	
3	Encoder supply ground 1M	
4	Reserved	
5	Functional earth FE	
Shield	Functional earth FE	

NOTICE**Short-circuit from encoder supply to measuring input**

In the operating mode current measurement a short-circuit from the encoder supply to the measuring input can destroy the input channel.

Table 3- 3 Pin assignment of the sockets for analog inputs (RTD/R 2-wire connection)

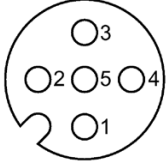
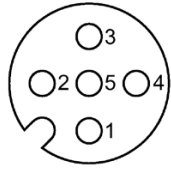
Pin	Assignment	Front view of the sockets
	X10 to X13 sockets for analog inputs (RTD/R 2-wire connection)	
1	Measurement cable I _{C0+} , M ₀₊ : Connector X10 Measurement cable I _{C1+} , M ₁₊ : Connector X11 Measurement cable I _{C2+} , M ₂₊ : Connector X12 Measurement cable I _{C3+} , M ₃₊ : Connector X13	
2	Reserved	
3	Measurement cable I _{C0-} , M ₀₋ : Connector X10 Measurement cable I _{C1-} , M ₁₋ : Connector X11 Measurement cable I _{C2-} , M ₂₋ : Connector X12 Measurement cable I _{C3-} , M ₃₋ : Connector X13	
4	Reserved	
5	Functional earth FE	
Shield	Functional earth FE	

Table 3- 4 Pin assignment of the sockets for analog inputs (RTD/R 3-wire connection)

Pin	Assignment	Front view of the sockets
	X10 to X13 sockets for analog inputs (RTD/R 3-wire connection)	
1	Constant current cable I_{c0+} : Connector X10 Constant current cable I_{c1+} : Connector X11 Constant current cable I_{c2+} : Connector X12 Constant current cable I_{c3+} : Connector X13	
2	Reserved	
3	Measurement cable I_{c0-} , M_{0-} : Connector X10 Measurement cable I_{c1-} , M_{1-} : Connector X11 Measurement cable I_{c2-} , M_{2-} : Connector X12 Measurement cable I_{c3-} , M_{3-} : Connector X13	
4	Measuring input M_{0+} : Connector X10 Measuring input M_{1+} : Connector X11 Measuring input M_{2+} : Connector X12 Measuring input M_{3+} : Connector X13	
5	Functional earth FE	
Shield	Functional earth FE	

NOTICE

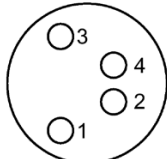
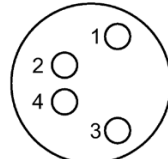
Incorrect connection of sensors at channel

If the measurement type current or voltage measurement is configured at the I/O module, a connected resistance thermometer could be destroyed.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

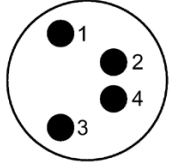
Table 3- 5 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the core color of the bus cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	yellow		
2	RXP	TXP	white		
3	RXN	TXN	blue		
4	TXN	RXN	orange		
Shield	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

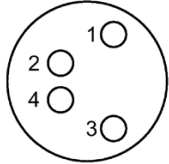
Table 3- 6 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the core color of the power cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	brown	
2	Ground 2M (switched)	white	
3	Ground 1M (non-switched)	blue	
4	Load voltage 2L+ (switched)	black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3- 7 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the core color of the power cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	brown	
2	Ground 2M (switched)	white	
3	Ground 1M (non-switched)	blue	
4	Load voltage 2L+ (switched)	black	

NOTICE

ET-Connection/supply voltage

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage. Mixing up the connector for ET-Connection and the connector for the supply voltage can destroy the module.

Parameters/address space

4.1 Measurement types and measuring ranges

The table below indicates which measuring range is configurable.

Table 4- 1 Measurement type and measuring ranges

Measurement type	Measuring range	Temperature coefficient	Resolution
Deactivated	–	–	–
Voltage	1 V to 5 V 0 V to 10 V	–	max. 16-bit
Current (4-wire transducer)	0 mA to 20 mA 4 mA to 20 mA	–	max. 16-bit
Current (2-wire transducer)	4 mA to 20 mA	–	max. 16-bit
Resistance (3-wire connection) Resistance (2-wire connection)	150 Ω , 300 Ω	–	max. 15-bit
Resistance thermometer (3-wire connection) Resistance thermometer (2-wire connection)	Pt 100 climatic range/ Pt 100 standard range	Pt 0.003850, Pt 0.003916, Pt 0.003902, Pt 0.003920, Pt 0.003851 EN 60751	max. 16-bit incl. sign
	Ni 100 climatic range/ Ni 100 standard range	Ni 0.006180, Ni 0.006720	max. 16-bit incl. sign

4.2 Parameters

Parameters of the analog input module AI 4xU/I/RTD 4xM12

The table below lists the parameters that can be set. The effective range of the parameters that can be set depends on the type of configuration. The following configurations are possible:

- Distributed operation on PROFINET IO
- Distributed operation with PROFIBUS DP

NOTICE
<p>Match of encoder and parameters</p> <p>The default setting of the analog inputs is voltage measurement (1 V to 5 V). Make sure that the connected encoders and the selected parameters match. The connected encoder can be destroyed in the case of incorrect parameters.</p>

The table below shows the PROFINET and PROFIBUS parameters for the analog input module AI 4xU/I/RTD 4xM12 for configuration with GSD file.

Explanation of abbreviations in table below:

4-DMU 4-wire transducer

2-DMU 2-wire transducer

R-3L Resistance 3-wire transducer

R-2L Resistance 2-wire transducer

RTD-3L Resistance thermometer 3-wire transducer

RTD-2L Resistance thermometer 2-wire transducer

4.2 Parameters

Table 4- 2 Configurable parameters and their defaults

Parameters	Value range	Default	GSD file PROFINET IO	GSD file PROFIBUS DP
Temperature unit	<ul style="list-style-type: none"> • Degrees Celsius • Degrees Fahrenheit • Kelvin 	Degrees Celsius	Module	Module
Measurement type/measuring range channel n	<ul style="list-style-type: none"> • Deactivated • 1 V to 5 V • 0 V to 10 V • 0 mA to 20 mA (4-DMU) • 4 mA to 20 mA (4-DMU) • 4 mA to 20 mA (2-DMU) • R-3L 150 ohm • R-3L 300 ohm • R-2L 150 ohm • R-2L 300 ohm 	1 V to 5 V	Channel	Channel

Parameters	Value range	Default	GSD file PROFINET IO	GSD file PROFIBUS DP
Measurement type/measuring range channel n	<ul style="list-style-type: none"> • RTD-3L Pt100 3851 cl. EN 60751 • RTD-3L Pt100 3851 std. EN 60751 • RTD-3L Pt100 3916 cl. • RTD-3L Pt100 3916 std. • RTD-3L Pt100 3902 cl. • RTD-3L Pt100 3902 std. • RTD-3L Pt100 392 cl. • RTD-3L Pt100 392 std. • RTD-3L Pt100 3850 cl. • RTD-3L Pt100 3850 std. • RTD-2L Pt100 3851 cl. • RTD-2L Pt100 3851 std. • RTD-2L Pt100 3916 cl. • RTD-2L Pt100 3916 std. • RTD-2L Pt100 3902 cl. • RTD-2L Pt100 3902 std. • RTD-2L Pt100 392 cl. • RTD-2L Pt100 392 std. • RTD-2L Pt100 3850 cl. • RTD-2L Pt100 3850 std. • RTD-3L Ni100 618 cl. • RTD-3L Ni100 618 std. • RTD-3L Ni100 672 cl. • RTD-3L Ni100 672 std. • RTD-2L Ni100 618 cl. • RTD-2L Ni100 618 std. • RTD-2L Ni100 672 cl. • RTD-2L Ni100 672 std. 	1 V to 5 V	Channel	Channel
Smoothing channel n	<ul style="list-style-type: none"> • None • Weak • Medium • Strong 	None	Channel	Channel
Interference frequency suppression	<ul style="list-style-type: none"> • 3600 Hz • 60 Hz • 50 Hz • 16.67 Hz 	50 Hz	Channel	Module

4.2 Parameters

Parameters	Value range	Default	GSD file PROFINET IO	GSD file PROFIBUS DP
Short-circuit to ground channel n	<ul style="list-style-type: none"> Disable Enable 	Disable	Channel	Channel
Wire break channel n	<ul style="list-style-type: none"> Disable Enable 	Disable	Channel	Channel
Diagnostics: Overflow/underflow	<ul style="list-style-type: none"> Disable Enable 	Disable	---	Module
Diagnostics: Underflow channel n	<ul style="list-style-type: none"> Disable Enable 	Disable	Channel	---
Diagnostics: Overflow channel n	<ul style="list-style-type: none"> Disable Enable 	Disable	Channel	---
Hardware interrupt high limit 1 channel n	<ul style="list-style-type: none"> Disable Enable 	Disable	Channel	---
Hardware interrupt low limit 1 channel n	<ul style="list-style-type: none"> Disable Enable 	Disable	Channel	---
Hardware interrupt high limit 2 channel n	<ul style="list-style-type: none"> Disable Enable 	Disable	Channel	---
Hardware interrupt low limit 2 channel n	<ul style="list-style-type: none"> Disable Enable 	Disable	Channel	---
High limit 1 channel n	The value range depends on the measurement type. The value range (min./max.) permitted for the measurement type is listed in the table below.		Channel	---
Low limit 1 channel n			Channel	---
High limit 2 channel n			Channel	---
Low limit 2 channel n			Channel	---

Note**Unused channels**

"Deactivate" unused inputs in the parameter assignment to shorten the cycle time of the module.

A deactivated input always returns the value 7FFF_H.

The table below shows the permitted value ranges for the measurement type.

Table 4- 3 Measuring ranges of the hardware interrupts

Measurement type	Measuring range	Low limit	High limit	Default		Unit
				Low limit	High limit	
Voltage	1 V to 5 V	0.297	5.703	1	5	V
		-4863	32510	0	27648	Decimal
	0 V to 10 V	-1.758	11.758	0	10	V
		-4863	32510	0	27648	Decimal
Current	0 mA to 20 mA	-3.51	23.51	0	20	mA
		-4863	32510	0	27648	Decimal
	4 mA to 20 mA	1.19	22.81	4	20	mA
		-4863	32510	0	27648	Decimal
Resistance	150 ohm	0.01	176.37	0.01	150	Ω
		1	32510	1	27648	Decimal
	300 ohm	0.01	352.75	0.01	300	Ω
		1	32510	1	27648	Decimal
Resistance thermometer	Pt100 cl.	-144.99	154.99	-120	130	°C
		-14499	15499	-12000	13000	Decimal
		-228.99	310.99	-184	266	F
		-22899	31099	-18400	26600	Decimal
	Ni100 cl.	-104.99	154.99	-60	130	°C
		-10499	15499	-6000	13000	Decimal
		-156.99	310.99	-76	266	F
		-15699	31099	-7600	26600	Decimal
	Pt100 std.	-242.9	999.9	-200	850	°C
		-2429	9999	-2000	8500	Decimal
		-405.3	1831.9	-328	1562	F
		-4053	18319	-3280	15620	Decimal
		30.3	1273.1	73.2	1123.2	K
		303	12731	732	11232	Decimal
	Ni100 std.	-104.9	294.9	-60	250	°C
		-1049	2949	-600	2500	Decimal
		-156.9	562.9	-76	482	F
		-1569	5629	-760	4820	Decimal
		168.3	568.1	213.2	523.2	K
		1683	5681	2132	5232	Decimal

4.3 Explanation of the parameters

Temperature unit

You use this parameter to set the temperature unit with which you want to measure the temperature.

Measurement type/measuring range channel n

You use this parameter to set the measurement type or the measuring range for acquiring the measured values.

Note

Unused channels

"Deactivate" unused channels in the parameter assignment to improve the cycle time of the module.

A deactivated channel always returns the value 7FFF_H.

Temperature coefficient (for RTD, resistance thermometer)

The temperature coefficient depends on the chemical composition of the material. In Europe, only one value is used per sensor type (default value).

The correction factor for the temperature coefficient (α value) specifies how much the resistance of a certain material changes when the temperature is raised by 1 °C.

The further values facilitate sensor-specific setting of the temperature coefficient and enhance accuracy.

Smoothing channel n

The purpose of smoothing is to filter out interferences. The greater the smoothing factor, the better the filter effect. This is technically implemented in the form of a digital filter. The smoothing can be set in 4 levels. The smoothing factor k is equal to the number of module cycles. The time constant of the smoothing filter is the product of the smoothing factor k and the cycle time of the I/O module. The greater the smoothing, the greater the time constant of the filter.

Smoothing time = number of module cycles (k) × cycle time of the module.

The following figure shows how many module cycles it takes for the smoothed analog value to approach 100%, depending on the configured smoothing. This is valid for all signal changes at the analog input.

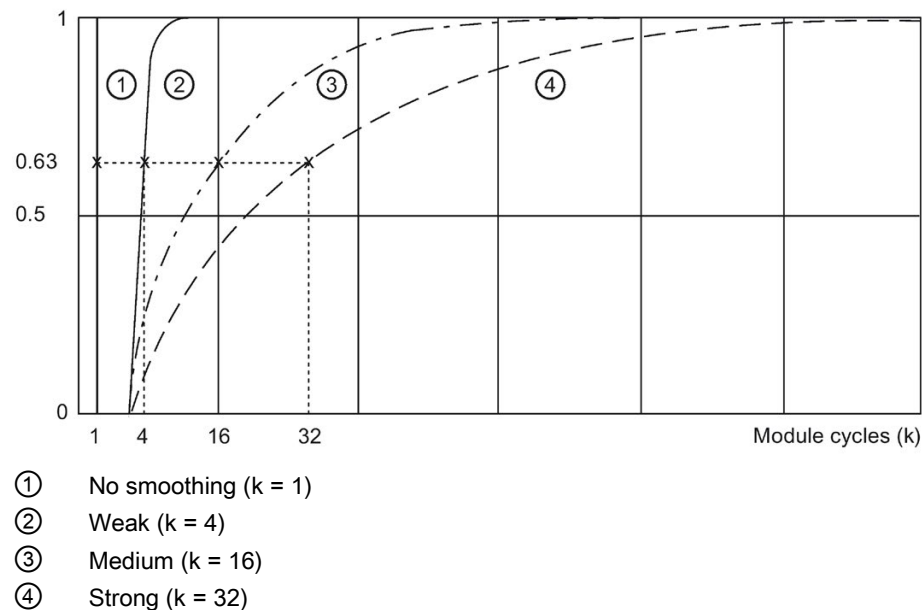


Figure 4-1 Smoothing

Interference frequency suppression channel n

This parameter suppresses interference for analog input modules which is caused by the frequency of the alternating voltage network in use.

The frequency of the alternating voltage network may negatively affect the measured value, in particular when measuring in the low voltage range and with thermocouples. With this parameter, the user specifies the line frequency that is predominant in the plant.

Diagnostics: Short-circuit to ground channel n

Enabling of the diagnostics if a short-circuit of the encoder supply to ground occurs.

4.3 Explanation of the parameters

Diagnostics: Wire break channel n

Enabling of the diagnostics if the analog input module has no current flow or the current is too weak for measurement at the correspondingly configured input.

Note

Wire break diagnostics

A wire break diagnostics is not possible for all measuring ranges and measurement types for analog input channels.

The table below shows the rules you must observe in the case of a wire break in the measuring ranges 1 to 5, 4 to 20 mA:

Table 4- 4 Parameters for wire break

Parameter	Event	Measured value	Explanation
Wire break enabled ¹	Wire break	7FFF _H	Wire break diagnostics
Wire break disabled ¹	Wire break	8000 _H	Measured value after leaving the under-range
Underflow enabled			Diagnostics alarm Low limit violated
Wire break disabled ¹ Underflow disabled	Wire break	8000 _H	Measured value after leaving the under-range
¹ Measuring range limits for detection of wire break and measuring range undershoot: <ul style="list-style-type: none"> • 1 V to 5 V: at 0.296 V • 4 mA to 20 mA: at 1.185 mA 			

The table below shows the diagnostics that can occur for wire break with the measurement type RTD/R.

Table 4- 5 Diagnostics with RTD/R

Diagnostics: Wire break	Diagnostics: Overflow	Diagnostics: Underflow*	Event	Process data	Diagnostics alarm per channel
activated	Deactivated	Deactivated	Wire break	0x7FFF	Wire break
Deactivated	Deactivated	Activated	Wire break	0x7FFF	-
Deactivated	Activated	Deactivated	Wire break	0x7FFF	High limit exceeded
Deactivated	Activated	Activated	Wire break	0x7FFF	High limit undershot
Deactivated	Deactivated	Deactivated	Wire break	0x7FFF	-

* This column does not apply to the measurement type resistance.

Diagnostics: Underflow channel n

Enabling of the diagnostics when the measured value falls below the underrange.

Diagnostics: Overflow channel n

Enabling of the diagnostics when the measured value exceeds the overrange.

Diagnostics: Overflow/Underflow (for PROFIBUS only)

Enabling of the diagnostics when the measured value exceeds the overrange or falls below the underrange.

The diagnostic enable has an effect on all channels.

Hardware interrupt high/low limit 1 or 2 channel n

Enabling of a hardware interrupt when the high limit 1 or 2 or the low limit 1 or 2 is violated.

Requirement: An OB 4x must be assigned to the CPU/device.

Additional information on the structure of hardware interrupts is available in the section Interrupts (Page 31).

High/low limit 1 or 2 channel n

Specify a threshold at which a hardware interrupt is triggered when it is exceeded or undershot.

4.4 Address space

The figure below shows the assignment of the address space for the analog input module AI 4xU/I/RTD 4xM12 with value status (Quality Information, QI). If you are using PROFINET and the value status was enabled, the addresses for the value status are available. The value status is not available for PROFIBUS.

Assignment in the process image input (PII)

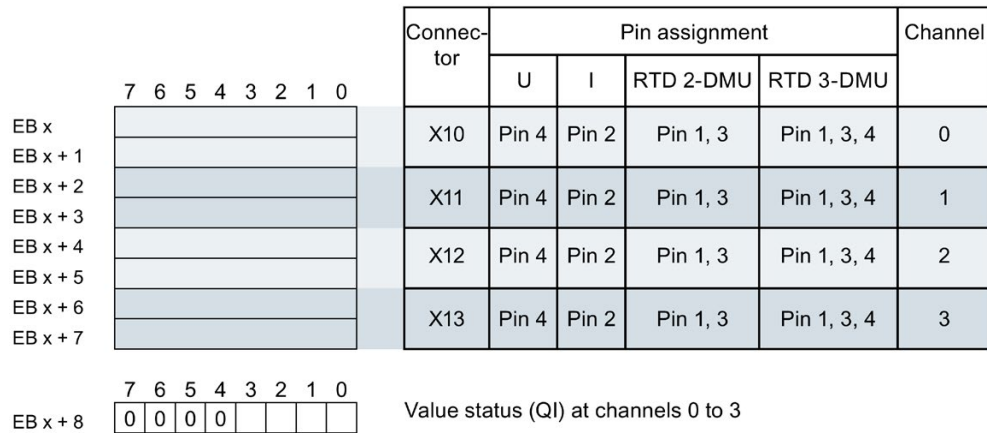


Figure 4-2 Address space

Configuration options of analog input module AI 4xU/I/RTD 4xM12

You have the following configuration options:

- Configuration 1: without value status
- Configuration 2: with value status

Evaluating the value status

If you enable the value status for the analog input module, a bit is also assigned in the input address space. Bits 0 to 3 in this byte are assigned to a channel and provide information on the validity of the analog value. The value status is independent of whether or not diagnostics was configured.

Bit = 1: No error on channel.

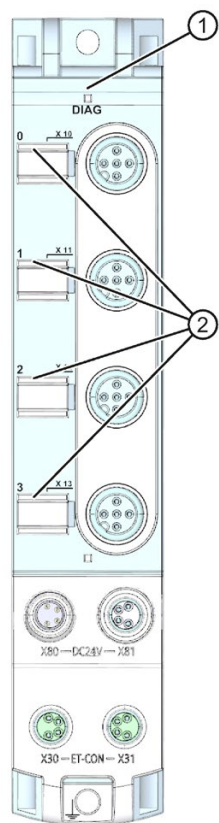
Bit = 0: Error on channel.

Interrupts/diagnostics alarms

5.1 Status and error displays

LED displays

The figure below shows the LED display (status and error displays) of the analog input module AI 4xU/I/RTD 4xM12.



- ① Diagnostic status (DIAG) (red/green)
- ② Channel status (0, 1, 2 and 3) (green)





Figure 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Corrective measures for diagnostics alarms can be found in the section Diagnostics alarms (Page 34).



DIAG LED

Table 5- 1 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> • Module parameters not assigned • Loading firmware (while the firmware update is being performed, all LEDs retain their current status)
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics

LED for the channel status

Table 5- 2 Status display of the LEDs 0, 1, 2 and 3

LED 0, 1, 2 and 3	Meaning
 Off	<ul style="list-style-type: none"> • Channel deactivated • Channel activated and incorrect parameter assignment • Parameter error possible with GSD
 On	<ul style="list-style-type: none"> • Channel activated and correct parameter assignment

5.2 Interrupts

Analog input module AI 4xU//RTD 4xM12 supports the following diagnostic and hardware interrupts.

Diagnostic interrupt

The table below shows the events for which the analog input module returns a diagnostic interrupt, depending on the parameter assignment.

Table 5- 3 Diagnostic interrupts

Measurement type	Measuring range	Diagnostics				
		Short-circuit to ground	Wire break	Underflow ¹	Overflow ¹	Underflow/ Overflow ²
Voltage	1 V to 5 V	x	x	x	x	x
	0 V to 10 V	x	-	x	x	x
Current	2-DMU 4 mA to 20 mA	x	x	x	x	x
	4-DMU 0 mA to 20 mA	x	-	x	x	x
	4-DMU 4 mA to 20 mA	x	x	x	x	x
Resistance	150 Ω	-	x	-	x	x
	300 Ω	-	x	-	x	x
Resistance thermometer	PT100	-	x	x	x	x
	Ni100	-	x	x	x	x

¹ Column valid for configuration with PROFINET GSD file

² Column valid for configuration with PROFIBUS GSD file

Hardware interrupt

The analog input module generates a hardware interrupt with the following events:

- Low limit 1 violated
- High limit 1 violated
- Low limit 2 violated
- High limit 2 violated

Detailed information on the event is available in the hardware interrupt organization block with the instruction "RALRM" (Read additional interrupt information) and in the STEP 7 online help.

The start information of the organization block includes information on which channel of the analog input module triggered the hardware interrupt.

Note

Violation of two limits

If two limits are violated at the same time, limit 1 is always signaled first, followed by limit 2.

The figure below shows the assignment to the bits of the local data double word 8.

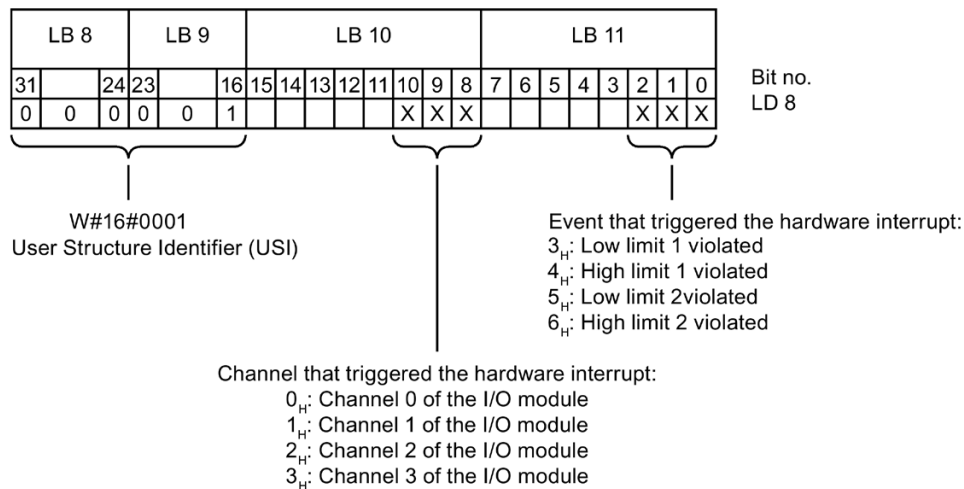


Figure 5-2 Start information of the organization block

Structure of the additional interrupt information

Table 5- 4 Structure of USI = W#16#0001

Data block name	Contents	Comment	Bytes
USI (User Structure Identifier)	W#16#0001	Additional interrupt info for hardware interrupts of the I/O module	2
The channel that triggered the hardware interrupt follows.			
Channel	B#16#00 to B#16#03	Number of channel which triggered the event	1
The error event that triggered the hardware interrupt follows.			
Event	B#16#03	Low limit 1 violated	1
	B#16#04	High limit 1 violated	
	B#16#05	Low limit 2 violated	
	B#16#06	High limit 2 violated	

5.3 Diagnostics alarms

A diagnostics alarm is output for each diagnostic event and the DIAG LED flashes red on the analog input module. You can read out the diagnostics alarms, for example, in the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

The following tables set out the diagnostics alarms for the set measuring range.

Table 5- 5 Diagnostics alarms - for the measuring range: 1 V to 5 V, 2-DMU 4 mA to 20 mA and 4-DMU 4 mA to 20 mA

Diagnostics alarm	Error code	Meaning	Remedy
Short-circuit	1H	Short-circuit encoder supply to ground	Correct interplay between module and encoder
Wire break	6H	Wire break between the module and sensor	Connect the cable
		Channel not connected (open)	<ul style="list-style-type: none"> • Deactivate diagnostics • Connect the channel • Deactivate channel
High limit violated	7H	Value is above overrange.	Correct interplay between module and sensor
Low limit violated	8H	Value is below underrange.	Correct interplay between module and sensor
Error	9H	Value is significantly above or below underrange/overrange.	Correct interplay between module and sensor
Parameter error	10H	Module parameter assignment is faulty	Correct the parameter assignment
Hardware interrupt lost	16H	At least one hardware interrupt could not be signaled because too many hardware interrupts are pending.	Correct the program or the process

Table 5- 6 Diagnostics alarms - for the measuring range: 0 V to 10 V and 4-DMU 0 mA to 20 mA

Diagnostics alarm	Error code	Meaning	Remedy
Short-circuit	1 _H	Short-circuit encoder supply to ground	Correct interplay between module and encoder
High limit violated	7 _H	Value is above overrange.	Correct interplay between module and sensor
Low limit violated	8 _H	Value is below underrange.	Correct interplay between module and sensor
Error	9 _H	Value is significantly above or below underrange/overrange.	Correct interplay between module and sensor
Parameter error	10 _H	Module parameter assignment is faulty	Correct the parameter assignment
Hardware interrupt lost	16 _H	At least one hardware interrupt could not be signaled because too many hardware interrupts are pending.	Correct the program or the process

Table 5- 7 Diagnostics alarms - for the measuring range: 150 Ω and 300 Ω

Diagnostics alarm	Error code	Meaning	Remedy
Wire break	6 _H	Impedance of encoder circuit too high	Use a different encoder type or modify the wiring, for example, using cables with larger cross-section
		Wire break between the module and sensor	Connect the cable
		Channel not connected (open)	<ul style="list-style-type: none"> • Deactivate diagnostics • Connect the channel • Deactivate channel
High limit violated	7 _H	Value is above overrange.	Correct interplay between module and sensor
Parameter error	10 _H	Module parameter assignment is faulty	Correct the parameter assignment
Hardware interrupt lost	16 _H	At least one hardware interrupt could not be signaled because too many hardware interrupts are pending.	Correct the program or the process

Table 5- 8 Diagnostics alarms - for the measuring range: Pt100 and Ni100

Diagnostics alarm	Error code	Meaning	Remedy
Wire break	6 _H	Impedance of encoder circuit too high	Use a different encoder type or modify the wiring, for example, using cables with larger cross-section
		Wire break between the module and sensor	Connect the cable
		Channel not connected (open)	<ul style="list-style-type: none"> • Deactivate diagnostics • Connect the channel • Deactivate channel
High limit violated	7 _H	Value is above overrange.	Correct interplay between module and sensor
Low limit violated	8 _H	Value is below underrange.	Correct interplay between module and sensor
Parameter error	10 _H	Module parameter assignment is faulty	Correct the parameter assignment
Hardware interrupt lost	16 _H	At least one hardware interrupt could not be signaled because too many hardware interrupts are pending.	Correct the program or the process

Technical specifications

Technical specifications of the analog input module AI 4xU/I/RTD 4xM12

The following table shows the technical specifications as of 05/2019. You will find a data sheet including daily updated technical specifications on the Internet (<https://support.industry.siemens.com/cs/ww/en/pv/6ES7144-5KD00-0BA0/td?dl=en>).

Article number	6ES7144-5KD00-0BA0
General information	
Product type designation	AI 4xU/I/RTD
HW functional status	FS04
Firmware version	V1.0.x
Product function	
<ul style="list-style-type: none"> I&M data 	Yes; I&M0 to I&M3
Engineering with	
<ul style="list-style-type: none"> STEP 7 TIA Portal configurable/integrated as of version 	STEP 7 V13 SP1 or higher
<ul style="list-style-type: none"> STEP 7 configurable/integrated as of version 	From V5.5 SP4 Hotfix 3
<ul style="list-style-type: none"> PROFIBUS as of GSD version/GSD revision 	GSD as of Revision 5
<ul style="list-style-type: none"> PROFINET as of GSD version/GSD revision 	GSDML V2.3.1
Supply voltage	
Load voltage 1L+	
<ul style="list-style-type: none"> Rated value (DC) 	24 V
<ul style="list-style-type: none"> permissible range, lower limit (DC) 	20.4 V
<ul style="list-style-type: none"> permissible range, upper limit (DC) 	28.8 V
<ul style="list-style-type: none"> Reverse polarity protection 	Yes; against destruction
Input current	
Current consumption (rated value)	35 mA; without load
from load voltage 1L+ (unswitched voltage)	4 A; Maximum value
from load voltage 2L+, max.	4 A; Maximum value
Encoder supply	
Number of outputs	4

Article number	6ES7144-5KD00-0BA0
24 V encoder supply	
<ul style="list-style-type: none"> Short-circuit protection Output current, max. 	<p>Yes; per channel, electronic</p> <p>0.5 A; Per channel, total current of all channels max. 1 A</p>
Power loss	
Power loss, typ.	1.5 W
Analog inputs	
Number of analog inputs	4
<ul style="list-style-type: none"> For current measurement For voltage measurement For resistance/resistance thermometer measurement 	<p>4</p> <p>4</p> <p>4</p>
permissible input voltage for voltage input (destruction limit), max.	30 V
permissible input current for current input (destruction limit), max.	50 mA
Cycle time (all channels), min.	8 ms
Technical unit for temperature measurement adjustable	Yes; Degrees Celsius / degrees Fahrenheit / Kelvin
Input ranges (rated values), voltages	
<ul style="list-style-type: none"> 0 to +10 V Input resistance (0 to 10 V) 1 V to 5 V Input resistance (1 V to 5 V) 	<p>Yes</p> <p>10 MΩ</p> <p>Yes</p> <p>10 MΩ</p>
Input ranges (rated values), currents	
<ul style="list-style-type: none"> 0 to 20 mA Input resistance (0 to 20 mA) 4 mA to 20 mA Input resistance (4 mA to 20 mA) 	<p>Yes</p> <p>50 Ω</p> <p>Yes</p> <p>50 Ω</p>
Input ranges (rated values), resistance thermometer	
<ul style="list-style-type: none"> Ni 100 Input resistance (Ni 100) Pt 100 Input resistance (Pt 100) 	<p>Yes; Standard/climate</p> <p>10 MΩ</p> <p>Yes; Standard/climate</p> <p>10 MΩ</p>

Article number	6ES7144-5KD00-0BA0
Input ranges (rated values), resistors	
<ul style="list-style-type: none"> • 0 to 150 ohms 	Yes
<ul style="list-style-type: none"> • Input resistance (0 to 150 ohms) 	10 MΩ
<ul style="list-style-type: none"> • 0 to 300 ohms 	Yes
<ul style="list-style-type: none"> • Input resistance (0 to 300 ohms) 	10 MΩ
Cable length	
<ul style="list-style-type: none"> • shielded, max. 	30 m
Analog value generation for the inputs	
Measurement principle	integrating
Integration and conversion time/resolution per channel	
<ul style="list-style-type: none"> • Resolution with overrange (bit including sign), max. 	16 bit
<ul style="list-style-type: none"> • Integration time, parameterizable 	Yes; channel by channel
<ul style="list-style-type: none"> • Integration time (ms) 	0,3 / 16,7 / 20 / 60
<ul style="list-style-type: none"> • Interference voltage suppression for interference frequency f1 in Hz 	3 600 / 60 / 50 / 16.7
<ul style="list-style-type: none"> • Conversion time (per channel) 	2 / 18 / 21 / 61 ms
Smoothing of measured values	
<ul style="list-style-type: none"> • parameterizable 	Yes
<ul style="list-style-type: none"> • Step: None 	Yes; 1x cycle time
<ul style="list-style-type: none"> • Step: low 	Yes; 4x cycle time
<ul style="list-style-type: none"> • Step: Medium 	Yes; 16x cycle time
<ul style="list-style-type: none"> • Step: High 	Yes; 32x cycle time
Encoder	
Connection of signal encoders	
<ul style="list-style-type: none"> • for voltage measurement 	Yes
<ul style="list-style-type: none"> • for current measurement as 2-wire transducer 	Yes
<ul style="list-style-type: none"> • for current measurement as 4-wire transducer 	Yes
<ul style="list-style-type: none"> • for resistance measurement with two-wire connection 	Yes
<ul style="list-style-type: none"> • for resistance measurement with three-wire connection 	Yes

Article number	6ES7144-5KD00-0BA0
Errors/accuracies	
Linearity error (relative to input range), (+/-)	0.025 %
Temperature error (relative to input range), (+/-)	0.01 %/K
Crosstalk between the inputs, max.	-70 dB
Repeat accuracy in steady state at 25 °C (relative to input range), (+/-)	0.01 %
Operational error limit in overall temperature range	
<ul style="list-style-type: none"> Voltage, relative to input range, (+/-) Current, relative to input range, (+/-) Resistance, relative to input range, (+/-) Resistance thermometer, relative to input range, (+/-) 	<ul style="list-style-type: none"> 0.35 % 0.45 % 0.25 % 0.25 %
Basic error limit (operational limit at 25 °C)	
<ul style="list-style-type: none"> Voltage, relative to input range, (+/-) Current, relative to input range, (+/-) Resistance, relative to input range, (+/-) Resistance thermometer, relative to input range, (+/-) 	<ul style="list-style-type: none"> 0.25 % 0.25 % 0.15 % 0.15 %
Interference voltage suppression for $f = n \times (f_1 \pm 0.5 \%)$, $f_1 =$ interference frequency	
<ul style="list-style-type: none"> Series mode interference (peak value of interference < rated value of input range), min. 	40 dB
Interrupts/diagnostics/status information	
Alarms	
<ul style="list-style-type: none"> Diagnostic alarm Limit value alarm 	<ul style="list-style-type: none"> Yes; Parameterizable Yes; Parameterizable
Diagnostic messages	
<ul style="list-style-type: none"> Wire-break Short-circuit Overflow/underflow 	<ul style="list-style-type: none"> Yes; at 4 mA to 20 mA and 1 V to 5 V Yes; Encoder supply to M, channel by channel Yes
Diagnostics indication LED	
<ul style="list-style-type: none"> Channel status display for module diagnostics 	<ul style="list-style-type: none"> Yes; Green LED Yes; Green/red LED
Potential separation	
between the load voltages	Yes

Article number	6ES7144-5KD00-0BA0
Potential separation channels	
<ul style="list-style-type: none"> • between the channels 	No
<ul style="list-style-type: none"> • between the channels and backplane bus 	Yes
<ul style="list-style-type: none"> • between the channels and the power supply of the electronics 	No
Isolation	
Isolation tested with	707 V DC (type test)
Degree and class of protection	
IP degree of protection	IP65/67
Standards, approvals, certificates	
Suitable for safety-related tripping of standard modules	Yes; From FS02
Highest safety class achievable for safety-related tripping of standard modules	
<ul style="list-style-type: none"> • Performance level according to ISO 13849-1 	PL d
<ul style="list-style-type: none"> • Category according to ISO 13849-1 	Cat. 3
<ul style="list-style-type: none"> • SILCL according to IEC 62061 	SILCL 2
Ambient conditions	
Ambient temperature during operation	
<ul style="list-style-type: none"> • min. 	-30 °C
<ul style="list-style-type: none"> • max. 	55 °C
Connection method	
Design of electrical connection for the inputs and outputs	M12, 5-pole
Design of electrical connection for supply voltage	M8, 4-pole
ET-Connection	
<ul style="list-style-type: none"> • ET-Connection 	M8, 4-pin, shielded
Dimensions	
Width	30 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	168 g

PROFenergy

7.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific response of the analog input module is explained in the section below.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<http://support.automation.siemens.com/WW/view/en/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V13 (<http://support.automation.siemens.com/WW/view/en/49948856>).

Application examples (<http://support.automation.siemens.com/WW/view/en/41986454>) are also available on the Internet.

7.2 Response of the analog input module

Requirement

You can use the PROFenergy function when you use the internal encoder supply.

Display

The channel status LEDs are not affected by PROFenergy.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- Encoder supply switch-off upon the start of "pause" does not result in the alarm "Wire break".
- "Wire break", "Short circuit", "High limit violated" and "Low limit violated" error detection is not possible during the "pause":
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.
- Hardware interrupts are not signaled.

Mode parameter

The following table shows the "Mode" parameter.

Table 7- 1 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> Encoder supply U_S switched off ¹ Pause substitute value: 7FFF_H Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> Encoder supply U_S switched off ¹ Pause substitute value: Last input value Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> Encoder supply U_S switched off ¹ Pause substitute value: Configured pause substitute value Value status "BAD"

¹ Encoder supply U_S is only provided for measurement type current and voltage and can only be deactivated in these measurement types.

Dimension drawing

The figure below shows the dimension drawing of the AI 4xU/I/RTD 4xM12 analog input module in front and side view.

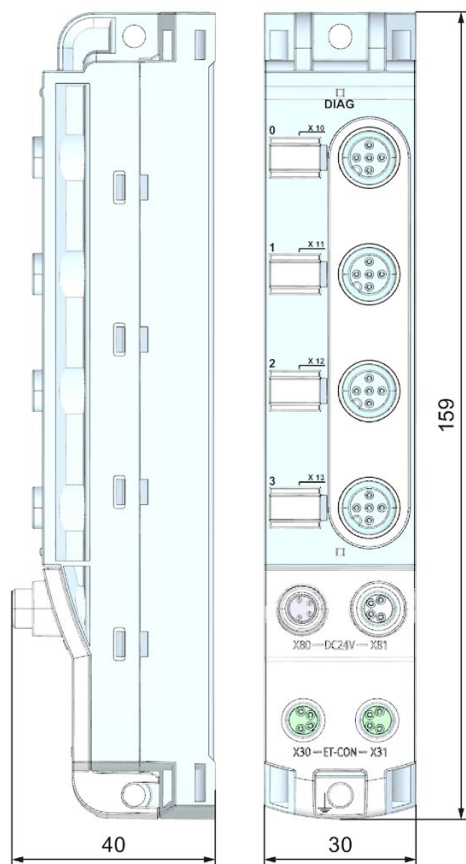


Figure A-1 Dimension drawing

Representation of analog values

B.1 Representation of analog values in voltage measuring ranges

Table B- 1 Voltage measuring range 1 V to 5 V and 0 V to 10 V

Values		Voltage measuring range		Range
Dec.	Hex.	1 V to 5 V	0 V to 10 V	
32767	7FFF	>5.704 V	>11.759 V	Overflow
32511	7EFF	5.704 V	11.759 V	Overrange
27649	6C01			
27648	6C00	5 V	10 V	Nominal range
20736	5100	4 V	7.5 V	
1	1	1 V + 144.7 μ V	0 V + 361.7 μ V	
0	0	1 V	0 V	
-1	FFFF			Underrange
-4864	ED00	0.296 V	-1.759	
-32768	8000	<0.296 V	< -1.759	Underflow

B.2 Representation of analog values in current measuring ranges

Table B- 2 Current measuring ranges 0 mA to 20 mA and 4 mA to 20 mA

Values		Current measuring range		Range
Dec.	Hex.	0 mA to 20 mA	4 mA to 20 mA	
32767	7FFF	>23.52 mA	>22.81 mA	Overflow
32511	7EFF	23.52 mA	22.81 mA	Overrange
27649	6C01			
27648	6C00	20 mA	20 mA	Nominal range
20736	5100	15 mA	16 mA	
1	1	723.4 nA	4 mA + 578.7 nA	
0	0	0 mA	4 mA	
-1	FFFF			Underrange
-4864	ED00	-3.52 mA	1.185 mA	
-32768	8000	<-3.52 mA	<1.185 mA	Underflow

B.3 Representation of analog values for resistance-based sensors

Resistance-based sensor

Table B- 3 Resistance-based sensor of 150 Ω and 300 Ω

Values		Resistance-based sensor range		Range
Dec.	Hex.	150 Ω	300 Ω	
32767	7FFF	>176.38 Ω	>352.77 Ω	Overflow
32511	7EFF	176.38 Ω	352.77 Ω	Overrange
27649	6C01			
27648	6C00	150 Ω	300 Ω	Nominal range
20736	5100	112.5 Ω	225 Ω	
1	1	5.43 m Ω	10.85 m Ω	
0	0	0 Ω	0 Ω	
-1 : -4864	FFFF : ED00	(negative values are physically impossible)		Underrange ¹
-32768	8000			Underflow ¹

¹ If the sensors are not connected correctly

B.4 Representation of analog values for resistance thermometer

Table B- 4 Resistance thermometer Pt 100 standard

Pt x00 standard in $^{\circ}\text{C}$ (1 digit = 0.1 $^{\circ}\text{C}$)	Values		Pt x00 standard in $^{\circ}\text{F}$ (1 digit = 0.1 $^{\circ}\text{F}$)	Values		Pt x00 standard in K (1 digit = 0.1 K)	Values		Range
	Dec.	Hex.		Dec.	Hex.		Dec.	Hex.	
>1000.0	32767	7FFF	>1832.0	32767	7FFF	>1273.2	32767	7FFF	Overflow
1000.0	10000	2710	1832.0	18320	4790	1273.2	12732	31BC	Overrange
:	:	:	:	:	:	:	:	:	
850.1	8501	2135	1562.1	15621	3D05	1123.3	11233	2BE1	Nominal range
850.0	8500	2134	1562.0	15620	3D04	1123.2	11232	2BE0	
:	:	:	:	:	:	:	:	:	
-200.0	-2000	F830	-328.0	-3280	F330	73.2	732	2DC	
-200.1	-2001	F82F	-328.1	-3281	F32F	73.1	731	2DB	Underrange
:	:	:	:	:	:	:	:	:	
-243.0	-2430	F682	-405.4	-4054	F02A	30.2	302	12E	
<-243.0	-32768	8000	<-405.4	-32768	8000	<30.2	32768	8000	Underflow

Representation of analog values

B.4 Representation of analog values for resistance thermometer

Table B- 5 Resistance thermometer Pt 100 climatic

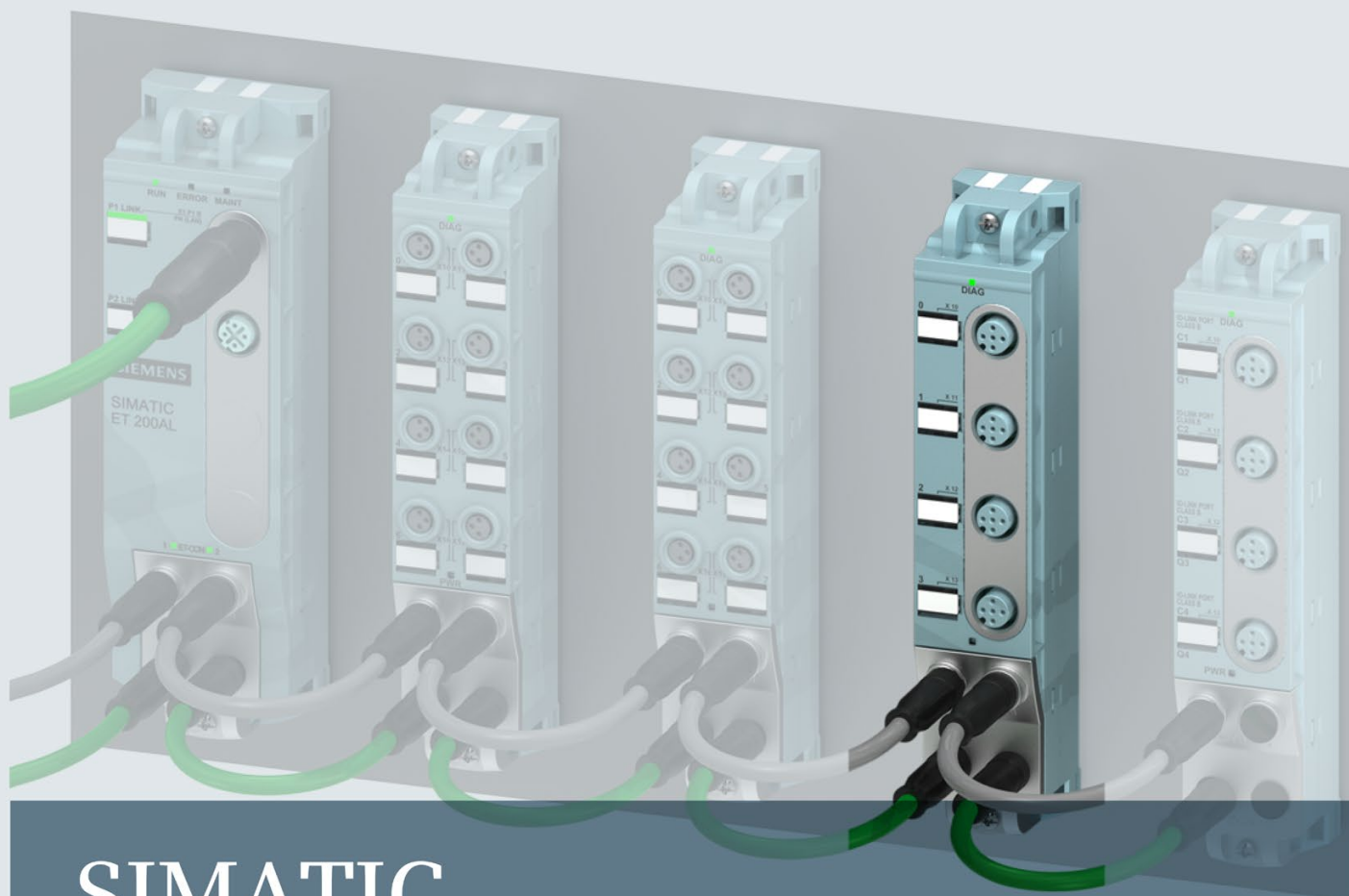
Pt x00 climatic in °C (1 digit = 0.01 °C)	Values		Pt x00 climatic in °F (1 digit = 0.01 °F)	Values		Range
	Dec.	Hex.		Dec.	Hex.	
>155.00	32767	7FFF	>311.00	32767	7FFF	Overflow
155.00	15500	3C8C	311.00	31100	797C	Overrange
:	:	:	:	:	:	
130.01	13001	32C9	266.01	26601	67E9	
130.00	13000	32C8	266.00	26600	67E8	Nominal range
:	:	:	:	:	:	
-120.00	-12000	D120	-184.00	-18400	B820	
-120.01	-12001	D11F	-184.01	-18401	B81F	Underrange
:	:	:	:	:	:	
-145.00	-14500	C75C	-229.00	-22900	A68C	
<-145.00	-32768	8000	<-229.00	-32768	8000	Underflow

Table B- 6 Resistance thermometer Ni 100 standard

Ni x00 standard in °C (1 digit = 0.1 °C)	Values		Ni x00 standard in °F (1 digit = 0.1 °F)	Values		Ni x00 standard in K (1 digit = 0.1 K)	Values		Range
	Dec.	Hex.		Dec.	Hex.		Dec.	Hex.	
>295.0	32767	7FFF	>563.0	32767	7FFF	>568.2	32767	7FFF	Overflow
295.0	2950	B86	563.0	5630	15FE	568.2	5682	1632	Overrange
:	:	:	:	:	:	:	:	:	
250.1	2501	9C5	482.1	4821	12D5	523.3	5233	1471	
250.0	2500	9C4	482.0	4820	12D4	523.2	5232	1470	Nominal range
:	:	:	:	:	:	:	:	:	
-60.0	-600	FDA8	-76.0	-760	FD08	213.2	2132	854	
-60.1	-601	FDA7	-76.1	-761	FD07	213.1	2131	853	Underrange
:	:	:	:	:	:	:	:	:	
-105.0	-1050	FBE6	-157.0	-1570	F9DE	168.2	1682	692	
<-105.0	-32768	8000	<-157.0	-32768	8000	<168.2	32768	8000	Underflow

Table B- 7 Resistance thermometer Ni 100 climatic

Ni x00 climatic in °C (1 digit = 0.01 °C)	Values		Ni x00 climatic in °F (1 digit = 0.01 °F)	Values		Range
	Dec.	Hex.		Dec.	Hex.	
>155.00	32767	7FFF	>311.00	32767	7FFF	Overflow
155.00	15500	3C8C	311.00	31100	797C	Overrange
:	:	:	:	:	:	
130.01	13001	32C9	266.01	26601	67E9	Nominal range
130.00	13000	32C8	266.00	26600	67E8	
:	:	:	:	:	:	Underrange
-60.00	-6000	E890	-76.00	-7600	E250	
-60.01	-6001	E88F	-76.01	-7601	E24F	Underflow
:	:	:	:	:	:	
-105.00	-10500	D6FC	-157.00	-15700	C2AC	
<-105.00	-32768	8000	<-157.00	-32768	8000	



SIMATIC

ET 200AL

Analog output module AQ 4xUI/4xM12 (6ES7145-5ND00-0BA0)

Manual

Edition

07/2019

SIEMENS

SIMATIC

ET 200AL Analog output module AQ 4xU/I 4xM12 (6ES7145-5ND00-0BA0)

Manual

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Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Changes compared to the previous version

Compared to the previous version, this manual contains the following adaptations in the section Technical specifications (Page 24).

Conventions

Please also observe notes marked as follows:

Note

A note contains important information on the product described in the documentation and on the handling of the product to which particular attention should be paid.

See also

ET 200AL Documentation Guide (Page 6)

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

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To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed visit (<https://www.siemens.com/industrialsecurity>).

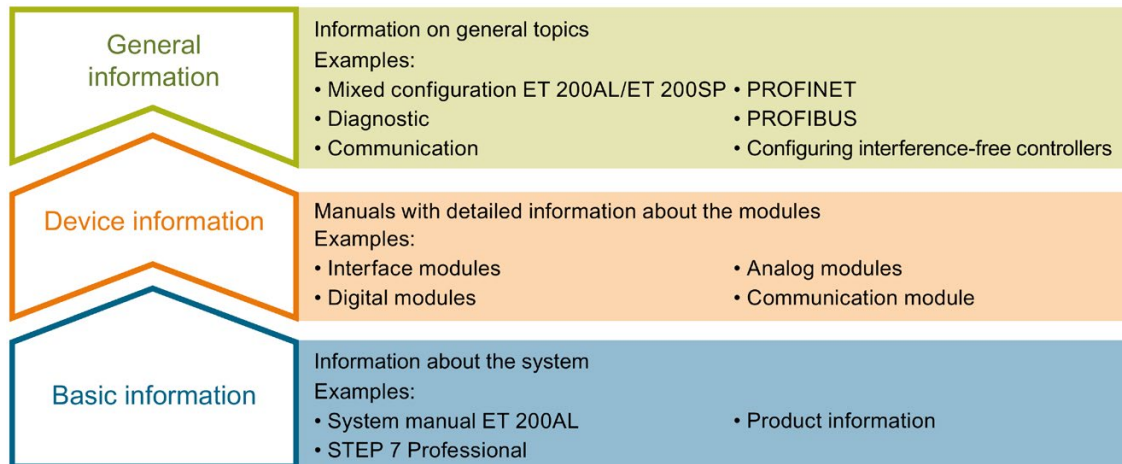
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ET 200AL Documentation Guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742667>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<https://support.automation.siemens.com/WW/view/en/95242965>).

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You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

Product overview

2.1 Properties

Article number

6ES7145-5ND00-0BA0

View of the module

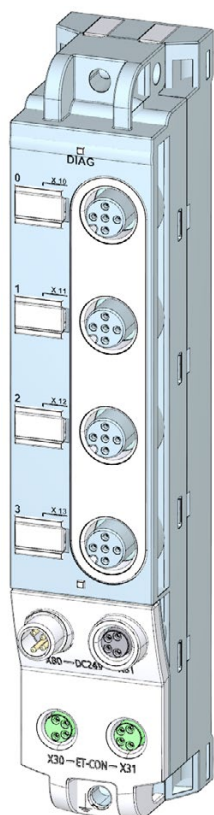


Figure 2-1 View of the analog output module AQ 4xU/I 4xM12

Properties

The module has the following technical properties:

- 4 analog outputs
- M12 sockets for connection of actuators
- Voltage output can be set for each channel
- Current output can be set for each channel
- Resolution: 16-bit
- Dimensions 30 x 159 mm
- Configurable diagnostics can be set for each channel

The module supports the following functions:

- Firmware update
- Identification and maintenance data I&M0 to I&M3
- Value status (Quality Information)
- PROFIenergy

Accessories

The following components are included in the module package:

- Identification labels
- Spacers

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

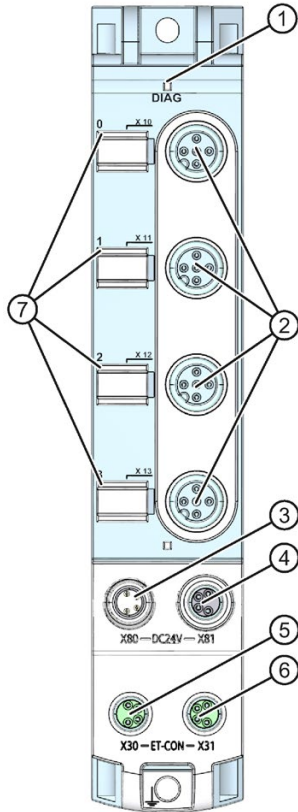
See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system

(<https://support.industry.siemens.com/cs/us/en/view/89254965>) system manual.

2.2 Operator controls and display elements

The figure below shows the operator controls and display elements of the AQ 4xU/I 4xM12 analog output module.



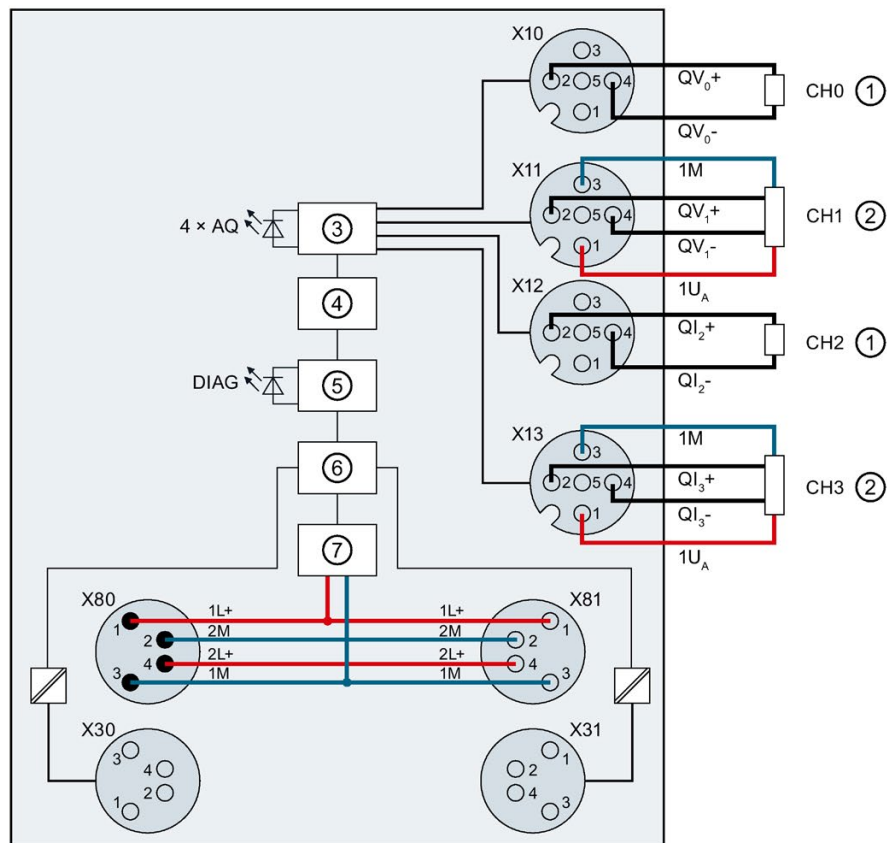
- ① DIAG: LED display for the diagnostic status
- ② X10 to X13: Sockets for the output signal
- ③ X80: Connector for infeed of the supply voltage (POWER input)
- ④ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑤ X30: Socket for ET-Connection IN
- ⑥ X31: Socket for ET-Connection OUT
- ⑦ LED displays 0 to 3 for the channel status

Figure 2-2 Operator controls and display elements

Wiring

3.1 Terminal and block diagram

The example in the following figure shows the pin assignment for voltage and current output of the analog output module AQ 4xU/I 4xM12.



①	Voltage/current output as 2-wire connection	X31	Loop-through of the ET-Connection
②	Voltage/current output as 4-wire connection	1L+	Supply voltage 1L+ (non-switched)
③	Output driver	1M	Ground 1M (non-switched)
④	Digital-to-analog converter (DAC)	2L+	Load voltage 2L+ (switched)
⑤	Microcontroller	2M	Ground 2M (switched)
⑥	ET-Connection interface	1U _A	24 V actuator supply
⑦	Internal supply voltage	QV _n /QI _n +	Voltage/current output positive, channel n
X10 to X13	Channels 0 to 3	QV _n /QI _n -	Voltage/current output negative, channel n
X80	Infeed of supply voltages	AQ	Channel status LEDs (0, 1, 2 and 3) (green)
X81	Loop-through of supply voltages	DIAG	Diagnostic status LED (red/green)
X30	Infeed of the ET-Connection		

Figure 3-1 Terminal and block diagram for voltage and current output

3.2 Pin assignment

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

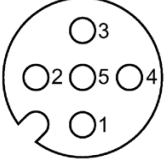
Pin assignment of the sockets for analog outputs

The tables below show the pin assignments of the 4 sockets for connection of the analog outputs.

Table 3- 1 Pin assignment of the sockets for analog outputs (voltage output)

Pin	Assignment	Front view of the sockets
	X10 to X13 - sockets for analog outputs (voltage output)	
1	24 V actuator supply 1U _A (derived from 1L+ Non-Switched)	
2	Voltage output positive QV ₀₊ : Connector X10 Voltage output positive QV ₁₊ : Connector X11 Voltage output positive QV ₂₊ : Connector X12 Voltage output positive QV ₃₊ : Connector X13	
3	Ground for actuator supply 1M	
4	Voltage output negative QV ₀₋ : Connector X 10 Voltage output negative QV ₁₋ : Connector X11 Voltage output negative QV ₂₋ : Connector X12 Voltage output negative QV ₃₋ : Connector X13	
5	Functional earth FE	
Shield	Functional earth FE	

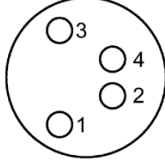
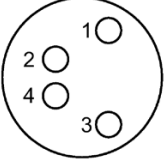
Table 3- 2 Pin assignment of the sockets for analog outputs (current output)

Pin	Assignment	Front view of the sockets
	X10 to X13 - sockets for analog outputs (current output)	
1	24 V actuator supply 1U _A (derived from 1L+ Non-Switched)	
2	Current output positive QI ₀ +: Connector X10 Current output positive QI ₁ +: Connector X11 Current output positive QI ₂ +: Connector X12 Current output positive QI ₃ +: Connector X13	
3	Ground for actuator supply 1M	
4	Current output negative QI ₀ -: Connector X10 Current output negative QI ₁ -: Connector X11 Current output negative QI ₂ -: Connector X12 Current output negative QI ₃ -: Connector X13	
5	Functional earth FE	
Shield	Functional earth FE	

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

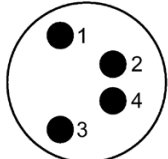
Table 3- 3 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the core color of the bus cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	yellow		
2	RXP	TXP	white		
3	RXN	TXN	blue		
4	TXN	RXN	orange		
Shield	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

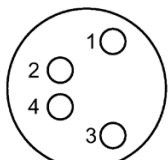
Table 3- 4 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the core color of the power cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	brown	
2	Ground 2M (switched)	white	
3	Ground 1M (non-switched)	blue	
4	Load voltage 2L+ (switched)	black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3- 5 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the core color of the power cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	brown	
2	Ground 2M (switched)	white	
3	Ground 1M (non-switched)	blue	
4	Load voltage 2L+ (switched)	black	

NOTICE

ET-Connection/supply voltage

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage. Mixing up the connector for ET-Connection and the connector for the supply voltage can destroy the module.

Parameters/address space

4.1 Output ranges

The table below indicates which output types and ranges are configurable.

Output type and output ranges

Table 4- 1 Output type and output ranges

Output type	Output range
Disabled	-
Voltage	+/- 10 V 0 V to 10 V 1 V to 5 V
Current	+/- 20 mA 0 mA to 20 mA 4 mA to 20 mA

The tables of the output ranges, overflow, overrange, etc. are provided in the appendix Representation of analog values (Page 32).

4.2 Parameters

Parameters of the AQ 4xU/I 4xM12 analog output module

The table below lists the parameters that can be set. The effective range of the parameters that can be set depends on the type of configuration. The following configurations are possible:

- Distributed operation on PROFINET IO
- Distributed operation with PROFIBUS DP

The following parameter settings are possible:

Table 4- 2 Configurable parameters and their defaults

Parameters	Value range	Default	GSD file PROFINET IO	GSD file PROFIBUS DP
Output type/range	<ul style="list-style-type: none"> • Disabled • Voltage ± 10 V • Voltage 0 V to 10 V • Voltage 1 V to 5 V • Current ± 20 mA • Current 0 mA to 20 mA • Current 4 mA to 20 mA 	Current 4 mA to 20 mA	Channel	Channel
Diagnostics: Actuator supply short circuit to ground	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module	Module*
Diagnostics: Short circuit to ground (output type voltage)	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Channel	
Diagnostics: Wire break (output type current)	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Channel	Module
Diagnostics: Underflow	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Channel	Module
Diagnostics: Overflow	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Channel	Module

Parameters	Value range	Default	GSD file PROFINET IO	GSD file PROFIBUS DP
Reaction to CPU/master STOP	<ul style="list-style-type: none"> • Shut down • Keep last value • Output substitute value 	Shut down	Channel	Module
Substitute value	See section Explanation of the parameters (Page 18)	0	Channel	Channel

* = With configuration via PROFIBUS GSD file, the two short-circuit diagnostics ("Diagnostics: Actuator supply short circuit to ground" and "Diagnostics: Short circuit to ground" for voltage outputs) are activated or deactivated using a module-wide parameter "Diagnostics: Short circuit to ground". They cannot be adjusted independently of one another.

Short-circuit detection

The diagnostics for short circuit to ground can be configured for the voltage output type. Short-circuit detection cannot be guaranteed for small output values (between 0.1 V and +0.1 V).

Wire break detection

The diagnostics for wire break can be configured for the current output type. Wire break detection cannot be guaranteed for small output values (between -0.2 mA and +0.2 mA).

4.3 Explanation of the parameters

Output type/range channel n

With this parameter, you set the output type or output range for the channel to control the actuator.

Note

Unused channels

"Deactivate" unused channels in the parameter assignment to improve the power consumption of the module.

A deactivated channel always returns the value "no voltage or current".

Diagnostics: Actuator supply short circuit to ground

Enabling of the diagnostics if a short-circuit of the actuator supply to ground occurs.

Diagnostics: Short circuit to ground

Enabling of the diagnostics if a short-circuit of the output to ground occurs.

Diagnostics: Wire break

Enabling of the diagnostics if the line to the actuator is broken.

Diagnostics: Underflow

Enabling of the diagnostics when the output value violates the underrange, falls below the minimum output value or reaches the underflow.

Diagnostics: Overflow

Enabling of the diagnostics when the output value exceeds the overrange.

Reaction to CPU/master STOP

Adjusts the reaction of the module after a CPU/master STOP.

- Shut down: The analog output is de-energized.
- Keep last value: The last value of the analog output remains activated.
- Output substitute value: The channel outputs a configured substitute value.

Substitute value

With this parameter, you set substitute values for the analog outputs.

The table below shows the permitted value ranges for the substitute values:

Table 4- 3 Permissible substitute values for the output ranges

Output type	Output range	Valid substitute value
Current	±10 V	-32512 to 32511
	0 V to 10 V	0..32511
	1 V to 5 V	-6912 to 32511
Voltage	±20 mA	-29031..29030
	0 mA to 20 mA	0..29030
	4 mA to 20 mA	-692 to 29376

4.4 Address space

The following figure shows the assignment of the address space for the AQ 4xU/I 4xM12 analog output module with value status (Quality Information (QI)).

The address space for the value status is occupied by the module if the value status is configured using the PROFINET interface module.

Assignment in the process image output (PIQ)

	7 6 5 4 3 2 1 0								Connec-tors	Pin assignment		Channel				
										U	I					
QB x									X10	Pin 2, 4	Pin 2, 4	0				
QB x+1																
QB x+2																
QB x+3													X11	Pin 2, 4	Pin 2, 4	1
QB x+4																
QB x+5													X12	Pin 2, 4	Pin 2, 4	2
QB x+6																
QB x+7									X13	Pin 2, 4	Pin 2, 4	3				

Assignment in the process image input (PII)

	7	6	5	4	3	2	1	0	
QB x	0	0	0	0					Value status (QI) at channels 0 to 3

Figure 4-1 Address space

Configuration options of the AQ 4xU/I 4xM12 analog output module

You have the following configuration options:

- Configuration 1: without value status
- Configuration 2: with value status

Evaluating the value status

An additional byte is occupied in the input address space if you enable the value status for the analog output module. Bits 0 to 3 in this byte are assigned to a channel and return information about the validity of the analog values or the channel status.

Bit = 1: No error on channel.

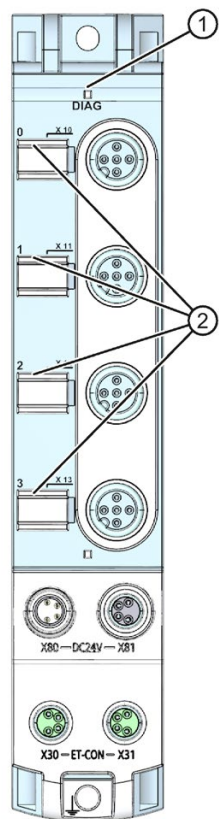
Bit = 0: Error on channel.

Interrupts/diagnostics alarms

5.1 Status and error displays

LED displays

The figure below shows the LED display (status and error displays) of the AQ 4xU/I 4xM12 analog output module.



- ① Diagnostic status (DIAG) (red/green)
- ② Channel status (0, 1, 2 and 3) (green)





Figure 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Corrective measures for diagnostics alarms can be found in the section Diagnostics alarms (Page 23).



DIAG LED

Table 5- 1 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> • Module parameters not assigned (after switching on the supply voltage 1L+) • Loading firmware (while the firmware update is being performed, all LEDs retain their current status) • No connection to the ET-Connection and/or the fieldbus
 On	Module parameters assigned and no diagnostics
 Flashes	Module parameters assigned and diagnostics

LED for the channel status

Table 5- 2 Status display of the LEDs 0, 1, 2 and 3

LED 0, 1, 2 and 3	Meaning
 Off	<ul style="list-style-type: none"> • Channel deactivated • Channel activated and incorrect parameter assignment • Parameter error possible with GSD
 On	<ul style="list-style-type: none"> • Channel activated and correct parameter assignment

5.2 Interrupts

The AQ 4xU/I 4xM12 analog output module supports diagnostics interrupts.

Diagnostic interrupt

The module generates a diagnostic interrupt at the following events:

- Short-circuit of the actuator supply
- Short-circuit (voltage)
- Wire break (current)
- High limit violated
- Low limit violated
- Parameter assignment error

5.3 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the DIAG LED flashes red on the analog output module. You can read out the diagnostics alarms, for example, in the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

The following tables show the diagnostics alarms for all measuring ranges.

Table 5- 3 Diagnostics alarms

Diagnostics alarm	Error code	Meaning	Solution
Short circuit to ground	1H	<ul style="list-style-type: none"> • Short-circuit of actuator supply to ground • Short-circuit of output to ground 	Correct the process wiring
Wire break	6H	Actuator circuit impedance too high	Use a different actuator type or modify the wiring, e.g. use cables with larger cross-section
		Wire break between the module and sensor	Connect the cable
		Channel not connected (open)	<ul style="list-style-type: none"> • Deactivate diagnostics • Connect the channel • Deactivate channel
High limit violated	7H	The output value set by the user program violates the valid rated range/overrange.	Correct the output value
Low limit violated	8H	The output value set by the user program violates the valid rated range/underrange.	Correct the output value
Parameter assignment error	10H	Module parameter assignment is faulty	Correct the parameter assignment

Technical specifications

Technical specifications of the AQ 4xU/I 4xM12 analog output module

The following table shows the technical specifications as of 05/2019. You will find a data sheet including daily updated technical specifications on the Internet (<https://support.industry.siemens.com/cs/ww/en/pv/6ES7145-5ND00-0BA0/td?dl=en>).

Article number	6ES7145-5ND00-0BA0
General information	
Product type designation	AQ 4xU/I
HW functional status	FS03
Firmware version	V1.0.x
Product function	
<ul style="list-style-type: none"> I&M data 	Yes; I&M0 to I&M3
Engineering with	
<ul style="list-style-type: none"> STEP 7 TIA Portal configurable/integrated as of version 	STEP 7 V14 or higher
<ul style="list-style-type: none"> STEP 7 configurable/integrated as of version 	V5.5 SP4 Hotfix 7 or higher
<ul style="list-style-type: none"> PROFIBUS as of GSD version/GSD revision 	GSD as of Revision 5
<ul style="list-style-type: none"> PROFINET as of GSD version/GSD revision 	GSDML V2.3.1
Supply voltage	
Load voltage 1L+	
<ul style="list-style-type: none"> Rated value (DC) 	24 V
<ul style="list-style-type: none"> permissible range, lower limit (DC) 	20.4 V
<ul style="list-style-type: none"> permissible range, upper limit (DC) 	28.8 V
<ul style="list-style-type: none"> Reverse polarity protection 	Yes; Against destruction; actuator power supply outputs applied with reversed polarity
Input current	
Current consumption (rated value)	110 mA; without load
from load voltage 1L+ (unswitched voltage)	4 A; Maximum value
from load voltage 2L+, max.	4 A; Maximum value
Actuator supply	
Number of outputs	4
Short-circuit protection	Yes; per module, electronic

Article number	6ES7145-5ND00-0BA0
Output current	
<ul style="list-style-type: none"> Rated value 	Total current 1 A up to 45 °C; 0.5 A up to 55 °C
Power loss	
Power loss, typ.	2.6 W
Analog outputs	
Number of analog outputs	4
Voltage output, short-circuit protection	Yes
Voltage output, short-circuit current, max.	24 mA
Current output, no-load voltage, max.	15 V
Cycle time (all channels) max.	1 ms
Output ranges, voltage	
<ul style="list-style-type: none"> 0 to 10 V 	Yes; 15 bit
<ul style="list-style-type: none"> 1 V to 5 V 	Yes; 14 bit
<ul style="list-style-type: none"> -10 V to +10 V 	Yes; 16 bit incl. sign
Output ranges, current	
<ul style="list-style-type: none"> 0 to 20 mA 	Yes; 15 bit
<ul style="list-style-type: none"> -20 mA to +20 mA 	Yes; 16 bit incl. sign
<ul style="list-style-type: none"> 4 mA to 20 mA 	Yes; 14 bit
Connection of actuators	
<ul style="list-style-type: none"> for voltage output two-wire connection 	Yes
<ul style="list-style-type: none"> for voltage output four-wire connection 	Yes
<ul style="list-style-type: none"> for current output two-wire connection 	Yes
<ul style="list-style-type: none"> for current output four-wire connection 	Yes
Load impedance (in rated range of output)	
<ul style="list-style-type: none"> with voltage outputs, min. 	1 kΩ
<ul style="list-style-type: none"> with voltage outputs, capacitive load, max. 	1 μF
<ul style="list-style-type: none"> with current outputs, max. 	500 Ω
<ul style="list-style-type: none"> with current outputs, inductive load, max. 	1 mH
Destruction limits against externally applied voltages and currents	
<ul style="list-style-type: none"> Voltages at the outputs towards MANA 	16 V
Cable length	
<ul style="list-style-type: none"> shielded, max. 	30 m
Settling time	
<ul style="list-style-type: none"> for resistive load 	1 ms
<ul style="list-style-type: none"> for capacitive load 	1 ms
<ul style="list-style-type: none"> for inductive load 	1 ms

Article number	6ES7145-5ND00-0BA0
Errors/accuracies	
Output ripple (relative to output range, bandwidth 0 to 50 kHz), (+/-)	0.02 %
Linearity error (relative to output range), (+/-)	0.1 %
Temperature error (relative to output range), (+/-)	0.005 %/K
Crosstalk between the outputs, max.	-70 dB
Repeat accuracy in steady state at 25 °C (relative to output range), (+/-)	0.03 %
Operational error limit in overall temperature range	
<ul style="list-style-type: none"> Voltage, relative to output range, (+/-) Current, relative to output range, (+/-) 	0.25 % from 55 °C to -25 °C and 0.35 % to -30 °C 0.25 %
Basic error limit (operational limit at 25 °C)	
<ul style="list-style-type: none"> Voltage, relative to output range, (+/-) Current, relative to output range, (+/-) 	0.15 % 0.15 %
Interrupts/diagnostics/status information	
Substitute values connectable	Yes; channel by channel, parameterizable
Alarms	
<ul style="list-style-type: none"> Diagnostic alarm 	Yes; Parameterizable
Diagnostic messages	
<ul style="list-style-type: none"> Wire-break Short-circuit 	Yes; channel-by-channel, only for output type "current" Yes; Actuator supply module by module; channel by channel for output type "voltage"
Diagnostics indication LED	
<ul style="list-style-type: none"> Channel status display for module diagnostics 	Yes; Green LED Yes; Green/red LED
Potential separation	
between the load voltages	Yes
Potential separation channels	
<ul style="list-style-type: none"> between the channels between the channels and backplane bus between the channels and the power supply of the electronics 	No Yes No
Isolation	
Isolation tested with	707 V DC (type test)
Degree and class of protection	
IP degree of protection	IP65/67

Article number	6ES7145-5ND00-0BA0
Ambient conditions	
Ambient temperature during operation	
• min.	-30 °C
• max.	55 °C
Connection method	
Design of electrical connection for the inputs and outputs	M12, 5-pole
Design of electrical connection for supply voltage	M8, 4-pole
ET-Connection	
• ET-Connection	M8, 4-pin, shielded
Dimensions	
Width	30 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	175 g

PROFenergy

7.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific response of the analog output module is explained in the section below.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<https://support.industry.siemens.com/cs/ww/en/view/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V14 (<https://support.industry.siemens.com/cs/ww/en/view/49948856>).

Application examples (<https://support.industry.siemens.com/cs/ww/en/view/41986454>) are also available on the Internet.

7.2 Response of analog output module

Display

The channel status LEDs are not affected by PROFlenergy.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following conditions apply to all channels which switch to the pause mode "PE_MODE_SHUTDOWN":

- "Wire break" and "Short circuit" error detection is **not** possible during the pause:
 - Alarms for errors already pending before the "pause" are retained.
 - Incoming and outgoing errors are reported once the "pause" has ended.

The following applies for all channels which switch to a different pause mode:

- "Wire break" and "Short circuit" error recognition is possible during the pause. These errors are reported.
- The selection of an incorrect pause substitute value which does not correspond to the output range may result in the message "High limit violated" or "Low limit violated". The pause substitute output value effective at the channel is limited to the high or low control limit for the output range.

Mode parameter

The following table shows the "Mode" parameter.

Table 7- 1 Mode parameter

Element	Code	Explanation
Mode	0D: PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> Value status "GOOD"
	1D: PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> Actuator supply U_A switched off Outputs de-energized Value status "BAD"
	3D: PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> Pause substitute value: Last output value: Value status "BAD"
	4D: PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> Pause substitute value: Configured pause substitute value Value status "BAD"

¹ As there is only one actuator supply U_A for all channels, the supply can only be switched off during a "pause" if all channel parameters have been set to switch off.

Dimension drawing

The figure below shows the dimension drawing of the AQ 4xU/I 4xM12 analog output module in front and side view.

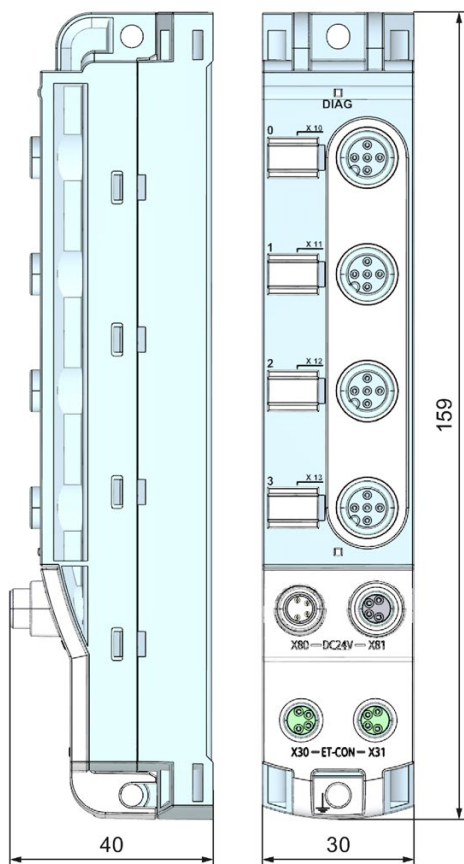


Figure A-1 Dimension drawing

B

Representation of analog values

This appendix shows the analog values for all output ranges supported by the AQ 4xU/I 4xM12 analog output module.

Measured value resolution

The digitized analog value is the same for all output values at the same nominal range. Analog values are output as fixed point numbers in two's complement.

Table B- 1 Resolution of the analog values

Resolution in bits including sign	Values		Analog value	
	Decimal	Hexadecimal	High byte	Low byte
16	1	1H	Sign 0 0 0 0 0 0 0	0 0 0 0 0 0 0 1

B.1 Representation of analog values in the voltage output ranges

The tables below list the decimal and hexadecimal values (codes) of the possible voltage output ranges.

Table B- 2 Voltage output range +/-10 V

Values			Voltage output range	Range
	Dec.	Hex.	± 10 V	
118.5149%	32767	7FFF	11.76 V	Maximum output value
	32512	7F00		
117.589%	32511	7EFF	11.76 V	Overrange
	27649	6C01		
100%	27648	6C00	10 V	Nominal range
75%	20736	5100	7.5 V	
0.003617%	1	1	361.7 μ V	
0%	0	0	0 V	
	-1	FFFF	-361.7 μ V	
-75%	-20736	AF00	-7.5 V	
-100%	-27648	9400	-10 V	
	-27649	93FF		
-117.593%	-32512	8100	-11.76 V	Underrange
	-32513	80FF	-11.76	
-118.519%	-32768	8000		Minimum output value

Table B- 3 Voltage output range 0 V to 10 V

Values			Voltage output range	Range
	Dec.	Hex.	0 V to 10 V	
118.519%	32767	7FFF	11.76 V	Maximum output value
	32512	7F00		
117.589%	32511	7EFF	11.76 V	Overrange
	27649	6C01		
100%	27648	6C00	10 V	Nominal range
75%	20736	5100	7.5 V	
0.003617%	1	1	361.7 μ V	
0%	0	0	0 V	
	-1	FFFF	0 V	
-118.519%	-32768	8000		

Table B- 4 Voltage output range 1 to 5 V

Values			Voltage output range	Range
	Dec.	Hex.	1 V to 5 V	
118.519%	32767	7FFF	5.70 V	Maximum output value
	32512	7F00		
117.589%	32511	7EFF	5.70 V	Overrange
	27649	6C01		
100%	27648	6C00	5 V	Nominal range
75%	20736	5100	4 V	
0.003617%	1	1	1 V + 144.7 μ V	
0%	0	0	1 V	
	-1	FFFF	1 V - 144.7 μ V	
-25%	-6912	E500	0 V	Underrange
	-6913	E4FF	0 V	
-118.519%	-32768	8000		

B.2 Representation of analog values in the current output ranges

The tables below list the decimal and hexadecimal values (codes) of the possible current output ranges.

Table B- 5 Current output range +/-20 mA

Values			Current output range	Range
	Dec.	Hex.	± 20 mA	
118.5149%	32767	7FFF	21 mA	Maximum output value
	29031	7167		
105%	29030	7166	21 mA	Overrange
	27649	6C01	20 mA + 723.4 nA	
100%	27648	6C00	20 mA	Nominal range
75%	20736	5100	15 mA	
0.003617%	1	1	723.4 nA	
0%	0	0	0 mA	
	-1	FFFF	-723.4 nA	
-75%	-20736	AF00	-15 mA	
-100%	-27648	9400	-20 mA	
	-27649	93FF	-20 mA + 723.4 nA	Underrange
-105%	-29031	8E99	-21 mA	
	-29032	8E98	-21 mA	Minimum output value
-118.519%	-32768	8000		

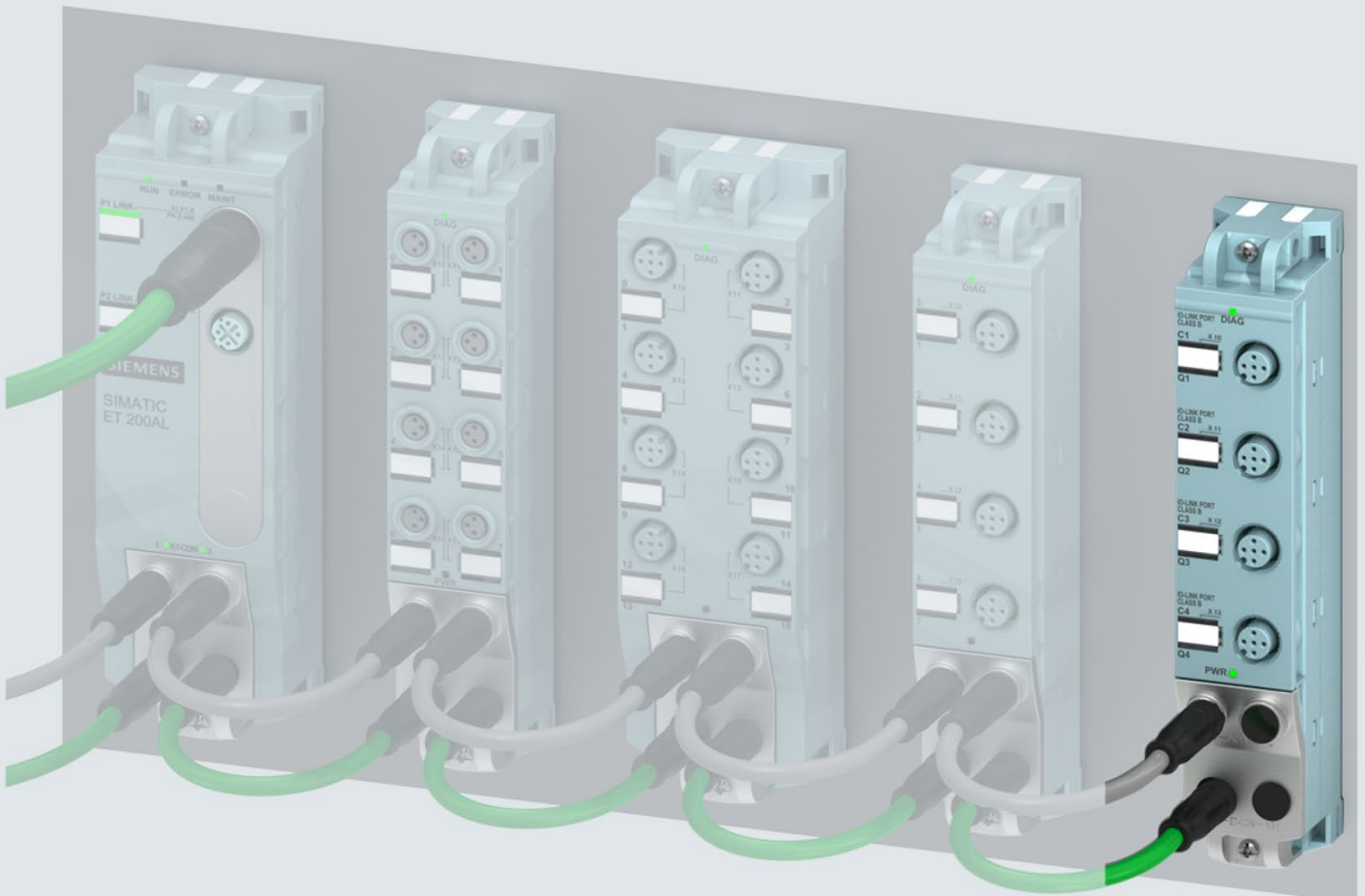
Table B- 6 Current output range 0 mA to 20 mA

Values			Current output range	Range	
	Dec.	Hex.	0 mA to 20 mA		
118.5149%	32767	7FFF	21 mA	Maximum output value	
	29031	7167			
105%	29030	7166	21 mA	Overrange	
	27649	6C01	20 mA + 723.4 nA		
100%	27648	6C00	20 mA	Nominal range	
75%	20736	5100	15 mA		
0.003617%	1	1	723.4 nA		
0%	0	0	0 mA		
	-1	FFFF	0 mA		
-118.519%	-32768	8000			Minimum output value

Table B- 7 Current output range 4 mA to 20 mA

Values			Current output range	Range
	Dec.	Hex.	4 mA to 20 mA	
118.5149%	32767	7FFF	21 mA	Maximum output value
	29377	72C1		
106.25%	29376	72C0	21 mA	Overrange
	27649	6C01	20 mA + 578.7 nA	
100%	27648	6C00	20 mA	Nominal range
75%	19008	4A40	16 mA	
0.003617%	1	1	4 mA + 578.7 nA	
0%	0	0	4 mA	
	-1	FFFF	3.9995 mA	Underrange
-2.5%	-692	FD4C	3.6 mA	Minimum output value
	-693	FD4B	3.6 mA	
-118.519%	-32768	8000		

SIEMENS



Manual

SIMATIC

ET 200AL

Communication module CM 4xIO-Link 4xM12
(6ES7147-5JD00-0BA0)

Edition

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SIEMENS

SIMATIC




ET 200AL
Communication module
CM 4xIO-Link 4xM12
(6ES7147-5JD00-0BA0)
Manual

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This manual supplements the ET 200AL distributed I/O system (<http://support.automation.siemens.com/WW/view/en/89254965>) system manual. Functions that are generally applicable to the ET 200AL distributed I/O system are described there.

The information provided in the present manual, the system manual and the function manuals enables you to commission the ET 200AL distributed I/O system.

Conventions

Please also observe notes marked as follows:

Note

Indicates important product information to which particular attention should be paid.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions constitute one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For additional information on industrial security measures that may be implemented, please visit (<https://www.siemens.com/industrialsecurity>).

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customers' exposure to cyber threats.

To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed under (<https://www.siemens.com/industrialsecurity>).

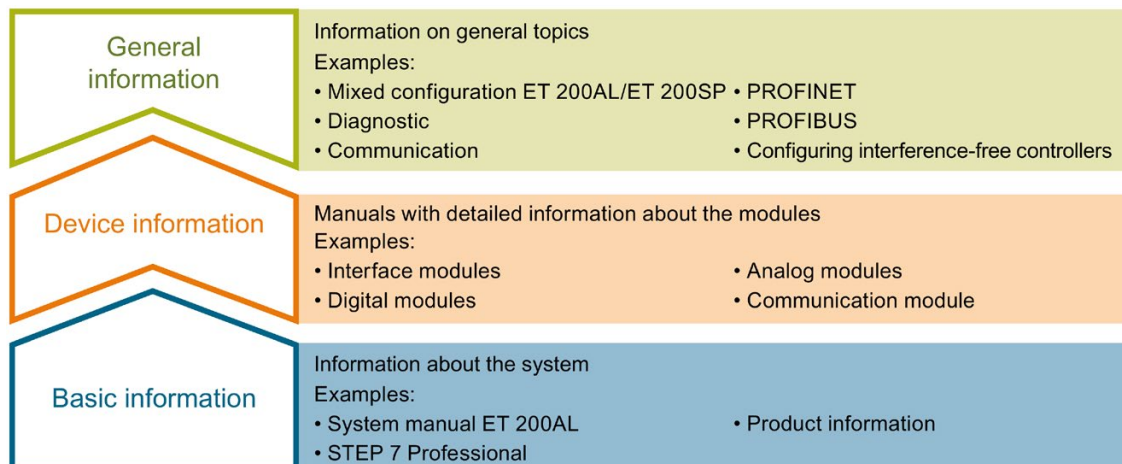
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Documentation guide

The documentation for the SIMATIC ET 200AL distributed I/O system is arranged into three areas.

This arrangement enables you to access the specific content you require.



Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200AL distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200AL distributed I/O system, e.g. diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742667>).

Manual Collection ET 200AL

The Manual Collection contains the complete documentation on the SIMATIC ET 200AL distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (<http://support.automation.siemens.com/WW/view/en/95242965>).

"mySupport"

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

"mySupport" - Documentation

In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.

You can export the manual as PDF file or in a format that can be edited later.

You can find "mySupport" - Documentation on the Internet (<http://support.industry.siemens.com/My/ww/en/documentation>).

"mySupport" - CAx data

In the CAx data area in "mySupport", you can access the current product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

SIMATIC Automation Tool

You can use the SIMATIC Automation Tool to perform commissioning and maintenance activities simultaneously on different SIMATIC S7 stations as a bulk operation, independently of the TIA Portal.

General function overview:

- Network browsing and creation of a table showing the accessible devices in the network
- Flashing of device LEDs or HMI display to locate a device
- Downloading of addresses (IP, subnet, gateway) to a device
- Downloading the PROFINET name (station name) to a device
- Placing a CPU in RUN or STOP mode
- Setting the time in a CPU to the current time of your PG/PC
- Downloading a new program to a CPU or an HMI device
- Downloading from CPU, downloading to CPU or deleting recipe data from a CPU
- Downloading from CPU or deleting data log data from a CPU
- Backup/restore of data from/to a backup file for CPUs and HMI devices
- Downloading service data from a CPU
- Reading the diagnostics buffer of a CPU
- Performing a CPU memory reset
- Resetting devices to factory settings
- Downloading a firmware update to a device

You can find the SIMATIC Automation Tool on the Internet

(<https://support.industry.siemens.com/cs/ww/en/view/98161300>).

PRONETA

With SIEMENS PRONETA (PROFINET network analysis), you analyze the system network during commissioning. PRONETA features two core functions:

- The topology overview independently scans the PROFINET network and all connected components.
- The IO check is a fast test of the wiring and the module configuration of a system.

You can find SIEMENS PRONETA on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/67460624>).

SINETPLAN

SINETPLAN, the Siemens Network Planner, supports you in planning automation systems and networks based on PROFINET. The tool facilitates professional and predictive dimensioning of your PROFINET installation as early as in the planning stage. In addition, SINETPLAN supports you during network optimization and helps you to exploit network resources optimally and to plan reserves. This helps to prevent problems in commissioning or failures during productive operation even in advance of a planned operation. This increases the availability of the production plant and helps improve operational safety.

The advantages at a glance

- Network optimization thanks to port-specific calculation of the network load
- Increased production availability thanks to online scan and verification of existing systems
- Transparency before commissioning through importing and simulation of existing STEP 7 projects
- Efficiency through securing existing investments in the long term and optimal exploitation of resources

You can find SINETPLAN on the Internet (<https://www.siemens.com/sinetplan>).

Product overview

2.1 Properties

Article number

6ES7147-5JD00-0BA0

View of the module

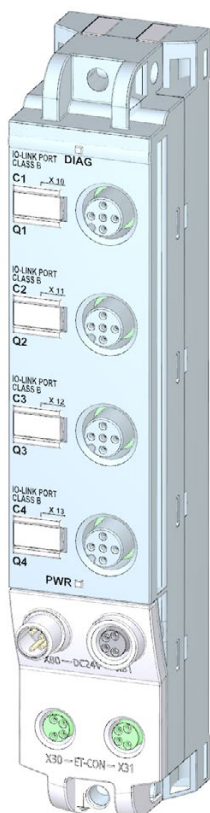


Figure 2-1 View of the CM 4xIO-Link 4xM12 communication module

Properties

The module has the following technical properties:

- IO-Link Master according to IO-Link specification V1.1
- 4 ports, type class B
- 4 M12 connectors
- SIO mode (standard IO mode)
- Supported data transmission rates:
 - COM1 (4.8 kBd)
 - COM2 (38.4 kBd)
 - COM3 (230.4 kBd)
- Configuration limits:
 - Max. 32 bytes input and output data per port
 - Max. 32 bytes input and output data per module
- Automatic backup of device parameters during replacement of the IO-Link device (only for V1.1 devices)
- Suitable for connection of IO-Link devices with 3-wire and 5-wire connection
- Configurable diagnostics can be set for each channel
- Dimensions 30 x 159 mm

The module supports the following functions:

Table 2- 1 Version dependencies of the module functions

Function	Firmware version of the module
Firmware update	V1.0 or higher
Identification and maintenance data (I&M)	V1.0 or higher
PROFenergy	V1.0 or higher
IO-Link port configuration with S7-PCT (as of V3.2)	V1.0 or higher
IO-Link port configuration without S7-PCT	V1.1 or higher
Master backup with "IO_LINK_MASTER" function block	V1.1 or higher
Port Qualifier Information (PQI)	V1.1 or higher

Accessories

The following components are included in the module package:

- Identification labels
- Spacers

Other components

The following component can be ordered as spare part:

- Identification labels

The following components can be ordered as accessories:

- Connectors
- Cables
- Stripping Tool for ET-Connection
- M8 sealing cap
- M12 sealing cap

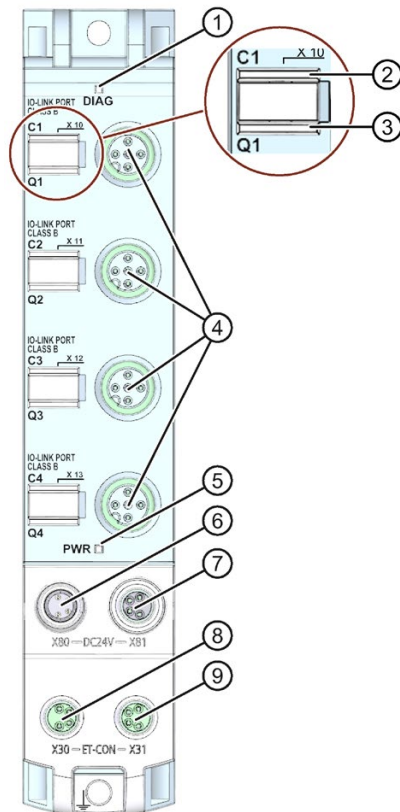
See also

You can find more information on accessories in the Accessories/spare parts section of the ET 200AL distributed I/O system

(<http://support.automation.siemens.com/WW/view/en/89254965>) system manual.

2.2 Operator controls and display elements

The following figure shows the operator controls and display elements of the CM 4xIO-Link 4xM12 communication module.



- ① DIAG: LED display for mode and diagnostic status
- ② C1 to C4: LED displays for port status
- ③ Q1 to Q4: LED displays for channel status in SIO mode
- ④ X10 to X13: Sockets for device connection
- ⑤ PWR: LED display for the load voltage 2L+
- ⑥ X80: Connector for infeed of the supply voltage (POWER input)
- ⑦ X81: Socket for loop-through of the supply voltage (POWER output)
- ⑧ X30: Socket for ET-Connection IN
- ⑨ X31: Socket for ET-Connection OUT

Figure 2-2 Operator controls and display elements

2.3 Functions

IO-Link is a point-to-point connection between an IO-Link master and an IO-Link device. On the IO-Link master, you can use IO-Link devices as well as conventional sensors/actuators with unshielded standard cables using proven 3-wire technology. IO-Link is backward compatible to conventional digital sensors or actuators. Switching status channel and data channel are in proven 24 V DC technology.

Reference

For more information on the IO-Link system, please see the IO-Link system (<http://support.automation.siemens.com/WW/view/en/65949252>) function manual.

2.4 Reset communication module to factory settings

Effects of resetting to the factory settings

Use the "Reset to factory settings" function to restore the parameter assignments of your CM 4xIO-Link 4xM12 communication module made with S7-PCT to the factory state.

After a "Reset to factory settings", the parameters of the CM 4xIO-Link 4xM12 communication module are assigned as follows:

- The ports are in DI mode
- The ports are mapped to the relative addresses 0.0 ... 0.3
- The PortQualifier is disabled
- The I&M data 1 ... 3 are deleted

Note

The device parameters are deleted and the factory state is restored.

You should reset a removed CM 4xIO-Link 4xM12 communication module to the factory settings before you place it in storage.

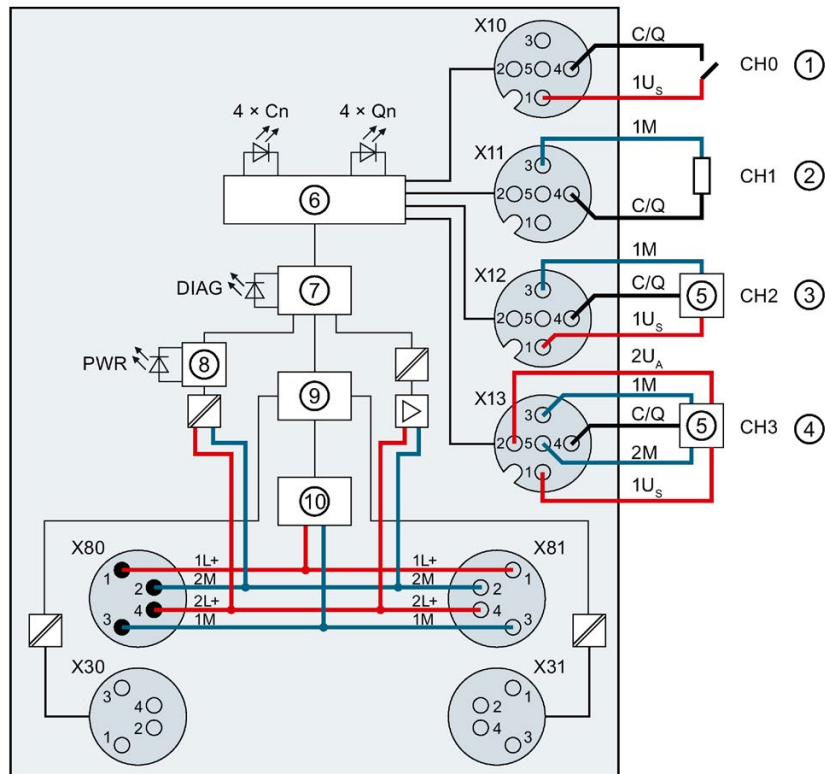
Procedure

To perform a "Reset to factory settings", proceed as described in the S7-PCT online help.

Wiring

3.1 Terminal and block diagram

The following figure shows an example of the pin assignment for Port Class A (Type A) and Port Class B (Type b).



①	SIO input	X31	Loop-through of the ET-Connection
②	SIO output	1L+	Supply voltage 1L+ (non-switched)
③	Port Class A (Type A)	1M	Ground 1M (non-switched)
④	Port Class B (Type B)	2L+	Load voltage 2L+ (switched)
⑤	IO-Link device	2M	Ground 2M (switched)
⑥	IO-Link switching	1Us	24 V encoder supply
⑦	Microcontroller	2U _A	24 V actuator supply
⑧	Monitoring	1M	Ground for encoder supply
⑨	ET-Connection interface	2M	Ground for actuator supply
⑩	Internal supply voltage	C/Q	Port n
X10 to X13	Channels 0 to 3	Cn	LEDs channel status (green)
X80	Infeed of supply voltages	Qn	LED status in SIO mode (green)
X81	Loop-through of supply voltages	DIAG	LED diagnostic status (red/green)
X30	Infeed of the ET-Connection	PWR	LED supply voltage 2L+ (green)

Figure 3-1 Terminal and block diagram

3.2 Pin assignment

Note

Color coding

The sockets for ET-Connection and the power supply of the modules are color-coded. These colors correspond to the colors of the offered cables.

Pin assignment of the IO-Link sockets

Note

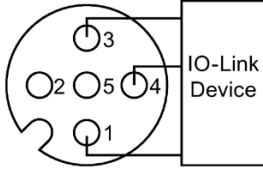
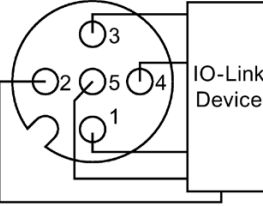
Port Class B

The pin assignment of the IO-Link interface corresponds to the IO-Link specification as per Port Class B. Port Class B is specially suited for the connection of actuators with additional supply (e.g. valve terminals).

To connect devices with Port Class A (e.g. sensors) to the communication module CM 4xIO-Link 4xM12, a 3-wire connection cable should be used (Port Class A compatibility).

The table below shows the pin assignments of the 4 sockets for the connection of IO-Link.

Table 3- 1 Pin assignment of the IO-Link

Pin	Assignment	Front view of the sockets
	X10 to X13 - sockets for IO-Link	
1	24 V encoder supply 1Us (from 1L+)	<p>Port Class A (Type A)*</p>  <p>Port Class B (Type B)</p> 
2	24 V actuator supply 2UA (from 2L+)	
3	Encoder supply ground 1M	
4	Port 1 (C/Q): Connector X10 Port 2 (C/Q): Connector X11 Port 3 (C/Q): Connector X12 Port 4 (C/Q): Connector X13	
5	Ground for actuator supply 2M	
* If you use the sockets for IO-Link as Port Class A, you may not place any signals on pins 2 and 5.		

The M12 connectors are designed according to IO-Link specification as port type Class B. Pins 2 and 5 contain an additional power supply.

Reaction-free connection of devices with different port types (Class A and Class B) is possible using a 3-wire connecting cable (assignment of pins 1, 3 and 4).

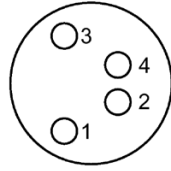
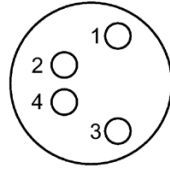
NOTICE**24 V encoder supply 1Us**

For the supply of devices, only use the 24 V 1Us encoder supply provided by the communication device.

Pin assignment of the sockets for ET-Connection

The table below shows the pin assignments of the 2 sockets for the connection of ET-Connection.

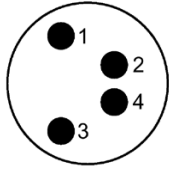
Table 3- 2 Pin assignment for ET-Connection

Pin	Assignment		Assignment of the wire color of the bus line cable for ET-Connection	Front view of the sockets	
	X30 socket (ET-Connection IN)	X31 socket (ET-Connection OUT)		X30	X31
1	TXP	RXP	Yellow		
2	RXP	TXP	White		
3	RXN	TXN	Blue		
4	TXN	RXN	Orange		
Shield	Functional earth FE		-		

Pin assignment of the connector for infeed of the supply voltage

The table below shows the pin assignment of the connector for infeed of the supply voltage.

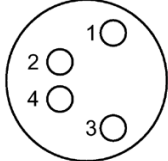
Table 3- 3 Pin assignment of the supply voltage connector

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the connector
	X80 connector (POWER input)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

Pin assignment of the socket for loop-through of the supply voltage

The table below shows the pin assignment of the socket for loop-through of the supply voltage.

Table 3- 4 Pin assignment of the supply voltage socket

Pin	Assignment	Assignment of the wire color of the power line cable	Front view of the socket
	X81 socket (POWER output)		
1	Supply voltage 1L+ (non-switched)	Brown	
2	Ground 2M (switched)	White	
3	Ground 1M (non-switched)	Blue	
4	Load voltage 2L+ (switched)	Black	

NOTICE

ET-Connection/supply voltage

Observe the correct wiring of the M8 sockets for ET-Connection and the supply voltage. Mixing up the connector for ET-Connection and the connector for the supply voltage can destroy the module.

Parameters/address space

4.1 Parameters

Parameters

The following table shows the general parameters for the communication module CM 4xIO-Link 4xM12.

Table 4- 1 General parameters

Parameters	Value range	Default	Scope
Diagnostics			
Diagnostics: No supply voltage 2L+	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module
Diagnostics port 1	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Channel
Diagnostics port 2	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Channel
Diagnostics port 3	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Channel
Diagnostics port 4	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Channel
Configuration			
Input / output type	See table in section Explanation of the parameters (Page 21)	32I/32O	Module
Port configuration without S7-PCT	<ul style="list-style-type: none"> • Disable • Enable 	Disable	Module
Port Qualifier Information (PQI)	<ul style="list-style-type: none"> • Disable • Enable 	Enable	Module

4.1 Parameters

The following table shows the port parameters for the communication module CM 4xIO-Link 4xM12 with firmware version V1.1.

Table 4- 2 Port parameters

Parameters	Range of values	Default
Port configuration		
Operating mode	<ul style="list-style-type: none"> • IO-Link autostart • IO-Link manual • DI • DQ • Disabled 	IO-Link autostart
Length of input data (without PQL)	Depending on the total length of the module*	Depending on the total length of the module*
Length of output data	Depending on the total length of the module*	Depending on the total length of the module*
Vendor ID**	Vendor ID of the connected IO-Link device	0
Device ID**	Device ID of the connected IO-Link device	0
Testing accuracy / data storage**	<ul style="list-style-type: none"> • Same type (V1.0) without Backup&Restore • Type compatible (V1.1) without Backup&Restore • Type compatible (V1.1) with Backup&Restore • Type compatible (V1.1) with Restore 	Type compatible (V1.1) with Backup&Restore

* Take care not to exceed the maximum possible length of the input or output data for all ports.
 Example:
 You have selected the 32I/32O configuration. You have assigned the first port 16 bytes of input data.
 You can still assign a total of 16 bytes of input data for the remaining three ports.

** Only in effect when "IO-Link manual" port mode is used.

4.2 Explanation of the parameters

Diagnostics: No supply voltage 2L+

Enabling of the diagnostics for no or insufficient supply voltage 2L+.

Diagnostics port

This parameter enables the diagnostics for the selected port.
The diagnostics possible depends on the IO-Link device in use. Additional information about the diagnostic interrupts can be found in the description of the utilized IO-Link device.

Input / output type

This parameter sets the maximum length of the input and output data of the module.

Port configuration without S7-PCT

This parameter releases the port configuration without S7-PCT for the module.

Port Qualifier Information

This parameter releases the Port Qualifier Information (PQI).
The PQI provides information on the device status of the port and IO-Link.

Operating mode

This parameter determines the mode in which the selected port should be operated.
You can select from the following options:

- IO-Link autostart
- IO-Link manual
- DI
- DQ
- Disabled

IO-Link autostart

The connected IO-Link device starts automatically (Plug&Play functionality). The IO-Link device is immediately ready for operation.

4.2 Explanation of the parameters

IO-Link manual

The connected IO-Link device is **not** started automatically.
 You must store the Vendor ID and Device ID of the connected IO-Link device in STEP 7.
 In addition, you can select the inspection severity for data storage:

- Identical type (V1.0) without Backup&Restore
- Type-compatible (V1.1) without Backup&Restore
- Type-compatible (V1.1) with Backup&Restore
- Type-compatible (V1.1) with Restore

You can find the Vendor ID and Device ID on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109748852>).

DI

The port is operating as a standard digital input.

DQ

The port is operating as a standard digital output.

Disabled

The port is disabled.

Configuration options of the communication module CM 4xIO-Link 4xM12

The CM 4xIO-Link 4xM12 communication module supports a variable address space for I/O data.

The following table provides an overview of the configuration options for the supported address spaces for I/O data:

Module configuration/ supporting address space for I/O data	IO-Link Master with Firmware V1.0	IO-Link Master with Firmware V1.1
1 byte input/1 byte output	X	
2 bytes inputs/2 bytes outputs	X	
4 bytes inputs/4 bytes outputs	X	X*
8 bytes inputs/0 bytes outputs		X
8 bytes inputs/8 bytes outputs	X	X
12 bytes inputs/8 bytes outputs		X
16 bytes inputs/16 bytes outputs	X	X
20 bytes inputs/16 bytes outputs		X
32 bytes inputs/32 bytes outputs	X	X

* No Port Qualifier Information is transferred with this configuration.

Port configuration

You can use a CM 4xIO-Link 4xM12 communication module as of firmware version V1.1 to commission the IO-Link ports of the IO-Link master or the connected IO-Link devices in two different ways:

- Port configuration without S7-PCT
- Port configuration with S7-PCT

Port configuration without S7-PCT

Requirement

You have enabled the check box "Port configuration without S7-PCT" for the configuration of the IO-Link master in STEP 7.

Procedure

You configure the IO-Link master directly in STEP 7:

- Enabling of the diagnostics
- Configuration of the I/O data lengths per port
- Enabling of the Port Qualifier Information (PQI)
- Port mode:
 - Operation in "IO-Link autostart" mode (default)
 - Operation in "IO-Link manual" mode
 - Operated as DI
 - Operated as DQ
 - Disabled

Port configuration with S7-PCT

Requirement

You have **disabled** the check box "Port configuration without S7-PCT" for the configuration of the IO-Link master in STEP 7.

Procedure

You configure the port configuration of the IO-Link master using the port configuration tool S7-PCT as of V3.2.

Port Qualifier Information (PQI)

You can enable the Port Qualifier Information (PQI) for your IO-Link master as of firmware version V1.1.

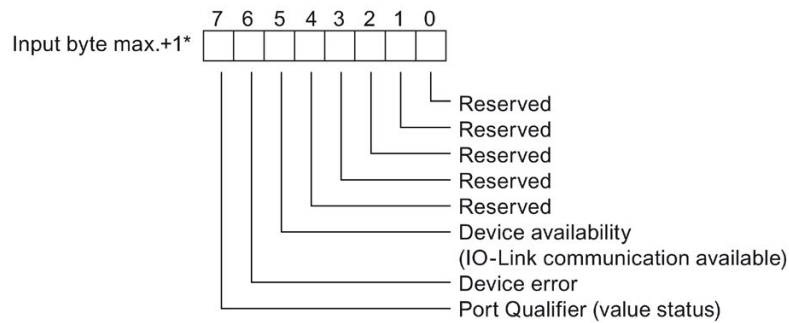
Note

Port Qualifier Information (PQI)

If you have enabled the Port Qualifier Information (PQI), this information is always sent with the size of 1 byte together with the input data of the IO-Link device.

The following figure show the structure of the PQI byte.
You enable a parameter by setting the corresponding bit to "1".

Port Qualifier Information (PQI)



* The PQI byte is always located after the last input byte of the port. Depending on the configuration, the PQI byte is therefore located in the process image of the inputs at byte 2, 3, 4, 5, 8, 9, 16, 17, 32 or 33.

Figure 4-1 Structure of the PQI byte

Reference

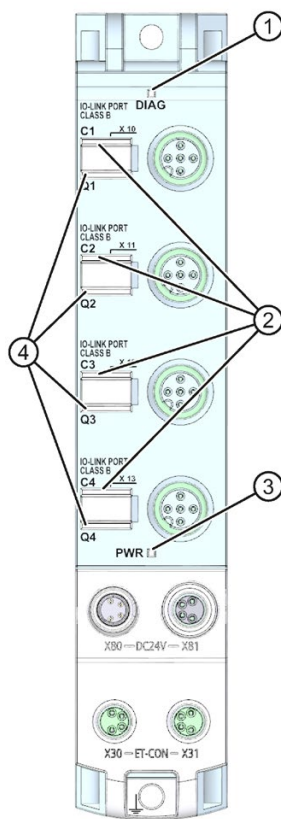
For more information, please refer to the IO-Link system (<http://support.automation.siemens.com/WW/view/en/65949252>) function manual.

Diagnostics alarms

5.1 Status and error displays

LED displays

The following figure shows the LED display of the CM 4xIO-Link 4xM12 communication module.



- | | | |
|---|-----------------------------------|-------------|
| ① | Diagnostics (DIAG) | (green/red) |
| ② | Port status / IO-Link status (Cn) | (green) |
| ③ | Load voltage 2L+ (PWR) | (green) |
| ④ | Channel status in SIO mode (Qn) | (green) |





Figure 5-1 LED displays

Meaning of the LEDs

The following tables set out the meaning of the status and error displays. Corrective measures for diagnostics alarms can be found in the section Diagnostics alarms (Page 27).

DIAG LED




Table 5- 1 Error display of the DIAG LED

DIAG LED	Meaning
 Off	No supply voltage 1L+
 Flashes	<ul style="list-style-type: none"> Module parameters not assigned (after switching on the supply voltage 1L+) Loading firmware (while the firmware update is being performed, all LEDs retain their current status) No connection to the ET-Connection and/or the fieldbus
 On	Module parameters assigned and no module diagnostics
 Flashes	Module parameters assigned and module diagnostics

LEDs Cn



Valid for IO-Link port in IO-Link mode.

Table 5- 2 Status displays of the C1, C2, C3, and C4 LEDs

C1, C2, C3, or C4 LED	Meaning
 Off	Port disabled or in SIO mode
 Flashes	Port in IO-Link mode, device not connected or port not connected with the configured device
 On	Port in IO-Link mode, device not connected

PWR LED



Table 5- 3 Status display of the PWR LED

PWR LED	Meaning
 Off	Load voltage 2L+ is missing or too low
 On	Load voltage 2L+ present

LEDs Qn

Valid for IO-Link port in SIO mode.

Table 5- 4 Status displays of the Q1, Q2, Q3, and Q4 LEDs

Q1, Q2, Q3, and Q4 LEDs	Meaning
 Off	Process signal = 0 in SIO mode, deactivated or in IO-Link mode
 On	Process signal = 1 in SIO mode

5.2 Diagnostics alarms

For each diagnostic event, a diagnostics alarm is issued and the DIAG LED flashes red on the communication module. You can read out the diagnostics alarms, for example, in the diagnostics buffer of the CPU. You can evaluate the error codes with the user program.

Table 5- 5 Error types

Diagnostics alarm	Error code	Meaning (IO-Link error code)	IO-Link master	IO-Link device
Short-circuit	1H	• Short-circuit at the process cables on the IO-Link device (1804H)	X	
		• Short-circuit on IO device (7710H)		X
Undervoltage	2H	• Supply voltage too low (5111H, 5112H)		X
Overvoltage	3H	• Supply voltage too high (5110H)		X
Overtemperature	5H	• Temperature exceeded on master (1805H)	X	
		• Temperature exceeded on device (4000H, 4210H)		X
Wire break	6H	<ul style="list-style-type: none"> • No IO-Link device connected • There is a break on the signal line to the IO-Link device • IO-Link device cannot communicate due to a different error (1800H) 	X	
Overflow	7H	<ul style="list-style-type: none"> • Process tag range exceeded (8C10H) • Measuring range exceeded (8C20H) 		X
Underflow	8H	• Process tag range too low (8C30H)		X
Error	9H	• All IO-Link error codes which are not listed here are mapped to this PROFIBUS DP error		X

Diagnosics alarm	Error code	Meaning (IO-Link error code)	IO-Link master	IO-Link device
Parameter assignment error	10 _H	<ul style="list-style-type: none"> • Incorrect device (1802_H) • Vendor ID and Device ID not defined (1817_H) • Process data length of the IO-Link device exceeded (1818_H) • No cycle time configured (1819_H) • IO-Link master could not be configured (1882_H, 1883_H) • Memory error (1886_H) • Process data length exceeded (1887_H) • PQI not supported (1889_H) 	X	
		<ul style="list-style-type: none"> • Device was not configured correctly (6320_H, 6321_H, 6350_H) 		X
Supply voltage missing	11 _H	<ul style="list-style-type: none"> • 24 V encoder supply 1U_S (of 1L+) for device missing (1806_H) • 24 V encoder supply 1U_S (of 1L+) for device too low (<20 V) (1807_H) • Load voltage 2L+ (switched) missing (1888_H) • 24 V actuator supply 2 UA (of 2L+) for device missing (180E_H) 	X	
Defective fuse	12 _H	<ul style="list-style-type: none"> • Fuse on device is defective (5101_H) 		X
Safety shutdown	19 _H	<ul style="list-style-type: none"> • Serious error (master has to be replaced) (1880_H) 	X	
External fault	1A _H	<ul style="list-style-type: none"> • Error during data backup (1809_H, 180A_H, 180B_H, 180C_H, 180D_H) • More than six errors are pending simultaneously on the IO-Link device (1808_H) • Consistency error in electronic coding element (1885_H) • Process data length exceeded (1887_H) 	X	

Technical specifications

Technical specifications of the CM 4xIO-Link 4xM12 communication module

Article number	6ES7147-5JD00-0BA0
General information	
Product type designation	CM 4 x IO-Link
HW functional status	E03
Firmware version	V1.1.x
Product function	
<ul style="list-style-type: none"> I&M data 	Yes; I&M0 to I&M3
Engineering with	
<ul style="list-style-type: none"> STEP 7 TIA Portal configurable/integrated as of version 	STEP 7 V15 or higher
<ul style="list-style-type: none"> STEP 7 configurable/integrated as of version 	From V5.5 SP4 Hotfix 3
<ul style="list-style-type: none"> PROFIBUS as of GSD version/GSD revision 	GSD as of Revision 5
<ul style="list-style-type: none"> PROFINET as of GSD version/GSD revision 	GSDML V2.3.1
Supply voltage	
Load voltage 1L+	
<ul style="list-style-type: none"> Rated value (DC) 	24 V
<ul style="list-style-type: none"> permissible range, lower limit (DC) 	20.4 V
<ul style="list-style-type: none"> permissible range, upper limit (DC) 	28.8 V
<ul style="list-style-type: none"> Reverse polarity protection 	Yes
Load voltage 2L+	
<ul style="list-style-type: none"> Rated value (DC) 	24 V
<ul style="list-style-type: none"> permissible range, lower limit (DC) 	20.4 V
<ul style="list-style-type: none"> permissible range, upper limit (DC) 	28.8 V
<ul style="list-style-type: none"> Reverse polarity protection 	Yes; against destruction; load increasing
Input current	
Current consumption (rated value)	40 mA; without load
from load voltage 1L+ (unswitched voltage)	4 A; Maximum value
from load voltage 2L+, max.	4 A; Maximum value

Article number	6ES7147-5JD00-0BA0
Encoder supply	
Number of outputs	4
24 V encoder supply	
<ul style="list-style-type: none"> Short-circuit protection Output current, max. 	<p>Yes; per module, electronic</p> <p>1.4 A; Total current of all ports</p>
Power loss	
Power loss, typ.	2.6 W
IO-Link	
Number of ports	4
<ul style="list-style-type: none"> of which simultaneously controllable 	4
IO-Link protocol 1.0	Yes
IO-Link protocol 1.1	Yes
Transmission rate	4.8 kBaud (COM1); 38.4 kBaud (COM2), 230 kBaud (COM3)
Size of process data, input per port	32 byte
Size of process data, input per module	32 byte
Size of process data, output per port	32 byte
Size of process data, output per module	32 byte
Memory size for device parameter	2 kbyte; for each port
Master backup	Possible with function block IO_LINK_MASTER
Configuration without S7-PCT	Possible; autostart/manual function
Cable length unshielded, max.	20 m
Operating modes	
<ul style="list-style-type: none"> IO-Link DI DQ 	<p>Yes</p> <p>Yes</p> <p>Yes; max. 100 mA</p>
Connection of IO-Link devices	
<ul style="list-style-type: none"> Port type A Port type B 	<p>Yes; via 3-core cable</p> <p>Yes; Additional device supply: 1.6 A total current of all ports</p>
Interrupts/diagnostics/status information	
Alarms	
<ul style="list-style-type: none"> Diagnostic alarm 	Yes; Parameterizable
Diagnostic messages	
<ul style="list-style-type: none"> Monitoring the supply voltage Wire-break Short-circuit 	<p>Yes</p> <p>Yes</p> <p>Yes</p>

Article number	6ES7147-5JD00-0BA0
Diagnostics indication LED	
<ul style="list-style-type: none"> Channel status display 	Yes; Green LED
<ul style="list-style-type: none"> for module diagnostics 	Yes; Green/red LED
<ul style="list-style-type: none"> For load voltage monitoring 	Yes; Green LED
Potential separation	
between the load voltages	Yes
Potential separation channels	
<ul style="list-style-type: none"> between the channels 	No
<ul style="list-style-type: none"> between the channels and backplane bus 	Yes
<ul style="list-style-type: none"> between the channels and the power supply of the electronics 	No
Isolation	
Isolation tested with	707 V DC (type test)
Degree and class of protection	
IP degree of protection	IP65/67
Standards, approvals, certificates	
Suitable for safety-oriented group deactivation	Yes
Highest safety class achievable in safety mode	
<ul style="list-style-type: none"> Performance level according to ISO 13849-1 	PL d
<ul style="list-style-type: none"> SIL acc. to IEC 61508 	SIL 2
Ambient conditions	
Ambient temperature during operation	
<ul style="list-style-type: none"> min. 	-25 °C
<ul style="list-style-type: none"> max. 	55 °C
Connection method	
Design of electrical connection for the inputs and outputs	M12, 5-pole
Power supply	M8, 4-pole
ET-Connection	
<ul style="list-style-type: none"> ET-Connection 	M8, 4-pin, shielded
Dimensions	
Width	30 mm
Height	159 mm
Depth	40 mm
Weights	
Weight, approx.	145 g

Replacing modules

What do you need to know when replacing modules?

When you replace the communication module CM 4xIO-Link 4xM12, you must transfer the IO-Link parameter settings (master/device) again. You can transfer the IO-Link configuration using S7-PCT or save it with the Master Backup function.

Master Backup

The "IO_LINK_MASTER" function block is used to read all relevant IO-Link device and IO-Link master parameters. These can be stored retentively at a central location, such as in a data block in the IO controller.

The status of the IO-Link devices or IO-Link ports stored in the IO-Link master can be restored with the "IO_LINK_MASTER" function block.

As a result, the IO-Link ports and the IO-Link master are configured with the values stored in the master backup.

A typical application is the restoration of parameters after replacement of the IO-Link master.

Note

Availability

Note that the Master Backup function is available only for IO-Link devices that are specified for the IO-Link Standard as of V1.1.

You will find information on the Master Backup and Master Restore functions in section "Master backup" of chapter "Integration into the automation system" of the IO-Link System (<https://support.industry.siemens.com/cs/ww/en/view/65949252>) function manual.

Reference

You will find additional information on replacing modules in the system manual ET 200AL distributed I/O system (<http://support.automation.siemens.com/WW/view/en/89254965>) in the "Module" section.

You will find additional information on replacing IO-Link masters in the S7-PCT online help.

PROFenergy

8.1 Pause function

Introduction

PROFenergy is a PROFINET-based data interface for switching off consumers centrally and in a coordinated manner during pause times regardless of the manufacturer or device type. This has the aim that the process is only provided with the energy that is absolutely required. In so doing, the majority of the energy savings come from the process itself; the PROFINET device contributes only a few watts to the possible savings. In PROFenergy, this operating state is referred to as a "pause".

Start and end of a pause

You enable and disable the pause function of the system at the beginning and end of pauses, respectively; the IO controller then sends the PROFenergy command "Start_Pause" or "End_Pause" to the modules.

Use the "Start_Pause" command to start a pause.

Use the "End_Pause" command to end a pause.

The following conditions will also cause a pause to be ended:

- Reconfiguration in RUN
- Controller failure
- Firmware update
- Station stop
- Restart of the interface module through:
 - POWER OFF/POWER ON of an interface module
 - POWER OFF/POWER ON of an I/O module
 - Termination of ET-Connection1 or ET-Connection2

The specific behavior of the communication module is explained in the following sections.

Additional information

You can find additional information on working with PROFenergy in the "PROFenergy" section of the manual IM 157-1 PN interface module (<http://support.automation.siemens.com/WW/view/en/89254863>) and the "Saving energy with PROFenergy" section of function manual PROFINET with STEP 7 V13 (<http://support.automation.siemens.com/WW/view/en/49948856>).

Application examples (<http://support.automation.siemens.com/WW/view/en/41986454>) are also available on the Internet.

8.2 DI operating mode

Display

If no external supply voltage is connected, switching off supply voltages 1U_S and 2U_A also leads to switching off the associated channel status LED Q_n.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- During the "pause", error detection of "Load voltage 2L+" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 8- 1 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> • Supply voltages 1U_S and 2U_A off • Pause substitute value: 0_B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> • Supply voltages 1U_S and 2U_A off • Pause substitute value: Last input value • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> • Supply voltages 1U_S and 2U_A off • Pause substitute value: Configured pause substitute value • Value status "BAD"

Note

Supply voltages 1U_S and 2U_A

Supply voltages 1U_S and 2U_A can only be switched off separately for each module.

If all channels require switching off during the pause, all supply voltages are switched off if no channel is assigned in PE_MODE_PROCEED.

8.3 DQ operating mode

Display

The channel status LEDs Qn show the output value.

Response to error detection

All channels that are in pause mode on "PE_MODE_PROCEED" report their diagnostic status as in productive mode.

The following applies for all channels which switch to a different pause mode:

- During the "pause", error detection of "Load voltage 2L+ missing" is not possible:
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 8- 2 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" <ul style="list-style-type: none"> • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" <ul style="list-style-type: none"> • Supply voltages 1U_S and 2U_A off • Pause substitute value: 0_B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" <ul style="list-style-type: none"> • Pause substitute value: Last output value is maintained • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" <ul style="list-style-type: none"> • Pause substitute value: Configured pause substitute value is output • Value status "BAD"

Note

Supply voltages 1U_S and 2U_A

Supply voltages 1U_S and 2U_A can only be switched off separately for each module.

If all channels require switching off in the pause, the supply voltages are switched off.

8.4 IO-Link operating mode

Display

Switching off the supply voltage $1U_S$ also switches off the associated port status LED Cn.

Response to error detection

All channels which are set to "PE_MODE_PROCEED" and "PE_MODE_LAST_VALUE" in pause mode report errors as in productive operation.

The following conditions apply to all channels (ports) which switch to a different pause mode ("PE_MODE_SHUTDOWN" and "PE_MODE_SUBST_VALUE"):

- Switching off the supply voltage U_{Sn} (port) upon starting the "pause" does not lead to generation of the alarms "Wire break" and "Short circuit".
- Error detection is not possible during the "pause" (no IO-Link device communication):
 - Alarms for errors already pending before the "pause" are retained.
 - After the "pause" is over, the error status is updated and incoming/outgoing errors are reported correspondingly.

Mode parameter

The following table shows the "Mode" parameter.

Table 8- 3 Mode parameter

Element	Code	Explanation
Mode	0 _D : PE_MODE_PROCEED	Proceed at "pause" • Value status "GOOD"
	1 _D : PE_MODE_SHUTDOWN	Switch off at "pause" • Supply voltages $1U_S$ and $2U_A$ off ¹ • Pause substitute value (input): 0 _B • Value status "BAD"
	3 _D : PE_MODE_LAST_VALUE	Last value at "pause" • Pause substitute value: Last input value • Value status "BAD"
	4 _D : PE_MODE_SUBST_VALUE	Substitute value at "pause" • Supply voltages $1U_S$ and $2U_A$ off ¹ • Pause substitute value (input): 0 _B • Value status "BAD"

¹ Supply voltage $1U_S$ of the assigned port is switched off. Result: The IO-Link device is no longer supplied with voltage.

Note

Supply voltages 1U_S and 2U_A

Supply voltages 1U_S and 2U_A can only be switched off separately for each module.

If all channels require switching off in the pause, the supply voltages are switched off.

Dimension drawing

The following figure shows the dimension drawing of the CM 4xIO-Link 4xM12 communication module in front and side view.

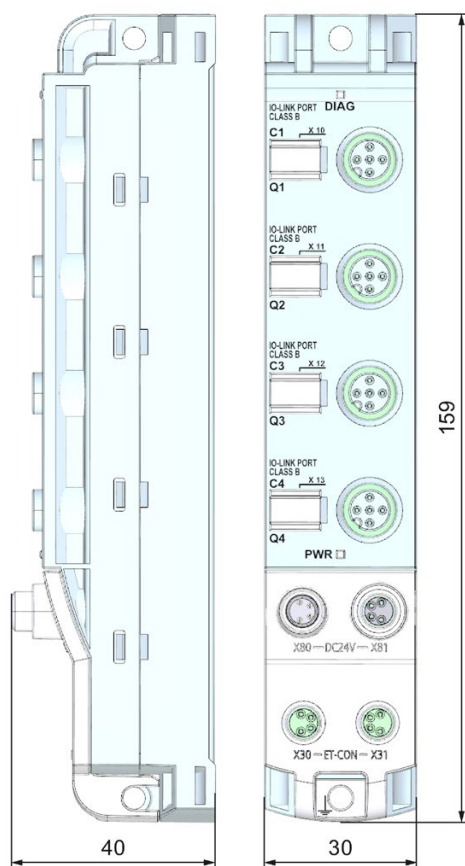
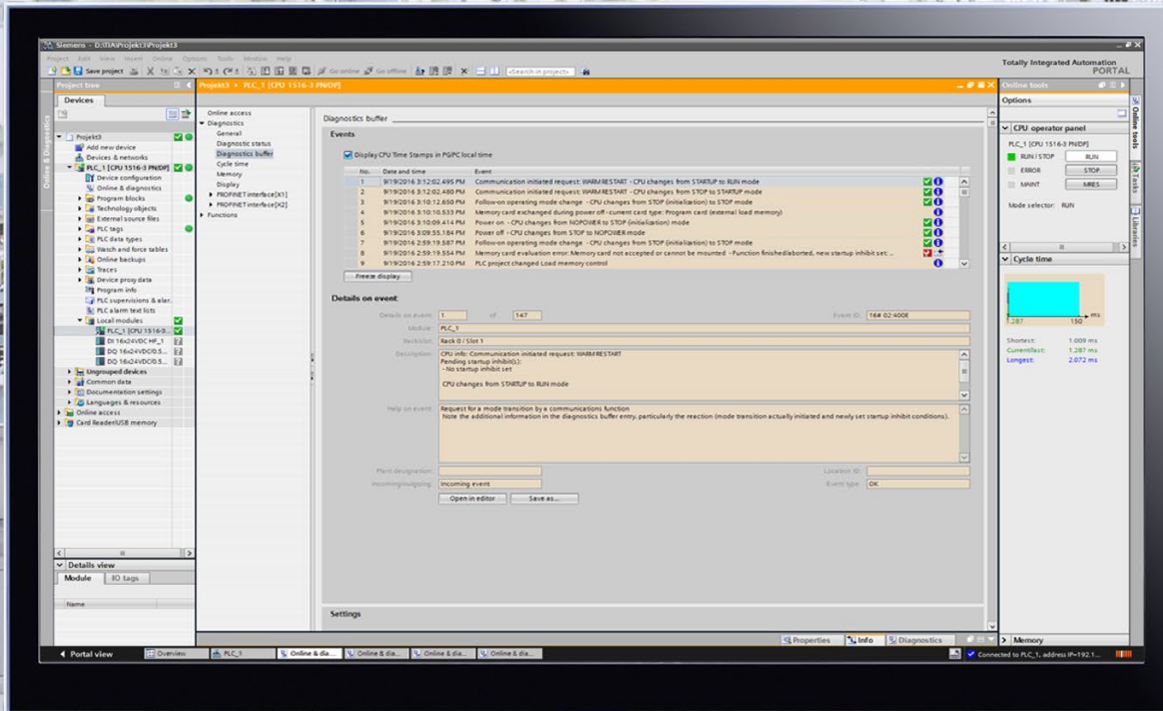


Figure A-1 Dimension drawing

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Function manual

SIMATIC

S7-1500, ET 200MP, ET 200SP,
ET 200AL, ET 200pro

Diagnostics

Edition

11/2019

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SIMATIC

S7-1500, ET 200MP, ET 200SP, ET 200AL, ET 200pro Diagnostics

Function Manual

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1500R/H redundant system **7**

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This function manual provides an overview of the diagnostics options for the automation system SIMATIC S7-1500, for the CPUs 1513pro-2 PN and 1516pro-2 PN based on SIMATIC S7-1500, and for the distributed I/O systems SIMATIC ET 200MP, ET 200SP and ET 200AL.

The documentation covers the following:

- Illustration of the uniformity and consistency of system diagnostics
- Overview of the options for establishing system diagnostics information

Basic knowledge required

The following knowledge is required in order to understand the function manual:

- General knowledge in the field of automation technology
- Knowledge of the industrial automation system SIMATIC
- Knowledge of working with STEP 7 and WinCC
- Knowledge about the use of Microsoft Windows operating systems

Scope of the documentation

This documentation is the basic documentation for all products of the S7-1500, ET 200MP, ET 200SP and ET 200AL systems, as well as for the CPUs 1513pro-2 PN und 1516pro-2 PN. The product documentation is based on this documentation.

What's new in the Diagnostics function manual, Edition 11/2019 compared to Edition 10/2018

What's new?		What are the customer benefits?	Where can I find the information?
Changed contents	Updated restrictions for the S7-1500R/H redundant system	Functions with which you are familiar from the SIMATIC S7-1500 automation system are implemented for the S7-1500R/H redundant system.	Section Diagnostics of the S7-1500R/H redundant system (Page 97)

What's new in the Diagnostics function manual, Edition 10/2018 compared to Edition 09/2016

What's new?		What are the customer benefits?	Where can I find the information?
New contents	Description of the diagnostics of the S7-1500R/H redundant system	You obtain information in compact form on the special features of the diagnostics in the S7-1500R/H redundant systems.	Section Diagnostics of the S7-1500R/H redundant system (Page 97)
Changed contents	Scope of the function manual expanded to include the S7-1500R/H redundant system	Functions with which you are familiar from the SIMATIC S7-1500 automation system are implemented for the S7-1500R/H redundant system.	Redundant System S7-1500R/H System Manual (https://support.industry.siemens.com/cs/ww/en/view/109754833)

What's new in the Diagnostics function manual, Edition 09/2016 compared to Edition 06/2014

What's new?		What are the customer benefits?	Where can I find the information?
New contents	Extended functionality of the Web server	<ul style="list-style-type: none"> • You obtain information about: <ul style="list-style-type: none"> – Know-how protection or copy protection of the PLC program – Program/communication load and cycle time – F-collective signatures, cycle times and runtimes of the F-runtime group(s) (with an F-CPU) • You can monitor statuses, errors, technology alarms and the current values of technology objects (TOs) with the Web server. • You can read, view and save trace recordings via the Web server and thus obtain plant and project information for diagnostics and maintenance without STEP 7. • You can set four additional languages for the Web server interface. 	Section Diagnostics information using the web server (Page 48), Web server http://support.automation.siemens.com/WW/view/en/59193560) function manual, Using the trace and logic analyzer function https://support.industry.siemens.com/cs/ww/en/view/64897128) function manual
	Assignment of different project languages extended	You can assign up to three different project languages for comments and alarm texts to the user interface languages of display devices.	Section Editing alarms in the alarm editor (Page 78)
Changed contents	Scope of the function manual expanded to include CPU 1516pro-2 PN	Functions that you will be familiar with from the SIMATIC S7-1500 CPUs are implemented in the CPU 1516pro-2 PN (degree of protection IP65, IP66 and IP67).	Operating instructions CPU 1516pro-2 PN https://support.industry.siemens.com/cs/ww/en/view/109482416)
	Security events added	You know which types of events are registered as security events in the diagnostics buffer and can configure group alarms for them.	Section CPU diagnostics buffer (Page 42)
	Influence of the value status explained	You know which factors influence the bit in the value status and can take this into account during configuration.	Section System diagnostics using process image inputs (Page 73)
	Note added on the maximum configuration limits of program alarms.		Section Creating alarms with the "Program_Alarm" instruction (Page 77).

Conventions

STEP 7: We refer to "STEP 7" in this documentation as a synonym for the configuration and programming software "STEP 7 as of V12 (TIA Portal)" and subsequent versions.

This document contains illustrations of the described devices. The illustrations may differ slightly from the device supplied.

You should also pay particular attention to notes such as the one shown below:

Note

A note contains important information on the product, on the handling of the product or on the section of the documentation to which particular attention should be paid.

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The Industry Mall is the catalog and order system of Siemens AG for automation and drive solutions on the basis of Totally Integrated Automation (TIA) and Totally Integrated Power (TIP).

Catalogs for all the products in automation and drives are available on the Internet (<https://mall.industry.siemens.com>).

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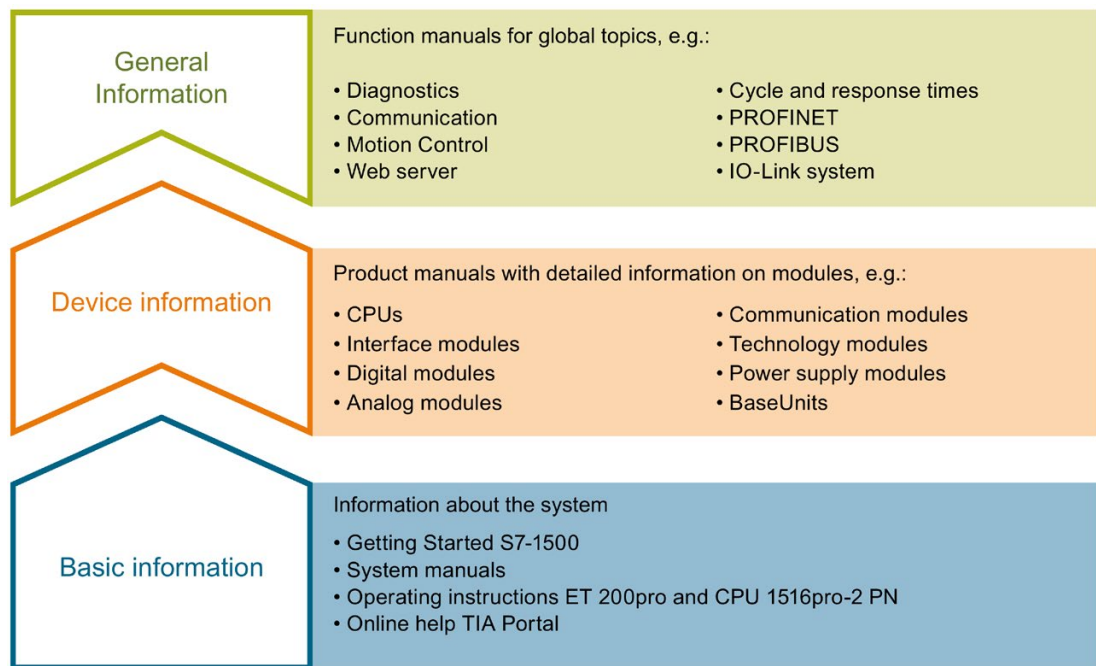
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Function manuals Documentation Guide

The documentation for the SIMATIC S7-1500 automation system, for CPU 1516pro-2 PN based on SIMATIC S7-1500, and for the distributed I/O systems SIMATIC ET 200MP, ET 200SP and ET 200AL is divided into three areas.

This division allows you easier access to the specific information you require.



Basic information

System manuals and Getting Started manuals describe in detail the configuration, installation, wiring and commissioning of the SIMATIC S7-1500, ET 200MP, ET 200SP and ET 200AL systems; use the corresponding operating instructions for CPU 1516pro-2 PN. The STEP 7 online help supports you in configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics such as diagnostics, communication, Motion Control, Web server, OPC UA.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742705>).

Changes and additions to the manuals are documented in product information sheets.

You will find the product information on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/us/en/view/68052815>)
- ET 200SP (<https://support.industry.siemens.com/cs/us/en/view/73021864>)
- ET 200AL (<https://support.industry.siemens.com/cs/us/en/view/99494757>)

Manual Collections

The Manual Collections contain the complete documentation of the systems put together in one file.

You will find the Manual Collections on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/ww/en/view/86140384>)
- ET 200SP (<https://support.industry.siemens.com/cs/ww/en/view/84133942>)
- ET 200AL (<https://support.industry.siemens.com/cs/ww/en/view/95242965>)

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Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

Overview of system diagnostics

2.1 Properties of system diagnostics

Introduction

In the SIMATIC environment, the term "system diagnostics" refers to diagnostics of devices and modules.

All SIMATIC products have integrated diagnostic functions that you can use to detect and remedy faults. The components automatically flag a potential fault in the operation and provide detailed information. You can minimize unscheduled standstill times with plant-wide diagnostics.

The SIMATIC automation system monitors the following states in the running plant:

- Device failure/recovery
- Insert/remove event
- Module fault
- I/O access error
- Channel fault
- Parameter assignment error
- Failure of the external auxiliary voltage

Properties of SIMATIC system diagnostics

- Integrated as standard in the hardware
- System-wide across bus limits
- Automatic localization of the error source
- Automatic output of the cause of the error in plain text
- Plant-wide diagnostics of all components
- Archiving and logging of alarms
- Configurability of alarms

Consistent diagnostics from the field level all the way to the management level

The various diagnostics media give you a uniform view of maintenance-related information of every automation component in the plant: System status (module and network status, alarms for system errors) are available plant-wide in a uniform display.

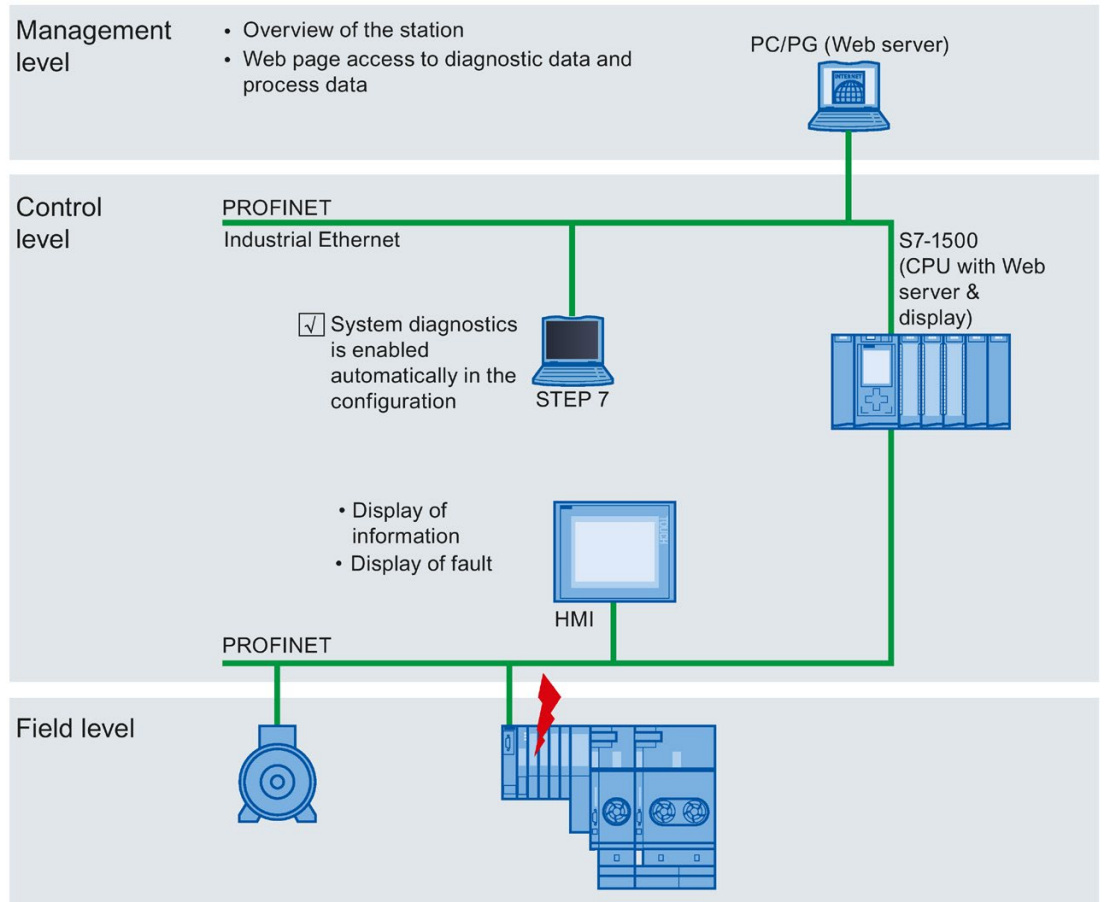


Figure 2-1 Overview of system diagnostics in a plant

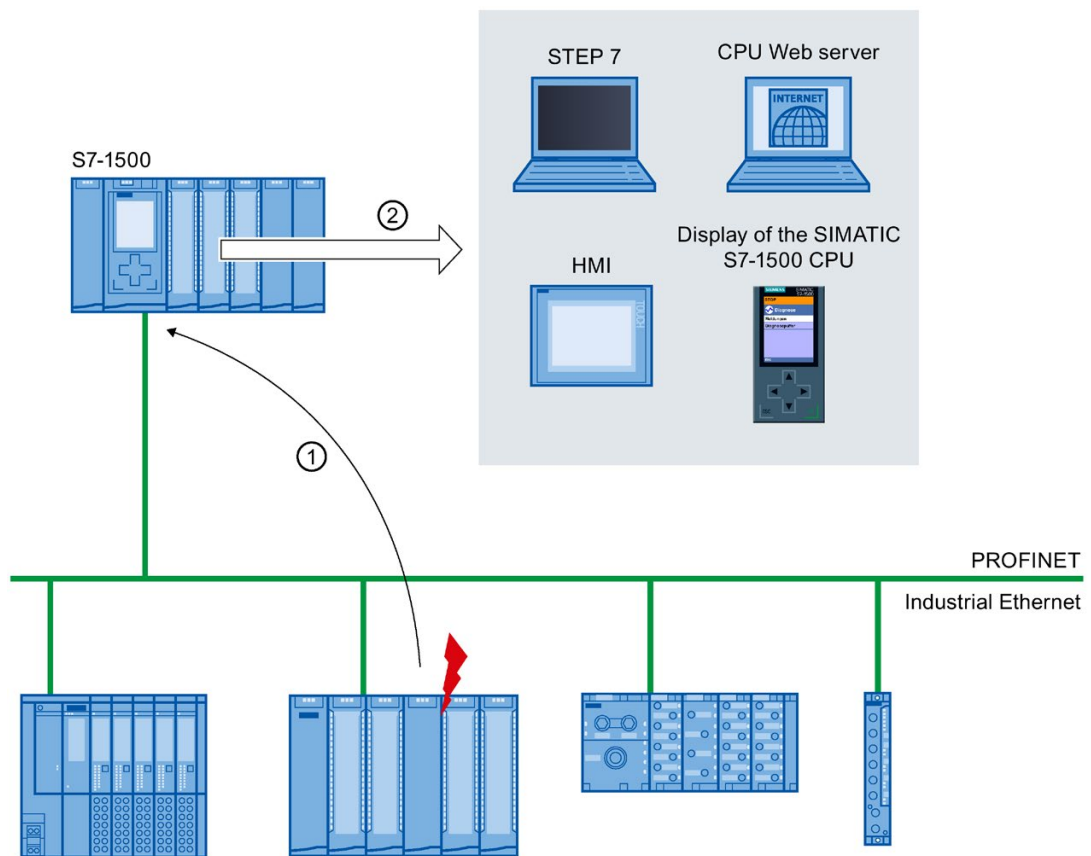
2.2 Benefits of innovative system diagnostics

System diagnostics is also possible in STOP

The system diagnostics is integrated in the firmware of the CPU and works independently of the cyclic user program. This means it is also available in the STOP CPU operating mode. Faults are detected immediately and signaled to the higher-level HMI devices, the Web server and the display of the SIMATIC S7-1500 CPU, even in STOP mode. This makes system diagnostics consistent with the actual plant state at all times.

Uniform display concept

All clients of a system are provided with diagnostics information by a uniform mechanism. The same system diagnostics information is used regardless of the display medium.



Step	Description
①	The device detects an error and sends diagnostics data to the assigned CPU.
②	The CPU informs the connected display media. The display of the system diagnostics is updated.

Figure 2-2 Sequence of the system diagnostics

Quick start

Introduction

The following chapters of this documentation describe the different options for establishing system diagnostics. All described options can be used independently of one another.

This chapter gives you an overview of the basic procedure to get initial diagnostics information fast.

Note

System diagnostics is generally available for the devices of the SIMATIC series.

3.1 Using the display of the CPU

The display of the SIMATIC S7-1500 CPU offers a fast and direct option to get diagnostics information. You can call up status information in different menus on the display.

Requirements

- A project has been created.
- The project has been downloaded to the CPU.

Determining diagnostics information using the display of the SIMATIC S7-1500 CPU

To determine diagnostics information using the display, follow these steps:

1. Select the "Diagnostics" menu on the display.
2. Select the "Diagnostics buffer" command from the "Diagnostics" menu.



Figure 3-1 Display of SIMATIC S7-1500 CPU

Result

The diagnostics events are displayed in the diagnostics buffer in the sequence in which they occur.

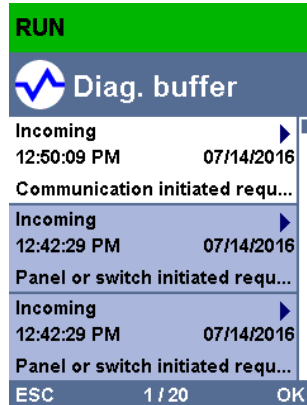


Figure 3-2 Display of the diagnostics buffer in the display of the SIMATIC S7-1500 CPU

Note

Automatic updating of diagnostics information

You set automatic updating of the diagnostics information under: "Display" > "DiagnosticRefresh".

Additional information

You can find information about the configuration of alarms in the section Configuring alarms for system diagnostics (Page 23).

3.2 Using STEP 7

Getting started with STEP 7 gives you fast access to detailed diagnostics information.

Requirements

- A project has been created.
- The project has been downloaded to the CPU.
- An error has occurred.
- The programming device must be able to establish a connection to the CPU via an interface.

Determining diagnostics information using STEP 7

To determine diagnostics information using STEP 7, follow these steps:

1. Open the respective project in STEP 7.
2. Open the portal view of STEP 7.
3. Select the "Online & Diagnostics" portal.
4. Select the "Online status" action.

The "Select device" dialog opens. The dialog is an image of the configured devices in the project.

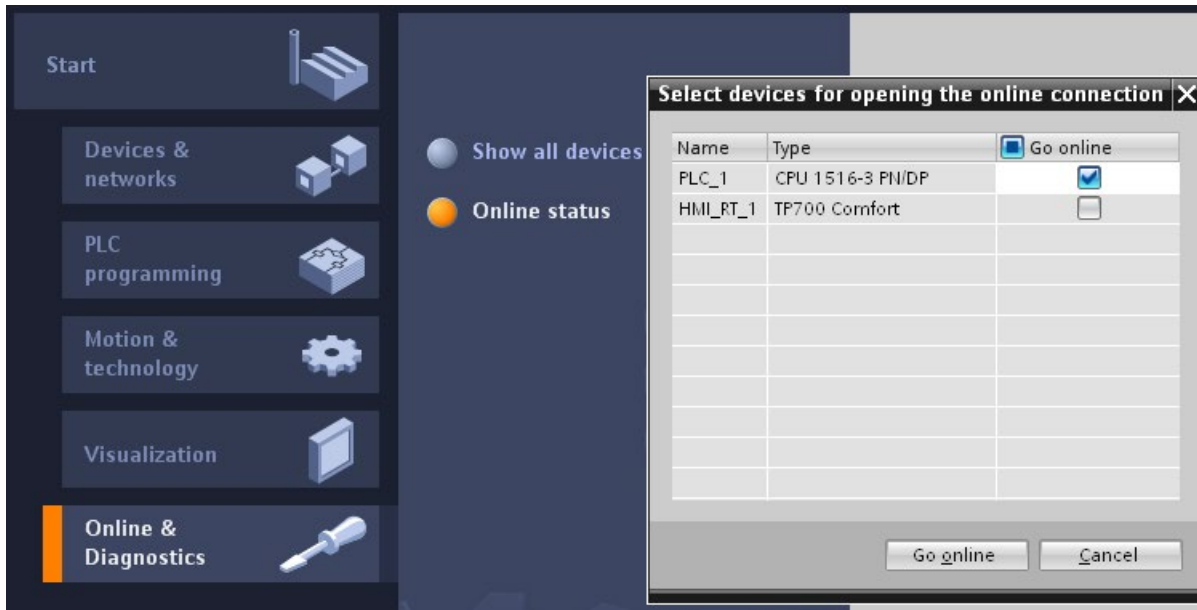


Figure 3-3 Device selection for online connection in the portal view

5. Activate the "Go online" option button for the device that you want to use to establish an online connection.
6. Click on the "Go online" button.

7. The "Go online" dialog opens.

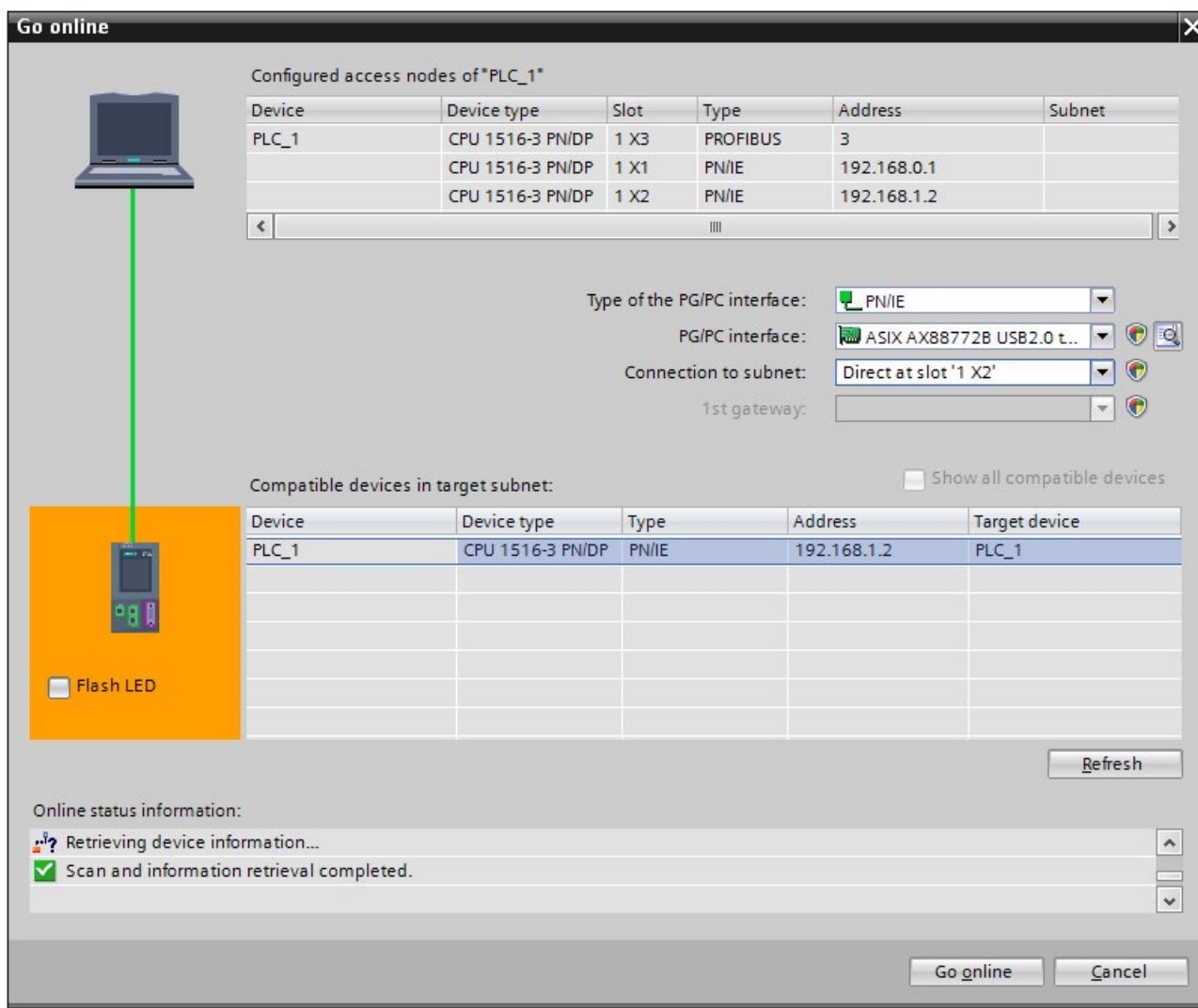


Figure 3-4 Establishing an online connection

8. Make the settings for the interface.

- 9. Click on the "Go online" button.

The project view of STEP 7 opens. The network view is opened in the work area.

The symbols in the project tree provide initial information about the faulty modules.

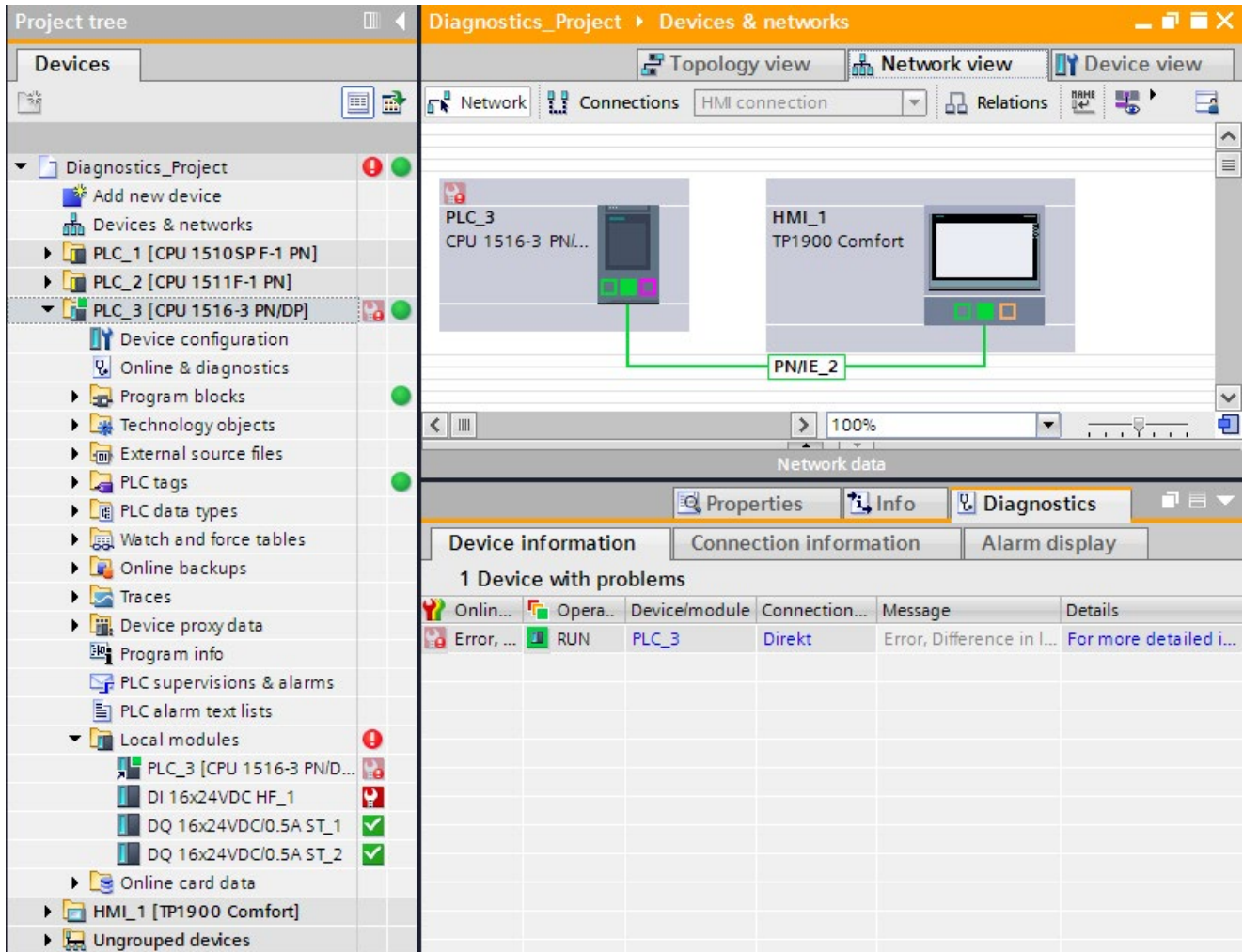


Figure 3-5 Display of the fault in the network view

10. Double-click the device which displays an alarm message to access the faulty module directly. This is the CPU in the example.

The device view of the CPU is opened in the work area. In this view you can see directly in which module the error has occurred.

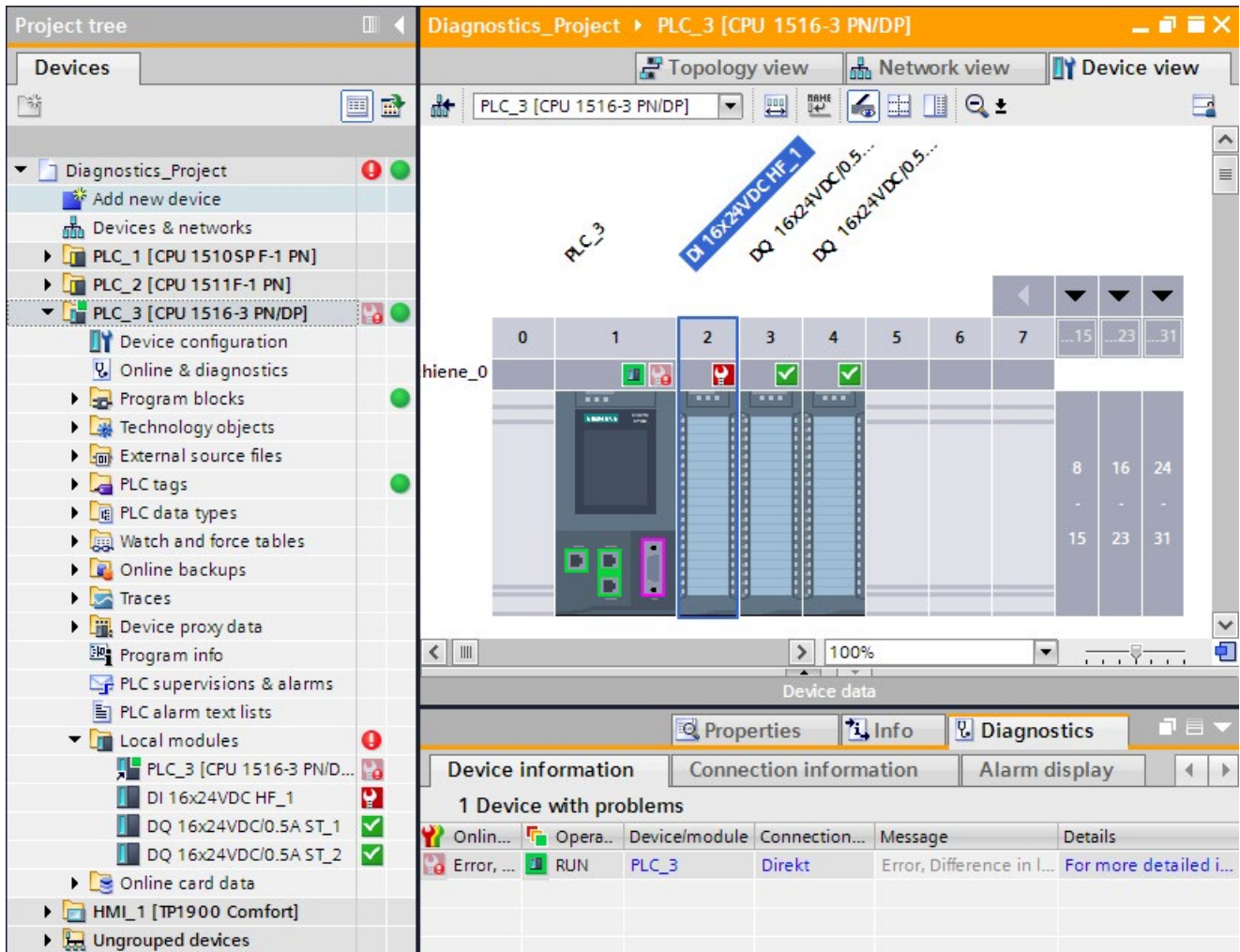


Figure 3-6 Display of the faulty module in the device view

11. Open the "Diagnostics" tab and the subordinate "Device information" tab in the Inspector window for a more detailed error description.

Result

The link in the "Details" table column takes you to the online and diagnostics view of the device and to the diagnostics buffer there, for example. This includes more information on all diagnostics events in the order in which they occurred.

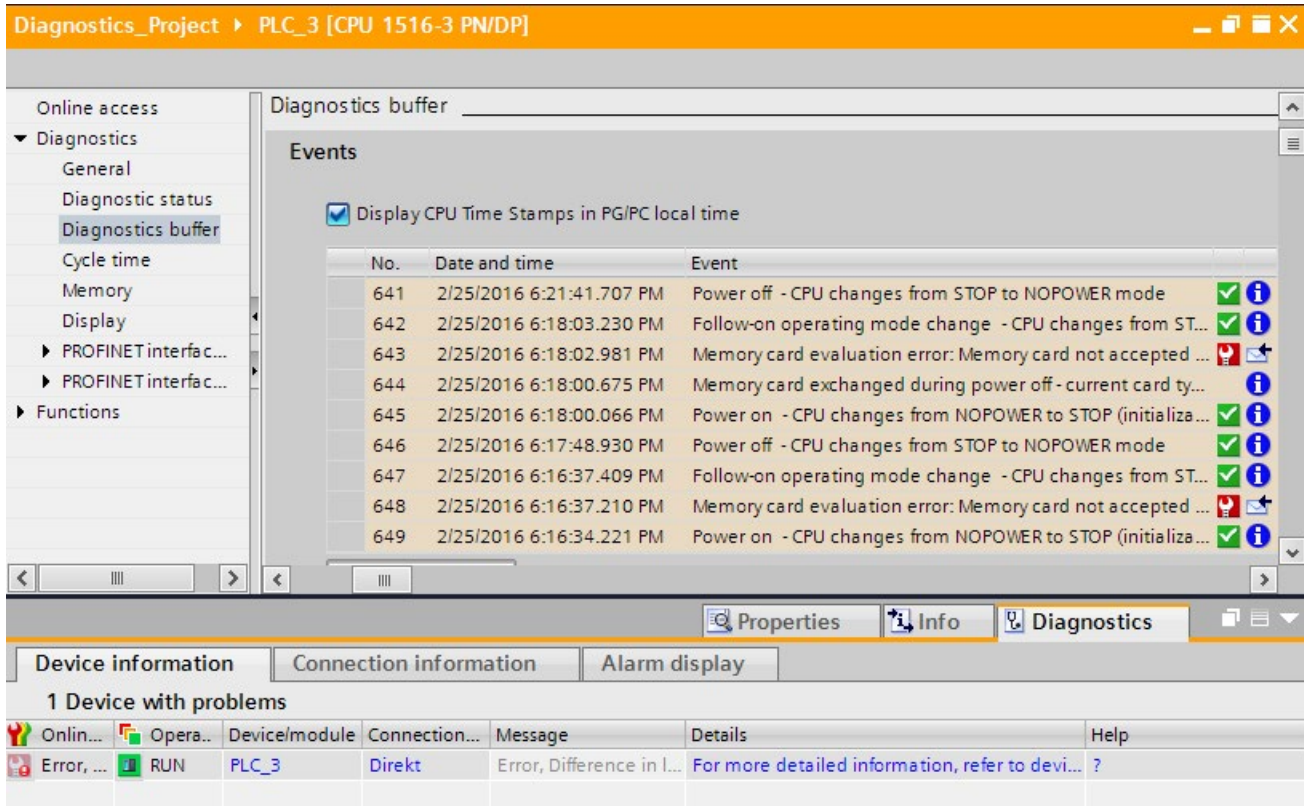


Figure 3-7 Diagnostics buffer with detailed error description

Note

Symbols and their meaning

You can find a legend with the meaning of each symbol in Explanation of diagnostics symbols (Page 29) and in the online help for STEP 7.

Setting and determining system diagnostics

Introduction

System diagnostics is generally available for the devices of the SIMATIC series.

In the properties of each individual CPU, you can specify if you want to receive alarms for system diagnostics on your display device. Alarms are provided on the display of the SIMATIC S7-1500 CPU, the CPU Web server and the HMI device. Alarms are enabled by default. If you do not want to receive alarms for system diagnostics on your display devices, you can disable the sending of alarms.

4.1 Configuring alarms for system diagnostics

Predefined alarm texts are available for establishing the system diagnostics.

Requirements

- STEP 7 is open.
- A project is open.

Procedure

To make alarm settings for system diagnostics of the project in STEP 7, follow these steps:

1. Open the "Common data" folder in the project tree.
2. Double-click the "System diagnostics settings" entry.

You now have access to the alarm settings. System diagnostics is enabled by default. System diagnostics cannot be disabled for the use of a CPU from the SIMATIC S7-1500 product series.

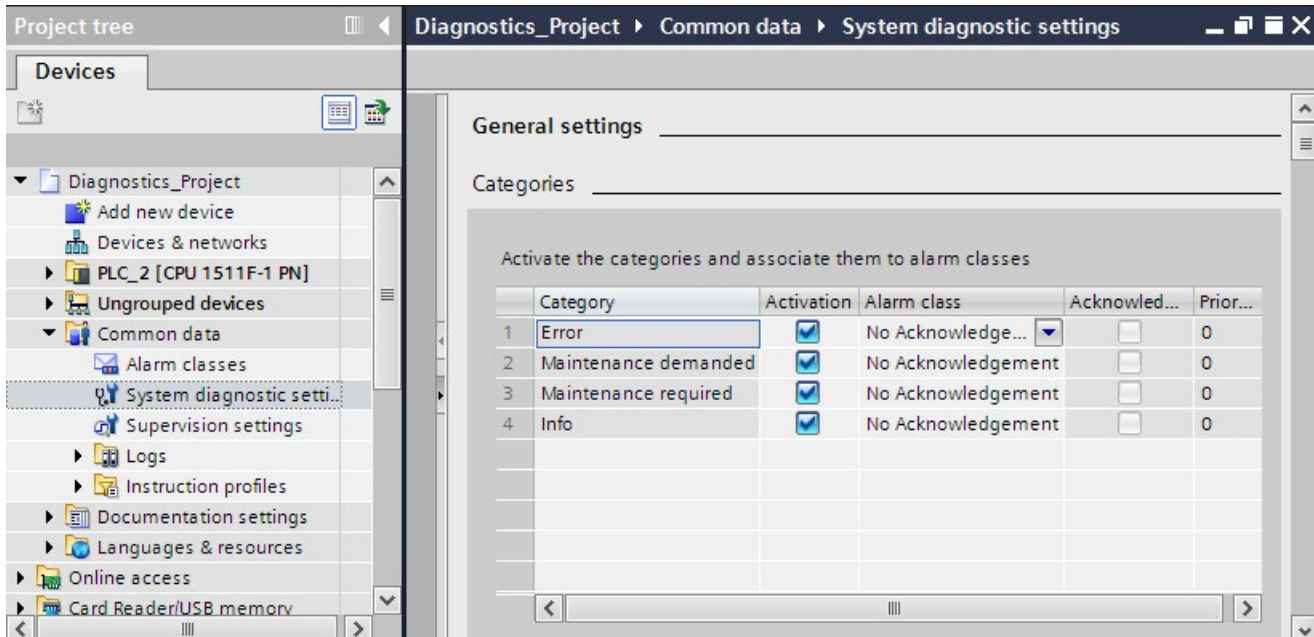


Figure 4-1 Properties of system diagnostics and alarm settings

3. In the settings, specify the alarm category that is to be displayed and if it needs to be acknowledged.

The check boxes in the "Activation" column are enabled by default. When you disable all check boxes, the status of the HMI system diagnostics view is still updated with the "Info Report" functionality.

Result

You have configured the alarms for system diagnostics of the project in STEP 7.

The settings are saved with the project and become effective after the compiling and downloading of the hardware configuration to the involved components.

Maintenance events (maintenance demanded, maintenance required) are entered in the alarm buffer of the CPU just like any other event.

4.2 Options for displaying system diagnostics

Example

This section includes a diagnostics example to show how system diagnostics is established with the help of different display options. The example includes a CPU from the SIMATIC S7-1500 product series that is connected to an ET 200S distributed I/O system and an HMI Comfort Panel via PROFINET.

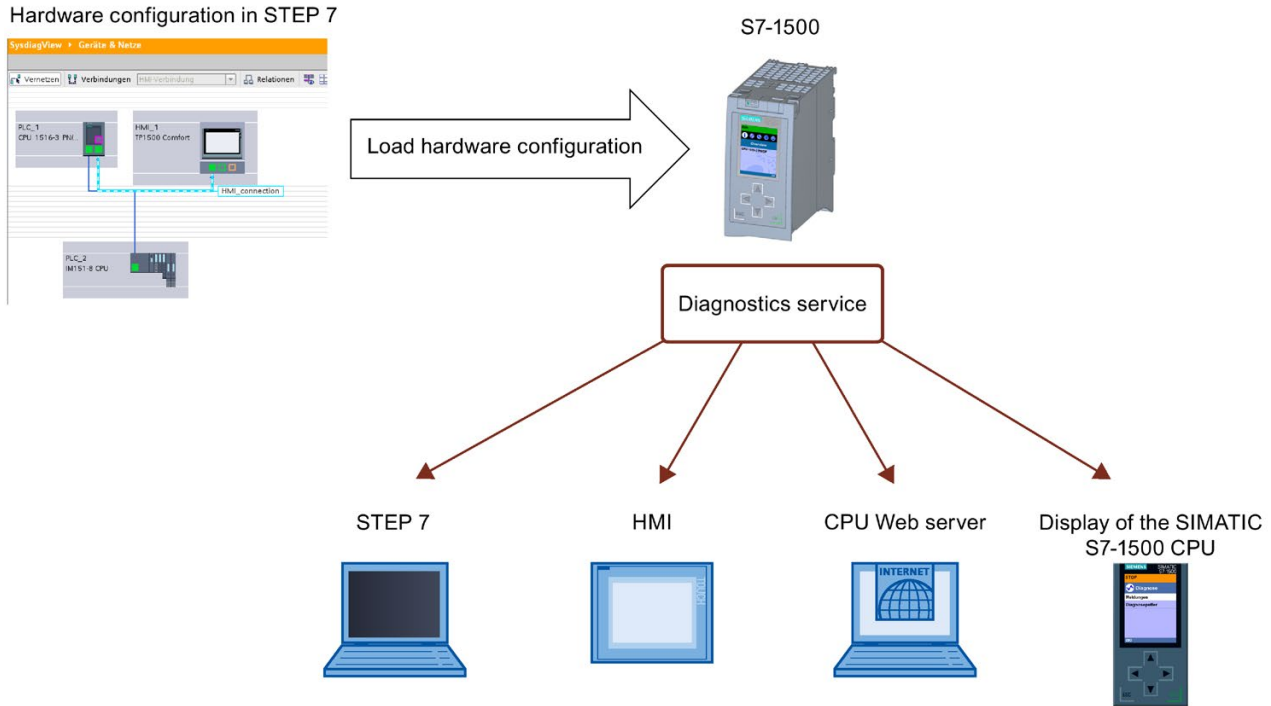


Figure 4-2 System diagnostics display options

The following sections include figures that illustrate how diagnostics information is displayed with the help of different display options.

- Using the LEDs on the hardware (Page 26)
- Local error analysis via the display of the CPU (Page 27)
- Using STEP 7 as of V12 (Page 29)
- Remote diagnostics using the Web server (Page 48)
- Stationary system diagnostics using the HMI diagnostics view (Page 59)

4.2.1 Diagnostics information at the devices

4.2.1.1 LEDs

Overview

All hardware components, such as CPUs, interface modules and modules, provide information about their operating mode as well as internal and external errors through their LEDs. Diagnostics by means of LEDs is an initial tool for error localization.

The graphics below include examples for the arrangement of LEDs on some modules.

Table 4- 1 LED displays on the modules

	CPU 1516-3 PN/DP	IM 155-5 PN ST	DI 32x24VDC HF	PS 25W 24VDC
①	RUN/STOP LED (two-colored LED: green/yellow)	RUN LED (two-colored LED: green/yellow)	RUN LED (single-colored LED: green)	RUN LED (single-colored LED: green)
②	ERROR LED (single-colored LED: red)	ERROR LED (single-colored LED: red)	ERROR LED (single-colored LED: red)	ERROR LED (single-colored LED: red)
③	MAINT LED (single-colored LED: yellow)	MAINT LED (single-colored LED: yellow)	without function	MAINT LED (single-colored LED: yellow)
④	X1 P1 (two-colored LED: green/yellow)	X1 P1 (single-colored LED: green)	LED CHx (two-colored LED: green/red)	

	CPU 1516-3 PN/DP	IM 155-5 PN ST	DI 32x24VDC HF	PS 25W 24VDC
⑤	X1 P2 (two-colored LED: green/yellow)	X1 P2 (single-colored LED: green)		
⑥	X2 P1 (two-colored LED: green/yellow)			

Additional information

The meaning of the individual LED displays, their different combinations and the remedial measures resulting from them in case of errors are device-specific. The explanation can be found in the manuals of the modules.

4.2.1.2 Display of the CPU

Introduction

Each CPU in the S7-1500 automation system has a front cover with a display and operating keys. You can display status information in various menus on the display of the CPU. You use the operating keys to navigate through the menus.



Figure 4-3 Display - diagnostics screen

Display options

The display of the SIMATIC S7-1500 CPU shows the following diagnostics information:

- CPU operating state

"Diagnostics" menu

- Error and alarm texts (system diagnostics alarms)
- Information entered in the diagnostics buffer
- Watch tables
- Information on the cycle times of the user program
- Utilization of the CPU memory

"Modules" menu

- Information on modules and the network
- Detailed device view with diagnostics symbols
- Order number, CPU version and central I/O modules
- Module status for central and distributed modules
- Information about the currently installed firmware

Additional information

For additional information on the topic "Functions and operation of the display of the SIMATIC S7-1500 CPU", see the documentation for the S7-1500 automation system (<http://support.automation.siemens.com/WW/view/en/59191792>).

You can find detailed information on the individual options, a training course and a simulation of the available menu commands of the display for the CPU in the SIMATIC S7-1500 Display Simulator (http://www.automation.siemens.com/salesmaterial-as/interactive-manuals/getting-started_simatic-s7-1500/disp_tool/start_en.html).
















4.2.2 Diagnostics information in STEP 7

4.2.2.1 Explanation of diagnostics symbols

Diagnostics symbols for modules and devices

When the online connection to a device is established in STEP 7, the diagnostics status of the device and its lower-level components and, if applicable, the device operating mode are also determined. The following table shows the possible symbols and their meaning.







Table 4- 2 Diagnostics symbols for modules and devices

Symbol	Meaning
	The connection with a CPU is being established.
	The CPU is not reachable at the set address.
	The configured CPU and the CPU actually present are of incompatible types. Example: An existing CPU 315-2 DP is incompatible with a configured CPU 1516-3 PN/DP.
	On establishment of the online connection to a protected CPU, the password dialog was terminated without specification of the correct password.
	No fault
	Maintenance required
	Maintenance demanded
	Error
	The module or device is deactivated.
	The module or the device cannot be reached from the CPU (valid for modules and devices below a CPU).
	Diagnostics data is not available because the current online configuration data differ from the offline configuration data.
	The configured module or device and the module or device actually present are incompatible (valid for modules or devices under a CPU).
	The configured module does not support display of the diagnostics status (valid for modules under a CPU).
	The connection is established, but the module status has not yet been determined or is unknown.
	Hardware error in lower-level component: A hardware fault has occurred in at least one lower-level hardware component (occurs as a separate symbol only in the project tree).

Symbols for the comparison status

The diagnostics symbols can be combined at the bottom right with additional smaller symbols that indicate the result of the online/offline comparison. The following table shows the possible comparison symbols and their meaning.







Table 4- 3 Symbols for the comparison status

Symbol	Meaning
	Hardware error in lower-level component: The online and offline versions differ (only in the project tree) in at least one lower-level hardware component.
	Software error in lower-level component: The online and offline versions differ (only in the project tree) in at least one lower-level software component.
	Online and offline versions of the object are different
	Object only exists online
	Object only exists offline
	Online and offline versions of the object are the same

Operating mode symbols for CPUs and CPs

The following table shows the possible symbols and their respective operating states.

Table 4- 4 Operating mode symbols for CPUs and CPs

Symbol	Operating mode
	RUN
	STOP
	STARTUP
	DEFECTIVE
	Unknown operating mode
	The configured module does not support display of the operating mode.





Event table

The following information is displayed in the table for each diagnostics event:

- Sequential number of the entry
The first entry contains the latest event.
- Date and time of the diagnostics event
If no date and time are shown, the module has no integrated clock.
- Short designation of the event and, if applicable, the reaction of the CPU
- Symbol for information on incoming/outgoing status

The following table shows the possible symbols and their meaning.

Table 4- 5 Symbols in the event table

Symbol	Meaning
	Incoming event
	Outgoing event
	Incoming event for which there is no independent outgoing event
	User-defined diagnostics event

Additional information

For additional information on the individual symbols, please refer to the online help for STEP 7.

4.2.2.2 Accessible devices (without project)

Accessible devices

Accessible devices are all devices that are connected to a PG/PC either directly by an interface or by means of a subnet and that are switched on. These devices can display diagnostic information even without an offline project.

Requirements

- STEP 7 is open.
- The portal view or project view is open.

Procedure

To display diagnostic information for specific devices even without an offline project, follow these steps:

1. Establish a connection to the respective CPU.
2. Select the command "Accessible devices" from the "Online" menu.

The "Accessible devices" dialog opens.

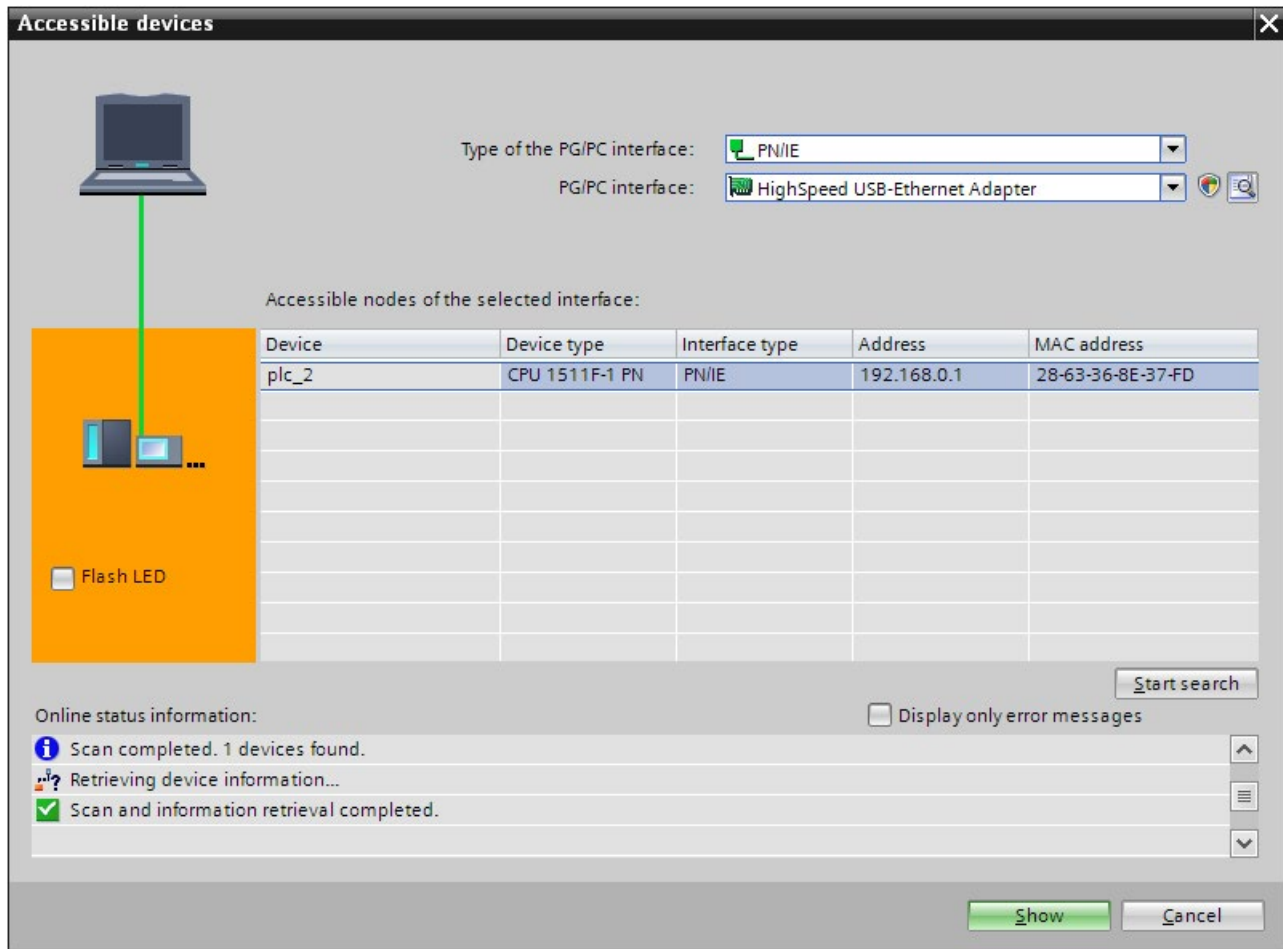


Figure 4-4 "Accessible devices" dialog

3. Make the settings for the interface.
4. Select the respective device under "Accessible nodes of the selected interface".
5. Confirm the dialog with the "Display" button.

Result

The device is displayed in the project tree. You open the diagnostic information in the work area with a double-click on "Online & Diagnostics".

Information is available on the diagnostic status, cycle times, memory usage and the diagnostics buffer.

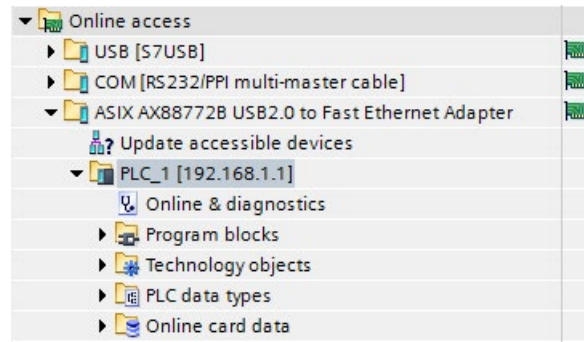


Figure 4-5 Device in the project tree

4.2.2.3 Devices & networks

Devices & networks - Go online

You can get an overview of the current state of your automation system in the device view or network view.

You implement the following tasks in the device view:

- Device configuration and parameter assignment
- Module configuration and parameter assignment

You implement the following tasks in the network view:


- Device configuration and parameter assignment
- Networking devices

Requirements

- STEP 7 is open.
- A project is open.
- The project view is open.

Procedure

To get an overview of the current state of your automation system, follow these steps:

1. Open the "Network view" in the working area.
2. Select the CPU.
3. Click the "Go online"  **Go online** button in the toolbar.

The "Go online" dialog opens.

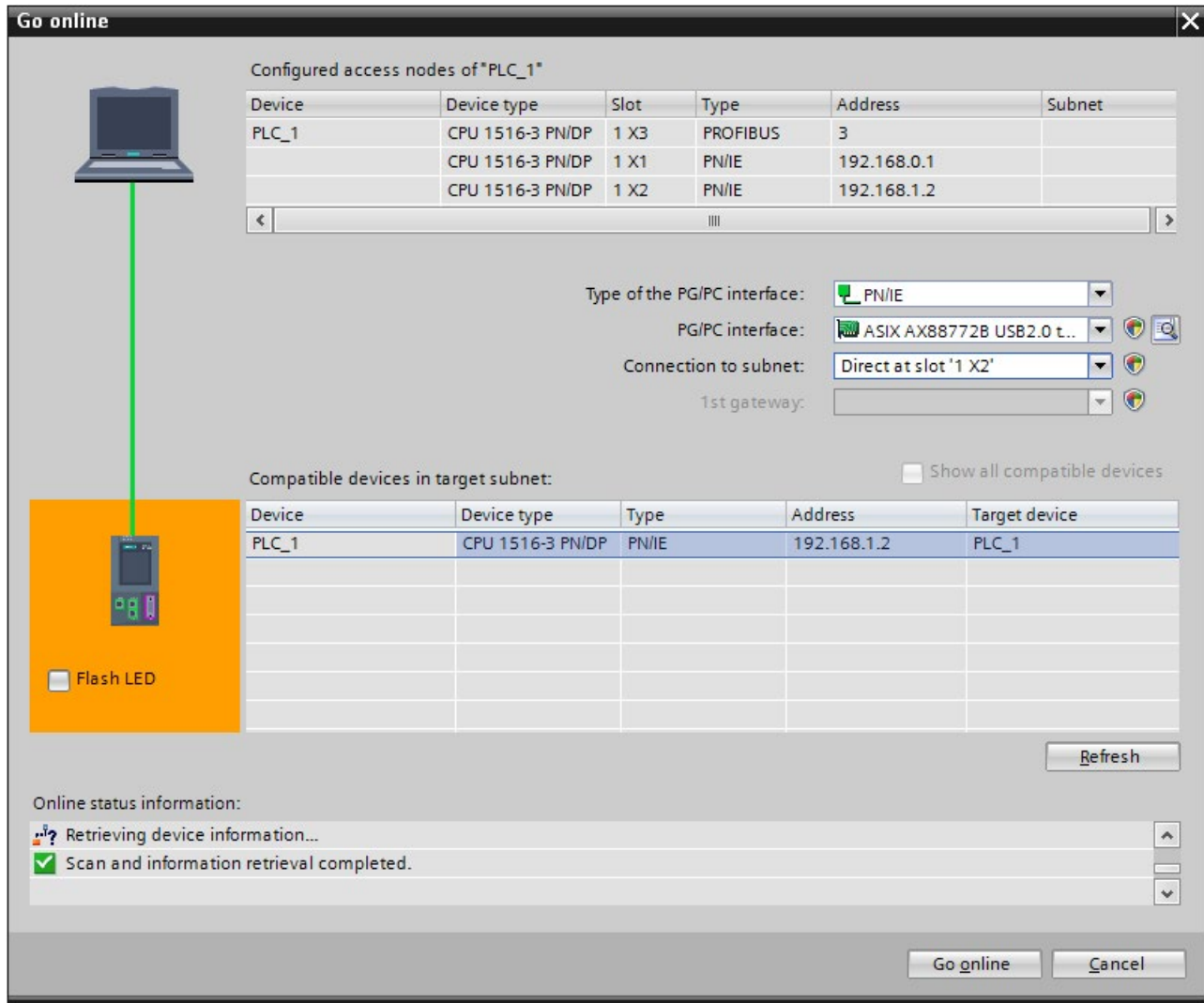


Figure 4-6 Go online

4. Make the settings for the interface.
5. Select the respective device under "Compatible devices in the target subnet".
6. Confirm the dialog with the "Connect" button.

The online mode is started.

Result

The connected devices are now displayed with diagnostic information in the network view in the working area. Here you get an overview of the current state of your automation device.

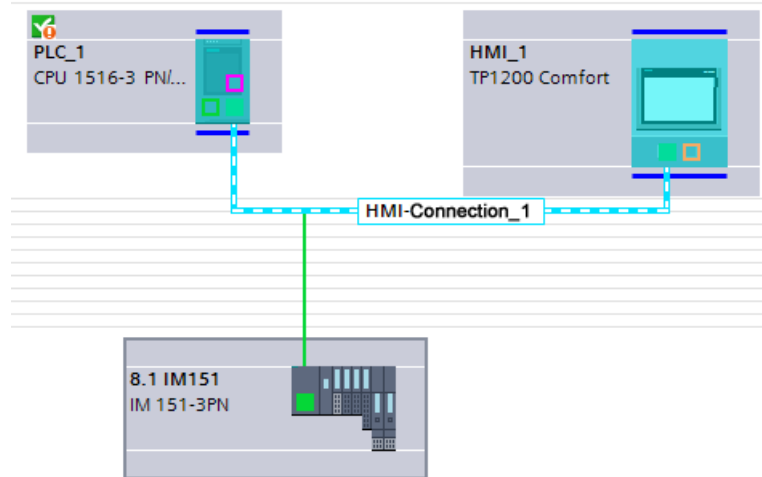


Figure 4-7 CPU with diagnostic information

You get to the "Device view" with a double-click on the device. The diagnostic information for the individual modules is displayed in this view.

Note

Symbols and their meaning

You will find a legend with the meaning of each symbol in Explanation of diagnostics symbols (Page 29) and in the online help for STEP 7.

4.2.2.4 Online & diagnostics

Online mode

In online mode there is an online connection between your PG/PC and one or several devices. Depending on the properties of a device, you are offered specific diagnostics options and certain functions in online mode.

- Diagnostics
 - General module information
 - Diagnostics status
 - Cycle time
 - Memory
 - Diagnostics buffer
 - Display
 - Interface information (e.g. IP parameter, port information)
- Functions
 - Assign IP address
 - Set time and date of the CPU
 - Firmware update (e.g. for PLC, display)
 - Assign device name
 - Reset to factory settings
 - Format memory card
 - Save service data

To establish an online connection at least one PG/PC interface must be installed that is physically connected with a device, for example, with an Ethernet cable. The current online status of a device is indicated by a symbol to the right of the device in the project tree.

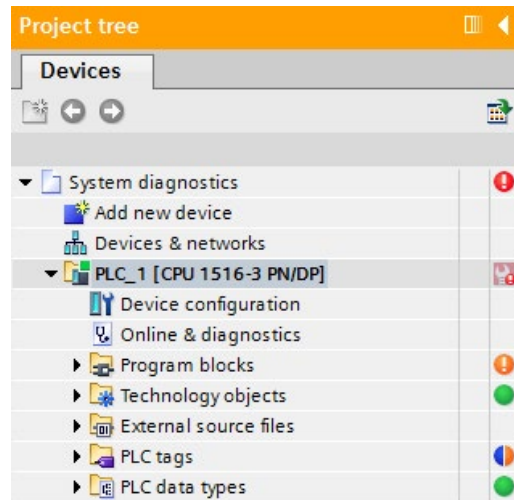


Figure 4-8 Partial view of network view

Requirements

- STEP 7 is open.
- A project is open.
- The project view is open.

Procedure

To display an overview of the faulty devices, follow these steps:

1. Select the affected device folder in the project tree.
2. Select the shortcut menu command "Online & Diagnostics".

The online and diagnostics view of the module to be diagnosed is started.

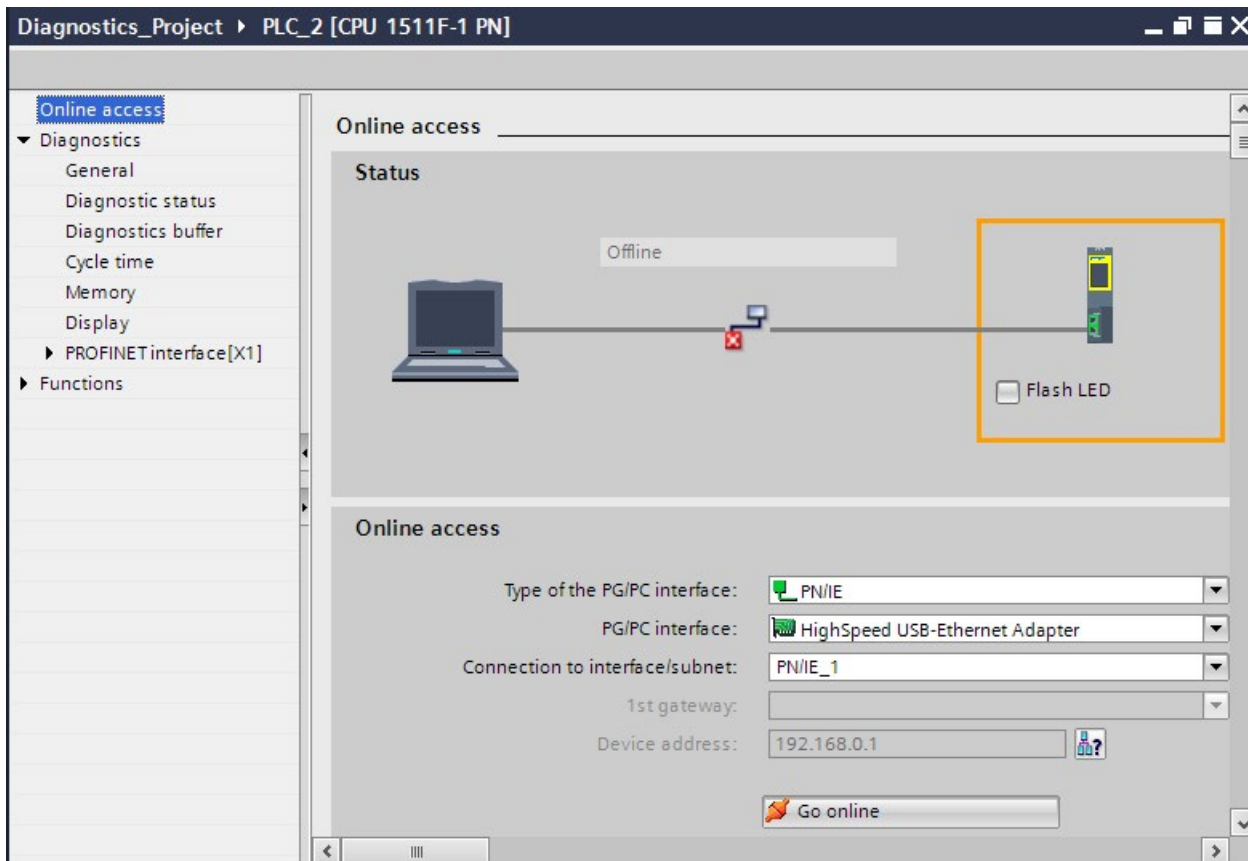


Figure 4-9 Setting online access

3. Make the settings for the interface.

Here you can change an interface access that has already been set for an online connection that was successfully established previously.

4. Click on the "Go online" button.

The online connection is established.

Result

You can find detailed diagnostics information on each device in the Inspector window, in the "Diagnostics" section of the area navigation on the "Properties" tab.

4.2.2.5 "Diagnostics" tab in the Inspector window

"Diagnostics" tab in the Inspector window

The "Diagnostics" tab of the Inspector window includes information on diagnostics events and configured alarm events.

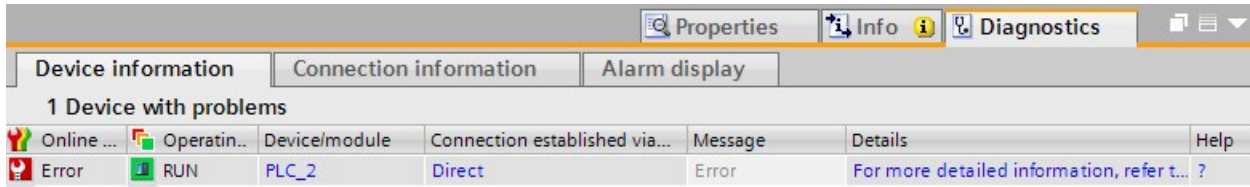


Figure 4-10 Diagnostics in the Inspector window, "Device information" tab

Note

Symbols and their meaning

You can find a legend with the meaning of each symbol in Explanation of diagnostics symbols (Page 29) and in the online help for STEP 7.

Subordinate "Device information" tab

This tab gives you an overview of faulty devices to which an online connection exists or has existed. The table provides the following diagnostics information on the faulty devices:

- Online status: Includes the online status as diagnostics symbol and in words
- Operating mode: Includes the operating mode as symbol and in words
- Device/module: Name of the affected device or the affected module
- Connection established via ...: Specifies the path used to establish the connection to the failed device.
- Alarm: This explains the entry in the previous columns and displays an alarm, if necessary
- Details: The link opens the online and diagnostics view associated with the device or puts it in the foreground.
If the device cannot be reached, the link opens the "Go online" dialog.
- Help: The link provides additional information on the fault.

Note

Communication and access errors

Errors that occur in the user program (e.g., communication errors, access errors) are not reported in the "Diagnostics" tab of the device information. You must read out the diagnostics buffer of the CPU in the online and diagnostics view to get this information. The link in the "Details" column opens the diagnostics buffer.

Subordinate "Connection information" tab

The "Connection information" tab displays detailed diagnostics information for connections. There will only be information on the "Connection information" tab if there is an active online connection to at least one end point of the relevant connection.

If a connection has been selected (connection table), the tab contains the following groups:

- Connection details
- Address details of the connection

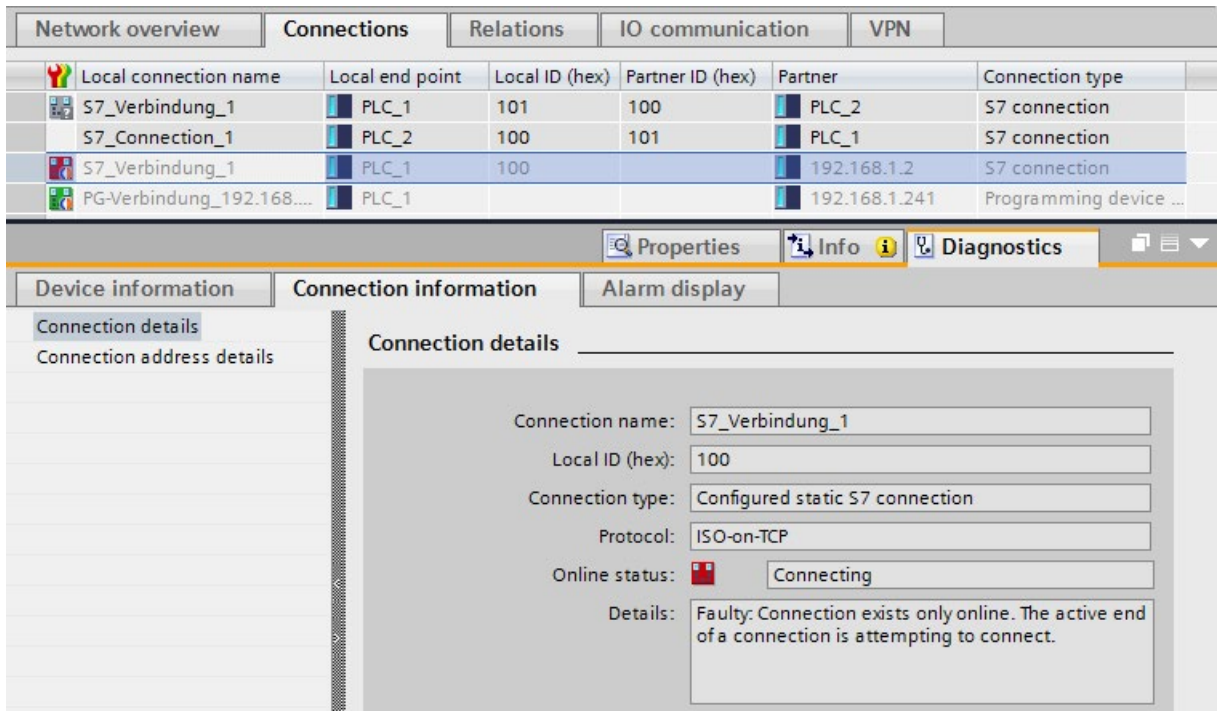


Figure 4-11 "Connection information" tab and open connection overview

If a module has been selected (network view), the tab contains the following group:

- Connection resources

Subordinate "Alarm display" tab

System diagnostics alarms are output in the "Alarm display" tab.

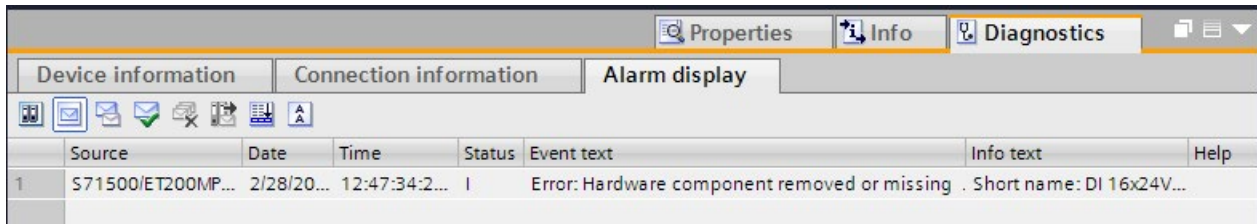


Figure 4-12 "Alarm display" tab

To receive alarms in STEP 7, follow these steps:

1. Open the project view.
2. Select the required CPU in the project tree.
3. To connect online with the respective CPU, select the shortcut menu command "Go online".
4. Select the required CPU once again in the project tree and select the shortcut menu command "Receive alarms".

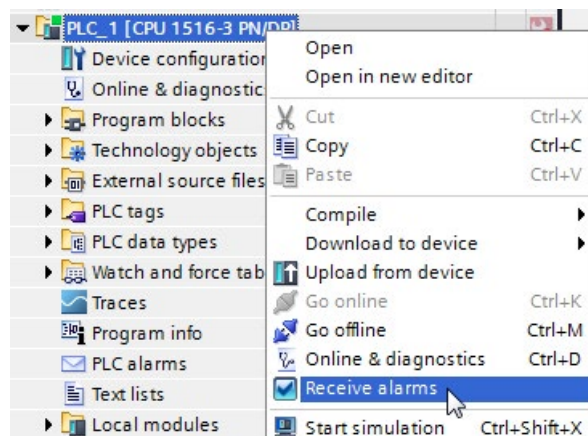



Figure 4-13 Receive alarms

5. Alarms are now displayed in the alarm display. "Archive view" is enabled by default.
6. To display the latest alarms, click the "Active alarms" icon .

4.2.2.6 CPU diagnostics buffer

Definition

Each CPU and some other modules have their own diagnostics buffer, in which detailed information on all diagnostic events is entered in the order in which they occurred.

The CPU diagnostics buffer can be displayed on all display media (STEP 7, SIMATIC HMI devices, SIMATIC S7-1500 Web server and display of the CPU).

Diagnostic events

The entries available in the diagnostics buffer include:

- Internal and external errors on a module
- System errors in the CPU
- Operating mode transitions (e.g., from RUN to STOP)
- Errors in the user program
- Removal/insertion of modules
- Security events

The contents of the diagnostics buffer are stored in the retentive memory in case of a memory reset of the CPU. Errors or events can be evaluated even after a longer period of time thanks to the diagnostics buffer to determine the cause of a STOP or to trace the occurrence of a single diagnostic event and to be able to assign it.

Procedure

To display the diagnostics buffer of a CPU in STEP 7, follow these steps:

1. Select the respective CPU.
2. Select the shortcut menu command "Online & Diagnostics".

The "Online access" view is opened in the work area.

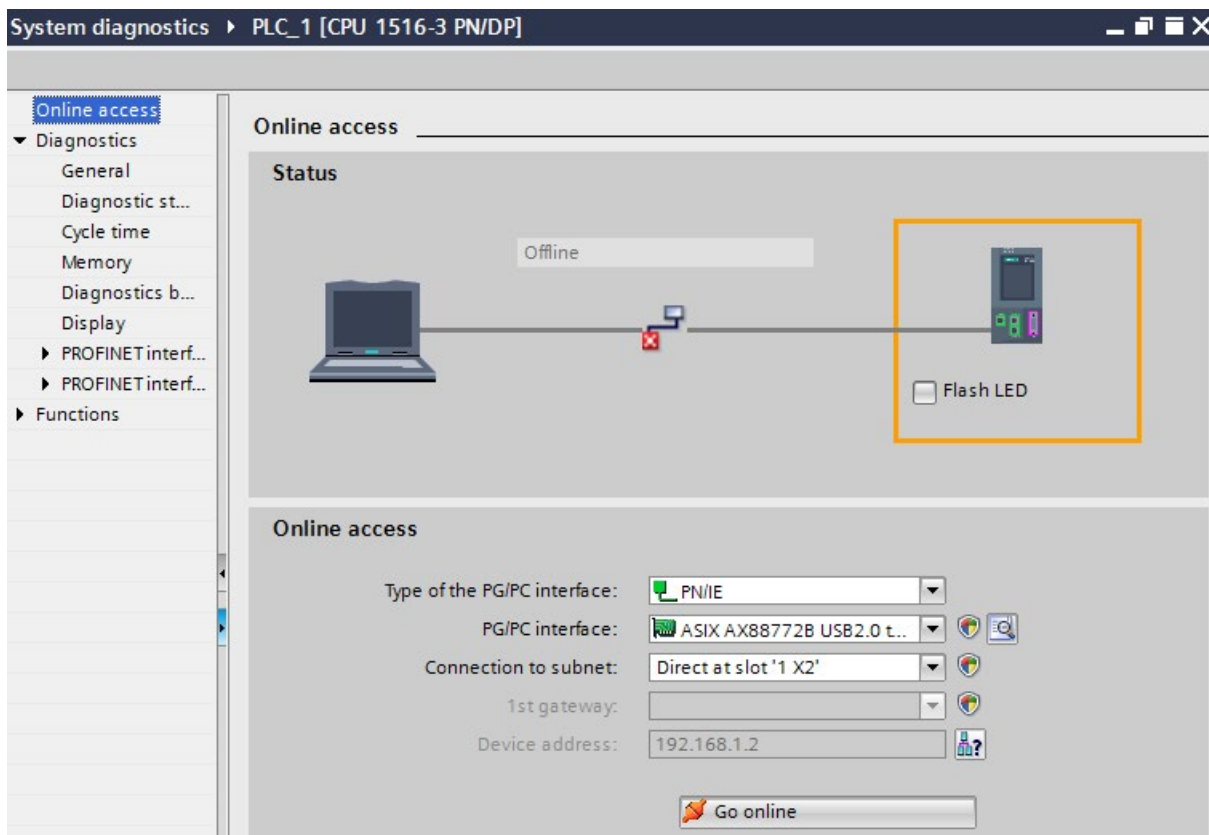



Figure 4-14 Setting up online access

3. Set the interface.

- 4. Click  Go online.
- 5. Select the area "Diagnostics buffer".

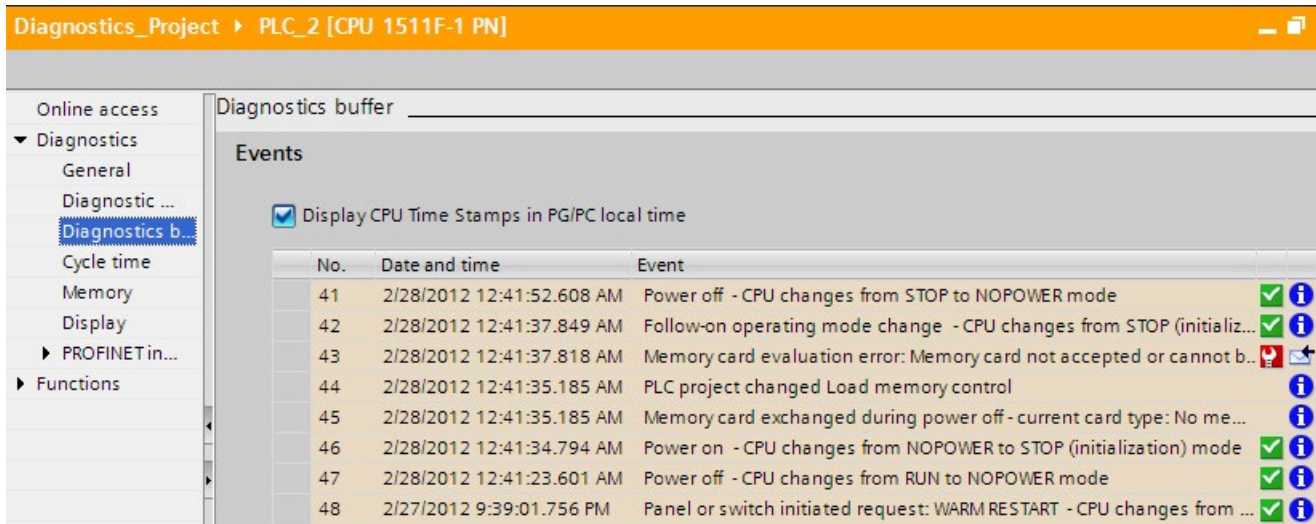


Figure 4-15 Diagnostics buffer in STEP 7

Note

Filtering events

You can filter the entries in the diagnostics buffer in the settings of the "Diagnostics buffer" area to only display specific types of events. This means that specific events, such as "CPU and configuration-internal events" or "Connection diagnostics events", can be displayed separately.

Security events

The following security events (event types) result in an entry in the diagnostics buffer.

- Going online with the correct or incorrect password
- Manipulated communications data detected
- Manipulated data detected on memory card
- Manipulated firmware update file detected
- Changed protection level (access protection) downloaded to the CPU
- Password legitimization restricted or enabled (by instruction or CPU display)
- Online access denied due to the possible number of simultaneous access attempts being exceeded
- Timeout when an existing online connection is inactive
- Logging on to the Web server with the correct or incorrect password
- Creating a backup of the CPU
- Restoring the CPU configuration (Restore)

To prevent the diagnostics buffer being "swamped" by large numbers of identical security events, you can set parameters so that these events are entered in the diagnostics buffer as a group alarm. For every interval (monitoring time), the CPU then only generates one group alarm per event type.

Configuring a group alarm for security events

To configure group alarms for security events, follow these steps:

1. Click on the CPU icon in the network view.
The properties of the CPU are displayed in the Inspector window.
2. Navigate to the "Protection" > "Security event" area.
3. Click "Security event".
4. Select the option "Summarize security events in case of high message volume" to enable group alarms for security events.
5. Set the duration of an interval (monitoring period); the default is 20 seconds.

4.2.2.7 "Online tools" task card

Online view in the "Online tools" task card

The following requirements must be met to display the online view of the "Online tools" task card in STEP 7:

- An online connection to the CPU is available.
- You have selected the CPU in the topology view, network view or device view.

The "Online tools" task card provides an overview of the CPU state, the cycle time and the memory usage.

- The "CPU operator panel" pane displays the current state of some LEDs and the mode selector of a CPU.
- The "Cycle time" pane displays the cycle time diagram and below it the measured cycle times as absolute values.
- The "Memory" pane contains the current memory usage of the associated CPU. The free memory is shown both as a bar graph and as a numerical value (percentage). The display for "Load memory" contains, in addition to the online project data (program code, data blocks, hardware configuration etc.), all other data that may be on the SIMATIC memory card, such as recipes, data logs, HMI backups or non-SIMATIC files that have been copied to the memory card via the Web server of the CPU or offline in Explorer (for example, PDF files).

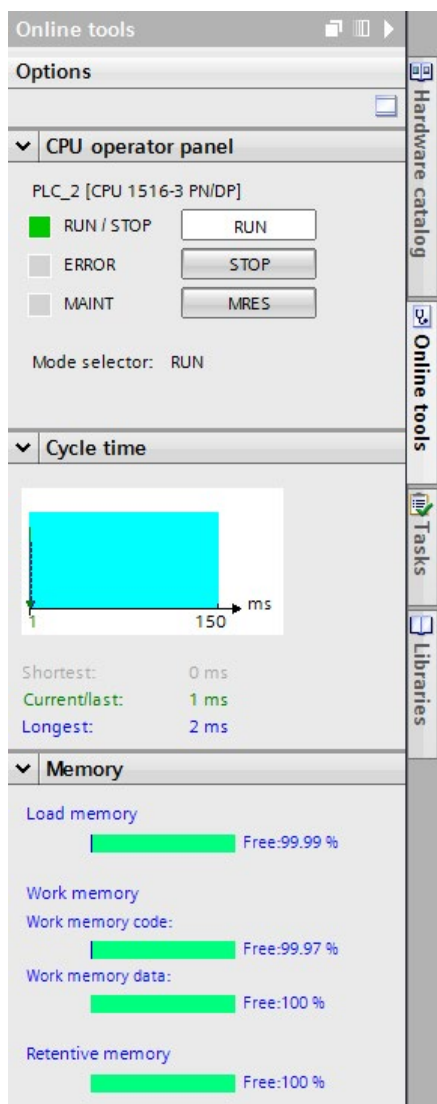


Figure 4-16 "Online tools" task card

4.2.2.8 Configuring the settings for I/O modules in STEP 7

You can also make settings for system diagnostics in STEP 7 for I/O modules. The parameters you have to configure depend on the I/O module.

The settings are optional.

Requirements

- STEP 7 is open.
- A project is open.
- The project view is open.
- A design with I/O modules has been configured.

Procedure

To make settings for system diagnostics of I/O modules in STEP 7, follow these steps:

1. Select the respective I/O module in the device view.
2. Open the "Properties" tab in the Inspector window.
3. Select the area "Inputs", for example.

You have access to the settings for system diagnostics of the I/O module. If you select "Wire break", for example, a possible wire break for the channel is signaled during operation.

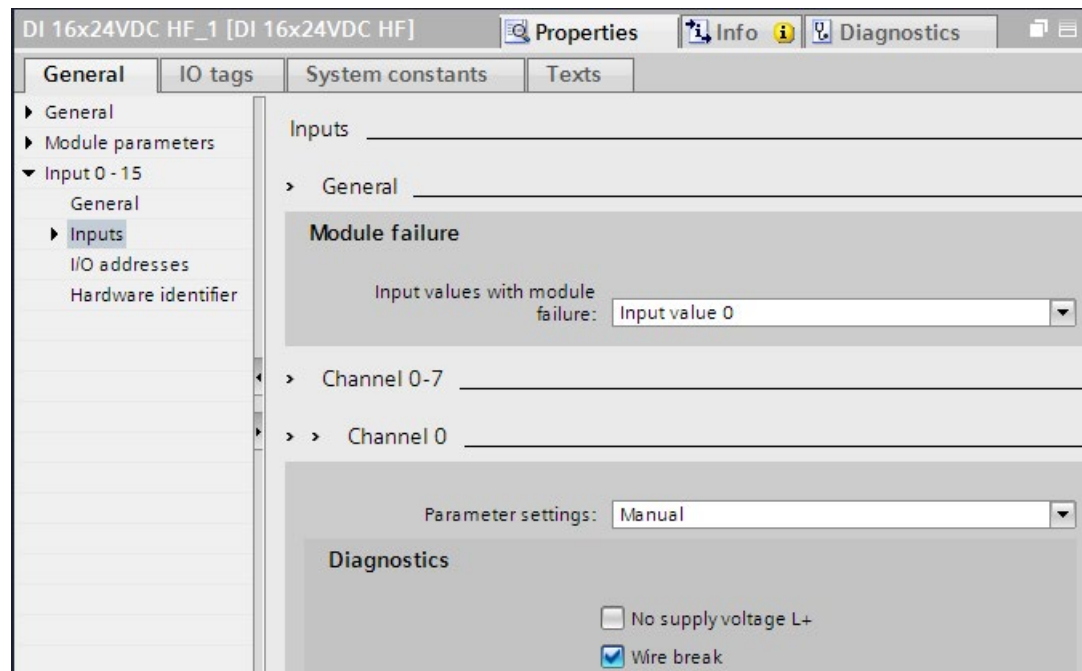


Figure 4-17 I/O setting with a digital input module

4. Save the hardware configuration.
5. Download the new hardware configuration to the CPU.

Additional information

The documentation for the respective module includes additional information on parameter assignment of I/O modules.

4.2.3 Diagnostics information using the web server

System diagnostics using the CPU Web server

The CPUs of the SIMATIC series have an integrated Web server and let you display the system diagnostics information by means of PROFINET. Any terminal devices, such as PCs or smartphones, can thus access module data, user program data and diagnostics data of a CPU by using an Internet browser. This means access to CPUs is possible without installed STEP 7.

In addition to normal websites, the Web server provides so-called basic websites with reduced content that are adapted to the requirements of small screens with low resolution.

Using CPU 1516-3 PN/DP as an example, the following figure shows the start page of the Web server:

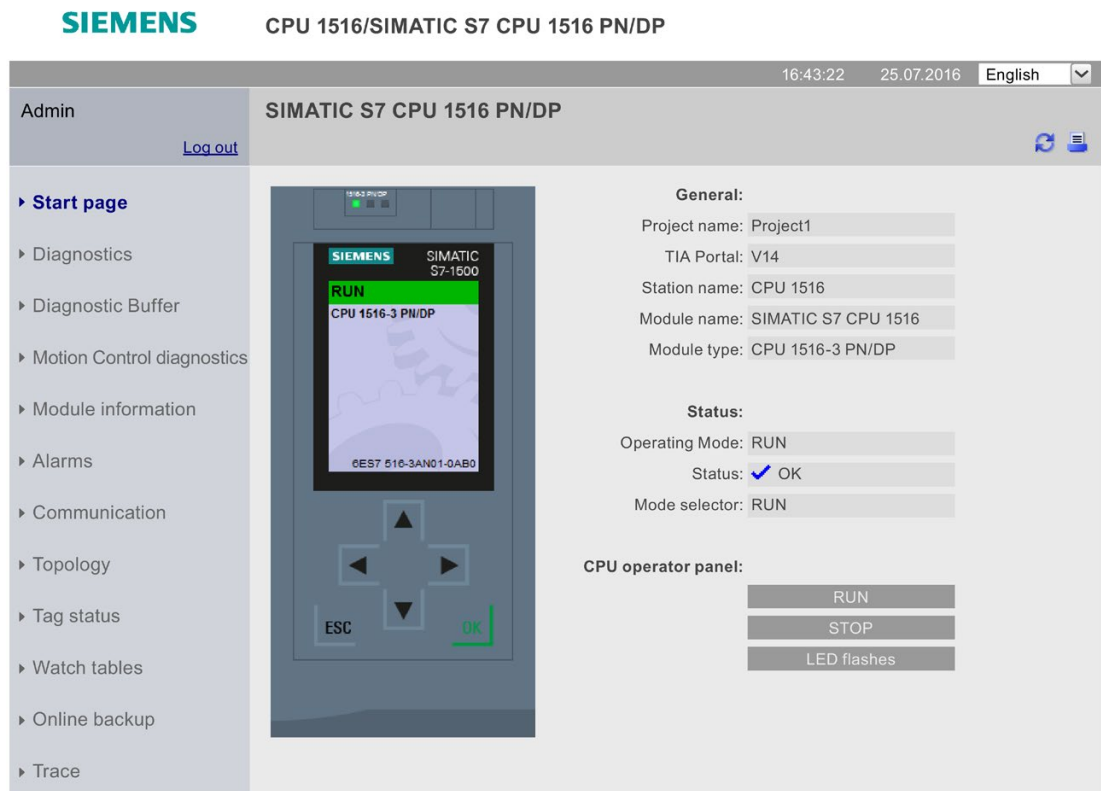


Figure 4-18 Web server, Start page

The following diagnostics options are available with the integrated Web server:

- Start page with general CPU information
- Information on diagnostics
- Contents of the diagnostics buffer
- Module information
- Alarms
- Information about communication
- PROFINET topology
- Motion Control diagnostics
- Trace

Configuring the Web server in STEP 7

Proceed as follows to activate the Web server:

Requirements

- You have opened STEP 7.
- You have added a CPU to the project.
- You have opened the project view.

Procedure

1. Open the network view.
2. Select the CPU.
3. Open the "Properties" tab in the Inspector window.
4. Select the entry "Web server" in the "General" area navigation.

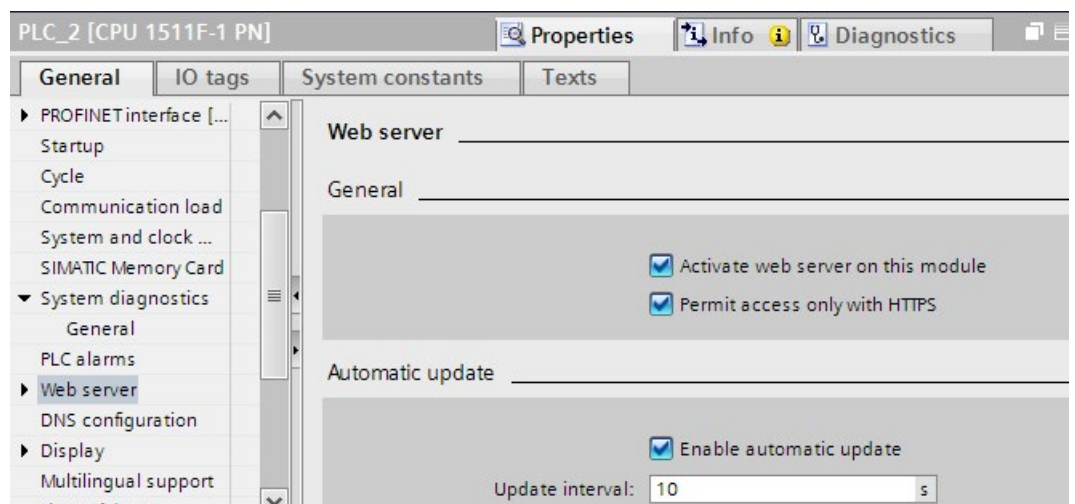


Figure 4-19 Activate the Web server

5. Select the "Activate web server on this module" check box.
6. "Permit access only with HTTPS": The activation of the Web server using the secure transmission protocol "HTTPS" requires a valid Web server certificate in the CPU.

NOTICE

Utilizing the full functionality of the Web server

A valid CA-signed Web server certificate in the CPU is a requirement for:

- User management with password-protected users
- Saving and downloading diagnostic information in csv files
- Using the following safety-related functions:
 - Backing up and restoring the CPU configuration

To use the full functionality of the Web server, we recommend that you create a CA-signed server certificate and assign it to the CPU.

To create a CA-signed Web server certificate, you must enable the Certificate Manager in the global security settings of STEP 7 and assign a CA-signed server certificate to the Web server in the properties of the CPU.

You can find additional information on handling Web server certificates in the "Configuring the Web server" section of the Web server function manual (<http://support.automation.siemens.com/WW/view/en/59193560>).

Detailed information on Certification Authority (CA) certificates, device certificates (End Entity certificate), "Public Key Infrastructure" (PKI) and certificate management can be found in the Communication function manual (<https://support.industry.siemens.com/cs/ww/en/view/59192925>) and in the online help for STEP 7, keyword "Secure communication".

7. Automatic updating is activated in the default setting of a configured CPU.
8. Activate the Web server also for each interface via which you want to access the Web server.
To do this, open the "Properties" tab in the Inspector window and select the "Web server" entry in the "General" area navigation. In the "Overview of interfaces" area, select the "Enabled web server access" check box for the corresponding interface.
9. Compile and load the configuration into the CPU.

Accessing the Web server

To access the Web server, proceed as follows:

1. Connect the display device (PG/PC, HMI, mobile terminal device) with the CPU or a communication module using a PROFINET interface.
If you are working with WLAN, activate the WLAN on the display device and establish a connection to the access point (e.g. SCALANCE W788-1RR or SCALANCE W784-1), which is in turn connected to the CPU.
2. Open the web browser on the display device.
3. Enter the IP address of the interface of the CPU which is connected to the client in the "Address" field of the web browser in the following format: http://a.b.c.d or https://a.b.c.d (example input: https://192.168.3.141).
The intro page of the CPU opens.
4. You need to perform the installation of the CA certificate again for each display device you want to use. A valid CA certificate is available for download from the "Intro" web page under "Download certificate". You can find instructions for installing the certificate in the help system of your Web browser and in the FAQ with the entry ID 103528224 at the Service&Support (<https://support.industry.siemens.com/cs/ww/en/view/103528224>) website.
5. Click the NEXT link to go to the Web server pages.

Note

Managing access rights

In STEP 7, you can create users, define access rights and assign passwords under "Web server > User management". Users only have access to the options that are permanently linked to the access rights.

You can find additional information on managing access rights in the "Configuring the Web server" section of the Web server function manual (<http://support.automation.siemens.com/WW/view/en/59193560>).

"Diagnostics" option

The "Diagnostics" web page provides more information about the tabs:

- Identification
This tab contains the characteristics of the CPU (serial number, article number, hardware and firmware version, etc.).
- Program protection
This tab provides information on whether the PLC program contains know-how protection or copy protection.
- Memory
This tab contains current values on the memory currently in use.
- Runtime information
Current information on program/communication load and cycle time can be found in this tab.
- Fail-safe (only with an F CPU)
The safety program of an F-CPU consists of one or two F-runtime groups. You can find their cycle time (F-monitoring time) and runtime in this tab.

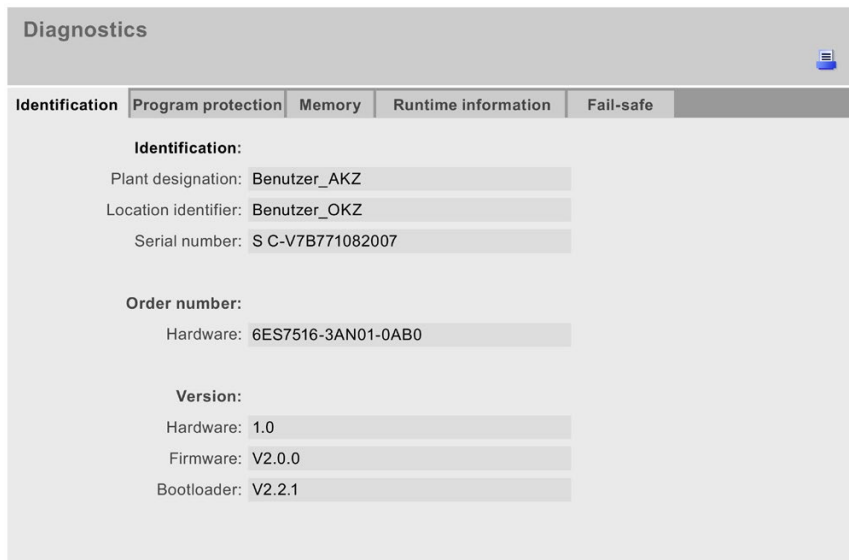


Figure 4-20 Web server, "Diagnostics" Web page

Diagnostics option "Diagnostics buffer"

The browser displays the content of the diagnostics buffer on the "Diagnostics buffer" Web page.

Diagnostic Buffer				
Number	Time	Date	Status	Event
1	10:45:20:907	13.11.2014	incoming event	Mode transition from STARTUP to RUN
2	10:45:20:905	13.11.2014	incoming event	Request for Automatic warm restart
3	10:45:20:873	13.11.2014	incoming event	Parameter assignment error
4	10:45:20:856	13.11.2014	incoming event	Parameter assignment error
5	10:45:20:834	13.11.2014	incoming event	Mode transition from STOP to STARTUP
6	10:45:16:805	13.11.2014	incoming event	Distributed I/Os: end of the synchronization with a DP ...
7	10:44:57:159	13.11.2014	incoming event	All modules are ready for operation
8	10:42:36:635	13.11.2014	incoming event	Module monitoring time started
9	10:42:36:467	13.11.2014	incoming event	Power on backed up
10	10:42:36:321	13.11.2014	incoming event	Power failure

Details: 1	Event ID: 16# 4302
Mode transition from STARTUP to RUN Startup information: - Startup with modified system configuration - Difference between setpoint and actual configuration - Time for time stamp at the last backed up power on - Single processor operation Current/last startup type: - Automatic warm restart after backed up power on Permissibility of certain startup types: - Manual warm restart permitted - Automatic warm restart permitted Last valid operation or setting of automatic startup type at power on: - Automatic warm restart after backed up power on Previous operating mode: STARTUP (warm restart) Requested operating mode: RUN Incoming event	

Figure 4-21 Web server, "Diagnostics buffer" Web page

Diagnostics option "Module information"

The status of a device is indicated by the Web browser with symbols and comments on the "Module information" Web page.

Modules are displayed on the "Module information" Web page in the "Name" column with a link. You can thus get to the faulty module in hierarchical order.

The screenshot shows the 'Module information' web page. At the top, there is a title 'Module information' and a breadcrumb path: 'CPU1516 - Ethernet(1); PROFINET-IOSystem (100) - IM155-5PNST'. Below this is a table with columns: Slot, Status, Name, Order number, I address, Q address, and Comment. Slot 3 is highlighted in red, indicating a fault. Below the table, there is a 'Status' section with a sub-section 'Identification' containing the text: 'PN device 3 on PN system 100 Slot 3: Module removed', 'Name: IM155-5PNST Module: DQ 16x24VDC/0.5 ST', and 'I/O address: Q1'.

Slot	Status	Name	Order number	I address	Q address	Comment
0	✓	IM155-5PNST	6ES7155-6AA00-0BN0			
1	✓	PS 1505 25Wx24 VDC	6ES7505-5KA00-0AB0			...Module PS (3)
2	✓	DI 16x24VDC HF	6ES7521-1BH00-0AB0	2		...Module DI (3)
3	✗	DQ 16x24VDC/0.5A ST	6ES7522-1BH00-0AB0		5	...Module DQ (3)

Status Identification

PN device 3 on PN system 100 Slot 3: Module removed
 Name: IM155-5PNST Module: DQ 16x24VDC/0.5 ST
 I/O address: Q1

Figure 4-22 Web server, "Module information" Web page

Diagnostics option "Messages"

The Web browser displays the content of the message buffer on the "Messages" Web page. The messages can be acknowledged via the Web server if you have the appropriate user rights.

The screenshot shows the 'Alarms' web page. At the top, there is a title 'Alarms' and a dropdown menu for 'Entries 1-50'. Below this is a table with columns: AlarmNr., Date, Time, Alarm text, State, and Acknowledgement. Two alarm entries are shown. Below the table, there is a 'Details on alarm number: 31' section with the text: 'Short name: DI 16/DQ 16x24VDC/0.5A BA Order number: 6ES7 523-1BL00-0AA0' and 'incoming event'.

AlarmNr.	Date	Time	Alarm text	State	Acknowledgement
31	07/14/2018	11:12:18.814 am	Error: Hardware component not available due to type mismatch PLC_1 / DI 16/DQ 16x24VDC/0.5A BA_1	incoming	Acknowledge alarm
35	07/14/2018	11:13:25.550 am	CPU status message: CPU not in RUN Current CPU operating mode: RUN PLC_1 / PLC_1	outgoing	Acknowledge alarm

Details on alarm number: 31
 Short name: DI 16/DQ 16x24VDC/0.5A BA Order number: 6ES7 523-1BL00-0AA0
 incoming event

Figure 4-23 Web server, "Messages" Web page

Diagnostics option "Communication"

The "Communication" web page provides detailed information about the following tabs:

- Parameter

A summary of the information on the PROFINET and Ethernet interfaces of the selected CPU is available in this tab.

- Statistics

You will find information on data transmission in this tab.

- Resources

Information about the resource consumption of the connections is available in this tab.

- Connections

Information about the status of the communication connections is available in this tab.

Communication Off

Parameter | Statistics | Resources | Connections

PROFINET Interface [X1]:

Network connection:

MAC address: 00-0E-8C-84-DE-F0
Name: PNIO

IP parameter:

IP Address: 192.168.2.80
Subnet mask: 255.255.255.0
Default router: ---
IP settings: IP address set in project

Physical properties:

Port number	Link status	Settings	Mode	Connection medium
X1 P1	OK	automatic	100 MBit/s full-duplex	Copper cable
X1 P2	OK	automatic	100 MBit/s full-duplex	Copper cable

Figure 4-24 Web server, "Communication" Web page

"Topology" diagnostics option

The "Topology" Web page provides information on the topological configuration and status of the PROFINET devices in your PROFINET IO system.

Topology					
PLC 1 [X1]					
Graphic view		Table view		Status overview	
Port			Partner port		
Status	Name	Module type	Port	Name	Port
	CPU 1516-3PN/DP	CPU 1516-3PN/DP	port-001	SCALANCE-X-204IRT	port-001
	IM155-6PN-2	IM 155-6PN ST			
	IM155-5PN	IM 155-5PN ST			
			port-001	SCALANCE-X-204IRT	port-004
			port-002	cpux6-7-1xet200mp	port-002
	SCALANCE-X-204IRT	SCALANCE-X-204IRT	port-001	CPU1516-3PN/DP	port-001
			port-002		
			port-003		
			port-004	IM155-5PN	port-001
	SCALANCE-X-208	SCALANCE-X-208			
	cpux6-7-1xet200mp		port-002	IM155-5PN	port-002

Figure 4-25 Web server, "Topology" Web page

"Motion Control Diagnostics" diagnostic option

The Web server displays statuses, errors, technology alarms and the current values of the configured technology objects (TOs).

The "Motion Control Diagnostics" web page provides detailed information on the configured technology objects in the following views:

- Diagnostics

This view provides an overview list of configured technology objects, the status and error messages of a selected technology object, as well as values and limits of the movement status for a selected axis.

- Service overview

This view contains diagnostic information for multiple technology objects and a filter option for selecting the displayed technology objects.

Motion control diagnostics On

Diagnostics | Service overview

State	Enabled	Homed	TO Name	TO Type
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PositioningAxis_1	PositioningAxis
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	SynchronousAxis_1	SynchronousAxis
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	ExternalEncoder_1	ExternalEncoder
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	OutputCam_1	OutputCam
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	CamTrack_1	CamTrack
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	MeasuringInput_1	MeasuringInput
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	SpeedAxis_1	SpeedAxis

Status and error bits | Motion status

<p>Axis status</p> <ul style="list-style-type: none"> <input checked="" type="checkbox"/> Simulation active <input type="checkbox"/> Enabled <input type="checkbox"/> Error <input type="checkbox"/> Restart active <input type="checkbox"/> Axis control panel active <input type="checkbox"/> Drive ready <input type="checkbox"/> Restart required 	<p>Motion status</p> <ul style="list-style-type: none"> <input checked="" type="checkbox"/> Done (no motion command) <input type="checkbox"/> Jog <input type="checkbox"/> Speed setpoint <input checked="" type="checkbox"/> Constant speed <input type="checkbox"/> Accelerating <input type="checkbox"/> Decelerating <input type="checkbox"/> Torque limiting command <p>Warnings</p> <ul style="list-style-type: none"> <input type="checkbox"/> Configuration <input type="checkbox"/> The task was rejected <input type="checkbox"/> Dynamic limitation 	<p>Error</p> <ul style="list-style-type: none"> <input type="checkbox"/> System <input type="checkbox"/> Configuration <input type="checkbox"/> User program <input type="checkbox"/> Drive <input type="checkbox"/> Data exchange <input type="checkbox"/> I/O <input type="checkbox"/> The task was rejected <input type="checkbox"/> Dynamic limitation
---	--	---

Figure 4-26 Web server, "Motion Control diagnostics" webpage

"Trace" diagnostic options

You can read, view and save the trace recordings via the Web server and thus obtain plant and project information for diagnostics and maintenance.

The web page of the trace and logic analyzer function consists of several areas. The example in the figure below shows how the Web server user interface is divided when the "Trace" web page is first called.

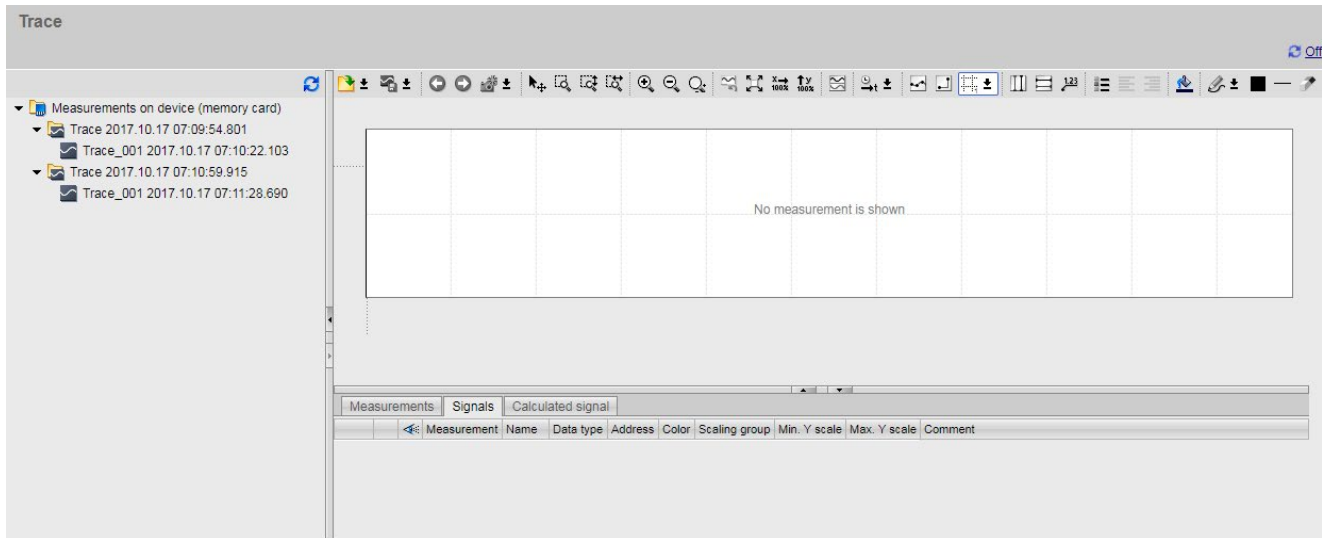


Figure 4-27 Web server, "Trace" home page (without measurement)

Additional information

Additional information on the topic is available in the Web server function manual (<http://support.automation.siemens.com/WW/view/en/59193560>).

You can find additional information on the trace function in the Using the trace and logic analyzer function (<https://support.industry.siemens.com/cs/ww/en/view/64897128>) function manual.

4.2.4 Diagnostics information using the HMI diagnostics view

Objects for system diagnostics

The full functionality of the HIM diagnostics view is only available with Comfort Panels and WinCC RT Advanced . Basic Panels do not support the complete range of system diagnostics functions.

Two objects are available for system diagnostics on an HMI device.

System diagnostics view

The system diagnostics view reflects the current status of all accessible devices in your plant. You navigate directly to the cause of the error and the associated device. You have access to all diagnostics-capable devices that you have configured in the STEP 7 hardware and network editor.

System diagnostics window

The system diagnostics window is an operating element and display object.

The functions of the system diagnostics window are the same as for the system diagnostics view. Because the system diagnostics window is configured in the "Global screen", you can also specify, for example, if the object can be closed in WinCC Runtime.

Note

Compatibility with Basic Panels

Only the "System diagnostics view" object is available with Basic Panels.

Basic Panels do not support the "System diagnostics window" object or the graphic symbol "System diagnostics indicator".

4.2.4.1 Configuring system diagnostics

Introduction

You add a system diagnostics view or a system diagnostics window to your project to get an overview of all devices available in your plant.

The system diagnostics window behaves like the system diagnostics view but is only available in the global screen.

Requirements

- At least one CPU has been set up in the project.
- An HMI device (e.g., Comfort Panel) has been set up in the project.
- CPU and the HMI device are connected with each other by an HMI connection.
- You have created a screen (for the system diagnostics view).
- The global screen is open (for the system diagnostics window).
- The Inspector window is open.

Procedure

Proceed as follows to configure the system diagnostics:

1. Double-click the "System diagnostics view" object in the "Tools" task card. The object is added to the screen.

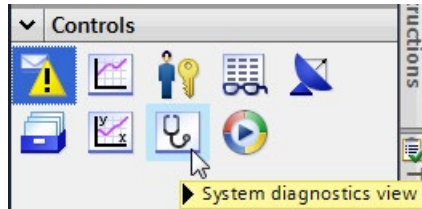


Figure 4-28 Adding a system diagnostics view

2. Select the "Properties" tab in the Inspector window.
3. Select the area "Columns".
4. Enable the columns that you require in the device view for WinCC Runtime, for example:
 - Status
 - Name
 - Operating mode
 - Slot
 - Address
5. Enable the columns that you require in the detail view for WinCC Runtime, for example:
 - Status
 - Name
 - Operating mode
 - Plant designation
 - Address
6. You can change the column headers in the "Columns" area, if necessary.
7. Select the "Display" area.
8. Enable "Column settings > Columns moveable" to move the columns in WinCC Runtime.
9. To close the system diagnostics window in WinCC Runtime, select "Properties > Window > Closable" in the "Properties" tab of the Inspector window.

Result

The system diagnostics view has been added to the screen. The diagnostics status of the entire plant is displayed in the system diagnostics view in WinCC Runtime.

Status	Name	Operati...	Slot	Type	Order num...	Address
✓	Rack_1					
✓	PLC_1	✓			36979	
✓	CP_443-1	✓			53939	
⚠	DI_1				5363	
✓	DI_2				22323	
✓	PS_1				39283	

Figure 4-29 System diagnostics view in the screen

The system diagnostics window has been added to the global screen. If there is an error message in the plant, the system diagnostics window responds and displays the affected device.

4.2.4.2 Different views of the HMI diagnostics view

Introduction

There are three different views available in the system diagnostics view and the system diagnostics window.

- Device view
- Details view
- Distributed I/O view (only for PROFIBUS and PROFINET systems)

Device view

The device view shows all the available devices of a layer in a table. Double-clicking on a device opens either the lower-level devices or the detail view. Symbols in the first column provide information about the current state of the device.

Status	Name	Operati...	Slot	Type	Order num...	Address
	S7-1500 statio...			S7-150...		32*
	CPU proxy_1		1	CPU 15...	6ES7 516-3...	49*
	DQ32		2	DQ32	6ES7 522-1...	258*
	DI32		3	DI32	6ES7 521-1...	259*

Figure 4-30 Device view

Details view

The detail view gives detailed information about the selected device and any pending errors. Check whether the data is correct in the detail view.

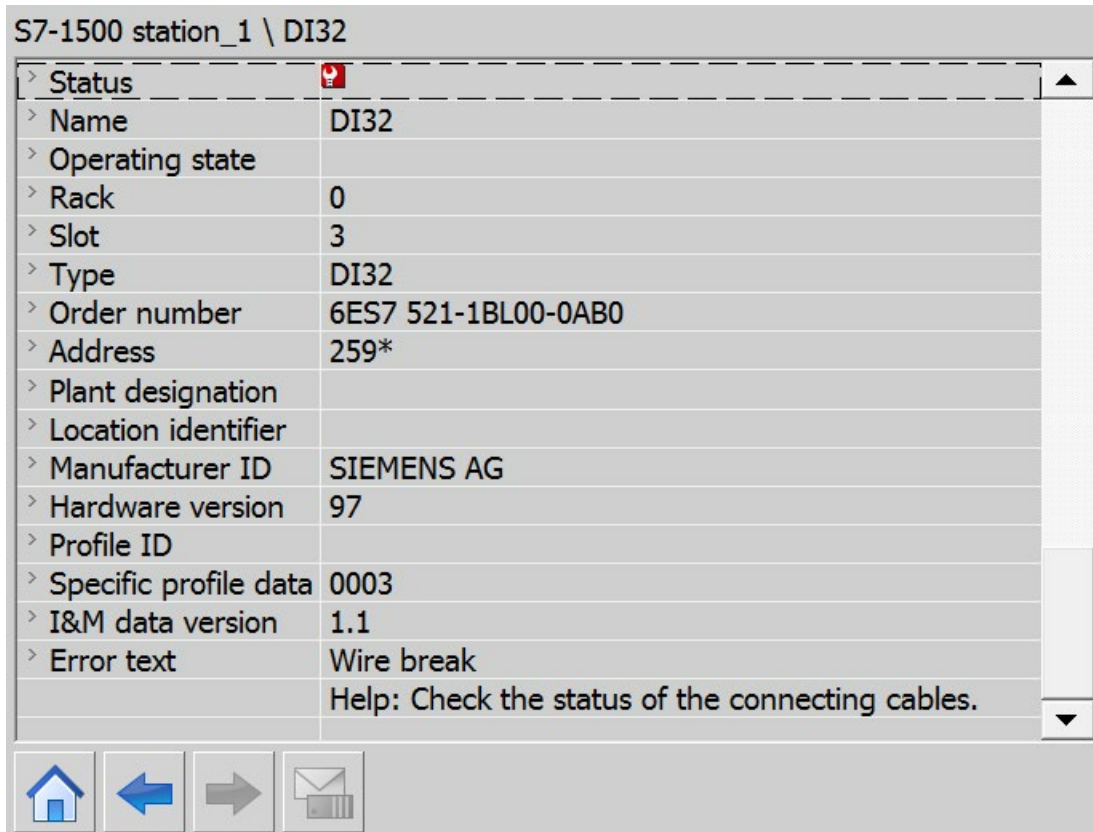


Figure 4-31 Details view

Distributed I/O view

The distributed I/O view is only available for distributed I/O systems. The distributed I/O view shows the status of the devices of the PROFIBUS/PROFINET subnet.

Each element in the view shows the device name, the device type and the IP address or the PROFIBUS address.

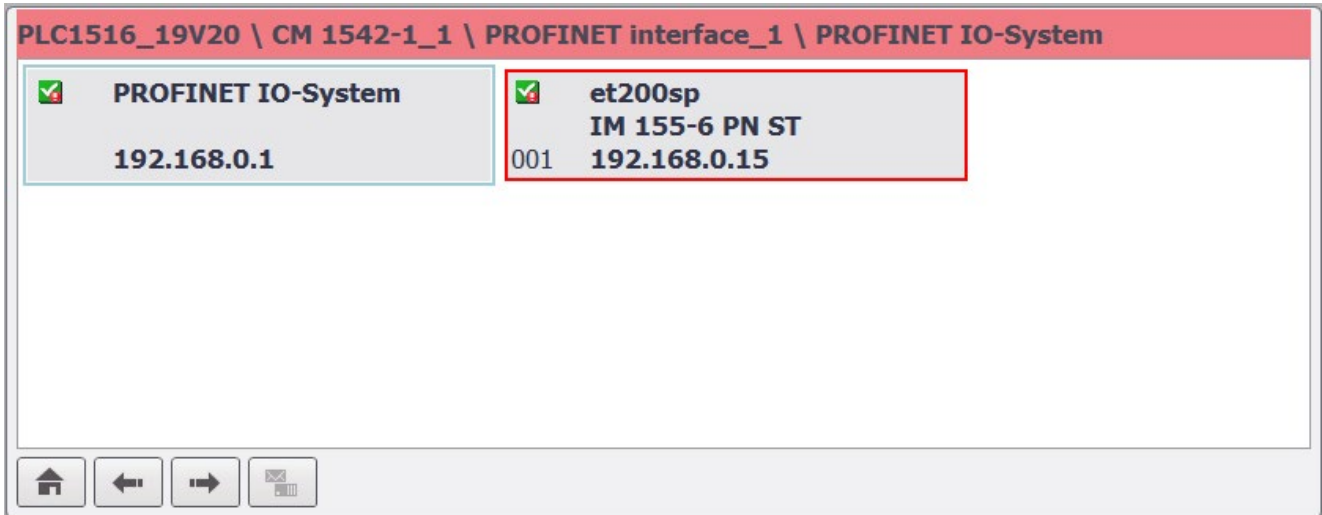





Figure 4-32 Distributed I/O view

Navigation buttons

Button	Function
	Opens the lower-level devices or the detail view if there are no lower-level devices.
	Opens the higher-level device or the device view if there is no higher-level device.
	Opens the device view.

4.2.4.3 Inserting system diagnostics indicator

Introduction

The system diagnostics indicator is a predefined graphic symbol of the library which alerts you to errors in your plant.

The library object shows two different states:

- No error
- Error

Requirements

- An HMI device (e.g., Comfort Panel) has been set up in the project.
- The "Libraries" task card is opened.
- The global library "Buttons and Switches > DiagnosticsButtons" is open.
- A screen is open.
- The system diagnostics window has been set up in the global screen.

Procedure

1. Select the "DiagnosticsIndicator" object in the library.
2. Drag-and-drop the library object to the position in the work area where you want to insert the object.

The library object is added.

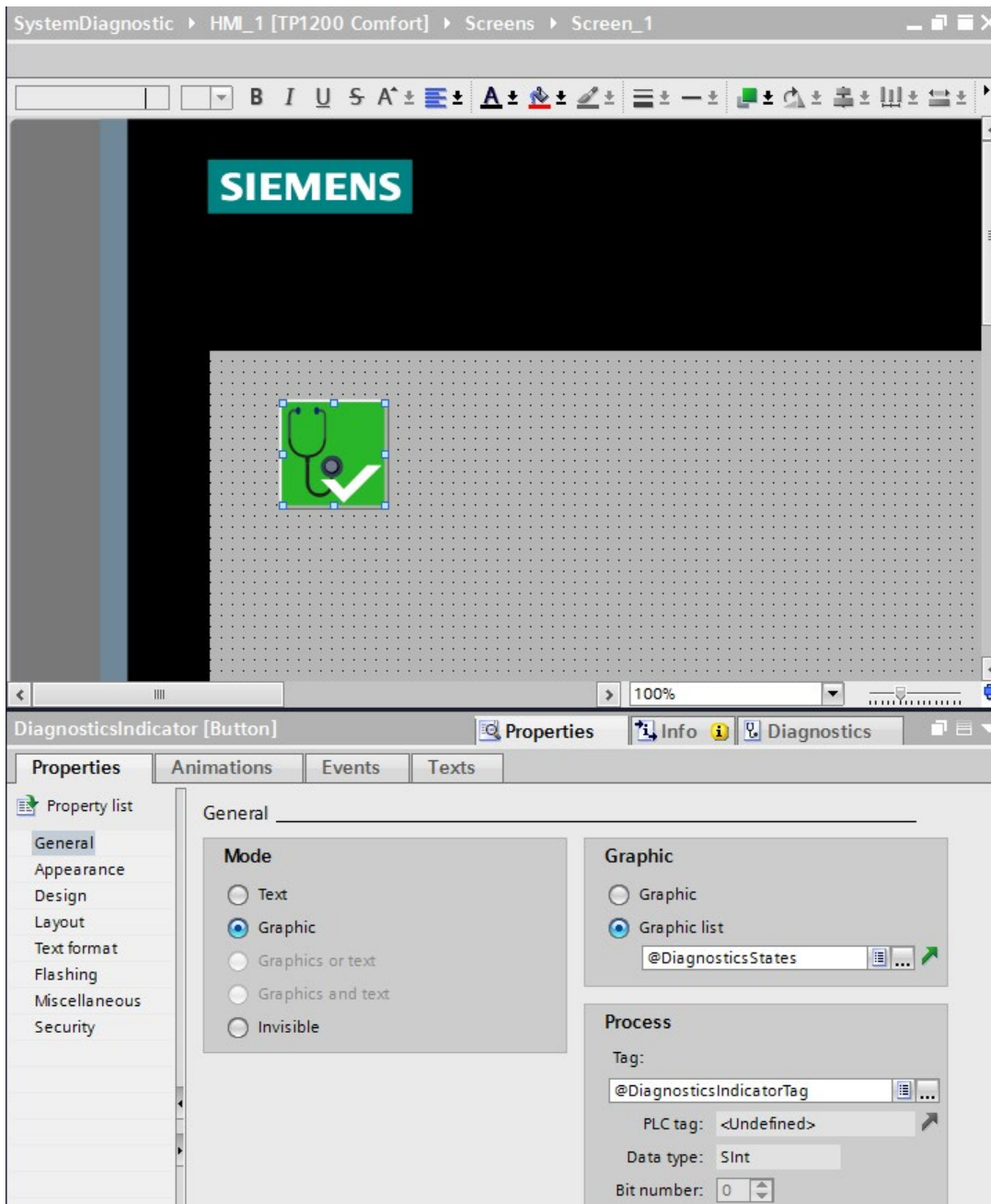


Figure 4-33 Inserting library object in the work area

3. Select the library object.
4. Open the "Events" tab in the Inspector window.
The "ShowSystemDiagnosticsWindow" is preset for the event "Click".

Result

The system diagnostics indicator has been added to the project and connected with the system diagnostics window.

The system diagnostics indicator changes its appearance if an error message is output in WinCC Runtime. The system diagnostics window opens when you click on the system diagnostics indicator. The system diagnostics window shows the detail view of the affected device.

Configuring access protection for the system diagnostics window

Configure access protection for the system diagnostics indicator to prevent unauthorized access to the system diagnostics windows.

1. Select the "DiagnosticsIndicator" object in the screen.
2. Open the "Properties" tab in the Inspector window.
3. Select an authorization in the "Security in Runtime" area.

A logon dialog opens when you click on the system diagnostics indicator in WinCC Runtime. The system diagnostics window does not open unless you have the required authorization.

4.2.4.4 Configuring button as system diagnostics indicator

Introduction

Instead of using the object "DiagnosticsIndicator" from the library, you can, for example, configure a button in "Graphic" mode to indicate errors in your plant.

Requirements

- At least one CPU has been created.
- An HMI device (e.g., Comfort Panel) has been set up in the project.
- The "Tools" task card is open.
- A bit graphics list has been created with two different graphics for the states.
- A screen is open.
- You have created a system diagnostics view.

Procedure

Follow these steps to configure a button as system diagnostics indicator:

1. Double-click the "Button" object in the "Tools" task card. A button is added to the screen.
2. Enable the "Properties" tab in the Inspector window and the "Graphic" mode in the "General" area.
3. Select the bit graphics list as graphics list.
4. Select the "Properties" tab in the Inspector window and select the tag @DiagnosticsIndicatorTag under "Tag" in the "General" area.
5. To assign a function to the button, select the "Events" tab in the Inspector window.
6. Select the "Click" event.
7. Click on "Add function" in the table.
8. Select "EnableSystemDiagnosticsView".
9. Select the system diagnostics view.

Result

You have configured an interface that reacts to error events from the CPU. The button changes when an error event occurs in Runtime.

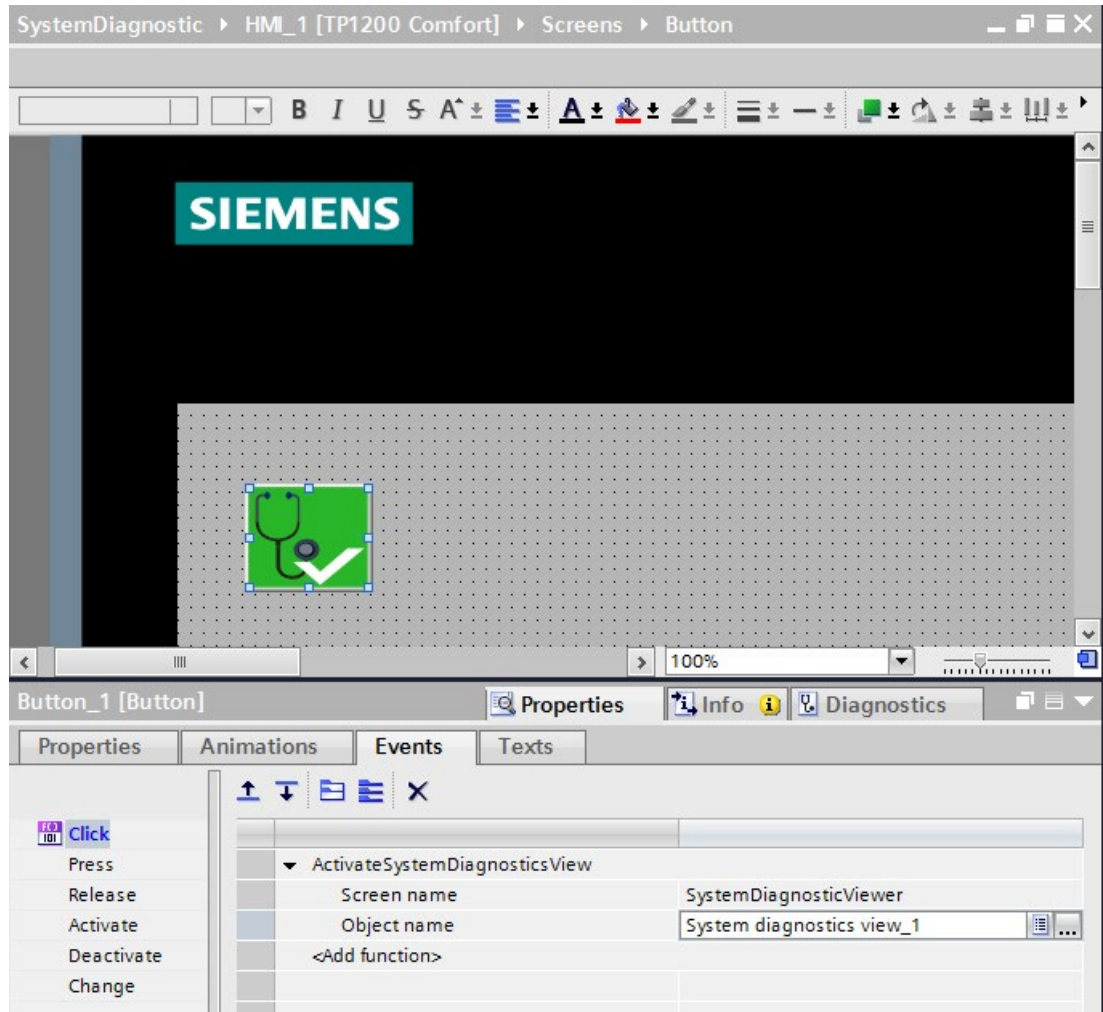


Figure 4-34 Configured button

The button has two states.

- Error
The system diagnostics view opens when you click on the button. The system diagnostics view shows the detail view of the affected device.
- No error
The system diagnostics view opens when you click on the button. The system diagnostics view shows the device view.

System diagnostics by means of the user program

5.1 Options of system diagnostics in the user program

Introduction

You can configure responses to diagnostics alarms in the user program. You can, for example, specify that your plant is stopped in case of specific diagnostics alarms.

Instructions

A vendor-independent structure of data records with diagnostics information applies. The following instructions are available for determining the system diagnostics of a device:

Table 5- 1 Instructions for determining the system diagnostics

Instruction	Description
RDREC	<ul style="list-style-type: none"> Reads data records of a component (module or submodule) of a DP slave/IO device that may contain error information Works asynchronously, which means processing takes place across several calls
RALRM	<ul style="list-style-type: none"> Reads the start information of the OB when calling the diagnostics interrupt OB (OB 82) Provides information on cause and location of error
DPNRM_DG	<ul style="list-style-type: none"> Reads the current diagnostics data of a DP slave (DP standard diagnostics)
GEN_DIAG	<ul style="list-style-type: none"> Generates diagnostics information To generate diagnostics information, the module or submodule is identified with its logical address
Gen_UsrMsg	<ul style="list-style-type: none"> Generates an alarm that is entered in the diagnostics buffer
GET_DIAG	<ul style="list-style-type: none"> Provides diagnostics information To provide diagnostics information, the module or submodule is selected
GET_Name	<ul style="list-style-type: none"> Reads the name of an IO device
T_DIAG	<ul style="list-style-type: none"> Provides diagnostics and status information on a connection Works asynchronously, which means processing takes place across several calls
RD_SINFO	<ul style="list-style-type: none"> Reads the start information of the OB called last that has not been processed completely and the startup OB started last Provides general error information
LED	<ul style="list-style-type: none"> Reads the status of the module LED
Get_IM_Data	<ul style="list-style-type: none"> Reads the Information&Maintenance data of the CPU Works asynchronously, which means processing takes place across several calls
DeviceStates	<ul style="list-style-type: none"> Outputs the state of all devices of an IO system
ModuleStates	<ul style="list-style-type: none"> Outputs the state of all modules of a device

Additional information

Online help

In the online help for STEP 7, you can find:

- Additional information on instructions for system diagnostics
- Information about further options for evaluating diagnostic information in the user program (e.g. with the "RDREC", "RALRM", "GET_DIAG" instructions)
- Information on SIMATIC ProDiag. This functionality enables targeted and fast machine and plant diagnostics for SIMATIC S7-1500 and SIMATIC HMI:
 - Standardized diagnostics concept for different SIMATIC components
 - No additional configuration work for diagnostics functionality
 - Reduces the load on PLC memory and program run time

You can find details in the online help under "Supervising machinery and plants with ProDiag".

Manuals

You can find additional information about evaluating diagnostic information in the user program in the following manuals:

- PROFINET function manual
(<http://support.automation.siemens.com/WW/view/en/49948856>)
- From PROFIBUS DP to PROFINET IO
(<https://support.industry.siemens.com/cs/ww/en/view/19289930>) programming manual
- Manual for the respective module

Application examples

You can find detailed application examples with further documentation and example projects on the Service&Support Website:

- Diagnostic overview for SIMATIC S7-1200 and S7-1500
(<https://support.industry.siemens.com/cs/ww/en/view/109752283>)

FAQ

For more information about how to realize channel diagnostics in the user program of the SIMATIC S7-1500, refer to the FAQ with entry ID 109480387 on the Service&Support Website (<https://support.industry.siemens.com/cs/ww/en/view/109480387>).

5.2 System diagnostics using process image inputs

Introduction

In addition to event-driven system diagnostics, the input and output modules of the SIMATIC series provide diagnostics information using the process image input.

The system diagnostics described in the preceding sections is made available asynchronously to the program processing. To ensure the correct processing of the input and output data in the case of faults while reading the input and output data, some modules offer the so-called value status (QI = Quality Information) for evaluation.

Requirement for evaluation of the value status

The diagnostics information about the process image input is transmitted synchronized with the user data. Select the "Value status" check box in the properties of the I/O module in STEP 7 if you want to evaluate the value status of the channel.

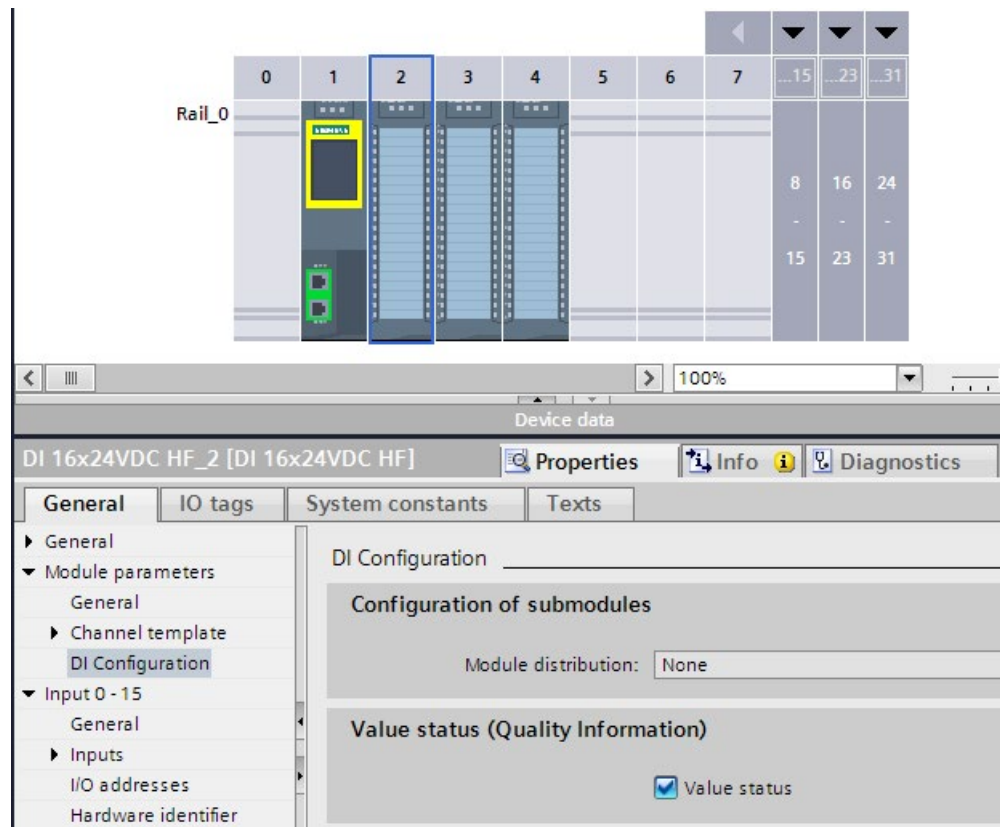


Figure 5-1 Enable value status

Evaluation of the value status

If you have enabled the value status for an I/O module, this module provides additional information on the value status in addition to the user data. This information is directly available in the process image input and can be called with simple binary operations.

Each channel is uniquely assigned one bit in the value status. The bit in the value status indicates the validity of the read-in value in the user data.

Table 5- 2 Example for evaluation of the user datum in case of a wire break for a digital input module

	Bit in user datum	Bit in value status	Value in user datum
Faulty channel	Logical 0	0	Invalid
Fault-free channel	Logical 0 (actual value)	1	Valid

Influence of the value status

The value status of an active channel is "Invalid" when any **one** of the following factors is given:

- Channel diagnostics pending (regardless of whether diagnostics, for example wire break, is configured for this channel)
- For output channels: "Reaction to CPU STOP" feature is active (due to CPU STOP, interrupted connection)
- For output channels of the digital on-board I/O of compact CPUs: If a channel is used for technology functions, it returns the value status 0 ("Invalid"). It does not matter in this context whether the output value is incorrect or not.
- PROFIenergy is active, i.e. hibernation is enabled (except in "Continue working mode")

When working with non-fail-safe modules, note that an invalid active channel also sets the value status of all other active channels to "Invalid". We therefore recommend that you disable all unconnected or unused channels.

Example - Evaluation of the value status for the input channel of an analog input module

The example below shows the basic evaluation of the value status for the input channel of an analog input module in the user program. The diameter of a cylinder is measured by means of a channel and its circumference is calculated.

- If the value status indicates the channel is error-free, the circumference is to be calculated.
- If the value status indicates the channel is defective, the value "0" is to be output as substitute value for the circumference.

The figure below shows the evaluation of the value status in the user program.

Perimeter				
	Name	Data type	Default value	Comment
1	▼ Input			
2	■ Diameter	Real	0.0	Tag for analog input channel
3	■ QualityInformation	Bool	false	Tag for QI of analog input channel
4	▼ Output			
5	■ Perimeter	Real	0.0	Tag for result of calculation
6	▶ InOut			
7	▶ Static			
8	▶ Temp			
9	▼ Constant			
10	■ PI	Real	3.14	Constant for pi
11	■ SubstituteValue	Real	0.0	Constant for substitute value


```

IF... CASE... FOR... WHILE... (*...*)
OF... TO DO... DO...

1 IF #QualityInformation = true //Validity check of diameter
2
3 THEN //Program run, if quality information is positive
4     #Perimeter := #Diameter * #PI; //Calculation of perimeter
5
6 ELSE //Program run, if quality information is negative
7     #Perimeter := #SubstituteValue; //Substitute value assigned to perimeter

```

Figure 5-2 Example - Evaluation of the value status in the user program

Additional information

Depending on the I/O module, the value status reserves different addresses in the process image input. The manual for the module used includes specific information on the assignment and arrangement.

Alarms

Introduction

Alarms allow you to display events from processing in the automation system and to quickly detect errors, to precisely localize them and to remove them. Downtimes are significantly reduced in a plant.

Before alarms can be output, they need to be configured.

You can create, edit and compile event-dependent alarms along with their alarm texts and alarm attributes and display them on display devices.

In STEP 7, you create program alarms in the user program with the "Program_Alarm" instruction. You edit the attributes and alarm texts in the alarm editor in STEP 7.

You can output the alarm status with the "Get_AlarmState" instruction.

Advantages of program alarms

Compared to other alarm methods, such as HMI discrete alarms, program alarms offer the following advantages:

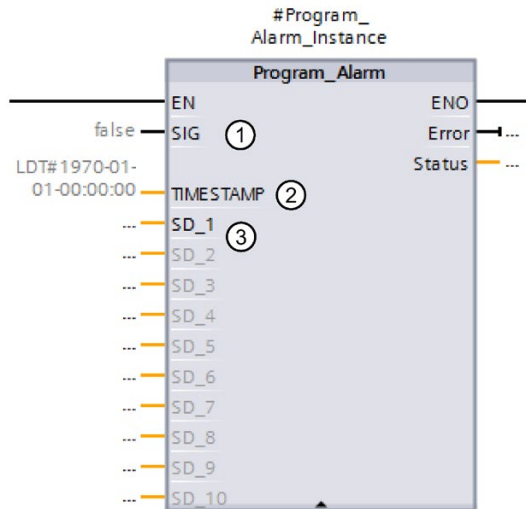
- Central engineering in STEP 7: You only configure a program alarm once for the CPU. The program alarm is automatically transferred from the CPU to all registered HMI devices.
- System-supported acknowledgment: The acknowledgment of a program alarm on an HMI device is automatically updated on other HMI devices by the CPU.
- Time stamping close to the event in the CPU
- Identical time stamps of the alarms on multiple HMI devices without time synchronization

6.1 Creating alarms with the "Program_Alarm" instruction

"Program_Alarm" instruction

You create a program alarm in STEP 7 with the "Program_Alarm" instruction.

The figure below shows the "Program_Alarm" instruction with the most important input tags.



- ① The "Program_Alarm" instruction monitors the signal at the SIG block input and generates a program alarm in case of a signal change at the SIG parameter. The instruction generates an incoming alarm when the signal changes from 0 to 1 and an outgoing program alarm if the signal changes from 1 to 0. The program alarm is triggered synchronously to program execution.
- ② The time stamp is automatically created when the alarm event occurs in the automation system and is passed along with the alarm.
- ③ You can append up to ten associated values to the program alarm at the parameters SD_i (1 ≤ i ≤ 10). The associated values are acquired at the time of the signal change at the SIG parameter and assigned to the program alarm. Associated values are used to display dynamic contents in alarms.
Example: The temperature in the tank <associated value 1> is <associated value 2> °C.
You can find more information on associated values in the STEP 7 online help.

Figure 6-1 "Program_Alarm" instruction

Note

The "Program_Alarm" instruction can only be called in a function block.

A program alarm can be up to 256 bytes long in total (with associated values and texts from the text list).

The associated values can be a maximum of 512 bytes in length. Text lists are not affected by this.

The CPUs of the SIMATIC S7-1500 product series have the following memory for text lists:

- CPU 1510-x to CPU 1513-x: 2.25 MB
- CPU 1515-x to CPU 1516-x: 4.5 MB
- CPU 1517-x to CPU 1518-x: 6.75 MB

The number of configurable program alarms depends on the CPU used. With a CPU 1515-2 PN, for example, a maximum of 10,000 program alarms are possible. You can find this information in the device manual for the respective CPU under "Number of configurable alarms".

The number of simultaneously active "Program_Alarms" depends on the CPU used. With a 1515-2 PN CPU, for example, a maximum of 600 program alarms are possible. You can find this information in the device manual for the respective CPU under "Number of reserved user interrupts".

Sometimes, it is not possible for all program alarms that are active at the same time to be output within one cycle. Query the status of each "Program_Alarm" and activate the instruction again, if necessary. The cycle time is increased for a short time by simultaneously activating/sending multiple "Program_Alarms".

A maximum of 40,000 program alarms should be configured in a STEP 7 project on a 64-bit operating system.

Additional information

You can find more information on creating program alarms in the STEP 7 online help under "Creating and editing alarms".

6.2 Editing alarms in the alarm editor

Introduction

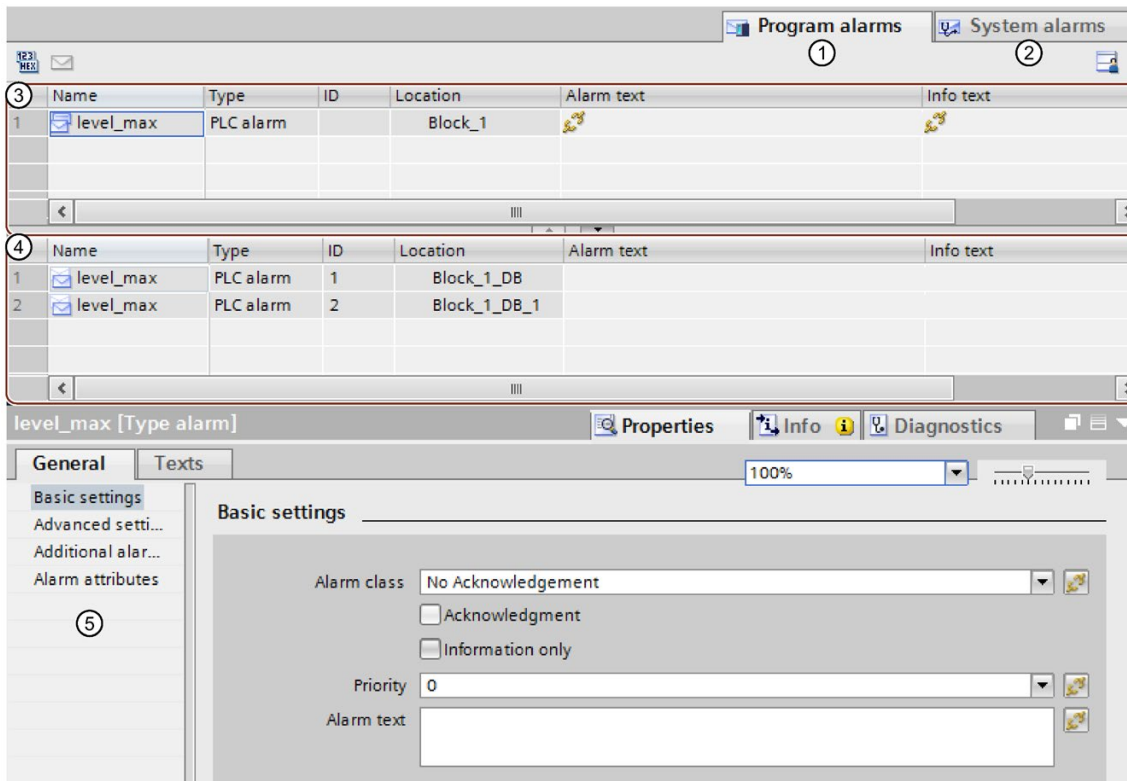
You can edit the created alarms in STEP 7 either in the program editor or in the alarm editor. You can find additional information on editing alarms in the program editor in the STEP 7 online help under "Creating and editing alarms".

Editing alarms in the alarm editor

You can edit alarm texts in the alarm editor and specify attributes such as alarm class or priority for the alarms.

1. Double-click "PLC supervisions & alarms" in the project tree. Select the "Alarms" tab. The alarm editor opens.
2. Enter the required texts and attributes in the appropriate columns.

The figure below shows the layout of the alarm editor.



- ① "Program alarms" tab: You can edit program alarms here.
- ② "System alarms" tab: System alarms can only be viewed but not edited. To edit these alarms, you must navigate to the device view ("Go to device" menu command), where you can modify the system diagnostics alarms in the Inspector window.
- ③ "Type alarms" area:
This is where the type alarms created in a function block with the "Program_Alarm" instruction are displayed. Type alarms serves as templates for instance alarms (④).
All the inputs you make for the type alarm are automatically included in the instance alarms derived from it.
You can find more information on type alarms in the STEP 7 online help under "Alarm types and alarms".
- ④ "Instance alarms" area:
When you assign an instance DB to the message block (for example, call in an OB, FB, FC), instance alarms are automatically generated based on the template of the type alarm and alarm numbers are assigned.
You can modify the instance alarms for specific instances.
You can find more information on instance alarms in the STEP 7 online help under "Alarm types and alarms".
- ⑤ Properties of the selected type and instance alarm in the Inspector window

Figure 6-2 Layout of the alarm editor

You can enter or modify the necessary parameters, texts and attributes in the table or in the Inspector window.

Multilingual alarms

You can have program alarms displayed in multiple languages by assigning different project languages to the interface languages of the display devices.

Note

The project languages you want to assign must be activated and the corresponding texts (translations) must be available in the project. The project language selection can be found in the project tree under "Languages & Resources".

To create the texts of the program alarm as multilingual, follow these steps:

1. In the Inspector window of the alarm editor, open the "Properties" tab and the lower-level "Texts" tab.
2. Enter the text in the desired project language.
3. Open the "Properties" tab in the Inspector window of the CPU and select the "Display" command in the "General" area navigation. Under "Multilingual", assign one of the activated project languages to each interface language of the display devices. Overall, you can assign up to three different project languages to the user interface languages. All assigned project languages are loaded into the CPU.

Additional information

You can find additional information on texts and attributes in the STEP 7 online help under "Texts and attributes".

You can find more information on text lists in the STEP 7 online help under "Text lists for alarms".

6.3 Display of program alarms

Program alarms you create with the "Program_Alarm" instruction are automatically made available to the display devices.

You have the following options to display the alarms:

- STEP 7
- HMI
- Web server of the CPU
- Display of the CPU

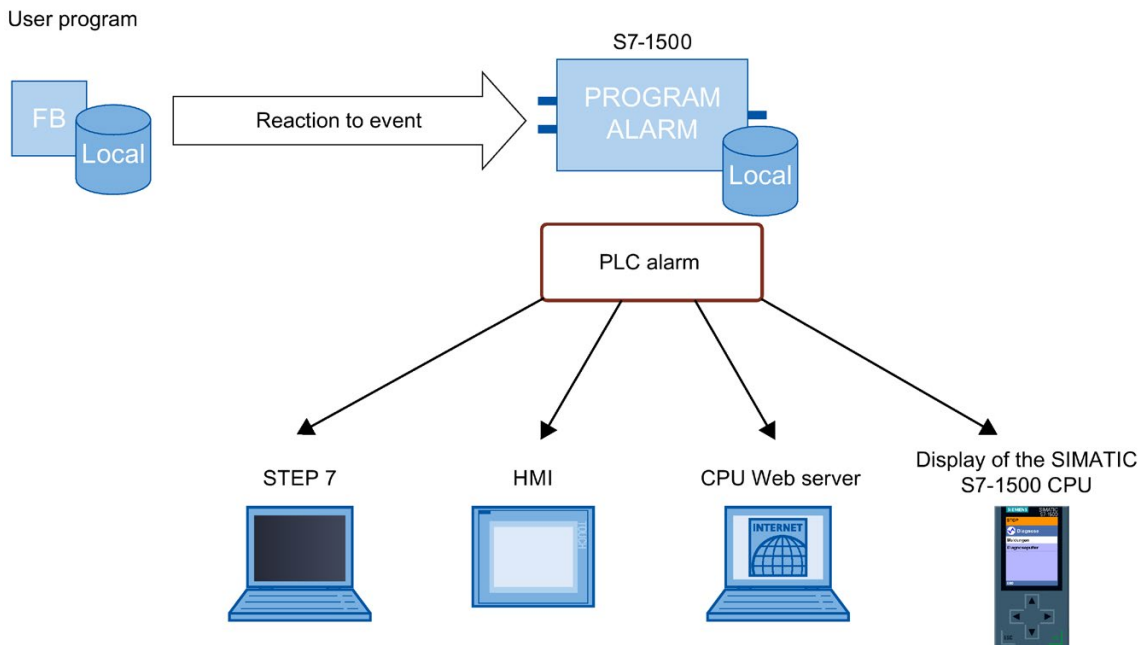


Figure 6-3 Display of program alarms

Multilingual alarms

You can have program alarms displayed in multiple languages by assigning different project languages to the interface languages. See section Editing alarms in the alarm editor (Page 78).

6.4 Output of the alarm state with the "Get_AlarmState" instruction

"Get_AlarmState" instruction

The "Get_AlarmState" instruction outputs the alarm state of a program alarm. The output of the alarm state always refers to a program alarm that was created using the "Program_Alarm" instruction.

The program alarm is selected with the "Alarm" input parameter. Specify the instance DB of the "Program_Alarm" instruction at the "Alarm" parameter.

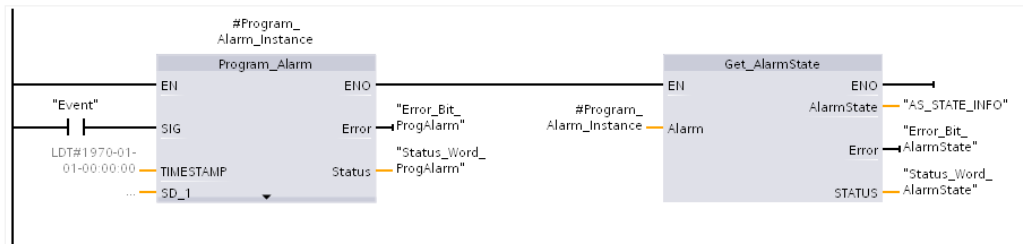


Figure 6-4 Call - Get_AlarmState

Additional information

You can find additional information on evaluation of the "Get_AlarmState" instruction in the STEP 7 online help.

6.5 Example program for program alarms

6.5.1 Task

Introduction

This section describes the basic configuration of program alarms with the "Program_Alarm" instruction based on two examples. The two examples solve the same problem but use a different approach. Example 1 does not use associated values. In example 2, an associated value is assigned to the program alarm to reference a text list.

Example - Minimum/maximum fill level of a tank

A tank is filled with a liquid. The fill level is monitored by two sensors.

If the liquid in the tank drops below a minimum fill level, an alarm is output for low fill level.

If the liquid in the tank exceeds a maximum fill level, an alarm is output for high fill level.

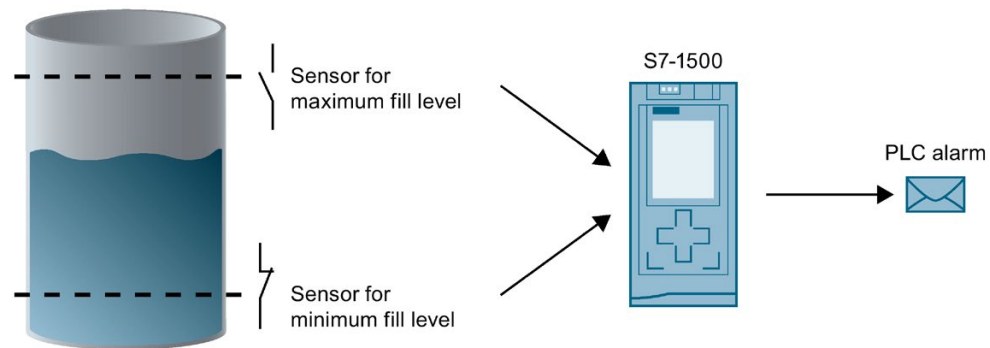


Figure 6-5 Example for fill level alarms

6.5.2 Example 1: Program alarm without associated values

Introduction

In this example, you create a program alarm for the maximum and the minimum fill level.

How the example works

When the maximum fill level is exceeded in the tank, a program alarm with the alarm text for the excessive fill level is output.

When the minimum fill level is undershot in the tank, a program alarm with the alarm text indicating that the fill level is too low is output.

Steps

The following steps are necessary for this example:

1. Define tags for signal acquisition
2. Create function block
3. Create program alarms
4. Call function block
5. Edit alarm text

Define tags for signal acquisition

The following table shows the tags that are used in this example. Define these tags in the standard tag table. The standard tag table is available in the project tree under "PLC tags".

Table 6- 1 Tags for fill level alarms

Name	Data type	Description
max	BOOL	Tag for maximum fill level If "max" = 1, the maximum fill level is exceeded.
min	BOOL	Tag for minimum fill level If "min" = 1, the minimum fill level is undershot.

The figure below shows the standard tag table with the defined tags "max" and "min".

	Name	Data type	Address	Retain	Visible i...	Accessible ..
1	max	Bool	%I0.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
2	min	Bool	%I0.1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
3	<Add new>			<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Figure 6-6 Define tags

Create function block

To create a function block, follow these steps:

1. Open the "Program blocks" folder in the project tree.
2. Double-click "Add new block".
The "Add new block" dialog opens.
3. Select the button "Function block".

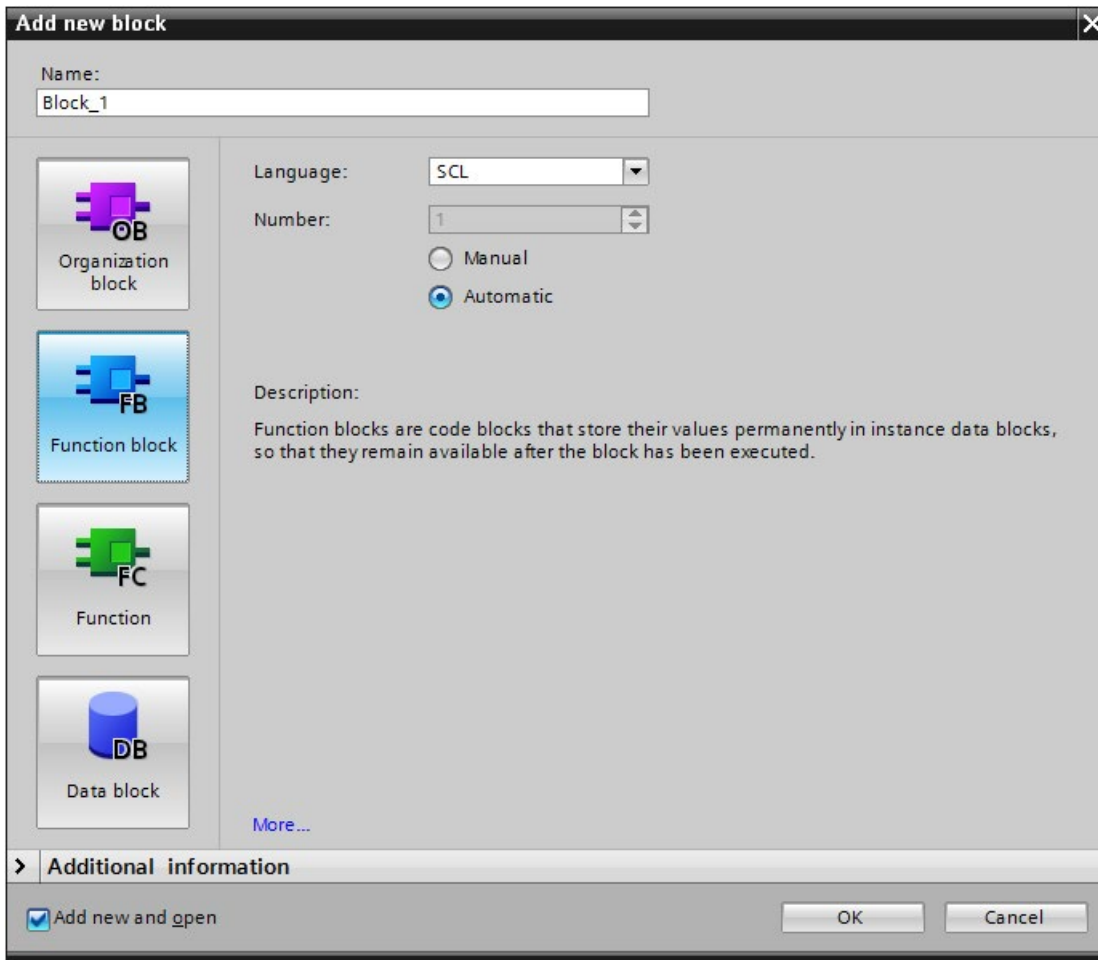


Figure 6-7 Create FB

4. Enter a name for the new block.
 5. Select the language SCL.
 6. Click on "OK" to confirm your input.
- Result: You have created a function block.

Create program alarms

To create the program alarm for the example program, follow these steps:

1. Select the created function block (FB) in the "Program blocks" folder in the project tree and double-click the function block to open it.
2. Insert the call of the "Program_Alarm" instruction in the instruction part of the function block. The "Program_Alarm" instruction is available in the "Instructions" task card under "Extended instructions" > "Alarms".

The "Call options" window opens.

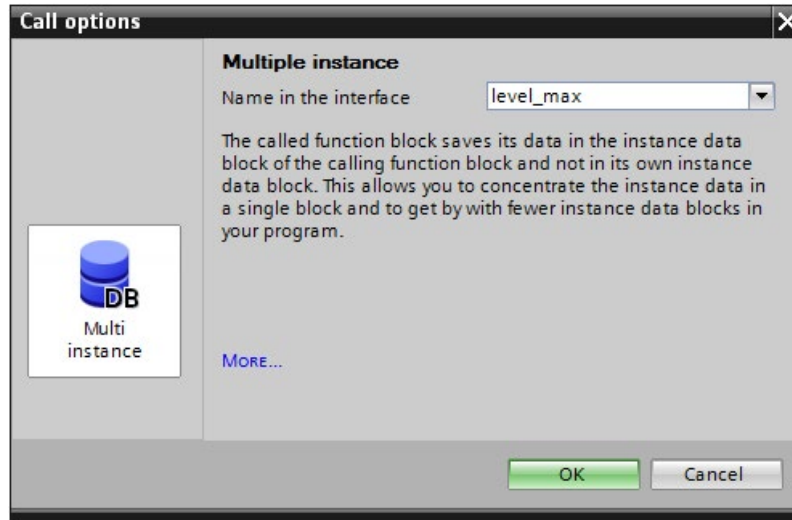


Figure 6-8 Call Program_Alarm

3. Enter "level_max" as the name and confirm the call options by clicking "OK".

Result: The input tags of the "Program_Alarm" instruction are displayed in the instruction part.

4. Supply the SIG input tag of the "Program_Alarm" instruction with the tags for the maximum fill level.

```
#level_max(SIG:="max");
```

SIG: If a signal change occurs at the SIG input tag, the "Program_Alarm" instruction generates a program alarm.

5. Insert another call of the "Program_Alarm" instruction.
The "Call options" window opens.

6. Enter "level_min" as the name and confirm the call options by clicking "OK".

Result: The input tags of the "Program_Alarm" instruction are displayed in the instruction part.

7. Supply the SIG input tag of the "Program_Alarm" instruction with the tags for the minimum fill level.

```
#level_min(SIG:="min");
```

Result: You have created two type alarms.

Call function block

To call the function block in the user program, follow these steps:

1. In the "Program blocks" folder, select the cycle OB (e.g., OB1) in which you want to call the function block and open the cycle OB with a double-click.
2. Select the function block you want to call in the "Program blocks" folder.
3. Drag the function block into the instruction part of the cycle OB.
The "Call options" window opens.

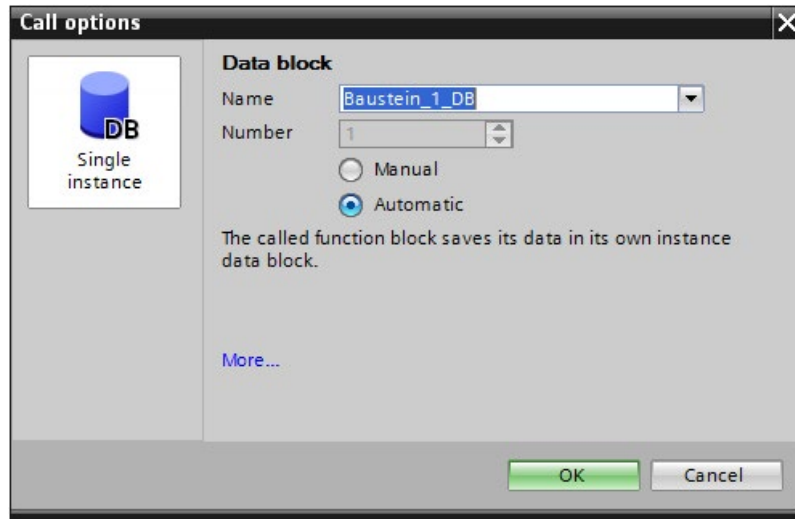


Figure 6-9 Call function block

4. Confirm the call options by clicking "OK".

Result: You have called the alarm block in the user program and created an instance alarm.

Edit alarm text

To edit the alarm text, follow these steps:

1. Double-click "PLC supervisions & alarms" in the project tree. Select the "Alarms" tab. The alarm editor opens.
2. Select the type alarm for the maximum fill level.
3. Enter the alarm text for the maximum fill level in the "Alarm text" column.
4. Select the type alarm for the minimum fill level.
5. Enter the alarm text for the minimum fill level in the "Alarm text" column.

Program alarms							System alarms						
Name	Type	ID	Location	Alarm text	Info text								
1	level_max	PLC alarm	Baustein_1	level too high									
2	level_min	PLC alarm	Baustein_1	level too low									

Name	Type	ID	Location	Alarm text	Info text	
1	level_min	2	Baustein_1...	level too low		

Figure 6-10 Edit alarm text

Result: You have created the alarm texts for both type alarms.

Additional information

You can learn how to create multilingual texts under "Multilingual alarms" in the section Editing alarms in the alarm editor (Page 78).

6.5.3 Example 2: Program alarm with associated value

Introduction

In this example, you create a shared program alarm for the maximum and the minimum fill level. The program alarm is given an associated value. The program alarm uses the associated value to access a text list entry and outputs a separate alarm text for the minimum and the maximum fill level.

How the example works

The program alarm is output if either the minimum fill level is undershot or the maximum fill level is exceeded.

The associated value 1 of the "Program_Alarm" instruction is assigned the tag for the maximum fill level. The associated value references a text list with the entries "0" and "1".

The following scenarios are possible for output of the alarm text:

- Associated value is "0": The entry "0" of the text list with the alarm text for the undershot fill level is output.
- Associated value is "1": The entry "1" of the text list with the alarm text for the excessive fill level is output.

Steps

The following steps are necessary for this example:

1. Define tags for signal acquisition
2. Create function block
3. Create program alarm
4. Call function block
5. Create a text list
6. Edit alarm text

Define tags for signal acquisition

The following table shows the tags that are used in this example. Define these tags in the standard tag table. The standard tag table is available in the project tree under "PLC tags".

Table 6-2 Tags for fill level alarms

Name	Data type	Description
max	BOOL	Tag for maximum fill level If "max" = 1, the maximum fill level is exceeded.
min	BOOL	Tag for minimum fill level If "min" = 1, the minimum fill level is undershot.

The figure below shows the standard tag table with the defined tags "max" and "min".

	Name	Data type	Address	Retain	Visible i...	Accessible ..
1	max	Bool	%I0.0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
2	min	Bool	%I0.1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
3	<Add new>			<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Figure 6-11 Define tags

Create function block

To create a function block, follow these steps:

1. Open the "Program blocks" folder in the project tree.
2. Double-click "Add new block".
The "Add new block" dialog opens.
3. Select the button "Function block".

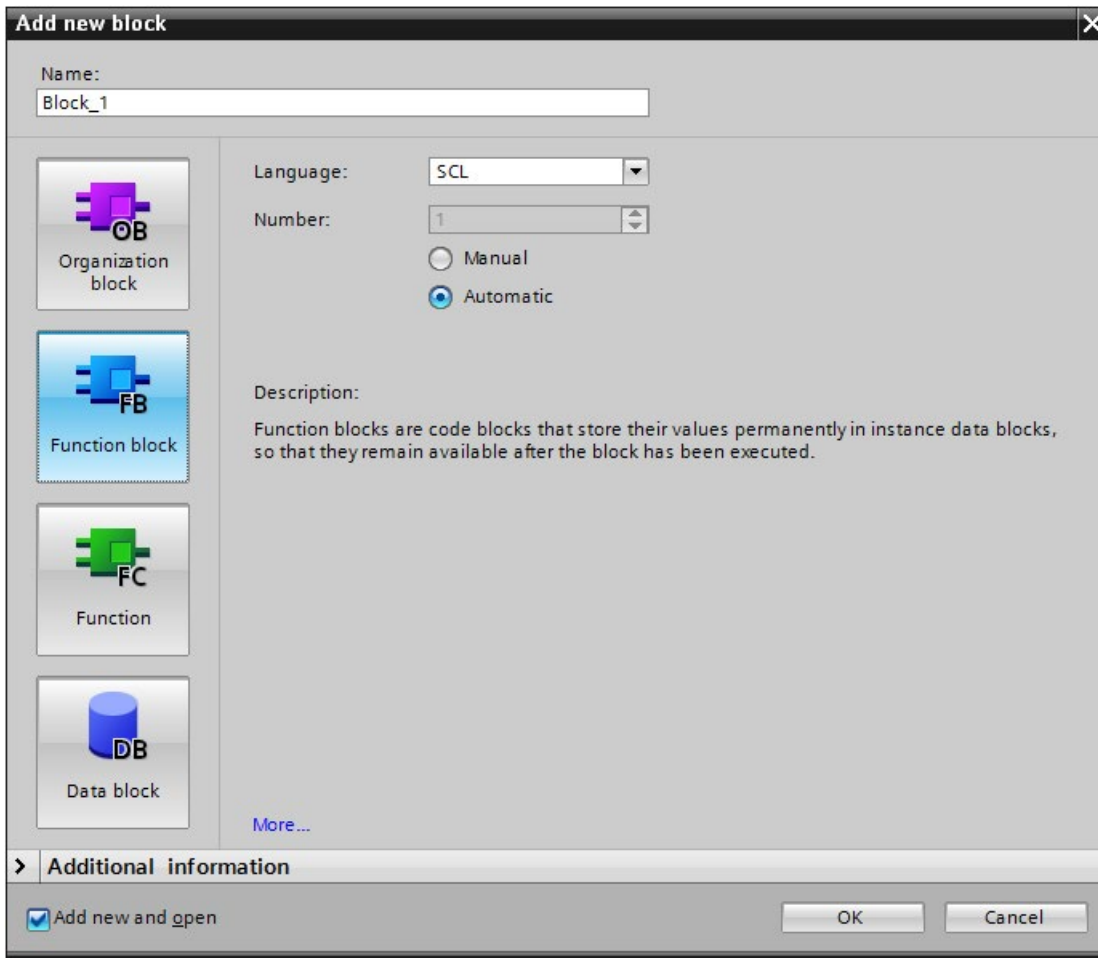


Figure 6-12 Create FB

4. Enter a name for the new block.
 5. Select the language SCL.
 6. Click on "OK" to confirm your input.
- Result: You have created a function block.

Create program alarm

To create the program alarm for the example program, follow these steps:

1. Select the created function block (FB) in the "Program blocks" folder in the project tree.
2. Insert the call of the "Program_Alarm" instruction in the instruction part of the function block. The "Program_Alarm" instruction is available in the "Instructions" task card under "Extended instructions" > "Alarms".

The "Call options" window opens.

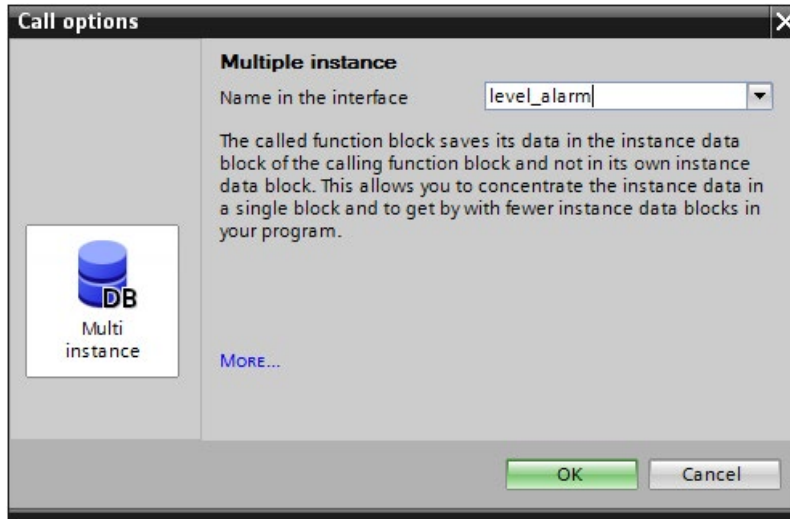


Figure 6-13 Call Program_Alarm

3. Enter "level_alarm" as the name and confirm the call options by clicking "OK".

Result: The input tags of the "Program_Alarm" instruction are displayed in the instruction part.

4. Supply the SIG input tag of the "Program_Alarm" instruction with the XOR logic operation of the tags for minimum and maximum fill level and the input tag SD_1 with the tag for the maximum fill level.

```
#level_alarm(SIG:="min"XOR"max",SD_1:="max");
```

SIG: If a signal change occurs at the SIG input tag, the "Program_Alarm" instruction generates a program alarm.

SD_1: The associated value is acquired at the time of the signal change at the input tag and assigned to the program alarm.

Result: You have created a type alarm.

Call function block

To call the function block in the user program, follow these steps:

1. In the "Program blocks" folder, select the cycle OB (e.g., OB1) in which you want to call the function block and open the cycle OB with a double-click.
2. Select the function block you want to call in the "Program blocks" folder.
3. Drag the function block into the instruction part of the cycle OB.
The "Call options" window opens.

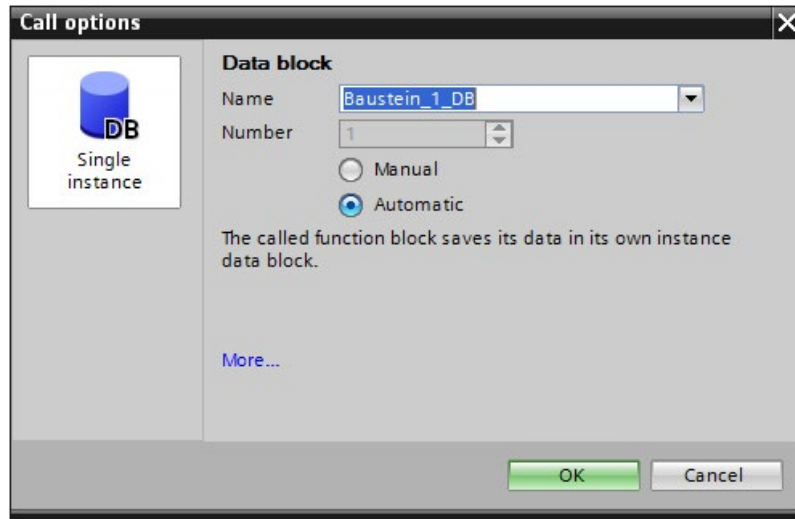


Figure 6-14 Call function block

4. Confirm the call options by clicking "OK".

Result: You have called the alarm block in the user program and created an instance alarm.

Creating a text list

To create the text list for the example program, follow these steps:

1. Double-click on the "Text lists" command in the program tree.
The text list editor opens.
2. Double-click "<Add>" in the Text lists area.
A new text list is added.
3. Name the text list "level_textlist".
4. Double-click "<Add>" in the Text list entries area of level_textlist.
A new text list entry is added in the level_textlist text list.
5. Enter the alarm text for the maximum fill level in the "Entry" column.
6. Add another entry in the text list.
7. Enter the alarm text for the minimum fill level in the "Entry" column.

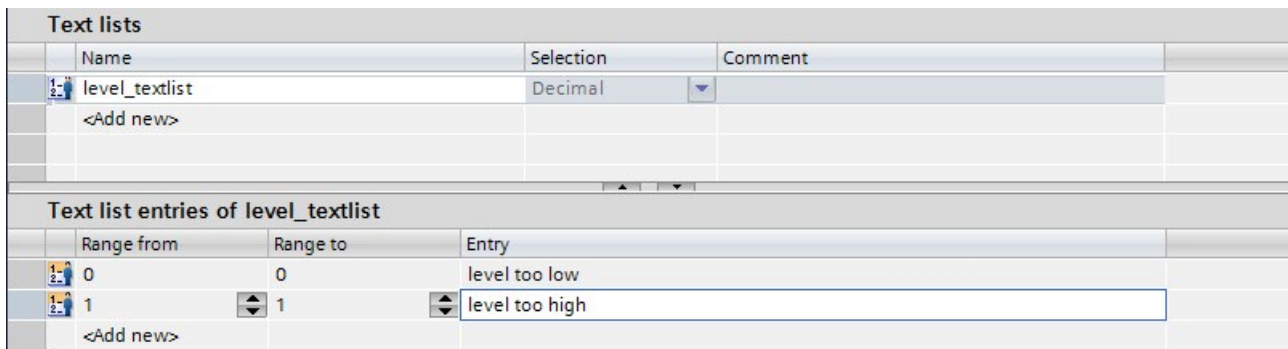


Figure 6-15 Creating a text list

Result: You have created the text list for the alarm text.

Edit alarm text

To edit the alarm text for the example program, follow these steps:

1. Double-click "PLC supervisions & alarms" in the project tree. Select the "Alarms" tab. The alarm editor opens.
2. Select the type alarm created for the example.
3. Click in the "Alarm text" column.
4. Open the shortcut menu and select the command "Insert a dynamic parameter (text list)".

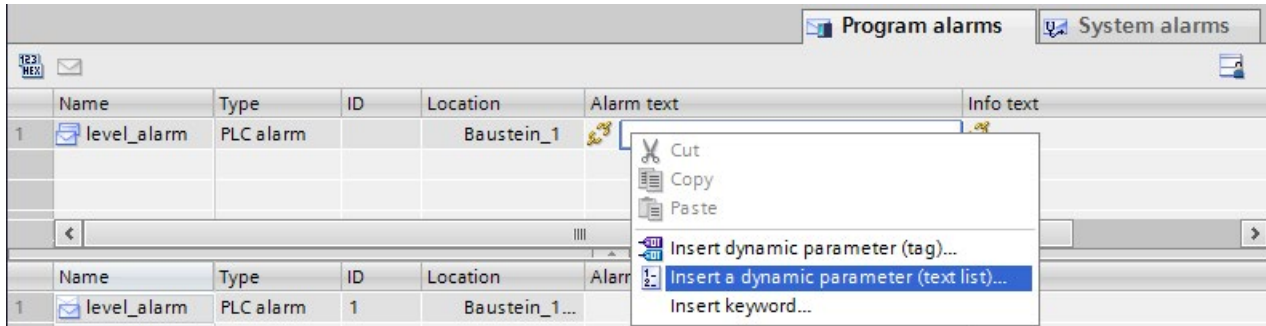


Figure 6-16 Edit alarm text

The window below opens.

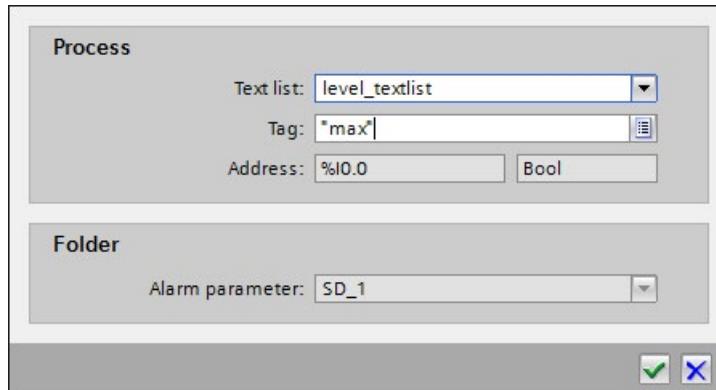


Figure 6-17 Insert a dynamic parameter (text list)

5. Select the text list "level_textlist" and the tag "max". Confirm your selection by clicking "OK".

Result: You have created the alarm text for the type alarms.

If the tag "max" (associated value 1) is 0, the alarm text "level too low" is output.

If the tag "max" (associated value 1) is 1, the alarm text "level too high" is output.

Additional information

You can learn how to create multilingual texts under "Multilingual alarms" in the section Editing alarms in the alarm editor (Page 78).

6.5.4 Displaying the alarm

Displaying the alarm in the Web server

The figure below shows the display of the alarm in the Web server for both examples.

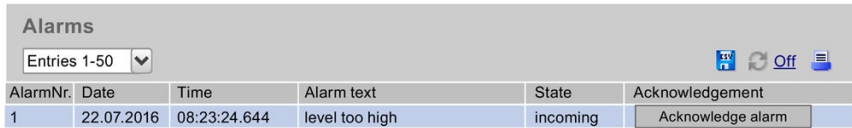


Figure 6-18 Displaying the alarm in the Web server

Displaying the alarm in STEP 7

Note

Displaying alarms in STEP 7

To display alarms in STEP 7, enable the option "Receive alarms" in the shortcut menu of the CPU.

The figure below shows the display of the alarm in STEP 7 for both examples.

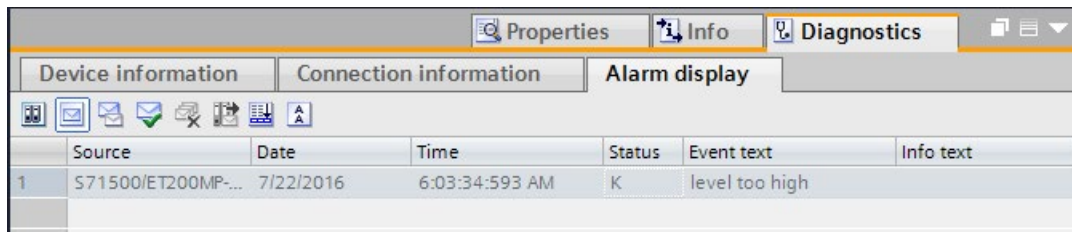


Figure 6-19 Display in STEP 7

Diagnostics of the S7-1500R/H redundant system

S7-1500R/H diagnostics

Diagnostics for a S7-1500R/H redundant system is basically the same as a standard S7-1500. You have the following display options:

- Via STEP 7
- Via HMI devices
- Via the display of the CPUs

The CPUs provide information about their operating states as well as internal and external errors through their LEDs.

The special features of the diagnostics of S7-1500R/H redundant systems are described below. In addition, the information of the current function manual and the STEP 7 online help also apply to S7-1500R/H redundant systems.

Diagnostics information in STEP 7

Hardware diagnostics can be performed as follows:

- Via the Online and Diagnostics view
- Via the "Online Tools" task card
- Via the "Diagnostics > Device Information" area of the Inspector window
- Via diagnostics icons, for example, in the device view and in the project tree

Diagnostics view in STEP 7 in dependence on the online connection and system states

The diagnostics view for S7-1500R/H redundant systems is partly dependent on:

- Which of the two CPUs the programming device / PC currently has a connection to
- The current system state in the redundant system

The table below provides an overview. The following sections illustrate the diagnostics view for S7-1500R/H using examples.

Table 7- 1 Diagnostics view in dependence on the online connection and system states

Diagnostics view in STEP 7	An online connection is available to the	System state	Examples in section
Online data and diagnostics of the redundant system	Primary CPU or backup CPU	RUN-Redundant	Online and Diagnostics view (Page 100)
Online data and diagnostics of the primary CPU The following are not displayed: • Online data and diagnostics from the backup CPU	Primary CPU	RUN-Solo or STOP	Online and Diagnostics view (Page 100) and
Online data and diagnostics of the backup CPU The following are not displayed: • Online data and diagnostics from the primary CPU • Online data and diagnostics of the distributed I/O	Backup CPU	RUN-Solo or STOP	Restrictions in the RUN-Solo system state (Page 117)
Display of the 3 operator panels in the "Online Tools" task card	Primary CPU or backup CPU	Not relevant	"Online Tools" task card (Page 103)
Cycle time of the primary CPU (of the system) and memory of the primary CPU in "Online Tools" task card	Primary CPU or backup CPU	RUN-Redundant	
Cycle time and memory of the primary CPU in the "Online Tools" task card	Primary CPU	RUN-Solo or STOP	
Cycle time and memory of the backup CPU in the "Online Tools" task card	Backup CPU	RUN-Solo or STOP	
Memory reset of the primary CPU via "Online Tools" task card	Primary CPU	STOP	
Memory reset of the backup CPU via "Online Tools" task card	Backup CPU	RUN-Solo or STOP	
"Alarm display" tab: Alarms from the primary CPU	Primary CPU	Not relevant	
"Alarm display" tab: Alarms from the backup CPU	Backup CPU	Not relevant	
Diagnostics of the distributed I/O	Primary CPU or backup CPU	RUN-Redundant	Diagnostics in the RUN-Redundant system state (Page 111)
Diagnostics of the distributed I/O	Primary CPU	RUN-Solo	Restrictions in the RUN-Solo system state (Page 117)

Accessible devices

As for standard S7-1500 systems, the following can be displayed in STEP 7:

- All devices accessible from programming device/PC
- The diagnostics information of devices of a redundant system, for example, from the R/H CPUs

The procedure is described in the section Accessible devices (without project) (Page 31).

7.1 Online and Diagnostics view

Introduction

You open the Online and Diagnostics view for the redundant system or for each CPU of the redundant system.

Online & diagnostics for the redundant system

"Online access":

For the S7-1500R/H redundant system, it is displayed whether an online connection exists between the programming device/PC and a CPU. The additional note "Online (via Primary CPU)" or "Online (via Backup CPU)" indicates which role the "Online" connected CPU has.

If you enable "Receive alarms", you receive asynchronous alarms of diagnostics events from the CPU with online connection. The display corresponds to the representation for standard CPUs.

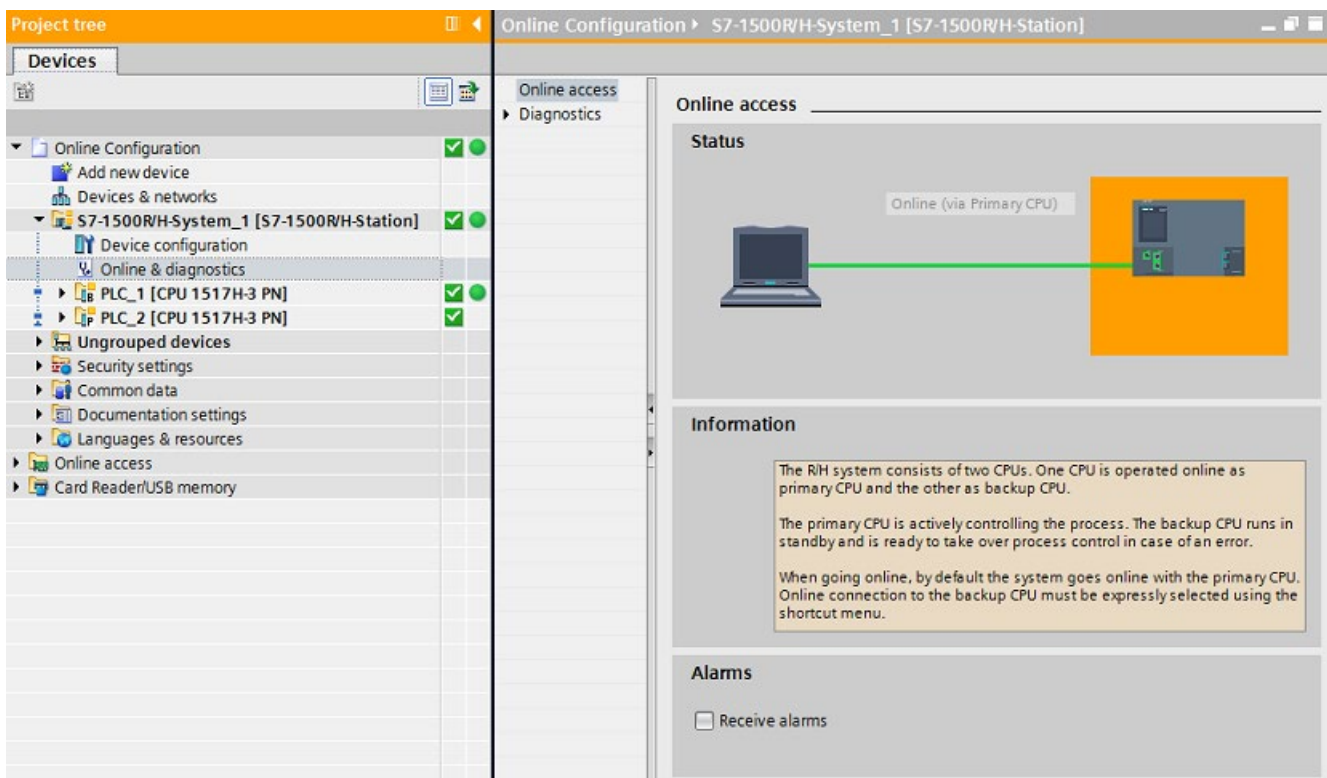


Figure 7-1 Online and Diagnostics view: Redundant system S7-1500R/H

"Diagnostics":

"Diagnostics" provides an overview for the redundant system about the:

- System state
- Pairing state
- Operating states of the CPU
- Status of which CPU is the primary CPU and which CPU is the backup CPU

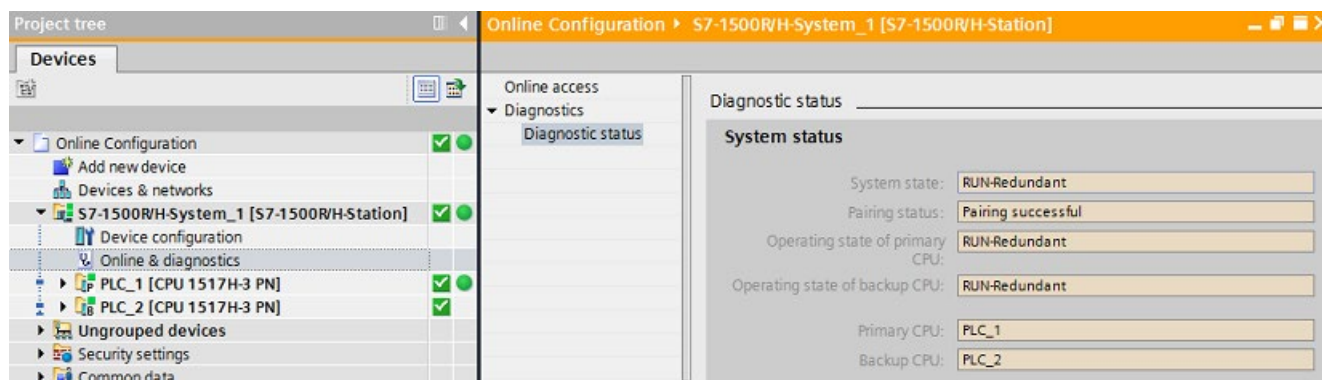


Figure 7-2 Online and Diagnostics view: Diagnostics status of the S7-1500R/H system

Online & diagnostics for the primary CPU or backup CPU

The Online and Diagnostics view for the CPUs of the redundant system match the display for standard CPUs.

In the RUN-Redundant system state, the primary and backup CPU display the online data of the redundant system irrespective of which of the two CPUs the online connection has been made.

In non-redundant mode, the programming device/PC displays the data of the CPU for which there is an online connection, i.e. either the primary CPU or of the backup CPU.

You select the CPU for display of the online data in the project tree.

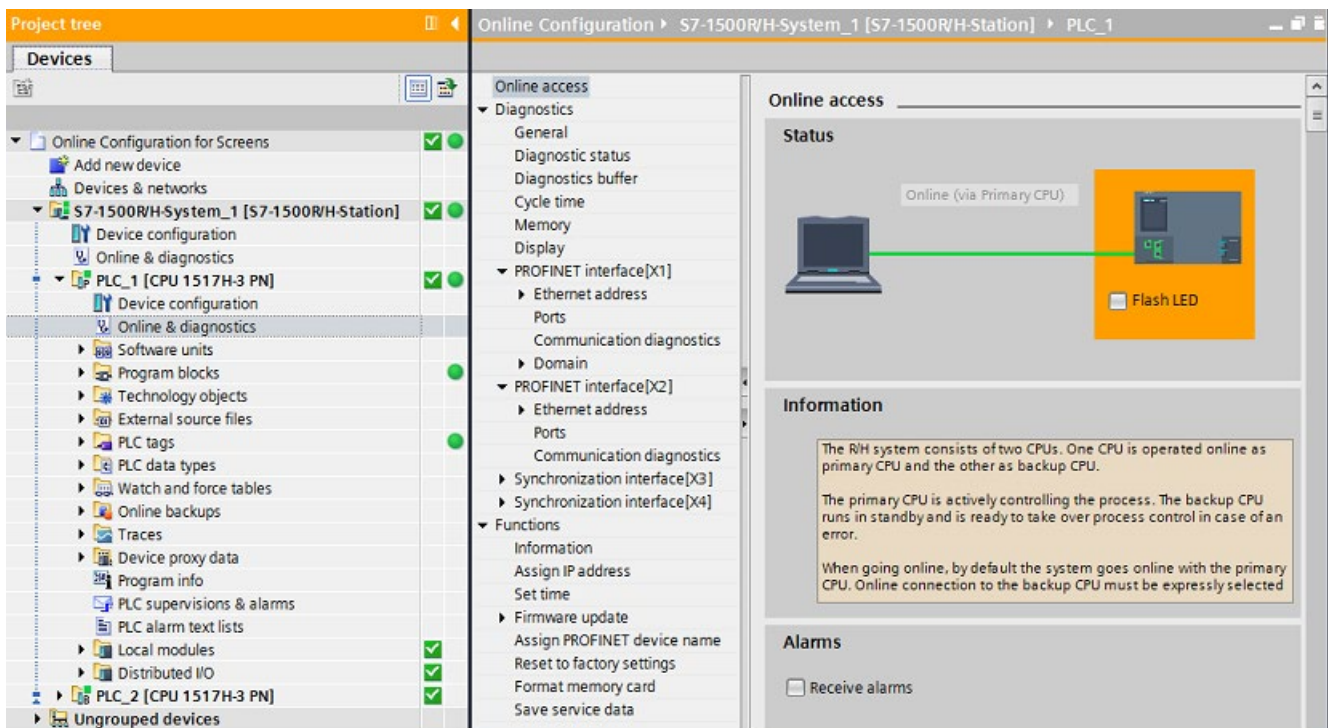


Figure 7-3 Online and Diagnostics view: CPU (RUN-Redundant system state)

Reference

You can find information on the operating and system states in the Redundant System S7-1500R/H System Manual (<https://support.industry.siemens.com/cs/ww/en/view/109754833>).

7.2 "Online Tools" task card

Introduction

If an online connection exists to a CPU of the redundant system, the "Online Tools" task card displays online information for the redundant system.

For a S7-1500R/H redundant system, "Online Tools" displays:

- 3 panes operator panel
- Cycle time
- Memory

R/H system operator panel

For the redundant system, the "R/H system operator panel" pane shows the:

- Current states of the LEDs of the primary CPU
- System state
- Status of which CPU is the primary CPU and which CPU is the backup CPU with their current operating states

The "STOP R/H-System" button can be used to switch the S7-1500R/H system to the system state STOP.

Note

Reaching RUN-Redundant system state

Note that you cannot switch the S7-1500R/H to RUN-Redundant system state using the R/H-System operator panel. You reach the RUN-Redundant system state by switching the operating state for each CPU to RUN in the operator panel of the respective CPU.

CPU operator panel

The two "CPU operator panel" panes show for the respective CPU of the redundant system:

- The role of the CPU, primary CPU or backup CPU
- The current states of the LEDs
- The operating state of the CPU

Use the "RUN / STOP" button to change the operating state for the respective CPU.

Use the "MRES" button to perform a memory rest for the CPU, under the following conditions:

- Online connection to this CPU is available
- The CPU is in STOP operating state.

The switch position at the real CPU is displayed under "Mode selector".

Example

The following figure shows an example of the "Online Tools" task card for the RUN-Solo system state. The primary CPU is in RUN operating state, the backup CPU in STOP operating state.

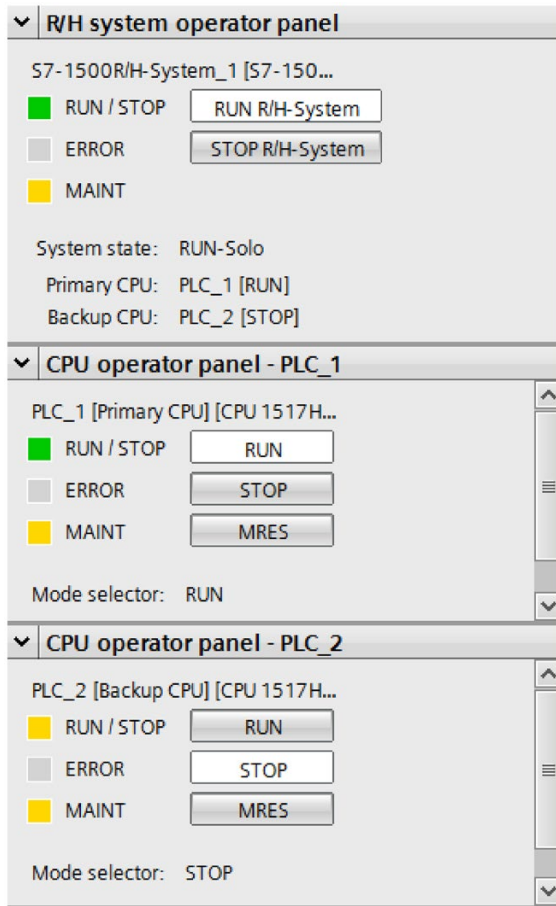


Figure 7-4 "Online Tools" task card: Operator panel (RUN-Solo system state)

Cycle time and memory

In the RUN-Redundant system state, the "Cycle time" and "Memory" panes show the current values of the primary CPU. In redundant mode, the cycle time of the primary CPU matches the cycle time of the system.

In the RUN-Solo system state, the panes show the current values for the CPU for which there is an online connection.

The display corresponds to the representation for standard CPUs.

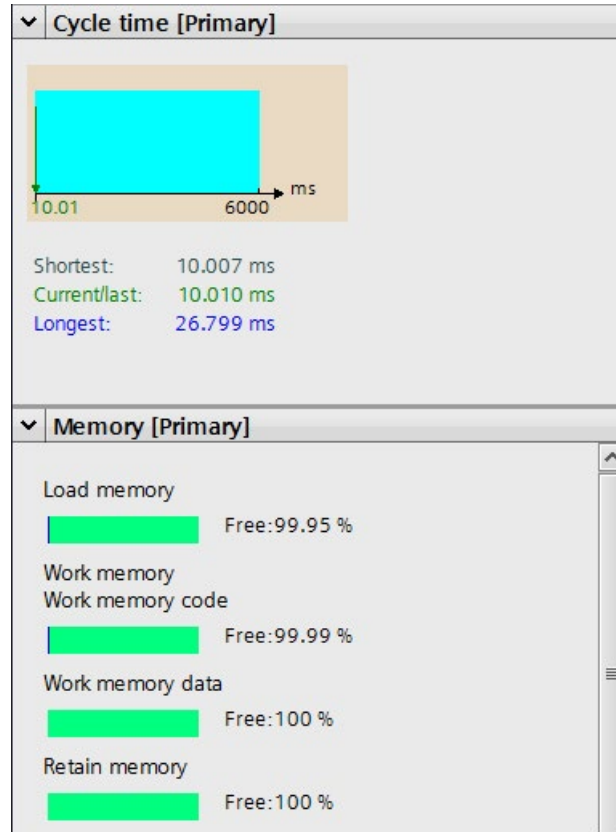


Figure 7-5 "Online Tools" task card: Cycle time and memory of the primary CPU

Reference

You can find information on the operating and system states in the Redundant System S7-1500R/H System Manual

(<https://support.industry.siemens.com/cs/ww/en/view/109754833>).

7.3 Diagnostics view in the project tree and in the device view and network view

Additional icons for redundant systems in the project tree

Table 7- 2 Icons for redundant systems in the project tree of STEP 7

Icon in the project tree	Meaning
	Identifier of the folder S7-1500R/H-System: RUN-Redundant system state
	Identifier of the folder S7-1500R/H-System: RUN-Solo system state
	Identifier of the folder S7-1500R/H-System: STARTUP system state
	Identifier of the folder S7-1500R/H-System: STOP system state
	Identifier of the folder for the primary CPU: RUN operating state
	Identifier of the folder for the backup CPU: RUN operating state
	Identifier of the folder for the primary CPU: STARTUP operating state
	Identifier of the folder for the backup CPU: STARTUP operating state
	Identifier of the folder for the primary CPU: STOP operating state
	Identifier of the folder for the backup CPU: STOP operating state
	Identifier of the folder of a CPU of the redundant system: "Online via partner": The other CPU of the redundant system is connected online to the programming device / PC.

Example: Diagnostics view in the project tree and in the device view and network view

An example of the diagnostics view for a S7-1500R/H system is shown below.



The sample configuration consists of two CPUs S7-1517H-3 PN and one interface module IM 155-6 PN HF as PROFINET IO device. PLC_1 is the primary CPU (in RUN operating state). PLC_2 is the backup CPU (in STOP operating state). The hardware configuration and the user program were loaded in the primary CPU.


The system is connected online via PLC_1 (primary CPU) and is in RUN-Solo system state.

View of the system in the project tree

The system is in RUN-Solo system state . PLC_1 is in RUN operating state , PLC_2 is in STOP operating state .

Because the system is in RUN-Solo system state, the following is displayed:

- For the system, maintenance demanded with problem in lower-level component 
- For PLC_1, maintenance demanded 

For PLC_2, online connection via partner  is displayed, as the programming device/PC is connected online to PLC_1.

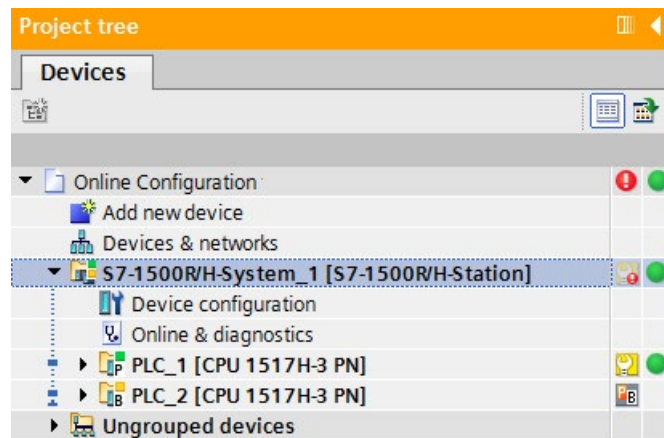


Figure 7-6 Diagnostics example: Redundant system project tree (RUN-Solo)

Network view of the system

The network view shows no faults for the H-CPU or the IO device.

Maintenance demanded in lower-level component indicated for the system, since the system is not in the RUN-Redundant system state.

No operating states and system states of the redundant system are displayed in the network view.

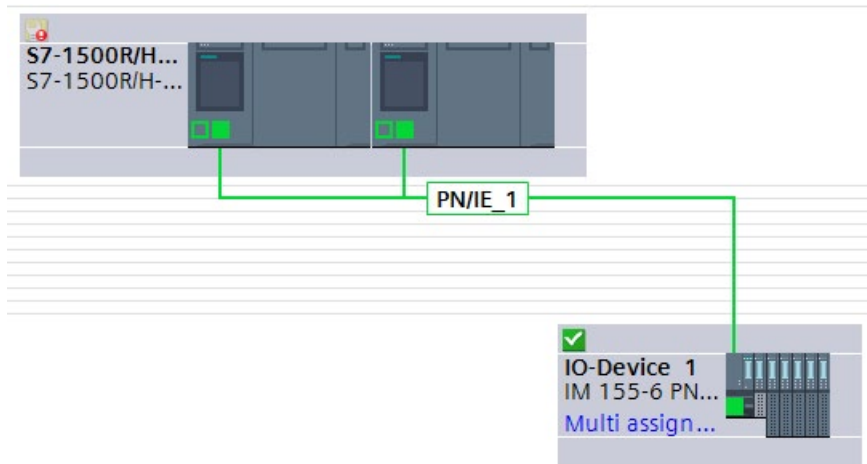


Figure 7-7 Diagnostics example: Network view of redundant system (RUN-Solo)

Doubling-clicking on the system gives you access to the device view of both CPUs.

Device view of the system

In the device view, you see the operating states of the CPUs based on the icons above PLC_1:

- Green icon: PLC_1 is in the RUN operating state.
- Yellow icon (wrench) for maintenance demanded: PLC_2 is in the STOP operating state.

PLC_2 indicates that the online connection is available through the partner (PLC_1).

You can find more detailed information on the system faults in the "Diagnostics" tab, in "Device information". The device information indicates maintenance demanded and RUN operating state for PLC_1.

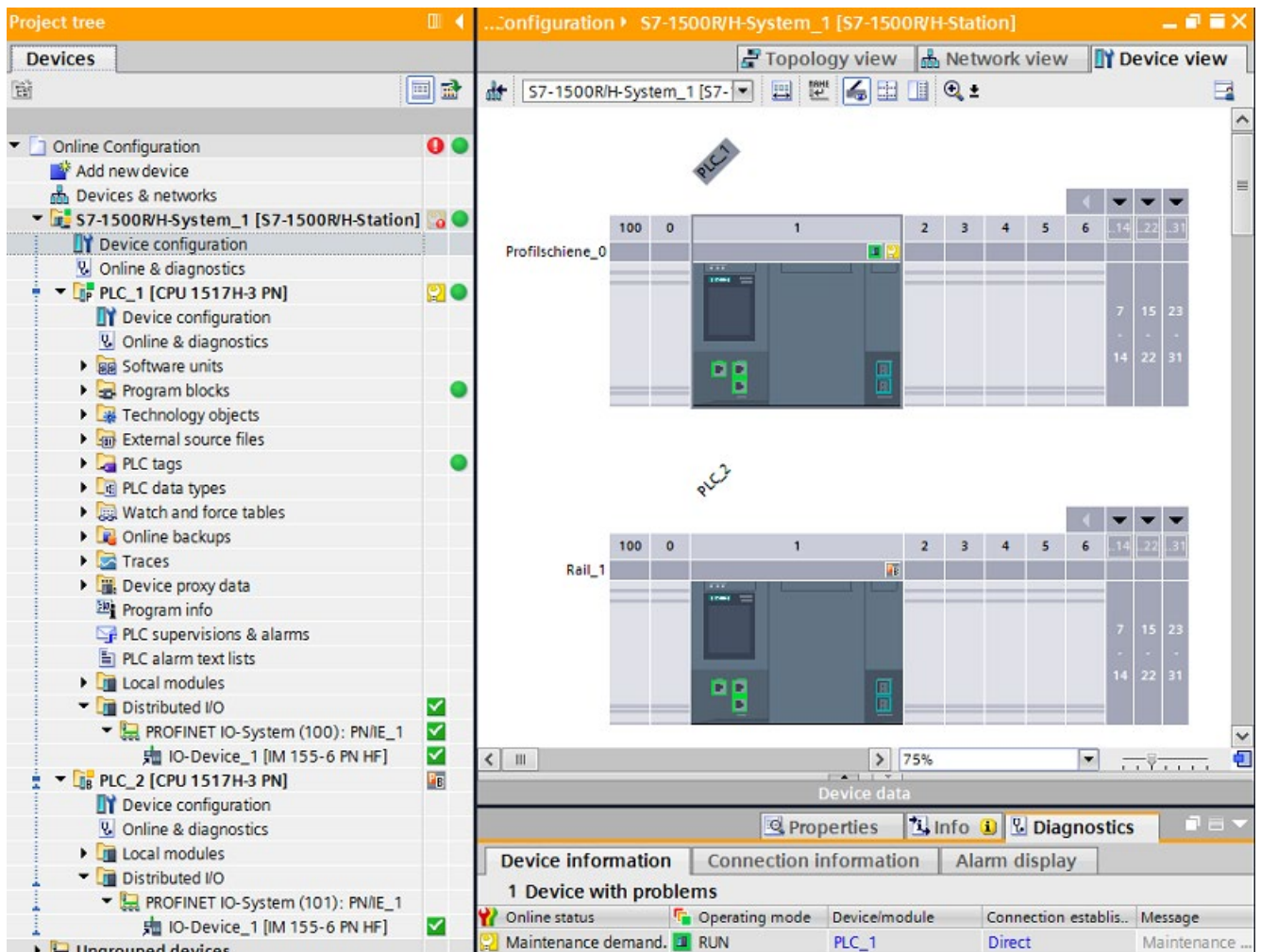


Figure 7-8 Diagnostics example: Device view of redundant system (RUN-Solo)

Alarm display of the system

As in the RUN-Solo system state, the alarms of the CPU for which there is an online connection are displayed via the "Alarm display" tab (in the example from PLC_1).

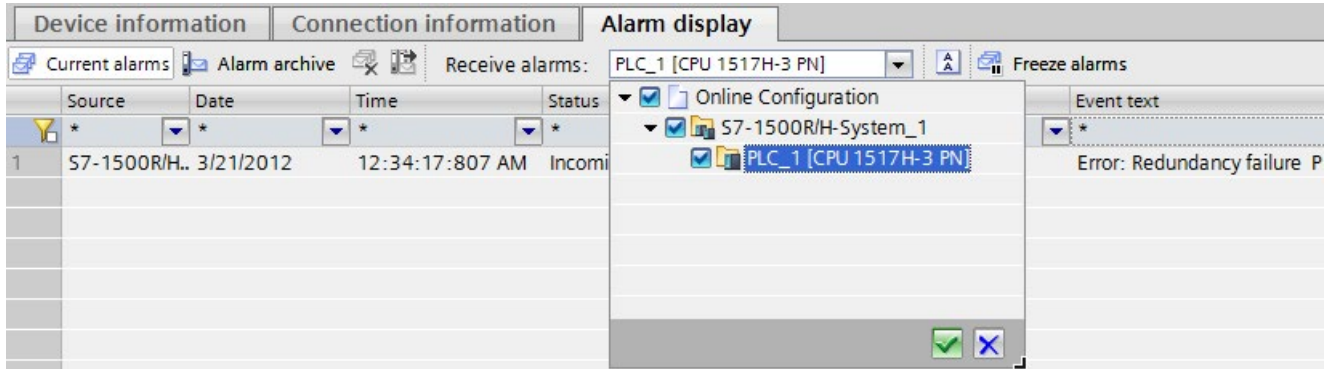


Figure 7-9 Diagnostics example: Alarm display of redundant system (RUN-Solo)

Device view of the IO device

The IO device is an interface module IM 155-6 PN HF with two I/O modules and one server module. The device view shows that there is no faults in the modules.

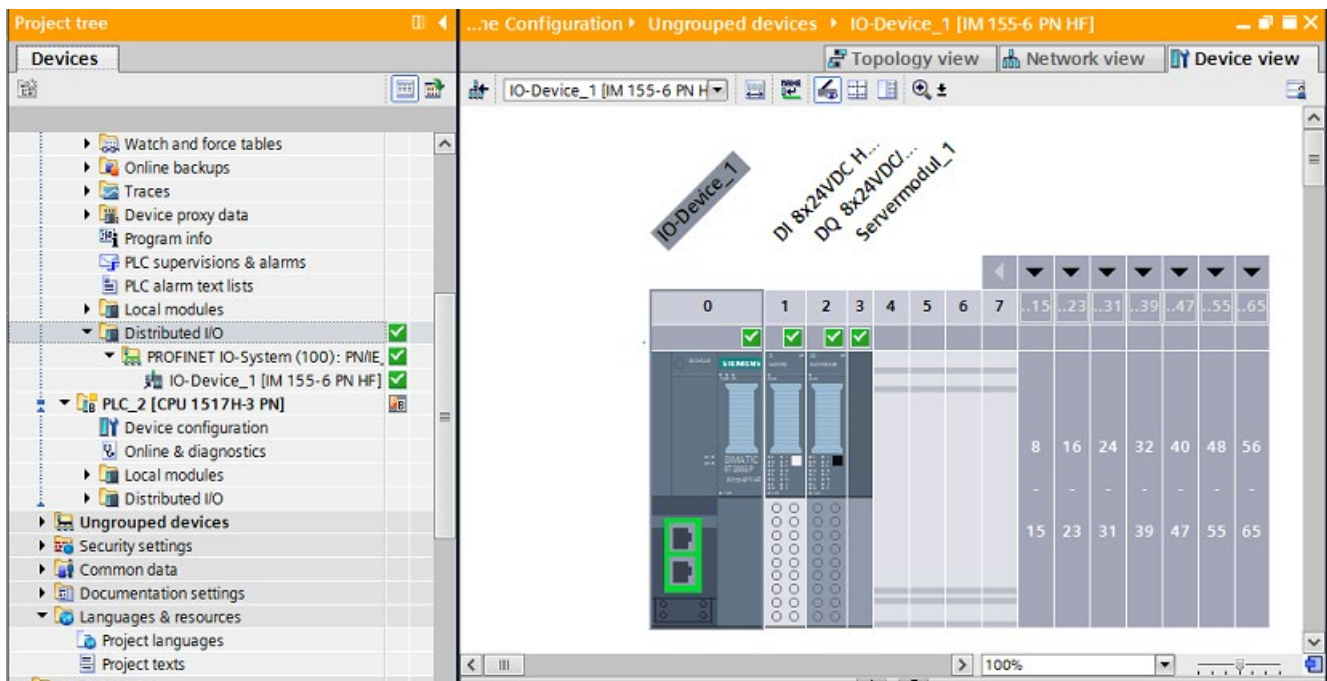


Figure 7-10 Diagnostics example: Device view of IO device

7.4 Diagnostics in the RUN-Redundant system state

Diagnostics view in redundant mode

Primary CPU and backup CPU are each in the RUN-Redundant operating state.


In the RUN-Redundant system state, the primary and backup CPU display the online data of the redundant system irrespective of which of the two CPUs the online connection has been made.

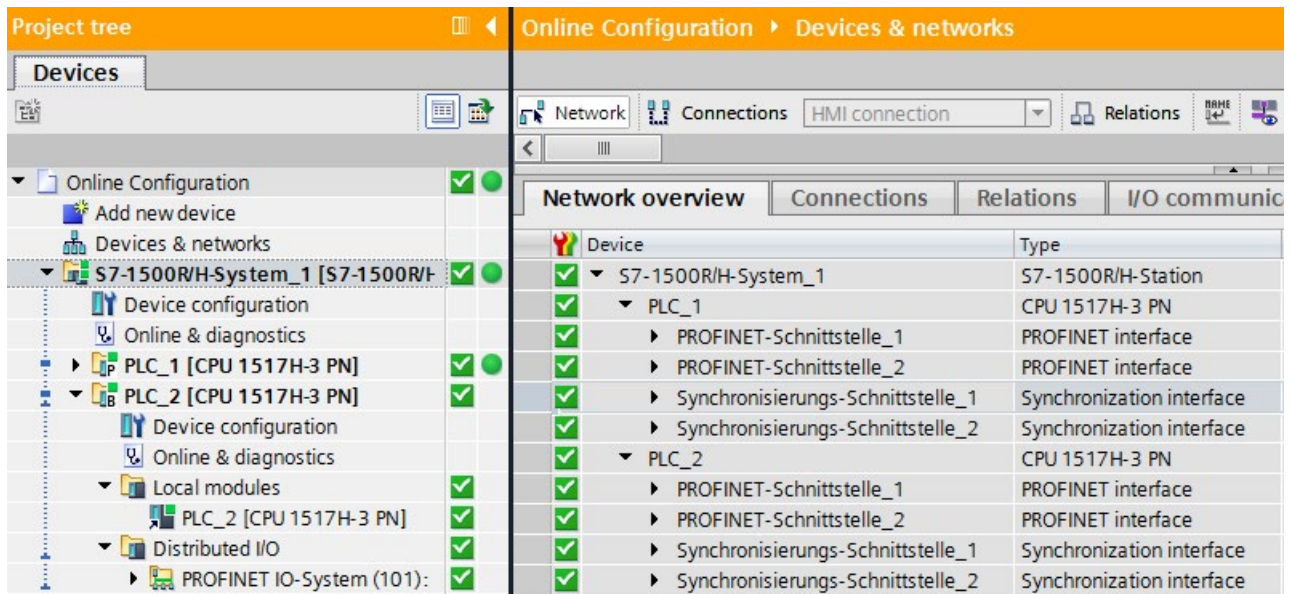
The diagnostics between the two CPUs is synchronized (diagnostics entries, diagnostics events).

The "Alarm display" tab shows the alarms of the redundant system.

You can find more information in the Diagnostics view in the project tree and in the device view and network view (Page 106).

No error in RUN-Redundant system state

If no error is detected in the RUN-Redundant system state, all diagnostics icons in the project tree and in the network view show "No fault" .



Device	Type
✓ S7-1500R/H-System_1	S7-1500R/H-Station
✓ PLC_1	CPU 1517H-3 PN
✓ PROFINET-Schnittstelle_1	PROFINET interface
✓ PROFINET-Schnittstelle_2	PROFINET interface
✓ Synchronisierungs-Schnittstelle_1	Synchronization interface
✓ Synchronisierungs-Schnittstelle_2	Synchronization interface
✓ PLC_2	CPU 1517H-3 PN
✓ PROFINET-Schnittstelle_1	PROFINET interface
✓ PROFINET-Schnittstelle_2	PROFINET interface
✓ Synchronisierungs-Schnittstelle_1	Synchronization interface
✓ Synchronisierungs-Schnittstelle_2	Synchronization interface

Figure 7-11 Diagnostics example: No fault in the RUN-Redundant project tree

Error in the RUN-Redundant system state

Most errors in the redundant system do not result in a loss of redundancy. The RUN-Redundant system state is retained, for example, if a module in an IO device fails. The diagnostics view is similar to the standard S7-1500 systems.

In the RUN-Redundant system state the redundancy of the system can be restricted, e.g. during the interruption of one of the two redundancy connections in S7-1500H. You can find information on the redundancy scenarios in the Redundant System S7-1500R/H System Manual (<https://support.industry.siemens.com/cs/ww/en/view/109754833>).

Special examples of a redundant system S7-1500H are shown below:

S7-1500H Example 1:

The PROFINET ring between the CPU of the redundant S7-1500H system and an IO device was interrupted.

Evaluate diagnostics via LINK TX/RX LEDs on the CPU

TX/RX X1 P1 LED is not illuminated. This means:

- No Ethernet connection between the P1 port of the respective PROFINET interface and the communication partner

Diagnostics in STEP 7

The diagnostics buffer of the CPU displays that the PROFINET ring is open.

The diagnostics in the project tree shows:

- Maintenance demanded in lower-level component in the S7-1500H system
- Maintenance demanded in lower-level components of PLC_1 and PLC_2
- Maintenance demanded in lower-level components of local modules of PLC_2

The diagnostics in the network view indicates errors at the affected port of the PROFINET interfaces of PLC_2.

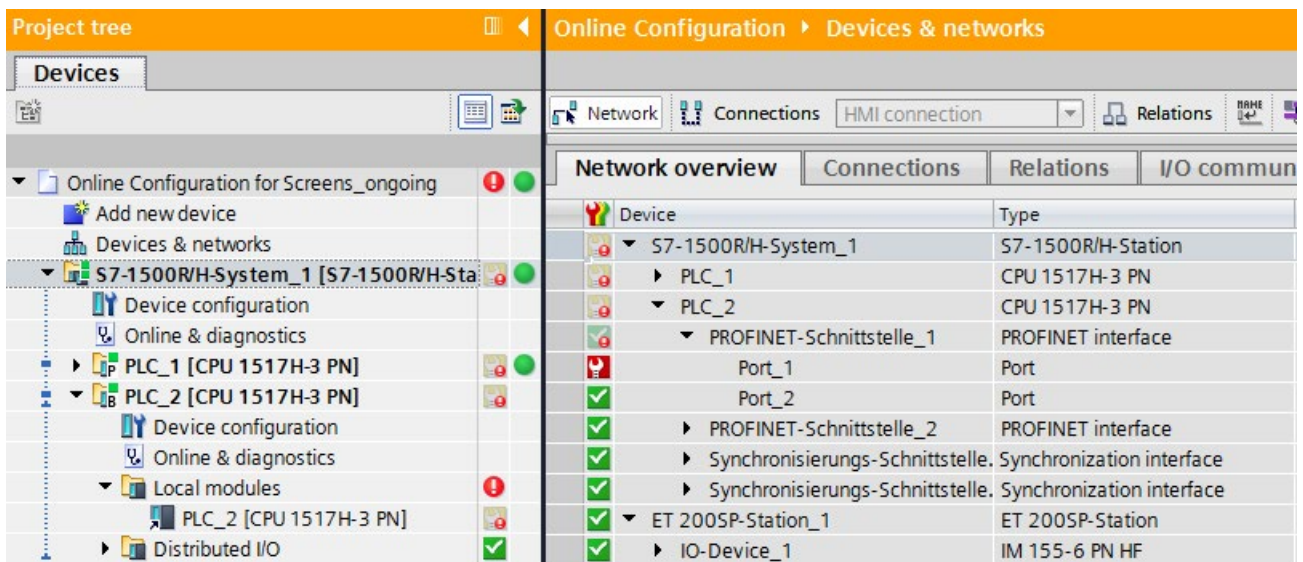


Figure 7-12 Diagnostics example: RUN-Redundant system state, open PROFINET ring

You can evaluate the diagnostics using the displays of the CPUs via the "Diagnostics" menu as with standard CPUs. You can find additional information in the section Display of the CPU (Page 27).

S7-1500H Example 2:

A synchronization module has been removed from a CPU of the redundant S7-1500H system.

Evaluating diagnostics via X3 and X4 LEDs on the CPU

The X3 LED on PLC_2 CPU is not illuminated. This means:

- The redundancy connection on the synchronization module was interrupted at the H-Sync interface X3.
- or
- There is no synchronization module at the H-Sync interface X3.

Diagnostics in STEP 7

The diagnostics buffer of the CPU displays:

- that there is only one redundancy connection
- which synchronization module has failed on which CPU

The diagnostics in the project tree shows:

- Maintenance demanded in lower-level component in the S7-1500H system
- Maintenance demanded in lower-level components of PLC_1 and PLC_2
- Maintenance demanded in lower-level components of local modules of PLC_1 and PLC_2

The diagnostics in the network view displays:

- Errors for the Synchronisationsmodul_1 of the Synchronisationsschnittstelle_2 of PLC_1
- Synchronisationsmodul_1 of Synchronisationsschnittstelle_1 of PLC_2 not reachable

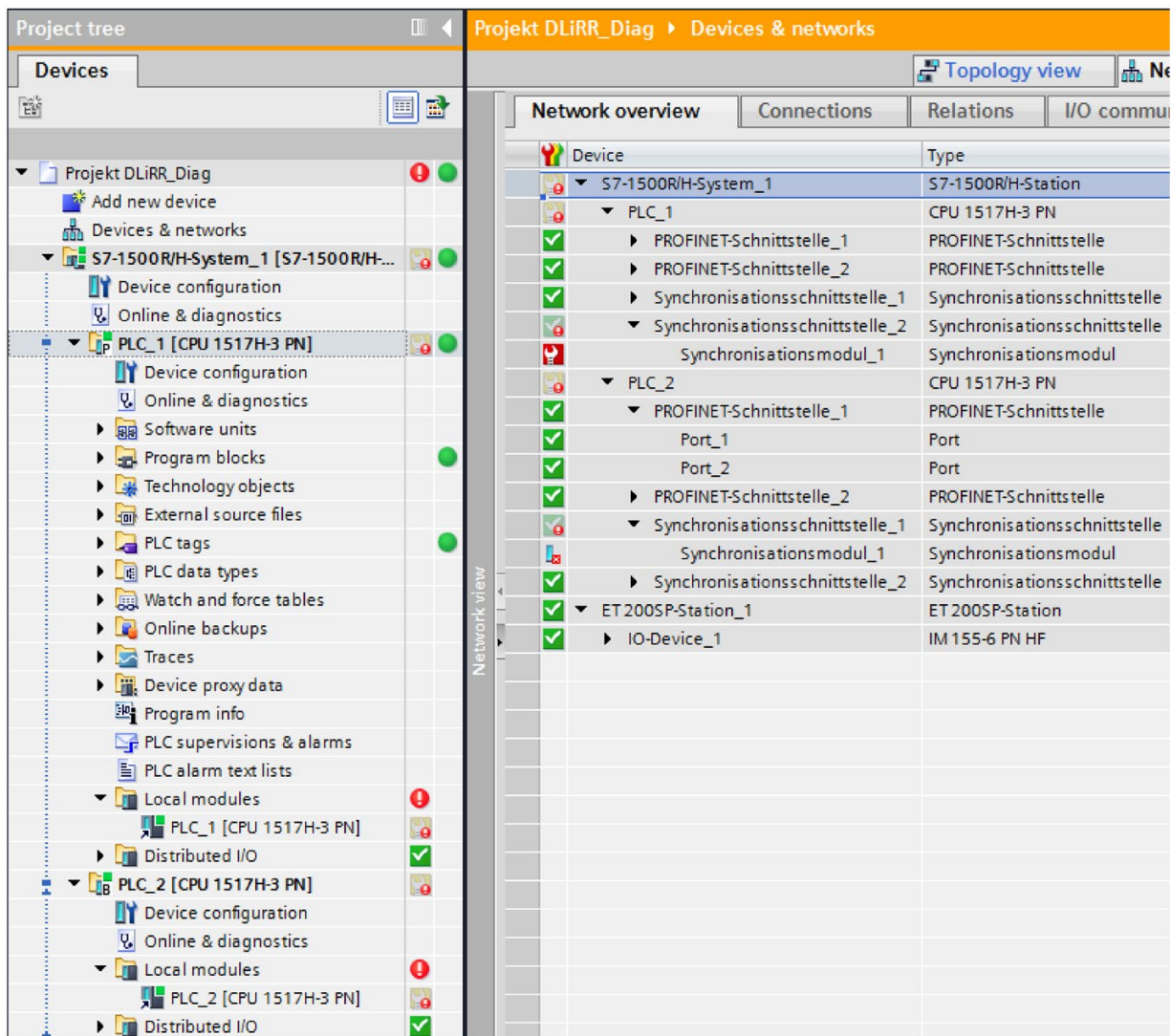


Figure 7-13 Diagnostics example: RUN-Redundant system state, a synchronization module fails

Evaluate diagnostics on the display

For example 2, display of the PLC_2 CPU shows:



- In the "Overview" menu command: A message is available in the next lower level page.
- In the "Diagnostics" menu command: A message is available in the next lower level page.
- In the Module menu command: An error has occurred.

To evaluate the display, proceed as follows:

1. Navigate to "Pairing state" via the menu commands "Overview" > "Redundancy".
2. This is displayed as the pairing state: Single paired (X4).

This means that the redundancy connection is available at the H-Sync interface X4, but not at the X3.

3. Navigate to "Alarms" via the "Diagnostics" menu command.
4. View the details of the alarm (evaluate diagnostics buffer).

S7-1500H Example 3:

A redundancy connection in S7-1500H is interrupted.

Evaluating diagnostics via X3 and X4 LEDs on the CPU

The LED X4 on CPU PLC_1 does not light up. This means:

- The redundancy connection on the synchronization module was interrupted at the H-Sync interface X4.
- or
- There is no synchronization module at the H-Sync interface X4.

Diagnostics in STEP 7

The diagnostics buffer of the CPU displays:

- that there is only one redundancy connection
- Fiber-optic error with specification of the CPU and the synchronization module

The diagnostics in the project tree shows:

- Maintenance demanded in lower-level component in the S7-1500H system
- Maintenance demanded in lower-level components of PLC_1 and PLC_2
- Maintenance demanded in lower-level components of local modules of PLC_1 and PLC_2

The diagnostics in the network view displays:

- Errors for the Synchronisationsmodul_1 of the Synchronisationsschnittstelle_2 of PLC_1
- Errors for the Synchronisationsmodul_1 of the Synchronisationsschnittstelle_1 of PLC_2

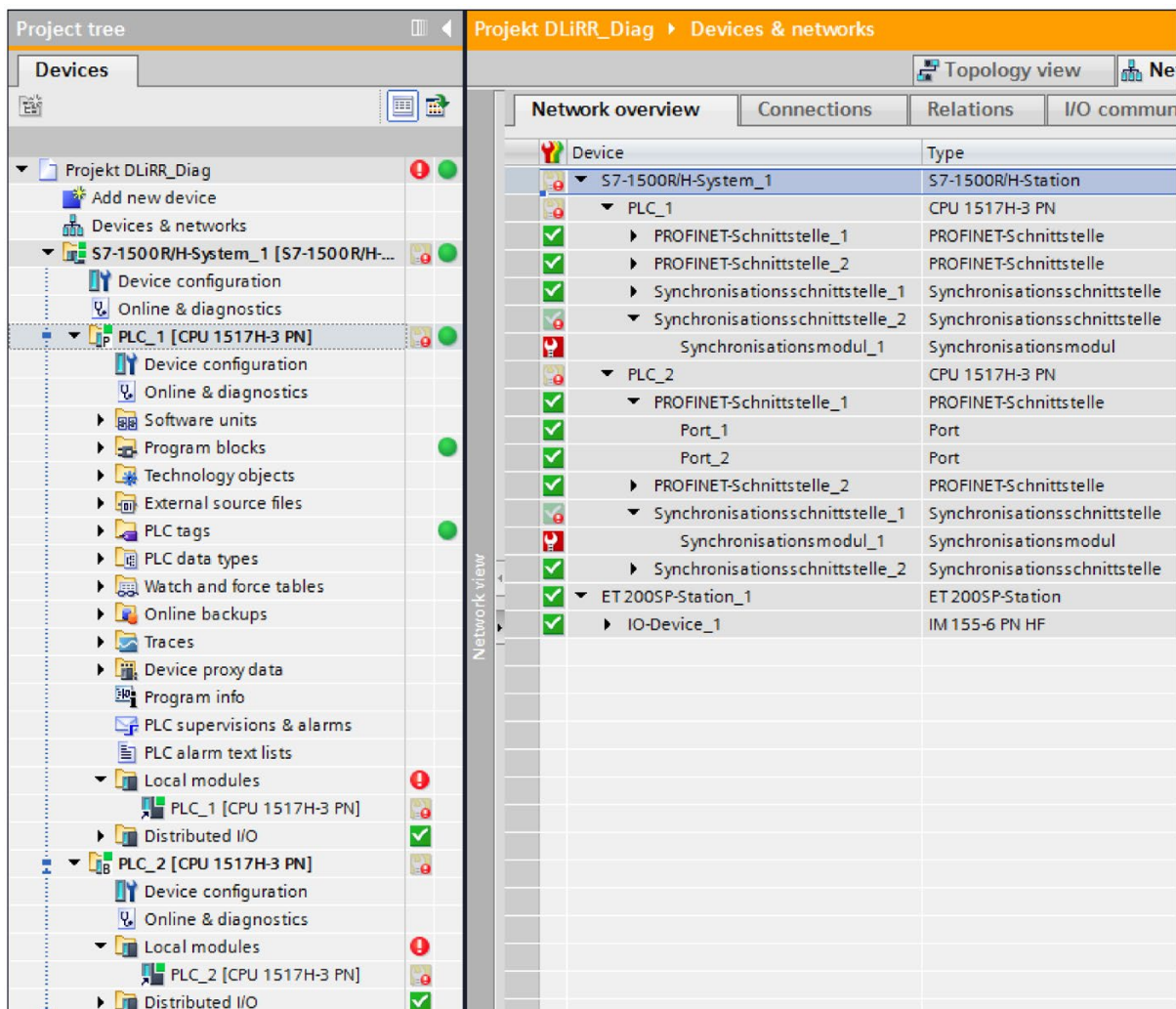


Figure 7-14 Diagnostics example: RUN-Redundant system state, a redundancy connection has failed

Evaluate diagnostics on the display

Perform the analysis of the display of PLC_2 CPU exactly as for example 2.

7.5 Restrictions in the RUN-Solo system state

The primary CPU is in RUN operating state. The Backup CPU is in STOP operating state, is switched off, defective, or not available.

Restrictions in the RUN-Solo system state

The primary CPU records the diagnostics states of the distributed I/O.

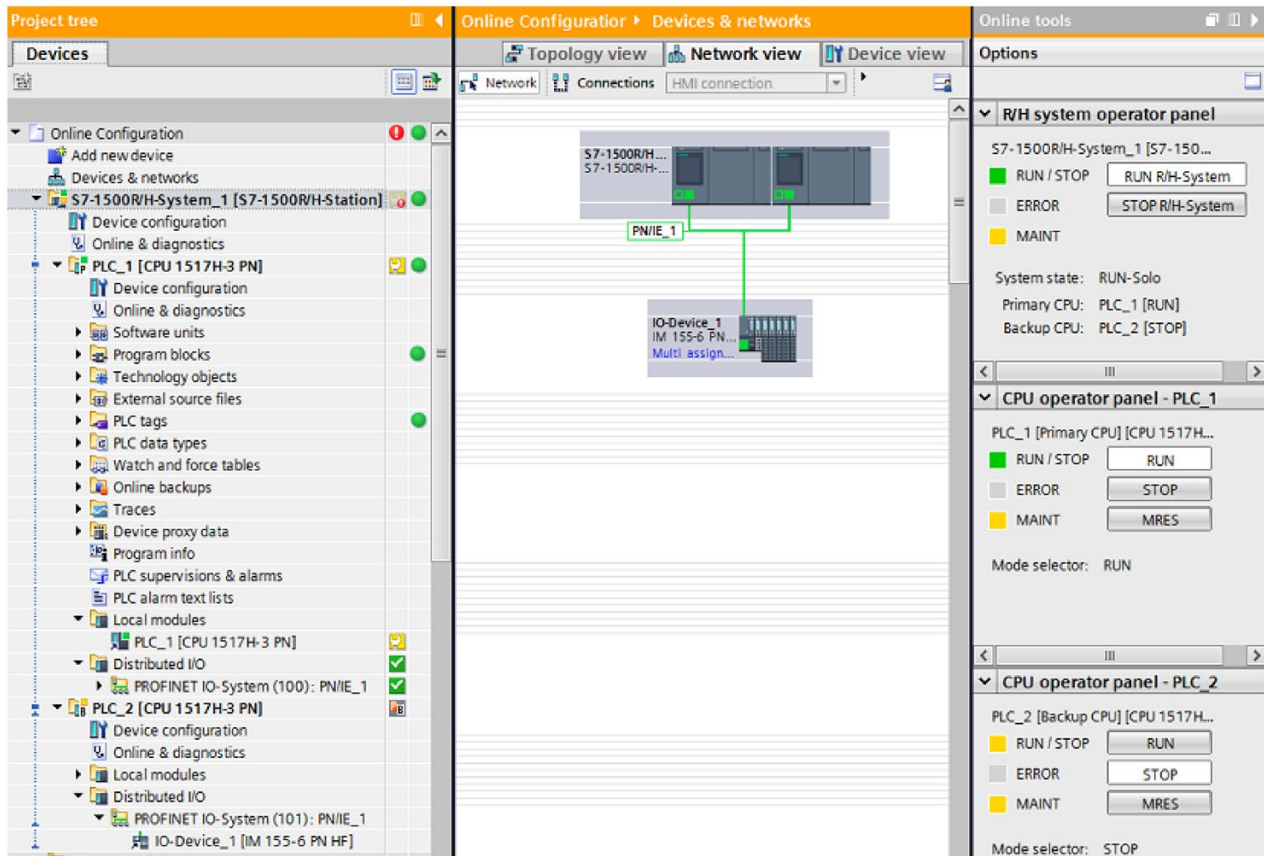


Figure 7-15 Diagnostics of the primary CPU and backup CPU in RUN-Solo system state

Diagnostics of the backup CPU

The following restrictions apply to the backup CPU:

- Diagnostics information from the backup CPU is only available when there is an online connection to the backup CPU.
- A memory reset can only be performed with the backup CPU operator panel when an online connection to the backup CPU is available.

Reference

You can evaluate the diagnostics using the displays of the CPUs via the "Diagnostics" menu as with standard CPUs. You can find additional information in the section Display of the CPU (Page 27).

7.6 System diagnostics by means of the user program

Instructions

Instructions for determining the system diagnostics are listed in the section System diagnostics options in the user program (Page 71).

The following instruction for diagnostics cannot be used for S7-1500R/H redundant systems:

- DPNRM_DG: Read diagnostics data from a DP slave

Organization blocks

You can find the description of the applicable OBs for S7-1500R/H in the S7-1500R/H redundant system (<https://support.industry.siemens.com/cs/ww/en/view/109754833>) system manual.

Glossary

Alarm

An message sent to the operator due to events or states of the system.

Backup CPU

Role of a CPU in the S7-1500R/H redundant system. If the R/H system is in RUN-Redundant system state, the primary CPU controls the process. The backup CPU processes the user program synchronously and can take over the process control if the primary CPU fails.

Button (WinCC)

Object in WinCC that points out faults in the plant

Channel fault

Channel-related error of an individual channel - an I/O with inputs, for example, wire break or short circuit

Device

Modules with a network connection are referred to as device. Devices are installed on racks where they can be interconnected with other modules.

Diagnostics buffer

A buffered memory area in the CPU; it stores diagnostics events in the order of their occurrence

Firmware of the CPU

In SIMATIC, a distinction is made between the firmware of the CPU and user programs.

The firmware is a software embedded in electronic devices, which means it is permanently connected with the hardware functionally. It is usually saved in a flash memory, such as EPROM, EEPROM or ROM, and cannot be replaced by the user or only with special means or functions.

User program: see glossary entry "User program"

Global screen (WinCC)

A screen that is opened in the system diagnostics window is a global screen.

HMI device

Human Machine Interface, device for visualization and control of automation processes.

HMI diagnostics view (WinCC)

The HMI diagnostics view is an object in WinCC. The HMI diagnostics view can only be used with Comfort Panels and WinCC Advanced RT.

I/O module

Device of the distributed I/O that is used as interface between the controller and the process.

Industrial Ethernet

Guideline for setting up Ethernet in an industrial environment. The main difference to the standard Ethernet is the mechanical current carrying capacity and interference immunity of the individual components.

Memory reset

Procedure to set the memories of the CPU to a defined initial state.

Operating states

Operating states describe the behavior of a single CPU at a specific time.

The CPUs of the SIMATIC standard systems feature the STOP, STARTUP and RUN operating states.

The primary CPU of the S7-1500R/H features the STOP, STARTUP, RUN, RUN-Syncup and RUN-Redundant operating states. The backup CPU features the STOP, SYNCUP and RUN-Redundant operating states.

PLC

Programmable Logic Controller: Component of the CNC by which the machine manufacturer coordinates the interaction between the NC requirements (part program), the inputs of the machine operator and the current machine state.

Primary CPU

Role of a CPU in the S7-1500R/H redundant system. If the R/H system is in RUN-Redundant system state, the primary CPU controls the process. The backup CPU processes the user program synchronously and can take over the process control if the primary CPU fails.

PROFIBUS

Standard for fieldbus communication in automation technology.

PROFINET

PROcess FieId NETwork, open industrial Ethernet standard which further develops PROFIBUS and industrial Ethernet. A cross-manufacturer communication, automation, and engineering model defined by PROFIBUS International e.V., as an automation standard.

Redundant systems

Redundant systems are identified by the fact that important automation components are available in multiple units (redundant). Process control is maintained if a redundant component fails.

Subnet

Part of a network whose parameters must be synchronized with the devices (e.g., with PROFINET). It includes the bus components and all connected stations. Subnets can be linked by means of gateways, for example, to form a network.

Synchronization module

The synchronization module is used to provide a redundant connection between the CPUs of the S7-1500H redundant system. You require two synchronization modules per CPU, which you connect using a fiber-optic cable.

System diagnostics

In the SIMATIC environment, the term "system diagnostics" refers to diagnostics of devices and modules. System diagnostics is used, for example, to monitor the states of the following components in the system: Power supply, device, I/O.

System diagnostics indicator (WinCC)

The system diagnostics indicator is a predefined graphic symbol of the library which alerts you to errors in your plant and displays two states: No error, error

System states

The system states of the S7-1500R/H redundant system result from the operating states of the primary and backup CPU. The term 'system state' is used as simple expression that identifies the operating states of the two CPUs that occur at the same time. The S7-1500R/H redundant system features the system states STOP, STARTUP, RUN-Solo, SYNCUP and RUN-Redundant.

Topology

Structure of a network. Common structures include:

- Linear bus topology
- Ring topology
- Star topology
- Tree topology

User program

In SIMATIC, a distinction is made between user programs and the firmware of the CPU.

The user program contains all instructions, declarations and data by which a plant or process can be controlled. It is assigned to a programmable module (for example, CPU, FM) and can be structured in smaller units.

Firmware: see glossary entry "Firmware of the CPU"

Value status

The value status describes a specific signal state. The value status is constantly updated and cyclically transmitted by the field device as quality statement together with the measured value.

Web server

Software/ communication service for data exchange using Ethernet. The web server provides the documents by means of standardized transmission protocols (HTTP, HTTPS) to a web browser. Documents can be static or dynamic upon request by the web browser composed from different sources by the web server.

WinCC

Windows Control Center: a PC-based process visualization system

WinCC Runtime

Component of the basic software WinCC

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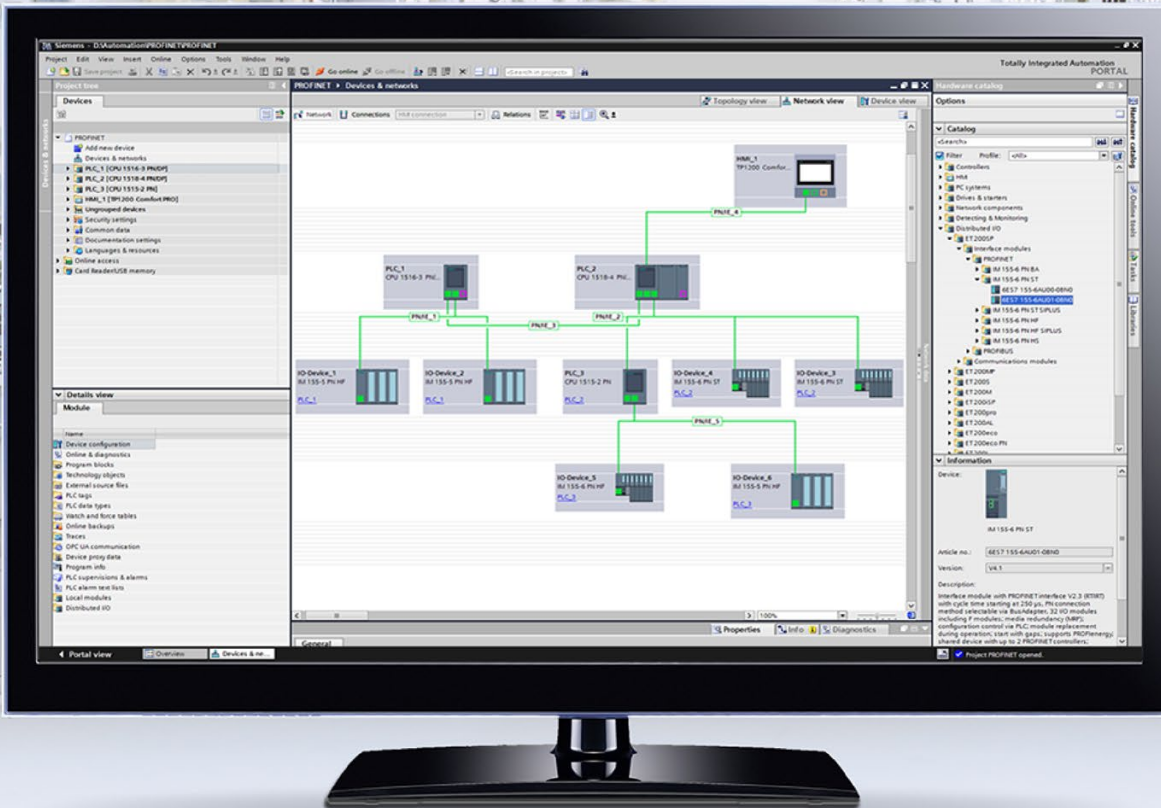
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Function manual

SIMATIC

S7-1500, ET 200MP, ET 200SP, ET 200AL, ET 200pro

Communication

Edition

11/2019

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SIMATIC

S7-1500, ET 200MP, ET 200SP, ET 200AL, ET 200pro Communication




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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This function manual provides you with an overview of the communication options, the CPUs, communication modules and processors and PC systems of the systems SIMATIC S7-1500, ET 200MP, ET 200SP, ET 200AL, ET 200pro and SIMATIC Drive Controller. This function manual describes the connection-oriented, asynchronous communication.

The documentation covers the following:

- Overview of the communication services
- Properties of the communication services
- Overview of the user activities for setting up the communication services

Basic knowledge required

The following knowledge is required in order to understand the Function manual:

- General knowledge of automation technology
- Knowledge of the industrial automation system SIMATIC
- Knowledge about how to use STEP 7 (TIA Portal)

Scope of the documentation

This documentation is the basic documentation for all products of the SIMATIC S7-1500, ET 200MP, ET 200SP, ET 200AL and ET 200pro systems. The product documentation is based on this documentation.

What's new in the Communication Function Manual, Edition 11/2019 as compared to Edition 10/2018?

What's new?	What are the customer benefits?	Where can I find the information?
IP forwarding	Simple access from the control level to the field level for configuration and parameter assignment of devices, e.g. via PDM or Web browser.	IP forwarding (Page 294)
OPC UA server expansion	<p>For S7-1500 CPUs as of firmware V2.8 and TIA Portal version 16, with a corresponding Runtime license, you can benefit from the following expansions of the integrated OPC UA server:</p> <ul style="list-style-type: none"> • Improved diagnostics: The OPC UA user receives information on the status of the OPC UA server via messages in the diagnostic buffer, an OPC UA category in the Online & Diagnostics area of TIA Portal as well as an improved connection resources display. • Download behavior: In RUN mode, the OPC UA server only performs a restart during download from the TIA Portal when the newly downloaded data has an effect on the data management of the OPC UA server. • Server interface modeling: It is now possible in the TIA Portal to model server interfaces or import OPC UA Companion Specifications and map them to the PLC data management. 	Section OPC UA communication (Page 126)

What's new in the Communication Function Manual, Edition 10/2018 as compared to Edition 12/2017?

What's new?	What are the customer benefits?	Where can I find information?
Description of communication with the redundant system S7-1500R/H	You receive information on the particularities of communication with the redundant system S7-1500R/H	Section Communication with the redundant system S7-1500R/H (Page 324)
Scope of the function manual expanded to include the redundant system S7-1500R/H	Functions with which you are familiar from the SIMATIC S7-1500 automation system are implemented for the redundant system S7-1500R/H.	Redundant System S7-1500R/H System Manual (https://support.industry.siemens.com/cs/ww/en/view/109754833)

What's new in the Communication Function Manual, Edition 12/2017 compared to Edition 09/2016

What's new?	What are the customer benefits?	Where can I find the information?
OPC UA Companion Specification	Through OPC UA Companion Specification, methods can be specified in a uniform and manufacturer-neutral way. Using these specified methods, you can easily integrate devices from various manufacturers into the plant and the production processes.	Section OPC UA server interface configuration (Page 199)
Setting up a secure connection to a mail server over the CPU interface	You can set up a secure connection to a mail server without additional hardware.	Section Secure OUC via e-mail (Page 107)
Secure communication over Modbus TCP	You can establish secure TCP connections between a Modbus TCP client and a Modbus TCP server.	Section Secure OUC with Modbus TCP (Page 106)

What's new in the Communication Function Manual, Edition 09/2016 compared to Edition 12/2014

What's new?	What are the customer benefits?	Where can I find the information?
OPC UA server	<p>OPC UA is a uniform standard for data communication and is independent of any particular operating system platforms.</p> <p>OPC UA uses integrated safety mechanisms on various automation systems, for example with data exchange, at application level, for the legitimization of the user.</p> <p>The OPC UA server provides a large amount of data:</p> <ul style="list-style-type: none"> • Values of PLC tags that clients can access • Data types of these PLC tags • Information about the OPC UA server itself and the CPU <p>In this way, clients can gain an overview of the tag management and can read and write values.</p>	Section OPC UA communication (Page 126)
Secure Open User Communication	Secure data exchange with other devices.	Section Secure Open User Communication (Page 92)
Certificate handling in STEP 7	<p>You can manage certificates for the following applications in STEP 7:</p> <ul style="list-style-type: none"> • OPC UA server • Secure Open User Communication • Web server of the CPU 	Section Managing certificates with STEP 7 (Page 43)
Deactivating SNMP for the CPU	You can deactivate SNMP for the CPU. This can make sense under certain conditions, for example if the security guidelines in your network do not permit SNMP.	Section Disabling SNMP (Page 57)

Conventions

STEP 7: We refer to "STEP 7" in this documentation as a synonym for the configuration and programming software "STEP 7 as of V12 (TIA Portal)".

"S7-1500 CPUs" also refers to the CPU variants S7 1500F, S7 1500T, S7 1500TF, S7 1500C, S7-1500R/H, S7 1500pro, ET200S, S7 1500 Software Controller as well as SIMATIC Drive Controller.

This documentation contains pictures of the devices described. The figures may differ slightly from the device supplied.

You should also pay particular attention to notes such as the one shown below:

Note

A note contains important information on the product, on handling of the product and on the section of the documentation to which you should pay particular attention.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions constitute one element of such a concept.

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For additional information on industrial security measures that may be implemented, please visit (<https://www.siemens.com/industrialsecurity>).

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customers' exposure to cyber threats.

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- **Application examples**

Tools and examples to solve your automation tasks – as well as function blocks, performance information and videos.

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- **Forums**

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This information is provided by the Siemens Industry Online Support in the Internet (<http://www.siemens.com/automation/service&support>).

Industry Mall

The Industry Mall is the catalog and order system of Siemens AG for automation and drive solutions on the basis of Totally Integrated Automation (TIA) and Totally Integrated Power (TIP).

You can find catalogs for all automation and drive products on the Internet (<https://mall.industry.siemens.com>).

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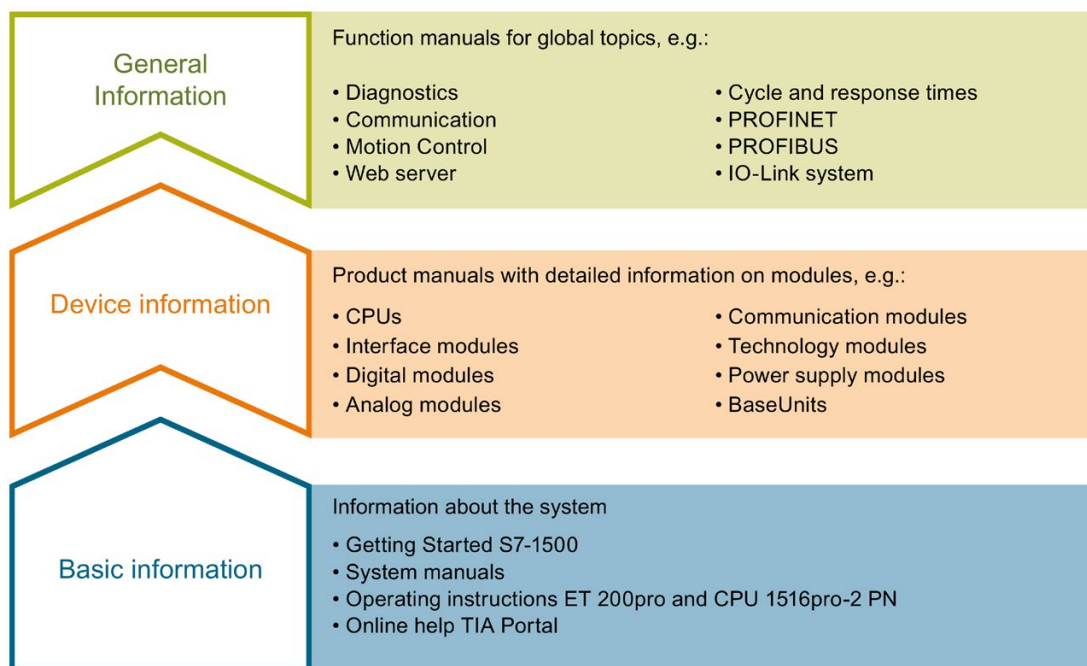
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Function manuals Documentation Guide

The documentation for the SIMATIC S7-1500 automation system, for CPU 1516pro-2 PN based on SIMATIC S7-1500, and for the distributed I/O systems SIMATIC ET 200MP, ET 200SP and ET 200AL is divided into three areas.

This division allows you easier access to the specific information you require.



Basic information

System manuals and Getting Started manuals describe in detail the configuration, installation, wiring and commissioning of the SIMATIC S7-1500, ET 200MP, ET 200SP and ET 200AL systems; use the corresponding operating instructions for CPU 1516pro-2 PN. The STEP 7 online help supports you in configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics such as diagnostics, communication, Motion Control, Web server, OPC UA.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742705>).

Changes and additions to the manuals are documented in product information sheets.

You will find the product information on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/us/en/view/68052815>)
- ET 200SP (<https://support.industry.siemens.com/cs/us/en/view/73021864>)
- ET 200AL (<https://support.industry.siemens.com/cs/us/en/view/99494757>)

Manual Collections

The Manual Collections contain the complete documentation of the systems put together in one file.

You will find the Manual Collections on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/ww/en/view/86140384>)
- ET 200SP (<https://support.industry.siemens.com/cs/ww/en/view/84133942>)
- ET 200AL (<https://support.industry.siemens.com/cs/ww/en/view/95242965>)

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You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

Product overview

CPUs, communications modules and processors, and PC systems of the S7-1500, ET 200MPET 200SPET 200pro and ET 200AL systems provide you with interfaces for communication via PROFINET, PROFIBUS and point-to-point connections.

CPUs, communications modules and communications processors

PROFINET and PROFIBUS DP interfaces are integrated in the S7-1500 CPUs. The CPU 1516-3 PN/DP for example has two PROFINET interfaces and one PROFIBUS DP interface. Other PROFINET and PROFIBUS DP interfaces are available by using communications modules (CM) and communications processors (CP).

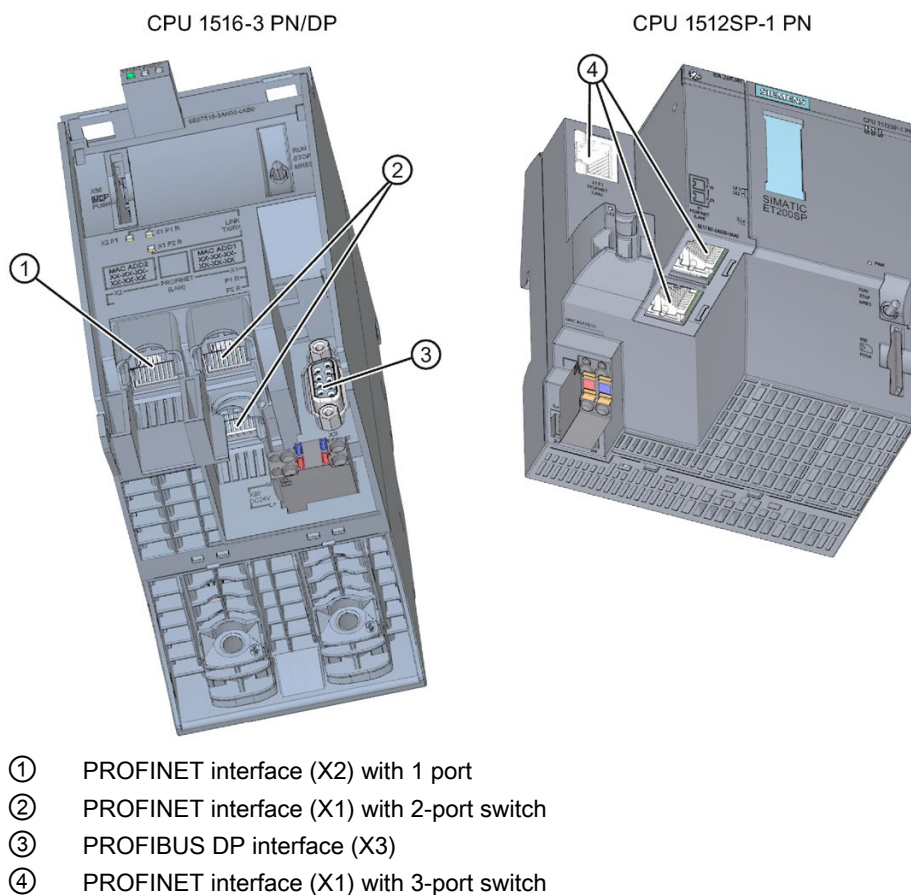


Figure 2-1 Interfaces of the CPU 1516-3 PN/DP and CPU 1512SP-1 PN

Interfaces of communications modules

Interfaces of communications modules (CMs) extend the interfaces of CPUs (for example, the communication module CM 1542-5 adds a PROFIBUS interface to S7-1500 automation system).

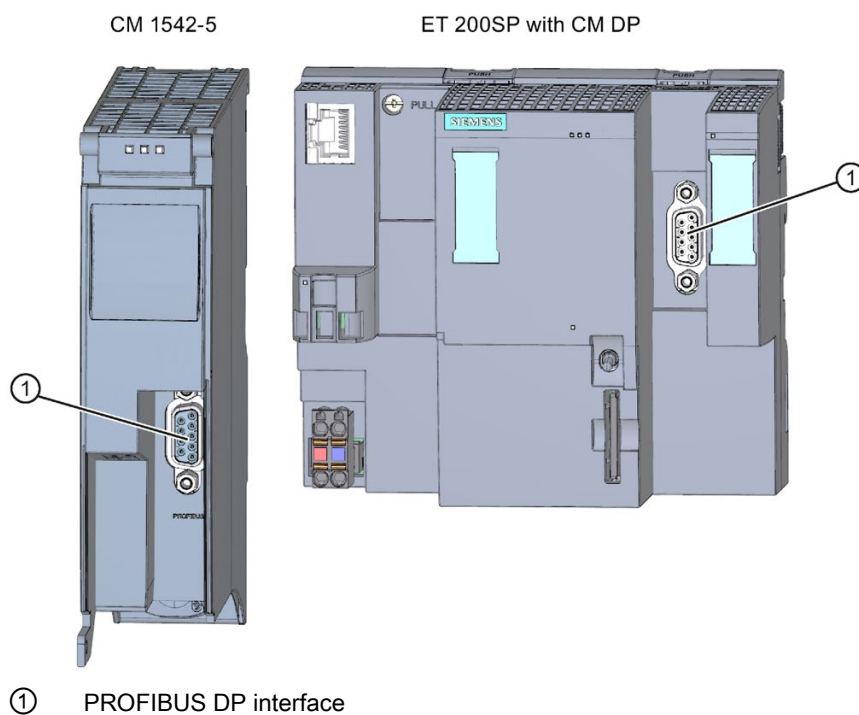
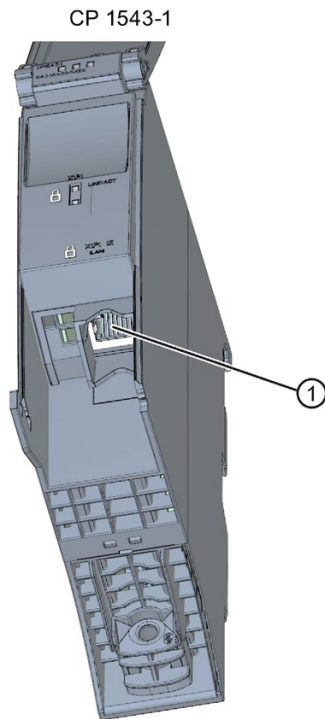


Figure 2-2 PROFIBUS DP interface of the CM 1542-5 and CM DP (to an ET 200SP CPU)

Interfaces of communications processors

Interfaces of communication processors (CP) offer additional functionality to what is provided by the integrated interfaces of the CPUs. CPs allow special applications, for example the CP 1543-1 provides Industrial Ethernet security functions for protecting Industrial Ethernet networks via its Industrial Ethernet interface.



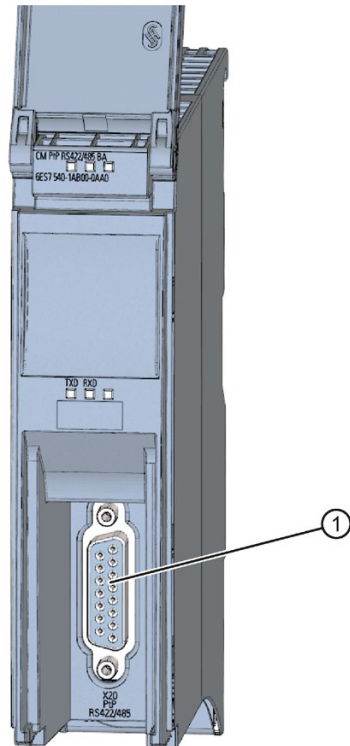
① Industrial Ethernet interface

Figure 2-3 Industrial Ethernet interface of the CP 1543-1

Interfaces of communications modules for point-to-point connections

The communication modules for point-to-point connections provide communication via their RS 232-, RS 422- and RS 485 interfaces, for example, Freepoint or Modbus communication.

CM PtP RS422/485 BA

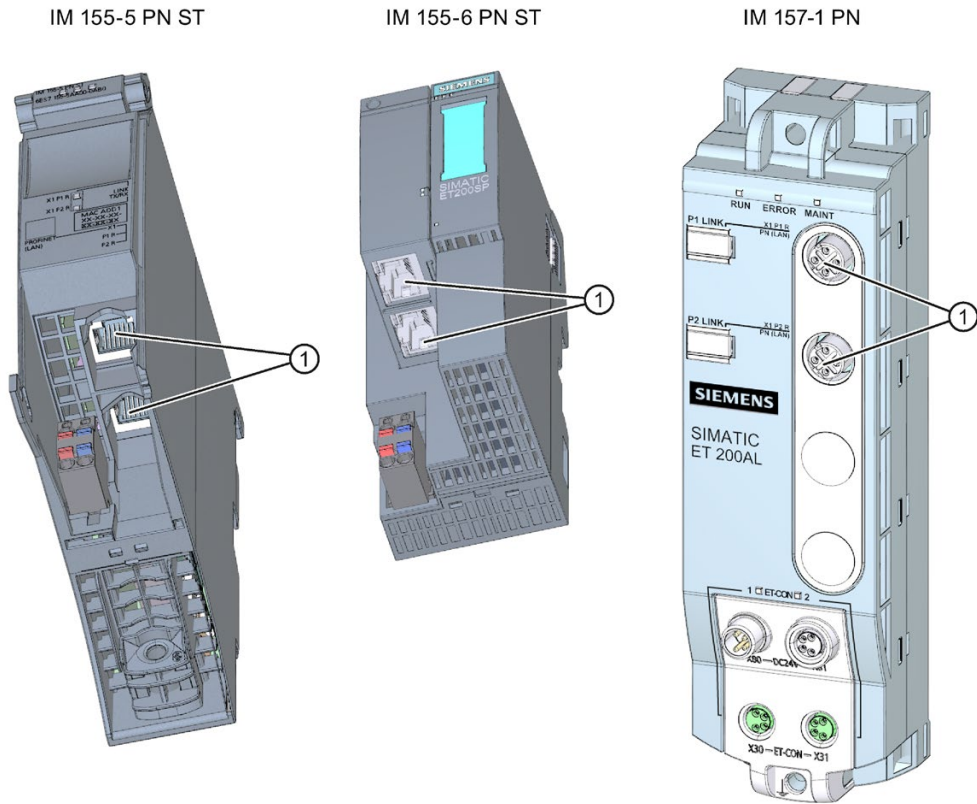


- ① Interface for point-to-point connections

Figure 2-4 Example of interface for point-to-point connection at the CM PtP RS422/485 BA

Interfaces of interface modules

PROFINET and PROFIBUS DP interfaces of the interface modules (IM) in ET 200MP, ET 200SP and ET 200AL are used to connect the distributed I/O ET 200MP, ET 200SP and ET 200AL to PROFINET or PROFIBUS of the higher-level IO controller or DP master.



① PROFINET interface with 2-port switch

Figure 2-5 PROFINET interfaces IM 155-5 PN ST (ET 200MP), IM 155-6 PN ST (ET 200SP), and IM 157-1 PN (ET 200AL)

Communications services

The communications services described below use the interfaces and communication mechanisms provided by the system via CPUs, communication modules and processors.

Communications services

3.1 Overview of communication options

Overview of communications options

The following communications options are available for your automation task.

Table 3- 1 Communications options

Communications options	Functionality	Via interface:		
		PN/IE ¹	DP	serial
PG communication ²	On commissioning, testing, diagnostics	X	X	-
HMI communication ²	On operator control and monitoring	X	X	-
Open communication via TCP/IP ²	Data exchange via PROFINET/Industrial Ethernet with TCP/IP Instructions: <ul style="list-style-type: none"> • TSEND_C/TRCV_C • TSEND/TRCV • TCON • T_DISCON 	X	-	-
Open communication using ISO-on-TCP ²	Data exchange via PROFINET/Industrial Ethernet with ISO-on-TCP Instructions: <ul style="list-style-type: none"> • TSEND_C/TRCV_C • TSEND/TRCV • TCON • T_DISCON 	X	-	-
Open communication via UDP ²	Data exchange via PROFINET/Industrial Ethernet with UDP Instructions: <ul style="list-style-type: none"> • TSEND_C/TRCV_C • TUSEND/TURCV • TCON • T_DISCON 	X	-	-

3.1 Overview of communication options

Communications options	Functionality	Via interface:		
		PN/IE ¹	DP	serial
Open communication via ISO (only CPs with PROFINET/Industrial Ethernet interface)	Data exchange via PROFINET/Industrial Ethernet with the ISO protocol Instructions: <ul style="list-style-type: none"> • TSEND_C/TRCV_C • TSEND/TRCV • TCON • T_DISCON 	X	-	-
Open communication with FDL (only CM 1542-5 as of firmware V2.0)	Data exchange via PROFIBUS with the FDL protocol Instructions: <ul style="list-style-type: none"> • TSEND_C/TRCV_C • TSEND/TRCV • TUSEND/TURCV • TCON • T_DISCON 	-	X	-
OPC UA server ³	Data exchange with OPC UA clients	X	-	-
Communication via Modbus TCP	Data exchange via PROFINET with Modbus TCP protocol Instructions: <ul style="list-style-type: none"> • MB_CLIENT • MB_SERVER 	X	-	-
E-mail	Sending process alarms via e-mail Instruction: <ul style="list-style-type: none"> • TMAIL_C 	X	-	-
FTP (only CPs with PROFINET/Industrial Ethernet interface)	File management and file access via FTP (File Transfer Protocol); CP can be FTP client and FTP server Instruction: <ul style="list-style-type: none"> • FTP_CMD 	X	-	-
Fetch/Write (only CPs with PROFINET/Industrial Ethernet interface)	Server services via TCP/IP, ISO-on-TCP and ISO Via special instructions for Fetch/Write	X	-	-
S7 communication	Data exchange via PROFINET/PROFIBUS with the S7 protocol. Instructions: <ul style="list-style-type: none"> • PUT/GET • BSEND/BRCV • USEND/URCV 	X	X	-
Serial point-to-point connection	Data exchange via point-to-point with Freeport, 3964(R), USS or Modbus protocol Via special instructions for PtP, USS or Modbus RTU	-	-	X

Communications options	Functionality	Via interface:		
		PN/IE ¹	DP	serial
Web server	Data exchange via HTTP(S), for example for diagnostics	X	-	-
SNMP (Simple Network Management Protocol)	For monitoring and error recognition of IP networks, possibly parameterization of the IP network components via standard SNMP protocol	X	-	-
Time-of-day synchronization	Via PN/IE interface: CPU is NTP client (Network Time Protocol)	X	-	-
	Via DP interface: CPU/CM/CP is time-of-day master or time slave	-	X	-

¹ IE - Industrial Ethernet

² Observe the special characteristics for S7-1500R/H

³ Only via internal PROFINET interface of the CPU and via Ethernet interface CP 1543 1 with activated "Access to PLC via communication module" function.

Information on S7-1500R/H

You can find information on the communication possibilities with the redundant system S7-1500R/H in the section Communication with the redundant system S7-1500R/H (Page 324).

Additional information

- Application example: CPU-CPU communication with SIMATIC controllers (compendium) You can find the application example on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/20982954>).
- This FAQ (<https://support.industry.siemens.com/cs/ww/en/view/102420020>) describes how to configure fetch/write communication via CP1543-1 with S7-1500.
- Additional information about the Fetch/Write services is available in the STEP 7 online help.
- You can find additional information on the PtP link in the function manual CM PtP - Configurations for Point-to-Point Connections (<http://support.automation.siemens.com/WW/view/en/59057093>).
- You will find the description of the web server functionality in the function manual Web server (<http://support.automation.siemens.com/WW/view/en/59193560>).
- You will find information about the standard protocol SNMP on the Service & Support pages on the Internet (<http://support.automation.siemens.com/WW/view/en/15166742>).
- You will find information about time-of-day synchronization in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/86535497>).

3.2 Communications protocols and port numbers used for Ethernet communication

This section provides an overview of the supported protocols and port numbers used for communication over PN/IE interfaces. For each protocol the address parameters, the respective communications layer as well as the communications role and the communications direction are specified.

This information makes it possible to match the security measures for protection of the automation system to the used protocols (for example firewall). Because the security measures are limited to Ethernet or PROFINET networks, the tables do not include PROFIBUS protocols.

Note

Port numbers used

The specified port numbers are the standard port numbers used by the S7-1500 CPU. Many communication protocols and implementations enable you to use other port numbers.

The following tables show the different layers and protocols used in the S7-1500 CPUs and S7 1500 communication modules.

The following table shows the protocols supported by the S7-1500 CPUs, ET 200SP CPUs and the CPUs 1513/1516pro 2 PN. The S7-1500 software controllers also support the protocols listed in the following table for the Ethernet interfaces that are assigned to the software controller.

Table 3-2 Layers and protocols of the S7-1500 CPUs and software controllers (via PROFINET interface of the CPU)

Protocol	Port number	(2) Link layer (4) Transport layer	Function	Description
PROFINET protocols				
DCP Discovery and basic configuration protocol	Not relevant	(2) Ethertype 0x8892 (PROFINET)	Accessible devices PROFINET Discovery and configuration	DCP is used by PROFINET to discover PROFINET devices and provide basic settings.
LLDP Link Layer Discovery protocol	Not relevant	(2) Ethertype 0x88CC (LLDP)	PROFINET Link Layer Discovery protocol	LLDP is used by PROFINET to discover and manage neighbor relationships between PROFINET devices. LLDP uses the special multicast MAC address: 01-80-C2-00-00-0E
MRP Media Redundancy Protocol	Not relevant	(2) Ethertype 0x88E3 (IEC 62493-2-2010)	PROFINET medium redundancy	MRP provides control of redundant transmission paths by means of a ring topology. MRP uses standard-compliant Multicast MAC addresses.

3.2 Communications protocols and port numbers used for Ethernet communication

Protocol	Port number	(2) Link layer (4) Transport layer	Function	Description
PTCP Precision Transparent Clock Protocol	Not relevant	(2) Ethertype 0x8892 (PROFINET)	PROFINET send clock and time syn- chronization, based on IEEE 1588	PTCP provides a time delay measure- ment between RJ45 ports and thus send clock synchronization and time synchro- nization. PTCP uses standard-compliant Multicast MAC addresses.
PROFINET IO data	Not relevant	(2) Ethertype 0x8892 (PROFINET)	PROFINET Cyclic IO data transfer	The PROFINET IO frames are used to transmit IO data cyclically between PROFINET IO controller and IO devices via Ethernet.
PROFINET Context Man- ager	34964	(4) UDP	PROFINET connection less RPC	The PROFINET Context Manager pro- vides an endpoint mapper in order to establish an application relation (PROFINET AR).
Connection-oriented communications protocols				
SMTP Simple mail transfer proto- col	25	(4) TCP	Simple mail transfer proto- col	SMTP is used for sending e-mails.
SMTPS (SMTP over TLS)	465	(4) TCP	Secure SMTP	SMTP is used for sending e-mails over secure connections.
SMTP with STARTTLS	25 587	(4) TCP	Simple mail transfer proto- col with the SMTP com- mand "STARTTLS"	SMTP with STARTTLS is used for send- ing e-mails over secure connections.
HTTP Hypertext transfer proto- col	80	(4) TCP	Hypertext transfer protocol	HTTP is used for communication with the CPU-internal web server.
ISO-on-TCP (according to RFC 1006)	102	(4) TCP	ISO-on-TCP protocol	ISO-on-TCP (according to RFC 1006) is used for message-oriented data ex- change with remote CPU or software controller. S7 communication with ES, HMI, OPC server, etc.
NTP Network time protocol	123	(4) UDP	Network time protocol	NTP is used for synchronization of the CPU system time with the time of an NTP server.
SNMP Simple net- work man- agement protocol	161 162 (trap)	(4) UDP	Simple network manage- ment protocol	SNMP is used for reading and setting of network management data (SNMP managed Objects) by the SNMP Man- ager.
HTTPS Secure Hyper- text transfer protocol	443	(4) TCP	Secure Hypertext transfer protocol	HTTPS is used for communication with the CPU-internal web server via Secure Socket Layer (SSL).

3.2 Communications protocols and port numbers used for Ethernet communication

Protocol	Port number	(2) Link layer (4) Transport layer	Function	Description
Modbus TCP Modbus Transmission Control Proto- col	502	(4) TCP	Modbus/TCP protocol	Modbus/TCP is used by MB_CLIENT/MB_SERVER instructions in the user program.
OPC UA Open Platform Communica- tions Unified Archi- tecture	4840	(4) TCP	Based on the TCP/IP proto- col	Communication standard ranging from the enterprise level to the field level.
OUC ¹ Open User Communica- tion and Secure OUC	1 ... 1999 can be used to limited extent ² 2000 ... 5000 Recom- mended 5001 ... 49151 can be used to limited extent ²	(4) TCP (4) UDP	Open User Communication (TCP/UDP) Secure Open User Com- munication (TLS)	OUC instructions provide connection establishment, connection termination and data transfer based on the socket layer.
IGMPv2 Internet Group Management Protocol	Not relevant	(3) Network layer	Internet Group Management Protocol	Network protocol for the organization of multicast groups.
Reserved	49152 ... 65535	(4) TCP (4) UDP	-	Dynamic port area used for active connection end point if the application does not determine the local port number.

¹ Note: The open communication provides direct access to the UDP/TCP for the user. The user is responsible for observing the port restrictions/definitions of the IANA (Internet Assigned Numbers Authority).

² Do not use ports for OUC, which are already used by other protocols.

3.2 Communications protocols and port numbers used for Ethernet communication

The following table shows the protocols that are supported by the S7-1500 software controller via the Ethernet interfaces assigned to Windows.

Table 3- 3 Layers and protocols of the S7-1500 Software Controller (via Ethernet interface on the Windows side)

Protocol	Port number	(2) Link layer (4) Transport layer	Function	Description
PROFINET protocols				
DCP Discovery and basic configuration protocol	Not relevant	(2) Ethertype 0x8892 (PROFINET)	Accessible devices PROFINET Discovery and configuration	DCP is used by PROFINET to discover PROFINET devices and provide basic settings.
Connection-oriented communications protocols				
SMTP Simple mail transfer protocol	25	(4) TCP	Simple mail transfer protocol	SMTP is used for sending e-mails.
HTTP Hypertext transfer protocol	Adjustable ¹	(4) TCP	Hypertext transfer protocol	HTTP is used for communication with CPU-internal web server. You can change the port number to avoid conflict with other web servers on Windows. If you want to use web server access, you must activate the port in the Windows Firewall.
ISO-on-TCP (according to RFC 1006)	102	(4) TCP	ISO-on-TCP protocol	ISO-on-TCP (according to RFC 1006) for S7 communication with PG/PC or HMI.
OUC ² Open User Communication and Secure OUC	1 ... 1999 can be used to limited extent ^{3, 4} 2000 ... 5000 recommended ⁴ 5001 ... 49151 can be used to limited extent ^{3, 4}	(4) TCP (4) UDP	Open User Communication (TCP/UDP) Secure Open User Communication (TLS)	OUC instructions provide connection establishment, connection termination and data transfer based on the socket layer. If you want to use OUC, you must activate the ports in the Windows Firewall.

3.2 Communications protocols and port numbers used for Ethernet communication

Protocol	Port number	(2) Link layer (4) Transport layer	Function	Description
IGMPv2 Internet Group Management Protocol	Not relevant	(3) Network layer	Internet Group Management Protocol	Network protocol for the organization of multicast groups.
Reserved	49152 ... 65535	(4) TCP (4) UDP	-	Dynamic port range that is used for the active connection end point, if the application does not determine the local port number. If you wish to use this communication, you must activate the ports in the Windows Firewall.

- ¹ Default setting for Windows assigned interfaces: 81
- ² Note: The open user communication provides direct access to the UDP/TCP for the user. The user is responsible for observing the port restrictions/definitions of the IANA (Internet Assigned Numbers Authority).
- ³ Do not use ports for OUC, which are already used by other protocols.
- ⁴ Do not use ports for OUC, which are already used by other Windows applications.

The following table shows the protocols that are supported in addition to those listed in the tables for the S7-1500 communications modules (e.g. CP 1543-1).

Table 3- 4 Layers and protocols of S7-1500 communications modules

Protocol	Port number	(2) Link layer (4) Transport layer	Function	Description
PROFINET/Industrial Ethernet protocols				
Connection-oriented communications protocols				
FTP File transfer protocol	20 (data) 21 (control)	(4) TCP	File transfer protocol	FTP is used for the transmission of files (only in connection with CP 1543-1).
secureFTP File transfer protocol	20 (data) 21 (control)	(4) TCP	File transfer protocol	SecureFTP is used for the transmission of files by means of a TSL connection (only in connection with CP 1543-1).
DHCP Dynamic Host Configuration Protocol	68	(4) UDP	Dynamic Host Configuration Protocol	DHCP is used to retrieve the IP Address Suite from a DHCP server when starting up the IE interface.
Secure NTPv3 Network time protocol	123	(4) UDP	Network time protocol	Secure NTP is used to synchronize the CP 1543-1 internal system clock with an NTP server.
SNMP Simple network management protocol	161 162 (trap)	(4) UDP	Simple network management protocol	SNMPv3 permits the CP 1543-1 to read network management data (MIBs) from SNMPv3 agent with authentication.

Special consideration S7-1500 MFP:
Port 111: The S7-1500 MFP uses Port 111 to the NFS service for internal communication.

3.3 Overview of connection resources

Connection resources

Some communications services require connections. Connections allocate resources on the CPUs, CPs and CMs involved (for example memory areas in the CPU operating system). In most cases one resource per CPU/CP/CM is allocated for a connection. In HMI communication, up to 3 connection resources are required per HMI connection.

The connection resources available depend on the CPU being used, the CPs and CMs and must not exceed a defined high limit for the automation system.

Available connection resources in a station

The maximum number of resources of a station is determined by the CPU.

Each CPU has reserved connection resources for PG, HMI and web server communication. In addition, there are available resources for other communication services, e.g. for SNMP, e-mail connections, HMI and S7 communication as well as for open communication.

When are connection resources allocated?

The time for allocation of connection resources depends on how the connection is set up, automatic, programmed or configured (see section Setting up a connection (Page 27)).

Additional information

You will find more detailed information on the allocation of connection resources and the display of connection resources in STEP 7 in the section Connection resources (Page 307).

3.4 Setting up a connection

Automatic connection

STEP 7 sets up a connection automatically (for example PG or HMI connection) if you have connected the PG/PC interface to an interface of the CPU physically and have made the interface assignment in STEP 7 in the "Go online" dialog.

Setting up a programmed connection

You set up the programmed connection in the program editor of STEP 7 in the context of a CPU by assigning instructions for communication, for example TSEND_C.

When specifying the connection parameters (in the Inspector window, in the properties of the instruction), you are supported by the easy-to-use user interface.

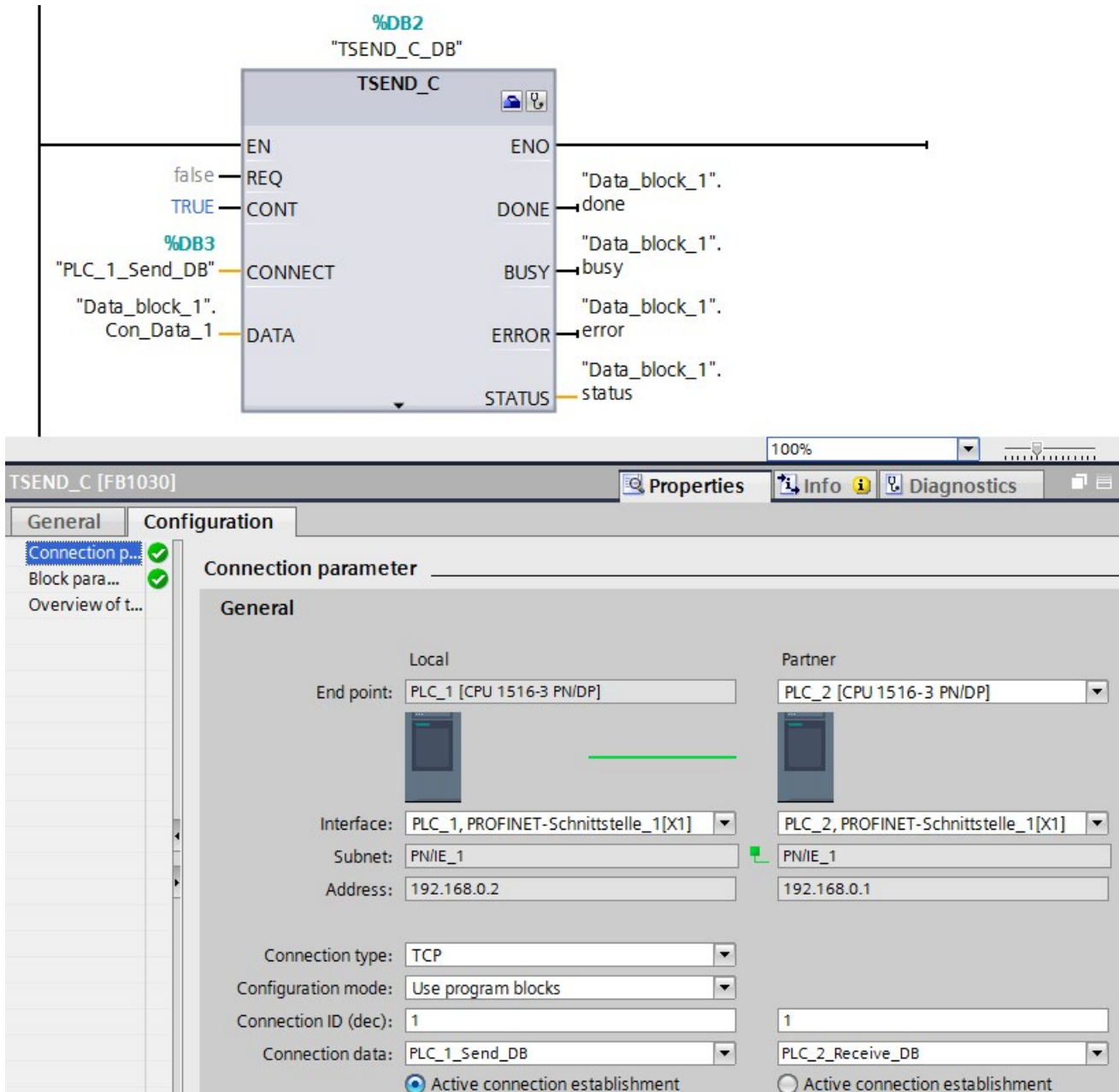


Figure 3-1 Programmed setup

Setting up a configured connection

You set up the configured connection in the network view of the Devices & networks editor of STEP 7 in the context of a CPU or a software controller.

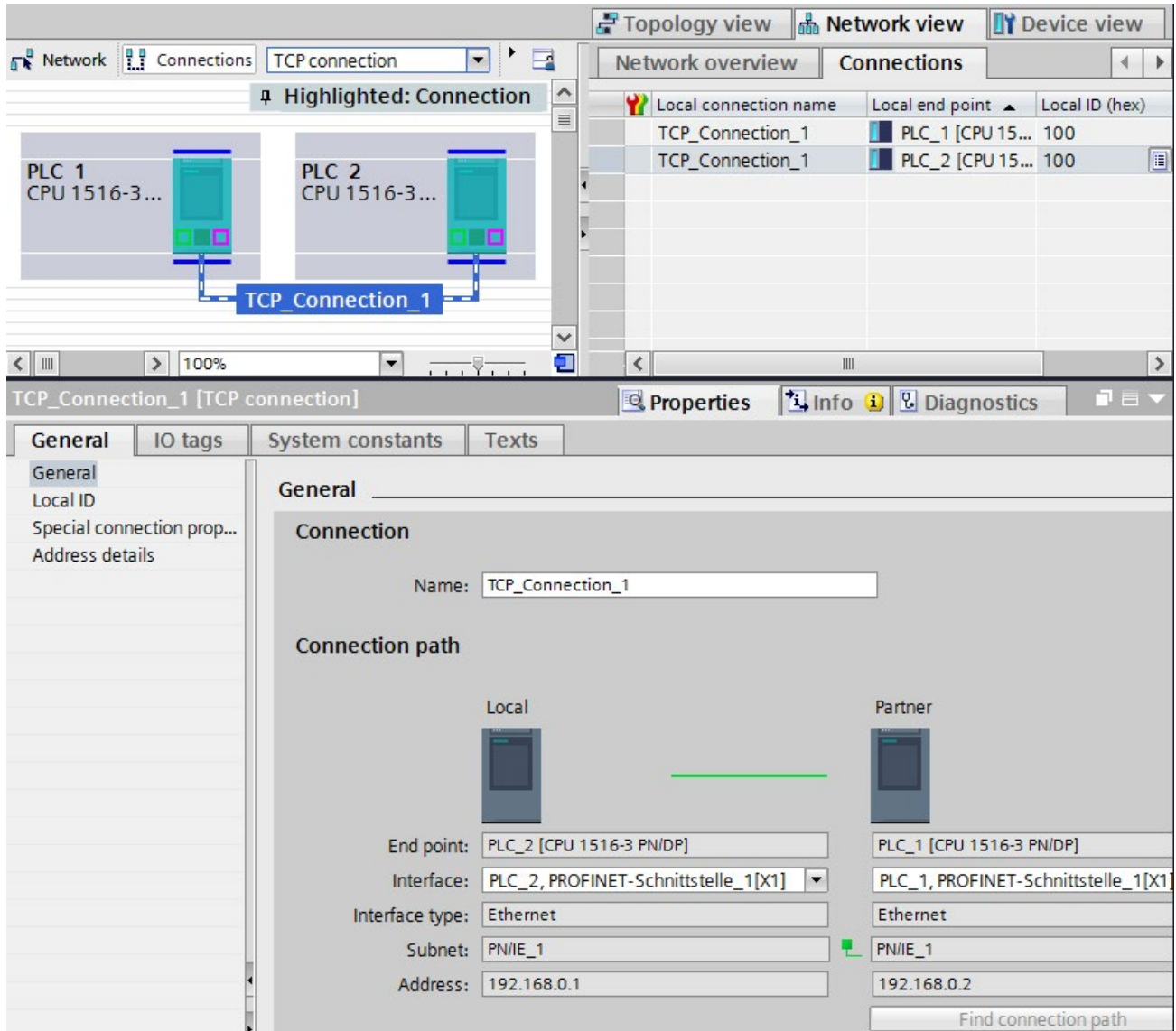


Figure 3-2 Configured setup

Effects on the connection resources of the CPU

You can often choose between a configured or a programmed connection. Programmed connection setup allows connection resources to be released following data transfer. Like routed connections, programmed connections are not guaranteed, meaning that they are only established when resources are available. With configured connection setup, the resource is available after download of the configuration until the configuration changes again. Corresponding resources are therefore reserved for connection establishment via configured connections. The "Connection resources" table in the Inspector window of the CPU displays an overview of connection resources already used and those still available.

How do I set up a connection?

Table 3- 5 Setting up the connection

Connection	Automatically	Programmed setup	Configured setup
Programming device connection	X	-	-
HMI connection	X	-	X
Web communication	X	-	-
OPC UA server communication	X	-	-
OPC UA client communication	-	X	-
Open communication via TCP/IP connection	-	X	X
Open communication via ISO-on-TCP connection	-	X	X
Open communication via UDP connection	-	X	X
Open communication via ISO connection	-	X	X
Open communication via FDL connection	-	X	X
Communication via Modbus TCP connection	-	X	-
E-mail connection	-	X	-
FTP connection	-	X	-
S7 connection*	-	-	X

* Note that for an S7-1500 CPU you must enable the use of PUT/GET communication in the properties of the CPU. You can find more information on this topic in the STEP 7 online help.

Additional information

You will find further information on the allocation of connection resources and the display of connection resources in STEP 7 in the section Connection resources (Page 307).

3.5 Data consistency

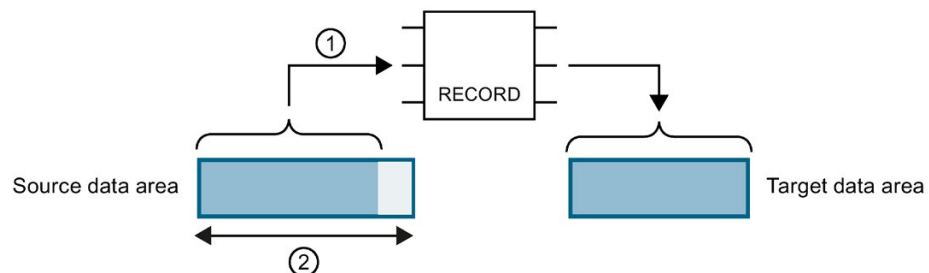
Definition

Data consistency is important for data transfer and you need to take this into account when configuring the communication task. Otherwise, malfunctions may occur.

A data area which cannot be modified by concurrent processes is called a consistent data area. This means that a data area which belongs together and which is larger than the maximum size of the consistent data area can consist in part of new and of old data at the same time.

An inconsistency can occur when an instruction for communication is interrupted, for example by a hardware interrupt OB with higher priority. This interrupts the transfer of the data area. If the user program in this OB now changes the data that has not yet been processed by the communication instruction, the transferred data originates from different times:

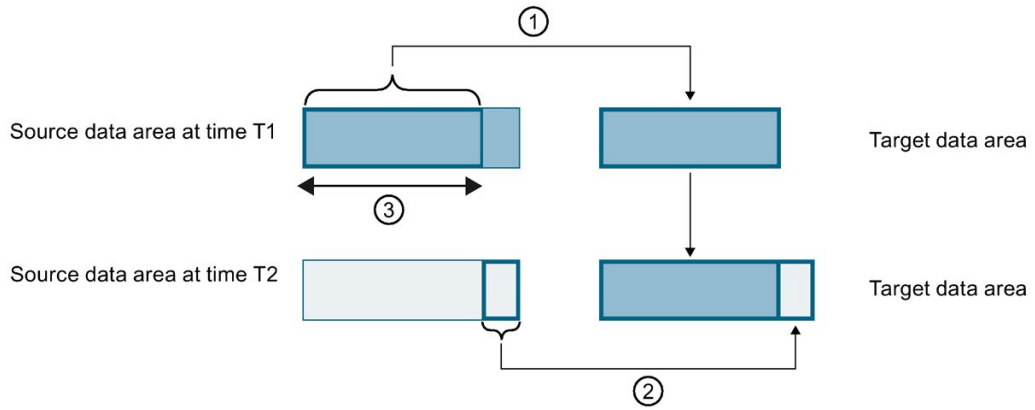
The following figure shows a data area that is smaller than the maximum size of the consistent data area. In this case, when transferring the data area, it is ensured that there is no interruption by the user program during data access so that the data is not changed.



- ① The source data area is smaller than the maximum size of the consistent data area (②). The instruction transfers the data together to the destination data area.
- ② Maximum size of the consistent data area

Figure 3-3 Consistent transfer of data

The following figure shows a data area that is larger than the maximum size of the consistent data area. In this case, the data can be changed during an interruption of the data transfer. An interruption also occurs if, for example, the data area needs to be transferred in several parts. If the data is changed during the interruption, the transferred data originates from different times.

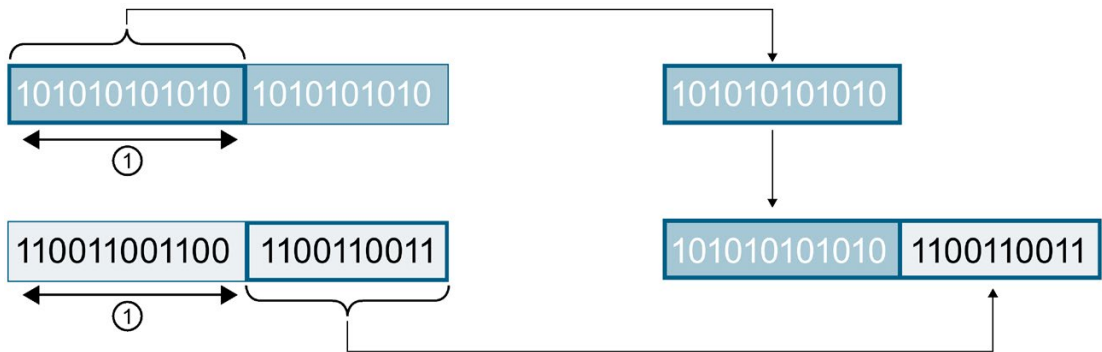


- ① The source data area is larger than the maximum size of the consistent data area (③). At time T1, the instruction only transfers as much data from the source data area into the destination data area as fits in the consistent data area.
- ② At time T2, the instruction transfers the rest of the source data area to the destination data area. After the transfer, data from different points in time exist in the destination data area. If the data in the source data area has changed in the meantime, an inconsistency may result.
- ③ Maximum size of the consistent data area

Figure 3-4 Transfer of data larger than the maximum consistency area

Example of an inconsistency

The figure below shows an example of changing data during the transfer. The destination data area contains data from different points in time.



- ① Maximum size of the consistent data area

Figure 3-5 Example: Changing data during the transfer

System-specific maximum data consistency for S7-1500:

No inconsistency occurs if the system-specific maximum size of the consistent data is kept to. With an S7-1500, communication data is copied consistently into or out of the user memory in blocks of up to 512 bytes during the program cycle. Data consistency is not ensured for larger data areas. Where defined data consistency is required, the length of communication data in the user program of the CPU must not exceed 512 bytes. You can then access these data areas consistently, for example from an HMI device by reading/writing tags.

If more data than the system-specific maximum size needs to be transferred consistently, you yourself must ensure the data consistency with suitable measures in the user program.

Ensuring data consistency**Use of instructions for access to common data:**

If the user program contains instructions for communication that access common data, for example TSEND/TRCV, you can coordinate access to this data area yourself, for example using the "DONE" parameter. The data consistency of the data areas that are transferred with an instruction for communication can therefore be ensured in the user program.

Note**Measures in the user program**

To achieve data consistency, you can copy transferred data to a separate data area (for example, global data block). While the user program continues to work with the original data, you can transfer the data saved in the separate data area consistently with the communication instruction.

For the copying, use uninterruptible instructions such as UMOVE_BLK or UFILL_BLK. These instructions ensure data consistency up to 16 KB.

Use of PUT/GET instructions or Write/Read via HMI communication:

In S7 communication with the PUT/GET instructions or Write/Read via HMI communication, you need to take into account the size of the consistent data areas during programming or configuration. In the user program of an S7-1500 as server, there is no instruction available that can coordinate the data transfer in the user program. The data exchanged using PUT/GET instructions updates the S7-1500 while the user program is running. There is no point in time within the processing of the cyclic user program at which the data is exchanged consistently. The length of the data area to be transferred should be smaller than 512 bytes.

Additional information

- You will also find the maximum amount of consistent data in the device manuals of the communications modules in the Technical Specifications.
- You will find further information on data consistency in the description of the instructions in the STEP 7 online help.

3.6 Secure Communication

3.6.1 Basics of Secure Communication

For STEP 7 (TIA Portal) as of V14 and for S7-1500 CPUs as of firmware V2.0, the options for secure communication have been broadened considerably.

Introduction

The attribute "secure" is used for the identification of communication mechanisms that are based on a Public Key Infrastructure (PKI) (for example RFC 5280 for Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List Profile). A Public Key Infrastructure (PKI) is a system that can issue, distribute and check digital certificates. The digital certificates issued are used in the PKI to secure computer-based communication. If a PKI uses asymmetric key cryptography, the messages in a network can be digitally signed and encrypted.

Components that you have configured in STEP 7 for secure communication use an asymmetric key encryption scheme with a Public Key and Private Key. TLS (Transport Layer Security) is used as the encryption protocol. TLS is the successor for the SSL (Secure Sockets Layer) protocol.

Objectives of secure communication

Secure communication is used to achieve the following objectives:

- Confidentiality
i.e. the data are secret / cannot be read by eavesdroppers.
- Integrity
i.e. the message that reaches the recipient is the same message, unchanged, that the sender sent. The message has not been altered on the way.
- End point authentication
i.e. the end point communication partner is exactly who it claims to be and the party who is to be reached. The identity of the partner has been checked.

These objectives were in the past primarily relevant to IT and networked computers. Now, industrial machinery and control systems with sensitive data are at equally high risk, as they are also networked, and consequently pose strict security requirements for data exchange.

Protection of the automation cell by means of the cell protection concept through firewall, or via connection through VPN, for example with the security module, was common in the past and remains so.

However, it is becoming increasingly necessary to also transfer data to external computers in encrypted form via Intranet or public networks.

Common principles of secure communication

Independent of the context, secure communication is based on the concept of the Public Key Infrastructure (PKI) and contains the following components:

- An asymmetric encryption scheme that allows:
 - Encryption or decryption of messages using public or private keys.
 - The verification of signatures in messages and certificates.
The messages/certificates are signed by the sender/certificate subject with their private key. The recipient/verifier checks the signature with the public key of the sender/certificate subject.
- Transport and storage of the public key using X.509 certificates:
 - X.509 certificates are digitally signed data that allow public key authentication in terms of the bound identity.
 - X.509 certificates can contain information that describes in more detail or restricts use of the public key. For example the date as of which a public key in a certificate is valid and when it expires.
 - X.509 certificates contain information about the issuer of the certificate in secure form.

The following paragraphs give an overview of these basic concepts, which are required for managing certificates in STEP 7 (TIA Portal), for example, and for programming communication instructions for secure Open User Communication (sOUC).

Secure communication with STEP 7

STEP 7 as of V14 provides the required PKI for the configuration and operation of secure communication.

Examples:

- The Hypertext Transfer Protokoll (HTTP) turns into Hypertext Transfer Protokoll Secure (HTTPS) with the help of the TLS (Transport Layer Security) protocol. Since HTTPS is a combination of HTTP and TLS, it is called "HTTP over TLS" in the corresponding RFC. You can see in the browser that HTTPS is being used; this is indicated by the URL "https://" instead of "http://" in the address bar of the browser. Most browsers highlight such secure connections.
- Open User Communication turns into secure Open User Communication. The underlying protocol is also TLS.
- E-mail providers also offer access over the "Secure SMTP over TLS" protocol to increase the security of e-mail communication.

The figure below shows the TLS protocol in the context of communication layers.

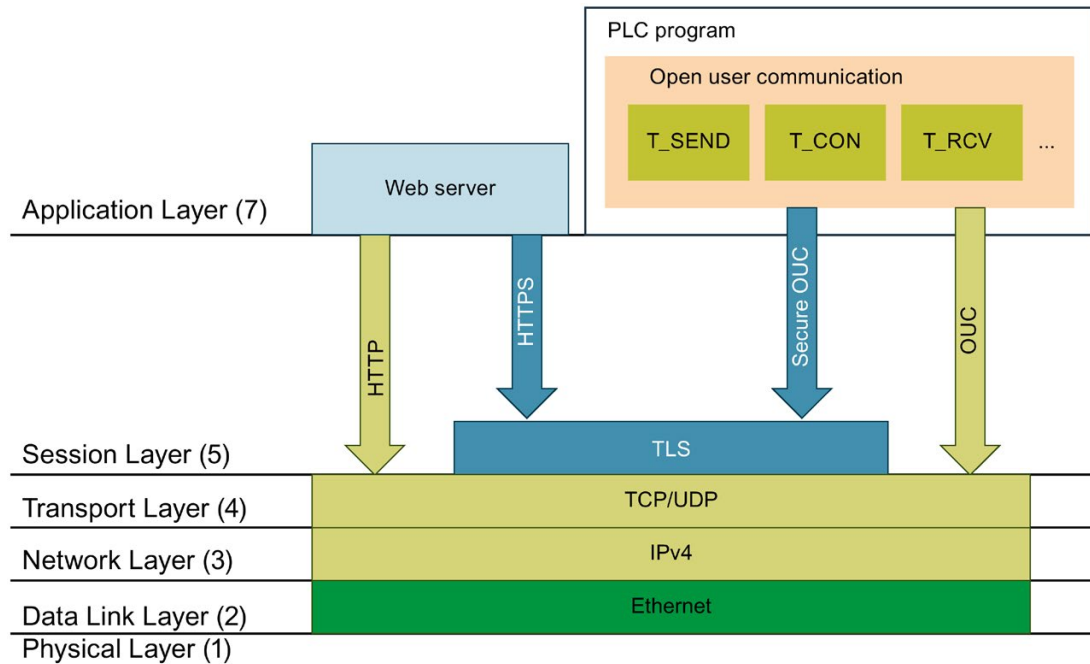


Figure 3-6 TLS protocol in the context of communication layers

Secure communication with OPC UA

An OPC UA server is implemented in S7-1500 CPUs as of firmware V2.0. OPC UA Security also covers authentication, encryption and data integrity with digital X.509 certificates and also uses a Public Key Infrastructure (PKI). Depending on the requirements placed by the application, you can select different security levels for the end point security. You will find the description of the OPC UA server functionality in the section Using the S7-1500 as an OPC UA server (Page 159).

3.6.2 Confidentiality through encryption

Message encryption is an important element of data security. When encrypted messages are intercepted by third parties during communication, these potential eavesdroppers cannot access the information they contain.

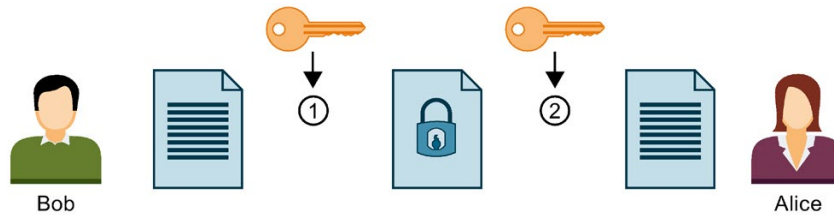
There is a wide range of mathematical processes (algorithms) for encrypting messages.

All algorithms process a "key" parameter to encrypt and decrypt messages.

- Algorithm + key + message => encrypted message
- Encrypted message + key + algorithm => (decrypted) message

Symmetric encryption

The central aspect of symmetric encryption is that both communication partners use the same key for message encryption and decryption, as shown in the figure below. Bob uses the same key for encryption as Alice uses for decryption. In general, we also say that the two sides share the secret key with which they encrypt or decrypt a message as a secret.



- ① Bob encrypts his message with the symmetric key
- ② Alice decrypts the encrypted message with the symmetric key

Figure 3-7 Symmetric encryption

The process can be compared to a briefcase to which the sender and recipient have the same key, which both locks and opens the case.

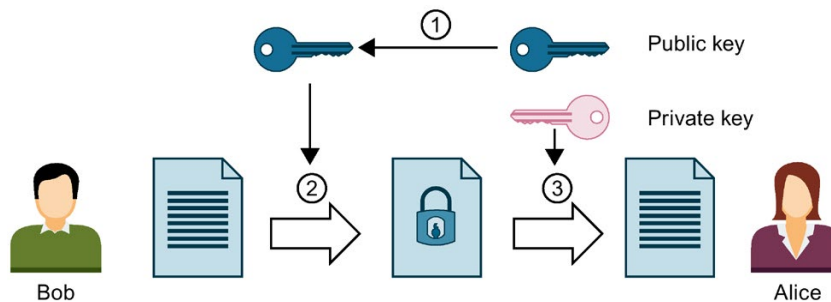
- Advantage: Symmetric encryption algorithms (such as AES, Advanced Encryption Algorithm) are fast.
- Disadvantages: How can the key be sent to a recipient without getting into the wrong hands? This is a key distribution problem. If enough messages are intercepted, the key can also be worked out and must therefore be changed regularly.

If there are a large number of communication partners, there is also a large number of keys to distribute.

Asymmetric encryption

Asymmetric encryption works with a pair of keys consisting of one public key and one private key. Used with a PKI, it is also known as Public Key cryptography or simply PKI cryptography. A communication partner, Alice in the figure below, has a private key and a public key. The public key is provided to the public, in other words any potential communication partner. Anyone with the public key can encrypt messages for Alice. In the figure below, this is Bob.

Alice's private key, which she must not disclose, is used by Alice to decrypt an encrypted message addressed to her.



- ① Alice provides Bob with her public key. No precautionary measures are required to this purpose: Anyone can use the public key for messages to Alice if they are sure that it is actually Alice's public key.
- ② Bob encrypts his message with Alice's public key.
- ③ Alice decrypts the encrypted message from Bob with her private key. As only Alice has the private key and never discloses it, only she can decrypt the message. With her private key, she can decrypt any message encrypted with her public key - not only messages from Bob.

Figure 3-8 Asymmetric encryption

The system can be compared to a mailbox into which anyone can put a message, but from which only the person with the key can remove messages.

- **Advantages:** A message encrypted with a public key can only be decrypted by the owner of the private key. As another (private) key is required for decryption, it is also much harder to work out the decryption key on the basis of large numbers of encrypted messages. This means that the public key does not have to be kept strictly confidential, unlike with symmetric keys.

Another advantage is easier distribution of public keys. No specially secured channel is required in asymmetric cryptography to transfer the public key from the recipient to the sender encrypting the messages. Less work is thus required in managing the keys than would be the case in symmetric encryption procedures.

- **Disadvantages:** Complex algorithm (e.g. RSA, named after the three mathematicians Rivest, Shamir and Adleman), and therefore poorer performance than with symmetric encryption.

Encryption processes in practice

In practice, for example with a CPU Web server and Secure Open User Communication, the TLS protocol is used below the relevant application layer. Application layers are HTTP or SMTP, for example, as detailed above.

TLS (Transport Layer Security) uses a combination of asymmetric encryption and symmetric encryption (hybrid encryption) for secure data transfer, for example, over the Internet, and uses the following subprotocols:

- TLS Handshake Protocol, responsible for authentication of communication partners and negotiation of the algorithms and keys to be used for subsequent data transfer on the basis of asymmetric encryption.
- TLS Record Protocol, responsible for encryption of user data with symmetric encryption and data exchange.

Both asymmetric and symmetric encryption are considered secure encryption schemes - there is basically no difference in security between the two procedures. The degree of security depends on parameters such as the selected key length.

Abuse of encryption

You cannot tell what identity is assigned to a public key from the bit string. A fraud could provide their public key and claim to be someone else. If a third party then uses this key thinking that they are addressing their required communication partner, confidential information could end up with the fraud. The fraud then uses their private key to decrypt the message that was not intended for them, and sensitive information falls into the wrong hands.

To prevent this type of abuse, the communication partners must be confident that they are dealing with the right communication partner. This trust is established by using digital certificates in a PKI.

3.6.3 Authenticity and integrity through signatures

Attacks from programs that intercept communication between the server and client and act as if they themselves were client or server, are called man-in-the-middle attacks. If the false identity of these programs is not detected, they can obtain important information about the S7 program, for example, or set values in the CPU and attack a machine or plants. Digital certificates are used to avoid such attacks.

Secure communication uses digital certificates that meet the X.509 standard of the International Telecommunication Union (ITU). This allows the identity of a program, a computer or an organization to be checked (authenticated).

How certificates establish trust

The main role of X.509 certificates is to bind an identity with the data of a certificate subject (for example, e-mail address or computer name) to the public key of the identity. Identities can be people, computers or machines.

Certificates are issued by certificate authorities (Certificate Authority, CA) or by the subject of a certificate itself. PKI systems specify how users can trust the certificate authorities and the certificates that they issue.

The certificate process:

1. Anyone wishing to own a certificate submits a certificate application to a registration authority linked to the certificate authority.
2. The certificate authority assesses the application and applicant on the basis of set criteria.
3. If the identity of the applicant can be clearly established, the certificate authority confirms that identity by issuing a signed certificate. The applicant has now become the certificate subject.

The figure below is a simplified overview of the process. It does not show how Alice can check the digital signature.

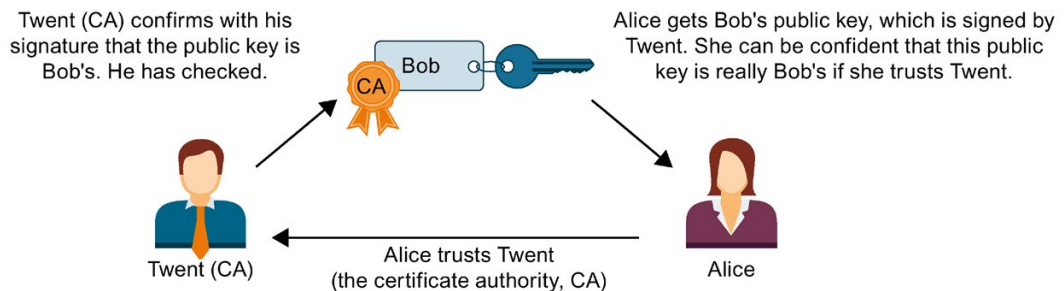


Figure 3-9 Signing of a certificate by a certificate authority

Self-signed certificates

Self-signed certificates are certificates whose signature comes from the certificate subject and not from an independent certificate authority.

Examples:

- You can create and sign a certificate yourself, for example, to encrypt messages to a communication partner. In the example above, Bob (instead of Twent) could himself sign his certificate with his private key. Using Bob's public key, Alice can check that the signature and public key from Bob match. This procedure is sufficient for simple internal plant communication that is to be encrypted.
- A root certificate is, for example, a self-signed certificate, signed by the certificate authority (CA), that contains the public key of the certificate authority.

Features of self-signed certificates

The "CN" (Common Name of Subject) for the certificate subject and "Issuer" attributes of self-signed certificates are identical: You have signed your certificate yourself. The field "CA" (Certificate Authority) must be set to "False"; the self-signed certificate should not be used to sign other certificates.

Self-signed certificates are not embedded in a PKI hierarchy.

Certificate content

A certificate to the X.509 V3 standard, the standard that is also used by STEP 7 and the S7-1500 CPUs, consists primarily of the following elements:

- Public key
- Details of the certificate subject (i.e. the holder of the key), for example, the Common Name (CN) of Subject .
- Attributes such as serial number and validity period
- Digital signature from the certificate authority (CA) confirming that the information is correct.

There are also extensions, for example:

- Specification of what the public key may be used for (Key Usage), for example, signing or key encryption.
When you create a new certificate with STEP 7, for example in the context of Secure Open User Communication, select the correct entry from the list of possible usages, e.g. "TLS".
- Specification of a Subject Alternative Name (SAN), which is used in secure communication with Web servers (HTTP over TLS), for example, to ensure that the certificate in the address bar of the Web browser also belongs to the Web server specified in the URL.

How signatures are generated and verified

Asymmetric key usage ensures that certificates can be verified: The example of the "MyCert" certificate illustrates the "Sign" and "Verify signature" processes.

Generating a signature:

1. The issuer of the "MyCert" certificate generates a hash value from the certificate data using a specific hash function (for example SHA-1, Secure Hash Algorithm).
The hash value is a bit string of a constant length. The advantage of the constant length of the hash value is that it always takes the same amount of time to sign.
2. Using the hash value generated in this way and the private key, the issuer of the certificate then generates a digital signature. The RSA signature scheme is often used.
3. The digital signature is saved in the certificate. The certificate is now signed.

Verifying a signature:

1. The authenticator of the "MyCert" certificate obtains the certificate of the issuer and thus the public key.
2. A new hash value is formed from the certificate data with the same hash algorithm that was used for signing (for example SHA-1).
3. This hash value is then compared with the hash value that is determined by means of the public key of the certificate issuer and the signature algorithm for checking the signature.
4. If the signature check produces a positive result, both the identity of the certificate subject as well as the integrity, meaning authenticity and genuineness, of the certificate content are proven. Anyone who has the public key, i.e. the certificate from the certificate authority, can check the signature and thus recognize that the certificate was actually signed by the certificate authority.

The figure below shows how Alice uses the public key in the certificate from Twent (who represents the certificate authority, CA) to verify the signature on Bob's public key. All that is required for verification is therefore the availability of the certificate from the certificate authority at the moment of checking. The validation itself is executed automatically in the TLS session.

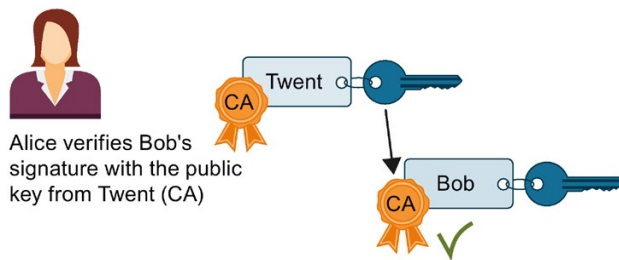


Figure 3-10 Verification of a certificate with the public key of the certificate of a certificate authority

Signing messages

The method described above for signing and verifying also uses the TLS session for signing and verifying messages.

If a hash value is generated by a message and this hash value is signed with the private key of the sender and attached to the original message, the recipient of the message is able to check the integrity of the message. The recipient decrypts the hash value with the public key of the sender, puts together the hash value from the message received and compares the two values. If the values are not the same, the message has been tampered with on the way.

Chain of certificates to root certificate

The certificates of a PKI are often organized hierarchically: The top of the hierarchy is formed by root certificates. Root certificates are certificates that are not signed by a higher-level certificate authority. The certificate subject and certificate issuer of root certificates are identical. Root certificates enjoy absolute trust. They form the "anchor" of trust and must therefore be known to the receiver as trusted certificates. They are stored in an area provided for trusted certificates.

Depending on the PKI, the function of root certificates is, for example, to sign certificates from lower-level certificate authorities, so-called intermediate certificates. This transfers the trust from the root certificate to the intermediate certificate. An intermediate certificate can sign a certificate just like a root certificate; both are therefore referred to as "CA certificates".

This hierarchy can be continued over multiple intermediate certificates until the end-entity certificate. The end-entity certificate is the certificate of the user who is to be identified.

The validation process runs through the hierarchy in the opposite direction: As described above, the certificate issuer is established and the signature checked with the issuer's public key, then the certificate of the higher-level certificate issuer is established along the entire chain of trust to the root certificate.

Conclusion: The chain of intermediate certificates to the root certificate, the certificate path, must be available in every device that is to validate an end-entity certificate of the communication partner, irrespective of the type of secure communication that you configure.

3.6.4 Managing certificates with STEP 7

STEP 7 as of version V14 together with the S7-1500-CPU as of firmware version 2.0 support the Internet PKI (RFC 5280) in as far as an S7-1500-CPU is able to communicate with devices that also support the Internet PKI.

The usage of X.509 certificates for verifying certificates as described in the preceding sections, for example, is a result of this.

STEP 7 as of V14 uses a PKI similar to Internet PKI. Certificate Revocation Lists (CRLs), for example, are not supported.

Creating or assigning certificates

You create certificates for various applications in STEP 7 for devices with security properties, such as an S7-1500 CPU as of firmware V2.0.

The following areas in the Inspector window of the CPU allow the creation of new certificates or the selection of existing ones:

- "Protection & Security > Certificate manager" - for the generation and assignment of all types of certificates. TLS certificates for Secure Open User Communication are preset for the generation of certificates.
- "Web server > Security" - for the generation and assignment of Web server certificates.
- "OPC UA > Server > Security" - for the generation and assignment OPC UA certificates.

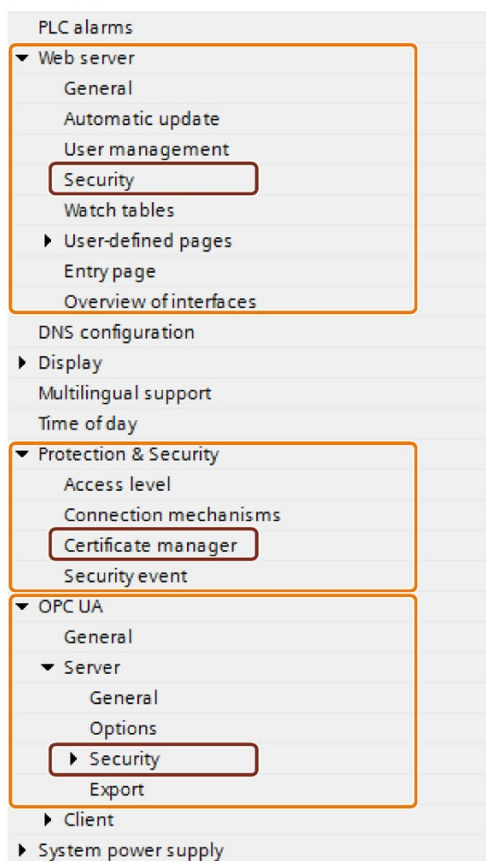


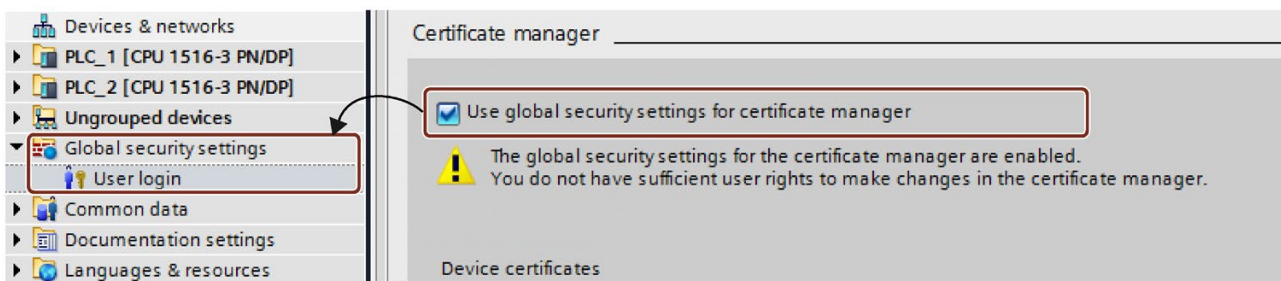
Figure 3-11 Security settings for an S7-1500 CPU in STEP 7

Special features of the section "Protection & Security > Certificate manager"

Only in this section of the Inspector window do you switch between the global, i.e. project-wide, and the local, i.e. device-specific, certificate manager (option "Use global security settings for the certificate manager"). The option decides whether you have access to all the certificates in the project or not.

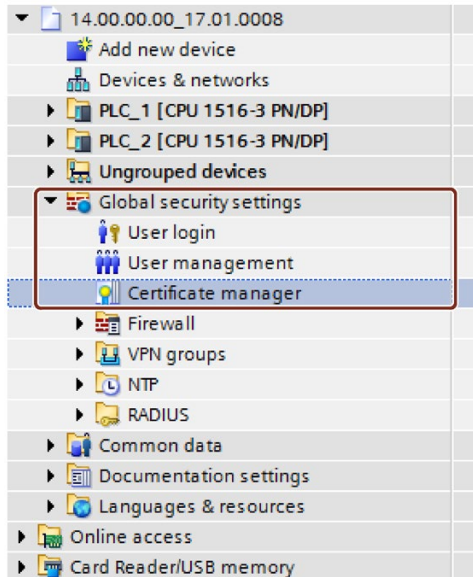
- If you do **not** use the certificate manager in the global security settings, you only have access to the local certificate memory of the CPU. You do not have access, for example, to imported certificates or root certificates. Without these certificates only a restricted functionality is available. You can, for example, only generate self-signed certificates.
- If you use the certificate manager in the global security settings and you are logged on as an administrator, you have access to the global, project-wide certificate memory. You can, for example, assign imported certificates to the CPU, or create certificates that are issued and signed by the project CA (certificate authority of the project).

The figure below shows how the "Global security settings" are shown in the project tree after the "Use global security settings for certificate manager" option has been activated in the Inspector window of the CPU.



When you double-click "User login" in the project tree below the global security settings and log in, a line called "Certificate manager" is displayed, among other data.

When you double-click the "Certificate manager" line, you obtain access to all the certificates in the project, divided into the tabs "CA" (certificate authorities), "Device certificates" and "Trusted certificates and root certificate authorities".



Private keys

STEP 7 generates private keys while generating device certificates and server certificates (end-entity certificates). The location where the private key is stored encrypted depends on the use of the global security settings for the certificate manager:

- If you use global security settings, the private key is stored encrypted in the global (project-wide) certificate memory.
- If you do not use global security settings, the private key is stored encrypted in the local (CPU-specific) certificate memory.

The existence of the private key, which is required to decrypt data, for example, is displayed in the "Private key" column of the "Device certificates" tab of the certificate manager in the global security settings.

When the hardware configuration is loaded, the device certificate, the public key as well as the private key are loaded into the CPU.

NOTICE
The "Use global security settings for certificate manager" option influences the previously used private key: If you have already created certificates without using the certificate manager in the global security settings and then change the option for using the certificate manager, the private keys are lost and the certificate ID can change. A warning draws your attention to this fact. Therefore specify at the beginning of the project configuration which option is required for the certificate manager.

3.6.5 Examples for the management of certificates.

As explained in the preceding sections, certificates are required for every type of secure communication. The following section shows as an example how you handle the certificates with STEP 7 so that the requirements for Secure Open User Communication are fulfilled.

The devices which are involved at the respective communication partners are differentiated below. The respective steps for supplying the required certificates to the communications participants are described. An S7-1500 CPU or an S7-1500 software controller as of firmware version 2.0 is always required.

The general rule is:

While a secure connection is being established (handshake"), the communication partners as a rule only communicate their end-entity certificates (device certificates).

Therefore the CA certificates required to verify the transmitted device certificate must be located in the certificate memory of the respective communication partner.

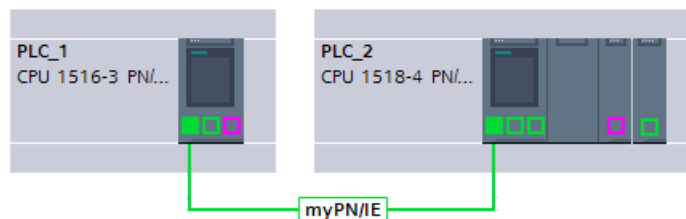
Secure Open User Communication between two S7-1500 CPUs

Two S7-1500-CPU's, PLC_1 and PLC_2, are to exchange data with each other via Secure Open User Communication.

You generate the required device certificates with STEP 7 and assign them to the CPUs as described below.

STEP 7 project certificate authorities (CA of the project) are used to sign the device certificates.

The certificates are to be referenced by their certificate ID in the user program (TCON communication instruction in combination with the associated system data type, for example TCON_IPV4_SEC). STEP 7 assigns the certificate ID automatically during the generation or creation of certificates.



Procedure

STEP 7 automatically loads the required CA certificates together with the hardware configuration to the participating CPUs so that the requirements for certificate verification exist for both CPUs. You therefore only have to generate the device certificates for the respective CPU; STEP 7 does the rest for you.

1. Mark PLC_1 and activate the "Use global security settings for certificate manager" option in the "Protection & Security" section.
2. Log in as a user in the project tree in the "Global security settings" section. For a new project, the "Administrator" role is planned for the first login.
3. Return to the PLC-1 in the "Protection & Security" section. Click in an empty line in the "Certificate subject" column in the "Device certificates" table to add a new certificate.
4. In the drop-down list for selecting a certificate click the "Add" button.

The "Create Certificate" dialog opens.

5. Leave the default settings in this dialog. They are tailored to the usage of Secure Open User Communication (usage: TLS).

Tip: Supplement the default name of the certificate subject, in this case the CPU name. In order to differentiate you better leave the default CPU name in case you have to manage a large number of device certificates.

Example: PLC_1/TLS becomes PLC_1-SecOUC-Chassis17FactoryState.

6. Compile the configuration.

The device certificate and the CA certificate are part of the configuration.

7. Repeat the steps described above for PLC_2.

In the next step you have to create the user programs for the data exchange and load the configurations together with the program.

Using self-signed certificates instead of CA certificates

When creating device certificates you can select the "Self-signed" option. You can create self-signed certificates without being logged in for the global security settings. This procedure is not recommended because the resulting certificates do not exist in the global certificate memory and can therefore not be assigned directly to a partner CPU.

As described above, you should select the name of the certificate subject with care so that the right certificate can be assigned to a device without any doubt.

Verification with the CA certificates of the STEP 7 project is not possible for self-signed certificates. To ensure that self-signed certificates can be verified you have to include the self-signed certificates of the communication partner into the list of trusted partner devices for each CPU. To this purpose you must have activated the "Use global security settings for certificate manager" option and be logged in as a user in the global security settings.

Proceed as follows to add the self-signed certificate of the communication partner of the CPU:

1. Mark PLC_1 and navigate to the "Certificates of partner devices" table in the "Protection & Security" section.
2. Click in an empty line in the "Certificate subject" column in the "Device certificates" table to add a new certificate.
3. Select the self-signed certificate of the communication partner from the drop-down list and confirm the selection.

In the next step you have to create the user programs for the data exchange and load the configurations together with the program.

Secure Open User Communication between S7-1500 CPU as a TLS client and an external device as a TLS server

Two devices are to exchange data with each other via TLS connection or TLS session, for example, exchanging recipes, production data or quality data:

- An S7-1500 CPU (PLC_1) as TLS client; the CPU uses Secure Open User Communication
- An external device, for example a Manufacturing Execution System (MES), as TLS server

The S7-1500 CPU establishes the TLS connection / session to the MES system as TLS client.



- ① TLS client
- ② TLS server

The S7-1500 CPU requires the CA certificates of the MES system to authenticate the TLS server: The root certificate and, if appropriate, the intermediate certificates for verifying the certificate path.

You have to import these certificates into the global certificate memory of the S7-1500 CPU.

Proceed as follows to import certificates of the communication partner:

1. Open the certificate manager in the global security settings in the project tree.
2. Select the appropriate table (trusted certificates and root certificate authorities) for the certificate to be imported.
3. Right-click in the table to open the shortcut menu. Click "Import" and import the required certificate or the required CA certificates.

Through the import the certificate has a certificate ID assigned to it and can be assigned to a module in the next step.

4. Mark PLC_1 and navigate to the "Certificates of partner devices" table in the "Protection & Security" section.
5. Click in an empty line in the "Certificate subject" column to add the imported certificates.
6. Select the required CA certificates of the communication partner from the drop-down list and confirm the selection.

Optionally the MES system can also request a device certificate of the CPU to authenticate the CPU (i.e., the TLS client). In this case, the CA certificates of the CPU must be made available to the MES system. The prerequisite for importing the certificates into the MES system is a preceding export of the CA certificates from the STEP 7 project of the CPU. Follow these steps:

1. Open the certificate manager in the global security settings in the project tree.
2. Select the matching table (CA certificate) for the certificate to be exported.
3. Right-click the selected certificate to open the shortcut menu.
4. Click "Export".
5. Select the export format of the certificate.

In the next step you have to create the user programs for the data exchange and load the configurations together with the program.

Secure Open User Communication between an S7-1500 CPU as TLS server and an external device as TLS client

If the S7-1500 CPU acts as TLS server and the external device, for example an ERP system (Enterprise Resource Planning System) establishes the TLS connection / session, you require the following certificates:

- For the S7-1500 CPU, you generate a device certificate (server certificate) with a private key and download it with the hardware configuration into the S7-1500 CPU. You use the "Signed by certificate authority" option when generating the server certificate.

The private key is required for the key exchange as explained in the figure for the example "HTTP over TLS".

- You have to export the CA certificate of the STEP 7 project for the ERP system and import / load it into the ERP system. With the CA certificate the ERP system verifies the server certificate of the S7-1500 that was transferred from the CPU to the ERP system during the establishment of the TLS connection / session.



- ① TLS server
- ② TLS client

Figure 3-12 Secure OUC between an S7-1500 CPU and ERP system

The required steps are described in the preceding sections.

Secure Open User Communication to a mail server (SMTP over TLS)

An S7-1500 CPU can establish a secure connection to an e-mail server with the communication instruction TMAIL-C.

The system data types TMail_V4_SEC and TMail_QDN_SEC allow you to determine the partner port of the e-mail server and thus to reach the e-mail server via "SMTP over TLS".



Figure 3-13 Secure OUC between a S7-1500 CPU and a mail server

Requirement for secure e-mail connection is the importing of the root certificate and the intermediate certificates of the mail server (provider) into the global certificate memory of the S7-1500 CPU. By means of these certificates the CPU can check the server certificate that is sent by the mail server during the establishment of the TLS connection / session.

Proceed as follows to import certificates of the mail server:

1. Open the certificate manager in the global security settings in the project tree.
2. Select the appropriate table (trusted certificates and root certificate authorities) for the certificate to be imported.
3. Right-click in the table to open the shortcut menu. Click "Import" and import the required certificate or the required CA certificates.

As a result of the import, the certificate has a certificate ID assigned to it and can be assigned to a module in the next step.

4. Mark PLC_1 and navigate to the "Certificates of partner devices" table in the "Protection & Security" section.
5. Click in an empty line in the "Certificate subject" column to add the imported certificates.
6. Select the required CA certificates of the communication partner from the drop-down list and confirm the selection.

In the next step you have to create the user programs for the e-mail client function of the CPU and load the configurations together with the program.

3.6.6 Example: HTTP over TLS

The following paragraphs show how the mechanisms described are used to establish a secure communication between a Web browser and the Web server of an S7-1500 CPU.

Initially the changes for the "Permit access only with HTTPS" option in STEP 7 are described. As of STEP 7 V14 you have the possibility to influence the server certificate of the Web server of an S7-1500 CPU as of firmware V2.0: The server certificate is generated as of these versions with STEP 7.

In addition it illustrates the processes that are executed when a website of the CPU Web server is called with a Web browser of a PC through an encrypted HTTPS connection.

Using Web server certificates for S7-1500 CPUs, FW V2.0 or higher

For S7-1500 CPUs with a firmware version before V2.0, you were able to set "Permit access only with HTTPS" when setting the Web server properties, without specific requirements applying.

You did not have to handle certificates for these CPUs; the CPU automatically generates the certificates required for the Web server.

For S7-1500 CPUs as of firmware V2.0, STEP 7 generates the server certificate (end-entity certificate) for the CPU. You assign a server certificate to the Web server in the properties of the CPU (Web server > Security).

Because a server certificate name is always preset, there is no change to the easy configuration of the Web server: You activate the Web server. The "Permit access only with HTTPS" option is enabled by default - STEP 7 generates a server certificate with the default name during compiling.

Irrespective of whether you use the certificate manager in the global security settings or not: STEP 7 has all the information required to generate the server certificate.

In addition, you have the possibility to determine the properties of the server certificate, for example, the name or the validity period.

Loading the Web server certificate

The server certificate generated by STEP 7 is then automatically also loaded to the CPU when the hardware configuration is loaded.

- If you use the certificate manager in the global security settings, the certificate authority of the project (CA certificate) signs the server certificate of the Web server: During loading the CA certificate of the project is loaded as well automatically.
- If you do not use the certificate manager in the global security settings, STEP 7 generates the server certificate as a self-signed certificate.

When you address the Web server of the CPU over the IP address of the CPU, a new server certificate (end-entity certificate) must be generated and loaded with each change in the IP address of an Ethernet interface of the CPU. This is necessary because the identity of the CPU changes with the IP address – and the identity requires a signature in accordance with the PKI rules.

You can avoid this problem by addressing the CPU with a domain name instead of its IP address, for example "myconveyer-cpu.room13.myfactory.com". For this purpose, you have to manage the domain names of the CPU via a DNS server.

Supplying a Web browser with a CA certificate of the Web server

In the Web browser the user who accesses the websites of the CPU through HTTPS should install the CA certificate of the CPU. If no certificate is installed, a warning is output recommending that you do not use the page. To view this page, you must explicitly "Add an exception".

The user receives the valid root certificate for download from the "Intro" Web page of the CPU Web server under "Download certificate".

STEP 7 offers a different possibility: Export the CA certificate of the project with the certificate manager into the global security settings in STEP 7. Subsequently import the CA certificate into the browser.

Course of the secure communication

The figure below shows, in simplified terms, how communication is established ("handshake") focusing on the negotiation of keys used for data exchange (here with HTTP over TLS).

However, the course can be applied to all communication options that are based on the usage of TLS, i.e. also for Secure Open User Communication (see Basics for secure communication).

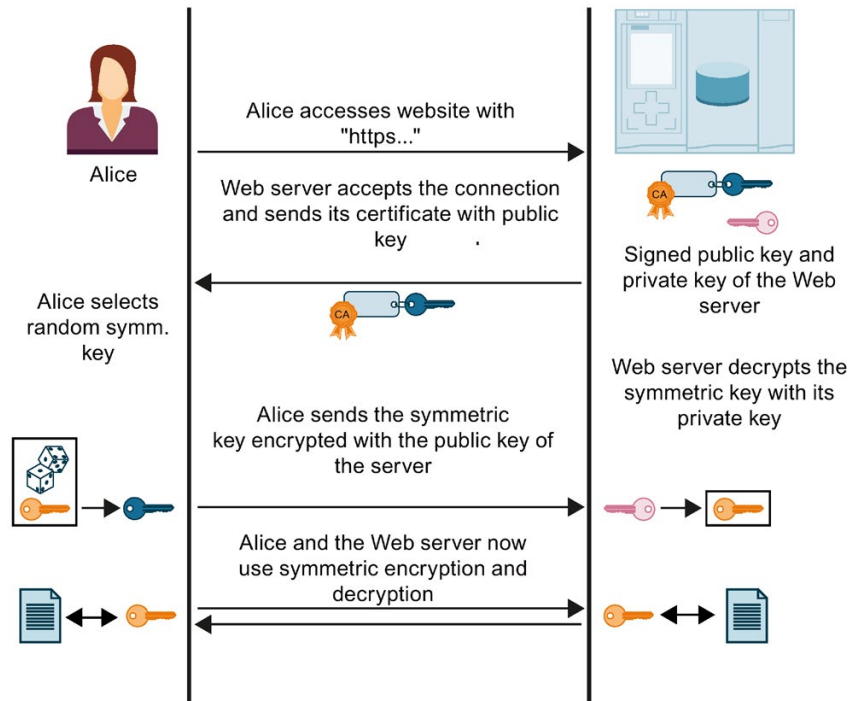


Figure 3-14 Handshake with https

The figure does not show the measures taken at Alice's end (browser) to verify the certificate sent by the Web server. Whether Alice can trust the Web server certificate received and therefore the identity of the Web server, and can accept the exchange of data, depends on positive verification.

The steps for verifying the authenticity of the Web server:

1. Alice must know the public keys of all relevant certificate authorities, which means she requires the complete certificate chain to verify the Web server certificate (i.e. the end-entity certificate of the Web server):

Alice will generally have the required root certificate in her certificate memory. When a Web browser is installed, a range of trusted root certificates is also installed. If she does not have the root certificate, she has to download it from the certificate authority and install it in the certificate store of the browser. The certificate authority can also be the device on which the Web server is located.

You have the following options for obtaining the intermediate certificates:

- The server itself sends the required intermediate certificates to Alice along with its end-entity certificate – in the form of a signed message so that Alice can verify the integrity of the certificate chain.
- The certificates often contain the URLs of the certificate issuer. Alice can load the required intermediate certificates from these URLs.

When you work with certificates in STEP 7 it is always assumed that you have imported the intermediate certificates and the root certificate into the project and assigned them to the module.

2. Alice validates the signatures in the certificate chain with the public keys of the certificates.
3. The symmetric key must be generated and transferred to the Web server.
4. If the Web server is addressed by its domain name, Alice also verifies the identity of the Web server in accordance with the Internet PKI rules defined in RFC 2818. She is able to do this because the URL of the Web server, in this case the "Fully Qualified Domain Name" (FQDN), is saved in the end-entity certificate of the Web server. If the certificate entry in the "Subject Alternative Name" field corresponds to the entry in the address bar of the browser, everything is fine.

The process continues with the exchange of data with the symmetric key, as shown in the figure above.

3.7 SNMP

3.7.1 Disabling SNMP

The network management protocol SNMP (Simple Network Management Protocol) is a protocol that uses various services and tools for detection and diagnostics of the network topology.

Which SNMP requests the S7-1500 CPUs and the S7-1200 CPUs can receive, is described in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/79993228>).

SNMP uses the transport protocol UDP. SNMP recognizes two network components, the SNMP manager and the SNMP client. The SNMP manager monitors the network nodes: The SNMP clients collect the various network-specific information in the individual network nodes and store it in a structured form in the MIB (Management Information Base). Various services and tools can run detailed network diagnostics with the help of these data.

Under certain conditions, it is useful to disable SNMP. Examples:

- The security guidelines in your network do not allow the use of SNMP.
- You use your own SNMP solution, e.g. with your own communications instructions.

If you disable SNMP for a device, various diagnostics options for the network topology (e.g. in the PRONETA tool or in the Web server of the CPU) are no longer available.

Disabling SNMP

To disable SNMP for one of the integrated interfaces of an S7 1500 CPU, proceed as follows:

1. In STEP 7, create a data block that contains the structure of data record B071_H.
 - The following table shows the structure of the data record B071_H.

Byte	Element	Code	Explanation
0-1	BlockID	F003 _H	Header The data record length is counted starting at byte 4 "Version".
2-3	BlockLength	8	
4	Version	01 _H	
5	Subversion	00 _H	
6-7	Reserved	-	-
8-11	SNMP controller	Disable/enable SNMP	If you want to disable SNMP, enter the value 0. If you want to enable SNMP, enter the value 1.

2. Transfer the data record B071_H in the startup OB (OB100) with the WRREC instruction (write data record) to the CPU.
Use the hardware ID of an integrated interface of the CPU here.

3.7.2 Example: Disabling SNMP for a CPU 1516-3 PN/DP

Task

As the security guidelines in your network do not allow SNMP, you want to disable SNMP for a CPU 1516-3 PN/DP.

Requirements

- CPU 1516-3 PN/DP with firmware version V2.0
- STEP 7 as of V14

Solution

First, create a data block that contains the structure of data record B071_H. The figure below shows the data block "Deactivate SNMP". The data block "Deactivate SNMP" contains the data record B071_H as well as additional tags that you use to transfer the data record. The tag "snmp_deactivate" is used to trigger the job for WRREC. Place this tag in the retentive memory area so that the value is also available in the startup OB (OB100).

Deactivate SNMP								
	Name	Data type	Start value	R...	A...	W..	V...	Comment
1	Static			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
2	snmp_deactivate	Bool	TRUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Tag for deactivation
3	snmp_record	Struct		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Data record 16#B071
4	BlockID	UInt	16#F003	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
5	BlockLenght	UInt	8	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
6	Version	USInt	1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
7	Subversion	USInt	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
8	Reserved	UInt	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
9	SNMPControl	UDInt	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
10	snmp_done	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
11	snmp_error	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
12	snmp_status	DWord	16#0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	

Figure 3-15 Example: Data block for disabling SNMP

Transfer the data record B071_H in the startup OB (OB100) to CPU 1516-3 PN/DP with the WRREC instruction (write data record).

In the following program code, the data record B071_H is transferred with the WRREC instruction in a REPEAT UNTIL loop.

```

ORGANIZATION_BLOCK "Startup"
TITLE = "Complete Restart"
{ S7_Optimized_Access := 'TRUE' }
VERSION : 0.1
BEGIN
  REPEAT
    "WRREC_DB_1"
    (REQ := "Deactivate SNMP".snmp_deactivate,
     //Transfer data record
     INDEX:=16#B071,
     //Data record number for SNMP deactivation
     ID:="Local~PROFINET_interface_1",
     //any integrated PROFINET Interface
     DONE => "Deactivate SNMP".snmp_done,
     ERROR => "Deactivate SNMP".snmp_error,
     STATUS => "Deactivate SNMP".snmp_status,
     RECORD := "Deactivate SNMP".snmp_record)
     //Data record
  UNTIL "Deactivate SNMP".snmp_done OR "Deactivate SNMP".snmp_error
  END_REPEAT;
END_ORGANIZATION_BLOCK

```

Using program code

You will find the full program code here.

Follow these steps to apply the program code to your project:

1. Copy the entire program code to the clipboard with Ctrl+A, Ctrl+C.
2. Open a text editor (e.g. "Editor").
3. Paste the content of the clipboard to the text editor with Ctrl+V.
4. Save the document as an scl file, e.g. SNMP_DEACT.scl.
5. Open your project in STEP 7.
6. Import the scl file as an external source.
You will find further information on importing external sources in the STEP 7 online help.
7. Generate the startup OB and the data blocks. (right-click on the scl file, shortcut menu: "Generate blocks from source")

Re-enabling SNMP

With small changes, you can use the program code used above to enable SNMP.

In the user program, assign the "Deactivate SNMP".snmp_record.SNMPControl tag the value "1":

```
"Deactivate SNMP".snmp_record.SNMPControl := 1;
```

SNMP will then be enabled again the next time the CPU is started.

PG communication

Properties

Using PG communication, the CPU or another module capable of communication exchanges data with an engineering station (for example PG, PC). The data exchange is possible via PROFIBUS and PROFINET subnets. The gateway between S7 subnets is also supported.

PG communication provides functions needed to load programs and configuration data, run tests, and evaluate diagnostic information. These functions are integrated in the operating system of the module capable of communication.

Requirements

- The PG/PC is physically connected to the communication-capable module.
- If the communication-capable module is to be reached via S7 routing, the hardware configuration has to be loaded in the participating stations (S7 router and end point).

Procedure for connecting online

You must establish an online connection to the CPU for the programming device communication:

1. Select the CPU in the project tree in STEP 7.
2. Select the "Online > Go online" menu command.

3. In the "Go online" dialog, make the following settings for your online connection:
 - Select interface type (e.g. PN/IE) in the "Type of PG/PC interface" drop-down list.
 - In the "PG/PC interface" drop-down list, select the PG/PC interface (e.g. Ind. Ethernet card) you want to use to establish the online connection.
 - Select the interface or the S7 subnet with which the programming device/PC is physically connected from the "Connection to interface/subnet" drop-down list.
 - If the communication-capable module can be reached via an S7 router (gateway), select the S7 router that connects the subnets in question from the "1st gateway" drop-down list.

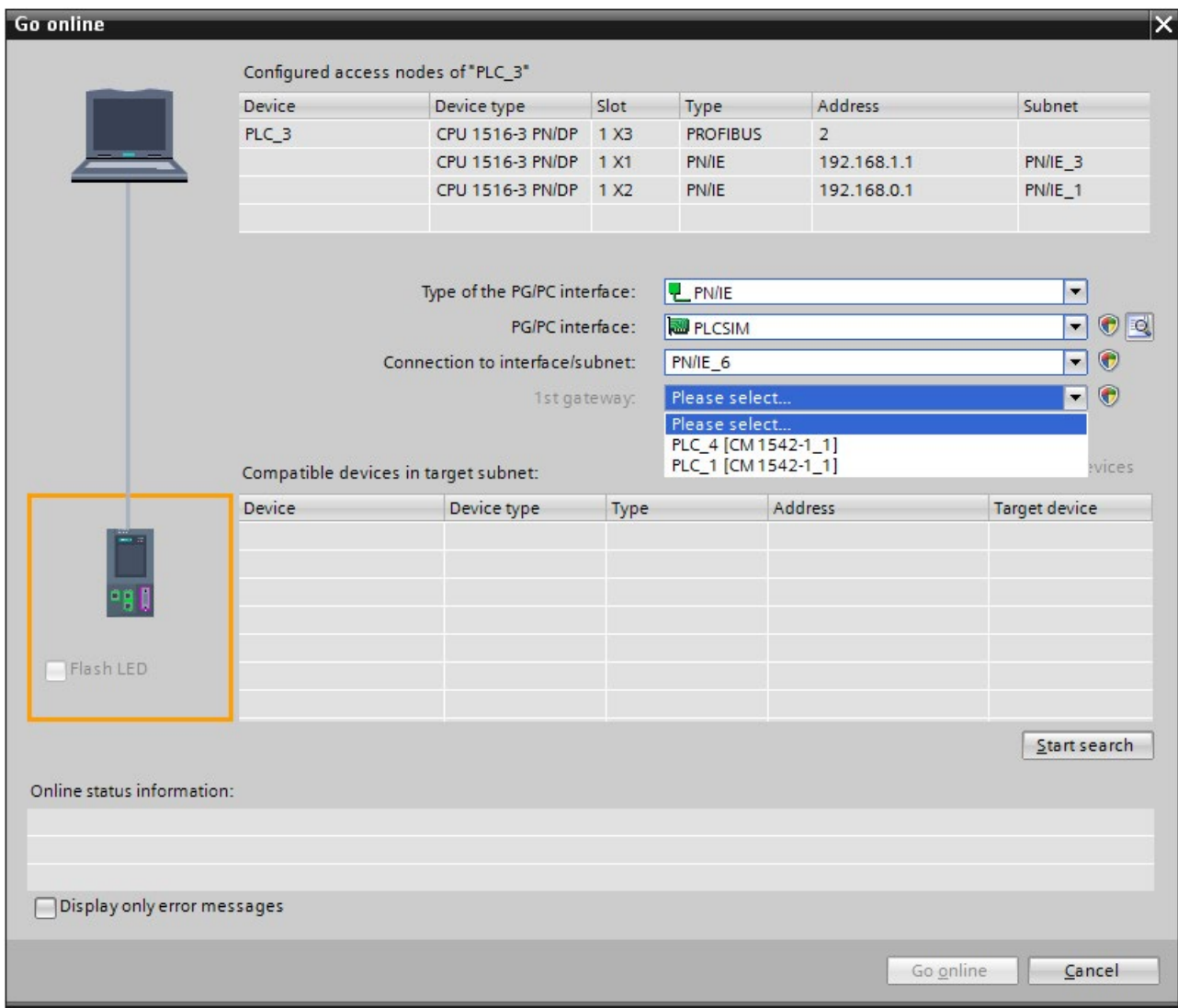


Figure 4-1 Setting up PG communication

4. Click "Start search".
All devices that you can address with PG communication appear shortly thereafter in the table "Compatible devices in target subnet".
5. In the "Compatible devices in target subnet" table, select the relevant CPU and confirm with "Go online".

Additional information

You can find more information on "Go online" in the STEP 7 online help.

HMI communication

Properties

Using HMI communication, one or more HMI devices (for example HMI Basic/Comfort/Mobile Panel) exchanges data with a CPU for operator control and monitoring with via the PROFINET or PROFIBUS DP interface. The data exchange is via HMI connections.

If you want to set up several HMI connections to a CPU, use for example:

- The PROFINET and PROFIBUS DP interfaces of the CPU
- CPs and CMs with the relevant interfaces

Procedure for setting up HMI communication

As soon as you drag-and-drop a tag, for example a tag from a global data block into an HMI screen or into the HMI tag table, STEP 7 automatically sets up an HMI connection. Alternatively, you can also set up the HMI connection yourself.

To set up an HMI connection, follow these steps.

1. Configure the HMI device in an existing configuration with a CPU in the network view of the Devices & networks editor of STEP 7.
2. Select the "Connections" button and then "HMI connection" from the drop-down list.
3. Drag-and-drop a line between the end points of the connection (HMI device and CPU). The end points are highlighted in color. If the required S7 subnet does not yet exist, it is created automatically.

- In the "Connections" tab, select the row of the HMI connection.

In the "General" area of the "Properties" tab, you see the properties of the HMI connection, some of which you can change.

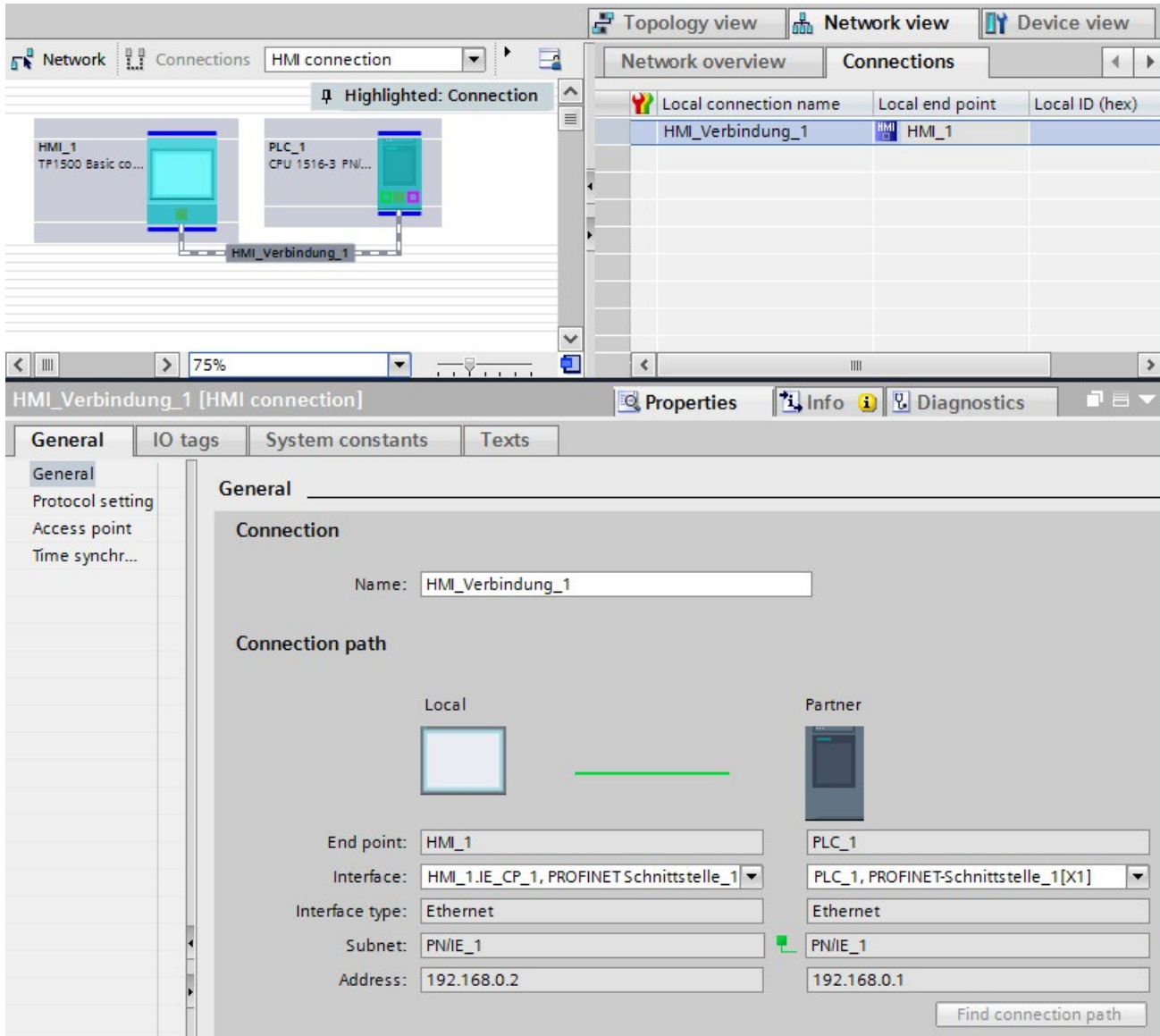


Figure 5-1 Setting up HMI communication

- Download the hardware configuration to the CPU.
- Download the hardware configuration to the HMI device.

Additional information

You can find information on S7 routing for HMI connections in the section S7 Routing (Page 289).

You can find more information on setting up HMI connections in the STEP 7 online help.

Open User Communication

6.1 Overview of Open User Communication

Features of Open User Communication

Through Open User Communication, also called "open communication", the CPU exchanges data with another device capable of communication. Open User Communication has the following features and characteristics:

- Open standard (communication partners can be two SIMATIC CPUs or a SIMATIC CPU and a suitable third-party device).
- Communication via various protocols (in STEP 7 known as "Connection types")
- High degree of flexibility in terms of the data structures transferred; this allows open data exchange with any communications devices as long as these support the connection types available.
- Secure Communication: To protect your automation system, you can exchange data securely over Open User Communication. With Secure Open User Communication, the data is sent signed and encrypted.
- Open User Communication is possible in various automation systems, see technical specifications of the respective manuals.

Examples:

- Integrated PROFINET / Ind. Ethernet interfaces of CPUs (S7-1500, ET 200SP CPU, S7-1500 Software Controller, CPUs 1513/1516pro 2 PN)
- PROFINET / Ind. Ethernet interfaces of communications modules (for example CP 1543-1, CM 1542-1, CP 1543SP-1)

Information on Secure Open User Communication is available in the section Secure Communication (Page 34).

Information on S7-1500R/H

You can find information on Open User Communication with the S7-1500R/H redundant system in section Communication with the redundant system S7-1500R/H (Page 324).

6.2 Protocols for Open User Communication

Protocols for Open User Communication

The following protocols are available for open communication:

Table 6- 1 Transport protocols for open communication

Transport protocol	Via interface
TCP according to RFC 793	PROFINET/Industrial Ethernet
ISO-on-TCP according to RFC 1006 (Class 4)	PROFINET/Industrial Ethernet
ISO according to ISO/IEC 8073	Industrial Ethernet (only CP 1543-1)
UDP according to RFC 768	PROFINET/Industrial Ethernet
FDL	PROFIBUS

Table 6- 2 Application protocols for open communication

Application protocol	Used transport protocol
Modbus TCP	TCP according to RFC 793
E-mail	TCP according to RFC 793
FTP	TCP according to RFC 793

TCP, ISO-on-TCP, ISO, UDP

Prior to data transfer, these protocols (except UDP) establish a transport connection to the communications partner. Connection-oriented protocols are used when potential loss of data needs to be avoided.

The following is possible with UDP:

- Unicast to one device or broadcast to all devices on PROFINET via the PROFINET interface of the CPU or the Industrial Ethernet interface of the CP 1543-1
- Multicast to all recipients of a multicast group via the PROFINET interface of the CPU* or the PROFINET / Industrial Ethernet interface of the CP 1543-1

* As of firmware version V2.0, the PROFINET interface of the CPU supports a maximum of 5 multicast groups

Maximum user data length: You can find the maximum user data lengths supported in the technical specifications of the respective device manuals.

Protocol for communication via PROFIBUS: FDL

Data transfer via an FDL connection (Fieldbus Data Link) is suitable for the transfer of related blocks of data to a communications partner on PROFIBUS that supports the sending and receiving of data according to the FDL service SDA (Send Data with Acknowledge) according to EN 50170, Vol 2. Both partners have the same rights; in other words, each partner can initiate sending and receiving event-driven.

In keeping with the FDL service SDN (Send Data with No Acknowledge) according to EN 50170, Vol 2, the following is possible with FDL:

- Broadcast to all devices on PROFIBUS via the PROFIBUS interface of the CM 1542-5
- Multicast to all recipients of a multicast group via the PROFIBUS interface of the CM 1542-5

Modbus TCP

The Modbus protocol is a communication protocol with linear topology based on a master/slave architecture. In the Modbus TCP (Transmission Control Protocol), the data is transmitted as TCP/IP packets.

Communication is controlled solely by suitable instructions in the user program.

E-mail and FTP

You can use email to send for example, data block contents (e.g. process data) as an attachment.

You can use the FTP connection (FTP = File Transfer Protocol) to transmit files to and from S7 devices.

The communication is controlled by instructions in the user program at the client end.

Application example: MQTT Publisher for the SIMATIC S7-1500 CPU

The "Message Queue Telemetry Transport" (MQTT) is a simple protocol on the TCP/IP level. It is suitable for the exchange of messages between devices with lower functionality and for the transfer via unreliable networks.

The application example provides a function block with which you can implement the MQTT protocol into the SIMATIC S7-1500.

You can find the application example on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109748872>).

Block library for SYSLOG messages

Syslog is a simply structured binary profile on UDP/IP level. It enables applications to send messages, warnings or error states to a Syslog server. Syslog is typically used for computer system management and security monitoring, and has established itself as a standard in the field of protocols.

The "LSyslog" library offers you a solution to implement the Syslog protocol in an S7-1500. In addition to the library, an application example is provided that shows you how to generate Syslog messages in your controller and send them to the Syslog server.

You can find the block library "LSyslog" and the associated application example on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/51929235>).

6.3 Instructions for Open User Communication

Introduction

You set up Open User Communication via the corresponding connection (for example, TCP connection) as follows:

- By programming in the user programs of the communications partners or
- By configuring the connection in STEP 7 in the hardware and network editor

Regardless of whether you set up the connection by programming or configuring, instructions are always required in the user programs of both communications partners for sending and receiving the data.

Setting up the connection via the user program

If the connection is set up by programming, the connection establishment and termination is implemented using instructions in the user program.

In certain application areas, it is advantageous not to set up the communication connections statically via hardware configuration, but via the user program instead. You can set up the connections via a specific application program-controlled and therefore when necessary. Programmed connection setup also allows connection resources to be released following data transfer.

A data structure is necessary for each communications connection that contains the parameters for establishing the connection (for example system data type "TCON_IP_v4" for TCP).

The system data types (SDT) are provided by the system and have a predefined structure that cannot be changed.

The various protocols have their own data structures (see table below). The parameters are stored in a data block ("connection description DB") for example of the system data type TCON_IP_v4.

There are two ways in which you can specify the DB with the data structure:

- Recommendation: Have the data block created automatically in the properties in the program editor during parameter assignment of the connection for the TSEND_C, TRCV_C and TCON instructions.
- Create the data block manually, assign parameters to it and write it directly to the instruction
Necessary for:
 - Secure OUC
 - Connection over DNS
 - E-mail
 - FTP

You can modify the connection parameters in the "connection description DB".

This FAQ (<https://support.industry.siemens.com/cs/ww/en/view/58875807>) describes how to program the TCON instruction to set up a connection for Open User Communication between two S7-1500 CPUs.

Protocols, system data types and employable instructions for programmed setup

The following table shows the protocols of the Open User Communication and the matching system data types and instructions.

Table 6- 3 Instructions for programmed setup of the connection

Protocol	System data type	Instructions
TCP	<ul style="list-style-type: none"> • TCON_QDN • TCON_IP_v4 	Establish connection and send/receive data via:
ISO-on-TCP	<ul style="list-style-type: none"> • TCON_IP_RFC 	<ul style="list-style-type: none"> • TSEND_C/TRCV_C or • TCON, TSEND/TRCV or
ISO according to ISO/IEC 8073 (Class 4)	<ul style="list-style-type: none"> • TCON_ISO^{native}1 • TCON_Configured 	<ul style="list-style-type: none"> • TCON, TUSEND/TURCV (connection can be terminated via TDISCON)
UDP	<ul style="list-style-type: none"> • TCON_IP_v4 • TADDR_Param • TADDR_SEND_QDN • TADDR_RCV_IP 	Establish connection and send/receive data via: <ul style="list-style-type: none"> • TSEND_C/TRCV_C • TUSEND/TURCV/TRCV (connection can be terminated via TDISCON)
FDL ¹	<ul style="list-style-type: none"> • TCON_FDL 	Establish connection and send/receive data via: <ul style="list-style-type: none"> • TSEND_C/TRCV_C or • TCON, TSEND/TRCV or • TCON, TUSEND/TURCV (connection can be terminated via TDISCON)

6.3 Instructions for Open User Communication

Protocol	System data type	Instructions
Modbus TCP	<ul style="list-style-type: none"> • TCON_IP_v4 • TCON_QDN • TCON_Configured 	<ul style="list-style-type: none"> • MB_CLIENT • MB_SERVER
E-mail	<ul style="list-style-type: none"> • TMAIL_v4 • TMAIL_v6 • TMAIL_FQDN 	<ul style="list-style-type: none"> • TMAIL_C
FTP ²	<ul style="list-style-type: none"> • FTP_CONNECT_IPV4³ • FTP_CONNECT_IPV6³ • FTP_CONNECT_NAME³ 	<ul style="list-style-type: none"> • FTP_CMD

¹ This protocol can only be used with the CM 1542-5

² This protocol can only be used with the CP 1543-1

³ User-defined data type

The following table shows you the different connections of the Secure Open User Communication and the matching system data types and instructions.

Secure OUC connection	System data type	Instructions
Secure TCP connection from an S7-1500 CPU as TLS client to a third-party PLC (TLS server) Secure TCP connection from an S7-1500 CPU as TLS server to a third-party PLC (TLS client)	<ul style="list-style-type: none"> • TCON_QDN_SEC 	<ul style="list-style-type: none"> • TSEND_C/TRCV_C • TCON, TSEND/TRCV
Secure TCP connection between two S7-1500 stations	<ul style="list-style-type: none"> • TCON_IP_V4_SEC¹ 	
Secure connection to a mail server ²	<ul style="list-style-type: none"> • TMAIL_V4_SEC • TMAIL_QDN_SEC 	<ul style="list-style-type: none"> • TMAIL_C (V5.0 or higher)
Secure Modbus TCP connection	<ul style="list-style-type: none"> • TCON_IP_V4_SEC¹ 	<ul style="list-style-type: none"> • MB_Client
	<ul style="list-style-type: none"> • TCON_QDN_SEC 	<ul style="list-style-type: none"> • MB_Server

¹ Also possible for CP 1543-1

² Secure connection to a mail server also possible with CP1543-1 und TMAIL_C (V4.0)

Setting up the connection with connection configuration

When setting up through the configuration of the connection, the address parameters of the connection are specified in the hardware and network editor of STEP 7.

To send and receive the data, use the same instructions as when the connections are set up by programming:

Table 6- 4 Instructions for sending/receiving with configured connections

Protocol	Send/receive with configured connections
Supported instructions:	
TCP	Send/receive data via:
ISO-on-TCP	<ul style="list-style-type: none"> • TSEND_C/TRCV_C or
ISO according to ISO/IEC 8073 (Class 4)	<ul style="list-style-type: none"> • TSEND/TRCV or • TUSEND/TURCV
UDP	Send/receive data via: <ul style="list-style-type: none"> • TSEND_C/TRCV_C or • TUSEND/TURCV
FDL	Send/receive data via: <ul style="list-style-type: none"> • TSEND_C/TRCV_C or • TSEND/TRCV or • TUSEND/TURCV
Modbus TCP	Not supported
E-mail	Not supported
FTP	Not supported

Additional instructions for open communication

You can use the following instructions for connections set up in the user program as well as for configured connections:

- T_RESET: Terminating and establishing a connection
- T_DIAG: Check the connection

Basic examples for Open User Communication

The Siemens Online Support offers you function blocks (FBs) that facilitate the handling of the instructions of the Open User Communication. You can find the function block with corresponding examples on the Internet

(<https://support.industry.siemens.com/cs/ww/en/view/109747710>).

Additional information

The STEP 7 online help describes:

- The user and system data types
- The instructions for open communication
- The connection parameters

You will find information about the allocation and release of connection resources in the section Allocation of connection resources (Page 311).

See also

Secure Open User Communication (Page 92)

6.4 Open User Communication with addressing via domain names

As of firmware version V2.0, S7-1500 CPUs, ET 200SP CPUs and the CPUs 1513/1516pro-2 PN support Open User Communication with addressing via Domain Name System (DNS). A DNS client is integrated in the CPU. In the case of communication via DNS, you use domain names as an alias for IP addresses to address communication partners. Addressing of the communication partners via domain names is possible for open communication via TCP and UDP.

At least one DNS server must be located in your network as a requirement for communication via DNS.

The S7-1500 software controller supports communication via DNS for all interfaces that are assigned to the software controller.

Setting up communication via DNS

The DNS client of the CPU must know the IPv4 address of at least one DNS server so that a CPU can establish a connection to a communication partner via its domain name. The CPU supports up to 4 different DNS servers.

To set up communication via domain names for an S7-1500 CPU, follow these steps:

1. Select the CPU in the network view of STEP 7.
2. In the Inspector window, navigate to "Properties" > "General" > "Advanced configuration" > "DNS configuration".
3. Enter the IPv4 address of a DNS server in the "DNS server addresses" column of the "Server list" table.

You can enter up to 4 IPv4 addresses of DNS servers.

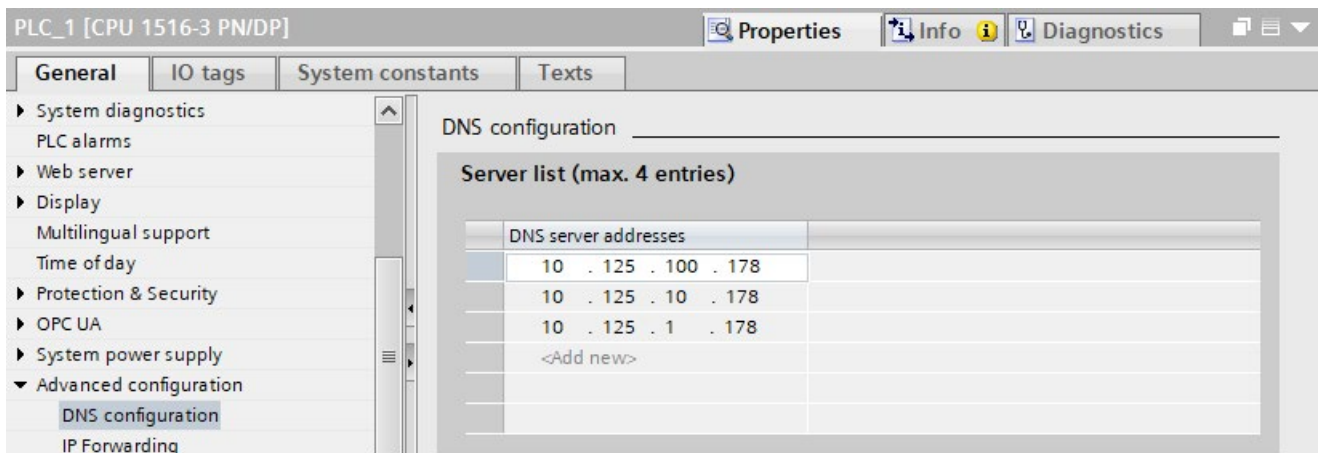


Figure 6-1 Entering DNS server addresses using a CPU 1516-3 PN/DP as an example

Setting up a TCP connection via the domain name of the communication partner

For TCP communication via the domain name you need to create a data block with the TCON_QDN system data type yourself, assign parameters and call it directly at the instruction. The TCON, TSEND_C and TRCV_C instructions support the system data type TCON_QDN:

To set up a TCP connection via the domain name of the communication partner, follow these steps:

1. Create a global data block in the project tree.
2. Define a tag of the data type TCON_QDN in the global data block.

The example below shows the global data block "Data_block_1" in which the tag "DNS Connection1" of data type TCON_QDN is defined.

Data_block_1				
	Name	Datentyp	Startwert	Kommentar
1	Static			
2	DNS Connection1	TCON_QDN		
3	Interfaceld	HW_ANY	0	not relevant
4	ID	CONN_OUC	16#0	connection reference / identifier
5	ConnectionType	Byte	16#0B	type of connection: 16#0B=11=TCP/IP, 16#13=19=UDP
6	ActiveEstablished	Bool	false	active/passive connection establishment
7	RemoteQDN	String[254]	"	fully or partially qualified domain name of remote partner
8	RemotePort	UInt	0	remote UDP / TCP port number
9	LocalPort	UInt	0	local UDP / TCP port number

Figure 6-2 Data type TCON_QDN

3. Program the parameters of the TCP connection (for example the fully qualified domain name (FQDN)) in the tag of data type TCON_QDN.
4. Create a TCON instruction in the program editor.
5. Interconnect the CONNECT parameter of the TCON instruction with the tag of the data type TCON_QDN.

In the example below, the CONNECT parameter of the TCON instruction is interconnected with the tag "DNS connection1" (data type TCON_QDN).

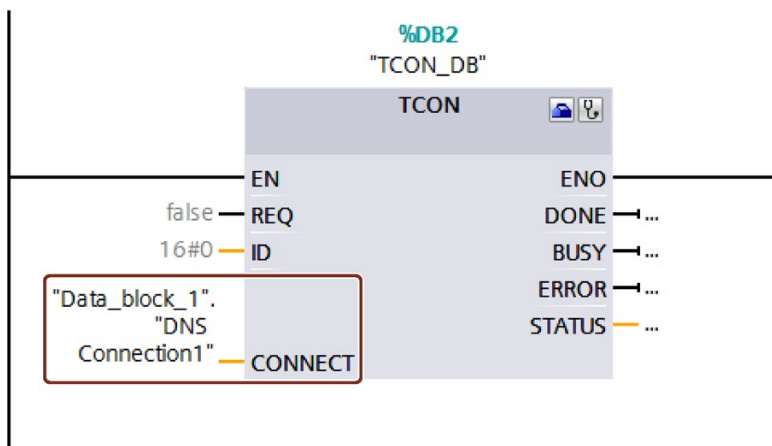


Figure 6-3 TCON instruction

Addressing a UDP connection via the domain name of the communication partner

For S7-1500 CPUs as of firmware version V2.0, you can address the recipient with its fully qualified domain name (FQDN) when sending data via UDP. With the instruction TUSEND at the parameter ADDR, you hereby reference a structure of the type TADDR_SEND_QDN.

The receiver can return an IPv4 or an IPv6 address. With the TURCV instruction at the ADDR parameter, you therefore reference a structure of the TADDR_RCV_IP type. Only this structure can include both IP address types.

Note**Network load**

In contrast to the TCP the UDP protocol does not work connection-oriented. For every edge at the block parameter REQ, the TUSEND or TURCV command performs queries of the DNS server. This can lead to high network load or load on the DNS server.

Additional information

You can find more information about the system data types TCON_QDN, TADDR_SEND_QDN and TADDR_RCV_IP in the STEP 7 online help.

How to set up a secure TCP connection via the domain name of the communication partner is described in the section Secure Open User Communication (Page 92).

6.5 Setting up Open User Communication via TCP, ISO-on-TCP, UDP and ISO

Configuring a connection for the TSEND_C, TRCV_C or TCON instructions

Requirement: A TSEND_C, TRCV_C or TCON instruction is created in the programming editor.

1. Select a TCON, TSEND_C or TRCV_C block of Open User Communication in the program editor.
2. Open the "Properties > Configuration" tab in the inspector window.

3. Select the "Connection parameters" group. Until you select a connection partner, only the empty drop-down list for the partner end point is enabled. All other input options are disabled.

The connection parameters already known are displayed:

- Name of the local end point
- Interface of the local end point
- IPv4 address of the local end point

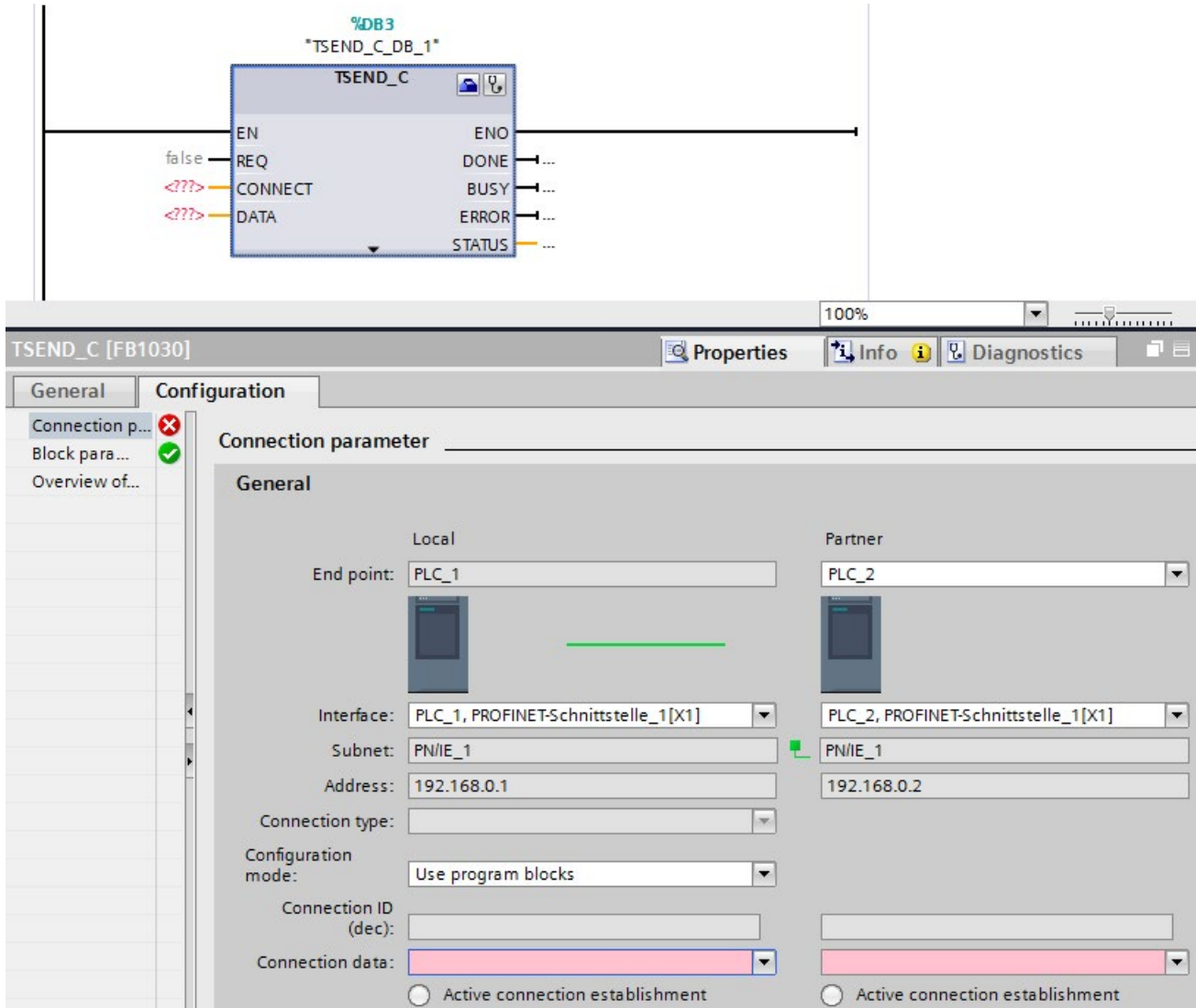


Figure 6-4 Connection parameters for TSEND_C

4. In the drop-down list box of the partner end point, select a connection partner. You can select an unspecified device or a CPU in the project as the communication partner. Certain connection parameters are then entered automatically.

The following parameters are set:

- Name of the partner end point
- Interface of the partner end point
- IPv4 address of the partner end point

If the connection partners are networked, the name of the subnet is displayed.

5. In the "Configuration type" drop-down list, select between using program blocks or configured connections.

6. Select an existing connection description DB in the "Connection data" drop-down list or for configured connections select an existing connection under "Connection name". You can also create a new connection description DB or a new configured connection. Later, you can still select other connection description DBs or configured connections or change the names of the connection description DBs in order to create new data blocks:
 - You can also see the selected data block at the interconnection of the CONNECT input parameter of the selected TCON, TSEND_C or TRCV_C instruction.
 - If you have already specified a connection description DB for the connection partner using the CONNECT parameter of the TCON, TSEND_C or TRCV_C instruction, you can either use this DB or create a new DB.
 - If you edit the name of the displayed data block in the drop-down list, a new data block with the changed name but with the same structure and content is generated and used for the connection.
 - Changed names of a data block must be unique in the context of the communication partner.
 - A connection description DB must have the structure TCON_Param, TCON_IP_v4 or TCON_IP_RFC, depending on CPU type and connection.
 - A data block cannot be selected for an unspecified partner.

Additional values are determined and entered after the selection or creation of the connection description DB or configured connection.

The following is valid for specified connection partners:

- ISO-on-TCP connection type
- Connection ID with default of 1
- Active connection establishment by local partner
- TSAP ID
for S7-1200/1500: E0.01.49.53.4F.6F.6E.54.43.50.2D.31

The following is valid for unspecified connection partners:

- TCP connection type
- Partner port 2000

The following applies for a configured connection with a specified connection partner:

- TCP connection type
- Connection ID with default of 257
- Active connection establishment by local partner
- Partner port 2000

The following applies for a configured connection with an unspecified connection partner:

- TCP connection type
- Local port 2000

7. Enter a connection ID as needed for the connection partner. No connection ID can be assigned to an unspecified partner.

Note

You must enter a unique value for the connection ID at a known connection partner. The uniqueness of the connection ID is not checked by the connection parameter settings and there is no default value entered for the connection ID when you create a new connection.

8. Select the desired connection type in the relevant drop-down list. Default values are set for the address details depending on the connection type. You can choose between the following:
 - TCP
 - ISO-on-TCP
 - UDP
 - ISO (only with Configuration mode "Use configured connection")

You can edit the input boxes in the address details. Depending on the selected protocol, you can edit the ports (for TCP and UDP) or the TSAPs (for ISO-on-TCP and ISO).

9. Use the "Active connection establishment" check box to set the connection establishment characteristics for TCP, ISO and ISO-on-TCP. You can decide which communication partner establishes the connection actively.

Changed values are checked immediately for input errors by the connection configuration and entered in the data block for the connection description.

Note

Open User Communication between two communication partners can only work when the program section for the partner end point has been downloaded to the hardware. To achieve fully functional communication, make sure that you load not only the connection description of the local CPU on the device but also that of the partner CPU as well.

Configuring connections, e.g. for TSEND/TRCV

If you want to use the instructions for TSEND/TRCV for open communication, for example, you first need to configure a connection (e.g. TCP connection).

To configure a TCP connection, follow these steps:

1. Configure the communications partners in the network view of the Devices & networks editor of STEP 7.
2. Click the "Connections" button and select the "TCP connection" connection type from the drop-down list.
3. Using drag-and-drop, connect the communication partner with each other (via an interface or local end point). If the required S7 subnet does not yet exist, it is created automatically.

You can also set up a connection to unspecified partners.

4. Select the created connection in the network view.
5. Set the properties of the connection in the "Properties" tab in the "General" area, for example the name of the connection and the interfaces of the communications partner that will be used.

For connections to an unspecified partner, set the address of the partner.

You can find the local ID (reference of the connection in the user program) in the "Local ID" area.

6. In the Project tree, select the "Program blocks" folder for one of the CPUs and open OB1 in the folder by double-clicking on it. The program editor opens.
7. Select the required instruction from the "Instructions" task card, "Communication" area, "Open user communication", for example TSEND and drag it to a network of OB1.
8. At the ID parameter of the instruction, assign the local ID of the configured connection to be used for the transmission of data.
9. Interconnect the "DATA" parameter of the TSEND instruction with the user data, for example in a data block.
10. Download the hardware configuration and user program to the CPU.

Based on the procedure described above, set up the connection on the partner CPU with the instruction for receiving, TRCV, and download it to the CPU.

Point to note with ISO connections with CP 1543-1

If you use the "ISO connection" connection type, you will need to select the "Use ISO protocol" check box in the properties of the CP so that addressing using MAC addresses will work.

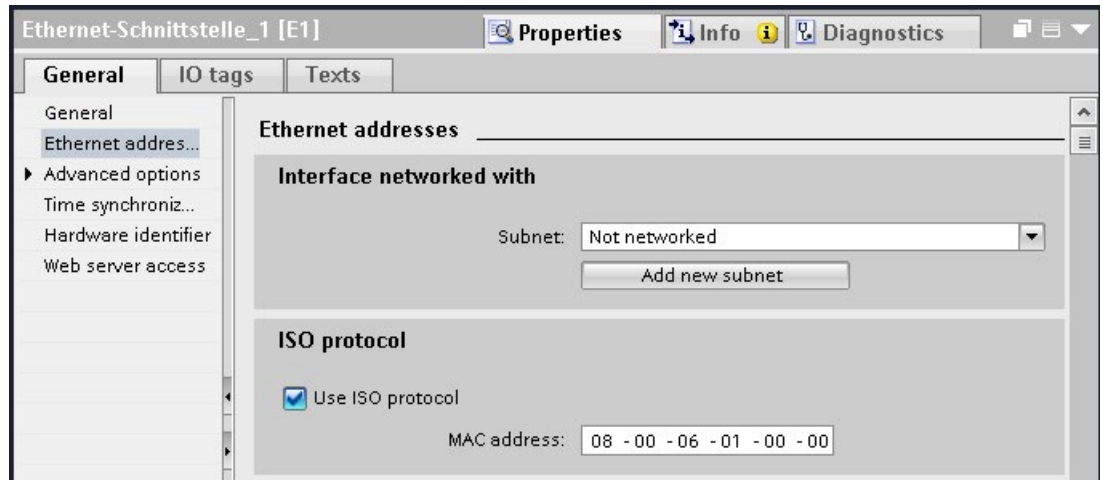


Figure 6-5 Select CP 1543-1 ISO protocol

Additional information

The STEP 7 online help describes:

- The instructions for open communication
- The connection parameters

This FAQ (<https://support.industry.siemens.com/cs/ww/en/view/109479564>) describes how the instructions TSEND_C and TRCV_C behave in the S7-1500.

6.6 Setting up communication over FDL

Requirements

- Configuration software: STEP 7 Professional V14
- End point of the connection: CPU S7-1500 firmware version V2.0 or higher with communication module CM 1542-5 with firmware version V2.0

Setting up a configured FDL connection

Proceed as follows to set up a configured FDL connection in STEP 7:

1. Create a TSEND_C instruction in the program editor.
2. Select the TSEND_C instruction and go to "Properties" > "General" > "Connection parameters" in the Inspector window.
3. Under End point, select the partner end point. Use one of the two partner end points below:
 - CPU S7-1500 with CM 1542-5
 - Unspecified
4. Under Configuration type, select "Use configured connection".
5. Under Connection type, select "FDL".
6. Under Interface, select the following interfaces:
 - Local: PROFIBUS interface of CM 1542-5
 - Specified partner: PROFIBUS interface of CM 1542-5
7. Under Connection data, select the setting <new>.

The figure below shows a fully configured FDL connection in STEP 7.

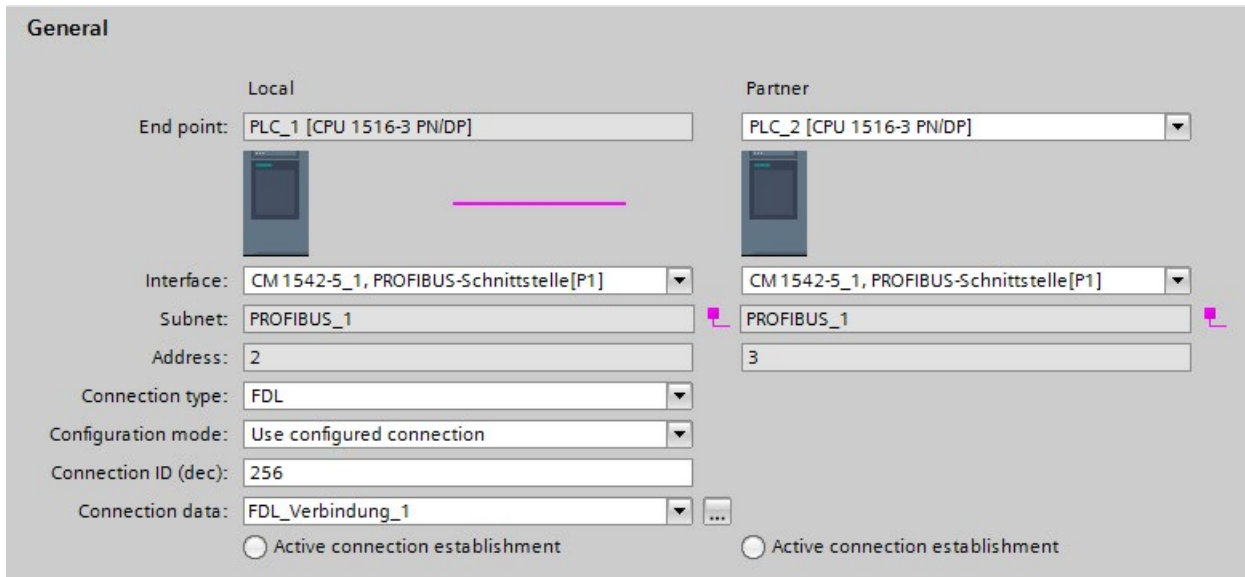


Figure 6-6 Configuring the FDL connection

Setting up an FDL connection in the user program

For communication via FDL, you need to create the data block of the TCON_FDL system data type yourself in each case, assign parameters and call it directly at the instruction. Follow these steps:

1. Create a global data block in the project tree.
2. In the global data block, define a tag of the data type TCON_FDL.

The example below shows the global data block "FDL_connection" in which the tag "FDL_connection" of the data type TCON_FDL is defined.

FDL_connection										
	Name	Data type	Start val..	R...	A...	...	V...	S...	Super...	Comment
1	Static			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
2	FDL_connection	TCON_FDL		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
3	InterfaeId	HW_ANY	0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		HW identifier of PB interface submodule
4	ID	CONN_OUC	16#0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		connection reference / identifier
5	ConnectionType	Byte	16#15	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		type of connection: 21= FDL connection
6	ActiveEstablished	Bool	false	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		active/passive connection establishment
7	ServiceId	Byte	16#0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		service id: 0 – default, 1 – SDA, 2 – SDN
8	RemotePBAddress	Byte	16#0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		remote Profibus partner address
9	LocalPBAddress	Byte	16#0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		local Profibus partner address
10	RemoteLSAP	Byte	16#0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		remote PB link-layer service access point
11	LocalLSAP	Byte	16#0	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		local PB link-layer service access point

Figure 6-7 Programming an FDL connection

3. Program the parameters of the FDL connection (e.g. the PROFIBUS addresses) in the tag of the data type TCON_FDL.

4. Create a TCON instruction in the program editor.
5. Interconnect the CONNECT parameter of the TCON instruction with the tag of the data type TCON_FDL.

In the example below, the CONNECT parameter of the TCON instruction is interconnected with the tag "FDL_Connection" (data type TCON_FDL).

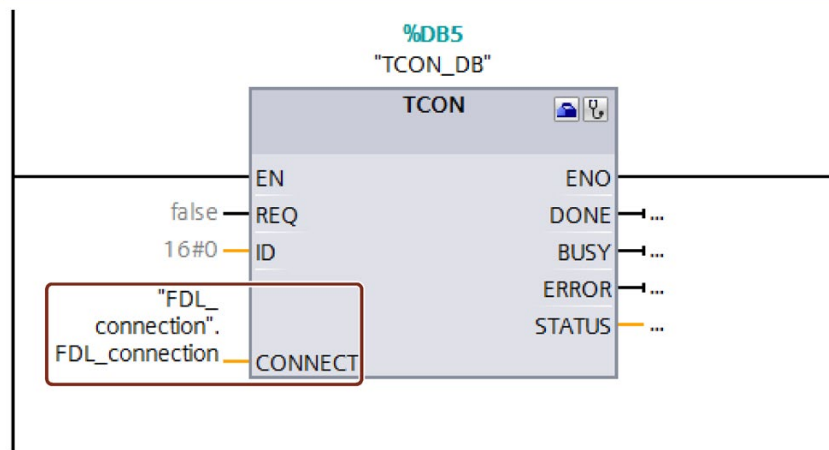


Figure 6-8 Example: TCON Instruction for FDL connection

6.7 Setting up communication with Modbus TCP

Setting up a connection for Modbus TCP via the user program

The parameter assignment takes place in the program editor at the instruction MB_CLIENT or MB_SERVER.

Procedure for setting up communication using Modbus TCP

The MB_CLIENT instruction communicates as a Modbus TCP client via the TCP connection. You establish a connection between the client and the server with the instruction, send Modbus requests to the server and receive the corresponding Modbus responses. You also control the setup of the TCP connection with this instruction.

The MB_SERVER instruction communicates as a Modbus TCP server via the TCP connection. The instruction processes connection requests of a Modbus client, receives and processes Modbus requests and sends responses. You also control the setup of the TCP connection.

Requirement: The client can reach the server via IP communication in the network.

1. Configure an S7-1500 automation system with CPU in the network view of the Devices & networks editor of STEP 7.
2. In the Project tree, select the "Program blocks" folder and open OB1 in the folder by double-clicking on it. The program editor opens.

3. Select the required instruction, for example MB_CLIENT, from the "Instructions" task card, "Communication" area, "Other", "MODBUS TCP" and drag it to a network of OB1.
4. Assign the parameters of the MB_CLIENT or MB_SERVER instruction. Observe the following rules:

An IPv4 server address must be specified for each MB_CLIENT connection.

Each MB_CLIENT or MB_SERVER connection must use a unique instance DB with one of the data structures TCON_IP_v4, TCON_QDN or TCON_Configured.

Each connection requires a unique connection ID. The connection ID and instance DB belong together in pairs and must be unique for each connection.

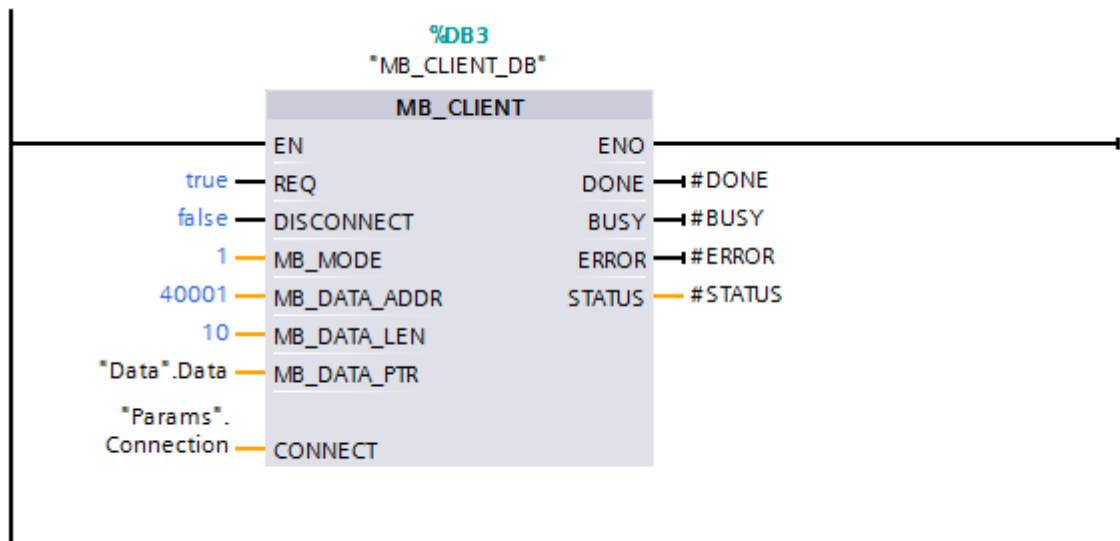


Figure 6-9 MB_CLIENT

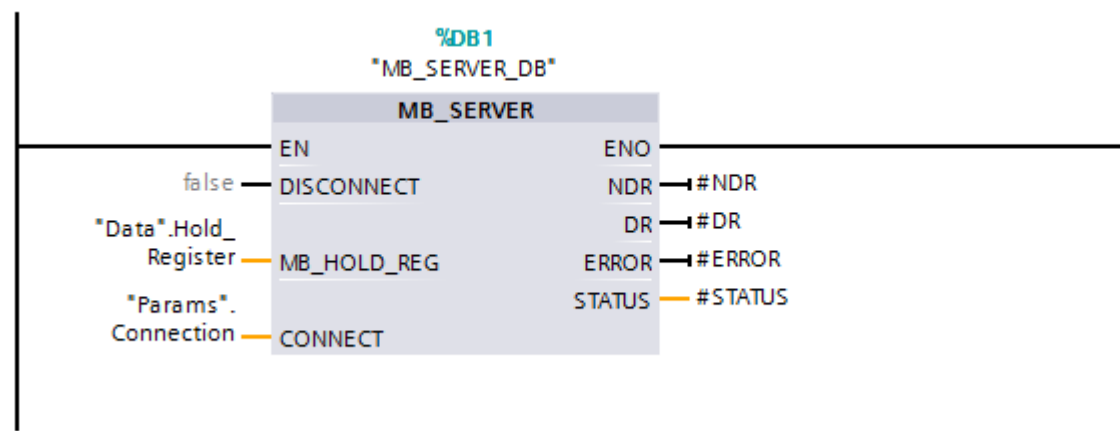


Figure 6-10 MB_SERVER

5. Download the hardware configuration and user program to the CPU.

Modbus TCP server as gateway to Modbus RTU

If you use a Modbus TCP server as a gateway to a Modbus RTU protocol, address the slave device in the serial network using the static parameter, MB_UNIT_ID. The MB_UNIT_ID parameter corresponds to the field of the slave address in the Modbus RTU protocol. The MB_UNIT_ID parameter in this case would forward the request to the correct Modbus RTU slave address.

You do not have to program the gateway function yourself.

You can find the MB_UNIT_ID parameter in the instance data block associated with MB_CLIENT instruction.

You can find more information on the MB_UNIT_ID parameter in the STEP 7 online help.

Reference

- This FAQ (<https://support.industry.siemens.com/cs/ww/en/view/94766380>) describes how to program and configure the Modbus TCP communication between two S7-1500 CPUs.
- This FAQ (<https://support.industry.siemens.com/cs/ww/en/view/102020340>) describes how to program and configure Modbus TCP communication between an S7-1500 CPU and an S7-1200 CPU.

6.8 Setting up communication via e-mail

Setting up a connection for e-mail via the user program

For communication using e-mail, you need to create the data block of the relevant system data type yourself, assign parameters and call the instruction directly. This procedure is introduced below.

Procedure for setting up communication using e-mail

A CPU can send e-mails. To send e-mails from the user program of the CPU, use the TMAIL_C instruction.

Requirement: The SMTP server can be reached via the IPv4 network.

1. Configure an S7-1500 automation system with CPU in the network view of the Devices & networks editor of STEP 7.
2. Assign parameters to the instruction TMAIL_C, for example enter the subject of the e-mail in Subject.
3. In a global data block create a variable of the type TMAIL_v4, TMAIL_v6 (only CP 1543-1) or TMAIL_FQDN (only CP 1543-1).
4. Set the connecting parameters of the TCP connection in the variable in the "Start value" column. Enter the IPv4 address of the mail server, for example, for the "MailServerAddress" (for TMAIL_v4)

Note

Connection parameter Interface ID

Note that you can enter the value "0" for the interface ID with instruction version V5.0 or higher of the instruction TMAIL_C in the data type TMAIL_V4_SEC. In this case, the CPU itself searches for a suitable local CPU interface.

Interconnect the variable to the MAIL_ADDR_PARAM parameter of the TMAIL_C instruction.

5. Download the hardware configuration and user program to the CPU.

Additional information

The STEP 7 online help describes:

- The system data types
- The instructions for open communication
- The connection parameters

6.9 Setting up communication via FTP

Setting up a connection for FTP via the user program

For communication via FTP, you need to create the data block of the relevant system data type yourself, assign parameters and call the instruction directly. This procedure is introduced below.

FTP client and server functionality

Files can be sent by a CPU to an FTP server and can be received from the FTP server. Communication with FTP is only possible for the S7-1500 using the CP 1543-1. The CP can be an FTP server, FTP client or both. FTP clients can also be third-party systems/PCs.

For the FTP server functionality, configure the CP accordingly in STEP 7.

You can use the FTP client functionality to implement, for example, the establishment and termination of an FTP connection, the transfer and deletion of files on the server. For the FTP client functionality, use the FTP_CMD instruction.

Procedure for setting up FTP server functionality

Requirement: The FTP server can be reached via the IPv4 network.

1. Configure an S7-1500 automation system with CPU and CP 1543-1 in the device view of the Devices & networks editor of STEP 7.

At the same time, you need to select the option "Permit access with PUT/GET communication from remote partner (PLC, HMI, OPC, ...)" in the HW configuration of the S7-1500 CPU under the "Protection" area navigation in the section "Connection mechanisms".

2. Make the following settings in the properties of the CP under "FTP configuration":
 - Select the "Use FTP server for S7 CPU data" check box.
 - Assign the CPU, a data block and a file name under which the DB for FTP will be stored.

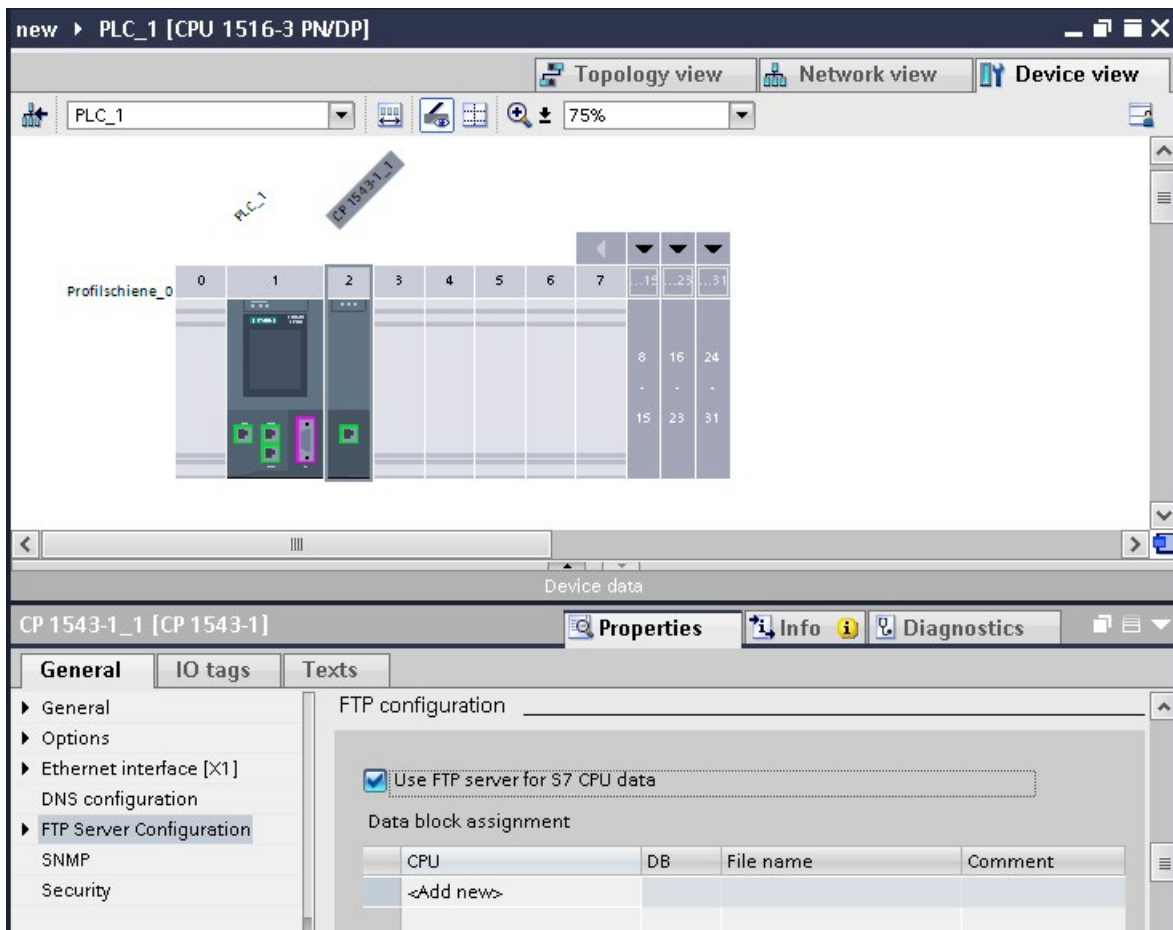


Figure 6-11 Setting up the FTP configuration

3. Download the hardware configuration to the CPU.

Procedure for setting up FTP client functionality

Requirement: The FTP server can be reached via the IPv4 network.

1. Configure an S7-1500 automation system with CPU and CP 1543-1 in the device view of the Devices & networks editor of STEP 7.

At the same time, you need to select the check box "Permit access with PUT/GET communication from remote partner (PLC, HMI, OPC, ...)" in the HW configuration of the S7-1500 CPU under the "Protection" area navigation in the section "Connection mechanisms".

2. Call the FTP_CMD instruction in the user program of the CPU.
3. Set the connection parameters for the FTP server in the FTP_CMD instruction.
4. Create a global DB and within this DB a tag of the type FTP_CONNECT_IPV4, FTP_CONNECT_IPV6 or FTP_CONNECT_NAME.
5. Interconnect the tag within the data block with the FTP_CMD instruction.
6. For the connection to the FTP server, specify the following in the DB:
 - The user name, the password and the IP address for the FTP access in the relevant data type (FTP_CONNECT_IPV4, FTP_CONNECT_IPV6 or FTP_CONNECT_NAME)
7. Download the hardware configuration and user program to the CPU.

Application examples

- Application example: FTP communication with S7-1500 and CP 1543-1
You can find the application example on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/103550797>).
- Application example: FTP client communication with S7-1200/1500
You can find the application example on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/81367009>).

Additional information

The STEP 7 online help describes:

- The system data types
- The instructions for open communication
- The connection parameters

6.10 Establishment and termination of communications relations

Establishment and termination of communications

The table below shows the establishment and termination of communications as part of open communication.

Table 6- 5 Establishment and termination of communications

Setting up the connection	Establishing communication	Terminating communication
With the user program	<p>After downloading the user program to the CPUs:</p> <p>The passive communications partner sets up the local connection access by calling TSEND_C/TRCV_C or TCON. Calling TSEND_C/TRCV_C or TCON on the active partner starts connection establishment. If the connection could be established, there is positive feedback to the instructions in the user program.</p> <p>After you have terminated a connection using the instruction T_RESET, the connection is reestablished.</p> <p>If the connection aborts, the active partner attempts to re-establish the connection. This applies only if the connection was successfully established beforehand with TCON.</p>	<ul style="list-style-type: none"> • Using the TSEND_C/TRCV_C, TDISCON and T_RESET instructions • When the CPU changes from RUN to STOP mode • With POWER OFF/POWER ON on a CPU
By configuring a connection	<p>After downloading the connection configuration and the user program to the CPUs.</p>	<p>By deleting the connection configuration in STEP 7 and downloading the changed configuration to the CPU.</p>

6.11 Secure Open User Communication

6.11.1 Secure OUC of an S7-1500 CPU as TLS client to an external PLC (TLS server)

The following section describes how you can set up Open User Communication via TCP from an S7-1500 CPU as TLS client to a TLS server.

Setting up a secure TCP connection from an S7-1500 CPU as TLS client to a TLS server

S7-1500 CPUs as of firmware version V2.0 support secure communication with addressing via a Domain Name System (DNS).

For secure TCP communication over the domain name you need to create a data block with the TCON_QDN_SEC system data type yourself, assign parameters and call it directly at one of the instructions TSEND_C, TRCV_C or TCON.

Requirements:

- Current date and time are set in the CPU.
- Your network includes at least one DNS server.
- You have configured at least one DNS server for the S7-1500 CPU.
- TLS client and TLS server have all the required certificates.

To set up a secure TCP connection to a TLS server, follow these steps:

1. Create a global data block in the project tree.
2. Define a tag of the data type TCON_QDN_SEC in the global data block.

The example below shows the global data block "Data_block_1" in which the tag "DNS ConnectionSEC" of the data type TCON_QDN_SEC is defined.

Data_block_1				
	Name	Data type	Start value	Comment
1	Static			
2	DNS Connection SEC	TCON_QDN_SEC		
3	ConnPara	TCON_QDN		parameter of the TCP connection
4	Interfaceld	HW_ANY	0	not relevant
5	ID	CONN_OUC	5	connection reference / identifier
6	ConnectionType	Byte	11	type of connection: 16#0B=11=TCP/IP, 16#13
7	ActiveEstablished	Bool	true	active/passive connection establishment
8	RemoteQDN	String[254]	'plc_1.factory127.'	fully or partially qualified domain name of rem
9	RemotePort	UInt	4000	remote UDP / TCP port number
10	LocalPort	UInt	0	local UDP / TCP port number
11	ActivateSecureConn	Bool	true	activate the security functionality of that conn
12	TLSServerReqClientCert	Bool	false	Just for server side: The TLS server requests a
13	ExtTLSCapabilities	Word	16#0	Bit 0: Just for client side: validate given IPv4 ad
14	TLSServerCertRef	UDInt	7	for Server side: Reference to own X.509 V3 se
15	TLSClientCertRef	UDInt	0	for Client side: add id of own X.509 V3 client c

Figure 6-12 Data type TCON_QDN_SEC

3. Set the connection parameters of the TCP connection in the "Start value" column. Enter the fully qualified domain name (FQDN) of the TLS server, for example, for "RemoteQDN".
4. Set the parameters for secure communication in the "Start value" column.
 - "ActivateSecureConn": Activation of secure communication for this connection. If this parameter has the value FALSE, the subsequent security parameters are irrelevant. You can set up a non-secure TCP or UDP connection in this case.
 - "ExtTLSCapabilities": If you enter the value 1, the client validates the subjectAlternateName in the X.509-V3 certificate of the server to verify the identity of the server. This validation is executed in the context of the instruction.
 - "TLSServerCertRef": ID of the X.509-V3 certificate (usually a CA certificate) that is used by the TLS client to validate the TLS server authentication. If this parameter is 0, the TLS client uses all (CA) certificates currently loaded in the client certificate store to validate the server authentication.

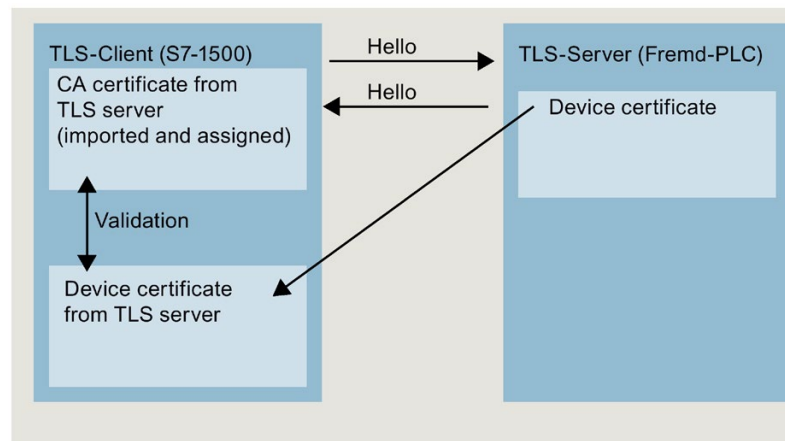


Figure 6-13 Certificate handling from the perspective of the S7-1500 as a TLS client

- "TLSClientCertRef": ID of the own X.509-V3 certificate.

- 5. Create one of the instructions TSEND_C, TRCV_C or TCON in the program editor.
- 6. Interconnect the CONNECT parameter of one of the instructions TSEND_C, TRCV_C or TCON with the tags of the data type TCON_QDN_SEC.

In the example below, the CONNECT parameter of the TCON instruction is interconnected with the tag "DNS connectionSEC" (data type TCON_QDN_SEC).

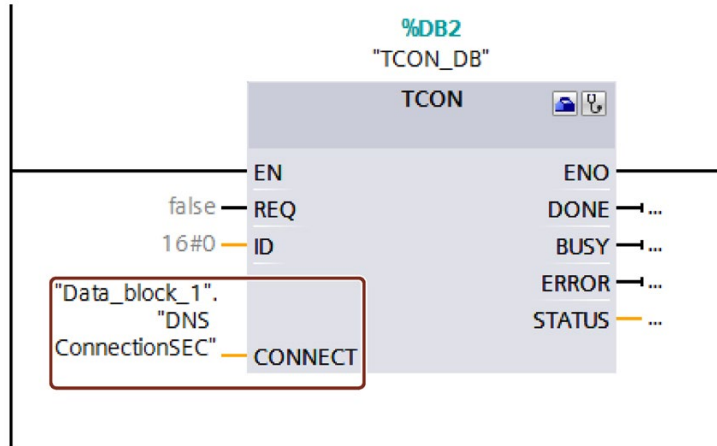


Figure 6-14 TCON instruction

Additional information

You can find more information on the TCON_QDN_SEC system data type in the STEP 7 online help.

For additional information on secure communication, refer to the section Secure Communication (Page 34).

6.11.2 Secure OUC of an S7-1500 CPU as TLS server to an external PLC (TLS client)

The following section describes how you can set up Open User Communication via TCP from an S7-1500 CPU as TLS server to a TLS client.

Setting up a secure TCP connection via the domain name of the communication partner

S7-1500 CPUs as of firmware version V2.0 support secure communication with addressing via a Domain Name System (DNS).

For secure TCP communication over the domain name you need to create a data block with the TCON_QDN_SEC system data type yourself, assign parameters and call it directly at one of the instructions TSEND_C, TRCV_C or TCON.

Requirements:

- Current date and time are set in the CPU.
- Your network includes at least one DNS server.
- You have configured at least one DNS server for the S7-1500 CPU.
- TLS client and TLS server have all the required certificates.

To set up a secure TCP connection to a TLS client, follow these steps:

1. Create a global data block in the project tree.
2. Define a tag of the data type TCON_QDN_SEC in the global data block.

The example below shows the global data block "Data_block_1" in which the tag "DNS ConnectionSEC" of the data type TCON_FDL_SEC is defined.

Data_block_1				
	Name	Data type	Start value	Comment
1	Static			
2	DNS Connection SEC2	TCON_QDN_SEC		
3	ConnPara	TCON_QDN		parameter of the TCP connection
4	Interfaceld	HW_ANY	0	not relevant
5	ID	CONN_OUC	8	connection reference / identifier
6	ConnectionType	Byte	11	type of connection: 16#0B=11=TCP/IP, 16#13=...
7	ActiveEstablished	Bool	false	active/passive connection establishment
8	RemoteQDN	String[254]	"	fully or partially qualified domain name of rem
9	RemotePort	UInt	0	remote UDP / TCP port number
10	LocalPort	UInt	2010	local UDP / TCP port number
11	ActivateSecureConn	Bool	true	activate the security functionality of that conn
12	TLSServerReqClientCert	Bool	false	Just for server side: The TLS server requests a
13	ExtTLSCapabilities	Word	16#0	Bit 0: Just for client side: validate given IPv4 ad
14	TLSServerCertRef	UDInt	5	for Server side: Reference to own X.509 V3 se
15	TLSClientCertRef	UDInt	0	for Client side: add id of own X.509 V3 client c

Figure 6-15 TCON_QDN_SEC_Server

3. Set the connection parameters of the TCP connection in the "Start value" column. Enter, for example, the local ID of the TCP connection for "ID".

4. Set the parameters for secure communication in the "Start value" column.
 - "ActivateSecureConn": Activation of secure communication for this connection. If this parameter has the value FALSE, the subsequent security parameters are irrelevant. You can set up a non-secure TCP or UDP connection in this case.
 - "TLSServerReqClientCert": Request for an X.509-V3 certificate from the TLS client.
 - "TLSServerCertRef": ID of the own X.509-V3 certificate.

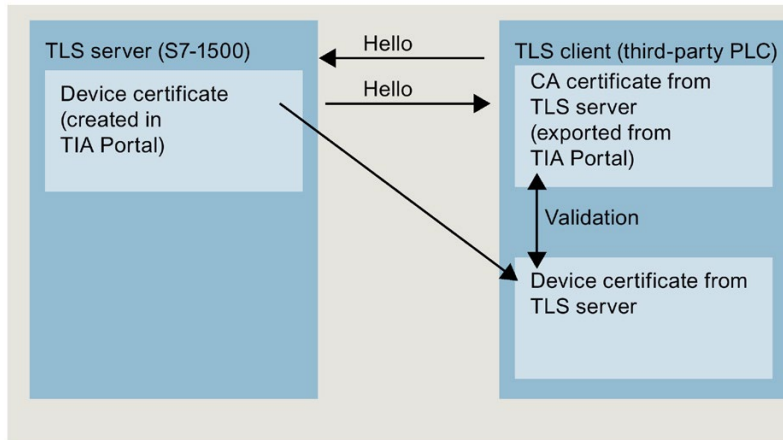


Figure 6-16 Certificate handling from the perspective of the S7-1500 as TLS server

- "TLSCClientCertRef": ID of the X.509-V3 certificate (or a group of X.509-V3 certificates) that is used by the TLS server to validate TLS client authentication. If this parameter is 0, the TLS server uses all (CA) certificates currently loaded in the server certificate store to validate the client authentication.
5. Create one of the instructions TSEND_C, TRCV_C or TCON in the program editor.
 6. Interconnect the CONNECT parameter of one of the instructions TSEND_C, TRCV_C or TCON with the tags of the data type TCON_QDN_SEC.

In the example below, the CONNECT parameter of the TCON instruction is interconnected with the tag "DNS connectionSEC" (data type TCON_QDN_SEC).

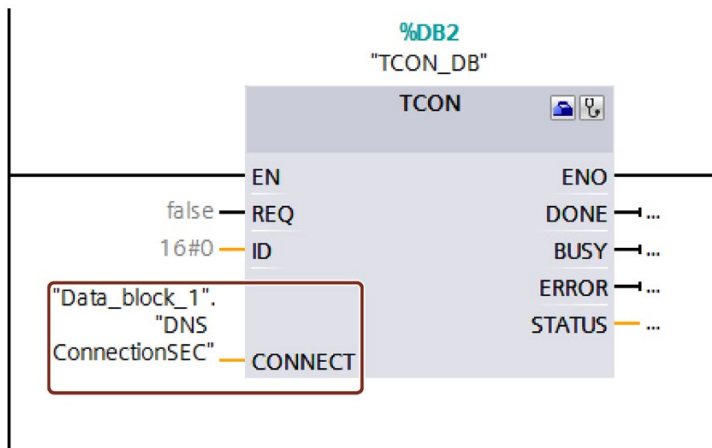


Figure 6-17 TCON instruction

Additional information

You can find more information about the system data types TCON_QDN_SEC in the STEP 7 online help.

For additional information on secure communication, refer to the section Secure Communication (Page 34).

6.11.3 Secure OUC between two S7-1500 CPUs

The following section describes how you can set Secure Open User Communication via TCP between two S7-1500 CPUs. In the process one S7-1500 CPU acts as TLS client (active establishing of the connection) and the other S7-1500 CPU as TLS server (passive establishing of the connection).

Setting up a secure TCP connection between two S7-1500 CPUs

For secure TCP communication between two S7-1500 CPUs you need to create a data block with the TCON_IP_V4_SEC system data type yourself in every CPU, assign parameters and call it directly at one of the instructions TSEND_C, TRCV_C or TCON.

Requirements:

- Current date and time are set in the CPU.
- Both S7-1500 CPUs have at least firmware version V2.0
- TLS client and TLS server have all the required certificates.

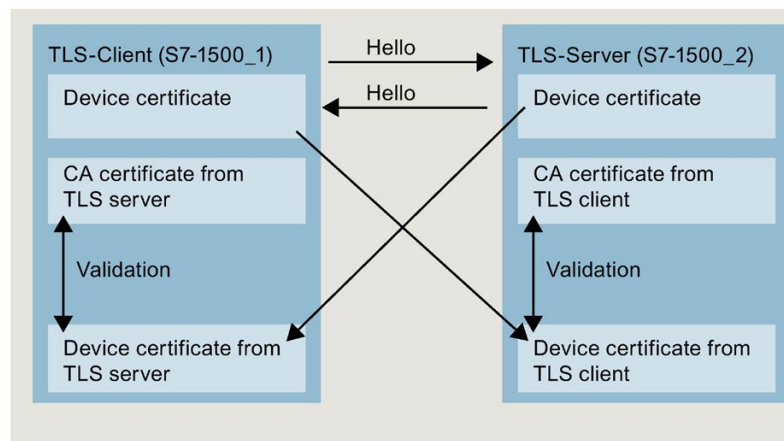


Figure 6-18 Certificate handling for Secure OUC between two S7-1500 CPUs

Settings at the TLS client

To set up a secure TCP connection in the TLS client, follow these steps:

1. Create a global data block in the project tree.
2. Define a tag of the data type TCON_IP_4_SEC in the global data block.

The example below shows the global data block "Data_block_1" in which the tag "SEC connection 1 TLS-Client" of the data type TCON_IP_V4_SEC is defined.

Data_block_1				
	Name	Data type	Start value	Comment
1	▼ Static			
2	▼ SEC connection 1 TLS-Client	TCON_IP_V4_SEC		
3	▼ ConnPara	TCON_IP_v4		parameter of the TCP connection
4	InterfaceId	HW_ANY	72	HW-identifier of IE-interface submodule
5	ID	CONN_OUC	10	connection reference / identifier
6	ConnectionType	Byte	11	type of connction: 11=TCP/IP, 19=UDP (17=TCP/IP)
7	ActiveEstablished	Bool	true	active/passive connection establishment
8	▼ RemoteAddress	IP_V4		remote IP address (IPv4)
9	▼ ADDR	Array[1..4] of Byte		IPv4 address
10	ADDR[1]	Byte	192	IPv4 address
11	ADDR[2]	Byte	168	IPv4 address
12	ADDR[3]	Byte	1	IPv4 address
13	ADDR[4]	Byte	100	IPv4 address
14	RemotePort	UInt	4711	remote UDP/TCP port number
15	LocalPort	UInt	4711	local UDP/TCP port number
16	ActivateSecureConn	Bool	true	activate the security functionality of that connection in general
17	TLSServerReqClientCert	Bool	false	Just for server side: The TLS server requests a client certificate
18	ExtTLSCapabilities	Word	16#0	Bit 0: Just for client side: validate given IPv4 address against the
19	TLSServerCertRef	UDInt	1	for Server side: Reference to own X.509 V3 server certificate; for
20	TLSClientCertRef	UDInt	5	for Client side: add id of own X.509 V3 client certificate; for Sen

Figure 6-19 IP_V4_SEC_Client

3. Set the connection parameters of the TCP connection in the "Start value" column. For example, enter the IPv4 address of the TLS server for "RemoteAddress".

Note

Connection parameter Interface ID

Note that you can enter the value "0" for the interface ID in the data type TCON_IP_V4_SEC. In this case, the CPU itself searches for a suitable local CPU interface.

4. Set the parameters for secure communication in the "Start value" column.
 - "ActivateSecureConn": Activation of secure communication for this connection. If this parameter has the value FALSE, the subsequent security parameters are irrelevant. You can set up a non-secure TCP or UDP connection in this case.
 - "TLSServerCertRef": Enter the value 2 (reference to the CA certificate of the TIA Portal project (SHA256)) or the value 1 (reference to the CA certificate of the TIA Portal project (SHA1)). If you use a different CA certificate, enter the corresponding ID from the certificate manager of the global security settings.
 - "TLSClientCertRef": ID of the own X.509-V3 certificate.
5. Create one of the instructions TSEND_C, TRCV_C or TCON in the program editor.
6. Interconnect the CONNECT parameter of one of the instructions TSEND_C, TRCV_C or TCON with the tags of the data type TCON_IP_V4_SEC.

Settings at the TLS server

To set up a secure TCP connection in the TLS server, follow these steps:

1. Create a global data block in the project tree.
2. Define a tag of the data type TCON_IP_4_SEC in the global data block.

The example below shows the global data block "Data_block_1" in which the tag "SEC connection 1 TLS-Server" of the data type TCON_IP_V4_SEC is defined.

Data_block_1				
	Name	Data type	Start value	Comment
1	Static			
2	SEC connection 1 TLS-Server	TCON_IP_V4_SEC		
3	ConnPara	TCON_IP_v4		parameter of the TCP connection
4	Interfaceld	HW_ANY	120	HW-identifier of IE-interface submodule
5	ID	CONN_OUC	10	connection reference / identifier
6	ConnectionType	Byte	11	type of connetion: 11=TCP/IP, 19=UDP (17=TCP/IP)
7	ActiveEstablished	Bool	false	active/passive connection establishment
8	RemoteAddress	IP_V4		remote IP address (IPv4)
9	ADDR	Array[1..4] of Byte		IPv4 address
10	ADDR[1]	Byte	192	IPv4 address
11	ADDR[2]	Byte	168	IPv4 address
12	ADDR[3]	Byte	1	IPv4 address
13	ADDR[4]	Byte	10	IPv4 address
14	RemotePort	UInt	4711	remote UDP/TCP port number
15	LocalPort	UInt	4711	local UDP/TCP port number
16	ActivateSecureConn	Bool	true	activate the security functionality of that connection in general
17	TLSServerReqClientCert	Bool	true	Just for server side: The TLS server requests a client certificate
18	ExtTLSCapabilities	Word	16#0	Bit 0: Just for client side: validate given IPv4 address against the
19	TLSServerCertRef	UDInt	6	for Server side: Reference to own X.509 V3 server certificate; fo
20	TLSClientCertRef	UDInt	1	for Client side: add id of own X.509 V3 client certificate; for Serv

Figure 6-20 IP_V4_SEC_Server

3. Set the connection parameters of the TCP connection in the "Start value" column. For example, enter the IPv4 address of the TLS client for "RemoteAddress".

4. Set the parameters for secure communication in the "Start value" column.
 - "ActivateSecureConn": Activation of secure communication for this connection. If this parameter has the value FALSE, the subsequent security parameters are irrelevant. You can set up a non-secure TCP or UDP connection in this case.
 - "TLSServerReqClientCert ": Request for an X.509-V3 certificate from the TLS client. Enter the value "true".
 - "TLSServerCertRef": ID of the own X.509-V3 certificate.
 - "TLSClientCertRef": Enter the value 2 (reference to the CA certificate of the TIA Portal project (SHA256) or the value 1 (reference to the CA certificate of the TIA Portal project (SHA1)). If you use a different CA certificate, enter the corresponding ID from the certificate manager of the global security settings.
5. Create one of the instructions TSEND_C, TRCV_C or TCON in the program editor.
6. Interconnect the CONNECT parameter of one of the instructions TSEND_C, TRCV_C or TCON with the tags of the data type TCON_IP_V4_SEC.

In the example below, the CONNECT parameter of the TSEND_C instruction is interconnected with the "SEC connection 1 TLS-Server" tags (data type TCON_IP_4_SEC).

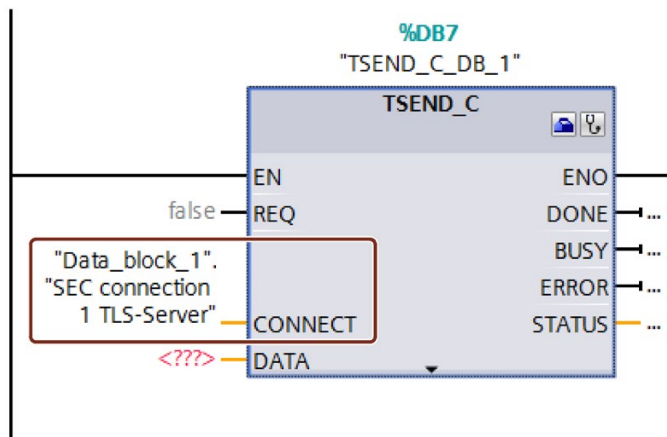


Figure 6-21 TSEND_C

Additional information

You can find more information about the system data types TCON_IP_4_SEC in the STEP 7 online help.

For additional information on secure communication, refer to the section Secure Communication (Page 34).

6.11.4 Secure OUC via CP interface

The following sections describes the particular points to be taken into consideration in the case of Secure Open User Communication via a CP interface. At least one station is an S7-1500 station with the following modules:

- S7-1500 CPU as of firmware version V2.0 (with the exception of S7-1500 Software Controller)
- CP 1543-1 as of firmware version V2.0 or CP 1543SP-1 as firmware version V1.0

The CP acts in an S7-1500 station as a TLS client (active connection establishment) or a TLS server (passive connection establishment).

The fundamental procedure and the concept for using secure communication via a CP interface is similar to that of secure communication via the interfaces of the S7-1500 CPUs. Essentially, you have to assign the certificates to the CPU in the role of a TLS server or TLS client and not to the CP. Other rules and procedures therefore apply. These are described below.

Handling certificates for CPs

The following applies in general: You have to be logged on at the certificate manager in the global security settings. The generation of self-signed certificates also requires logon for the global security settings. You have to have sufficient rights as a user (administrator or user with the "Standard" role with the right to "Configure security").

The starting point for the generation or assignment of certificates at the CP is the section "Security > Security properties". In this section, you log on for the global security settings.

Procedure:

1. In the network view of STEP 7, mark the CP and select the section "Security > Security properties" in the Inspector window.
2. Click on the "User logon" button.
3. Log on using your user name and password.
4. Enable the "Activate security functions" option.

The security properties are initialized.

5. Click in the first line of the "Device certificates" table to generate a new certificate or select an existing device certificate.
6. If the communication partner is also an S7-1500 station, you also have to assign a device certificate to the communication partner with STEP 7 as described here or for the S7-1500 CPU.

Example: Setting up a secure TCP connection between two S7-1500 CPUs via CP interfaces

For secure TCP communication between two S7-1500 CPUs you need to create a data block with the TCON_IP_V4_SEC system data type yourself in every CPU, assign parameters and call it directly at one of the instructions TSEND_C, TRCV_C or TCON.

Requirements:

- Both S7 1500 CPUs have at least firmware version V2.0. If you use the CP 1543SP-1: Firmware version as of V1.0.
- Both CPs (for example CP 1543-1) must have at least firmware version V2.0
- TLS client and TLS server have all the required certificates.
 - A device certificate (end-entity certificate) for the CP must be generated and be located in the certificate memory of the CP. If a communication partner is an external device (for example an MES or ERP system), a device certificate also has to exist for this device.
 - The root certificate (CA certificate) with which the device certificate of the communication partner is signed must also be located in the certificate memory of the CP or in the certificate memory of the external device. If you use intermediate certificates, you have to ensure that the complete certificate path exists in the validating device. A device uses these certificates to validate the device certificate of the communication partner.
- The communication partner must always be addressed via its IPv4 address, not via its domain name.

The following figure shows the different certificates in the devices for the case that both communication partners communicate via a CP 1543-1. In addition, the figure shows the transfer of the device certificates during establishment of the connection ("Hello").

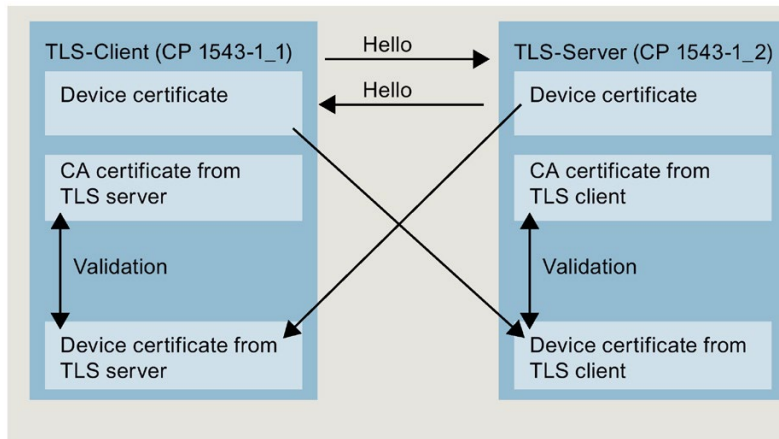


Figure 6-22 Certificate handling in secure OUC between two S7-1500 CPUs via CP interfaces.

Settings at the TLS client

To set up a secure TCP connection in the TLS client, follow these steps:

1. Create a global data block in the project tree.
2. Define a tag of the data type TCON_IP_4_SEC in the global data block. To do so, enter the string "TCON_IP_V4_SEC" in the "Data type" field.

The example below shows the global data block "Data_block_1" in which the tag "SEC connection 1 TLS-Client" of the data type TCON_IP_V4_SEC is defined.

The Interface ID has the value of the HW identifier of the IE interface of the local CP (TLS client).

Data_block_1				
	Name	Data type	Start value	Comment
1	Static			
2	SEC connection 1 TLS-Client	TCON_IP_V4_SEC		
3	ConnPara	TCON_IP_v4		parameter of the TCP connection
4	Interfaceld	HW_ANY	258	HW-identifier of IE-interface submodule
5	ID	CONN_OUC	10	connection reference / identifier
6	ConnectionType	Byte	11	type of connetion: 11=TCP/IP, 19=UDP (17=TCP/IP)
7	ActiveEstablished	Bool	true	active/passive connection establishment
8	RemoteAddress	IP_V4		remote IP address (IPv4)
9	ADDR	Array[1..4] of Byte		IPv4 address
10	ADDR[1]	Byte	192	IPv4 address
11	ADDR[2]	Byte	168	IPv4 address
12	ADDR[3]	Byte	1	IPv4 address
13	ADDR[4]	Byte	100	IPv4 address
14	RemotePort	UInt	4711	remote UDP/TCP port number
15	LocalPort	UInt	4711	local UDP/TCP port number
16	ActivateSecureConn	Bool	true	activate the security functionality of that connection in general
17	TLSServerReqClientCert	Bool	false	Just for server side: The TLS server requests a client certificate
18	ExtTLSCapabilities	Word	16#0	Bit 0: Just for client side: validate given IPv4 address against the
19	TLSServerCertRef	UDInt	1	for Server side: Reference to own X.509 V3 server certificate; for
20	TLSClientCertRef	UDInt	5	for Client side: add id of own X.509 V3 client certificate; for Ser

Figure 6-23 IP_V4_SEC_Client

3. Set the connection parameters of the TCP connection in the "Start value" column. For example, enter the IPv4 address of the TLS server for "RemoteAddress".
4. Set the parameters for secure communication in the "Start value" column.
 - "ActivateSecureConn": Activation of secure communication for this connection. If this parameter has the value FALSE, the subsequent security parameters are irrelevant. You can set up a non-secure TCP or UDP connection in this case.
 - "TLSServerCertRef": Enter the value 2 (reference to the CA certificate of the TIA Portal project (SHA256) or the value 1 (reference to the CA certificate of the TIA Portal project (SHA1)). If you use a different CA certificate, enter the corresponding ID from the certificate manager of the global security settings.
 - "TLSClientCertRef": ID of the own X.509-V3 certificate.

5. Create one of the instructions TSEND_C, TRCV_C or TCON in the program editor.
6. Interconnect the CONNECT parameter of one of the instructions TSEND_C, TRCV_C or TCON with the tags of the data type TCON_IP_V4_SEC.

Settings at the TLS server

To set up a secure TCP connection in the TLS server, follow these steps:

1. Create a global data block in the project tree.
2. Define a tag of the data type TCON_IP_4_SEC in the global data block.

The example below shows the global data block "Data_block_1" in which the tag "SEC connection 1 TLS-Server" of the data type TCON_IP_V4_SEC is defined.

The interface ID has the value of the HW identifier of the IE interface of the local CP (TLS server).

Data_block_1				
	Name	Data type	Start value	Comment
1	Static			
2	SEC connection 1 TLS-Server	TCON_IP_V4_SEC		
3	ConnPara	TCON_IP_v4		parameter of the TCP connection
4	InterfaceId	HW_ANY	260	HW-identifier of IE-interface submodule
5	ID	CONN_OUC	10	connection reference / identifier
6	ConnectionType	Byte	11	type of connction: 11=TCP/IP, 19=UDP (17=TCP/IP)
7	ActiveEstablished	Bool	false	active/passive connection establishment
8	RemoteAddress	IP_V4		remote IP address (IPv4)
9	ADDR	Array[1..4] of Byte		IPv4 address
10	ADDR[1]	Byte	192	IPv4 address
11	ADDR[2]	Byte	168	IPv4 address
12	ADDR[3]	Byte	1	IPv4 address
13	ADDR[4]	Byte	10	IPv4 address
14	RemotePort	UInt	4711	remote UDP/TCP port number
15	LocalPort	UInt	4711	local UDP/TCP port number
16	ActivateSecureConn	Bool	true	activate the security functionality of that connection in general
17	TLSServerReqClientCert	Bool	true	Just for server side: The TLS server requests a client certificate
18	ExtTLSCapabilities	Word	16#0	Bit 0: Just for client side: validate given IPv4 address against the
19	TLSServerCertRef	UDInt	6	for Server side: Reference to own X.509 V3 server certificate; for
20	TLSClientCertRef	UDInt	1	for Client side: add id of own X.509 V3 client certificate; for Serv

Figure 6-24 IP_V4_SEC_Server

3. Set the connection parameters of the TCP connection in the "Start value" column. For example, enter the IPv4 address of the TLS client for "RemoteAddress".

4. Set the parameters for secure communication in the "Start value" column.
 - "ActivateSecureConn": Activation of secure communication for this connection. If this parameter has the value FALSE, the subsequent security parameters are irrelevant. You can set up a non-secure TCP or UDP connection in this case.
 - "TLSServerReqClientCert ": Request for an X.509-V3 certificate from the TLS client. Enter the value "true".
 - "TLSServerCertRef": ID of the own X.509-V3 certificate.
 - "TLSClientCertRef": Enter the value 2 (reference to the CA certificate of the TIA Portal project (SHA256) or the value 1 (reference to the CA certificate of the TIA Portal project (SHA1)). If you use a different CA certificate, enter the corresponding ID from the certificate manager of the global security settings.
5. Create one of the instructions TSEND_C, TRCV_C or TCON in the program editor.
6. Interconnect the CONNECT parameter of the instruction TSEND_C, TRCV_C or TCON with the tags of the data type TCON_IP_V4_SEC.

Upload device as new station

When you upload a configuration with certificates and configured secure Open User Communication as a new station into your STEP 7 project, the certificates of the CP are not uploaded, in contrast to the certificates of the CPU. After the device has been loaded as a new station, no more certificates are contained in the corresponding tables of the CPs for the device certificates.

You have to perform configuration of certificates again after the upload. Otherwise, renewed loading of the configuration results in the certificates that originally exist in the CP being deleted so that secure communication does not function.

Secure OUC connections via CPU and CP interfaces - similarities

- Connection resources:
No differences between OUC and secure OUC. A programmed secure OUC connection uses a connection resource just like an OUC connection, irrespective of which IE/PROFINET interface communicates with the station.
- Connection diagnostics:
No differences between OUC and secure OUC connection diagnostics.
- Loading of projects with secure OUC connections into the CPU:
Only possible in STOP of the CPU, if certificates are loaded as well.
Recommendation: Load to device > Hardware and software. Reason: Ensuring the consistency between the program with secure OUC, hardware configuration and certificates.
Certificates are loaded with the hardware configuration - therefore loading requires a stop of the CPU. The reloading of blocks that utilize further secure OUC connections is only possible in RUN if the certificates required for this purpose are already located on the module.

6.11.5 Secure OUC with Modbus TCP

For secure Modbus TCP connection you need to create a data block with one of the system data types TCON_IP_V4_SEC or TCON_QDN_SEC yourself, assign parameters and call it directly at the MB_Server or MB_CLIENT instruction.

Requirements:

- S7-1500 CPU CPU firmware version V2.5 or higher
- The Modbus client (TLS client) can reach the Modbus server (TLS server) over IP communication in the network.
- TLS client and TLS server have all the required certificates.

Example of setting up a secure Modbus TCP connection to a Modbus TCP server

The following section describes how you can set up a Secure Open User Communication over Modbus TCP from a Modbus TCP client to a Modbus TCP server.

To set up a secure connection from a Modbus TCP client (TLS client) to a Modbus TCP server (TLS server) and set up the IPv4 address of the mail server, follow these steps:

1. Create a global data block in the project tree.
2. Define a tag of the data type TCON_IP_V4_SEC in the global data block.

Data_block_1				
	Name	Data type	Start value	Comment
1	Static			
2	SEC_ModbusTCP_1	TCON_IP_V4...		
3	ConnPara	TCON_IP_v4		parameter of the TCP connection
4	InterfaceId	HW_ANY	64	HW-identifier of IE-interface submodule
5	ID	CONN_OUC	15	connection reference / identifier
6	ConnectionType	Byte	11	type of connection: 11=TCP/IP, 19=UDP (17=TCP/IP)
7	ActiveEstablished	Bool	true	active/passive connection establishment
8	RemoteAddress	IP_V4		remote IP address (IPv4)
9	ADDR	Array[1..4] of B...		IPv4 address
10	ADDR[1]	Byte	192	IPv4 address
11	ADDR[2]	Byte	168	IPv4 address
12	ADDR[3]	Byte	10	IPv4 address
13	ADDR[4]	Byte	100	IPv4 address
14	RemotePort	UInt	502	remote UDP/TCP port number
15	LocalPort	UInt	502	local UDP/TCP port number
16	ActivateSecureConn	Bool	true	activate the security functionality of that connection in general
17	TLSReqClientCert	Bool	false	Just for server side: The TLS server requests a client certificate
18	ExtTLSCapabilities	Word	0	Bit 0: Just for client side: validate given IPv4 address against the subjectAltName
19	TLSReqServerCertRef	UDInt	2	for Server side: Reference to own X.509 V3 server certificate; for Client side: Reference to own X.509 V3 client certificate
20	TLSClientCertRef	UDInt	7	for Client side: add id of own X.509 V3 client certificate; for Server side: add id of own X.509 V3 server certificate

Figure 6-25 TCON_IP_V4_SEC

3. Set the connection parameters of the TCP connection in the "Start value" column. Enter the IPv4 address of the mail server, for example, for the "MailServerAddress".

4. Set the parameters for secure communication in the "Start value" column. Enter the certificate ID of the CA certificate of the communication partner, for example, for "TLSServerCertRef".
 - "ActivateSecureConn": Activation of secure communication for this connection. If this parameter has the value FALSE, the subsequent security parameters are irrelevant. In this case you can set up an unsecured Modbus TCP connection.
 - "TLSServerCertRef": Reference to the X.509 V3 (CA) certificate of the Modbus TCP server, which is used by the TLS client to validate the authentication of the Modbus TCP server.
5. Create an MB_CLIENT instruction in the program editor.
6. Interconnect the CONNECT parameter of the MB_Client instruction with the tags of the data type TCON_IP_4_SEC.

6.11.6 Secure OUC via e-mail

Setting up a secure connection to a mail server over the CPU interface

For secure communication to a mail server you need to create a data block with one of the system data types TMAIL_V4_SEC, TMAIL_QDN_SEC yourself, assign parameters and call it directly at the TMAIL_C instruction.

Requirements:

- TMAIL_C instruction version V5.0 or higher
- STEP 7 V15 and higher
- S7-1500 CPU V2.5 and higher
- You have assigned all the CA certificates of the mail server (TLS server) to the CPU (TLS client) and have downloaded the configuration to the CPU.
- Current date and time are set in the CPU.

Process for establishing a secure connection to the mail server

You can choose between two processes for establishing the secure connection to the mail server:

- **SMTPS:** The client attempts to immediately establish a TLS connection to the mail server ("handshake" process). If the mail server does not support TLS, then no connection is established.
- **STARTTLS:** Client establishes a TCP connection to the mail server. The client sends a request to "upgrade" the existing connection to a secure TLC connection over the TCP connection. If the mail server supports TLS, the client sends the command to establish a secure connection. The mail server uses the SMTP command "STARTTLS" to do this. The client then establishes a secure connection to the mail server. Advantage: If the mail server does not support TLS, client and mail server can communicate unsecured with each other.

You use the "Remote Port" setting in the data types at the block parameter "MAIL_ADDR_PARAM" to define which process is used for the communication.

Table 6- 6 Port numbers for the SMTPS and STARTTLS processes

Process	Port
SMTPS:	465 ¹
STARTTLS	Any (≠465) ²

¹ The instruction TMAIL_C uses SMTPS only for Port 465. For all other ports STARTTLS is used.

² According to RFC, mail servers use Ports 25 and 587 for secure connections with STARTTLS. The use of other port numbers for SMTP is not RFC-compliant, successful communication with such a mail server is not guaranteed.

Example: Setting up a secure connection to a mail server over IPv4

The following section describes how to set up a secure connection to an IPv4 mail server with the TMAIL_C communication instruction.

To set up a secure connection via the IP4 address of the mail server, follow these steps:

1. Create a global data block in the project tree.
2. Define a tag of the data type TMAIL_V4_SEC in the global data block.

The example below shows the global data block "MailConnDB" in which the tag "MailConnectionSEC" of the data type TMAIL_V4_SEC is defined.

MailConnDB				
	Name	Datentyp	Startwert	Kommentar
	Static			
	MailConnectionSEC	TMail_V4_SEC		
	InterfaceId	HW_ANY	"Local~CP_1543-1_1~Ethernet-Schnittstelle_1"	Use HWidentifier of the IE-interface to specify the connection reference / identifier
	ID	CONN_OUC	100	connection reference / identifier
	ConnectionType	Byte	16#20	type of connection 16#20=32=TMail_V4 or TMail_V4_SEC
	ActiveEstablished	Bool	true	active / passive connection establishment
	WatchDogTime	Time	T#5000ms	watchdog time to monitor SMTP server association
	MailServerAddress	IP_V4		IPv4 address of mail server
	ADDR	Array[1..4] of Byte		IPv4 address
	ADDR[1]	Byte	144	IPv4 address
	ADDR[2]	Byte	145	IPv4 address
	ADDR[3]	Byte	2	IPv4 address
	ADDR[4]	Byte	20	IPv4 address
	UserName	String[254]	'myName'	user name which is necessary to login into the mail server
	PassWord	String[254]	'myPW'	user password which is necessary to login into the mail server
	From	EMAIL_ADDR		source mail address
	LocalPartPlusAt...	String[64]	'Mustermann@'	local part of e-mail address plus "@" sign
	FullQualifiedD...	String[254]	'siemens.com'	full qualified domain name part of e-mail address
	RemotePort	UInt	587	remote TCP port number
	ActivateSecureConn	Bool	TRUE	activate the security functionality of that connection
	ExtTLSCapabilities	Byte	16#0	for further capability extensions of the TLS handshake
	TLSServerCertRef	UDInt	7	Reference to the X.509 V3 (CA-) certificate of the mail server

Figure 6-26 Data type TMAIL_V4_SEC

3. Set the connection parameters of the TCP connection in the "Start value" column. Enter the IPv4 address of the mail server, for example, for the "MailServerAddress".

Note

Connection parameter Interface ID

Note that as of instruction version V5.0 of TMAIL_C instruction in the TMAIL_V4_SEC data type, you need to enter the value "0" for the Interface ID. In this case, the CPU itself searches for a suitable local CPU interface.

4. Set the parameters for secure communication in the "Start value" column. Enter the certificate ID of the CA certificate of the communication partner, for example, for "TLSServerCertRef".
 - "ActivateSecureConn": Activation of secure communication for this connection. If this parameter has the value FALSE, the subsequent security parameters are irrelevant. You can set up a non-secure TCP or UDP connection in this case.
 - "TLSServerCertRef": Reference to the X.509 V3 (CA) certificate of the mail server, which is used by the TLS client to validate the authentication of the mail server.
5. Create a TMAIL_C instruction in the program editor.
6. Interconnect the MAIL_ADDR_PARAM parameter of the TMAIL_C instruction with the tag of the data type TMAIL_V4_SEC.

In the following example the MAIL_ADDR_PARAM parameter of the TMAIL_C instruction is interconnected with the tag "MailConnectionSEC" (data type TMAIL_V4_SEC).

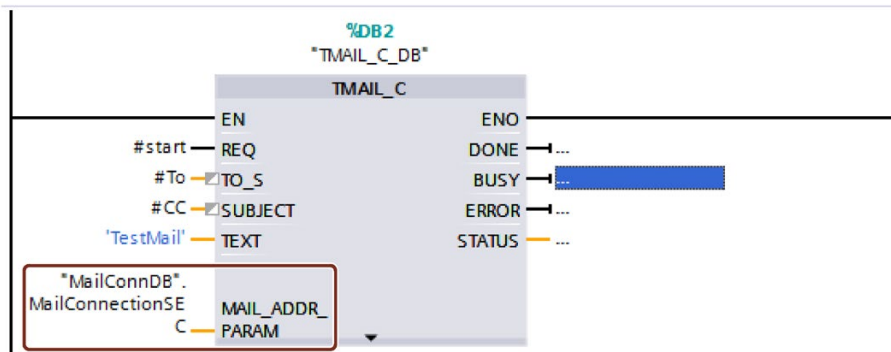


Figure 6-27 TMAIL_C instruction

Setting up a secure connection to a mail server over the interface of a communication module

For secure communication to a mail server over a communication module, you need to create a data block with one of the system data types TMAIL_V4_SEC, TMAIL_QDN_SEC or TMAIL_V6_SEC yourself, assign parameters and call it directly at the TMAIL_C instruction.

Requirements:

- TMAIL_C instruction with version **V4.0**
- S7-1500 CPU as of firmware version V2.0 with communication module CP 1543-1 as of firmware version V2.0
- ET 200SP CPU as of firmware version V2.0 with communication module CP 1542SP-1 (IRC) as of firmware version V1.0
- You have assigned all the CA certificates of the mail server (TLS server) to the CP (TLS client) and have downloaded the configuration to the CPU.
- Current date and time are set in the CPU.

The STEP 7 online help describes how to set up a secure connection to a mail server over the interface of a communication module.

Application example

This application example (<https://support.industry.siemens.com/cs/ww/en/view/46817803>) show how you can use the CP of an S7-1500 or S7-1200 station to set up a secure connection to an email server and send an email with the default application "TMAIL_C" from the S7 CPU.

Additional information

You can find more information about the system data types TMail_V4_SEC and TMAIL_QDN_SEC in the STEP 7 online help.

For additional information on secure communication, refer to the section Secure Communication (Page 34).

S7 communication

Characteristics of S7 communication

S7 communication as homogeneous SIMATIC communication is characterized by vendor-specific communication between SIMATIC CPUs (not an open standard). S7 communication is used for migration and for connecting to existing systems (S7-300, S7-400).

For data transfer between two S7-1500 automation systems, we recommend that you use open communication (see section Open User Communication (Page 65)).

Properties of S7 communication

Using S7 communication, the CPU exchanges data with another CPU. Once the user has received the data at the receiver end, the reception data is automatically acknowledged to the sending CPU.

The data is exchanged via configured S7 connections. S7 connections can be configured at one end or at both ends.

S7 communication is possible via:

- Integrated PROFINET or PROFIBUS DP interface of a CPU
- Interface of a CP/CM

S7 connections configured at one end

For an S7 connection configured at one end, the configuration for this connection takes place in only one communication partner and is only downloaded to it.

A one-sided S7 connection can be configured to a CPU that is only a server of an S7 connection (e.g. CPU 315-2 DP). The CPU is configured and the address parameters and interfaces are thus known.

In addition, a one-sided S7 connection can be configured to a partner who is not in the project and whose address parameters and interface and therefore are not known. You need to enter the address; it is not checked by STEP 7. The partner is initially unspecified (no partner address is registered when you create the S7 connection). Once you enter the address, it is "unknown" (i.e. it is named, but the project is unknown).

This makes it possible to use S7 connections beyond the boundaries of a project. The communication partner is unknown to the local project (unspecified) and is configured in another STEP 7 or third-party project.

S7 connections configured at both ends

When an S7 connection is configured at both ends, the configuration and download of the configured S7 connection parameters takes place in both communication partners.

Instructions for S7 communication

For S7 communication with S7-1500, the following instructions can be used:

- **PUT/GET**

You write data to a remote CPU with the PUT instruction. You can use the GET instruction to read data from a remote CPU. The PUT and GET instructions are one-sided instructions, i.e. you need only an instruction in one communication partner. You can easily set up the PUT and GET instructions via the connection configuration.

Note

Data blocks for PUT/GET instructions

When using the PUT/GET instructions, you can only use data blocks with absolute addressing. Symbolic addressing of data blocks is not possible.

You must also enable this service for protection in the CPU configuration in the "Protection" area.

This FAQ (<https://support.industry.siemens.com/cs/ww/en/view/82212115>) provides information about how to configure and program an S7 instruction and the GET and PUT communication instructions for data exchange between two S7-1500 CPUs.

- **BSEND/BRCV**

The BSEND instruction sends data to a remote partner instruction of the type BRCV. The BRCV instruction receives data from a remote partner instruction of the type BSEND. You use the S7 communication via the BSEND/BRCV instruction pair for secure transmission of data.

- **USEND/URCV**

The USEND instruction sends data to a remote partner instruction of the type URCV. The URCV instruction receives data from a remote partner instruction of the type USEND. You use the S7 communication via the USEND/URCV instruction pair for fast, non-secure transmission of data regardless of the timing of the processing by the communications partner; for example for operating and maintenance messages.

S7 communication via PROFIBUS DP interface in slave mode

You can find the "Test, commissioning, routing" check box in STEP 7 in the properties of the PROFIBUS DP interface of communications modules (e.g. CM 1542-5). Using this check box, you decide whether the PROFIBUS DP interface of the DP slave is an active or passive device on PROFIBUS.

- Check box selected: The slave is an active device on PROFIBUS.
- Check box cleared: The DP slave is a passive device on PROFIBUS. You can only set up S7 connections configured at one end for this DP slave.

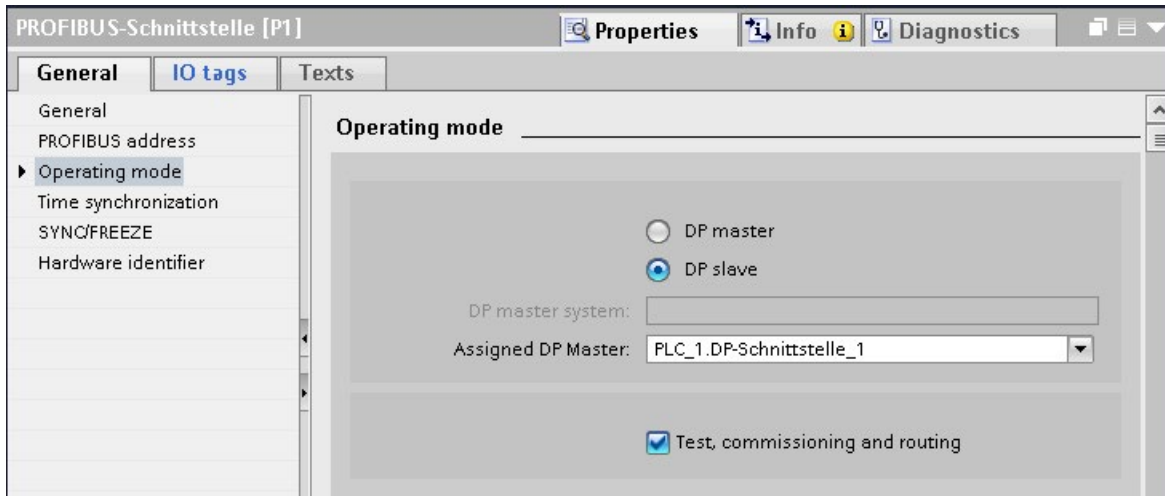


Figure 7-1 "Test, commissioning, routing" check box

Configuring S7 connections for PUT/GET instructions

You can create S7 connections and assign the parameters for these in the connection parameter assignment of the PUT/GET instructions. Changed values are checked immediately by the connection parameter assignment for input errors.

Requirement: A PUT or GET instruction is created in the programming editor.

To configure an S7 connection using PUT/GET instructions, follow these steps:

1. In the program editor, select the call of the PUT or GET instruction.
2. Open the "Properties > Configuration" tab in the inspector window.

3. Select the "Connection parameters" group. Until you select a connection partner, only the empty drop-down list for the partner end point is enabled. All other input options are disabled.

The connection parameters already known are displayed:

- Name of the local end point
- Interface of the local end point
- IPv4 address of the local end point

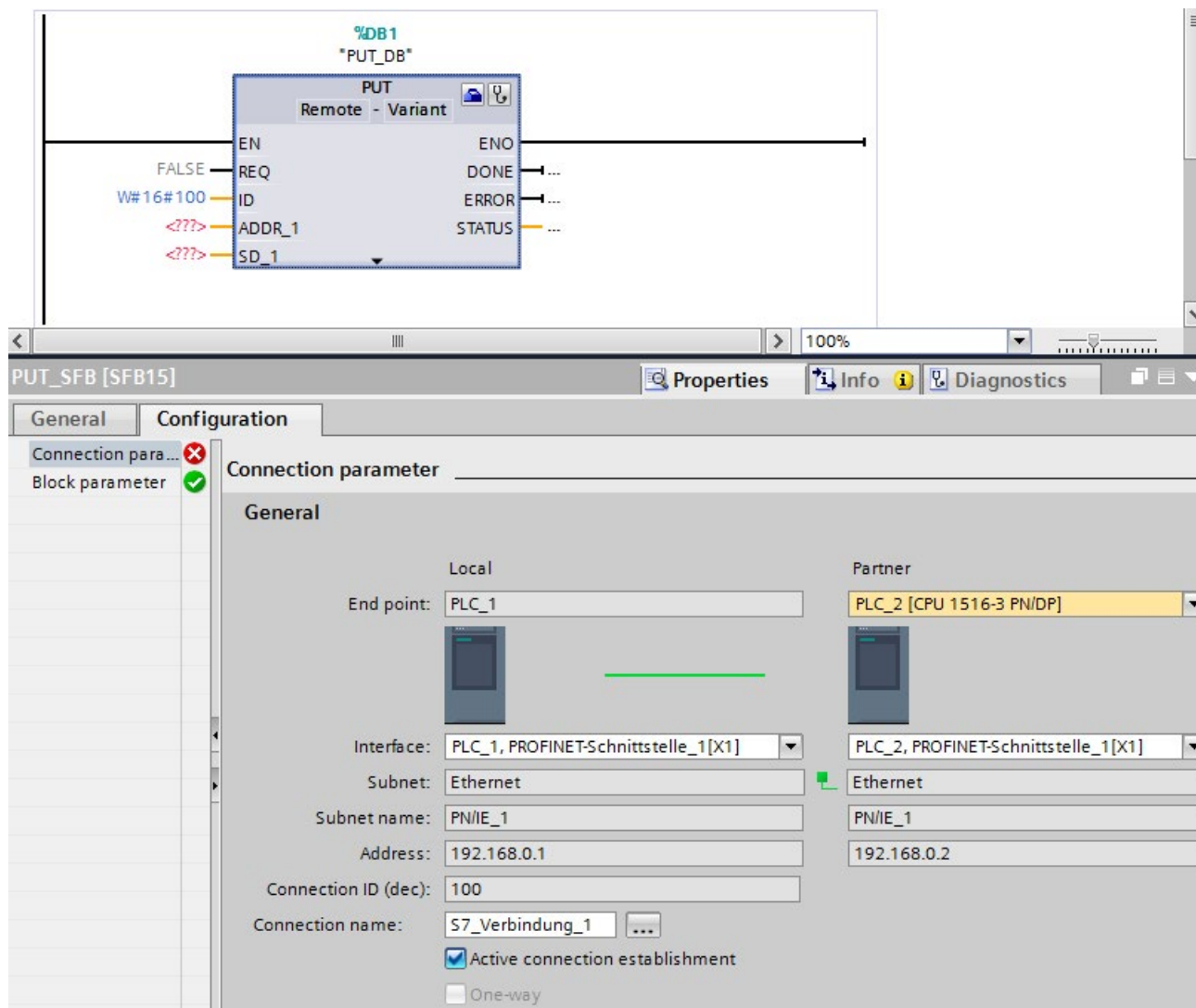


Figure 7-2 Connection configuration for PUT instruction

4. In the drop-down list box of the partner end point, select a connection partner. You can select an unspecified device or a CPU in the project as the communication partner.

The following parameters are automatically entered as soon as you have selected the connection partner:

- Name of the partner end point
 - Interface of the partner end point. If several interfaces are available, you can change the interface as required.
 - Interface type of the partner end point
 - Subnet name of both end points
 - IPv4 address of the partner end point
 - Name of the connection which is used for the communication.
5. If required, change the connection name in the "Connection name" input box. If you want to create a new connection or edit an existing connection, click on the "Select connection" button on the right side next to the input box for the connection name.

Note

The PUT and GET instructions between two communication partners can only run if both the hardware configuration and the program part for the partner end point have been loaded into the hardware. To achieve fully functional communication, make sure that you load not only the connection description of the local CPU on the device but also that of the partner CPU as well.

Configuring S7 connections for e.g. BSEND/BRCV

If you want to use the instructions for BSEND/BRCV for S7 communication, for example, you first need to configure an S7 connection.

To configure a S7 connection, follow these steps:

1. Configure the communications partners in the network view of the Devices & networks editor of STEP 7.
2. Select the "Connections" button and the "S7 connection" entry from the drop-down list.
3. Using drag-and-drop, connect the communication partner with each other (via an interface or local end point). If the required S7 subnet does not yet exist, it is created automatically.

You can also set up a connection to unspecified partners.

4. In the "Connections" tab, select the row of the S7 connection.
5. Set the properties of the S7 connection in the "Properties" tab in the "General" area, for example the name of the connection and the interfaces of the communications partner that will be used.

For S7 connections to an unspecified partner, set the address of the partner.

You can find the local ID (reference of the S7 connection in the user program) in the "Local ID" area.

6. In the Project tree, select the "Program blocks" folder for one of the CPUs and open OB1 in the folder by double-clicking on it. The program editor opens.
7. In the program editor, call the relevant instructions for S7 communication in the user program of the communication partner (configured at one end) or in the user programs of the communication partners (configured at both ends). Select the BSEND and BRCV instructions from the "Communication" area of the "Instructions" task card, for example, and drag them to a network of OB1.
8. At the ID parameter of the instruction, assign the local ID of the configured connection to be used for the transmission of data.
9. Assign the parameters for the instructions indicating which data will be written to where and which data will be read from where.
10. Download the hardware configuration and user program to the CPU(s).

S7 communication via CP 1543-1

If you set up S7 communication via the Industrial Ethernet interface of the CP 1543-1, you can select the transport protocol for data transfer in the properties of the S7 connection under "General":

- "TCP/IP" check box selected (default): ISO-on-TCP (RFC 1006): for S7 communication between S7-1500 CPUs
- "TCP/IP" check box cleared: ISO protocol (ISO/IEC 8073): Addressing using MAC addresses

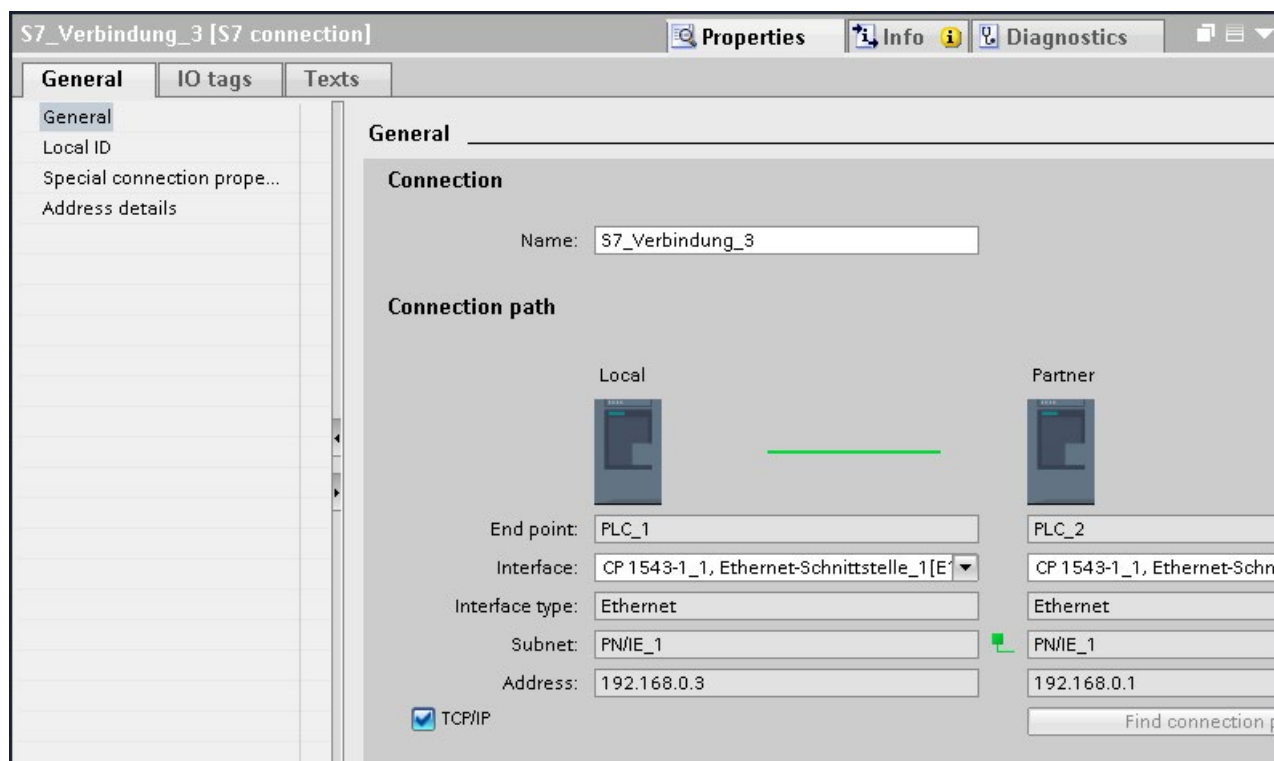


Figure 7-3 Selecting the CP 1543-1 transport protocol

Procedure for setting up an S7 connection via different S7 subnets

You have the option of using an S7 connection over multiple S7 subnets (PROFIBUS, PROFINET/Industrial Ethernet) (S7 routing (Page 289)).

1. Configure the communications partners in the network view of the Devices & networks editor of STEP 7.
2. Select the "Network" button.
3. Connect the relevant interfaces with the S7 subnets (PROFIBUS, PROFINET/Industrial Ethernet) using drag-and-drop.

4. Select the "Connections" button and the "S7 connection" entry from the drop-down list.
5. Using drag-and-drop in our example, connect PLC_1 in the left S7 subnet (PROFIBUS) to PLC_3 in the right S7 subnet (PROFINET).

The S7 connection between CPU 1 and CPU 3 is configured.

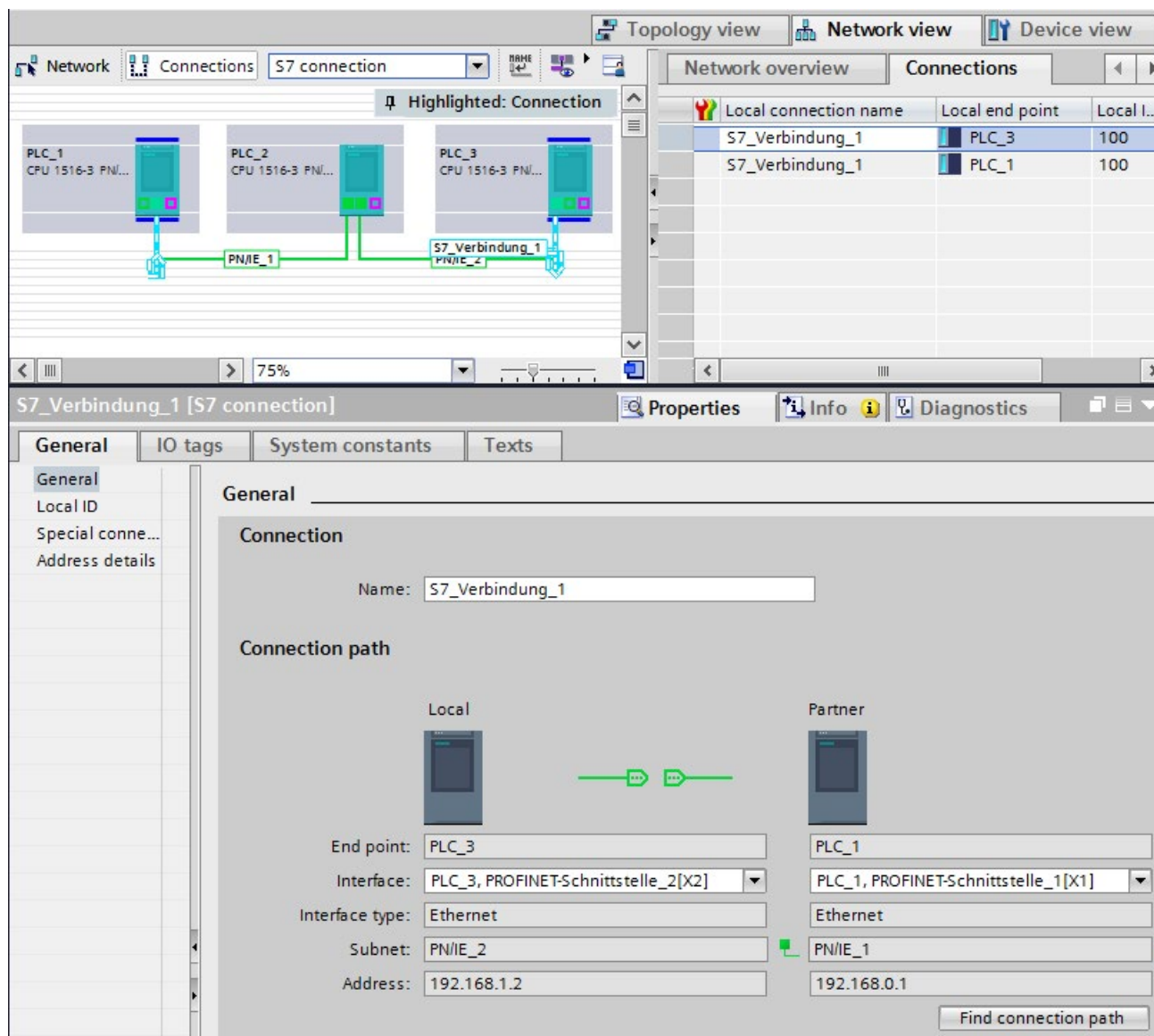


Figure 7-4 S7 connections via different subnets

ET 200SP Open Controller as router for S7 connections

If you assign the "PROFINET onboard [X2]" interface to the CPU 1515SP PC (F) of the SIMATIC PC station, the CPU 1515SP PC (F) can be used as a router for S7 connections. If you use the CP interface for "None, or a different Windows setting", you cannot use the Open Controller as a router for routed S7 connections.

An existing S7 connection routed by the CPU 1515SP PC (F) becomes invalid if the assignment of the interface of the CPU 1515SP PC (F) is changed from "SIMATIC PC station" to "None, or a different Windows setting". Since the PLC now no longer handles routing functions for this connection, when the CPU 1515SP PC (F) is compiled, no message relating to the invalid connection is displayed. The invalid routed S7 connection is displayed only when the end points of the connection are compiled.

The interfaces required for routed S7 connections must remain explicitly assigned on the CPU 1515SP PC (F) . You can edit the assignment of the interface of the CPU 1515SP PC (F) in the properties under "PROFINET onboard [X2] > Interface assignment".

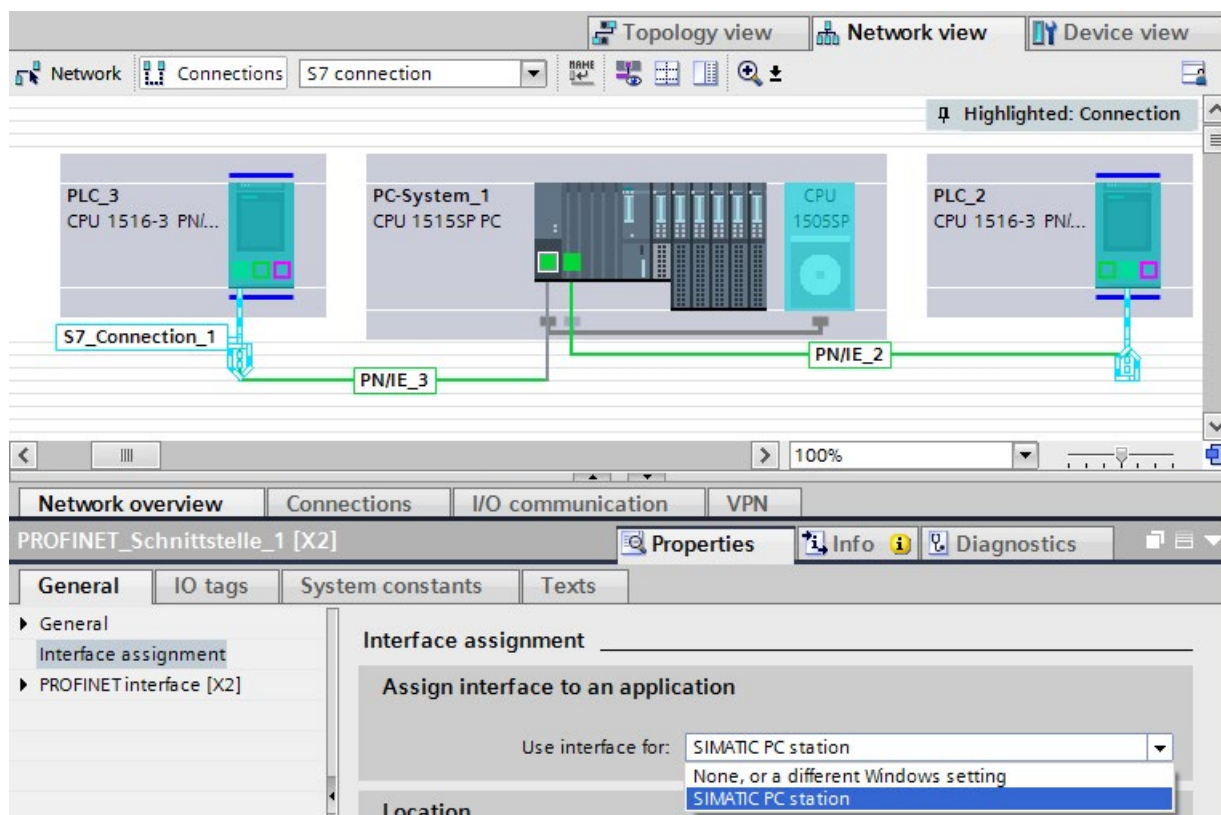


Figure 7-5 S7 routing PC station

Additional information

You can find detailed information on configuring S7 connections and how to use the instructions for S7 communication in the user program in the STEP 7 online help.

Point-to-point link

Functionality

A point-to-point connection for S7-1500, ET 200MP and ET 200SP is established via communications modules (CMs) with serial interfaces (RS232, RS422 or RS485):

- S7-1500/ET 200MP:
 - CM PtP RS232 BA
 - CM PtP RS422/485 BA
 - CM PtP RS232 HF
 - CM PtP RS422/485 HF
- ET 200SP:
 - CM PtP

The bidirectional data exchange via a point-to-point connection works between communications modules or third-party systems or devices capable of communication. At least 2 communication partners are required for communication ("point-to-point"). With RS422 and RS485, more than two communications partners are possible.

Protocols for communication via a point-to-point connection

- Freeport protocol (also called ASCII protocol)
- Procedure 3964(R)
- Modbus protocol in RTU format (RTU: Remote Terminal Unit)
- USS protocol (universal serial interface protocol)

The protocols use different layers according to the ISO/OSI reference model:

- Freeport: Uses layer 1 (physical layer)
- 3964 (R), USS and Modbus: Use layer 1 and 2 (physical layer and data link layer; therefore greater transmission reliability than with Freeport). USS and Modbus use additionally layer 4.

Properties of the Freeport protocol

- The recipient recognizes the end of the data transfer by means of a selectable end criterion (e.g. character delay time elapsed, receipt of end character, receipt of a fixed amount of data).
- The sender cannot recognize whether the sent data arrived free of errors at the recipient.

Properties of procedure 3964 (R)

- When the data is sent, control characters are added (start, end and block check characters). Make sure that these control characters are not included as data in the frame.
- Connection establishment and termination makes use of control characters.
- If transfer errors occur, data transfer is automatically repeated.

Data exchange using Freeport or 3964 (R) communication

The data to be sent is stored in the user program of the corresponding CPU in data blocks (send buffer). A receive buffer is available on the communications module for the received data. Check the properties of the receive buffer and adapt them if necessary. You must create a data block for receiving in the CPU.

In the user program of the CPU, the "Send_P2P" and "Receive_P2P" instructions handle the data transfer between the CPU and CM.

Procedure for setting up Freeport or 3964 (R) communication

1. Configure an S7-1500 configuration with CPU and CM in the device view of the hardware and network editor of STEP 7.
2. Select the interface of the CM in the device view of STEP 7.
3. Assign the parameters of the interface (for example connection communication, configuration of message sending) in the Inspector window of STEP 7 under "Properties" > "General".
4. Select the "Send_P2P" or "Receive_P2P" instruction in the "Instructions" task card under "Communication" > "Communications processor" and drag-and-drop the instruction into the user program (for example into a FB).
5. Assign the parameters for the instructions according to your configuration.
6. Download the hardware configuration and user program to the CPU.

Otherwise: Dynamic parameter assignment of the communications module

In certain types of application it is an advantage to set up communication dynamically; in other words, program-controlled by a specific application.

Typical applications for this, could be, for example manufacturers of serial machines. To make the user interfaces as convenient as possible for their customers, these manufacturers adapt the communications services to the particular operator entries.

Instructions for Freeport communication

There are 3 instructions available for the dynamic configuration in the user program for Freeport communication. The following applies to all 3 instructions: the previously valid configuration data is overwritten but not stored permanently in the target system.

- The "Port_Config" instruction is used for the program-controlled configuration of the relevant port of the communications module.
- The "Send_Config" instruction is used for the dynamic configuration, for example of time intervals and breaks in transmission (serial transmission parameters) for the relevant port.
- The "Receive_Config" instruction is used for dynamic configuration, for example of conditions for the start and end of a message to be transferred (serial receive parameters) for the relevant port.

Instructions for 3964 (R) communication

There are 2 instructions available for dynamic configuration in the user program for 3964 (R) communication. The following applies to the instructions: the previously valid configuration data is overwritten but not stored permanently in the target system.

- The "Port_Config" instruction is used for the program-controlled configuration of the relevant port of the communications module.
- The "P3964_Config" instruction is used for the dynamic configuration of protocol parameters.

Properties of the USS protocol

- Simple, serial data transfer protocol with cyclic message frame traffic in half duplex mode that is tailored to the requirements of drive technology.
- Data transfer works according to the master-slave principle.
 - The master has access to the functions of the drive and can, among other things, control the drive, read status values and read and write the drive parameters.

Data exchange using USS communication

The communications module is the master. The master continuously sends frames (job frames) to the up to 16 drives and expects a response frame from each addressed drive.

A drive sends a response frame under the following conditions:

- When a frame is received without errors
- When the drive is addressed in this frame

A drive must not send if these conditions are not met or the drive was addressed in the broadcast.

The connection to the relevant drives exists for the master once it receives a response frame from the drive after a specified processing time (response delay time).

Procedure for setting up USS communication

1. Configure an S7-1500 configuration with CPU and CM in the device view of the hardware and network editor of STEP 7.
2. In the Project tree, select the "Program blocks" folder and open OB1 in the folder by double-clicking on it. The program editor opens.
3. Select the instructions for USS communication according to your task in the "Communication" area, "Communications processor" folder of the "Instructions" task card and drag them to a network of OB1:
 - The "USS_Port_Scan" instruction allows you to communicate via the USS network.
 - The "USS_Drive_Control" instruction prepares send data for the drive and evaluates the response data of the drive.
 - The "USS_Read_Param" instruction is used to read out parameters from the drive.
 - The "USS_Write_Param" instruction is used to change parameters on the drive.
4. Assign the parameters for the instructions according to your configuration.
5. Download the hardware configuration and user program to the CPU.

Properties of the Modbus protocol (RTU)

- Communication takes the form of serial, asynchronous transfer with a transmission speed of up to 115.2 kbps, half duplex.
- Data transfer works according to the master-slave principle.
- The Modbus master can send jobs for reading and writing operands to the Modbus slave:
 - Reading inputs, timers, counters, outputs, memory bits, data blocks
 - Writing outputs, memory bits, data blocks
- Broadcast to all slaves is possible.

Data exchange using Modbus communication (RTU)

The communications module can be a Modbus master or Modbus slave. A Modbus master can communicate with one or more Modbus slaves (the number depends on the physical interface). Only the Modbus slave explicitly addressed by the Modbus master is permitted to return data to the Modbus master. The slave detects the end of the data transfer and acknowledges it. If an error occurs, it provides an error code to the master.

Procedure for setting up Modbus communication (RTU)

1. Configure an S7-1500 configuration with CPU and CM in the device view of the hardware and network editor of STEP 7.
2. In the Project tree, select the "Program blocks" folder and open OB1 in the folder by double-clicking on it. The program editor opens.
3. Select the instructions for Modbus communication according to your task in the "Communication" area, "Communications processor" folder of the "Instructions" task card and drag them to a network of OB1:
 - The "Modbus_Comm_Load" instruction configures the port of the CM for Modbus communication.
 - The "Modbus_Master" instruction is used for Modbus master functionality.
 - The "Modbus_Slave" instruction is used for Modbus slave functionality.
4. Assign the parameters for the instructions according to your configuration.
5. Download the hardware configuration and user program to the CPU.

Additional information

- You can find more detailed information on communication via point-to-point connections and basics of serial data transmission in the function manual CM PtP communication module - Configurations for point-to-point connections (<http://support.automation.siemens.com/WW/view/en/59057093>).
- You can find a description of how to use the instructions for point-to-point connections in the user program in the STEP 7 online help.
- You can find information about the communications modules with a serial interface in the manual of the particular communications module.

OPC UA communication

9.1 What you need to know about OPC UA

9.1.1 OPC UA and Industrie 4.0

Uniform standard for information and data exchange

Industry 4.0 stands for the intensive utilization, evaluation and analysis of the large volumes of data from production in IT systems at the enterprise level. With Industry 4.0, data exchange between the production and enterprise levels is rapidly increasing. However, a prerequisite for success is a uniform standard for the information and data exchange.

Classic OPC only runs on Windows operating systems. To get around this restriction, the OPC Foundation developed the OPC UA (OPC Unified Architecture) standard.

The OPC UA standard is particularly suitable for data exchange across different levels thanks to its independence from specific operating systems, its secure transfer procedures and the semantic description of data. Machine data (controlled variables, measured values or parameters) can also be transferred in this way.

An important component of this concept is that OPC UA communication can take place in parallel with real-time communication for time-critical, machine-level data transfer.

OPC UA is highly scalable so that a consistent information exchange between sensors, controllers and MES or ERP systems is possible.

OPC UA makes available not only data but also information about the data (data types), at the same time making possible machine-interpretable access to the data.

9.1.2 General features of OPC UA

OPC UA and PROFINET

OPC UA and PROFINET can be used together. The two protocols use the same network infrastructure.

Independence from the operating system

The OPC UA standard is platform-independent and uses an optimized TCP-based binary protocol for high-performance applications.

OPC UA can be used, for example, under Windows, Linux, Mac OS X, a realtime operating system or a mobile operating system (Android or iOS).

Independence of a specific transport layer

OPC UA currently supports the following transport mechanisms and protocols:

- The transfer of messages as a binary stream directly via TCP/IP
- The transfer of messages with XML via TCP/IP and HTTP. This transport mechanism allows only a slow transfer and is therefore almost never used. S7-1500 CPUs do not support this transport mechanism.

Binary data exchange is supported by all OPC UA applications (required in OPC UA specification).

Simple client-server principle

An OPC UA server provides a great deal of information within a network, e.g. relating to the CPU, the OPC UA server itself, the data and the data types. An OPC UA client accesses this information.

Implementation in different programming languages

The OPC Foundation has implemented the OPC UA standard in several programming languages: Stacks for .NET, ANSI C and Java are available, although maintenance has been discontinued for the stacks for ANSI C and Java.

The OPC Foundation offers the .NET stack as well as example programs as open source software. See Github (<https://github.com/opcfoundation>).

A number of companies offer Software Development Kits (SDK). These development packages contain the stacks of the OPC Foundation and other functionalities that facilitate the development of solutions.

Advantages of using SDKs:

- Support from the supplier
- Tested software
- Detailed documentation
- Clear license conditions (important for selling of solutions)

Scalability

OPC UA can be used for devices of different performance classes:

- Sensors
- Embedded systems
- Controllers
- PC systems
- Smartphones
- Servers running MES or ERP applications.

The performance class of the devices is differentiated by profiles. Different OPC UA profiles offer the possibility to scale OPC UA for very small and simple devices as well as for very high-performance devices.

An OPC UA profile describes functions and services that must be supported by the server and client. In addition, other functionalities/services that are not required by the profile can be optionally provided.

OPC UA profiles differ from PROFINET profiles; the latter define additional cross-vendor properties and behavior for installations and systems in the sense of a vendor-neutral software interface.

Nano Embedded Device 2017 Server Profile

For the smallest devices with severely limited functionality, there is the "Nano Embedded Device 2017 Server Profile" of the OPC Foundation. This profile is functionally equivalent to the core server facet and defines the OPC UA TCP binary protocol as the required transport profile. The profile allows for connections without UA Security and does not allow subscriptions or method calls. Support for diagnostic objects and variables is optional for this profile.

Additional profiles build on the "Nano Embedded Device 2017 Server Profile", requiring more resources and offering more functionality.

Micro Embedded Device 2017 Server Profile

This profile provides limited functionality; it requires at least two parallel connections. Additionally, it allows subscriptions/data monitoring, but no UA Security and no method calls.

- S7-1200 Basic Controllers support the "Micro Embedded Device 2017 Server Profile". The S7-1200 additionally supports UA Security.

Embedded 2017 UA Server Profile

This profile has been developed for devices with more than 50 MB RAM and a more high-performance processor. It is based on the Micro Embedded Device Server profile. In addition, it requires UA security and method calls.

In addition, the servers must make their used type model (data types, reference types, variable types, etc.) available.

- S7-1500 Advanced Controllers support the "Embedded 2017 UA Server Profile".

Standard and global discovery profiles

The "OPC UA Specification Part 7" defines additional profiles:

- The "Standard 2017 UA Server Profile", which is suitable for PC-based OPC UA servers
- 2 global profiles, "Global Discovery Server 2017 Profile" and "Global Discovery and Certificate Management 2017 Server Profile", that cover the required service and information models of a Global Discovery Server

Type-instance concept

OPC UA offers a fully networked (full-meshed network), object-oriented information model for namespaces, including metadata for the object description. Any object structures can be generated via referencing of the instances among each other and their types. Because servers disclose their instance and type systems, clients can navigate through this network and obtain all the information they need. Both instances and their type definitions are available in runtime.

Procedures or concepts on how to handle references to types are optimized over time. These optimizations lead to new versions of the OPC UA Specification (e.g. V1.03 => V1.04).

PLC tag mapping

The information of the OPC UA server (for example the PLC tags) is modeled as nodes connected to one another via references. The semantics are displayed by the server in the address space and can be acquired by clients (while navigating). This makes it possible to browse from node to node with an OPC UA client and find out what content can be read, monitored or written.

Integrated security mechanisms

OPC UA uses security mechanisms at various levels:

- A secure connection can only be established between an OPC UA server and an OPC UA client if the client and server can register with X.509-v3 certificates and accept each other's certificates (security at the application level). Various security policies are possible, including an unsecured connection between server and client (Security Policy: "No security").
- A server can always request the following information from the user for authorized access (authentication):
 - A user certificate (not configurable in STEP 7)
 - User name and password
 - No user authorization

The security mechanisms are optional and configurable.

See also

OPC Foundation (<https://opcfoundation.org>)

9.1.3 OPC UA for S7-1200/S7-1500 CPUs

In OPC UA, one system operates as a server and provides data the existing information to other systems (clients).

OPC UA clients, for example, have read and write access to data on an OPC UA server. OPC UA clients call methods on the OPC UA server.

You can access this data online with a client, including e.g. information on performance and diagnostics. In OPC UA terminology, this function is called "Browse". The "Subscription" function eliminates regular reading of a tag; with this function, the server informs a client about value changes.

A system can be both a client and a server at the same time.

OPC UA server of the S7-1500 CPU

As of firmware version 2.0, an S7-1500 CPU is equipped with an OPC UA server.

The following sections describe how you configure the OPC UA server of the S7-1500 CPU to make data and methods available for OPC UA clients so that clients have read or write access to PLC tags on the CPU and can call server methods.

The following sections also set out how to integrate companion specifications into the address space of the OPC UA server.

OPC UA server of the S7-1200 CPU

As of firmware V4.4, an S7-1200 CPU is equipped with an OPC UA server.

The OPC UA server is generally configured as it is for an S7-1500 CPU; the scope of functions and the quantity limits are limited according to the supported "Micro Embedded Device 2017 Server Profile". Unlike for an S7-1500 CPU, the following functions are **not** available:

- Server methods
- Structured data type (structures and arrays)
- Registered Read and Registered Write

You can find additional information in the STEP 7 online help.

OPC UA client of the S7-1500 CPU

As of firmware version V2.6, an S7-1500 CPU is additionally equipped with an OPC UA client.

The following sections show how to use standardized instructions (PLCOpen function blocks) to create a user program that, as an OPC UA client, provides the following functions:

- Reading data from an OPC UA server
- Writing data to an OPC UA server
- Calling methods of an OPC UA server

STEP 7 (TIA Portal) assists you in creating user programs by providing an editor for client interfaces and a parameter assignment for OPC UA connections.

The OPC UA instructions for an S7-1500 CPU as client are described in detail in the help to the instructions (Instructions > Communication > OPC UA).

OPC UA client for test purposes

The following description uses various different OPC UA clients to illustrate the use of OPC UA clients:

- "UaExpert" of Unified Automation. An extensive client that can be used free of charge:
Link for downloading UaExpert (<https://www.unified-automation.com/downloads/opc-ua-clients.html>)
- "UA Sample Client" of the OPC Foundation. This client is available free of charge for users who are registered with the OPC Foundation :
Link for downloading the example client of the OPC Foundation (<https://opcfoundation.org>)

Application example in Industry online support

Siemens Industry Online Support provides a free application example with a client API for various applications. You use the functions of this interface to create your own OPC UA clients that match your application. To simplify handling the API, we offer a higher-level .NET helper class.

The client API is based on the .NET OPC UA stack of the OPC Foundation.

The application example shows how to establish connections between servers and clients, for example. It also demonstrates the reading and writing of PLC tags.

Link to download: OPC UA .NET client for the SIMATIC S7-1500 OPC UA Server (<http://support.automation.siemens.com/WW/view/en/109737901>)

9.1.4 Access to OPC UA applications

The access possibilities that an S7-1500 CPU with an OPC UA application (client or server) has via a CP in the same station are described below. In addition, an approach for combining these access possibilities with the "IP Forwarding" function to allow access to devices of another IP subnet via an S7-1500 station is presented.

All the settings for this can be found in the CPU properties, "Advanced configuration" area in the Inspector window.

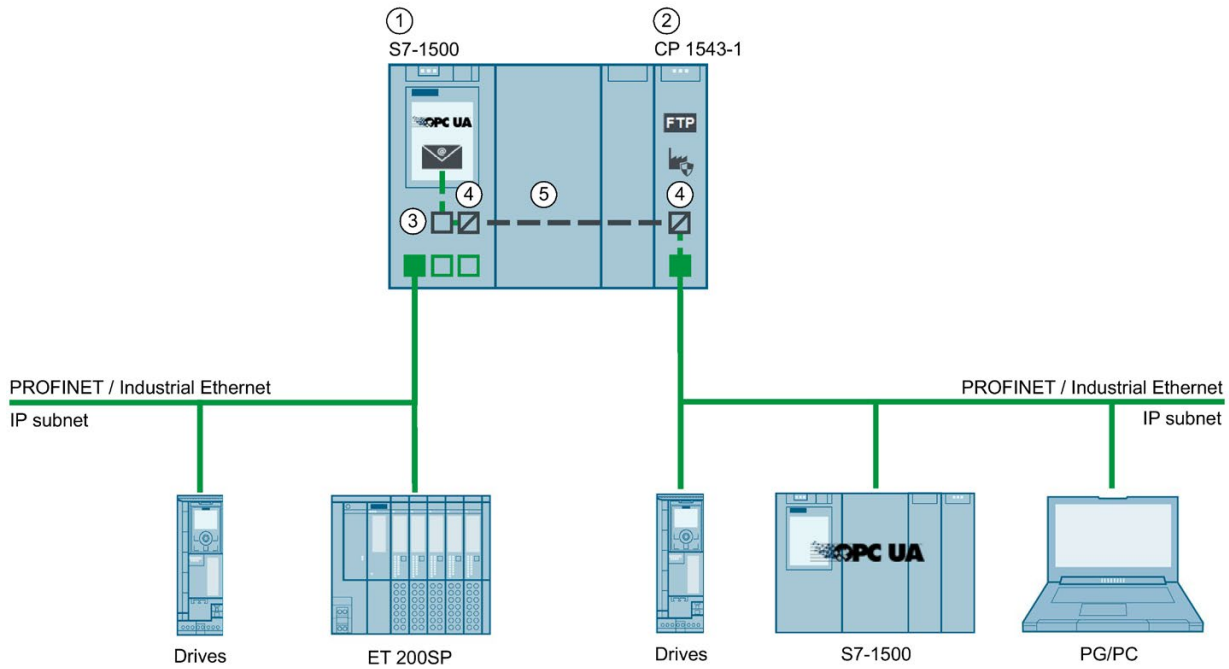
The possibility of accessing the OPC UA application in the CPU via CP interface is subject to the following requirements:

- S7-1500 CPU (except S7-1500 R/H) as of firmware version V2.8
- CP 1543-1 firmware version V2.2 or higher

Principle: Interface for access via communication module

For a CPU application, such as OPC UA, to be accessed via CP interface, you must configure a virtual interface (W1). IP-based applications can then be accessed via the IP address parameters of this virtual interface.

The schematic is shown in the following figure.



- ① CPU S7-1500 FW V2.8 or higher (e.g. CPU 1515-2 PN)
- ② CP 1543-1 (FW V2.2 or higher)
- ③ Virtual interface (W1)
- ④ Protocol conversion PROFINET / Industrial Ethernet on backplane bus or backplane bus on PROFINET / Industrial Ethernet
- ⑤ Backplane bus

Figure 9-1 Principle: Interface for access via communication module

Example: Access of OPC UA clients to the OPC UA server of the CPU

For access of an OPC UA client to the OPC UA server of the CPU, the following interfaces of the S7-1500 station are available:

- The local PROFINET interfaces of the S7-1500 CPU
- The Ethernet interface of a CP 1543-1 (firmware version V2.2 and higher)

The following figure shows an example of a possible configuration: The CPU could also have the role OPC UA client and the device on the subnet of the CP could have the role OPC UA server.

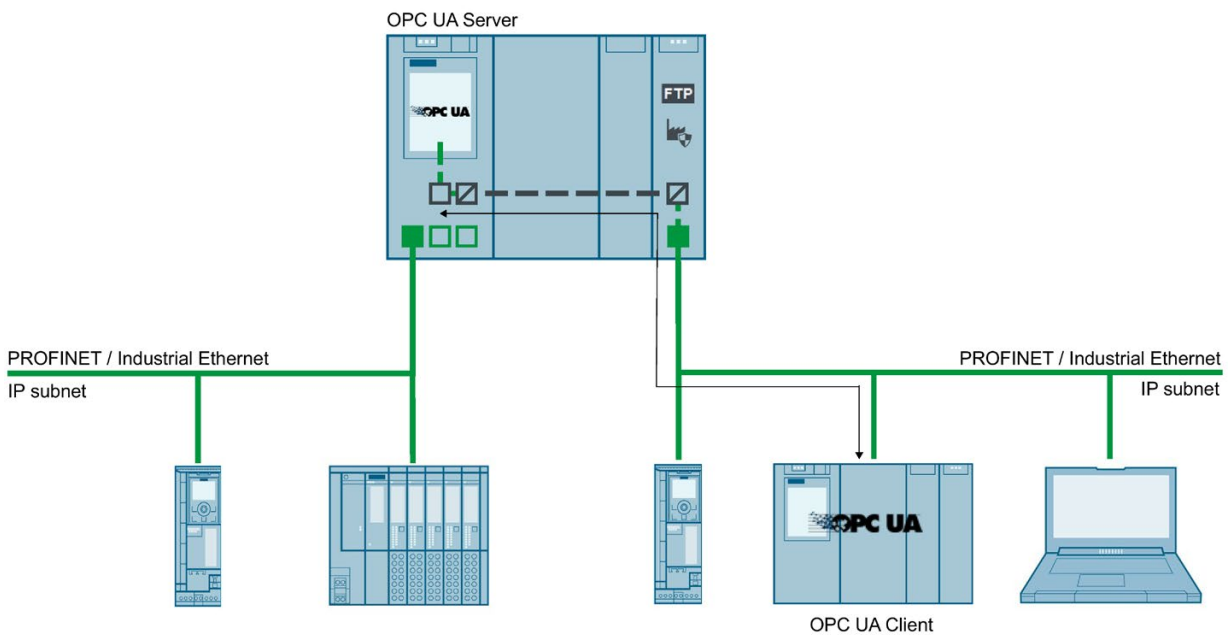


Figure 9-2 Example: Access of OPC UA clients to the OPC UA server of the CPU

Example: Access of OPC UA clients to OPC UA servers via S7-1500 CPU with activated IP Forwarding

OPC UA client and OPC UA server can also be connected to one another via an S7-1500 CPU, in which case the S7-1500 CPU operates as an IP Forwarder. This configuration option allows for flexible expansion of existing systems.

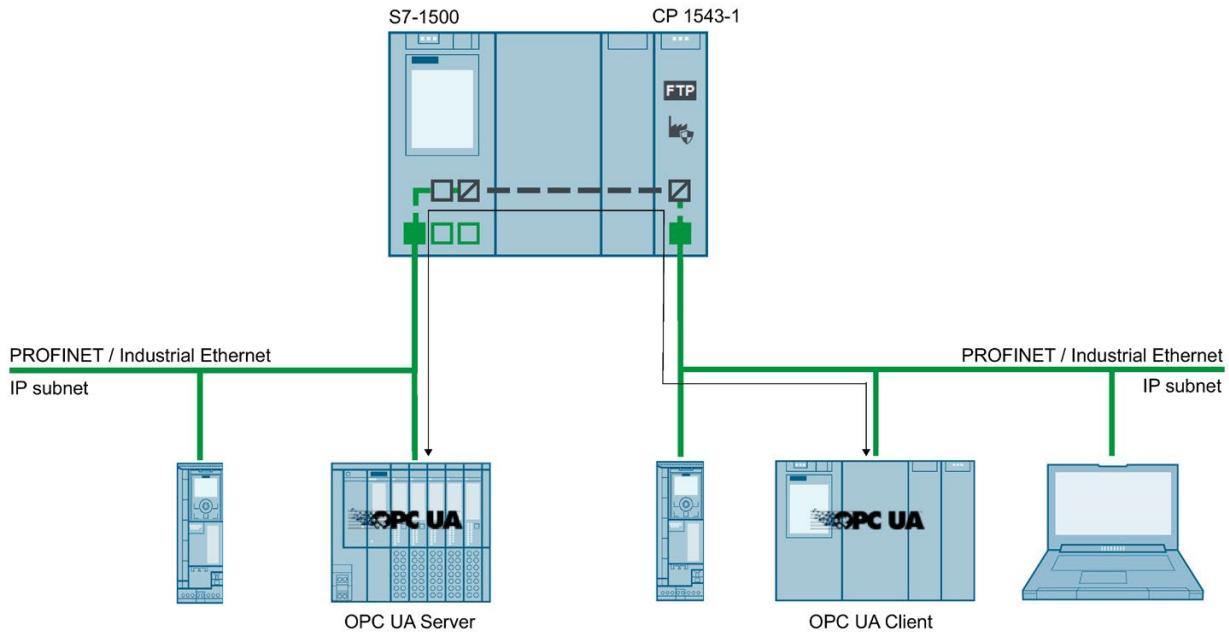


Figure 9-3 Example: Access of OPC UA clients to OPC UA servers via S7-1500 CPU with activated IP Forwarding

Additional information

Additional information on access options via the virtual interface and via IP forwarding can be found in the following sections:

- IP forwarding (Page 294)
- Virtual interface for IP-based applications (Page 303)

9.1.5 Addressing nodes

Nodes are the basic elements of OPC UA, they are comparable with objects from object-oriented programming. Nodes are used, for example, for user data (tags) or other metadata. Nodes are used to model an OPC UA address space that also contains a type model with type definitions.

Node ID (NodeId)

Nodes in the OPC UA address space are uniquely identified by a NodeId (Node Identifier).

The NodeId consists of an identifier, identifier type and a namespace index. Namespaces are used to avoid naming conflicts.

The OPC Foundation has defined a wide range of nodes that provide information about the given OPC UA server. These nodes can be found in the namespace of the OPC Foundation and have the index 0.

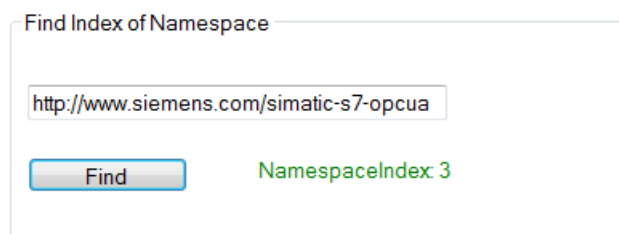
The OPC Foundation also defines data types and tag types.

Namespace (Namespace)

In addition to the above-described namespace of the OPC Foundation, the namespace for accessing CPU data is of interest: All the tags or methods of an S7-1500 OPC UA server are contained in the namespace (Namespace) of the standard server interface "http://www.siemens.com/simatic-s7-opcua".

By default this namespace has the Index 3. The index may change later if additional namespaces are inserted into the server or if existing ones are deleted. It is therefore necessary for an OPC UA client to request the current index of the namespace (e.g. "http://www.siemens.com/simatic-s7-opcua") from the server before reading or writing its values.

The following figure shows an example of the result of such a request.



Identifier

The Identifier corresponds to the name of the PLC tag in quotation marks. The quotation mark is the only sign that is not permitted as part of a name in STEP 7. Quotation marks avoid naming conflicts.

The following example reads the value of the "StartTimer" tag:

Index	Boolean Variable		Result
3	"StartTimer"	Read	True

The Identifier can consist of several components. The individual components are then separated by a dot.

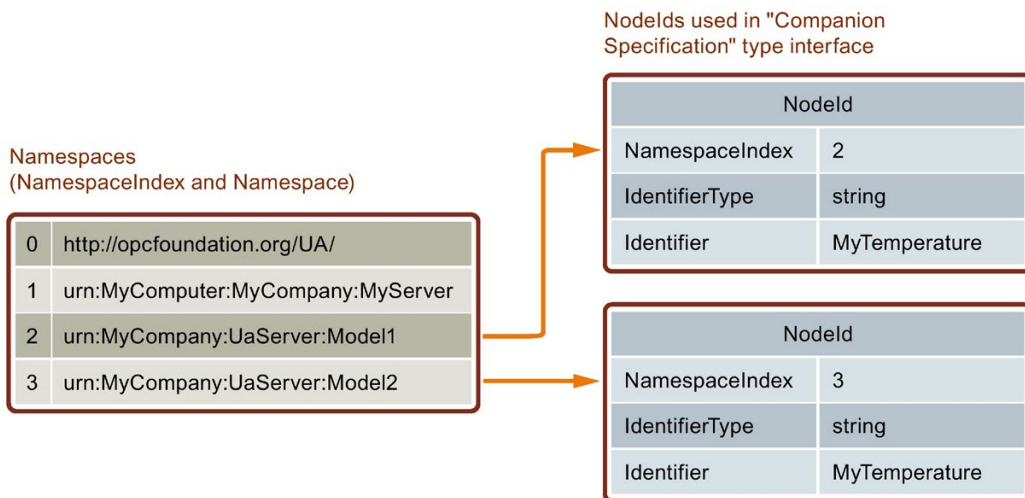
The following example reads the "MyDB" array data block completely. This data block contains an array with ten integer values. All ten values should be read in one pass. Therefore, "0:9" is entered at the array range.

Index	Array Datablock of Int16		Results										
3	"MyDB"."THIS"	Read	<table border="1"> <thead> <tr> <th>Index</th> <th>Values</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>7050</td> </tr> <tr> <td>1</td> <td>7051</td> </tr> <tr> <td>2</td> <td>7052</td> </tr> <tr> <td>3</td> <td>7053</td> </tr> </tbody> </table>	Index	Values	0	7050	1	7051	2	7052	3	7053
Index	Values												
0	7050												
1	7051												
2	7052												
3	7053												
	Array Range (for instance 0:9)												
	0:9												

Example of NodeIds, identifiers and namespaces

The following figure illustrates the relation between NodeIds, identifiers and namespaces: It is no problem if two nodes have the same identifiers but belong to different namespaces.

STEP 7 (TIA Portal) allows you to easily import namespaces via a server interface.



PLC tags in the address space of the OPC UA server

The figure below shows where the PLC tags in the example are located in the address space of the OPC UA server (excerpt from UA client):

The "MyDB" data block is a global data block. The data block is therefore located below the node "DataBlocksGlobal". "StartTimer" is a memory tag and is therefore stored below the "Memory" node.

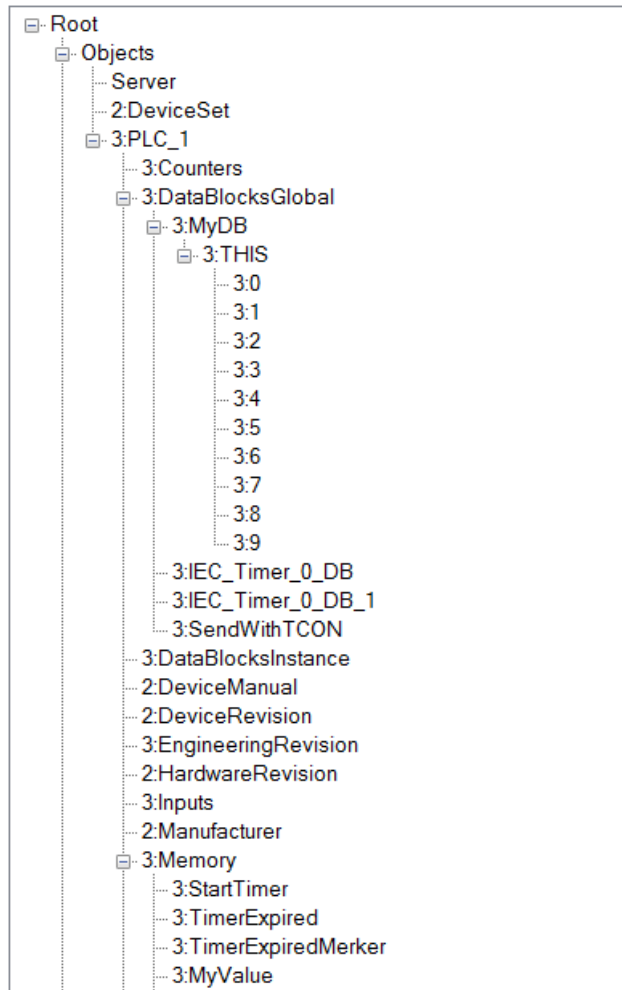


Figure 9-4 PLC tags in the address space of the OPC UA server

Methods in the address space of the OPC UA server

If you implement a method via your user program, it takes the following form in the address space of the OPC UA Server

(see Providing methods on the OPC UA server (Page 227)):

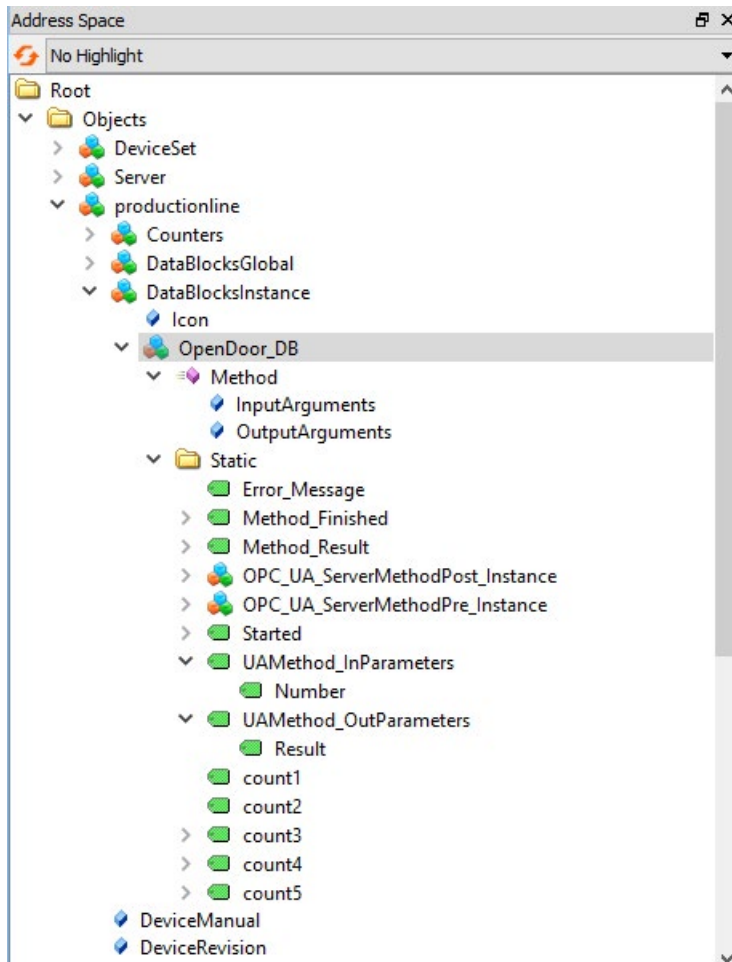


Figure 9-5 Methods in the address space of the OPC UA server

9.1.6 What you need to know about OPC UA clients

Basics of OPC UA clients

OPC UA clients are programs that do the following:

- Access the information from an OPC UA server (for example an S7-1500 CPU):
read/browse access, write access, subscriptions
- Execute methods through the OPC UA server

However, OPC UA clients can only access data that is enabled for this purpose (see "Managing write and read rights (Page 165)").

You need the endpoint of the server to establish a connection to an OPC UA server (see "Endpoints of the OPC UA servers (Page 161)").

Reading out information from the OPC UA server

When a connection to an end point of the server exists, you can use the navigation function of the client: You navigate starting from a defined starting point (from the "root" node) through the address space of the server.

The following information is provided in the process:

- Enabled PLC tags, data blocks and data block components
- Namespace index and identifiers of these PLC tags, data blocks and DB components
- Data types of the PLC tags and DB components
- Number of components in arrays (required for reading and writing arrays)

In addition, you receive information about the OPC UA server itself as well as information about the S7-1500 based on the "OPC UA for Devices" standard of the OPC Foundation (for example, serial number, firmware version).

Reading data from the server and writing to the server

You now know the namespace, identifier and data type of PLC tags. This means that you can now specifically read individual PLC tags and DB components as well as complete arrays and structures.

You can find examples of the reading of Boolean tags and array data blocks in Addressing nodes (Page 135).

Rules for access to structures are available here (Page 266).

With the information that you obtain while navigating through the address space of the server (index, identifier and data type), you can also transfer values to the S7-1500 with the OPC UA client. The following example overwrites the first three values in the array data block "MyDB".

Index	Array Datablock of Int16	Values	Write	Status Code	
<input type="text" value="3"/>	<input "starttimer"'="" type="text" value='"MyDB"."THIS""/></td> <td><input type="text" value="1"/>
<input type="text" value="2"/>
<input type="text" value="3"/></td> <td><input type="button" value="Write"/></td> <td><input type="text" value="Good"/></td> </tr> <tr> <td></td> <td>Array Range (for instance 0:9)</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td><input type="text" value="0:2"/></td> <td></td> <td></td> <td></td> </tr> </table> </div> <div> <p>For "Array Range" you specify which components of the array you want to overwrite. The "Good" status code indicates that the values were transferred successfully. However, you can only write the values to the S7-1500 but not the time stamps of these values. The time stamps can only be read.</p> </div> <div> <h3>Faster access through registration</h3> </div> <div> <p>Registered Read/Write lends itself to repeated, optimized access to data – with maximum performance. When tag nodes are registered, the OPC UA server creates a numerical Identifier (numerical NodeId) that directly references the registered node. For read or write jobs of the client to this numerical Identifier, the server does not have to resolve any strings as Identifier and can access the requested tag in an optimized manner.</p> </div> <div> <p>This Identifier applies solely to the current session and has to be queried again when the session connection is terminated/lost.</p> </div> <div> <p>In the following example, the "StartTimer" tag is first registered on the server. Afterwards, the rapid function "RegisteredWrite" is used for setting the value.</p> </div> <div> <table border="0"> <tr> <td>Index</td> <td>Boolean Variable</td> <td>Register</td> <td>Value</td> <td>Write</td> <td>Status Code</td> </tr> <tr> <td><input type="text" value="3"/></td> <td><input type="text" value='/>	<input type="button" value="Register"/>	<input checked="" type="checkbox"/> <input type="text" value="True"/>	<input type="button" value="Write"/>	<input type="text" value="Good"/>
				<input type="button" value="Unregister"/>	

In accordance with the same scheme, the "RegisteredRead" function can also be used, which is particularly useful for recurring data readouts. Take into account, however, that depending on the application it may be advisable to use a Subscription instead.

Recommendation: It is best to place registrations in the startup program of the OPC UA client, since the registration takes up time.

Please note that you can set the maximum number of registered nodes in the properties of the S7-1500 CPU and that the Clients have to respect this number, see General settings of the OPC UA server (Page 179).

Subscription

The term "Subscription" is used for a function in which only those tags for which an OPC UA client has registered at the OPC UA server are transferred. The OPC UA server only sends a message to the OPC UA client for these registered tags (monitored Items) when a value has changed. The monitoring of these tags makes constant sampling by the OPC UA client (Polling) superfluous, which reduces the network load.

You have to create a Subscription to use this function. For this purpose, you specify the "Publishing Interval" at the UA client and click the "Create" button. The publishing interval is the time interval in which the server sends new values to the client in a notification (data change notification).

In the following example a subscription has been created: The client receives a message with the new values (publishing interval 50 ms) every 50 milliseconds here.

The screenshot shows a dialog box titled "Create a Subscription". Inside the dialog, there is a label "Publishing Interval" followed by a text input field containing the number "50" and the unit "(ms)". Below this, the status is displayed as "Status: Active Subscription" in green text. At the bottom of the dialog, there are two buttons: "Create" on the left and "Delete" on the right.

Preventing server overload

You can set the OPC UA server of the S7-1500 CPU by means of the "Minimum publishing interval" so that it does not serve extremely short send intervals requested by the client, see Settings of the server for subscriptions (Page 181).

Example: A client wants to be operated at a publishing interval of 50 ms as detailed above. Such a short publishing interval would, however, result in a high network and server load. You should therefore set 1000 ms as the "Minimum publishing interval" for the server. Clients whose subscription requires shorter publishing intervals are "slowed" to 1000 ms and the server is protected from overload.

Sampling and transmission (Sampling & Publishing) within the scope of a subscription are communication processes which, like other communication processes (TCP/UDP/Web server communication...), are processed by the CPU with priority 15. OBs with higher priority interrupt the communication. If you set the sampling and transmission intervals too short, this setting causes a high communication load. Therefore, select intervals as large as possible, which are still sufficient for the application.

For information about the consistency of tags, refer to Consistency of CPU tags (Page 171).

Monitoring of PLC tags

When the Subscription has been created, you inform the server which tags are to be monitored with it. In the following example, the "Voltage" tag was added to the subscription.

Index	LREAL Variable	Sampling Interval		Value
<input type="text" value="3"/>	<input type="text" value="Voltage"/>	<input type="text" value="-1"/>	<input type="button" value="Add and Monitor"/>	<input type="text" value="2.214265046"/>
Queue Size	Deadband			
<input type="text" value="1"/>	<input type="text" value="0,1"/>			

The "Voltage" tag contains the value of a voltage that is detected by an S7-1500 CPU.

The sampling interval ("Sampling Interval") contains a negative value (-1). This determines that the default setting of the OPC UA server is used for the sampling interval. The default setting is defined by the transmission interval ("Publishing Interval") of the subscription. If you want to set the smallest possible sampling interval, select the value "0".

In this example, the length of the queue is set to "1": Only one value is read from the CPU at an interval of 50 milliseconds and subsequently sent to the OPC UA client when the value has changed.

The "Deadband" parameter in this example is "0.1": Changes in value have to amount to 0.1 Volt; only then does the sender send the new value to the client. The server does not send smaller changes in value. You can use this parameter, for example, to disable signal noise: Slight changes in a process variable which do not have a real meaning.

9.1.7 Mapping of data types

SIMATIC and OPC UA data types

SIMATIC data types do not always correspond with OPC UA data types.

S7-1500 CPUs provide SIMATIC tags (with SIMATIC data types) to their own OPC UA server as OPC UA data types. OPC UA clients can then access these tags with OPC UA data types via the server interface.

A client can read the attribute "DataType" from such a tag and reconstruct the original data type in SIMATIC.

Example

A tag has the SIMATIC data type "COUNTER". You read COUNTER → UInt16 in the table. You now know that you do not need to convert; the COUNTER value is sent over the line as a UInt16 data type.

The client detects from the attribute "DataType" that the tag is actually the SIMATIC data type "COUNTER". With this knowledge, the client reconstructs the data type.

Table 9- 1 SIMATIC and OPC UA data types

SIMATIC data type	OPC UA data type
BOOL	Boolean
BYTE	BYTE → Byte
WORD	WORD → UInt16
DWORD	DWORD → UInt32
LWORD	LWORD → UInt64
SINT	SByte
INT	Int16
DINT	Int32
LINT	Int64
USINT	Byte
UINT	UInt16
UDINT	UInt32
ULINT	UInt64
REAL	Float
LREAL	Double
S5TIME	S5TIME → UInt16
TIME	TIME → Int32
LTIME	LTIME → Int64
DATE	DATE → UInt16
TIME_OF_DAY (TOD)	TOD → UInt32
LTIME_OF_DAY (LTOD)	LTOD → UInt64
DATE_AND_TIME (DT)	DT → Byte[8]
LDT	DateTime

9.1 What you need to know about OPC UA

SIMATIC data type	OPC UA data type
DTL Special note: You can only describe the structure completely with an OPC UA client. You have read-only access individual elements of this structure (e.g. "YEAR")	mapped as structure
CHAR	CHAR → Byte
WCHAR	WCHAR → UInt16
STRING (Code page 1252 or Windows-1252)	STRING → String
WSTRING (UCS-2; Universal Coded Character Set)	String
TIMER	TIMER → UInt16
COUNTER	COUNTER → UInt16

Arrays

A read or write job with OPC UA is always an array access, which means that it always has an index and length. A single tag is a special case of an array (index 0 and length 1). The data type is simply sent repeatedly on the line. For the tags, the "DataType" attribute indicates the basic data type. The attributes "ValueRank" and "ArrayDimensions" show whether or not you are dealing with an array and how large the array is.

Data types based on arrays

There are SIMATIC data types for which an OPC UA value is mapped to an array of bytes. An array of these data types is then mapped to a two-dimensional array.

Example: The SIMATIC data type DATE_AND_TIME (DT) is mapped on the OPC UA side to an 8-byte array (Byte[8]), see table above. When you define an array of the SIMATIC data type DATE_AND_TIME (DT), then it is considered as two-dimensional array.

This fact affects the use of system data types such as OPC-UA_NodeAdditionalInfo and OPC-UA_NodeAdditionalInfoExt, for example:

For the data types described above, you must use the system data type OPC-UA_NodeAdditionalInfoExt for multidimensional arrays instead of OPC-UA_NodeAdditionalInfo.

Structures

Structures are transferred as ExtensionObject. The S7-1500 server uses binary representation for transmission of the ExtensionObjects over the line; the individual structure elements come one after the other. At the front is the NodId of the data type; this is used by the client to establish the structure.

For OPC UA Specification <= V1.03, a client has to read, decode and interpret the complete DataTypeDictionary for this (unless it has already learned this library offline through an XML import).

Starting in OPC UA V1.04, the DataTypeDescription attribute is also available for this, which can be read and interpreted more quickly and easily. A client only determines the setup of the structure once, before or during the first access, and then uses this information for the duration of the session.

Special SIMATIC data types

SIMATIC data types that are not in the table above and cannot be defined as elements of a structure or PLC data type are not supported by the OPC UA client.

These are, for example, "ANY" or "POINTER" pointers, function block "Block_FB", function "Block_FC" or hardware data type "REMOTE".

The selection of an unsupported data type leads to an error message.

Additional information

More details on mapping of basic data types, arrays and structures can be found in the OPC UA Specification Part 6, "Mappings" (see OPC UA BINARY there).

What must be considered with arrays and data types DTL and LDT in the OPC UA server of a SIMATIC S7-1500? FAQ (<https://support.industry.siemens.com/cs/ww/en/view/109766726>)

9.2 Security at OPC UA

9.2.1 Security settings

Addressing risks

OPC UA allows the exchange of data between different systems, both within the process and production levels and to systems at the control and enterprise level.

This possibility also entails security risks. That is why OPC UA provides a range of security mechanisms:

- Verification of the identity of OPC UA server and clients.
- Checking of the identity of the users.
- Signed/encrypted data exchange between OPC UA server and clients.

These security policies should only be bypassed in cases where it is absolutely necessary:

- During commissioning
- In stand-alone projects without external Ethernet connection

If you have selected the endpoint "None" for "UA Sample Client" of the OPC Foundation, for example, the program issues a clear warning:

Warning: Selected Endpoint has no security.

When STEP 7 compiles your project it also checks whether you have considered the setting options for the protection and warns you of possible risks. This also includes an OPC UA security policy with the setting "no security", which corresponds to the end point "None".

Note

Disabling security policies you do not want

If you have enabled all security policies in the secure channel settings of the S7-1500 OPC UA server – thus, also the end point "None" (no security) – unsecured data traffic (neither signed nor encrypted) between the server and client is also possible. The OPC UA server of the S7-1500 CPU also sends its public certificate to the client at "None" (No security). And some clients check this certificate. However, the client is not forced to send a certificate to the server. The identity of the client may possibly remain unknown. Each OPC UA client can then connect to the server irrespective of any subsequent security settings.

When configuring the OPC UA server, make sure that only security policies that are compatible with the security concept of your machine or plant are selected. All other security policies should be disabled.

Recommendation: Use the setting "Basic256Sha256 - Sign and Encrypt", which means that the server only accepts Sha256 certificates. The security policies "Basic128Rsa15" and "Basic256" are deactivated by default and should not be used as an end point. Select end points with a higher security policy.

Additional security rules

- Only use the end point "None" in exceptional cases.
- Only use the "guest authentication" of the user in exceptional cases.
- Only allow access to PLC tags and DB components via OPC UA if it is genuinely necessary.
- Use the list of trusted clients in the settings of the S7-1500 OPC UA client to allow access to certain clients only.

9.2.2 Certificates pursuant to ITU X.509

Security mechanisms are integrated in several layers in OPC UA. Digital certificates have an important role here. An OPC UA client can only establish a secure connection to an OPC UA server when the server accepts the digital certificate of the client and classifies it as trusted.

See section Handling client and server certificates (Page 183).

The client must also check and trust the certificate of the server. The server and client must show their identities and prove that they are what they claim to be: They must prove their identity. Mutual authentication of client and server, for example, prevents man-in-the-middle attacks.

Man-in-the-middle attacks

A "man-in-the-middle" could have positioned itself between server and client. A man-in-the-middle is a program that intercepts communication between server and client and claims to be a client or server, and is thus able to obtain information about the S7 program or to set values in the CPU and attack a machine or plant.

OPC UA uses digital certificates that meet standard X.509 of the International Telecommunication Union (ITU).

This allows the identity of a program, a computer or an organization to be proven (authenticated).

X.509 certificates

An X.509 certificate includes the following information:

- Version number of the certificate
- Serial number of the certificate
- Information on the algorithm used by the certificate authority to sign the certificate.
- Name of the certificate authority
- Start and end of the validity period of the certificate
- Name of the program, person or organization for which/whom the certificate has been signed by the certificate authority.
- The public key of the program, person or organization.

An X509 certificate thus links an identity (name of a program, person or an organization) to the public key of the program, person or organization.

Check during connection establishment

When a connection is being established between the client and server, the devices check all information from the certificate that is required to determine its integrity, such as signature, period of validity, application name (URN) and, in case of firmware version V2.5 only, also the IP address of the client in the client certificate.

Note

The validity period stored in the certificate is also checked. The CPU clock must therefore be set and date/time must be within the validity period, otherwise no communication takes place.

Signing and encryption

To allow you to check whether a certificate has been manipulated, certificates are signed.

There are various possible procedures here:

- Within the TIA Portal you have the possibility to generate and sign certificates. If you have protected your project and are logged in as a user with the function right to make security settings, you can use the global security settings. The global security settings allow access to the certificate manager and therefore to the certificate authority (CA) of the TIA Portal.
- Additional options are available for creating and signing certificates. In the TIA Portal, you can import certificates into the global certificate manager.

- You contact a certificate authority (CA) and have your certificate signed.

In this case, the certificate authority checks your identity and signs your certificate with the private key of the certificate authority. For this purpose you send a CSR (Certificate Signing Request) to the certificate authority.

- You yourself create a certificate and sign it.

To this purpose you use, for example, the "Opc.Ua.CertificateGenerator" program of the OPC Foundation. Alternatively, you use OpenSSL.

You can find additional information in Generating PKI key pairs and certificates yourself (Page 153).

Useful information: Certificate types

- Self-signed certificate:

Each device generates and signs its own certificate. Application examples: Static configuration with limited number of communication nodes.

No new certificates can be derived from a self-signed certificate. However, you need to load all self-signed certificates from partner devices to the CPU (STOP required).

- CA certificate:

All certificates are generated and signed by a certificate authority. Application examples: Dynamically growing plants.

You only need to download the certificate from the certificate authority to the CPU. The certificate authority can generate new certificates (partner devices can be added without CPU STOP).

Signing

The signature makes it possible to prove the integrity and source of a message as detailed below.

Signing starts with the sender creating a hash value from the plain text (plain text message). The sender then encrypts the hash value with its private key and subsequently transfers the plain text together with the encrypted hash value to the recipient. To verify the signature, the recipient needs the public key of the sender (this is contained in the X509 certificate of the sender). The recipient uses the sender's public key to decrypt the hash value received. The recipient then forms the hash value themselves from the plain text received (the hash process is contained in the sender's certificate). The recipient compares the two hash values:

- If the two hash values are identical, the plain text message has reached the receiver unchanged and has not been manipulated.
- If the two hash values do not match, the plain text message has not reached the receiver unchanged. The plain text message has been manipulated or has been distorted during transfer.

Encryption

Encrypting data prevents unauthorized parties from reading the content. X509 certificates are not encrypted; they are public and can be viewed by anyone.

Encryption involves the sender encrypting the plain text message with the public key of the recipient. To do so, the sender requires the recipient's X509 certificate, as it contains the public key of the recipient. The recipient decrypts the message with their private key. Only the recipient can decrypt the message: They alone hold the private key. The private key must therefore never be disclosed.

Secure channel

OPC UA uses the private and public key of client and server to establish a secure connection, the secure channel. Once the secure connection has been established, the client and server generate an internal key only known to them which they both use for signing and encrypting messages. This symmetric process (a shared key) is much faster than asymmetric processes (private and public key).

See also

Creating self-signed certificates (Page 152)

Certificates with OPC UA (Page 151)

Secure Communication (Page 34)

Using certificates with TIA Portal

<https://support.industry.siemens.com/cs/ww/en/view/109769068>

9.2.3 Certificates with OPC UA

Usage of X509 certificates with OPC UA

OPC UA uses various types of X.509 certificates for establishing a connection from client to server:

- OPC UA application certificates

Such X.509 certificates identify the software instance, the installation of client or server software. For the "Organization name" attribute, you enter the name of the company that uses the software.

Note

The OPC UA server of the S7-1500 uses application certificates even for the security setting "None" (no security). This ensures compatibility to OPC UA V1.1 and earlier versions.

- OPC UA software certificates

This X-509 certificate identifies a specific version of the client or server software. These certificates contain attributes that describe which tests this version of the software has passed during certification by the OPC Foundation (or recognized test laboratories). For the "Organization name" attribute, you enter the name of the company that has developed or markets the software.

Note

Software certificates are not supported in STEP 7.

- OPC UA user certificates

This X.509 certificate identifies the specific user who, for example, retrieves process data from the OPC UA server of an S7-1500 CPU. This certificate is not required if the user can authenticate itself with a password, or if anonymous access is configured.

Note

User certificates are not supported in STEP 7.

These certificates are end-entity certificates: They identify, for example, a person, an organization, a company or an instance (installation) of a software.

9.2.4 Creating self-signed certificates

Using the client's certificate generator

Many OPC UA client applications or SDKs are integrated in a sample application that allows you to generate certificates for the client from this application.

The description for certificate generation can generally be found in the context for describing the OPC UA client application.

Example client from the online support

The OPC UA .NET client for the SIMATIC S7-1500 OPC UA server (<https://support.industry.siemens.com/cs/ww/en/view/109737901>) creates a self-signed software certificate of the client application in the Windows Certificate Store during the first program start. The documentation for this example describes the procedure for handling these certificates.

Using the certificate generator of the TIA Portal

If you use an OPC UA client that does not generate a client certificate, you can create self-signed certificates with STEP 7.

To do this, follow these steps:

1. In the properties of the CPU, double-click "<Add new>" under "Protection & Security > Certificate manager > Device certificates".
2. Click "Add".
3. In the "Create a new certificate" dialog, select the "OPC UA client" option for "Usage".
4. Click "OK".

In the field "Subject Alternative Name" STEP 7 automatically enters the URI for the generated certificate. In the program-specific certificate generation by means of the .NET stack of the OPC Foundation, the field is called, for example, "ApplicationUri" - it can have a different name in other tools for certificate generation.

See also

Handling of the client certificates of the S7-1500 CPU (Page 272)

9.2.5 Generating PKI key pairs and certificates yourself

This section is only relevant if you want to use an OPC UA client that cannot itself create a PKI key pair and a client certificate. In this case, you generate a private and a public key using OpenSSL, generate an X.509 certificate, and sign the certificate yourself.

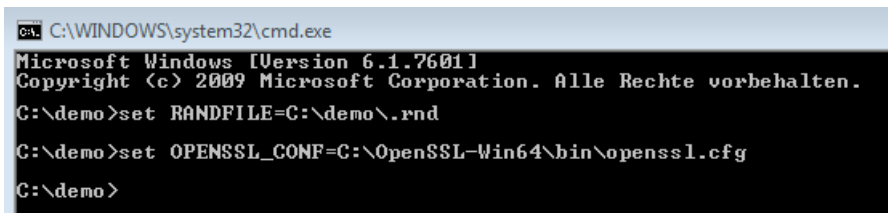
Using OpenSSL

OpenSSL is a tool for Transport Layer Security that you can use to create certificates. You can also use other tools, for example XCA, a type of key management software with a graphical user interface for an improved overview of certificates issued.

To work with OpenSSL under Windows, follow these steps:

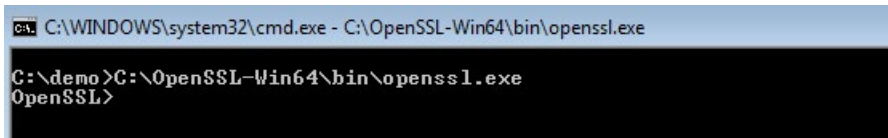
1. Install OpenSSL under Windows. If you are using a 64-bit version of the operating system, install OpenSSL in the "C:\OpenSSL-Win64" directory, for example. You can obtain OpenSSL-Win64 as a download from various providers for open source software.
2. Create a directory, for example "C:\demo".
3. Open the command prompt. To do so, click "Start" and enter "cmd" or "command prompt" in the search field. Right-click "cmd.exe" in the results list and run the program as an administrator. Windows opens the command prompt.
4. Change to the "C:\demo" directory. To do this, enter the following command: "cd C:\demo".
5. Set the following network variables:
 - set RANDFILE=c:\demo\.rnd
 - set OPENSSL_CONF=C:\OpenSSL-Win64\bin\openssl.cfg

The figure below shows the command line with the following commands:



```
C:\WINDOWS\system32\cmd.exe
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. Alle Rechte vorbehalten.
C:\demo>set RANDFILE=C:\demo\.rnd
C:\demo>set OPENSSL_CONF=C:\OpenSSL-Win64\bin\openssl.cfg
C:\demo>
```

6. Now start OpenSSL. If OpenSSL has been installed in the C:\OpenSSL-Win64 directory, enter the following: C:\OpenSSL-Win64\bin\openssl.exe The figure below shows the command line with the following command:



```
C:\WINDOWS\system32\cmd.exe - C:\OpenSSL-Win64\bin\openssl.exe
C:\demo>C:\OpenSSL-Win64\bin\openssl.exe
openssl>
```


7. Generate a private key. Save the key to the "myKey.key" file. The key in this example is 1024 bits long; for greater RSA security, use 2048 bits in practice. Enter the following command: "genrsa -out myKey.key 2048" ("genrsa -out myKey.key 1024" in the example). The figure below shows the command line with the command and the output of OpenSSL:

```

C:\WINDOWS\system32\cmd.exe - C:\OpenSSL-Win64\bin\openssl.exe
C:\demo>C:\OpenSSL-Win64\bin\openssl.exe
openssl> genrsa -out myKey.key 1024
Generating RSA private key, 1024 bit long modulus
.....+++++
.....+++++
e is 65537 (0x10001)
openssl>
    
```

8. Generate a CSR (Certificate Signing Request). To do this, enter the following command: "req -new -key myKey.key -out myRequest.csr". During execution of this command, OpenSSL queries information about your certificate:
 - Country name: for example "DE" for Germany, "FR" for France
 - State or province name: for example "Bavaria".
 - Location Name: for example "Augsburg".
 - Organization Name: Enter the name of your company.
 - Organizational Unit Name: for example "IT"
 - Common Name: for example "OPC UA client of machine A"
 - Email Address:

Note

Note for S7-1500 CPU as server with firmware version V2.5

The IP address of the client program has to be stored in the "Subject Alternative Name" field of the created certificate for S7-1500 CPUs version V2.5 (only for this version); otherwise, the CPU will not accept the certificate.

The information you enter is added to the certificate. The figure below shows the command line with the command and the output of OpenSSL:

```

C:\WINDOWS\system32\cmd.exe - C:\OpenSSL-Win64\bin\openssl.exe
openssl> req -new -key myKey.key -out MyRequest.csr
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name <2 letter code> [AU]:
    
```

The command creates a file in the C:\demo directory containing the Certificate Signing Request (CSR); in the example, this is "myRequest.csr".

Using the CSR

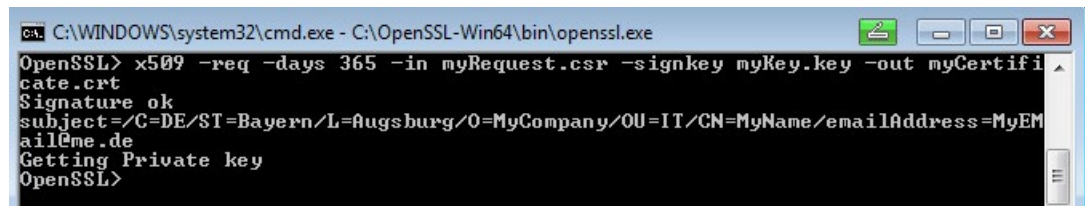
There are two ways to use a CSR:

- You send the CSR to a certificate authority (CA): Read the information of the respective certification authority. The certificate authority (CA) checks your information and identity (authentication) and signs the certificate with the private key of the certificate authority. You receive the signed X.509 certificate and use this certificate for OPC UA, HTTPS or Secure OUC (secure open user communication), for example. Your communication partners use the public key of the certificate authority to check whether your certificate was really issued and signed by that CA (i.e. that the certificate authority has confirmed your information).
- You sign the CSR yourself: Using your private key. This option is shown in the next step.

Signing the certificate yourself

Enter the following command so that you can generate and sign your certificate (self-signed certificate) yourself: "x509 -req -days 365 -in myRequest.csr -signkey myKey.key -out myCertificate.crt".

The figure below shows the command line with the command and OpenSSL:



```
cmd: C:\WINDOWS\system32\cmd.exe - C:\OpenSSL-Win64\bin\openssl.exe
OpenSSL> x509 -req -days 365 -in myRequest.csr -signkey myKey.key -out myCertificate.crt
Signature ok
subject=/C=DE/ST=Bayern/L=Augsburg/O=MyCompany/OU=IT/CN=MyName/emailAddress=MyEmail@me.de
Getting Private key
OpenSSL>
```

The command generates an X.509 certificate with the attributes that you transfer with the CSR (in the example "myRequest.csr"), for example with a validity of one year (-days 365). The command also signs the certificate with your private key ("myKey.key" in the example). Your communication partners can use your public key (contained in your certificate) to check that you are in possession of the private key that belongs to this public key. This also prevents your public key from being misused by an attacker.

With self-signed certificates, you yourself confirm that the information in your certificate is correct. There is no independent body that checks your information.

See also

Handling of the client certificates of the S7-1500 CPU (Page 272)

9.2.6 Secure transfer of messages

Establishing secure connections with OPC UA

OPC UA uses secure connections between client and server. OPC UA checks the identity of the communication partners. OPC UA uses certificates in accordance with X.509-V3 from the ITU (International Telecommunication Union) for client and server authentication. Exception: A secure connection is not established with the "No security" security policy.

Message security mode

OPC UA uses the following security policies to protect messages:

- No security

All messages are unsecured. In order to use this security policy, establish a connection to a None end point of a server.

- Signing

All message are signed. This allows the integrity of the messages received to be checked. Manipulations are detected. In order to use this security policy, establish a connection to a Sign end point of a server.

- Sign & Encrypt

All messages are signed and encrypted. This allows the integrity of the messages received to be checked. Manipulations are detected. What is more, no attacker can read the content of the message (protection of confidentiality). In order to use this security policy, establish a connection to a "SignAndEncrypt" end point of a server.

The security policies are also named according to the algorithms used. Example: "Basic256Sha256 - Sign & Encrypt" means: Secure endpoint, supports a series of algorithms for 256-bit hashing and 256-bit encryption.

Layers required

The figure below shows the three layers that are always required for establishing a connection: the transport layer, the secure channel and the session.

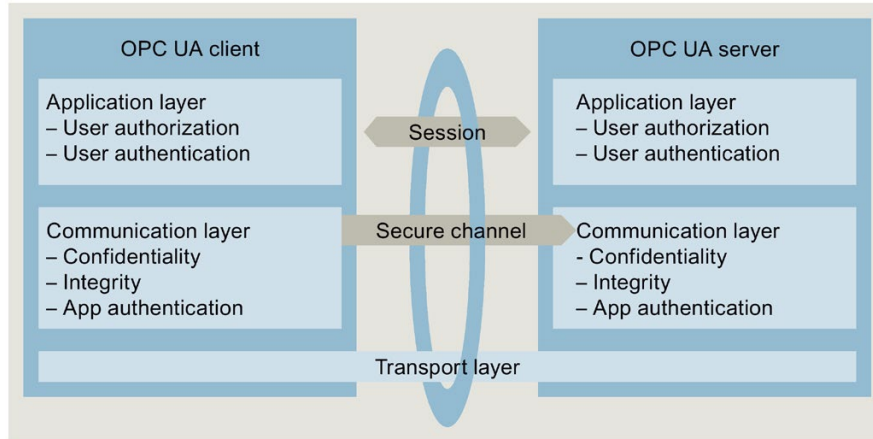


Figure 9-6 Necessary layers: transport layer, secure channel and session

- **Transport layer:**
This layer sends and receives messages. OPC UA uses an optimized TCP-based binary protocol here. The transport layer is the basis for the subsequent secure channel.
- **Secure channel**
The secure channel receives the data received from the transport layer, and forwards that data to the session. The secure channel forwards data of the session that is to be sent to the transport layer.

In "Sign" security mode, the secure channel signs the data (messages) that is sent. When a message is received, the secure channel checks the signature to detect any manipulations.

With a "SignAndEncrypt" security policy, the secure channel signs and encrypts the send data. Data received is decrypted by the secure channel, and the secure channel then checks the signature.

With the "No security" security policy, the message packages pass the secure channel unchanged (the messages are received and sent in plain text).
- **Session**
The session forwards the messages from the secure channel to the application, or receives from the application the messages that are to be sent. The application uses the process values or provides the values.

Establishing the secure channel

The secure channel is established as follows:

1. The server starts establishing the secure channel when it receives a request to this effect from the client. This request is signed or signed and encrypted, or the message is sent in plain text (security mode of the selected server end point). With "Sign" and "Sign & Encrypt", the client sends a "secret" (random number) with the request.
2. The server validates the client certificate (contained in the request, unencrypted) and checks the identity of the client. If the server trusts the client certificate,
 - it decrypts the message and checks the signature ("Sign & Encrypt"),
 - checks the signature only ("Sign"),
 - or leaves the message unchanged ("No security")
3. The server then sends a response to the client (same level of security as the request). The server secret is contained in the response. The client and server calculate a symmetric key from the client and server secret. The secure channel is now established.

The symmetric key (instead of the private and public key of client and server) is now used for signing and encrypting messages.

Establishment of the session

The session is executed as follows:

1. The client starts establishing the session by sending a CreateSessionRequest to the server. This message contains a Nonce, a random number that is only used once. The server must sign this random number (Nonce) to prove that it is the owner of the private key. The private key belongs to the certificate that the server uses to establish the secure channel. This message (and all subsequent messages) is secured in line with the security policies of the selected server endpoint (selected security policies).
2. The server responds with the CreateSession Response. This message contains the public key of the server and the signed Nonce. The client checks the signed Nonce.
3. If the server passes the test, the client sends a SessionActivateRequest to the server. This message contains the information that is required for user authentication:
 - User name and password, or
 - X.509 certificate of the user (not supported in STEP 7), or
 - No data (if anonymous access is configured).
4. If the user has the necessary rights, the server returns a message to the client (ActivateSessionResponse). This activates the session.

The secure connection between the OPC UA client and server has been established.

Establishing a connection to PLCopen function block

The PLCopen specification defines a range of IEC 61131 function blocks for OPC UA clients. The instruction UA_Connect initiates both a secure channel and a session following the pattern described above.

9.3 Using the S7-1500 as an OPC UA server

9.3.1 Interesting information about the OPC UA server of the S7-1500 CPUs

9.3.1.1 The OPC UA server of the S7-1500 CPUs

The S7-1500 CPUs as of firmware V2.0 are equipped with an OPC UA server. Apart from the Standard-S7-1500 CPUs this applies to the variants S7-1500F, S7-1500T, S7-1500C, S7-1500pro CPUs, ET 200SP CPUs, SIMATIC S7-1500 SW controllers and PLCSIM Advanced.

Convention: "S7-1500 CPUs" also includes the above-mentioned CPU variants.

S7-1500 CPU OPC UA server basics

Access to the OPC UA server of the CPU is possible via all integrated PROFINET interfaces of the S7-1500 CPU.

Direct access to the OPC UA server of the CPU over the backplane bus of the automation system is not possible via CPs under the following conditions:

- Configuration with TIA Portal Version V16 or higher
- S7-1500 CPU firmware version 2.8 or higher and CP 1543-1 firmware version V2.2 or higher

For configuration, see Access to OPC UA applications (Page 131).

Direct access to the OPC UA server of the CPU over the backplane bus of the automation system is not possible via CMs.

For access by clients, the server saves the enabled PLC tags and other information in the form of nodes (see Configuring access to PLC tags (Page 165)). These nodes are interconnected and form a network. OPC UA defines access points to this network (well-known nodes) that enable navigation to subordinate nodes.

With an OPC UA client you can read, observe or write values of tags of the PLC program as well as call methods that are available to the server. As of firmware version 2.5 you can implement methods, see Useful information about server methods (Page 227).

Node classes

OPC UA servers provide information in the form of nodes. A node can be, for example, an object, a tag, a method or a property.

The example below shows the address space of the OPC UA server of an S7-1500 CPU (extract from the OPC UA client "UaExpert" from Unified Automation).

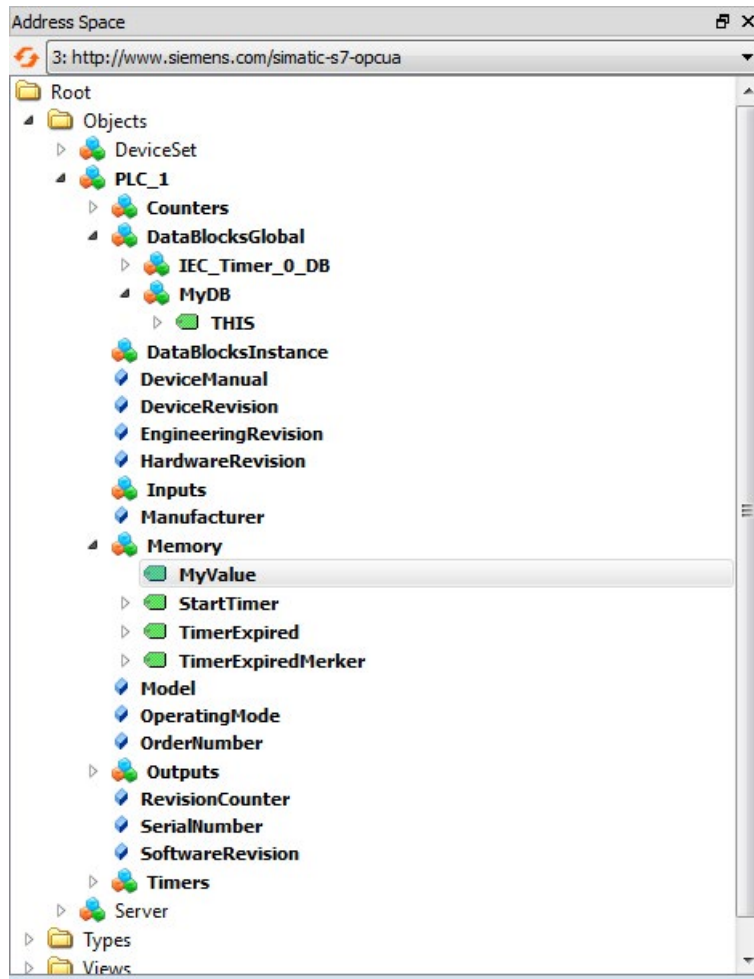


Figure 9-7 Example of the address space of the OPC UA server of an S7-1500 CPU

In the figure above, the "MyValue" tag is selected (highlighted in gray).

This tag is located below the "Memory" node, which has the node class "Object".

"Memory" is below the "PLC_1" node (also an Object).

Address space

The nodes are linked over references, for example, the reference "HasComponent", which represents a hierarchical relationship between a node and its subordinate nodes. With their references, the nodes form a network that can, for example, take the form of a tree.

A network of nodes is also called an address space. Starting from the root, all nodes can be reached in the address space.

9.3.1.2 End points of the OPC UA server

The end points of the OPC UA server define the security level for a connection. Depending on the purpose of use or desired security level, you have to carry out the corresponding settings for the connection at the end point.

Different security settings

Before establishing a secure connection, OPC UA clients ask the server with which security settings connections are possible. The server returns a list with all the security settings (endpoints) that the server offers.

Structure of end points

End points consist of the following components:

- Identifier for OPC: "opc.tcp"
- IP address: 192.168.178.151 (in the example)
- Port number for OPC UA: 4840 (standard port)
The port number can be configured.
- Security setting for messages (Message Security Mode): None, Sign, SignAndEncrypt.
- Encryption and hash procedures (Security Policy): None, Basic128Rsa15, Basic256, Basic256Sha256 (in the example).

The following figure shows the "UA Sample Client" of the OPC Foundation.

The client has established a secure connection to the OPC UA server of an S7-1500 CPU to the end point "opc.tcp://192.168.178.151:4840 - [SignAndEncrypt: Basic256Sha256:Binary]". The security settings "SignAndEncrypt:Basic256Sha256" are contained in the end point.

Note

Select an endpoint with as strict as possible a security policy

Select an application-appropriate security policy for the end point and disable the less strict security policy at the OPC UA server.

A Sha256 certificate is required for the most secure end points (Basic256Sha256) of the S7-1500 CPU OPC UA server.

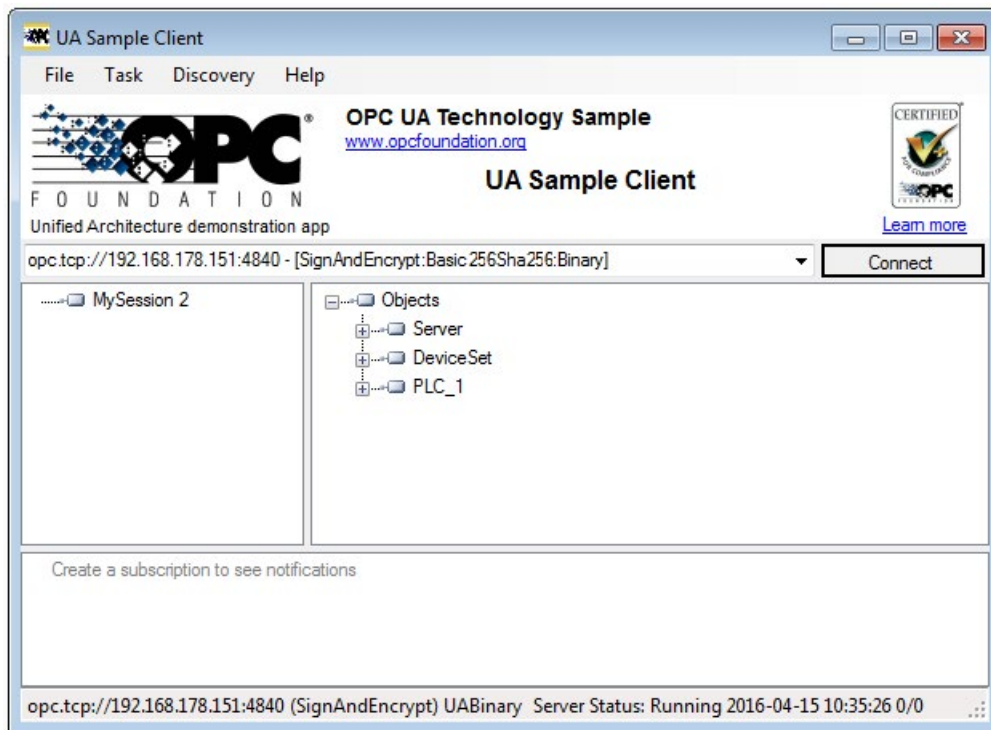


Figure 9-8 "UA Sample Client" program of the OPC Foundation

A connection to a server end point is only established if the OPC UA client complies with the security policies of that end point.

Through the information provided by the OPC UA server

OPC UA servers provide a wide range of information:

- The values of PLC tags and DB components which clients may access.
- The data types of these PLC tags and DB components.
- Information on the OPC UA server itself and on the CPU.

This gives clients an overview and allows them to read out specific information. Previous knowledge of the PLC program and the CPU data is not required. You do not need to ask the developer of the PLC program when PLC tags are to be read. All necessary information is stored on the server itself (for example, the data types of the PLC tags).

Display of the information of the OPC UA server

You have the following options:

- **Online:** You have all the available information displayed during the runtime of the OPC UA server. To do so, navigate (browse) the address space of the server.
- **Offline:** You export an XML file that is based on the XML schemes of the OPC Foundation.

Server methods created by the user (FB instance that can be called by an OPC UA client) are not exported as of STEP 7 V15.1), see Providing methods on the OPC UA server (Page 227).

- **Offline with the Openness API:** In your program, you use the API (Application Programming Interface) of the TIA Portal to access the function for exporting all PLC tags that can be read by OPC UA. This requires .NET Framework 4.0; see TIA Portal Openness, Automating SIMATIC projects with scripts (<https://support.industry.siemens.com/cs/ww/en/view/109477163>).
- If you already know the syntax and the PLC program, you can access the OPC UA server without first researching the information.

9.3.1.3 Runtime behavior of the OPC UA server

OPC UA server in operation

The OPC UA server of the S7-1500 CPU starts when you activate the server and download the project to the CPU.

How to activate the OPC UA server is described here.

Behavior in the operating state STOP of the CPU

An activated OPC UA server remains in operation even if the CPU switches to "STOP". The OPC UA server continues to respond to requests from OPC UA clients.

Server response in detail:

- If you request the values of PLC tags, you will get what were the latest values before the CPU switched to or was set to "STOP".
- If you write values to the OPC UA server, the OPC UA server will accept those values.

However, the CPU will not process the values because the user program is not executed in "STOP" mode.

An OPC UA client can nonetheless read the values written at STOP from the OPC UA server of the CPU.

During restart, the CPU overwrites the values written at STOP with the start of the PLC tags.

- If you call a server method, the error message 16#00AF_0000 (BadInvalidState) is output because the server method (user program) is not running.
- Connections to the OPC UA server remain active during an operating mode transition (STOP > RUN or RUN > STOP). Exception: OPC UA-relevant data is loaded, see next section.

Download to the CPU may affect OPC UA server

If you load a CPU with running OPC UA server, you may need to stop and restart the server depending on the loaded objects. In this case, active connections are interrupted and must be re-established once the server restarts.

The duration of the restart depends mainly on the following parameters:

- The scope of the data structure
- The number of variables visible in the OPC UA address space
- The setting for downward compatible data type definition according to OPC UA specification to V1.03 (TypeDictionary enabled)
- Settings for the communication load and minimum cycle time, you can find additional information here (Page 284)

With CPU FW versions older than V2.8, the OPC UA server was stopped at each download to the CPU and then restarted.

As of FW version V2.8, the behavior of the OPC UA server has been optimized as follows:

- When objects are downloaded in STOP operating state of the CPU, the OPC UA server still always stops and then restarts. STEP 7 does not show a warning in this case.
- When objects are downloaded in RUN operating state of the CPU, the OPC UA server only stops if the downloaded objects are, or could be, OPC UA-relevant. The OPC UA server restarts after re-initialization due to the modified OPC UA data.

Before OPC-UA-relevant objects are loaded into the CPU and stop the OPC UA server, STEP 7 displays a warning in the preview dialog for loading. You can then decide whether a server restart is compatible for the running process or whether you want to cancel the download. These warnings are only displayed when the OPC UA server is running. If the OPC UA server is not enabled, modified OPC UA data have no influence on the download process.

Examples

- You only want to add another code module to the program.
Neither data blocks nor inputs, outputs, flags, times or counters are affected.
Reaction during loading: A running OPC UA server is not interrupted.
- You want to load a new data module and you have flagged the data module as non-OPC-UA-relevant:
Reaction during loading: A running OPC UA server is not interrupted.
- You want to overwrite a data module.
Reaction during loading: A warning appears that the server will be restarted.
Background: STEP 7 cannot determine whether the changes refer to OPC-UA-relevant data or not.

Reading CPU operating mode over OPC UA server

The OPC UA server allows you to read out the CPU mode, see figure below:

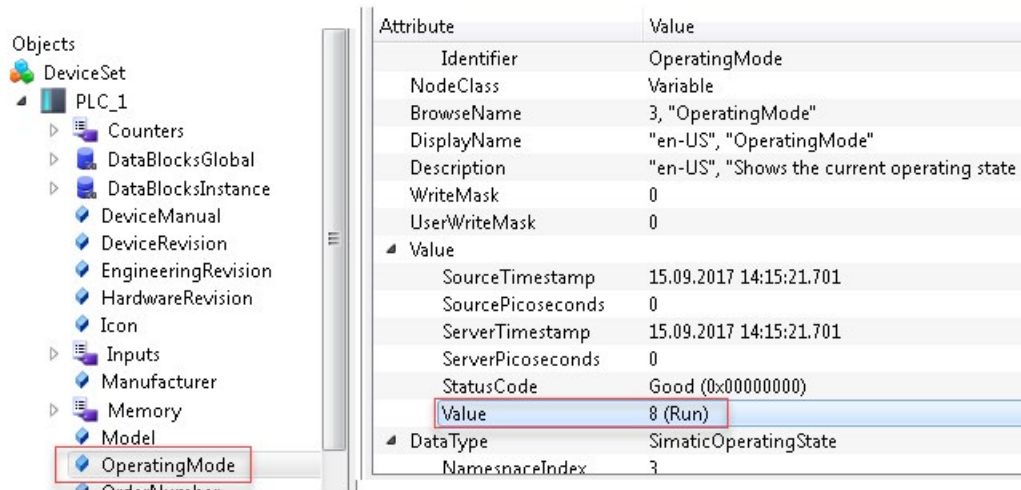


Figure 9-9 Reading CPU operating mode over OPC UA server

In addition to the operating mode of the CPU you can, for example, read out information in the manual (DeviceManual) or firmware version (HardwareRevision).

9.3.2 Configuring access to PLC tags

9.3.2.1 Managing write and read rights

Enabling PLC tags and DB tags for OPC UA

OPC UA clients can have read and write access to PLC tags and DB tags if the tags are enabled for OPC UA (default setting). For an enabled tag the check box "Accessible from HMI/OPC UA" is activated.

You can change the default setting in the settings of the TIA Portal: Command "Settings > PLC programming > General" in "Options" menu. You will find the corresponding options in the "Block interface/data block elements" area.

The following example shows an array data block:

MyDB					
Name	Data type	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Visible in HMI engineering	
MyDB	Array[0..9] o...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[0]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[1]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[2]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[3]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[4]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[5]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[6]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[7]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[8]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
MyDB[9]	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	

Figure 9-10 Enabling PLC tags and DB tags for OPC UA tags

This array can be read completely in one pass by OPC UA clients (see Addressing nodes (Page 135)). The check boxes at "Accessible from HMI/OPC UA" and "Writable from HMI/OPC UA" are activated for all the components of the array.

Result: OPC UA clients can both read and write these components.

Removing write rights

If you want to write-protect a tag, deselect the "Writable from HMI/OPC UA" option for that tag. This removes the write right for the OPC UA clients and HMI devices.

Result: Only read access by OPC UA clients and HMI devices is possible. OPC UA clients cannot assign values to this tag and therefore cannot influence execution of the S7 program.

Removing write and read rights

To write-protect and read-protect a tag, disable the "Accessible from HMI/OPC UA" option for that tag (checkbox not selected). This makes the OPC UA server remove the tag from its address space. OPC UA clients can no longer see that CPU tag.

Result: OPC UA clients and HMI devices can neither read nor write the tag.

Write and read rights of structures

If you remove the read or write right for the component of a structure, the structure or the data block cannot be written or read as a whole.

If you remove read and write rights for individual components of a PLC data type (UDT), the rights will also be removed from any data block based on that data type!

Visible in HMI engineering

The option "Visible in HMI Engineering" applies to Siemens engineering tools. If you disable the option "Visible in HMI Engineering" (check mark not set), you can no longer configure the tag in WinCC (TIA Portal).

The option does not have any effect on OPC UA.

Rules

- Only allow read access to PLC tags and tags of data blocks in STEP 7 if this is necessary for communication with other systems (controllers, embedded systems or MES).
You should not enable other PLC tags.
- Only allow write access over OPC UA if write rights are genuinely necessary for specific PLC tags and tags of data blocks.
- If you have reset the "Accessible from HMI/OPC UA" option for all elements of a data block, the data block for an OPC UA client is no longer visible in the address space of the OPC UA server of the S7-1500 CPU.
- You can also prevent access to an entire data block centrally (see Managing write and read rights for a complete DB (Page 167)). This setting "overrides" the settings for the components in the DB editor.

See also

Coordinating write and read rights for CPU tags (Page 169)

9.3.2.2 Managing write and read rights for a complete DB

Hiding DBs or DB contents for OPC UA clients

You can easily prevent access to a complete data block by an OPC UA client.

With this option, the data of the corresponding DB, including instance DBs of function blocks, remains hidden for OPC UA clients.

In the default setting, data blocks can be read and written from OPC UA clients. You can change this default setting in the settings of the TIA Portal: Command "Settings > PLC programming > General" in "Options" menu. You will find the corresponding option in the "Default settings for new blocks" area.

Procedure

Proceed as follows to completely hide a data block for OPC UA clients or to protect a data block from write access from OPC UA clients:

1. Select the data block to be protected in the project tree.
2. Select the "Properties" shortcut menu.

3. Select the "Attributes" area.
4. Select/clear the "DB accessible from OPC UA" checkbox as required.

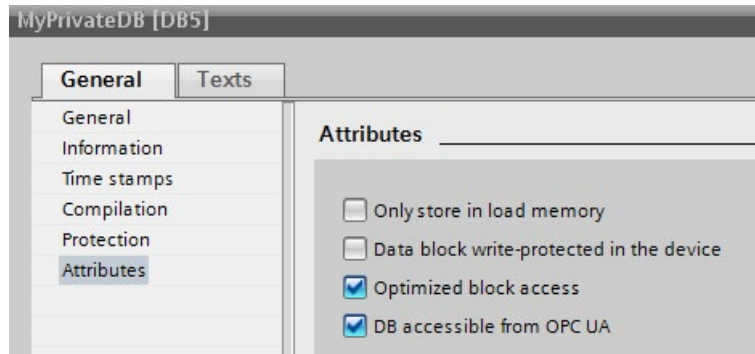


Figure 9-11 Hiding DBs or DB contents for OPC UA clients

Note

Effect on settings in the DB editor

If you hide a DB using the DB attribute described here, the settings for the components in the DB editor are no longer relevant; individual components can no longer be accessed or written.

Tip: Using the overview of all program blocks

If you are using multiple data blocks, it is appropriate to use the detailed overview of the "Program blocks" folder for selective activation or deactivation of the OPC UA accessibility.

Follow these steps:

1. Select the "Program blocks" folder in the project tree.
2. Select the "Overview" command in the "View" menu.
3. Select the "Details" tab.
 - An overview of the blocks with their attributes is displayed.
4. Ensure that the "Data block accessible via OPC UA" column is selected.
5. Select only the data blocks that are to be accessible via OPC UA.

	Name	Data block accessible from OPC UA	Comment
Projekt761	Add new block	<input type="checkbox"/>	
PLC_1 [CPU 1518-4 P...]	Main [OB1]	<input type="checkbox"/>	
Software units	myPrivateDB1 [DB1]	<input checked="" type="checkbox"/>	OPC UA relevant
Program blocks	myPrivateDB2 [DB1]	<input type="checkbox"/>	local data
Technology objects	myPrivateDB3 [DB1]	<input checked="" type="checkbox"/>	OPC UA relevant

Figure 9-12 Overview of the program blocks

9.3.2.3 Coordinating write and read rights for CPU tags

Definition of write and read rights in the information model (OPC UA XML)

In the OPC UA information model, the attribute "AccessLevel" regulates access to tags.

AccessLevel is defined bit by bit:

Bit 0 = CurrentRead and Bit 1 = CurrentWrite. The meaning of the bit combinations is as follows:

- AccessLevel = 0: no access
- AccessLevel = 1: read only
- AccessLevel = 2: write only
- AccessLevel = 3: read+write

Example of the assignment of write and read rights (read+write)

```
<UAVariable NodeId="ns=3;s=&quot;Data_block_2&quot;;.&quot;Static_1&quot;"
BrowseName="3:Static_1"
ParentNodeId="ns=3;s=&quot;Data_block_2&quot;"
DataType="INT"
AccessLevel="3">
  <DisplayName>Static_1</DisplayName>
```

Definition of write and read rights in STEP 7

When you define tags, you specify the access rights using the properties "Accessible from HMI/OPC UA" and "Writable from HMI/OPC UA".

Example of the assignment of write and read rights

Name	Data type	Accessible from HMI/OPC UA	Writable from HMI/OPC UA
Static_1	Int	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
<Add new>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Figure 9-13 Example of the assignment of write and read rights

Interaction between write and read rights

If you have imported an OPC UA server interface and AccessLevel attributes are set in this OPC UA XML file, the write and read rights are defined by the following rule: The least extensive access rights for each setting apply.

Example

- AccessLevel = 1 (read only) in the OPC UA server interface
- Both "Accessible from HMI/OPC UA" and "Writable from HMI/OPC UA" are selected in the PLC tag table

Result: This tag can only be read.

Rules

If write rights are required:

- AccessLevel = 2 oder 3
- "Writable from HMI/OPC UA" enabled

If read rights are required:

- AccessLevel = 1 (AccessLevel 3 is also possible, but misleading. The settings suggests that an OPC UA client has write and read rights)
- "Accessible from HMI/OPC UA" enabled, "Writable from HMI/OPC UA" disabled

If neither read nor write rights are to be granted (no access):

- AccessLevel = 0
- "Accessible from HMI/OPC UA" disabled

Only one of the two conditions needs to be met to block all access. In this case, review whether the tag in the OPC UA server interface is actually necessary at all.

Access table

"Accessible from HMI/OPC UA" must be set if access over OPC UA is to be possible at all. "Writable from HMI/OPC UA" must be set to allow an OPC UA client to write a tag / DB element.

Please see the table for the resulting access right.

Table 9- 2 Access table

OPC UA XML	STEP 7 (TIA Portal), for example tag table		
AccessLevel	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	Resulting access right
0	x	x	No access
x	0	x	No access
1	Enabled	x	Read only
2	Enabled	Disabled	No access
3	Enabled	Disabled	Read only
2	Enabled	Enabled	Write only
3	Enabled	Enabled	Read+write

(x = don't care)

See also

Consistency of CPU tags (Page 171)

Managing write and read rights (Page 165)

9.3.2.4 Consistency of CPU tags

"AccessLevelEx" attribute extends access properties

As of firmware version V2.6, the OPC UA server of the S7-1500 CPU supports not only the attribute "AccessLevel" (see Coordinating write and read rights for CPU tags (Page 169)) but also the attribute "AccessLevelEx" which, in addition to the already explained bits for read access and write access, provides information on the consistency of a OPC UA tag. The new attribute was introduced with version V1.04 of the OPC UA specification (Part 3, Address Space Model).

Reading consistency properties

In the OPC UA information model of the OPC UA server, the attribute "AccessLevel" defines the access.

AccessLevelEx is defined bit by bit; in this case the relevant bits are:

- Bit 0 = CurrentRead
- Bit 1 = CurrentWrite
- Bits 2 to 7 are not relevant for the OPC UA server of an S7-1500 CPU

The meaning of the bit combinations is explained in the section on read and write rights.

The following bits for consistency are also added:

- Bit 8 = NonatomicRead; the bit is set if the tag cannot be read consistently. For read consistency of tags, bit 8=0.
- Bit 9 = NonatomicWrite; is set if the tag cannot be written consistently. For write consistency of tags, or if no write access is granted, bit 9=0.

Examples

An OPC UA tag (structure) is readable and writable; but inconsistent for reading and writing access.

Consequently: Bits 0, 1, 8 and 9 are set: AccessLevelEx = "771" (1+2+256+512).

Another structure is read-only.

Consequently: Bits 0 and 8 are set, bit 1 and bit 9 are not set: AccessLevelEx = "257" (1+0+256+0).

Handling of the attribute in the server

The "AccessLevelEx" attribute is only available in the OPC UA server. The attribute is not present in a node set file (XML export file).

However, the attribute "AccessLevel", which is exported, includes the information from "AccessLevelEx", see next section.

Export

During XML export of the standard SIMATIC server interface, the server sets the "AccessLevel" attribute, which was expanded to 32 bits in V1.04 compared to V1.03, to the value of the "AccessLevelEx" attribute.

Import

When importing a node set file (e.g. from an export of a server interface), the S7-1500 CPU sets the attribute "AccessLevelEx" according to its own estimate of the consistency of the imported data type, see next section. The imported value is ignored.

Consistency of data types at the server interface

The consistency of tags ("atomicity" in the language usage of OPC UA) within a program cycle of an S7-1500 CPU is ensured at the nodes of the server interface for the following data types:

- BOOL, BYTE, WORD, DWORD, LWORD
- SINT, INT, LINT, DINT, USINT, UINT, ULINT, UDINT
- REAL, LREAL
- DATE, LDT, TIME, LTIME, TIME_OF_DAY, LTIME_OF_DAY, S5TIME
- CHAR, WCHAR
- System data types and hardware data types that are based on the above-mentioned data types are also consistent.

Example: HW_ANY, derived from UINT (UInt16).

Tip: If you browse in the address space of the S7-1500 CPU (e.g. with the OPC UA Client UaExpert), you can find the consistent data types under Types > BaseDataType > Enumeration/Number/String.

Tags of the following data types are **not** consistent ("nonatomic" in the language usage of OPC UA):

- SIMATIC structures are generally not consistent. This means that all tags which, for example, have unknown structures or a UDT data type are not consistent.
- System data types such as DTL, IEC_Counter, IEC_TIMER, etc. are data types that are derived from structures.

Tip: If you browse in the address space of the S7-1500 CPU (e.g. with the OPC UA Client UaExpert), you can find data types based on structures under Types > BaseDataType > Structure.

9.3.2.5 Accessing OPC UA server data

High performance in line with application

OPC UA is designed for the transfer of a high volume of data within a short period of time. You can increase the performance significantly if you do not access individual PLC tags, but rather read and write arrays and structures as a whole.

It is fastest to access arrays. Therefore, you should combine the data for OPC UA clients into arrays.

Recommendations for access to the OPC UA server by the OPC UA client

- For one-off or infrequent data access, use standard read/write access.
- For cyclic access to small amounts of data (up to ca. every 5 seconds), use subscriptions.
Optimize the settings for the smallest publishing interval and the smallest sampling interval at the OPC UA server.
- If you access specific tags regularly (recurring access), you should use the functions "RegisteredRead" and "RegisteredWrite".

Allow a greater communication load for the PLC by increasing the value for "Cycle load due to communication". Make sure that your application still works properly with the changed settings.

Procedure for creating an array DB

You can create arrays for example in global data blocks, in the instance data block of a function block or as an array DB . The following sections describe how to create an Array-DB.

To create a data block with an array (array data block), follow these steps:

1. Select the CPU with the OPC UA server in the project tree.
2. Double-click "Program blocks".
3. Double-click "Add new block".
4. Click "Data block".
5. Select a unique name for the data block and accept the name that is already entered.
6. Select the "Array DB" entry from the drop-down list for "Type".
7. Select the data type for the individual components of the array from the drop-down list for "Array data type".
8. Enter the high limit of the array for "Array limit".
9. Click "OK".

9.3.2.6 MinimumSamplingInterval attribute

MinimumSamplingInterval attribute of tags

In addition to "Value", "DataType" and "AccessLevel", you can also set the "MinimumSamplingInterval" attribute for a tag in the XML file that represents the server address space.

The attribute specifies how fast the server can sample the tag value.

The OPC UA server of the S7-1500 CPU handles the values for MinimumSamplingInterval as follows:

- Negative values and values greater than 4294967 are set to -1; this means: The minimum sampling rate is indeterminate. The server does not specify how fast the tag value can be sampled.
- Decimal numbers are rounded to three decimal places.

9.3.2.7 Export OPC UA XML file

Generating an OPC UA export file

The OPC Foundation has specified a standard XML-based format for describing information models. It allows the information model of an OPC UA server to be provided to a client in advance, or information models can be downloaded to an OPC UA server. A file in this format is called a nodeset file because it describes an information model as a set of nodes.

With STEP 7 (TIA Portal) you can easily export the standard SIMATIC information model of the S7-1500 CPU as a server to an OPC UA XML file (node set file); including all PLC variables and methods you have enabled for OPC UA.

You use the OPC UA XML file for the offline configuration of an OPC UA client; it is structured according to the OPC UA specification and acts as a standard SIMATIC server interface.

To create and export the OPC UA XML file, follow these steps:

1. Select the CPU. Click on the CPU symbol (for example in the network view).
2. Click "General > OPC UA > Server > Export" in the properties of the CPU.
3. Click "Export OPC UA XML file".
4. Select the directory in which you want to save the export file.
5. Select a new name for the file or keep the name that is already entered.
6. Click "Save".

Note

As of STEP 7 (TIA Portal) V15.1, server methods are contained in the OPC UA export file (node set) together with their input and output parameters.

Exporting all array elements separately

If the "Export all array elements as separate nodes" option is selected in the CPU properties under "OPC UA > Server > Export", the OPC UA XML file contains all elements of arrays as individual XML elements. In addition, the arrays themselves are each described in an XML element in the XML file.

If an array contains many array elements, the XML file can be very large.

Tip

The following FAQ contains a converter with which you can convert the export file into CSV format. You then obtain a list of the tags of the CPU that can be accessed by OPC UA.

You can find the FAQ on the Internet

(<https://support.industry.siemens.com/cs/ww/en/view/109742903>).

9.3.3 Configuring the OPC UA server

9.3.3.1 Enabling the OPC UA server

Requirement

- If you use **certificates** for secured communication, e.g. HTTPS, Secure OUC, OPC UA, make sure that the modules involved have the **current time of day and the current date**. Otherwise, the modules evaluate the used certificates as invalid and secure communication does not work.
- You have acquired a runtime license for the operation of the OPC UA functions, see License for OPC UA (Page 198).

Commissioning an OPC UA server

By default, the OPC UA server of the CPU is not enabled for reasons of security: OPC UA clients have neither write nor read access to the S7-1500 CPU.

Follow these steps to activate the OPC UA server of the CPU:

1. Select the CPU. Click on the CPU symbol (for example in the network view).
2. Click "OPC UA > Server" in the properties of the CPU.
3. Activate the OPC UA server of the CPU.
4. Confirm the security notes.
5. Go to the CPU properties, select "Runtime licenses" and set the runtime license acquired for the OPC UA server.
6. Compile the project.
7. Download the project to the CPU.

The OPC UA server of CPU now starts.

Settings remain stored

If you have already enabled the server and made settings, those settings are not lost if the server is disabled. The settings are saved as before and are available when you enable the server again.

Application name

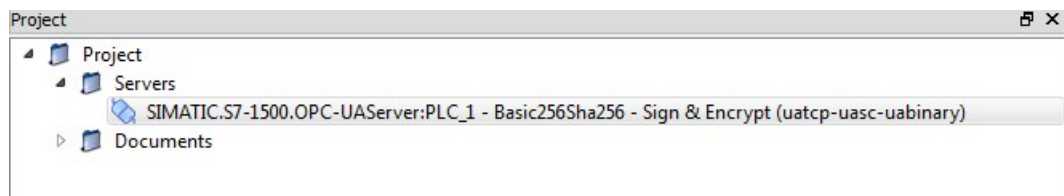
The application name is the name of the OPC UA application and applies to the server and the client. The name is displayed under "OPC UA > General":

- The default for the application name is: "SIMATIC.S7-1500.OPC-UA.Application:PLC_1".
- The default consists of "SIMATIC.S7-1500.OPC-UA.Application:" and the name of the CPU selected under "General > Product information > Name", in this case "PLC_1".
- The OPC UA server uses this application name to identify itself to a communication partner (OPC UA client), for example, when an OPC UA client uses the discovery service to detect accessible servers.
- The displayed application name uses the OPC UA client of the CPU when connecting to an OPC UA Server. This means that the CPU enters this application name automatically as "ApplicationName" for the instruction "OPC-UA_Connect" (tag of type "OPC-UA_SessionConnectInfo" at the parameter "SessionConnectInfo" of the instruction "OPC-UA_Connect").

When you program the instruction "OPC-UA_Connect" you must therefore assign an empty string to the "ApplicationName". You can use the application name, for example, to identify the client and its sessions (SessionNames) for diagnostic purposes.

If you have activated the server, you can also use a different name that is meaningful in your project and that fulfills the requirements of your project, e.g. for worldwide uniqueness.

The example below originates from UaExpert:



Changing the application name

To change the application name, follow these steps:

1. Select the CPU. Click on the CPU symbol (for example in the network view).
2. Click "OPC UA > General" in the properties of the CPU.
3. Enter a meaningful name.

Please note that the application name is also entered on the certificate (Subject Alternative Name) and you may have to generate an existing certificate again after changing the application name.

9.3.3.2 Access to the OPC UA server

Server addresses

The OPC UA server of the S7-1500 CPU can be reached over all integrated PROFINET interfaces of the CPU (firmware V2.0 and higher).

Direct access to the OPC UA server of the CPU over the backplane bus of the automation system is not possible via CPs under the following conditions:

- Configuration with TIA Portal Version V16 or higher, S7-1500 CPU firmware version 2.8 or higher and CP 1543-1 firmware version V2.2 or higher.

For configuration, see Access to OPC UA applications (Page 131).

Direct access to the OPC UA server of the CPU over the backplane bus of the automation system is not possible via CMs.

With SIMATIC S7-1500 SW controllers, access to the OPC UA server is possible via PROFINET interfaces that are assigned to the software PLC.

Additional access options of SW controllers are described in the following application example: Internal and external OPC UA connection via the virtual Ethernet interface of the software controller V2.5 or higher

(<https://support.industry.siemens.com/cs/ww/en/view/109760541>).

Example for URLs (Uniform Resource Locator) that can be used to set up connections to the OPC UA server of the CPU:

The screenshot shows a configuration window titled "Accessibility of the server". Under the heading "Server addresses:", there is a table with two rows of addresses. The first row has the address "opc.tcp://192.168.178.151:4840" and the second row has "opc.tcp://192.168.1.1:4840".

Address
opc.tcp://192.168.178.151:4840
opc.tcp://192.168.1.1:4840

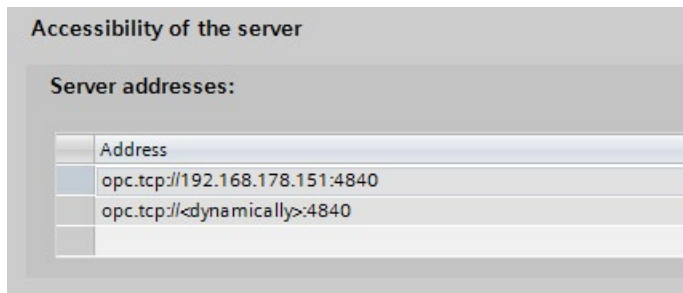
Figure 9-14 Display of the server addresses

The URLs are structured as follows:

- Protocol identifier "opc.tcp://"
 - IP address
 - 192.168.178.151
The IP address at which the OPC UA server can be accessed from the Ethernet subnet 192.168.178.
 - 192.168.1.1
The IP address at which the OPC UA server can be accessed from the Ethernet subnet 192.168.1.
 - TCP Port number
 - Default: 4840 (standard port)
The port number can be changed under "OPC > UA > Server > Port".

Dynamic IP addresses

In the example below, the IP address for the PROFINET interface [X2] has not yet been specified.



The screenshot shows a configuration window titled "Accessibility of the server". Inside, there is a section "Server addresses:" containing a table with two rows. The first row has a fixed IP address, and the second row has a dynamic IP placeholder.

Address
opc.tcp://192.168.178.151:4840
opc.tcp://<dynamically>:4840

Figure 9-15 Display of the server addresses with dynamic IP address

The placeholder "<dynamically>" appears in the table.

The IP address of this PROFINET interface is set later on the device, e.g. via the display of the CPU.

Activating the standard SIMATIC Server interface

If the "Enable standard SIMATIC server interface" option is selected, the OPC UA server of the CPU provides the enabled PLC tags and server methods to the clients, as was specified by SIEMENS in the self-defined namespace.

This option is selected in the default setting.

Leave the option selected so that OPC UA clients can automatically connect to the OPC UA server of the CPU and exchange data.

If you do not select this option, you must add the server interface by entering the "OPC UA communication" entry in the project tree. This interface is then used as OPC UA server interface, see OPC UA server interface configuration (Page 199).

Note

General device information is readable even with deactivated standard SIMATIC server interface

Even if you disable the standard SIMATIC server interface, OPC UA clients can read general device information about the OPC UA server of the CPU.

Examples of such device information: DeviceManual, DeviceRevision, OrderNumber. In this case, however, all objects of the application program remain invisible to clients.

If you want to prevent that this device information is not visible, you have to disable the OPC UA server of the CPU.

9.3.3.3 General settings of the OPC UA server

TCP port for OPC UA

By default, OPC UA uses TCP port 4840. You can, however, select a different port. Entries from 1024 to 49151 are possible. You must, however, make sure that there are no conflicts with other applications. OPC UA clients must use the selected port when establishing a connection.

In the example below, port 48400 is selected:

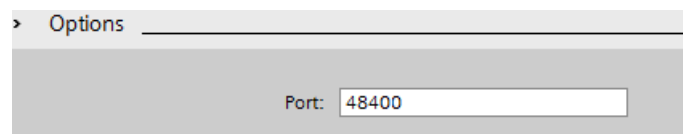


Figure 9-16 TCP port for OPC UA

An overview of the supported protocols and the port numbers used by the S7-1500 CPUs can be found in section Communications protocols and port numbers used for Ethernet communication (Page 22).

Settings for sessions

- Maximum timeout for sessions

In this field, you specify the maximum time period before the OPC UA server closes a session without data exchange.

Possible values between 1 and 600000 seconds.

- Maximum number of OPC UA sessions

In this field, you specify the maximum number of sessions the OPC UA server starts and simultaneously operates.

The maximum number of sessions is dependent on the performance capability of the CPU. Each session ties up resources.

Maximum number of registered nodes

In this field, you specify the maximum number of nodes the OPC UA server registers.

The maximum number of registered nodes depends on the capacity of the CPU and is displayed when you configure the field content (place cursor in field). Each registration ties up resources.

Note

No error message following attempt to register more than the configured maximum number of registrable nodes

If a client tries to register more nodes during runtime than the configured maximum number, the server of the S7-1500 CPU only registers the configured maximum number. Starting from the configured maximum number of registrable nodes, the server returns the regular string node IDs unchanged to the client so that the speed advantage gained by registration for these nodes is lost. The client does not receive an error message.

When configuring, make sure you have a sufficient reserve by taking into account the maximum number of nodes that can be registered (for example, using the technical data of the CPU).

Additional information

Details on which ports are used by the various services for data transfer via TCP and UDP, and what are the points to note when using routers and firewalls can be found in the FAQ (<https://support.industry.siemens.com/cs/ww/en/view/8970169>).

Backward compatible data type definitions according to OPC UA specification \leq V1.03

The OPC UA specification (\leq V1.03) defines mechanisms in order to read out data type definitions, for example for user-defined structures (UDTs), from a server by means of the TypeDictionaries.

In the OPC UA server properties of the CPU, you can set whether the CPU generates these backward compatible data type definitions according to the OPC UA specification \leq V1.03 for the standard SIMATIC server interface or not.

Because TypeDictionaries are complex and result in large OPC UA XML files (server interfaces) which the client has to interpret, a simpler solution was introduced with OPC UA Specification V1.04 (attribute "DataTypeDefinition" at the data type node). If your client supports the OPC UA specification V1.04 or higher, then disable the option.

Advantages of the data type definitions according to OPC UA specification as of V1.04:

- The server starts faster
- The memory is used more efficiently
- The "Browse" function is faster

9.3.3.4 Settings of the server for subscriptions

Subscription instead of cyclic queries

An alternative to cyclic queries for a PLC tag (polling) is to monitor this value. Use a Subscription: The server informs the client if the value of PLC tags changes. See "The OPC UA client".

One server usually monitors a large number of PLC values. For this reason, the server sends notifications to the client at regular intervals containing the new values of the PLC tags.

Advantages of subscriptions:

- The server starts faster
- The memory is used efficiently

How frequently does the server send notifications?

When a Subscription is set up, the OPC UA client specifies the intervals at which it wants to be sent the new values in the event of changes. To limit the communication load through OPC UA, set a minimum interval for the messages. For this purpose, use the parameters for the minimum publishing interval and the minimum sampling interval.

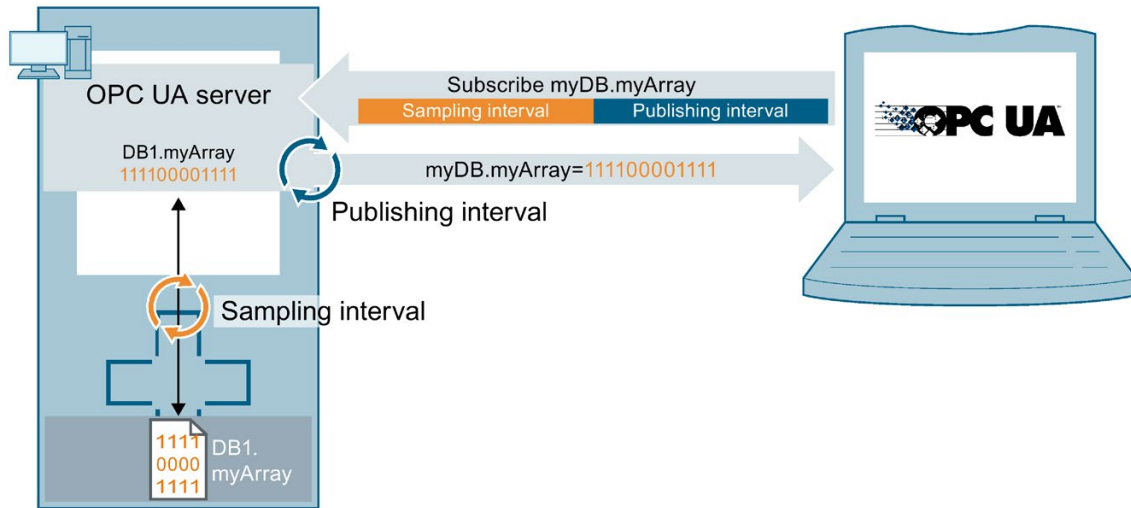


Figure 9-17 Principle of a subscription

Minimum publishing interval

With "Minimum publishing interval", you set the time intervals at which the server sends a message to the client with the new values in the event of changes.

250 ms is used as the "Minimum sampling interval" in the figure below. The value 200 ms is entered as the "Minimum publishing interval".

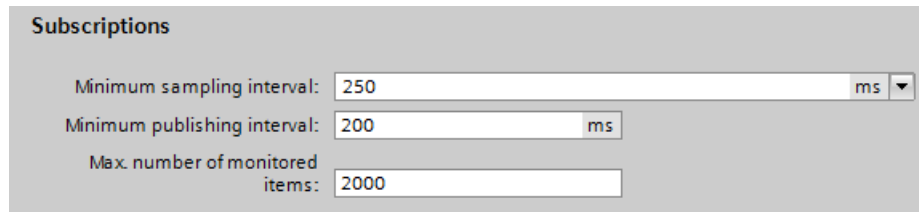


Figure 9-18 Subscription settings

In the example, following a value change the OPC UA server will send a new message every 200 ms if the OPC UA client requests an update.

If the OPC UA client requests an update every 1000 ms, the OPC UA server will only send a message with the new values once every 1000 ms (one second).

If the OPC UA client requests an update every 100 ms, the server will still only send a message every 200 ms (minimum publishing interval).

Minimum sampling interval

With "Minimum sampling interval", you set the time intervals at which the OPC UA server records the value of a CPU tag and compares it with the previous value to detect any changes.

If the sampling interval is selected smaller than the publishing interval and an OPC UA client requests a high sampling rate for certain PLC tags, two or more values may be measured during each publishing interval.

In this case, the OPC UA server writes the value changes into the queue and sends all value changes to the client after the completion of the publishing interval. If more value changes occur in the publishing interval than fit in the queue, the OPC UA server overwrites the oldest values (depending on the set "Discard Policy" of the client subscribing to the data, the option "Discard Oldest" has to be activated in this case). The most recent values are sent to the client.

Maximum number of monitored elements (monitored items)

In this field, you specify the maximum number of elements that the OPC UA server of the CPU simultaneously monitors for a value change.

The monitoring ties up resources. The maximum number of monitored elements is dependent on the utilized CPU.

Additional information

Information about the system limits of the OPC UA server of the S7-1500 CPUs (firmware V2.0 and V2.1) regarding subscriptions, sampling intervals and publishing intervals can be found in the following FAQ

(<https://support.industry.siemens.com/cs/ww/en/view/109755846>).

When using subscriptions, certain status codes of errors provide information on the error that occurred. For information on causes and remedies for status codes of OPC UA client that appear, see the list of error codes in the online help of STEP 7 (TIA Portal) or in the following FAQ (<https://support.industry.siemens.com/cs/ww/en/view/109755860>).

See also

Rules for subscriptions (Page 284)

Subscription diagnostics (Page 240)

9.3.3.5 Handling client and server certificates

A secure connection between the OPC UA server and an OPC UA client is only established when the server can prove its identity to the client. This is done with the server certificate.

Certificate of the OPC UA server

When you have activated the OPC UA server and have confirmed the security prompts, STEP 7 automatically generates the certificate for the server and saves it in the local certificate directory of the CPU. You can view and manage this directory with the local certificate manager of the CPU (exporting or deleting certificates).

The figure below shows the local certificate manager of the CPU with the automatically generated certificate for the OPC UA server:



Figure 9-19 Local certificate manager of the CPU

Alternatively, you can also generate a server certificate yourself.

The certificate of the server is transferred from the server to the client during establishment of a connection. The client checks the certificate.

The client user decides whether the server certificate is to be trusted.

The user at the client side now has to decide whether the server certificate is to be trusted. If the user trusts the server certificate, the client stores the server certificate in its directory containing the trusted server certificates.

The following example shows a dialog of the client "UA Sample Client". When the user clicks the "Yes" button, the client trusts the server certificate:

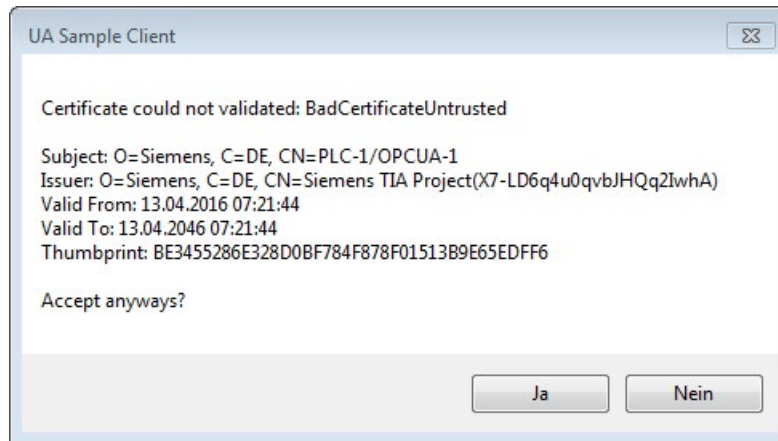


Figure 9-20 Dialog of the client "UA Sample Client"

Where does a client certificate come from?

Client of the S7-1500

If you are using the OPC UA client of an S7-1500 CPU (OPC UA client enabled), you can create certificates for these clients with STEP 7 V15 and higher.

1. In the project tree, select the CPU you want to use as a client.
2. Double-click "Device configuration".
3. In the properties of the CPU, click "Protection & Security > Certificate manager".
4. Double-click "<Add new>" in the "Device certificates" table.

STEP 7 opens a dialog.

5. Click the "Add" button.
6. Select the "OPC UA client" entry from the "Usage" list.

Note:

The IP addresses under which the CPU can be accessed in your system must be entered under "Subject Alternative Name (SAN)".

You must therefore configure the IP interfaces of the CPU before you generate a client certificate.

7. Click "OK".

STEP 7 now shows the client certificate in the "Device certificates" table.

8. Right-click this line and select the "Export certificate" entry from the shortcut menu.
9. Select a directory where you will store the client certificate.

Clients of other manufacturers

When you use UA clients from manufacturers or the OPC Foundation, a client certificate is generated automatically during installation or upon the first program call. You have to import these certificates via the global certificate manager in STEP 7 and use them for the corresponding CPU (as shown above).

When you program an OPC UA client yourself, you can have the certificates generated by the program; see the section "Instance certificate for the client". Alternatively, you can generate certificates with tools, for example with OpenSSL or the certificate generator of the OPC Foundation:

- The procedure for OpenSSL is described here: "Generating PKI key pairs and certificates yourself".
- Working with the certificate generator of the OPC Foundation is described here: "Creating self-signed certificates".

Announcing client certificates to the server

You need to send client certificates to the server to allow a secure connection to be established.

To do this, follow these steps:

1. Select the "Use global security settings for certificate manager" option in the local certificate manager of the server. This makes the global certificate manager available.

You will find this option under "Protection & Security > Certificate manager" in the properties of the CPU that is acting as server.

If the project is not yet protected, select "Security settings > Settings" in the STEP 7 project tree, click the "Protect this project" button and log on.

The "Global security settings" item is now displayed under "Security settings" in the STEP 7 project tree.

2. Double click "Global security settings".
3. Double click "Certificate manager".

STEP 7 opens the global certificate manager.

4. Click on the "Trusted certificates" tab.
5. Right-click in the tab on a free area (not on a certificate).
6. Select the "Import" command from the shortcut menu.

The dialog for importing certificates is displayed.

7. Select the client certificate that the server is to trust.
8. Click "Open" to import the certificate.

The certificate of the client is now contained in the global certificate manager.

Note the ID of the client certificate just imported.

9. Click the "General" tab in the properties of the CPU that is acting as server.
10. Click "OPC UA > Server > Security > Secure Channel".
11. Scroll down in the "Secure Channel" dialog to the section "Trusted clients".
12. Double-click in the table on the empty row with "<add new>". A browse button is displayed in the row.
13. Click this button.
14. Select the client certificate that you have imported.
15. Click the button with the green check mark.
16. Compile the project.
17. Load the configuration onto the S7-1500 CPU.

Result:

The server now trusts the client. If the server certificate is also considered trusted, the server and client can establish a secure connection.

Accepting client certificates automatically

When you select the option "Automatically accept all client certificates during runtime" (below the "Trusted clients" list), the server automatically accepts all client certificates.

NOTICE**Setting after commissioning**

In order to avoid security risks, deactivate the "Automatically accept client certificates during runtime" option again after commissioning.

Configuring security settings of the server

The figure below shows the available server security settings for signing and encrypting messages.

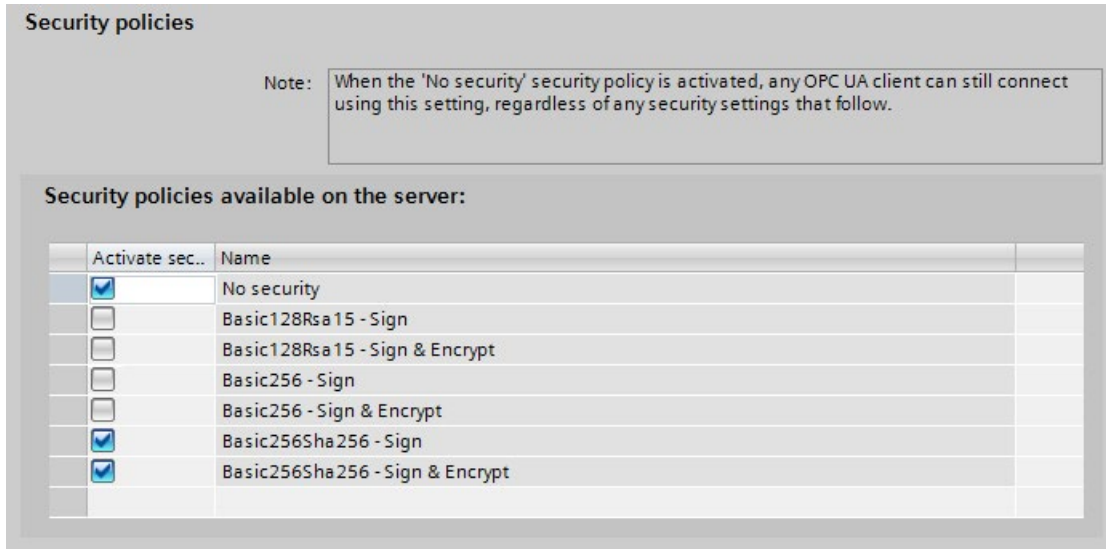


Figure 9-21 Configuring security settings of the server

By default, a server certificate is created that uses SHA256 signing. The following security policies are enabled:

- None
Unsecured end point

Note

Disabling security policies you do not want

If you have enabled all security policies in the secure channel settings of the S7-1500 OPC UA server (default setting) – thus, also the end point "None" (no security) – unsecured data traffic (neither signed nor encrypted) between the server and client is also possible. The identity of the client remains unknown with "No security". Each OPC UA client can then connect to the server irrespective of any subsequent security settings.

When configuring the OPC UA server, make sure that only security policies that are compatible with the security concept of your machine or plant are selected. All other security policies should be disabled.

Recommendation: If possible, use the setting "Basic256Sha256".

- Basic128Rsa15 -Sign
Insecure end point, supports a series of algorithms that use the hash algorithm RSA15 and 128-bit encryption.
This endpoint protects the integrity of the data through signing.

- **Basic128Rsa15 -Sign & Encrypt**
Secure endpoint, supports a series of algorithms that use the hash algorithm RSA15 and 128-bit encryption.
This endpoint protects the integrity and confidentiality of the data through signing and encrypting.
- **Basic256Rsa15 -Sign**
Secure endpoint, supports a series of algorithms that use the hash algorithm RSA15 and 256-bit encryption.
This endpoint protects the integrity of the data through signing.
- **Basic256Rsa15 -Sign & Encrypt**
Secure endpoint, supports a series of algorithms that use the hash algorithm RSA15 and 256-bit encryption.
This end point protects the integrity and confidentiality of the data through signing and encrypting.
- **Basic256Sha256 - Sign**
Secure endpoint, supports a series of algorithms for 256-bit hashing and 256-bit encryption.
This endpoint protects the integrity of the data through signing.
- **Basic256Sha256 - Sign & Encrypt**
Secure endpoint, supports a series of algorithms for 256-bit hashing and 256-bit encryption.
This endpoint protects the integrity and confidentiality of the data through signing and encryption.

To enable the security setting, click the check box in the relevant line.

Note

If you use the settings "Basic256Sha256 -Sign" and "Basic256Sha256 -Sign & Encrypt", the OPC UA server and OPC UA clients must use "SHA256"-signed certificates.

For the settings "Basic256Sha256 -Sign" and "Basic256Sha256 -Sign & Encrypt", the certificate authority of STEP 7 automatically signs the certificates with "SHA256".

"No Security" security policy and authentication via user name and password

You can set the following combination:

Security policy = "No Security" and authentication via user name and password.

- The OPC UA server of the S7-1500 supports this combination. OPC UA clients can connect and encrypt the authentication data or not.
- OPC UA client of the S7-1500 CPU also supports this combination: However, in runtime it only connects if it can send the authentication data encrypted via cable!

See also

Generating server certificates with STEP 7 (Page 190)

9.3.3.6 Generating server certificates with STEP 7

The description below shows the procedure for generating new certificates with STEP 7 and applies in principle to various uses of the certificates. STEP 7 sets the appropriate purpose - in this case "OPC UA Client & Server" - depending on which area of the CPU properties is used to start the following dialog.

Recommendation: To use the full functionality for the security of the OPC UA server, use the global security settings.

The global security settings are enabled in the CPU properties under "Protection & Security > Certificate manager".

Customizing server certificates

STEP 7 automatically generates a certificate for the OPC UA server of the S7-1500 when you activate the server (see "Activating the OPC UA server (Page 175)"). In the process STEP 7 uses the default values for the parameters of the certificate. If you want to change the parameters, follow these steps:

1. Click the Browse button under "General > OPC UA > Server > Security > Secure channel > Server certificate" in the properties of the CPU. A dialog is displayed that shows the certificates available locally.
2. Click the "Add" button.

3. The dialog for generating new certificates is displayed (figure below). The values for an example are already entered:

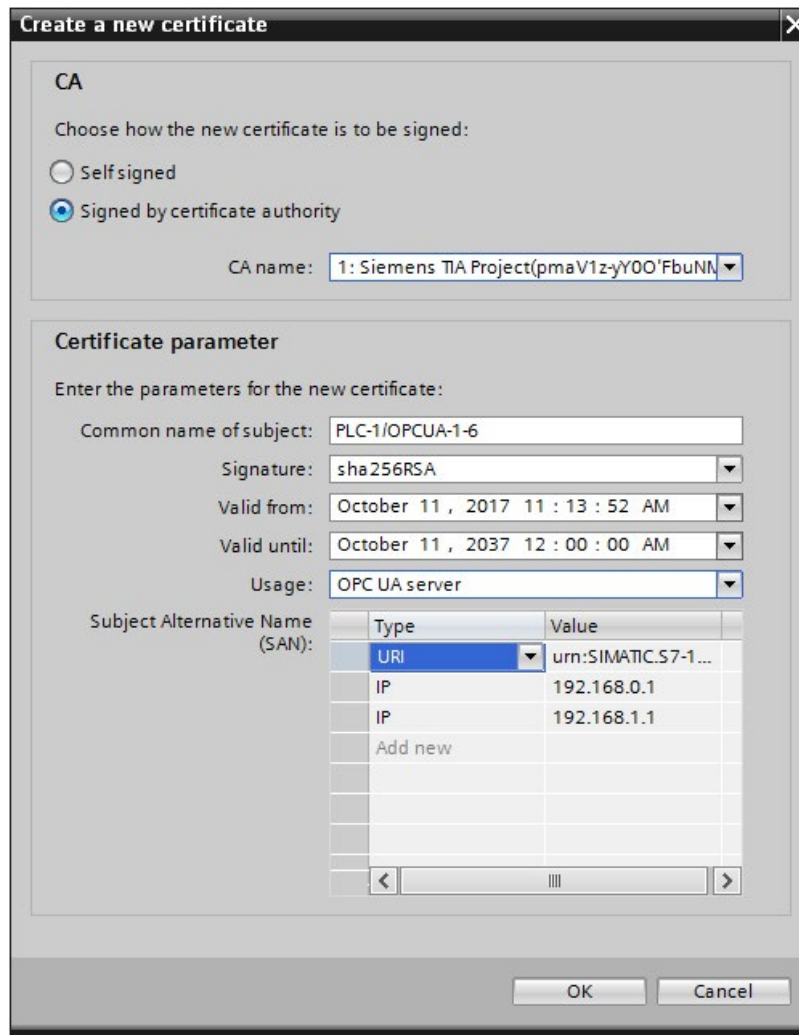


Figure 9-22 Customizing server certificates

4. Use other parameters if this is necessary in accordance with the security specifications in your company or your customer.

Explanation of fields for certificate generation

- CA

Select whether the certificate is to be self-signed or signed by one of the CA certificates of the TIA Portal. The certificates are described under "Certificates with OPC UA". If you want to generate a certificate that is to be signed by one of the CA certificates of the TIA-Portal, the project must be protected and you must be logged in as a user with all the required function rights. Further information can be found under "Basics of user administration in the TIA Portal".

- Certificate holder

The default setting always consists of the name of the project and "OPCUA-1". In the example, the project name is "PLC1". In the properties of the CPU set the project name under "General > Project information" > Name". Keep the default or enter a different name that is more meaningful for the OPC-UA server under "Certificate holder".

- Signature

Here you select the hash and encryption process that is to be used when signing the server certificate. The following entries are available:

- "sha1RSA",
- "sha256RSA".

- Valid from

Here you enter the date and time for the beginning of the validity of the server certificate.

- Valid until

Here you enter the date and time for the end of the validity of the server certificate. Ensure that the certificate is valid not only for one year or a few years. In the example the certificate is valid for 30 years. However, for reasons of security you should renew the certificate at much shorter intervals. The long period of validity gives you the opportunity to decide when a suitable moment would be, for example, when the system is being serviced.

- Usage

The default is "OPC UA client & server". Keep this default for the OPC UA server. The "Create a new certificate" dialog can be called from several points in STEP 7. If, for example, you call this dialog for the Web server of the CPU, "Web server" is entered under "Usage". The following entries are available in the Usage drop-down list:

- "OPC UA client"
- "OPC UA client & server"
- "OPC UA server"
- "TLS"
- "Web server"

- Subject Alternative Name (SAN)

The following is entered in the example above: "URI:urn:SIMATIC.S7-1500.OPC-UA:Server:PLC1,IP:192.168.178.151,IP:192.168.1.1". This URI must be correctly entered because it is checked against the communicated application description.

The following entry would also be valid: "IP: 192.168.178.151, IP: 192.168.1.1". The important thing here is that the IP addresses via which the OPC UA server of the CPU can be accessed are entered here.

See "Access to the OPC UA server (Page 177)".

This allows OPC UA clients to verify whether a connection to the OPC UA server of the S7-1500 is really to be established or whether in fact an attacker is trying to send manipulated values from another PC to the OPC UA client.

9.3.3.7 User authentication

Types of user authentication

For the OPC UA server of the S7-1500, you can set what authentication is required for a user of the OPC UA client wishing to access the server.

You have the following options:

- **Guest authentication**

The user does not have to prove their authorization (anonymous access). The OPC UA server does not check the authorization of the client user

If you want to use this type of user authentication, select the "Enable guest authentication" option under "OPC UA > Server > Security > User authentication".

Note

To increase security, you should only allow access to the OPC UA server with user authentication.

- **User name and password authentication**

The user has to prove their authorization (no anonymous access). The OPC UA server checks whether the client user is authorized to access the server. Authorization is given by the user name and the correct password.

If you want to use this type of user authentication, select the "Enable user name and password authentication" option under "OPC UA > Server > Security > User authentication".

Deactivate the guest authentication.

Enter the user in the "User management" table.

To do so, click the "<Add new user>" entry. A new user is created with an automatically assigned name. You can edit the user name and enter the password for the user name. You can add a maximum of 21 users.

- **Additional user administration via the security settings of the project**

The "Enable additional user administration via the security settings of the project" option can be found under the general OPC UA settings (CPU properties: OPC UA > General). If you select this option, the user management for the open project will also be used for user authentication for the OPC UA server: The same user names and passwords are then valid in OPC UA as in the current project.

Proceed as follows to activate user management for the project:

- Click "Security settings > Settings" in the project tree.
- Click the "Protect this project" button.
- Enter your user name and your password.
- Enter additional users under "Security settings > Users and roles".

If you configure an additional OPC UA server in your project, also select the option "Enable additional user administration via the security settings of the project". Repeated input of user names and passwords is then unnecessary.

See also

User authentication (Page 275)

Users and roles with OPC UA function rights (Page 194)

9.3.3.8 Users and roles with OPC UA function rights

The following options for user authentication use central project settings for project users:

- For the server:
 - For configuration of CPU properties (OPC UA > Server > Security > User authentication). Option: "Enable additional user administration via the security settings of the project"
- For the client:
 - For configuration of client interface ("Configuration" tab, "Security"). Option: "User (TIA Portal - security settings)"

Requirement

Before you can edit the security settings, the project must be protected and you must be logged on with sufficient rights, for example as administrator.

Settings in the project tree > "Security settings"

You access the central user settings and roles in the protected project in the project tree under "Security settings". This is where you centrally define users with user name, password and function rights. You can simply use these settings elsewhere.



Figure 9-23 Setting user and roles

Reusing central security settings

Examples for reusing elsewhere:

- User selection for user authentication for OPC UA server
With this setting, you tell the server which client (user) with which user name and which password is allowed to access the server.
- User selection for OPC UA client authentication
With this setting, you tell the client the user name and password that it is to use for client authentication for the server.

The settings for the client and server must correspond: The user name and password used by the client to log on must have been set up on the server and assigned the required authorizations.

Function rights for server and client

The corresponding function rights for the client or the server must also be enabled for users of the client function and users of the server function on an S7-1500 CPU. It is not enough simply to save the user name and password centrally.

Here is an example to illustrate this type of rights use.

1. Under "Security settings > Users and roles", you define a new role in the "Roles" tab with the name "PLC-opcua-role-all-inclusive", for example.
Tip: The tab may be covered by an information window ("The current status has not yet been checked..."). In this case, first close the information window.
2. In the "Categories of function rights" section, you navigate to the runtime rights and then to the CPU function rights, and select the CPU whose function rights you want to set, for example PLC_2.

3. You will find the following function rights in the "Function rights" section:

- OPC UA server access

This function right applies on the OPC UA server of the S7-1500 CPU. Only when this option is selected does a user of the CPU PLC_2 server who has been assigned the role "PLC-opcua-role-all-inclusive" have the following right: For the establishment of a session with the server, the user requires client authentication with one of the user names and corresponding passwords that have been centrally defined (and loaded to the CPU).

- User authentication of the OPC UA client

This function right applies on the OPC UA client of the S7-1500 CPU (with client instructions). Only when this option is selected can the user of the client of CPU PLC_2 who has been assigned the role "PLC-opcua-role-all-inclusive" use the user name and password for authentication to establish a session with a server.

Function rights categories	Function rights						
<ul style="list-style-type: none"> ▼ Engineering rights <ul style="list-style-type: none"> General ▼ Runtime rights <ul style="list-style-type: none"> ▼ PLC Function Rights <ul style="list-style-type: none"> Software PLC_2 	<table border="1"> <thead> <tr> <th>Name</th> <th></th> </tr> </thead> <tbody> <tr> <td>OPC UA server access</td> <td><input type="checkbox"/></td> </tr> <tr> <td>OPC UA client user authentication</td> <td><input type="checkbox"/></td> </tr> </tbody> </table>	Name		OPC UA server access	<input type="checkbox"/>	OPC UA client user authentication	<input type="checkbox"/>
Name							
OPC UA server access	<input type="checkbox"/>						
OPC UA client user authentication	<input type="checkbox"/>						

Figure 9-24 Setting function rights

4. The role "PLC-opcua-role-all-inclusive" still needs to be assigned to the relevant users ("Users" tab under "Security settings" in the project tree).

See also

User authentication (Page 193)

User authentication (Page 275)

9.3.3.9 Diagnostic settings of the server

Diagnostics

You can specify the scope of the diagnostics of the OPC UA server in the CPU settings. To change the diagnostics scope, navigate to the "OPC UA > Server > Diagnostics" area.

> Diagnostics

Diagnostics on status changes

- Change of OPC UA server status
- Change of session status

Diagnostics of additional events

- Check on security events
- Request of remote OPC UA client failed
- Subscriptions: Change of status
- Subscriptions: Sampling time errors

Summarize diagnostics

- Summarize diagnostics in case of high message volume

Length of an interval: s

Figure 9-25 Diagnostic settings of OPC UA server

Default setting

The default setting is a diagnostics behavior that supports the most important diagnostics without appreciably increasing the communication load.

You enable diagnostics for subscriptions when the OPC UA server also uses subscriptions, i.e. if necessary during the commissioning phase only.

Reason: A large volume of diagnostic activity generates a high communication load in the CPU and may suppress other important messages. Or, the high volume of diagnostics may result in important messages disappearing in the mass of messages and being ignored.

Additional information

You will find additional information on the meaning and effect of the settings shown above here (Page 233).

9.3.3.10 License for OPC UA

Runtime licenses

A license is required to run the OPC UA server of the S7-1500 CPU. The type of license required depends on the performance of the respective CPU. The following license types are differentiated:

- SIMATIC OPC UA S7-1500 small (required for CPU 1511, CPU 1512, CPU 1513, ET 200SP CPUs, CPU 1515SP PC)
- SIMATIC OPC UA S7-1500 medium (required for CPU 1515, CPU 1516, Software Controller CPU 1507, CPU 1516pro-2PN)
- SIMATIC OPC UA S7-1500 large (required for CPU 1517, CPU 1518)

The required license type is displayed under "Properties > General > Runtime licenses > OPC-UA > Type of required license":

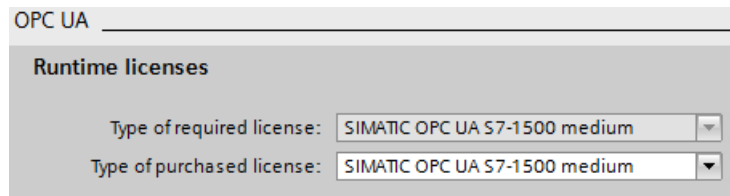


Figure 9-26 OPC UA server Runtime licenses

To confirm purchase of the required license, follow these steps:

1. Click "Runtime licenses > OPC UA" in the properties of the CPU.
2. Select the required license from the "Type of purchased license" drop-down list.

9.3.4 OPC UA server interface configuration

9.3.4.1 What is a server interface?

Definition

A server interface combines nodes of an OPC UA address space of a CPU into a unit, so that a specific view on this CPU is provided for OPC UA clients.

Each server interface defines one or more namespaces in the OPC UA server of the CPU.

STEP 7 (TIA Portal) differentiates between the following types of server interfaces:

- Companion specification

For this type of server interface, you use a Companion Specification created by a workgroup, for example.

The workgroup is typically composed of members of the OPC Foundation and another industry organization who have jointly specified an OPC UA information model for a specific purpose (for example, for data exchange with RFID devices or with injection molding machines).

This information model is realized in the form of OPC UA nodes in the address space of an OPC UA server. OPC UA clients can access these OPC UA nodes.

You can also use the server interface type "Companion specification", for example, to download company-internal information models, e.g. in SiOME.

If you implement a certain companion specification in your project, you apply the specifications of this companion specification into your project as server interface.

For "Companion specification"-type server interfaces, you can import multiple namespaces which the Companion specification uses.

Additional information on companion specifications is available here (Page 218).

Additional information on SiOME is available here

(<https://support.industry.siemens.com/cs/ww/en/view/109755133>).

- User-defined server interface:

For this type of server interface you combine OPC UA nodes of an OPC UA server into a unit.

To do this, use the specifications for your project or the requirements for your machine or your plant as a basis.

Additional information on the user-defined server interface is available here (Page 201).

Injection molding machine as an example for companion specification

In this example, a server interface contains the following elements:

- OPC UA nodes which you can write with an OPC UA client to receive information about this injection molding machine (in readable PLC tags)
- OPC UA nodes which you can write with an OPC UA client to transfer values to the injection molding machine (in writable PLC tags)
- OPC UA nodes which you can call with an OPC UA client to start functions of the injection molding machine (via server methods)

This server interface enables a default view of a CPU, which can be used to control an injection molding machine.

For injection molding machines, the companion specification "Euromap" defines a whole series of OPC UA nodes which you can combine in a server interface.

Other OPC UA nodes of the CPU are not included in this server interface. This provides a better overview.

Example of user-defined server interface

A CPU should control the production of workpieces. Production begins when a production job arrives from the higher-level control system.

The production jobs are transferred via a server method: A control system transmits information on a workpiece by calling the server method in the CPU. This server method also starts production.

The control system, i.e. the connected OPC UA client, should only see this one server method. Therefore, you create a user-defined server interface in the CPU and assign the server method to this server interface. You enable only this server interface for OPC UA clients and thus limit the view of the CPU to this one function.

See also

Using OPC UA companion specifications (Page 206)

9.3.4.2 Creating a user-defined server interface

Introduction

The description is based on the following example:

A protective fence surrounds the production cell "Cell_1". The fence is equipped with the gate "Gate_1".

An S7-1500 CPU controls the entire production cell and also controls access through Gate_1.

A robot packs drugs into boxes in the production cell and then stacks the boxes on pallets.

Self-driving vehicles for automated material transport move the pallets to the central warehouse, thereby passing through Gate_1.

The CPU publishes a server interface via which the driverless transport systems arrange for Gate_1 to open.

The server interface contains the server method "smOpenGate" for opening the gate and the tag "Gate_1_State" which indicates the status of the gate (open or closed).

Creating a user-defined server interface

To create an Server interface, follow these steps:

1. Select the CPU that you have used and configured as OPC UA server.
2. Click "OPC UA communication > Server interfaces".
3. Double-click "Add new server interface".

STEP 7 displays the following dialog.

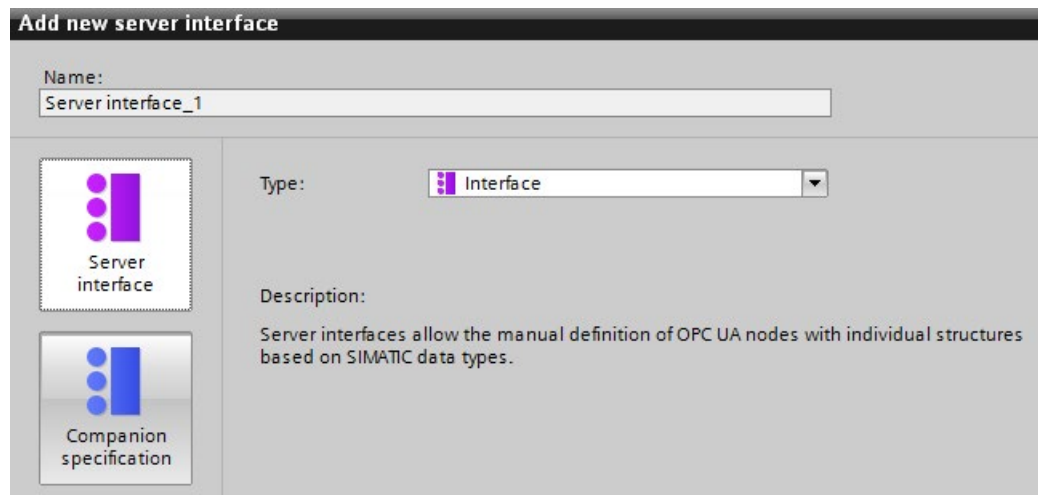


Figure 9-27 Adding the server interface

4. Change the name of the new server interface so that it is descriptive in your project.
In the example, change the name "Server-interface_1" suggested by STEP 7 to "Cell_1".
5. Click "Server interface" and then "OK".

- Click on the triangle in front of "Program blocks" in the area "OPC UA elements" to open the "Program blocks" folder.

STEP 7 displays the following table for editing:

OPC UA server interface				OPC UA elements	
	Browse Name	Node type	Local data	Project data	Data type
1	Cell_1	Interface		Software units	
2	<Add new>			Program blocks	
				Cell_1 [DB1]	Cell_1
				Robot_1 [DB2]	Robot_1
				smOpenGate_DB [DB3]	smOpenGate_DB
				Technology objects	
				PLC tags	

Figure 9-28 Editing the server interface

The editor is divided into two areas.

– **OPC UA server interface**

On the left is the root node of the server interface "Cell_1".

This interface is currently still empty: No OPC UA elements have been added to the server interface yet.

– **OPC UA elements**

On the right are the OPC UA elements.

OPC UA elements are objects that have been created so far in the STEP 7 project and have the property "Accessible from HMI/OPC UA".

You can add the OPC UA elements to the new server interface "Cell_1".

- Drag the OPC UA elements into the "<Add new>" line of the new server interface.

Note

The following applies in general: If you store data blocks or technology objects in the left area of the table, STEP 7 (TIA Portal) creates an object in the server interface. The elements of the data blocks are arranged as separate nodes below this.

If you store structures in the left area of the table, STEP 7 creates a node for the structure as a whole and nodes for each element of the structure.

The same applies to arrays: Again, STEP 7 creates a node for the array as a whole and nodes for each element of the array.

When you place a method in the left area of the table, STEP 7 creates a single node; the arguments of the inserted method are displayed for information purposes.

In the example, you drag the "Gate_1_State" tag from the right area to the left area to "<Add new>".

Then, drag the server method into the left area.

This server method is located within the "smOpenGate_DB [DB3]" data block in the right area.

STEP 7 (TIA Portal) displays the dialog as follows:

Name	Node type	Local data	Project data	Data type
Cell_1	Interface		1 Software units	
Gate_1_State	BOOL	"Cell_1"."Gate_1_State"	2 Program blocks	
Method	Method	"smOpenGate_DB".Method	3 Cell_1 [DB1]	Cell_1
<Add new>			4 Gate_1_State	Bool
			5 Robot_1 [DB2]	Robot_1
			6 smOpenGate_DB [DB3]	smOpenGate
			7 Method	Method
			8 Static	
			9 Technology objects	
			10 PLC tags	

Figure 9-29 Adding OPC UA elements to the server interface

Limiting the view to OPC UA servers

By selecting the OPC UA elements, you limit the view to the OPC UA server and the options of the OPC UA clients.

In the server interface of the example, the "Robot_1" data block is missing because industrial trucks do not need access to the server methods and tags of the robot.

In this case, it is best to disable the standard server interface (SIMATIC namespace) in the OPC UA properties of the S7-1500 CPU so that the filtered nodes cannot be accessed any other way.

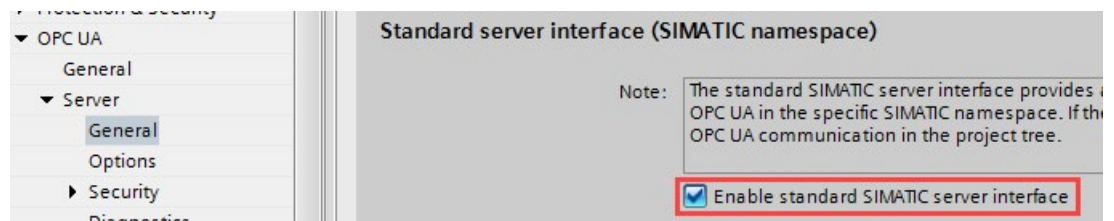


Figure 9-30 Disabling the standard server interface

You can also disable the visibility of each configured server interface in the properties of the server interface and thus prevent that this server interface can be used by clients during operation. This option lets you define multiple server interfaces, for example, and download only the required server interface.

Once a server interface has been defined, you can drag it to another CPU in the project tree.

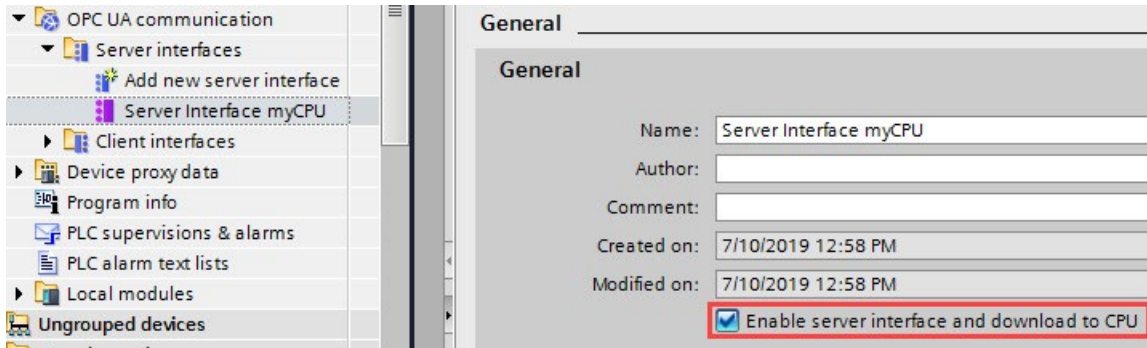


Figure 9-31 Disabling the visibility of the server interface

Information on the server interface

The "OPC UA Server Interface" dialog is structured as a table and provides the following information:

Note that not all columns are displayed initially. You determine what is displayed by right-clicking on the header line of the table.

When a row is selected, you can display the OPC UA attributes of the node in the Inspector window ("OPC UA attributes" area), such as node ID, node class, node type, and description.

- **BrowseName**

The language neutral name of the user-defined server interface is at the top (BrowseName). This name can be freely selected.

The names (BrowseNames) of the individual OPC UA nodes that have been added to the server interface are under the name of the interface.

You cannot change the name of an OPC UA node in this dialog. The names come from the STEP 7 project.

You can delete an OPC UA node from the table. This means that it no longer belongs to the server interface and is no longer visible to OPC UA clients.

- **DisplayName**

Similar to BrowseName. However, the name can be translated and is displayed, if available, in the corresponding language.

- **Node ID**

Nodeld of the OPC UA node, e.g. `http://Server-Node_1; i=1`

- **Node type**

Type of the OPC UA node, for example BOOL, BYTE, INT.

These node types were defined by Siemens, not by the OPC Foundation. For example, the OPC Foundation uses the Boolean node type for BOOL. BOOL is directly derived from Boolean.

The specified node type cannot be changed in this dialog: If you want to use a different node type, you must change the type of the respective PLC tags in the STEP 7 project.

- **Data type**

The SIMATIC data type used in the STEP 7 project is specified, for example, Bool, Byte, Int. etc.

- **Access level**

- If an OPC UA node is a tag (UAVariable type), the node can only be readable (RD) or readable and writable (RD/WR).
- If an OPC UA node is a method (UAMethod type), this node can always be called.

- **Local data**

The SIMATIC data type of the data block in the CPU, from which the value of an OPC UA node (UAVariable type) is read, or to which a value is written.

Consistency check

You have the option to check the server interface.

During the consistency check, STEP 7 checks whether the OPC UA nodes of the server interface are each assigned to a suitable OPC UA element (identical data type) or whether the used element still exists in the CPU.

To check the consistency of the server interface, click on the following icon in the toolbar of the OPC UA server interface editor:

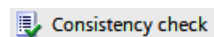


Figure 9-32 "Consistency check" button

Export interface

You have the option of exporting the OPC UA server interface as an XML file. This XML file contains all data type definitions referenced by the server interface.

To export the OPC UA server interface, click on the following icon in the toolbar of the OPC UA server interface editor:

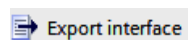


Figure 9-33 "Export interface" button

See also

Master copies for OPC UA communication (Page 286)

9.3.4.3 Using OPC UA companion specifications

Introduction

OPC UA is universally applicable: The standard itself does not, for example, specify how PLC tags are to be named. It is also up to the individual user (application developer) to program and name server methods that can be called over OPC UA.

Information modeling and standardization for devices and sectors

For applications of the same kind, it is worth standardizing your device or machine interface with the "OPC UA toolkit".

Many different bodies and working groups have driven forward standardization and developed a range of companion specifications.

These specifications define:

- The objects, methods and tags with which a typical device or machine is to be described.
- The namespace intended for the specified objects.

Machines are typically structured in functional or technological units, and these units are then standardized.

Companion specifications offer machine and plant operators the benefits of a standardized interface. For example, all RFID readers that comply with the AutoID specifications can be integrated in the same way. This means that all RFID readers that comply with the AutoID specifications can be addressed by OPC UA clients in the same way irrespective of manufacturer.

Another example of companion specifications is the Euromap 77 Companion Specifications from the injection molding machinery sector.

The following section uses the example of Euromap 77 to detail how to apply companion specifications in STEP 7 (TIA Portal) and create the necessary PLC tags.

Example: Euromap 77

Euromap 77 standardizes the exchange of data between injection molding machines and the higher-level MES (Manufacturing Execution System). This allows the MES to connect all lower-level injection molding machines in the same way.

The standardized data interface facilitates the integration of injection molding machines into a plant.

Using companion specifications: Overview

Euromap 77 is described in the OPC UA XML file "Opc_Ua.EUROMAP77.NodeSet2.xml".

Note

Euromap 77, Euromap 83 and OPC UA for Devices (DI)

With Release Candidate 2, some of the Euromap definitions have been transferred from Euromap 77 to Euromap 83. You will therefore also need to import the OPC UA server interface of Euromap 83.

"OPC UA for Devices" is a generally applicable information model for the configuration of hardware and software components. The information model also serves as the basis for other companion standards and is therefore also imported.

The OPC UA XML files are available here:

Euromap77 (<http://www.euromap.org/euromap77>)

Euromap83 (<http://www.euromap.org/euromap83>)

OPC UA for Devices (<https://opcfoundation.org/UA/schemas/DI/>)

These XML files define an OPC UA interface of an injection molding machine that complies with Euromap 77.

Using Euromap 77: Overview

To use Euromap 77, proceed as follows:

1. Generate an XML file by creating an instance of the type "IMM_MES_InterfaceType" using the SiOME program.

How to proceed is described below in "Step 1: Create instances in SiOME".

2. In STEP 7 (TIA Portal), create PLC tags and server methods that correspond to the instance of the type "IMM_MES_InterfaceType" (created in Step 1).

See below for information on how to proceed in "Step 2: Create PLC tags in STEP 7".

An example of OPC UA nodes and the corresponding PLC tags can be found in section "Creating a server interface for companion specification (Page 218)".

3. In STEP 7 (TIA Portal), add a new server interface of companion specification type and import the XML file you created in step 1.

The "Creating a server interface for companion specification (Page 218)" section describes how to proceed.

4. Assign the OPC UA nodes of the new server interface to the corresponding PLC tags, which you created in step 2.

The "Creating a server interface for companion specification (Page 218)" section describes how to proceed.

Step 1: Create instances in SiOME

The following section describes how to use the free program "SiOME", the "Siemens OPC UA Modeling Editor".

With SiOME, you can create an OPC UA XML file, which describes the server interface (an information model).

Download link and explanations about SiOME are available here (<https://support.industry.siemens.com/cs/ww/en/view/109755133>).

Procedure in STEP 7

To use the new server interface, import the server interface into the STEP 7 project, see section "Creating a server interface for companion specification (Page 218)".

When the project is loaded into the CPU, the new server interface is available for OPC UA clients.

Procedure in SiOME 1.7.3

The following description shows the work steps in SiOME 1.7.3.

To use Euromap 77, create an XML file with an instance of "IMM_MES_InterfaceType".

The object type must be instantiated in order for the information model of the specific machine to appear in the address space of the OPC UA server.

The object type "IMM_MES_InterfaceType" is the root object type of Euromap 77. "IMM" stands for "Injection Moulding Machine".

Follow these steps:

1. Download the files "Opc_Ua.EUROMAP77.NodeSet2.xml" and "Opc_Ua_EUROMAP83_NodeSet2.xml" from the Euromap website (see above).
2. Download the file "Opc.Ua.Di.NodeSet2.xml" from the OPC Foundation website.
The "Opc.Ua.Di.NodeSet2.xml" file contains type definitions which Euromap 77 uses.
3. Start SiOME.
4. First, import the namespace "http://opcfoundation.org/UA/DI/".

To do so, click the "Import XML" button in the "Information model" area.



Figure 9-34 "Import XML" button in SiOME

SiOME displays the dialog for the opening files.

5. To import the file, select the "Opc.Ua.Di.NodeSet2.xml" file and click "Open".
Result: SiOME imports the XML file and shows the namespace "http://opcfoundation.org/UA/DI/" in the "Namespaces" area.

The standard namespace "http://opcfoundation.org/UA/" is always available in SiOME and does not have to be imported.

6. Now import the namespace "http://www.euromap.org/euromap83/"

To do so, click the "Import XML" button again in the "Information model" area.

Select the file "Opc_Ua.EUROMAP83.NodeSet2.xml".

Result: SiOME imports the XML file and shows the namespace "http://www.euromap.org/euromap83/" in the "Namespaces" area.
7. Now import the namespace "http://www.euromap.org/euromap77/"

To do so, click the "Import XML" button again in the "Information model" area.

Select the file "Opc_Ua.EUROMAP77.NodeSet2.xml".
8. Create your own namespace for your project.

To do this, right-click in the "Namespaces" area on "OPC UA Modelling Editor Project" or on "Namespaces" and select "Add Namespace".

SiOME opens the "Add Namespace" dialog.
9. Enter the name of a new namespace.

The "YourCompany.org" namespace is used in the example.

SiOME now also displays the new namespace:

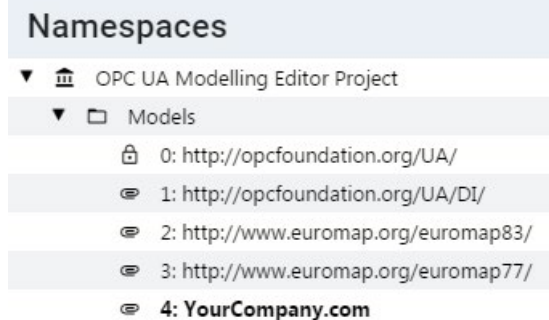


Figure 9-35 Display of the namespace in SiOME

10. Create an instance from the root object type IMM_MES_InterfaceType of the Companion specification Euromap 77.

To do so, in the "Information model" area, right-click the "DeviceSet" directory and select "Add Instance".

SiOME displays the "Add Instance" dialog.
11. For "Name", enter a meaningful name for your instance.

In the example, enter "IMM_Manufacturer_01234".

For "TypeDefinition", select "IMM_MES_InterfaceType".

This object type is the root object type of Euromap 77: If you generate an instance of this object type, then use the Euromap 77 once in the address space of your OPC UA server.

12. Click "OK".

SiOME shows the new instance "IMM_Manufacturer_01234" in the "Information model" area under "DeviceSet":

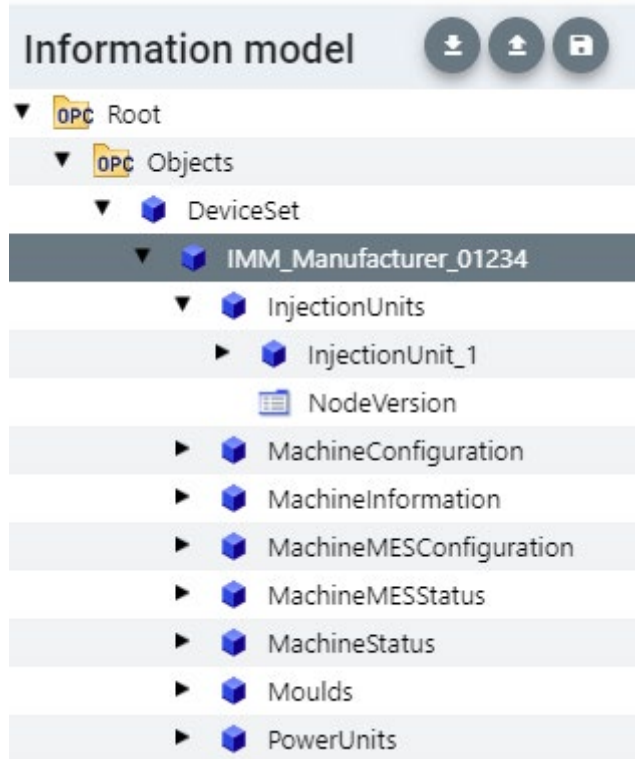


Figure 9-36 Display information model

13. Create an instance of the data type "InjectionUnitType".

To do this, right-click on the "InjectionUnits" directory in the "Information model" area and select "Add Instance".

SiOME displays the "Add Instance" dialog.

For "Name", enter a meaningful name for the instance.

In the example, enter "InjectionUnit_1".

For "TypeDefinition", select "InjectionUnitType".

Click "OK".

14. Create a new "Mould_1" instance of the "MouldType" object type in the "Moulds" directory.

15. Create a new instance "PowerUnit_1" of the "PowerUnitType" object type in the "PowerUnits" directory.

16. Save the XML file.

To do so, click the "Quick save" button in the "Information model" area:



Figure 9-37 "Quick save" button in SiOME

17. Export the XML file.

To do so, click the "Export XML" button in the "Information model" area.



Figure 9-38 "Export XML" button in SiOME

SiOME shows the "Export XML" dialog.

18. Leave all namespaces activated and click "OK".

SiOME displays the "Save as" dialog.

19. Select a meaningful name and save the exported file.

In the example, name the XML file "IMM_Manufacturer_01234".

Result:

You have now created an XML file which uses the companion specification "Euromap 77" once (with one instance).

Step 2: Creating PLC tags for the Euromap 77 instance in STEP 7.

For Euromap 77, you must provide PLC tags and server methods in your user program and assign the instance of the "IMM_MES_InterfaceType" type.

To create PLC tags for the instance of the "IMM_MES_InterfaceType" type, proceed as follows.

1. Create a user-defined data type (UDT).

The figure below shows the beginning of the user-defined data type "InjectionUnit" as example.

This data type has the same structure as "InjectionUnit" in the type "IMM_MES_InterfaceType".

Make sure that you use SIMATIC data types that are compatible with the OPC UA data types (see "Mapping of data types" below).

InjectionUnit					
Name	Data type	Default value	Accessible from HMI/OPC UA	Writable from HMI/OPC UA	
BarrelId	String	"	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Index	UDInt	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
InProduction	Bool	false	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
IsPresent	Bool	false	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Figure 9-39 Creating a UDT in STEP 7

2. Add a new global data block to your STEP 7 project.

In the example, name the data block "IMM_Manufacturer_01234", so that there is a reference to the injection molding machine of the respective manufacturer and the serial number.

3. Create a new element in this data block.

In the example, name this element "InjectionUnit_1"

4. Assign the new user-defined data type "InjectionUnit" to this element.

Result

In your STEP 7 project, you have created a tag for the Euromap 77 in the "IMM_Manufacturer_01234" data block.

9.3.4.4 Rules for OPC UA XML files

Importing exported OPC UA XML files to an S7-1500 CPU

Please note the following information when importing server interfaces that come from the OPC UA XML export of an S7-1500.

Note**Import blocked for namespace "http://www.siemens.com/simatic-s7-opcua"**

You cannot import server interfaces with the namespace "http://www.siemens.com/simatic-s7-opcua" to an S7-1500 CPU because this namespace is reserved for S7-1500 CPUs (standard SIMATIC server interface) and is not available for imports.

If you want to import a server interface with the namespace "http://www.siemens.com/simatic-s7-opcua", open the server interface to be imported (OPC UA XML file) and change the namespace in the relevant places. The file thus changed can then be imported.

Integrity of the OPC UA XML files

OPC UA XML files represent the server address space. These files are, for example, imported by you in the context of OPC UA Companion specifications as a server interface after adaptation to the application, loaded with the hardware configuration into the S7-1500 CPU and tested.

**WARNING****No checking of imported OPC UA XML files**

Protect these OPC UA XML files against unauthorized manipulation since STEP 7 does not check the integrity of these files.

Recommendation

To minimize risks in the case of an extension or adaptation of the server address space, follow these steps:

1. Protect the project (project navigation: Security settings > Settings).
2. Export the corresponding server interface before the extension or adaptation.
3. Revise this OPC UA XML file.
4. Import the file again as a server interface.

9.3.4.5 Data types for companion specifications

Mapping of data types

The table below shows the compatible SIMATIC data type for each OPC UA data type.

Assign the data types as shown below (SIMATIC data type - OPC UA data type). Other assignments are not permitted. STEP 7 does not check the observance of this rule and does not prevent an incorrect assignment. You are responsible for the rule-compliant selection and assignment of the data types.

You can also use the listed data types, for example, as elements of structures/UDTs for input and output parameters of self-created server methods (UAMethod_InParameters and UAMethod_OutParameters).

Table 9-3 Mapping of data types

SIMATIC data type	OPC UA data type
BOOL	Boolean
SINT	SByte
INT	Int16
DINT	Int32
LINT	Int64
USINT	Byte
UINT	UInt16
UDINT	UInt32
ULINT	UInt64
REAL	Float
LREAL	Double
LDT	DateTime
WSTRING	String
DINT	Enumeration (Encoding Int32) and all derived data types
User-defined data type required (UDT, user-defined data type) The user-defined data type must be created with the prefix "Union_", for example "Union_MyDatatype". See example below the table. The first element (Selector) in this UDT must have the data type "UDINT".	UNION and all derived data types

User-defined data type for UNION required

The figure below shows the tag "MyVariable", which has the "Union_MyDatatype" data type.

This SIMATIC data type corresponds to an OPC UA tag with the data type UNION.

The figure shows an example of the declaration: When Selector = 1, Union takes a ByteArray; when Selector = 2, Union takes a WString.

Name	Data type
▼ Static	
■ Selector	UDInt
■ ▶ ByteArray	Array[0..1] of Byte
■ WString	WString[42]

Using other OPC UA basic data types

Apart from the OPC UA data types listed in the section "Mapping of data types" and their correspondences on the SIMATIC side, there are the following OPC UA basic data types which you can also use:

- OpcUa_NodeId
- OpcUa_QualifiedName
- OpcUa_Guid
- OpcUa_LocalizedText
- OpcUa_ByteString
- OpcUa_XmlElement

Requirement for the use of the basic data types listed above as variables in the application program: The basic data types have to exist as complex data types that are structured exactly like the corresponding OPC UA basic data types.

- OpcUa_NodeId and OpcUa_QualifiedName exist as system data types; that's why you can use these data types not only for single variables but also as elements of a structure.
- For the remaining basic types you have to create a PLC data type in accordance with the OPC UA specification and subsequently use it as an element in a structure so that the data types of the elements can be resolved. What each PLC data type must look like is described below for every single basic data type. "EUInformation" is an example of a data structure in which, for example, the UDT "LocalizedText" is used. EUInformation contains information on EngineeringUnits. You can find an example of the implementation of the EUInformation data structure at the end of the PLC data type descriptions.

System data type "OPC-UA_NodId"

For the OPC UA basic data type "OpcUa_NodId", please refer to the following table for the meaning of the parameters. Use OPC-UA_NodId for the identification of a node in the OPC UA server.

Parameter	S7 data type	Meaning
NamespaceIndex	UINT	Namespace index of the node in the OPC UA server. A node can, for example, be a tag.
Identifier	WSTRING[254]	The designation of the node (object or tag) depends on the identifier type: <ul style="list-style-type: none"> • Numeric identifier: The node is labeled with a number, for example "12345678". • String identifier: The node is labeled with a name, for example "MyTag". No distinction is made between upper and lower case.
IdentifierType	UDINT	Type of identifier <ul style="list-style-type: none"> • 0: Numeric identifier • 1: String identifier • 2: GUID • 3: Opaque

System data type "OPC-UA_QualifiedName"

See the following table for the structure of the system data type "OPC-UA_QualifiedName":

Name	S7 data type	Meaning
NamespaceIndex	UINT	The namespace index of the name.
Name	WSTRING[64]	Name of the node or tag.

UDT "Guid"

For the basic data type "Guid", create the following PLC data type. The default values used as examples can also be set differently.

Guid			
	Name	Data type	Default value
1	Data 1	UDInt	16#11223344
2	Data 2	UInt	16#5566
3	Data 3	UInt	16#7788
4	Data 4	ULInt	16#99AABBCCDDEEFF11

Figure 9-40 "Guid" UDT

UDT "LocalizedText"

For the basic data type "LocalizedText", create the following PLC data type:

LocalizedText			
	Name	Data type	Default value
1	EncodingByte	Byte	16#3
2	Locale	WString[5]	WSTRING#'de-DE'
3	Text	WString[255]	WSTRING#'Text'

Figure 9-41 "LocalizedText" UDT

The EncodingByte indicates which fields (Locale or Text) are available:

EncodingByte	Meaning
0	The fields Locale and Text are empty
1	The field Locale has content, the field Text is empty
2	The field Locale is empty, the field Text has content
3	The fields Locale and Text have content

UDT "ByteString"

For the basic data type "ByteString", create the following PLC data type; in this case, for example, a ByteString array with 12 elements:

ByteString			
	Name	Data type	Default value
1	ByteString	Array[0..11] of Byte	
2	ByteString[0]	Byte	16#0
3	ByteString[1]	Byte	16#0
4	ByteString[2]	Byte	16#0
5	ByteString[3]	Byte	16#0
6	ByteString[4]	Byte	16#0
7	ByteString[5]	Byte	16#0
8	ByteString[6]	Byte	16#0
9	ByteString[7]	Byte	16#0
10	ByteString[8]	Byte	16#0
11	ByteString[9]	Byte	16#0
12	ByteString[10]	Byte	16#0
13	ByteString[11]	Byte	16#0

Figure 9-42 "ByteString" UDT

UDT "XmlElement"

An XmlElement is a serialized XML fragment (UTF-8 string).

For the basic data type "XmlElement", create the following PLC data type:

XmlElement			
	Name	Data type	Default value
1	XmlElement	WString	WSTRING#''

Figure 9-43 "XmlElement" UDT

Example: Structure of EUInformation with UDT "LocalizedText"

▼ Velocity	*EUInformation*		
■ NamespaceUri	WString[255]	WSTRING#'http://yourorganization.org'	Identifies the organization (company, standards organization) that defines the EUInformation
■ UnitId	DInt	1	Identifier for programmatic evaluation. -1 is used if a unitid is not available.
■ ▼ DisplayName	*LocalizedText*		
■ Encoding...	Byte	16#3	
■ Locale	WString[5]	WSTRING#'en-EN'	
■ Text	WString[255]	WSTRING#'m/s'	
■ ▼ Description	*LocalizedText*		
■ Encoding...	Byte	16#3	
■ Locale	WString[5]	WSTRING#'en-EN'	
■ Text	WString[255]	WSTRING#'meter per second'	

Figure 9-44 Example: Structure of EUInformation with UDT "LocalizedText"

9.3.4.6 Creating a server interface for companion specification

For basic information on companion specifications, refer to the section "Using OPC UA companion specifications (Page 206)". The benefits of the Euromap 77 companion specification, which provides a model for injection molding machines, is also discussed in detail there.

Using this companion standard, the S7-1500 CPU can control an injection molding machine, for example, and provide an OPC UA client, such as a higher-level MES system, with an interface for accessing the functions and tags of injection molding machine.

An OPC UA server interface of the type "Companion Standard" limits the access of clients to exactly those functions and tags that are required, for example, for higher-level systems (MES systems).

The following description shows how to create a server interface in STEP 7 (TIA Portal) which contains only the Euromap 77 companion specification.

If you want to make OPC UA clients accessible to other tags or methods than those required for the management of an injection molding machine, simply create another OPC UA server interface. In this way, you can clearly arrange the functionality of the CPU as OPC UA server.

Creating a server interface for a companion specification

To create a server interface for a companion specification with STEP 7 (TIA Portal), proceed as follows:

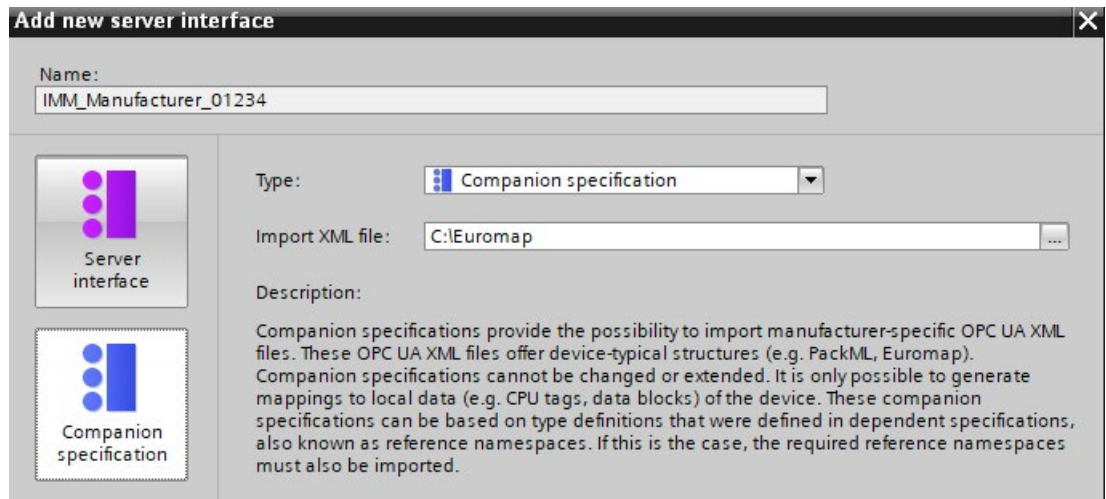
1. Select the CPU that you want to use as an OPC UA server.
2. In the project tree, click "OPC UA communication > Server interfaces".
3. Double-click "Add new server interface".
4. To select this type of server interface, click "Companion specification".

A general name for the new server interface is entered in the dialog, for example "Server_Interface_1".

5. Change the name of the new server interface so that it is descriptive in your project.

The name should have the following structure according to Euromap 77: "IMM_<Manufacturer>_<Serial number>".

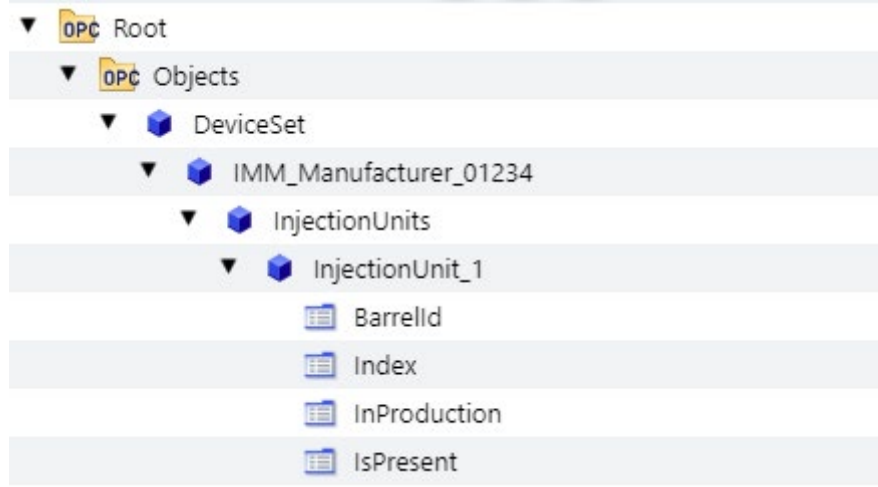
The example uses the name "IMM_Manufacturer_01234".



- 6. In the "Import XML file" field, select an XML file that describes an information model.

The "Using OPC UA companion specifications (Page 206)" section describes how to create such an XML file with the SiOME tool.

The figure below shows a section from the information model:
"IMM_MANUFACTURER_0123456" an instance (use) of the type
"IMM_MES_InterfaceType" which was defined by Euromap 77 . "InjectionUnit_1" is an instance of the "InjectionUnitType" type of Euromap 77.



7. Click "OK".

STEP 7 (TIA Portal) imports the information model described in the selected XML file.

An error occurs when type definitions are used in the imported XML file that are not yet present in STEP 7 (TIA Portal) and that are also not contained in the imported XML file.

In the example, an XML file is imported that uses type definitions defined in the following namespaces (Namespaces):

- http://opcfoundation.org/UA/DI/
- http://www.euromap.org/euromap83/
- http://www.euromap.org/euromap77/

Tip: STEP 7 displays missing namespaces in the lower area of the OPC UA interface editor ("Properties" tab).

To do this, select the server interface in the project tree (here: IMM_Manufacturer_01234) and select the "Namespaces" area in the inspector window. Missing namespaces are selected.

If one or more namespaces are missing in your STEP 7 project, create a new server interface of the "Reference namespace" type for each namespace.

The "Creating a server interface for reference namespace (Page 223)" section describes the procedure.

If all reference namespaces are available, STEP 7 displays the table without errors:

DeviceSet	Object
IMM_Manufacturer_01234	Object
InjectionUnits	Object
InjectionUnit_1	Object
TemperatureZones	Object
BarrelId	String
Index	UInt32
InProduction	Boolean
IsPresent	Boolean

8. Drag the OPC UA elements from the right area of the table (OPC UA elements) to the left part of the table (OPC UA server interface) so that the respective OPC UA elements (the local PLC tags) are assigned to the respective OPC UA nodes of Euromap 77.

The figure below shows a section from the assignment of the local data (PLC tags) to the OPC UA nodes of the Euromap 77:

OPC UA-Server-Schnittstelle				
Name	Node type	Local data		Data type
DeviceSet	Object			
IMM_Manufacturer_01234	Object			
InjectionUnits	Object			
InjectionUnit_1	Object			
TemperatureZones	Object			
NodeVersion	String			
BarrelId	String	"IMM_Manufacturer_01234".InjectionUnit_1.BarrelId		String
Index	UInt32	"IMM_Manufacturer_01234".InjectionUnit_1.Index		UDInt
InProduction	Boolean	"IMM_Manufacturer_01234".InjectionUnit_1.InProduction		Bool
IsPresent	Boolean	"IMM_Manufacturer_01234".InjectionUnit_1.IsPresent		Bool

Information on the server interface

The editor for configuring the OPC UA server interface is structured as a table and provides the following information:

- **Name**

The top node (root node) is named "IMM_Manufacturer_01234" in the example. If a client browses in the address space of the server, this node is the container for all lower-level nodes. BrowseName and the DisplayName of this node depend on the name you have assigned for the server interface.

In this case, for example, this name stands for the injection molding machine as a whole. It is the name of the instance of the Euromap 77 companion specification that is used here. According to the companion specification, the instance name should begin with "IMM", followed by the name of the manufacturer of the injection molding machine; the serial number of the machine is added to the end. This allows a unique identification of the machine.

The names of all other (lower-level) nodes are defined by the specification (in the example above by Euromap 77). These node names must not be changed. This ensures a uniform view of all injection molding machines, which complies with the specification.

- **Node type**

Type of the OPC UA node. The type is specified by the companion specification that is used.

In the following cases, STEP 7 marks a node type in the table in color:

- No definition is included for this in the imported XML file or
- The namespace in which the type was defined is not available in STEP 7.

In this case, create a server interface of the "Reference namespace" type for the missing namespace or for each of the missing namespaces.

The missing namespaces can be found under "Namespaces" in the properties of the server interface.

- **Local data**

STEP 7 displays the data block which is assigned to the OPC UA node: The CPU reads the value of the OPC UA node from this data block.

If a data block is highlighted in color (e.g. after a consistency check), the specified data block is not available in the CPU.

In this case, you have to create the missing data block in the CPU (of user program) and supply it with values.

- **Data type**

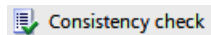
The SIMATIC data type of the PLC tag (e.g. element of a data block) in the CPU, from which the value of an OPC UA node (UAVariable type) is read, or to which a value is assigned.

Consistency check

You have the option to check the server interface.

STEP 7 (TIA Portal) checks whether the OPC UA node of the server interface PLC tags (data blocks) has been assigned compatible SIMATIC data types.

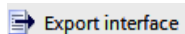
To check the consistency of the server interface, click on the following icon in the toolbar of the OPC UA server interface editor:



Export interface

You have the option of exporting the OPC UA server interface as an XML file. This XML file contains all data type definitions referenced by the server interface.

To export the OPC UA server interface, click on the following icon in the toolbar of the OPC UA server interface editor:



9.3.4.7 Creating a server interface for reference namespace

Companion specifications and referenced namespaces

A series of OPC UA object types (as well as additional definitions) are defined in a companion specification. These object types are each defined in namespaces so that the names of the object types (type definitions) are unique.

To use a companion specification in your project, create instances of object types of this companion specification.

To do this the object definitions must be available in your STEP 7 project. If this is not the case, you must import the object definitions. To import all definitions of a namespace, create a server interface of type "Reference namespace" for each namespace in STEP 7.

Example Euromap 77

You have added a server interface for the companion specification Euromap 77 .

The server interface uses object types defined in OPC UA DI as well as in Euromap 83 and Euromap 77 in their corresponding namespaces.

Therefore, in addition to the server interface Euromap 77 of the "Companion Specification" type, create additional server interfaces of "Reference namespace" type in STEP 7, in each case for the following namespaces:

- <http://opcfoundation.org/UA/DI/>
- <http://www.euromap.org/euromap83/>
- <http://www.euromap.org/euromap77/>

The following description shows you how to proceed.

Creating a server interface for a reference namespace

To create a server interface for a namespace, proceed as follows:

1. Select the CPU that you want to use as an OPC UA server.
2. Click "OPC UA communication > Server interfaces".
3. Double-click "Add new server interface".

STEP 7 (TIA) now displays the dialog "Add new server interface".

A general name for the new server interface is entered in the dialog, for example "Server_Interface_1".

4. Assign a descriptive name for the new server interface.

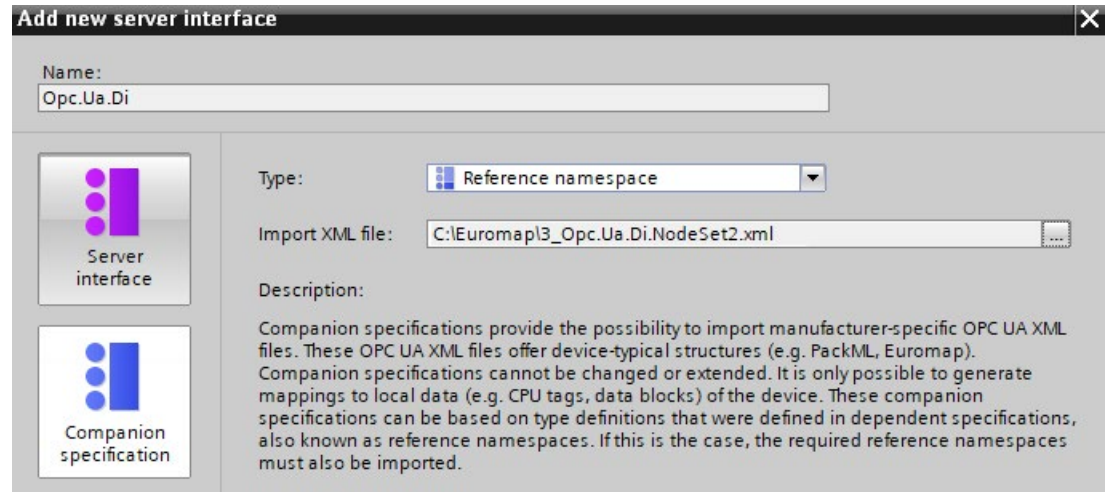
In the example, select the name "OPC.Ua.Di" or a similar name that clearly references the namespace "<http://opcfoundation.org/UA/DI/>".

This namespace must be imported first. It contains basic definitions (for example, the UAObjectType "DeviceType").

5. For "Import XML file", select an XML file that contains the definitions of the namespace "http://opcfoundation.org/UA/DI/".

Select the file "Opc.Ua.Di.NodeSet2.xml" in the example. You can download this file here: (<https://opcfoundation.org/UA/schemas/DI/>)

The figure below shows the dialog with the entries:



6. Click "OK".

STEP 7 (TIA) now generates the new server interface.

You can find the server interface in the project navigation of STEP 7 (TIA Portal), under "OPC UA Communication > Server interfaces > Namespace references".

If a companion specification uses additional namespaces, add a new server interface for each namespace.

Add additional server interfaces for Euromap77

For Euromap 77, you still need the following namespaces:

- <http://www.euromap.org/euromap83/>
- <http://www.euromap.org/euromap77/>

First, add a server interface for the namespace "http://www.euromap.org/euromap83/".

This namespace contains basic definitions for Euromap 77, therefore it is required here first. All definitions of this namespace are included in the XML file "Opc_Ua.EUROMAP83NodeSet2.xml", which you can download from the Euromap website (www.euromap.org/en/euromap83).

Then add a server interface for the namespace "http://www.euromap.org/euromap77". All definitions of this namespace are included in the XML file "Opc_Ua.EUROMAP77.NodeSet2.xml", which you can also download from the Euromap website (www.euromap.org/en/euromap77).

9.3.4.8 Notes on configuration limits when using server interfaces

When you use OPC UA server interfaces, you must comply with limits for the following objects in line with the S7-1500 CPU performance class:

- Number of server interfaces
- Number of OPC UA nodes
- Load object data volume
- If you have implemented methods: Number of server methods or server method instances

Configuration limits for OPC UA server interfaces and methods

The table below sets out the configuration limits for S7-1500 CPUs; these must also be taken into account when you compile and load a configuration (up-to-date technical specifications of the CPUs can be found on the Internet (<https://support.industry.siemens.com/cs/ww/en/ps/td>)).

A violation of configuration limits results in an error message.

Table 9- 4 Configuration limits for OPC UA server interfaces

Technical specification value	CPU 1510SP (F) CPU 1511 (C/F/T/TF) CPU 1512C CPU 1512SP (F) CPU 1513 (F)	CPU 1505 (S/SP/SP F/SP T/SP TF) CPU 1515 (F/T/TF) CPU 1515 SP PC (F/T/TF) CPU 1516 (F/T/TF)	CPU 1507S (F) CPU 1517 (F/T/TF) CPU 1518 (F)
Use of imported companion specifications (information models)			
Maximum number of OPC UA server interfaces:			
• "Companion specification" type	10	10	10
• "Reference namespace" type	20	20	20
• "Server interface" type	10	10	10
• Maximum number of OPC UA nodes in user-defined server interfaces	1000	5000	30000
• Maximum size of loadable OPC UA server interfaces	1024 KB	5120 KB	15360 KB
Provision of methods			
Maximum number of usable server methods or max. number of server method instances (instructions OPC-UA_ServerMethodPre, OPC-UA_ServerMethodPost)	20	50	100

9.3.5 Providing methods on the OPC UA server

9.3.5.1 Useful information about server methods

Providing user program for server methods

On the OPC UA server of an S7-1500 CPU (as of firmware V2.5), you have the option of providing methods via your user program. These methods can be used by OPC UA clients, for example to start a manufacturing job using the method call of the S7-1500 CPU.

OPC UA methods, an implementation of "Remote Procedure Calls", provide an efficient mechanism for interactions between different communication nodes. The mechanism provides both job confirmation and feedback values so you no longer have to program handshaking mechanisms.

Using OPC UA methods, you can transfer data consistently without trigger bits/handshaking, for example, or trigger specific actions on the controller.

How does an OPC UA method work?

An OPC UA method in principle operates like a know-how protected function block that is called by an external OPC UA client in runtime.

The OPC UA client only "sees" the defined inputs and outputs. The content of the function block, the method or algorithm, remains hidden to the external OPC UA client. The OPC UA client receives feedback on successful execution and values returned by the function block (method), or an error message if execution has not been successful.

As the programmer, you have full control over and responsibility for the program context in which the OPC UA method runs.

Rules for programming a method and runtime behavior

- Make sure that the values returned by the OPC UA method are consistent with the input values provided by the OPC UA client.
- Follow the rules on assigning name and the structure of parameters, and the permitted data types (see description of the OPC UA server instructions).
- Behavior during runtime: The OPC UA server accepts **one** call per instance. The method instance is not available for other OPC UA clients until the call has been processed by the user program or has timed out.

The basic procedure for implementing a user program as a server method is set out below.

Implementing a server method

A program (function block) for implementing a server method is structured as follows:

1. Querying the server method call with OPC_UA_ServerMethodPre

You first call the "OPC_UA_ServerMethodPre" instruction in your user program (i.e. in your server method).

This instruction has the following tasks:

- With this instruction you ask the OPC UA server of the CPU whether your server method was called from an OPC UA client.
- If the method was called and the server method has input parameters, your server method now receives the input parameters.

The input parameters of the server method come from the calling OPC UA client.

2. Editing the server method

In this section of the server method, you provide the actual user program.

You have the same options as in any other user program (for example, access to other function blocks or global data blocks).

If the server method uses input parameters, these parameters are available to you.

This section of the server method should only be executed if an OPC UA client has called the server method.

After successful execution of the method, you set the output parameters of the server method if the method has output parameters.

3. Responding to server method with OPC_UA_ServerMethodPost

To complete the server method, call the "OPC_UA_ServerMethodPost" instruction.

Use the parameters to notify the "OPC_UA_ServerMethodPost" instruction whether or not the user program has been processed.

If the user program has been successfully executed, the OPC UA server is notified via the relevant parameters. The OPC UA server then sends the output parameters of the server method to the OPC UA client.

Always call the instructions "OPC_UA_ServerMethodPre" and "OPC_UA_ServerMethodPost" as a pair irrespective of whether the user program is processed by both instructions or continued in the next cycle.

You will find an example of a server method implementation in the STEP 7 online help.

Integrating the server method

The diagram below shows how an OPC UA client (A) calls the server method "Cool":

The CPU executes the instance "Cool1" of the server method "Cool" in the cyclic user program ⑥.

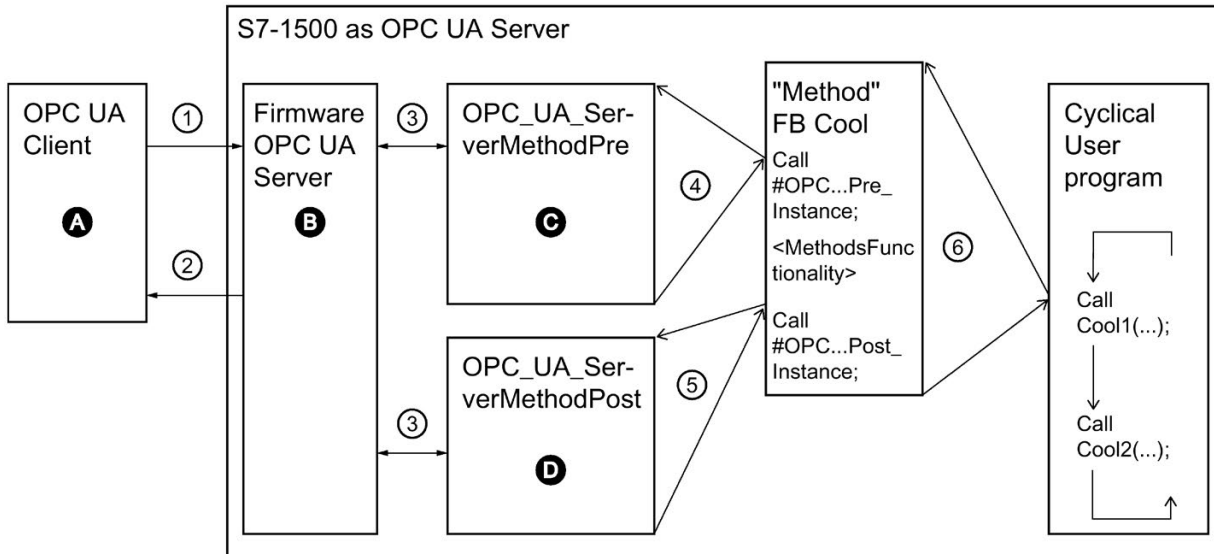
The CPU first uses the instruction "OPC-UA_ServerMethodPre" to query ④ whether an OPC UA client has called the server method "Cool" ①.

- If the server method has not been called, program execution returns directly to the cyclic user program over ④ and ⑥. The CPU resumes the cyclic user program after "Cool1".
- If the server method has been called, this information is returned to the server method "Cool" over ④. The actual functionality is now executed in the Cool server method, see "<Method Functionality>" in the graphic.

The server method then uses the instruction "OPC-UA_ServerMethodPost" ⑤ to notify the firmware (B) that the instruction has been executed ③.

The firmware returns this information over ② to the calling OPC UA client (A).

The CPU resumes the cyclic user program after "Cool1".



- A** Call of the server method and management of the "Done" information (method complete)
- ① Asynchronous call of the server method
- ② Asynchronous "Done" information for the method called (method complete)
- B** Wait for OPC UA client calls, management of calls in the queue, forwarding of "Done" information from the cyclic user program to the OPC UA client
- ③ Data transfer from the OPC UA server to the method instances of the user program and vice versa
- C** Check whether method has been called.
If it has, forwarding of input data from the OPC UA server to the method instance of the user program and feedback to the method instance that the method has been called ("called")
- ④ Synchronous call of the instruction OPC-UA-ServerMethodPre as a multi-instance stating the storage area for the input data from the OPC UA server.
The return value indicates whether or not the method has been called by the OPC UA client.
- ⑤ Check whether the method has been completed or is still active ("busy").
- D** Check whether the method has been completed.
If it has, the output data of the method instance is forwarded to the OPC UA server and the method instance is notified that the method has been completed. The OPC UA server is notified.
- ⑥ Call of the method FB (in this case: FB Cool) with the required instance and the process parameters

Figure 9-45 Example: Calling the "Cool" server method

Information about server instructions

The "OPC-UA-ServerMethodPre" and "OPC-UA-ServerMethodPost" are described in detail in the help to the Instructions > Communication > OPC UA > OPC UA server.

See also

Boundary conditions for using server methods (Page 231)

9.3.5.2 Boundary conditions for using server methods

Permitted data types

If you provide server methods, observe the following rule:

- Assign the data types as shown below (SIMATIC data type - OPC UA data type). Other assignments are not permitted.

STEP 7 does not check the observance of this rule and does not prevent an incorrect assignment. You are responsible for the rule-compliant selection and assignment of the data types.

You can also use the listed data types, for example, as elements of structures/arrays/UDTs for input and output parameters of self-created server methods (UAMethod_InParameters and UAMethod_OutParameters).

SIMATIC data type	OPC UA data type
BOOL	Boolean
SINT	SByte
INT	Int16
DINT	Int32
LINT	Int64
USINT	Byte
UINT	UInt16
UDINT	UInt32
ULINT	UInt64
REAL	Float
LREAL	Double
LDT	DateTime
WSTRING	String
DINT	Enumeration (Encoding Int32) and all derived data types
User-defined data type required (UDT, user-defined data type) The user-defined data type must be created with the prefix "Union_", for example "Union_MyDatatype". The first element (Selector) in this UDT must have the data type "UDINT".	UNION and all derived data types

Number of implementable server methods and number of arguments

If you implement server methods via your user program, the number of usable methods is limited depending on the CPU type, see the following table (up-to-date technical data of the CPUs can be found in the Internet (<https://support.industry.siemens.com/cs/ww/en/ps/td>)).

Technical specification value	CPU 1510SP (F) CPU 1511 (C/F/T/TF) CPU 1512C CPU 1512SP (F) CPU 1513 (F)	CPU 1505 (S/SP/SP F/SP T/SP TF) CPU 1515 (F/T/TF) CPU 1515 SP PC (F/T/TF) CPU 1516 (F/T/TF)	CPU 1507S (F) CPU 1517 (F/T/TF) CPU 1518 (F)
Maximum number of usable server methods or max. number of server method instances (OPC_UA_ServerMethodPre, OPC_UA_ServerMethodPost instructions)	20	50	100
Maximum number of arguments per method (More than the specified number of arguments can be configured and loaded into the CPU, but an OPC UA client cannot call the method).	20	20	20

Error message when exceeded

If the maximum number of server methods is exceeded, the OPC_UA_ServerMethodPre or OPC_UA_ServerMethodPost instructions report the error code 0xB080_B000 (TooManyMethods).

Supply of structured data types with nested arrays

If a structured data type (Struct/UDT) contains an array, the OPC UA server does not provide information about the length of this array.

If you use such a structure as the input or output parameter of a server method, for example, you must ensure that the nested array is supplied with the correct length when the method is called.

If you do not adhere to this rule, the method fails with the error code "BadInvalidArgument".

9.3.6 Using diagnostics options

9.3.6.1 Diagnostics of the OPC UA server

Online diagnostics of the OPC UA server

The S7-1500 CPU OPC UA server can be diagnosed online with standard OPC UA clients, such as UaExpert.

The diagnostic information is subdivided into the following areas:

- Server Diagnostics
- Sessions Diagnostics
- Subscriptions Diagnostics

In the address space of the server, for example, the following nodes are available with diagnostic information:

- **ServerDiagnosticsSummary**: Server diagnostics summary
 - CurrentSessionCount: Number of active sessions
 - SecurityRejectedSessionCount: Number of sessions rejected due to mismatching endpoint security settings between client and server
- **SessionsDiagnosticsSummary**: Session diagnostics summary
 - ActualSessionTimeout: Set time that a session lasts, e.g. in the event of disconnection
- **SubscriptionsDiagnosticsArray**: ARRAY with one element per subscription for each session

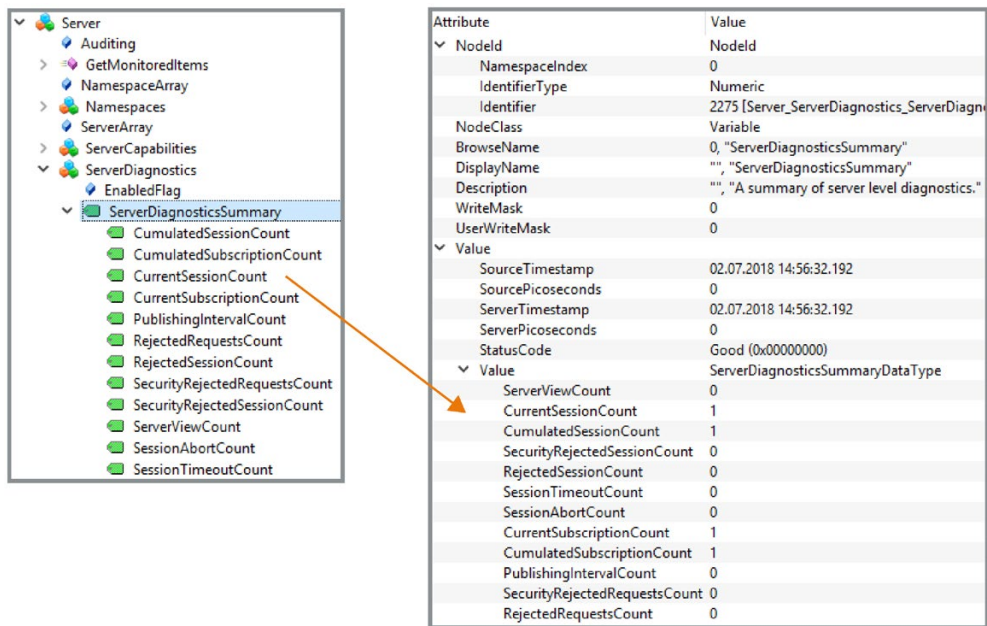


Figure 9-46 Server diagnostics

The SessionsDiagnosticsSummary node also shows the properties of the client application accessing the server within the session.

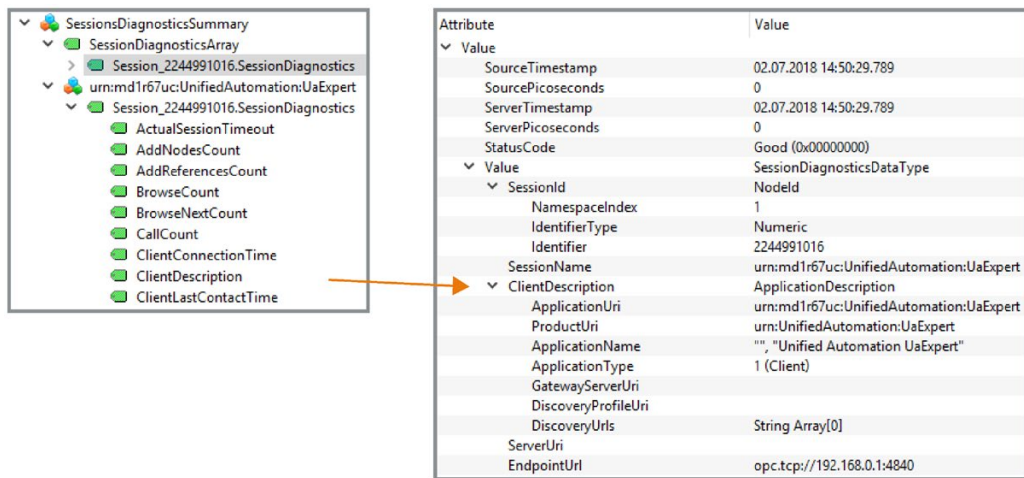


Figure 9-47 Sessions diagnostics with the properties of the client application

Diagnostics of the connection between client and server

To diagnose the status of the connection during program runtime in the client, use the following instruction:

OPC-UA-ConnectionGetStatus: Read connection status.

9.3.6.2 Server state transition diagnostics

Information on the server state

S7-1500 CPUs as of firmware version V2.8 are able to create an entry in the diagnostic buffer upon state changes of the OPC UA server.

The diagnostic buffer displays the new state.

The cause of the state change is also displayed, such as download to the CPU, POWER OFF - POWER ON transition, user program instruction or service request from a partner (client).

Requirement

The "Change of OPC UA server status" option is selected (OPC UA > Server > Diagnostics) in the OPC UA properties of the CPU.

Note

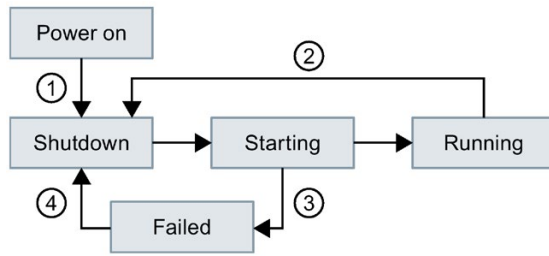
If this option is selected, the CPU also automatically enters the lowest set security policy into the diagnostic buffer after startup.

Examples

If the OPC UA server of the CPU shuts down due to a download process and then starts with a valid new configuration, the diagnostic buffer shows new server state, e.g. Shutdown => Starting => Running.

If the OPC UA server shuts down due to a download process and the server cannot start because the type dictionary is too large, the diagnostic buffer finally shows the state "Failed" (Shutdown => Starting => Failed).

Server states and state transitions



- ①, ④ POWER ON or Load in RUN, if OPC UA relevant data could be affected.
- ② Loading the hardware configuration with deactivated OPC UA server. The server remains shut down.
Loading the hardware configuration with activated OPC UA server and faulty OPC UA data (for example, too many structures with the result that the type dictionary becomes too large). In this case, the server cannot start (see ③).
- ③ OPC UA server cannot start due, for example, to faulty configuration.

Figure 9-48 Server states and state transitions

Description of the server states

The individual states that the OPC UA server can assume are explained below.

Server states	Explanation
Shutdown	Initial status <ul style="list-style-type: none"> • After POWER ON • After loading the hardware configuration with activated or deactivated OPC UA server. • After loading OPC UA relevant data
Starting	OPC UA address space in server is initialized.
Running	OPC UA server running (normal productive state for OPC UA server).
Failed	Error state. OPC UA server cannot start due, for example, to faulty configuration.

9.3.6.3 Session state transition diagnostics

Information on the session state

S7-1500 CPUs as of firmware version V2.8 are able to create an entry in the diagnostic buffer for state changes of an OPC UA session.

The diagnostic buffer displays the new state. The corresponding session ID is also displayed.

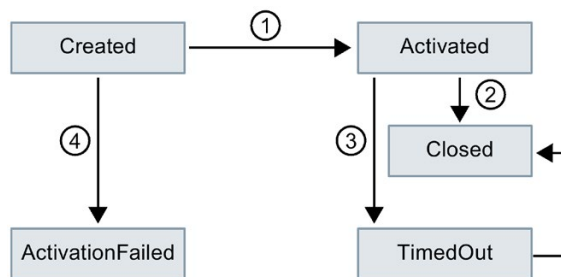
Requirement

The "Change of session states" option (OPC UA > Server > Diagnostics) is selected in the OPC UA properties of the CPU.

Example

A client transmits incorrect authentication data (for example, incorrect password) when a connection is established. The new state of the "ActivationFailed" session is entered with the corresponding session ID in the diagnostic buffer.

Subscription states and state transitions



- ① Client connects to server, login with correct authentication data (correct credentials).
- ② Client closes connection correctly.
- ③ Client no longer sends messages; session ends with timeout.
- ④ Client connects to server, login with incorrect authentication data.

Figure 9-49 Session states and state transitions

9.3.6.4 Check for security events

If the CPU diagnostics detects a security event during the OPC UA communication, it can enter it in the diagnostic buffer.

Requirements

- S7-1500 CPUs as of firmware version 2.8
- The "Check for security events" option is activated (properties of the CPU > OPC UA > Server > Diagnostics).

Security events detected in diagnostics

S7-1500 CPUs perform diagnostics on the following OPC UA relevant security events:

- Client-certificate is invalid (for example, syntactically or semantically incorrect, incorrect signature, current date is not in the validity period)
- User name/password login failed (deactivated or incorrect data)
- Client wants to use a specific security policy or a specific message security mode; the server does not support the security policy or the requested security mode.
- Client does not establish connection according to specification (OPC UA Spec) (for example, unexpected SecureChannelID/SessionID/client Nonce)

Example

If an attempt is made to compromise communications (for example, by session hijacking, man-in-the-middle attacks etc.), the server detects this via analysis.

9.3.6.5 Request of a remote client failed

S7-1500 CPUs as of firmware version V2.8 are able to create an entry in the diagnostic buffer for the following events:

- Bad client requests (incorrect use)
- Service error occurred
- CPU-specific high limits of the OPC UA server were violated

Example of a faulty client request

For example, there is an incorrect request when a client addresses a node (tag) that does not exist or if a resource is requested that does not exist.

In this case, the corresponding service that caused the fault is entered in the diagnostic buffer and the corresponding session ID is also entered.

Service fault

If a service itself fails, the server returns a ServiceFault. In this case, the status code (Bad...) and the according session ID are entered in the diagnostics buffer.

Example of limit violations

If a service request exceeds a CPU-specific limit, for example, number of sessions, number of monitored items, number of subscriptions, etc., this diagnostics is entered in the diagnostics buffer. Together with the message, it is indicated which limit has been violated.

Exception: If you summarize diagnostics and the message occurs frequently, the limit causing the error is not entered. You receive general information that the supported configuration limit has been violated.

Possible entries for the service that is causing the error

Depending on the client application used, requests to the server can be triggered differently from the user's viewpoint, for example, by an online tool with a graphical user interface or by instructions in a client's program.

With its service-oriented architecture, OPC UA follows a request-response paradigm, therefore the respective client application converts the requests into the service requests defined in OPC UA.

The names of these services are defined and grouped according to their use, see also opcfoundation.org.

In the case of an incorrect use, you can find precisely these names of the services, together with the corresponding session ID, in the diagnostic buffer as the service that caused the error.

The services available with OPC UA are listed below.

Discovery Service Set

FindServers

GetEndpoints

Session Service Set

CreateSession

ActivateSession

CloseSession

Cancel

View Service Set

Browse

BrowseNext

TranslateBrowsePathsToNodeIds

RegisterNodes

UnregisterNodes

Attribute Service Set

Write

Read

Method Service Set

Call

Monitored Item Service Set

CreateMonitoredItems

ModifyMonitoredItems

DeleteMonitoredItems

SetMonitoringMode

SetTriggering

Subscription Service Set

CreateSubscription

ModifySubscription

DeleteSubscriptions

Publish

Republish

SetPublishingMode

9.3.6.6 Subscription diagnostics

Information about a subscription

S7-1500 CPUs as of firmware version V2.8 are able to create an entry in the diagnostic buffer at state changes of a subscription.

The diagnostic buffer displays the new state; exception: "KeepAlive".

Requirement

In the OPC UA properties of the CPU, the option "Subscriptions: Change of status" (OPC UA > Server > Diagnostics) is selected.

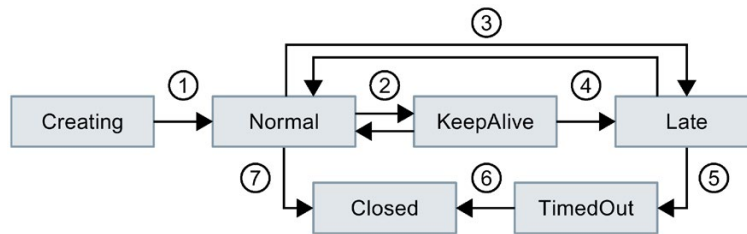
Example

An OPC UA client is connected to an S7-1500 CPU as OPC UA server and generates a subscription in the server.

The diagnostic options for subscriptions are selected in the OPC UA properties of the CPU.

The "Creating" and "Normal" states are entered one after the other with the corresponding subscription ID in the diagnostic buffer.

Subscription states and state transitions



- ① Subscription is generated and is then active.
- ② Status change is not entered in the diagnostic buffer because too many entries may be made in the diagnostic buffer depending on the amount of data.
- ③ See explanation in table for "Late"; for example, no requests to send from client.
- ④ Maximum KeepAlive value reached.
- ⑤ See explanation in table for "TimedOut".
- ⑥ Maximum lifetime of subscription reached.
- ⑦ Client has deleted subscription.

Figure 9-50 Subscription states and state transitions

Description of the subscription states

A subscription in the OPC UA server can have the following states:

Status	Meaning
Creating	Client has requested a subscription in the server; the server creates the subscription.
Normal	Subscription is created in the server and active.
Closed	Client has deleted the subscription.
KeepAlive	Status if the monitored items do not change over a long period of time. These state transitions are not entered in the diagnostic buffer.
Late	Client has generated a subscription with minimal sampling and publishing intervals. The amount of monitored items is not transmitted to the client during this time. Client no longer transmits requests to send (for example, due to failure).
TimedOut	The client has requested a subscription. The server can only honor the subscription (send Publish Response) when there is a sufficient number of send requests (Publish Requests) from the client. When the client stops sending subscription requests, the subscription enters the "TimedOut" state after a certain time.

Subscription: Error in the sampling times

As of firmware V2.5 of the SIMATIC S7-1500 CPU, the OPC UA server can transmit the status code "GoodOverload" when using subscriptions, if an overload of the CPU occurs when sampling the items.

As of firmware V2.8 of the SIMATIC S7-1500 CPU, the OPC UA server can also enter this event into the diagnostic buffer.

Requirement

In the OPC UA properties of the CPU, the option "Subscriptions: Sampling time errors" (OPC UA > Server > Diagnostics) is selected.

Error-free subscription

In the case of an OPC UA subscription to various elements (such as tags), the OPC UA server of the SIMATIC S7-1500 must check the elements for value changes at specified intervals (sampling interval). This check, referred to as "sampling", requires some time, which depends on the number and the data type of the items. After the sampling is completed and a publishing request has been received, the server sends the elements to the client.

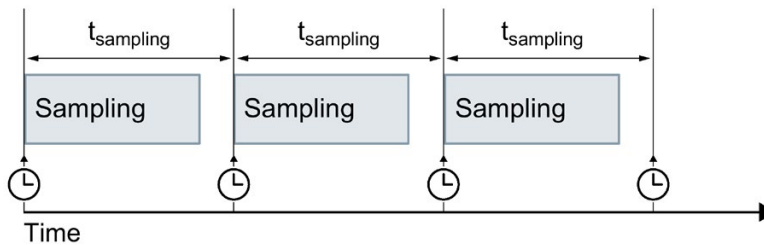
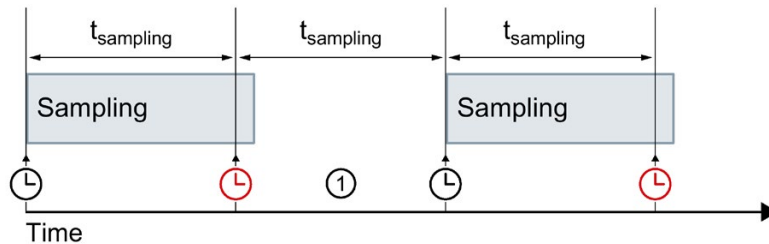


Figure 9-51 Error-free subscription

Subscription with error

If there are too many elements in the queue, there may be an overload of the communication stack. The CPU cannot check all elements in the given sampling interval and must therefore skip the next sampling job.

In this case, the CPU sends the status code "GoodOverload" (0x002F0000) per element, even though the elements were not checked. The meaning of the status code according to IEC 61131-3 is as follows: "Sampling has slowed down due to resource limitations".



① Sampling job is skipped

Figure 9-52 Subscription with error

See also FAQ 109763090.

See also

Settings of the server for subscriptions (Page 181)

Meaning of the "GoodOverload" status

(<https://support.industry.siemens.com/cs/ww/en/view/109763090>)

9.3.6.7 Summarizing diagnostics

To prevent the diagnostics buffer being "swamped" by large numbers of identical OPC UA diagnostics, as of STEP 7 V16 service pack 1, you can set parameters so that these diagnostics are entered in the diagnostics buffer as group alarm. Per interval (monitoring time), the CPU then only generates one group alarm per OPC UA diagnostics.

The following sections describe which diagnostics the CPU groups together and how the process runs with a high message volume.

Requirement

The "Summarize diagnostics in case of high message volume" option is activated in the OPC UA properties of the CPU (OPC UA > Server > Diagnostics, "Summarize diagnostics" area).

Example

An OPC UA client repeatedly "overloads" an S7-1500 CPU as OPC UA server with a sampling rate that the server cannot handle (overload).

The "Summarize diagnostics in case of high message volume" setting is activated.

A message appears in the diagnostics buffer for this diagnostic option. It states that the sampling rate cannot be reached; followed by the number of these events within the configured interval.

OPC UA diagnostics that can be summarized

The diagnostics listed below each form their own groups (type). Diagnostic events from the same group are combined using the setting "Summarize diagnostics in case of high message volume":

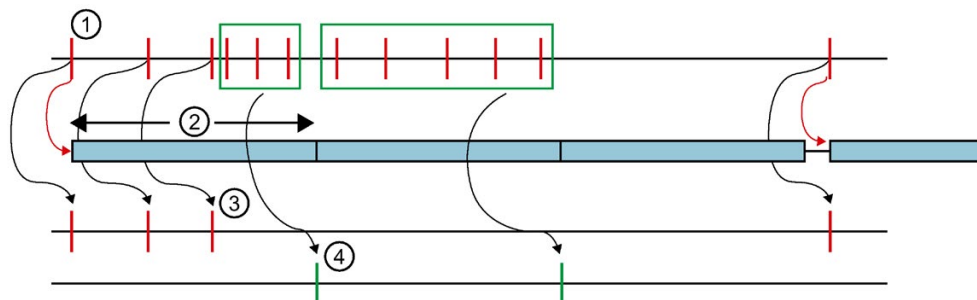
- Incorrect use of an OPC UA service
- OPC UA Service error
- Subscription status has changed
- Sampling rate could not be achieved (subscriptions, overload)
- OPC UA security check failed
- Configuration limit of the OPC UA server violated

Principle of operation

The CPU enters the first three events of an event type in the diagnostics buffer. It then ignores all subsequent diagnostics of this group.

At the end of the monitoring time (interval), the CPU generates a group alarm in which it enters the diagnostics and the frequency of this diagnostics during the elapsed interval. If these diagnostics also occur in the intervals that follow, the CPU only generates one group alarm per subsequent interval.

A diagnostic surge leaves the following pattern in the diagnostics buffer: Three individual messages followed by a series of group alarms. This series can consist of two, three or more group alarms depending on the selected monitoring time and duration of the diagnostic surge.



- ① Diagnostic results of a group (of a type), for example "Sampling rate could not be reached".
- ② Interval (monitoring time): When a diagnostic event occurs the first time (or reoccurs), the monitoring time is started (or restarted).
- ③ Single alarms: The first three diagnostic events from the same group are entered in the diagnostics buffer immediately. Starting with the fourth diagnostic event, the CPU generates only group alarms. If a diagnostic event of this group occurs after a pause of at least one interval, the CPU enters a single alarm in the diagnostics buffer and restarts the monitoring time.
- ④ Group alarms: After three diagnostic events, the CPU only generates a group alarm as a summary of all additional diagnostic events in this interval. If these diagnostic events also occur in the intervals that follow, the CPU only generates one group alarm per subsequent interval.

Figure 9-53 Summary of diagnostics

9.4 Using the S7-1500 CPU as an OPC UA client

9.4.1 Overview and requirements

With STEP 7 (TIA Portal) Version V15.1 and higher, you can assign parameters and program an OPC UA client that can read PLC tags in an OPC UA server. Furthermore it is possible to transfer new values for PLC tags to an OPC UA server. In addition, you can call methods that an OPC UA server provides in your user program. You use the instructions for OPC UA clients in your user program for this.

The instructions of the OPC UA client are based on the standard "PLCopen OPC UA Client for IEC61131-3".

PLCopen specification

With these standardized instructions, you can develop an OPC UA client functions in your user program that can be executed in an S7-1500 CPU.

In addition, it is possible with just a few adaptations to run this user program in controllers of other manufacturers if these manufacturers have also implemented the OPC UA Specification "PLCopen OPC UA client for IEC61131-3".

Convenient editors in STEP 7

For the parameter assignment of the instructions for OPC UA clients, a convenient editor is available in the TIA Portal – the connection parameter assignment (Page 175).

As of Version 15.1, STEP 7 also features an editor for client interfaces (Page 251).

This section describes how you work with these editors.

First, you will be shown how to create and configure a new interface with the interface editor, because you need this type of interface for the subsequent connection parameter assignment.

The description uses an example for better comprehensibility, see Description of the example (Page 249).

Requirements

- You have the required runtime license for OPC UA and have configured the license in STEP 7 (CPU Properties > Runtime Licenses).
- The client of the S7-1500 CPU is activated.

To use the client of the S7-1500 CPU, you must enable it:

1. Select the area "OPC UA > Client" in the properties of the CPU.
2. Select the "Enable OPC UA client" option.

If you do not enable the client, the connection is not established. You receive a corresponding error message at the instructions, for example "OPC_UA_Connect".

For information about the application name, which also applies to the server and the client, see here (Page 175).

Overview

To use the editor and the connection parameter assignment, follow these steps:

1. First, specify a client interface. Add to this the PLC tags and PLC methods interface that you want to access ("First step (Page 251)").
2. Next, configure the connection to the OPC UA server (Second step (Page 268)).
3. Finally, use the configured connection for the OPC UA client instructions (Third step (Page 276)).

9.4.2 Useful information about the client instructions

With the standardized OPC UA client instructions you are able to control communication for the following tasks with the S7-1500 CPU as an OPC UA client:

- Read/write tags of the OPC UA server
- Call methods in the OPC UA server

Optional instructions can be used to determine the following information:

- The status of the connection between the OPC UA client and OPC UA server
- Node IDs of nodes with known hierarchy of the address space

Standardized sequence of OPC UA communication

The sequence of the communication, and thus the order of the instructions, follows a pattern that is illustrated in the following.

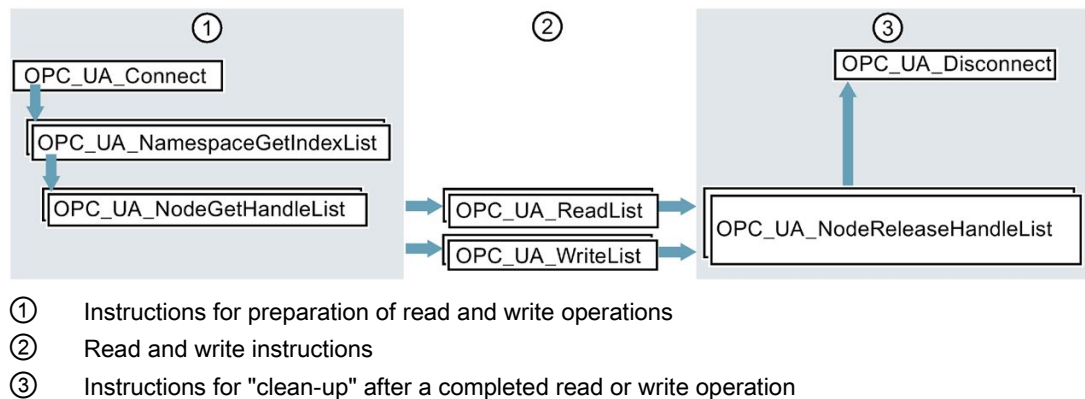
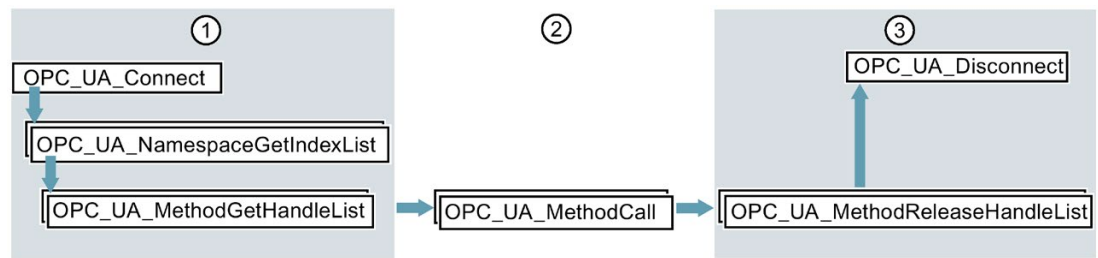


Figure 9-54 Run sequence for a read or write operation

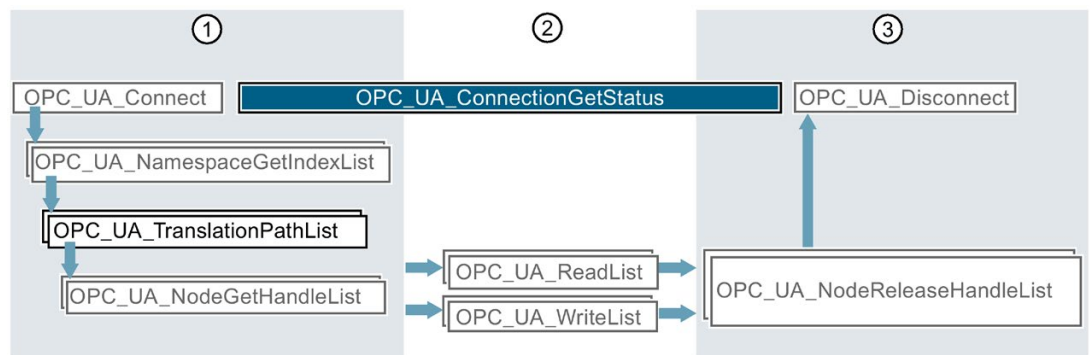


- ① Instructions for preparation of method calls
- ② Method calls
- ③ Instructions for "clean-up" after completed method calls

Figure 9-55 Run sequence for a method call in the OPC UA server

Optional instructions (reading out the status of a connection / reading out node IDs of nodes with known hierarchy of the address space)

- OPC_UA_ConnectionGetStatus
- OPC_UA_TranslatePathList



- ① Instructions for preparation of read and write operations with inserted instruction for requesting, for example, the NodeIDs of nodes of the OPC UA server.
- ② You can determine the connection status between the establishment and termination of the connection in parallel with other instructions.
- ③ Instructions for "clean-up"

Figure 9-56 Run sequence of optional instructions

Convenient editors in STEP 7

The OPC UA client instructions are described in detail in the reference part (STEP 7 information system). For parameter assignment of the instructions, a convenient editor is available in the TIA Portal – the connection parameter assignment (Page 268).

We recommend starting with the connection parameter assignment for the first program draft and using additional instructions and manually optimizing the program as required.

Information about the client instructions

The client instructions are described in detail in the help to the Instructions > Communication > OPC UA > OPC UA client.

Application example in Online Support

This application example (<https://support.industry.siemens.com/cs/ww/en/view/109762770>) provides you with an S7 user block "OpcUaClient" that summarizes the most important functions of the OPC UA instructions, accelerates the implementation for you and simplifies the programming. The OPC UA server in the example is an S7-1500 controller with a simple simulation program for process values.

The S7 user block performs the following:

- Establishment and termination of the connection to the server
- Diagnostics of the connection and automatic reconnection after connection terminations
- Registered Read
- Registered Write
- Registered Method Call

9.4.3 Number of client instructions that can be used simultaneously

SIMATIC error codes for OPC UA client instructions

The following limits apply to the simultaneous use of OPC UA client instructions (up-to-date technical specifications of the CPUs can be found on the Internet (<https://support.industry.siemens.com/cs/ww/en/ps/td>)):

Table 9- 5 Quantity structures for OPC UA client instructions

OPC UA instruction	Maximum number for CPU 1510SP (F) CPU 1511 (C/F/T/TF) CPU 1512C CPU 1512SP (F) CPU 1513 (F)	Maximum number for CPU 1505 (S/SP/SP F/SP T/SP TF) CPU 1515 (F/T/TF) CPU 1515 SP PC (F/T/TF) CPU 1516 (F/T/TF)	Maximum number for CPU 1507S (F) CPU 1517 (F/T/TF) CPU 1518 (F)
OPC_UA_Connect	4	10	40
OPC_UA_NamespaceGetIndexList	4*	10*	40*
OPC_UA_NodeGetHandleList	4*	10*	40*
OPC_UA_MethodGetHandleList	4*	10*	40*
OPC_UA_TranslatePathList	4*	10*	40*
OPC_UA_ReadList	20 in total (max. 5 per connection, see OPC_UA_Connect)	50 in total (max. 5 per connection, see OPC_UA_Connect)	200 in total (max. 5 per connection, see OPC_UA_Connect)

OPC UA instruction	Maximum number for CPU 1510SP (F) CPU 1511 (C/F/T/TF) CPU 1512C CPU 1512SP (F) CPU 1513 (F)	Maximum number for CPU 1505 (S/SP/SP F/SP T/SP TF) CPU 1515 (F/T/TF) CPU 1515 SP PC (F/T/TF) CPU 1516 (F/T/TF)	Maximum number for CPU 1507S (F) CPU 1517 (F/T/TF) CPU 1518 (F)
OPC-UA_WriteList	20 in total (max. 5 per connection, see OPC-UA_Connect)	50 in total (max. 5 per connection, see OPC-UA_Connect)	200 in total (max. 5 per connection, see OPC-UA_Connect)
OPC-UA_MethodCall	20 in total (max. 5 per connection, see OPC-UA_Connect)	50 in total (max. 5 per connection, see OPC-UA_Connect)	200 in total (max. 5 per connection, see OPC-UA_Connect)
OPC-UA_NodeReleaseHandleList	4*	10*	40*
OPC-UA_MethodReleaseHandleList	4*	10*	40*
OPC-UA_Disconnect	4*	10*	40*
OPC-UA_ConnectionGetStatus	4*	10*	40*

* maximum 1 per connection

Maximum number of usable OPC UA client interfaces

If you create OPC UA client interfaces using the connection parameter assignment, the number of client interfaces is limited to 40.

Create the OPC UA client interfaces by double-clicking the "Add new client interface" symbol in the project tree of the "OPC UA communication" area.

The maximum number of OPC UA client interfaces is independent of whether you also use the CPU as OPC UA server.

9.4.4 Example configuration for OPC UA

The following sections describe how you can use the client interfaces editor and the connection parameter assignment.

The description is based on a specific example: Two S7-1500 CPUs operate in the system: One CPU serves as the OPC UA client and the other as the OPC UA server.

You can, of course, also use controllers, sensors and IT systems of other manufacturers as OPC UA clients or servers. In particular, the data exchange between different systems (interoperability) is a major advantage of OPC UA.

Connection parameter assignment using an example:

The plant produces blanks in a production line.

The following controllers are used:

1. An S7-1511 CPU serves as the controller of the production line.

The controller is named "**Productionline**" in the example.

The OPC UA server of the controller is enabled.

The CPU has the IP address 192.168.1.1 in the example.

This CPU publishes the values of following tags via the OPC UA server:

- **NewProduct**

The tag has the data type "BOOL".

When this PLC tag has the value TRUE, the production line has processed a blank.

The blank is ready for pick-up.

- **ProductNumber**

This tag contains the identification number of the blank.

The tag has the data type "Int".

- **Temperature**

This tag contains temperature values recorded during the production of the blank.

The tag is an array with elements of the "Real" data type.

In addition, this CPU provides the following writable tag:

- **ProductionEnabled**

The tag is set by the OPC UA client.

The tag has the data type "BOOL".

If the value is set to TRUE, the production line is released and may produce blanks.

In addition, this CPU provides the following method via the OPC UA server:

- **OpenDoor.**

OPC UA clients can hereby arrange for an access door to be opened to the production line.

2. An S7-1516 CPU controls the interaction with other production lines.

This CPU is named "**Supervisor**" in the example.

The OPC UA client of this CPU is enabled.

Using OPC UA, this CPU can read the NewProduct and ProductNumber tags, set the ProductionEnabled tag and call the OpenDoor method.

The CPU has the IP address 192.168.1.2 in the example.

The following figure shows the example in the network view of the TIA Portal:

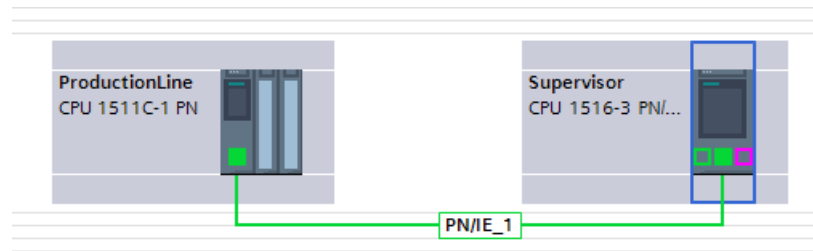


Figure 9-57 Example of assigning connection parameters in the network view

9.4.5 Creating client interfaces

As of Version 15.1, the TIA Portal has an editor for client interfaces.

You group all PLC tags that you want to read or write from an OPC UA server in a client interface.

In addition, the client interface contains all methods that the OPC UA server provides and that you want to call with your user program (that acts as an OPC UA client).

If you create a client interface, STEP 7 also creates data blocks for the parameter assignment of the connection to the OPC UA server from which you want to read data or to which you want to write data.

Maximum number of client interfaces

You can create a maximum of 40 client interfaces.

Editor for client interfaces

To create a client interface, follow these steps:

1. Select the project view in the TIA Portal.
2. In the "Devices" area, select the CPU you want to use as an OPC UA client.
3. Click "OPC UA communication > Client interfaces".

4. Double-click "Add new client interface".

STEP 7 creates a new client interface and display in the editor.

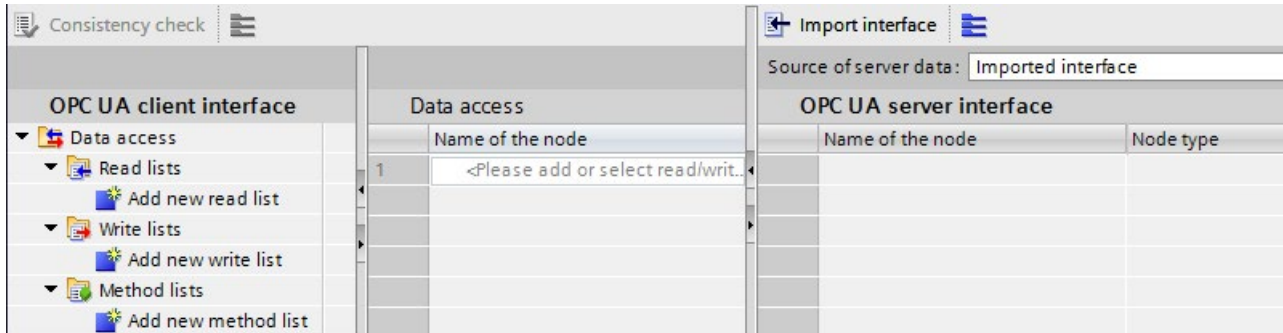


Figure 9-58 Adding OPC UA client interface

STEP 7 names the new interface "Client interface_1". If a "Client interface_1" already exists, the new interface receives the designation "Client interface_2" etc.

In addition, STEP 7 creates the following data blocks:

- Client_Interface_1_Configuration

The data block already contains all system data types that are needed for the instructions of the OPC UA client.

This data block is filled when you configure the connection to the OPC UA server.

You configure a connection in the properties of the client interface, see: Example configuration for OPC UA (Page 249).

- Client_Interface_1_Data

A data block for the PLC tags that you want to read or write from an OPC UA server as well as for methods that you want to call in the OPC UA server.

You use this data block in your user program.

This data block is currently still empty.

5. Select a descriptive name for the new client interface.

Select "Productionline" in the example.

This also changes the names of the associated data blocks to:

- Productionline_Data
- Productionline_Configuration

6. To import an OPC UA server interface, click the "Import interface" button in the top right of the editor.

This allows you to import an XML file which describes the server interface of an OPC UA server.

Alternative: To determine online the server interface of a connected OPC UA server, see: Determine server interface online (Page 260).

7. STEP 7 displays a dialog with which you can select an XML file.

This XML file describes a address space of an OPC UA server.

The address space of an OPC UA server contains all PLC tags and server methods published by an OPC UA server.

OPC UA clients can access this address space:

- Read PLC tags
- Write PLC tags
- Calling Server Methods

The address space of an OPC UA server can be divided into one or more server interfaces.

For creating server interfaces, see: Creating a server interface for companion specification (Page 218).

8. Create a **read list** in this client interface.

To do this, follow these steps:

- Click "Add new read list" in the left section of the editor.

STEP 7 adds a new list named "ReadList_1".

For the example, change the name to "ReadListProduct"

- Now add the new read list of the PLC tags that you want to read from the OPC UA server.

In the example the "NewProduct" and "ProductNumber" tags are added to the "ReadListProduct" read list.

Select the "NewProduct" tag in the right-hand field of the editor ("OPC UA Server interface"). Drag the "NewProduct" tag to the "ReadProduct" read list in the middle field of the editor. Follow the same procedure with the "ProductNumber" tag.

The figure below shows the right field of the editor.

OPC UA server interface				
	Name of the node	Node type	Access level	Node ID
■	Productionline	Object		http://www.sie...
■	OPC DataBlocksGlobal	Folder		http://www.sie...
■	Data_for_OPC_UA_Clients	Object		http://www.sie...
■	NewProduct	Boolean	RD	http://www.sie...
■	ProductNumber	Int16	RD	http://www.sie...
■	Temperature	Array of Float	RD	http://www.sie...
■	Data_from_OPC_UA_Clients	Object		http://www.sie...
■	ProductionEnabled	Boolean	RD/WR	http://www.sie...
■	OPC DataBlocksInstance	Folder		http://www.sie...
■	OpenDoor_DB	Object		http://www.sie...
■	InOuts	Folder		http://www.sie...
■	Static	Folder		http://www.sie...
■	Method	Method		http://www.sie...

Figure 9-59 Read list in the OPC UA server interface

Alternative:

You can also select a new read list by dragging the right field of the editor ("OPC UA Server interface") to a node of the type Object or Folder and then dragging it to "Add new read list" in the left field of the editor. The new read list then contains all PLC tags of the node that has been moved.

In the example, select the object "Data_for_OPC_UA_Clients", which contains the tags "NewProduct" and "ProductNumber". STEP 7 generates the new read list "Data_for_OPC_UA_Clients". In addition, the object contains the tag "Temperature". Delete the "Temperature" tag from the read list. Since they should not be read in the example.

Change the name of the read list in "ReadListProduct".

The following figure shows the content of the read list:

ReadListProduct				
	Name of the node	Node type	Access level	Node ID
■	NewProduct	BOOL	RD	http://www.siem...
■	ProductNumber	INT	RD	http://www.siem...

Figure 9-60 Read list

Note

Read and write lists do not support all node types.

The OPC UA client of the S7-1500 CPU does not support all OPC UA data types (node types) that can be made available via an OPC UA server interface. If you place an unsupported node type, for example, in a read list or write list a corresponding error signal appears. In this case, you cannot include the corresponding node in the read or write list.

Which types are supported is described here: [Mapping of data types \(Page 142\)](#)

9. If you want assign new values to PLC tags, create a **write list** in this client interface.

To do this, follow these steps:

- Click "Add new write list" in the left section of the editor.
STEP 7 adds a new list with the name "ReadList_1".
For the example, change the name to "WriteListStatus".
- Now add the new write list of all OPC UA server tags to which you want to assign new values.

In the example, add the "WriteListStatus" tag to the write list "ProductionEnabled".

Select the Tag of right field of the editor ("OPC UA Server interface"). Drag the tag to the write list in the middle field of the editor.

Alternative:

You can also create a new write list by selecting a node of the type Object or Folder in the right field of the editor ("OPC UA server interface") and then dragging to "Add new write list" in the left field of the editor.

The new write list then contains all tags of the relevant node.

In the example, select the object "Data_from OPC UA Clients", which contains the tag "ProductionEnabled". STEP 7 generates the new write list "Data_from OPC UA Clients". Change the name in "WriteListStatus".

The following figure shows the content of the write list:


WriteListStatus			
Name of the node	Node type	Access level	Node ID
 ProductionEnabled	BOOL	RD/WR	http://www.siemens...

Figure 9-61 Write list

10.If you want to call a method of this OPC UA server, generate a new method list.

To do this, follow these steps:

- In the left section of the editor, click "Add new method list".
STEP 7 adds a new list with the name "Method list_1".
For the example, change the name to "MethodListOpenDoor".
- Now add a method of the OPC UA server to the new method list.

In this example, add the method "OpenDoor" to the method list "MethodListOpenDoor".

Select the method of right field of the editor ("OPC UA Server interface"). Drag the method to the method list in the middle field of the editor.

Alternative:

You can also generate a new method list by selecting a method (node of the type Object) in the right field of the editor (OPC UA Server interface) and then dragging it to "Add new method list" in the left field of the editor. The new method list then contains the method of the relevant node.

The following figure shows the content of the method list:

MethodListOpenDoor			
Name of the node	Node type	Access level	Node ID
▶ Method			http://www.siemens...

Figure 9-62 Methods list

If you want to call another method of the OPC UA server, you must create a new method list. Each method list contains only one method.

See also Useful information about server methods (Page 227).

11.Compile the project.

To do so, select the project and click the following button in the toolbar:



STEP 7 compiles the project and updates the data blocks that belong to the "Productionline" client interface.

Note

During compilation, STEP 7 overwrites all data in the data blocks belonging to the client interface. For this reason, you should neither add to nor correct these data blocks manually.

Note**Renaming node names (DisplayNames)**

In read lists, write lists and method lists you can rename the name of a node by means of the shortcut menu. This is the "DisplayName" in the OPC UA language usage.

If you rename the name of a method list node and the node is already used in a programmed block for the method call "OPC-UA-MethodCall", the compilation of the project leads to consistency errors: During the compilation the UDTs of the method are generated with the changed name. The references to the method used in the program are then no longer correct.

To correct the consistency errors, you can either undo the name change of the method in the client interface or navigate to the method call and assign the relevant parameters again there under "Properties > Block parameters" ("Configuration" tab).

Data blocks of client interface

The following data blocks belong to the "Productionline" client interface:

- **Productionline_Configuration**

A data block for the configuration.

In the example, this data block is called "Productionline_Configuration".

The data block already contains all system data types that are needed for the instructions of the OPC UA client.

In addition, the data block contains general default values for parameter assignment of the connection to an OPC UA server.

If you are working with connection parameter assignment, this data block will be filled.

- **ProductionLine_Data**

A data block for the PLC tags that you have entered in the client interface editor.

In the example, this data block is called "Productionline_Data".

The figure below shows the data block.

Static	
▼ ReadListProduct	Struct
■ ▼ Variable	*Productionline.ReadListProduct*
■ NewProduct	Bool
■ ProductNumber	Int
■ ▼ NodeStatusList	Array[0..1] of DWord
■ NodeStatusList[0]	DWord
■ NodeStatusList[1]	DWord
■ ▼ TimeStamps	Array[0..1] of LDT
■ TimeStamps[0]	LDT
■ TimeStamps[1]	LDT
▼ WriteListStatus	Struct
■ ▼ Variable	*Productionline.WriteListStatus*
■ ProductionEnabled	Bool
■ ▼ NodeStatusList	Array[0..0] of DWord
■ NodeStatusList[0]	DWord
▼ MethodListOpenDoor	Struct
■ ▼ MethodStatusList	Array[0..0] of DWord
■ MethodStatusList[0]	DWord
■ ▼ MethodResultList	Array[0..0] of DWord
■ MethodResultList[0]	DWord
■ ▼ Method	Struct
■ ▼ Inputs	*Productionline.MethodListOpendoor.Method.Inputs*
■ Number	Int
■ ▼ Outputs	*Productionline.MethodListOpendoor.Method.Outputs*
■ Result	Int

Figure 9-63 "Productionline_Data" data block

Use the "Productionline_Data" data block in your user program and access the read values of the "NewProduct" and "ProductNumber" PLC tags. This is explained in the following section using an example.

Reading and writing PLC tags of the client interface

Example: Reading the "ProductNumber" value

For example, you write in an SCL program:

```
#MyLocalVariable :=  
"Productionline_Data".ReadListProduct.Variable.ProductNumber;
```

You use this, for example, to assign the number of the blank that was just produced in the production line to the local tag "#MyLocalVariable".

Requirements:

- A connection exists to the OPC UA server of the CPU, which controls the production line.
- The OPC UA client has read the current values.

For this reason you check whether a read value is valid:

- Check whether the value in "Productionline_Data".ReadListProduct.NodeStatusList[1] is equal to 0.
- Optional: Check when this value was sent from the OPC UA server. This value is in "Productionline_Data".Product.TimeStamps[1]. If no time stamp is requested, the communication load is reduced.

Example: Writing the "ProductEnabled" value

Transfer the new values for PLC tags, in the example for the "ProductionEnabled" tag, to the OPC UA server using the data block.

With the following assignment, you enable the production line in the example plant:

```
"Productionline_Data".WriteListStatus.Variable.ProductionEnabled :=  
TRUE;
```

This is only successful, however, if the following requirements are met:

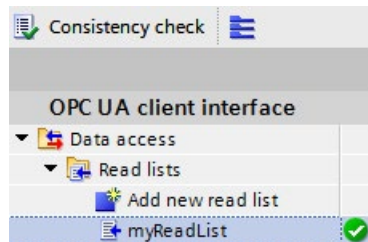
- A connection exists to the OPC UA server of the CPU, which controls the production line.
- Current values are being written via the OPC UA client

Consistency check

Finally, check the consistency of the read/write list or method list.

1. Select the list that you want to check.
2. Click the "Consistency check" button above the "OPC UA client interface" area.

A green check mark indicates an error-free assignment of the tags or methods to the corresponding elements of the server interface.



You can assume that the data exchange between client and server and method calls operate without problem in runtime.

In the event of an error a list appears in the Inspector window. From this list you can jump to the respective error.

During the consistency check, STEP 7 checks:

- Whether all elements that you use in the respective list are also present in the server.
- Do the data types used match?
- For methods: Do the number, name, order, and data types of method arguments match?

9.4.6 Determine server interface online

With STEP 7 (TIA Portal) you can determine the interface of an OPC UA server online. This provides information on which tags of a connected OPC UA server you can read or set (write) with OPC UA clients. It also provides information on which server methods of the OPC UA server are available for OPC UA clients.

If you are work offline you can create the interface of the OPC UA server by means of an OPC UA XML file. The address space of the server is described in the OPC UA XML file, see: Export OPC UA XML file (Page 174).

Determine online server interfaces

To determine a server interface online, follow these steps:

1. In the STEP 7 project tree, select the CPU which is configured as OPC UA client (Supervisor in the example).
2. Select the client interface (in the example, OPC UA Communication > Client interfaces > Productionline).

If no client interface has been created, double-click "Add new client interface".

3. Double-click the selected client interface.

The editor for client interfaces is displayed.

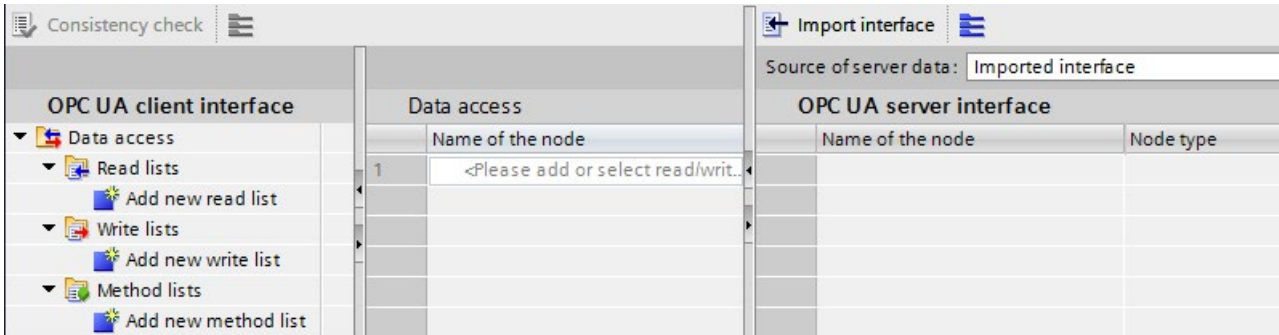


Figure 9-64 Editor for client interface

4. In the left section of the editor, click "Add new read list", "Add new write list", or "Add new method list".
5. In the right field of the editor, select "Online[]" as data source for "Source of server data":



- 6. Click the "Online Access" button.

STEP 7 displays the "Connect to OPC UA server" dialog.

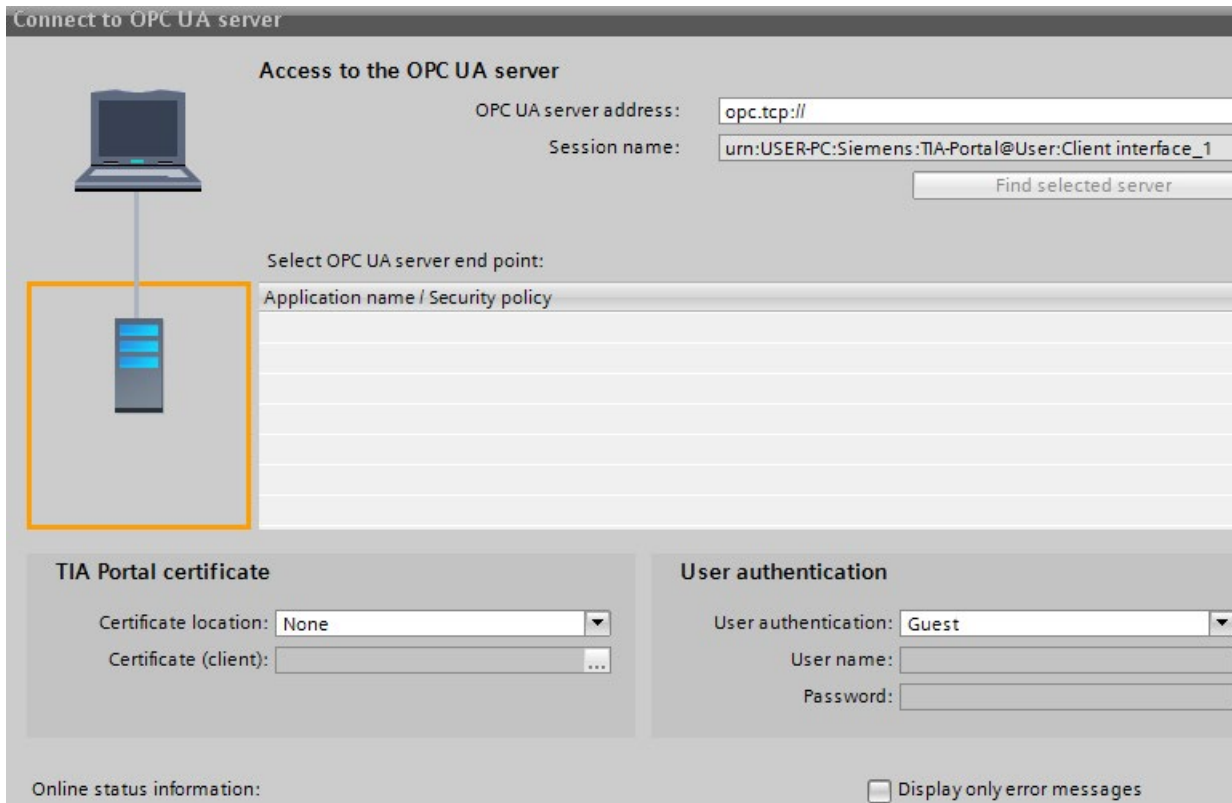


Figure 9-65 "Connect to OPC UA server" dialog

Tip: When establishing an online connection to an OPC UA server for the first time, use the "Online access" button. When reconnecting after a disconnection, select the "Connect to Online Server" button next to the "Online" selection field.

In the top right, enter the IP address of the OPC UA server whose server interface you want to determine online.

- 7. Click "Find selected server".

STEP 7 establishes a connection to the OPC UA server and determines all security settings (server endpoints) that the server holds in readiness.

STEP 7 displays the end points as list:

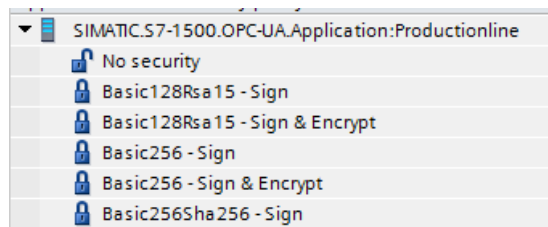


Figure 9-66 Found OPC UA server with all server endpoints

- 8. Click on the end point you want to use for a connection of STEP 7 to the OPC UA server.

9. Do you want to use a secure connection?

- If you have selected a secure end point, then select the entry "TIA Portal" for the "Certificate location".

And under "Certificate (Client)", select a client certificate for your PC on which STEP 7 (TIA Portal) is currently running.

If a client certificate does not yet exist for your PC, you can generate a client certificate here in the TIA Portal.

Proceed as follows to generate a certificate for your PC:

- Click on the button in the "Certificate (Client)" input field.
- Click "Add".
- For "Certificate owners" enter "STEP 7 (TIA Portal)".
- Select the "OPC UA client" entry at "Usage".
- For "Subject Alternative Name (SAN)", enter the IP address of your PC, on which you are currently running STEP 7 (TIA Portal), under "Value". Overwrite the already entered IP address.
- If your PC uses a second IP address, enter this address as well. If your PC does not use a second IP address, delete the second IP address already entered.
- Click "OK".
- If you have not selected a secure end point, then keep the default ("None").

10. How do you want to log on?

- If you want to log onto the OPC UA server as guest, then apply the default with "User authentication".
- If you want to log on with user name and password, select "User name and password".

Use the user name and password which was stored during the configuration of the OPC UA server in the properties of the CPU under "General > OPC UA > Server > Security > User authentication > User management".

11. Click on the "Go online" button.

When a secure connection is established, a message appears that you must accept the server certificate for the secure connection to be established. In the message window, you can display further details about the server certificate via a link.

This standard Windows window only provides information about the server certificate. If you click on the button to install the server certificate, the server certificate is not saved to the certificate memory of the TIA Portal, i.e. at the next connection attempt you will be prompted again to accept the server certificate.

STEP 7 then establishes a connection to the OPC UA server and again displays the editor for client interfaces.

In the right field of the editor, STEP 7 displays the uppermost level of the address space of the OPC UA server:



12. Click on the small black triangle next to "Objects".
STEP 7 now also displays the level below Objects.
13. Click on the small black triangle next to "Productionline".
STEP 7 now also displays the level below Productionline.
14. Now open additional lower-level folders:

OPC UA server interface		
Name of the node	Node type	Access level
▶ Server	Object	
▶ DeviceSet	Object	
▼ Productionline	Object	
▪ ▶ Counters	Object	
▪ ▼ DataBlocksGlobal	Object	
▪ ▶ Icon	ImagePNG	RD
▪ ▼ Data_from_OPC_UA_Clients	Object	
▪ ▶ ProductionEnabled	Boolean	RD/WR
▪ ▼ Data_for_OPC_UA_Clients	Object	
▪ ▶ ProductNumber	Int16	RD
▪ ▶ Temperature	Array of Float	RD
▪ ▶ NewProduct	Boolean	RD
▪ ▼ DataBlocksInstance	Object	
▪ ▶ Icon	ImagePNG	RD
▪ ▶ OpenDoor_DB	Object	
▪ ▶ DeviceManual	String	RD

Figure 9-67 Online view of OPC UA server interface

See also

- Mapping of data types (Page 142)
- Creating client interfaces (Page 251)

9.4.7 Using multilingual texts

In the client interface editor, you are also importing texts that can be displayed in different languages with the OPC UA XML files (information models). Multilingualism is optional, and each node can be defined differently regarding the languages it offers.

In the XML file, these are the following fields that can be prepared for different languages:

- Display name
- Description

Example for multilingual texts in an OPC UA XML file

In the XML file below, the display name and the description, for example, are entered with a "default" text and multiple localizable texts.

- Default text is the first entry without localization information.
- Localized text is the text after "Locale=" followed by a language code, e.g. "it-IT" for Italian

```
<UAVariable NodeId="ns=3;i=6070" BrowseName="3:EngineeringRevision" ParentNodeId="ns=3;i=1002"
DataType="String">
  <DisplayName>EngineeringRevision</DisplayName>
  <DisplayName Locale="en-US">EngineeringRevision</DisplayName>
  <DisplayName Locale="de-DE">Revisionsstand</DisplayName>
  <Description>Revision Level of the engineering environment.</Description>
  <Description Locale="en-US">Revision Level of the engineering environment.</Description>
  <Description Locale="de-DE">Revisionsstand der Engineeringumgebung.</Description>
  <Description Locale="fr-FR">Niveau de révision de l'environnement d'ingénierie.</Description>
  <Description Locale="it-IT">Livello di revisione dell'ambiente di ingegneria.</Description>
</References>
  <Reference ReferenceType="HasTypeDefinition">i=68</Reference>
  <Reference ReferenceType="HasModellingRule">i=78</Reference>
</References>
</UAVariable>
```

Figure 9-68 Example of multilingual texts in an OPC UA XML file

Display of multilingual texts

When importing a server interface, the available multilingual texts are saved internally and downloaded to a CPU together with the project.

The client editor displays the text from the OPC UA XML file in the columns "Name of the node" (corresponds to "DisplayName") and "Description" (corresponds to "Description").

The following cascading rules determine which language is shown for a node:

- When the node contains text in the currently used editing language, the text is also displayed in the editing language.
(Setting the editing language: In the project tree, select the area "Languages & resources > Project languages")
- When the node does not contain text in the editing language but a default text is defined there (without language code), the default text is displayed.
- "Name of the node" column: If no default text is defined either but a text in any other language exists, the DisplayName text is displayed in the first available language. This rule does not apply to description texts.
- If none of the conditions listed above is met, no text is displayed.

OPC UA server interface					
Node Name	Node type	Access level	Node ID	Description	
5 Server	Object		http://opcfoundation...		
6 ServerStatus	ServerStat..	RD	http://opcfoundation...	The current status of	
7 StartTime	UtcTime	RD	http://opcfoundation...		

Figure 9-69 Display for multilingual texts

When you change the editing language, the multilingual text in the imported interface will also change according to the rules explained above.

You can then apply the nodes in the corresponding lists (read list, write list, method list) with drag and drop.

You cannot change the language in the lists (read list, write list, method list).

Applying the displayed description texts as comment in PLC data types

When you compile the program, STEP 7 automatically creates PLC data types (UDTs) for each read list, for each write list and for inputs or outputs of each method. These UDTs each have one element for each node.

The UDTs apply the description text as comment according to the rules stated above. STEP 7 creates the comment in only one language, just like the texts in the OPC UA server interface can only be displayed in one language.

9.4.8 Rules for the access to structures

The rules for the access to structures are explained below. Note these rules when reading and writing values of complete structures provided by an OPC UA server.

How the client of the S7-1500 CPU accesses structures

The OPC UA client of the S7-1500 CPU uses neither TypeDictionaries nor DataTypeDefinition attributes, which a server offers for the resolution of these structures.

These options of the OPC UA client for checking structural elements in runtime are limited in the client.

Rules for the access to structures

If you use the client interfaces to configure the read and write lists (connection parameterization) and assign the PLC data types to the imported or online determined address model of the server, the read and write accesses to structures operate trouble-free in runtime.

The configuration by means of client interface automatically ensures that the sequence and the data type of the structural elements are coordinated on client and server side.

Recommendation: Update an S7-1500 CPU (as server) to the current firmware version (e.g. V2.0 > V2.5.2 or higher).

In runtime the OPC UA client only checks the total length of the transmitted value; more detailed checks are not possible.

Mapping rules apply to the assignment of OPC UA structures to PLC tags or DB tags (see Mapping of data types (Page 142)). Non-executed data type (such as OPC UA byte strings) are not supported.

Example of an error-free assignment of the structure elements

In the imported node set file (XML export), the structure is defined as follows:

opcUaStruct	Object
allOk	Boolean
myOPCstruct1	myOPCUAstruct
varA	Int64
VarB	Byte
nestedStructZ	"myOPCUAstruct"."nestedStructZ"
varD	Float
varE	Double
varC	Double
DeviceManual	String

The structure mapped in the read list matches, both in the order and in the assigned data types, the corresponding nodes of the node set file.

myOPCstruct1	myOPCUAstruct
varA	LINT
VarB	USINT
nestedStructZ	"myOPCUAstruct"."nestedStructZ"
varD	REAL
varE	LREAL
varC	LREAL

If the structure now changes on the server, for example tagA and tagB are swapped, and the read list remains the same in the client, the assignment is no longer correct:

- The total length of the data remains the same (only the order has changed)
- The configuration of the structure is different for client and server!

<p>! WARNING</p> <p>No error message in the case of different structure configuration between client and server</p> <p>If the structures of client and server do not match, this rule violation will possibly not generate any error during compilation and also not in runtime.</p> <p>Make sure not to change the configured assignments for structures in runtime. If required, reconfigure the assignment in the read and write lists!</p>
--

9.4.9 Using connection parameter assignment

9.4.9.1 Creating and configuring connections

With the instructions for OPC UA clients, you create a user program that exchanges data with an OPC UA server. A series of system data types are required for this.

To simplify your work with these system data types, a connection parameter assignment for OPC UA clients is available starting in STEP 7 (TIA Portal) Version 15.1.

Use of the connection parameter assignment is optional and not mandatory. You can also manually create the required system data types.

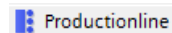
We use an example to make the description easier to follow, see description of the example (Page 249).

Opening the connection parameter assignment

To configure the connection to an OPC UA server, follow these steps:

1. In the "OPC UA communication" area, double-click the client interface whose parameters you want to assign in the project tree.

For the example configuration: Double-click the "ProductionLine" client interface.



The section "Create client interface (Page 251)" describes how to create a client interface.

2. Click the "Properties" tab (Inspector window) if the tab is not already displayed.

STEP 7 now displays the connection parameter assignment for the instructions of the OPC UA client.

The "General" tab is open.

3. Click on the "Configuration" tab and set the connection to the OPC UA server.

Setting the connection parameters

1. Select a descriptive name for the session. For the example, select the name "OPC UA Connection to ProductionLine".
2. In the "Address" field, enter the IP address of the OPC UA server to which your user program (that operates as an OPC UA client) is to establish a connection. In the example configuration, the CPU that controls the production line has the IP address "192.168.1.1". A connection to the OPC UA server of this CPU is to be established. For this reason, you enter this IP address in the "Address" field. In this case, the OPC UA server uses the default port 4840.

Alternatively, you can enter a valid DNS name in the "Address" field. The length of the DNS name is limited to 242 characters.

If the address is not valid, the error message is shown: "Enter a valid address".

If the string of the "Address", "Port" and "Path" fields contains more than 254 characters, an error message is also displayed.

3. Enter a path within the OPC UA server to restrict access to this path. The information is optional. However, some servers only establish a connection if a server path is specified.

When you specify a path, it is automatically entered at the "ServerEndpointUrl" entry in the configuration DB for the client interface. The entry then consists of the components "OPC Schematic Prefix", "IP address", "Port number" and "Server path", for example: "opc.tcp://192.168.0.10:4840/example/path".

The following figure shows the entry of the IP address for the OPC UA server:

	Client	Server
Session name:	OPC UA connection to Productionline	
Device:	Supervisor [CPU 1516-3 PN/DP]	Unspecified device
Address:		192.168.1.1
Port:		4840
Path (optional):		
Server address:		opc.tcp://192.168.1.1:4840
Session timeout:	30	s
Monitoring time:	5	s

Figure 9-70 Connection parameters

4. If the OPC UA server is not using the standard port 4840, you must insert the port number here.

For example, enter the number 65535 in the field, if the OPC UA server to which you want to establish a connection uses this port number.

5. In addition, you accept the default settings for session timeout (30 seconds) and monitoring time (5 seconds).

Setting the security parameters

1. Click the "Security" area in the "Configuration" tab.

This area contains all security settings for the connection to the OPC UA server.

The following settings are possible:

"General" area

Security mode:

Select the security mode that the connection to the OPC UA server must meet from the drop-down list.

If the server does not meet the selected mode, a session is not established.

The following settings are available:

- No security: No secure connection!
- Sign: OPC UA server and OPC UA client sign the data transmission (all messages): Manipulations can thus be detected.
- Sign & Encrypt: OPC UA server and OPC UA client sign and encrypt the data transmission (all messages):

Security policy:

Set the encryption techniques for the signing and encryption of messages.

The following settings are possible:

- No security
- Basic128Rsa15
- Basic256
- Basic256Sha256

To configure a secure connection, you must observe the following items:

- A certificate is required for the client for a secure connection.
- You have to make the client certificate known to the server.

To find out how to proceed, see the section "Handling client and server certificates (Page 183)" under "Certificate of the OPC UA client".

"Certificates" area

Client certificate:

The certificate confirms the authenticity of the OPC UA client.

To select a certificate, click the following symbol:



STEP 7 displays a list of certificates.

Select the certificate that you have made known to the server.

Click the symbol with the green check mark:



Or, create a new certificate. To do so, click the "Add" symbol.

If you create a new certificate, you must make this certificate known to the server.

"User authentication" area

The following settings are possible for user authentication:

- Guest
- User name and password
- Users (TIA Portal - Security Settings)

For more information, see Users and roles with OPC UA function rights (Page 194).

Setting languages

UA tags of the String type can be localized with OPC UA, that is, texts (values for the UA tag) can be available in different languages for the server. For example, localized texts can be available for DisplayName (Name of the node) and Description (Description).

In the "Languages" area of the "Configuration" tab you can, for example, influence the language of the texts returned by the server as follows:

In the "Languages" area, enter a number of languages that the server transfers to the client during connection setup.

The language or the local ID ("language code") associated with it that you enter in the first line is the language preferred by the client.

- If the server can provide the UA tag in the requested language, it is transferred to the client.
- If the server cannot provide the UA tag in the requested language, it checks whether it can provide the UA tag in the language you have entered in the second line (first substitute language).
- The server works its way down the list, and when it can provide neither the requested language nor a substitute language, it will provide the default language.

Additional information

What causes the connection to an OPC UA server to fail? FAQ
(<https://support.industry.siemens.com/cs/ww/en/view/109766709>)

See also

Handling of the client certificates of the S7-1500 CPU (Page 272)

9.4.9.2 Handling of the client certificates of the S7-1500 CPU

Where does the client certificate come from?

If you are using the OPC UA client of an S7-1500 CPU (OPC UA client enabled), you can create certificates for these clients with STEP 7 V15.1 and higher as described in the following sections.

When you use UA clients from manufacturers or the OPC Foundation, a client certificate is generated automatically during installation or upon the first program call. You have to import these certificates with the global certificate manager in STEP 7 and use them for the respective CPU.

If you program an OPC UA client yourself, you can generate certificates through the program. Alternatively, you can generate certificates with tools, for example with OpenSSL or the certificate generator of the OPC Foundation:

- The procedure for OpenSSL is described here: "Generating PKI key pairs and certificates yourself (Page 153)".
- Working with the certificate generator of the OPC Foundation is described here: "Creating self-signed certificates (Page 152)".

Certificate of the OPC UA client of the S7-1500 CPU

A secure connection between the OPC UA server and an OPC UA client is only established if the server classifies the certificate of the client as trusted.

Therefore you have to make the client certificate known to the server.

The following sections describe how you can initially generate a certificate for the OPC UA client of the S7-1500 CPU and then make it available to the server.

1. Generate and export a certificate for the client

For a secure connection you have to generate a client certificate and - if the server and client are located in different projects - export the certificate.

If client and server are in the same project, exporting the client certificate and subsequent import are not necessary.

Requirements

The IP interface of the CPU is configured, an IP address is available.

Background: The IP address under which the CPU can be accessed in your system is entered under "Subject Alternative Name (SAN)".

Creating an OPC UA Client certificate

The easiest way to generate a client certificate for an S7-1500 CPU is to configure a client interface.

The configuration of the client interface provides for the selection or generation of a client certificate, see *Creating and configuring connections* (Page 268).

Alternatively, you can generate the client certificate as follows:

1. In the project tree, select the CPU you want to use as a client.
2. Double-click "Device configuration".
3. In the properties of the CPU, click "Protection & Security > Certificate manager".
4. Double-click "<Add new>" in the "Device certificates" table.

STEP 7 opens a dialog.

5. Click the "Add" button.
6. Select the "OPC UA client" entry from the "Usage" list.
7. Click "OK".

STEP 7 now shows the client certificate in the "Device certificates" table.

8. If the server is in another project: Right-click this line and select "Export certificate" from the shortcut menu.
9. Select a directory where you will store the client certificate.

2. Announcing the client certificate to the server

You have to make the client certificate available to the server to allow a secure connection to be established.

To do this, follow these steps:

1. If the client was configured in another project and you created and exported the client certificate there:
 - Select the "Use global security settings for certificate manager" option in the local certificate manager of the server. This makes the global certificate manager available.

You will find this option under "Protection & Security > Certificate manager" in the properties of the CPU that is acting as server.
 - If the project is not yet protected, select "Security settings > Settings" in the STEP 7 project tree, click the "Protect this project" button and log on.

The "Global security settings" item is now displayed under "Security settings" in the STEP 7 project tree.
 - Double click "Global security settings".
 - Double click "Certificate manager".

STEP 7 opens the global certificate manager.
 - Click the "Device certificates" tab.
 - Right-click in the tab on a free area (not on a certificate).
 - Select the "Import" shortcut menu.

The dialog for importing certificates is displayed.
 - Select the client certificate that the server is to trust.
 - Click "Open" to import the certificate.

The certificate of the client is now contained in the global certificate manager. Note the ID of the client certificate just imported.
2. Click the "General" tab in the properties of the CPU that is acting as server.
3. Click "OPC UA > Server > Security > Secure Channel".
4. Scroll down in the "Secure Channel" dialog to the section "Trusted clients".
5. Double-click in the table on the empty row with "<add new>". A browse button is displayed in the row.
6. Click this button.
7. Select the prepared client certificate.
8. Click the button with the green check mark.
9. Compile the project.
10. Load the configuration onto the S7-1500 CPU (server).

Result

The server now trusts the client. If the server certificate is also considered trusted, the server and client can establish a secure connection.

9.4.9.3 User authentication

In the OPC UA client interface of the S7-1500, you can set what authentication is required for a user of the OPC UA client wishing to access the server. To do so, you must select the corresponding client interface in the project tree of the requested S7-1500 CPU under "OPC UA communication > Client interfaces" and select the type of user authentication in the Inspector window under "Properties > Configuration > Security".

Types of user authentication

The following options are available for user authentication:

- **Guest**

The user does not need to verify authorization (anonymous access). The CPU creates an anonymous session for the user, and the OPC UA server does not check the authorization of the client user.

- **User name and password**

The user must prove authorization (no anonymous access). The OPC UA server checks whether the client user is authorized to access the server. Authorization is given by the user name and the correct password. These inputs cannot be checked by the client interface, which means all values are accepted as being valid.

Note

STEP 7 stores user name and password unencrypted in the data block/instance data block. Recommendation: Use the user authentication "User (TIA Portal - Security Settings)".

- **Users (TIA Portal - Security Settings)**

You can enter a user name from the list of users entered in the project for authentication. The names of the registered users for the current project are available in the user administration in the project tree under "Security Settings > Users and roles". There you can also enter additional users.

You can also enter a name that is not listed in the user administration of the project or leave the field blank. This is necessary when the corresponding user name is only provided by a different source during runtime, for example, via HMI or from a different OPC UA client.

"No Security" security policy and authentication via user name and password

You can set the following combination:

Security policy = "No Security" and authentication via user name and password.

- The OPC UA server of the S7-1500 supports this combination. OPC UA clients can connect and encrypt the authentication data or not.
- OPC UA client of the S7-1500 CPU also supports this combination: However, in runtime it only connects if it can send the authentication data encrypted via cable!

Result: With the following configuration, not connection can be established in runtime.

- S7-1500 as OPC UA client
- OPC UA server which supports no encryption of authentication data when "No Security" (= "none") is set as security policy.

See also

Users and roles with OPC UA function rights (Page 194)

9.4.9.4 Using a configured connection

Introduction

This section shows you how to use a configured connection for OPC UA instructions (third step).

Requirements

- You have created a client interface and added PLC tags and PLC methods to this interface, see ("First step (Page 251)").
- You have configured a connection to an OPC UA server (Second step (Page 268)).

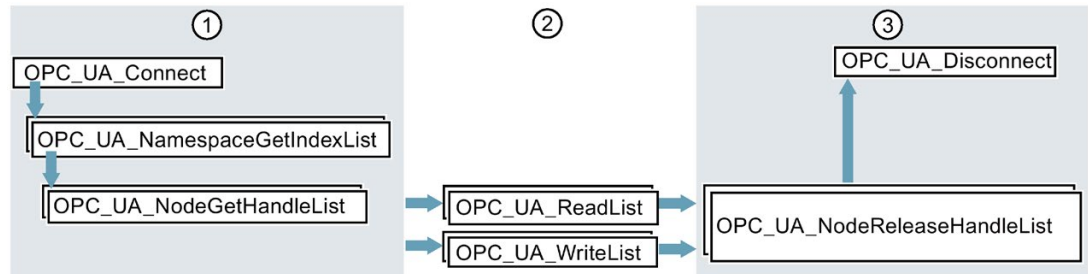
Overview

To read data from an OPC UA server or write data to an OPC UA server, use the following instructions:

- OPC_UA_Connect
- OPC_UA_NamespaceGetIndexList
- OPC_UA_NodeGetHandleList
- OPC_UA_ReadList or OPC_UA_WriteList
- OPC_UA_NodeReleaseHandleList
- OPC_UA_Disconnect

Order of the OPC UA instructions

The following figure shows the order in which the OPC UA instructions are called in a user program in order to use these instructions to read or write PLC tags:



- ① Instructions for preparation of read and write operations
- ② Read and write instructions
- ③ Instructions for "clean-up" after a completed read or write operation

The "OPC-UA-NodeReleaseHandleList" instruction can be omitted if "OPC-UA-Disconnect" is called immediately afterwards.

Figure 9-71 Call sequence for write and read operations

STEP 7 (TIA Portal) automatically supplies the parameters of these instructions if you are using a client interface and a configured connection to an OPC UA server.

The procedure is shown in the following section.

Using a client interface and configured connection

To use a configured OPC UA connection, follow these steps:

1. Open your user program in the TIA Portal.
2. Using drag-and-drop, move the "**UA_Connect**" instruction into the program editor.

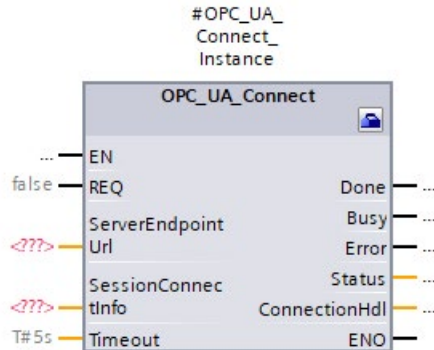
You will find the instruction under "Instructions > Communication > OPC UA" in the TIA Portal.

3. Select a call option for the instruction

The example uses a multi-instance.

STEP 7 displays the instruction in the program editor.

The editor for the Function Block Diagram (FBD) programming language uses the following display:



The editor for the Ladder Logic (LAD) programming language displays the instruction similarly.

4. Click the toolbox symbol in the editor for FBD or LAD.

The symbol is located in the heading of the instruction:



If you are using the editor for STL or SCL: Click the small green rectangle below the first character of the instance name:

#OPC-UA-Connect_Instance

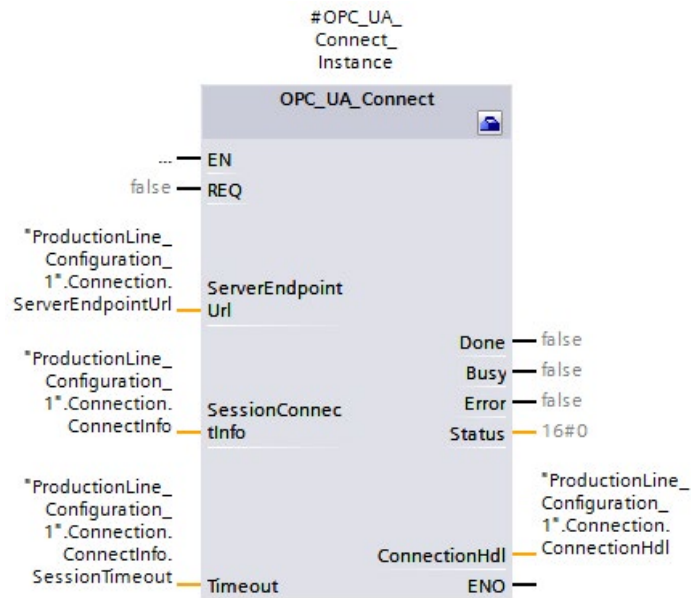
The example (Page 249) uses "#OPC-UA-Connect_Instance" as the instance name.

STEP 7 displays the properties of the instruction in a separate dialog.

- For "Client interface" select the client interface that you want to use for the instruction.

We select the "ProductionLine" client interface in the example.

STEP 7 now interconnects the "ProductionLine" client interface with the parameters of the OPC_UA_Connect instruction:



"ProductionLine" is the interface that the OPC UA client of the example (Page 249) uses for data exchange with the OPC UA server "ProductionLine".

- Using drag-and-drop, move the "**UA_NamespaceGetIndexList**" instruction into the program editor.

You will find the instruction under "Instructions > Communication > OPC UA" in the TIA Portal.

Select the "Multi-instance" call option.

Click the toolbox symbol (LAD and FBD) or the small green box below the instance name (STL and SCL) if the editor is not already open.

Select the client interface that you want to use ("ProductionLine" in the example).

STEP 7 now automatically interconnects all parameters of the "OPC_UA_NamespaceGetIndexList" instruction:

7. Using drag-and-drop, move the **"UA_NodeGetHandleList"** instruction into the program editor.

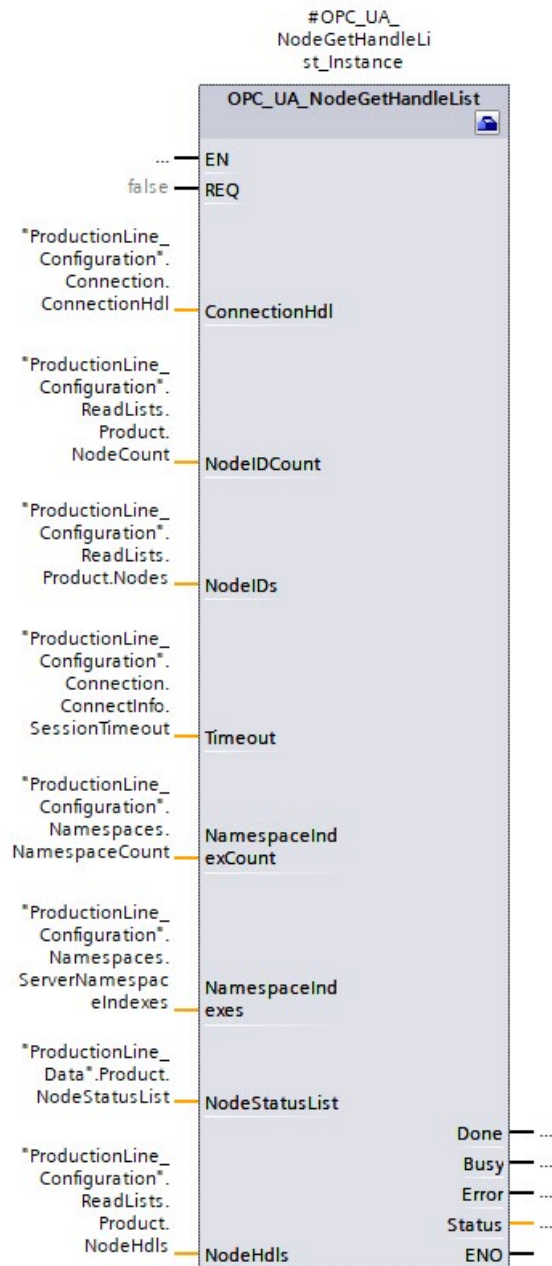
Select the "Multi-instance" call option.

Click the toolbox symbol (LAD and FBD) or the small green box below the instance name (STL and SCL) if the editor is not already open.

Select the client interface that you want to use. The example uses the "ProductionLine" client interface.

Under "Data access > Read/Writelists" select the read list that you want to use (in the example the read list "Product").

STEP 7 now automatically interconnects all parameters of the "OPC-UA-NodeGetHandleList" instruction:



If you want to write data to an OPC UA server, select the write list you want to use under "Data access > Read/Writelist" (the "ProductionStatus" write list in the example).

8. Using drag-and-drop, move the **"UA_ReadList"** instruction into the program editor.

Select the "Multi-instance" call option.

Click the toolbox symbol (LAD and FBD) or the small green box below the instance name (STL and SCL) if the editor is not already open.

Select the client interface that you want to use. The example uses the "ProductionLine" client interface.

Under "Data access > Read/Writelist" select the read list that you want to use (in the example the "Product" read list).

STEP 7 now automatically interconnects all parameters of the "OPC-UA_ReadList" instruction.

If you want to write data to an OPC UA server, use the **"OPC-UA_Write"** instruction and select the list of tags you want to send to the server under "Data access > Writelist" ("ProductionStatus" write list in the example).

9. If you use different read lists or write lists as program-controlled lists in your user program, move the **"UA_NodeReleaseHandleList"** instruction to the program editor using drag-and-drop operation.

Select the client interface that you want to use.

Now select a read list or write list that you want to release: Only release read or write lists that you rarely use, since re-registering is time-consuming.

Then, repeat the steps starting with step 7 with the "UA_NodeGetHandleList" instruction.

10. Using drag-and-drop, move the **"UA_Disconnect"** instruction into the program editor.

Select the "Multi-instance" call option.

Click the toolbox symbol (LAD and FBD) or the small green box below the instance name (STL and SCL) if the editor is not already open.

Select the client interface that you want to use. The example uses the "ProductionLine" client interface.

STEP 7 now automatically interconnects all parameters of the "OPC-UA_Disconnect" instruction.

Supported instructions

For the following instructions, STEP 7 automatically supplies the parameters if you are using a client interface and a configured connection to an OPC UA server:

- OPC_UA_Connect
- OPC_UA_NamespaceGetIndexList
- OPC_UA_NodeGetHandleList
- OPC_UA_MethodGetHandleList
- OPC_UA_MethodReleaseHandleList
- OPC_UA_ReadList
- OPC_UA_WriteList
- OPC_UA_MethodCall
- OPC_UA_NodeReleaseHandleList
- OPC_UA_Disconnect

9.5 Tips and recommendations

9.5.1 Rules for subscriptions

The following rules apply to subscriptions:

- Group subscriptions in the client according to different sampling and publishing intervals and distribute the monitored elements (variables) to these groups.

Example: Create a subscription for longer publishing intervals (e.g. 5 seconds) and a subscription for shorter publishing intervals (e.g. 0.1 second).

- Disable unneeded subscriptions.

Reason: The "Deactivated" subscription mode reduces resource consumption.

- Consider the maximum number of monitored items of subscriptions for the corresponding S7-1500 CPU.

The information can be found in the technical specification of the respective CPU. The information is based on a sampling / publishing interval of 1 second.

You can find additional information in the FAQ 109755846

(<https://support.industry.siemens.com/cs/us/en/view/109755846>).

- Select the same sampling and publishing intervals for the OPC UA client and for the OPC UA server.

- Avoid arrays and structures as elements of subscriptions – if the process allows.

Reason: If even one value of an array/structure changes, the entire structure is transferred, creating an unnecessary communication load.

- Occasional non-compliance with the required sampling rate is acknowledged by the OPC UA server of the S7-1500 CPU according to OPC UA specification with a "GoodOverload" error code, see also TIA Portal Help. Different OPC UA clients handle "Good" error codes unequal to "0" differently. Consider this behavior and, if needed, reduce the communication load according to the measures described above.

See also

Settings of the server for subscriptions (Page 181)

9.5.2 Rules for the user program

User programs for OPC UA

The following rules apply to user programs:

- If your application allows it and the communication load is high, you should set a minimum time for cycle OBs.

Advantages:

- The cycle time remains constant for the most part
- The CPU has more time for communication tasks throughout

Tip: Use the instruction "Runtime_Info"; mode 21 or mode 25 (see TIA Portal Help) to analyze the CPU utilization (e.g. communication).

- Reduce the number of variables or data blocks that can be reached from OPC UA/HMI. By default, all variables from OPC UA/HMI are accessible when creating variables/DBs/IDBs. This measure leads to improved performance when loading in RUN.

Tip: Using the detailed object display in the TIA Portal, you can easily mark the non-OPC-UA-relevant data blocks as "not accessible from OPC UA".

- Consistent transfer of data beyond the limits of simple data types is only possible with OPC UA methods. If you use other OPC UA functions (Subscriptions, Read/Write), you must ensure data consistency in the application.
- OPC UA offers the "RegisterNodes" service for repeated read and write accesses to the same variables. Servers can use this service to prepare for optimized access to variables. The instruction "OPC-UA_NodeGetHandleList" of the S7-1500 as OPC UA client implicitly calls this service to prepare the server for optimized accesses (in OPC UA usage "Registered Read/Write").

Calling detailed object display in the TIA Portal

To call up the detailed object display, proceed as follows:

1. Switch to the "PLC Programming" portal in the portal view.
2. Select "Show all objects".

3. Switch to the "Details" tab in the selection window.
4. In the "DB accessible from OPC UA" column, disable the accessibility from OPC UA for individual objects.

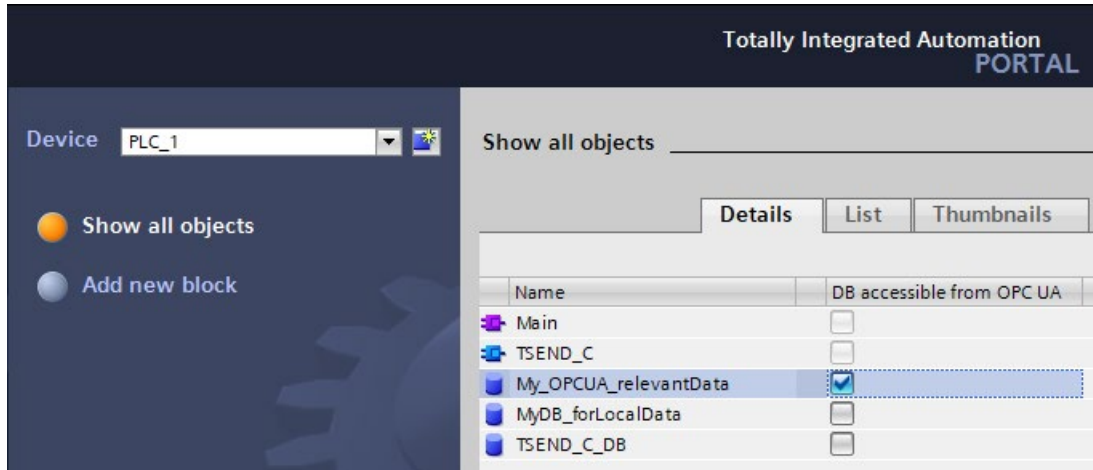


Figure 9-72 Calling detailed object display in the TIA Portal

9.5.3 Master copies for OPC UA communication

Master copies for the OPC UA interfaces

Interfaces of OPC UA servers and OPC UA clients that you want to use multiple times can be stored either in the project library or in a global library. Master copies in the project library can only be used within the project. When you create the master copy in a global library, it can be used in different projects.

The OPC UA capable CPUs differentiate between 3 interface types of the OPC UA server:

- Standard OPC UA server interface
- Companion specification interface
- Namespace reference

When adding the OPC UA interface in the project tree under "OPC UA Communication" each interface type gets its own symbol. The same symbol is used by the master copy.

Create either single master copies or a master copy with multiple interfaces.

Creating multiple master copies from selection

You select one or more elements and create individual master copies from them

1. Open the library in the "Libraries" task card.
2. Select the desired elements.
3. Using a drag-and-drop operation, move the elements to the "Master copies" folder or any subfolder of "Master copies".

Creating a master copy from selection

You select multiple elements and create a single master copy from them that contains all selected elements.

1. Copy to the clipboard the elements that you want to create as master copies.
2. Right-click on the "Master copies" folder or any of its subfolders in the library.
3. In the shortcut menu, select "Paste as a single master copy" command.

If multiple interfaces are added to a master copy from the OPC UA server or OPC UA client, the label and the symbol in the library are changed accordingly.

A symbol with "+" is displayed instead of the simple symbol.

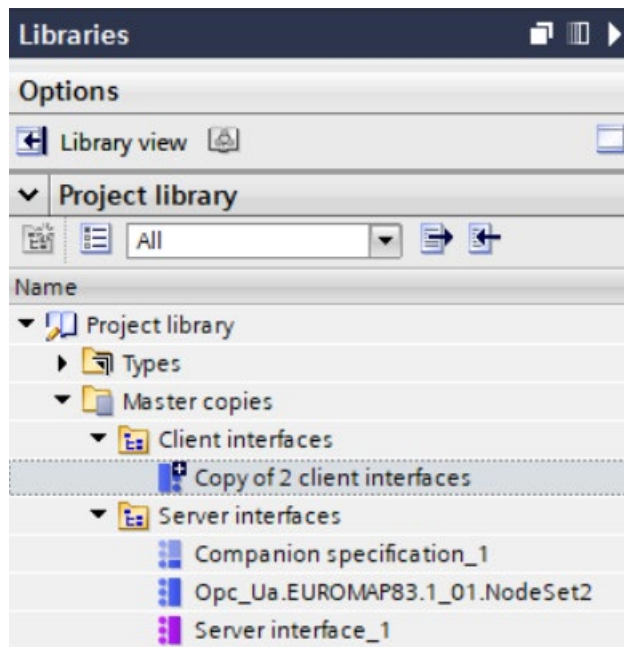


Figure 9-73 Create copy template in STEP 7

See also

Creating a user-defined server interface (Page 201)

Routing

10.1 Overview of the routing mechanisms of S7-1500 CPUs

The following table gives an overview of the routing mechanisms of the S7-1500 CPU.

Routing mechanism	Description	Applications	Section
S7 routing	S7 routing is the transfer of data beyond S7 subnet boundaries. You can send information from a transmitter to a receiver across several s7 subnets.	Download user programs Load hardware configuration Execute testing and diagnostics functions	S7 routing (Page 289)
IP forwarding	IP forwarding is a function of devices to forward IP packets between two connected IP subnets.	Simple access from the control level to the field level for configuration and parameter assignment of devices, e.g. via PDM or Web browser. Simplified integration of devices for remote access, e.g. for diagnostics during remote maintenance or firmware update.	IP forwarding (Page 294)
Data record routing	Data can be sent over PROFINET from an engineering station to field devices via multiple networks. Since the engineering station addresses the field devices using standardized records and these records are routed via S7 devices, the term "data record routing" is used to refer to this type of routing.	Data record routing is used, for example, when field devices of different manufacturers are used. The field devices are addressed using standardized data records (PROFINET) for configuration and diagnostics.	Data record routing (Page 301)

10.2 S7 routing

Definition of S7 routing

S7 routing is the transfer of data beyond S7 subnet boundaries. You can send information from a transmitter to a receiver across several s7 subnets. The gateway from one S7 subnet to one or more other subnets is provided by the S7 router. The S7 router is a device which has interfaces to the respective S7 subnets. S7 routing is possible via various S7 subnets (PROFINET/Industrial Ethernet and/or PROFIBUS).

Requirements for S7 routing

- All devices that can be reached in a network have been configured in a project in STEP 7 and downloaded.
- All devices involved in the S7 routing must receive routing information about the S7 subnets that can be reached through specific S7 routers. The devices obtain the routing information by downloading the hardware configuration to the CPUs, since the CPUs play the role of an S7 router.

In a topology with several consecutive S7 subnets, the following order must be kept to when downloading: First download the hardware configuration to the CPU(s) directly connected to the same S7 subnet as the PG/PC, then download one by one the CPUs of the S7 subnets beyond this starting with the nearest S7 subnet through to the S7 subnet furthest away.

- The PG/PC you want to use to establish a connection via a S7 router must be assigned to the S7 subnet it is physically connected to. You can assign the PG/PC to a PG/PC in STEP 7 under Online & Diagnostics > Online accesses > Connection to interface/subnet.
- For S7 subnets of the type PROFIBUS: Either the CPU must be configured as DP master or, if it is configured as a DP slave, the "Test, commissioning, routing" check box must be selected in the properties of the DP interface of the DP slave.
- S7 routing for HMI connections is possible as of STEP 7 V13 SP1.

Note

Firewall and S7 routing

A firewall does not recognize the IP address of the sender during S7 routing when the sender is located outside the S7 subnet adjacent to the firewall.

An overview of the devices that support the "S7 routing" function is provided in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/584459>).

S7 routing for online connections

With the PG/PC, you can reach devices beyond S7 subnets, for example to do the following:

- Download user programs
- Download a hardware configuration
- Execute test and diagnostics functions

In the following figure, CPU 1 is the S7 router between S7 subnet 1 and S7 subnet 2.

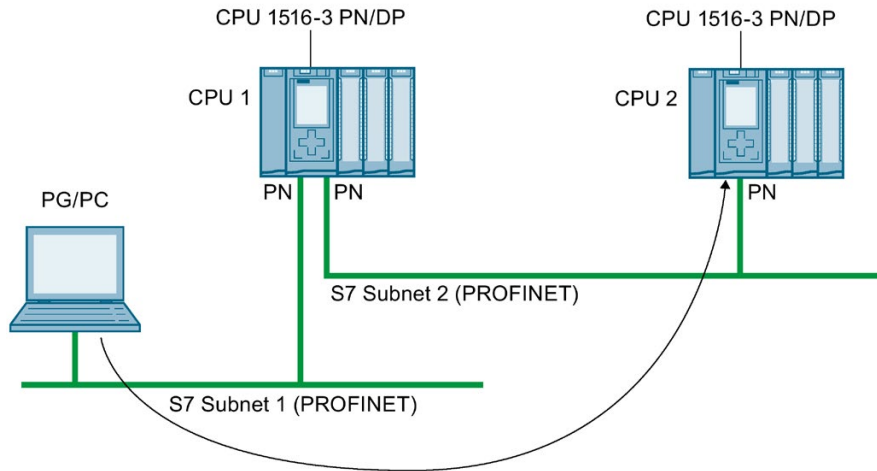


Figure 10-1 S7 routing: PROFINET - PROFINET

The following figure shows the access from a PG via PROFINET to PROFIBUS. CPU 1 is the S7 router between S7 subnet 1 and S7 subnet 2; CPU 2 is the S7 router between S7 subnet 2 and S7 subnet 3.

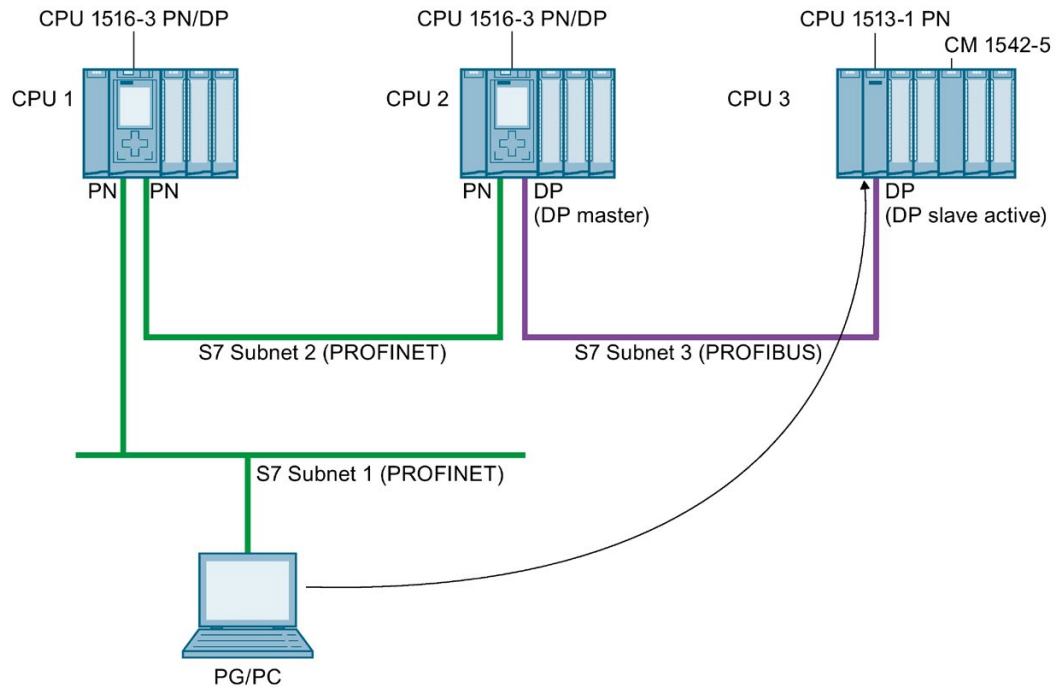


Figure 10-2 S7 routing: PROFINET - PROFIBUS

S7 routing for HMI connections

You have the option of setting up an S7 connection from an HMI to a CPU via different subnets (PROFIBUS and PROFINET or Industrial Ethernet). In the following figure, CPU 1 is the S7 router between S7 subnet 1 and S7 subnet 2.

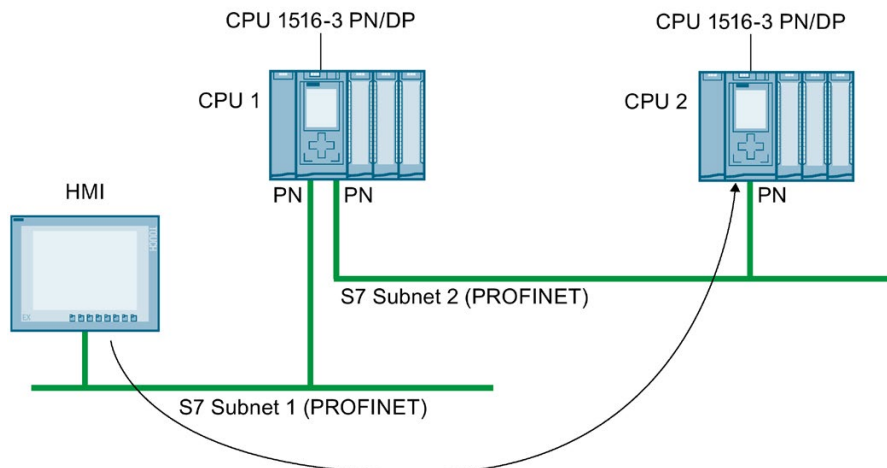


Figure 10-3 S7 routing via HMI connections

S7 routing for CPU-CPU communication

You have the option of setting up an S7 connection from a CPU to another CPU via different subnets (PROFIBUS and PROFINET or Industrial Ethernet). The procedure is described based on examples in the section S7 communication (Page 112).

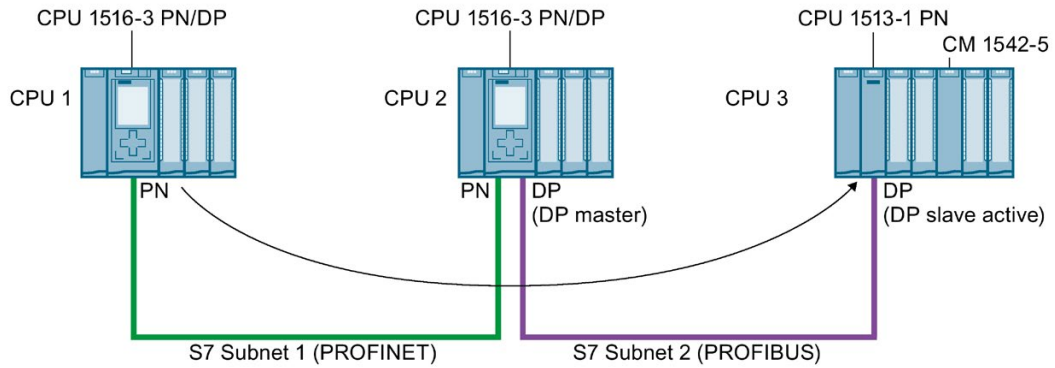


Figure 10-4 S7 routing via CPU-CPU communication

Using S7 routing

For the CPU, select the PG/PC interface and the S7 subnet in the "Go online" dialog of STEP 7. S7 routing is performed automatically.

Number of connections for S7 routing

The number of connections available for S7 routing in the S7 routers (CPUs, CMs or CPs) can be found in the technical specifications in the manuals of the relevant CPU/CM/CP.

S7 routing: Example of an application

The figure below shows the example of an application for remote maintenance of a system using a PG. The connection is made here beyond two S7 subnets via a modem connection.

You configure a remote connection via TeleService in STEP 7 using "Online access" or "Go online".

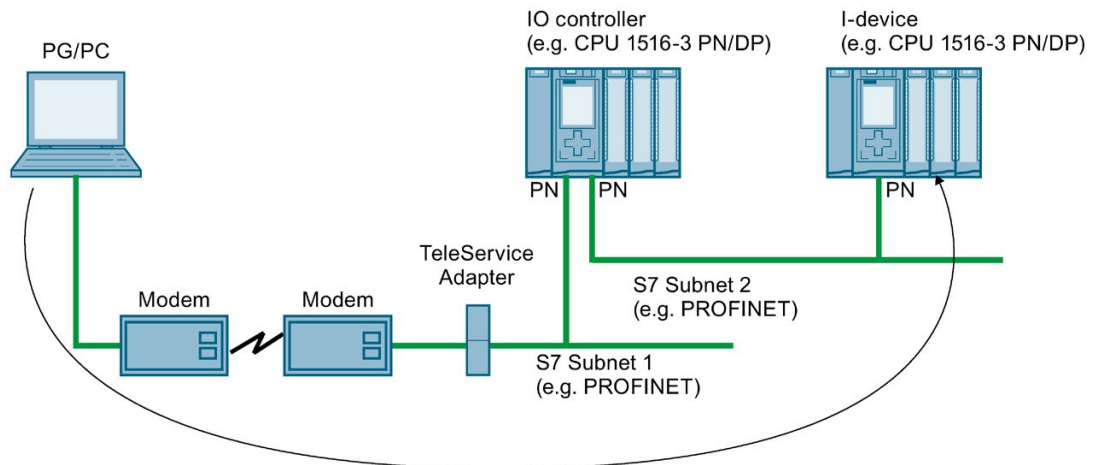


Figure 10-5 Remote maintenance of a plant using TeleService

Additional information

- The allocation of connection resources with S7 routing is described in the section Allocation of connection resources (Page 311).
- You can find more information on setting up TeleService in the STEP 7 online help.
- You can find more information on S7 routing and TeleService adapters when you search the Internet using the following links:
 - Device manual Industrial Software Engineering Tools TS Adapter IE Basic (<http://support.automation.siemens.com/WW/view/en/51311100>)
 - Downloads for the TS Adapter (<http://support.automation.siemens.com/WW/view/en/10805406/133100>)

See also

HMI communication (Page 63)

10.3 IP forwarding

Forwarding of IP packets with IP forwarding

IP forwarding is a function of devices to forward IP packets between two connected IP subnets.

Enable/disable the IP forwarding function in STEP 7. When IP forwarding is enabled, the S7-1500 CPU forwards received IP packets not addressed to the CPU to locally connected IP subnets or to a configured router.

The following figure shows how a programming device accesses data of an HMI device. Programming device and HMI device are located in different IP subnets. The IP subnets are connected to the two interfaces X1 and X2 of the CPU.

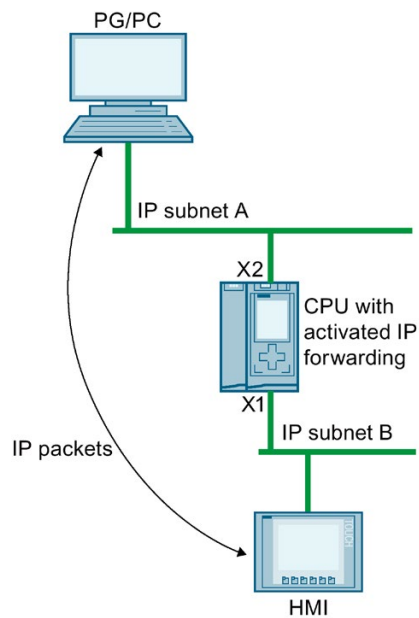


Figure 10-6 Access of a programming device to an HMI via IP forwarding

Areas of application

- Easy access from the control level to the field level for configuration and parameter assignment of field devices, e.g. via PDM or web browser
- Simplified integration of devices for remote access, e.g. for diagnostics during remote maintenance or firmware update

Requirements for using IP forwarding

- S7-1500 CPU as of firmware version V2.8
- Number of Ethernet interfaces:
 - The CPU has at least two Ethernet interfaces.
 - Or the CPU has one Ethernet interface, and a CP 1543-1 as of firmware version V2.2 provides the other Ethernet interface. In this case, the "Access to PLC via communication module" function must be enabled for the CP in the CPU.
- IP forwarding is enabled.
- Suitable standard gateways/routes are configured in each participating device along the outgoing and return paths of the IP packets.

IP route table

When IP forwarding is enabled, the CPU forwards received IP packets that are not addressed to itself. How the CPU forwards the IP packets is defined in its internal IP route table.

The CPU automatically creates the IP route table from the following information of the loaded hardware configuration:

- IP configuration of the Ethernet interfaces
- Configured router

Example of a configuration with IP forwarding

The following figure shows a sample configuration along with the required IP address settings and router settings.

- A PC on the IP subnet 192.168.4.0 communicates with an HMI device on the IP subnet 192.168.2.0.
- The IP address of a router ("Standard Gateway") is configured at the CPU, Ethernet interface X3; in the figure below it is the device that is designated as "IP Router". In STEP 7, you configure a router in the interface properties under "Ethernet Addresses" > "IP Protocol".

The screenshot shows the 'IP protocol' configuration window. It contains the following elements:

- IP protocol** (Section Header)
- Set IP address in the project (Selected)
- IP address:
- Subnet mask:
- Use router
- Router address:
- IP address is set directly at the device

Figure 10-7 Configuring the router

- For the PC, the IP router, the IO device and the HMI device, the IP addresses of a standard gateway or the corresponding routes are also entered.

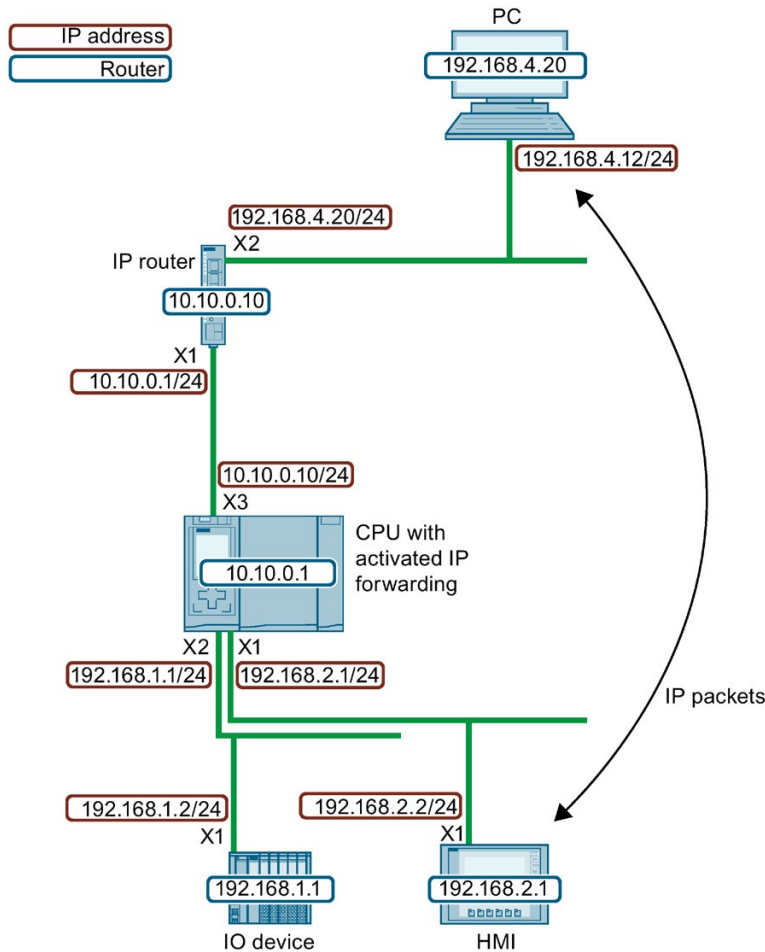


Figure 10-8 Sample configuration

This example configuration results in the following IP routing table for the CPU.

Table 10- 1 IP route table of the CPU

Network destination	Interface	Gateway
0.0.0.0/0	10.10.0.10	10.10.0.1
192.168.1.0/24	192.168.1.1	-
192.168.2.0/24	192.168.2.1	-
10.10.0.0/24	10.10.0.10	-

For IP communication between the PG/PC and the HMI device, you need to set up additional IP routes to the IP subnet of the HMI device both in the PC and in the IP router. In the HMI device, you configure the IP address of the CPU interface X1 as the standard gateway.

In a Windows computer, for example, you set up an additional IP route from the command prompt using the command "route add <destination IP subnet> mask <subnet mask> <gateway>". However, you need certain access rights for this. For this example, enter the following prompt:

- "route add 192.168.2.0 mask 255.255.255.0 192.168.4.20"

In an IP router, you set up additional routes, e.g. via a web interface. Set up the following route for this example:

- Destination IP subnet: 192.168.2.0
- Subnet mask: 255.255.255.0
- Gateway: 10.10.0.10

Restrictions

You cannot configure any additional IP routes other than the router ("Standard Gateway") for an S7-1500 CPU. The network destination is either a connected IP subnet, or the network destination can be reached via exactly one configurable router. Because the S7-1500 CPU does not support additional IP routes, you cannot build bi-directional IP router cascades.

In the following configuration, you can configure either "Router 1" or "Router 2" in the CPU. "Router 1" is configured as an example. In this case, you cannot configure "Router 2". IP communication between the PC and the HMI device is not possible because the route is not continuous in both directions.

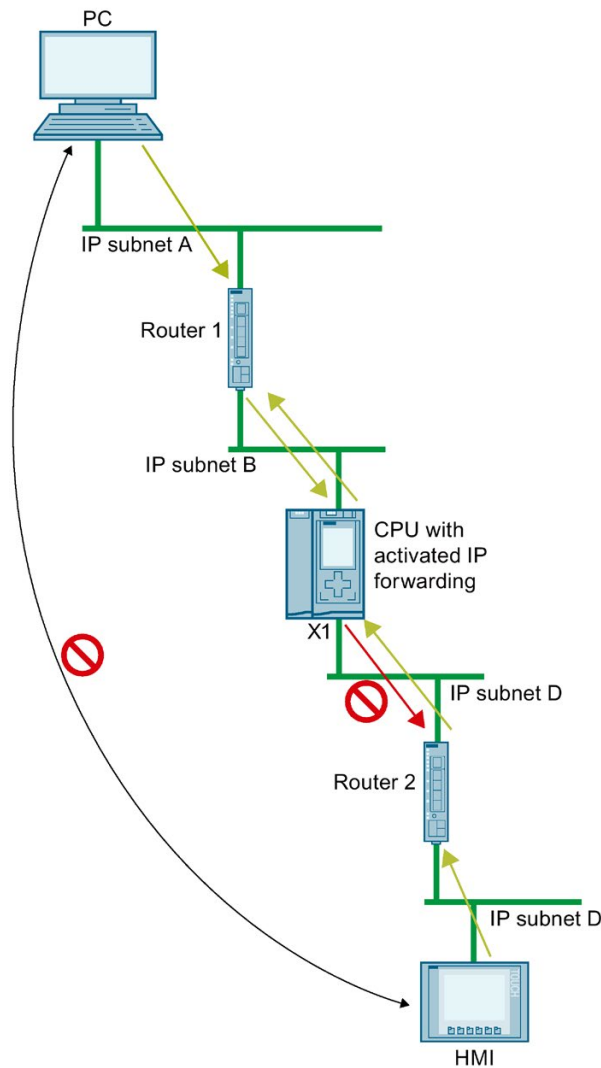


Figure 10-9 Unsupported IP router cascade

IP forwarding via the interface of a CP

IP forwarding also works via the interface of a CP. For this you have to activate the "Access to PLC via communication module" function for this CP in the CPU.

How you enable the "Access to PLC via communication module" function is described in the online help of STEP 7.

Reaching C/C++ Runtime of the CPU 1518 4 PN/DP MFP via interfaces X1 or X2

If you activate PN/DP MFP IP forwarding for the CPU 1518 4 PN/DP, you will not only reach devices in the IP subnet of interface X3 via interfaces X1 and X2, but also C/C++ Runtime. From the C/C++ Runtime of the CPU 1518 4 PN/DP MFP, you reach all devices in the IP subnets of the interfaces X1, X2 and X3.

Conditions:

- IP forwarding is enabled for the CPU 1518 4 PN/DP MFP.
- The IP address of C/C++ Runtime and the IP address of interface X3 are located in the same IP subnet.
- The routes to the IP subnets at X1 and X2 are entered in C/C++ Runtime.
In C/C++ Runtime, enter a route with the following command: "Route add-net <destination IP subnet> mask <subnet mask> gw <gateway>"

The following figure shows a configuration in which a PC accesses the C/C++ Runtime of CPU 1518-4 PN/DP MFP via interface X2.

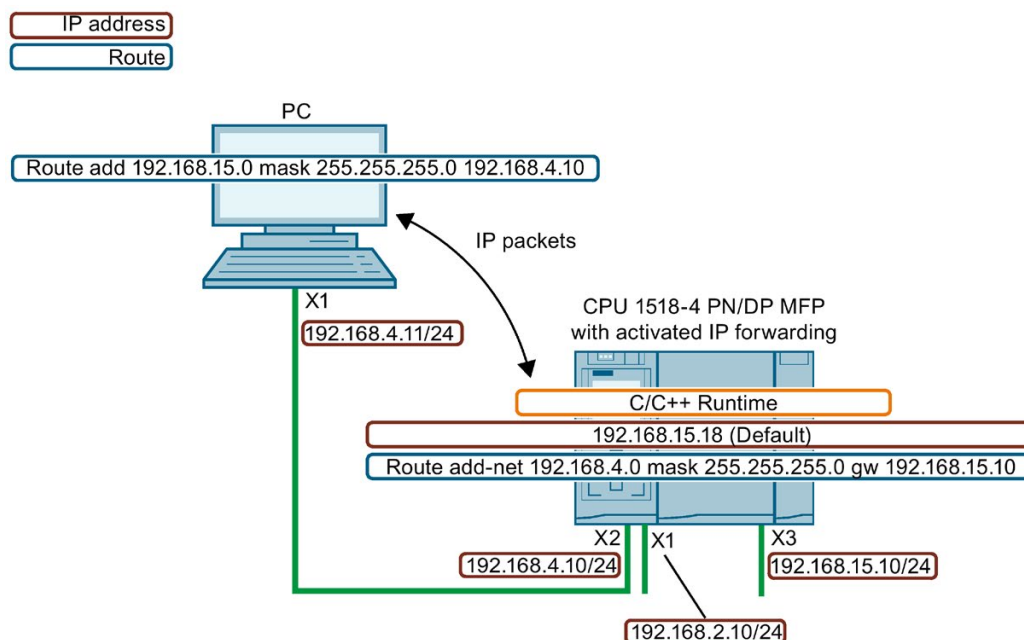


Figure 10-10 Access to C/C++ Runtime via interface X2

Take network security into account for IP forwarding

If you activate IP forwarding for a CPU, you enable "external" access to devices that are actually only accessible and controlled by the CPU. These devices are therefore usually not protected against attacks.

The following figure shows how to protect your automation system against unauthorized access.

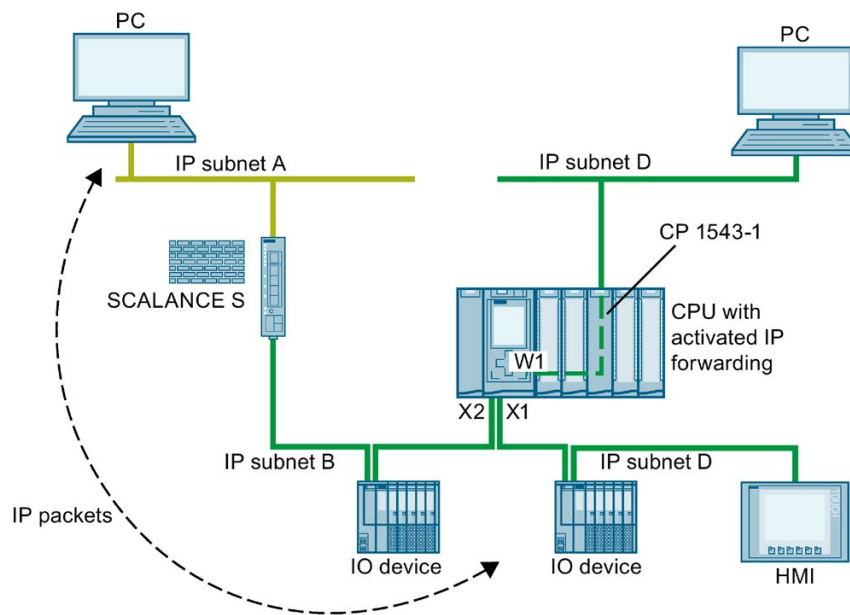


Figure 10-11 Network security for IP forwarding

- The CPU accesses all devices within the dark green IP subnets B and C close to the CPU via the interfaces X1 and X2.
- A SCALANCE S router is configured in the CPU. The CPU accesses the devices in the remote, light green IP subnet A via the router.
- The "Access to PLC via communication module" function is enabled for the CP 1543 in the CPU. The CPU reaches all devices within the IP subnet D via W1 interface.

If IP forwarding is enabled in the CPU, then a device from IP subnet A can access any device within IP subnets B,C and D close to the CPU.

Protect your automation system and connected devices against unauthorized access from outside.

Separate the CPU-related IP subnets from the remote IP subnets with a firewall. For example, use the SCALANCE S security modules with integrated firewall.

This application example (<https://support.industry.siemens.com/cs/ww/en/view/22376747>) describes how to protect an automation cell with a firewall using the SCALANCE S602 V3 and SCALANCE S623 security modules.

Enabling/disabling IP forwarding

To enable IP forwarding, proceed as follows:

1. Select the CPU in the network view of STEP 7 (TIA Portal).
2. In the properties of the CPU of the Inspector window, navigate to "General" > "Advanced Configuration" > "IP forwarding".
3. In the "Configuration IPv4 Forwarding" area, select the check box "Activate IPv4 for interfaces of this PLC".

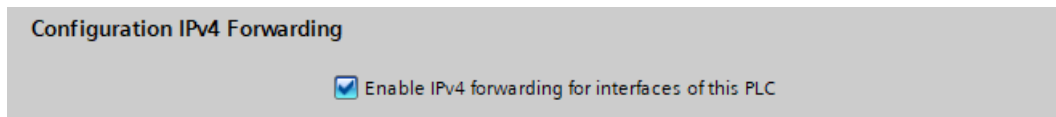


Figure 10-12 Enabling IP forwarding

Result: IP forwarding is enabled for all interfaces of the S7-1500 CPU.

You disable IP forwarding by clearing the check box "Enable IPv4 forwarding for interfaces of this PLC".

10.4 Data record routing

Definition of data record routing

Data can be sent over PROFINET from an engineering station to field devices via multiple networks. Since the engineering station addresses the field devices using standardized records and these records are routed via S7 devices, the term "data record routing" is used to refer to this type of routing.

The data sent using data record routing include the parameter assignments for the participating field devices (slaves) and device-specific information (e.g. setpoint values, limit values).

Data record routing is used, for example, when field devices of different manufacturers are used. The field devices are addressed using standardized data records (PROFINET) for configuration and diagnostics.

Data record routing with STEP 7

You can perform data routing with STEP 7 by calling a device tool (for example, PCT) via the TCI interface (Tool Calling Interface) and passing call parameters. The device tool uses the communication paths that STEP 7 also uses for communication with the field device.

No configuration is required for this type of routing except the installation of the TCI tools on the STEP 7 computer.

Example: Data record routing with the Port Configuration Tool (PCT)

You can use the Port Configuration Tool (PCT) to configure the IO link master of the ET200 and assign parameters to connected IO link devices. The subnets are connected via data record routers. Data record routers are, for example, CPUs, CPs, IMs, IO link master.

You can learn about the constellations of data record routers supported by the PCT in this FAQ (<http://support.automation.siemens.com/WW/view/en/87611392>).

The figure below shows an example configuration with the data record routing with PCT.

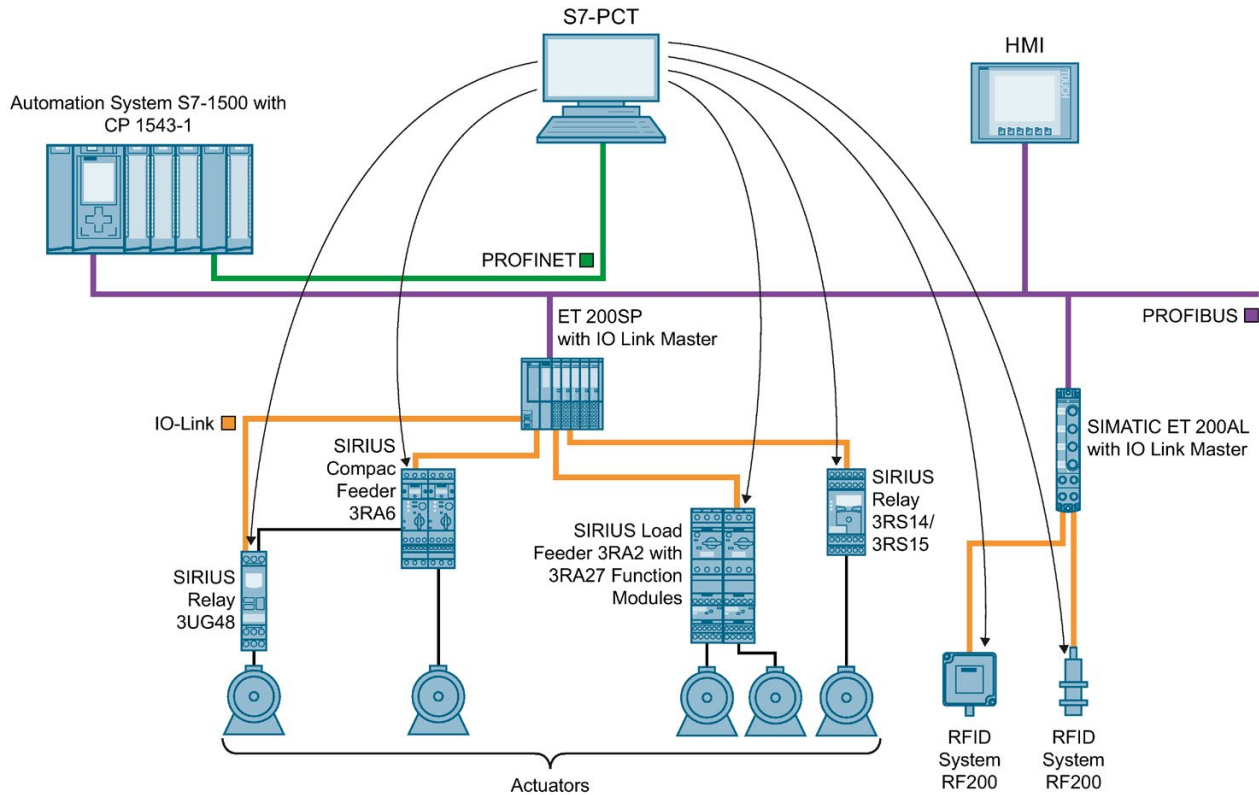


Figure 10-13 Example configuration for data record routing with PCT

Additional information

- The differences that exist between "normal" routing and data record routing are described in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/7000978>).
- Whether or not the CPU, CP or CM you are using supports data record routing can be found in the relevant manuals.
- The allocation of connection resources with data record routing is described in the section Allocation of connection resources (Page 311).
- You can find additional information on configuration with STEP 7 in the STEP 7 online help.

10.5 Virtual interface for IP-based applications

As of firmware version 2.8, the S7-1500 CPU offers the option of reaching its IP-based applications, such as OPC UA, not only via its local (PN) interfaces, but also via the interfaces of communication processors in the same station. A communication partner reaches these IP-based applications via a virtual interface that can be configured in the TIA Portal as of version V16. The virtual interface is called W1 (according to IEC 81346-2).

Features of the virtual interface

The virtual interface is not a fully diagnosable interface with the familiar properties of conventional interfaces. The virtual interface is not displayed in the graphical views, because the internal connection via the backplane bus does not represent an S7 subnet and does not have any ports. A physical connection by means of a network cable therefore cannot be established.

The IP address of the virtual interface is displayed (e.g. in the TIA Portal, in the display of the CPU) and can be configured.

The following IP-based services can be used e.g. via the virtual interface W1:

- OPC UA (client and server)
- Programmed OUC connections
- S7 communication (ES/HMI access and instructions for S7 communication such as PUT, GET)

The activated interface can be used in dialogs where IP-based connections are configured.

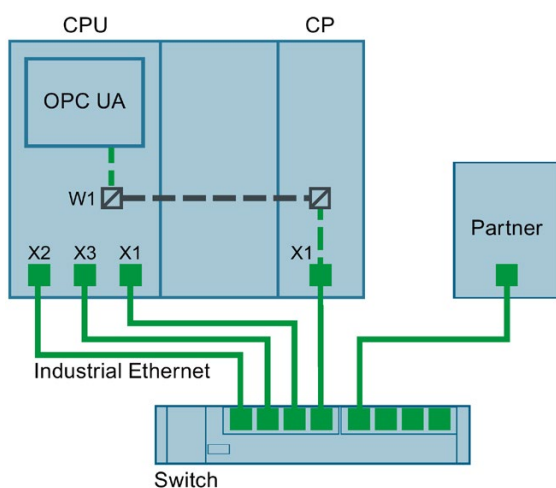


Figure 10-14 Principle of the virtual interface

Compared to conventional interfaces, the virtual interface has the following restrictions:

- No access to the web server over the virtual interface.
- Online backup is not possible via a connected programming device with the TIA Portal.
- If the CPU and communication partners are connected via the virtual interface, they cannot exchange data via LLDP (Link Layer Discovery Protocol).
- The S7 routing service does not use the virtual interface W1.

Requirement

For a CPU service to be accessible via the Ethernet interface of a CP, the following requirements must be fulfilled:

- S7-1500 CPU firmware V2.8 or higher
- CP 1543-1 firmware V2.2 or higher

R/H CPUs do not support this function because R/H CPUs do not support CPs.

Configuration of the virtual interface W1

In the properties of an S7-1500 CPU as of firmware V2.8, you can assign a plugged communication module to the virtual interface W1 under "Advanced Configuration > Access to PLC via communication module". You can then use this for external access to the CPU. If no CPs are plugged in or the plugged CPs do not support access to the CPU, the selection is empty.

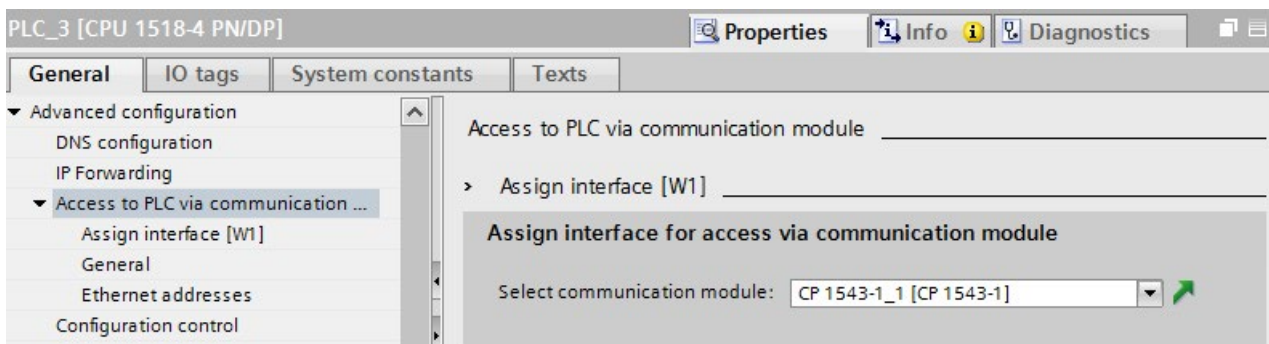


Figure 10-15 Selecting the CP in the CPU properties

After selecting the CP, the specifications and parameters for the virtual interface are displayed. Here, you can edit the settings for the IP protocol and the PROFINET parameters.

- The IP subnet is freely selectable, just like with the CP. The IP subnet is entered via the subnet mask and IP address of the virtual interface.
- When entering the IP subnet for the virtual interface, note that you are not using the same IP subnet as for the local interfaces of the CPU.

Once the IP address is entered, it is shown in the properties dialog of the OPC UA server in the list of server addresses. These settings provide the CPU with the new virtual interface W1 via which CPU services like the OPC UA server can be accessed via a communication module. The corresponding connections and S7 communication (e.g. HMI and BSEND, BRCV) are made via this interface. The OPC UA server does not allow selection of a specific interface (selection via an IP address), either all or none are possible.

Note

The IP address of the virtual interface is not listed as W1 in the device display under the currently displayed local interfaces (Xn) but is available under "Addresses" in the "Settings" section. The virtual interface is also visible when no CP is plugged or when the virtual interface is not activated. If no IP suite is available, the IP address and the subnet mask are 0.0.0.0.

If you change the configured and loaded IP address parameters of the virtual interface via display, T_CONFIG instruction or online, the loaded configuration is active again after the CPU restarts.

Configuration changes on the CP

A change of the assigned communication module may have an effect on the configuration of the virtual interface:

- In the properties of the CPU:
 - Assignment of a different CP: The configuration is used for the new CP.
 - Deselect the assigned CP: The virtual interface W1 is deactivated and the configuration is lost.
When a CP is assigned again, the configuration must be performed again.
- On the device:
 - Moving the CP: If the CP is only moved to another slot of the device, the configuration continues to be valid.
 - Removing the CP: If the CP is deleted or moved to another device, the configuration is retained. In the drop-down list of the CPU, the CP is displayed as missing and compiling the configuration indicates an error. The missing CP can be deselected or assigned to another CP.

Display in the diagnostics and the system constants

The virtual interface W1 is displayed in the diagnostics view under "Online & Diagnostics". The hardware ID of the virtual interface is displayed in the system constants of the CPU properties.

Settings in the communication module

The settings of the internal CP firewall do not have an effect on communication over the virtual interface. This means the security functions of the communication module cannot protect the data traffic via the virtual interface.

NOTICE
Connecting to non-secure networks
If you connect the CP to a non-secure network, it is absolutely necessary to connect an additional firewall between the CP and the non-secure network. For example, use the security modules SCALANCE S602 V3 and SCALANCE S623 with integrated firewall.

Connection resources

11.1 Connection resources of a station

Introduction

Some communications services require connections. Connections occupy resources in the automation system (station). The connection resources are made available to the station by the CPUs, communications processors (CPs) and communications modules (CMs).

Connection resources of a station

The connection resources available depend on the CPUs, CPs and CMs being used and must not exceed a maximum number per station.

The maximum number of resources of a station is determined by the CPU.

Reserved connection resources

Each CPU has reserved connection resources for PG, HMI and Web server communication. This ensures, for example, that a PG can always establish at least one online connection with the CPU regardless of how many other communications services are already using connection resources.

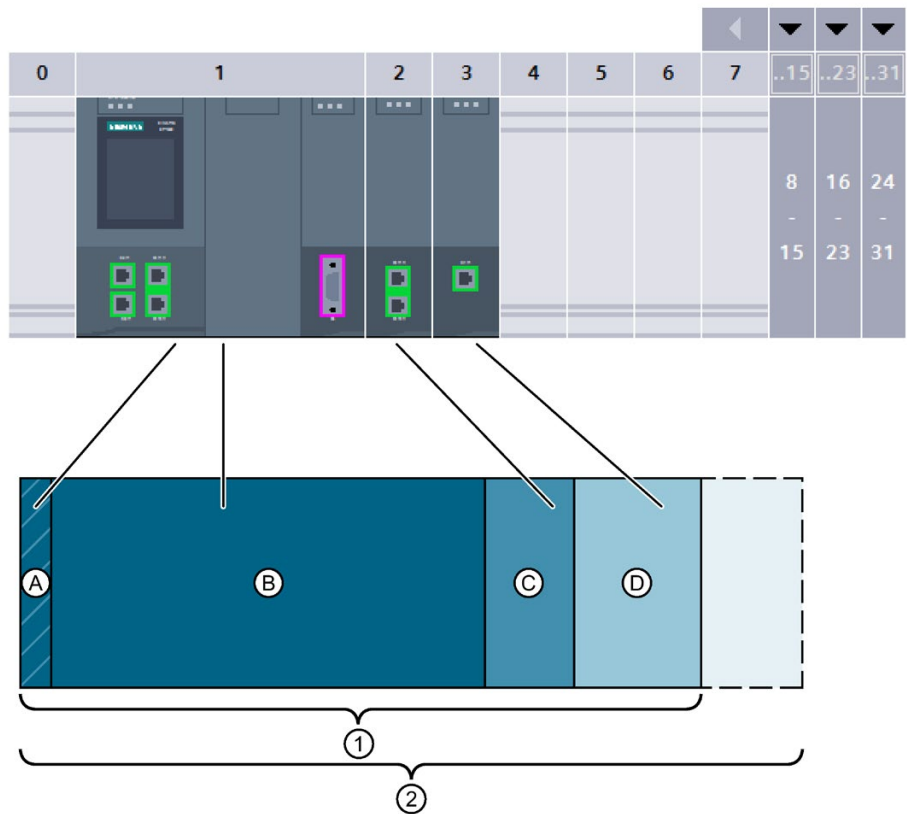
Dynamic connection resources

In addition, dynamic resources exist. The difference between the maximum number of connection resources and the number of reserved connection resources is the maximum number of dynamic connection resources.

The communication services PG Communication, HMI Communication, S7 Communication, Open User Communication, Web Communication, OPC UA Client/Server Communication and other communication from the pool of dynamic connection resources are used.

11.1 Connection resources of a station

The figure below shows an example of how individual components make connection resources available to an S7-1500 station.



- ① Available connection resources of the station, of which
 - A Reserved connection resources of the station
 - A + B Connection resources of CPU 1518
 - C Connection resources of communications module CM 1542-1
 - D Connection resources of communications processor CP 1543-1
- ② Maximum communications resources of the station using the example of a configuration from CPU 1518, CM 1542-1 and CP 1543-1

Figure 11-1 Connection resources of a station

Number of connection resources of a station

Table 11- 1 Maximum number of connection resources supported for some CPU types

Connection resources of a station	1511 1511C	1512C 1513	1515	1516	1517	1518
Maximum connection resources of the station	96	128	192	256	320	384
of which reserved	10					
of which dynamic	86	118	182	246	310	374
Connection resources of the CPU	64	88	108	128	288	320
Max. additionally usable connection resources by plugging in CMs/CPs	32	40	84	128	32	64
Additional connection resources CM 1542-1	64					
Additional connection resources CP 1543-1	118					
Additional connection resources CM 1542-5	40					
Additional connection resources CP 1542-5	16					

The number of connection resources that a CPU or a communication module supports is specified in the device manuals in the Technical Specifications.

Example

You have configured a CPU 1516-3 PN/DP with a CM 1542-1 communication module and a CP 1542-5 communication processor.

- Maximum connection resources of the station: **256**
- Available connection resources:
 - CPU 1516-3 PN/DP: 128
 - CM 1542-1: 64
 - CP 1542-5: 16
 - Total: **208**

The setup provides 208 connection resources. By adding further communication modules, the station can support a maximum of 48 additional connection resources.

Reserved connection resources

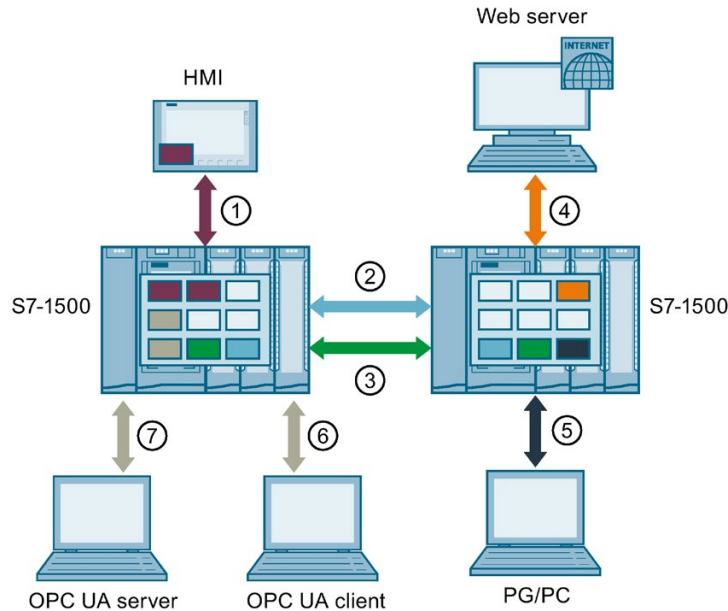
10 connection resources are reserved for stations with S7-1500 CPU, ET 200SP CPU and ET 200pro CPU based on S7-1500:

- 4 for PG communication required by STEP 7, for example, for test and diagnostics functions or downloading to the CPU
- 4 for HMI communication which are occupied by the first HMI connections configured in STEP 7
- 2 for communication with the Web server

11.2 Allocation of connection resources

Overview - occupation of connection resources

The following figure shows how different connections occupy the resources of the S7-1500.



- ① HMI communication: See below.
- ② Open User Communication: Connections of Open User Communication occupy a connection resource in every end point.
- ③ S7 communication: Connections of S7 communication occupy a connection resource in every end point.
- ④ Web communication: The Web server connection occupies at least one connection resource in the station. The number of occupied connections depends on the browser.
- ⑤ PG communication: The PG connection occupies one connection resource in the station.
- ⑥ OPC UA client/server communication: Connection resource allocation for the server, see below
- ⑦ OPC UA client/server communication: Connection resource allocation for the client, see below







-  Connection resource for HMI communication
-  Connection resource for Open User Communication
-  Connection resource for S7 communication
-  Connection resource for Web communication
-  Connection resource for PG communication
-  Connection resources for OPC UA server communication

Figure 11-2 Allocation of connection resources

Connection resources for HMI communication

With HMI communication, the occupation of connection resources in the station depends on the HMI device being used.

Table 11- 2 Maximum occupied connection resources for different HMI devices

HMI device	Maximum occupied connection resources of the station per HMI connection
Basic Panel	1
Comfort Panel	2 ¹
RT Advanced	2 ¹
RT Professional	3

¹ If you do not use system diagnostics or alarm configuration, the station occupies only one connection resource per HMI connection.

Example: You have configured the following HMI connections for a CPU 1516-3 PN/DP:

- Two HMI connections to an HMI TP700 Comfort. (2 connection resources each)
- One HMI connection to an HMI KTP1000 Basic. (1 connection resource)

In total 5 connection resources are occupied for HMI communication in the CPU.

Connection resources for OPC UA client communication

Each connection that the OPC UA client of the CPU has established to an OPC UA server occupies a connection resource in the station.

When establishing and closing an OPC UA connection, the OPC UA client temporarily occupies an additional connection resource. According to RFC 793, this connection resource is released again after a wait of approx. 60 seconds.

Note

Lack of resources due to temporary connection resources

A lack of connection resources occurs in the following situation:

- The OPC UA client of the CPU establishes or closes several connections simultaneously.
- The number of available connection resources of the station is insufficient for permanent and temporary connection resources of the OPC UA client communication.

Ensure that there are always enough available connection resources in the station to establish and end OPC UA connections.

Measures:

- Plan enough reserve for the OPC UA client connections.
 - If necessary, establish or close the OPC UA connections one after the other.
-

Connection resources for routing

To transfer data beyond S7 subnets ("S7 routing"), an S7 connection is established between two CPUs. The S7 subnets are connected via gateways known as S7 routers. CPUs, CMs and CPs in S7-1500 are S7 routers.

The following applies for a routed S7 connection:

- A routed connection occupies one connection resource each in both end points. STEP 7 shows these connection resources in the "Connection resources" table.
- On the S7 router, two special connection resources are occupied for S7 routing. STEP 7 does not show the special connection resources for S7 routing in the "Connection resources" table. The number of resources for S7 routing depends on the CPU. You will find the resources for S7 routing in the technical specifications of the CPU in "Number of S7 routing connections".

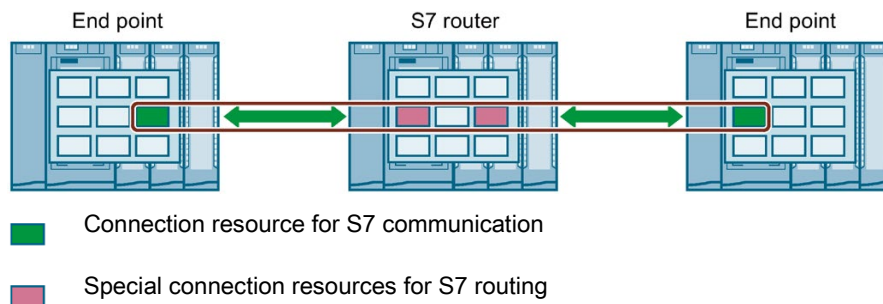


Figure 11-3 Connection resources with S7 routing

Data record routing also enables transfer of data beyond S7 subnets from an engineering station connected to PROFINET to various field devices via PROFIBUS.

With data record routing, as with S7 routing, two of the special connection resources for S7 routing are also occupied on every data record router.

Note

Connection resources with data record routing

With data record routing, on the data record router, two special connection resources for S7 routing are occupied. Neither the data record connection nor the allocated connection resources are displayed in the table of connection resources.

When are connection resources occupied?

The time for the occupation of connection resources depends on how the connection is set up (see section Setting up a connection (Page 27)).

- **Programmed setup of a connection:**

As soon as an instruction to establish a connection is called in the user program (TSEND_C/TRCV_C or TCON), a connection resource is occupied.

With suitable parameter assignment of the CONT parameter of the TSEND_C/TRCV_C instructions or by calling the TDISCON instruction, the connection can be terminated following data transfer and the connection resource is available again. When the connection is terminated, the connection resources on the CPU/CP/CM are available again.

- **Configured connections** (e.g. S7 connection):

If you have configured a connection in STEP 7, the connection resource is occupied as soon as the hardware configuration is downloaded to the CPU.

After using a configured connection for data transfer, the connection is not terminated. The connection resource is permanently occupied. To release the connection resource again, you need to delete the configured connection in STEP 7 and download the modified configuration to the CPU.

- **PG connection:**

As soon as you have connected the PG to a CPU online in STEP 7, connection resources are occupied.

- **Web server:**

As long as you have opened the Web server of the CPU in a browser, connection resources are occupied in the CPU.

- **OPC UA server**

Each connection to the OPC UA server of the CPU occupies a connection resource in the station. This connection resource is released immediately when the connection is terminated.

- **OPC UA client**

Each connection that the OPC UA client of the CPU has established to an OPC UA server occupies a connection resource in the station. When an OPC UA connection is established, the OPC UA client temporarily occupies an additional connection resource. When an OPC UA connection is terminated, the connection resource is not released again until after a wait time of approx. 60 seconds in accordance with RFC 793.

Monitoring the maximum possible number of connection resources

Offline

During configuration of connections, STEP 7 monitors the occupation of the connection resources. If the maximum possible number of connection resources is exceeded, STEP 7 signals this with a suitable warning.

Online

The CPU monitors the use of connection resources in the automation system. If you establish more connections in the user program than those provided by the automation system, the CPU acknowledges the instruction to establish the connection with an error.

S7-1500 and S7-300 comparison

You will find a comparison of how the communication resources of the S7-1500 and S7-300 are managed in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/109747092>).

11.3 Display of the connection resources

Display of the connection resources in STEP 7 (offline view)

You can display the connection resources of an automation system in the hardware configuration. You will find the connection resources in the Inspector window in the properties of the CPU.

Connection resources						
	Station resources			Module resources		
	Reserved	Dynamic		PLC_1 [CPU 15...	CM 1542-1_1 [...	CP 1543-1_1 [...
Maximum number of resources:	10	246		128	64	118
	Maximum	Configured	Configured	Configured	Configured	Configured
PG communication:	4	-	-	-	-	-
HMI communication:	4	4	6	6	0	4
S7 communication:	0	-	7	4	3	0
Open user communication:	0	-	13	8	5	0
Web communication:	2	-	-	-	-	-
OPC UA client/server communicatio...	0	-	-	-	-	-
Other communication:	-	-	0	0	0	0
Total resources used:		4	26	18	8	4
Available resources:		6	220	110	56	114

Figure 11-4 Example: Reserved and available connection resources (offline view)

① Station-specific connection resources

The columns of the station-specific connection resources provide information about the used and available connection resources of the station.

In the example, a maximum of 256 station-specific connection resources are available for the automation system.

- 10 reserved connection resources, of which 4 are already in use and a further 6 available. The used resources are divided up as follows:
 - 4 Resources for HMI communication
- 246 dynamic connection resources, of which 26 are already in use and a further 220 available. The used resources are divided up as follows:
 - 6 resources for HMI communication
 - 7 resources for S7 communication
 - 13 resources for Open User Communication

The warning triangle in the column of the dynamic station resources is displayed because the sum of the maximum available connection resources of CPU, CP and CM (= 310 connection resources) exceeds the station limit of 256.

Note**Available connection resources exceeded**

STEP 7 signals the exceeding of the station-specific connection resources with a warning. To make full use of the connection resources from the CPU, CP and CM, either use a CPU with a higher maximum number of available station-specific connection resources or reduce the number of communications connections.

② Module-specific connection resources

The columns of the module-specific connection resources provide information about the use of resources on the CPUs, CPs and CMs of an automation system:

The display is per module and not per interface.

In the example, the CPU makes a maximum of 128 connection resources available, of which 18 are already in use and 110 still available.

The used resources are divided up as follows:

- 6 resources for HMI communication
- 4 resources for S7 communication
- 8 resources for Open User Communication

Display of the connection resources in STEP 7 (online view)

If you are connected to the CPU online, you can also see how many resources are currently being used under "Connection information".

	Station resources						Module resources	
	Reserved			Dynamic			CPU 1516-3 PN/DP (RO/S1)	
	Maximum	Configured	Used	Configured	Used	Configured	Used	
Maximum number of resources:	10	10		194	194	86	86	
PG communication:	4	-	4	-	0	-	0	
HMI communication:	4	4	4	4	4	8	8	
S7 communication:	0	-	0	72	68	34	34	
Open user communication:	0	-	0	118	118	45	45	
Web communication:	2	-	0	-	0	-	0	
OPC UA client/server communicati...	0	-	0	-	0	-	0	
Other communication:	-	-	0	0	0	0	0	
Total resources used:		4	8	194	190	82	82	
Available resources:		6	0	0	4	4	4	

Figure 11-5 Connection resources - online

The online view of the "Connection resources" table in addition to the offline view also contains columns with the connection resources currently being used. Thus, the online view displays **all** used connection resources in the automation system, regardless of how the connection was set up.

The "Other communication" row displays connection resources assigned for communication with external devices. The table is updated automatically.

Note

If a routed S7 connection goes through a CPU, the required connection resources of the CPU do not appear in the table of connection resources.

Display of the connection resources for HMI

For information regarding the availability and assignment of connection resources for HMI connections, refer to the "Connection resources" properties in the Inspector window of the offline view (in the context of the HMI device).

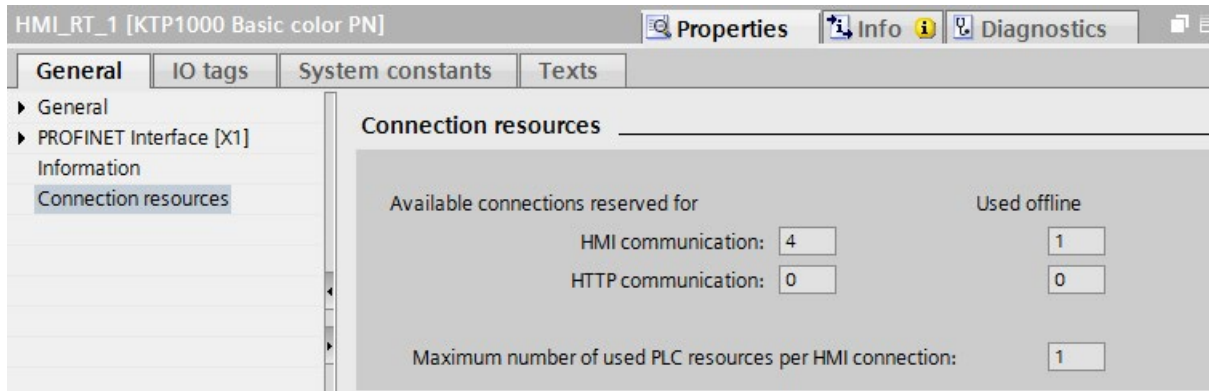


Figure 11-6 Connection resources - HMI communication

The following is displayed in the connection resources area:

- Number of available connections on the HMI reserved for HMI communication and HTTP communication
- Number of connection resources for HMI communication and HTTP communications used offline in the HMI

If the maximum number of available connection resources for an HMI device is exceeded, a corresponding message is output by STEP 7.

- "Maximum number of used PLC resources per HMI connection". This parameter is a factor that is to be multiplied by the number of HMI connections used offline. The product is the number of HMI resources occupied on the CPU.

Displaying the connection resources in the Web server

You can display the connection resources not only in STEP 7, but also with a browser that displays the relevant page of the Web server.

You will find information on displaying connection resources in the Web server in the Web Server (<http://support.automation.siemens.com/WW/view/en/59193560>) function manual.

Diagnostics and fault correction

12.1 Connection diagnostics

Connections table in the online view

After selecting a CPU in the Devices & networks editor of STEP 7, you will see the status of your connections displayed in the online view of the connections table.

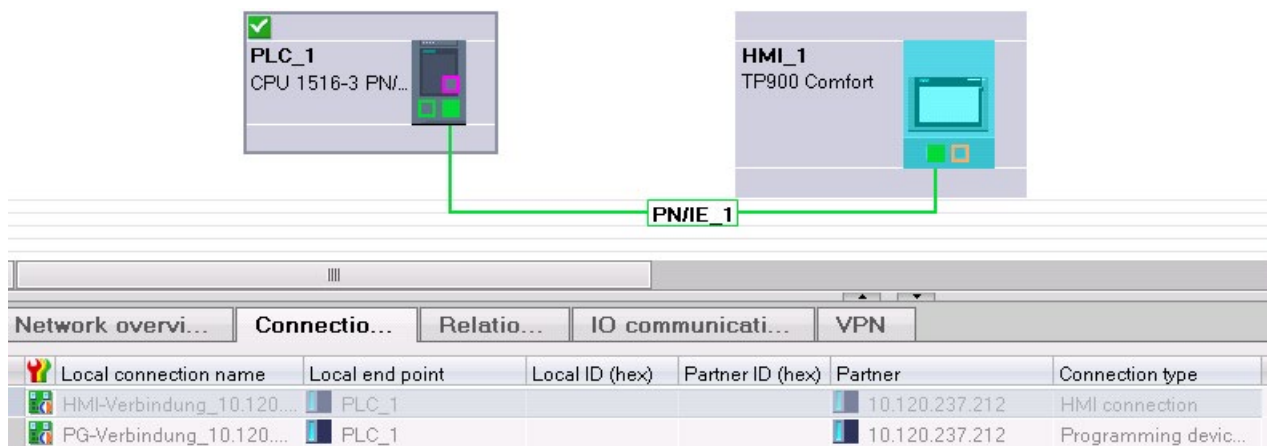


Figure 12-1 Online view of the connections table

After selecting the connection in the connections table, you obtain detailed diagnostic information in the "Connection information" tab.

"Connection information" tab: Connection details

The screenshot shows a software interface with several tabs: "Network overview...", "Connection...", "Relation...", "IO communication...", and "VPN". The "Connection..." tab is active, displaying a table of connections. Below the table, the "Connection details" section is expanded, showing the following information:

Local connection name	Local end point	Local ID (hex)	Partner ID (hex)	Partner	Connection type
HMI-Verbindung_10.120...	PLC_1			10.120.237.212	HMI connection
Established, exists online only.	PLC_1			10.120.237.212	Programming devic...

Connection details

- Connection name: HMI-Verbindung_10.120.237.212_1 (ConnEnd_187)
- Local ID (hex):
- Connection type: Connection from HMI+ client
- Protocol: ISO-on-TCP
- Online status: ■ Connected
- Details: Established: Connection exists only online. Connection is connected.

Figure 12-2 Diagnostics of connections - connection details

"Connection information" tab: Address details

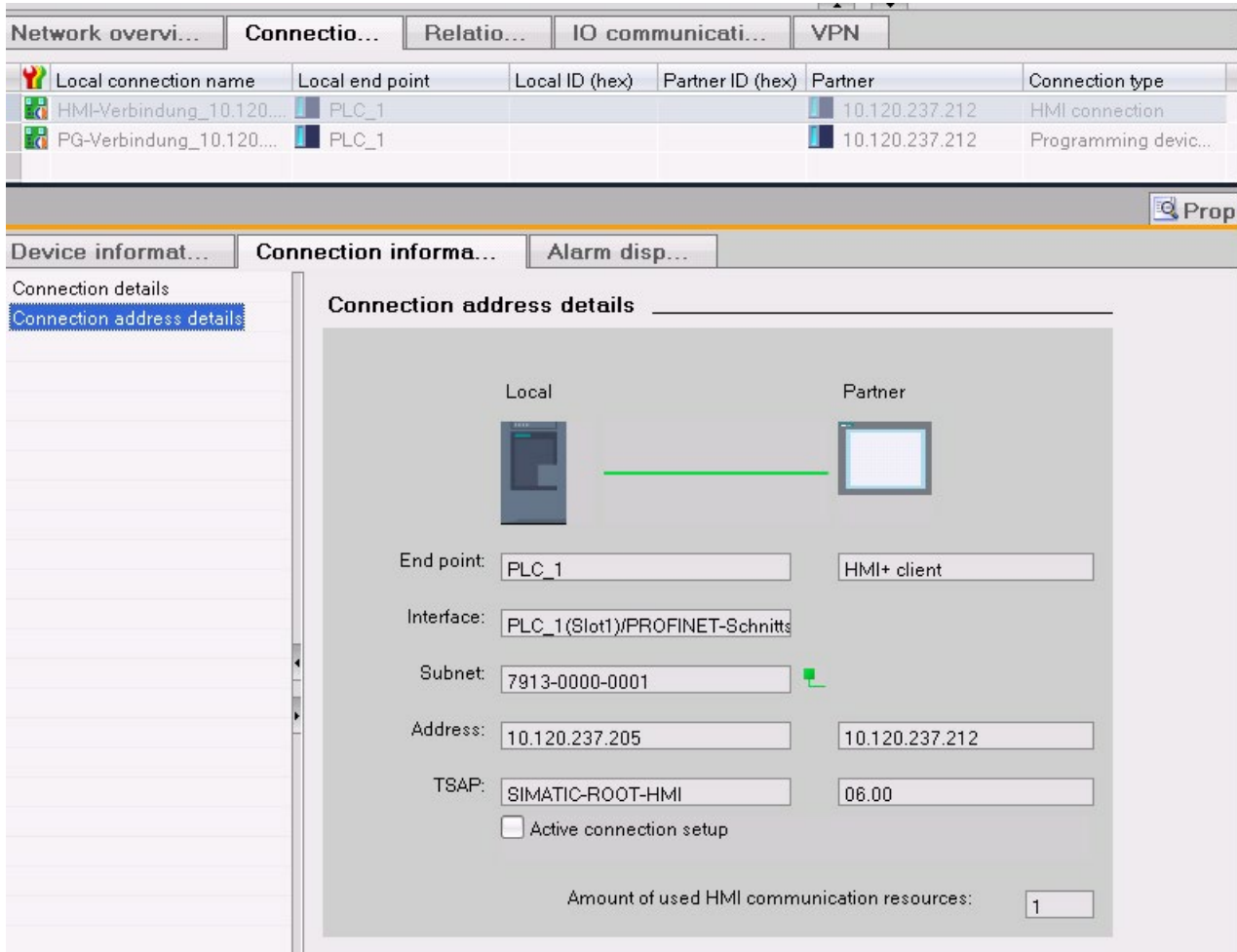


Figure 12-3 Diagnostics of connections - address details

Diagnostics via web server

You can evaluate diagnostic information from the CPU using a web browser via the integrated web server of a CPU.

On the "Communication" Web page, you will find the following information about communication via PROFINET in various tabs:

- Information on the PROFINET interfaces of the CPU (for example addresses, subnets, physical properties).
- Information on the quality of the data transfer (for example number of data packets sent/received error-free).
- Information about the allocation/availability of connection resources.
- The "Connection status" page is similar to the online view in STEP 7 and also provides an overview of all connections with detail view.

Diagnostics with the user program

When you program the T_DIAG instruction, you can evaluate diagnostic information about the configured and programmed connections of the CPU using the user program.

Additional information

You will find the description of the web server functionality in the function manual Web server (<http://support.automation.siemens.com/WW/view/en/59193560>).

12.2 Emergency address

If you cannot reach the CPU via the IP address, you can set a temporary emergency address (emergency IP) for the CPU. Via this emergency address, you can re-establish the connection with a CPU in order to load a device configuration with a valid IP address.

You can set an emergency address regardless of the protection level of the CPU

When do you need an emergency address?

Your CPU cannot be reached in the following cases:

- The IP address of your PROFINET interface is assigned twice.
- The subnet mask is set incorrectly.

Requirements

- You have selected "Set IP address in the project" for the IP protocol in the device configuration in STEP 7.
- The CPU is in STOP mode.

Restoring a valid device configuration with an emergency address

1. Set the emergency address for the interface of the CPU with a DCP tool. For example, the SIMATIC Automation Tool has a DCP command "Define IP address".
The maintenance LED of the CPU lights up. The diagnostic buffer also shows that an emergency address was activated for an Ethernet interface.
2. Load a STEP 7 project with a valid IP address into the CPU.
3. Switch the CPU off and on again.
The emergency address is reset.

Result

The CPU starts up with the valid IP address.

Introduction

Communication with the S7-1500R/H redundant system basically functions as with the S7-1500 standard system.

This chapter describes the special features and restrictions for communication with the S7-1500R/H redundant system.

Communication options for the S7-1500R/H redundant system

- Open User Communication via TCP/IP, UDP, ISO on-TCP and Modbus/TCP
- S7 communication as server
- HMI communication
- PG communication
- SNMP
- Time-of-day synchronization via NTP

Restrictions for communication with the S7-1500R/H redundant system

- Open User Communication:
 - no configured connections
 - Secure Open User Communication: Not supported, as certificate management is not possible for the R/H CPUs.
If you have activated Secure OUC, then although you can compile the user program and load it, you cannot add certificates to the R/H-CPU's.
 - no FDL connections
 - Email: The S7-1500R/H CPUs with firmware version V2.6 support the versions < V5.0 of the "TMAIL_C" instruction. Versions from V5.0 are not supported.
 - No support of connection descriptions according to "TCON_Param"
- no OPC UA
- no S7 communication as client
- no web server
- PG communication: It is not possible to access two CPUs online at the same time. You can either access the primary CPU or the backup CPU.
- The CPUs of the S7-1500R/H do not support centrally plugged communication modules.

13.1 System IP addresses

The system IP address of the S7-1500R/H redundant system

In addition to the device IP addresses of the CPUs, the S7-1500R/H redundant system supports system IP addresses:

- System IP address for the PROFINET interfaces X1 of the two CPUs (system IP-address X1)
- System IP address for the PROFINET interfaces X2 of the two CPUs (system IP-address X2)

You use the system IP addresses for communication with other devices (for example, HMI devices, CPUs, PCs). The devices always communicate via the system IP address with the primary CPU of the redundant system. This ensures, for example, that the communication partner can communicate with the new primary CPU (previously backup CPU) in the RUN-Solo system state after failure of the original primary CPU in redundant operation.

There is a virtual MAC address for each system IP address.

You enable the system IP addresses in STEP 7.

Advantages of the system IP addresses compared to device IP addresses

- The communication partner communicates specifically with the primary CPU.
- Communication of the S7-1500R/H redundant system via a system IP address still also works in the event of the failure of the primary CPU.

Applications

You use the system IP addresses for the following applications:

- HMI communication with the S7-1500R/H redundant system: You can use an HMI device to control or monitor the process on the redundant S7 1500R/H system.
- Open User Communication with the S7-1500R/H redundant system:
 - Another CPU or an application on a PC accesses data of the S7-1500R/H redundant system.
 - The S7-1500R/H redundant system accesses a different device.TCP, UDP and ISO-on-TCP-connections are possible.
- IP forwarding: If you use the system IP addresses as the gateway/default route for IP routes through the S7-1500R/H redundant system, IP packets are forwarded even if one CPU fails.

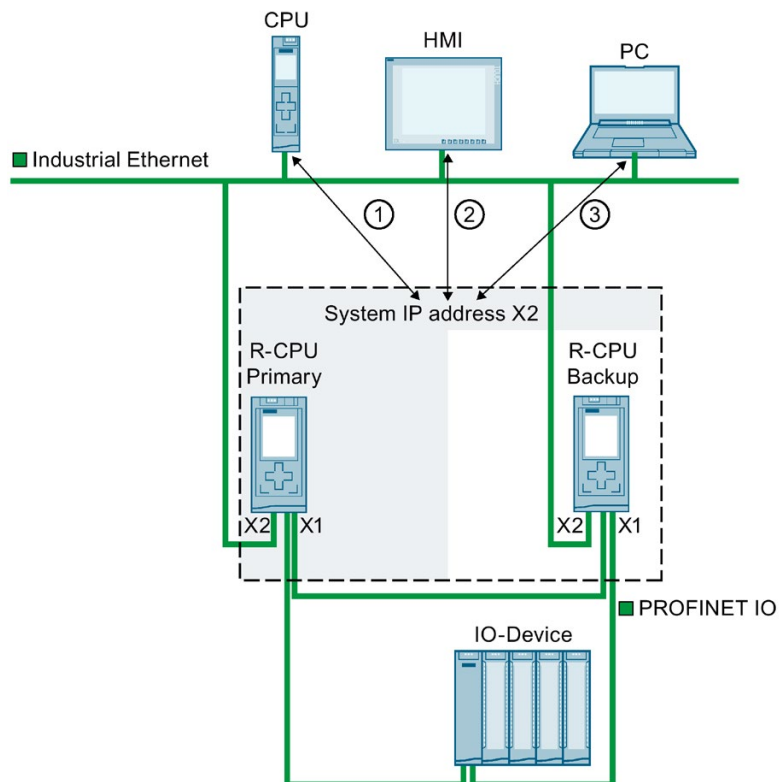
Requirements

- The interface of the communication partner and the PROFINET interfaces of the two CPUs are located in the same subnet.
- The interface of the communication partner is connected to both CPUs, each via the same interface (e.g. X2).
- The system IP address for the interfaces of the S7-1500R/H system is enabled.

Communication via the system IP address X2

If the CPUs of the S7-1500R/H redundant system have two PROFINET interfaces, preferably use the PROFINET interface X2 for communication with other devices.

The following figure shows a configuration in which the communication partners are connected via the respective PROFINET interfaces X2 with the CPUs of the redundant system S7-1500R/H.



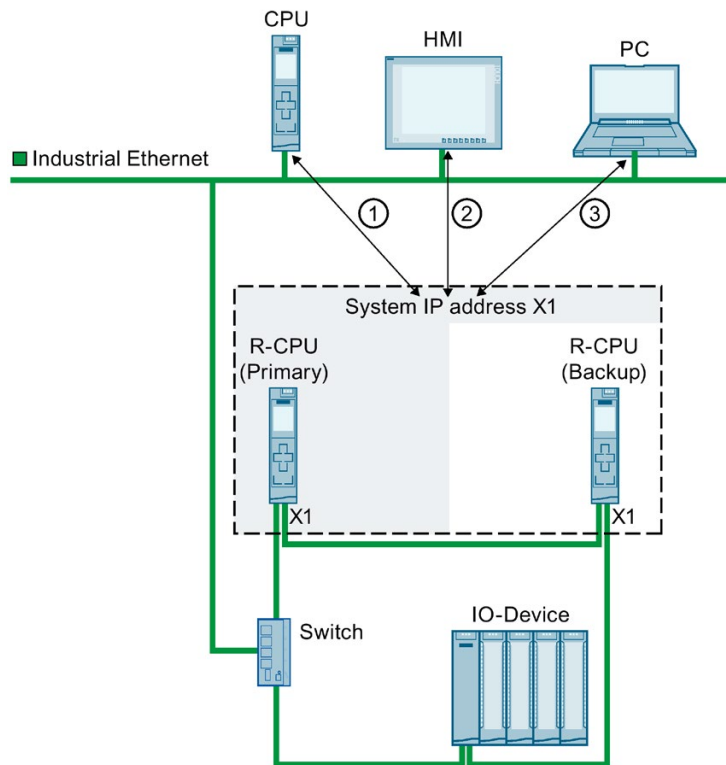
- ① Open User Communication between a different CPU and the S7-1500R/H redundant system
- ② HMI communication with the S7-1500R/H redundant system
- ③ Open User Communication between the S7-1500R/H redundant system and a PC

Figure 13-1 Example: Communication of the S7-1515R redundant system via the system IP address X2

Communication via the system IP address X1

The following diagram shows a configuration where the communication partners are connected with a switch to the PROFINET ring of the S7-1500R/H redundant system. The PROFINET ring connects the communication partners with the respective PROFINET interfaces X1 of the two CPUs.

As the CPU 1513R only has one PROFINET interface, connection via the PROFINET ring is the only possibility of communicating via the system IP address X1.

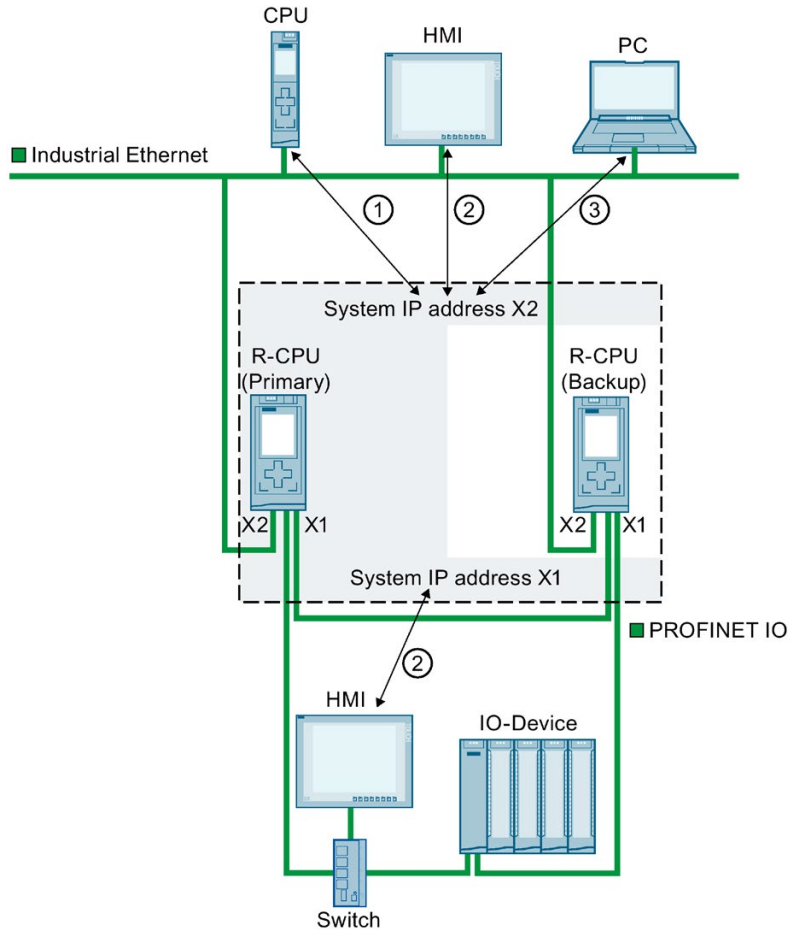


- ① Open User Communication between the S7-1500R/H redundant system and a different CPU
- ② HMI communication with the S7-1500R/H redundant system
- ③ Open User Communication between the S7-1500R/H redundant system and a PC

Figure 13-2 Example: Communication of the S7-1513R redundant system via the system IP address X1

Communication via the system IP addresses X1 and X2

If the CPUs of the redundant system S7-1500R/H have two PROFINET interfaces (X1 and X2), you can use the a system IP address for each PROFINET interface. PROFINET devices which are connected to the interfaces X1 of the CPUs communicate via the system IP address X1. PROFINET devices which are connected to the interfaces X2 of the CPUs communicate via the system IP address X2.



- ① Open User Communication between the S7-1500R/H redundant system and a different CPU.
- ② HMI communication with the S7-1500R/H redundant system
- ③ Open User Communication between the S7-1500R/H redundant system and a PC

Figure 13-3 Example: Communication of the S7-1515R redundant system via the system IP addresses X1 and X2

IP forwarding via the system IP address

If you use the system IP addresses as the gateway/default route for IP routes through the S7-1500R/H redundant system, IP packets are forwarded even if one CPU fails.

In the following figure, the PC is connected to the two X2 interfaces of the S7-1500R CPUs. Enter the system IP address X2 as gateway in the PC for the route to the HMI device. The HMI device is connected to the PROFINET ring of the redundant system S7-1500 via a switch. The system IP address X1 is configured as router in the HMI device.

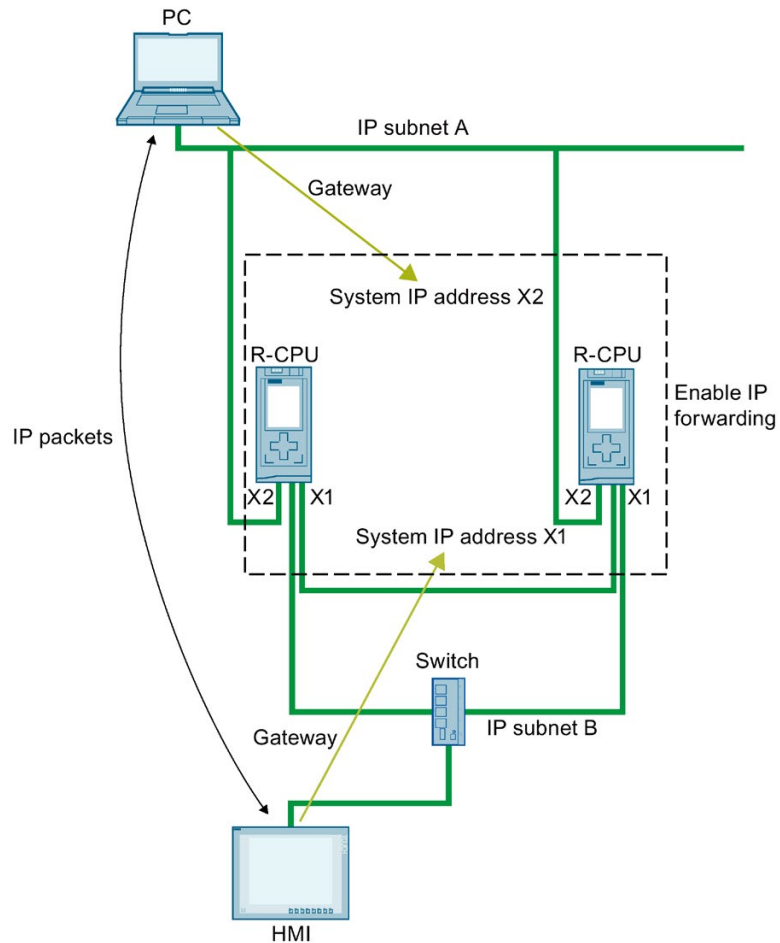


Figure 13-4 Example: IP forwarding via the system IP address

Enable system IP addresses

Requirements:

- STEP 7 V15.1 or higher
- redundant system S7-1500R/H with two CPUs, e.g. two CPUs 1513R-1PN

If the CPUs of the S7-1500R/H redundant system have two PROFINET interfaces (X1 and X2), then you can use a system IP address for both PROFINET interfaces. The following section describes how to enable the system IP address for the interface X1.

Proceed as follows to enable the system IP address for your S7-1500R/H redundant system:

1. In the network view of STEP 7, select the interface X1 of one of the two CPUs.
2. In the Inspector window go to "Properties" > "General" > "Ethernet addresses" in the area "System IP address for switched communication".
3. Select the check box "Enable the system IP address for switched communication".

STEP 7 automatically creates a system IP address.

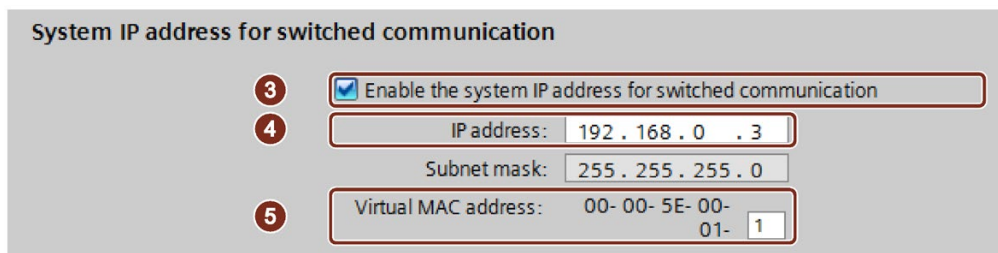


Figure 13-5 Configure IP address

4. Change the system IP address if necessary.
5. If required, change the virtual MAC address. To do this, in "Virtual MAC address", assign a project-wide unique value (value range 01_H to FF_H) for the last byte.

Note

Uniqueness of the virtual MAC address

The redundant system S7-1500R/H uses a MAC address from the address range 00-00-5E-00-01-00 to 00-00-5E-00-01-00 for each system IP address. This address range is also used for VRRP (Virtual Redundancy Protocol).

If you use devices with VRRP, e.g. switches, ensure the uniqueness of the MAC addresses within an Ethernet broadcast domain.

Result: The system IP address X1 for the PROFINET interface X1 of the two CPUs is enabled.

13.2 Response to Ssyncup

Response of communication connections via the system IP address in the system state SYNCUP

- HMI, PG- and S7-connections are temporarily closed. For a short time during the SYNCUP it is not possible to establish connections to the S7-1500R/H redundant system.
- All existing connections of Open User Communication are interrupted:
 - Connections set up by the CPUs of the redundant system as an active connection partner are set up again after the SYNCUP.
 - The S7-1500R/H redundant system sets up connection endpoints again for the passive connection establishment after the SYNCUP.
- The processing of running instances of the instructions TSEND and TRCV is stopped. The block parameter STATUS returns 80C4_H (temporary communication error).

13.3 Response to primary-backup switchover

Response of communication connections via the system IP address during a primary-backup switchover

- Running instances of the instructions TSEND and TRCV are stopped and return the status 80C4_H (temporary communication error).
- Connections successfully established by the S7-1500R/H redundant system are established again by the new primary CPU.
- The new primary CPU sets up connection endpoints again for the passive connection establishment.

Note

Increased duration of connection interruption

If the remote system does not transmit actively after the primary-backup switchover, the connection monitoring (e.g. TCP-Keep-Alive or application) may have to be performed by the remote system until the connection can be re-established.

13.4 Connection resources of the redundant system S7-1500R/H

Maximum number of connection resources of the S7-1500R/H redundant system

The S7-1500R/H redundant system supports a maximum number of connection resources.

The CPU used determines the maximum number of resources for the redundant system:

- CPU 1513R: max. 88 connection resources
- CPU 1515R: max. 108 connection resources
- CPU 1517H: max. 288 connection resources

Allocation of connection resources

Communication connections occupy communication resources in the S7-1500R/H redundant system.

Each communication connection to the redundant system S7 1500R/H occupies connection resources in the S7 1500R/H station. The S7-1500R/H station comprises the hardware setup of both CPUs of the redundant S7-1500R/H system.

Depending on the IP address used, a communication connection also uses connection resources in one or both CPUs of the redundant S7-1500R/H system. The S7-1500R/H station can also be used to establish a communication connection.

The following table shows in which CPU a communication connection occupies connection resources depending on the IP address used.

Connect via...	Connection resources of the station	Connection resources CPU with redundancy ID 1	Connection resources CPU with redundancy ID 2
a system IP address	X	X	X
a device IP address of the CPU with redundancy ID 1	X	X	-
a device IP address of the CPU with redundancy ID 2	X	-	X

Display of the occupied connection resources in STEP 7

Requirements: Online connection to the redundant system S7-1500R/H

You will find the online display of the connection resources in the inspector window under "Diagnostics" > "Connection information". STEP 7 always displays the connection resources of the selected CPU and the S7-1500R/H-station.

Connection resources							
	Station resources					Module resources	
	Reserved			Dynamic		CPU 1517H-3 PN (R0/S1)	
	Maximum number of resources:	10	10	150	150	160	160
	Maximum	Configured	Used	Configured	Used	Configured	Used
PG communication:	4	-	2	-	0	-	2
HMI communication:	4	0	0	0	0	0	0
S7 communication:	0	-	0	0	0	0	0
Open user communication:	0	-	0	0	0	0	0
Web communication:	2	-	0	-	0	-	0
Other communication:	-	-	0	0	0	0	0
Total resources used:		0	2	0	0	0	2
Available resources:		10	8	150	150	160	158

Figure 13-6 Display of the connection resources of the S7-1500R/H redundant system in STEP 7

13.5 HMI communication with the redundant system S7-1500R/H

13.5.1 HMI connection via the system IP address

Requirements

- A redundant S7-1500R/H system, e.g. CPU 1513R-1PN
- System IP address is enabled
- HMI device with PROFINET interface

Procedure

To set up a HMI connection to an S7-1500R/H redundant system, follow these steps:

1. In the network view of STEP 7, select a PROFINET interface of the HMI device.
2. Using a drag&drop operation, draw a line between the PROFINET interface of the HMI device and a PROFINET interface of the S7-1500R/H redundant system. The HMI device and the S7-1500R/H redundant system are networked together.

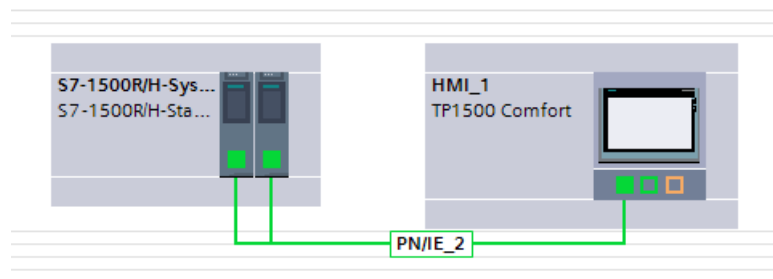


Figure 13-7 Networking an HMI device with the S7-1500R/H redundant system

3. In the list of functions, click the "Connections" icon. This activates connection mode.
4. Using a drag-and-drop operation, draw a line between the HMI device and a CPU of the S7-1500R/H redundant system. The list "Connection partners" opens.

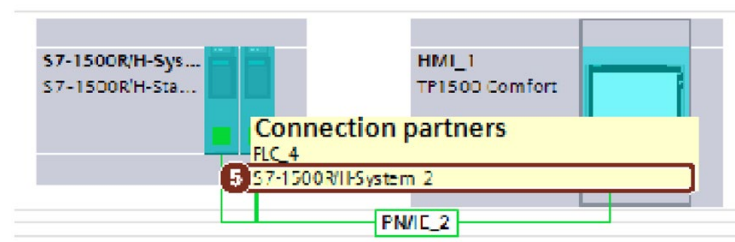


Figure 13-8 Setting up an HMI connection to the S7-1500R/H redundant system

5. Select the S7-1500R/H redundant system in the list "Connection partners".

Result: You have set up a HMI connection between the HMI device and the S7-1500R/H redundant system. The HMI connection uses the system IP address. The HMI device always connects to the primary CPU.

Changing the HMI connection over to the device IP address

To permanently change the HMI connection over to the selected CPU, clear the check box "Use the system IP address for switched communication" in the properties of the HMI connection. The HMI connection then uses the device IP address of the PROFINET interface. In the event of the failure of this CPU, then the HMI connection to this CPU permanently fails.

Connection

Name:

Connection path

Local Partner

End point:

Interface:

Interface type:

Subnet:

Address:

Use the system IP address for switched communication

Figure 13-9 Properties of the HMI connection

Note

Automatic setup of HMI connection

When you drag-and-drop a tag from the S7-1500R/H redundant system into an HMI screen or into the HMI tag table, STEP 7 automatically sets up an HMI connection. This HMI connection exists by default between the PROFINET interface of the HMI device and the PROFINET interface X1 of the CPU with redundancy ID 1. The connection uses the device IP address of the PROFINET interface X1.

You can change the HMI connection to a system IP address in the properties of the HMI connection.

13.6 Open User Communication with the redundant system S7-1500R/H

The following table shows which protocols of the Open User Communication you can use for the S7-1500R/H redundant system and the matching system data types and instructions.

Table 13- 1 Protocols, system data types and usable instructions for Open User Communication with the redundant system S7-1500R/H

Protocol	System data type	Instructions
TCP	<ul style="list-style-type: none"> TCON_QDN TCON_IP_v4 	Establish connection and send/receive data via: <ul style="list-style-type: none"> TSEND_C/TRCV_C or
ISO-on-TCP	<ul style="list-style-type: none"> TCON_IP_RFC 	<ul style="list-style-type: none"> TCON, TSEND/TRCV or TCON, TUSEND/TURCV (connection can be terminated via TDISCON)
UDP	<ul style="list-style-type: none"> TCON_IP_v4 TADDR_Param TADDR_SEND_QDN TADDR_RCV_IP 	Establish connection and send/receive data via: <ul style="list-style-type: none"> TSEND_C/TRCV_C TUSEND/TURCV/TRCV (connection can be terminated via TDISCON)
Modbus TCP	<ul style="list-style-type: none"> TCON_IP_v4 TCON_QDN 	<ul style="list-style-type: none"> MB_CLIENT MB_SERVER

13.6.1 Setting up the connection of the Open User Communication with the redundant S7-1500R/H system

Introduction

The S7-1500R/H redundant system can communicate with other devices via Open User Communication.

You set up the connections in the user program, e.g. via the "TSEND_C" instruction. The S7-1500R/H redundant system does not support configured connections.

You can either set up the connections either via the device IP addresses or via the system IP addresses of the PROFINET interfaces.

Open User Communication via a system IP address of the redundant system S7 1500R/H

If you set up the connection via a system IP address, then communication always takes place via the primary CPU.

Recommendation: Always use a system IP address for Open User Communication.

Open User Communication via a device IP address of the redundant system S7 1500R/H

In redundant mode, the redundant system can establish or terminate connections and send or receive data via every device IP address.

If you set up the connection via a device IP address, then communication takes place via the associated CPU. In the event of the failure of the CPU, then the entire communication via the device IP addresses of this CPU fails.

Setting up a connection via a system IP address

The following describes how to establish a connection to another CPU via a system IP address of a PROFINET interface of the redundant S7 1500R/H system.

You set up the connection in the user program of the redundant system S7-1500R/H with a TSEND_C instruction. You create a corresponding TRCV_C instruction in the user program of the other CPU.

The procedure is described using the example of a TCP connection between the S7-1500R/H redundant system and a CPU 1516-3PN/DP.

Requirements

- A redundant system S7 1500R/H, e.g. 2 CPUs 1513 1PN
- System IP address of the PROFINET interface X1 is enabled.
- CPU 1516-3PN/DP
- The PROFINET interfaces X1 of the CPUs 1513R and the PROFINET interface X2 of the CPU 1516-3PN/DP are located in the same subnet.

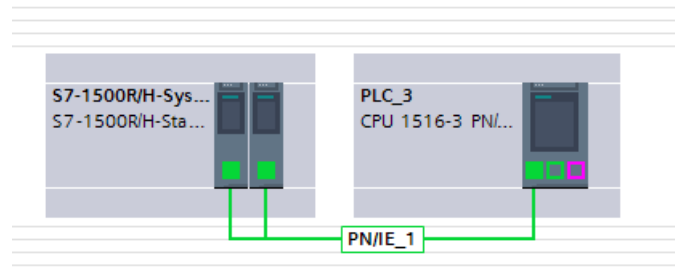


Figure 13-10 Example configuration for TCP-connection

TSEND_C instruction in the user program of the S7-1500R/H redundant system

To set up a TCP-connection to a different CPU, follow these steps:

1. Create a "TSEND_C" instruction in the user program.

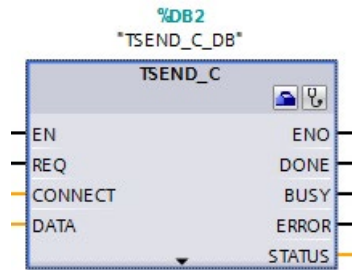


Figure 13-11 S7-1500R/H: "TSEND_C" instruction

2. Select the "TSEND_C" instruction.

3. In the Inspector window, go to "Properties" > "Configuration" > "Connection parameters". On the left-hand side you can see the S7-1500R/H redundant system as a local end point of the connection:
 - "Interface:": X1 is the preset interface.
 - "Subnet:": If the interface X1 is assigned to an S7-subnet, then STEP 7 displays the name of the S7-subnet.
 - The check box "Use address of the H-system" is selected. The system IP address of the S7-1500R/H redundant system is in "Address".

General

Local	Partner
End point: S7-1500R/H-System_1	PLC_3 [CPU 1516-3 PN/DP]
Interface: PLC_1, PROFINET-Schnittstelle_1 [X1]	PLC_3, PROFINET-Schnittstelle_2 [X2]
Subnet: PN/IE_1	PN/IE_1
Address: 192.168.0.3	192.168.0.10
<input checked="" type="checkbox"/> Use system IP address	
Connection type: TCP	
Configuration mode: Use program blocks	
Connection ID (dec): 1	1
Connection data: PLC_1_Send_DB	PLC_3_Receive_DB
<input checked="" type="radio"/> Active connection establishment	<input type="radio"/> Active connection establishment

Address details

Local Port	Partner Port
Port (decimal):	2000

Figure 13-12 S7-1500R/H: Assigning parameters to the TSEND_C instruction in STEP 7

4. In "Partners" under "End point:" select the CPU 1516-3PN/DP as the communication partner.
5. In "Partners" under "Interface:" select the PROFINET interface X2 of the CPU 1516-3PN/DP.
6. In "Local" under "Connection data" select the setting "<new>". STEP 7 creates a data block for the connection data in the user program of the S7-1500R/H redundant system, for example "PLC_1_Send_DB". "TCP" is set by default as the connection type.
7. In "Partners" under "Connection type" select the setting "NEW". STEP 7 creates a data block for the connection data in the user program of the other CPU, for example "PLC_3_Receive_DB".

TRCV_C instruction in the user program of the CPU 1516 3PN/DP

Create a TRCV_C instruction in the user program of the CPU 1516-3PN/DP and assign parameters as below:

General	
Local	Partner
End point: PLC_3 [CPU 1516-3 PN/DP]	S7-1500R/H-System_1 [S7-1500R/H-Station]
Interface: PLC_3, PROFINET-Schnittstelle_2[X2]	PLC_1, PROFINET-Schnittstelle_1[X1]
Subnet: PN/IE_1	PN/IE_1
Address: 192.168.0.10	192.168.0.3
Connection type: TCP	<input checked="" type="checkbox"/> Use system IP address
Configuration mode: Use program blocks	
Connection ID (dec): 1	1
Connection data: PLC_3_Receive_DB	PLC_1_Send_DB
<input type="radio"/> Active connection establishment	<input checked="" type="radio"/> Active connection establishment

Address details	
Local Port	Partner Port
Port (decimal): 2000	

Figure 13-13 S7-1500-3PN/DP: Assigning parameters to the TRCV_C instruction in STEP 7

Setting up a connection via a device IP address

To set up an OUC-connection via a device IP address of one of the two CPUs:

- Select a suitable PROFINET interface of the S7-1500R/H redundant system.
- Deselect the "Use address of H-system" check box.

The screenshot shows the 'General' configuration window for an OUC connection. It is divided into two columns: 'Local' and 'Partner'.
Local side:
- End point: S7-1500R/H-System_1 [S7-1500R/H-Station]
- Interface: PLC_1, PROFINET-Schnittstelle_1[X1]
- Subnet: PN/IE_1
- Address: 192.168.0.1
- A red box highlights the 'Use system IP address' checkbox, which is unchecked.
Partner side:
- End point: PLC_3 [CPU 1516-3 PN/DP]
- Interface: PLC_3, PROFINET-Schnittstelle_2[X2]
- Subnet: PN/IE_1
- Address: 192.168.0.10

Figure 13-14 OUC-connection via a device IP address

Reference

You can find additional information on system states in the S7-1500R/H (<https://support.industry.siemens.com/cs/ww/en/view/109754833>) system manual.

See also

PROFINET FUNCTION MANUAL (<https://support.industry.siemens.com/cs/ww/en/view/49948856>)

Industrial Ethernet Security with CP 1543-1

All-round protection - the task of Industrial Ethernet Security

With Industrial Ethernet Security, individual devices, automation cells or network segments of an Ethernet network can be protected. Data transfer can also be protected by a combination of different security measures:

- Data espionage
- Data manipulation
- Unauthorized access

Security measures

- Firewall
 - IP firewall with stateful packet inspection (layer 3 and 4)
 - Firewall also for Ethernet "non-IP" frames according to IEEE 802.3 (layer 2)
 - Bandwidth limitation
 - Global firewall rules

All network nodes located in the internal network segment of a CP 1543-1 are protected by its firewall. Exception: If you access the CPU via the interface of the CP with the "Access to PLC via communication module" function, the firewall does not protect this connection.

- Logging

To allow monitoring, events can be stored in log files that can be read out using the configuration tool or can be sent automatically to a Syslog server.
- HTTPS

For encrypted transfer of websites, for example during process control.
- FTPS (explicit mode)

For encrypted transfer of files.
- Secure NTP

For secure time-of-day synchronization and transmission.
- SNMPv3

For secure transmission of network analysis information safe from eavesdropping.

- **VPN groups**
You can combine the CP 1543-1 with other security modules into VPN groups through configuration. IPsec tunnels are established between all the security modules of a VPN group (VPN). All internal nodes of these security modules can communicate securely with each other through this tunnel.
- **Protection for devices and network segments**
The firewall and VPN groups protective functions can be applied to the operation of single devices, multiple devices, or entire network segments.

Additional information

An overview with links to the most important contributions on Industrial Security is available in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/92651441>).

14.1 Firewall

Tasks of the firewall

The purpose of the firewall functionality is to protect networks and stations from outside influences and disturbances. This means that only certain previously specified communications relations are permitted.

To filter the data traffic, IPv4 addresses, IPv4 subnets, port numbers or MAC addresses among other things can be used.

The firewall functionality can be configured for the following protocol levels:

- IP firewall with stateful packet inspection (layer 3 and 4)
- Firewall also for Ethernet "non-IP" frames according to IEEE 802.3 (layer 2)

Firewall rules

Firewall rules describe which packets are permitted or forbidden in which direction.

14.2 Logging

Functionality

For test and monitoring purposes, the security module has diagnostics and logging functions.

- Diagnostics functions

These include various system and status functions that you can use in online mode.

- Logging functions

This involves the recording of system and security events. Depending on the event type, the recording is made in volatile or non-volatile local buffer areas of the CP 1543-1. As an alternative, it is also possible to record on a network server.

The parameter assignment and evaluation of these functions is only possible with a network connection.

Recording events with logging functions

You specify which events should be recorded with the log settings. Here you can configure the following recording variants:

- Local logging

With this variant, you record the events in local buffers of the CP 1543-1. In the online dialog of the Security Configuration Tool, you can then access these recordings, visualize them and archive them on the service station.

- Network Syslog

With the network Syslog, you use a Syslog server in the network. This records the events according to the configuration in the log settings.

14.3 NTP client

Functionality

To check the time validity of a certificate and the time stamp of log entries, the date and time are maintained on the CP 1543-1 as on the CPU. This time can be synchronized with NTP. The CP 1543-1 forwards the synchronized time to the CPU via the backplane bus of the automation system. This way the CPU also receives a synchronized time for the time events in program execution.

The automatic setting and periodic synchronization of the time takes place either via a secure or non-secure NTP server. You can assign a maximum of 4 NTP servers to the CP 1543-1. A mixed configuration of non-secure and secure NTP servers is not possible.

14.4 SNMP

Functionality

Like the CPU, the CP 1543-1 supports the transfer of management information using the Simple Network Management Protocol (SNMP). To achieve this, an "SNMP agent" is installed on the CP/CPU that receives and responds to the SNMP queries. Information about the properties of devices capable of SNMP is contained in so-called MIB files (Management Information Base) for which the user needs to have the appropriate rights.

With SNMPv1, the "community string" is also sent. The "community string" is like a password that is sent along with the SNMP query. The requested information is sent when the "community string" is correct. The request is discarded when the string is incorrect.

With SNMPv3, data can be transferred encrypted. To do this, select either an authentication method or an authentication and encryption method.

Possible selection:

- Authentication algorithm: none, MD5, SHA-1
- Encryption algorithm: none, AES-128, DES

You can deactivate the use of SNMP for the CP/CPU. Deactivate SNMP if the security guidelines in your network do not permit SNMP or if you use your own SNMP solution.

To find out how to deactivate SNMP for the CPU, refer to section Disabling SNMP (Page 57).

14.5 VPN

Functionality

For security modules that protect the internal network, VPN (Virtual Private Network) tunnels provide a secure data connection through the non-secure external network.

The module uses the IPsec protocol (tunnel mode of IPsec) for tunneling.

In STEP 7 you can assign VPN groups to security modules. VPN tunnels are automatically established between all modules of a VPN group. A module in one project can belong to several different VPN groups at the same time in the process.

Glossary

Automation system

Programmable logic controller for the open-loop and closed-loop control of process chains of the process engineering industry and manufacturing technology. The automation system consists of different components and integrated system functions according to the automation task.

Backup CPU

If the R/H system is in RUN-Redundant system state, the primary CPU controls the process. The backup CPU processes the user program synchronously and can take over process control if the primary CPU fails.

Bus

Transmission medium that connects several devices together. Data transmission can be performed electrically or via optical fibers, either in series or in parallel.

Client

Device in a network that requests a service from another device in the network (server).

CM

→ *Communications module*

Communications module

Module for communications tasks used in an automation system as an interface expansion of the CPU (for example PROFIBUS) and providing additional communications options (PtP).

Communications processor

Module for expanded communications tasks covering special applications, for example in the area of security.

Consistent data

Data that belongs together in terms of content and must not be separated when transferred.

CP

→ *Communications processor*

CPU

Central Processing Unit - Central module of the S7 automation system with a control and arithmetic unit, memory, operating system and interface for programming device.

Device

Generic term for:

- Automation systems (PLC, PC, for example)
- Distributed I/O systems
- Field devices (for example, PLC, PC, hydraulic devices, pneumatic devices) and
- Active network components (for example, switches, routers)
- Gateways to PROFIBUS, AS interface or other fieldbus systems

Device certificates

Such certificates are signed by a certificate authority (CA).

The signature of an end-entity certificate is checked with the public key of the certificate authority certificate.

The "Subject" attribute must not be identical to the "Issuer" attribute.

The "Subject", for example, contains the name of a program as with the OPC UA application certificate.

"Issuer" is the certificate authority that signed the certificate.

The "CA" field must be set to "False".

DP master

Within PROFIBUS DP, a master in the distributed I/O that behaves according to the EN 50170 standard, Part 3.

→ *See also DP slave*

DP slave

Slave in the distributed I/O that is operated on PROFIBUS with the PROFIBUS DP protocol and behaves according to the EN 50170 standard, Part 3.

→ *See also DP master*

Duplex

Data transmission system; a distinction is made between full and half duplex.

Half duplex: One channel is available for alternate data exchange (sending or receiving alternately but not at the same time).

Full duplex: Two channels are available for simultaneous data exchange in both directions (simultaneous sending and receiving in both directions).

End-entity certificate

→ *See also device certificate*

Ethernet

International standard technology for local area networks (LAN) based on frames. It defines types of cables and signaling for the physical layer and packet formats and protocols for media access control.

Ethernet network adapter

Electronic circuitry for connecting a computer to an Ethernet network. It allows the exchange of data / communication within the network.

FETCH/WRITE

Server services using TCP/IP, ISO-on-TCP and ISO for access to system memory areas of S7 CPUs. Access (client function) is possible from a SIMATIC S5 or a third-party device/PC. FETCH: Read data directly; WRITE: Write data directly.

Field device

→ *Device*

Freeport

Freely programmable ASCII protocol; here for data transfer via a point-to-point connection.

FTP

File **T**ransfer **P**rotocol; a network protocol for transferring files via IP networks. FTP is used to download files from the server to the client or to upload files from the client to the server. FTP directories can also be created and read out and directories and files can be renamed or deleted.

HMI

Human **M**achine **I**nterface, device for visualization and control of automation processes.

IE

→ *Industrial Ethernet*

IM

→ *Interface module*

Industrial Ethernet

Guideline for setting up an Ethernet network in an industrial environment. The essential difference compared with standard Ethernet is the mechanical ruggedness and immunity to noise of the individual components.

Instruction

The smallest self-contained unit of a user program characterized by its structure, function or purpose as a separate part of the user program. An instruction represents an operation procedure for the processor.

Interface module

Module in the distributed I/O system. The interface module connects the distributed I/O system via a fieldbus to the CPU (IO controller/DP master) and prepares the data for the I/O modules.

Intermediate CA certificate

This is a certificate authority certificate that is signed with the private key of a root certificate authority.

An intermediate certificate authority signs end-entity certificates with its private key.

The signature of these end-entity certificates is verified with the public key of the intermediate certificate authority.

The "Subject" and "Issuer" attributes of the intermediate CA certificate must not be identical. This certificate authority has after all not signed its certificate itself.

The "CA" field must be set to "True".

IO controller, PROFINET IO controller

Central device in a PROFINET system, usually a classic programmable logic controller or PC. The IO controller sets up connections to the IO devices, exchanges data with them, thus controls and monitors the system.

IO device, PROFINET IO device

Device in the distributed I/O of a PROFINET system that is monitored and controlled by an IO controller (for example distributed inputs/outputs, valve islands, frequency converters, switches).

IP address

Binary number that is used as a unique address in computer networks in conjunction with the Internet Protocol (IP). It makes these devices uniquely addressable and individually accessible. An IPv4 address can be evaluated using a binary subnet mask that results in a network part or a host part as a structure. The textual representation of an IPv4 address consists, for example, of 4 decimal numbers with the value range 0 to 255. The decimal numbers are separated by periods.

IPv4 subnet mask

Binary mask, with which an IPv4 address (as a binary number) is divided into a "network part" and a "host part".

ISO protocol

Communications protocol for message or packet-oriented transfer of data in an Ethernet network. This protocol is hardware-oriented, very fast and allows dynamic data lengths. The ISO protocol is suitable for medium to large volumes of data.

ISO-on-TCP protocol

Communications protocol capable of S7 routing for packet-oriented transfer of data in an Ethernet network; provides network addressing. The ISO-on-TCP protocol is suitable for medium and large volumes of data and allows dynamic data lengths.

Linear bus topology

Network topology characterized by the arrangement of the devices in a line (bus).

MAC address

Worldwide unique device identification for all Ethernet devices. The MAC address is assigned by the manufacturer and has a 3-byte vendor ID and 3-byte device ID as a consecutive number.

Master

Higher-level, active participant in the communication/on a PROFIBUS subnet. The master has rights to access the bus (token) and can request and send data.

→ *See also DP master*

Modbus RTU

Remote Terminal Unit; Open communications protocol for serial interfaces based on a master/slave architecture.

Modbus TCP

Transmission Control Protocol; Open communications protocol for Ethernet based on a master/slave architecture. The data are transmitted as TCP/IP packets.

Network

A network consists of one or more interconnected subnets with any number of devices. Several networks can exist alongside each other.

NTP

The **Network Time Protocol (NTP)** is a standard for synchronizing clocks in automation systems via Industrial Ethernet. NTP uses the connectionless UDP transport protocol for the Internet.

OPC UA

OPC Unified Automation is a protocol for communication between machines, developed by the OPC Foundation.

Operating states

Operating states describe the behavior of a single CPU at a specific time.

The CPUs of the SIMATIC standard systems have the STOP, STARTUP and RUN operating states.

The primary CPU of the redundant system S7-1500R/H has the operating states STOP, STARTUP, RUN, RUN-Syncup and RUN-Redundant. The backup CPU has the operating states STOP, SYNCUP and RUN-Redundant.

Operating system

Software that allows the use and operation of a computer. The operating system manages resources such as memory, input and output devices and controls the execution of programs.

PG

→ *Programming device*

PNO

→ *PROFIBUS user organization*

Point-to-point connection

Bidirectional data exchange via communications modules with a serial interface between two communications partners (and two only).

Port

Physical connector to connect devices to PROFINET. PROFINET interfaces have one or more ports.

Primary CPU

If the R/H system is in RUN-Redundant system state, the primary CPU controls the process. The backup CPU processes the user program synchronously and can take over process control if the primary CPU fails.

Process image (I/O)

The CPU transfers the values from the input and output modules to this memory area. At the start of the cyclic program, the CPU transfers the process image output as a signal state to the output modules. The CPU then reads the signal states of the input modules into the process image input. The CPU then executes the user program.

PROFIBUS

Process Field Bus - European Fieldbus standard.

PROFIBUS address

Unique identifier of a device connected to PROFIBUS. The PROFIBUS address is sent in the frame to address a device.

PROFIBUS device

Device with at least one PROFIBUS interface either electrical (for example RS-485) or optical (for example Polymer Optical Fiber).

PROFIBUS user organization

Technical committee dedicated to the definition and development of the PROFIBUS and PROFINET standard.

PROFIBUS DP

A PROFIBUS with DP protocol that complies with EN 50170. DP stands for distributed I/O = fast, real-time capable, cyclic data exchange. From the perspective of the user program, the distributed I/O is addressed in exactly the same way as the centralized IO.

PROFINET

Open component-based industrial communications system based on Ethernet for distributed automation systems. Communications technology promoted by the PROFIBUS user organization.

PROFINET device

Device that always has a PROFINET interface (electrical, optical, wireless).

PROFINET interface

Interface of a module capable of communication (for example CPU, CP) with one or more ports. A MAC address is assigned to the interface in the factory. Along with the IP address and the device name (from the individual configuration), this interface address ensures that the PROFINET device is identified uniquely in the network. The interface can be electrical, optical or wireless.

PROFINET IO

IO stands for input/output; distributed I/O (fast, cyclic data exchange with real-time capability). From the perspective of the user program, the distributed I/O is addressed in exactly the same way as the centralized IO.

PROFINET IO as the Ethernet-based automation standard of PROFIBUS & PROFINET International defines a cross-vendor communication, automation, and engineering model.

With PROFINET IO, a switching technology is used that allows all devices to access the network at any time. In this way, the network can be used much more efficiently through the simultaneous data transfer of several devices. Simultaneous sending and receiving is enabled via the full-duplex operation of Switched Ethernet.

PROFINET IO is based on switched Ethernet with full-duplex operation and a bandwidth of 100 Mbps.

Programming device

Programming devices are essentially compact and portable PCs which are suitable for industrial applications. They are identified by a special hardware and software configuration for programmable logic controllers.

Protocol

Agreement on the rules by which the communication between two or more communication partners transpires.

PtP

Point-to-Point, interface and/or transmission protocol for bidirectional data exchange between two (and only two) communications partners.

Redundant systems

Redundant systems have multiple (redundant) instances of key automation components. Process control is maintained if a redundant component fails.

Ring topology

All devices of a network are connected together in a ring.

Root CA certificates

→ *See also root certificate*

Root certificate

This is the certificate of a certificate authority: It signs end-entity certificates and intermediate CA certificates with its private key.

The "Subject" attribute and the "Issuer" of this certificate must be identical. This certificate authority has signed its certificate itself.

The "CA" field must be set to "True".

TIA Portal V14 has such a root CA certificate:

If you configure the OPC UA server of an S7-1500 in the TIA Portal, the TIA Portal generates an end-entity certificate for the OPC UA server and signs that certificate with its own private key.

The signature of this end-entity certificate can be verified with the public key of the TIA Portal. This key can be found in the root CA certificate of the TIA Portal.

Router

Network node with a unique identifier (name and address) that connects subnets together and allows transportation of data to uniquely identified communications nodes in the network.

RS232, RS422 and RS485

Standard for serial interfaces.

RTU

Modbus RTU (RTU: **R**emote **T**erminal **U**nit, transfers the data in binary form; allows a good data throughput. The data must be converted to a readable format before it can be evaluated.

S7 routing

Communication between S7 automation systems, S7 applications or PC stations in different S7 subnets via one or more network nodes functioning as S7 routers.

SDA service

Send Data with Acknowledge. SDA is an elementary service with which an initiator (for example DP master) can send a message to other devices and then receives acknowledgment of receipt immediately afterwards.

SDN service

Send Data with No Acknowledge. This service is used primarily to send data to multiple stations and the service therefore remains unacknowledged. Suitable for synchronization tasks and status messages.

Security

Generic term for all the measures taken to protect against

- Loss of confidentiality due to unauthorized access to data
- Loss of integrity due to manipulation of data
- Loss of availability due to the destruction of data

Self-signed certificates

These are certificates that you sign with your private key and use as end-entity certificates.

The signature of these end-entity certificates is verified with your public key.

The "Subject" and "Issuer" attributes of self-signed certificates must be identical: You have signed your certificate yourself.

The "CA" field must be set to "False".

You can, for example, use self-signed certificates as application certificates for an OPC UA client.

The procedure required to generate a self-signed certificate with the certificate generator of the OPC Foundation is described here (Page).

Server

A device or more generally an object that can provide certain services; the service is performed at the request of a client.

Slave

Distributed device in a fieldbus system that can only exchange data with a master after the master has requested this.

→ *See also DP slave*

SNMP

Simple Network Management Protocol, uses the wireless UDP transport protocol. SNMP works in much the same way as the client/server model. The SNMP manager monitors the network nodes. The SNMP agents collect the various network-specific information in the individual network nodes and makes this information available in a structured form in the MIB (**Management Information Base**). This information allows a network management system to run detailed network diagnostics.

Subnet

Part of a network whose parameters must be matched up on the devices (for example in PROFINET). A subnet includes the bus components and all connected stations. Subnets can be linked together, for example using gateways or routers to form one network.

Switch

Network components used to connect several terminal devices or network segments in a local network (LAN).

Switched communication

In addition to the device IP addresses of the CPUs, the redundant system S7-1500R/H supports system IP addresses:

- System IP address for the X1 PROFINET interfaces of the two CPUs (system IP address X1)
- System IP address for the X2 PROFINET interfaces of the two CPUs (system IP address X2)

You use the system IP addresses for communication with other devices (for example, HMI devices, CPUs, PG/PC). The devices always communicate over the system IP address with the primary CPU of the redundant system. This ensures that the communication partner can communicate with the new primary CPU (previously backup CPU) in the RUN-Solo system state after failure of the original primary CPU in redundant operation.

System states

The system states of the redundant system S7-1500R/H result from the operating states of the primary and backup CPUs. The term system state is used as a simplified expression that refers to the operating states that occur simultaneously on both CPUs. The redundant system S7-1500R/H has the system states STOP, STARTUP, RUN-Solo, SYNCUP and RUN-Redundant.

TCP/IP

Transmission Control Protocol / Internet Protocol, connection-oriented network protocol, generally recognized standard for data exchange in heterogeneous networks.

Time-of-day synchronization

Capability of transferring a standard system time from a single source to all devices in the system so that their clocks can be set according to the standard time.

Tree topology

Network topology characterized by a branched structure: Two or more bus nodes are connected to each bus node.

Twisted-pair

Fast Ethernet via twisted-pair cables is based on the IEEE 802.3u standard (100 Base-TX). The transmission medium is a shielded 2x2 twisted-pair cable with an impedance of 100 Ohms (22 AWG). The transmission characteristics of this cable must meet the requirements of category 5.

The maximum length of the connection between the terminal and the network component must not exceed 100 m. The connectors are designed according to the 100Base-TX standard with the RJ-45 connector system.

UDP

User Datagram Protocol; communications protocol for fast and uncomplicated data transfer, without acknowledgment. There are no error checking mechanisms as found in TCP/IP.

User program

In SIMATIC, a distinction is made between the CPU operating system and user programs. The user program contains all instructions, declarations and data by which a system or process can be controlled. The user program is assigned to a programmable module (for example, CPU, FM) and can be structured in smaller units.

USS

Universal Serial Interface protocol (Universelles Serielles Schnittstellen-Protokoll); defines an access method according to the master-slave principle for communication via a serial bus.

Web server

Software/communications service for data exchange via the Internet. The web server transfers the documents using standardized transmission protocols (HTTP, HTTPS) to a Web browser. Documents can be static or put together dynamically from different sources by the web server on request from the Web browser.

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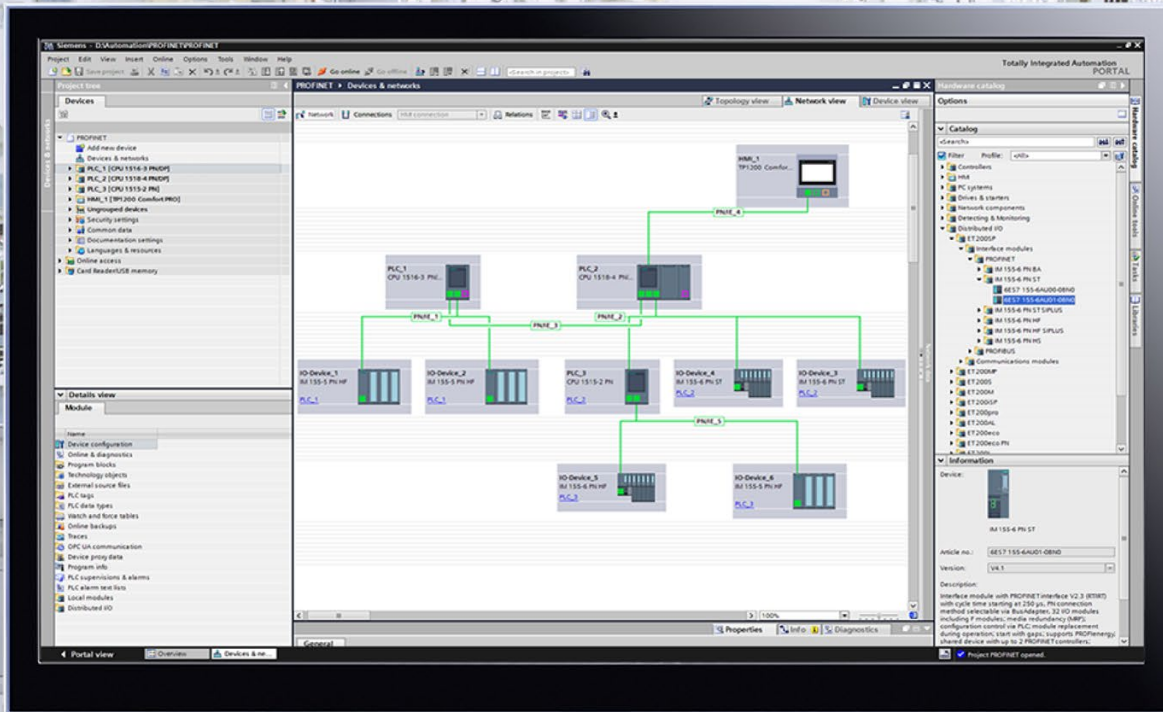
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Function Manual

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This function manual provides an overview of the PROFINET communication system with SIMATIC STEP 7 V16.

STEP 7 V16 is integrated into the high-performance graphical Totally Integrated Automation Portal (TIA Portal), the integration platform for all automation software tools.

This function manual supports you in planning a PROFINET system. The manual is structured into the following subject areas:

- PROFINET basics
- PROFINET diagnostics
- PROFINET functions

Basic knowledge required

The following knowledge is required in order to understand the manual:

- General knowledge of automation technology
- Knowledge of the industrial automation system SIMATIC
- Knowledge about the use of Windows-based computers
- Knowledge about how to use STEP 7 (TIA Portal)

Scope

This documentation is the basic documentation for all SIMATIC products from the PROFINET environment. The product documentation is based on this documentation.

The examples are based on the functionality of the S7-1500 automation system.

What's new in the PROFINET Function Manual, Edition 11/2019 compared to Edition 10/2018

Function	What are the customer benefits?	Where can I find this information?
Direct data exchange	In the case of direct data exchange, an S7-1500 CPU provides cyclic user data from the I/O area to one or more partners. The "Direct data exchange" function enables deterministic, isochronous IO communication between multiple S7-1500 CPUs.	Section Direct data exchange (Page 214)
Switched S1 device	The "Switched S1 device" function of the CPU enables operation of standard IO devices in the S7-1500R/H redundant system.	Section Switched S1 device (Page 277)

What's new in the PROFINET Function Manual, Edition 10/2018 compared to Edition 12/2017

This manual (version 10/2018) includes the following new functions compared to the previous version (version 12/2017):

Function	Applications	Your benefits
PROFINET IO with the redundant S7-1500R/H system	In a PROFINET IO system with the redundant S7-1500R/H system, the IO communication continues even when one CPU fails.	The redundant S7-1500R/H system offers a high degree of reliability and system availability. A redundant configuration of the most important automation components reduces the probability of production downtimes and the consequences of component failures.

What's new in the PROFINET function manual, version 12/2017 compared to version 09/2016

This manual (version 12/2017) encompasses the following new functions compared to the previous version (version 09/2016):

Function	Applications	Your benefits
Specifying the router for a PROFINET IO device	You can specify the IP address of a router for each IO device. You reach the IO device from outside the IP subnet through the router.	In the past, it was only possible to specify a router for a PROFINET IO interface at the IO controller. The IO devices inherited the setting of the IO controller interface. Now you can set the router address independently of the IO controller setting. This allows, for example, a router address at the IO device although you have not set a router address or have set a different address at the IO controller.
Configuring an IO device through hardware detection	You can detect an existing IO device and enter it in your project.	STEP 7 inserts the IO device with all the modules and submodules into the project. Article numbers and firmware versions between real and configured IO devices match. You reduce the project planning work required.
Asset management	You can centrally manage non-PROFINET components (assets) of a PROFINET device. The PROFINET device makes the identification data of the assets available for evaluation via a standardized data record.	The new standardized PROFINET service makes it possible to manage all the hardware and firmware components of PROFINET devices centrally. The possibilities available for filtering device data, for example, depend on the range of performance of the evaluating application.
Asset management data record for I-devices	Special application of asset management: From the point of view of a higher-level IO controller, the modules plugged into the I-device represent assets. The user program in the I-device compiles the asset management data record. The IO controller can read identification data of the I-device modules through this data record.	See Asset management.

What's new in the PROFINET function manual, Version 09/2016 compared to Version 12/2014

This manual (version 09/2016) encompasses the following new functions compared to the previous version (version 12/2014):

Function	Applications	Your benefits
PROFINET IO on the 2nd PROFINET interface	You can operate another PROFINET IO system on the CPU or connect additional IO devices.	You use a fieldbus type in the plant. The CPU can perform fast and deterministic data exchange as an I-device with a higher-level controller (PROFINET/Ethernet) through the second line.
IRT with very short data cycle times down to 125 µs	You realize high-end applications with IO communication which place very high performance demands on the IO processing.	You make PROFINET IO communication and standard communication possible via one cable even with a send clock of 125 µs.
MRPD: Media Redundancy with Planned Duplication of frames	PROFINET IO IRT enables you to realize applications that place particularly high demands on the reliability and accuracy (isochronous mode).	By sending the cyclic IO data in both directions in the ring, the communication to the IO devices is maintained even when the ring is interrupted and does not result in device failure even with fast update times. You achieve higher reliability than with MRP.
PROFINET performance upgrade	You can implement applications with high speed and send clock requirements. This is of interest to applications with high demands on performance.	Better utilization of the bandwidth results in short reaction times.
Limitation of the data infeed into the network	You limit the network load for standard Ethernet communication to a maximum value.	You flatten peaks in the data feed. You share the remaining bandwidth based on demand.

Conventions

STEP 7: We refer to "STEP 7" in this documentation as a synonym for the configuration and programming software "STEP 7 as of V12 (TIA Portal)" and subsequent versions.

This documentation contains pictures of the devices described. The figures may differ slightly from the device supplied.

You should also pay particular attention to notes such as the one shown below:

Note

A note contains important information on the product, on handling of the product and on the section of the documentation to which you should pay particular attention.

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

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- **Product support**

All the information and extensive know-how on your product, technical specifications, FAQs, certificates, downloads, and manuals.

- **Application examples**

Tools and examples to solve your automation tasks – as well as function blocks, performance information and videos.

- **Services**

Information about Industry Services, Field Services, Technical Support, spare parts and training offers.

- **Forums**

For answers and solutions concerning automation technology.

- **mySupport**

Your personal working area in Industry Online Support for messages, support queries, and configurable documents.

This information is provided by the Siemens Industry Online Support in the Internet (<https://support.industry.siemens.com>).

Industry Mall

The Industry Mall is the catalog and order system of Siemens AG for automation and drive solutions on the basis of Totally Integrated Automation (TIA) and Totally Integrated Power (TIP).

You can find catalogs for all automation and drive products on the Internet (<https://mall.industry.siemens.com>).

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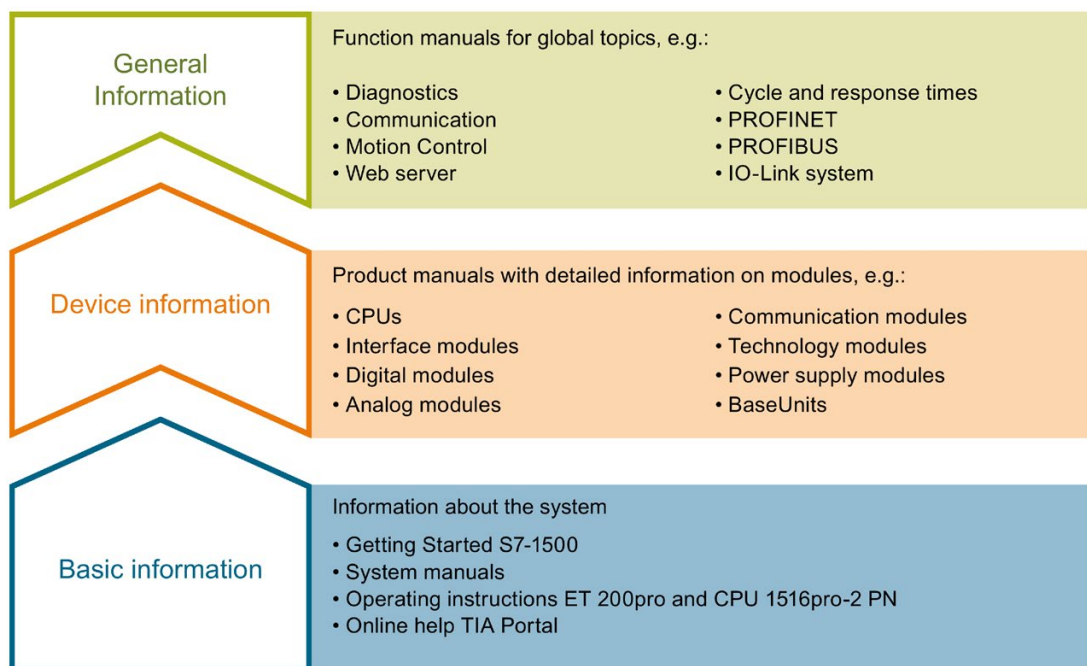
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Function manuals Documentation Guide

The documentation for the SIMATIC S7-1500 automation system, for CPU 1516pro-2 PN based on SIMATIC S7-1500, and for the distributed I/O systems SIMATIC ET 200MP, ET 200SP and ET 200AL is divided into three areas.

This division allows you easier access to the specific information you require.



Basic information

System manuals and Getting Started manuals describe in detail the configuration, installation, wiring and commissioning of the SIMATIC S7-1500, ET 200MP, ET 200SP and ET 200AL systems; use the corresponding operating instructions for CPU 1516pro-2 PN. The STEP 7 online help supports you in configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics such as diagnostics, communication, Motion Control, Web server, OPC UA.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742705>).

Changes and additions to the manuals are documented in product information sheets.

You will find the product information on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/us/en/view/68052815>)
- ET 200SP (<https://support.industry.siemens.com/cs/us/en/view/73021864>)
- ET 200AL (<https://support.industry.siemens.com/cs/us/en/view/99494757>)

Manual Collections

The Manual Collections contain the complete documentation of the systems put together in one file.

You will find the Manual Collections on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/ww/en/view/86140384>)
- ET 200SP (<https://support.industry.siemens.com/cs/ww/en/view/84133942>)
- ET 200AL (<https://support.industry.siemens.com/cs/ww/en/view/95242965>)

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Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

Description

2.1 Introduction to PROFINET

What is PROFINET IO?

Within the framework of Totally Integrated Automation (TIA), PROFINET IO is the logical further development of:

- PROFIBUS DP, the established fieldbus and
- Industrial Ethernet

PROFINET IO is based on 20 years of experience with the successful PROFIBUS DP and combines the normal user operations with the simultaneous use of innovative concepts of Ethernet technology. This ensures the integration of PROFIBUS DP into the PROFINET world.

PROFINET IO as the Ethernet-based automation standard of PROFIBUS/PROFINET International defines a cross-vendor communication, automation, and engineering model.

Objectives of PROFINET

The objectives of PROFINET:

- Industrial networking, based on Industrial Ethernet (open Ethernet standard)
- Compatibility of Industrial Ethernet and standard Ethernet components
- High robustness due to Industrial Ethernet devices. Industrial Ethernet devices are suited to the industrial environment (temperature, noise immunity, etc.).
- Use of IT standards such as TCP/IP, http.
- Real-time capability
- Seamless integration of other fieldbus systems

Implementation of PROFINET in SIMATIC

PROFINET is implemented in SIMATIC as follows:

- We have implemented communication between field devices in SIMATIC with **PROFINET IO**.
- Installation technology and network components are available as SIMATIC NET products.
- Ethernet standard protocol and procedures (e.g., SNMP = Simple Network Management Protocol for network parameter assignment and diagnostics) are used for remote maintenance and network diagnostics.

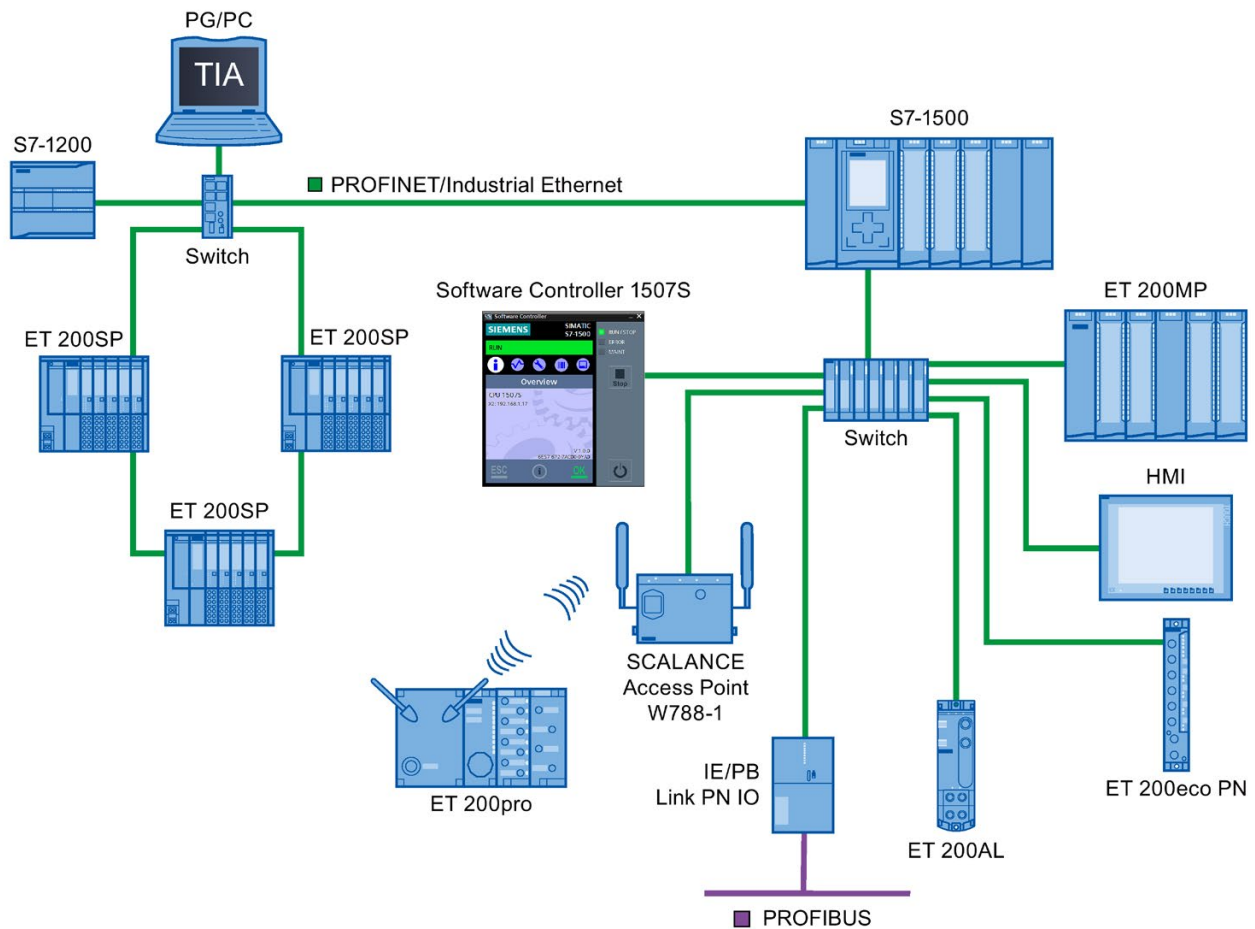


Figure 2-1 PROFINET overview configuration

STEP 7

The STEP 7 engineering tool supports you in setting up and configuring an automation solution. STEP 7 provides a uniform application view over all bus systems.

Documentation from PROFIBUS & PROFINET International on the Internet

You will find numerous documents on the topic of PROFINET at the Internet address (<http://www.profibus.com>) of the "PROFIBUS & PROFINET International" PROFIBUS user organization, which is also responsible for PROFINET.

Additional information can be found on the Internet (<http://www.siemens.com/profinet>).

Overview of the most important documents and links

A compilation of the most important PROFINET application examples, FAQs and other contributions in the Industry Online Support is available in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/108165711>).

2.1.1 PROFINET terms

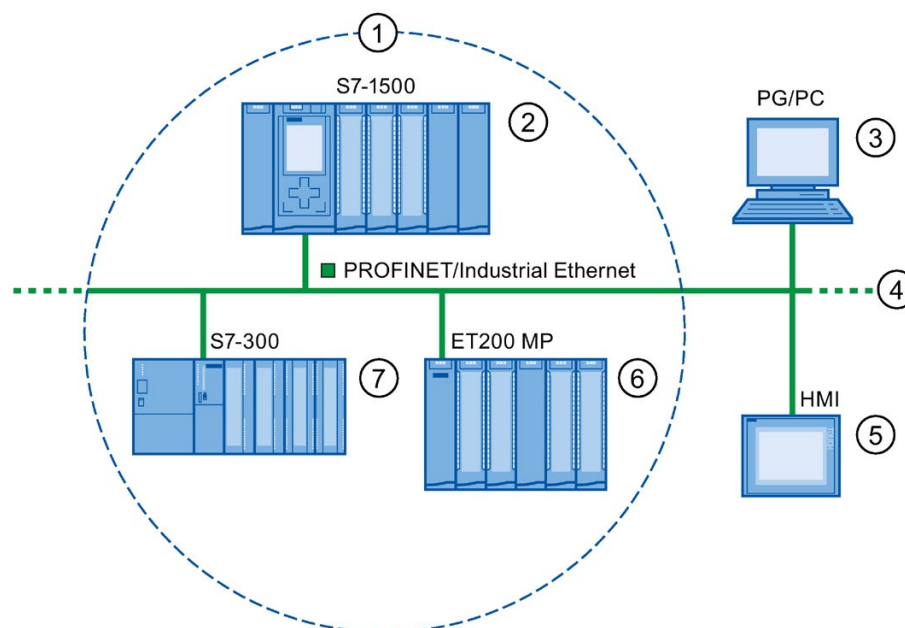
Definition: Devices in the PROFINET environment

In the PROFINET environment, "device" is the generic term for:

- Automation systems (PLC, PC, for example)
- Distributed I/O systems
- Field devices (for example, hydraulic devices, pneumatic devices)
- Active network components (for example, switches, routers)
- Gateways to PROFIBUS, AS interface or other fieldbus systems

PROFINET IO devices

The following graphic shows the general names used for the most important devices in PROFINET. In the table below the graphic you can find the names of the individual components in the PROFINET IO context.

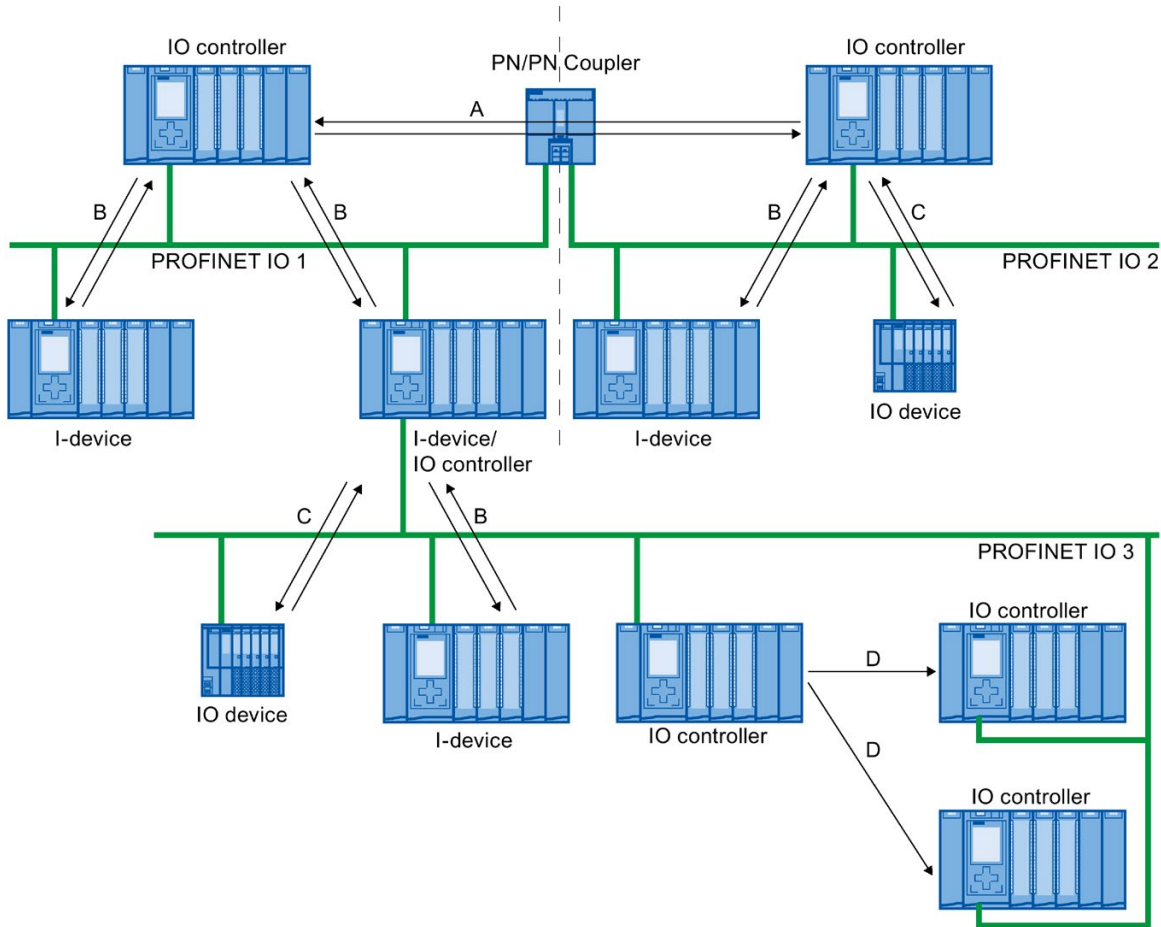


Number	PROFINET	Explanation
①	PROFINET IO System	
②	IO controller	Device used to address the connected IO devices. This means that: The IO controller exchanges input and output signals with field devices.
③	Programming device / PC (PROFINET IO supervisor)	PG/PC/HMI device used for commissioning and for diagnostics
④	PROFINET/Industrial Ethernet	Network infrastructure
⑤	HMI (Human Machine Interface)	Device for operating and monitoring functions.
⑥	IO device	A distributed field device that is assigned to one of the IO controllers (e.g., Distributed IO, valve terminals, frequency converters, switches with integrated PROFINET IO functionality)
⑦	I-device	Intelligent IO device

Figure 2-2 PROFINET devices

IO communication via PROFINET IO

The inputs and outputs of distributed I/O devices are read and written by means of PROFINET IO using what is referred to as IO communication. The following figure provides an overview of IO communication by means of PROFINET IO.



- A IO controller - IO controller communication via PN/PN coupler
- B IO controller - I-device communication
- C IO controller - IO-device communication
- D Direct data exchange between S7-1500-CPU

Figure 2-3 IO communication via PROFINET IO

IO communication via PROFINET IO

Table 2- 1 IO communication via PROFINET IO

Communication between ...	Explanation
IO controllers and IO devices	The IO controller sends data cyclically to the IO devices of its PROFINET IO system and receives data from these devices.
IO controller and I-device	<p>A fixed quantity of data is transferred cyclically between the user programs in CPUs of IO controllers and I-devices.</p> <p>The IO controller does not access the I/O module of the I-device, but instead accesses configured address ranges, i.e. transfer ranges, which may be located inside or outside the process image of the CPU of the I-device. If parts of the process image are used as transfer ranges, it is not permitted to use these for real I/O modules.</p> <p>Data transfer takes place using load- and transfer operations via the process image or via direct access.</p>
IO controller and IO controller (PN/PN coupler)	<p>A fixed quantity of data is cyclically transferred between the user programs in CPUs of IO controllers. A PN/PN coupler is required as additional hardware.</p> <p>The IO controllers mutually access configured address ranges, i.e. transfer ranges, which may be located inside or outside the process image of the CPU. If parts of the process image are used as transfer ranges, it is not permitted to use these for real I/O modules.</p> <p>Data transfer takes place using load- and transfer operations via the process image or via direct access.</p> <p>I/O communication with PN/PN coupler is possible between two PROFINET IO systems.</p>
S7-1500-CPU and S7-1500-CPU (direct data exchange)	<p>In the case of direct data exchange, an S7-1500 CPU provides cyclic user data from the I/O area to one or more partners.</p> <p>The direct data exchange is based on PROFINET with IRT and isochronous mode.</p> <p>The data exchange takes place via transfer areas.</p>

See also

Communication (<http://support.automation.siemens.com/WW/view/en/59192925>)

Network security (Page 36)

Functions (Page 113)

2.1.2 Basic terminology of communication

PROFINET communication

PROFINET communication takes place via Industrial Ethernet. The following transmission types are supported:

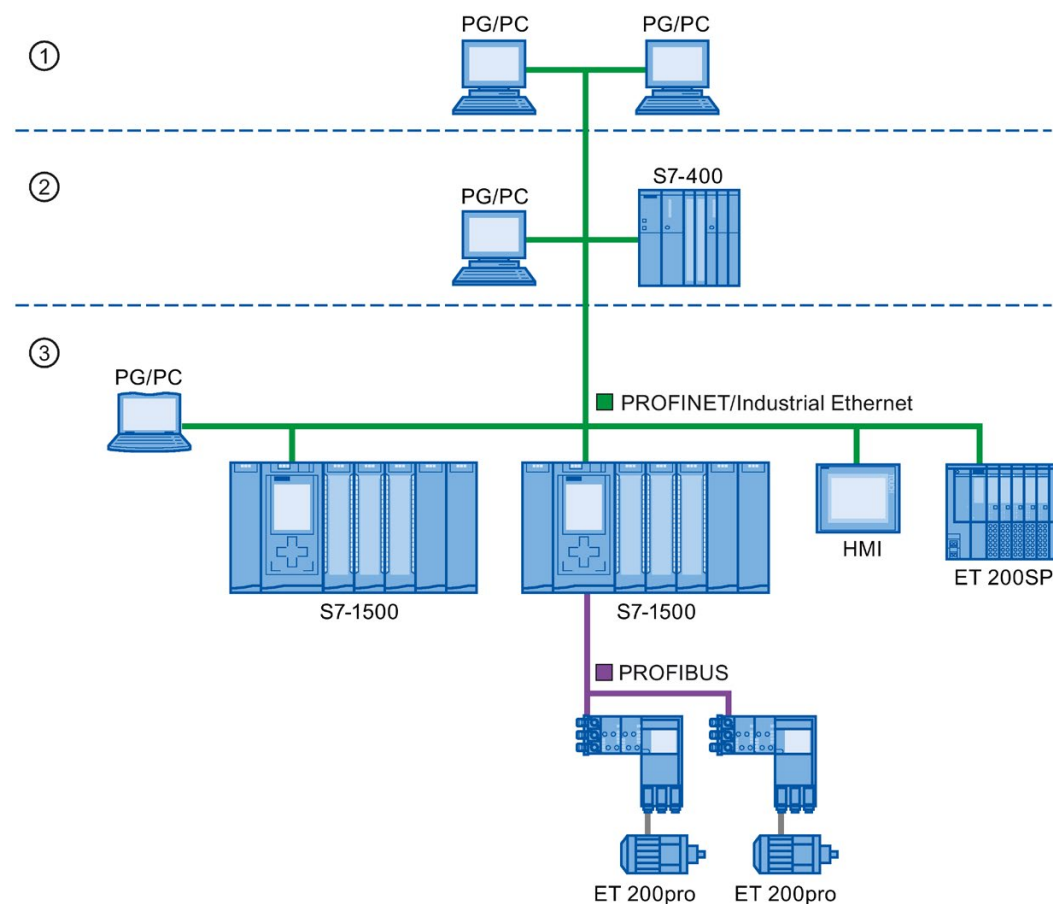
- Acyclic transmission of engineering and diagnostics data and interrupts
- Cyclic transmission of user data

The PROFINET-IO communication takes place in real-time.

For additional information on the real-time communication, refer to chapter Real-time communication (Page 175).

Transparent data access

Access to process data from different levels of the factory is supported by PROFINET communication. By using Industrial Ethernet, standard mechanisms of communication and information technology such as OPC/XML can now be used along with standard protocols such as UDP/TCP/IP and HTTP in automation engineering. This allows transparent access from company management level directly to the data from the automation systems at the control level and production level.



- ① Management level
- ② Control level
- ③ Production level

Figure 2-4 Access to process data

Update time

The update time is a time interval. IO controller and IO device/I-device exchange IO data cyclically in the IO system within this time interval. The update time can be configured separately for each IO device and determines the interval at which output data is sent from the IO controller to the IO device (output module/submodule) as well as input data from the IO device to the IO controller (input module/submodule).

STEP 7 calculates the update time automatically in the default setting for each IO device of the PROFINET IO system, taking into account the volume of data to be exchanged as well as the set send clock.

For additional information on the update time, refer to section Real-time communication (Page 175).

Watchdog time

The watchdog time is the time interval that an IO controller or IO device permits, without receiving IO data. If the IO device is not supplied by the IO controller with data within the watchdog time, the IO device detects the missing frames and outputs substitute values. This is reported in the IO controller as a station failure.

In STEP 7, the watchdog time is made up from an integral multiple of the update time and can be set by the user.

Send clock

The period of time between two consecutive communication cycles. The send clock is the shortest possible interval in data exchange and thus also the smallest value that can be set for the update time.

Relationship between the update time and send clock

The calculated update times are reduction ratios (1, 2, 4, 8, ..., 512) of the send clock. The minimum possible update time thus depends on the minimum send clock of the IO controller that can be set and the efficiency of the IO controller and IO device. Depending on the send clock, it can be that only some of the reduction ratios are available (STEP 7 guarantees this through a pre-selection).

The following tables illustrate the dependency of the update time that can be set on the send clock, using an example of the CPU 1516-3 PN/DP. The update times satisfy the requirements of the PROFINET standard IEC 61158.

Table 2- 2 With real-time communication the following applies:

Send clock	Update time	Reduction ratios
250 µs	250 µs to 128 ms	1,2, ..., 512
500 µs	500 µs to 256 ms	1,2, ..., 512
1 ms	1 ms to 512 ms	1,2, ..., 512
2 ms	2 ms to 512 ms	1,2, ..., 256
4 ms	4 ms to 512 ms	1,2, ..., 128

Additional information

For information on real-time communication, refer to the section Real-Time Communication (RT) (Page 176).

2.1.3 PROFINET interface

Overview

PROFINET devices of the SIMATIC product family have one or more PROFINET interfaces (Ethernet controller/interface). The PROFINET interfaces have one or more ports (physical connection options).

In the case of PROFINET interfaces with multiple ports, the devices have an integrated switch.

PROFINET devices with two ports on one interface allow you to configure the system in a line or ring topology. PROFINET devices with three or more ports on one interface are also ideal for setting up tree topologies.

Properties and rules for naming the PROFINET interface and its representation in STEP 7 are explained in the following.

Properties

Every PROFINET device on the network is uniquely identified via its PROFINET interface. For this purpose, each PROFINET interface has:

- A MAC address (factory default)
- An IP address
- A PROFINET device name

Identification and numbering of the interfaces and ports

Interfaces and ports for all modules and devices in the PROFINET system are identified with the following characters:

Table 2- 3 Identification for interfaces and ports of PROFINET devices

Element	Symbol	Interface number
Interface	X	In ascending order starting from number 1
Port	P	In ascending order starting from number 1 (for each interface)
Ring port	R	

Examples of identification

Three examples illustrate the rules for identifying PROFINET interfaces:

Table 2- 4 Examples for identifying PROFINET interfaces

Sample labeling	Interface number	Port number
X2 P1	2	1
X1 P2	1	2
X1 P1 R	1	1 (ring port)

Representation of PROFINET Interfaces in the Topology Overview in STEP 7

You can find the PROFINET interface in the topology overview in STEP 7. The PROFINET interface for an IO controller and an IO device is represented as follows in STEP 7:

Device / port	Slot	Partner station	Partner devi..	Partner interface	Partner port	Cable data
▼ S7300/ET200M-Station_1						
▼ PLC_1	2					
PROFINET-Schnittstelle	2 X2					
Port_1	2 X2 P1	ET 200eco-St...	IO-Device_1	PROFINET-Schnittst...	Port_1	< 100 m (0,6 µs)
Port_2	2 X2 P2				Any pa...	
▼ ET 200eco-Station_1						
▼ IO-Device_1	0					
PROFINET-Schnittstelle	0 X1					
Port_1	0 X1 P1	S7300/ET200...	PLC_1	PROFINET-Schnittst...	Port_1	< 100 m (0,6 µs)
Port_2	0 X1 P2				Any partner	
8 DI DC24V 4xM12	1					

- | Num-ber | Description |
|---------|--|
| ① | PROFINET interface of an IO controller in STEP 7 |
| ② | PROFINET interface of an IO device in STEP 7 |
| ③ | These lines represent the PROFINET interface. |
| ④ | These lines represent the "ports" of a PROFINET interface. |

Figure 2-5 Representation of the PROFINET interfaces in STEP 7

Schematic Representation of a PROFINET Interface with Integrated Switch

The following schematic diagram shows the PROFINET interface with integrated switch and its ports for all PROFINET devices.

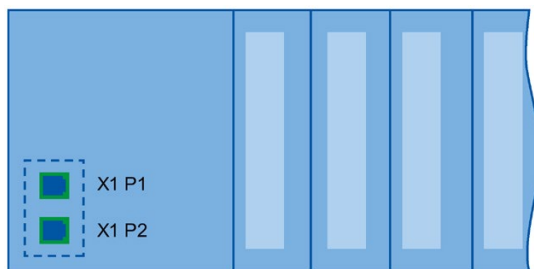


Figure 2-6 PROFINET interface with integrated switch

Functional differences of the PROFINET interfaces

PROFINET interfaces can provide different functions. PROFINET interface functions include identification, configuration, diagnostics and communication services (e.g., open communication). PROFINET interfaces that provide PROFINET IO functions and network security functions are also available.

The following table illustrates the differences using the example of the CPU 1516-3 PN/DP (as of firmware version V2.0), which features two PROFINET interfaces with different functionality.

Table 2- 5 Differences between the PROFINET interfaces of the CPU 1516-3 PN/DP (as of firmware version V2.0)

PROFINET interface (X1)	PROFINET interface (X2)
2 ports with PROFINET IO functionality:	1 port with PROFINET IO functionality:
Identification, configuration and diagnostics	
PG communication	
HMI communication	
S7 communication	
Time-of-day synchronization	
Web server	
Open communication	
OPC UA server	
IO controller	
I-device	
RT	
IRT	-
Isochronous mode	-
Media redundancy	-
Prioritized startup	-

Additional Information on the Functionality of PROFINET interfaces

You can find information on the number and functionality of the interfaces of a PROFINET device in the documentation for the specific PROFINET device.

PROFINET communication services are described in the Communication function manual (<http://support.automation.siemens.com/WW/view/en/59192925>).

In the Network security (Page 36) section you can find components that are used to protect networks against hazards.

The Functions (Page 113) section describes the PROFINET IO functions.

2.1.4 Implementation of the PROFINET device model in SIMATIC

Slots and modules

A PROFINET device can have a modular and compact structure. A modular PROFINET device consists of slots into which the modules are inserted. The modules have channels which are used to read and output process signals. A compact device has the same design and can include modules, however, it cannot be physically expanded, which means that no modules can be inserted.

This is illustrated by the following graphic.

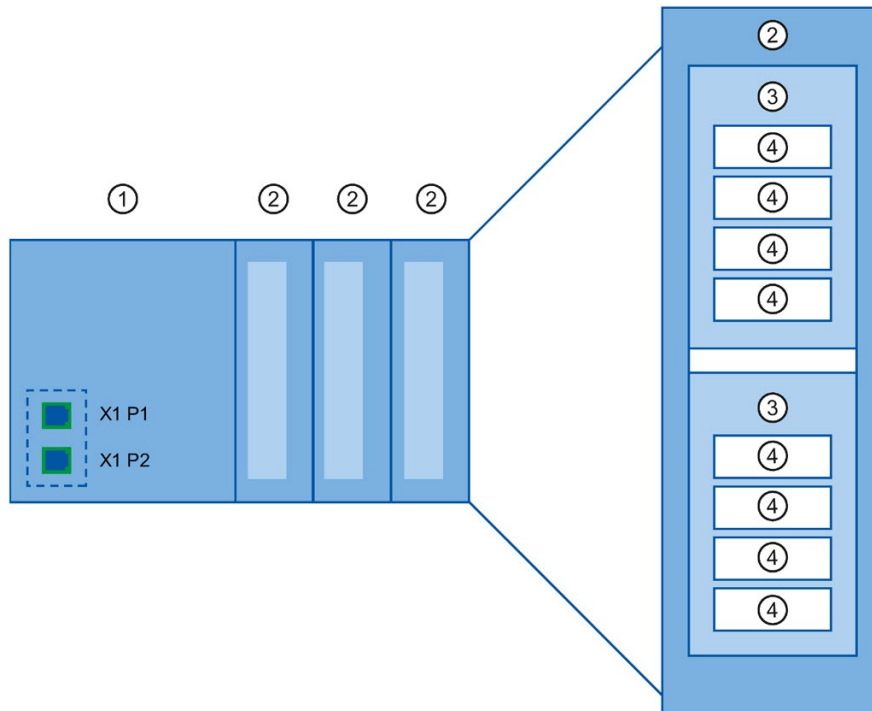


Figure 2-7 Configuration of a PROFINET device

Number	Description
①	Slot with bus interface
②	Slot with module
③	Subslot with submodule
④	Channel

A module can contain multiple submodules.

Representation of PROFINET Device Model in the Device View of STEP 7

The following figure shows the representation of the PROFINET device model in the device view of STEP 7, based on the example of a distributed I/O system ET 200MP:

Device overview						
Module	Rack	Slot	I address	Q address	Type	
▼ IO-Device_1	0	1			IM 155-5 PN ST	
▼ PROFINET-Schnittstelle	0	1 X1			PROFINET interface	
Port_1	0	1 X1 P1			Port	
Port_2	0	1 X1 P2			Port	
DI 32x24VDC HF_1	0	2	16...19		DI32 x 24VDC HF	
DQ 32x24VDC/0.5A ST_1	0	3		0...3	DQ32 x 24VDC / 0.5A ST	

Figure 2-8 PROFINET device model in the device view of STEP 7

2.2 Setting up PROFINET

Contents of this chapter

The following chapter provides background information on building your communication network.

- Overview of the most important passive network components: These are network components that forward a signal without the possibility of actively influencing it, for example, cables, connectors, etc.
- Overview of the most important active network components: These are network components that actively affect a signal, for example switches, routers, etc.
- Overview of the most common network structures (topologies).

Physical connections of industrial networks

PROFINET devices can be networked in industrial systems in two different physical ways:

- Connected line
 - By means of electrical pulses via copper cables
 - By means of optical pulses via fiber-optic cables
- Wireless via wireless network using electromagnetic waves

PROFINET devices and cabling technology in SIMATIC are suited for industrial use, as they are based on Fast Ethernet and Industrial Ethernet.

- **Fast Ethernet**

You can use Fast Ethernet to transfer data at a speed of 100 Mbps. This transmission technology uses the 100 Base-T standard for this.

- **Industrial Ethernet**

Structure of Ethernet in industrial environment.

The biggest difference from standard Ethernet is the mechanical current carrying capacity and noise immunity of the individual components.

2.2.1 Active Network Components

Introduction

The following active network components are available for PROFINET:

- Switch
- Router

Switched Ethernet

PROFINET IO is based on switched Ethernet with full-duplex operation and a bandwidth of 100 Mbps. In this way, the network can be used much more efficiently through the simultaneous data transfer of several devices. The PROFINET IO frames are processed with high priority.

Switches

Switches are network components used to connect several terminal devices or network segments in a local network (LAN).

For the communication of a device with several other devices on PROFINET, the device is connected to the port of a switch. Other communication devices (including switches) can then be connected to the other ports of the switch. The connection between a communication device and the switch is a point-to-point connection.

A switch has the task of receiving and distributing frames. The switch "learns" the Ethernet address(es) of a connected PROFINET device or additional switches and only forwards those frames that are intended for the connected PROFINET device or the connected switch.

Switch variants

Switches are available in two models:

- Integrated into a PROFINET device
For PROFINET devices with multiple ports (two or more), we are dealing with devices with an integrated switch (for example, CPU 1516-3 PN/DP).
- As autonomous device (for example, switches of the SCALANCE product family)

Selection Guide for Switches

To use PROFINET with the RT class "RT", you can use any switch of "PROFINET Conformance Class A" or higher. All switches of the SCALANCE product family meet these requirements.

If you want to use PROFINET functions that provide an additional value, such as topology recognition, diagnostics, device exchange without exchangeable medium/programming device, you have to use a switch of the "PROFINET Conformance Class B" or higher.

To use PROFINET with the RT class "IRT", you must use a switch of "PROFINET Conformance Class C". With switches of the SCALANCE product family, watch out for the catalog feature "IRT PROFINET IO switch".

To select appropriate switches, we recommend the SIMATIC NET Selection Tool on the Internet (<http://support.automation.siemens.com/WWW/view/en/39134641>).

Switches of the SCALANCE product family

Use the switches of the SCALANCE product family if you want to use the full scope of PROFINET. They are optimized for use in PROFINET IO.

In the SCALANCE X device family, you will find switches with electrical and optical ports and with a combination of both variants. SCALANCE X202-2IRT, for example, has two electrical ports and two optical ports and supports IRT communication.

Beginning with the SCALANCE X200, you can configure, diagnose and address switches of the SCALANCE X device series as PROFINET IO devices using STEP 7.

Router

A router connects separated network segments with each other (e.g. management level and control level). The volume of data volume must be coordinated with the services of the respective network segment. A router also separates two networks and acts as a mediator between both networks. It thus reduces the network load. Routing functionality is provided in the SCALANCE X device family, with SCALANCE X300 or higher.

Communication devices on different sides of a router can only communicate with one another if you have explicitly enabled communication between them via the router.

If you want to access manufacturing data directly from SAP, for example, use a router to connect your Industrial Ethernet in the factory with the Ethernet in your office.

Note

If devices need to communicate beyond the limits of a network, you must configure the router so that it allows this communication to take place.

Information on routing with STEP 7 is available in the function manual Communication (<http://support.automation.siemens.com/WW/view/en/59192925>).

2.2.2 Cabling technology

Cables for PROFINET

Electrical and optical cables are available for PROFINET. The type of cable depends on the data transfer requirements and on the ambient conditions.

Simple method for the prefabrication of twisted pair cables

When you set up your PROFINET system, you can cut the twisted-pair cable to the required length on site, strip it with the *stripping tool* (for Industrial Ethernet), and fit the *Industrial Ethernet Fast Connect RJ45 plugs* using the cut-and-clamp method. For more information on installation, refer to the installation instructions in the "SIMATIC NET Industrial Ethernet Network Manual" (<http://support.automation.siemens.com/WW/view/en/8763736>).

Note

A maximum of four plug-in pairs are allowed between two switches per Ethernet path.

Simple method for the prefabrication of fiber-optic cables

The FastConnect FO cabling system is available for the easy, fast and error-free prefabrication of fiber-optic cables. The glass-fiber optic cable consists of:

- FC FO Termination Kit for SC and BFOC plug (cleave tool, Kevlar scissors, buffer grip, fiber remains container)
- FC BFOC Plug
- FC SC Duplex plug
- FO FC Standard cable
- FO FC Trailing cable

Simple method for the prefabrication of POF and PCF cables

The following special tools provide an easy and safe way to prefabricate POF / PCF cables and fit the SC RJ POF plugs:

- POF cable
Prefabrication case IE Termination Kit SC RJ POF plug
- PCF cable
Prefabrication case IE Termination Kit SC RJ PCF plug

Overview of transmission media with PROFINET

The following table summarizes the technical specifications of a PROFINET interface with integrated switch or an external switch, and possible transmission media.

Table 2- 6 Transmission media with PROFINET

Physical properties	Connection methods	Cable type / transmission medium standard	Transmission rate / mode	Max. segment length (between two devices)	Advantages
Electrical	RJ45 connector ISO 60603-7	100Base-TX 2x2 twisted, symmetrical and shielded copper cable, CAT 5 transmission requirement IEEE 802.3	100 Mbps, full duplex	100 m	Simple and cheap cable connection
Optical	SCRJ 45 ISO/IEC 61754-24	100Base-FX POF fiber-optic cable (Polymer Optical Fiber, POF) 980/1000 μm (core diameter / external diameter) ISO/IEC 60793-2	100 Mbps, full duplex	50 m	Use when there are large differences in potential Insensitive towards electromagnetic radiation Low line attenuation Considerably longer segments possible ¹
		Plastic-cladded glass fiber (Polymer Cladded Fiber, PCF) 200/230 μm (core diameter / external diameter) ISO/IEC 60793-2	100 Mbps, full duplex	100 m	
	BFOC (Bayonet Fiber Optic Connector) and SC (Subscriber Connector) ISO/IEC 60874	Monomode glass fiber optic cable 10/125 μm (core diameter / external diameter) ISO/IEC 60793-2	100 Mbps, full duplex	26 km	
		Multimode glass fiber optic cable 50/125 μm and 62.5/125 μm (core diameter / external diameter) ISO/IEC 9314-4	100 Mbps, full duplex	3000 m	
Electromagnetic waves	-	IEEE 802.11 x	Depends on the extension used (a, g, h, etc.)	100 m	Greater mobility Cost-effective networking to remote, difficult to access devices

¹ Applies for fiber-optic cables only

See also

PROFINET interface (Page 23)

Assembly Instructions for SIMATIC NET Industrial Ethernet
(<http://support.automation.siemens.com/WW/view/en/27069465>)

PROFINET Installation Guideline (<http://www.profibus.com/nc/download/installation-guide/downloads/profinet-installation-guide/display/>)

2.2.3 Wireless design

2.2.3.1 Basics

What is Industrial Wireless LAN?

In addition to data communication in accordance with the IEEE 802.11 standard, the SIMATIC NET Industrial Wireless LAN provides a number of enhancements which offer significant benefits for industrial customers. IWLAN is particularly suitable for demanding industrial applications that require reliable wireless communication. This is supported by the following properties:

- Automatic roaming when the connection to Industrial Ethernet is interrupted (Forced Roaming)
- Cost savings generated by using a single wireless network for reliable operation of a process with both process-critical data (alarm message, for example) and non-critical communication (service and diagnostics, for example)
- Cost-effective connection to devices in remote environments that are difficult to access
- Predictable data traffic (deterministic) and defined response times
- Cyclical monitoring of the wireless link (link check)

Objectives and advantages of Industrial Wireless LAN

Wireless data transmission achieves the following objectives:

- Seamless integration of PROFINET devices into the existing bus system via the wireless interface
- Mobile use of PROFINET devices for different production-linked tasks
- Flexible configuration of the system components for fast development in accordance with customer requirements
- Maintenance costs are minimized by savings in cables

Application examples

- Communication with mobile subscribers (mobile controllers and devices, for example), conveyor lines, production belts, translation stages, and rotating machines
- Wireless coupling of communication segments for fast commissioning or cost-effective networking where routing of wires is extremely expensive (e.g. public streets, railroad lines)
- Stacker trucks, automated guided vehicle systems and suspended monorail systems

The following graphic illustrates the many possible applications and configurations for SIMATIC device family wireless networks.

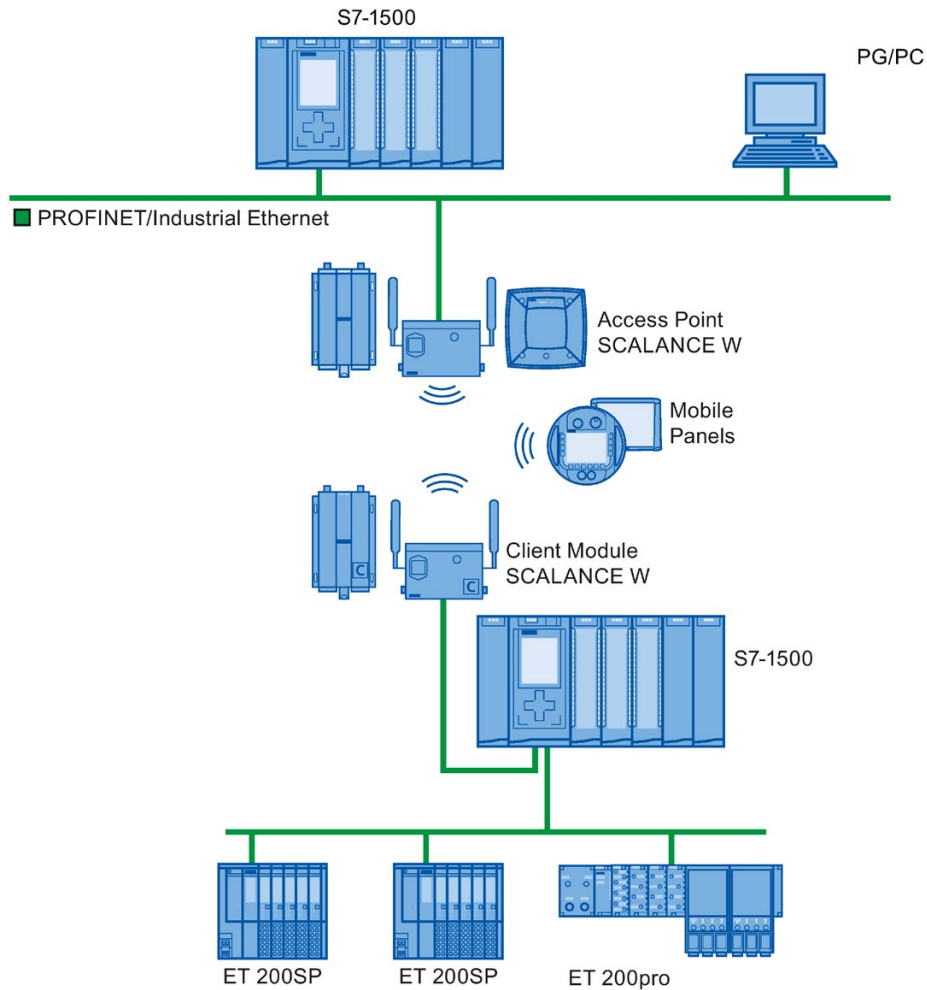


Figure 2-9 Application example for the use of Industrial Wireless LAN

Data transmission rate

In Industrial Wireless LAN, gross data transmission rates of 11 Mbps or 54 Mbps without full duplex are permitted.

Range

With SCALANCE W (access points), wireless networks can be set up indoors and outdoors. Multiple access points can be installed to create large wireless networks in which mobile subscribers are transferred seamlessly from one access point to another (roaming).

As an alternative to a wireless network, point-to-point connections of Industrial Ethernet segments can also be set up over large distances (several hundred meters). In this case, the range and characteristics of the RF field are determined by the antennas used.

Note

Range

The range can be considerably less, depending on spatial factors, the wireless standard used, the data rate, and the antennas on the send and receive sides.

2.2.3.2 Tips on assembly

Wireless networks, SCALANCE device family

With PROFINET, you can also set up wireless networks with Industrial Wireless Local Area Network (IWLAN) technology. We recommend implementing the SCALANCE W device line for this.

Update time in STEP 7

If you set up PROFINET with Industrial Wireless LAN, you may have to increase the update time for the wireless devices. The IWLAN interface provides lower performance than the wired data network: Several communication stations have to share the limited transmission bandwidth. For wired solutions, 100 Mbps is available for each communication device.

The Update time parameter can be found in the "Realtime settings" section in the Inspector window of IO devices in STEP 7.

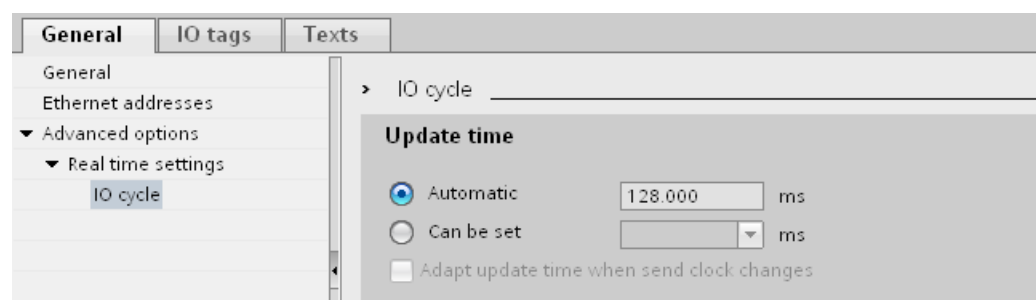


Figure 2-10 Update time in STEP 7

Additional information

More information about SCALANCE W Industrial Wireless LAN components can be found in the manual SIMATIC NET SCALANCE W-700 (<http://support.automation.siemens.com/WW/view/en/42784493>).

More information about wired data transmission can be found in the manual SIMATIC NET Twisted Pair and Fiber Optic Networks (<http://support.automation.siemens.com/WW/view/en/8763736>).

More information about wireless data transmission can be found in the manual Basics for configuring an industrial wireless LAN (<http://support.automation.siemens.com/WW/view/en/9975764>).

You should also read the PROFINET installation guideline of the PROFIBUS User Organization on the Internet (<http://www.profibus.com/nc/download/installation-guide/downloads/profinet-installation-guide/display/>). Various documents that assist with the setting up of your PROFINET automation solution are available here:

- PROFINET planning guideline
- PROFINET installation guideline
- PROFINET commissioning guideline
- Additional documents for setup of PROFINET

2.2.4 Network security

2.2.4.1 Basics

Introduction

The topic of data security and access protection (Security) has become increasingly important in the industrial environment. The increased networking of entire industrial systems, vertical integration and networking of levels within a company and new techniques such as remote maintenance all result in higher requirements for protecting the industrial plant.

Data security solutions for office environments cannot simply be transferred one-to-one to industrial applications to protect against manipulation in sensitive systems and production networks.

Requirements

Additional security requirements arise from the specific communication requirements in the industrial environment (real-time communication, for example):

- Protection against interaction between automated cells
- Protection of network segments
- Protection against faulty and unauthorized access
- Scalability of network security
- Must not influence the network structure

Definition of security

Generic term for all the measures taken to protect against:

- Loss of confidentiality due to unauthorized access to data
- Loss of integrity due to manipulation of data
- Loss of availability due to destruction of data, for example, through faulty configuration and denial-of-service attacks

Threats

Threats can arise from external and internal manipulation. The loss of data security is not always caused by intentional actions.

Internal threats can arise due to:

- Technical errors
- Operator errors
- Defective programs

Added to these internal threats there are also external ones. The external threats are not really any different to the known threats in the office environment:

- Software viruses and worms
- Trojans
- Man-in-the-middle attacks
- Password Phishing
- Denial of Service

Protective measures

The most important precautions to prevent manipulation and loss of data security in the industrial environment are:

- Physical access protection to the devices
- Filtering and control of data traffic by means of firewall
- A virtual private network (VPN) is used to exchange private data on a public network (Internet, for example).

The most common VPN technology is IPsec. IPsec (Internet Protocol Security) is a collection of security protocols that are used as the basis for the IP protocol at the mediation level and allow a secured communication via potentially unsecure IP networks.

- Segmenting in protected automation cells

This concept has the aim of protecting the lower-level network devices by means of security modules. A group of protected devices forms a protected automation cell.

- Authentication (identification) of the devices

The security modules identify each other over a safe (encrypted) channel using authentication procedures. It is therefore impossible for unauthorized parties to access a protected segment.

- Encrypting the data traffic

The confidentiality of data is ensured by encrypting the data traffic. Each security module is given a VPN certificate which includes the encryption key.

2.2.4.2 Network components and software

Protection against unauthorized access

The following solutions may be used to connect industrial networks to the intranet and Internet to protect against internal and external threats:

- Communication processors, such as the SIMATIC CP 1543-1
- SCALANCE X-300 and SCALANCE S - the data security components of the SIMATIC NET product family
- SOFTNET security client for use on PCs

Features

Both of these products have a wide variety of features, such as:

- Easy integration of existing networks without configuration, with integrated firewall.
- Segmenting in protected automation cells
- Authentication (identification) of the devices
- Encrypting the data traffic

2.2.4.3 Application example

Data security at the office and production levels

The following graphic contains an application example with protected areas at different levels of the company created using SCALANCE S and the security client. The protected areas are highlighted in light gray.

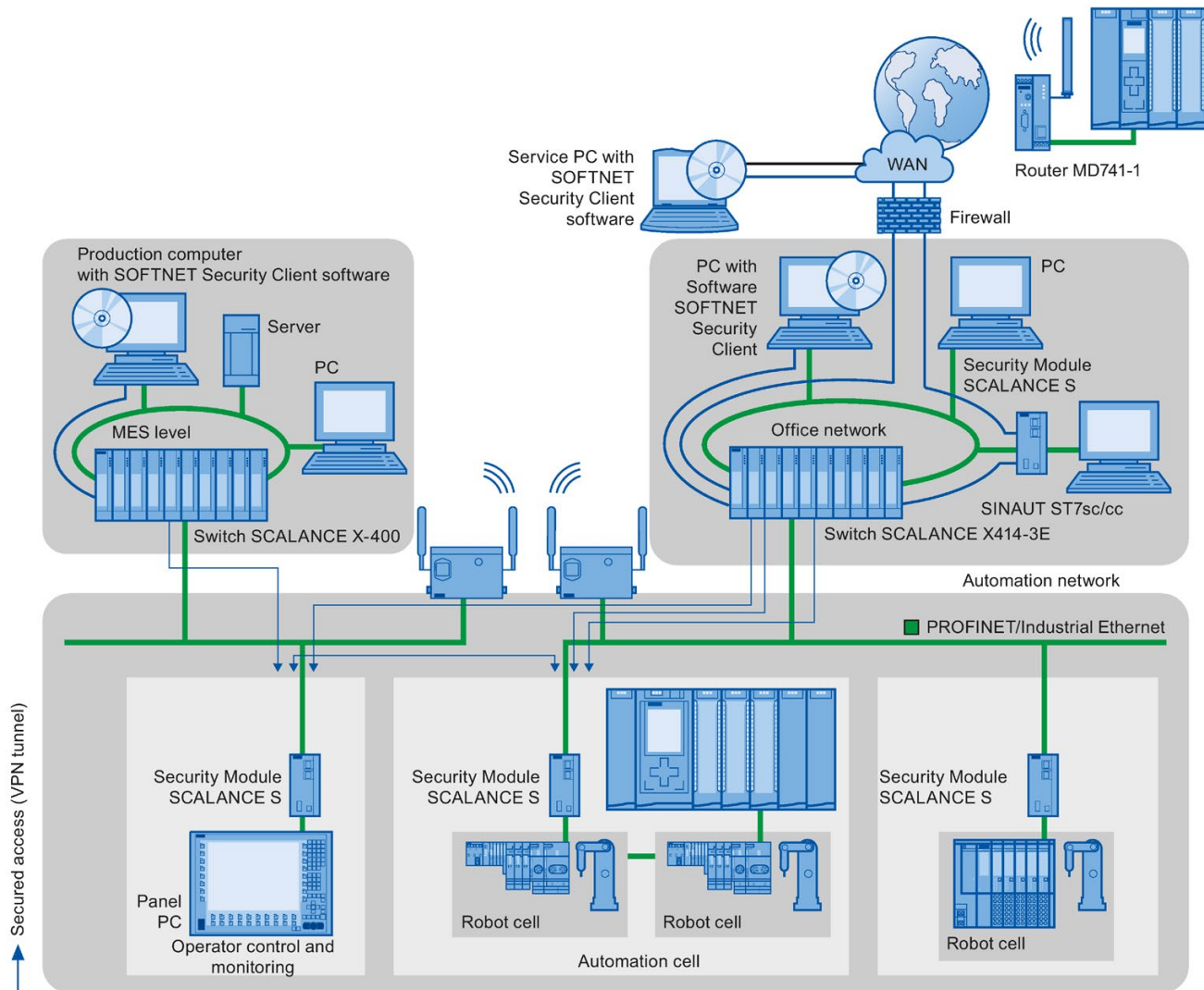


Figure 2-11 Network configuration with the SCALANCE S security module and the SOFTNET security client

Additional information

Additional information on the configuration of a security standard in PROFINET, is available:

- In the PROFINET security guideline. These guidelines can be found on the homepage of the PROFIBUS user organization on the Internet (<http://www.profinet.com>).
- In the Industrial Ethernet Security (<http://support.automation.siemens.com/WW/view/en/56577508>) manual
- In the SCALANCE S and SOFTNET Security Client (<http://support.automation.siemens.com/WW/view/en/21718449>) manual

You can find general information on industrial security concepts, functions and news on the Industrial Security website (<http://www.siemens.com/industrialsecurity>).

Parameter assignment/addressing

To set up an automation system, you will need to configure, assign parameters and interlink the individual hardware components. In STEP 7, the work needed for this is undertaken in the device, topology and network view.

Configuring

"Configuring" is understood to mean arranging, setting and networking devices and modules within the device, topology or network view.

An I/O address is automatically assigned to each module. The I/O addresses can be subsequently modified.

The CPU compares the configuration preset in STEP 7 with the actual current configuration of the system. In this way, potential errors can be detected and reported straight away.

The exact procedure for configuring devices is described in detail in the STEP 7 online help.

Assigning parameters

"Assigning parameters" is understood to mean setting the properties of the components used. The settings for the hardware components and for data communication are configured at the same time.

In STEP 7, you can "assign parameters" for the following settings PROFINET:

- Device names and IP address parameters
- Port interconnection and topology
- Module properties / parameters

The parameters are loaded into the CPU and transferred to the corresponding modules when the CPU starts up. Modules are easy to replace from spare parts, as the parameters assigned for the SIMATIC CPUs are automatically loaded into the new module at each startup.

Adjusting the hardware to the project requirements

You need to configure hardware if you want to set up, expand or change an automation project. To do this, add hardware components to your structure, link these with existing components, and adapt the hardware properties to the tasks.

The properties of the automation systems and modules are preset such that in many cases they do not have to be assigned parameters again.

Parameter assignment is however needed in the following cases:

- You want to change the default parameter settings of a module.
- You want to use special functions.
- You want to configure communication connections.

3.1 Assigning an IO device to an IO controller

PROFINET IO System

A PROFINET IO system is comprised of a PROFINET IO controller and its assigned PROFINET IO devices. After these devices have been placed in the network or topology view, STEP 7 assigns default values for them. Initially, you only have to worry about the assignment of IO devices to an IO controller.

Requirement

- You are in the network view of STEP 7.
- A CPU has been placed (e.g., CPU 1516-3 PN/DP).
- An IO device has been placed (e.g., IM 155-6 PN ST).

Procedure

To assign IO devices to an IO controller, proceed as follows:

1. Place the pointer of the mouse over the interface of the IO device.
2. Press and hold down the left mouse button.
3. Move the pointer.

The pointer now uses the networking symbol to indicate "Networking" mode. At the same time, you see the lock symbol on the pointer. The lock symbol disappears only when the pointer is over a valid target position.

4. Now move the pointer onto the interface of the IO controller. You can keep the left mouse button pressed or release it when performing this action.

5. Now release the left mouse button or press it again (depending on your previous action).

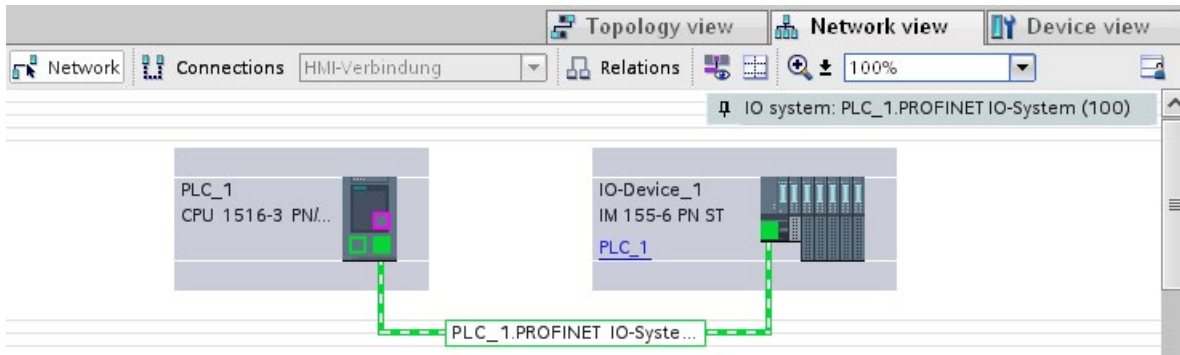


Figure 3-1 Assigning an IO device to an IO controller in the network view of STEP 7

Result

You have assigned an IO device to an IO controller.

Checking the assignment

You can find an overview of the communication relationships in the "IO communication" tab in the tabular area of the network view. This table is context-sensitive for selection in the graphic area:

- Selection of the interface shows the I/O communication of the respective interface.
- Selection of the CPU shows all I/O communication of the CPU (including PROFIBUS).
- Selection of the station (as in the above figure) interface shows the I/O communication of the complete station.

Information on S7-1500R/H

You can find the procedure for assigning an IO device with system redundancy S2 to the redundant S7-1500R/H system in section Assigning IO device to the redundant S7-1500R/H system (Page 287).

3.2 Device name and IP address

Introduction

In order that the PROFINET device can be addressed as node on PROFINET, the following are required:

- A unique PROFINET device name
- A unique IP address in the relevant IP subnet

STEP 7 assigns a device name during the arrangement of a PROFINET device in the hardware and network editor. The IP addresses are typically assigned automatically by STEP 7 and assigned to the devices based on the device name.

You can change the name and IP address manually.

In STEP 7

You can find the device name and the IP address under "Ethernet addresses" in the properties of the PROFINET interface in the Inspector window.

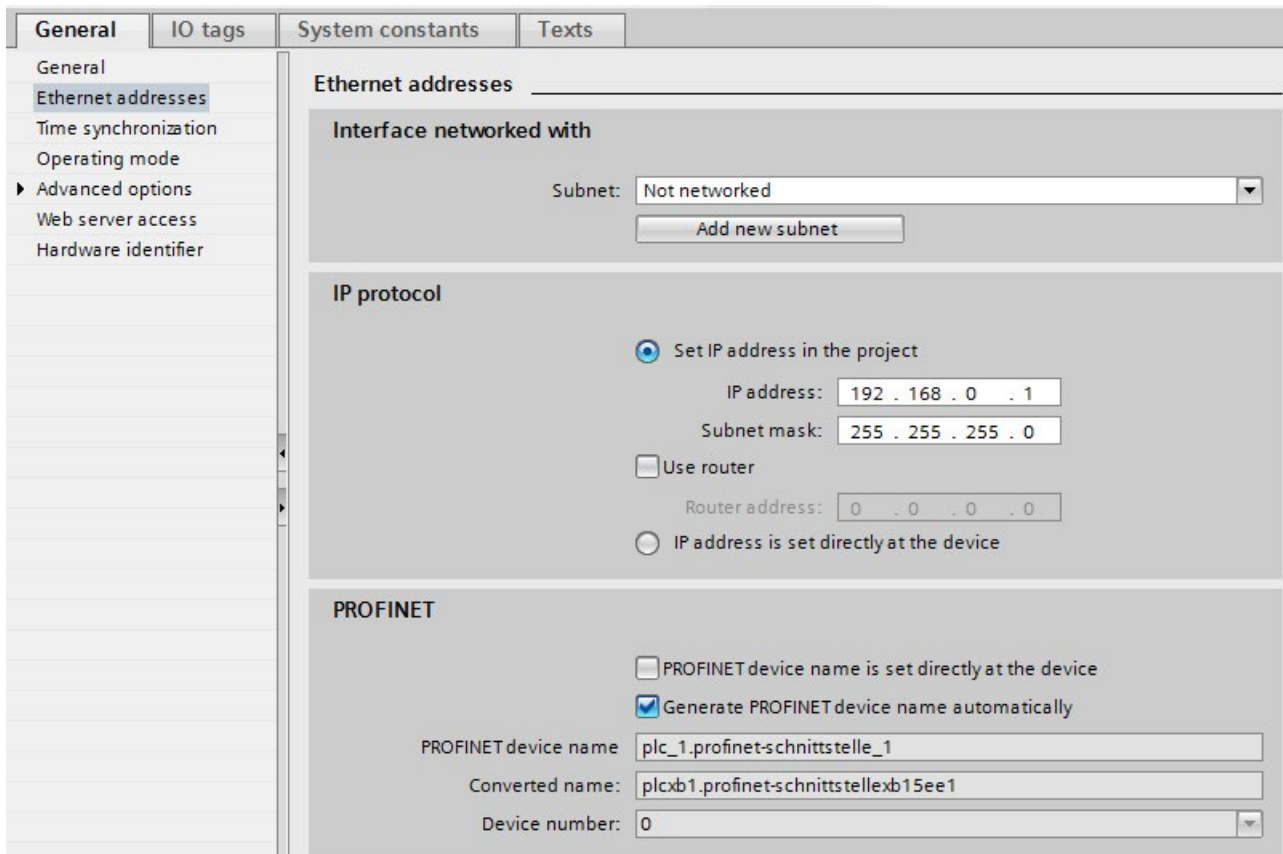


Figure 3-2 Device name and IP address in STEP 7

The function, the assignment and the changing of the device name and the IP address are described in the following sections.

3.2.1 Device name

Device names

Before an IO device can be addressed by an IO controller, it must have a device name. In PROFINET, this method was selected because it is simpler to work with names than with complex IP addresses.

The assignment of a device name for a specific IO device can be compared to setting the PROFIBUS address of a DP slave.

In delivery state, an IO device does not have a device name. A device name must first be assigned before an IO device can be addressed by an IO controller, for example, for transferring configuration data during startup or for exchanging user data in cyclic mode. You assign the device names to the IO device, for example, with the programming device / PC.

IO devices that have a slot for removable storage media provide the option of writing the device name directly to the removable storage medium in the programming device.

When a device is replaced by a device without removable medium, the IO controller assigns the device name based on topological configuration (see section Configuring topology (Page 64)).

Structured device names

The device name is automatically assigned by default for PROFINET devices S7-1200, S7-1500, ET 200MP, ET 200SP and ET 200AL when these are configured in STEP 7. The device names are formed from the name of the CPU or the name of the interface module. For devices with several PROFINET interfaces, the name of the interface is enhanced, for example, "plc_1.profinet-interface_2" or "io-device_1".

You can structure the device names using DNS conventions.

These conventions are defined by "Internationalizing Domain Names in Applications (IDNA). According to this, device names are written in lower case.

The "Domain Name System" (DNS) is a distributed database (<http://iana.org>), which manages the name space on the Internet. To structure the names, you use the dot ("."). The hierarchy is shown in ascending order from left to right.

...<Subdomain name>.<Domain name>.<Top-level domain name>

If the name is not DNS-compliant, the name will be converted by STEP 7, for example, to "plcxb1.profinet-schnittstellcxb2022c" or "io-devicexb15b32".

Device number

In addition to the device name, STEP 7 also assigns a device number beginning with "1" when an IO device is allocated.

The device number is located in the Inspector window in the properties of the PROFINET interface, under "Ethernet addresses" in the area PROFINET.

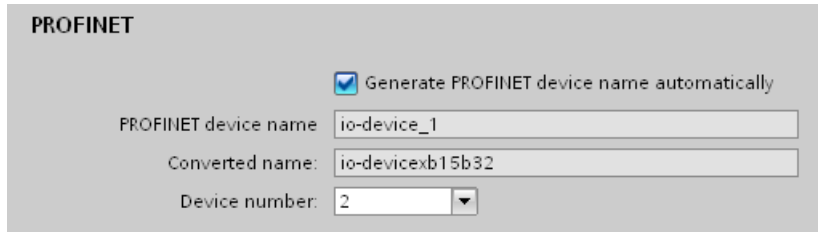


Figure 3-3 Device number

This device number can be used to identify an IO device in the user program (for example, with the instruction "LOG2GEO").

3.2.2 IP address

IP address

To allow a PROFINET device to be addressed as a device on Industrial Ethernet, this device also requires an IP address that is unique within the network. The IP addresses are typically assigned automatically by STEP 7 and assigned to the devices based on the device name. If it is a standalone network, you can apply the IP address and subnet mask suggested by STEP 7. If the network is part of an existing Ethernet company network, obtain the information from your network administrator.

Configuration of the IP address

In accordance with Internet Protocol version 4 (IPv4), the IP address is made up of four decimal numbers with a range of values from 0 through 255. The decimal numbers are separated by periods (for example, 192.162.0.0).

The IP address consists of the following:

- Address of the network
- Address of the device (PROFINET interface of the IO controller/IO device)

Generating IP addresses

You assign the IP addresses of the IO devices in STEP 7. The IO devices receive their IP addresses during parameter assignment by the IO controller. In addition, for some IO devices (e.g., SCALANCE X, S7-300 CPs), it is possible not to obtain the IP address during startup of the IO controller, but rather to set it beforehand on the device (see Permitting changes to the device name and IP address directly on the device (Page 57)).

The IP addresses of the IO devices always have the same subnet mask as the IO controller and are assigned from the IP address of the IO controller in ascending order. The IP address can be changed manually, if necessary.

For devices with several PROFINET interfaces (e.g., CPU 1516-3 PN/DP), the IP addresses must be located in different subnets.

Default router

The default router is used when data has to be forwarded via TCP/IP or UDP to a partner located outside the local network.

In STEP 7, the default router is named Router. You can activate the use of a router in the Inspector window of a CPU with the "Use router" check box in the "IP protocol" section. STEP 7 assigns the local IP address to the default router by default.

The router address that is set on the PROFINET interface of the IO controller is automatically transferred for the configured IO devices.

Subnet mask

The bits set in the subnet mask decide the part of the IP address that contains the address of the network.

In general, the following applies:

- The network address is obtained from the AND operation of the IP address and subnet mask.
- The device address is obtained from the AND NOT operation of the IP address and subnet mask.

Example of the subnet mask

Subnet mask: 255.255.0.0 (decimal) = 11111111.11111111.00000000.00000000 (binary)

IP address: 192.168.0.2 (decimal) = 11000000.10101000.00000000.00000010 (binary)

Meaning: The first 2 bytes of the IP address determine the network - i.e., 192.168. The last two bytes address the device, i.e. 0.2.

Relation between IP address and default subnet mask

An agreement exists relating to the assignment of IP address ranges and so-called "Default subnet masks". The first decimal number (from the left) in the IP address determines the structure of the default subnet mask with respect to the number of "1" values (binary) as follows:

IP address (decimal)	IP address (binary)	Address class	Default subnet mask
0 to 126	0xxxxxxx.xxxxxxxx....	A	255.0.0.0
128 to 191	10xxxxxx.xxxxxxxx...	B	255.255.0.0
192 to 223	110xxxxx.xxxxxxxx...	C	255.255.255.0

Note

Range of values for the first decimal point

A value between 224 and 255 is also possible for the first decimal number of the IP address (address class D etc.). However, this is not recommended because there is no address check for these values.

Masking other subnets

You can use the subnet mask to add further structures and form "private" subnets for a subnet that is assigned one of the address classes A, B or C. This is done by setting other, less significant bits of the subnet mask to "1". For each bit set to "1", the number of "private" networks doubles and the number of devices they contain is halved. Externally, the network continues to function as an individual network.

Example:

You have a subnet of address class B (for example, IP address 129.80.xxx.xxx) and change the default subnet mask as follows:

Masks	Decimal	Binary
Default subnet mask	255.255.0.0	11111111.11111111.00000000.00000000
Subnet mask	255.255.128.0	11111111.11111111.10000000.00000000

Result:

All devices with addresses from 129.80.001.000 to 129.80.127.254 are located in a subnet, all devices with addresses from 129.80.128.000 to 129.80.255.254 in a different subnet.

Reading out an IP address in the user program

You can read out the IP address of a PROFINET device in the user program of a S7-1500 CPU. You can find information in this FAQ

(<https://support.industry.siemens.com/cs/ww/en/view/82947835>).

3.2.3 Assigning a device name and IP address

Assigning an IP address and subnet mask for an IO controller for the first time

You have the following options:

- **Using a programming device or PC:**

Connect your programming device/PC to the same network as the relevant PROFINET device. The interface of the programming device/PC must be set to TCP/IP mode. During the download, first of all display all available devices via the "Accessible devices" download dialog box. Select the target device via its MAC address and then assign its IP address before you download the hardware configuration including the configured IP address (IP address is saved retentively).

- **Using the display of a S7-1500 CPU:**

The S7-1500 CPUs have a front cover with a display and operating keys. You can use this display to assign or change the IP address. To set the IP address, navigate on the display via the menu items "Settings" > "Addresses" > "X1 (IE/PN)" > "Parameters".

- **Using a memory card:**

If your PROFINET device is equipped for a memory card (Micro Memory Card/SIMATIC memory card), plug this into your programming device/PC and save the hardware configuration together with the configured IP address on this memory card. Then plug the memory card into the PROFINET device. Once inserted, the PROFINET device automatically applies the IP address.

If you have saved a configuration to the memory card with the "IP address is set directly at the device" option, you must assign the IP address using a different method after inserting the memory card (see section Permitting changes to the device name and IP address directly on the device (Page 57)).

Assigning device names and IP address for "Device replacement without exchangeable medium/programming device"

For devices without exchangeable medium (e.g., ET 200MP, ET 200SP) and devices that support "Device replacement without exchangeable medium/PG" (e.g., ET 200S), the IO controller can identify the device without name from the neighbor relationships specified by the set topology and from actual neighbor relationships determined by the real PROFINET devices. The IO controller then assigns the PROFINET device the configured name and incorporates the PROFINET device in the user data traffic. (See also Device replacement without exchangeable medium (Page 225)).

IP address assignment when replacing IO devices with exchangeable mediumPG

The following is contained on the memory card of the programmable logic controller:

- On the IO controller: Device name and IP address
- On the IO device: Device name

When you remove the memory card from a PROFINET device and insert it in another PROFINET device with exchangeable medium (e.g., ET 200S), device-specific information and the device name are loaded to the device.

If an IO device has to be replaced in its entirety due to a device or module defect, the IO controller automatically assigns parameters and configures the replaced device or module. The cyclic exchange of user data is then restarted. In addition to this, before the power ON of the IO device, the memory card with the valid name must be removed from the faulty IO device and added to the replaced device.

In the event of an error in the PROFINET device, the memory card allows you to replace a module without a programming device/PC. You can also transfer the device data directly from the programming device/PC to the memory card.

Procedure: Changing the device name using properties of the PROFINET interface

You can change the PROFINET name via the properties of the PROFINET interface. This is useful when the PROFINET device has not received its previous name from the automatic generation, for example, in the case of a migration.

1. In the network or device view of the STEP 7 hardware and network editor, select the PROFINET interface of a PROFINET device.
2. In the Inspector window, go to "Ethernet addresses" in the PROFINET area.
3. Clear the "Generate PROFINET device name automatically" check box.
4. Enter the new PROFINET device name in the relevant field.

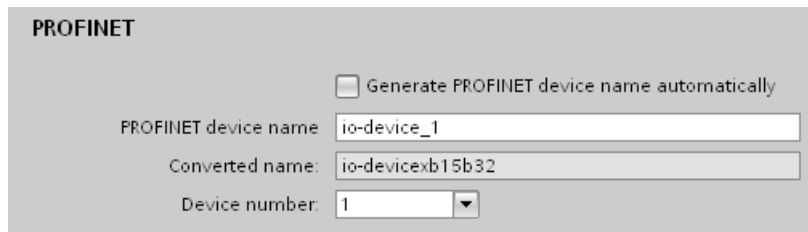


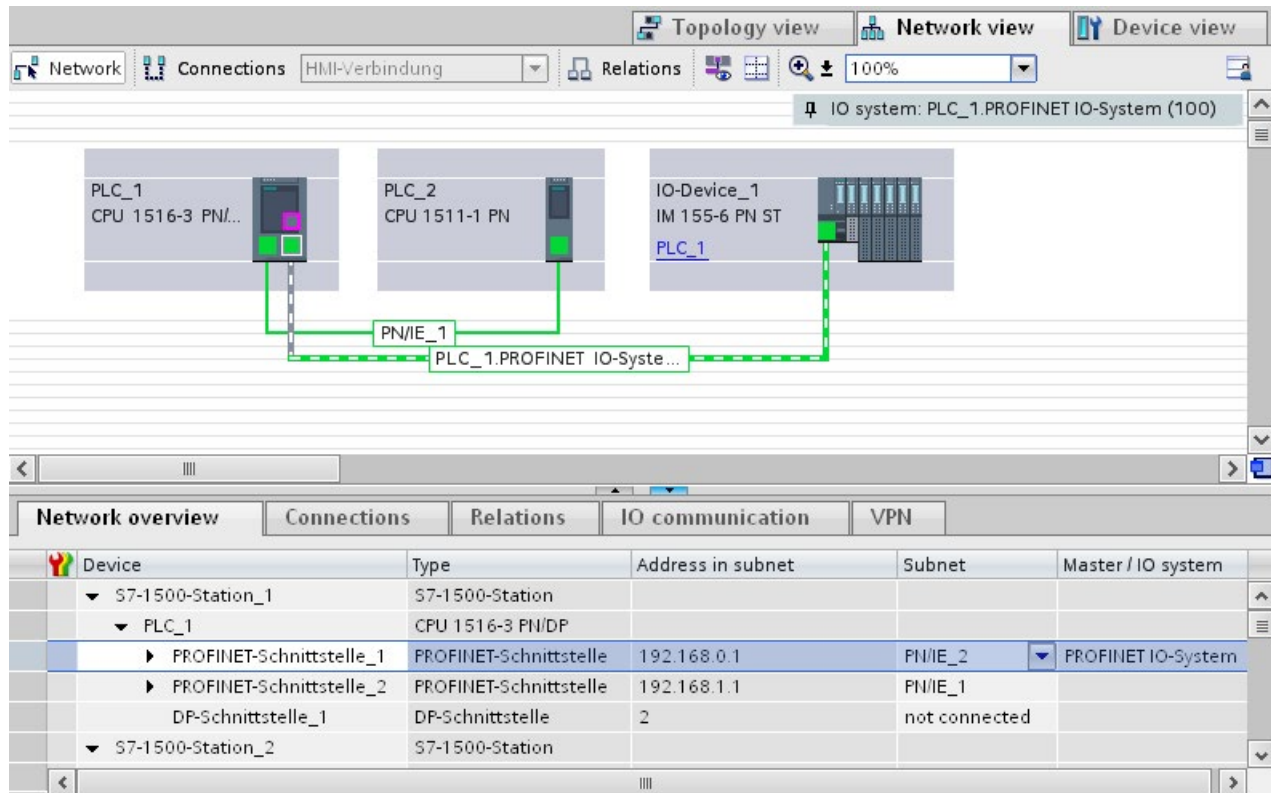
Figure 3-4 Changing the device name of a PROFINET device in the properties

Alternative procedure: Changing the device name of a PROFINET device in the network view

Requirement: The "Generate PROFINET device name automatically" check box is selected.

1. In STEP 7, select the "Network overview" tab in the tabular area of the network view.
2. In the "Device" column, overwrite the name in the row of the relevant PROFINET device.

The name is also changed accordingly in the graphic area of the network view.



Device	Type	Address in subnet	Subnet	Master / IO system
▼ S7-1500-Station_1	S7-1500-Station			
▼ PLC_1	CPU 1516-3 PN/DP			
▶ PROFINET-Schnittstelle_1	PROFINET-Schnittstelle	192.168.0.1	PN/IE_2	▼ PROFINET IO-System
▶ PROFINET-Schnittstelle_2	PROFINET-Schnittstelle	192.168.1.1	PN/IE_1	
DP-Schnittstelle_1	DP-Schnittstelle	2	not connected	
▼ S7-1500-Station_2	S7-1500-Station			

Figure 3-5 Changing the device name of a PROFINET device in STEP 7

Procedure: Changing the IP address

To change the IP address, follow these steps:

1. In the network or device view of the STEP 7 hardware and network editor, select the PROFINET interface of a PROFINET device.
2. In the Inspector window, go to "Ethernet addresses" in the "IP protocol" area.

3. Check that the option "Set IP address in the project" is selected.
4. Enter the new IP address in the relevant field.

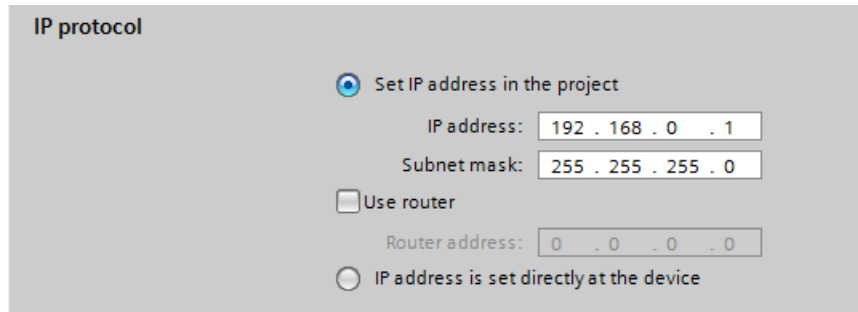


Figure 3-6 Changing the IP address of a PROFINET device in STEP 7

Downloading configured device name to IO device

To load the configured device names to the IO device, follow these steps:

1. Connect your programming device/PC to the same network as the relevant IO device. The interface of the programming device/PC must be set to TCP/IP mode.
2. In STEP 7, select the relevant IO device in the "Accessible devices" dialog based on the MAC address.
3. Click "Assign name" to download the configured device name to the IO device.

The IO controller recognizes the IO device automatically by its device name and automatically assigns the configured IP address to it.

Identification of the PROFINET device

To clearly identify a device from several identical devices in a control cabinet, for example, you can flash the link LED of the PROFINET device.

To do this, select the menu command **Online > Accessible devices...** in STEP 7. In the "Accessible devices" dialog, set the "PG/PC" interface by means of which you are connected to the devices. STEP 7 now automatically searches for the accessible devices and displays them in the "Accessible devices in target subnet" table. Select the desired PROFINET device and click on the "Flash LED" button. The PROFINET device is identified based on its MAC address.

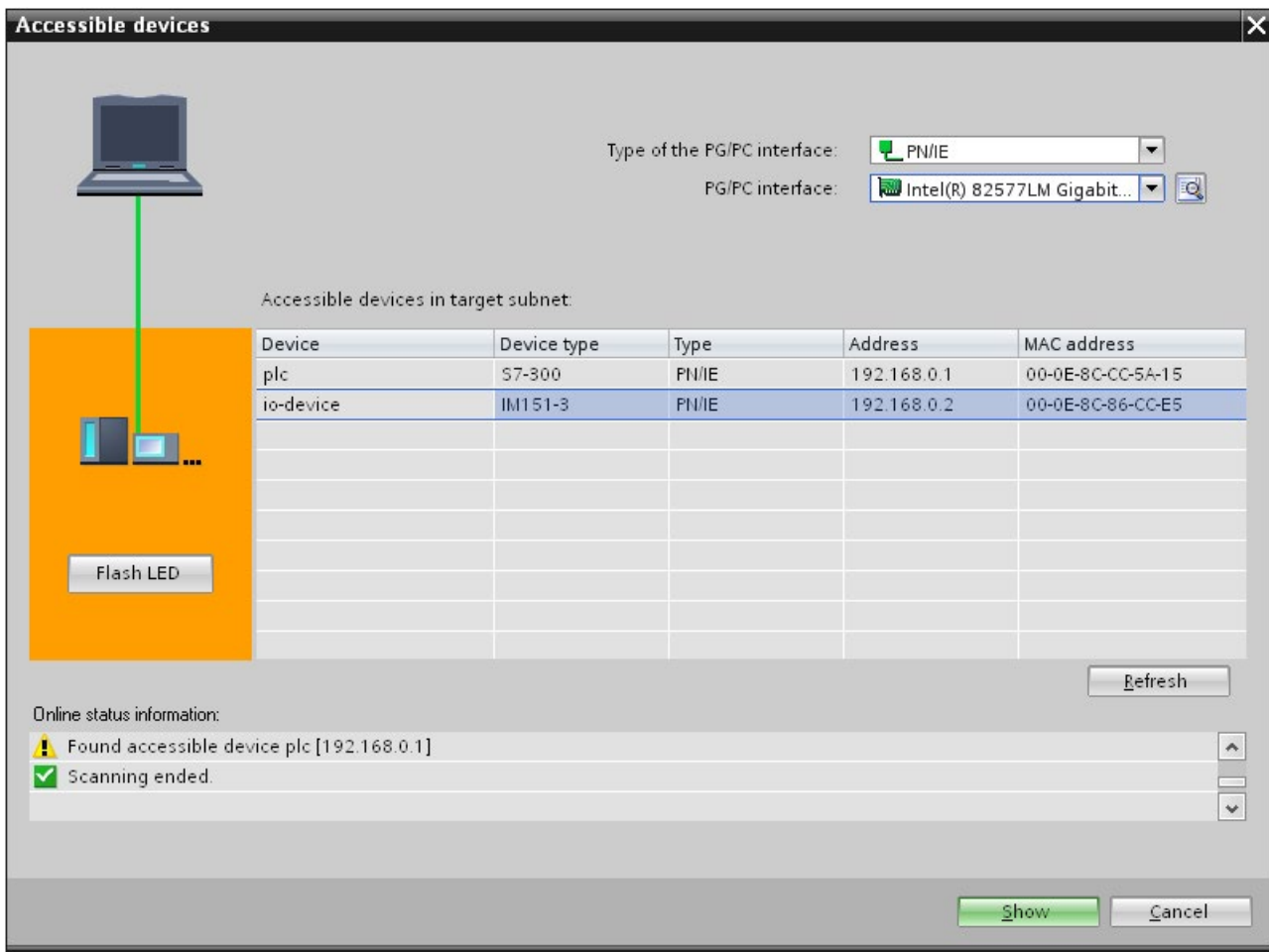


Figure 3-7 "Accessible devices" dialog

Using an different way to assign IP addresses for IO devices

Various IO devices, for example, SCALANCE X, S7-300 CPs, support the option of not having the IP addresses assigned by the IO controller during startup. In this case, the IP address is assigned in a different way. For additional information, refer to the manual of the respective PROFINET device of the SIMATIC device family.

Additional information

You can find a detailed description of the operation and functions of the display of the S7-1500 CPUs in the system manual S7-1500, ET 200MP (<http://support.automation.siemens.com/WW/view/en/59191792>).

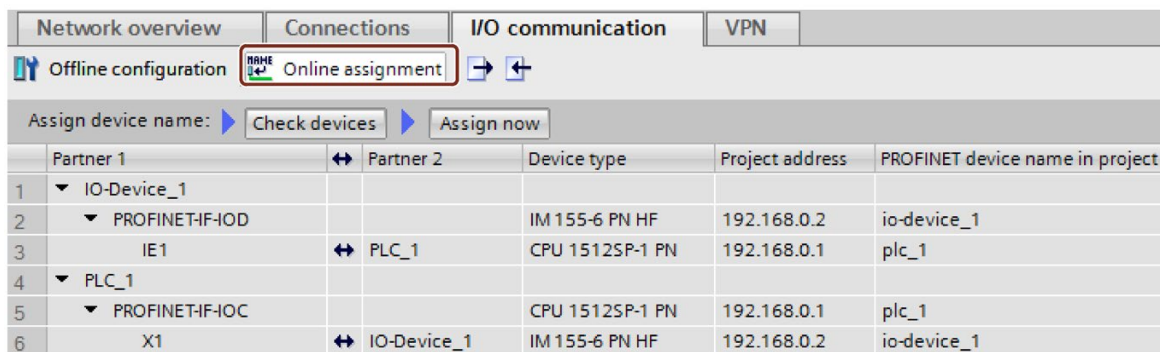
3.2.4 Assign device name via communication table

Introduction

You can assign the device names of PROFINET IO devices configured offline to the devices online. You can do this in the table area of the network view in the table "I/O communication". You can also assign the device names to several devices at the same time.

"Online assignment" tab

In the I/O communication table, you will find the tabs "Offline configuration" and "Online assignment". In the "Online assignment" tab, you can assign the PROFINET device names that were assigned offline to the corresponding IO devices online. To do this, use the buttons "Check devices" and "Assign now".



	Partner 1	↔	Partner 2	Device type	Project address	PROFINET device name in project
1	▼ IO-Device_1					
2	▼ PROFINET-IF-IOD			IM 155-6 PN HF	192.168.0.2	io-device_1
3	IE1	↔	PLC_1	CPU 1512SP-1 PN	192.168.0.1	plc_1
4	▼ PLC_1					
5	▼ PROFINET-IF-IOC			CPU 1512SP-1 PN	192.168.0.1	plc_1
6	X1	↔	IO-Device_1	IM 155-6 PN HF	192.168.0.2	io-device_1

Figure 3-8 Assign device name via communication table

The objects displayed in the table of the "Online assignment" tab depend on the setting of the filter function. If only selected objects should be displayed, only objects of the corresponding context are displayed depending on the selection in the network view.

- PROFINET subnet: All connected devices and their PROFINET interfaces
- IO system All devices involved and their PROFINET interfaces
- Sync domain: All devices involved and their PROFINET interfaces
- Devices: The device and any existing PROFINET interfaces
- Other subnets or interfaces such as MPI or PROFIBUS are not displayed

If the display is set for all devices using the filter function, all devices are displayed that have a PROFINET interface, regardless of whether they are connected via a PROFINET subnet or are part of an IO system. Devices without a PROFINET interface, for example only with a DP or MPI interface, are not displayed.

General procedure

To assign PROFINET device names, you must first detect the IO devices available online. With this procedure, it matters whether the MAC addresses are known or unknown. This results in a general procedure in two steps:

1. Detecting the IO devices available online
2. Assigning configured PROFINET device names to the IO devices available online

Requirements

- You are in the network view.
- There is an online connection to the devices.

Procedure (step 1)

To detect IO devices available online from the I/O communication table, follow these steps:

1. Optional: Entered known MAC addresses in the "MAC address" column. After every valid entry, the check box under "Assign device" is selected for the relevant row.

Note

You can enter, insert or import the MAC address in different formats. The correct format is automatically entered in the cell. The following entries are supported and then converted to the required format:






- "08:00:06:BA:1F:20"
- "08 00 06 BA 1F 20"
- "080006BA1F20"

The formats used in the example are automatically converted to "08-00-06-BA-1F-20".

2. Click "Check devices" to start the check of the IO devices available online.
3. Set the PG/PC interface in the dialog window and click "Start".

Intermediate result

After the check, the result is displayed for every device in the table. Online data found is automatically entered in the table and the check box "Assign device" is set to "checked" in the rows in which a MAC address was entered or found online. The result of the check is shown as an icon in the "Status" column.

Status	Meaning
	Matching device and compatible type
	Matching device and incompatible type
	Non-matching device
	Device cannot be reached (with a known MAC address)
	Ready for assignment (with known MAC address)

Note

The icon "Ready for assignment" appears when a MAC address exists and matching device data was found, but no PROFINET device name was found online.

You can update the data of the detected devices again via their MAC addresses at any time. To do this, you specify the MAC address and the status of the device is displayed immediately without having to re-detect the device.

Procedure (step 2)

All PROFINET device names configured offline will be assigned to the devices available online in a bulk operation.

1. Click the "Assign now" button.

Note

The bulk operation cannot be reversed. A message to this effect appears in a dialog window.

2. Click "Start" in the dialog window to start the assignment of the PROFINET device names.

Result

The PROFINET device names configured offline will be assigned to the devices available online. This relates to devices in whose row the check box under "Assign device" is selected, that have a MAC address and have the status "Ready for assignment".

Importing and exporting data

Using the import and export button, you can import or export the data of the I/O communication table for the online assignment:

- When you export, the currently displayed data of the table is exported to a CSV file. Using the filter function of the table, you can select which data will be exported.
- When you import, the data of the CSV file is written to the table. If there are conflicts with values already existing in the table, you can decide whether the data should be overwritten or whether the import needs to be stopped.

3.2.5 Permitting changes to the device name and IP address directly on the device

Introduction

Machines are frequently commissioned on site or integrated into the existing infrastructure without STEP 7. You can find typical applications in all areas of the series machine building. Alternative means for assigning the IP address are available for this.

Procedure

1. In the network or device view of the STEP 7 Hardware and Network editor, select the PROFINET interface of an IO controller.
2. Navigate in the Inspector window to "Ethernet addresses".

3.2 Device name and IP address

3. Select the "IP address is set directly at the device" option in the "IP protocol" area.
4. In the "PROFINET" area, select the "PROFINET device name is set directly at the device" check box.

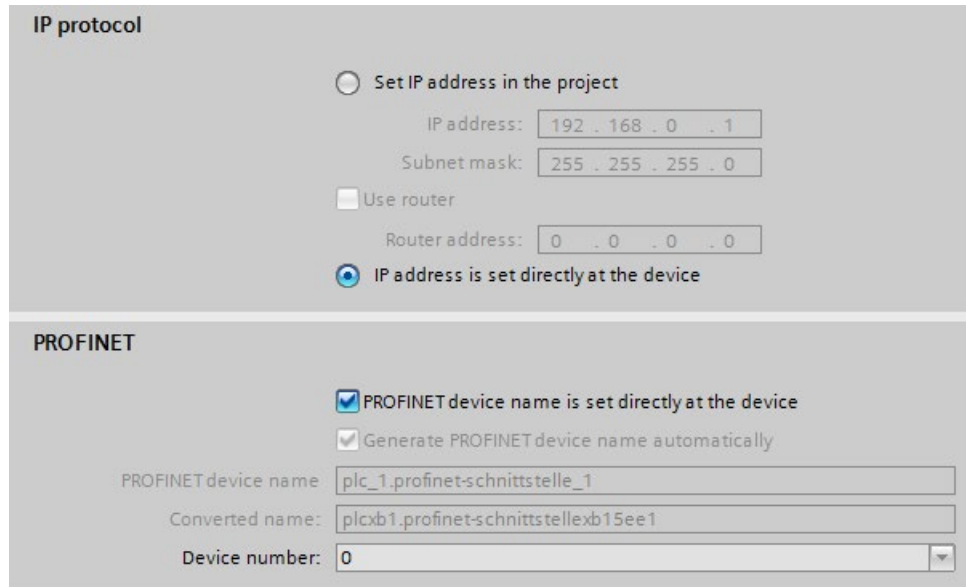


Figure 3-9 Setting the device name and IP address on the device

Note

Gateway

When you operate a PROFINET device with the option "Allow adaption of the device name/IP address directly on device", you cannot use this PROFINET device as gateway for S7 routing.

Options for assigning IP addresses and device names

Apart from the known address and device name assignment in the "Ethernet addresses" section of the Inspector window, there are other ways in which the IP address and name can be assigned:

- Assigning by means of the user program with the instruction "T_CONFIG"
- Assignment when downloading the configuration to the target system via the "Extended download to device" dialog box.
- Assignment via the Primary Setup Tool (PST)
- Assignment via the PRONETA ("PROFINET network analysis") commissioning and diagnostics tool
- Assignment via the SIMATIC Automation Tool

Additional information

For information on the "T_CONFIG" instruction and on downloading to the target system, refer to the STEP 7 online help.

A free Download (<http://support.automation.siemens.com/WW/view/en/14929629>) of the Primary Setup Tool (PST) can be found on the Internet. On this Internet page, you will also find a list of devices for which the PST is approved.

3.3 Configuring an IO device through hardware detection

Introduction

As of STEP 7 V15, you have the possibility to detect a real existing IO device and to import it into your project.

You find the IO device in STEP 7 through the "Hardware detection" function. A detected device can be imported into your project. STEP 7 inserts the IO device with all the modules and submodules.

Requirements

- STEP 7 (TIA Portal) as of V15
- It must be possible to technically access the IO device via IP

Procedure

To detect one or more existing IO devices in STEP 7 and add them to the project, follow these steps:

1. In STEP 7, navigate to "Online" > "Hardware detection".
2. Click "PROFINET devices from network...".
STEP 7 opens the "Hardware detection of PROFINET devices" window.
3. Select the interface of your programming device at "PG/PC interface:".
4. Click "Start search".
STEP 7 begins with the hardware detection. When the hardware detection is completed, STEP 7 displays the detected IO devices.
5. Select the IO devices that you want to add to the project by clicking the corresponding check box before the IO device.
6. Click "Add devices".
After a brief moment, a window is opens to report about the success or failure of the hardware detection.

Result of the hardware detection

If the hardware detection is successful, STEP 7 inserts the IO device with all the modules and submodules into the project.

An IO device configured via hardware detection responds as follows:

- Modules configured through the "Hardware detection" are configured as if they have been inserted from the catalog.
- MAC address: STEP 7 imports the MAC address of the detected IO device into the project.
- IP settings:
 - If the detected IO device already has an IP address, STEP 7 imports the IP address into the project.
 - If the detected IO device does not have an IP address, STEP 7 automatically assigns an IP address in the project.

PROFINET device name:

- If the detected IO device already has a PROFINET device name, STEP 7 imports the PROFINET device name into the project.
- If the detected IO device does not have a PROFINET device name, STEP 7 automatically assigns a PROFINET device name in the project.
- IO devices configured through "Hardware detection" have neither an IP subnet nor an IO controller assigned.

3.4 Specifying the router for a PROFINET IO device

Introduction

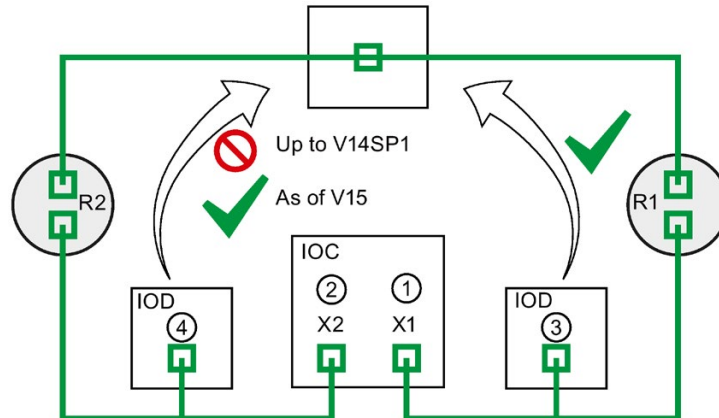
You always require a router (also referred to as a "Standard Gateway") when the PROFINET device has to communicate with a node whose IP addresses lie outside the own IP subnet. If the PROFINET device sends an IP packet to an IP address outside its own IP subnet, the IP packet first goes to the configured router. The router in turn checks the IP address. If this lies outside its own subnet, the router passes the IP packet on to the next router. The IP packet is routed to the next router until it has reached the target address.

Like all S7-1500 CPUs, S7-1500 CPUs with several PROFINET interfaces provide the possibility to configure the IP address of a router. However, there is the restriction that you can only enter the IP address of a router at a PROFINET interface.

You cannot configure an IP address of a router for the other PROFINET interfaces of the CPU. IO devices that are connected to this PROFINET interface adopt this setting. Up to and including STEP 7 V14 SP1, these IO devices did not have any possibility to reach devices in a different IP subnet.

As of STEP 7 V15, you have the possibility to assign the address of a router for an IO device independent of the setting of the IO controller. You can now, for example, set a router address at the IO device in the following cases as well:

- You have not set an IP address of a router for the interface of the associated IO controller.
- You have already set a router address for a different interface in the CPU.



- ① Router R1 configured at PROFINET X1
- ② If a router is configured at X1, you cannot configure a router at X2.
- ③ Because a router is configured at X1, the IO device adopts the IP address of the router R1. The IO device can be reached from a different IP subnet.
- ④ As of STEP 7 V15, you set the IP address of the router R2 at the IO device irrespective of the setting at the interface X2. The IO device can be reached from a different IP subnet.

Figure 3-10 Specifying the router for an IO device

Further information about the "User router" setting

You have the possibility to configure the use of a router including IP address of the router in the "IP protocol" section of the settings for the PROFINET interface (Ethernet addresses).

Rules

Observe the following rules if you want to configure a router for the PROFINET interface of an IO controller:

- A PROFINET IO device supports exactly one router, irrespective of the number of interfaces.
- You can configure a router for exactly one PROFINET interface. All IO devices that are assigned to the PROFINET interface adopt the configured router from the IO controller.
- You cannot configure a router for the further PROFINET interfaces of the CPU. The further PROFINET interfaces take on the IP address "0.0.0.0" as the router and pass it on to their IO devices.

As of STEP 7 V15, you can configure the use of a router for an IO device. This allows the IO device to communicate with a node outside its own IP subnet, irrespective of the setting of the PROFINET interface of the IO controller.

Configuration example: Configuring a router for an IO device

The following example shows a configuration in which you configure a router at the IO device so that the IO device reaches IP addresses in the higher-level network.

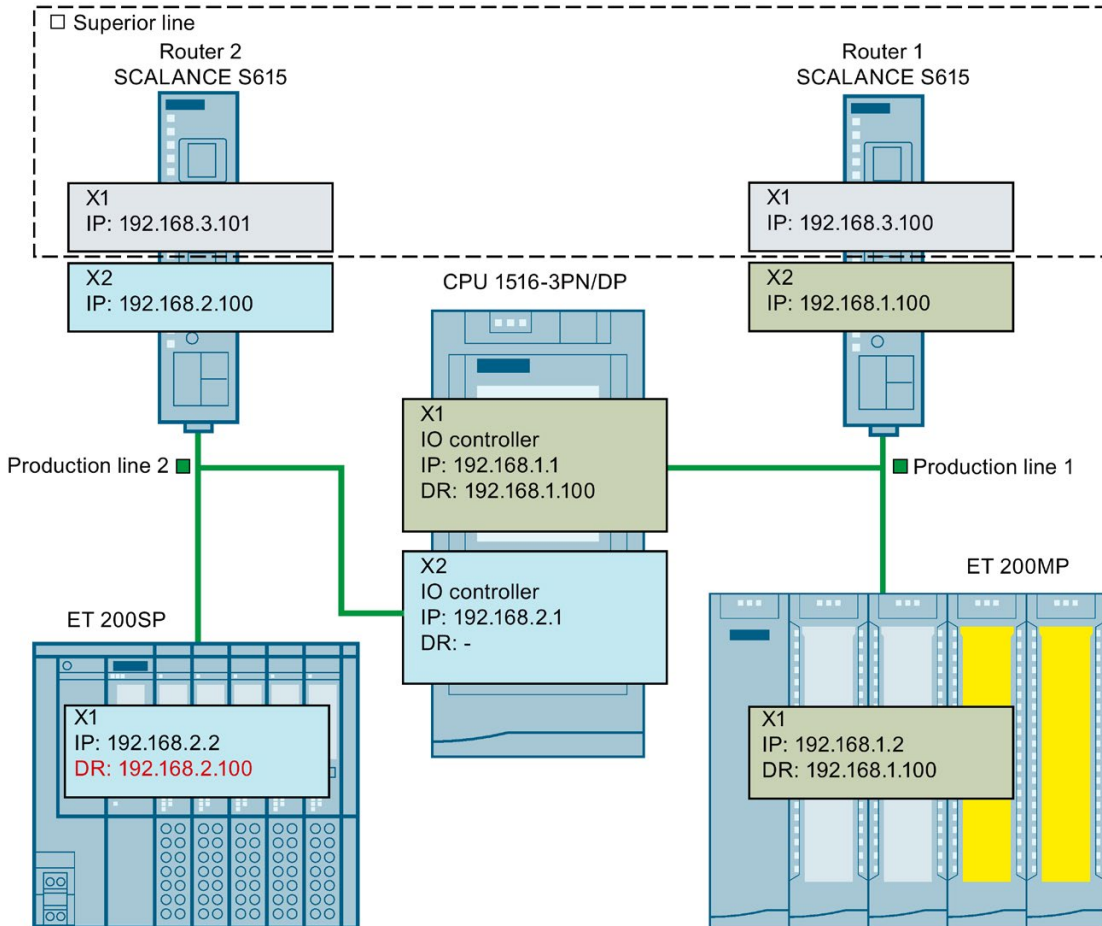


Figure 3-11 Configuration example: Configuring a router for an IO device

You have a CPU 1516-3PN/DP. The two PROFINET interfaces X1 and X2 of the CPU work in the "IO controller" operating mode. The PROFINET interface X1 is connected with the subnet "Production line 1". PROFINET interface X2 is connected with the subnet "Production line 2". The two subnets "Production line 1" and "Production line 2" are each connected via a router with the higher-level network "Superior line".

For PROFINET X1, you configure the router "Router 1" with the IP address 192.168.1.100.

The IO device (ET 200SP) in the "Production line 1" subnet adopts the router from the IO controller.

You cannot configure a router for the PROFINET interface X2 because you have already configured a router for the PROFINET interface X1 of the CPU.

No router is transferred by the PROFINET interface X2 to the IO device in the subnet "Production line 2".

In order for the IO device in the subnet "Production line 2" to reach nodes in the higher-level "Superior line", configure the router "Router 2" with the IP address 192.168.2.100 for the IO device.

Configuring the router for the IO controller

Requirements: You use the "Set IP address in the project" option for the PROFINET interface.

Follow these steps to configure a router for the IO controller in STEP 7:

1. In the network view of STEP 7, select the PROFINET interface of the IO controller.
2. In the Inspector window, navigate to "Properties" > "General" > "Ethernet addresses".
3. Select the "Use router" check box in the "IP protocol" field.
4. Enter the IP address of the router at "Router address".

Configuring a router for an IO device

Requirements:

- STEP 7 as of V15
- CPU 1500 as of firmware version V2.5
- IO device is assigned to the PROFINET interface of an IO controller. The PROFINET interface of the IO controller uses the "Set IP address in the project" option.

Follow these steps to configure a router for the IO device in STEP 7:

1. In the network view of STEP 7, select the PROFINET interface of the IO device.
2. In the Inspector window, navigate to "Properties" > "General" > "Ethernet addresses".
3. Clear the "Synchronize router settings with IO controller" check box.
4. Select the "Use router" check box.
5. Enter the IP address of the router at "Router address".

3.5 Configuring topology

Introduction

If an IO device is assigned to an IO controller, this does not yet specify how the ports are connected to each other.

A port interconnection is not required to use RT, but it provides the following advantages:

- A set topology is assigned with the port interconnection. Based on an online-offline comparison, it is possible to conduct a set-actual comparison with all devices that support this function.
- The "Device replacement without exchangeable medium" function can be used.

A port interconnection is an essential requirement for using IRT.

An overview of various options for setting up a PROFINET network is given below.

Line



All the communication devices are connected in a linear bus topology.

In PROFINET, the linear bus topology is implemented with switches that are already integrated into the PROFINET devices. Therefore, the linear bus topology at PROFINET is merely a special form of tree / star topology.

If a link element (switch, for example) fails, communication across the failed link element is no longer possible. The network is then divided into 2 subsegments.

Linear bus topology structures require the least cabling.

Star



If you connect communication devices to a switch with more than two PROFINET ports, you automatically create a star network topology.

If an individual PROFINET device fails, this does not automatically lead to failure of the entire network, in contrast to other structures. It is only if a switch fails that part of the communication network will fail as well

Tree



If you interconnect several star structures, you obtain a tree network topology.

Ring



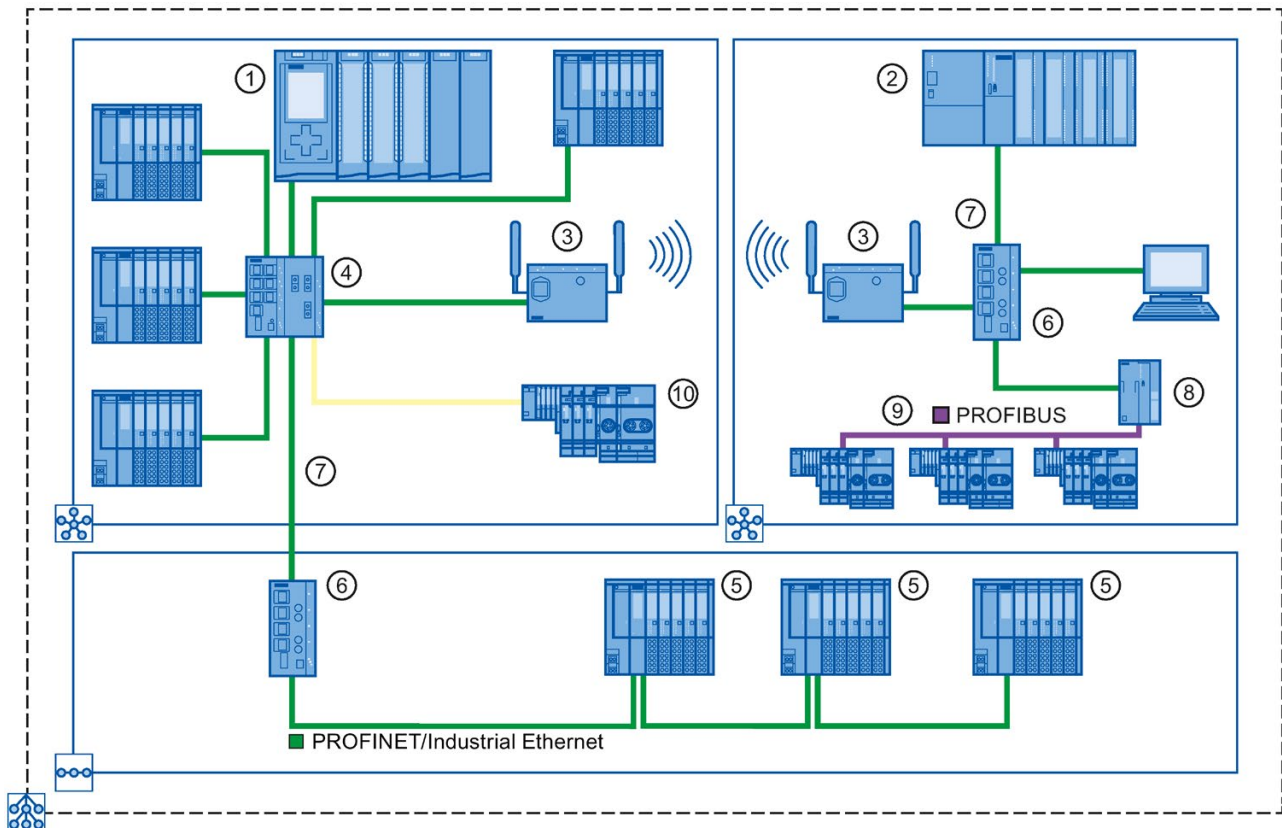
In order to increase the availability of a network, use ring structures. In principle, a linear bus topology is connected to a ring through a so-called redundancy manager.

The task of the redundancy manager is managed by an external switch SCALANCE X, a CPU that supports the Media Redundancy Protocol MRP (e.g., CPU 1516-3 PN/DP) or a CP (e.g., CP 343-1 Lean).

If there is a break in the network, the redundancy manager ensures that the data is redirected over an alternative network connection in the ring.

Example for topology

The following example shows a combination of different topologies.



Number Meaning

- ① S7-1500 as IO controller
- ② S7-300 as IO controller
- ③ Industrial WLAN with SCALANCE W
- ④ SCALANCE X 307-3 with seven electrical and three optical ports
- ⑤ ET 200SP with integrated 2-port switch
- ⑥ SCALANCE X 204 with four electrical ports
- ⑦ PROFINET/Industrial Ethernet
- ⑧ IE/PB-Link PN IO
- ⑨ PROFIBUS DP
- ⑩ ET 200S with two optical ports



Star topology



Linear bus topology



The combination of topology forms results in a tree topology.

Figure 3-12 Combined topology

Additional information

Observe the PROFINET Installation Guideline (<http://www.profibus.com/nc/download/installation-guide/downloads/profinet-installation-guide/display/>) of the PROFIBUS User Organization when planning your PROFINET topology.

For more detailed information, see the SIMATIC NET Twisted Pair and Fiber Optic Networks (<http://support.automation.siemens.com/WW/view/en/8763736>) manual.

You can find basic information in the Communication with SIMATIC (<http://support.automation.siemens.com/WW/view/en/1254686>) manual.

3.5.1 Topology view in STEP 7

Introduction

The topology view is one of three working areas of the hardware and network editor. You undertake the following tasks here:

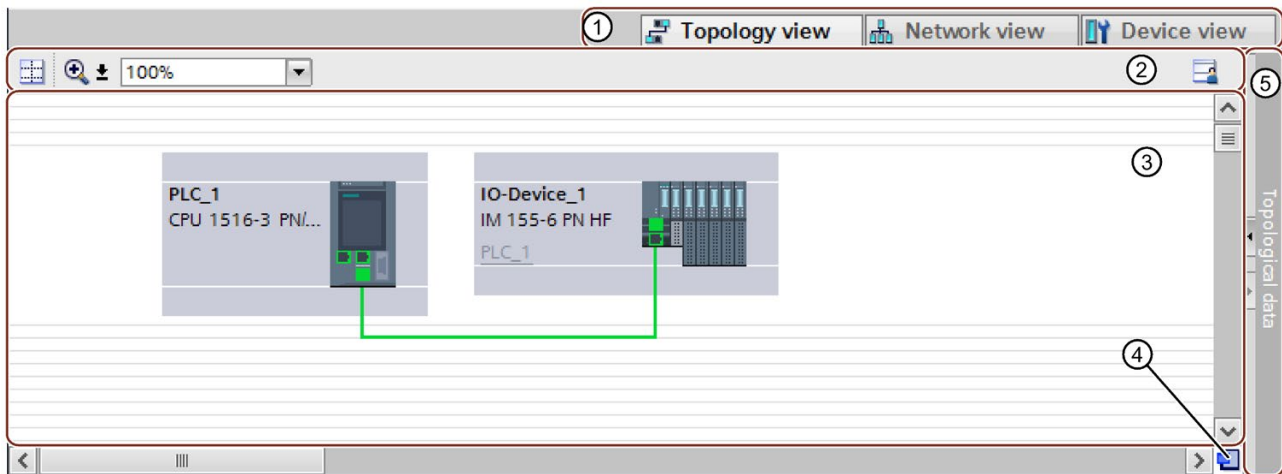
- Displaying the Ethernet topology
- Configuring the Ethernet topology
- Identify and minimize differences between the set and actual topology (online)

The topology view in STEP 7 consists of a graphic area and a table area.

Graphic area

The graphic area of the topology view displays PROFINET devices with their appropriate ports and port connections. Here you can add more PROFINET devices.

The following figure shows the graphic area of the topology view.



- ① Selector: Device view/Network view/Topology view
- ② Toolbar
- ③ Graphic area of the topology view
- ④ Overview navigation
- ⑤ Selector for the table area of the topology view

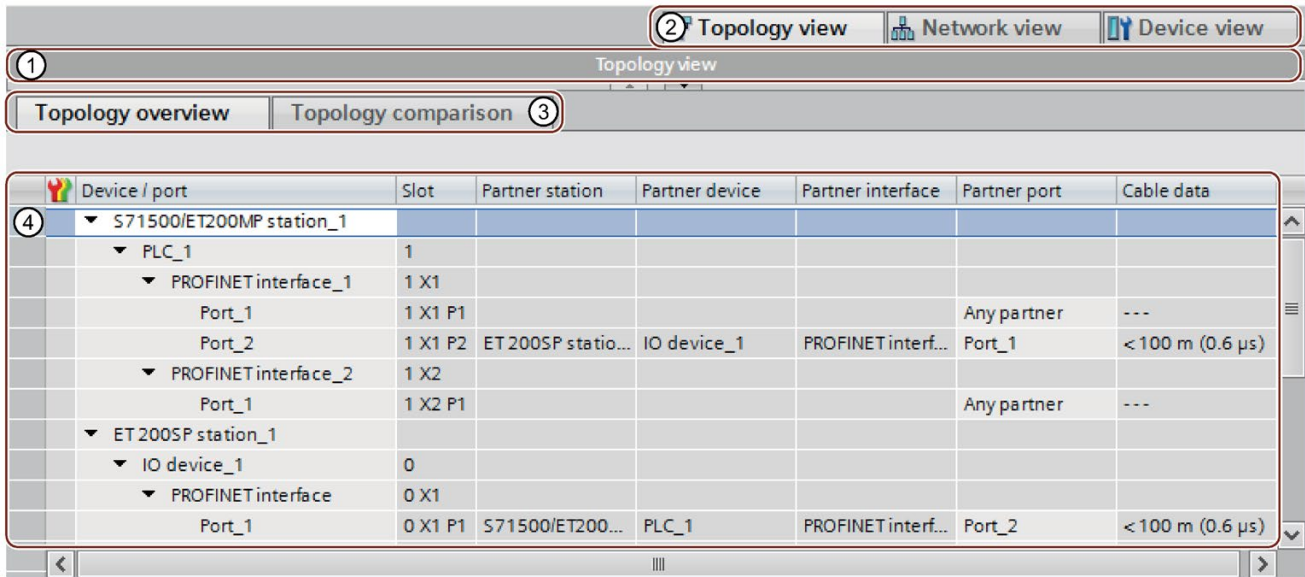
Figure 3-13 Graphic area of the topology view

Overview navigation

Click in the overview navigation to obtain an overview of the created objects in the graphic area. By holding down the mouse button, you can quickly navigate to the desired objects and display them in the graphic area.

Table area

- Topology overview: This displays the Ethernet or PROFINET devices with their appropriate ports and port connections in a table. This table corresponds to the network overview table in the network view.
- Topology comparison: Here you can import devices and port interconnections automatically through offline/online comparison or extended Offline/Online comparison into STEP 7.



- ① Selector for the graphic area of the topology view
- ② Selector: Device view/Network view/Topology view
- ③ Selector: Topology overview/Topology comparison
- ④ Table area of the topology view

Figure 3-14 Table area of the topology view

3.5.2 Interconnecting ports in the topology view

Requirement

You are in the graphic view of the topology view.

Procedure

To interconnect ports in the topology view, follow these steps:

1. Place the pointer of the mouse on the port you want to interconnect.
2. Press and hold down the left mouse button.
3. Move the pointer.

The pointer now uses the networking symbol to indicate "Interconnecting" mode. At the same time, you see the lock symbol on the pointer. The lock symbol disappears only when the pointer is over a valid target position.

4. Now drag the pointer to the target port. You can keep the left mouse button pressed or release it when performing this action.
5. Now release the left mouse button or press it again (depending on your previous action).

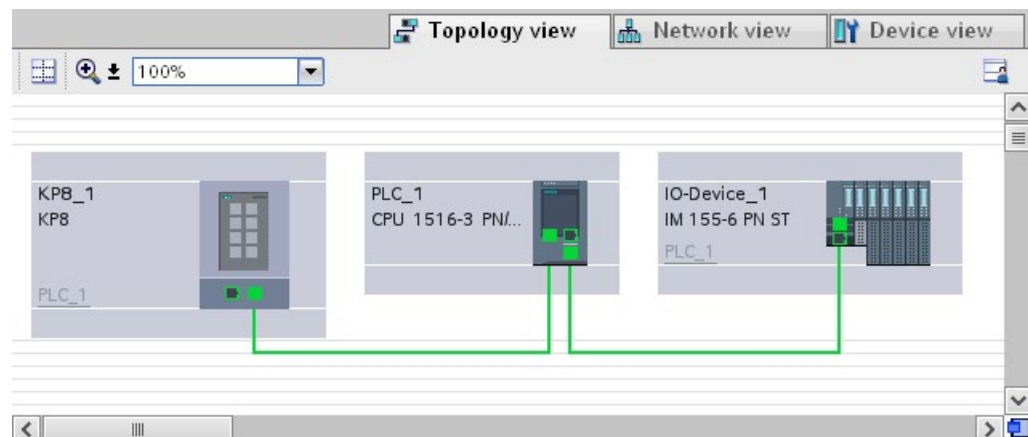


Figure 3-15 Interconnecting ports in the topology view

Result

You have created a port interconnection.

3.5.3 Interconnecting ports - Inspector window

Interconnecting ports in the Inspector window

To interconnect ports, follow these steps:

1. In the device or network view, select the PROFINET device or PROFINET interface.
2. In the Inspector window, navigate to the port property "Port interconnection".

When the PROFINET interface is selected, you can find this setting in the Inspector window as follows: "Properties > General > Advanced Options > Port [...] > Port Interconnection."

3. In the "Local port" section, you can find the settings at the local port. In the case of fiber-optic cable you can, for example, set the cable names here.

In the "Partner port" area, select the drop-down list for "Partner port" in order to display the available partner ports and make a selection.

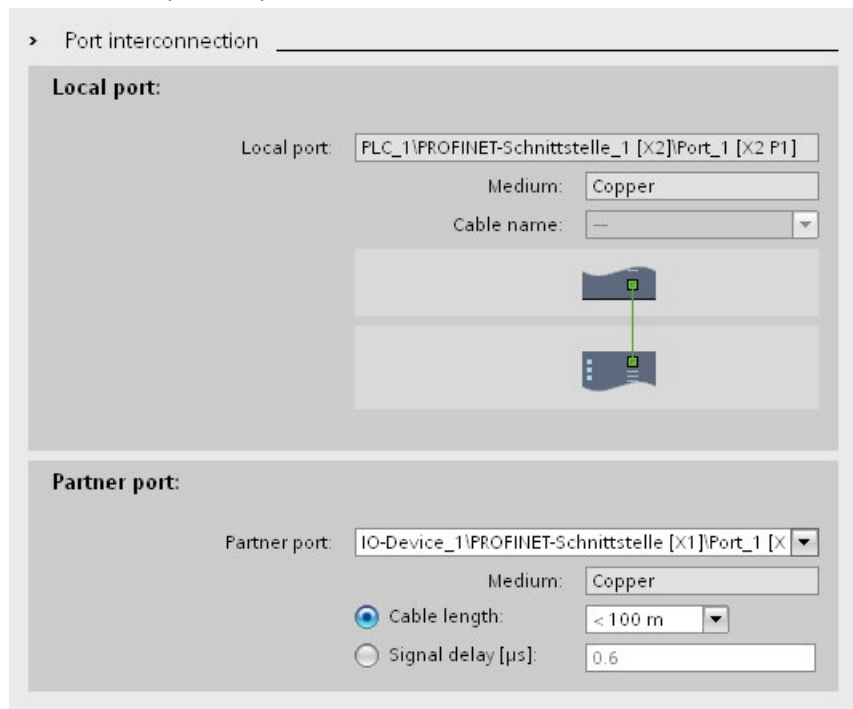


Figure 3-16 Interconnecting ports in the Inspector window in STEP 7

If the PROFINET interface was disconnected, it is automatically connected by this action. In the properties of the subnet you can set whether this subnet should or should not be used for the networking.

3.5.4 Automatic assignment of devices by offline/online comparison

Overview

During the offline/online comparison, the configured topology is compared with the actual existing topology. Devices identified online are automatically assigned to configured devices as far as this is possible.

Start of availability detection

You start the availability detection the first time by clicking the "Compare offline/online" button in the toolbar of the "Topology comparison" tab.

You restart availability detection by clicking the "Update" button.

Note

The availability detection can take several seconds. During this time, no user input is possible.

Automatic assignment of a PNIO device

A PNIO device identified online is automatically assigned to a configured device if the following properties of the two devices match up:

- Article no.
- Type
- PROFINET device name

No automatic assignment

In the following situations, no automatic assignment is possible:

- No device can be identified online to match a configured device. (This means that the corresponding columns in the "Online topology" area of the topology comparison table are empty.)

In this case, you should add the already configured device to your system or delete the configured device from the configuration.

- A device identified online can be assigned to a configured device, but there are differences in the port interconnections.

In this case, you can Apply the port interconnections identified online manually to the project (Page 72).

- A device identified online cannot be assigned to a configured device. (In this case, the corresponding columns in the "Offline topology" area of the topology comparison table are empty.)

In this case, you can Include the devices identified online manually in the project (Page 73).

3.5.5 Apply the port interconnections identified online manually to the project

Requirements

You have run an offline/online comparison in the topology view. The result of this is that at least one device identified online was automatically assigned to a configured device, but that there are differences relating to the interconnection.

Procedure

To adopt one more port interconnections identified online in the project manually, follow these steps:

1. Select the row belonging to the port interconnection.
2. If applicable, select further roles using multi-selection.
3. Select "Apply" > "Use selected" in the shortcut menu.

The content of the corresponding table cells in the "Action" column changes to "Apply".

4. If you have mistakenly prepared too many port interconnections to be included in the project:

Select the rows belonging to the port interconnections you have mistakenly prepared for inclusion in the project using multi-selection.

Select "Reset" > "Reset selected" in the shortcut menu.

The content of the corresponding table cells in the "Action" column change to "No action".

5. Click the "Synchronize" button.

Result

The port interconnections identified online for the corresponding devices are included in the project. Successful adoption is indicated by the diagnostics icon "Identical topology information" for each port.

Note

If other port interconnections are recognized for a device identified online and these differ from those that exist in the project, adopting these in the project means that the port interconnections that were previously in the project are replaced by those identified online. If no port interconnections are detected for a device identified online, adopting in the project means that all the port interconnections of this device are deleted in the project.

3.5.6 Include the devices identified online manually in the project

Requirements

You have run an offline/online comparison in the topology view. The result of this is that at least one device identified online could not be assigned to any configured device.

Procedure

To adopt one more devices identified online in the project manually, follow these steps:

1. For a configured device without an online partner, move the mouse pointer to the "Device/port" column of the online topology.
2. Select the device you want to assign to the configured device from the drop-down list of this box.
3. Repeat the previous steps if necessary for other configured devices without an online partner.

Result

The selected device that was identified online is moved up from the end of the table. Following this, it is in the row of the configured device to which you have just assigned it.

3.5.7 Automatic assignment of devices by advanced offline/online comparison

Overview

With the advanced offline/online comparison, ICMP is also used alongside DCP to be able to detect devices that do not support DCP.

Automatic assignment of devices detected by ICMP

With devices detected by ICMP, no type is available.

With passive devices, no article number is available. For this reason, passive devices can only be assigned automatically if you have not assigned an article number in the configured data and the offline and online IP addresses match.

With switches, automatic assignment is possible if the offline and online article number, IP address and PROFINET device name match.

Diagnostics and maintenance

4.1 Diagnostics mechanisms of PROFINET IO

Totally Integrated Diagnostics Concept

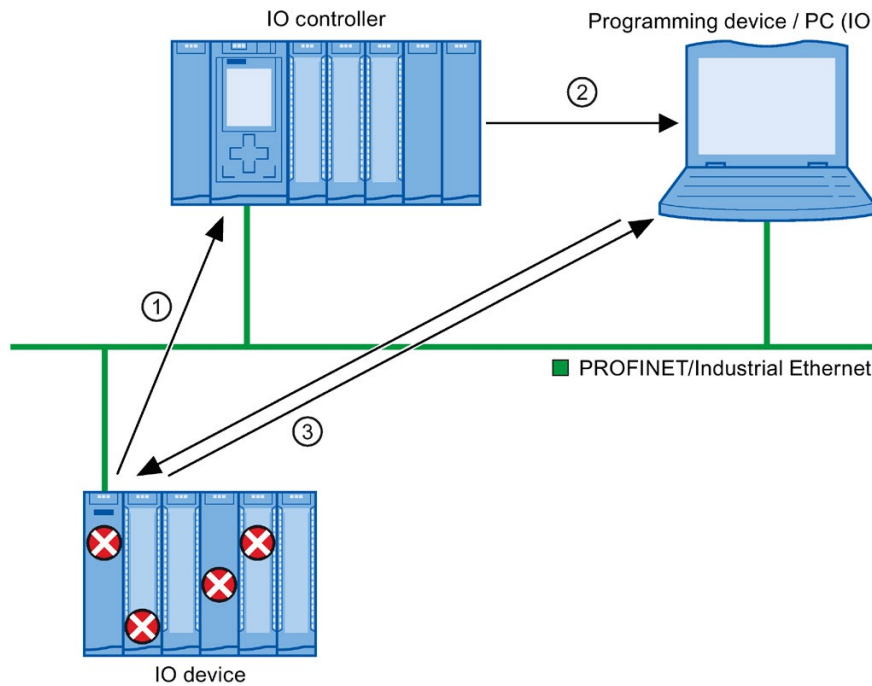
All SIMATIC products have integrated diagnostics functions that they can use to detect and remedy faults. The components automatically flag a potential fault in the operation and provide detailed information.

Each individual error or several errors occurring concurrently are transferred from the IO device to the IO controller. If you require the full status of the IO device including any pending errors, you can also read the status directly from the IO device.

The following sections provide basic information on using diagnostics via PROFINET IO. You can find a detailed description of the system diagnostics for S7-1500, ET 200MP, ET 200SP and ET 200AL in the Diagnostics (<http://support.automation.siemens.com/WW/view/en/59192926>) function manual.

Accessing the status of an IO device with a PG/PC or an HMI device

If you are connected to the Industrial Ethernet via a PG/PC with STEP 7 or an HMI device, you can also call up diagnostics information online. This is illustrated by the following graphic.



Num-ber	Description
---------	-------------

- | | |
|---|---|
| ① | The IO device detects an error and sends diagnostics data to the IO controller. |
| ② | The IO controller notifies the programming/HMI device. The display of the system diagnostics is updated. |
| ③ | In STEP 7, you can read the station status for "Accessible devices" directly from the IO device regardless of the IO controller. This is only possible if the programming device is connected to Industrial Ethernet.

This means that you can access diagnostics information during the commissioning phase or for servicing even if the IO controller is not operational. |

Figure 4-1 PROFINET IO diagnostics with PG/PC or HMI device

4.1.1 Diagnostics levels in PROFINET IO

Concept

The IO device sends all error messages that occur to the IO controller. The scope and volume of diagnostics information varies according to the level of diagnostics data evaluation and the PROFINET devices you are using.

Diagnostics levels

You can evaluate diagnostics data at different levels. The number and type of channels is selected, for example, at the diagnostics level 4.

The following figure shows the diagnostics levels with PROFINET IO.

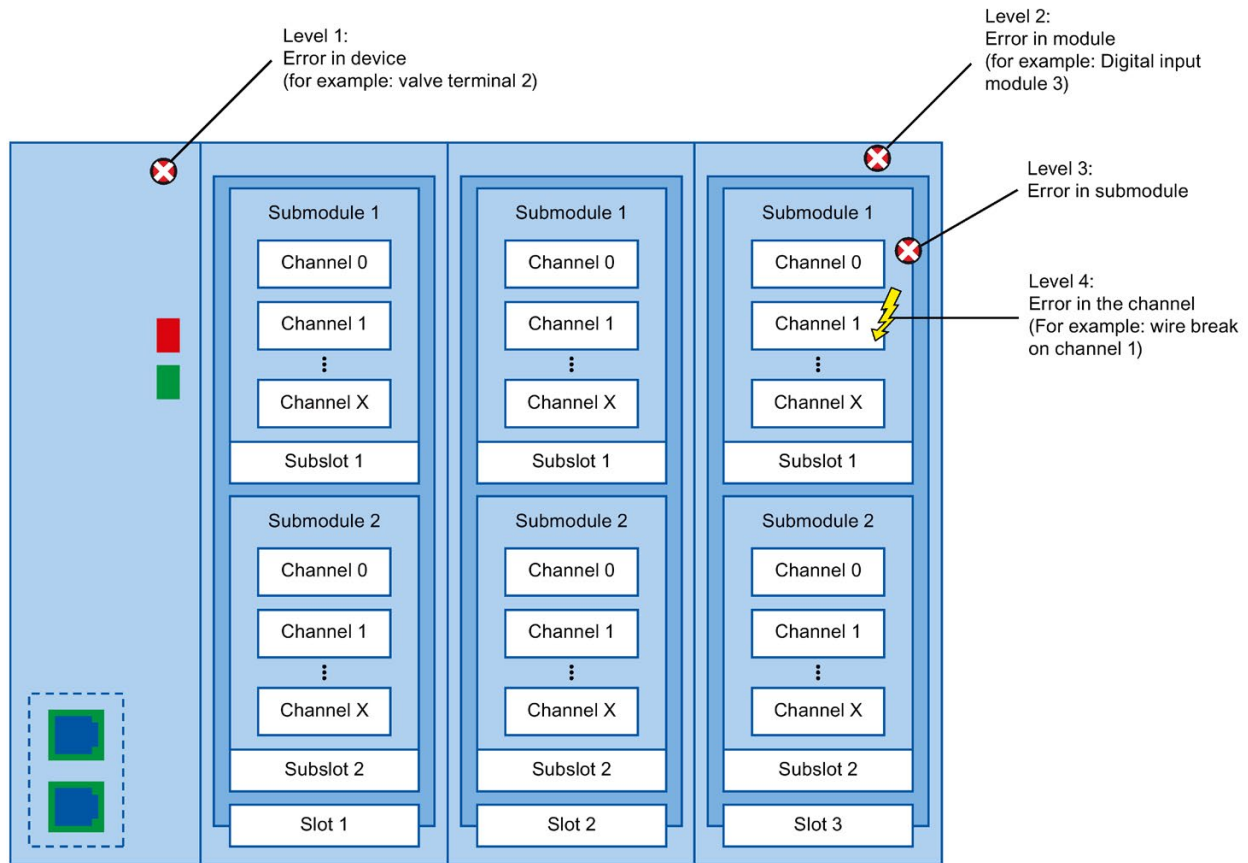
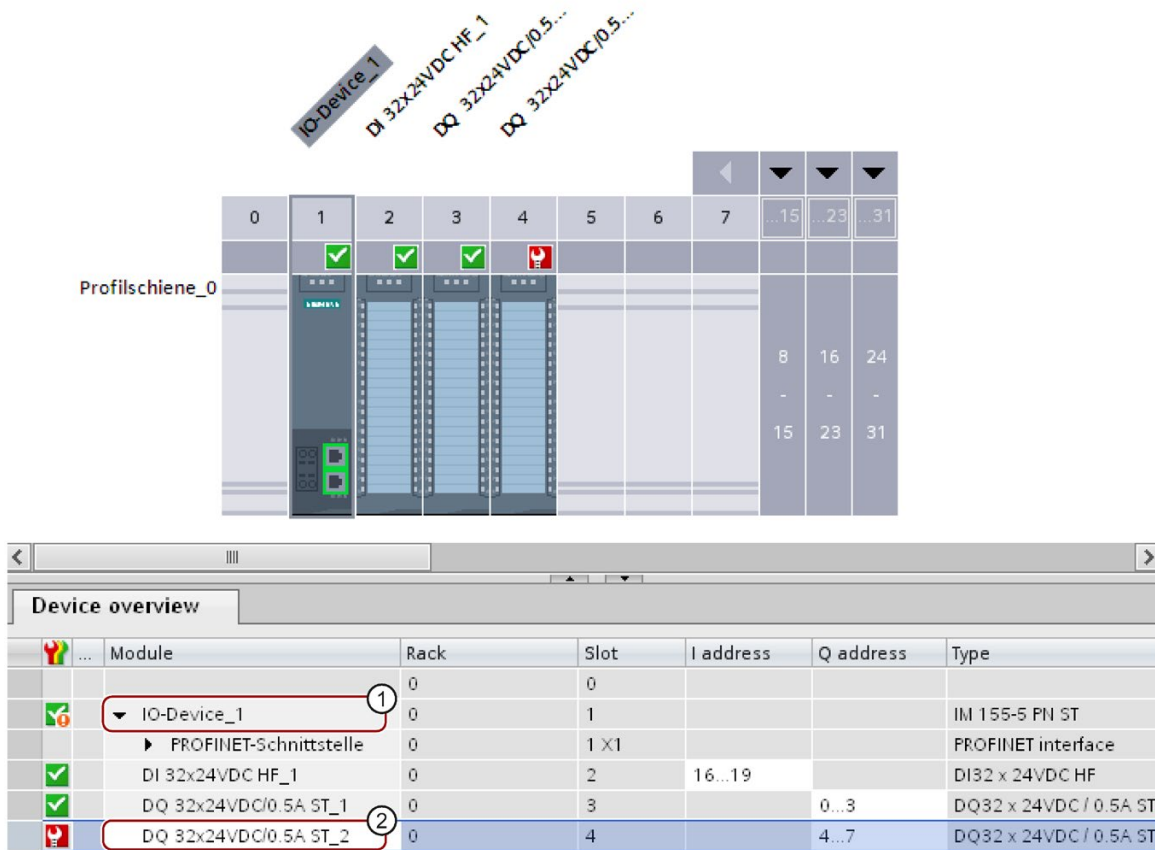


Figure 4-2 Diagnostics levels with PROFINET IO

Representation of diagnostics levels in the device view in STEP 7

The following figure shows the representation of the PROFINET device model in the device view of STEP 7, based on the example of a distributed I/O system ET 200MP:



- Number Description**
- ① Level 1: Error(s) in the device
 - ② Level 2: Error(s) in the module

Figure 4-3 Diagnostics levels in the device view of STEP 7

Which PROFINET nodes support the extended PROFINET diagnostics?

An overview of the PROFINET nodes that support extended PROFINET diagnostics and of what you have to configure is provided in this FAQ

<https://support.industry.siemens.com/cs/ww/en/view/23678970>.





4.2 Diagnostics via LEDs

LEDs for diagnostics on PROFINET

Each port of a PROFINET interface of a SIMATIC device has one LED.

The following table shows a summary of the meaning of these LEDs in the S7-1500, ET 200MP, ET 200SP and ET 200AL systems.

Table 4-1 S7-1500, ET 200MP, ET 200SP, ET 200AL: LEDs for diagnostics on PROFINET

LED image	Meaning	S7-1500	ET 200MP	ET 200SP	ET 200AL
		LINK/TX/RX LED		LK LED	P1 Link LED P2 Link LED
 LED off	There is no Ethernet connection between the PROFINET interface of the PROFINET device and the communication partner. No data is currently being sent/received via the PROFINET interface.	X	X	X	X
 LED green	There is an Ethernet connection between the PROFINET interface of your PROFINET device and a communication partner.	X	X	X	X
 LED flashes green	The "LED flashing test" is being performed.	X	X	X	X
 LED flickers yellow	Data is currently being received from or sent to a communications partner on Ethernet via the PROFINET interface of the PROFINET device.	X	X	-	-

Additional information

You can find a detailed description of all LEDs of the module with cause of the error and remedies in the relevant documentation for the module.

4.3 Diagnostics via the display of the S7-1500 CPUs

Display

The S7-1500 CPU has a display and operating keys. The display of the CPU shows you the control and status information in different menus. You use operating keys to navigate through the menus and make a variety of settings in the process.

Diagnostics via the display

The following indicators can be evaluated for diagnostics purposes on the display:

- Error and alarm texts (system diagnostics, alarm messages)
- Module status for central and distributed modules

In the following example of a display of the CPU 1516-3 PN/DP, you can see a warning on the diagnostics icon and an exclamation mark on the icon for module.

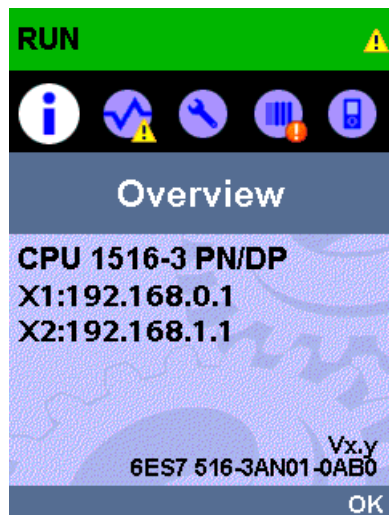


Figure 4-4 Display of overview

Module status

To show the module status, navigate on the display through the menu items "Module" > "PROFINET I/O (X1)" > "Station" > "Slot" > "Status" > "Module status".

The module status indicates that a fault has occurred in the module. The "lower-level status" is the status of the module in the diagnostics level below this. In the example, the status is "good", i.e., the fault is not in the lower diagnostics level submodule or channel, but instead in the module.

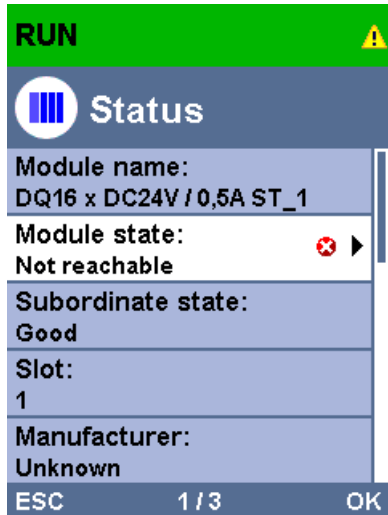


Figure 4-5 Display of module status

Error and alarm texts

You can show diagnostics buffer entries and alarm messages for the relevant automation system on the display.

To show the diagnostics buffer entries of the CPU, navigate on the display via the menu items "Diagnostics" > "Diagnostics buffer".

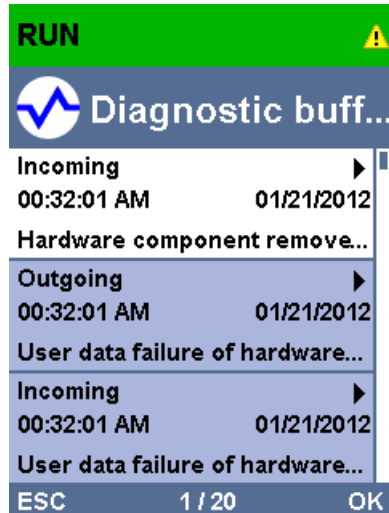


Figure 4-6 Display of diagnostics buffer

To show the alarm messages of the automation system, navigate through the menu items "Diagnostics" > "Alarms" > "Alarm text" on the display.

Note

Updating the alarm display

The display shows the currently read status of the CPU in static form, the display is not automatically updated. The alarm display is updated after it has been exited and opened again.

You set the automatic updating of the diagnostics information under: "Display" > "DiagnosticRefresh".



Figure 4-7 Display of alarms



Figure 4-8 Display of alarm message

Additional information

You can find the description of the operation and functions of the display in the SIMATIC S7-1500 Display Simulator (http://www.automation.siemens.com/salesmaterial-as/interactive-manuals/getting-started_simatic-s7-1500/disp_tool/start_de.html).

4.4 Diagnostics via Web server

The CPUs belonging to the S7 family have their own integrated Web server with a wide range of functions.

The following diagnostics options are available to you:

- Start page with general CPU information
- Information on diagnostics
- Contents of the diagnostics buffer
- Module information
- Alarms
- Information about communication
- PROFINET topology
- Motion Control diagnostics
- Trace
- Contents of the diagnostic buffer
- Module status
- Actual topology of the PROFINET system
- Set topology of the PROFINET system (from the configuration)

Set topology and actual topology - graphic view

Requirements for displaying the set and actual topology:

- You have configured the PROFINET ports in the topology editor of the hardware and network editor of STEP 7.
- You have loaded the entire project with STEP 7 in the CPU.

The following shows an example of the graphic view.

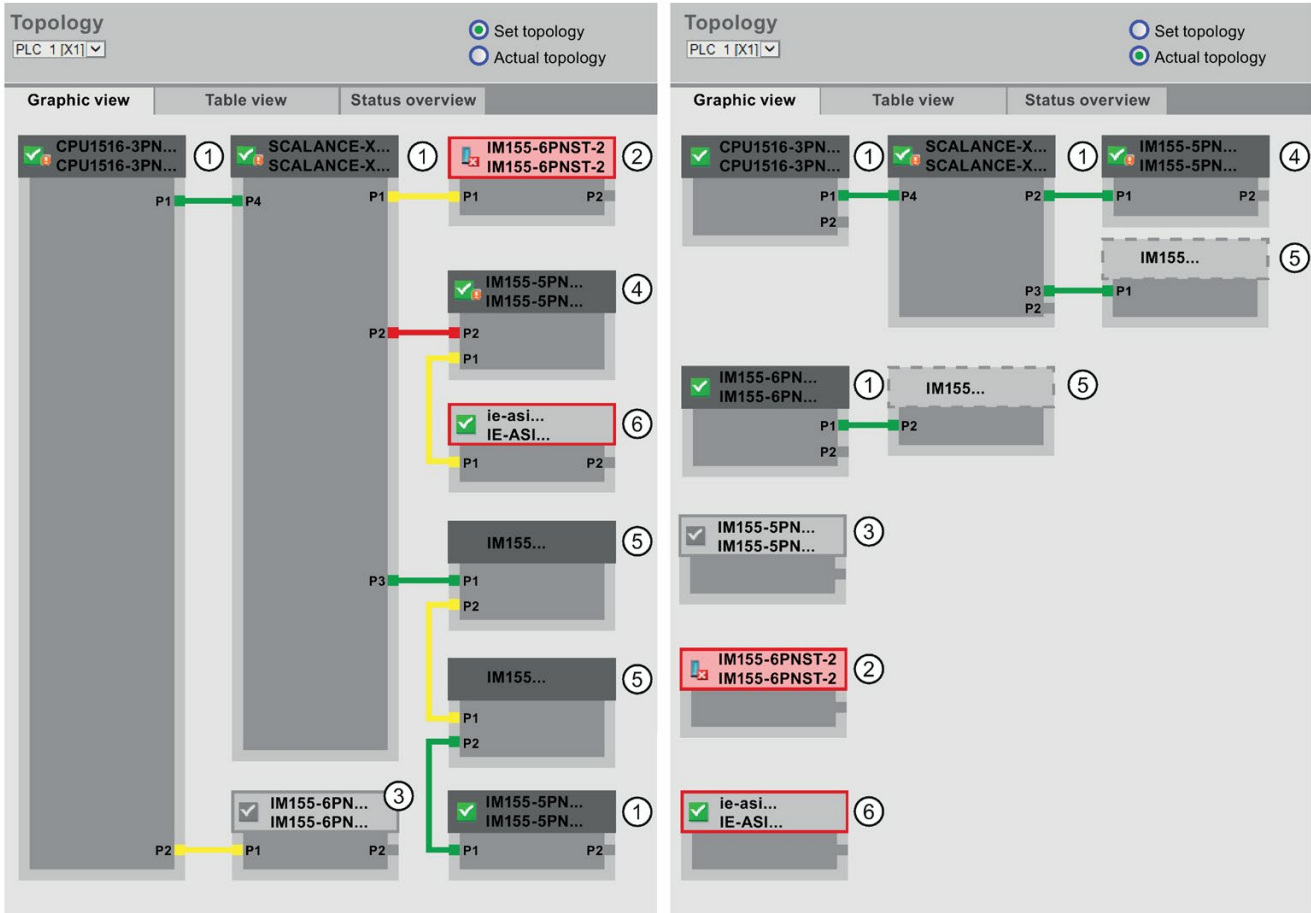


Figure 4-9 Topology - graphic view via the Web server

Meaning of the colored connections in the set/actual topology:

Table 4- 2 Meaning of the colored connections in the set/actual topology:

Connection	Meaning	
	Set topology	Actual topology
green	The current actual connection matches the configured set connection.	detected connections
red	The current actual connection does not match the configured set connection (e.g., port interchanged).	-
yellow	The connection cannot be diagnosed. Causes: <ul style="list-style-type: none"> • The communication to an IO device has been disrupted (e.g., cable removed) • Connection to a passive component • Connection to PROFINET devices of another IO controller or PROFINET system 	-

① Configured and accessible PROFINET devices

Configured and accessible PROFINET devices are displayed dark-gray. Connections show the ports through which the PROFINET devices of a station are connected.

① Configured but not accessible PROFINET devices

The configured but not accessible PROFINET devices are displayed in pink with red border (e.g., device has failed, cable disconnected).

③ Disabled devices

All disabled, configured PROFINET devices are displayed light-gray.

④ Interchanged ports

Interchanged ports are marked red in the set topology view. The currently connected ports are displayed in the actual topology, the configured set connection in the set topology.

⑤ PROFINET devices of another PROFINET IO system

- In the set topology:

A PROFINET device of another PROFINET IO system is displayed with a green connection (or red connected if the ports have been interchanged), when it is directly adjoining a configured and accessible PROFINET device ① and it is also accessible. When the PROFINET device of another PROFINET IO system is not accessible, a yellow connection line is displayed.

The connection between two PROFINET devices that both belong to a different PROFINET IO system, cannot be determined and is always displayed in yellow.

- In the actual topology:

A PROFINET device of another PROFINET IO system is only displayed if the PROFINET device is in direct proximity to a configured PROFINET device. The PROFINET device is displayed light-gray and with dashed line.

For PROFINET devices of a different PROFINET IO system, **no** status display is shown on the device head.

⑥ Representation of faulty neighbor relations

The devices whose neighbor relations cannot be read out completely or correctly are displayed light-gray with red border.

Additional information

The tabular view of the actual topology and the status overview of the PROFINET devices in the project are possible.

You can find these views, additional topology examples, and detailed information on the operation and the functions of the Web server in the Web server (<http://support.automation.siemens.com/WW/view/en/59193560>) manual.

4.5 Online diagnostics with STEP 7

For PROFINET, you have the following options to evaluate diagnostics in STEP 7:

- Online & diagnostics - Devices & networks
- Online & diagnostics - diagnostics of PROFINET ports

Online & diagnostics network view

In the hardware and network editor (launched from the "Project tree" by double-clicking "Devices & networks"), you can get an overview of the current state of your system by clicking on the "Go online" button. It also shows the configuration information (for example, non-configured modules). This option is also available in the topology view in similar form.

Schematic drawing of the network view (online):

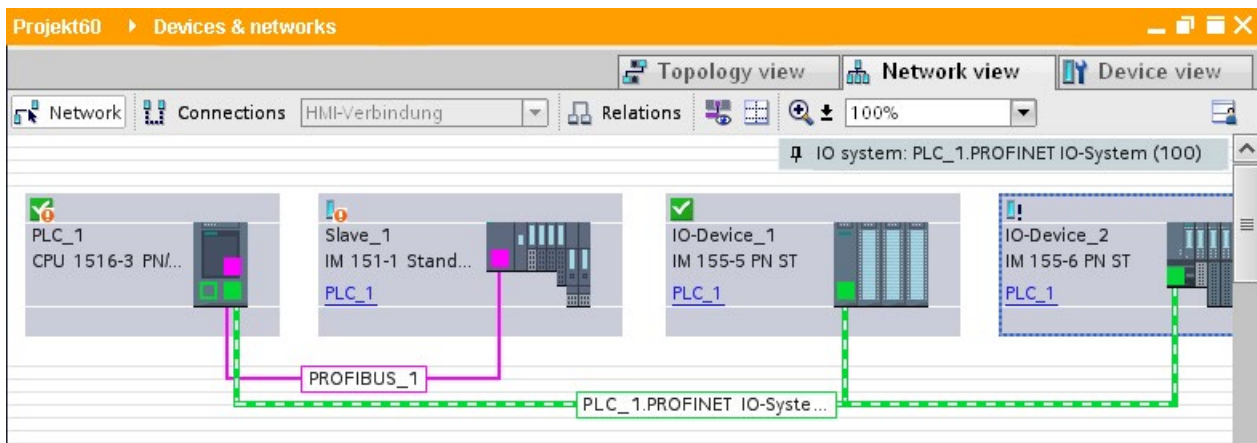


Figure 4-10 Online & diagnostics network view

Online & diagnostics device view

In STEP 7, you can display an overview of the modules in which faults have occurred. To do this, select the menu command "Online > Online & diagnostics". Once you are connected, you can see the status of the accessible devices in the project tree.

Double-click the device which displays an alarm message to access the faulty module directly. The device view is opened in the work area. In the device view of the device that reports the fault you can see directly in which module the fault occurs.

Open the "Diagnostics" tab and the subordinate "Device information" tab in the Inspector window for a more detailed error description.

Schematic drawing of the device view (online):

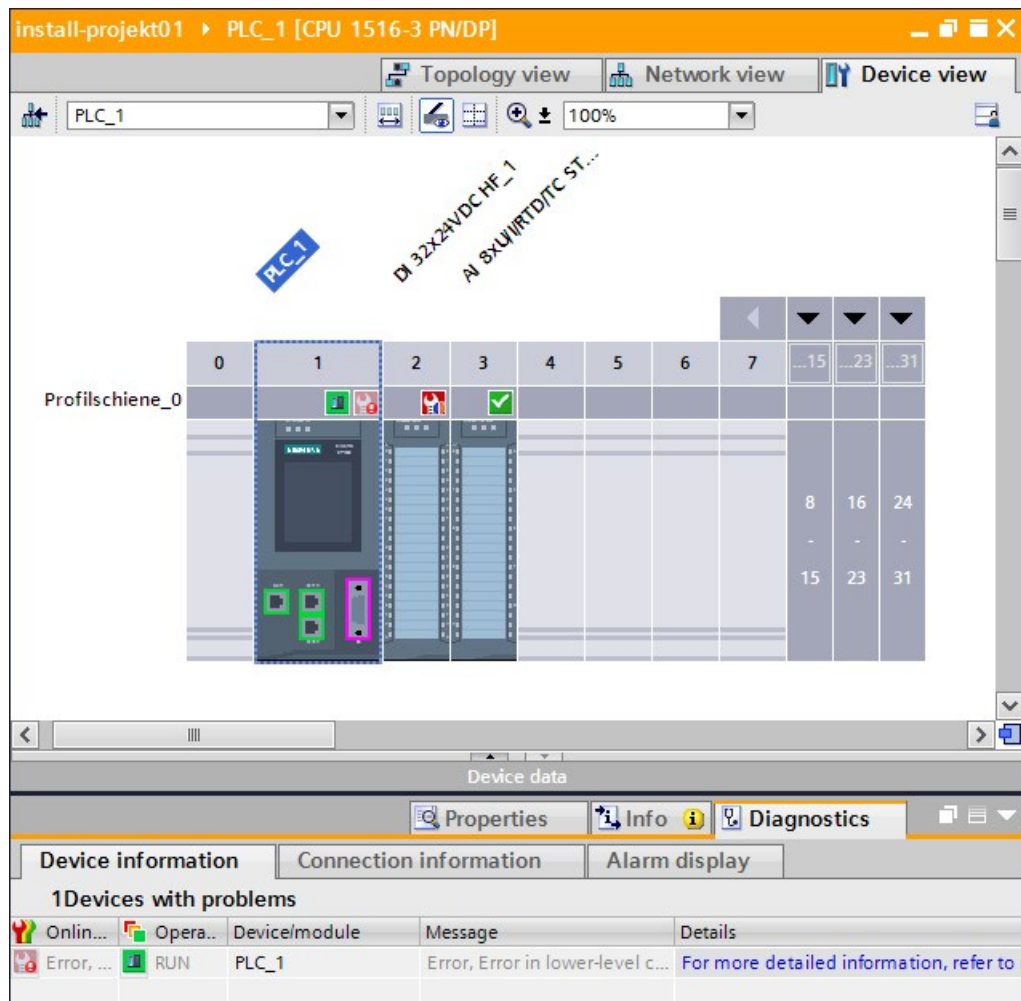


Figure 4-11 Online & diagnostics device view

Diagnostics of PROFINET ports

If you select "PROFINET interface > Ports" in the Diagnostics area in the online & diagnostics device view of a PROFINET device, the ports of the PROFINET interface are listed in a table.

The table provides you with the following information about the ports of the PROFINET interface.

- Name
- Status
- Settings
- Operating mode

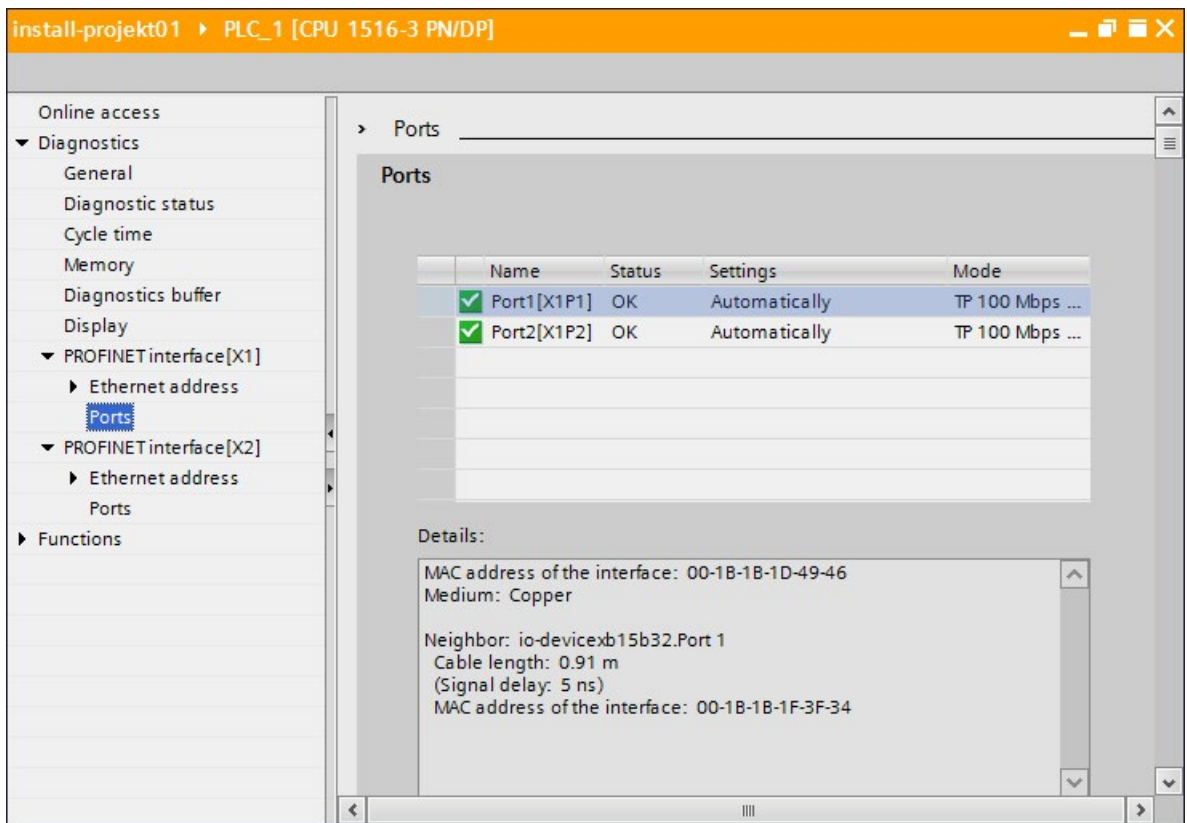


Figure 4-12 Diagnostics of PROFINET ports in STEP 7

Additional information


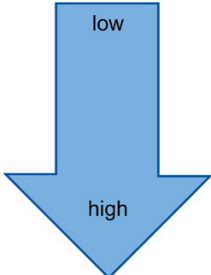



You can find information on the system diagnostics for S7-1500, ET 200MP, ET 200SP and ET 200AL in the Diagnostics (<http://support.automation.siemens.com/WW/view/en/59192926>) function manual and online help for STEP 7.

4.6 Extended maintenance concept

Extended maintenance concept

The PROFINET interfaces with integrated switch of the SIMATIC devices support the four-level diagnostics concept in accordance with PROFINET specification Version V2.3 or higher with the following status:

Table 4- 3 Classification of the diagnostic status

Diagnostic status	Symbol	Severity of the error
Good	Green checkmark 	
Maintenance required	Green wrench 	
Maintenance demanded	Yellow wrench 	
Bad	Red wrench 	

The aim of the diagnostics concept is the early detection and elimination of potential faults - before they cause a production outage.

Other status information is defined in addition to the Good (no fault) and Bad (fault) status information for a PROFINET device.

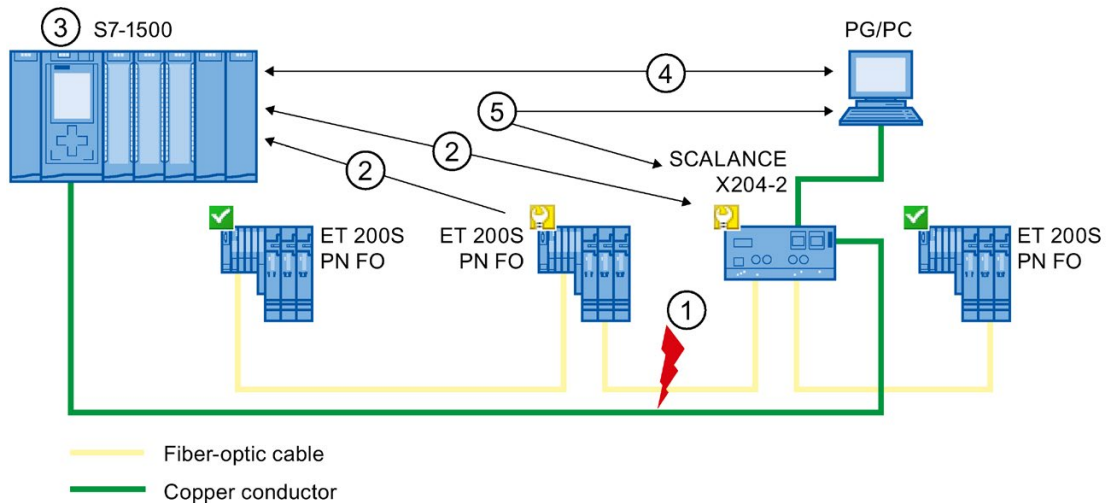
The maintenance information is generated with the following system alarms:

- Maintenance required (symbolized by a green wrench) and
- Maintenance demanded (symbolized by a yellow wrench)

The times at which the two system alarms are generated can be customized for most wear parameters.

Example: Maintenance demanded for a PROFINET cable

The following graphic illustrates how diagnostics information is exchanged when the transmission quality on the optical cable decreases due to ageing, for example. In this example, the scenario is considered after a maintenance required has already been diagnosed.



- | Number | Description |
|--------|---|
| ① | The system reserve of the fiber-optic cable drops below 0 dB. |
| ② | Both the ET 200S PN FO and the switch send the maintenance demanded alarm to the IO controller. |
| ③ | Based on the interrupts, the IO controller detects the maintenance demanded from the switch and from the IO device. The module information data is updated in the IO controller and the corresponding error OBs are called. Note: To be able to start the error OBs in the IO controller, the "Call the user program if communication errors occur" property must be selected in STEP 7 for the relevant IO controller. |
| ④ | In STEP 7 (on the programming device/PC), the maintenance demanded message is indicated on the IO device and at the switch by a yellow wrench symbol. |
| ⑤ | STEP 7 can also read out detailed information directly from the switch. |

Figure 4-13 Maintenance demanded for a PROFINET cable

4.7 Diagnostics of the network topology

Availability

As an open standard, you can use any SNMP based systems or software solutions for diagnostics in PROFINET.

Network diagnostics

The network management protocol SNMP (Simple Network Management Protocol) uses the wireless UDP transport protocol. It consists of two network components, similar to the client/server model. The SNMP manager monitors the network nodes and the SNMP clients collect the various network-specific information in the individual network nodes and store it in a structured form in the **MIB** (Management Information Base). This information allows a network management system to run detailed network diagnostics.

MIB

The MIB (Management Information Base) is the database of a device. SNMP clients access this database in the device. The S7 device family supports the following standard MIBs:

- MIB II, standardized in the RFC 1213
- LLDP-MIB, standardized in the international standard IEC 802.1AB
- LLDP-PNIO-MIB, standardized in the international standard IEC 61158-6-10

You will find the MIBs for ET 200 interface modules and couplers with PROFINET interface in this product note (<https://support.industry.siemens.com/cs/ww/en/view/109770525>).

Detecting the network topology

LLDP (Link Layer Discovery Protocol) is a protocol that is used to detect the closest neighbor. LLDP enables a device to send information about itself and to receive information from its neighbor devices. This information is then saved in the LLDP MIB, for example, and can be queried using SNMP. This information allows a network management system to determine the network topology.

Use of SNMP (Simple Network Management Protocol)

SNMP can be used as follows:

- By users to integrate network diagnostics into a central HMI/SCADA system using the SIMATIC NET OPC server
- By the IT administration of machine and plant operators to monitor their Industrial Ethernet network using standard network management systems.
- By the IT administration, to monitor the automation network, alongside the office network, using standard network management systems.

Use of SNMP in the SIMATIC NET environment

SNMP-compliant devices from the SIMATIC NET family can be monitored and operated via a conventional standard Internet browser. The management system known as web-based management offers a wide range of device-specific information (network statistics, status of redundant supply, for example).

4.8 Diagnostics in the user program

4.8.1 Diagnostics and configuration data records

Diagnostics mechanism

The IO device outputs a diagnostics interrupt to the IO controller when it detects faults such as wire break on an IO module. This interrupt calls a corresponding organization block in the user program (diagnostics interrupt OB82), in order to generate a defined (programmed) response to the fault and passes a diagnostics data record.

Diagnostics data records in PROFINET IO

There are two different types of diagnostics data record:

1. Channel diagnostics data records

Channel diagnostics data records are generated if a channel is in an error state and / or has triggered an interrupt.

A diagnostics data record of length 0 is returned if there is no fault.

2. Vendor-specific diagnostics data records

The structure and size of vendor-specific diagnostics data records depend on the vendor's settings.

For information about vendor-specific diagnostics data records, refer to the appropriate device manual.

Addressing levels of diagnostics data records

Diagnostics and configuration data is evaluated at the following addressing levels:

- Device level
- AR (Application Relation)
- API (Application Process Identifier)
- Slot
- Subslot

A group of diagnostics and configuration data records are available for each address level (exception: device level always 0xF80c). In HEX representation, the individual groups of data records are distinguished by the first letter of the data record number.

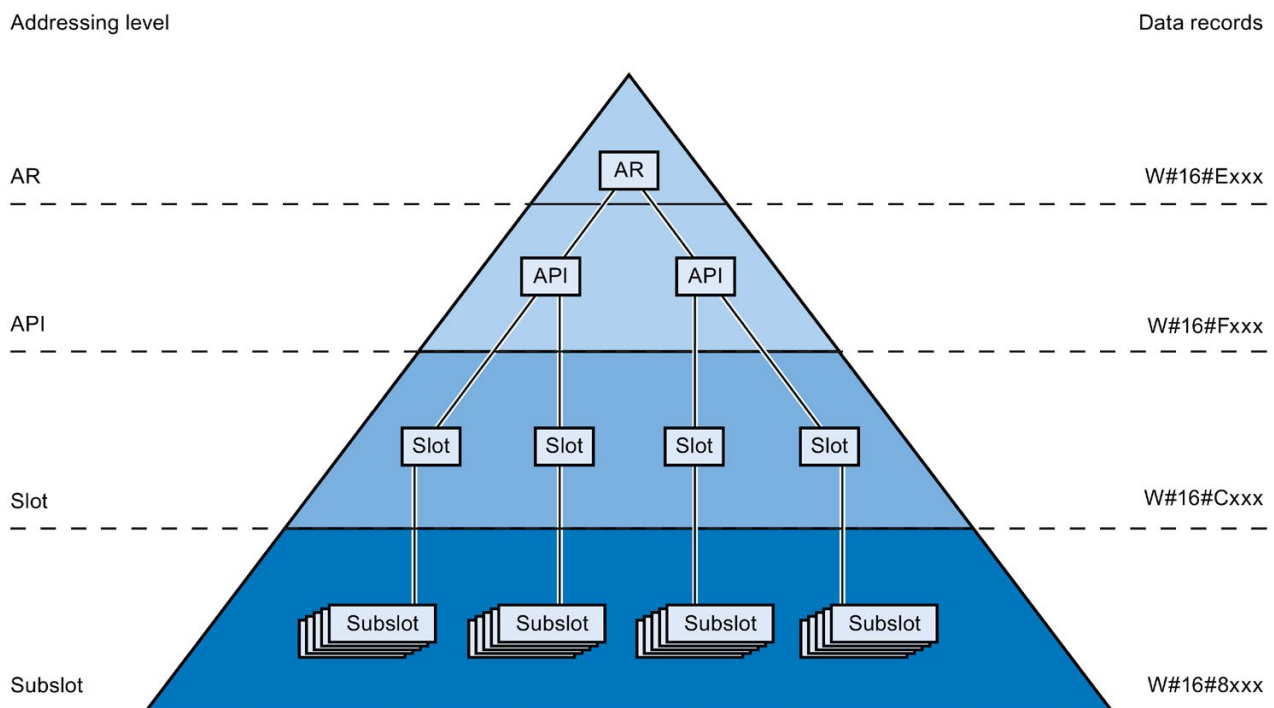


Figure 4-14 Addressing levels of diagnostics data records

The information for each IO device (addressing level AR), module (addressing level slot) or submodule (addressing level subslot) is always transferred in separate diagnostics or configuration data records. The data record returns diagnostics data or configuration data for one or more subslots, slots and APIs, depending on the addressing level.

Note

The diagnostics information is only generated for configured modules / submodules / channels.

Library for PROFINET data records

The "LPNDR" block library contains various function blocks. You can use these blocks to read out various device and status information from a PROFINET device and write parameters.

You can execute the following functions using the library blocks:

- Read device information:
 - Information about the interface, e.g. IP and MAC address
 - Information about the device interface, e.g. status, medium, name
 - Information about the link status of the interfaces, e.g. link down, link up
 - Information about the role of the device for MRP, e.g. client, manager
 - Information about the port statistics, e.g. number of received bytes
- Read the MRP status
- Modification of the parameters of analog input module of the ET 200SP in runtime, e.g. in order to disable/enable the channel diagnostics.

The finished functions are freely adaptable and can therefore be used universally.

The "LPNDR" block library with an example project can be found on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109753067>).

4.8.2 Evaluate diagnostics in the user program

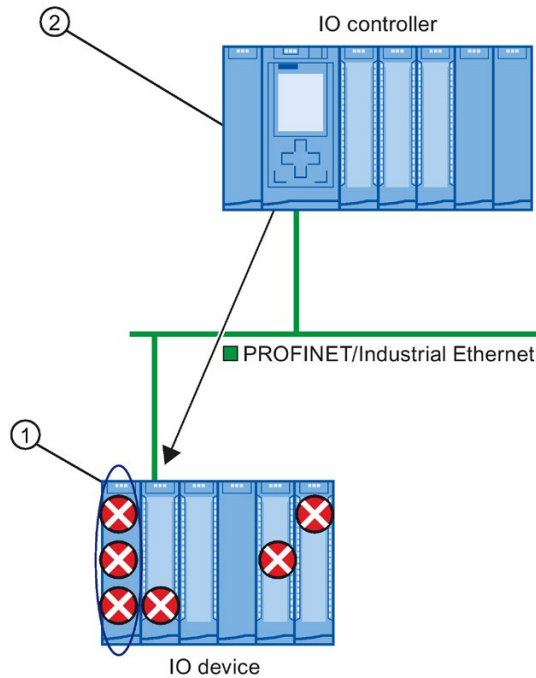
Diagnostics in the user program

For PROFINET IO, a cross-vendor structure of data records with diagnostics information applies. Diagnostics information is created only for channels on which a fault has occurred. With PROFINET, there are two basic ways to obtain diagnostics information.

1. Evaluating the diagnostics status

Read out the diagnostics of your PROFINET IO system using the instructions "DeviceStates" and "ModuleStates" to localize faulty stations / modules or station / modules with maintenance demanded or maintenance required within a PROFINET IO system.

The instruction RDREC (read data record) is then used to read various diagnostics data records directly from the module concerned and thus obtain detailed information about the error.

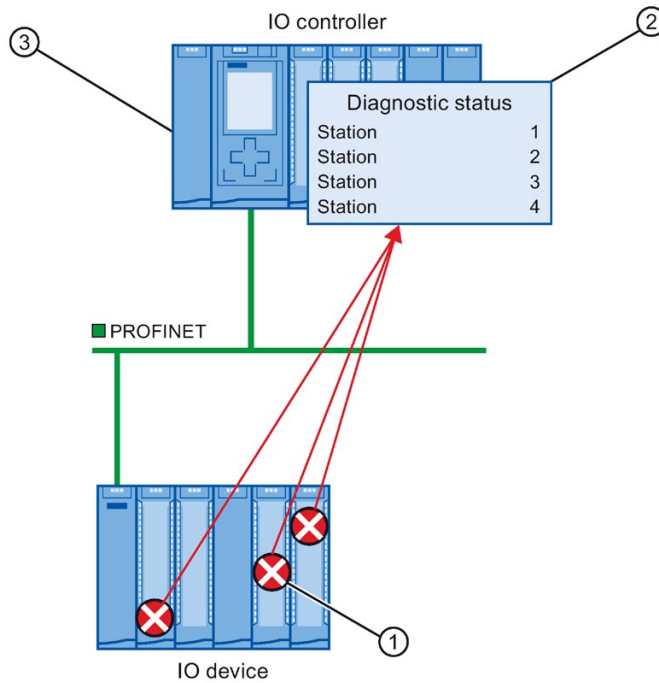


Number	Description
①	All individual errors are collected in a single data record on the interface module.
②	In your user program, the instruction "RDREC" reads the entire station status asynchronously directly from the IO device.

Figure 4-15 Example: Evaluating diagnostics data records with the instruction "RDREC"

2. Evaluation of interrupts

When the error OB (OB 82) is called, the OB's start information provides you with information on the cause and location of the error. Detailed information on the error event can be obtained in the error OB using the instruction "RALRM" (read additional interrupt information).



Number	Description
①	Every error is sent to the IO controller individually as channel diagnostics information in the form of an interrupt.
②	In the IO controller, the module status data is updated automatically and the error OB (OB 82) is started.
③	In your user program in the error OB (OB 82), the instruction "RALRM" reads the error synchronously from the IO controller without addressing the IO device.

Figure 4-16 Diagnostics with OB 82 and the instruction "RALRM"

Instructions and OBs

You will find information on the instructions and OBs in the STEP 7 online help.

4.9 Maintenance

4.9.1 I&M data (identification and maintenance)

Definition and properties

Identification and maintenance data (I&M) is information saved to module memory in order to provide support when:

- Checking the plant configuration
- Locating hardware changes in a plant

Identification data (I data) is module information (some of which may be printed on the module housing) such as the order and serial number. I data is read-only vendor-specific module data.

Maintenance data (M data) is plant-specific information such as the location identifier and installation date. M data is created during configuration.

The modules can be uniquely identified in online mode by means of the I&M data.

Further information

To find out whether and to what extent a PROFINET device supports I&M data, refer to the documentation of the relevant device.

4.9.2 Loading I&M data to PROFINET IO devices and your modules

Which I&M data can be loaded to PROFINET IO devices and your modules?

You can load I&M 1 data (plant designation and location identifier) and/or I&M 2 data (installation date) and/or I&M 3 data (additional information) to the actual hardware.

Requirements

- In the project settings (Options > Settings, Hardware configuration > Compiling and downloading), the option "Download I&M data" must be enabled.
- There is an online connection to the PROFINET IO devices and the modules to which you want to load I&M data.
- You have entered the I&M data you want to download in the properties of the respective PROFINET IO devices and your modules (Inspector window: "Properties" tab > "General" tab, Settings > Identification & Maintenance).

Where do I specify which I&M data is downloaded to which PROFINET IO devices?

You specify which I&M data you want to download to which PROFINET IO devices in the "Load preview" dialog. You will find the following alternatives in the drop-down list of the "Identification and maintenance data (I&M)" row:

- Load nothing
The check boxes for all PROFINET IO devices as well as the check boxes for the loadable I&M data are cleared.
No I&M data is transferred to the actual hardware during loading with this setting.
- Load data
The check boxes for all PROFINET IO devices as well as the check boxes for the loadable I&M data are selected.
The respective I&M 1, I&M 2 and I&M 3 data is transferred to all PROFINET IO devices during loading with this setting.
- Load selected
You select the check boxes of those PROFINET IO devices to which you want to load I&M data. You also select the check boxes of the identification data you want to load.
With this setting, you transfer the selected I&M data to the selected PROFINET IO devices during loading.

Note

Language dependency of the I&M data to be loaded

The I&M data are loaded to the real hardware in the form that you specified in the properties of the relevant PROFINET IO devices and your modules. There is no language dependency.

4.9.3 Asset management

4.9.3.1 Further information about asset management at PROFINET

Operation of machines and plants without a detailed knowledge of devices and assets is difficult to imagine.

Maintenance requires data for this – data that is extensive and up-to-date as far as possible.

The requirement of greater transparency with regard to the data made available by plant components has been fulfilled by PROFIBUS & PROFINET International (PI): The identification and maintenance data familiar since PROFIBUS times have been extended.

The current PROFINET fulfills this requirement through the definition of a special data record: the Asset Management Record (AMR).

The aim of this definition is to enable you to acquire **all** the components to be maintained online - and not only those components that can be addressed and accessed through the PROFINET device model (Device / Module / Submodule). PROFINET now also reaches non-PROFINET components!

Assets general and asset management data records

Assets are components (hardware and software / firmware) of a machine, for example a laser welding machine, or a plant.

A large number of these device components can already be identified through tried-and-tested I&M functions or corresponding data records (I&M0 to I&M5) in the PROFINET context: The device itself as well as its modules and submodules. Meaning all components that can be addressed through the PROFINET device model.

Components that **cannot** be addressed via the PROFINET device model, but whose data it should be possible to acquire online for operation and maintenance, can be identified through **asset management** functions. This asset management data (short: AM data) is stored in a defined structure in a special data record, the **asset management record (AMR)** mentioned above.

The PROFINET Guideline "Identification & Maintenance Functions" differentiates here between I&M functions (I&M data) and asset management functions (AM data): The following sections only deal with the AM data.

The components that can be read additionally online through asset management data records include both hardware components, such as backplane bus modules of a device as well as firmware components such as a drive control unit with own versioning.

Application examples

Importing asset management records enables you to read the following information during installation or operation, for example:

- Are only approved devices being used (whitelist check)?
- A firmware update is due. Obtain a fast overview: Which devices or components are affected and have to be upgraded?

Making asset management data available

The concept for the asset management of PROFINET devices stipulates that the manufacturers of PROFINET devices have to ensure that non-PROFINET automation components are made available through an asset management record. This data record is assigned to the PROFINET device.

In contrast to a "standard" IO device, with an I-device the project engineer has to make the asset management record available. In this case, the central modules of the I-device are assets. From the perspective of PROFINET, these central modules are not visible from the point of view of the higher-level IO controller. The higher-level IO controller only "sees" the transfer areas through which it exchanges IO data with the I-device.

The principle of this provision is explained in the section.

Reading asset management data

The asset management record has the index 0xF880 and is read with standard PROFINET mechanisms by the user of the records, for example a tool or program for evaluating these data.

A user program in the S7-1500 IO controller, for example, can read out the AMR of an IO device with the RDREC instruction (Index 0xF880).

It is not possible to write to this data record.

Further information

Whether and to which extent a PROFINET device supports asset management data, meaning whether it makes an AMR available, is specified in the documentation of the respective device.

4.9.3.2 Content and structure of an asset management record

Basic structure of the asset management record

You are first provided with an overview of the general structure of the record. The following table describes the framework within which the asset management data blocks are embedded. Each data block represents an asset, a terminal block for example.

Element of the data structure	Designation according to IEC 61158-6-10	Code	Data type / length in bytes
Header AssetManagementData	BlockType	0x0035	UINT / 2
	BlockLength	Number of bytes without counting the bytes for Block-Type and BlockLength	UINT / 2
	BlockVersion	0x0100	UINT / 2
AssetManagementInfo AssetManagementBlocks (n)	NumbersOfEntries	Number of AssetManagementBlocks	UINT / 2
	AssetManagementBlock 1	See the table below	
	AssetManagementBlock 2		
	...		
	AssetManagementBlock n		

Structure of asset management blocks

Each AssetManagementBlock contains identification data and localization information for an asset. An AssetManagementBlock has a substructure with basic characteristics described below.

The header of an AssetManagementBlock contains the coded information about which of the three possible AM data compilations the data record contains. Devices make a suitable BlockType available in accordance with the various device types:

- Complex devices with information about the hardware and firmware (BlockType "AM_FullInformation")
- Complex devices with information about the hardware (BlockType "AM_HardwareOnlyInformation")
- Devices with information about the firmware (BlockType "AM_FirmwareOnlyInformation")

The differentiation provides an efficient data structure below the header. Nevertheless, the data record can have a considerable size (maximum of 64 KB, depending on the number of assets that the IO device supplies).

Table 4- 4 Structure of AssetManagementBlock

Element of the data structure	Designation according to IEC 61158-6-10	Code	Data type / length in bytes
Header AssetManagementBlock	BlockType	0x0036 (AM_FullInformation) 0x0037 (AM_HardwareOnlyInformation) 0x0038 (AM_FirmwareOnlyInformation)	UINT / 2
	BlockLength	Number of bytes without counting the bytes for BlockType and BlockLength	UINT / 2
	BlockVersion	0x0100	UINT / 2
	Padding	0x0000 (padding byte)	USINT / 1
	Padding	0x0000 (padding byte)	USINT / 1
AssetManagementBlock (Structure depends on the BlockType. Here it is shown using AM_FullInformation as an example)	IM_UniqueIdentifier	Manufacturer-generated Universal Unique Identifier (UUID) conforming to ISO/IEC 9834-8. Used as a reference key to uniquely identify this asset. Example: 550c5300-d34a-22b4-11d3-5533991111b3	Array of Byte / 16
	AM_Location	Description of the location of the asset: Either slot-oriented ("Slot and Sub-slotNumber format") or hierarchical ("Twelve level tree format"). See following description	Array of Byte / 16
	IM_Annotation	Manufacturer-specific notation Example: "Terminal block, Type xyz123". 64 bytes are always used. Spaces are used for padding if the string is shorter.	Array of Char / 64

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Element of the data structure	Designation according to IEC 61158-6-10	Code	Data type / length in bytes
	IM_OrderID	Manufacturer-specific article number Example: "6ES7 131-6BF00-0BA0 ". 64 bytes are always used. Spaces are used for padding if the string is shorter.	Array of Char / 64
	AM_SoftwareRevision (not at AM_HardwareOnlyInformation)	Manufacturer-specific SW version Example: "V6.3.8 ". 64 bytes are always used. Spaces are used for padding if the string is shorter. If the asset supports IM_Software_Revision, the AM_SoftwareRevision is padded with spaces.	Array of Char / 64
	AM_HardwareRevision (not at AM_FirmwareOnlyInformation)	Manufacturer-specific hardware version Example: "A4 ". 64 bytes are always used. Spaces are used for padding if the string is shorter. If the asset supports IM_Hardware_Revision, the AM_HardwareRevision is padded with spaces.	Array of Char / 64
	IM_Serial_Number	Manufacturer-specific unique production-related number. The characters come from the visible range (0x20 ... 0x7E), no control characters. Example: "A78C-1C82 ". 16 bytes are always used. Spaces are used for padding if the string is shorter.	Array of Char / 16
	IM_Software_Revision (not at AM_HardwareOnlyInformation)	Software version, follows a strict structure (SW version prefix, for example "V", digits for functional extension, digits for BugFix, digits for internal change). Example: 'V' 0x01 0x2 0x3 If AM_SoftwareRevision is padded with spaces, you should evaluate IM_Software_Revision. If the asset does not support any hardware, the coding 'V' 0x00 0x00 0x00.	Array of Byte / 4 Prefix (character "V", "R", "P", "U", or "T"), then 3 digits "0" to "9"

Element of the data structure	Designation according to IEC 61158-6-10	Code	Data type / length in bytes
	AM_DeviceIdentification	<p>Identification of the device. The structure is as follows:</p> <p>AM_DeviceIdentification.DeviceSubID (for SIEMENS e.g. 0x0000)</p> <p>AM_DeviceIdentification.DeviceID (Device ID from manufacturer, 0x0000 to 0xFFFF)</p> <p>AM_DeviceIdentification.VendorID (Example for Siemens assets: 0x002A)</p> <p>AM_DeviceIdentification.Organization: Example for Siemens assets: 0x0000 (PROFINET)</p>	Array of Byte / 8
	AM_TypeIdentification	<p>Manufacturer-allocated type identification:</p> <p>0x0000: Unspecified</p> <p>0x0001: Controller (PLC)</p> <p>0x0002: PC-based</p> <p>0x0003: IO module, IO submodule</p> <p>0x0004: Communications module / submodule</p> <p>0x0005: Interface module / submodule</p> <p>0x0006: Active network component</p> <p>0c0007: Media attached unit (bus adapter)</p> <p>0x0100 to 0x7FF: Manufacturer-specific</p>	UINT / 2
	IM_Hardware_Revision (not at AM_FirmwareOnlyInformation)	<p>Version of the hardware (0x0000 to 0xFFFF)</p> <p>Example: 0x0003</p> <p>If AM_HardwareRevision is padded with spaces, you should evaluate IM_Hardware_Revision.</p>	UINT / 2

AM_Location

Asset management at PROFINET supports two formats for coding the location of an asset:

- Slot-oriented format ("Slot and SubslotNumber format")
- Hierarchical format ("Twelve Level Tree format" abbreviated LT format)

Assets that are part of the PROFINET device use the slot-oriented format. These assets are bound completely to the PROFINET modules and submodules.

Assets that are located outside the PROFINET device use the hierarchical format (LT format) for coding the location of an asset.

These assets are localized by their tree level. The tree level begins with Level 0. The value of Level 0 provides information about the proximity to the PROFINET device:

- If the asset is connected to a module that can be addressed through the PROFINET device model, Level 0 has the value 0. The subsequent levels (Level 1 to Level 3) then have the meaning of slot address, subslot address and channel number. If further assets are connected to this asset, the next Level 4 is used. The limit is reached at Level 11.
- If the asset belongs to a PROFINET device but is not connected to a module that can be addressed through the PROFINET device model, Level 0 has a value between 1 and 0x1FF. An example of such an asset is a power supply unit in the PROFINET device. If a further asset is connected to this power supply unit, for example a sensor, the next tree level is used to localize this sensor (Level 1).
- If the asset is located outside the PROFINET device, but, for example, belongs to a machine into which the PROFINET device is installed, Level 0 has a value between 0x200 and 0x3FE.

The value 0x3FF for a tree level shows that this tree level is not used. This means that no further asset is connected. In this case, all the lower tree levels down to Level 11 must also have this value.

Example AM_Location slot-oriented

A rack and the terminal blocks located on it each supply AM data. The slot assignments are shown in the figure.

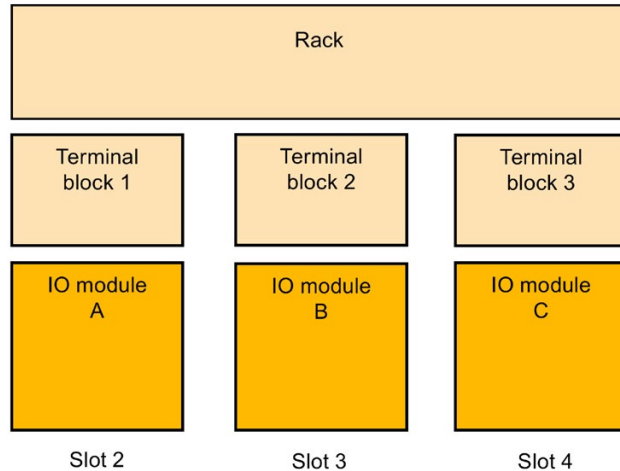


Figure 4-17 Example of assets with slot-oriented AM_Location coding.

Code the AM_Location as an asset for each module as follows:

Bit 0 – 7: AM_Location.Structure = 0x02 (coding "Slot and SubslotNumber format")

Bit 8 – 15: AM_Location.Reserved1 = 0x00 (padding byte)

Bit 16 – 31: AM_Location.BeginSlotNumber = 2 (the "Rack" asset begins from Slot 2 on)

Bit 32 – 47: AM_Location.BeginSubslotNumber = 0xFFFF (the asset encompasses all the subslots of Slot 2. Otherwise you specify the no. of the subslot at which the asset begins)

Bit 48 – 63: AM_Location.EndSlotNumber = 4 (the asset ends at Slot 4)

Bit 64 – 79: AM_Location.EndSubslotNumber = 0xFFFF (the asset encompasses all the subslots of Slot 4. Otherwise you specify the no. of the subslot at which the asset ends)

Bit 80 – 95: AM_Location.Reserved2 = 0x0000 (padding byte)

Bit 96 – 111: AM_Location.Reserved3 = 0x0000

Bit 112 – 127: AM_Location.Reserved4 = 0x0000

Example AM_Location level-oriented

A complex sensor is connected to an IO module (Slot 5, Subslot 1, Channel 1). Two simple sensors, in turn, are connected to the complex sensor. The module can be addressed within the PROFINET device model. Level 0 therefore has the value 0x0000. The next level (Level 1) is specified by the assigned slot. This is followed by the further levels for the subslot and channel and, if appropriate, further subordinate layers.

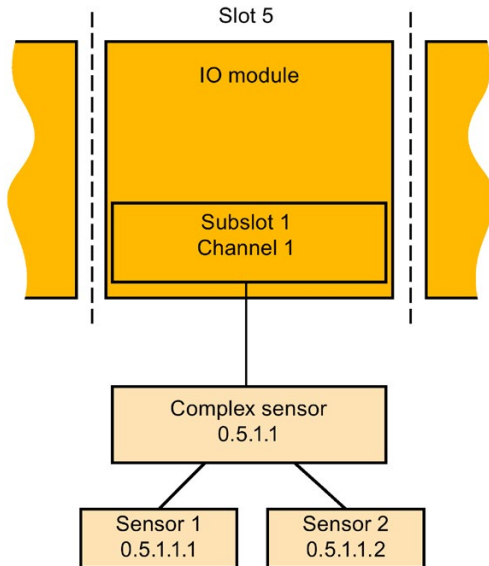


Figure 4-18 Example of assets with hierarchical AM_Location coding.

Detailed coding for the example:

Bit 0 – 7: AM_Location.Structure = 0x01 (LT format)

Bit 8 – 17: AM_Location.Level0 = 0x000 (assets that are assigned to modules always have the Level 0 value 0x000)

Bit 18 – 27: AM_Location.Level1 = 0x005 (Slot 5)

Bit 28 – 37: AM_Location.Level2 = 0x001 (Subslot 1)

Bit 38 – 47: AM_Location.Level3 = 0x001 (Channel 1)

Bit 48 – 57: AM_Location.Level4 = 0x3FF (coding for "Level not used")

Bit 58 – 67: AM_Location.Level5 = 0x3FF (coding for "Level not used")

...

Bit 118 – 127: AM_Location.Level11 = 0x3FF (coding for "Level not used")

Notation used in the screen for the LT coding of complex sensors: 0.5.1.1

The following correspondingly applies for the remaining sensors:

LT coding for simple Sensor 1 at complex sensor: 0.5.1.1.1

LT coding for second simple Sensor 2 at complex sensor: 0.5.1.1.2

4.9.3.3 Asset management data record for I-devices

With STEP 7 (TIA Portal) as of V15 and with S7-1500 CPUs as of firmware V2.5.2, you can compile an asset management data record via a user program. Configured as an I-device, these CPUs then supply the data from centrally plugged modules to a requesting IO controller as assets.

"S7-1500 CPUs" also refers to the CPU variants S7-1500F, S7-1500T, S7-1500C, S7-1500 SW Controller, S7-1500pro CPUs and ET 200SP CPUs.

Asset management records for I-devices

I-devices often represent machines. The PROFINET IO controller to which the I-device is assigned only sees the PROFINET interface (also configured as an IO device) and the transfer areas of the I-device configured by the machine manufacturer. The local modules of the I-device are not visible or cannot be accessed.

The assigned IO controller can read the central modules as assets of the I-device by means of an asset management record that the user program of the I-device compiles.

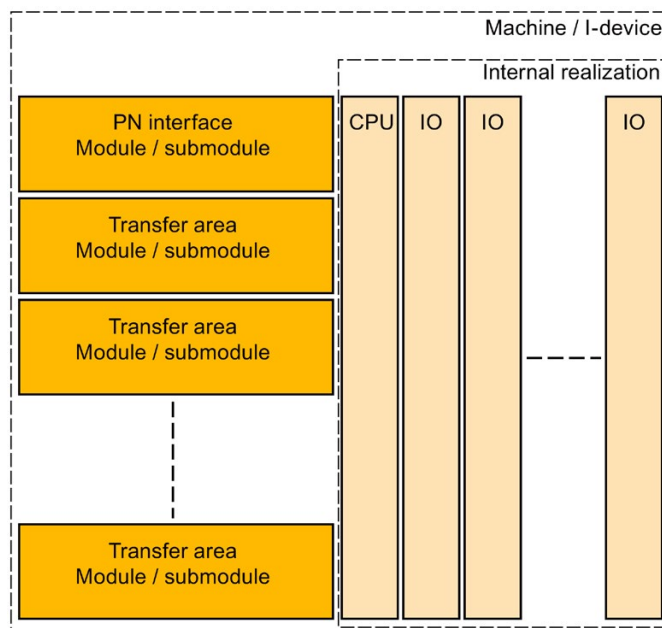


Figure 4-19 Assets of an I-device

Requirement

- S7-1500 CPU as of firmware V2.5.2, configured as I-device
- STEP 7 (TIA Portal) as of V15
- If an IO controller is to read the asset management record:

The PROFINET IO controller is programmed correspondingly to read an asset management record.

For a SIMATIC IO controller, for example, you call a read instruction (RDREC) with record index 0xF880. The instruction addresses any submodule of the I-device, for example the first configured transfer area submodule.

Basic procedure

The following steps are fundamentally required to create the requirements so that an I-device can make its local modules available as an asset management record to a requesting IO controller:

1. Make the settings in the properties of the PROFINET interface of the CPU.
 - Activate "IO device" operating mode
 - Activate the "Activate asset management using user program" option

PROFINET interface forwards a request of an IO controller to the user program of the I-device for reading the asset management record only if the option is selected.

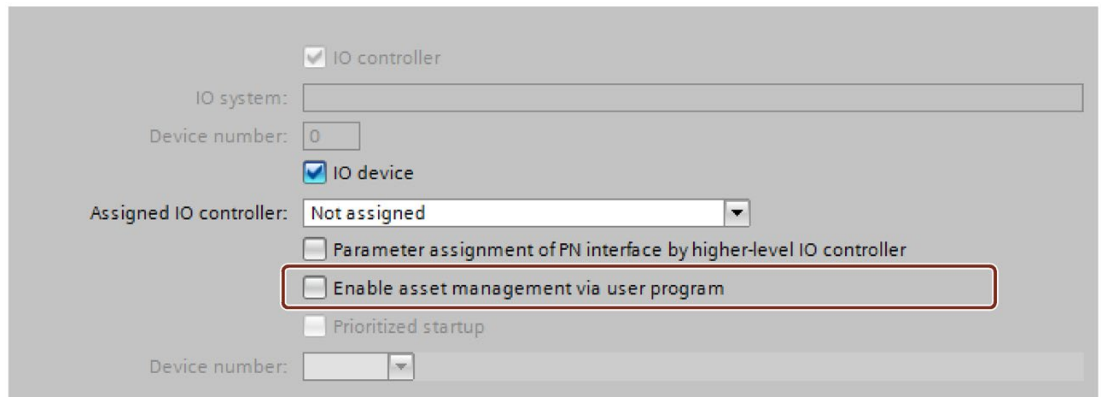


Figure 4-20 Activating asset management using a data record

2. Configure the program routine for compiling the asset management record. The program part collects the required I&M0 data of the plugged central modules and stores them in the corresponding fields of the data record structure of the asset management record.
3. Configure the program part for coordinating the data record provision:
For this, call the instruction PRVREC (Provide Record) in accordance with the following templates in the corresponding modes:

- Cyclic calling (for example in the cycle OB) of the PRVREC instruction with Mode 0, in order to recognize the AMR request.
- When the AM record request is recognized, the PRVREC program has to acknowledge within one second that the request has been recognized. This means that PRVREC must be called with the Mode 2, and with the required AM record. If the I-device does not adhere to the time frame, the I-device acknowledges the record request of the IO controller as negative.

Particular aspect for configuration of the PRVREC call: PRVREC has to be called with **F_ID = 0**. This codes that this is an IO-device-specific data record. The SLOT and SUBSLOT output parameters therefore also return the value 0.

- Within 10 seconds the AM record now has to be completed and PRVREC be called with Mode 3 (positive response to the IO controller with provision of the AM record). If the I-device does not adhere to the time frame, the I-device acknowledges the record request of the IO controller as negative.

A detailed description of the PRVREC instruction and possible error codes for evaluating the function can be found in the online help of STEP 7 (TIA Portal).

Compilation of the asset management record

You have various possibilities for compiling the asset management record for an I-device:

- Recommendation: The Siemens Industry Online Support makes an application available to you that helps you to compile the asset management record.
The data area of the asset management record is divided in two. The first part consists of an automatically determined area that packages the IMO data of the slots of the I-device into an asset management block. The second part consists of the user-specific asset management blocks. You configure the user-specific asset management blocks based on pre-configured asset management record structures, fill them with information and make them available to the application.

The application performs the following:

- The application determines the required size of all the asset management blocks.
- The application fills the data block in accordance with the specifications of an asset management record with the automatically determined asset management blocks and your user-specific asset management blocks.
- The application makes this asset management record available to the higher-level IO controller.

The application is described in this application example

(<https://support.industry.siemens.com/cs/ww/en/view/109748894>)

- You create the asset management record yourself.
The following section describes how you can compile an asset management record for an I-device yourself.
The concept assumes you yourself determine the I&M data for each centrally plugged module and fill the asset management record with this information. The I&M0 data of a module contains basic information about the module such as the manufacturer's code, article number, serial number, hardware and firmware version. These are the data that are also required in the AM record for an asset.

Determine the I&M data of centrally plugged modules

The central structure consists of an optionally plugged power supply unit (Slot 0), followed by the I-device CPU (Slot 1), and then followed by the further modules, such as digital modules, analog modules, etc. (as of Slot 2).

You determine the I&M data with the "Get_IM_Data" instruction for the plugged modules with exception of the CPU:

To assign parameters for the "Get_IM_Data" instruction, you require the hardware identifier (LADDR input parameter). You determine the hardware identifier for each occupied slot with the "GEO2LOG" instruction (Determine hardware identifier from slot).

Summary of the theoretical steps:

1. In a loop, determine the hardware identifiers of the plugged modules with the "GEO2LOG" instruction.
2. For each hardware identifier found, determine the I&M data by using the "Get_IM_Data" instruction and store these data in a data block that you address with the input parameter DATA. Use ARRAY of BYTE for the data storage. This corresponds to the description of the AM record contents in the preceding section.

Forming an AM record with the determined I&M data

The following sections are based on the description of the fundamental structure of the AM record, see the preceding section.

Since each module of an S7-1500 contains hardware and firmware information, select the coding for "AM_FullInformation" for the assigned BlockType.

For the data types used:

- IM_Annotation, IM_OrderID, AM_SoftwareRevision and AM_HardwareRevision: Characters (UTF-8)
- IM_Serial_Number: Characters ("ASCII characters") with the exception of the characters for DEL (0x7F)
- Do not use String data types. They require additional bytes and therefore do not conform to the conventions of the PROFINET standard 61158-6-10 "Application layer protocol specification".

Form the AM_FullInformationBlock for each module as follows:

Table 4- 5 AM_FullInformationBlock for modules

Data record element	Description
IM_UniquelIdentifier	<p>Generate a (pseudo) random UUID (hash value) in accordance with ISO 9834-8 as follows:</p> <ul style="list-style-type: none"> • Generate an 8-byte hash value across the I&M0 data of the module (as of Slot 2). Use the algorithm Fowler-Noll-Vo (in short: FNV); an algorithm for generating variance coefficients (hash values) across data field, see corresponding example code in the Internet or online support. • Generate an 8-byte hash value across the I&M0 data of the CPU. (Use the algorithm Fowler-Noll-Vo (in short: FNV) as described above) • IM_UniquelIdentifier Byte 0 to 7: Hash value of module I&M0 data Bytes 8 to 15: Hash value for CPU-I&M0 data Required customizations to ISO 9834-8: Byte 8, Bit 7 has to be set to 1, and Byte 8, Bit 6 to 0 (result of the AND operator with 0011 1111, subsequent OR operator with 1000 0000) Byte 6, Bit 4 to 7 have to be set to 0100 (result of the AND operation with 0000 1111, then OR operation with 0001 0000) <p>Since this algorithm is based on the I&M0 data of the CPU as well as of the modules, it generates a constant IM_UniquelIdentifier for an individual module. When the configuration changes the IM_UniquelIdentifier also changes.</p>
AM_Location	Byte 0 = 0x02 (slot-oriented coding), see description in the preceding section.
IM_Annotation	Example: "S7-1500 module" and pad the remaining bytes of IM_Annotation with spaces (0x20).
IM_OrderID	Copy 20 bytes of the I&M0 data of the module (beginning with offset 2 of the I&M0 data). Pad the remaining 44 bytes with spaces (0x20)
AM_SoftwareRevision	Pad the field with 64 spaces (0x20)
AM_HardwareRevision	Pad the field with 64 spaces (0x20)
IM_Serial_Number	Copy 16 bytes of the I&M0 data of the module (beginning with offset 22 of the I&M0 data)
IM_Software_Revision	Copy 4 bytes of the I&M0 data of the module (beginning with offset 40 of the I&M0 data)

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Data record element	Description
AM_DeviceIdentification	Byte 0, 1, 2, 6, 7 = 0x00 Byte 3 = 0x2A (Vendor = Siemens) Byte 4 = 01, Byte 5 = DeviceID (e.g. CPU 15xx = 0x0E)
AM_TypeIdentification	Copy 2 bytes of the I&M0 data of the module (beginning with offset 48 of the I&M0 data)
IM_Hardware_Revision	Copy 2 bytes of the I&M0 data of the module (beginning with offset 38 of the I&M0 data)

Functions

Introduction

The following section describes the PROFINET IO functions for field of application, properties and configuration in STEP 7.

Refer to the documentation for the respective device to see to what extent the PROFINET devices support the described functions.

You can find a tabular overview of the PROFINET devices and the functions these support on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/102325771>).

5.1 Connecting other bus systems

Fieldbus integration

PROFINET allows you to use a proxy-capable PROFINET device to integrate existing fieldbus systems (for example, PROFIBUS, AS interface). The devices of these fieldbus systems are mapped on proxy PROFINET devices. In this way, you can set up any hybrid systems consisting of fieldbus and Ethernet-based subsystems. This allows a continuous exchange of information.

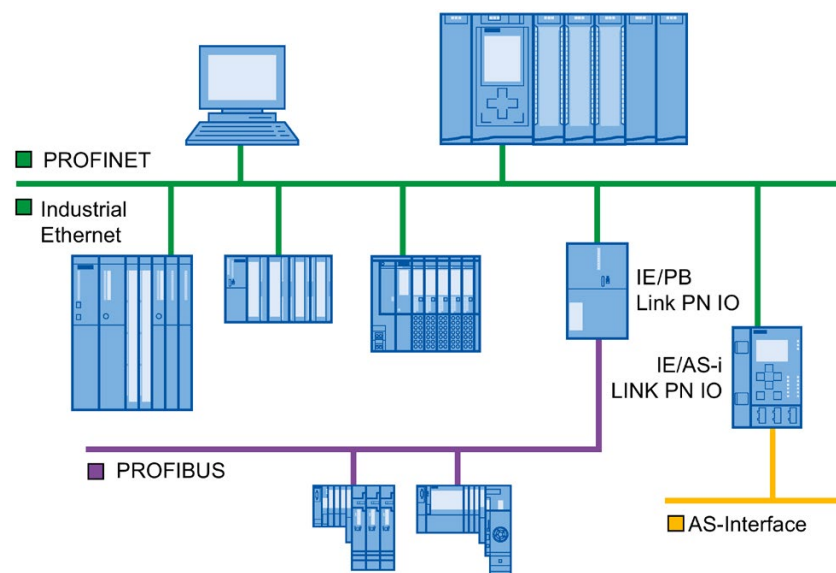


Figure 5-1 Gateways on PROFINET IO

Gateways of an S7-1500 CPU

An overview of the gateways at an S7-1500 CPU is provided in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/88778900>).

Connecting to building busses

- BACnet: You can find the procedure for configuring communication between a SIMATIC PLC and a BACnet network with a gateway in this application example (<https://support.industry.siemens.com/cs/ww/en/view/109476182>).
- M-bus: You can find the procedure for configuring communication between a SIMATIC PLC and an M-bus network with a gateway in this application example (<https://support.industry.siemens.com/cs/ww/en/view/109478527>).
- DALI: You can find the procedure for configuring communication between a SIMATIC PLC and a DALI network with a gateway in this application example (<https://support.industry.siemens.com/cs/ww/en/view/109740160>).
- KNX: You can find the procedure for configuring communication between a SIMATIC PLC and a KNX network with a gateway in this application example (<https://support.industry.siemens.com/cs/ww/en/view/109739689>).

5.1.1 Linking PROFINET and PROFIBUS

Linking PROFINET and PROFIBUS

With a proxy-capable PROFINET device which is equipped with a PROFINET interface in addition to a PROFIBUS interface (for example, IE/PB Link PN IO), you can integrate existing PROFIBUS configurations into the PROFINET configuration.

The following figure shows how a PROFIBUS system is connected via IE/PB Link to a CPU S7-1500 (as of firmware version 1.7).

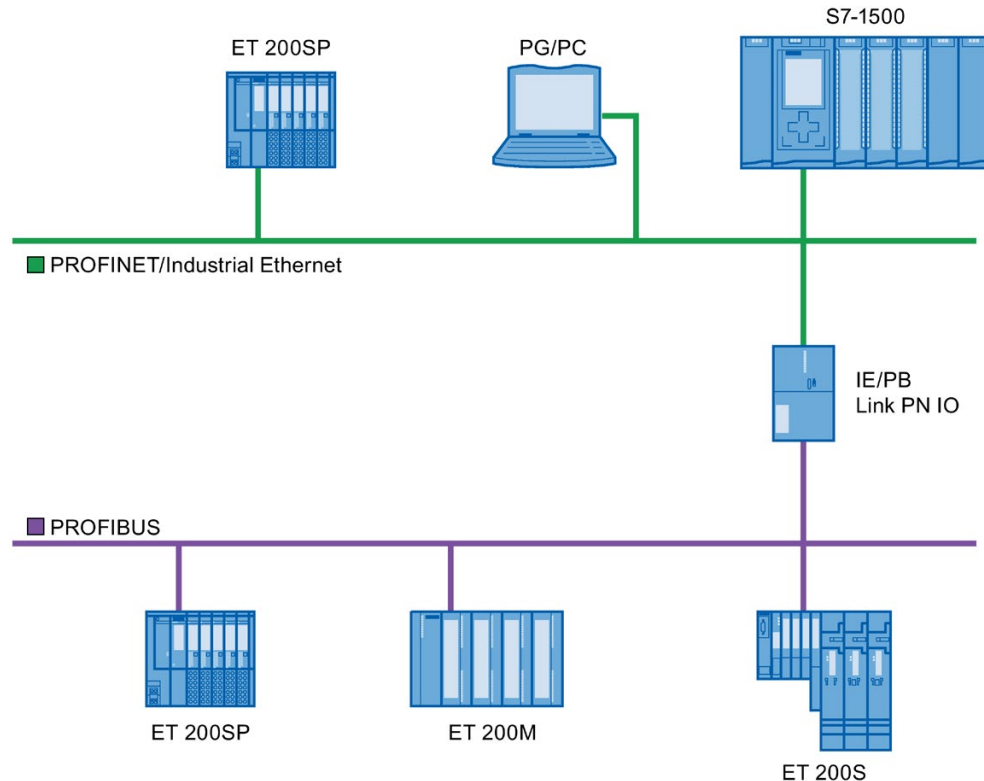


Figure 5-2 Gateway from PROFIBUS and PROFINET via IE/PB link

PROFINET device with proxy functionality

The PROFINET device with proxy functionality is the substitute for a PROFIBUS device on Ethernet. The proxy functionality allows a PROFIBUS device to communicate not only with its master but also with all devices on PROFINET.

With PROFINET you can connect an existing PROFIBUS system to an IO controller, for example with the help of an IE/PB Link PN IO.

From the IO controller perspective, the PROFIBUS DP slaves are connected to the same network as the IE/PB Link PN IO. These slaves have the same device name and IP address as the IE/PB Link PN IO, but different device numbers. Furthermore, each also has a specific PROFIBUS address.

In this way, you can link both DPV0 and DPV1 slaves to PROFINET.

For information on how to connect a DP slave to a PROFINET IO system, refer to section Connect the DP slave via the IE/PB Link to a PROFINET IO system (Page 116).

Diagnostic options with a CPU S7-1500 as IO controller

The CPU S7-1500 (as of firmware version 1.7) as IO controller detects disrupted DP slaves behind the IP/PB link.

5.1.2 Connect the DP slave via the IE/PB Link to a PROFINET IO system

Requirements

- STEP 7 as of V13 SP1
- CPU supports IE/PB link, e.g.:
 - S7-1500 CPU as of firmware version 1.7
 - S7-1500 Software Controller as of firmware version 1.7
 - S7-300/400 CPU

Procedure for connecting a DP slave via an IE/PB Link

To connect a DP slave to a PROFINET IO system via an IE/PB Link in STEP 7, follow these steps:

1. Drag-and-drop a PROFINET CPU, for example CPU 1513-1 PN, from the hardware catalog into the network view of STEP 7.
2. Drag-and-drop an IE/PB Link PN IO from the hardware catalog into the network view of STEP 7. The IE/PB Link PN IO is located under Network components > Gateways > IE/PB Link PN IO.
3. Assign the IE/PB Link PN IO to the CPU.
4. Drag a PROFIBUS interface module e.g. IM155-6 DP HF, from the hardware catalog to the network view.
5. Assign the interface module to the IE/PB Link.

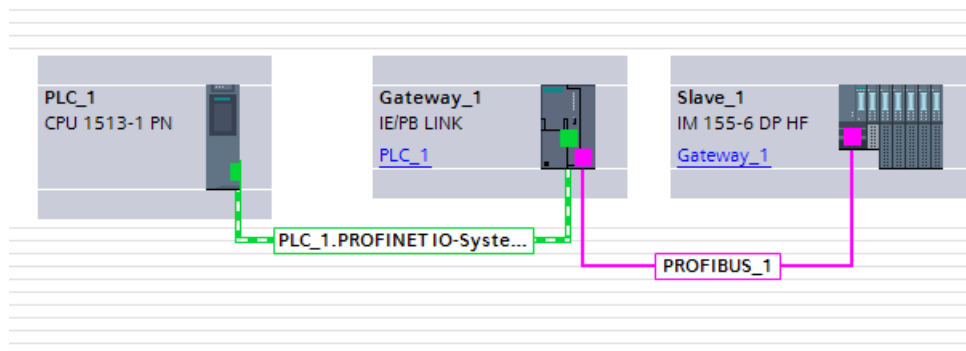


Figure 5-3 Configuring an IE/PB link

6. Select the IE/PB Link PN IO in the network view of STEP 7.

- In the Inspector window, go to the "Gateway" area and select the "Network gateway as PROFINET IO proxy" option.

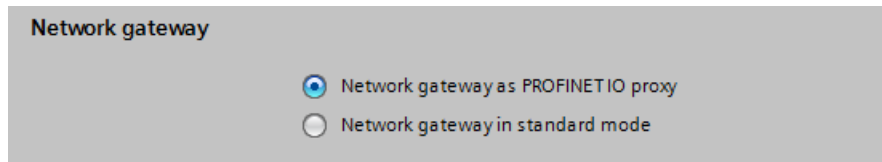


Figure 5-4 Setting a gateway

- In the PROFINET device number area, you can assign a PROFINET device number for the DP slave.

If you have selected the "Device number = PB address" check box (default), STEP 7 automatically assigns the device number according to the PROFIBUS address of the slave. In addition, you no longer need to update the device number if the PROFIBUS address changes.

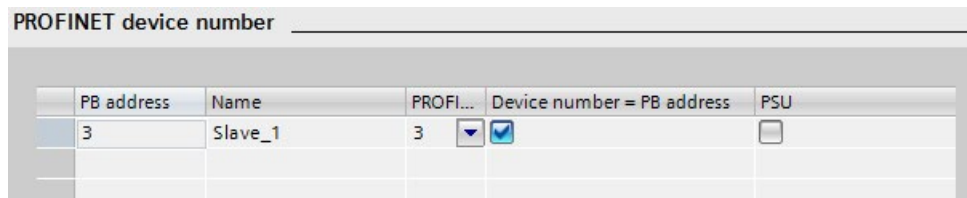


Figure 5-5 Assigning PN device numbers for IE/PB link

Result

You have connected the DP slave to the PROFINET IO system.

Reference

Additional information on the IE/PB link is available in the manual Gateway IE/PB Link PN IO (<http://support.automation.siemens.com/WW/view/en/19299692>).

5.2 Intelligent IO devices (I-devices)

5.2.1 I-device functionality

I-device functionality

The "I-device" (intelligent IO device) functionality of a CPU facilitates data exchange with an IO controller and operation of the CPU as intelligent preprocessing unit of sub processes, for example. The I-device is linked as an IO device to a "higher-level" IO controller.

The preprocessing is handled by the user program in the I-device. The process values acquired in the centralized or distributed (PROFINET IO or PROFIBUS DP) I/O are preprocessed by the user program and made available to the IO controller.

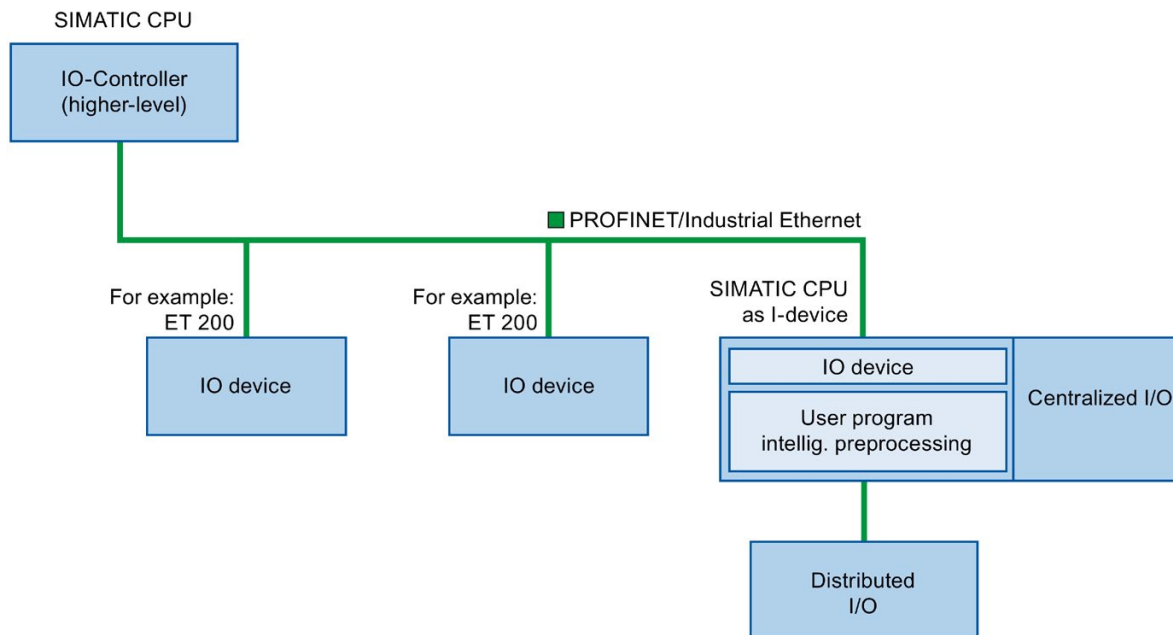


Figure 5-6 I-device

"I-device" naming conventions

In the remainder of this description, a CPU or a CP with I-device functionality is simply called an "I-device".

Application example: Configuration and application of the PROFINET I-device function

A detailed application example is available here (<https://support.industry.siemens.com/cs/ww/en/view/109478798>).

5.2.2 Properties and Advantages of the I-Device

Fields of application

Fields of application of the I-device:

- Distributed processing

A complex automation task can be divided into smaller units/subprocesses. This results in manageable processes which lead to simplified subtasks.

- Separating subprocesses

Complicated, widely distributed and extensive processes can be subdivided into several subprocesses with manageable interfaces by using I-devices. These subprocesses can be stored in individual STEP 7 projects if necessary, which can later be merged to form one master project.

- Know-how protection

Components can only be delivered with a GSD file for the I-device interface description instead of with a STEP 7 project. The know-how of the user program may no longer be published.

Properties

Properties of the I-device:

- Unlinking STEP 7 projects

Creators and users of an I-device can have completely separated STEP 7 automation projects. The GSD file forms the interface between the STEP 7 projects. This allows a link to standard IO controllers via a standardized interface.

- Real-time communication

The I-device is provided with a deterministic PROFINET IO system via a PROFINET IO interface and therefore supports RT (real-time communication) and IRT (isochronous real time).

Advantages

The I-device has the following advantages:

- Simple linking of IO controllers
- Real-time communication between IO controllers
- Relieving the IO controller by distributing the computing capacity to I-devices.
- Lower communication load by processing process data locally.
- Manageable, due to processing of subtasks in separate STEP 7 projects

5.2.3 Characteristics of an I-Device

Principle

An I-device is included in an IO system like a standard IO device.

I-device without lower-level PROFINET IO system

The I-device does not have its own distributed I/O. The configuration and parameter assignment of the I-devices in the role of an IO device is the same as for a distributed I/O system (for example ET 200).

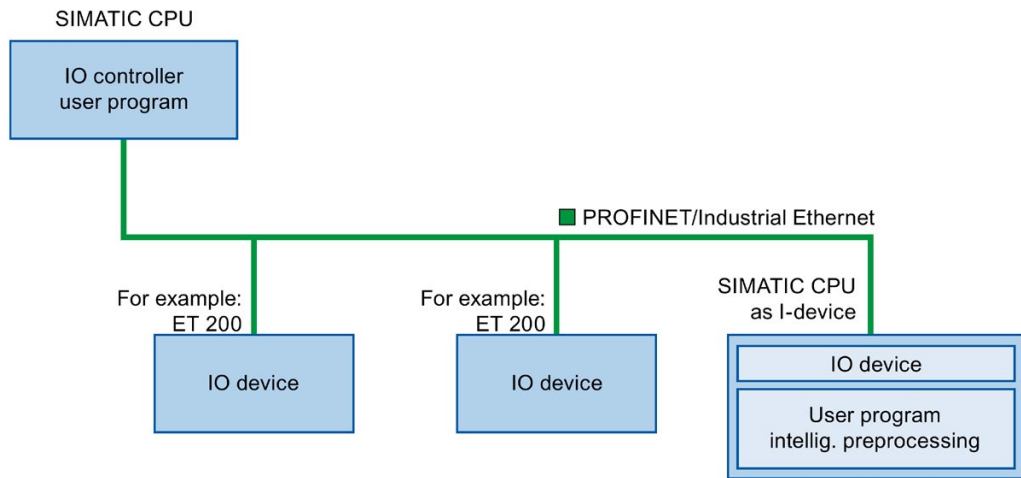


Figure 5-7 I-device without lower-level PROFINET IO system

I-device with lower-level PROFINET IO system

Depending on the configuration, an I-device can also be an IO controller on a PROFINET interface in addition to having the role of an IO device.

This means that the I-device can be part of a higher-level IO system via its PROFINET interface and as an IO controller can support its own lower-level IO system.

The lower-level IO system can, in turn, contain I-devices (see figure below). This makes hierarchically structured IO systems possible.

In addition to its role as IO controller, an I-device can also be used via a PROFIBUS interface as DP master for a lower-level PROFIBUS system.

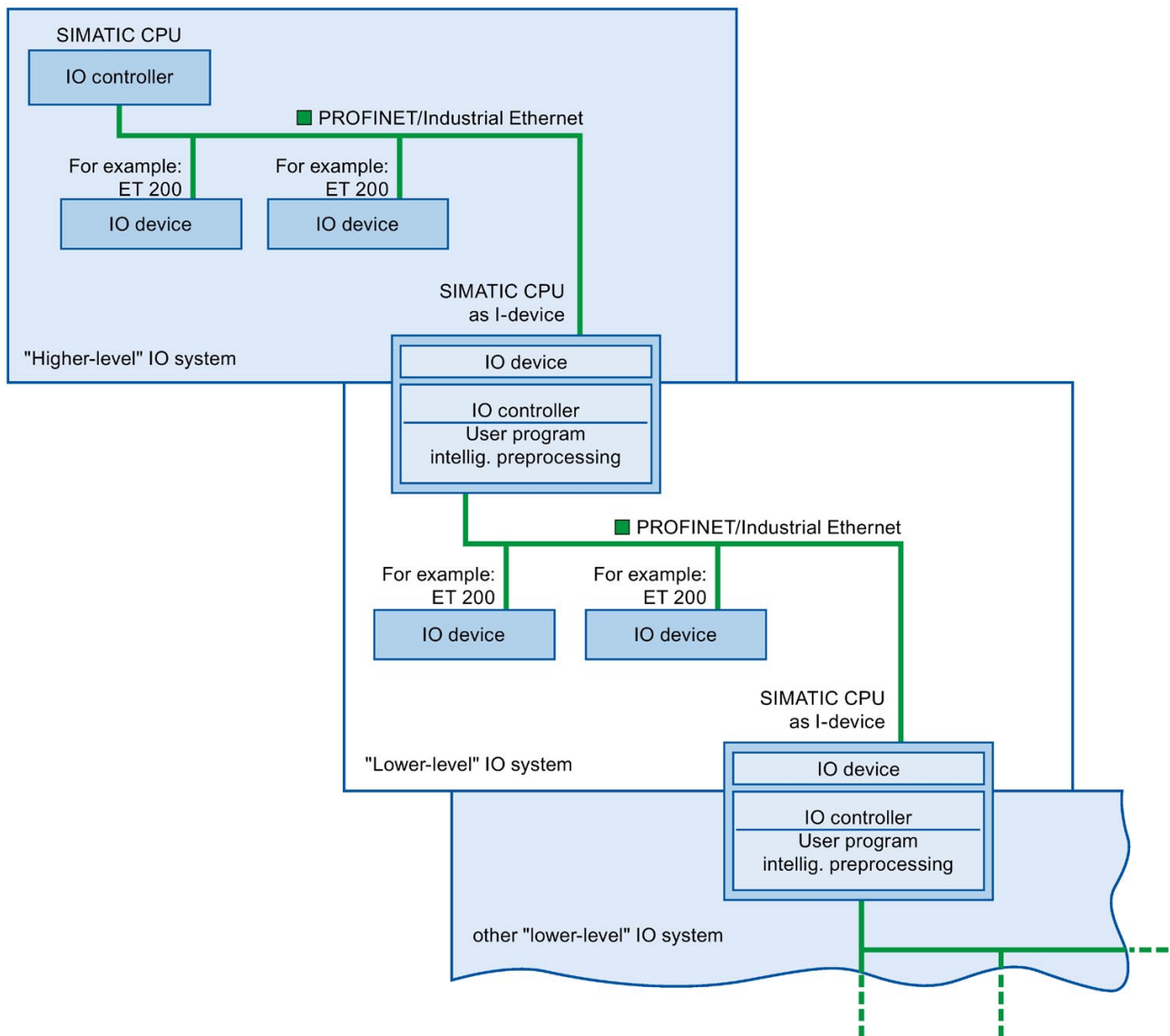


Figure 5-8 I-device with lower-level IO system

Example - the I-device as IO device and IO controller

The I-device as IO device and IO controller is explained based on the example of a print process. The I-device controls a unit (a subprocess). One unit is used, for example, to insert additional sheets such as flyers or brochures in a package of printed material.

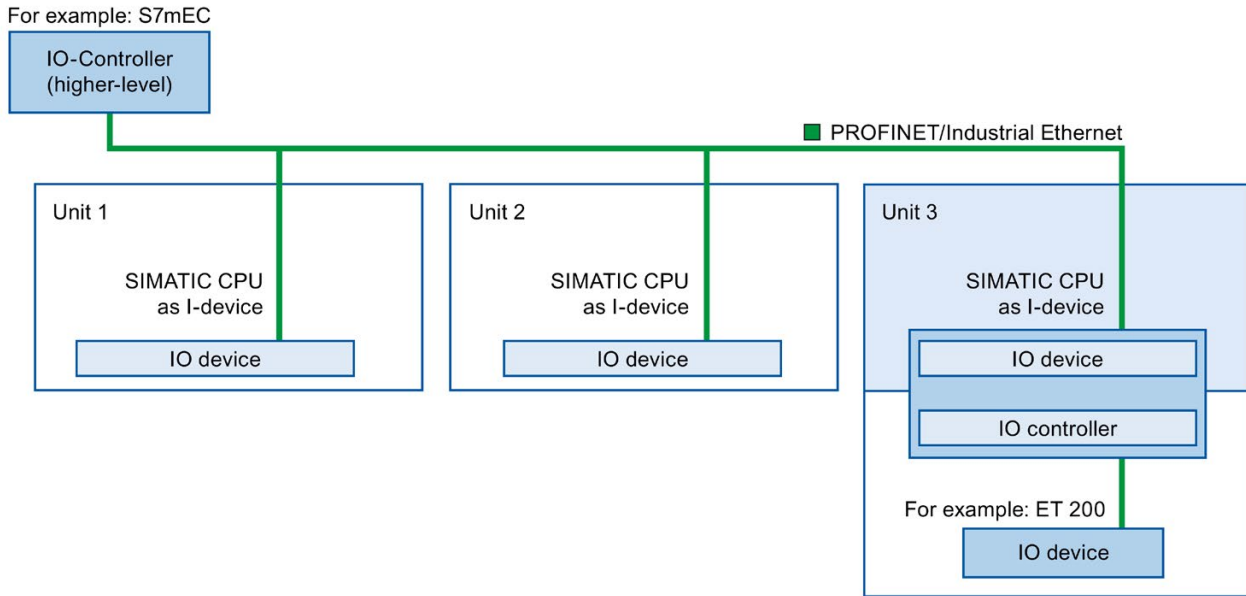


Figure 5-9 Example - the I-device as IO device and IO controller

Unit 1 and unit 2 each consist of an I-device with centralized I/O. The I-device along with the distributed I/O system (for example ET 200) forms unit 3.

The user program on the I-device is responsible for preprocessing the process data. For this task, the user program of the I-device requires default settings (for example control data) from the higher-level IO controller. The I-device provides the higher-level IO controller with the results (for example status of its subtask).

I-device as a shared device

An I-device can also be used simultaneously by multiple IO controllers as a shared device.

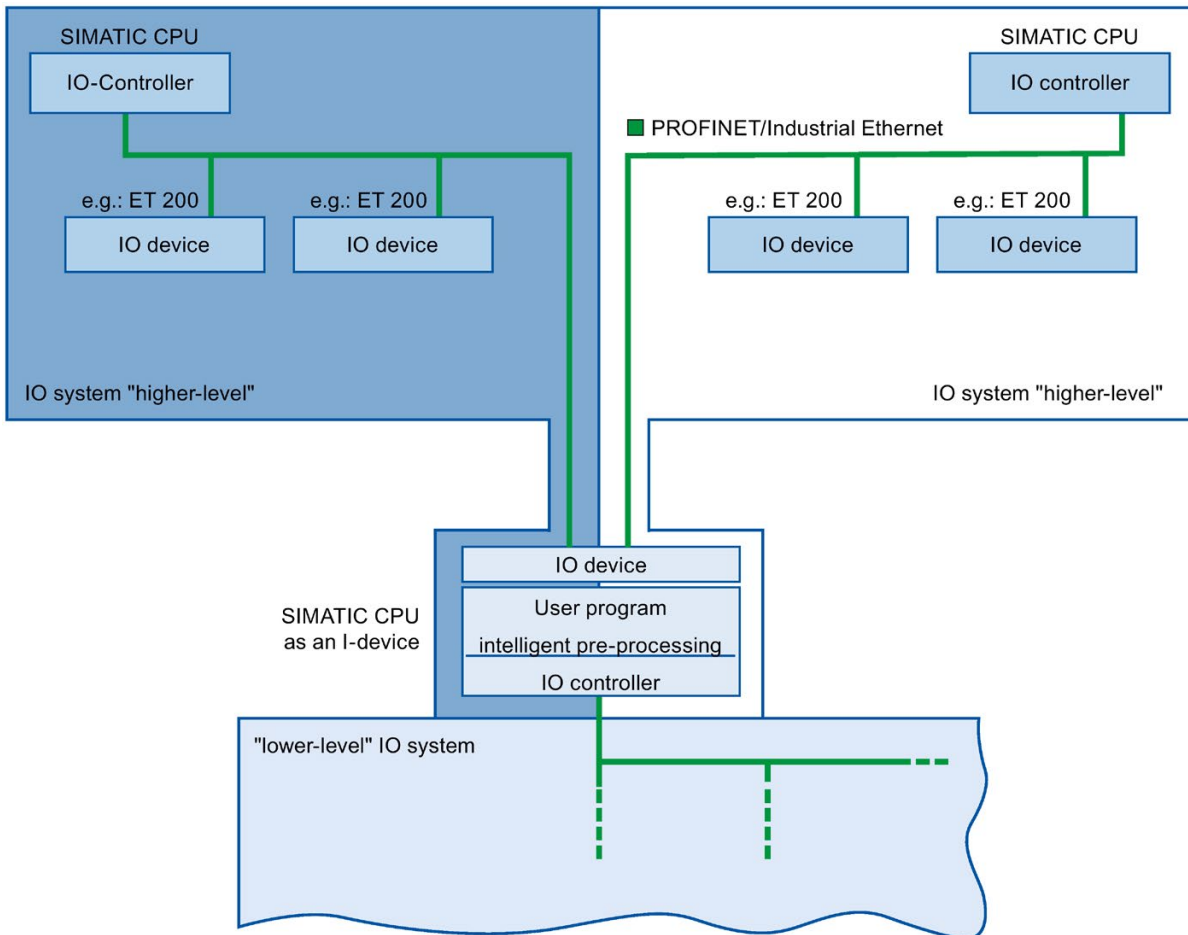


Figure 5-10 I-device as a shared device

Information about configuring an I-device as a shared device is available in the section [Configuring an I-device as a shared device \(Page 146\)](#).

5.2.4 Data Exchange between higher- and lower-level IO system

Introduction

The next chapter shows the data exchange between the higher- and lower-level IO system.

Transfer areas

Transfer areas are an interface to the user program of the I-device CPU. Inputs are processed in the user program and outputs are the result of the processing in the user program.

The data for communication between IO controller and I-device is made available in the transfer areas. A transfer area contains an information unit that is exchanged consistently between IO controller and I-device. You can find more information on configuration and use of transfer areas in the section Configuring the I-device (Page 126).

The next figure shows the data exchange between the higher- and lower-level IO system. The individual communication relations are explained below based on the numbers.

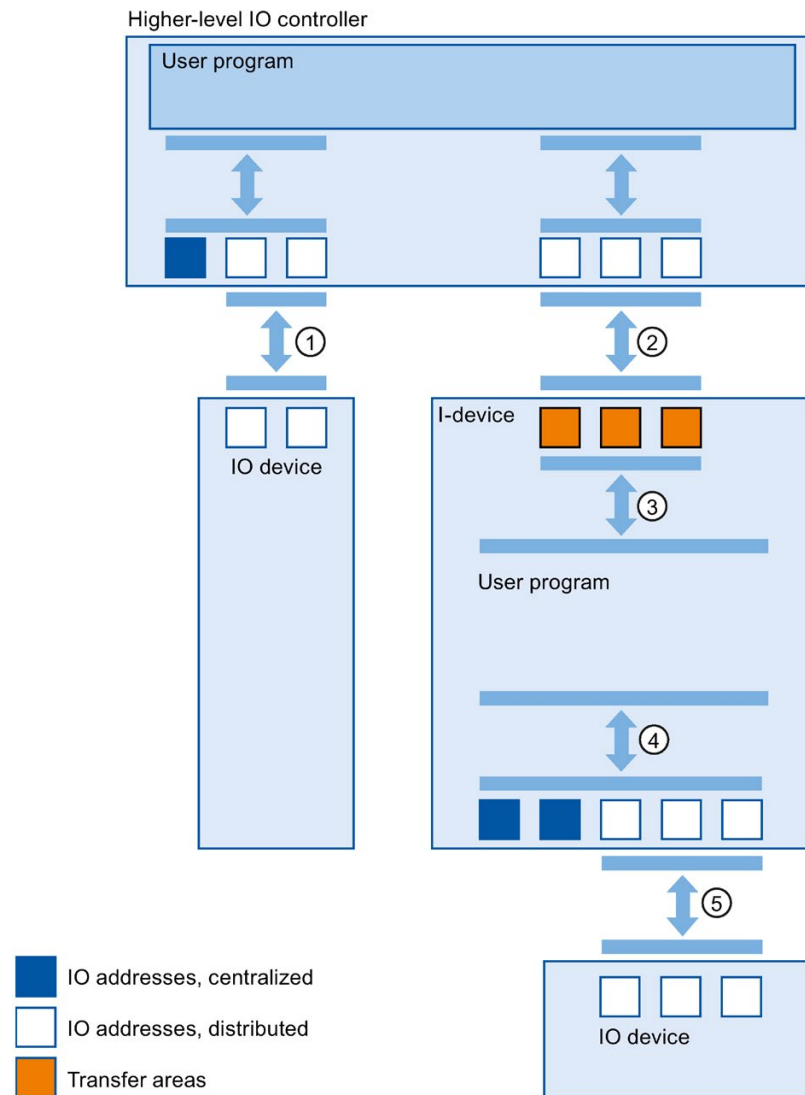


Figure 5-11 Data exchange between higher- and lower-level IO system

① Data exchange between higher-level IO controller and normal IO-device

In this way, the IO controller and IO devices exchange data through PROFINET.

② Data exchange between higher-level IO controller and I-device

In this way, the IO controller and the I-device exchange data through PROFINET.

The data exchange between a higher-level IO controller and an I-device is based on the conventional IO controller / IO device relationship.

For the higher-level IO controller, the transfer areas of the I-devices represent submodules of a preconfigured station.

The output data of the IO controller is the input data of the I-device. Analogously, the input data of the IO controller is the output data of the I-device.

③ Transfer relationship between the user program and the transfer area

In this way, the user program and the transfer area exchange input and output data.

④ Data exchange between the user program and the I/O of the I-device

In this way, the user program and the centralized / distributed I/O exchange input and output data.

⑤ Data exchange between the I-device and a lower-level IO device

In this way, the I-device and its IO devices exchange data. The data transfer is via PROFINET.

5.2.5 Configuring the I-device

Introduction

There are basically two possibilities for configuration:

- Configuration of an I-device within a project
- Configuration of an I-device that is used in another project or in another engineering system.

STEP 7 allows you to configure an I-device for another project or for another engineering system by exporting a configured I-device to a GSD file. You import the GSD file in other projects or engineering systems as with other GSD files. The transfer areas for the data exchange, among other data, are stored in this GSD file.

Configuration of an I-device within a project

1. Drag-and-drop a PROFINET CPU from the hardware catalog into the network view.
2. Drag-and-drop a PROFINET CPU, which can also be configured as an IO device, from the hardware catalog into the network view. This device is configured as I-device (e.g., CPU 1516-3 PN/DP).
3. Select the PROFINET interface for the I-device.
4. In the Inspector window in the area navigation choose "Operating mode" and select the check box "IO device".

- Now you have the option of choosing the IO controller in the "Assigned IO controller" drop-down list.

Once you have chosen the IO controller, the networking and the IO system between both devices are displayed in the network view.

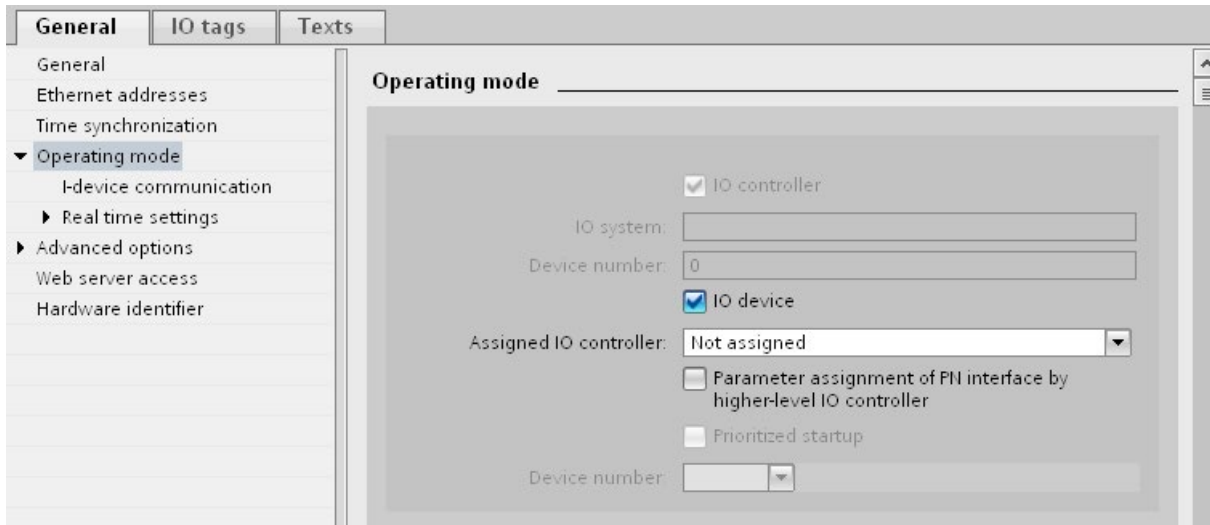


Figure 5-12 Configuring the I-device

- With the "Parameter assignment of PN interface by higher-level IO controller" check box, you specify whether the interface parameters will be assigned by the I-device itself or by a higher-level IO controller.

If you operate the I-device with a lower-level IO system, then the parameters of the I-device PROFINET interface (for example, port parameter) cannot be assigned with the higher-level IO controller.

7. Configure the transfer areas. The transfer areas are found in the area navigation section "I-device communication".
 - Click in the first field of the "Transfer area" column. STEP 7 assigns a default name which you can change.
 - Select the type of communication relation: you can currently only select CD or F-CD for "Controller-device communication relation".
 - Addresses are automatically preset; you can correct addresses if necessary, and determine the length of the transfer area which is to be consistently transferred.

Transfer areas						
	...	Transfer area	Type	Address in IO controller	↔	Address in I-device
1		Transfer area_1	CD	Q 4	→	I 0
2		Transfer area_2	CD	Q 5	→	I 1
3		<Add new>				

Figure 5-13 Configuring the transfer areas

8. A separate entry is created in the area navigation for each transfer area. If you select one of these entries, you can adjust the details of the transfer area, or correct them and comment on them.

Configuring an I-device with a GSD file

If you use an I-device in another project, or if the I-device is used in another engineering system, then configure the higher-level IO controller and the I-device as described above.

However, click on the "Export" button after configuring the transfer areas so a new GSD file is created from the I-device. This GSD file represents the configured I-device in other projects.

The "Export" button is found in the "I-device communication" section of the Inspector window.

The hardware configuration is compiled and the export dialog opened.

Assign a name for the I-device proxy as well as a description in the fields provided. Click the "Export" button to complete your process.

Finally, import the GSD file, for example, in another project.

5.2.6 Program examples

Introduction

This simple program example shows how you use the transfer areas of an I-device.

Requirements

You have configured an I-device.

Task

The result of an "AND logic operation" of two inputs (preprocessing) in the I-device is to be provided to the higher-level IO controller. This result is to be assigned to a local output in the IO master (further processing).

Use a transfer area with the following addresses for this purpose:

- Address in the I-device: Q568
- Address in the IO controller: I68

Required steps

The following steps to solve the task:

1. Configuring the transfer area
2. Programming I-device
3. Programming IO controller

Configuring the transfer area

Configure a transfer area with the following properties in the I-device:

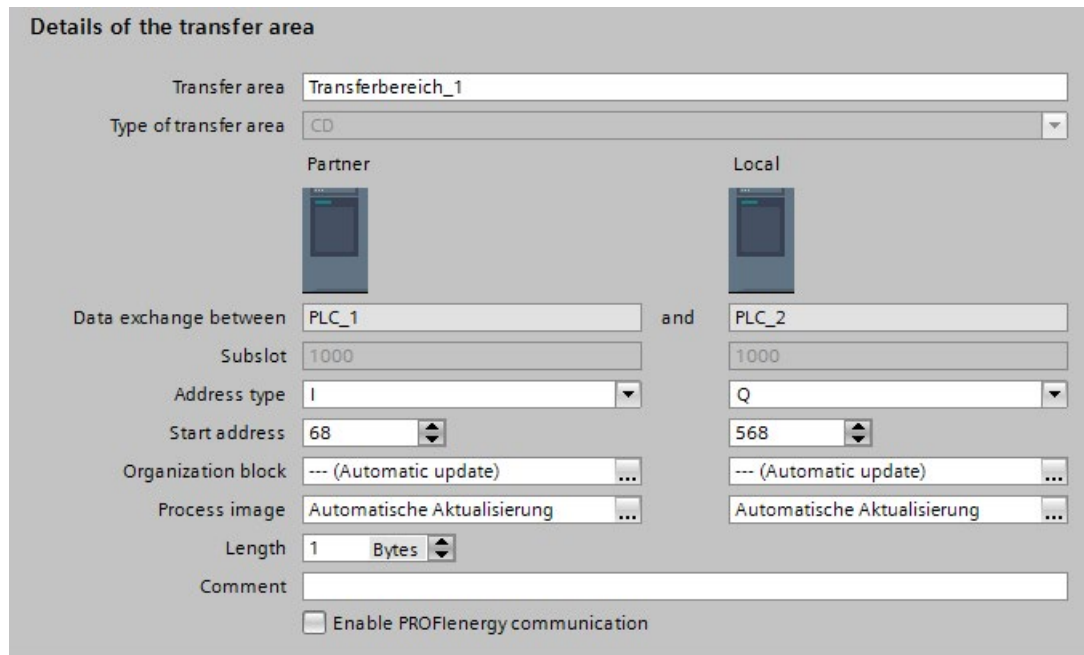


Figure 5-14 I-device transfer area, sample program

Programming I-device

To program the sample program for the I-device, follow these steps:

1. Using the SCL programming language, create a new function with the name "preprocessing" in the project tree in "Program blocks" > "Add new block". Open the function.
2. In the interface of the function "preprocessing", create the following tags:

Name	Data type	Input / output type
input 1	bool	Input
input 2	bool	Input
result	bool	Output

3. In the instruction window of the function "preprocessing", write the following program code:
#result:=#input 1&#input 2;
4. Call the function "preprocessing" in a program cycle OB, for example, in OB1.
5. Wire the function "preprocessing" in the program cycle OB as follows:

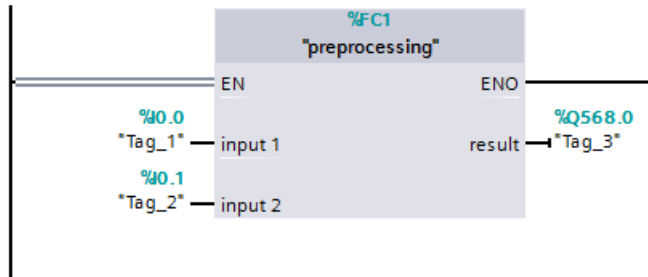


Figure 5-15 I-device sample program

Programming IO controller

To program the sample program for the IO controller, follow these steps:

1. Using the SCL programming language, create a new function with the name "further processing" in the project tree in "Program blocks" > "Add new block". Open the function.
2. In the interface of the function "further processing", create the following tags:

Name	Data type	Input / output type
result	bool	Input
output	bool	Output

3. In the instruction window of the function "further processing", write the following program code:
#output:=#result;

4. Call the function "further processing" in a program cycle OB, for example, in OB1.
5. Wire the function "further processing" in the program cycle OB as follows:

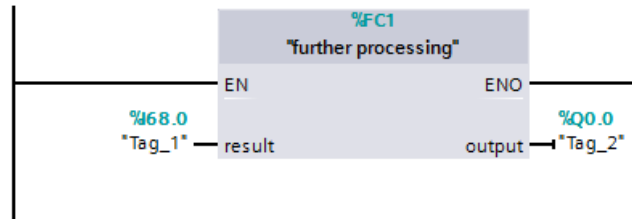


Figure 5-16 IO controller sample program

Result

The IO controller and the I-device can exchange data with each other through the input/output transfer areas.

5.2.7 Diagnostics and interrupt characteristics

Diagnostics and interrupt characteristics

S7 CPUs have numerous diagnostics and interrupt functions that can, for example, report errors or failures of lower-level IO systems. These diagnostics messages reduce down times and simplify localization and elimination of problems.

Diagnostics options in the higher-level IO controller and in the I-device

The following diagnostics functions are available to the higher-level IO controller and the I-device CPU:

- OB 83 (pull/plug)
- OB 86 (rack failure)
- OB 122 (I/O access error)

Note

The diagnostics messages of the I/O can be processed in the user program of the I-device CPU and passed on from there to the higher-level IO controller via transfer areas.

Operating state changes and station failure / station return

In the following table, you can see which consequences an operating state change or the failure of an IO controller / I-device of the SIMATIC family has on the respective other(s):

Table 5- 1 Operating state changes and station failure / station return

Initial status	Event	I-device response	Higher-level IO controller
I-device CPU is in RUN, higher-level IO controller is in RUN	The I-device CPU changes to STOP	-	During the updating of the process image with the instructions "UPDAT_PI" and "UPDAT_PO" an error report is returned at the parameter RET_VAL. With direct IO access to all transfer areas to the I-device: depending on the type of error handling, e.g., call of OB 122 (IO access error).
I-device CPU is in STOP higher-level IO controller is in RUN	The I-device CPU is starting up	Call of OB 100 (startup). Call of OB 83 (pull/plug) for input transfer areas to the higher-level IO controller. Until call of OB 83 in the case of direct access to the input transfer areas to the higher-level IO controller: depending on the type of error handling, e.g., call of OB 122 (IO access error).	Call of OB 83 (pull/plug) for all transfer areas to the I-device. Until call of OB 83 in the case of direct access to the transfer areas to the I-device: depending on the type of error handling, e.g., call of OB 122 (IO access error).
I-device CPU is in RUN, higher-level IO controller is in RUN	The higher-level IO controller changes to STOP	During the updating of the process image with the instructions "UPDAT_PI" and "UPDAT_PO" an error report is returned at the parameter RET_VAL. With direct IO access to the input transfer areas to the higher-level IO controller: depending on the type of error handling, e.g., call of OB 122 (IO access error). Note: Output transfer areas can still be accessed.	-
Higher-level IO controller is in STOP, I-device CPU in RUN	The higher-level IO controller starts up	Call of OB 83 (pull/plug) for input transfer areas to the higher-level IO controller. Until call of OB 83 in the case of direct access to the input transfer areas to the higher-level IO controller: depending on the type of error handling, e.g., call of OB 122 (IO access error).	Call of OB 100 (startup).

Initial status	Event	I-device response	Higher-level IO controller
I-device CPU is in RUN, higher-level IO controller is in RUN	Station failure I-device, for example, through bus interruption	If the I-device continues to run without a bus connection: Call of OB 86 (rack failure). During the updating of the process image with the instructions "UPDAT_PI" and "UPDAT_PO" an error report is returned at the parameter RET_VAL. With direct IO access to all transfer areas to the higher-level IO controller: depending on the type of error handling, e.g., call of OB 122 (IO access error).	Call of OB 86 (rack failure). During the updating of the process image with the instructions "UPDAT_PI" and "UPDAT_PO" an error report is returned at the parameter RET_VAL. With direct IO access to all transfer areas to the I-device: depending on the type of error handling, e.g., call of OB 122 (IO access error).
I-device CPU is in RUN, higher-level IO controller is in RUN, communication connection between IO controller and I-device is interrupted (bus interruption).	The bus connection between the IO controller and I-device has been reestablished and the I-device is again included in the user data traffic.	Call of OB 86 (rack failure). Call of OB 83 (pull/plug) for input transfer areas to the higher-level IO controller. Until call of OB 83 in the case of direct access to the input transfer areas to the higher-level IO controller: depending on the type of error handling, e.g., call of OB 122 (IO access error).	Call of OB 86 (rack failure). Until reporting of station re-integration by OB 86 with direct IO access to all transfer areas to the I-device: depending on the type of error handling, e.g., call of OB 122 (IO access error)

Note

Special characteristic during startup of the higher-level IO controller

In contrast to the station return message from IO devices in the IO controller, which are covered completely by the call of the OB 86, the station return message of a higher-level IO controller in the I-device is separated into 2 parts:

1. Call of the OB 86: The initial values for the outputs of the I-device are set. However, the input values are not yet valid. These values will first be valid with the opening of OB 86 in the higher-level IO controller.
2. Call of OB 83 for each input transfer area; with this call, the validity of an input transfer area is displayed. The starting up of the I device is first complete when the OB 83 has been called for the input transfer areas. This step can be delayed or not occur at all in the following situations:
 - Higher-level IO controller is in STOP: OB 83 is first called at the STOP-RUN transition of the higher-level IO controller.
 - The IRT communication has been disrupted (sync-master failure, topology error, ...). OB 83 is opened only after the IRT communication has taken place.

Reference

For more information on error handling in the case of direct I/O access, refer to "Error handling" in the STEP 7 online help.

5.2.8 Rules for the Topology of a PROFINET IO System with I-Device

Introduction

The following recommendations for the structure and configuration of an IO system when using I-devices will help you to keep the bandwidths required for keeping communication small.

The following communication paths should not overlap:

- Communication paths between the IO controller and the IO device of its IO system.
- Communication paths of the I-device CPU and the IO devices of your IO system.

I-device with one port

Connect an I-device with only one port to a PROFINET switch that is uncoupled from the higher-level IO system. Connect the lower-level IO system to another port of the switch as shown in the following figure.

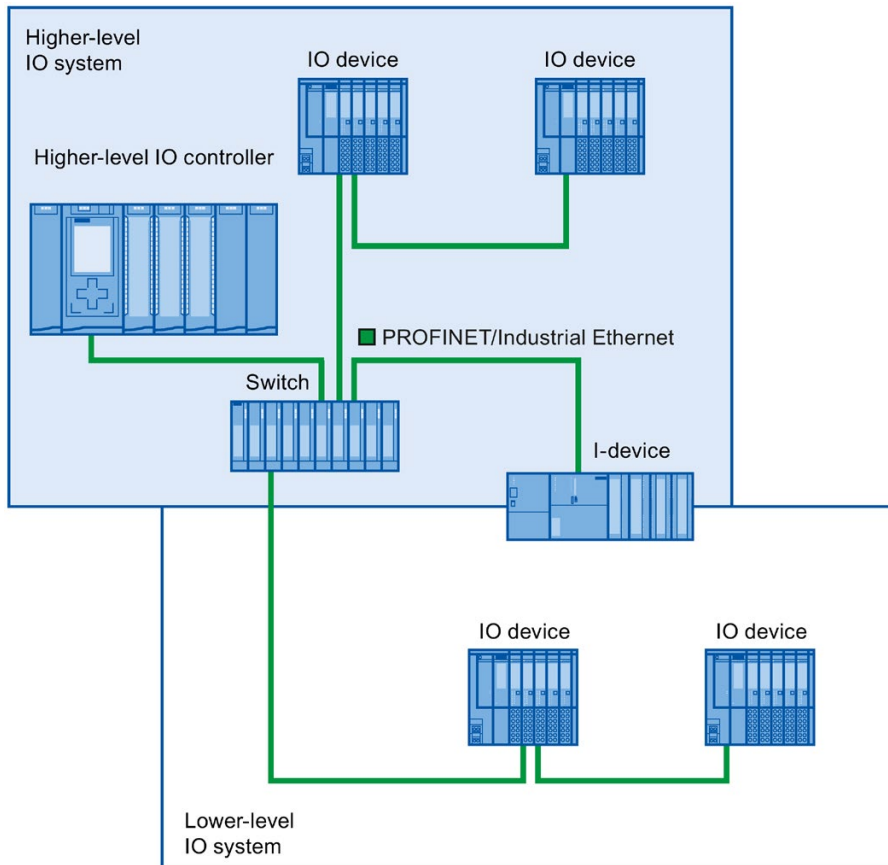


Figure 5-17 I-device with one port

I-device with two ports

With an I-device with two ports, connect one port, uncoupled from the higher-level IO system, to the port of the PROFINET switch. Use the second port for the lower-level IO system as shown in the following figure.

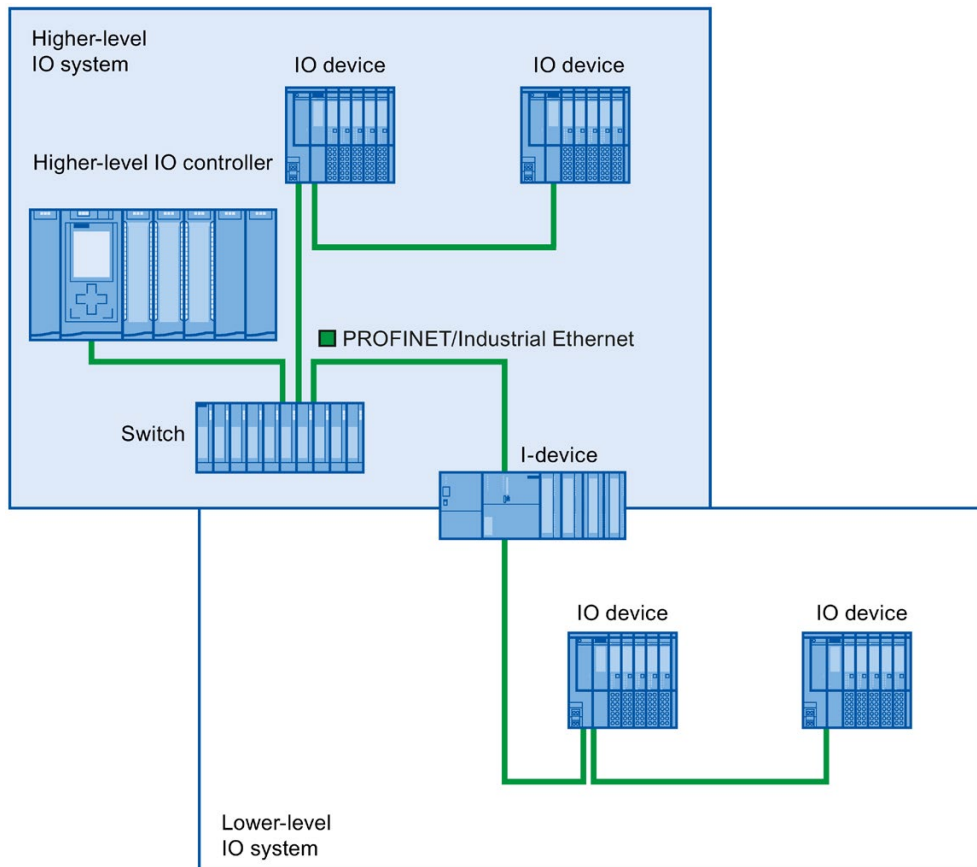


Figure 5-18 I-device with two ports

I-device with three or more ports

If you have an I-device with three or more ports, connect the I-device to one or both ports to the higher-level IO system in a linear bus topology. Connect the third port to the lower-level IO system uncoupled from the linear bus topology as shown in the following figure.

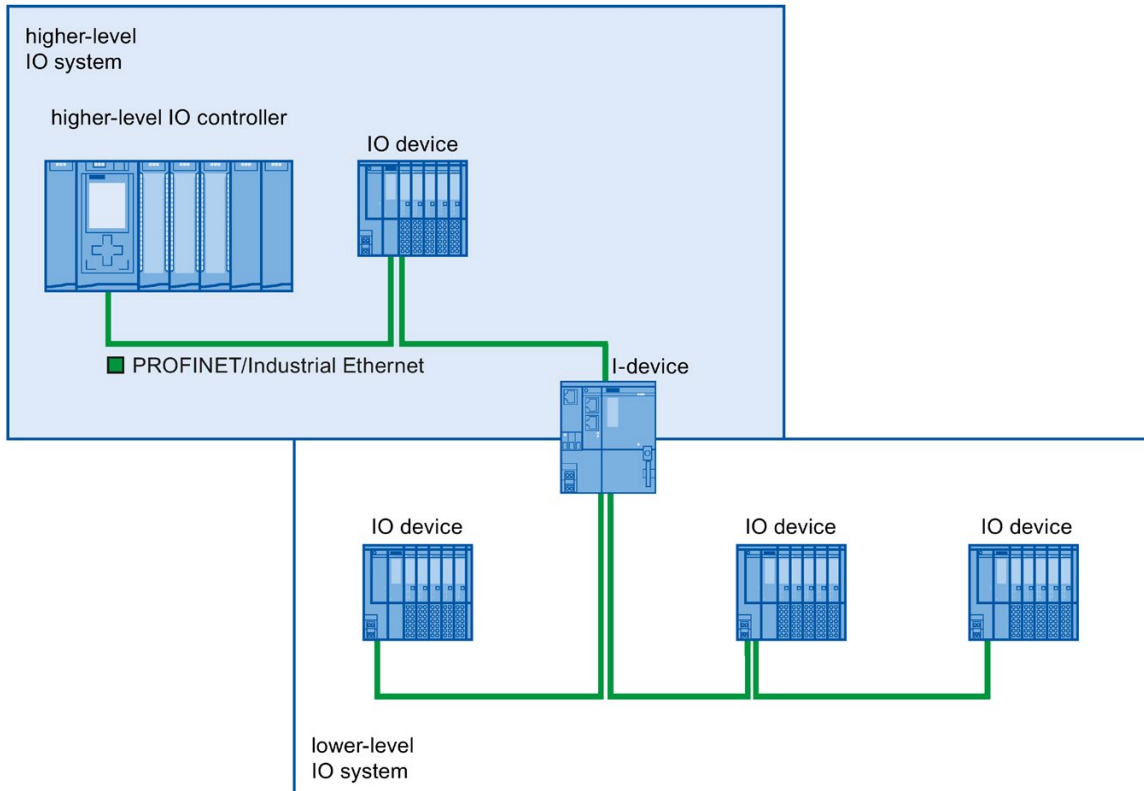


Figure 5-19 I-device with three or more ports

5.2.9 Boundary conditions when using I-devices

Note the following boundary conditions when using I-devices:

Bandwidth

The number of addresses of the configured transfer areas affects the usable bandwidth of the I-device:

- Bandwidth of the transfer areas + bandwidth of the lower-level IO system = total bandwidth used on the I-device

If the address space of the transfer areas is too large, this indicates a larger bandwidth requirement and can thus lead to longer update times.

Tip: Keep the address space of the transfer area as small as possible.

Rules for RT and IRT communication.

IO systems with I-devices are also suitable for setting up real-time applications with RT and IRT communication. The following rules must be followed for this:

- Both the higher-level and the lower-level IO system support RT communication. You can use RT communication for both IO systems at the same time.
- IRT communication can be combined with RT communication. You can use IRT communication in one of the two IO systems. Use IRT either in a higher-level or in a lower-level IO system.

5.2.10 Configuring PROFINergy with I-devices

The requirement for program-controlled pauses for saving energy with PROFINET devices is that the PROFINET devices support the PROFINergy protocol.

Only if a PROFINET device (I/O device) supports the PROFINergy protocol does an I/O controller actually send PE commands to this I/O device, for example to start or stop pauses.

If an I/O device supports the PROFINergy protocol, this property is saved in its PROFINET GSD file and is available for configuration in an engineering system.

For S7-1500 CPUs as intelligent I/O devices (I-devices), you have the option with STEP 7 V13 service pack 1 or later to set PROFINergy support for each transfer area.

If you have selected the "Enable PROFINergy communication" option for a transfer area and import the generated PROFINET GSD file into another project, you can handle an I-device as a PE entity there.

Requirements

- STEP 7 as of V13 service pack 1
- CPU supports PROFINergy with I-devices, for example CPU 1215C DC/DC/DC as of firmware version 4.2
- You use the PROFINET IO interface as an I-device and have created transfer areas.
- The user program in the I-device handles PROFINergy commands

Background: You need to program PROFINergy functions with I-devices in the user program using the "PE_I_DEV" instruction and corresponding auxiliary blocks; this is different compared with IO devices for which this functionality is made available by the firmware. You may therefore only activate the PROFINergy support for transfer areas if the user program in the I-device is configured correspondingly as well.

Enabling PROFINergy for transfer areas of I-devices

Proceed as follows to assign parameters for the support of PROFINergy:

1. Select the PROFINET interface (X1) of the CPU.
2. Select the required transfer area in the area navigation, for example:
Operating mode > I-device communication > Transfer_area_1.
3. Select the check box "Enable PROFINergy communication".

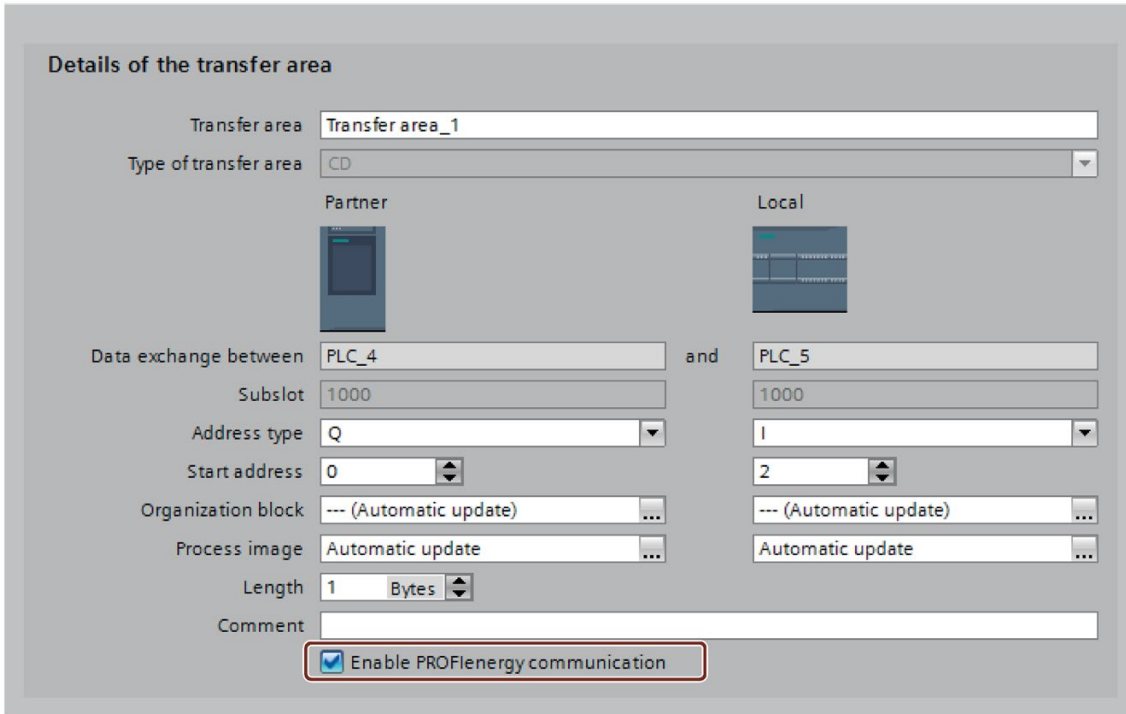


Figure 5-20 Configuring PROFINergy with I-devices

Once the I-device is fully configured, generate the GSD file for the I-device and import this file in the project for the I/O controller. The GSD file generated contains an entry that specifies that the I-device supports the PROFINergy profile.

To address the I-device, for example for the PE command "PE_START_END", use the hardware identifier of the "PROFINergy supporting" transfer area in the I-device.

To address the IO controller for the PE command "PE_I_DEV", use the hardware identifier of the transfer area that is supplied with the data for PROFINergy on the IO controller.

You can find more information on PROFINergy in the section Saving energy with PROFINergy (Page 258).

5.3 Shared device

5.3.1 Useful information on shared devices

Shared device functionality

Numerous IO controllers are often used in larger or widely distributed systems.

Without the "Shared Device" function, each I/O module of an IO device is assigned to the same IO controller. If sensors that are physically close to each other must provide data to different IO controllers, several IO devices are required.

The "Shared Device" function allows the modules or submodules of an IO device to be divided up among different IO controllers. Thus allowing flexible automation concepts. You have, for example, the possibility of combining I/O modules lying near other into an IO device.

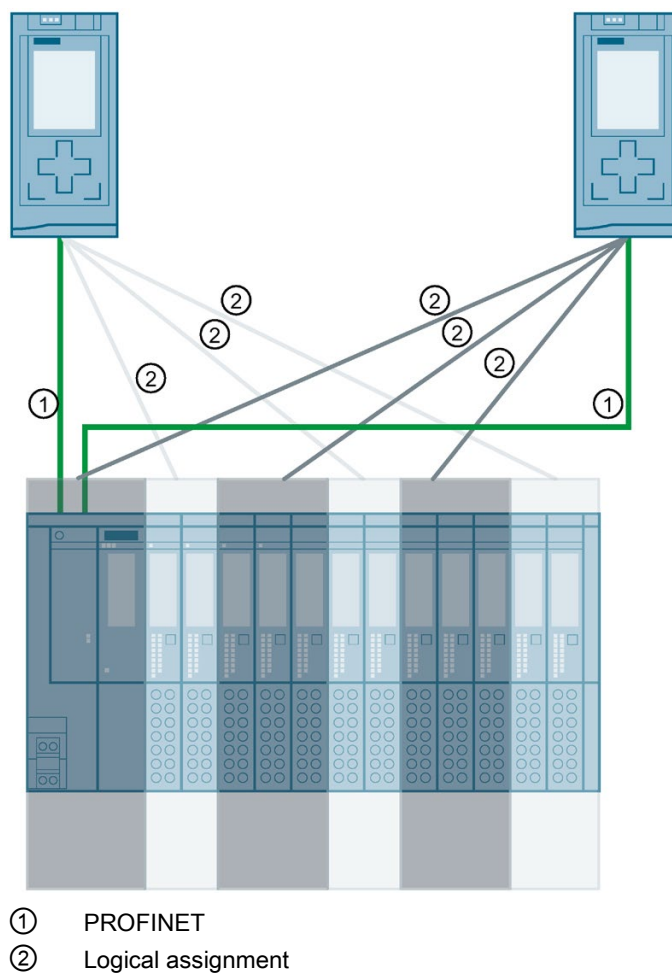


Figure 5-21 Example: Shared device with 2 IO controllers

Principle

Access to the submodules of the shared device is then divided up among the individual IO controllers. Each submodule of the shared device is assigned exclusively to one IO controller.

Requirement

- STEP 7 V12 Service Pack 1 or higher
- IO device supports the shared device function, e.g. interface module IM 155-5 PN ST
- IO controller supports the shared device function, for example CPU 1516-3 PN/DP as of firmware version 1.1 or CPU 1215 DC/DC/DC as of firmware version 4.1

Explanatory notes:

- A CPU that is configured as an I-device can be used as a shared device. For this purpose, you create a GSD file for the I-device in STEP 7 via "GSD export". You then import the GSD file into a different project and assign the I-device to the IO controller there. The CPU has to support the GSD export, for example CPU 1215C DC/DC/DC as of firmware version 4.1.
The maximum number of IO controllers that you can assign to a CPU configured as a shared I-device is given in the technical specifications in the CPU manuals.

Configuring the access

The IO device must be present in several projects so that the modules or submodules of an IO device can be assigned to different IO controllers. A separate project is required for each IO controller.

You use the "Shared device" parameter of the interface module to determine the modules or submodules to which the IO controller has access:

- If the local IO controller has access to the configured module, select the name of the IO controller from the list.
- If the IO controller from a different project and not the local IO controller is to have access to the configured module, select the entry "---".

The configuration is consistent regarding access if each module or submodule in exactly one project is assigned to an IO controller.

Module or submodule is assigned to another IO controller

The paragraph below describes the consequences of the "---" setting of the "Shared device" parameter from the point of view of the local IO controller.

In this case, the local IO controller does not have access to the module configured in this way. Specifically, this means:

- No data exchange with the module or submodule
- No reception of alarms or diagnostics, which means no display of the diagnostics status in the online view
- No parameter assignment of the module or submodule

Setting of the real-time properties

STEP 7 calculates the communication load and thus the resulting update times. You must enter the number of project-external IO controllers in the project in which the PROFINET interface of the shared device is assigned to the IO controller so that a calculation is possible with shared device configurations.

The maximum possible number of IO controllers for the shared device depends on the device. This number is stored in the GSD file of the shared device.

You can set a very short send clock with a CPU as IO controller. The send clock can be shorter than the shortest send clock supported by the shared device. In this case, the shared device is operated by the IO controller with a send clock that it supports (send clock adaptation).

Example:

A CPU supports send clocks starting from 0.25 ms. A configured IO device also supports send clocks starting at 0.25 ms; another IO device supports send clocks starting at 1 ms. In this case, you have the option of setting the short send clock of 0.25 ms for the CPU. The CPU operates the "slow" IO device with the send clock of 1 ms, for example.

Rules for the configuration

- IO controllers that use the shared device are created in different projects. In each project, care must be taken that the shared device is configured identically in each station. Only one IO controller may ever have full access to a submodule. Inconsistencies in the configuration result in a failure of the shared device.
- If you have selected the "Use router" option for the IO controllers involved, you must have set the same router address in all these IO controllers.
- I/O addresses of a module or submodule can only be edited if a module or submodule is assigned to the IO controller in the same project.
- The shared device must have the same IP parameters and the same device name in each project.
- The send clock must be identical for all IO controllers that have access to the shared device.
- The S7 subnet ID of the subnet to which the shared device is connected must be identical in all projects.
- The following functions are only available if the PROFINET interface of the shared device is assigned to the local IO controller:
 - IRT operation
 - Prioritized startup
 - Parameter assignment of the port properties

Boundary conditions

The following boundary conditions result because a shared device configuration is distributed across several projects:

- The addresses of modules or submodules that are not assigned to this IO controller are missing in the address overview of each IO controller that has access to a shared device.
- The modules or submodules that are not assigned are not taken into consideration in the configuration limit calculation for the shared device during the consistency check. For this reason, you must verify for yourself that the maximum number of submodules or the maximum amount of cyclic IO data for the shared device will not be exceeded. For information on the maximum quantities, refer to the documentation for the devices you are using.
- Configuration errors such as the assignment of a module or submodule to several IO controllers are not detected in STEP 7.
- CPUs that are loaded with a shared device configuration do not have any information on whether the IO device is a shared device. Modules or submodules that are assigned to other IO controllers and therefore other CPUs are missing in the loaded configuration. These modules or submodules are therefore displayed neither in the CPU web server nor in the CPU display.

Response in the event of fault

Information about how PROFINET IO controllers behave in the event of a fault when accessing the data of a shared device is available in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/109572804>).

5.3.2 Configuring shared device

Below, you will find a description of how to configure a distributed I/O system as a shared device with STEP 7 V12, Service Pack 1 or higher.

A "distributed" configuration with different engineering tools for different IO controller families is always possible. However, the description of the procedure is based solely on STEP 7 as of V12, service pack 1. The description is limited to two IO controllers of the S7-1500 family that share a shared device.

Two projects are created (Shared-Device-1 and Shared-Device-2), each with one IO controller (PLC1 and PLC2). You must create the shared device in both projects, even though it is physically one and the same IO device.

Requirements

- STEP 7 V12 Service Pack 1 or higher
- The IO controller supports the shared device function, for example CPU 1513-1 PN as of firmware version 1.1.
- IO device supports shared device functionality, for example interface module IM 155-5 PN ST as of firmware version 2.0.

Procedure - Creating project 1

To create the first project with a shared device, follow these steps:

1. Start STEP 7.
2. Create a new project with the name "Shared-Device-1".
3. Insert, for example, a CPU 1513-1 PN from the hardware catalog in the network view. Name it "PLC1".
4. Insert an IO device with the "Shared device" function from the hardware catalog.
5. Assign the IO controller "PLC1" to the IO device.
6. Double-click the IO device and insert all required modules and submodules from the hardware catalog in the device overview table.
7. Assign the module parameters.
8. Save the project.

Procedure - Creating project 2

To create the second project with a shared device, follow these steps:

1. Start STEP 7 once again.
A new instance of STEP 7 opens.
2. In the new instance, create a new project with the name "Shared-Device-2".
3. Insert, for example, a CPU 1513-1 PN in the network view. Name it "PLC2".
4. Copy the IO device from the project "Shared-Device-1" and insert it in the network view of project "Shared-Device-2".
5. Assign the IO controller "PLC2" to the IO device.
6. Save the project.

Both projects now have an identically structured IO device that must be configured in the next step for the different types of IO controller access.

Procedure - Configuring access to the shared device

The modules and submodules you insert in the shared device are automatically assigned to the local CPU. To change the assignment, follow these steps:

1. Select the interface module in the network view or device view of project "Shared-Device-1".
2. Select the "Shared Device" area in the Inspector window.

A table shows which CPU has access to the respective module or submodule for all configured modules. The default setting is that the local CPU has access to all modules and submodules.

- Keep the "PLC1" setting for all modules and submodules that are to remain in the address range of the local CPU.

Select the setting "---" for all modules and submodules that are to be located in the address range of the CPU from the "Shared-Device-2" project (PLC2). This means that an IO controller outside the project is to have access to the module or submodule.

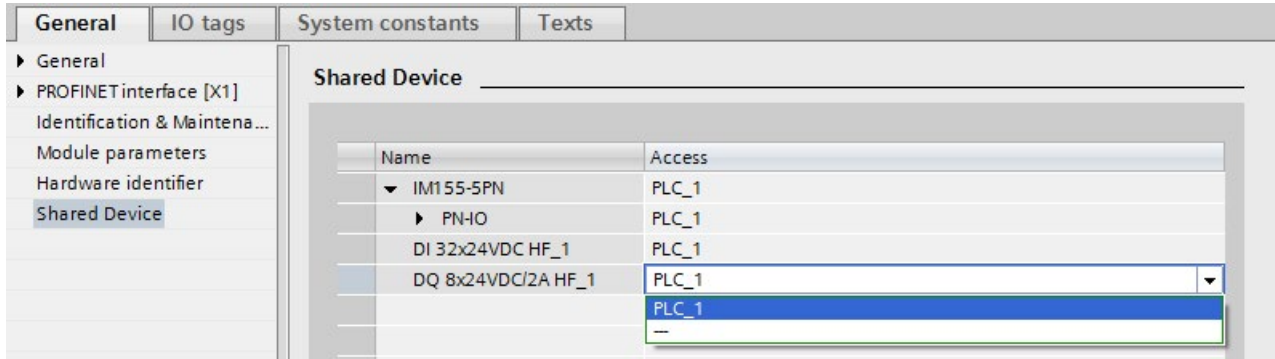


Figure 5-22 Configuring shared device

- Select the interface module in the network view or device view of project "Shared-Device-2".
- Select the "Shared Device" area in the Inspector window.

A table shows which CPU has access to the respective module or submodule for all configured modules.

- Select the setting "---" for all modules and submodules that are to be located in the address range of the CPU from the "Shared-Device-1" project (PLC1).
- Finally, check whether the settings for access are "complementary" for each module or submodule in both projects. This means that if the local CPU has access in one project, the option "---" must be set in the other project and vice versa.

Special consideration: The option "---" for the PROFINET interface and therefore for the ports makes the associated parameters read-only and not changeable. Parameters of the PROFINET interface and port parameters can only be edited in the project in which the PROFINET interface is assigned to the local CPU. The ports can be interconnected in both projects regardless of this.

- Check whether the same IP address parameters and device name are set for the shared device in all projects.

Check whether the same S7 subnet ID is set in all projects for the subnet to which the shared device is connected (subnet properties, "General" area in the Inspector window).

Note

If you make changes to the shared device: Make the same changes in each project on the shared device. Make sure that only one IO controller has access to a module or submodule.

Procedure - Adjusting the real-time settings

To ensure that all IO controllers and shared devices are operated with the appropriate send clock and that the update times are calculated correctly based on the communication load, you must adjust and check the following settings:

1. Select the project whose IO controllers have access to the PROFINET interface and the ports of the shared device.
2. Select the interface module of the shared device in the network view.
3. In the Inspector window, navigate to the "PROFINET interface > Advanced options > Real time settings > IO cycle" area.
4. In the "Shared Device" area, set the number of project-external IO controllers. The maximum number depends on the IO device (specification in GSD file).
5. You must set the same send clock for each IO controller that has access to modules and submodules of the shared device:
 - If you configure the IO controller with STEP 7 (TIA Portal):
Open the corresponding project.
Select the PROFINET interface of the IO controller.
Select the "Advanced options > Real time settings > IO communication" area in the Inspector window and set the shared send clock.
 - If you configure the IO controller with a different engineering tool:
Select the PROFINET interface of the shared device in STEP 7 (TIA Portal) and read out the send clock on the shared device ("Advanced options > Real time settings" area)
Enter the read send clock in the engineering tool.
 - Special consideration: If you configure **all** IO controllers that have access to the shared device in STEP 7 (TIA Portal or V5.5), you can set shorter send clocks on the IO controller than supported by the shared device (send clock adaptation).

Compiling and loading

You must compile the configurations for the different IO controllers and load them to the CPUs one after the other.

Due to the distributed configuration with separate projects, STEP 7 does not output consistency errors in the case of incorrect access parameter assignment. Example for incorrect access parameter assignment:

- Several IO controllers have access to the same module
- IP address parameters or send clocks are not identical

These errors do not show up until operation and are output as configuration errors, for example.

Note

After a configuration has been loaded in the IO controller, non-assigned modules or submodules retain their current parameterization state to ensure the independence from the parameterizations of other IO controllers.

5.3.3 Configuring an I-device as a shared device

Below, you will find a description of how you configure an S7-1500 as an I-device with STEP 7 Version 13 or higher and then use it in two projects as a shared device.

A "distributed" configuration with different engineering tools for different IO controller families is generally also possible here. The procedure described below is based on STEP 7 V13 and is limited to a configuration with two IO controllers of the S7-1500 family that share the transfer areas of an I-device as a shared device. The I-device itself is also an S7-1500 CPU.

Three projects are created with one IO controller each (PLC-I-Device, PLC_1, and PLC_2).

PLC-I-Device is used to configure the I-device. The PROFINET GSD variant of PLC-I-Device is used in the PLC_1 and PLC_2 projects in order to assign the transfer areas in the respective higher-level IO controller.

Shared I-device concept

For the introduction of the shared I-device concept, two roles are distinguished:

- The role of manufacturer (e.g., machine manufacturer): The manufacturer configures and programs an I-device that performs a particular automation task. Transfer areas are defined as the I/O interface to the operator of the machine. These transfer areas can be assigned to different IO controllers. For the connection to higher-level IO controllers, the manufacturer provides a PROFINET GSD file and discloses the transfer areas via which the I-device can be accessed.
- The role of the operator: The operator uses the I-device as a PROFINET GSD variant during configuration of the PROFINET IO system and, in this process, specifies the I/O addresses under which the IO controllers access the transfer areas.

Manufacturer view

You assign the following parameters for an S7-1500 CPU as an I-device: centralized and distributed I/O, the desired transfer areas, and the number of IO controllers having access to this I-device (always greater than 1 for a shared device!).

Special consideration: The I-device is configured without a higher-level IO controller. As a result, only the local I/O addresses of the transfer area are available (= "Address in the I-device") in order to create the user program for editing the addresses from the transfer area. The I-device that has been completely configured except for the connection to the higher-level IO controller is loaded to the S7-1500 CPU.

You export a PROFINET GSD file from the I-device configuration.

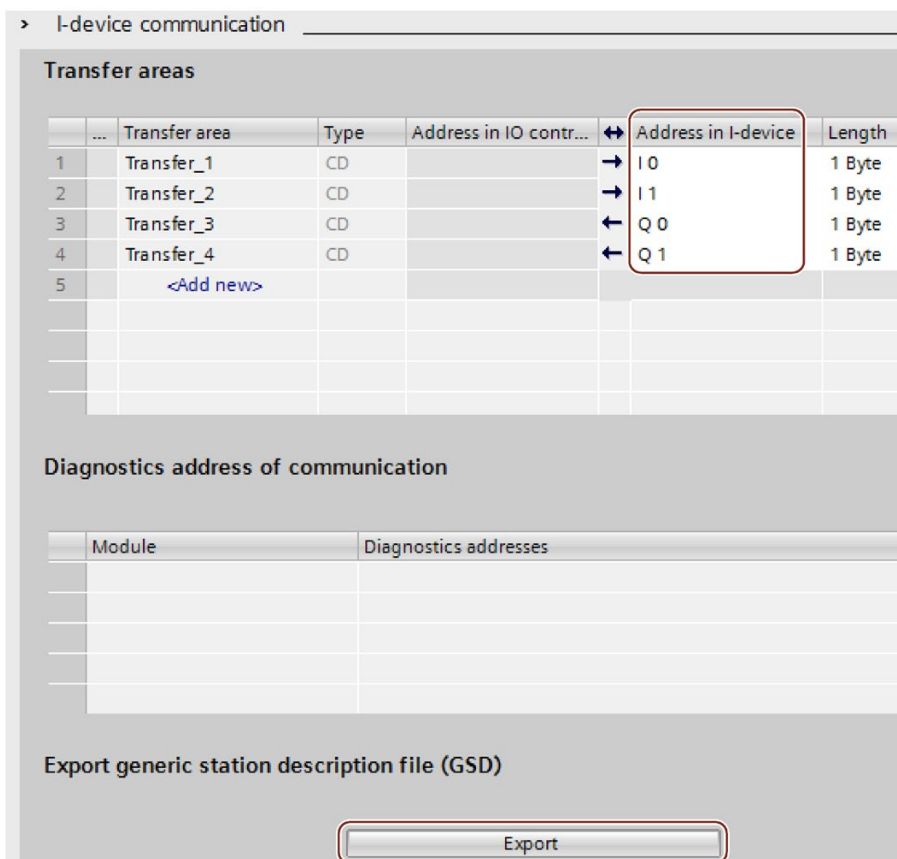


Figure 5-23 Exporting an I-device as a GSD file

Operator view

You must install the PROFINET GSD file created from the I-device configuration in all engineering systems that are involved in configuring a PROFINET IO system with this shared I-device. If all uses of this I-device will be configured with STEP 7 V13, it is sufficient to install the GSD file in STEP 7.

You configure the I-device as a GSD variant on the PROFINET IO system in the projects involved. In STEP 7 V13, this I-device can be found under "Other field devices > PROFINET IO > PLCs & CPs" following installation.

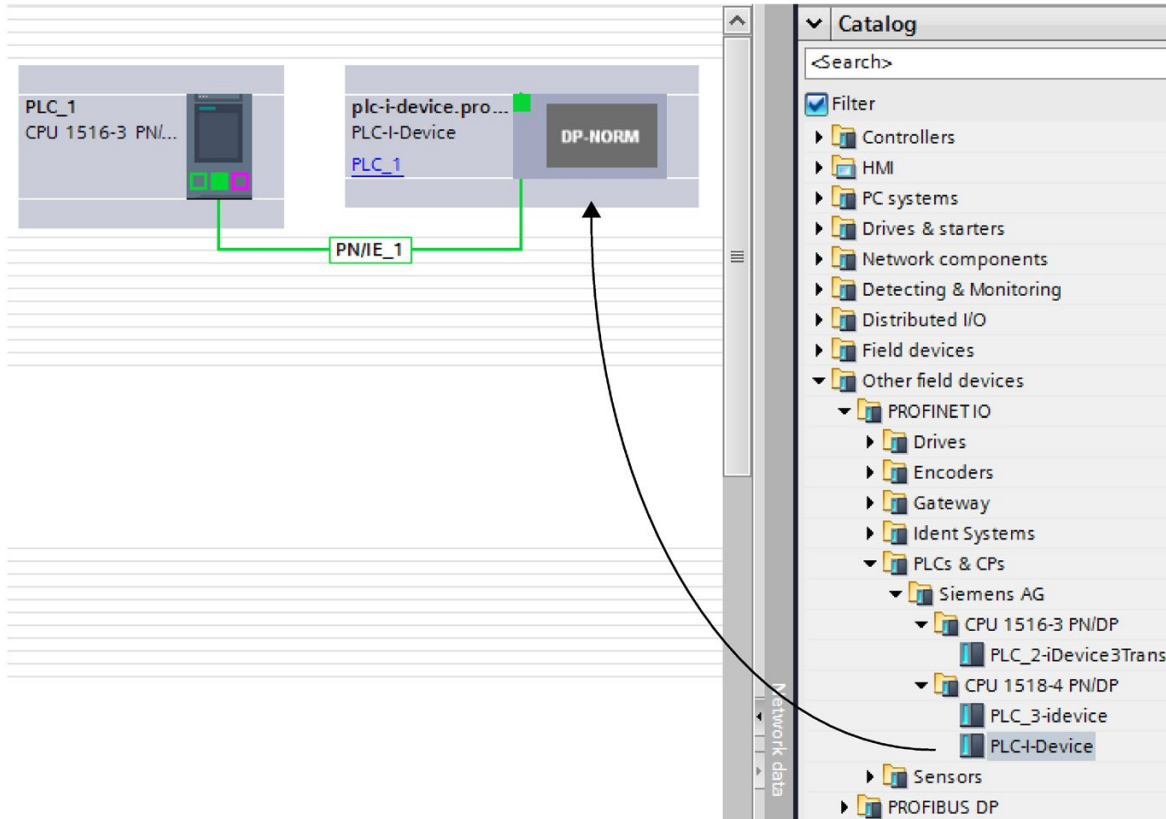


Figure 5-24 Configuring an I-device as a GSD file

In each of the projects involved, you define which transfer areas are assigned exclusively to the higher-level IO controller (default setting: all). You set the other transfer areas to "---" (not assigned). As a result of this setting, the local IO controller has no access to this transfer area and it can therefore be assigned to another IO controller in another project.

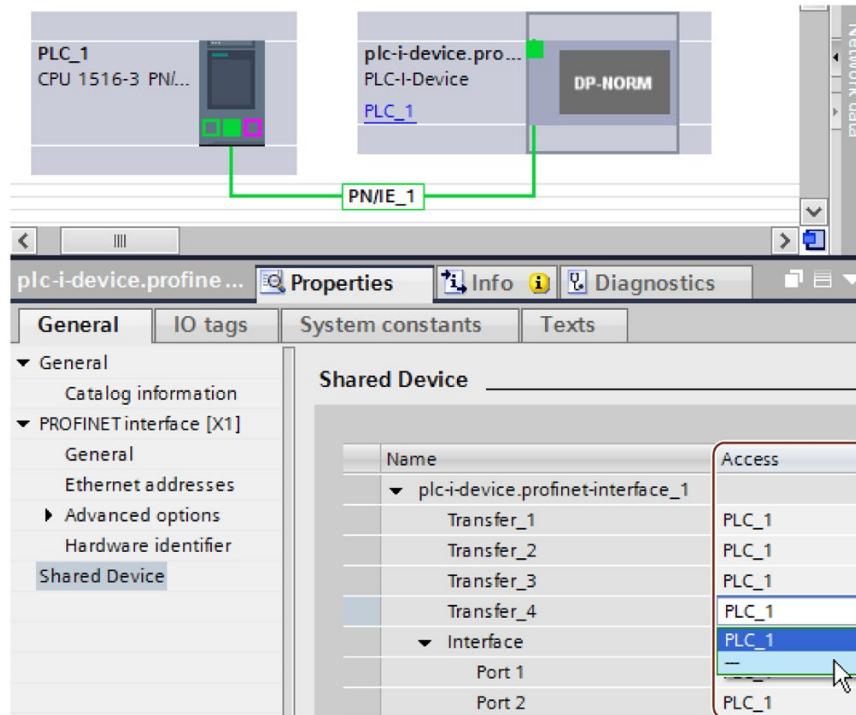


Figure 5-25 Setting the access to the shared I-device.

You adapt the addresses from the view of the IO controller in the device overview. To open the device overview, double-click the I-device.

Module	Rack	Slot	I address	Q address	Type	O...	Fir...	...	Access
plc-i-device.profinet-interfac...	0	1		256	PLC-I-Device	6...	V1.5		
Transfer_1	0	1 1000		256	Transfer_1				PLC_1
Transfer_2	0	1 1001		100	Transfer_2				PLC_1
Transfer_3	0	1 1002	256		Transfer_3				PLC_1
Transfer_4	0	1 1003			Transfer_4				---
Interface	0	1 X1			plc-i-device.profine...				PLC_1

Figure 5-26 I/O addresses of the transfer areas in the device overview

Requirements

- STEP 7 as of V13

Procedure - Creating the PLC-I-device project

To create the project with a shared I-device, follow these steps:

1. Start STEP 7.
2. Create a new project with the name "PLC-I-device".
3. Insert, for example, a CPU 1518-4 PN/DP from the hardware catalog in the network view.
Assign the name "PLC-I-device".
4. Double-click the IO device and configure all required modules and submodules.

5. Assign the module parameters.

In particular, the following settings for the CPU are necessary in the area of the PROFINET interface [X1]:

- Enable the "IO device" option in the "Operating mode" area.
- Configure the transfer areas in the "Operating mode" > "I-device configuration" area. The "Address in IO controller" column remains empty because no IO controller is assigned.

Note: To change an input area to an output area, and vice versa, you must navigate to the area of the corresponding transfer area.

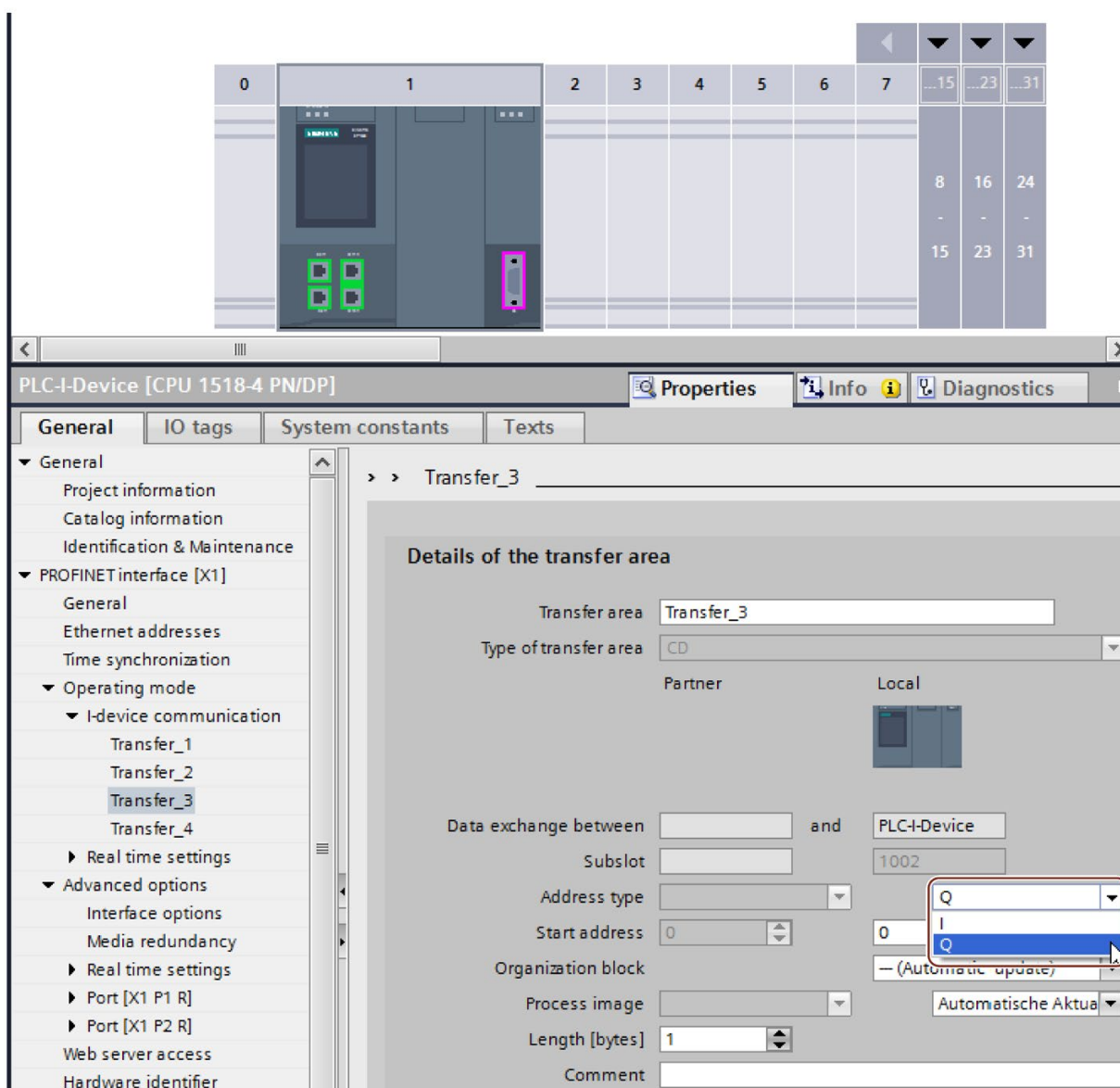


Figure 5-27 Changing the address type for the transfer area

- Select the number of IO controllers (at least two) that will access the shared I-device during operation ("Operating mode" > "Real time settings" area, "Shared Device" area).
- 6. Save the project.
- 7. Click the "Export" button ("Mode" > "I-device configuration" area, "Export general station description file (GSD)" section).

If you do not change the name in the Export dialog, the GSD file has a name in the form "GSDML-V2.31-#Siemens-PreConf_PLC-I-Device-20130925-123456", for example.

Procedure - Creating the PLC_1 project

To create the first project with a shared I-device, follow these steps:

1. Start STEP 7.
2. Install the PROFINET GSD file from the export of the I-device CPU (PLC-I-Device).
3. Create a new project with the name "PLC_1".
4. Insert, for example, a CPU 1516-3 PN/DP in the network view. The name of the CPU should be "PLC_1".
5. Insert the I-device from the hardware catalog (Hardware catalog: Other field devices > PROFINET IO > PLCs & CPs).
6. Assign the IO controller "PLC_1" to the I-device.
7. Select the "Shared Device" area in the properties of the I-device.

In the table, all transfer areas and the PROFINET interface are assigned to the local IO controller (PLC_1).

8. Define the transfer areas to which the PLC_1 CPU should **not** have access. Select the "---" entry for these areas. These transfer areas are provided for PLC_2.
9. Save the project.

Procedure - Creating the PLC_2 project

To create the second project with a shared I-device, follow these steps:

1. Start STEP 7 once again.
A new instance of STEP 7 opens.
2. In the new instance, create a new project with the name "PLC_2".
3. Insert, for example, a CPU 1516-3 PN/DP in the network view. Assign the name "PLC_2".
4. Insert the I-device from the hardware catalog (Hardware catalog: Other field devices > PROFINET IO > PLCs & CPs).
5. Assign the IO controller "PLC_2" to the I-device.
6. Adapt the access to the transfer areas as in the PLC_1 project. Ensure that no duplicate assignments result.

7. Adapt the parameters of the subnet and PROFINET interface. Because the shared I-device involves the same device in different projects, these data must match.
8. Save the project.

Both projects now have an identically configured shared I-device. The IO controller access and the parameters of the PROFINET interface should still be checked in the different projects during the next step.

Summary - Assigning parameters for access to the shared device

The transfer areas are automatically assigned to the local IO controller. To change the assignment, follow these steps:

1. Click the "PLC_I-Device" device in the network view of the "PLC_1" project, and select the "Shared Device" area.
2. A table shows which CPU has access to each of the configured transfer areas. The default setting is that the local CPU has access to all modules and submodules.
3. Keep the setting "PLC_1" for all transfer areas that are to remain in the address range of the local CPU

Select the setting "---" for all transfer areas that are to be located in the address range of the "PLC_2" CPU from the "PLC_2" project. This means that an IO controller outside the project is to have access to the transfer area.

4. Follow the same procedure for the remaining projects.
5. Finally, check whether the settings for access are "complementary" for each module or submodule in both projects. This means that if the local CPU has access in one project, the option "---" must be set in the other project and vice versa.

Special consideration: The option "---" for the PROFINET interface and therefore for the ports makes the associated parameters read-only and not changeable. Parameters of the PROFINET interface and port parameters can only be edited in the project in which the PROFINET interface is assigned to the local CPU. The ports can be interconnected in both projects regardless of this.

6. Check whether the same IP address parameters and device name are set for the shared device in all projects.

Check whether the same S7 subnet ID is set in all projects for the subnet to which the shared device is connected (subnet properties, "General" area in the Inspector window).

Note

If you make changes to the I-device (e.g., change the number or length of the transfer areas):

Export the I-device as a GSD file again. Re-install the GSD file in each project that uses the I-device as a shared device. Make sure that only one IO controller has access to a transfer area.

Procedure - Adjusting the real-time settings

To ensure that all IO controllers and shared devices are operated with the appropriate send clock and that the update times are calculated correctly based on the communication load, you must adjust and check the following settings:

1. You must set the same send clock for each IO controller that has access to modules and submodules of the shared device:
 - If you configure the IO controller with STEP 7 (TIA Portal):

Open the corresponding project.

Select the PROFINET interface of the IO controller.

Select the "Advanced options > Real time settings > IO communication" area in the Inspector window and set the shared send clock.
 - If you configure the IO controller with a different engineering tool:

Select the PROFINET interface of the shared device in STEP 7 (TIA Portal) and read out the send clock on the shared device ("Advanced options > Real time settings" area)

Enter the read send clock in the engineering tool.
 - Special consideration: If you configure **all** IO controllers that have access to the shared I-device in STEP 7 (TIA Portal or V5.5), you can set shorter send clocks on the IO controller than supported by the shared device (send clock adaptation).

Compiling and loading

You must compile the configurations for the different IO controllers and load them to the CPUs one after the other.

Due to the distributed configuration with separate projects, STEP 7 does not output consistency errors in the case of incorrect access parameter assignment. Example for incorrect access parameter assignment:

- Several IO controllers have access to the same module
- IP address parameters or send clocks are not identical

These errors do not show up until operation and are output as configuration errors, for example.

Note

After a configuration has been loaded in the IO controller, non-assigned modules or submodules retain their current parameterization state to ensure the independence from the parameterizations of other IO controllers.

5.3.4 Module-internal shared input/shared output (MSI/MSO)

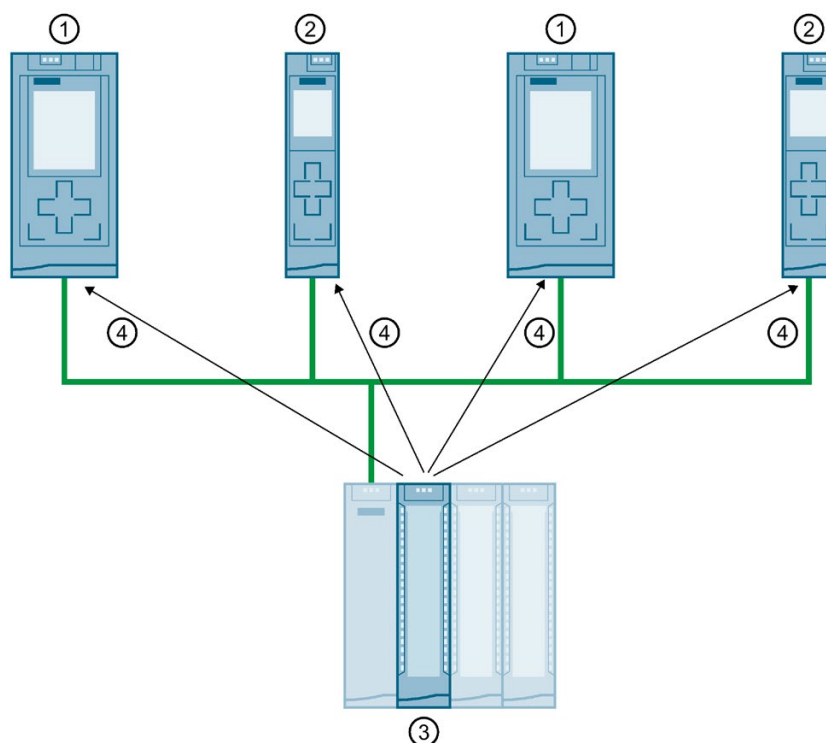
Introduction

This section describes the module-internal shared input/shared output (MSI/MSO) functionality for I/O modules that are operated on PROFINET.

Module-internal shared input/shared output functionality

The module-internal shared input (MSI) function allows an input module to make its input data available to up to four IO controllers. Each controller has read access to the same channels.

The following figure shows the MSI functionality.

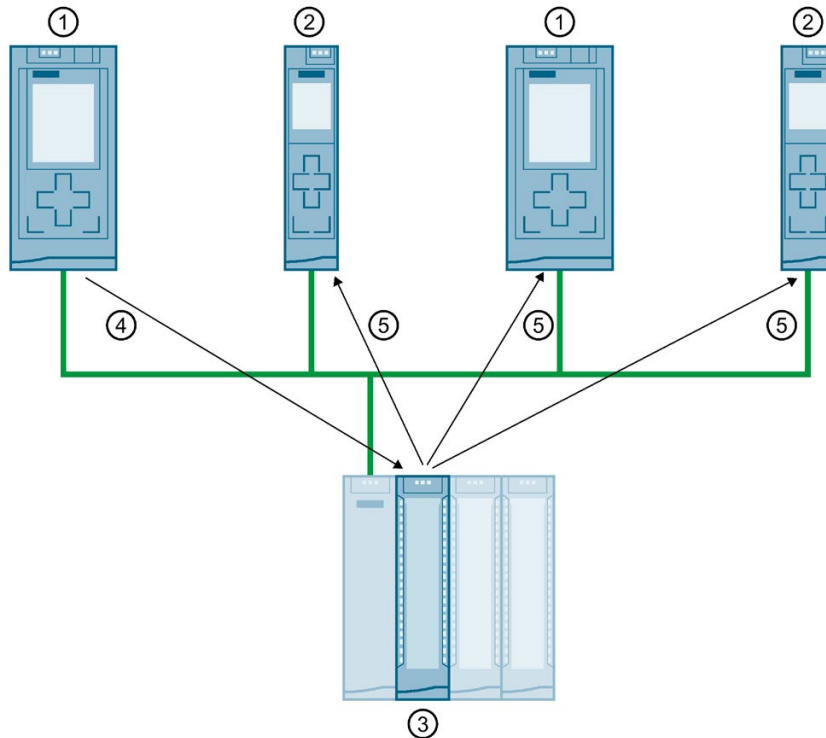


- ① CPU 1516-3 PN/DP as IO controller
- ② CPU 1511-1 PN as IO controller
- ③ Input module with MSI
- ④ Read access to the input channels of the input module
- ⑤ Write access to the channels of the I/O module (only with MSO)

Figure 5-28 Example configuration with MSI

The module-internal shared output (MSO) function allows an output module to make its output data available to up to four IO controllers. An IO controller has write access to the channels of the output module. Up to three IO controllers can additionally have read-access to the channels.

The following figure shows the MSO functionality.



- ① CPU 1516-3 PN/DP as IO controller
- ② CPU 1511-1 PN as IO controller
- ③ Output module with MSO
- ④ Write access to the output channels of the output module
- ⑤ Read access to the output channels of the output module

Figure 5-29 Example configuration with MSO

Advantages of MSI/MSO

Module-internal shared input/shared output (MSI/MSO) offers the following advantages:

- Real-time acquisition in multiple CPUs
- Lower costs due to saving on additional IO devices and modules
- Lower space requirements due to saving on additional IO devices and modules
- Reduced communication load because no CPU-CPU communication is needed
- No additional programming effort is needed for CPU-CPU communication

Requirements for the use of MSI/MSO

Observe the following requirements:

- MSI/MSO can only be used with PROFINET IO
- Configuration software: STEP 7 (TIA Portal) as of V12 SP1 with GSD file; the modules are integrated in the hardware catalog as of V13.
- The IM 155-5 PN ST interface module and the modules support MSI/MSO as of firmware version V2.0.0.

Boundary conditions for the use of MSI/MSO

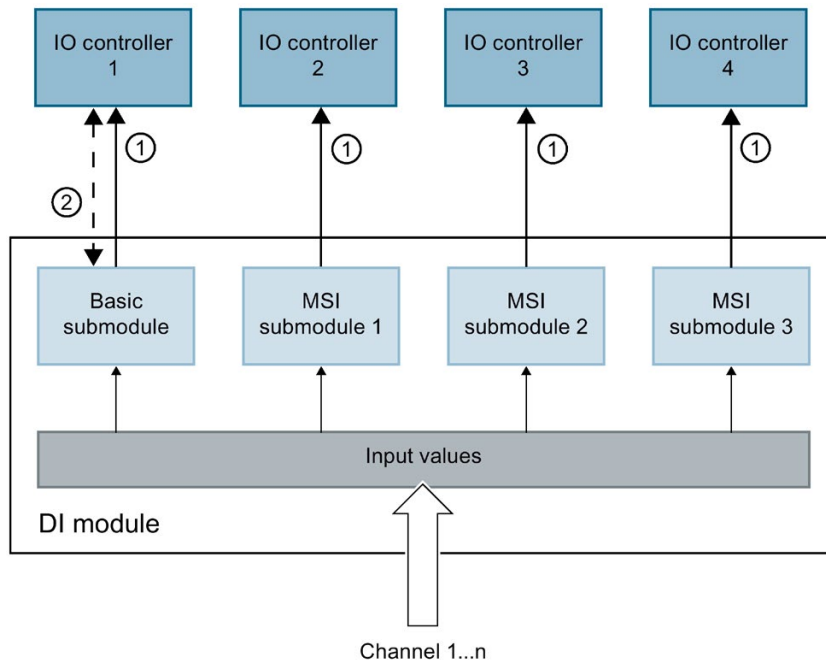
Note the following boundary conditions:

- The use of MSI/MSO is not possible in the case of module grouping.
- Modules with MSI/MSO cannot be operated in isochronous mode.
- The maximum number of IO controllers is dependent on the interface module. To find out how many IO controllers the interface module supports, refer to the manual for the respective interface module.

MSI submodules

The input values of all channels are copied to a basic submodule and up to three other MSI submodules during MSI configuration of an input module. The channels of the module are then available with identical input values in the basic submodule and the MSI submodules. The MSI submodules can be assigned to up to three IO controllers when the module is used in a shared device. Each IO controller has read access to the same channels.

The following figure shows a digital input module with the basic submodule and three MSI submodules. Each submodule is assigned to an IO controller. Diagnostics and parameter assignment of the digital input module can be performed from the IO controller 1 via the basic submodule.



- ① Read access
- ② Parameter assignment and system diagnostics

Figure 5-30 DI module with MSI submodules

Value status (Quality Information, QI)

The meaning of the value status depends on the submodule to which it pertains.

With basic submodule (= 1st submodule), the "0" value status indicates that the value is incorrect.

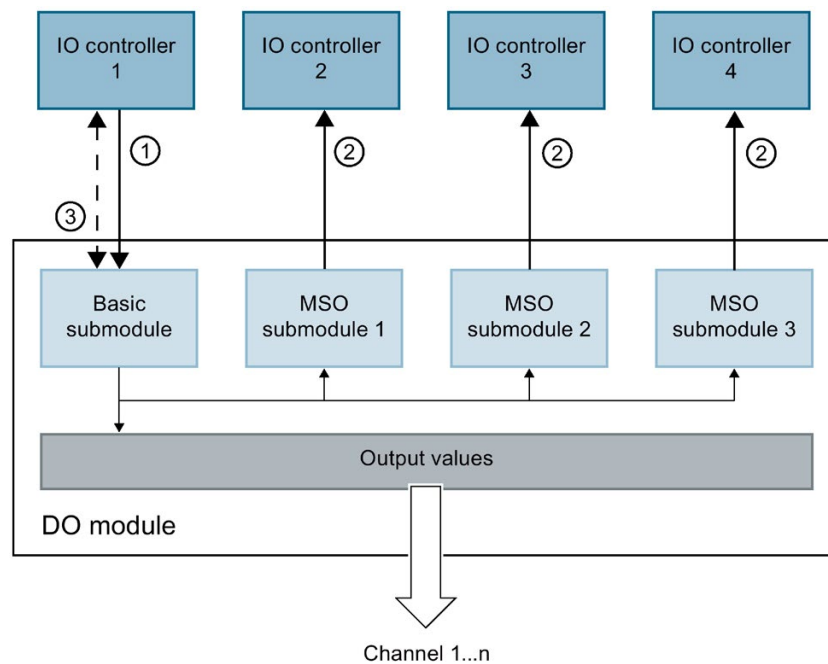
With an MSI submodule (2nd to 4th submodule), the "0" value status indicates that the value is incorrect or the basic submodule has not yet been configured (not ready).

MSO submodules

During MSO configuration of an output module, the output values of all channels of the module are copied from a basic submodule to up to three other MSO submodules. The channels of the module are then available with identical values in the basic submodule and the MSO submodules. The MSO submodules can be assigned to up to three IO controllers when the module is used in a shared device.

- The IO controller to which the basic submodule is assigned has write access to the outputs of the module. The basic submodule therefore occupies output addresses in the process image of the IO controller.
- The IO controllers to which the MSO submodules are assigned have read access to the outputs of the module. MSO submodules therefore occupy input addresses in the process image of the IO controller.

The following figure shows a digital output module with the basic submodule and three MSO submodules. Each submodule is assigned to an IO controller. Diagnostics and parameter assignment of the digital output module can be performed from IO controller 1 via the basic submodule.



- ① Write access
- ② Read access
- ③ Parameter assignment and system diagnostics

Figure 5-31 DQ module with MSO submodule

Value status (Quality Information, QI)

The meaning of the value status depends on the submodule to which it pertains.

With basic submodule (= 1st submodule), the "0" value status indicates that the value is incorrect.

With MSO submodule (= 2nd to 4th submodule) the "0" value status indicates that the value is incorrect or one of the following errors has occurred:

- The basic submodule parameters have not yet been assigned (not ready for operation).
- The connection between the IO controller and the basic submodule has been interrupted.
- The IO controller of the basic submodule is in STOP or POWER OFF state.

Configuring I/O modules with MSI/MSO submodules

Requirements

- Configuration software STEP 7 as of V13
- IO device supports MSI/MSO (for example IM 155-5 PN ST as of firmware version 2.0.0)

Procedure

1. In the network view of STEP 7, insert an IM 155-5 PN ST interface module as of V2.0.
2. Double-click the IO device.

You are now in the device view.

3. Place the I/O modules from the hardware catalog in a suitable slot.
4. Add MSI/MSO submodules to the I/O modules:
 - Input modules: Select the number of MSI submodules under "Module parameters" > "DI configuration" or "AI configuration" in the area "Copy of module for Shared Device (MSI)".
 - Output modules: Select the number of MSO submodules under "Module parameters" > "DQ configuration" or "AW configuration" in the area "Copy of module for shared device (MSO)".

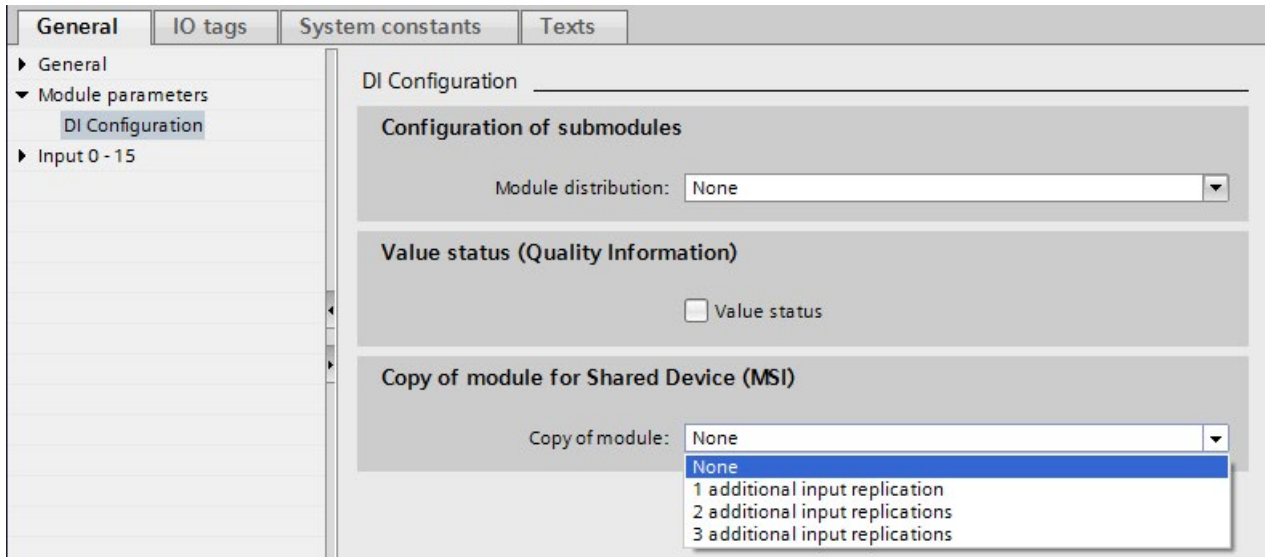


Figure 5-32 Configuring I/O modules with MSI/MSO

Assigning MSI/MSO submodules to an IO controller

You can assign the submodules in a shared device to an IO controller.
For more information, refer to [Configuring shared device](#) (Page 142).

Configuring access to a shared device and the module-internal shared input / shared output (MSI /MSO) function

You can learn how to access a shared device and the MSI /MSO function in STEP 7 with this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/109736536>).

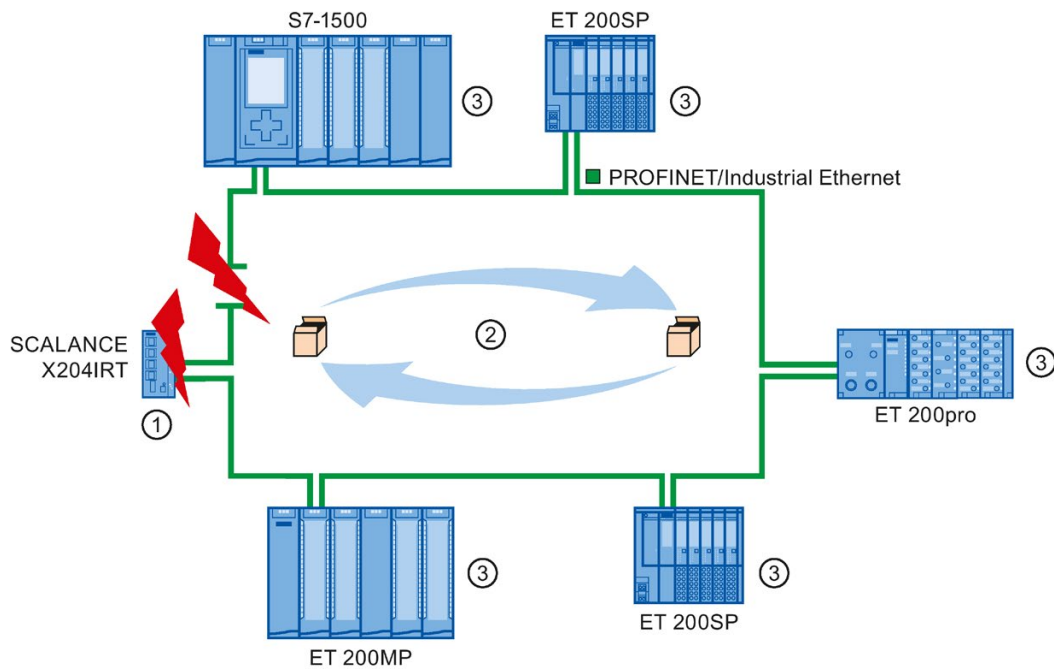
5.4 Media redundancy (ring topologies)

In order to increase the network availability of an Industrial Ethernet network with optical or electrical linear bus topologies, you can convert a linear bus topology to a ring topology by joining the ends together.

Media redundancy in ring topologies

Devices in a ring topology can be IO devices, IO controllers, external switches and/or the integrated switches of communication modules.

To set up a ring topology with media redundancy, you need to bring together the two free ends of a linear bus topology in one device. Closing the linear bus topology to form a ring is achieved with two ports (ring ports) of a device in the ring. One device of the resulting ring then takes over the role of the redundancy manager. All other devices in the ring are redundancy clients.



- ① Redundancy manager
- ② Test frames
- ③ Redundancy clients

Figure 5-33 Media redundancy in ring topology

The ring ports of a device are the ports that establish the connection to the two neighboring devices in the ring topology. The ring ports are selected and set in the configuration of the relevant device (is also preset, if applicable).

How media redundancy works in a ring topology

The data paths between the individual devices are automatically reconfigured if the ring is interrupted at any point. The devices are available again after reconfiguration.

In the redundancy manager, one of the two ring ports is blocked in uninterrupted network operation for normal communication so that no data frames are circulated. In terms of data transmission, the ring topology is a linear bus topology. The redundancy manager monitors the ring for interruptions. For this purpose, it sends test frames not only from ring port 1 but also from ring port 2. The test frames pass through the ring in both directions until they arrive at the other ring port of the redundancy manager.

An interruption of the ring can be caused by loss of the connection between two devices or by failure of a device in the ring.

If the test frames of the redundancy manager no longer arrive at the other ring port during an interruption of the ring, the redundancy manager connects its two ring ports. This substitute path once again restores a functioning connection between all remaining devices in the form of a linear bus topology.

The time between the ring interruption and restoration of a functional linear topology is known as the reconfiguration time.

As soon as the interruption has been eliminated, one of the two ring ports is blocked again in the redundancy manager. The redundancy clients are informed about the change and use the original paths to the other devices again.

Media redundancy method

The standard method of media redundancy in SIMATIC is MRP (Media Redundancy Protocol) with a typical reconfiguration time of 200 ms. Up to 50 devices can participate per ring.

In addition, the real-time capable media redundancy process MRPD (Media Redundancy with Planned Duplication of frames) is also available.

5.4.1 Media Redundancy Protocol (MRP)

Media Redundancy Protocol (MRP)

The "MRP" process works in conformity with the Media Redundancy Protocol (MRP) that is specified in the standard IEC 62439-2.

Requirements

- All devices in the ring support MRP.
- You have complied with the rules for topology set out below. STEP 7 monitors compliance with the rules during compilation and outputs corresponding alarms.

Topology

The following schematic shows a possible topology for devices in a ring with MRP. The devices inside the shaded oval are in the redundancy domain.

Example of a ring topology with the MRP media redundancy protocol:

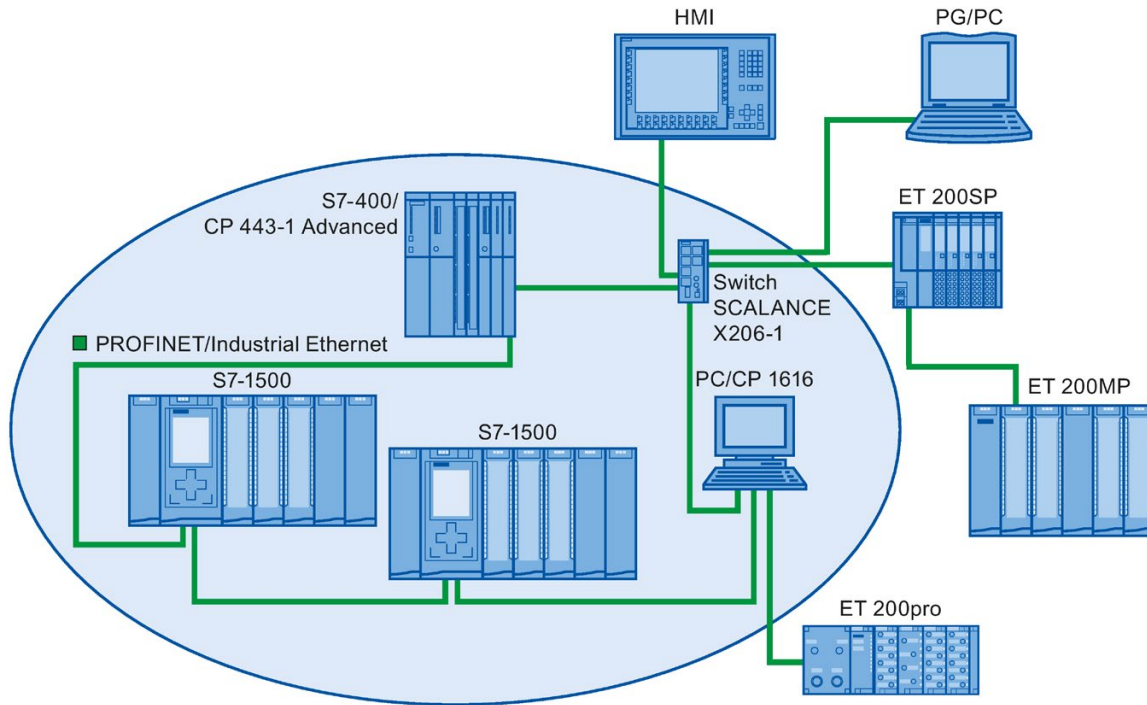


Figure 5-34 Example of a ring topology with the MRP media redundancy protocol:

The following rules apply to a ring topology with media redundancy using MRP:

- All devices must be connected to one other via their ring ports.
- All devices in the ring belong to the same redundancy domain.
- A device in the ring takes on the task of a redundancy manager.
 - One device only has the role of "Manager". No other device may have the role of "Manager". Or
 - Several devices in the ring have the role of "Manager (auto)". The devices with the role of "Manager (auto)" then negotiate between themselves which device is to take on the role of redundancy manager. In this case, no device is permitted to have the role of "Manager".
- All other devices in the ring are redundancy clients.
- You can connect up to 50 devices in a ring.

Non MRP-compliant devices can, for example, be connected to the ring via a SCALANCE X switch or via a PC with a CP 1616.

Rules for loading the devices of an MRP domain

When loading devices of an MRP domain, frame loops can occur and result in network failure if there is an invalid MRP configuration.

Example: You change the MRP roles of several devices and consecutively load the configuration into the devices involved. Configurations can arise that contradict the roles mentioned above, for example, there may be devices that simultaneously have the "Manager" and "Manager (auto)" roles in the ring.

In order to ensure that an invalid MRP configuration does not result in the failure of the network, delete the ring before loading.

Follow these steps:

1. Delete the ring.
2. Load the error-free and consistent MRP configuration from your project onto all the devices involved and ensure that the devices are in data exchange mode (i.e. the application relations (ARs) are set up).
3. Close the ring.

Boundary conditions

MRP and RT

RT operation is possible with the use of MRP.

Note

The RT communication is disrupted (station failure) if the reconfiguration time of the ring is greater than the selected response monitoring time of the IO device. This is why you should select a response monitoring time of the IO devices that is sufficiently large.

MRP and IRT

IRT mode is not possible together with MRP.

If you want to use media redundancy together with IRT in a ring, only use devices that support MRPD.

MRP and TCP/IP (TSEND, HTTP, ...)

The TCP/IP communication with MRP is possible, because lost data packages are resent, if applicable.

MRP and prioritized startup

If you configure MRP in a ring, you cannot use the "prioritized startup" function in PROFINET applications on the devices involved.

If you want to use the "prioritized startup" function, then you must disable MRP in the configuration (the device may also not be part of the ring).

Information on S7-1500R/H

You can find information on the media redundancy method MRP of the redundant S7-1500R/H system in section Configuring PROFINET IO on a redundant S7-1500R/H system (Page 281).

Application example: Reading the MRP status in the user program

The "LPNDR_ReadMRPState" function block from the "LPNDR" block library helps you to determine the status of the MRP ring per program. The block reads the MRP information from the PROFINET device (MRP Manager) and outputs the status.

The "LPNDR" block library and the corresponding documentation can be found in this application example (<https://support.industry.siemens.com/cs/ww/de/view/109753067>).

5.4.2 Configuring media redundancy

Configuring MRP

Proceed as follows to create a PROFINET IO configuration with MRP in STEP 7:

1. Generate a ring via the port interconnections in the topology view. First interconnect the devices to a line topology. Connect the unassigned port of the last device in the line with the unassigned port of the first device.

The following example shows one CPU 1516-3 PN/DP and two interface modules IM 155-6 PN HF that are interconnected in a ring in the topology view of STEP 7.

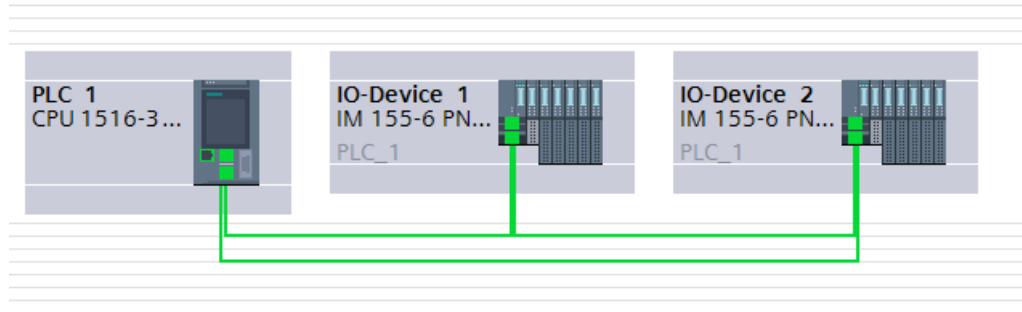


Figure 5-35 Configuring media redundancy

2. Select the PROFINET IO system in the network view.
3. In the Inspector window, navigate to "Properties" > "General" > "PROFINET" > "MRP domains" in the "Ring interconnections" field. This field shows you all the topological rings in the IO system with the associated MRP domains.

4. Select the ring generated above in the "Ring interconnections" field.
The table below it shows all the PROFINET devices in the ring.
5. Set the media redundancy role for the PROFINET devices in the MRP role column.

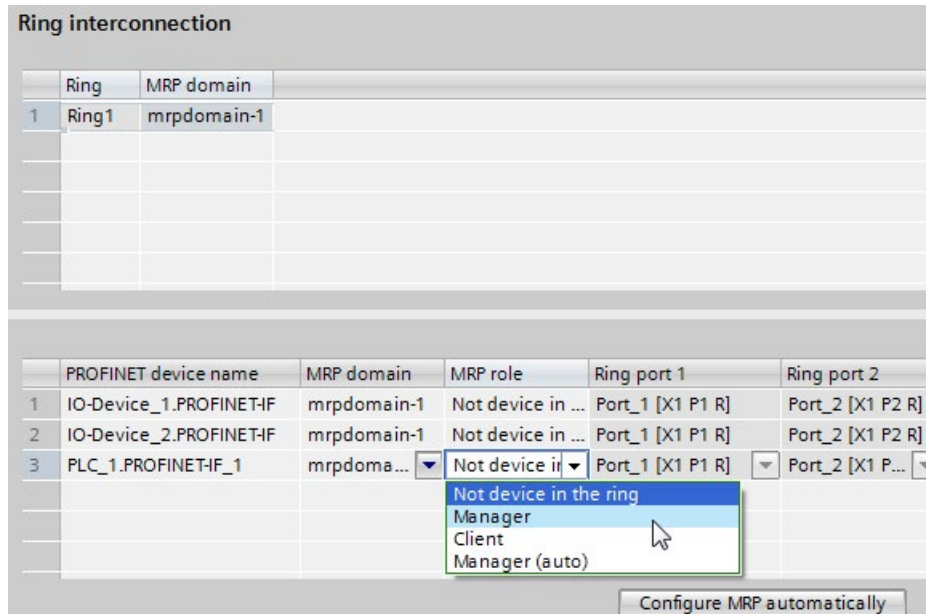


Figure 5-36 MRP domain

Automatic MRP configuration

You can also have the media redundancy roles assigned automatically for your PROFINET devices in the ring.

To have the media redundancy roles assigned automatically, click the "Configure MRP automatically" button. STEP 7 automatically assigns the media redundancy role for each device in the ring. After the automatic MRP configuration, you can make modifications to the media redundancy roles in the "MRP role" column.

"Media redundancy" setting options

Media redundancy role

Depending on the device used, the roles "Manager", "Manager (Auto)", "Client" and "Not device in the ring" are available.

Rules:

- A ring must have precisely one device with the role "Manager". No additional devices with the role "Manager" or "Manager (Auto)" are permissible. All the other devices may only have the "Client" role.
- If a ring has no device with the "Manager" role, the ring must at least have a device with the role "Manager (Auto)". Any number of devices with the "Client" role may exist.
- Managers and clients of an MRP domain can be configured in different projects. In the project without a manager, you need to select the "Redundancy manager outside the project" option so that the configuration can be compiled. For multiple ring configurations, you need to set the option identically for each MRP domain.

Ring port 1 / Ring port 2

Select one at a time those ports you want to configure as ring port 1 or ring port 2. The drop-down list box shows the selection of possible ports for each device type. If the ports are set at the factory, then the fields are unavailable.

If you use single-stage commissioning, use the preset ring ports in STEP 7.

Diagnostic interrupts

If diagnostic interrupts to the MRP state are to be output in the local CPU, select the "Diagnostic interrupts" check box. The following diagnostic interrupts can be configured:

- Wiring or port error

Diagnostic interrupts will be generated for the following errors in the ring ports:

- A neighbor of the ring port does not support MRP.
- A ring port is connected to a non-ring port
- A ring port is connected to the ring port of another MRP domain.

- Interruption / return (redundancy manager only)

If the ring is interrupted and the original configuration is returned, diagnostic interrupts will be generated. If both of these interrupts occur within 0.2 seconds, this indicates an interruption of the ring.

You can respond to these events in the user program by programming the appropriate response in the diagnostic error interrupt OB (OB 82).

Reference

You can find the procedure for configuring a common MRP ring and the topology with two projects in this FAQ (<https://support.industry.siemens.com/cs/ww/en/view/109741671>).

5.4.3 Media redundancy with planned duplication of frames (MRPD; not for S7-1500R/H)

MRP extension "Media Redundancy with Planned Duplication of frames" (MRPD)

The MRP extension "Media Redundancy with Planned Duplication of frames" (MRPD) provides the advantage that, in the case of a failure of a device or a line in the ring, all other devices continue to be supplied with IO data without interruption and with short update times.

MRPD is based on IRT and MRP. To realize media redundancy with short update times, the PROFINET devices participating in the ring send their data in both directions. The devices receive this data at both ring ports so that there is no reconfiguration time.

Requirements for media redundancy with MRPD

- All the devices of the ring must support MRPD, for example interface module IM 155-6 PN HS as of firmware version 4.0.
- You have configured MRP for all the devices of the ring. You have assigned the MRP role "Not device in the ring" to devices that are not located in the ring.
- You have configured IRT for all the involved components.

Configuring MRPD

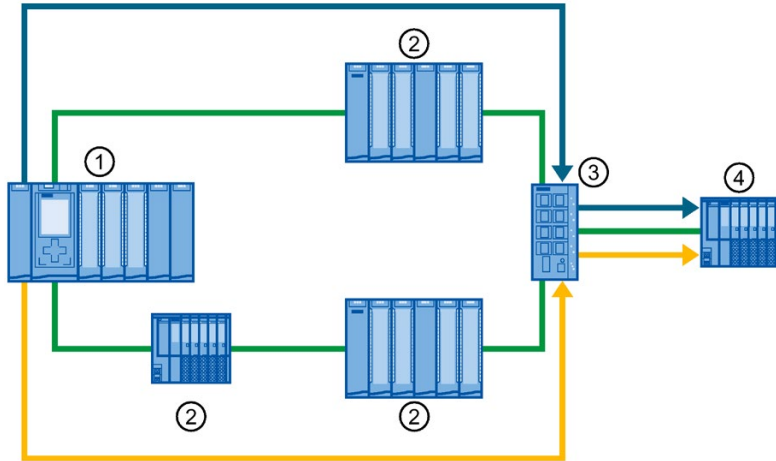
You do not have to explicitly activate MRPD in STEP 7. The function is available automatically as soon as all the requirements for MRPD are fulfilled.

Redundancy levels of IO devices with MRPD

The redundancy level of an IO device specifies how strongly the real-time communication is influenced in the case of a power interruption between an IO device and its IO controller.

- Full redundancy: No influence, because the IO controller and IO device are located in the same ring.
- Partial redundancy:
 - If the interruption takes place on a non-redundant part (line) between the IO device and IO controller, real-time communication is influenced.
 - If the interruption takes place on a redundant part (ring), real-time communication is not influenced.
- No redundancy: No redundant path between the IO device and its IO controller, communication is always influenced.

The figure below shows the redundancy levels of the IO devices for an example configuration with MRPD. The three devices in the ring and the switch have the redundancy level "Full redundancy". Device 4 has the redundancy level "Partial redundancy", because the connection between the switch and the device is not redundant.



- ① IO controller in the ring
- ② IO device in the ring with redundancy level "Full redundancy"
- ③ Switch in the ring with redundancy level "Full redundancy"
- ④ IO device in the spur with the redundancy level "Partial redundancy"

Figure 5-37 Example configuration with MRPD

The figure below shows the display of the redundancy levels in STEP 7 for the example configuration.

IO devices					
PROFINET device name	RT class		Synchronization role	Redundancy level	DFP group
plc_1.profinet interface_1	RT,IRT		Sync master		
io-device_1	IRT		Sync slave	Full redundancy	
io-device_2	IRT		Sync slave	Full redundancy	
io-device_3	IRT		Sync slave	Full redundancy	
io-device_4	IRT		Sync slave	Partial redundancy	
switch_1	IRT		Sync slave	Full redundancy	

Figure 5-38 Display of the redundancy levels in STEP 7

5.4.4 Multiple rings

Multiple rings

Use multiple rings to achieve higher availability for PROFINET IO networks with star topology.

In a multiple ring configuration, several PROFINET lines lead from a switch (star topology). The individual PROFINET lines lead from IO device to IO device. Redundant PROFINET cables run back to the switch from the last IO device on each individual line.

The switch operates as a manager. The manager must have two ring ports for each ring. Multiple rings are possible. The SCALANCE X414 as of firmware version 3.10, for example, supports up to 4 rings.

The manager monitors all the rings individually: It checks for each particular ring (an MRP domain) whether the transmission path is intact. To do this, it uses an MRP instance in each case. An MRP instance is required for each connected ring (set up automatically by STEP 7).

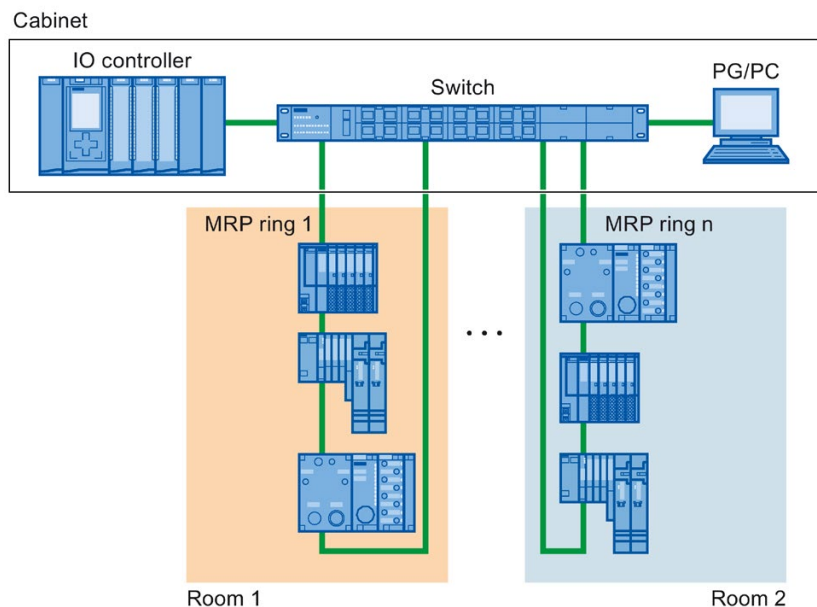


Figure 5-39 Configuration with several rings

Requirements

- SCALANCE X414 as of version 3.10
- SCALANCE X300 as of version 4.0 (configured via GSD file)

Rules for the configuration of multiple rings

- MRP role at multiple rings:
 - The device that belongs to all the rings must have the MRP role in every instance that is entered in the GSD file in the "SupportedMultipleRole" attribute.
 - The switches from the series SCALANCE X300 as of version 4.0 and the switch X414 as of version 4.10 support the MRP role "Manager" for multiple rings.
- If the device that belongs to all rings has the "Manager" role in one ring, no devices with the "Manager (Auto)" role may exist in this ring.

Configuring multiple rings

To configure an MRP configuration with multiple rings, follow these steps:

1. In the topology view, interconnect the ring ports of the devices that are intended to belong to an MRP domain to form a ring.
2. Select the PROFINET IO system in the network view.
3. In the Inspector window, navigate to "Properties" > "General" > "PROFINET" > "MRP domains" in the "Ring interconnections" field. This field shows you all the topological rings in the IO system with the associated MRP domains.
4. Select one of the rings generated above in the "Ring interconnections" field. The table below it shows all the PROFINET devices in the ring.
5. Set the media redundancy role for the PROFINET devices in the MRP role column.

Example of multiple rings

The following figure shows an example configuration for multiple rings.



Figure 5-40 Example configuration with two rings ① and ②

In the example, Switch 1 belongs to two MRP rings. Ring 1 is formed by Switch 1 and PLC 1, Ring 2 by Switch 1 and IO device 1.

STEP 7 automatically assigns the "Manager" role to the switch. The other devices receive the "Client" role.

The manager is located at the point of intersection of the two rings 1 and 2. The manager monitors the two rings separately. To do this, it uses two MRP instances.

One MRP instance checks whether all devices in ring 1 are reachable, another instance monitors whether all devices in ring 2 are reachable (only one device in each case in the example).

You can configure each MRP instance separately.

The following figure shows the two MRP instances in the manager (PROFINET interface of the switch). Here in the example, MRP instance 1 checks whether the devices in the MRP domain "mrpdomain-1" can be reached. The MRP instance 2 is responsible for monitoring the devices of the MRP domain "mrpdomain-2".

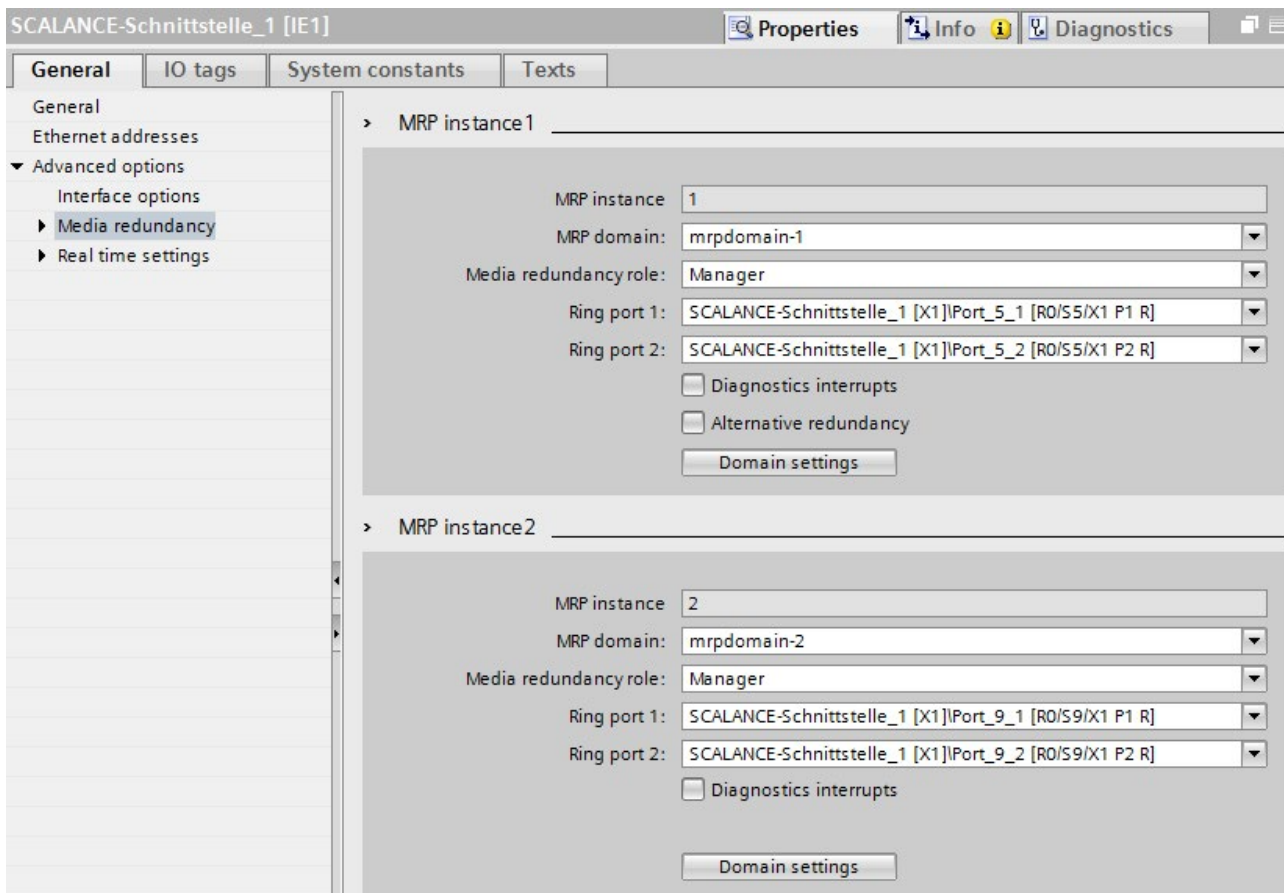


Figure 5-41 Setting media redundancy for multiple rings

5.4 Media redundancy (ring topologies)

The following figure shows Ring 1 (mrpdomain-1). The participants of the mrpdomain-1 are the PROFINET interface of the CPU as the "Client" and the MRP interface 1 of the PROFINET interface of the switch as the "Manager".

Ring interconnection						
	Ring	MRP domain				
1	Ring1	mrpdomain-1				
2	Ring2	mrpdomain-2				
PROFINET device name	MRP instance	MRP domain	MRP role	Ring port 1	Ring port 2	
1	PLC_1.PROFINET-IF_1		mrpdomain-1	Client	Port_1 [X1 P1 R]	Port_2 [X1 P2 R]
2	Switch_1.SCALANCE-IF_1	1	mrpdomain-1	Manager	Port_1 [R0/S5/X1 P1 R]	Port_2 [R0/S5/X1 P2 R]

Figure 5-42 Ring 1

The following figure shows Ring 2 (mrpdomain-2). The participants of the mrpdomain-2 are the PROFINET interface of the IO device as the "Client" and the MRP instance 2 of the PROFINET interface of the switch as the "Manager".

Ring interconnection						
	Ring	MRP domain				
1	Ring1	mrpdomain-1				
2	Ring2	mrpdomain-2				
PROFINET device name	MRP instance	MRP domain	MRP role	Ring port 1	Ring port 2	
1	IO-Device_1.PROFINET-IF		mrpdomain-2	Client	Port_1 [X1 P1 R]	Port_2 [X1 P2 R]
2	Switch_1.SCALANCE-IF_1	2	mrpdomain-2	Manager	Port_5 [R0/S9/X1 P1 R]	Port_6 [R0/S9/X1 P2 R]

Figure 5-43 Ring 2

5.5 Real-time communication

5.5.1 Introduction

Properties

PROFINET IO is a scalable real-time communication system based on the Layer 2 protocol for Fast Ethernet. With the RT transmission method, two real-time-support performance levels are available for time-critical process data and IRT for high-accuracy and also isochronous processes .

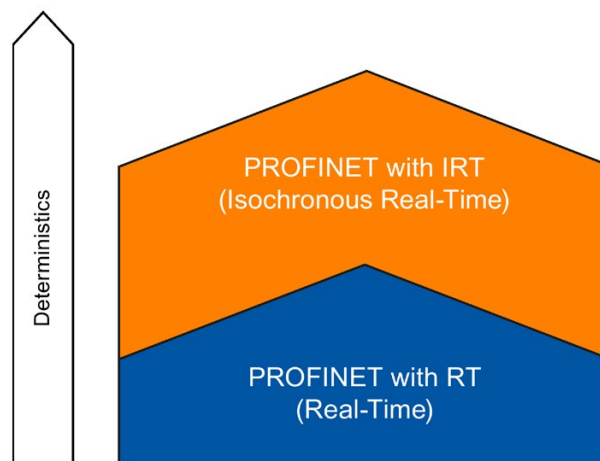


Figure 5-44 Real-time communication performance

Real-time communication and IT communication

Industrial communication, especially in the factory automation and process automation, requires a punctual and deterministic data transmission. This is why, for the cyclic exchange of time-critical IO user data, PROFINET IO does not use TCP/IP, it uses real-time communication (RT) or isochronous real-time communication (IRT) for the synchronized data exchange in reserved time intervals.

Fields of application of PROFINET with RT

PROFINET with RT is suited for:

- Time-critical applications in factory automation
- The implementation of large quantity structures in line process plants

Fields of application of PROFINET with IRT

PROFINET with IRT is particularly suitable for:

- Considerable deterministics with large quantity structures concerning the I/O user data communication (productive data)
- Considerable performance also with many devices concerning the I/O user data communication (productive data)
- Parallel transfer of productive and TCP/IP data via a cable, even with considerable data traffic whilst ensuring the forwarding of productive data by reserving the transmission bandwidth.

International standard IEC 61158

The communication procedures RT and IRT are standardized in the international standard IEC 61158.

5.5.2 RT

PROFINET IO with real-time communication (RT) is the ideal solution for integrating IO systems. This is a solution that also uses standard Ethernet in the devices and commercially available industrial switches as infrastructure components. A special hardware support is not required.

If you want to use PROFINET functions that provide an additional value, such as topology detection, diagnostics, device exchange without exchangeable medium/PG, you have to use switches that support the PROFINET standard according to the IEC 61158 standard. In the integrated switches of PROFINET devices and PROFINET switches (e.g., the SCALANCE product family), PROFINET functions in accordance with the PROFINET standard are implemented and can be used without restriction for integration in the PROFINET IO system (see also section Active network components (Page 28)).

Real-time communication (RT)

PROFINET IO frames have priority over standard frames in accordance with IEEE802.1Q. This ensures the required determinism in the automation technology. The data is transferred via prioritized Ethernet frames. With RT, you can achieve update times $\geq 250 \mu\text{s}$ with RT.

Switching mechanisms

Switches in SIMATIC meet the real-time requirements with two mechanisms on PROFINET: "Store and forward" and "Cut through".

Store and forward

In the Store and forward method, the switch stores the frames completely and places them in a queue. If the switch supports the international standard IEEE 802.1Q, then the data is sorted according to its priority in the queue. The frames are then forwarded selectively to the specific port that can access the addressed node (Store and forward).

Cut through

In the Cut through process the entire data package is not stored temporarily in a buffer, it is passed directly onto the target port as soon as the target address and the target port have been determined.

The times required by the data package to pass through the switch are then minimal and independent of the frame length. The data are only stored temporarily in accordance with the Store and forward process as per priority when the section between the target segment and the port of the next switch is occupied.

5.5.3 IRT

Isochronous real-time communication (IRT)

IRT is a synchronized communication protocol for cyclic exchange of IRT data between PROFINET devices. A reserved bandwidth is available in the send cycle for IRT data. The reserved bandwidth ensures that the IRT data can be transferred at reserved synchronized intervals, without being influenced also by higher other network loads (such as TCP/IP communication, or additional real-time communication).

Advantages

PROFINET with IRT is synchronized communication in reserved time intervals. With IRT you have the option to be able to control time-critical applications such as motion control via PROFINET. With IRT you use further advantages:

- High-precision deterministics allow highest control quality and thus, for example, exact positioning of axes
- Simple and flexible integration of PROFINET devices for real-time applications in existing company networks
- Shortest response times and highest deterministics by means of bandwidth reservation and thus also for applications that have to satisfy highest performance requirements (e.g., printing control/position control for presses, print-mark recognition with packaging machines)
- Secured standard communication parallel to real-time communication via the same transmission medium
- You can continue to use standard components for your PROFINET IO system outside of the sync domain

Properties of isochronous real-time

Topology configuration is a prerequisite for IRT.

In addition to the reserved bandwidth, the frames from defined transmission paths are exchanged for the further optimization of data transfers. For this, the topological information from the configuration is used for planning the communication. Transmission and reception points of every individual data frame at every communication node are thus guaranteed. This allows you to achieve optimal usage of the bandwidth and reach the best possible performance in the PROFINET IO system.

Use of IRT allows you to achieve update times with very high deterministic $\geq 125 \mu\text{s}$ and a jitter accuracy of the send clock $< 1 \mu\text{s}$. Isochronous applications are possible with IRT (see section Isochronous mode (Page 200)).

* The minimum update time depends on the CPU used. The update times supported by a CPU are listed in the technical specifications of the CPU manual.

Note

IWLAN and IRT

PROFINET devices that are connected to PROFINET IO via access points, do not support IRT.

Synchronization

The prerequisite for the IRT communication is a synchronization cycle for all PROFINET devices in a sync domain for distributing a mutual time basis. A synchronism of the transmission cycle of the PROFINET devices within a sync domain is achieved with this basic synchronization.

A sync master specifies the clock to which sync slaves are synchronized. An IO controller or an IO device can have the role of sync master. If the sync master fails, all IO devices with IRT will fail.

Sync master and sync slaves are always devices in a sync domain. Bandwidth is reserved within the sync domain for IRT communication. Real-time and non-real-time communication (TCP/IP communication) is possible outside of the reserved bandwidth.

Default sync domain

If you have created a PROFINET subnet, a special sync domain is automatically created, the default sync domain. All PROFINET devices configured for the PROFINET subnet automatically belong to this sync domain.

For additional information on creating sync domains, refer to the STEP 7 online help.

Time ranges of the communication cycle

The communication cycle is divided into three time ranges, which are shown in the following chart:

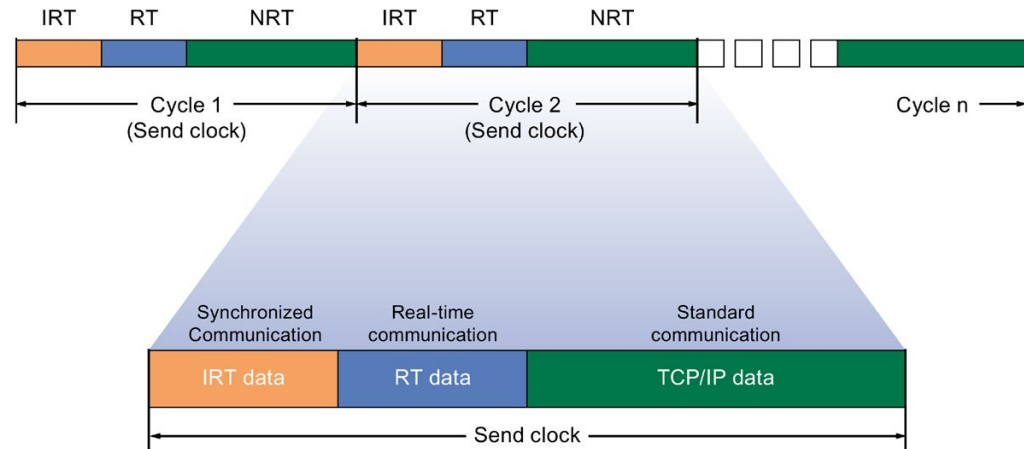


Figure 5-45 Reserving bandwidth

- IRT data (synchronized communication)
This time range can be reserved in specific steps, depending on the send clock. Only IRT data is transmitted during this time range.
- RT data (real-time communication)
The cyclic RT data is transferred in this time range. RT data is prioritized over "normal" TCP/IP data. TCP/IP data or Ethernet frames can have a priority of between 1 and 7. RT data have the Priority 6.
- TCP/IP data (standard communication)
Standard communication (e.g., TCP/IP) is transmitted in the remaining interval of the communication cycle.

In STEP 7, you can set the ratio of the bandwidth usage of cyclic IO data to standard communication. For information on how to set the bandwidth usage, refer to the section [Setting the bandwidth usage for the send clock \(Page 183\)](#)

5.5.4 Comparison of RT and IRT

The most important differences between RT and IRT

Table 5- 2 Comparison between RT and IRT

Property	RT	IRT
Transmission method	Prioritizing the RT frames through Ethernet priority (VLAN tag)	Path-based switching on the basis of a communication path plan; no transmission of TCP/IP frames in the time range with IRT communication.
Determinism	Variance of the duration of transmission by the shared use of the transmission bandwidth with other protocols (e.g., TCP/IP)	Exact, planned transmission, transmission and reception times are guaranteed for all topologies.
Hardware support through special Ethernet controllers is required	Not required	Required
Isochronous application	-	Yes
Starting time of the isochronous application	-	The point in time for the reception of the data is planned exactly. Application can be started synchronized to the cycle.

5.5.5 Configuring PROFINET IO with IRT

Introduction

If you want to configure a PROFINET IO system with IRT, you have to configure the PROFINET IO devices. These PROFINET devices must support IRT. Set which device acts as the sync master and synchronizes the other devices. This is done by configuring a sync domain with a sync master and at least one sync slave.

Requirement

- There is an IO system with an IO controller and at least one IO device.
- You have configured the topology for the IO system.
- The devices support IRT.

Procedure

Proceed as follows to enable an existing IO system for the use of IRT:

1. Select the PROFINET interface of the IO controller.
2. In the Inspector window, navigate to "Advanced options > Real time settings > Synchronization".

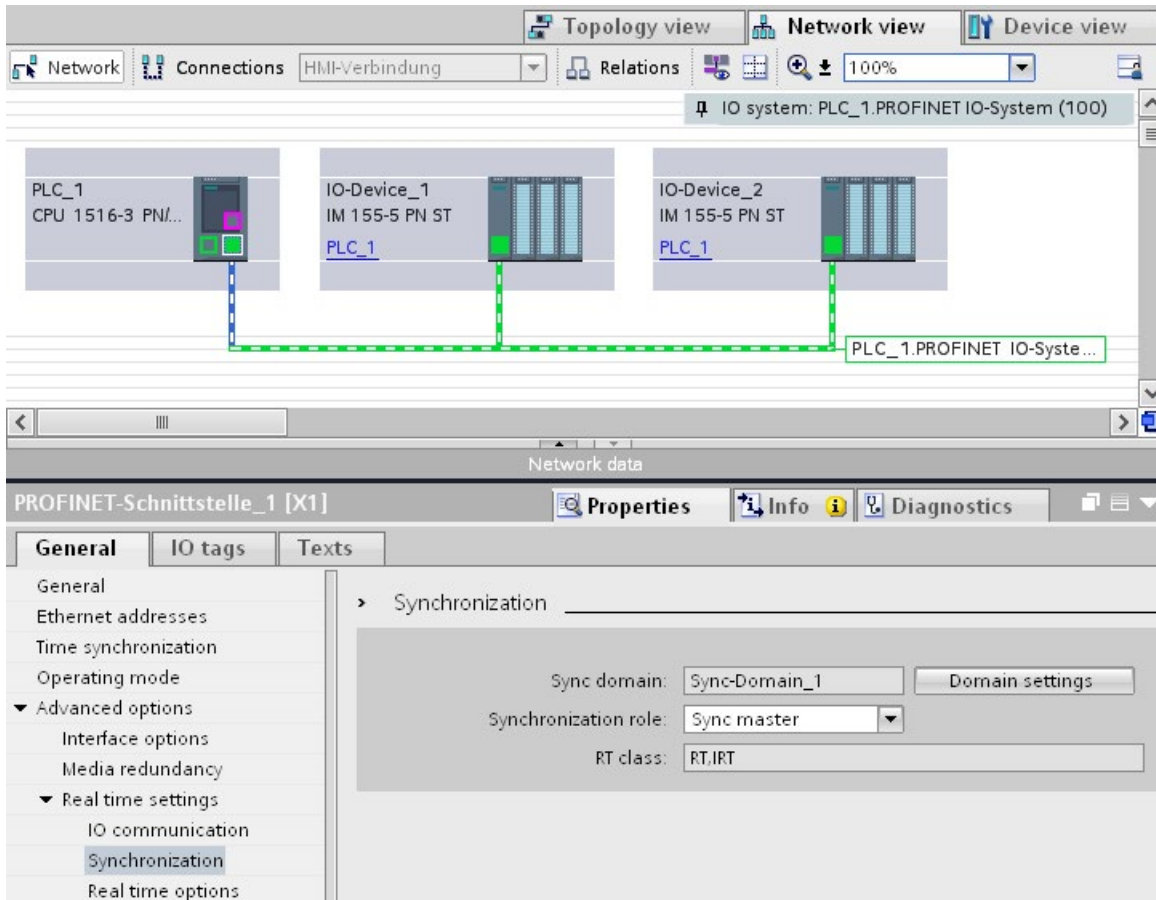


Figure 5-46 IRT configuring sync master

3. Assign the IO controller the role of sync master under "Synchronization role".
4. Select the PROFINET interfaces of an associated IO device.

5. In the Inspector window, navigate to "Advanced options > Real time settings > Synchronization".

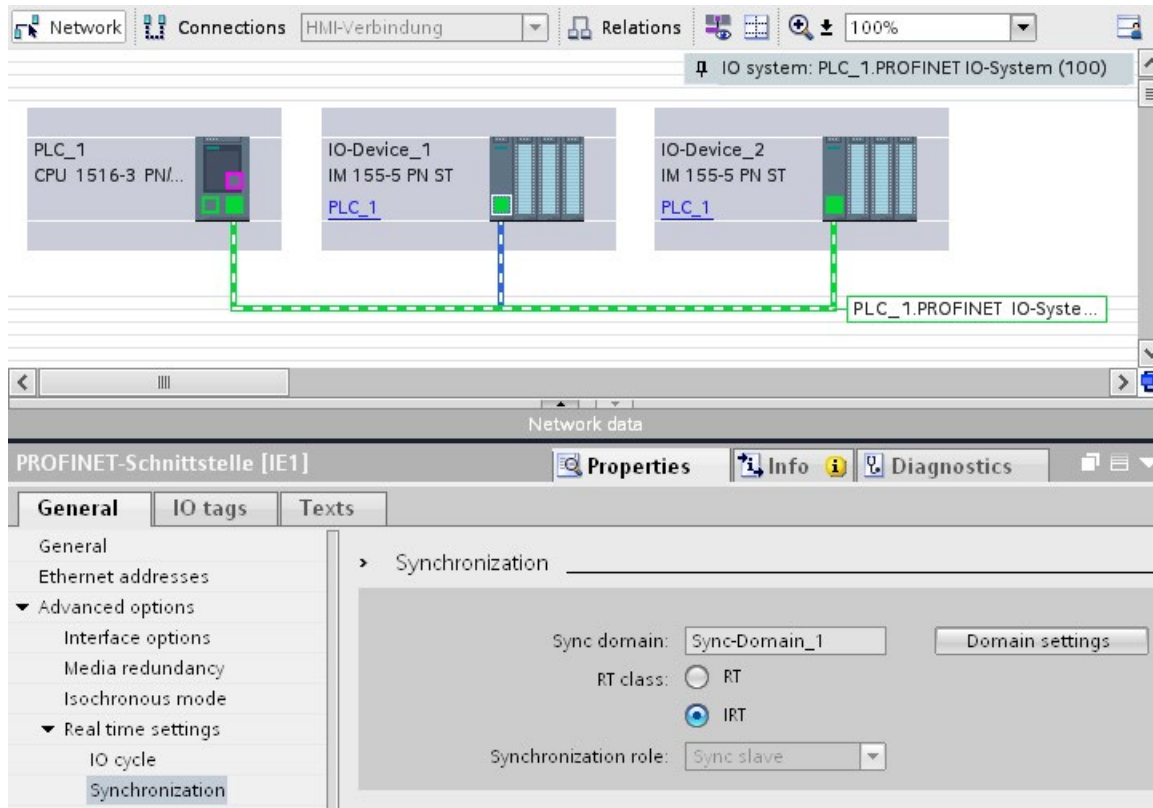


Figure 5-47 IRT configuring sync slave

6. Activate the RT class "IRT". The IO device will then automatically be assigned the synchronization role "sync slave".
 7. You can check and correct your settings at any time using the "Domain settings" button.
- Or
1. Highlight the PROFINET IO system in the network view.
 2. Click on the PROFINET IO system.

3. Navigate to the device of the required sync domain in the Inspector window.

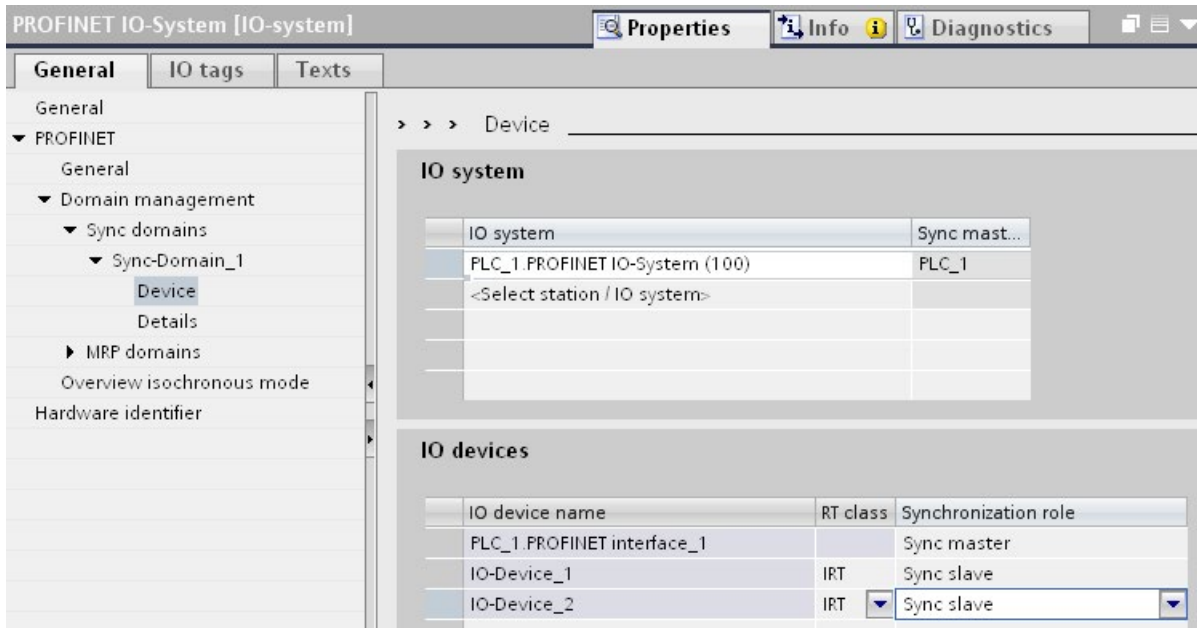


Figure 5-48 IRT configuring sync domain

4. Enter all necessary settings in the tables:

- Select an IO system.
- Set the synchronization role "sync master" for the IO controller.
- Set the RT class for the IO devices to "IRT". The IO devices will then automatically be assigned the synchronization role "sync slave".

You can now load the configuration to the relevant devices with PROFINET IRT.

5.5.6 Setting the bandwidth usage for the send clock

Bandwidth level

For PROFINET IO with IRT, you can specify the maximum portion of the send cycle that you want to use for cyclic IO communication.

You have the following setting options for the bandwidth usage in STEP 7.

- Maximum 25% cyclic IO data. Focus on non-cyclic data.
- Maximum 37.5% cyclic IO data. Focus on non-cyclic data.
- Maximum 50% cyclic IO data. Balanced proportion.
- Maximum 90% cyclic IO data. Focus on cyclic IO data. (Requirement: The "Make 'high performance' possible" option is activated)

Setting the bandwidth usage

To set the bandwidth usage for a PROFINET IO system in STEP 7, follow these steps:

1. Select your IO system in the network view of STEP 7.
2. In the Inspector window, go to "Properties" > "General" > "PROFINET" > "Domain management" > "Sync domains" > "Name of the sync domain" > "Details".
3. Select the desired level of bandwidth usage from the "Bandwidth use" drop-drop down list box.

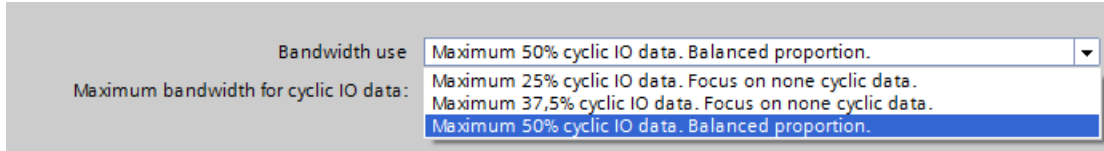


Figure 5-49 Setting the bandwidth usage

For information on how to set the bandwidth usage for IRT with maximum performance, refer to the section Configuration of IRT with high performance (Page 195)

5.5.7 Setup recommendations for optimizing PROFINET

Optimizing PROFINET with RT

PROFINET provides you with high-performance communication on all levels.

The following figures shows an example of an optimized PROFINET topology.

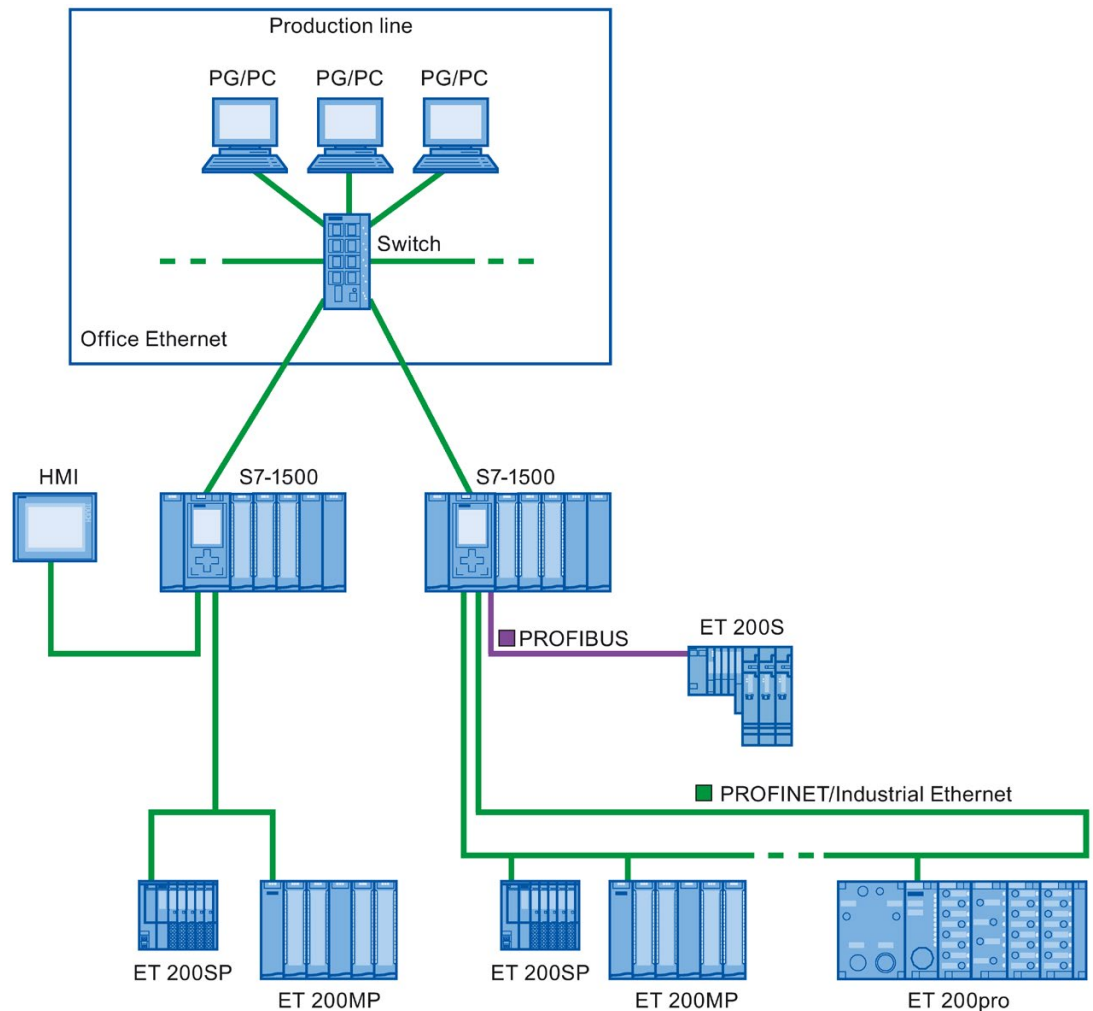


Figure 5-50 Optimized PROFINET topology

When setting up your PN network topology, take care that the various automation applications are distributed among separate network branches so that a sufficient bandwidth reserve will be available for future expansions.

- If you integrate standard Ethernet devices into the network topology or use standard Ethernet communication, take into account the network load caused by standard Ethernet and adapt the network topology as appropriate (max. bandwidth 100 Mbps).
- For communication with higher-level networks with a high data volume, use the most direct paths possible to the higher-level network infrastructure.

Also observe the Installation Guideline (<http://www.profibus.com/nc/download/installation-guide/downloads/profinet-installation-guide/display/>) of the PROFIBUS User Organization.

Setting up PROFINET with IRT

Keep in mind the following rules for setting up and operating a PROFINET IO system in IRT mode. These rules will ensure best possible operation of your PROFINET IO system.

- When using IRT, you must configure the topology. This will enable exact calculation of the update time, bandwidth, and other parameters.
- If you would like to use multiple sync domains, configure a sync boundary for the port which is currently connected to the PROFINET device of another sync domain.
- In a sync domain, you can only configure one sync master at a time.
- A PROFINET IO system may only be part of a single sync domain.
- If you configure PROFINET devices in a sync domain and want to synchronize with IRT, the PROFINET devices concerned must support IRT communication.
- If possible, use the same PROFINET device as the PROFINET IO controller and sync master.
- If only some of the PROFINET devices in a PROFINET IO system are synchronized, please keep in mind the following: Assign PROFINET devices that are not participating in the IRT communication to the RT class "RT" and the synchronization role "unsynchronized" in the sync domain.

Applications for CPU with multiple PROFINET IO interfaces

- Connecting machines: Your configuration contains machines located on separate IO lines. You can perform real-time communication between the CPUs over PROFINET IO interface X2. Use the I-device or shared I-device function for this purpose. The figure below shows an example configuration for two machines connected over the X2 interface with an I-device relationship.

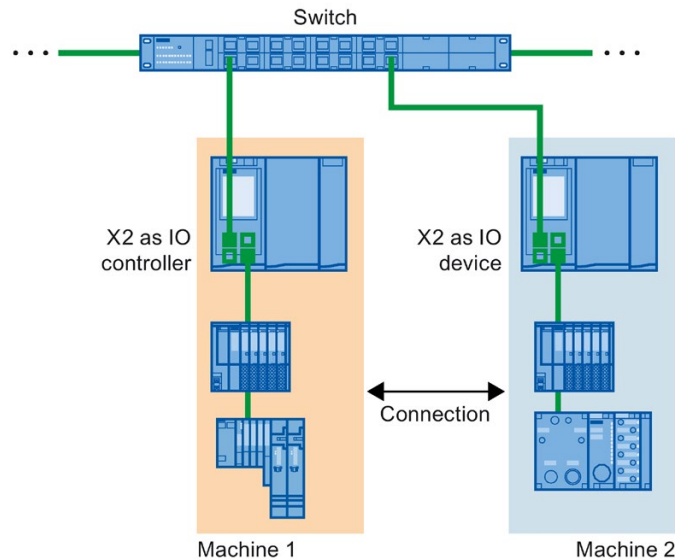


Figure 5-51 I-device connection over 2nd PNIO interface

- Distribution by automation tasks:
 - For automation tasks with high performance and deterministic requirements, use PROFINET with IRT over the X1 interface.
 - For other tasks that you can implement with RT, use the X2 interface.

If you use interface X2 as the PROFINET IO interface for one of the following CPUs, this can affect performance:

- CPU 1515(F)-2 PN
- CPU 1515T(F)-2 PN
- CPU 1516(F)-3 PN/DP
- CPU 1516T(F)-3 PN/DP
- CPU 1516(F)pro-2 PN

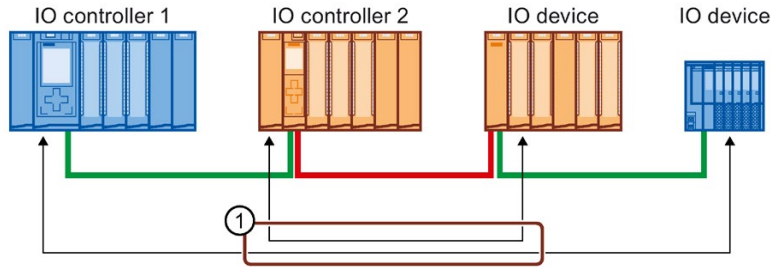
You can find additional information in the section PROFINET interface (Page 23) and in the Cycle and Response Times (<https://support.industry.siemens.com/cs/ww/en/view/59193558>) function manual.

Topological overlap of IO systems in multi-controller applications

In a configuration with multiple IO controllers, shared paths are subject to the combined network loads of all connected PROFINET IO systems.

To avoid high communication loads in multi-controller applications, observe the following recommendations:

- Avoid paths that are shared by multiple IO systems.
The figure below shows a configuration with two PROFINET IO systems that use the same paths.



① Shared path

Figure 5-52 Multi-controller application with shared path

In the figure below, the two PROFINET IO systems do not use shared paths.

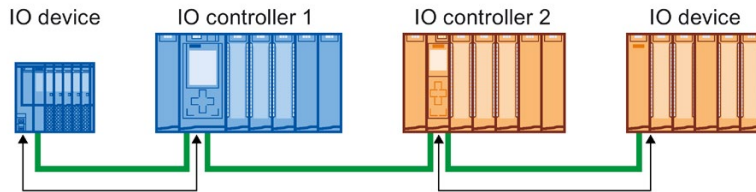


Figure 5-53 Multi-controller application with separate paths

- If separation is not possible: Increase the update time for the affected IO devices.

Installation guidelines of the PROFIBUS user organization

The installation guidelines can be found on the Internet

(<http://www.profibus.com/nc/download/installation-guide/downloads/profinet-installation-guide/display/>).

5.5.8 Limitation of the data infeed into the network

Limiting the data infeed into the network on PROFINET interfaces

The "Limit data infeed into the network" function limits the network load of standard Ethernet communication which is fed into the network by the interface to a maximum value. This does not apply to cyclic real-time communication (RT/IRT).

In a PROFINET IO system, critical network loads can occur quickly with standard Ethernet communication, especially in line topologies. Devices which feed a lot of standard Ethernet communication into the PROFINET IO system, should support the function "Limit data infeed into the network". If necessary, you should optimize your topology by avoiding e.g. standard Ethernet devices in line topologies. You can find additional information on this in section Setup recommendations for optimizing PROFINET (Page 185).

Depending on the interface, you can activate or deactivate the "Limit data infeed into the network" function. If you use the X1 interface of an S7-1500 CPU as the IO controller or I-device, the "Limit data infeed into the network" function is always enabled. Example: If you are not using the X1 interface of an S7-1500 CPU as IO controller or I-device, you can enable or disable the function.

Uses of the limitation of the data infeed to the network

- Division of the bandwidth for standard Ethernet communication between devices:
In PROFINET networks cyclic real-time communication and standard Ethernet communication share the same network. This means that only a limited bandwidth remains for standard Ethernet communication. The limitation of the data infeed ensures that the remaining bandwidth for standard Ethernet communication is not used just by one device, but is divided between several devices.
- Smoothing peaks in the data infeed:
The limitation of the data infeed smooths peak loads of standard Ethernet communication (for example, from Open User Communication, access by the Web server).
- Limiting problems in the data infeed:
If applications in a device generate too much data, this data is not forwarded to the PROFINET network. Negative effects (for example data loss, communication breakdown) remain limited to the device and its communications partner. Other nodes are not disturbed.

Setting limitation of the data infeed into the network for a CPU

To set the limitation of the data infeed into the network, follow these steps:

1. In the network view of STEP 7, select the interface of the CPU.
2. In the Inspector window, go to "Properties" > "General" > "Advanced options" > "Interface options".
3. Select or clear the "Limit data infeed into the network" check box.

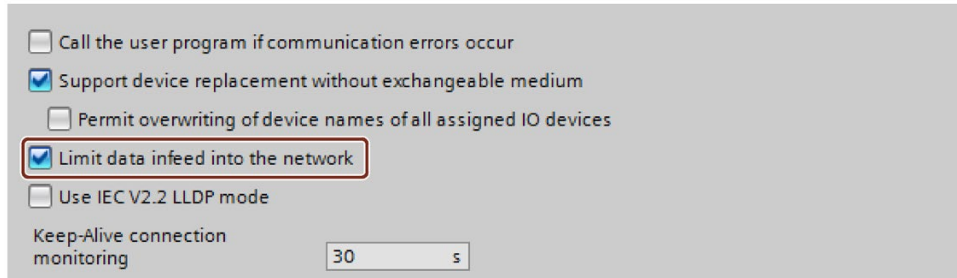


Figure 5-54 Limit data infeed into the network

5.6 PROFINET with performance upgrade

Performance upgrade

The performance upgrade implements the application class "High Performance" of the PROFINET specification V2.3.

The performance upgrade provides a series of measures that lead to the following improvements for PROFINET with IRT:

- Reduction of runtime delays in the IO devices
- Increase in the bandwidth for cyclic IO data
- Reduction of the bandwidth used for PROFINET frames
- Reduction of the send clocks

The improvements achieved with the performance upgrade mean that you can operate your PROFINET IO system with more devices with the same send clock or the same number of devices with a shorter send clock.

With PROFINET, it was previously possible to reach a send clock of 250 µs.

With the performance upgrade, it is now possible to achieve isochronous send clocks of up to 125 µs with the fast forwarding, dynamic frame packing and fragmentation procedures, depending on the performance capability of the CPU (see Technical Specifications in the device manuals). With short send clocks, standard communication remains possible.

The performance upgrade will help you to implement applications with high speed and send clock requirements.

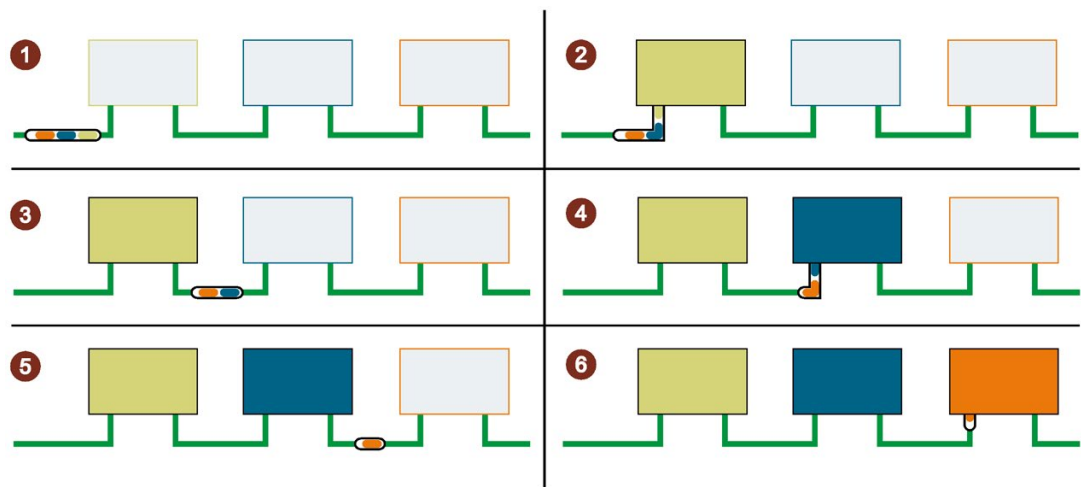
5.6.1 Dynamic frame packing

Dynamic frame packing

Previously, individual PROFINET IO frames were sent for every PROFINET IO device.

The performance upgrade uses the dynamic frame packing procedure that is based on the summation frame method. With the summation frame method, a frame contains the user data for neighboring devices on a line. With Dynamic Frame Packing, every IO device takes its data from the frame and forwards the rest. The frame is shortened from IO device to IO device. Dynamic frame packing improves the use of the bandwidth in a line topology.

The following figure shows how Dynamic Frame Packing works based on the example of a frame containing the user data for 3 IO devices.



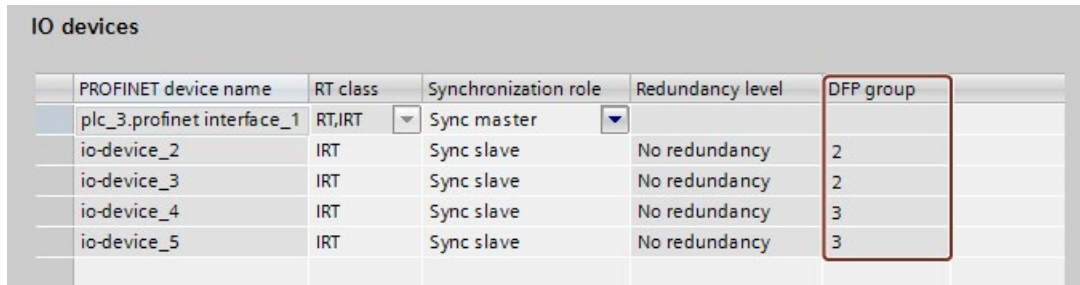
- ① The PROFINET IO frame contains the user data for all 3 IO devices (green, blue and orange).
- ② The PROFINET IO frame reaches the first IO device. The IO device takes its user data (green) from the frame and forwards the remaining frame.
- ③ The PROFINET IO frame contains the user data for two IO devices (blue and orange).
- ④ The PROFINET IO frame reaches the second IO device. The IO device takes its user data (blue) from the frame and forwards the remaining frame.
- ⑤ The PROFINET IO frame contains the user data for one IO device (orange).
- ⑥ The PROFINET IO frame reaches the last IO device. The IO device saves the entire frame including user data (orange).

Figure 5-55 Dynamic Frame Packing (DFP)

DFP groups

Dynamic frame packing automatically groups IO devices that support the performance upgrade into DFP groups. To be grouped together in a DFP group, the IO devices must be located one after the other in a line and must have the same update time and watchdog time. As soon as a maximum frame size for the DFP group is exceeded or a maximum number of members for a DFP group is reached, Dynamic Frame Packing automatically opens a new DFP group.

STEP 7 shows the DFP groups in "Domain management" > "Sync domains" > "Name of the sync domain" > "Device" in the "IO devices" box.



PROFINET device name	RT class	Synchronization role	Redundancy level	DFP group
plc_3.profinet interface_1	RT,IRT	Sync master		
io-device_2	IRT	Sync slave	No redundancy	2
io-device_3	IRT	Sync slave	No redundancy	2
io-device_4	IRT	Sync slave	No redundancy	3
io-device_5	IRT	Sync slave	No redundancy	3

Figure 5-56 Display of the DFP groups in STEP 7

Note

Dynamic frame packing with high watchdog times

If you set the "Accepted update cycles without IO data" parameter higher than 31 for an IO device, Dynamic Frame Packing does not place this IO device in a DFP group.

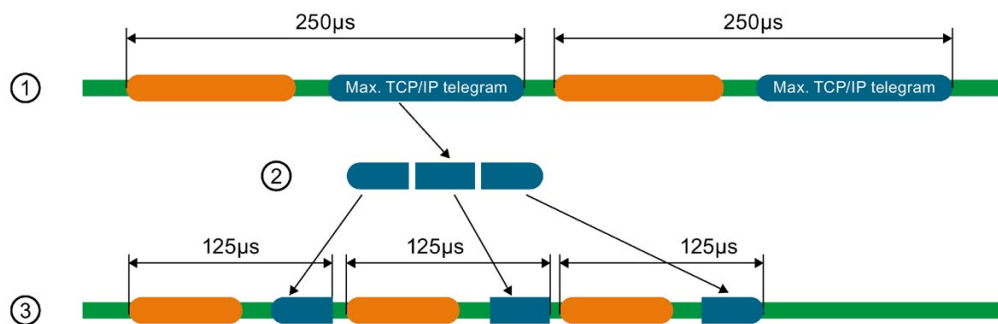
5.6.2 Fragmentation

The transfer of a complete standard Ethernet frame with TCP/IP data takes up to 125 μ s. This means that the cycle time for PROFINET IO data cannot be reduced by any desired amount.

The performance upgrade uses the fragmentation procedure, which breaks down TCP/IP frames into sub-frames. These frame segments are transferred to the target device over multiple send clocks; there they are reassembled to the original TCP/IP frame.

Fragmentation is a requirement for cycle times lower than 250 μ s. In these short send clocks, you can use more bandwidth for cyclic IO data, since the fragments of the standard Ethernet frames use significantly less bandwidth than a complete standard Ethernet frame.

The following figure shows how fragmentation works.



- ① A standard Ethernet frame with TCP/IP data is up to 125 μ s.
- ② During fragmentation, the standard Ethernet frame is divided into frame segments.
- ③ The frame segments are divided into multiple short send clocks.

Figure 5-57 Fragmentation

Note

The PROFINET IO interface of the IO controller supports fragmentation if all the ports except one are deactivated.

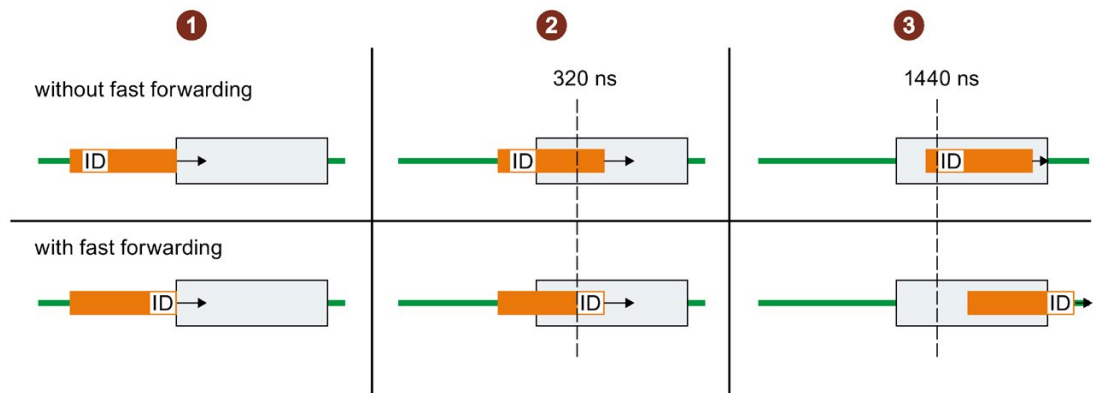
5.6.3 Fast forwarding

To be able to decide whether a frame should be forwarded or used, a PROFINET IO device requires the frame ID. It previously took 1440 ns until the frame ID was present in the IO device.

The performance upgrade uses the fast forwarding procedure in which the frame ID is located nearer the front of the frame. The throughput time in the device is reduced to 320 ns.

With fast forwarding, the throughput time of the frame is reduced in your PROFINET IO system. This results in decisive performance advantages, particularly in line, ring and tree topologies.

The figure below compares the throughput of a PROFINET IO frame in an IO device with and without fast forwarding.



- ① Start:
 - Both PROFINET frames reach the IO device.
The IO devices start to check the frames for the frame ID
- ② After 320 ns:
 - Without fast forwarding: The IO device is still checking the PROFINET frame for the frame ID.
 - With fast forwarding: The IO device receives the frame ID from the PROFINET frame and forwards the frame.
- ③ After 1440 ns:
 - Without fast forwarding: The IO device receives the frame ID from the PROFINET frame and forwards the frame.
 - The PROFINET frame with fast forwarding is "ahead" of the PROFINET frame without fast forwarding.

Figure 5-58 Fast forwarding

5.6.4 Configuration of IRT with high performance

High-end applications with IO communication require excellent performance in IO processing, for example in the control of wind turbines (converter control).

To use IRT communication with the highest performance in your PROFINET IO system, enable the option "Make 'high performance' possible".

When you enable the "Make 'high performance' possible" option, this has the following effects:

- You can set send clocks of 187.5 μ s and 125 μ s (for example CPU 1518-4 PN/DP) or 187.5 μ s (for example CPU 1517-3 PN/DP), see Technical specifications in the CPU device manuals.
- You can set more bandwidth use for cyclic IO data.
- You can use the option "Allows the use of 'fast forwarding'".

Requirements

- S7-1500 CPU as of firmware version V2.0

Enable the "Make 'high performance' possible" option.

Follow these steps to activate the "Make 'high performance' possible" option:

1. Select the PROFINET IO system in the network view of STEP 7.
2. In the Inspector window, go to "Properties" > "General" > "PROFINET" > "Domain management" > "Sync domains" > "Name of the sync domain".
3. Enable the "Make 'high performance' possible" option.

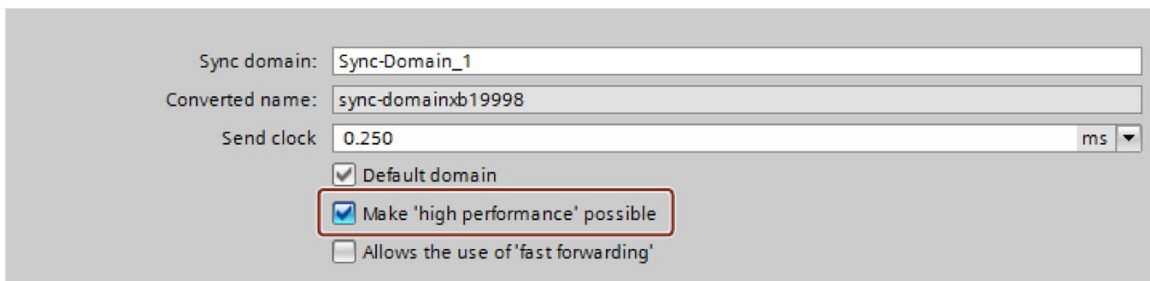


Figure 5-59 Activating high performance

Using more bandwidth for cyclic IO data

Requirement: The "Make 'high performance' possible" option is enabled.

To set more bandwidth for cyclic IO data for your PROFINET IO system, follow these steps:

1. Select your IO system in the network view of STEP 7.
2. In the Inspector window, go to "Properties" > "General" > "PROFINET" > "Domain management" > "Sync domains" > "Name of the sync domain" > "Details".
3. In the drop-down list, select "Maximum 90% cyclic IO data. Focus on cyclic IO data".

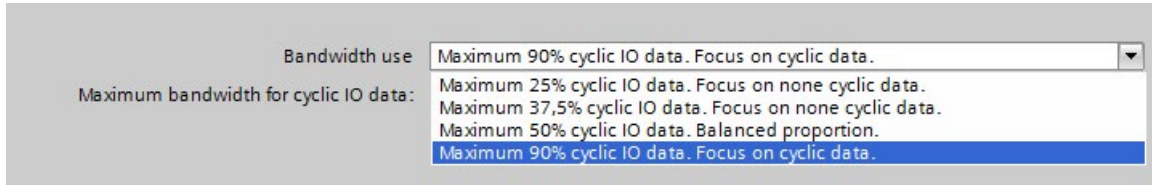


Figure 5-60 Using more bandwidth for cyclic IO data

Note

Bandwidth usage in isochronous mode

If you operate your PROFINET IO system in isochronous mode, avoid using the setting for the bandwidth usage "Maximum 90% cyclic IO data. Focus on cyclic IO data."

Setting low send clocks (example CPU 1518-4 PN/DP)

Requirement: The "Make 'high performance' possible" option is enabled.

1. Select the PROFINET IO system in the network view of STEP 7.
2. In the Inspector window, go to "Properties" > "General" > "PROFINET" > "Domain management" > "Sync domains" > "Name of the sync domain".
3. Select the send clock for "Send clock" in the drop-down list.

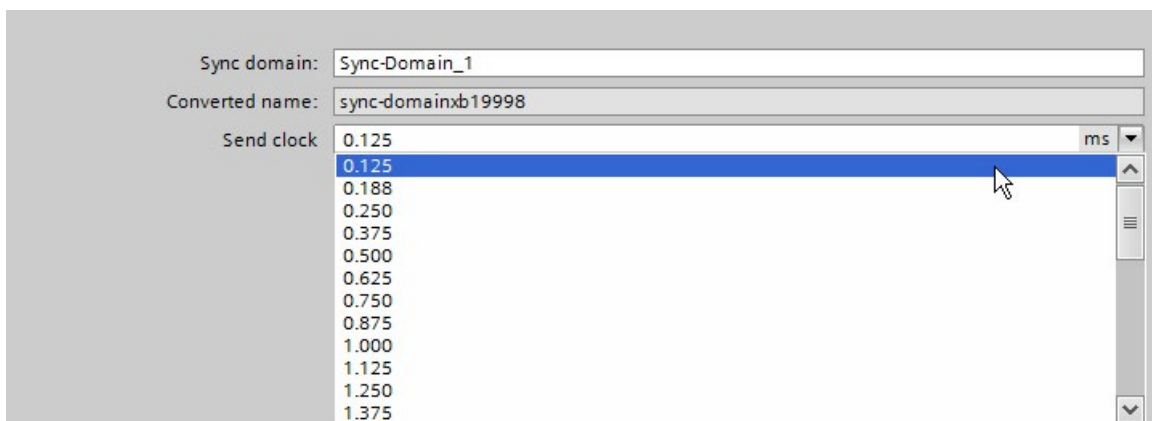


Figure 5-61 Setting low send clocks

Requirements for the fragmentation process (example CPU 1518-4 PN/DP)

If you use the following combinations for send clock and bandwidth settings, the devices in the IO system use the fragmentation process.

- Send clock cycle 125 μ s: Always fragmentation irrespective of the bandwidth setting.
- Send clock cycle 187.5 μ s: Fragmentation with the bandwidth settings "Maximum 50% cyclic IO data. Balanced proportion." and "Maximum 90% cyclic IO data. Focus on cyclic IO data."

The PROFINET IO interface of the controller supports fragmentation if all the ports except one are deactivated.

Optimizing port settings for low send clocks

You can further optimize the bandwidth use in your PROFINET IO system by using cables with a short cable length (< 20 m) or a short signal delay (max. 0.12 μ s) between the devices.

To configure cables with a shorter length or signal delay in STEP 7, follow these steps:

1. Select the port in the topology view of STEP 7.
2. Navigate in the Inspector window to "Port interconnection" in the "Partner port" box.
3. Select the option "Cable length" or "Signal delay:".
4. Select the cable length or enter the signal delay.

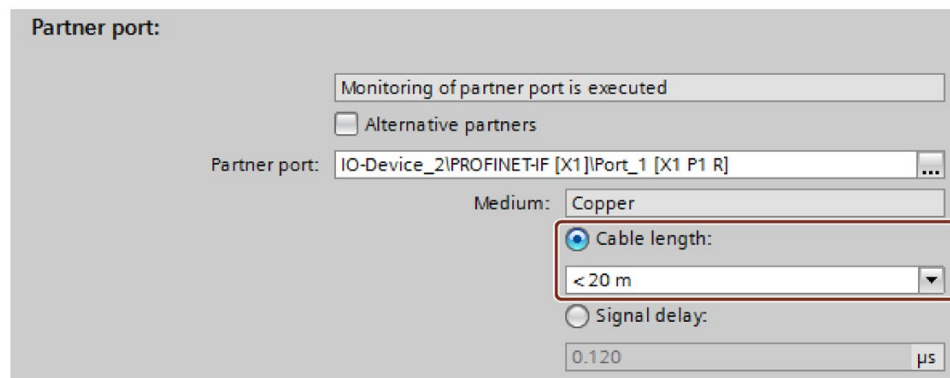


Figure 5-62 Optimizing port settings for low send clocks

Allowing fast forwarding

Requirements:

- The PROFINET IO device has to support the fast forwarding process so that the process can be used by the device.
- The "Make 'high performance' possible" option is enabled.
- The PROFINET IO interface supports fast forwarding if all the ports except one are deactivated.

Follow these steps to allow fast forwarding:

1. Select the PROFINET IO system in the network view of STEP 7.
2. In the Inspector window, go to "Properties" > "General" > "PROFINET" > "Domain management" > "Sync domains" > "Name of the sync domain".
3. Enable the "Allows the use of 'fast forwarding'" option.

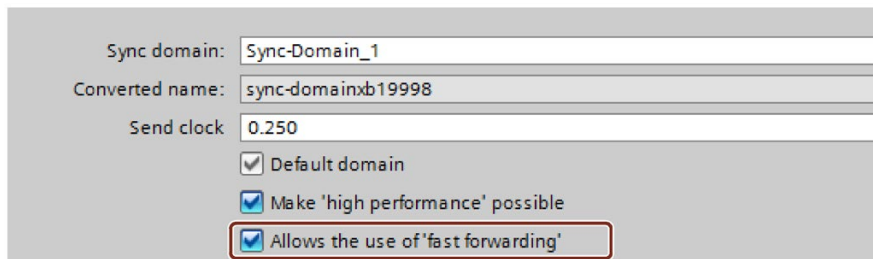


Figure 5-63 Allowing fast forwarding

Note

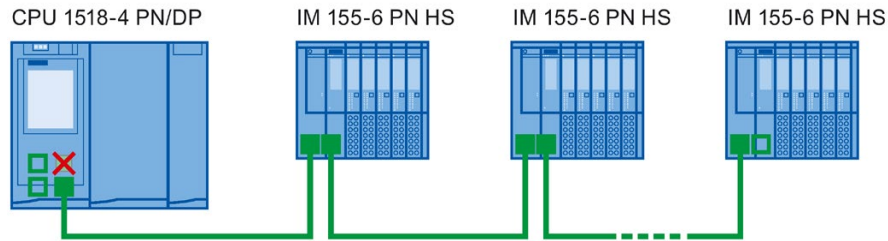
Fast forwarding and IPv6

The operation of fast forwarding in combination with IPv6 is not supported.

As soon as an IO device in the subnet uses an IPv6 address, you must not activate "fast forwarding".

5.6.5 Sample configuration for IRT with high performance

The figure below shows an example configuration with which you can achieve maximum performance.



- ✗ Port 1 of the X1 interface of the CPU is deactivated.
- Port 2 of the X1 interface and the ports of the interface modules on the bus use the following setting: Medium copper, cable length < 20 m or signal delay max. 0.12µs
- A programming device connection to the CPU can be established via the interfaces X2 and X3 of the CPU or via the free port at the end of the line.

Figure 5-64 Example configuration for IRT with high performance

Use the following settings for the Sync domain:

- Enable the "Make 'high performance' possible" option.
- Set the send clock to 125 µs.
- Enable the "Allows the use of 'fast forwarding'" option.

Standard Ethernet communication for IRT with high performance

Standard Ethernet communication is still possible even in a PROFINET IO system with high performance. Keep in mind that you first arrange the IRT nodes, as seen from the IO controller, and arrange the standard Ethernet nodes at the end of the line.

With a large volume of data through standard Ethernet communication, it makes sense to reduce the load on your network by separating standard Ethernet communication and cyclic real-time communication. Example: Use the interface X1 for the PROFINET IO communication and a different interface for the standard Ethernet communication.

5.7 Isochronous mode

5.7.1 What is isochronous mode?

Objectives of isochronous operation

The advantages of the isochronous mode function in automation engineering can be seen in an example from everyday life.

The transmission of data corresponds to the transport of people on public transport. Assuming public transport were to operate at maximum speed while reducing stop times at the passenger terminals to absolute minimum, the last thing many potential passengers would notice of the departing contraption are its red tail lights. The overall travel time is, however, decided by the train, bus or underground-railway clock, because well adjusted timing is essential to a good service. This also applies in automation engineering. Not only fast cycles but also the adaptation and synchronization of the individual cycles result in optimum throughput.

Just-In-Time

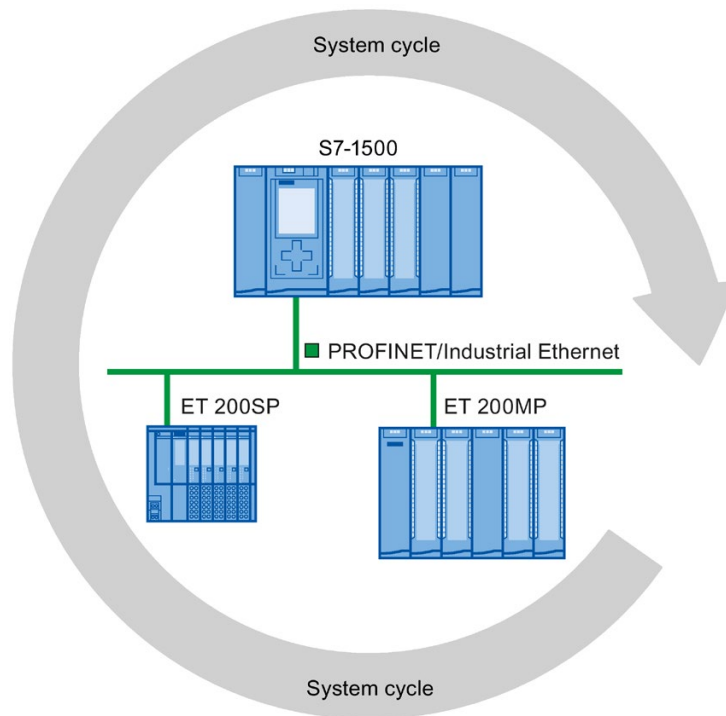


Figure 5-65 System cycle

The fast and reliable response time of a system operating in isochronous mode is due to the fact that all data is provided just-in-time. The basis for this is an equidistant cycle.

The isochronous mode function guarantees synchronization of the following at constant time intervals:

- Signal acquisition and output by the distributed I/O
- Signal transmission via PROFINET IO
- Program execution in the CPU in time with the equidistant PROFINET IO

The result is a system that acquires its input signals, processes them and outputs the output signals at constant time intervals. Isochronous mode guarantees precisely reproducible and defined process response times as well as equidistant and synchronous signal processing for distributed I/O.

Advantages of isochronous mode

The use of isochronous mode allows high-precision control.

- Optimized control loops through constant, calculable dead times
- Determinism, reliable reproducibility of response times
- Consistent (simultaneous) reading in of input data
- Consistent (simultaneous) output of output data

5.7.2 Use of isochronous mode

An isochronous system acquires measured values and process data within a fixed system cycle, processes the signals and outputs them synchronously to the process. Isochronous mode contributes to a high control quality and increased production accuracy. With isochronous mode, the possible fluctuations of process response times are drastically reduced. You make use of the time-assured processing to improve machine cycle times. Even fast processes can be reliably controlled thanks to the precise time reproducibility of all sequences. Shorter cycle times increase the processing speed and help to lower production costs.

In principle, isochronous mode is worthwhile whenever measured values must be acquired synchronously, movements must be coordinated, and process responses must be defined and simultaneously executed, as in the following example. Isochronous mode can thus be used in a wide variety of applications.

Example: Measuring at multiple measurement points with isochronous mode

Automation task

A camshaft production process requires precise measurement of the camshafts for quality assurance purposes.

Feature

For this purpose, a component is needed that can synchronously measure the positions and displacements of the cam during a rotation of the camshaft.

Solution

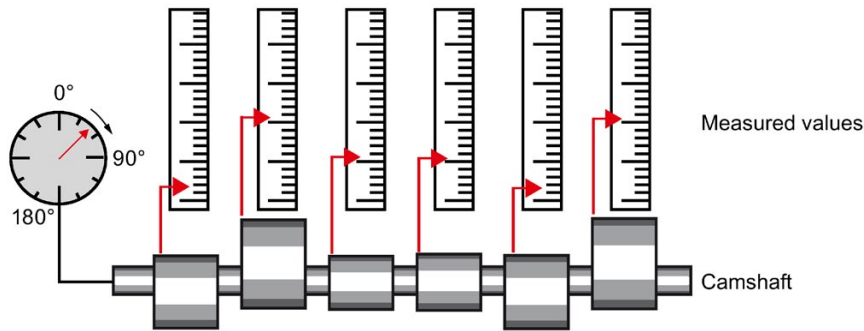


Figure 5-66 Measuring of camshafts

With use of isochronous mode, the measured values are simultaneously acquired at the various measuring points at fixed times. This results in the following workflow:

- Continuously rotate the camshaft
- During continuous rotation, synchronously measure the positions and cam displacements
- Process the next cam shaft

Thus, during a single rotation of the camshaft, all the positions of the camshaft and the associated measured values (red) are measured synchronously. The machine cycle time improves with the same or better measuring accuracy.

Advantage and benefits

The time required for measurement is reduced.

5.7.3 Time sequence of synchronization on PROFINET IO

Introduction

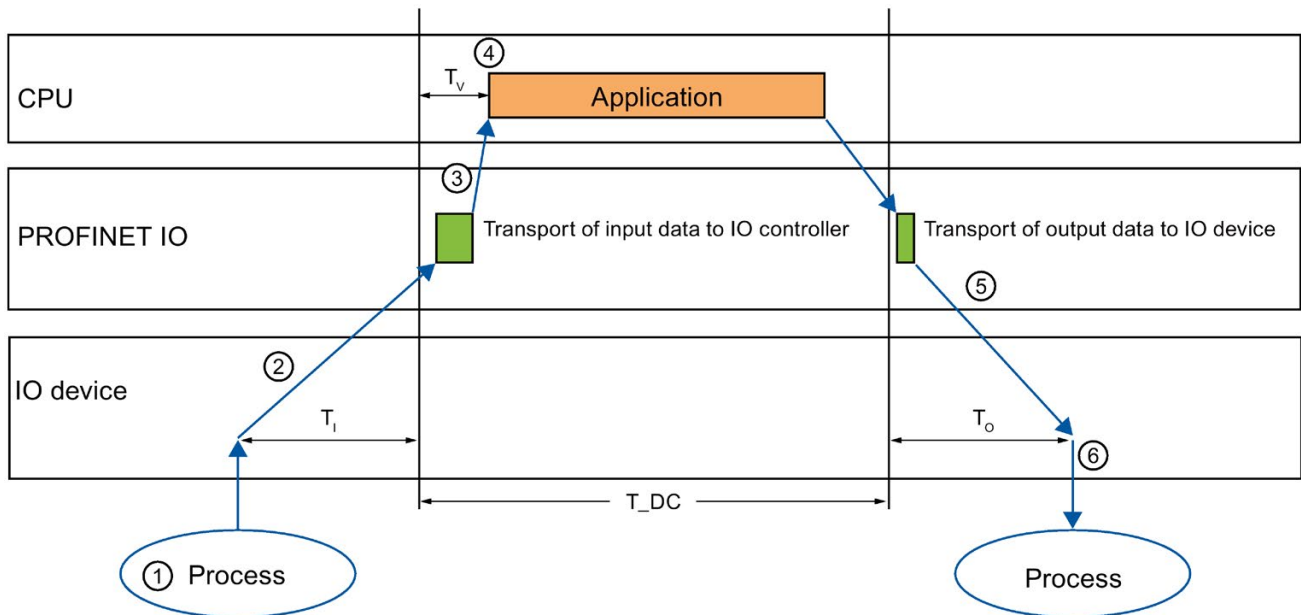
On PROFINET IO, you can isochronously operate I/O modules in distributed I/O systems on a CPU, e.g. in distributed I/O systems ET 200SP, ET 200MP.

Like the I/O modules, the interface modules of the I/O systems must support isochronous mode.

From reading in input data to outputting output data

The basic time sequence of all components involved in synchronization is explained below:

- ① Measured value acquisition in the process
- ② Isochronous read-in of input data
- ③ Transport of input data to the IO controller (CPU) via the subnet
- ④ Further processing in the isochronous application of the CPU
- ⑤ Transport of output data to the outputting IO device via the subnet
- ⑥ Isochronous output of output data



- T_{DC} Data cycle (Time_DataCycle)
- T_I Time for reading in the input data
- T_O Time for outputting the output data
- T_V Configured delay time

Figure 5-67 Time sequence of synchronization on PROFINET IO

To ensure that all input data is ready for transport via the subnet at the next start of the PROFINET IO cycle, the start of the I/O read-in cycle is advanced by the amount of lead time T_I . T_I is the "flashbulb" for the inputs; at this instant, all synchronized inputs are read in. T_I is necessary in order to compensate for analog-to-digital conversion, backplane bus times, and the like. The lead time T_I can be configured by STEP 7 or by you. Let the lead time T_I be assigned automatically by STEP 7. With the default setting, STEP 7 ensures that a common, minimum T_I is set.

The subnet transports the input data to the IO controller/DP master. The application is started synchronized to the cycle. That is, the isochronous mode interrupt OB is called after a configurable delay time T_V . The user program in the isochronous mode interrupt OB defines the process response and provides the output data in time for the start of the next data cycle. The length of the data cycle (send clock/DP cycle time) is always configured by you.

T_O is the time for the compensation arising from the backplane bus and the digital-to-analog conversion within the IO device/DP slave. T_O is the "flashbulb" for the outputs. The synchronized outputs are output at this time. Time T_O can be configured by STEP 7 or by you. Let time T_O be assigned automatically by STEP 7. STEP 7 automatically calculates a common, minimum T_O .

5.7.4 Configuring isochronous mode

5.7.4.1 Introduction

Configuring at a glance

Setting parameters for isochronous operation of the I/O module

You use the properties of the I/O addresses of the corresponding I/O module to:

- Set isochronous mode for the module.
- Assign the inputs and outputs of the module to a process image partition and an isochronous mode interrupt OB.

The data of the process image partition is updated synchronously to the assigned OB. Isochronous mode interrupts give you the option of starting programs isochronously with the PROFINET send clock. Isochronous mode interrupts are processed with high priority.

Setting the send clock

The send clock is the shortest possible transmission interval for the data exchange. In isochronous mode, the send clock corresponds to data cycle T_{DC} .

You set the send clock in the properties of the PROFINET interface of the CPU or in the sync domain.

Setting the application cycle

The application cycle is a multiple of data cycle T_{DC} . If the runtime of the isochronous mode interrupt OB is short, the application cycle can be identical to the data cycle (= send clock).

You can reduce the application cycle of the isochronous mode interrupt OB relative to the send clock of an isochronous PROFINET IO system. Set an integer multiple of the send clock as the reducing factor.

You use the factor to reduce the CPU utilization by executing the isochronous mode interrupt OB less frequently. You set the application cycle in the properties of the isochronous mode interrupt OB.

Setting the delay time

The delay time is the time between the start of the send clock and the start of the isochronous mode interrupt OB. During this time, the IO controller performs cyclic data exchange with the IO devices.

STEP 7 sets the default delay time in such a way that the isochronous update of the process image partition automatically falls within the execution window of the application cycle.

You set the delay time in the properties of the isochronous mode interrupt OB. A shorter delay time enables you to increase the processing time for your user program in the isochronous mode interrupt OB.

Additional configurations for isochronous mode on PROFINET IO:

- **Setting IRT as the RT class for the interconnected PROFINET interfaces**

A precondition for isochronous operation on PROFINET IO is IRT communication (Isochronous Real Time Communication). IRT means synchronized data exchange at reserved time intervals.

- **Configuring the topology of the configuration**

A precondition for IRT communication is the topology configuration. In addition to the reserved bandwidth, the exchange of frames on defined transmission paths is used for further optimization of data communication. For this, the topological information of the configuration is used for planning the communication.

- **Using a sync domain**, you assign the IO devices (sync slaves) to an IO controller (sync master) for the isochronous data exchange.

A precondition for IRT communication is a synchronization cycle for all PROFINET devices in a sync domain, for distribution of a common time base. With this basic synchronization, synchronous operation of the transmission cycle of the PROFINET devices within a sync domain is achieved.

5.7.4.2 Configuring isochronous mode on PROFINET IO

Introduction

The configuring of isochronous mode for a module is described as IO device in the following based on the ET 200MP distributed I/O system. The procedure described also applies to other distributed I/O systems (e.g., ET 200S or ET 200SP).

The IO controller is an S7-1500 CPU.

Requirements

- The STEP 7 network view is open.
- A S7-1500 CPU has been placed (e.g., CPU 1516-3 PN/DP).
- An IM 155-5 PN HF interface module (ET 200MP) has been placed and networked with the CPU via PROFINET IO.
- All requirements for an IRT configuration are met:
 - The ports of the networked PROFINET interfaces of the CPU and interface module are interconnected (topology configuration).
 - The RT class of the PROFINET interface of the interface module is set to "IRT" (area "Advanced options > Real time settings > Synchronization").
 - The "sync master" and "sync slave" roles are assigned for the PROFINET interfaces of the CPU and interface module (in the properties of a PROFINET interface: area "Advanced options" > "Media redundancy" > "Domain settings").

Procedure

To create an isochronous connection between the I/O and user program, follow these steps:

1. Select the IM 155-5 PN HF in the network view of STEP 7. Change to the device view.
2. Insert an I/O module that can be operated isochronously (e.g. DI 16 x 24VDC HF).

3. Go to the "I/O addresses" area in the Inspector window of the selected I/O module.

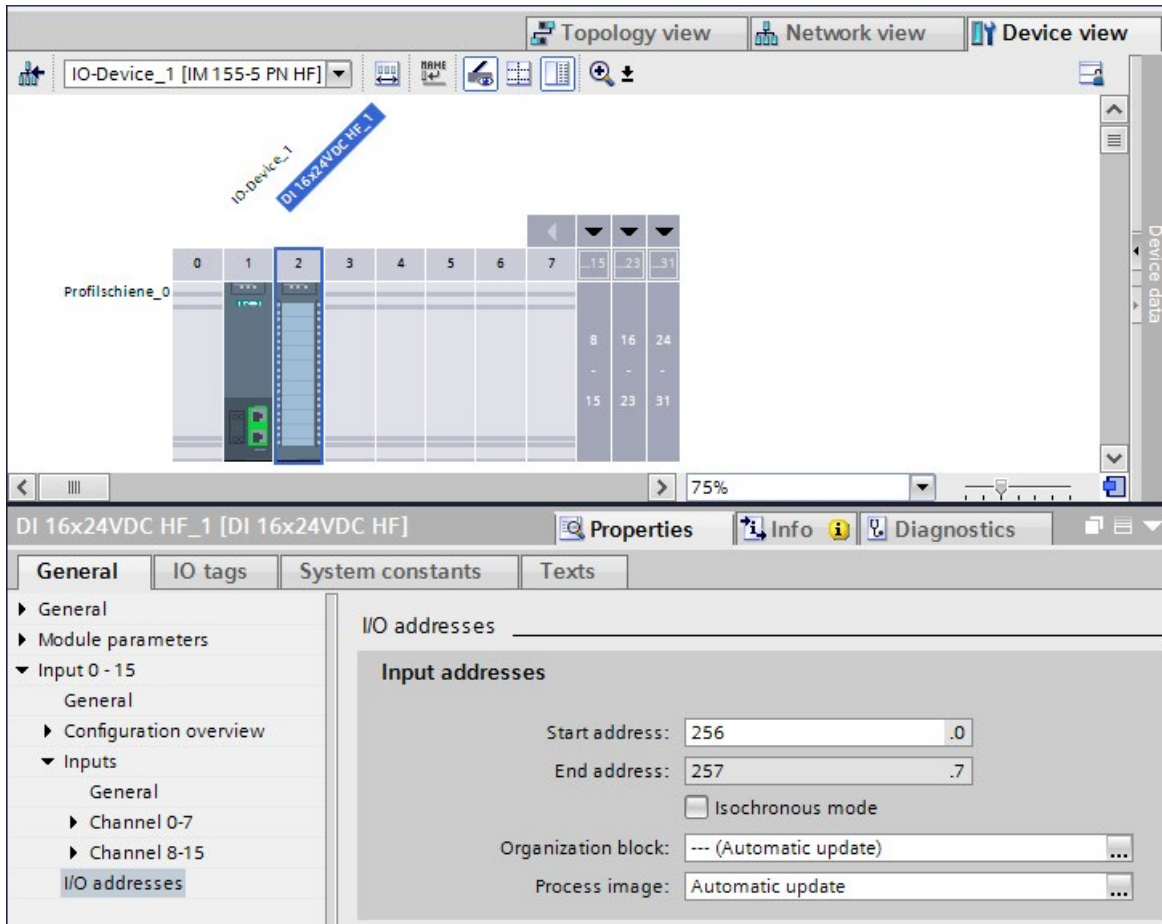


Figure 5-68 Configuring isochronous mode on PROFINET IO

4. Make the following settings in the I/O addresses area:

- Select the "Isochronous mode" option.
- Select a process image partition, e.g., process image partition 1.
- Click the "Organization block" drop-down list. Click the "Add" button or select an existing OB. A dialog box for selecting organization blocks opens.
- Select the "Synchronous Cycle" OB. Confirm the selection with "OK".

In the case of automatic number assignment, OB 61 will be generated and opened.

In the Inspector window, you can continue directly with the setting of the application cycle and delay time (Page 208) in the "Isochronous mode" area and start the programming of the OB in the instruction section.

5. If required, insert additional IO devices in the network view. Adapt the configuration and the settings for the isochronous mode.
6. You want to retrieve information about calculated bandwidths or on adapting the send clock. Select the sync domain in the network view and navigate to the corresponding area of the domain management in the Inspector window.

Reference

You can find examples of parameter assignment and possible settings of isochronous mode for distributed I/O and drives in STEP 7 in this FAQ on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109480489>).

5.7.4.3 Setting the application cycle and delay time

Requirements

- You have created an isochronous mode configuration in STEP 7.
- You have created an isochronous mode interrupt OB Synchronous Cycle (OB 6x).
- The isochronous mode interrupt OB is open.

Setting the application cycle

The application cycle is a multiple of data cycle T_DC (send clock). You use the application cycle setting to reduce the CPU utilization caused by execution of the isochronous mode interrupt OB. In the following example, the OB is called only after every 2nd data cycle T_DC in the CPU.

To set the application cycle for your isochronous mode application, follow these steps:

1. Open the "Properties" dialog of the isochronous mode interrupt OB under consideration.
2. In the area navigation, click the "Isochronous mode" group .
3. Set the application cycle in "Application cycle (ms)". Open the drop-down list box and select the application cycle. The drop-down list offers multiples of data cycle T_DC as possible values for the application cycle. Data cycle T_DC is set to 2 ms in the following figure.

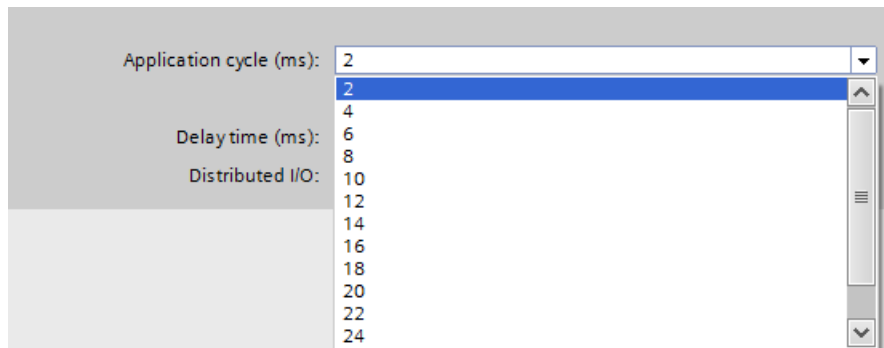


Figure 5-69 Setting the application cycle

Setting the delay time

The delay time is the time between the start of the send clock and the start of the isochronous mode interrupt OB. STEP 7 sets the delay time automatically to the start of the execution window by default. As a result, the isochronous mode update of the process image partition automatically falls within the execution window of the application cycle.

You can also set the delay time manually. A shorter delay time enables you to increase the processing time for your user program in the isochronous mode interrupt OB. If a manual setting is made, note that you must call the "SYNC_PI" and "SYNC_PO" instructions in the execution window of the application cycle.

To set the delay time for your isochronous mode application, follow these steps:

1. Open the "Properties" dialog of the isochronous mode interrupt OB under consideration.
2. In the area navigation, click the "Isochronous mode" group .
3. Clear the "Automatic setting" check box.
4. Enter your desired delay time in "Delay time (ms)".

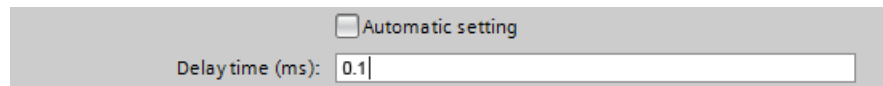


Figure 5-70 Setting the delay time

5.7.5 Programming isochronous mode

5.7.5.1 Basics of Programming

Programming in the isochronous mode interrupt OBs

You program the isochronous section of the program exclusively in the isochronous mode interrupt OBs Synchronous Cycle (OB 6x).

Because the isochronous mode interrupts are processed with high priority, only the time-critical sections of the program should be processed in the isochronous mode interrupt OB. The isochronous mode interrupt OB is called with a configured delay time.

Access to isochronous I/O through call of instructions

You access the isochronous I/O via a process image partition. That is, the addresses of the isochronous modules must be within one process image partition.

You program access to the isochronous IO in isochronous mode interrupt OB Synchronous Cycle (OB 6x) with the SYNC_PI and SYNC_PO instructions.

The isochronous I/O is updated by the call of the "SYNC_PI" and "SYNC_PO" instructions and therefore in the corresponding process image partition.

Note

Recommendation: To prevent inconsistent data from being returned to OB 6x, do not use the "DPRD_DAT" and "DPWR_DAT" instructions (direct data access) in the isochronous mode interrupt OB.

The "SYNC_PI" and "SYNC_PO" instructions update the process image partition only within the permitted execution window. The execution window stretches from the end of the cyclic data exchange to the point in time before the end of T_DC at which the outputs can still be copied in time. The data exchange must be started within this time window. If the execution window is violated by the processing of the "SYNC_PI" and "SYNC_PO" instructions, the instructions indicate a corresponding error message.

Program execution models

Depending on the order of the "SYNC_PI" and "SYNC_PO" instruction calls in OB 6x, there are two basic models for the program execution:

- **IPO** model (read Inputs - Processing - write Outputs)
- **OIP** model (write Outputs - read Inputs - Processing)

5.7.5.2 Program execution according to the IPO model

If the execution time of the isochronous mode interrupt OB is significantly shorter than one data cycle T_DC, use the IPO model. In the IPO model, you do not reduce the data cycle. That is, the application cycle of the isochronous mode interrupt OB is equal to data cycle T_DC.

The IPO model enables the shortest response times.

Programming according to the IPO model in the isochronous mode interrupt OB

For programming according to the IPO model:

1. Call the SYNC_PI instruction at the start of the isochronous mode interrupt OB.
2. Then call the actual user program.
3. Call the SYNC_PO instruction at the end of the isochronous mode interrupt OB.

Table 5-3 Programming according to the IPO model

Step	Action	Explanation
1	Read in (I)	The SYNC_PI instruction reads in the inputs of the process image partition and provides them to the isochronous mode interrupt OB.
2	Process (P)	You program the actual user program of the isochronous mode interrupt OB.
3	Output (O)	The SYNC_PO instruction outputs the data changed by the user program via the process image partition.

Signal sequence in the IPO model

The following figure shows the signal sequence in the IPO model from the acquisition and the processing in the CPU to the output of the process values:

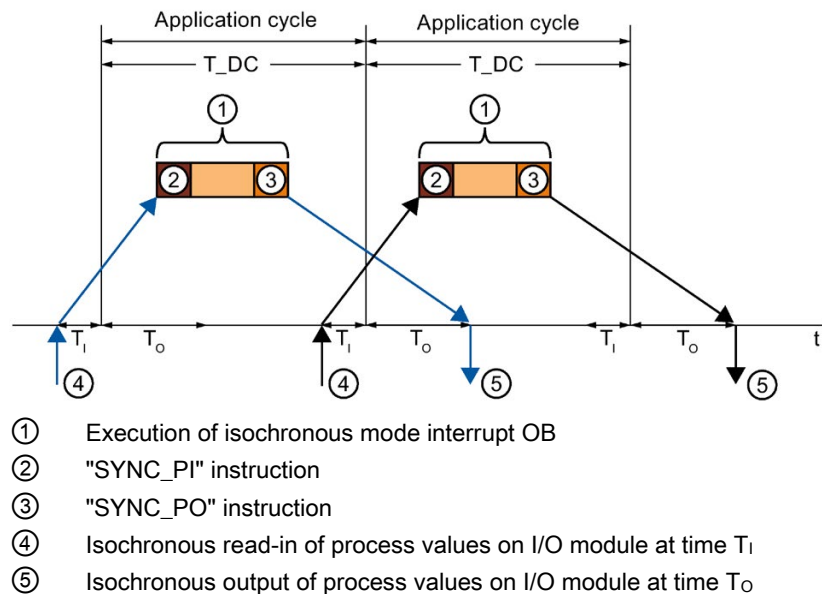


Figure 5-71 Signal sequence in the IPO model

At time T_I the process values are read in isochronously on the I/O. The processing of the data in the IPO model is completed within one data cycle T_{DC} . The output data is always available on the I/O in the next data cycle T_{DC} at time T_O .

With the IPO model, there is a constant execution time from the "input terminal" to the "output terminal" of $T_I + T_{DC} + T_O$.

$T_I + 2 \times T_{DC} + T_O$ can be guaranteed for the process response time.

5.7.5.3 Program execution according to the OIP model

Use the OIP model in the case of execution cycles of the isochronous mode interrupt OB of different lengths, if the application cycle is greater than data cycle T_DC.

The data exchange with the process is always deterministic in the OIP model, i.e. takes place at a precisely specified time.

Programming according to the OIP model in the isochronous mode interrupt OB

For programming according to the OIP model:

1. Call the SYNC_PO instruction at the start of the isochronous mode interrupt OB.
2. Then call the SYNC_PI instruction.
3. Then call the actual user program.

Table 5- 4 Programming according to the OIP model

Step	Action	Explanation
1	Output (O)	The SYNC_PO instruction outputs the data that was changed by the user program in the previous cycle via the outputs of the process image partition.
2	Read in (I)	The SYNC_PI instruction reads in the inputs of the process image partition of the current cycle and provides the inputs to the isochronous mode interrupt OB.
3	Process (P)	You program the actual user program of the isochronous mode interrupt OB.

Signal sequence in the OIP model

The following figure shows the signal sequence in the OIP model from the acquisition of process values and the processing in the CPU to the output of the process values. The application cycle is twice as long as data cycle T_{DC} in this example.

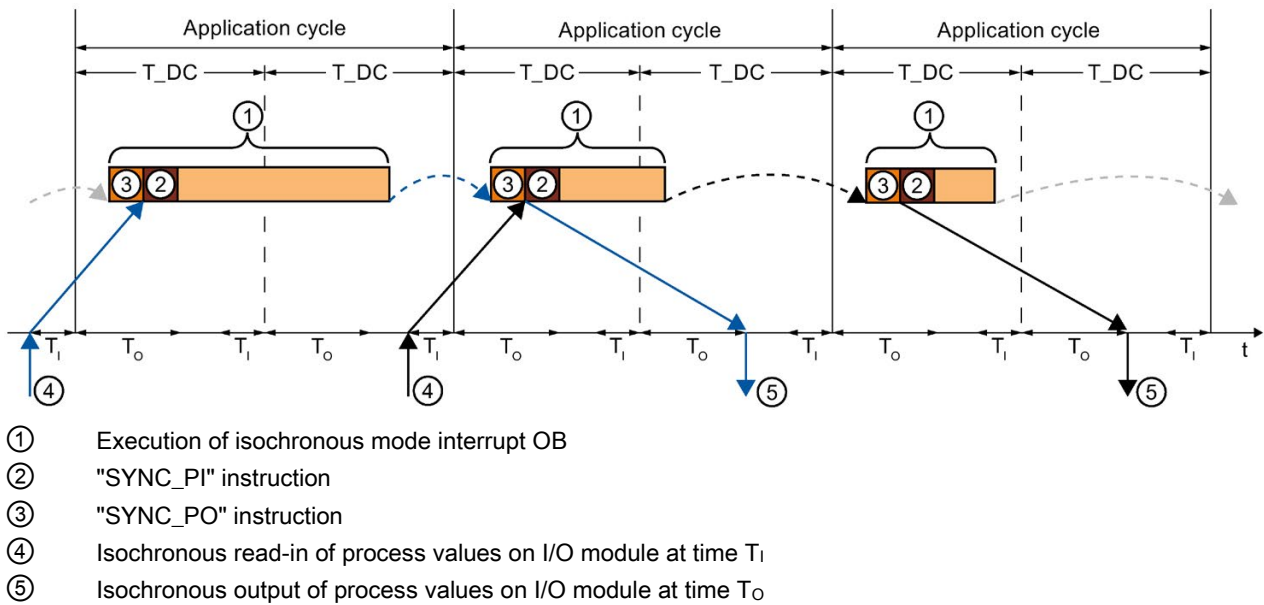


Figure 5-72 Signal sequence in the OIP model

At time T_I the process values are read in isochronously on the I/O. The data is processed over 2 application cycles in the OIP model. The output data is always available on the I/O in the following application cycle at time $T_{DC} + T_O$.

With the IPO model, there is a constant execution time from the "input terminal" to the "output terminal" of $T_I + \text{application cycle} + T_{DC} + T_O$.

$T_I + 2 \times \text{application cycle} + T_{DC} + T_O$ can be ensured as the process response time.

5.8 Direct data exchange

5.8.1 Introduction

This section describes the direct data exchange function.

Principle of operation

Starting with firmware version V2.8, the S7-1500 CPU supports direct data exchange with other S7-1500 CPUs.

In the case of direct data exchange, an S7-1500 CPU provides cyclic user data from the I/O area to one or more partners. The direct data exchange is based on PROFINET with IRT and isochronous mode.

The data exchange takes place via transfer areas.

Direct data exchange between two S7-1500 CPUs (1:1)

The figure below shows the direct data exchange between two S7-1500 CPUs. The output transfer areas of the sending S7-1500 CPU correspond to the input transfer areas of the receiving S7-1500 CPU.

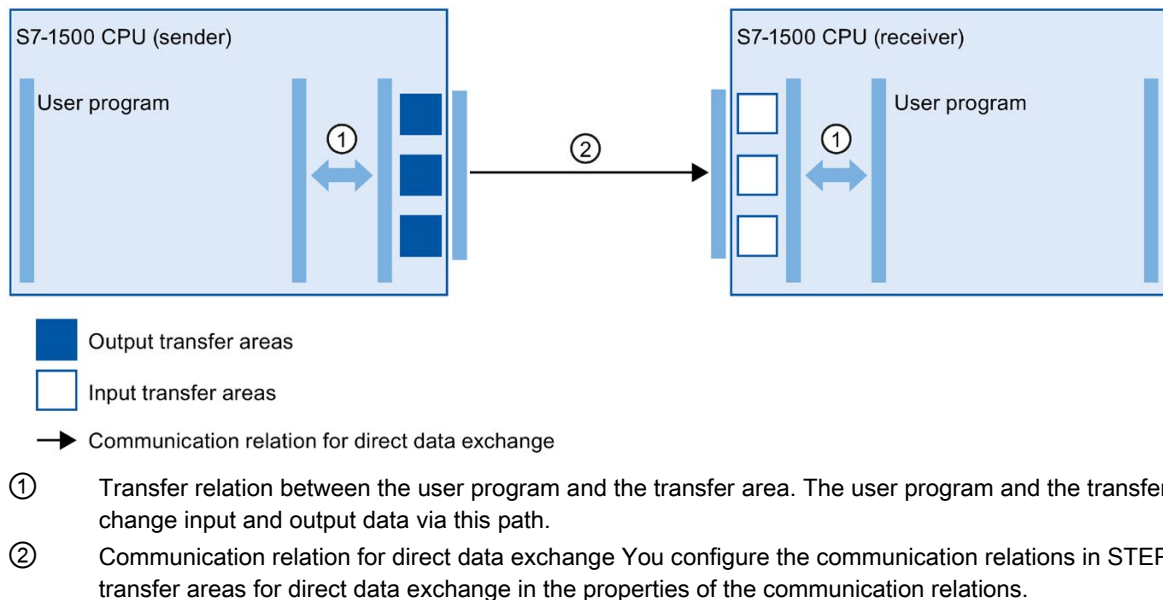


Figure 5-73 Direct data exchange between two S7-1500 CPUs (1:1)

Direct data exchange with multiple receivers (1:n)

The following figure shows the direct data exchange with multiple S7-1500 CPUs. In this case, the sending S7-1500 CPU provides the data of its output transfer areas to multiple S7-1500 CPUs. Each receiving S7-1500 CPU has its own input transfer areas.

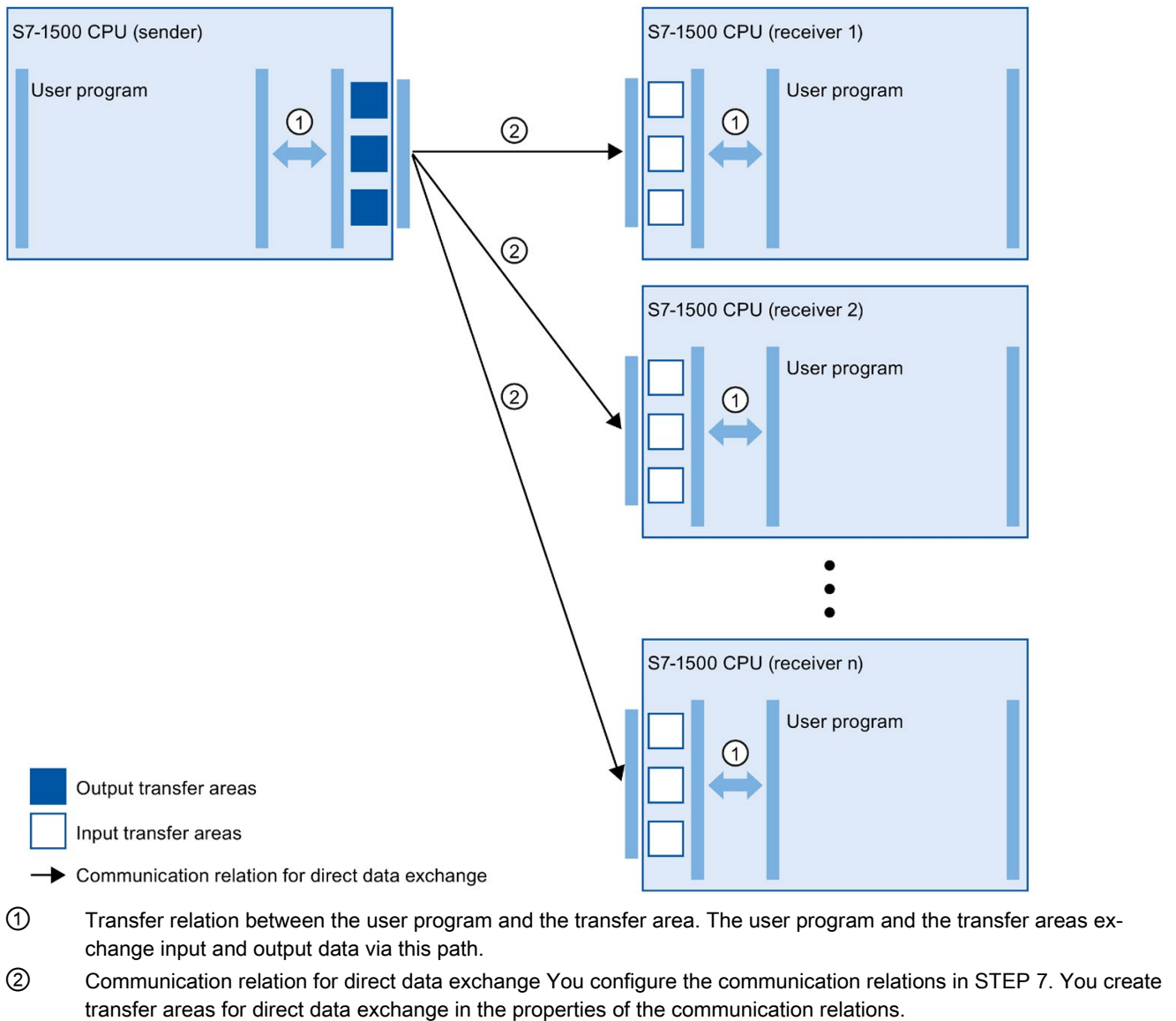


Figure 5-74 Direct data exchange with multiple receivers (1:n)

Applications

- Deterministic, isochronous I/O communication between multiple S7-1500 CPUs

Properties of direct data exchange

- Always isochronous
- Support of MRPD for MRP configuration
- No acyclic data exchange via PROFINET data record mechanisms
- No PROFINET alarms
- Configuration limits:
 - Maximum data length for direct data exchange 3075 bytes including user data qualifier
 - Maximum data length for a transfer area: 1024 bytes without user data qualifier
 - Maximum number of transfer areas of sender: 128
 - Maximum number of transfer areas of receiver: 512, distributed among a maximum of 64 receivable PROFINET frames and thus up to 64 sender CPUs

Diagnostics options of the receiver

Operating state change of sender:

- When the sender goes from RUN to STOP, the receiver behaves as follows:
 - The "SYNC_PI" and "SYNC_PO" instructions return an error message in parameter RET_VAL during synchronization of the process image.
 - With direct I/O access to the input transfer areas of the direct data exchange, OB 122 "I/O access error" is called, if present.
 - Incoming diagnostic message "I/O data failure in hardware component"
- When the sender goes from STOP to RUN, the receiver behaves as follows:
 - Call of OB 83 "Pull/plug interrupt" for input transfer areas of the direct data exchange
 - Up until the call of OB 83, OB 122 is called if present.
 - Outgoing diagnostic message "User data failure of hardware component"

Station failure/station recovery of the sender:

- When the sender fails, e.g. due to a bus interruption, the receiver behaves as follows:
 - Call of OB86 "Rack failure"
 - The "SYNC_PI" and "SYNC_PO" instructions return an error message in parameter RET_VAL during synchronization of the process image.
 - With direct I/O access to the input transfer areas of the direct data exchange, OB 122 "I/O access error" is called, if present.
- When the sender recovers after a station failure, e.g. because the bus connection is re-established, the receiver behaves as follows:
 - Call of OB86 "Rack failure"

5.8.2 Configuring direct data exchange between two S7-1500 CPUs

The procedure for configuring direct data exchange between two IO controllers is described below.

First, you create the communication relation for direct data exchange. You then configure transfer areas for the connection.

Requirements

- STEP 7 V16 or higher
- Two S7-1500 CPUs firmware version V2.8 or higher
- IRT is configured:
 - Both CPUs are in one sync domain.
 - One CPU is the sync master, and the other CPU is the sync slave.
 - Ports are interconnected.

Setting up the communication relation for direct data exchange

To set up the communication relation for direct data exchange between two S7-1500 CPUs, follow these steps:

1. Select the PROFINET interface X1 of the sending S7-1500 CPU.
2. Change to the table view of the network view, tab "I/O communication".
The PROFINET interface X1 of the CPU is shown in the "Partner 1" column.
3. In the "Partner 2" column at "<Drop or select the device here>", select the PROFINET interface of the communication partner from the drop-down list as the connection partner.
Note the communication direction:
 - ←: Communication partner is sender
 - →: Communication partner is receiver

The communication relation for direct data exchange between the two S7-1500 CPUs is set up.

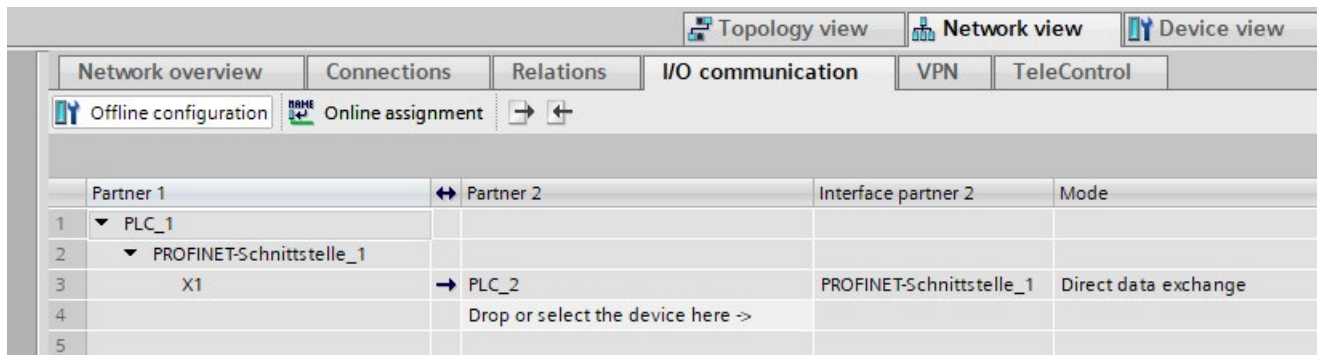


Figure 5-75 Communication relation for direct data exchange

Configuring transfer areas for direct data exchange

To configure a transfer area for direct data exchange, follow these steps:

1. Select the communication relation for direct data exchange.

	Partner 1	↔ Partner 2	Interface partner 2	Mode
1	▼ PLC_1			
2	▼ PROFINET-Schnittstelle_1			
3	X1	→ PLC_2	PROFINET-Schnittstelle_1	Direct data exchange
4		Drop or select the device here ->		
5				

Figure 5-76 Communication relation for direct data exchange

2. Navigate to the properties of the communication relation to "General" > "Direct data exchange" > "Transfer areas".
3. Create a new transfer area by double-clicking on "<Add new>". Assign a meaningful name for the transfer area.

A transfer area for direct data exchange is created.

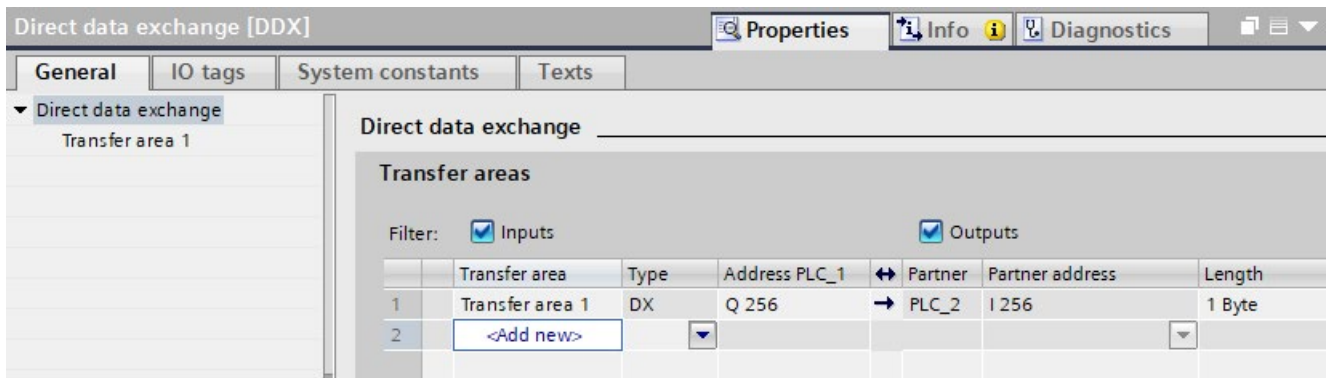


Figure 5-77 Transfer area for direct data exchange

The communication direction of the transfer area is specified by the communication relation. You cannot change the communication direction of the transfer area.

Editing the transfer area

Set the properties of the transfer area under "General" > "Direct data exchange" > "Name of transfer area" > "Detail of the transfer area".

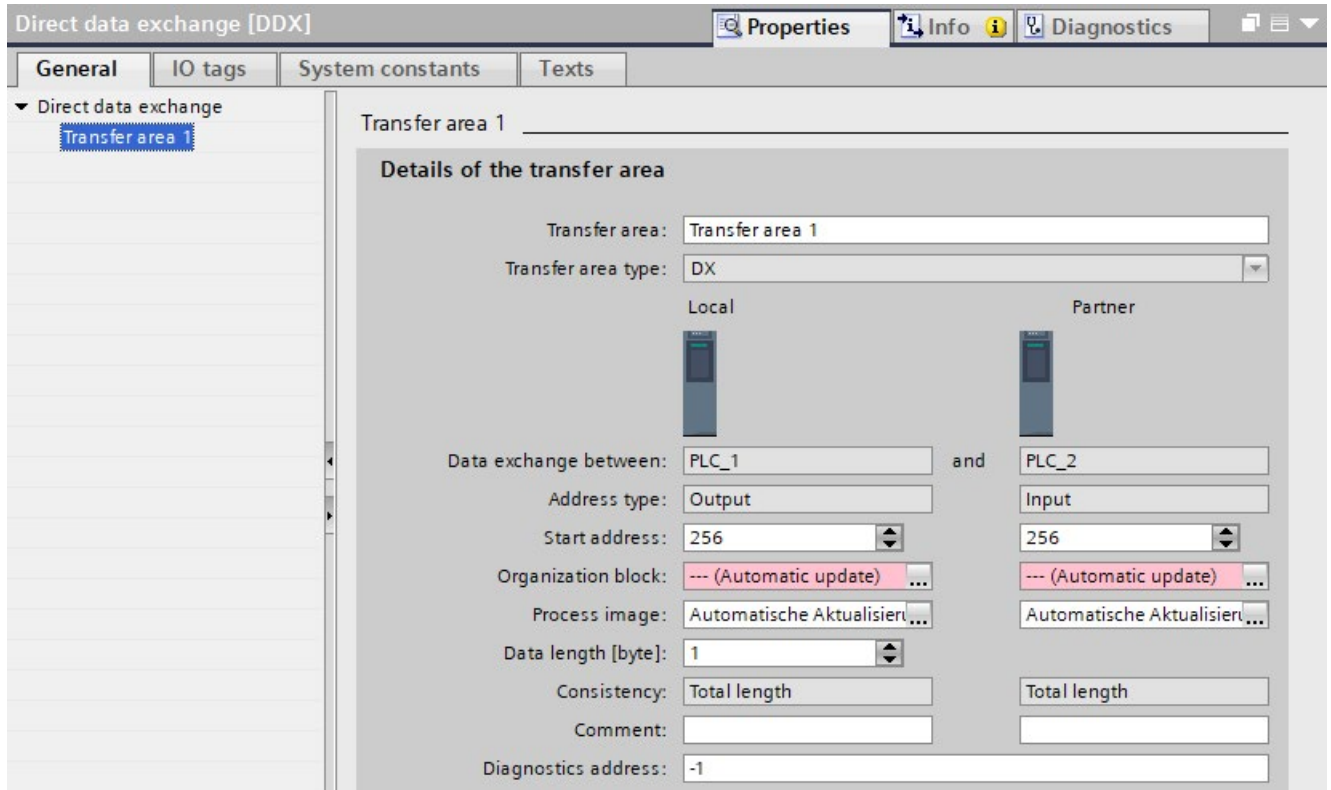


Figure 5-78 Properties of the transfer area

Table 5- 5 Overview of the settings of the transfer area

Parameter	Local	Partner
Start address	Set the start address of the input or output transfer areas in the local CPU.	Set the start address of the input or output transfer areas in the partner CPU.
Organization block	Assign the transfer area to an isochronous mode interrupt OB or the "MC-Servo" OB.	Assign the transfer area to an isochronous mode interrupt OB or the "MC-Servo" OB.
Process image	Select a process image partition, e.g. PIP 1. If you have assigned "MC-Servo" as the organization block, STEP 7 automatically sets "PIP OB Servo" as the process image.	Select a process image partition, e.g. PIP 1. If you have assigned "MC-Servo" as the organization block, STEP 7 automatically sets "PIP OB Servo" as the process image.
Data length [bytes]	Set the size of the transfer area.	-

Downloading the configuration to devices

Rules:

- Download the configuration to all CPUs involved.
- If you make changes to the configuration of the direct data exchange, download these changes to all CPUs involved.

5.8.3 Configuring direct data exchange between multiple IO controllers

The procedure for configuring direct data exchange between multiple S7-1500 CPUs is described below.

First, you set up the communication relations for direct data exchange. You then configure transfer areas for the communication relations.

Requirements

- STEP 7 V16 or higher
- S7-1500 CPUs firmware version V2.8 or higher
- IRT is configured:
 - All CPUs are in one sync domain.
 - One CPU is the sync master, and the other CPUs are sync slaves.
 - Ports are interconnected.

Setting up the communication relations for direct data exchange

To set up the connection for direct data exchange between multiple S7-1500 CPUs, follow these steps:

1. Select the PROFINET interface X1 of the sending CPU.
2. Change to the table view of the network view, "I/O communication" tab.
The PROFINET interface X1 of the CPU is shown in the "Partner 1" column.
3. In the "Partner 2" column at "<Drop or select the device here>", select the PROFINET interface of the communication partner from the drop-down list as the connection partner.
Note the transfer direction:
 - ←: Connection partner is sender
 - →: Connection partner is receiver

The connection for direct data exchange between the two S7-1500 CPUs is set up.

4. Repeat step 3 for every other receiving IO controller.

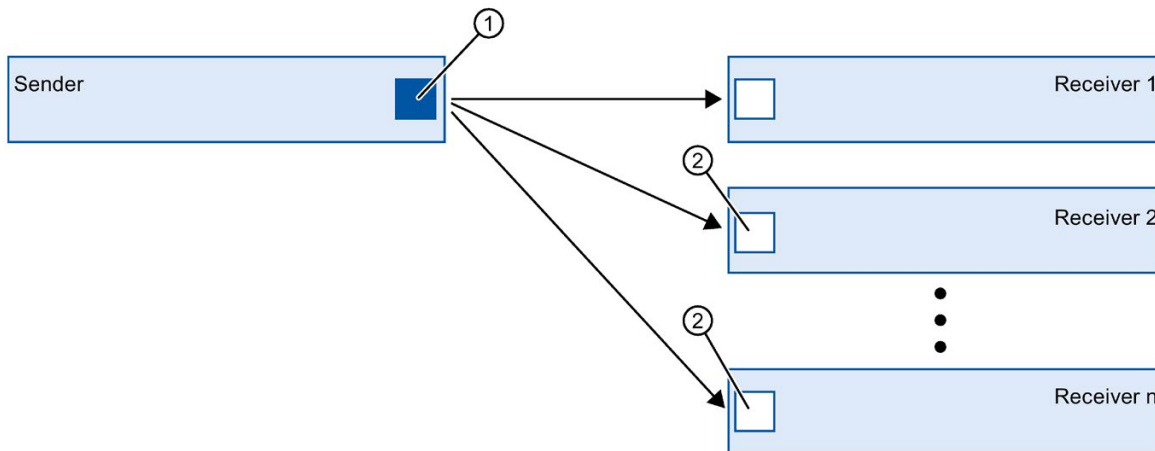
The connections for direct data exchange between the sending CPU and the receiving CPUs are set up.

Partner 1		↔	Partner 2	Interface partner 2	Mode
1	PLC_1				
2	PROFINET-Schnittstelle_1				
3	X1	→	PLC_2	PROFINET-Schnittstelle_1	Direct data exchange
4	X1	→	PLC_3	PROFINET-Schnittstelle_1	Direct data exchange
5	Drop or select the device here ->				

Figure 5-79 Connection for direct data exchange with multiple S7-1500 CPUs

Configuring transfer areas for direct data exchange

The following graphic shows the order for configuration of the transfer areas.



- ① First, you configure the transfer area between the sender and one receiver. You configure this transfer area at the PROFINET interface of the sender.
- ② You then configure the transfer areas between the sender and the other receivers. You configure these transfer areas at the PROFINET interfaces of the receivers.

Figure 5-80 Order of configuration of transfer areas in the case of multiple receivers

To configure a transfer area for direct data exchange, follow these steps:

1. Select the PROFINET interface X1 of the sending CPU and change to the table view, "I/O communication" tab.
2. In the table view of the network view, select a communication relation for direct data exchange between the sender and receiver 1.
3. Navigate to the properties of the I/O connection to "General" > "Direct data exchange" > "Transfer areas".

4. Create a new transfer area by double-clicking on "<Add new>". Assign a meaningful name for the transfer area.

A transfer area for direct data exchange between the sender and receiver 1 is configured.

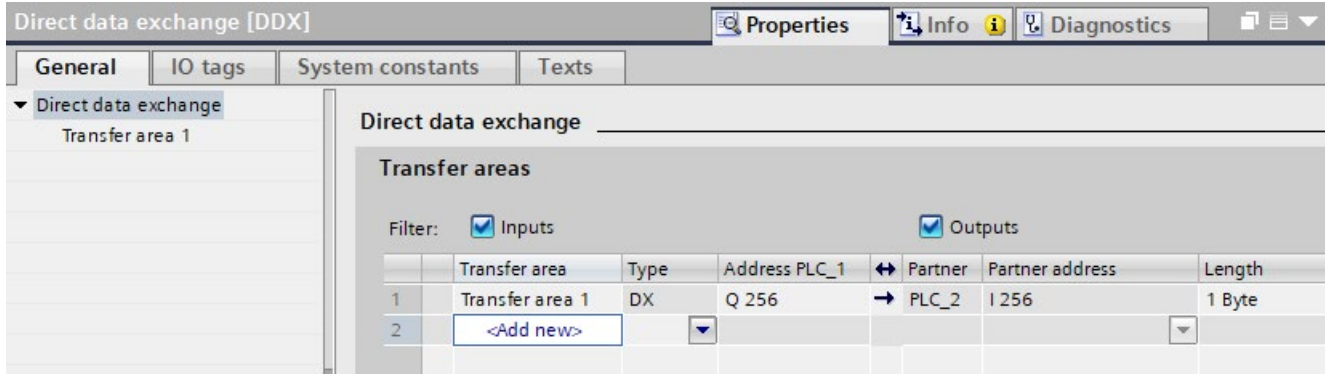


Figure 5-81 Transfer area for direct data exchange

5. Now, select the PROFINET interface of a receiver for which a transfer area is not yet set up, e.g. receiver 2.
6. Change to the table view of the network view to "I/O communication". The communication relation for direct data exchange with the sender is displayed.

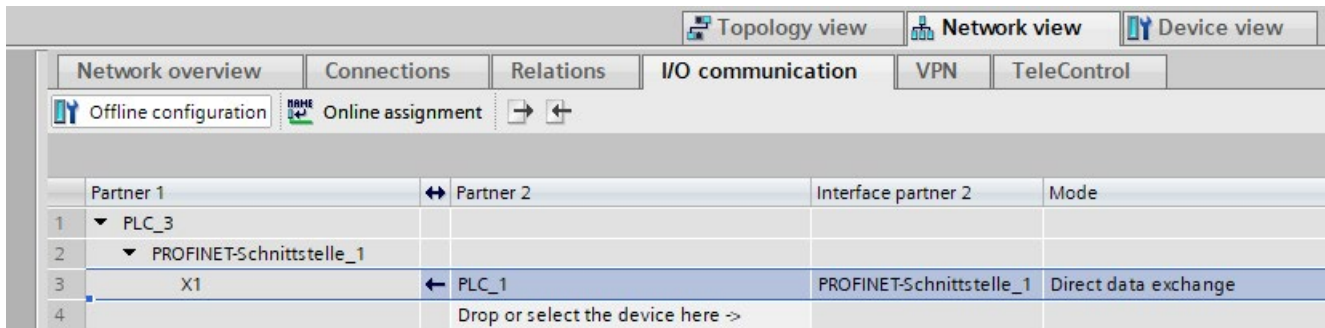


Figure 5-82 Connection for direct data exchange in receiver 2

7. Select the communication relation.
8. Navigate to the properties to "General" > "Direct data exchange" > "Transfer areas".
9. Create a new transfer area by double-clicking on "<Add new>". Assign a meaningful name for the transfer area.

A transfer area for direct data exchange is configured.

10. Select the transfer area.

11. For "Partner address", select the existing address area in the sender as the output transfer area.

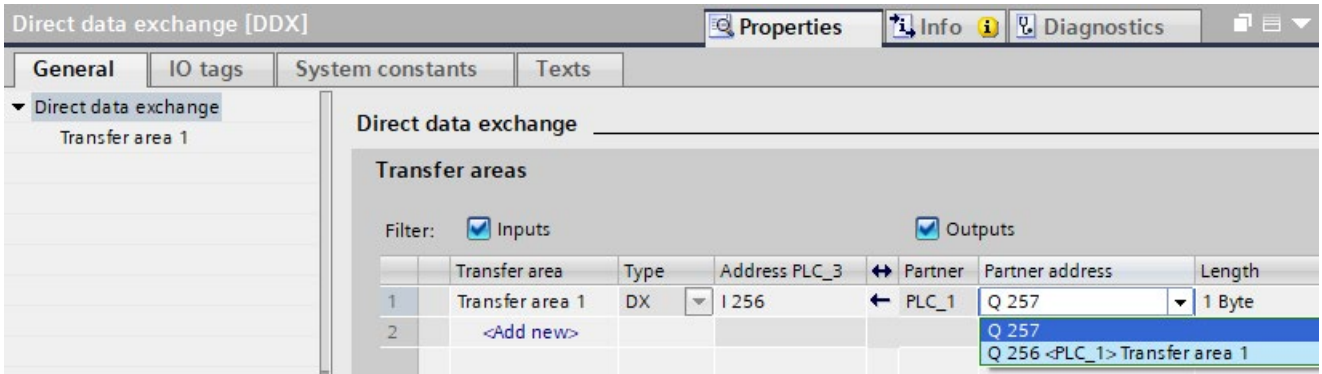


Figure 5-83 Transfer area for direct data exchange of multiple IO controllers

A transfer area for direct data exchange between receiver 2 and the sender is configured.

Editing the transfer area

Set the properties of the transfer area under "General" > "Direct data exchange" > "Name of transfer area" > "Detail of the transfer area".

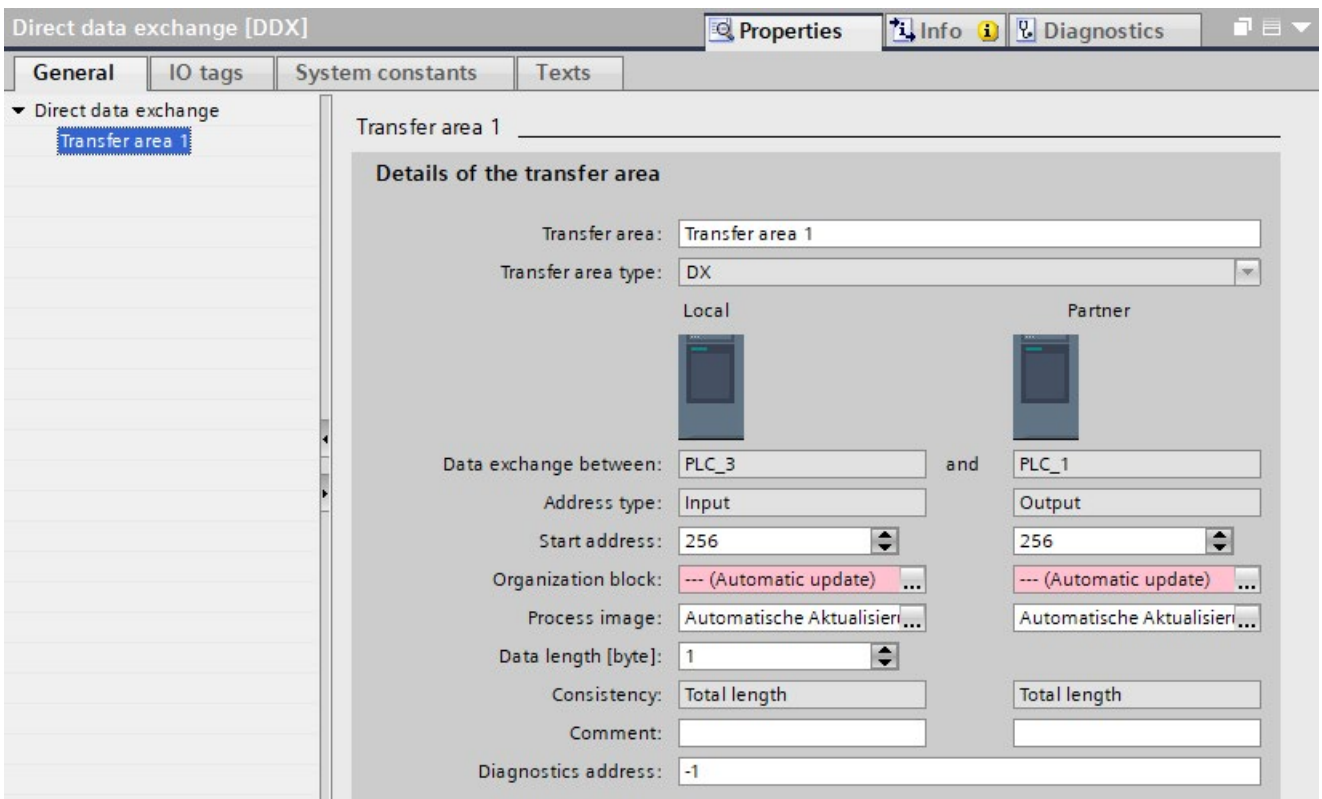


Figure 5-84 Properties of the transfer area

Table 5- 6 Overview of the settings of the transfer area

Parameter	Local	Partner
Start address	Set the start address of the input or output transfer areas in the local CPU.	Set the start address of the input or output transfer areas in the partner CPU.
Organization block	Assign the transfer area to an isochronous mode interrupt OB or the "MC-Servo" OB.	Assign the transfer area to an isochronous mode interrupt OB or the "MC-Servo" OB.
Process image	Select a process image partition, e.g. PIP 1. If you have assigned "MC-Servo" as the organization block, STEP 7 automatically sets "PIP OB Servo" as the process image.	Select a process image partition, e.g. PIP 1. If you have assigned "MC-Servo" as the organization block, STEP 7 automatically sets "PIP OB Servo" as the process image.
Data length [bytes]	Set the size of the transfer area.	-

Downloading the configuration to the device

Rules:

- Download the configuration to all CPUs involved.
- If you make changes to the configuration of the direct data exchange, download these changes to all CPUs involved.

5.9 Device replacement without exchangeable medium

Definition

IO devices which have no slot for exchangeable medium (e.g. ET 200SP, ET 200MP) or IO devices which support the PROFINET functionality "Device replacement without exchangeable medium/PG" can be replaced without having an exchangeable medium with saved device names inserted and without having to assign the device name with the PG. The new IO device is given a device name by the IO controller and not by the exchangeable medium or the PG.

To assign the device name, the IO controller uses the configured topology and the neighborhood relations established from the IO devices.

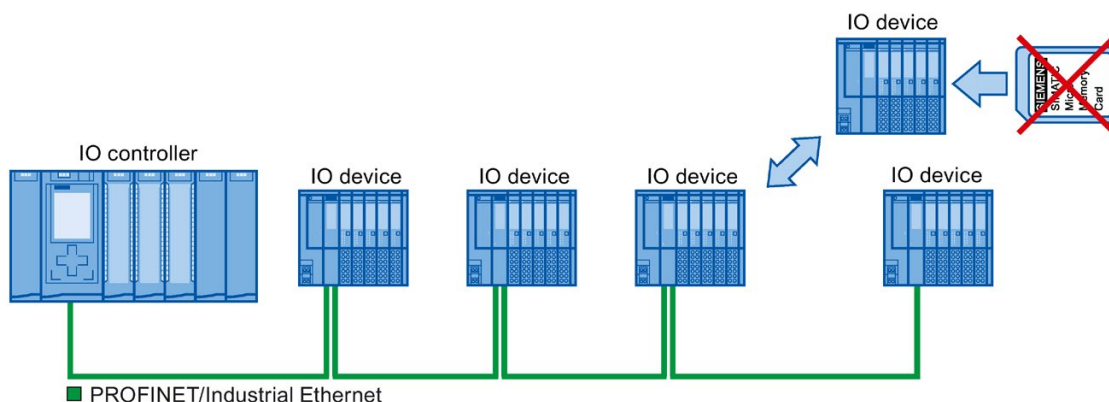


Figure 5-85 Device replacement without exchangeable medium

Note

When you exchange a device, make sure that the PROFINET cable is again inserted into the correct port, as it is configured in STEP 7.

Otherwise, the system will not run.

Advantages

With the Device replacement without exchangeable medium/PG PROFINET functionality, you can profit from the following advantages:

- After the replacement of the IO device, it automatically obtains its device name from the IO controller. You no longer have to assign device names with the PG or exchangeable medium.
- You can save on the storage medium for the IO device that replaces the removed one.
- Simple device name allocation with series machines that have the same configuration and set topology. It is no longer necessary to assign device names via exchangeable medium/PG.

Which devices support device replacement without exchangeable medium?

An overview of the devices that support the "Device replacement without exchangeable medium" function is provided in this FAQ

(<https://support.industry.siemens.com/cs/ww/en/view/36752540>).

5.9.1 Device replacement without exchangeable medium/PG function

Neighborhood

Neighborhood is the physical relationship between two ports of adjacent PROFINET devices. A PROFINET device is connected in this case through one of its ports over a physical Ethernet line to a specific port of the second PROFINET device in close proximity (neighbors).

Both terminal devices, for example, IO controllers and IO devices with a port, and network components, for example, switches, IO controllers and IO devices with multiple ports, are considered PROFINET devices.

Failure and replacement of an IO device

The following example describes device replacement without exchangeable medium in the case of failure of an IO device.

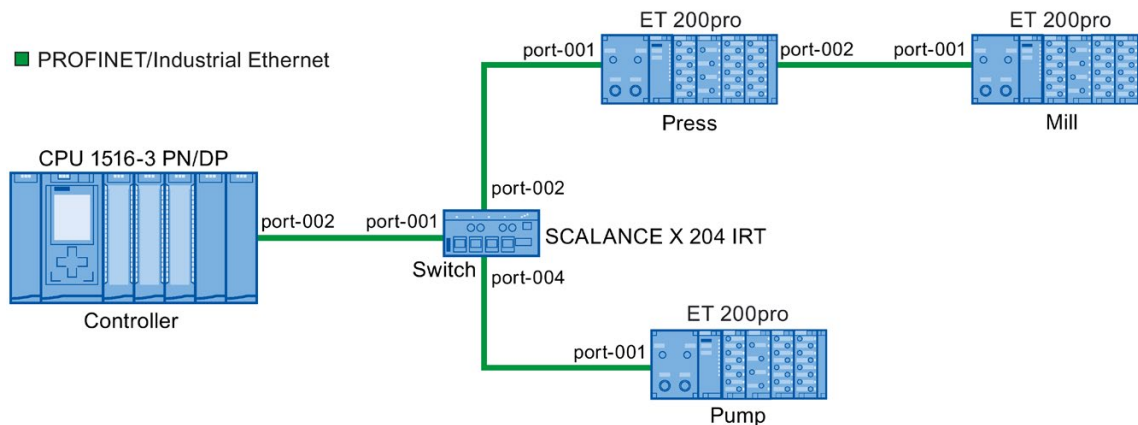


Figure 5-86 Example configuration of device replacement without exchangeable medium

For the device replacement, the following information is available to the IO controller:

PROFINET device	Device alias
Controller	"port-001.Switch"
Switch	"port-002.Controller", "port-001.Press", "port-001.Pump"
Press	"port-002.Switch", "port-001.Mill"
Mill	"port-002.Press"
Pump	"port-004.Switch"

The IO device with the device name "Mill" fails in this example:

Requirement

The PROFINET device replacing the removed one has no device name.

Principles of name assignment

The failure of the "Mill" IO device is considered here.

1. The IO controller queries the device name of the replaced IO device.
2. The IO controller detects that the IO device with the device alias "port-002.Press" does not have a device name.
3. The IO controller assigns the device name "Mill" to the replaced IO device via the device alias "port-002.Press" of the failed IO devices.

Note

If you insert a device with the Device replacement without exchangeable medium/PG PROFINET functionality at a different location than the configuration, a different device name is then assigned to the device.

Reset a wrongly inserted device to delivery state before you use it again.

5.9.2 Replacing an IO device without exchangeable medium

Introduction

Replacement of IO devices is sometimes frequently required in automation systems. The IO devices are generally assigned a device name by either inserting an exchangeable medium or via the programming device. The CPU identifies the IO device by using these device names.

Under certain circumstances, replacing an IO device can be done without inserting an exchangeable medium or without the PG.

Requirements

- The topology of the PROFINET IO system with the respective IO devices must be configured.

By configuring the topology, the neighbor relationships of all the PROFINET devices located in the PROFINET IO system are announced to the PROFINET IO system or the IO controller. From the neighbor relationships specified by the set topology and the actual neighbor relationships established by the real PROFINET devices, the IO controller can identify the replaced IO device without a name and assign to it the configured name and the IP address and then again list it in the user data traffic.

- The affected IO devices in the automation system must support device replacement without exchangeable medium.

If the individual IO devices in the automation system do not support device replacement without exchangeable medium, a corresponding alarm is output for the IO device.

Note

Use only new IO devices as replacements or restore configured IO devices to their delivery state.

Activating/deactivating device replacement without exchangeable medium

The "Device replacement without exchangeable medium" function is activated in the IO controller by default.

To deactivate device replacement without exchangeable medium, follow these steps:

1. In the device or network view of the STEP 7, select the PROFINET interface in the corresponding IO controller.
2. In the interface properties under "Advanced options > Interface options", clear the "Support device replacement without exchangeable medium" check box.

To reactivate device replacement without exchangeable medium, you must select the "Support device replacement without exchangeable medium" check box again.

5.9.3 Permit overwriting of PROFINET device name

With the option "Permit overwriting of PROFINET device names of all assigned IO devices", you can overwrite PROFINET device names of IO devices during startup of the CPU. This option reduces the effort during automatic commissioning, for example, when replacing a device.

Requirements

- IO controller supports the "Permit overwriting of device names of all assigned IO devices" option, for example CPU 1215C DC/DC/DC as of firmware version 4.0

How the "Permit overwriting of PROFINET device names of all assigned IO devices" option works

The IO controller (CPU) can overwrite the PROFINET device names of IO devices in the IO system when the "Permit overwriting of PROFINET device names of all assigned IO devices" option is enabled.

Multiple use IO systems can only be operated when this option is enabled. The IO controller checks prior to overwriting if the type of the IO device matches the configured type.

If the option is not selected, the IO controller cannot overwrite the device names of the IO devices. In this case, you must manually assign the PROFINET device name on the IO device if the PROFINET device name changes in the configuration or when a device is replaced, or delete the device names of the IO devices prior to an automatic commissioning.

Response during commissioning

Select the option "Permit overwriting of PROFINET device names of all assigned IO devices" only if the following requirements are fulfilled:

- All the configured IO devices are available.
- All IO devices are wired correctly in accordance with the topology configuration.
- No IO device is jumpered.

If configured IO devices are missing or are jumpered (partial commissioning), do not use the option.

 CAUTION
--

Error at partial commissioning

If device names are assigned incorrectly during partial commissioning or incorrect wiring, these have to be deleted manually after a correction of the wiring in order to attain correct assignment of the device names.
--

Behavior during operation

After commissioning, you may exchange or jumper IO devices as long as the IO devices do not have a PROFINET device name that is used for a different IO device in the project. Otherwise, incorrect assignment of PROFINET device names in the neighborhood or further vicinity of the IO device can occur.

 **WARNING**

Wrong PROFINET device name

When the "Permit overwriting of PROFINET device names of all assigned IO devices" option is enabled, incorrectly connected devices can be assigned an incorrect PROFINET device name from the configuration.

Depending on the connected I/O, there is risk of death, severe injuries or damage caused by malfunctions.

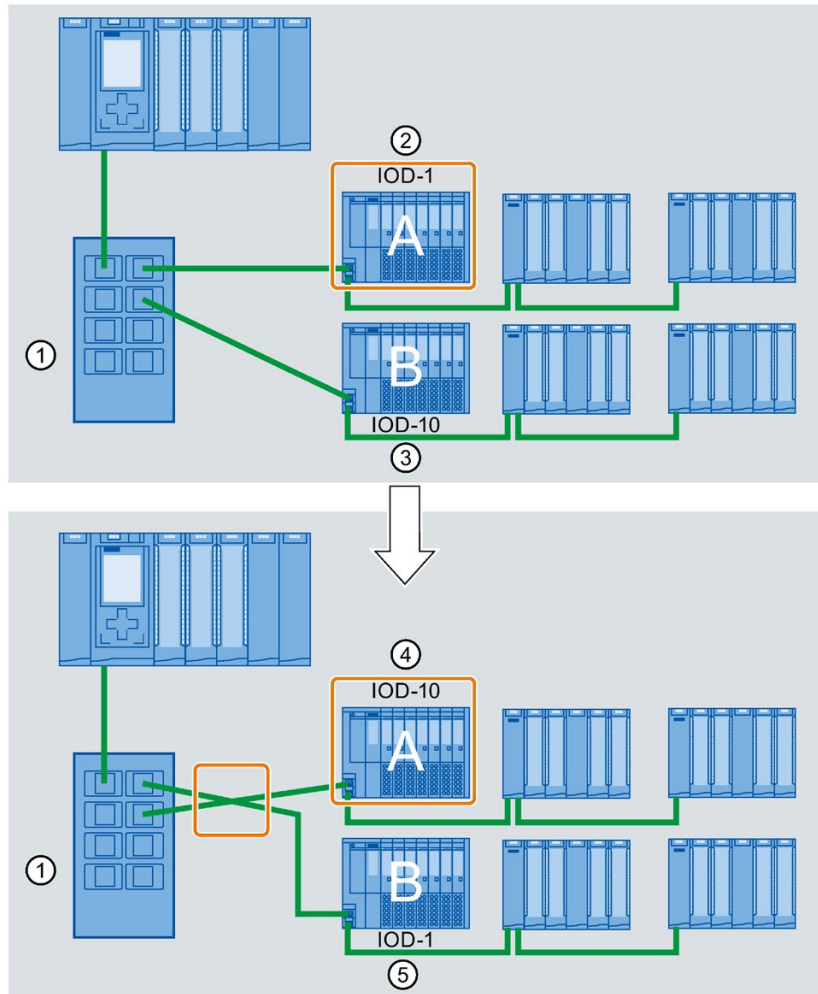
To rule out any danger, check whether the suitable replacement device has been connected in case of a device replacement and whether the port interconnection matches the configured preset topology.

Typical source of danger

When replacing an IO device ("standard case"), it is almost guaranteed that the replaced device will be connected according to the configured port interconnection.

The figure below shows a scenario whereby the connections of two identical PROFINET cables are swapped at two switch ports. Because the IO controller assigns the device names according to the preset topology, the incorrect connection of the devices has serious effects on the naming.

Due to the control of different actuators, the plant could become hazardous in this case.



- ① Switch with connected PROFINET cables
- ② Device A, device name "IOD-1": controls motor 1
- ③ Device B, device name "IOD-10": controls motor 10
- ④ Device A controls motor 10!
- ⑤ Device B controls motor 1!

Procedure

Proceed as follows to change the "Permit overwriting of PROFINET device names of all assigned IO devices" option:

1. Select the PROFINET interface of the CPU for which you want to change the option in the network view or in the device view.
2. Select the area "Advanced options", section "Interface options".
3. Change the option.

5.10 Standard machine projects

Introduction

Standard machine projects are STEP 7 projects that use a set of innovative functions allowing simple configuration and commissioning of flexible automation solutions for standard machines or for machines with a modular structure.

A hardware configuration consisting of an IO controller and any number of connected IO devices represents a "PROFINET IO system master". This master is configured with a maximum configuration based on a template from which various options can be derived for different standard machines, for example with different configuration variants of the IO system.

Greater flexibility at all levels

Standard machine projects have the following central characteristics:

- Different variants of a standard machine can be loaded from precisely one project with an engineered maximum configuration (IO system options). The standard machine project covers all variants (options) of the IO system.
- An IO system option can be integrated in an existing network locally using simple tools.

Flexibility is provided in more ways than one:

- With suitable configuration, adaptation of the IP address parameters of the IO controller is possible locally using simple tools. This allows a standard machine to be integrated in different plants with little effort or to be included in a network several times. IO systems with this property are known as **multiple use IO systems**.
- With suitable configuration and programming, different setups of IO system options can be operated locally that differ in terms of the selection of IO devices used or in terms of the arrangement of the IO devices. Since the specific configuration of the IO system is controlled by the user program, this is known as **configuration control for IO systems**.
- Independently of the functions described above, with suitable configuration and programming, you can use different station options of central devices or distributed I/O devices in one project. The devices can be different in terms of the selection and arrangement of the modules. Since the concrete configuration of the station is controlled by the user program, this is also known as **configuration control at the device layer**.

Application examples

You can find application examples for configuration control at the device layer, configuration control for IO systems and multiple-use IO systems on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/29430270>).

Additional information

For more information on multiple use IO systems, refer to section Multiple use IO systems (Page 233).

For more information on the configuration control for IO systems, refer to section Configuration control for IO systems (Page 241).

For more information on configuration control, refer to the system manual S7-1500, ET 200MP (<http://support.automation.siemens.com/WW/view/en/59191792>).

5.10.1 Multiple use IO systems

5.10.1.1 What you should know about multiple use IO systems

Multiple use automation solutions

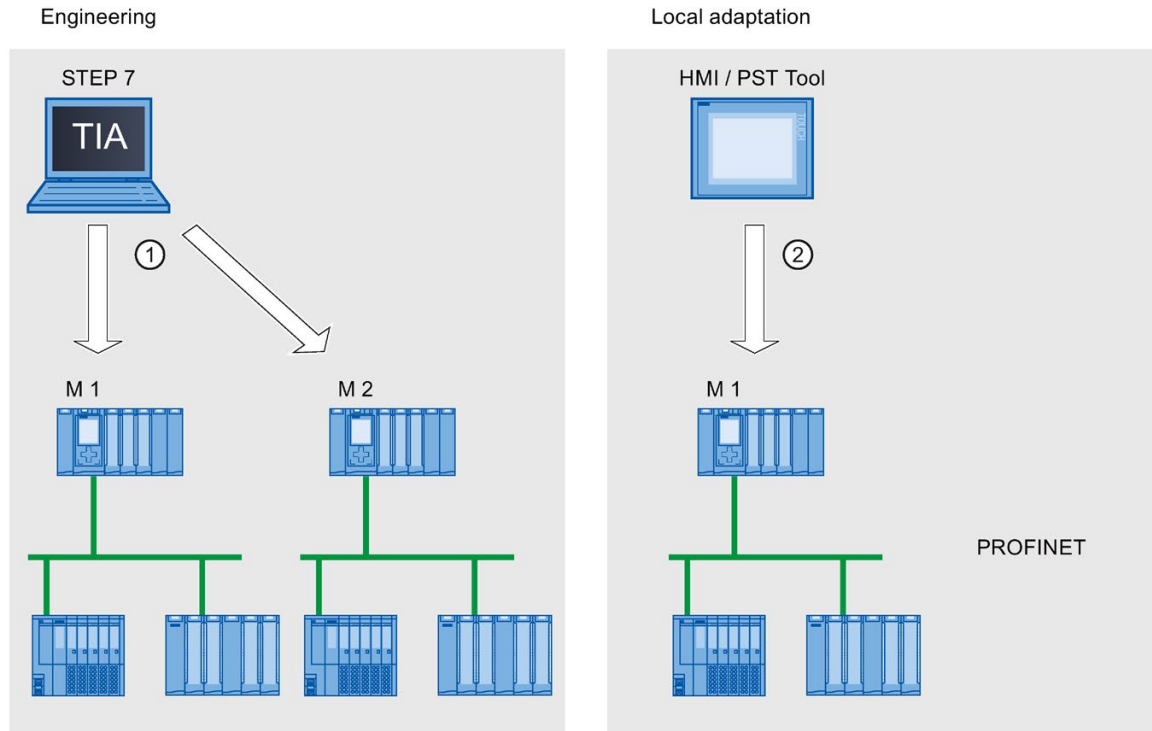
For a flexible reusable automation solution as is the case with series machines, the following use cases are typical:

- The machine (and therefore also the PROFINET IO system) is used more than once by the customers.
- The machine is used in different plants by various customers.

For this to be possible, the automation solution must meet the following requirements:

- A project (configuration and program) can be loaded on various machines of the same type without changes.
- Only a few easy adaptations need to be performed locally to integrate the machine into an existing network infrastructure.

The following figure shows how an automation solution with a multiple use IO system is loaded on different automation systems and then one automation system is adapted to the existing network infrastructure locally.



- ① Load configuration with multiple use IO system
- ② Set IP address and device name locally on the IO controller

Figure 5-87 "Multiple use IO system" principle

Principle

The automation components for a machine include a PROFINET IO system, consisting of an IO controller (PROFINET interface of a CPU) and the IO devices assigned to it.

With the "Multiple use IO system" setting for the IO system, you turn a STEP 7 project into a "Standard machine project".

The "Multiple use IO system" setting triggers various settings and checks of the configuration by STEP 7. The settings ensure that the IO system is self-contained and there are no dependencies on components outside the IO system.

Requirements

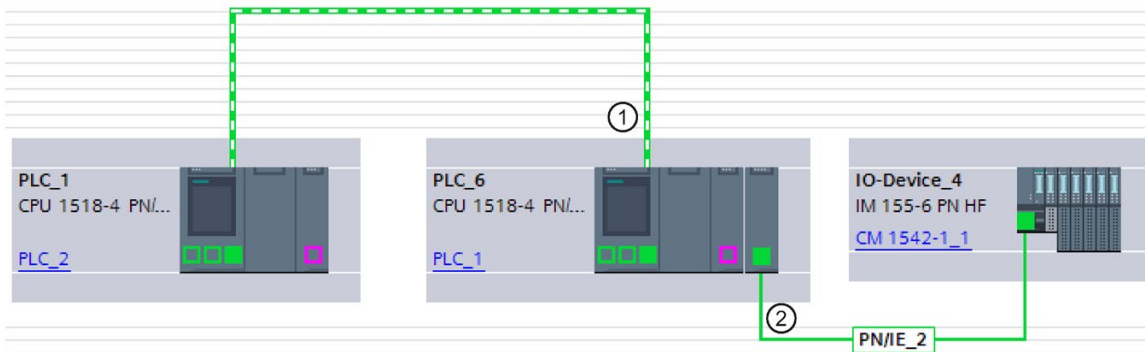
- STEP 7 as of V13
- The IO controller supports the "Multiple use IO system" function, for example a CPU 1512SP-1 PN as of firmware version 1.6.

Rules

The following rules apply to a multiple use IO system:

- No IO device can be configured as shared device.
- The ports of the devices must be interconnected.
Devices for which no port interconnection is configured, for example, interface module IM 154-6 IWLAN (ET 200pro PN), cannot be operated with STEP 7 V13 as IO devices on a multiple use IO system.
- If an IO device in a multiple use IO system is an I-device (CPU as an "intelligent" IO device):
 - If the I-device has a lower-level IO system, this I-device cannot be connected to the same PROFINET interface as the higher-level IO controller.

Note: If the I-device is configured using a PROFINET GSD, STEP 7 cannot check for compliance with this rule. In this case, you are responsible for ensuring compliance with the rule.



- ① I-device in multiple use IO system. The PROFINET interface is operated as IO device. No other IO system is connected here.
- ② A lower-level IO system on the I-device is connected to another PROFINET interface.

Figure 5-88 Example configuration for "Multiple use IO system" with I-device

- The PROFINET interface of the I-device must be set to "Parameter assignment of PN interface by higher-level controller".
- If MRP (Media Redundancy Protocol) is configured:
 - All IO devices on the multiple use IO system must belong to the same MRP domain.
- If IRT (Isochronous Real Time) is configured:
 - All IO devices in multiple use IO systems must belong to the same sync domain.
 - The sync domain must not include any other IO devices.
- IE/PB Links cannot be operated as an IO device in a multiple use IO system with STEP 7 V13.

Configuration

You specify whether or not a configuration can be used multiple times in the properties of the IO system.

All other parameter settings for the configured devices are then set automatically by STEP 7 and checked during compilation.

Boundary conditions

To prevent a standard machine project from having dependencies on other devices outside of the machine, observe the following:

- A standard machine project consists of an IO controller and the corresponding IO devices. You should therefore configure only one CPU as IO controller and the corresponding IO devices in the standard machine project.
- Do not use connection configured at both ends for the communication. Instead, use only a connection configured at one end or unspecified connections if necessary.

Background: To configure the communication in a STEP 7 project, it is always possible to set the IP address parameters in the project. For multiple use IO systems, however, this strategy is not possible since the IP address parameters of the IO controller and the assigned IO devices are assigned locally. At the time of the configuration, the IP address parameters are therefore unknown.

If you nevertheless want to configure communication with devices on PROFINET, for example with a central coordinator, you can only use communications mechanisms that allow dynamic assignment of the IP address parameters in the user program.

Example: Open User Communication

If, for example, the device is configured as an active end point (initiator of the connection), the IP address parameters can be stored, for example, in a data block. You then supply the data block with the currently valid IP address parameters during commissioning. For this dynamic type of IP address parameter assignment, there is no system support; in other words, if you change the configuration of the system, the IP address parameters are not automatically adapted.

You will find a description of handling instructions for Open User Communication under this keyword in the STEP 7 online help.

5.10.1.2 Configuring multiple use IO systems

Requirements

- STEP 7 as of V13
- The IO controller supports the "Multiple use IO system" function, for example a CPU 1512SP-1 PN as of firmware version 1.6.

Procedure

The configuration of a series machine using an S7-1500-CPU as an example is described below.

To create a standard machine project, follow these steps:

1. Create a project.
2. Configure a CPU as the IO controller, for example a CPU 1518-4 PN/DP as of firmware version 1.5.
3. Configure the required IO devices and assign the IO devices to the IO controller.
4. Configure the port interconnection between the devices.
5. Select the IO system so that you can edit the properties in the inspector window.
6. Select the "Multiple use IO system" check box in the "General" area of the inspector window.

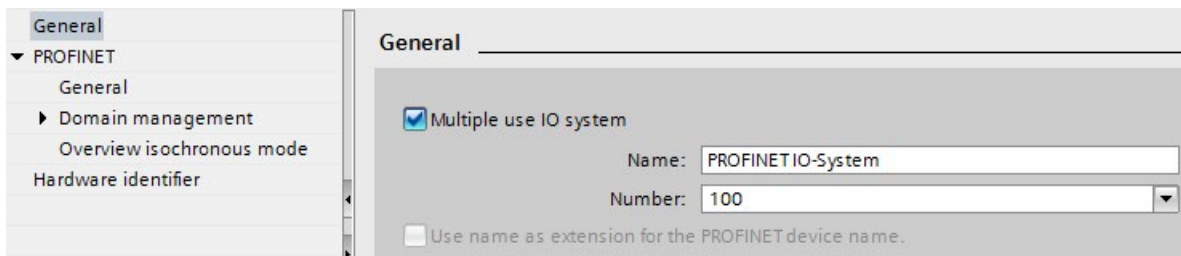


Figure 5-89 Activate "Multiple use IO system"

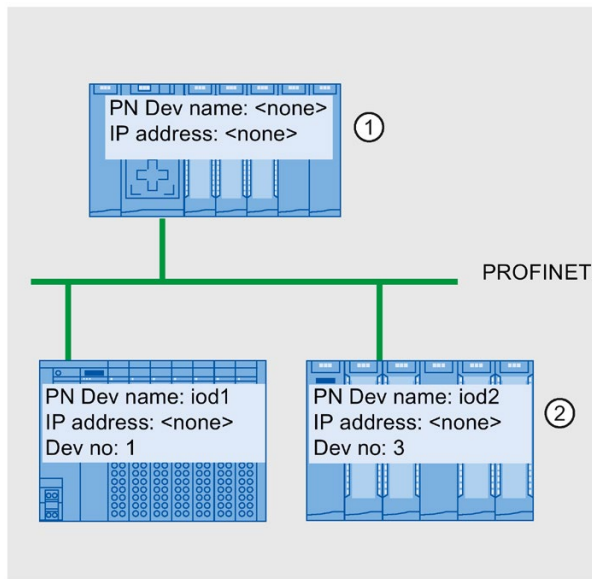
Result: The following settings are made by STEP 7:

- The device name of the IO controller (CPU) in the standard machine project is set to "PROFINET device name is set directly at the device". The IO controller (CPU) has no PROFINET device name initially.
- The IP protocol of the IO controller (CPU) is set to "IP address is set directly at the device". The CPU has no IP address initially.
- The "Support device replacement without exchangeable medium" option is selected automatically. This option enables automatic commissioning. A commissioning engineer does not have to assign device names to the IO devices locally. The IO controller assigns the device name and IP address to the IO devices based on the preset topology and other settings during startup.
- The device name of the IO devices is set to "Generate PROFINET device name automatically" (from the configured name of the IO device).
- The IP protocol of the IO devices is set to "IP address is set by the IO controller during runtime". The IO devices have no IP address initially. If an IO device is not a typical distributed I/O system (e.g., ET 200 systems), but rather another device such as an HMI device, change the option to "IP address is set directly at the device"; see below.
- The device number for the IO devices is automatically assigned and is used locally for making the IP address unique.

The option "Permit overwriting of PROFINET device name" must be selected (CPU parameters, properties of the PROFINET interface, Ethernet addresses area) so that the IO controller can adapt the device name later at the operator.

This option is disabled by default.

The following figure shows the above-described settings for the IP address and PROFINET device name.



- ① After the configuration is loaded from the standard machine project, the IO controller has no device name and no IP address.
- ② Following loading, the IO devices have a device name and a device number but no IP address.

Figure 5-90 Settings for the IP address and the PROFINET device name

How an IO device obtains an IP address locally

Below, you will find an explanation of the "IP address is set by the IO controller during runtime" and "IP address is set directly at the device" options, which can generally be configured for a multiple use IO system.

If you have set the "Multiple use IO system" option for the IO system, STEP 7 automatically sets the "IP address is set by the IO controller during runtime" option for the IO devices.

In this case, the IO controller assigns the IO device an IP address that results from the locally assigned IP address of the IO controller (see next section). This option is appropriate if the IO device is a field device, e.g., ET 200MP, ET 200SP, ET 200AL, or another distributed I/O system.

If the IO device is not a "standard" field device, for example, an HMI device for a Windows operating system, the "IP address is set by the IO controller during runtime" option described above does not work. In this case, choose the "IP address is set directly at the device" option. You must then assign the IP address to the device locally and take steps to ensure that this address is suitable for the IP addresses of the other IO devices and the IP address of the IO controller.

5.10.1.3 Adapt multiple use IO systems locally

A few steps are needed to adapt the machine that was loaded with the standard machine project.

Only the device name and IP address of the IO controller must be adapted locally. The device names and IP addresses of the IO devices result from these adaptations. In this example, the effects of local settings are described for two specific machine modules.

The local settings are possible, for example, with the CPU display and commissioning tools such as Primary Setup Tool (PST) or PRONETA. You do not need a programming device with STEP 7 to make these settings, even though it is possible to do so.

Requirements

- The machine was loaded with a standard machine project (see Configuring multiple use IO systems (Page 236)).
- The display is ready for operation and the desired tool for assigning the IP address and device name is available (e.g., PST Tool, STEP 7).
- The ports of the IO controller and IO devices are interconnected according to the configuration.

Procedure

Observe the boundary conditions and instructions for commissioning an S7-1500. For more information on commissioning an S7-1500 CPU, refer to the system manual S7-1500, ET 200MP (<http://support.automation.siemens.com/WW/view/en/59191792>).

To adapt a standard machine locally, follow these steps:

1. Integrate the machine into the network.
2. Connect the device for assigning the IP address and device name to the CPU, for example a PG/PC with the appropriate software.
3. Assign the desired device name and IP address to the IO controller.
4. Start up the CPU.

The IO controller then assigns the adapted PROFINET device name and a unique IP address to the IO devices.

The following rules apply to the assignment:

- The device names of the IO devices are formed by chaining together the following name components, separated by a period:
<configured name of the IO device from the standard machine project>.<name of the associated IO controller set on the device>
- The IP addresses of the IO devices result from the locally configured IP address of the associated IO controller and the device number (sum).

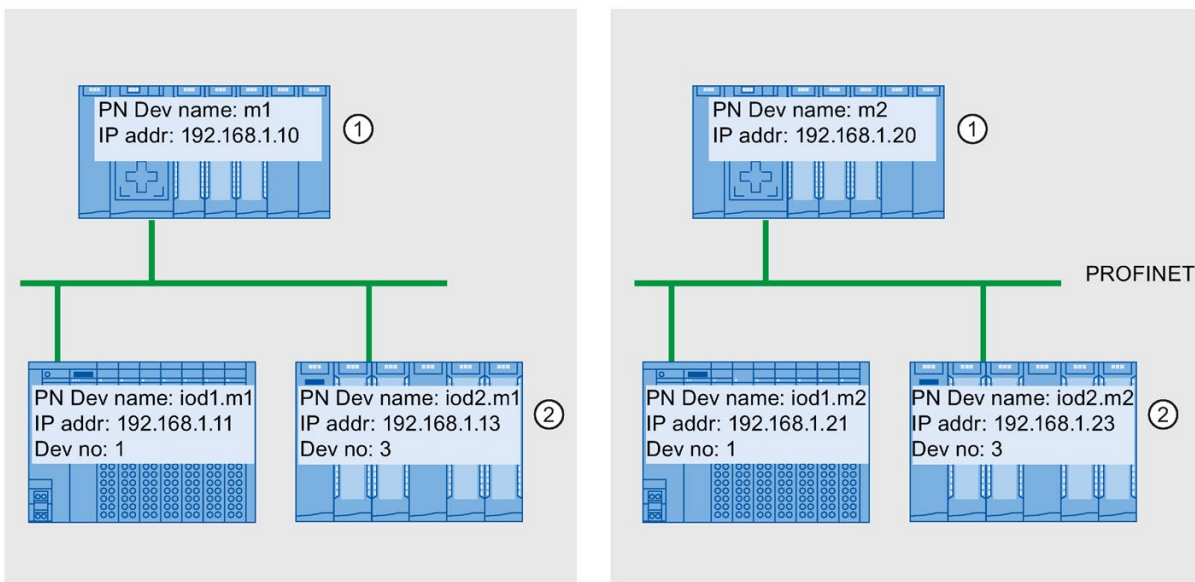
Note

Make sure that duplicate IP addresses cannot be created on the subnet during the assignment. The IO controller does not assign a new IP address in this case.

In the following figure, the device name "m1" and the IP address 192.168.1.10 have been assigned to the IO controller of the first machine.

The device name "m2" and the IP address 192.168.1.20 has been assigned for the second machine.

Refer to the figure for the resulting device names and IP addresses.



- ① Set device name and IP address on the IO controller
- ② After startup, the IO devices have an updated device name (<configured device name>.<device name of IO controller>) and an adapted IP address (= <IP address of IO controller> + <device number>)

Figure 5-91 Example of the assignment of IP addresses and device names at "Multiple use IO system"

See also

Configuring multiple use IO systems (Page 236)

5.10.2 Configuration control for IO systems

5.10.2.1 Information about configuration control of IO systems

Configuration control of IO systems makes it possible to generate several concrete versions of a standard machine from a standard machine project.

You are given the flexibility to vary the configuration of an IO system for a specific application as long as the real configuration can be derived from the set configuration. The configured configuration therefore represents the superset of all real configurations that can be derived from it.

The following figure shows an example of how two IO systems with a different number of IO devices arise from one standard machine project.

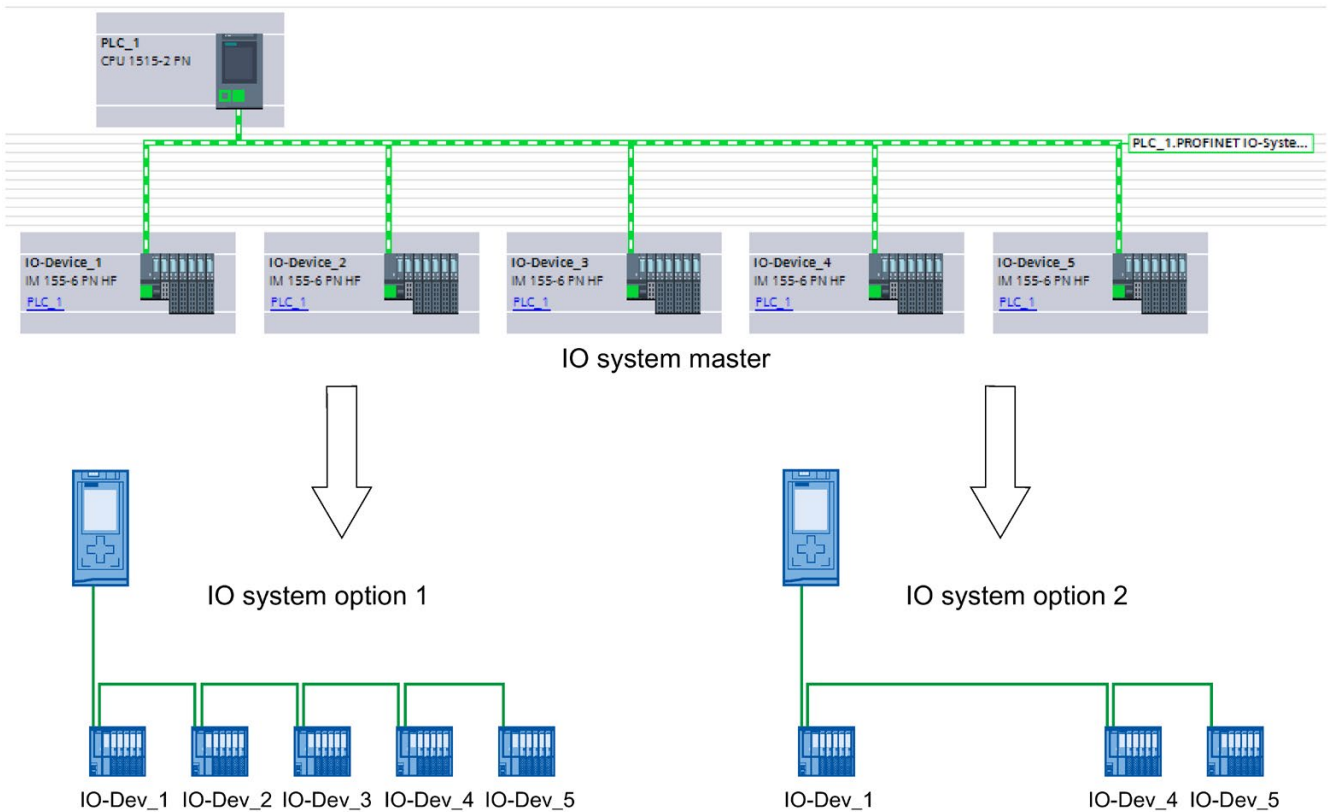


Figure 5-92 Example of configuration control for PROFINET IO systems

In the following sections, you find a description of how to configure and program a PROFINET IO system to commission, for example, a standard machine on-site without using configuration software.

Concept

The principle of configuration control is already known at the device level for the flexible use of submodules/modules ("option handling"). Different configurations can be derived from one engineering project both for central as well as for distributed I/O.

With S7-1500 CPUs as of firmware version V1.7, this principle can also be applied at the IO system level. You have the option of omitting, adding or changing the order of stations (IO devices) of a PROFINET IO system in a specific plant.

Configuration control for devices and configuration control for IO systems can be combined; the functions are independent of each other.

It is possible to operate variants deviating from a maximum configuration of an IO system. In a standard machine project, you can prepare a kit of IO devices which can be flexibly customized for various configurations using configuration control.

The following variations are available:

- Variation of the number of IO devices involved
You include optional IO devices for the configuration control in the configuration by transferring a suitable data record with the required configuration in the user program.
- Variation of the order of IO devices involved
You adapt the port interconnection of the IO devices to the topology being used by transferring a suitable data record with the required topology in the user program.

The following figure shows how you serve two different configurations with an IO device marked as optional in the network view of STEP 7.

- Configuration without the optional IO device:
In this case, you use the instruction "ReconfigIOSystem" to transfer a data record to the PROFINET interface containing the information that no optional IO device is to be included in the configuration.
- Configuration with the optional IO device:

In this case, you use the instruction "ReconfigIOSystem" to transfer a data record to the PROFINET interface adding the optional IO device to the configuration.

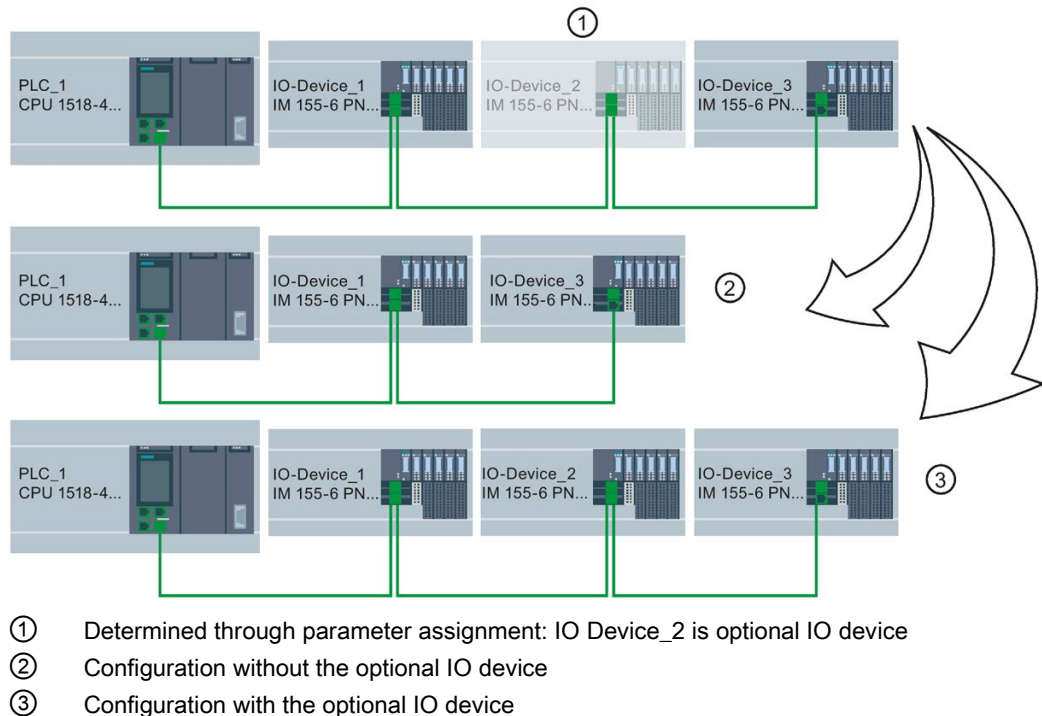


Figure 5-93 Example configuration with "Optional IO device" and the associated configuration options

Summary: The procedure in principle

The following phases are distinguished when it comes to the implementation of a standard machine concept:

1. Engineering phase: Creating a standard machine project and loading into specific machine or plant:
 - Completely configuring all IO devices (options) ever required in a specific machine or plant
 - Configuring as optional those IO devices that will be omitted in specific machines or plants
 - Preparing user program (see [Configuring flexible order of IO devices \(Page 251\)](#)) with the possibility of selecting on-site the actually existing configuration via switch or HMI device
2. Commissioning phase: Preparing specific machine or plant for operation:
 - Integrating machine or plant in the on-site network (see [Adapt multiple use IO systems locally \(Page 239\)](#))
 - Selecting the currently existing configuration of the IO system via configured option

5.10.2.2 Configuring IO devices as optional

Requirements

- IO controller supports configuration control for IO systems, for example CPU 1516-3 PN/DP as of firmware version 1.7
- STEP 7 V13 SP1 or higher
- The rules (Page 256) for the establishment and operation of a standard machine project have been considered.

Port interconnection

As of STEP 7 V15.1, port interconnection is not necessary for optional IO devices.

A port interconnection between the devices of the IO system that you want to customize with the user program is mandatory in the following cases.

- You have configured IRT.
- You have configured MRP.
- You are using STEP 7 <= V15.

Procedure

To configure an IO device as optional IO device, proceed as follows:

1. Create a project.
2. Configure an S7-1500 CPU firmware version V1.7 or higher as IO controller.
3. Configure the required IO devices and assign the IO devices to the IO controller.
4. Select the IO device you want to mark as optional.
5. Select the area "PROFINET interface [X1]" > Advanced options".
6. Enable the "Optional IO device" option.

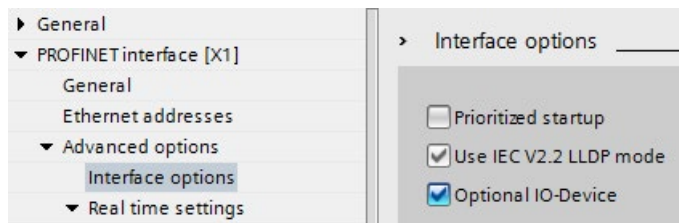


Figure 5-94 Configure the IO device as an optional IO device

7. Repeat steps 4 to 6 for all IO devices to be configured as optional.
8. Load the configuration onto the CPU.

Result: Once this configuration is loaded, the system behavior is as follows:

- The CPU is prepared for the configuration control of the IO system.
- All IO devices are disabled.
- Irrespective of whether you customize the configuration with the user program (adding optional IO devices) or make no changes to the loaded configuration: You must call the instruction "ReconfigIOSystem" in the user program and notify the current configuration to the system!

The system will not be operational without calling the instruction "ReconfigIOSystem".

For further information on the proceeding see Enabling optional IO devices in the program (Page 245).

Fast parameter assignment in the "IO communication" table

You can also specify whether or not an IO device is optional in the "IO communication" tab.

In an additional "Optional IO device" column, a selectable check box is available for each IO device that indicates whether or not an IO device is optional. Here, you can adjust the setting centrally.

5.10.2.3 Enabling optional IO devices in the program

Requirements

- IO controller supports configuration control for IO systems, for example CPU 1516-3 PN/DP as of firmware version 1.7
- STEP 7 V13 SP1 or higher
- At least one IO device was configured as optional IO device.
- The rules (Page 256) for the establishment and operation of a standard machine project have been considered.

Procedure

Observe the information on and rules for commissioning in the documentation for SIMATIC S7-1500, for the ET 200SP CPUs and for the CPU 1516pro-2 PN.

The following description of the proceeding only includes steps required to understand the program-controlled activation of an optional IO device.

To activate or deactivate IO devices, follow these steps:

1. Create a data record "CTRLREC" for the instruction "ReconfigIOSystem". You can find information on the structure of the data record in the STEP 7 online help.
2. Call the instruction "ReconfigIOSystem" and select MODE 1 to deactivate all IO devices.

If you set the CPU to STOP or POWER OFF state in order to modify the plant in this status (for example to add an optional IO device), explicit deactivation using "ReconfigIOSystem" with mode 1 is not necessary. In this case, i.e. following a STOP-RUN transition and following a POWER-OFF > POWER-ON transition, all IO devices are deactivated automatically.

3. When you have brought the plant to a safe status that allows restructuring without any danger:

Put the plant together according to your intended application. Add the required optional IO devices at the points at which you planned this in the configuration (observe the order!) or remove optional IO devices that you no longer require.

4. Network the IO devices.
5. Startup the S7-1500 system and call again the instruction "ReconfigIOSystem". Select MODE 2 to transfer the data record CTRLREC.
6. Following successful transfer of the data record, call again the instruction "ReconfigIOSystem". Select MODE 3 to activate all IO devices forming part of the current configuration.

Result: The CPU **activates** the following IO devices:

- All IO devices that you have not set as optional IO devices.
- All optional IO devices listed in the control data record (CTRLREC).

The following IO devices remain **disabled**:

- Docking units (IO devices changing during operation).
- Optional IO devices that are not listed in the control data record.

Note

Call the instruction "ReconfigIOSystem" for all values of the parameter MODE with the same control data record (CTRLREC)!

If you use different data records for the values of the MODE parameter, this results in an inconsistent customization of the configuration and thus to rather incomprehensible error messages.

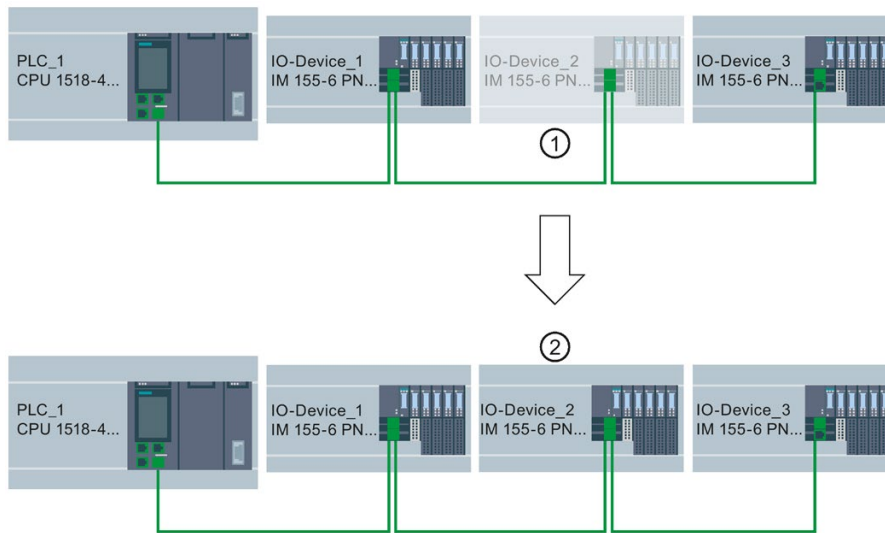
Example: Data record structure for the activation of an IO device

The IO device "IO-Device_2" is to be activated as the only IO device in the user program.

To do this, you only require the hardware identifier of "IO-Device_2".

Recommendation: Use the system constants of the hardware identifiers instead of the absolute values as shown in this example. With this procedure, the content of the DB is not influenced by changes to the hardware identifiers as the result of changes to the configuration.

The data record is to be stored in a data block and to be transmitted to the PROFINET interface of the IO controller in the user program using the instruction "ReconfigIOSystem".



- ① IO device_2 is configured as optional IO device.
- ② Once the data record is transmitted and the configuration is activated using the instruction "ReconfigIOSystem" IO device_2 is included in the configuration and participates in the data exchange with the IO controller.

Figure 5-95 Example: Activating an optional IO device

Creating data block

In this example, the control data record is created in a data block. The data block is structured as follows:

Line 2: Array definition: Array of type Word with 4 elements. Array of Word is permitted as the data type.

Line 3: Version of the data record (currently: V1.0).

Line 4: Number of optional IO devices to be activated (here: 1).

Line 5: List of the hardware identifiers of the IO devices, inserted here as system constants.

Line 6: Number of port interconnections that are set in the user program (here: 0).

Line 7: Additional data records (optional)

myCTRLREC				
	Name	Data type	Start value	Comment
1	Static			
2	ArrMachineConfig0	Array[0..3] of Word		Array for one optional IO device
3	ArrMachineConfig0[0]	Word	16#0100	
4	ArrMachineConfig0[1]	Word	16#0001	
5	ArrMachineConfig0[2]	Word	"IO-Device_2~IODevice"	
6	ArrMachineConfig0[3]	Word	16#0000	
7	ArrMachineConfig1	Array[0..8] of Word		

Figure 5-96 Data block with control records

Parameter MODE of instruction "ReconfigIOSystem"

You control how the "ReconfigIOSystem" instruction works with the MODE parameter.

The following values are possible for the MODE input parameter:

MODE	Description
1	<p>All IO devices of the IO system can be disabled by calling the instruction with MODE 1. The "ReconfigIOSystem" instruction uses the "D_ACT_DP" instruction internally. "ReconfigIOSystem" returns errors that are detected by D_ACT_DP in the following output parameters:</p> <ul style="list-style-type: none"> • STATUS (error code) • ERR_INFO (hardware identifier of the IO device causing the error). <p>In STATUS and ERR_INFO, the CPU enters the last determined error/HW identifier and in so doing overwrites an existing error code. For this reason, additional errors can be present besides the entered error.</p>
2	<p>For controlling the actual configuration of the IO system, the instruction transfers the data record to the PROFINET interface, which is addressed with LADDR block parameter (HW identifier of the PROFINET interface).</p>
3	<p>All non-optional IO devices in the IO system and optional IO devices that are listed in the control data record CTRLREC are enabled.</p> <p>The optional IO devices that are not listed in the CTRLREC data record remain disabled.</p> <p>If IO devices that are part of docking units (alternating IO devices in operation) are listed in the CTRLREC control data record, the PN IO system reacts as follows:</p> <ul style="list-style-type: none"> • IO devices of the docking units remain disabled when ReconfigIOSystem is called with MODE 3. <p>This reaction corresponds to the reaction of a configuration without configuration-controlled IO devices. IO devices of docking units are disabled by default and must be enabled in the user program.</p> <p>For more information on docking units, refer to the section Docking systems (Page 260).</p>

Rules for the call sequence of "ReconfigIOSystem"

- Always supply the instruction "ReconfigIOSystem" with the same control data record (CTRLREC input parameter)!
- Call sequence following POWER OFF -> POWER ON transition:
 - ReconfigIOSystem call with MODE 1 (optional).
 - ReconfigIOSystem call with MODE 2 (mandatory, even without previous reconfiguration!).
 - ReconfigIOSystem call with MODE 3 (mandatory).
- Call sequence following STOP > RUN transition:
 - ReconfigIOSystem call with MODE 1 (optional).
 - ReconfigIOSystem call with MODE 2 (mandatory, even when configuration was modified in STOP state). Otherwise not required).
 - ReconfigIOSystem call with MODE 3 (mandatory).
- Call sequence for reconfiguration in RUN state:
 - ReconfigIOSystem call with MODE 1 (mandatory).
 - ReconfigIOSystem call with MODE 2 (mandatory).
 - ReconfigIOSystem call with MODE 3 (mandatory).

Explanations and recommendations concerning the rules

- If you do not list an IO device to be configured as optional IO device in the control data record or data block resp. this IO device does not form part of the configuration and does not take part in data exchange with the CPU.
- If you do not activate any optional IO device at all and work with the loaded configuration without reconfiguration, you still have to follow the proceeding described in the above section and transmit the control data record to the CPU.

The control data record has the simple structure with the following tags:

- Version (High Byte =1, Low Byte = 0)
 - Number of optional devices to be activated = 0
 - Number of port interconnections that are set in the user program = 0
- Following a STOP > RUN transition and following a POWER-OFF > POWER-ON transition, all IO devices are deactivated automatically. For this reason, no ReconfigIOSystem call with MODE 1 is required for configuration control to function properly.

If you use your project as a universally valid sample for programming the configuration control, we still recommend to perform the ReconfigIOSystem call with MODE 1 prior to any reconfiguration. This way, the sample can also be used for reconfigurations in RUN mode.

- Commissioning extensive I/O systems (more than 8 optional IO devices) while using IRT at the same time:

To keep the startup times short when activating the optional IO devices (ReconfigIOSystem, mode 3), note the following tip: Check the device numbers of the IO devices. The device numbers should follow the topological interconnection starting at the IO controller in ascending order. The further an IO device is from the IO controller topologically, in other words the more IO devices there are between the IO controller and the IO device in question, the higher the device number should be.

You set the device numbers in the "Ethernet addresses - PROFINET" area in the Inspector window with the PROFINET interface selected.

Example of the assignment of device numbers with a linear topology:

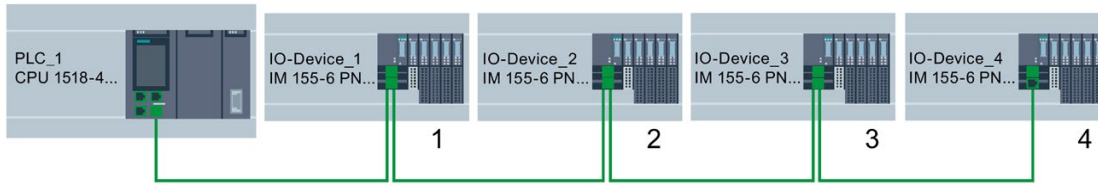


Figure 5-97 Example: Device numbers in a line topology

- The CPU processes the instruction "ReconfigIOSystem" to transfer the control data record asynchronously.

For this reason, you must call "ReconfigIOSystem" in a loop repeatedly when calling the instruction in the startup program until the output parameter "BUSY" or "DONE" indicate that the data record has been transferred.

Tip: To program the loop, use the SCL programming language with the instruction REPEAT ... UNTIL.

```

REPEAT

    "ReconfigIOSystem"(REQ := "start_config_ctrl",

        MODE := 1,

        LADDR := 64,

        CTRLREC := "myCTRLREC".ArrMachineConfig0,

        DONE => "conf_DONE",

        BUSY => "conf_BUSY",

        ERROR => "conf_ERROR",

        STATUS => "conf_STATUS");

UNTIL NOT "conf_BUSY"

END_REPEAT;
    
```

Additional information

For information on the basic structure of the data record and on using the instruction "ReconfigIOSystem" see the STEP 7 online help.

See also

Configuring IO devices as optional (Page 244)

5.10.2.4 Configuring flexible order of IO devices

The following section shows how you can create the conditions required to change the order of IO devices in a PROFINET IO system.

This function is also supported with optional IO devices. For simplicity, a maximum configuration without optional IO devices is shown below.

Concept

A typical application for a standard machine project consists of composing an entire plant from a set of various plant units which only differ with respect to the different arrangement of the units, e.g. in the case of transport systems. Each plant unit consists of a functional unit of mechanics (rails or conveyor belts) and electrics (power supply, IO device with IO modules, sensors, actuators, motors, PROFINET port for data exchange with central control ...).

The following figure shows how, simply by exchanging two rail segments, a new transport system is created that is adapted with an upstream points to the local conditions.

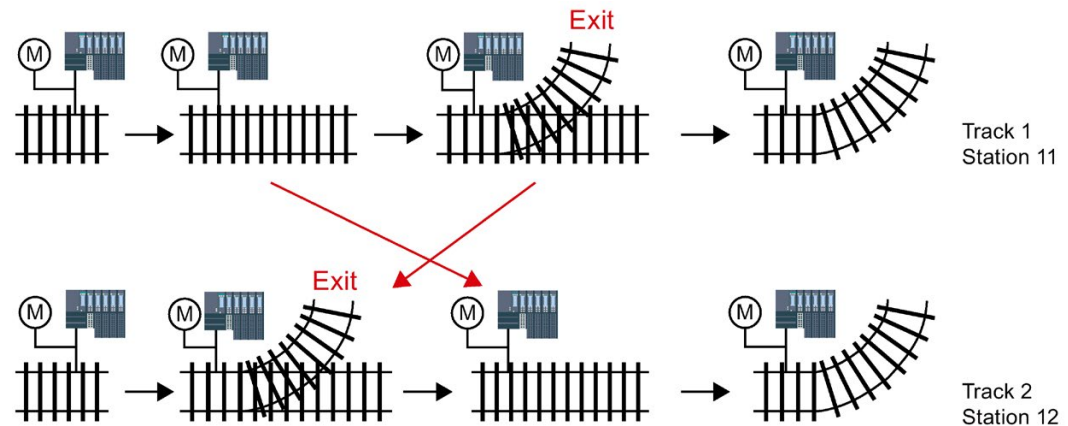


Figure 5-98 Example: Changing the arrangement of IO devices

From the automation viewpoint, no change in the project is required for the flexible adjustment of the PROFINET configuration.

The order of the IO devices is determined by the port interconnection. For each IO device, you define in the port properties the partner port and thus the neighboring device connected at the respective local port. If the partner port is to be defined by the user program, the option "Partner set by user program" is to be selected as partner port.

The figure below shows the initial configuration of the transport system shown above, which is to permit the order of the connected IO devices to be changed via the user program. In the example, the order of IO-Device_2 and IO-Device_3 is to be controlled via the user program.

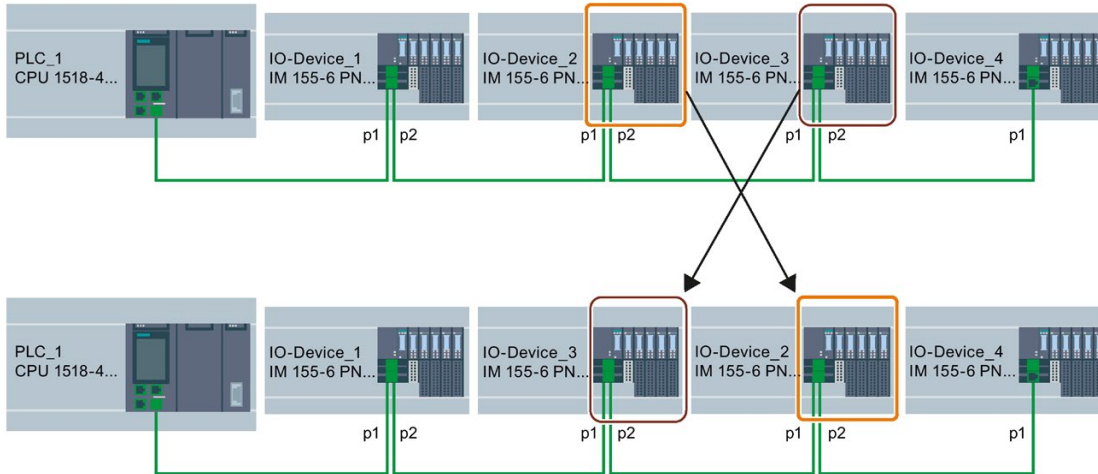


Figure 5-99 Example configuration: Configuring flexible order of IO devices

To determine how the partner port settings are to be selected, you must note for each device and each port of a device which partner can be interconnected.

- If the partner is always the same in the different configurations provided, you select the partner port for this partner.
- If the partners vary in the different configurations, you select "Setting partner by user program".

For the example in the figure above, the following port settings result:

Device	Local port	Partner port setting	Explanation
PLC_1	p1	p1 (IO device_1)	Partner of PLC_1 at port 1 is IO device_1 (always)
IO device_1	p1	p1 (PLC_1)	Partner of IO device_1 at port 1 is PLC_1 (always)
IO device_1	p2	Partner is set by user program	Partner of IO device_1 at port 2 is either IO device_2 or IO device_3 => Setting partner by user program
IO device_2	p1	Partner is set by user program	Partner of IO device_2 at port 1 is either IO device_1 or IO device_3 => Setting partner by user program
IO device_2	p2	Partner is set by user program	Partner of IO device_2 at port 2 is either IO device_3 or IO device_4 => Setting partner by user program
IO device_3	p1	Partner is set by user program	Partner of IO device_3 at port 1 is either IO device_2 or IO device_1 => Setting partner by user program

Device	Local port	Partner port setting	Explanation
IO device_3	p2	Partner is set by user program	Partner of IO device_3 at port 2 is either IO device_4 or IO device_2 => Setting partner by user program
IO device_4	p1	Partner is set by user program	Partner of IO device_4 at port 1 is either IO device_3 or IO device_2 => Setting partner by user program
IO device_4	p2	Any partner	No partner planned at port 2

Requirement

- IO controller supports configuration control for IO systems, for example CPU 1515-2 PN as of firmware version 1.7
- STEP 7 V13 SP1 or higher
- The rules (Page 256) for the establishment and operation of a standard machine project have been considered.

Procedure

To set the partner port for a program controlled interconnection, proceed as follows:

1. Select the PROFINET interface of the device (IO controller or IO device) whose port you want to set.
2. In the properties of the PROFINET interface, select the area "Port interconnection" (Extended options > Port [...] > Port interconnection).
3. From the drop-down list, select "Setting partner by user program" as partner port.
4. Repeat steps 1 to 3 for each port to be interconnected via the user program.

See also

Customizing arrangement of IO devices in the program (Page 253)

5.10.2.5 Customizing arrangement of IO devices in the program

Requirements

- IO controller supports configuration control for IO systems, for example CPU 1516pro-2 PN as of firmware version 1.7 as an IO controller
- STEP 7 V13 SP1
- At least one partner port was configured as "Partner set by user program".
- The rules (Page 256) for the establishment and operation of a standard machine project have been considered.

Procedure

The proceedings corresponds to the proceeding for activating optional IO devices. Only the structure of the data record must be extended for the program-controlled assignment of the ports. The extension is described in the following sections.

Example: Data record structure for the assignment of partner ports

For the data record structure, you need the HW identifications of the ports. The data record is to be stored in a data block and to be transmitted to the PROFINET interface of the IO controller in the user program using the instruction "ReconfigIOSystem". As the input parameter RECORD of the instruction "ReconfigIOSystem" is of the VARIANT data type, you first have to create a data type for the data block. In the following sections, you find a description of the structure of the PLC data type as well as of the structure of the data block based on this type.

Selecting derived configuration

For the following selected configuration it is shown below what the data record must look like so that the IO devices are interconnected in the planned order by the user program.

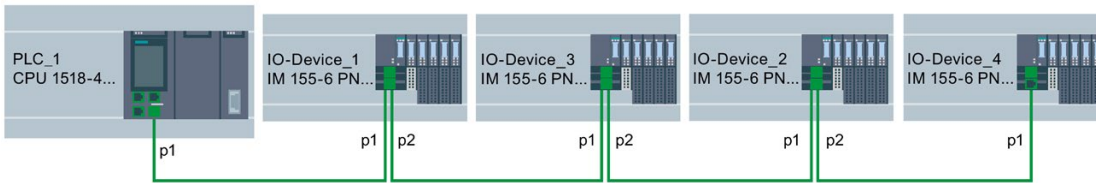


Figure 5-100 Example configuration: Customizing arrangement of IO devices in the user program

This example is based on the flexible configuration from the previous section (Page 251) with the settings for the respective partner ports described there.

The partner ports in the specific derived configuration have been defined so that it is possible to name the HW identifications of the ports involved.

The following table only contains those devices whose ports can be defined by the user program. Only these devices are relevant for the data record structure.

Device	Local port	Partner port setting	Partner port of the selected configuration
IO device_1	p2 = Port 2 HW identifier: 251	Partner is set by user program	Port 1 of IO device_3 HW identifier: 261
IO device_2	p1 = Port 1 HW identifier: 281	Partner is set by user program	Port 2 of IO device_3 HW identifier: 291
IO device_2	p2 = Port 2 HW identifier: 311	Partner is set by user program	Port 1 of IO device_4 HW identifier: 321

Creating data block

For the derived configuration, the structure of the data block "DB-IO-SYSTEM-Port-Interconnections" is explained as an example.

This data block is used when calling the instruction "ReconfigIOSystem" at input parameter "CTRLREC".

Instead of the absolute values for the hardware identifiers of the ports, the system constants of the hardware identifiers are used here.

The data block is structured as follows:

Line 2: Declaration of an Array of Word (only this data type is possible).

Line 3: Version of the control data record: V1.0.

Line 4: Number of optional IO devices: 0.

Line 5: Number of specified port interconnections: 3.

Line 6: Port interconnection 1, local port.

Line 7: Port interconnection 1, partner port.

Line 8: Port interconnection 2, local port.

Line 9: Port interconnection 2, partner port

Line 10: Port interconnection 3, local port.

Line 11: Port interconnection 3, partner port.

IO-SYSTEM-Port-Interconnections				
	Name	Datentyp	Startwert	Kommentar
1	Static			
2	ArrMachineConfig	Array[0..8] of Word		data record for port interconn settings
3	ArrMachineConfig[0]	Word	16#0100	
4	ArrMachineConfig[1]	Word	16#0000	
5	ArrMachineConfig[2]	Word	16#0003	
6	ArrMachineConfig[3]	Word	"IO_device_1~PROFINET_interface~Port_2"	
7	ArrMachineConfig[4]	Word	"IO_device_3~PROFINET_interface~Port_1"	
8	ArrMachineConfig[5]	Word	"IO_device_2~PROFINET_interface~Port_1"	
9	ArrMachineConfig[6]	Word	"IO_device_3~PROFINET_interface~Port_2"	
10	ArrMachineConfig[7]	Word	"IO_device_2~PROFINET_interface~Port_2"	
11	ArrMachineConfig[8]	Word	"IO_device_4~PROFINET_interface~Port_1"	

Figure 5-101 Data block with data record for port interconnections

Interconnection not listed in data block

If the partner port was configured as "Setting partner by user program" in the port properties and this port is not listed in the data record or data block resp., then the CPU sets this port to the setting "any partner". If no data record is transmitted at all, the CPU sets this "any partner" setting for all program-controlled assignments.

Additional information

For information on the basic structure of the data record and on using the instruction "ReconfigIOSystem" see the STEP 7 online help.

5.10.2.6 System behavior and rules

Below, you find a description of how an IO system whose configuration is controlled by the user program behaves in operation.

In addition, rules and restrictions are listed here which must be considered when configuring the maximum structure of the configuration in a standard machine project.

System behavior

- System diagnostics:

If an optional IO device is deactivated, the IO device is displayed as "deactivated" from the system diagnostics viewpoint (online view or Online & Diagnostics).

- Topology view:

Offline view: As configured. No interconnection is shown for ports with partner ports configured as "Setting partner by user program".

Online view: Ports and interconnections with deactivated IO devices are shown in a different shade of green as error-free ports and interconnections of activated IO devices.

- Representation in the Web server:

The names of devices are shown as configured (Properties > General > Project information).

The assigned PROFINET device name for the CPU is shown on the "Communication" website, at the "Parameter" tab.

IP address parameters: Currently assigned IP address parameters are shown on the site "Module state".

Topology: The current topology resulting from any customizations via user program is shown in the Web server. IO devices configured as optional are shown as "deactivated" IO devices in the Web server.

Rules

The rules for standard machine projects as described here (Page 233) apply.

For configuration-controlled IO systems, the following additional rules apply:

- When configuring MRP (Media Redundancy Protocol):

The ports configured as ring ports must not be interlinked via user program.

However, devices with ring ports (devices of an MRP domain) can be optional IO devices.

- When configuring docking stations (= IO devices changing during operation):

Neither the docking station nor the first IO device of a docking unit may be optional IO devices.

The ports of the docking units must not be interlinked via user program.

- When configuring IRT:

The order of synchronized IO devices ("IRT devices") must be defined by the configuration and must not be changed in the different variants of a standard machine. For this reason, the ports of the IRT devices must not be interlinked via user program.

However, you have the possibility to configure IRT devices primarily as optional IO devices.

You also have the option to interconnect, by user program, RT devices that are, for example, separated from this line by a switchport (see figure).

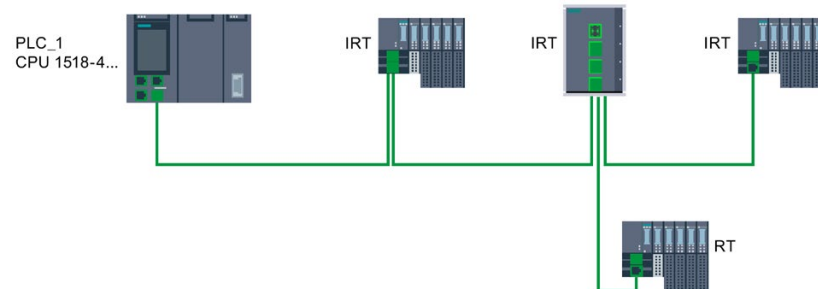


Figure 5-102 Example: Configuration control for IO systems with separated RT device

5.11 Saving energy with PROFlenergy

Saving energy with PROFlenergy

PROFlenergy is a PROFINET-based data interface for switching off consumers centrally and with full coordination during pause times regardless of the manufacturer or device type. Through this, the process should only be provided with the energy that is absolutely required. The majority of the energy is saved by the process; the PROFINET device itself only contributes a few watts of savings potential.

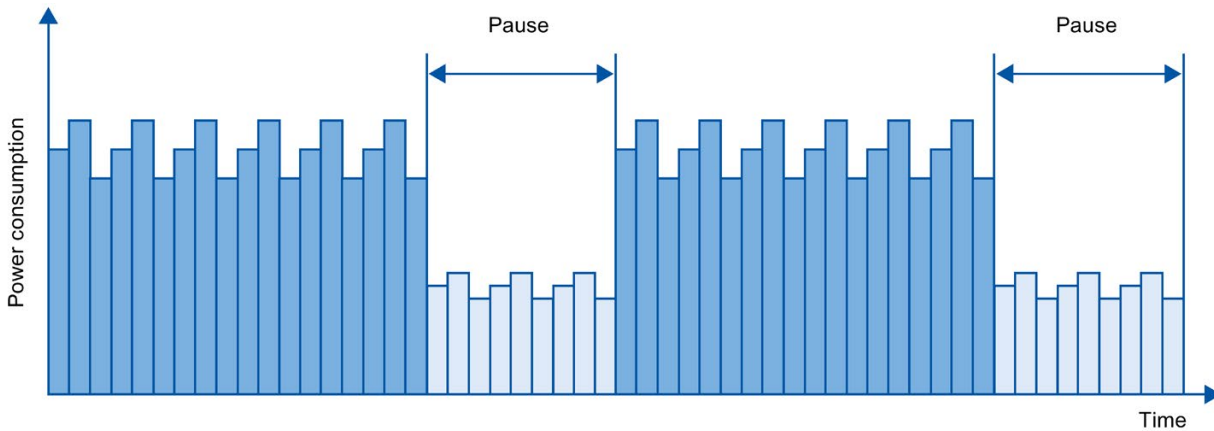


Figure 5-103 Energy savings during pauses with PROFlenergy

Basic information

In order to use the PROFlenergy functionality, the existing IO controller has to be "upgraded" to a so-called "PROFlenergy controller" by means of a function block in the PROFINET IO system and at least one PROFlenergy-capable IO device ("PROFlenergy device") has to exist. The PROFlenergy commands (for example to start or end a pause) are sent by the "PROFlenergy controller" to the individual "PROFlenergy devices". Each "PROFlenergy device" decides individually how it responds to the PROFlenergy command (response is device- and manufacturer-specific).

No additional hardware is needed; the PROFlenergy commands are directly interpreted by the PROFINET devices.

Principle of operation

At the beginning and end of pauses, the system manager enables or disables the pause function of the system; then the IO controller sends the PROFlenergy command "Start_Pause"/"End_Pause" to the PROFINET devices. The device interprets the contents of the PROFlenergy command and switches off or back on.

Through other PROFlenergy functions, device information can be accessed during pauses. The user can use this information in order to optimally time the transfer of the "Start_Pause"/"End_Pause" command.

PROFlenergy instructions for IO controllers

Two instructions are needed for controlling and monitoring the PROFlenergy functions.

The instruction PE_START_END allows you to easily activate and deactivate the idle state of PROFINET devices. This occurs by means of an incoming edge or outgoing edge. The instruction PE_START_END provides a simple interface for implementing the PROFlenergy commands Start_Pause and End_Pause.

The instruction PE_CMD allows you to transmit all PROFlenergy commands, including Start_Pause and End_Pause. The other commands can be used, for example, to query the current status of the PROFINET device or the behavior during the pauses. The instruction PE_CMD is a convenient means for handling all PROFlenergy functions.

PROFlenergy instruction for I-devices

The instruction PE_I_DEV allows you to also implement PROFlenergy on I-devices. The instruction receives PROFlenergy commands on the I-device and forwards these to the user program for execution. After executing the command, the user program calls the PE_I_DEV instruction again in order to send the acknowledgment to the IO controller. For these replies, each command offers you a helper instruction that supplies the reply data to the instruction.

The instructions can be found in the "Instructions" task card of the STEP 7 program editor.

Configuration and programming

The functions can be comfortably integrated into existing systems. No configuration is required for the use of PROFlenergy. However, amendments to the user program are required:

- Before the "Start_Pause" command, you must ensure that your system is brought into a condition that is suitable for a pause.
- A sequential control system for the beginning of the pause of the devices and for the punctual restarting of the device on break must be programmed (depending on the required startup times that the respective PROFINET device demands).
- The error messages of the PE_CMD instruction must be evaluated, and the required reaction must be programmed (for example, cancellation or continuation of further commands on lower-level PROFINET devices).

Note

In the case of the ET 200S distributed I/O system, you have to configure the application of PROFlenergy in STEP 7. You configure PROFlenergy by selecting the "Use energy saving for this potential group" check box in the PM-E DC24V/8A RO power module.

If you want to use PROFlenergy for an I-device, you have to configure this in STEP 7. Information about configuring PROFlenergy for an I-device is available in the section Configuring PROFlenergy with I-devices (Page 137).

Application examples

- SIMATIC S7 library for simple configuration of PROFINergy.
The application example is available here
(<https://support.industry.siemens.com/cs/ww/en/view/109478388>).
- Application guide for implementation of shutdown concepts with PROFINergy.
The application example is available here
(<https://support.industry.siemens.com/cs/ww/en/view/96837137>).
- Saving energy with SIMATIC S7 PROFINergy with I-device
The application example is available here
(<https://support.industry.siemens.com/cs/ww/en/view/41986454>).

5.12 Docking systems

Using alternating IO devices ("alternating partners") during operation in a docking station

The following figure shows an automation cell with a docking station and several docking units.

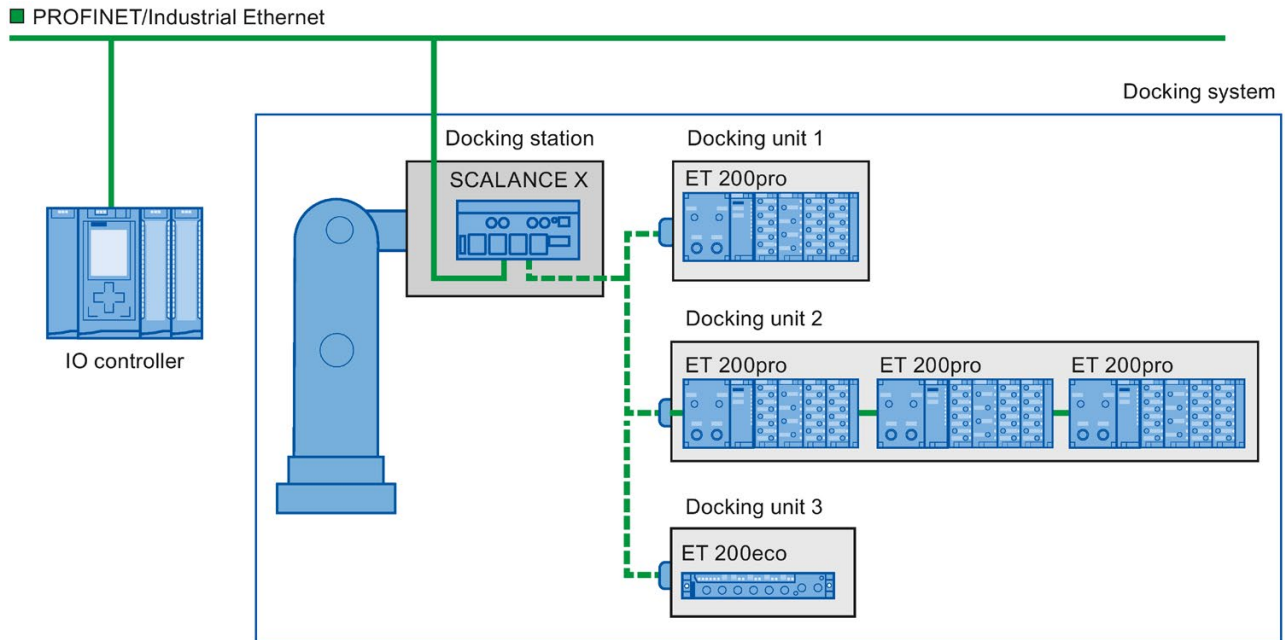


Figure 5-104 Alternating IO devices (partner ports) in a docking system

Area of application for alternating IO devices during operation

You can use the PROFINET function "Alternating IO devices during operation" ("alternating partners"), for the tool changeover for robots, for example. Typical tools include:

- Welding guns
- Positioning tools for manufacturing parts

Requirements for interconnecting alternating partner ports during operation

You can interconnect IO devices with alternating partner ports during operation in the following situations:

- The alternating IO device (docking unit) has no IRT communication configured.
- The PROFINET interface is connected to the Ethernet subnet.
- The PROFINET devices support topology configuration.
- The IO controller, the alternating IO devices (docking unit) and the switch (docking station) on which the alternating IO devices are to be operated support this feature.

Note

Unique IP address

Each docking unit of a docking system must be configured with a unique IP address in a shared project and operated on the same IO controller as all other docking units of the system.

Applicative conditions

The following points should be observed when implementing a docking system with alternating IO devices during operation:

- The IO devices of all docking units must be deactivated by default in the configuration.
- At any time, only one docking unit can be active, i.e., only the IO devices of one docking unit can be activated. All IO devices of other docking units must be deactivated or become deactivated before the IO devices of a docking unit can be activated. You activate an IO device with the "D_ACT_DP" instruction.
- A physical connection to this docking unit and its IO devices must be created in order to activate a docking unit. The IO devices are then switched on (power on). At the same time, all the IO devices of this docking unit must be activated in the user program with the "D_ACT_DP" instruction.

Note

Automatic deactivation in "Startup" mode of the CPU

If the CPU is in "Startup" mode, IO devices of a docking system that alternate during operation are deactivated automatically.

- After the feedback "IO device activated", you can access the IO device by means of direct I/O access.
- Call the "D_ACT_DP" instruction to activate and deactivate the IO device as close as possible to the start of the OB 1 cycle.

Note

Number of alternating IO devices during operation ("alternating partner port") - number of docking units

If you wish to achieve the shortest possible tool changeover times, you must observe the following points that are dependent on the CPU or the CP that is being used:

- Only those IO devices that have been configured with the PROFINET function "Prioritized startup" can start up in an optimized fashion. The number of IO devices with configuration for this PROFINET function is restricted.
- Only a limited number of IO devices can be activated at the same time. This number depends on the available "D_ACT_DP" resources. A docking unit should not contain more than the corresponding number of IO devices. If more IO devices are operated in a docking unit, the IO devices must be activated one after the other, which takes correspondingly longer.

Example: An S7-CPU 1516-3 PN/DP can operate a maximum of 32 IO devices with prioritized startup and can simultaneously activate 8 IO devices by means of "D_ACT_DP".

Therefore, for a scheduled optimum use, a docking unit should include no more than 8 IO devices and no more than 32 IO devices should be used in all the alternating docking units.

5.12.1 Configuring docking systems

Configuring docking systems

The possible connections to the individual IO devices must be configured in STEP 7.

Procedure in STEP 7

1. Configure your system as usual, but do not yet configure the topological interconnections of the individual PROFINET devices.
2. Navigate to the "Topology view" tab.
3. Select the port which you want to operate with alternating partners during operation.
4. Navigate to the "Properties" tab of the inspector window and select "Port interconnection" in the area navigation.

5. Under "Partner port", select the "Alternative partners" option.
6. Select the desired partner ports: To do this, click "<Add alternative partners..." and choose a partner port. Repeat this process until all required partner ports are connected.

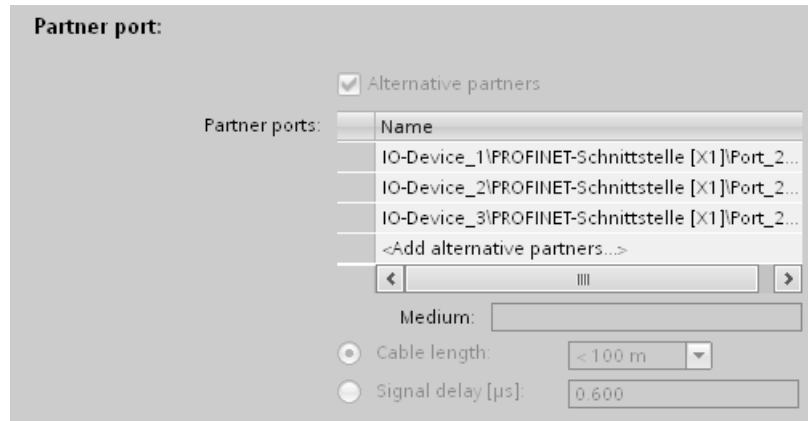


Figure 5-105 Configuring docking systems in STEP 7

Tip: You can also use drag-and-drop operation to connect alternative partner ports in the topology view.

Result

You have interconnected the respective port with one or more alternating IO devices. The connections with the individual alternating partner ports during operation are shown in the topology view by a green, dashed line.

Multiple IO devices as a docking unit ("Alternating partner port")

A docking unit may also consist of several IO devices connected in series. If you use IO devices connected in series as a docking unit, ensure that the topology of the IO devices is configured. A docking unit consisting of two IO devices connected in series (Tool_3_1 and Tool_3_2) is shown at the bottom right in the figure below.

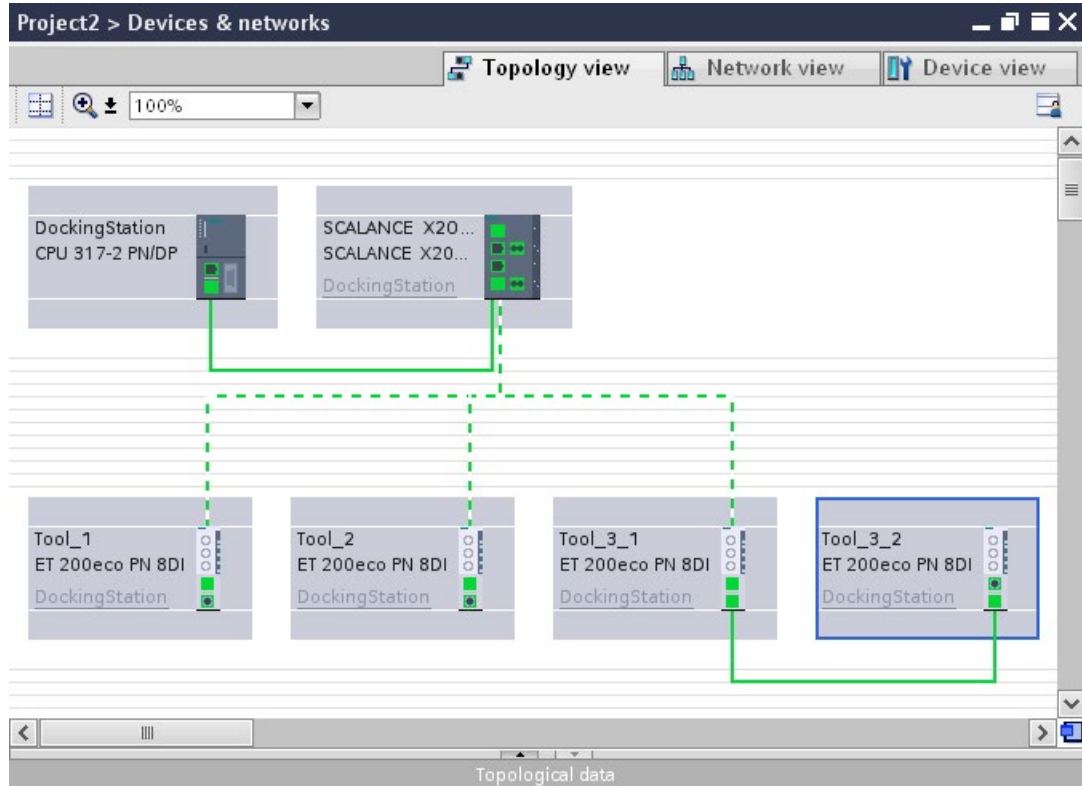


Figure 5-106 Docking system in the topology view of STEP 7

Restriction in the interconnection

The interconnection with a partner port is not possible in the following cases:

- The partner port does not have a suitable type of cable. In this case, a media convertor from the catalog must be inserted.
- The partner port is blocked (deactivated).
- The two ports that are to be interconnected belong to the same interface (it is only possible to interconnect the ports from different interfaces in a station).
- The two ports that are to be interconnected belong to different Ethernet subnets.

Deleting interconnections

Select the port of the alternating partner and remove the interconnection with the "Remove" button.

5.13 Accelerating startup

5.13.1 Options for accelerating the startup of IO devices

Reducing the startup time of IO devices

The time needed for the startup of IO devices depends on various factors and can be reduced in different ways.

You can achieve a significant reduction in the startup time using the "Prioritized startup" PROFINET function.

To further reduce the startup times, use the following measures in addition to the "Prioritized startup":

- Optimize the port settings
- Optimize the cabling of the ports
- Perform measures in the user program (for docking systems only)

These measures will accelerate the startup of IO devices even without "Prioritized startup". However, you can only achieve the fastest startup times of about 500 ms by combining all the measures with "Prioritized startup".

Note

Startup time up to 8 s

In the following situation, despite prioritized startup, a startup time of up to 8 s may occur:

On a docking point, multiple physical IO devices dock as an IO device with identical device names and identical IP configurations (for example, docking point for automatic transport system).

Dependencies

The length of the startup time for an IO device (distributed I/O) with the "Prioritized startup" PROFINET function depends on the following factors:

- IO devices (distributed I/O)
- IO structure of the IO device (distributed I/O)
- Modules of the IO device (distributed I/O)
- IO controller
- Switch
- Port setting

5.13 Accelerating startup

- Cabling
- Configured RT class of the IO device

Note

Startup time and RT class of the IO device

An IO device with IRT communication requires longer than an IO device with RT communication for the accelerated startup.

The longer startup for IRT is due to the necessity of synchronizing the IO device before the communication can be set up.

Note

IWLAN and prioritized startup


PROFINET devices which are connected via access points to PROFINET IO do not support the "Prioritized startup" PROFINET function.

5.13.2 Prioritized startup

Definition

Prioritized startup refers to the PROFINET function for accelerating the startup of IO devices in a PROFINET IO system with RT communication. It shortens the time that the respective configured IO devices require in order to reach the cyclic user data exchange in the following cases:

- After the power supply has returned
- After a station has returned
- After activation of IO devices

 WARNING
Data exchange despite multiple use IP addresses/device names in PROFINET IO system
To achieve higher ramp-up times, the IO controller checks the uniqueness of device name of IP address parallel to the device ramp-up. In the case of incorrect or double assignment of device name or IP address, a short-time data exchange is possible until the IO controller reacts to the error. In this time the IO controller can exchange IO data with the false device.
During commissioning, ensure that no IP addresses / device names are assigned multiple times in the PROFINET IO system.

Advantages

The PROFINET functionality "prioritized startup" enables PROFINET IO applications in which machine parts or tools and their IO devices have been permanently replaced. Waiting times of several seconds between the scheduled processes of the restart are reduced to a minimum by this optimization. This accelerates the production process with alternating IO devices (PROFINET functionality "docking systems"), e.g. in tool changer applications, and enables a greater throughput in production.

The PROFINET functionality "prioritized startup" also offers a considerable increase in performance for applications where a quick startup time of the IO devices after "power on" or after station failure / station return is required, or when activating IO devices.

Area of application

You can use prioritized startup, for example, for changing tools for robots in the automotive industry. Typical tools are, for example:

- Welding guns
- Positioning tools for the manufacture of car body parts

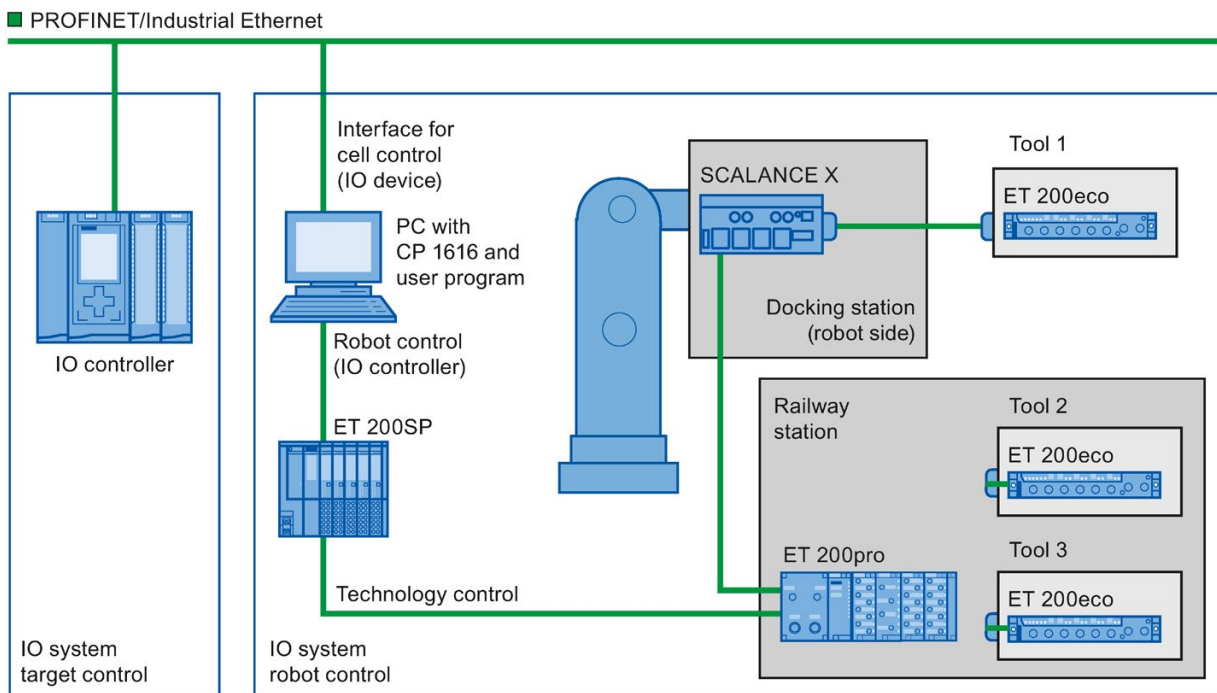


Figure 5-107 Example configuration of a tool changer: Tools 1-3 configured with "Prioritized startup".

5.13.3 Configuring prioritized startup

Requirements

You can enable the "Prioritized startup" PROFINET function for the IO devices (distributed I/O) only in the following cases:

- The IO controller used can prioritize selected IO devices during startup.
- The IO device used supports prioritization.

Procedure

1. Select the IO device in the network view or device view for which you wish to accelerate startup.
2. Open the IO device properties in the Inspector window.
3. Select "PROFINET interface > Advanced options > Interface options".
4. Select the "Prioritized startup" check box.

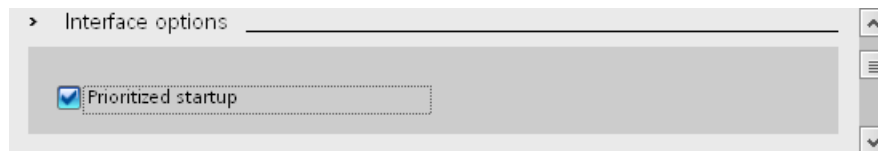


Figure 5-108 Configuring prioritized startup in STEP 7

5. Download the configuration to the IO controller.

Note

Prioritized startup after a startup for the first time

A prioritized startup of the IO device is always available to you after the first configuration of this IO device in the very first startup of the PROFINET IO system. Even in the case of spare parts or a reset to factory settings, the first startup is a standard startup for the respective configured IO devices.

Note

Number of IO devices (distributed I/O) with prioritized startup

You can only start up a maximum number of IO devices with the "Prioritized startup" PROFINET functionality within one PROFINET IO system. This maximum number depends on the IO controller used.

5.13.4 Optimize the port settings

Optimizing port settings on the IO device and IO controller

The transfer medium and the duplex option are checked during startup of the IO device in the case of copper cabling.

These checks require time, but with specific presets of these options you can save the time the check requires. Make certain that the settings made correspond to the actual conditions (using the correct cables).

Optimizing port settings for accelerated startup

To optimize port settings for accelerated startup, follow these steps:

1. Select the ports of the IO controller or the partner port of the corresponding IO device.
2. Navigate to "Port options > Connection" in the Inspector window. Select the setting "TP 100 Mbps full duplex" under "Transmission rate/duplex"
3. Clear the "Enable autonegotiation" check box.

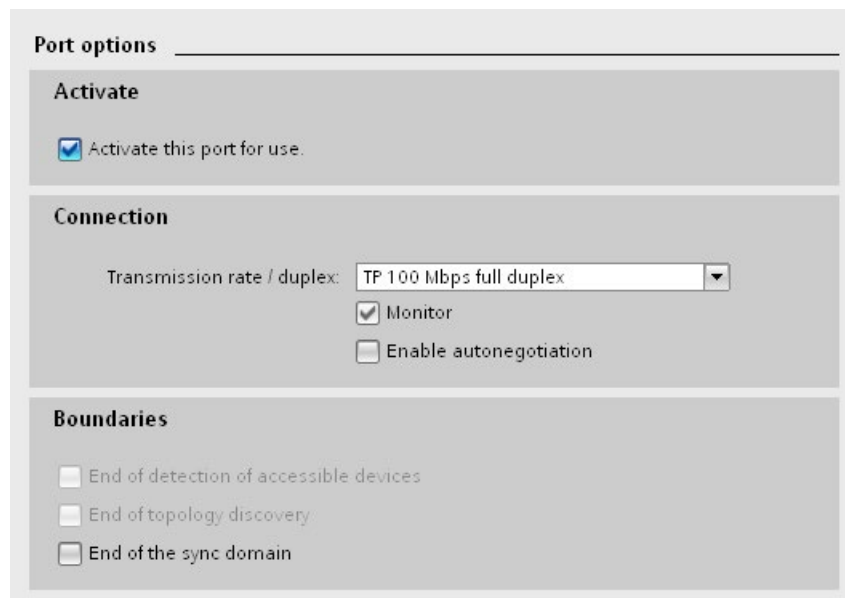


Figure 5-109 Optimizing port settings for accelerated startup in STEP 7

These settings are automatically applied during topology configuration for the partner port.

5.13.5 Optimize the cabling of the ports

Requirements

You have made the following settings for the port in question to reduce the startup time of the IO device:

- Fixed transmission rate
- Autonegotiation deactivated

The time for negotiating the transmission rate during startup is saved.

If you have disabled autonegotiation, you must observe the cabling rules.

Properties of ports

PROFINET devices have the following two types of ports:

Type of port	PROFINET devices
Switch port with crossed pin assignment	For IO devices: Port 2 For S7-CPU with two ports: Ports 1 and 2
Terminal device port with normal pin assignment	For IO devices: Port 1 For S7-CPU with one port: Port 1

Crossed pin assignment means that the pin assignment for the ports for sending and receiving between the respective PROFINET devices is inverted internally.

Validity of the cabling rules

The cabling rules described in the following paragraph apply exclusively for the situation in which you have specified a fixed port setting in STEP 7.

Rules for cabling

You can connect several IO devices in series using patch cables. To do this, connect port 2 of the IO device (distributed I/O) with port 1 of the next IO device. The following graphic provides an example with two IO devices.

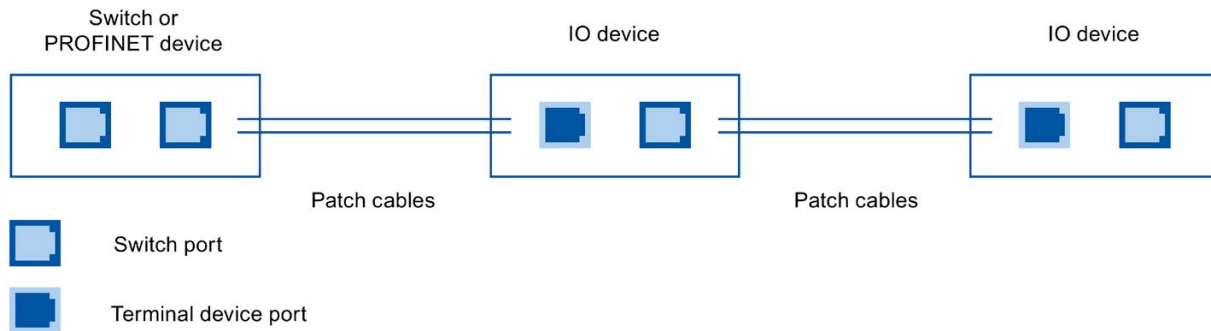


Figure 5-110 Optimized cabling for accelerated startup

5.13.6 Measures in the user program

Introduction

You can make certain changes in the user program to accelerate the startup for IO devices of docking systems that alternate during operation.

Making the required changes to the user program

To accelerate the startup by making changes to the user program, follow these steps:

1. Call the "D_ACT_DP" instruction to activate and deactivate the IO device at the start of the OB 1 cycle.

If the IO device is replaced, the device that is no longer required must be deactivated and the new device must be activated.

2. If you control the "Power ON" command of the IO devices via the application, then start the activation of the IO devices via the corresponding call of the "D_ACT_DP" instruction as near to the same time as possible. The IO device has to be physically connected for this.
3. You access the IO device using direct access commands after the "D_ACT_DP" instruction has provided the feedback "IO device activated".

PROFINET with the redundant S7-1500R/H system

Introduction

The same basic rules apply to PROFINET IO communication with the redundant S7-1500R/H as with the S7-1500 automation system. The redundant S7-1500R/H system exchanges IO data cyclically with the IO devices.

The redundant S7-1500R/H system supports a limited scope of PROFINET functions.

The redundant S7-1500R/H system uses media redundancy (MRP) in the PROFINET ring.

You can use the following IO devices on the redundant S7-1500R/H system:

- IO devices with S2 system redundancy
- Standard IO devices over the "Switched S1 device" function of the CPU

When configuring PROFINET with the redundant S7-1500R/H system, you must observe a few specifics, e.g. special configuration requirements.

Limitations

- Real-time communication:
 - RT with a fixed send clock of 1 ms
 - No IRT
 - No MRPD redundancy procedure
 - No PROFINET with performance upgrade
- No isochronous mode
- No direct data exchange
- No operation as I-device
- No access to shared devices
- No support of docking systems
- No support of series machine projects
- Port options (only for PROFINET interface X1):
 - No port disabling possible
 - No configuring of boundaries possible

- Functionality as IO controller:
 - No prioritized startup
 - No enabling/disabling of IO devices
 - No support of series machine projects, e.g. IO systems that can be used multiple times
- PROFINET interface X2 does not support IO functionality (CPU 1515R/CPU 1517H)
- No diagnostics using the web server

6.1 Media redundancy in the redundant S7-1500R/H system

The two CPUs of the redundant system must be located in a PROFINET ring that uses the media redundancy method MRP. All PROFINET devices in the PROFINET ring are connected to the S7-1500R/H in a media-redundant manner. If the PROFINET ring is interrupted, reconfiguration may occur. After a short reconfiguration time, the PROFINET devices can be accessed again via an alternative path.

6.2 H-Sync Forwarding

Introduction

H-Sync Forwarding enables a PROFINET device with MRP to forward synchronization data (synchronization frames) of a S7-1500R redundant system only within the PROFINET ring.

In addition, H-Sync Forwarding forwards the synchronization data even during reconfiguration of the PROFINET ring. H-Sync Forwarding avoids a cycle time increase if the PROFINET ring is interrupted.

Note

Support of H-Sync Forwarding

The technical specifications typically state whether a PROFINET device supports H-Sync Forwarding.

The GSD file will also indicate whether the device supports H-Sync Forwarding. The device supports H-Sync Forwarding when the "AdditionalForwardingRulesSupported" attribute in the "MediaRedundancy" element is set to "true".

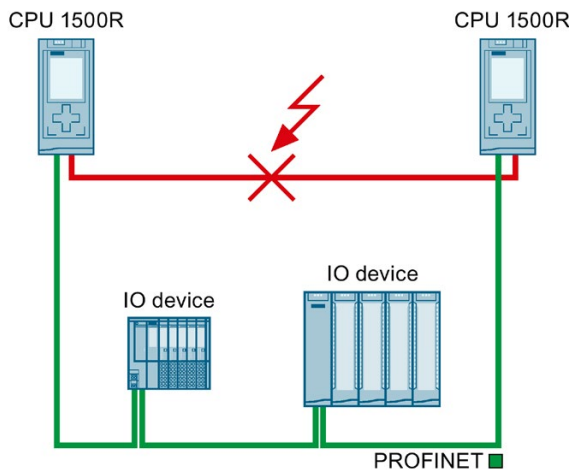
Conditions

- H-Sync Forwarding is not relevant for redundant S7-1500H systems. With the redundant S7-1500H system, the H-Sync frames are transmitted exclusively via the fiber-optic cables.
- **When you use PROFINET devices with more than two ports (e.g. switch) in the PROFINET ring of an R-system, these devices must support H-Sync Forwarding.**

H-Sync frames leave the PROFINET ring with a switch without H-Sync Forwarding. This results in an additional load on the network. Another serious result is that the redundancy of other R-systems in the network can fail or startup can be prevented.

- **H-Sync Forwarding is recommended if you are using PROFINET devices with only 2 ports in the PROFINET ring of an R-system.**

When you operate PROFINET devices without H-Sync Forwarding in the PROFINET ring of the redundant S7-1500R/H system, the following scenario will result in an additional cycle time increase:



1. The redundant S7-1500R system is in the RUN-Redundant system state.
2. The PROFINET cable which directly connects the two CPUs fails.
3. The PROFINET ring is interrupted.
4. The PROFINET ring is being reconfigured.
5. PROFINET devices without H-Sync Forwarding do not forward any H-Sync frames during the reconfiguration time of the PROFINET ring.
6. The cycle time increases by the reconfiguration time of the PROFINET ring.

Figure 6-1 Failure of the PROFINET cable between the CPUs

If the cyclic program exceeds the cycle monitoring time, the timeout OB (OB 80) can be started. Redundancy is lost if the time error OB (OB 80) is not present or the cycle time was exceeded twice with OB 80.

Note

If failure of the PROFINET cable that directly connects the two CPUs of the redundant S7-1500R system is unlikely, you can use PROFINET devices without H-Sync Forwarding in the PROFINET ring of the redundant S7-1500R system.

Example: Both CPUs of the redundant S7-1500R/H system are located next to each other in the control cabinet. In this case, it is unlikely that the PROFINET cable will fail.

6.3 System redundancy S2

Introduction

IO devices with S2 system redundancy enable uninterrupted process data exchange with the S7-1500R/H redundant system in the event of a CPU failure.

An IO device with system redundancy S2 supports system redundancy ARs. The system redundancy ARs can be present in duplicate (redundantly). Thus, an IO device supports ARs of 2 IO controllers simultaneously (with respect to the same modules).

A system redundancy AR can be either a primary AR or a backup AR. An IO device activates the data of the primary AR at the outputs. The data of the backup AR is only saved.

In STEP 7, you configure system redundancy S2 for an IO device by assigning the IO device to both CPUs of the S7-1500R/H redundant system.

Behavior in system state RUN-Redundant

Both CPUs are IO controllers. The PROFINET communication runs simultaneously on both system redundancy ARs, in each case between one of the CPUs (IO controllers) and the IO device. If the primary CPU now fails, the backup CPU becomes the primary CPU and, at the same time, the backup AR changes over to primary AR. The data of this AR becomes active at the outputs.

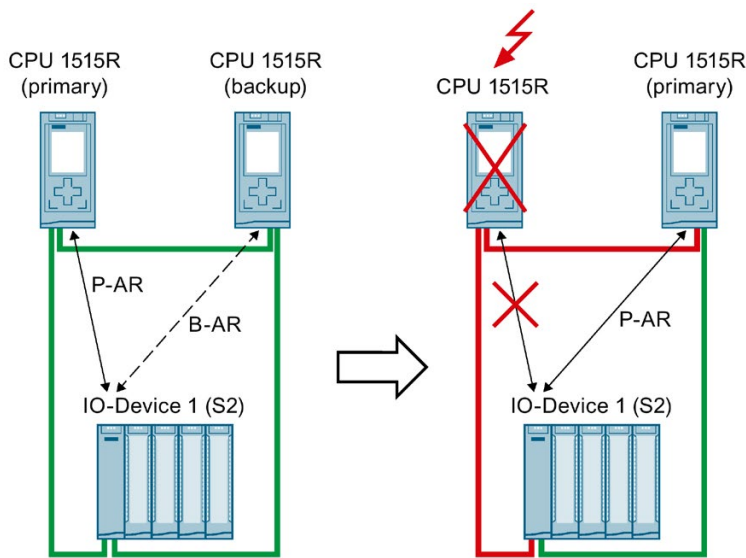


Figure 6-2 Primary backup AR

Behavior in system state RUN-Solo

Only the primary CPU is an IO controller. The PROFINET communication runs on the primary AR between the primary CPU (IO controller) and the IO device. There is no AR between the backup CPU and the IO device.

6.4 Switched S1 device

Introduction

As of firmware version V2.8, the S7-1500R/H redundant system supports the "Switched S1 device" function.

The "Switched S1 device" function of the CPU enables operation of standard IO devices on the S7-1500R/H redundant system.

Standard IO devices, too, are always assigned to both CPUs of the S7-1500R/H redundant system. In contrast to an IO device with S2 system redundancy, a standard IO device supports only one AR. The AR always exists only to the primary CPU of the S7-1500R/H redundant system.

In STEP 7 you configure an IO device connected via the "Switched S1 device" function by assigning a standard IO device to both CPUs of the redundant S7-1500R/H system.

Note

Standard IO devices in the redundant system S7-1500R

Standard IO devices usually do not support H-Sync Forwarding (Page 273).

To avoid a cycle time increase when the PROFINET ring is interrupted, integrate the standard IO devices behind a switch and not in the PROFINET ring.

Behavior in system state RUN-Redundant

PROFINET communication runs on the AR between the primary CPU (IO controller) and the standard IO device. There is no AR between the backup CPU and the standard IO device. If the primary CPU fails or is switched to STOP, the S7-1500R/H redundant system responds as follows:

- The AR between the primary CPU and the standard IO device is disconnected.
- The previous backup CPU becomes the new primary CPU.
- The S7-1500R/H redundant system temporarily has no access to the inputs and no control over the outputs of the standard IO device. During this time, the configured substitute value behavior applies to the standard IO device.
- The new primary CPU builds an AR to the standard IO device.

6.4 Switched S1 device

- As soon as the new primary CPU has set up the AR, the S7-1500R/H redundant system has access to the inputs again and control over the outputs of the standard IO device.

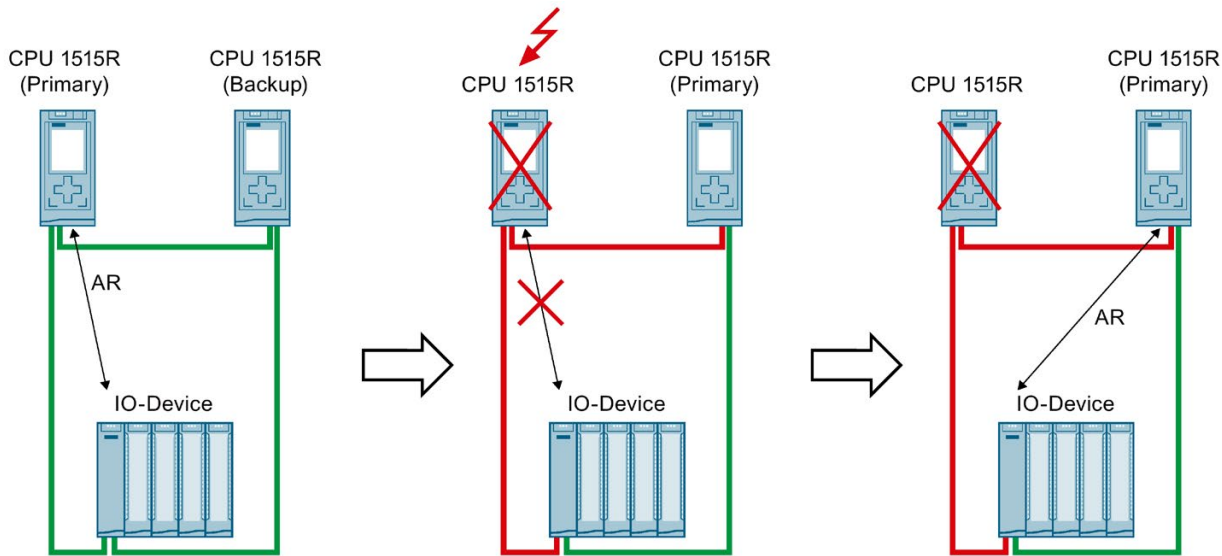


Figure 6-3 Behavior of standard IO devices in case of failure of the primary CPU

Behavior in system state RUN-Solo

Only the primary CPU is an IO controller. PROFINET communication runs on the AR between the primary CPU and the standard IO device. There is no AR between the backup CPU and the IO device.

OB behavior for standard IO devices with primary backup switching

If the primary CPU fails or goes to STOP, the standard IO devices temporarily fail. OB 72 "Redundancy error" is called, additional OB 86 "Module rack failure" for the failed IO devices are not called. To detect the failed IO devices, call the DeviceStates instruction in OB 72.

With the "Switched S1 device" function, the new primary CPU establishes the ARs to the standard IO devices again. OB 86 is called for each return of an IO device.

6.5 Main differences between IO device with S2 system redundancy and standard IO device

Table 6- 1 Main differences between IO device with S2 system redundancy and standard IO device

Property	IO device with S2 system redundancy	Standard IO device
Requirement for IO device	Device supports S2 system redundancy	-
Maximum simultaneously supported ARs with regard to the same modules	2	1
Behavior when replacing the primary CPU	Continuous connection with S7-1500R/H redundant system Process data is transferred further.	Temporary disconnection from S7-1500R/H redundant system. No process data is transferred until the standard IO device is available again. The status of the outputs depends on the substitute value behavior of the respective channels.

6.6 Installation guidelines

Configuration requirements for a ring topology with the redundant S7-1500R system

- The two CPUs have the media redundancy role "Manager (auto)".
- All other devices in the PROFINET ring have the media redundancy role "Client".
- No other redundant S7-1500R/H system is present in the PROFINET ring.
- Port interconnection:
 - The two CPUs are directly interconnected via one of the two ports of PROFINET interface X1. No other devices of the ring are located in between.
 - The two CPUs can be indirectly interconnected via the other two ports. The other devices of the ring are located in between. See the examples below.
- Max. number of IO devices: 64

Note

Standard IO devices in the redundant system S7-1500R

Standard IO devices usually do not support H-Sync Forwarding.

To avoid a cycle time increase when the PROFINET ring is interrupted, integrate the standard IO devices behind a switch and not in the PROFINET ring.

- Number of PROFINET devices (IO devices, switches, S7-1500R CPUs, S7-1500 CPUs (V2.5 or later) and HMI devices) in the PROFINET ring:
 - Max. 50 (recommended: max. 16)

Note

Recommendation: The number of devices in the PROFINET ring influences the availability of the S7-1500R system. The number of PROFINET devices including R-CPU's in the PROFINET ring should not exceed 16. If you operate significantly more devices in the PROFINET ring, the availability of the IO devices and R-CPU's is reduced. The technical specifications in the documentation are based on the recommended maximum of 16 PROFINET devices in the ring in S7-1500R.

Configuration requirements for a ring topology with the redundant S7-1500H system

- The two CPUs have the media redundancy role "Manager (auto)".
- All other devices in the PROFINET ring have the media redundancy role "Client".
- No other redundant S7-1500R/H system is present in the PROFINET ring.

6.7 Configuring PROFINET IO on a redundant S7-1500R/H system

PROFINET IO configurations with the redundant S7-1500R/H system

The following figures show you examples of PROFINET IO configurations with the redundant S7-1500R/H system.

All the figures use the following abbreviations for AR:

- SR-AR: System redundancy AR between an IO device (S2) and one of the CPUs of the redundant S7-1500R/H system
- AR: "normal" AR between a standard IO device and the associated IO controller

All configurations use the CPU 1515R as an example. The PROFINET configurations shown also work with the CPU 1513R and CPU 1517H.

IO devices in the PROFINET ring

The redundant S7-1500R system consists of the two CPUs 1515R and two IO devices in the PROFINET ring. The IO devices support system redundancy S2, media redundancy and H-Sync Forwarding.

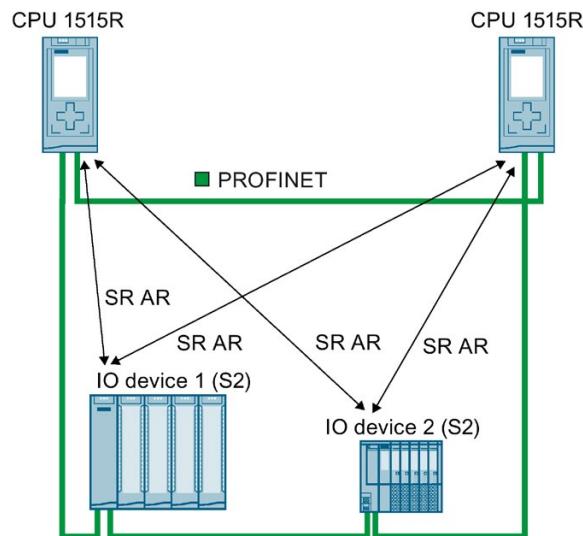


Figure 6-4 Example of a S7-1500R redundant system with two IO devices in the PROFINET ring

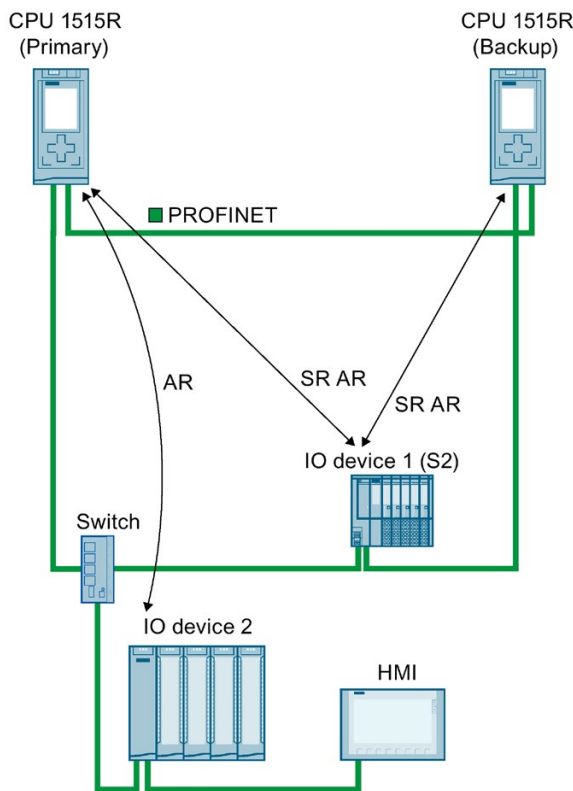
PROFINET devices downstream of a switch

To connect additional PROFINET devices to the PROFINET ring, use a switch. For the redundant S7-1500R system, ensure that a switch in the PROFINET ring supports H-SYNC Forwarding in addition to MRP.

You connect the following devices to the PROFINET ring with a switch.

- PROFINET devices with one port
- Non MRP-capable PROFINET devices
- PROFINET devices that do not support H-Sync Forwarding, such as standard IO devices.

The following figure shows a redundant S7-1500R system with connected PROFINET devices downstream of a switch.



- IO device 1 (S2)** IO device 1 is located in the PROFINET ring. The IO device 1 supports system redundancy S2, MRP and H-Sync Forwarding.
- Switch** The switch is located in the PROFINET ring. The switch supports MRP and H-SYNC Forwarding.
- IO device 2** IO device 2 is connected to the PROFINET ring via the switch. IO device 2 is a standard IO device that is connected to the redundant S7-1500R system via the "Switched S1 device" function.
- HMI device** The HMI device is connected to the PROFINET ring via the switch.

Figure 6-5 PROFINET devices downstream of a switch

Additional PROFINET IO system in the configuration

The configuration can also contain additional IO controllers with their own IO devices. To ensure that enough bandwidth is available in the PROFINET ring for the redundant S7-1500R/H system, place additional IO controllers with their I/O downstream of a switch.

When determining the maximum number of IO devices inside and outside the PROFINET ring, the redundant system does not detect the S7-1500 CPUs and their IO devices. If you use S7-1500 CPUs, you must check the maximum number yourself.

The following figure shows a redundant S7-1515R system. An additional PROFINET IO system with a CPU 1516 as IO controller is located downstream of the switch. A separate standard IO device has been assigned to the IO controller.

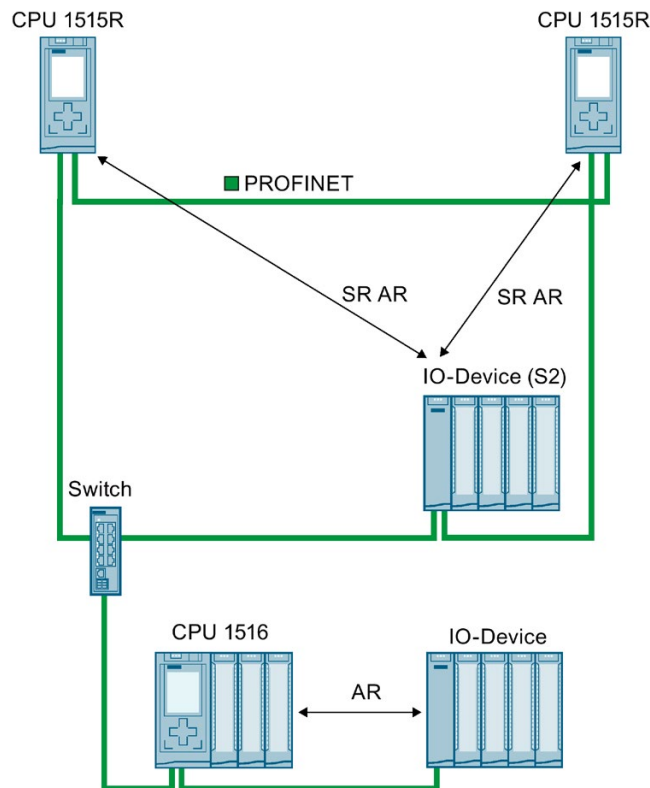


Figure 6-6 Example of a redundant S7-1500R system with an additional PROFINET IO system

6.7 Configuring PROFINET IO on a redundant S7-1500R/H system

Additional IO controllers can also be connected as I-device to the redundant S7-1500R/H system. An I-device is connected like a standard IO device to the redundant S7-1500R/H system.

The redundant S7-1500R/H system supports the use of I-devices only via GSD file and as standard IO device.

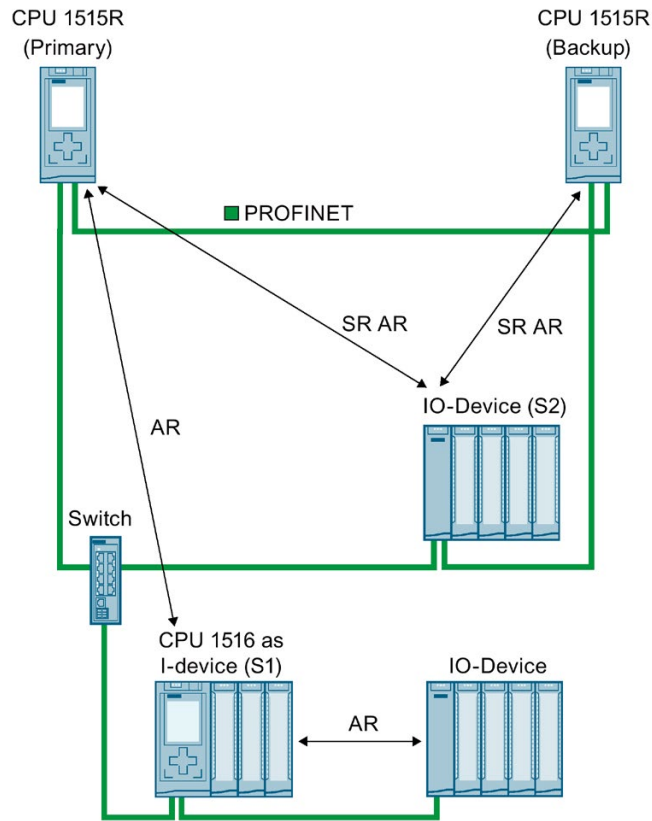


Figure 6-7 I-device downstream of a switch

Connection to another PROFINET IO system via the PN/PN coupler

The redundant S7-1500R/H system cyclically exchanges IO data with another PROFINET IO system via a PN/PN coupler.

In the following figure, the PN/PN coupler connects a redundant S7-1515R system to another PROFINET IO system. The left side of the PN/PN coupler is assigned to the redundant S7-1515R system. The assignment is system-redundant and media-redundant. The right side of the PN/PN coupler is assigned to the CPU 1516 (IO controller). The PROFINET IO system of the CPU 1516 has no redundancy in this example.

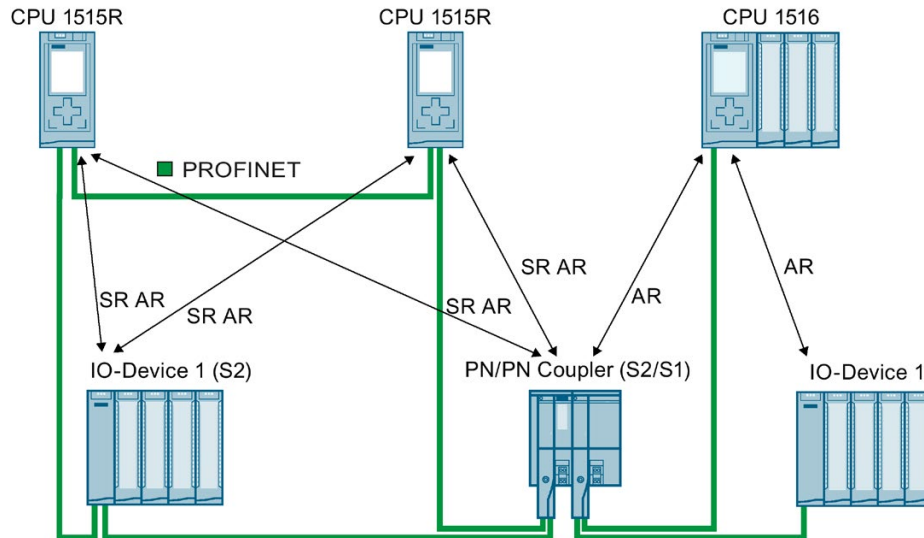


Figure 6-8 Configuration with the PN/PN coupler with one-sided system redundancy (S2/S1)

Connection to an additional redundant S7-1500R/H system via the PN/PN coupler

Two redundant S7-1500R/H systems cyclically exchange IO data via the PN/PN coupler.

In the following figure, the PN/PN coupler connects two redundant S7-1515R systems to each other. Each of the two PN/PN coupler sides are assigned to a redundant S7-1515R system. Each of the two sides of the PN/PN coupler are connected to the respective redundant S7-1515R system in a system-redundant and media-redundant manner.

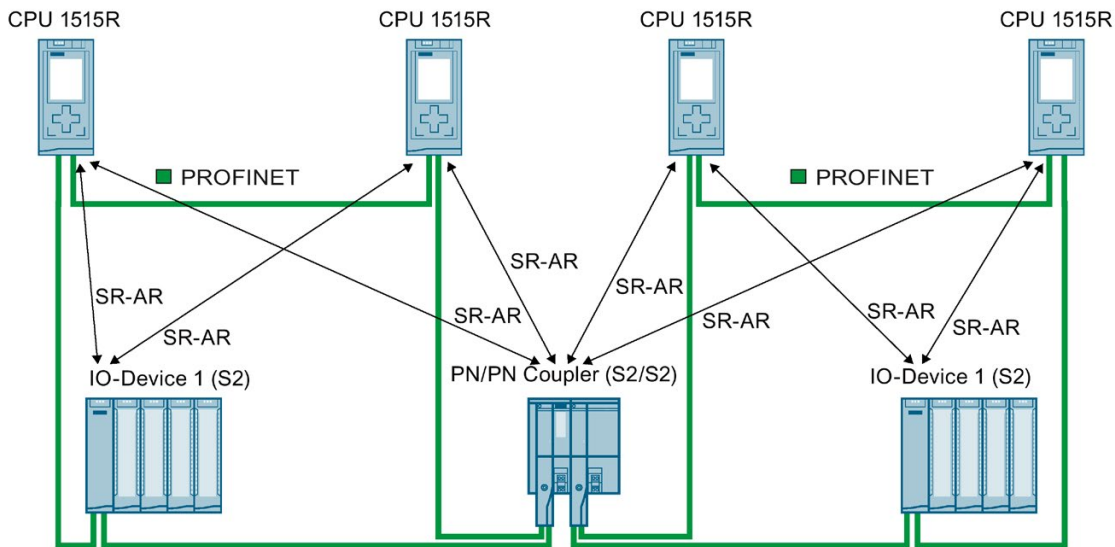


Figure 6-9 Configuration with the PN/PN coupler with two-sided system redundancy (S2/S2)

Reference

You can find more information on the PN/PN coupler in the PN/PN Coupler (<https://support.industry.siemens.com/cs/ww/en/view/44319532>) manual.

6.8 Assigning IO device to the redundant S7-1500R/H system

Requirements

- Redundant S7-1500R/H system
- IO device:
 - As of firmware version V2.8, the redundant S7-1500R/H system supports IO devices with system redundancy S2 and standard IO devices.
 - The redundant S7-1500R/H system with firmware version before V2.8 only supports IO devices with system redundancy S2, e.g. IM 155-6 PN HF as of firmware version V4.2.

Procedure

To assign an IO device to the redundant S7-1500R/H system, follow these steps:

1. In the network view of STEP 7, select the PROFINET interface of the IO device.
2. Using drag-and-drop, draw a line between the PROFINET interface of the IO device and the PROFINET interface X1 of the left CPU.

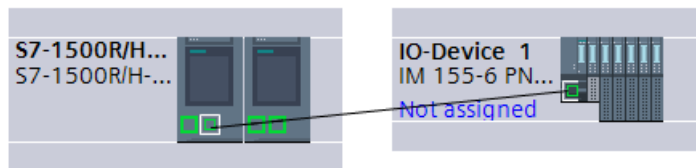


Figure 6-10 Assigning IO device to the left CPU

The IO device is assigned to the left CPU.

3. Using drag-and-drop, draw a line between the PROFINET interface of the IO device and the PROFINET interface X1 of the right CPU.

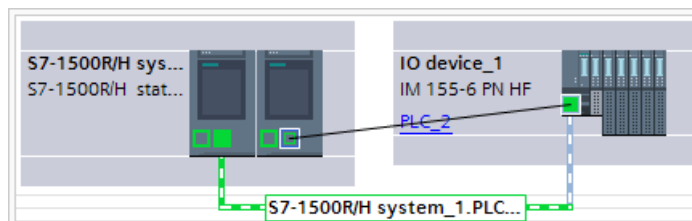


Figure 6-11 Assigning IO device to the right CPU

Result: The IO device is connected to the redundant S7-1500R/H system.

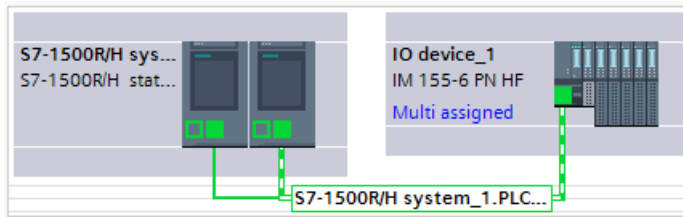


Figure 6-12 Assigned IO device

Note

I-device as standard IO device

You cannot assign a device that you configured in STEP 7 as an I-device to the S7-1500R/H redundant system.

In order to operate an I-device as a standard IO device on the S7-1500R/H redundant system, always configure the I-device via **GSD file**.

- SIMATIC CPU as I-device
 - First, configure the SIMATIC CPU in STEP 7 as an I-device with all transfer areas.
 - Export the I-device as a GSD file. The GSD export can be found in the properties of the PROFINET interface under "Operating mode" > "I-device communication" > "Export Generic System Description file (GSD)".
 - Install the GSD file in STEP 7.
- HMI device as I-device ("Direct key" function)
 - The GSD files for SIMATIC Comfort Panel and SIMATIC Mobile Panel can be found in this application example (<https://support.industry.siemens.com/cs/ww/en/view/73502293>).

Assign the device configured via GSD file to the S7-1500R/H redundant system.

Display of the IO device assignments in STEP 7

Regardless of whether an IO device is connected as system redundant or as standard IO device to the redundant S7-1500R/H system, the network view always shows "Multi assigned".

To determine which IO devices are connected system redundant and which ones are connected as standard IO devices, follow these steps:

1. In the network view of STEP 7, select the redundant S7-1500R/H system.
2. In the tabular view of the network view switch to "I/O communication".

The table contains all assignments of IO devices to the PROFINET interfaces of the redundant S7-1500R/H system.

The "Operating mode" column shows how the IO device is connected to the redundant S7-1500R/H system:

- IO device (S2): IO device is connected system redundant.
- IO device (S1): IO device is connected over the "Switched S1 device" function.

	Partner 1	↔ Partner 2	Interface partner 2	Mode
1	▼ PLC_1			
2	▼ PROFINET-Schnittstelle_1			
3	X1	↔ IO-Device_1	PROFINET-Schnittstelle	IO-Device(S2)
4	X1	↔ IO-Device_2	PROFINET-Schnittstelle	IO-Device(S1)
5	▼ PLC_2			
6	▼ PROFINET-Schnittstelle_1			
7	X1	↔ IO-Device_1	PROFINET-Schnittstelle	IO-Device(S2)
8	X1	↔ IO-Device_2	PROFINET-Schnittstelle	IO-Device(S1)
9				

Figure 6-13 Display of the IO device assignments in STEP 7

6.9 Configuring media redundancy (MRP) for a configuration with the redundant S7-1500R/H system

Requirements

- Redundant S7-1500R/H system
- All devices in the ring support the media redundancy protocol MRP.
- IO devices are assigned to the redundant S7-1500R/H system.

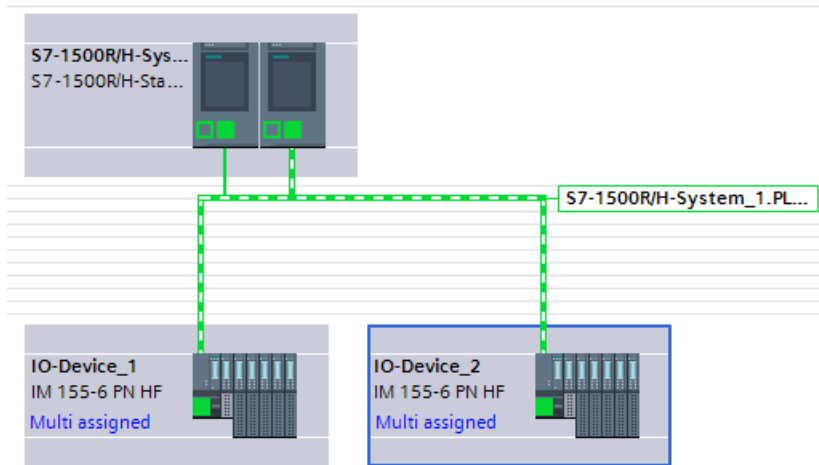


Figure 6-14 Example configuration: Configuring MRP for S7-1500R/H

MRP role of the CPUs of the redundant S7-1500R/H system

As soon as you create a redundant S7-1500R/H system in STEP 7, STEP 7 automatically assigns the MRP role "Manager (auto)" to the PROFINET interfaces X1 of both CPUs.

Defining the MRP role for additional devices of the ring in STEP 7

To specify the media redundancy for additional devices in the ring, follow these steps:

1. In the network view of STEP 7, select the PROFINET interface X1 of one of the two CPUs of the redundant S7-1500R/H system.
2. In the Inspector window navigate to "Properties" > "General" > "Advanced options" > "Media redundancy".

3. Click the "Domain settings" button.

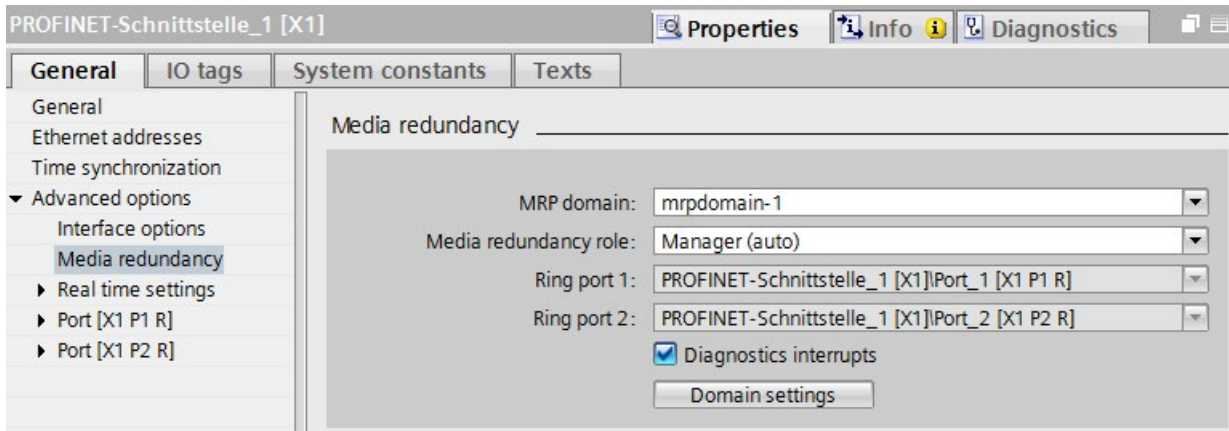


Figure 6-15 S7-1500R/H: MRP role "Manager (auto)"

In the Inspector window, STEP 7 displays the properties of the MRP domain in which the PROFINET interface X1 of the CPU is located.

4. In the "MRP role" column of the "Devices" table, assign the MRP role "Client" to all the other devices of the ring.

Devices					
	PROFINET device name	MRP domain:	MRP role	Ring port 1	Ring port 2
1	io-device_1	mrpdomain-1	Client	Port_1 [X1 P1 R]	Port_2 [X1 P2 R]
2	io-device_2	mrpdomain-1	Client	Port_1 [X1 P1 R]	Port_2 [X1 P2 R]
3	plc_1.profinet-schnittstel..	mrpdomain-1	Manager (auto)	Port_1 [X1 P1 R]	Port_2 [X1 P2 R]

Figure 6-16 S7-1500R/H: Assigning MRP roles for ring devices

Parameter assignment for devices outside the STEP 7 project

- Set the MRP role "Client" for the devices of the ring that are not located in STEP 7.
Example: For a switch in the PROFINET ring, set the MRP role "Client" via the Web interface of the switch.
- For PROFINET devices outside of the ring, set the MRP role to "Not device in the ring".
Example: For a router outside of the PROFINET ring, set the MRP role "Not device in the ring" via the Web interface of the router.

Glossary

API

API (**A**pplication **P**rocess **I**dentifier) is a parameter, the value of which specifies the IO data processing process (application).

The PROFINET standard IEC 61158 assigns profiles to specific APIs (PROFIdrive, PROFIsave), which are defined by the PROFINET user organization.

The standard API is 0.

Application

An application is a program that runs directly on the MS-DOS/Windows operating system. An application on the PG is STEP 7, for example.

AR

The AR (**A**pplication **R**elation) comprises all the communication relationships between IO controller and IO device (e.g. IO data, data records, interrupts).

AR is also an addressing level for diagnostic data records.

Asset

An asset is a component of a machine or plant This can be either hardware or software/firmware.

Automation system

Programmable logic controller for the open-loop and closed-loop control of process chains of the process engineering industry and manufacturing technology. The automation system consists of different components and integrated system functions according to the automation task.

Backplane bus

The backplane bus is a serial data bus for module intercommunication and the distribution of the necessary power to the modules. Bus connectors interconnect the modules.

Backup AR

The backup AR is the system redundancy AR between an IO device with system redundancy S2 and the backup CPU of the redundant S7-1500R/H system.

Backup CPU

If the R/H system is in RUN-Redundant system state, the primary CPU controls the process. The backup CPU synchronously executes the user program and can take over the process control on failure of the primary CPU.

Bus

A bus is a transfer medium that interconnects several devices. Data transmission can be performed electrically or via optical fibers, either in series or in parallel.

Communications Cycle and Reservation of Transmission Bandwidth

PROFINET IO is a scalable real-time communication system based on the Layer 2 protocol for Fast Ethernet. With the RT transmission method, two real-time-support performance levels are available for time-critical process data and IRT for high-accuracy and also isochronous processes .

Communications processor

Communication processors are modules used for point-to-point and bus connections.

Configuring

Selecting and putting together individual components of an automation system or installing necessary software and adapting it for a specific application (for example, by configuring the modules).

Consistent data

Data which belongs together in terms of content and must not be separated is known as consistent data.

For example, the values of analog modules must always be handled as a whole, that is, the value of an analog module must not be corrupted as a result of reading out at two different points in time.

CP

→ *Communications processor*

CPU

Central Processing Unit - Central module of the S7 automation system with a control and arithmetic unit, memory, operating system and interface for programming device.

DCP

DCP (**D**iscovery and **B**asic **C**onfiguration **P**rotocol). Enables the assignment of device parameters (for example, the IP address) using manufacturer-specific configuration/programming tools.

Default router

The default router is used when data has to be forwarded via TCP/IP to a partner located outside the local network.

Determinism

Determinism means that a system responds in a predictable (deterministic) manner.

Device

In the PROFINET environment, "device" is the generic term for:

- Automation systems (for example, PLC, PC)
- Distributed I/O systems
- Field devices (for example, PLC, PC, hydraulic devices, pneumatic devices)
- Active network components (for example, switches, routers)
- Gateways to PROFIBUS, AS interface or other fieldbus systems

Device name (PROFINET device name)

In the PROFINET IO environment, the device name is a unique identifier for the PROFINET IO interface of a device.

Diagnostics

→ *System diagnostics*

Diagnostics buffer

The diagnostics buffer represents a backup memory in the CPU, used to store diagnostics events in their order of occurrence.

Diagnostics error interrupt

Modules capable of diagnostics operations report detected system errors to the CPU by means of diagnostics interrupts.

→ *See also CPU*

Direct data exchange

In the case of direct data exchange, an S7-1500 CPU provides cyclic user data from the I/O area to one or more partners.

The direct data exchange function enables deterministic, isochronous I/O communication between multiple S7-1500 CPUs.

DP master

A master which behaves in accordance with EN 50170, Part 3, is known as a DP master.

→ *See also Master*

DP slave

A slave operated on PROFIBUS with PROFIBUS DP protocol and in accordance with EN 50170, Part 3 is referred to as DP slave.

→ *See also Slave*

DPV1

The designation DPV1 refers to the functional extension of acyclic services (to include new interrupts, for example) provided by the DP protocol. The DPV1 functionality is integrated in IEC 61158/EN 50170, Volume 2, PROFIBUS.

Duplex

Half duplex: One channel is available for alternating exchange of information.

Full duplex: Two channels are available for simultaneous exchange of information in both directions.

Ethernet

Ethernet is an international standard technology for local area networks (LAN) based on frames. It defines types of cables and signaling for the physical layer and packet formats and protocols for media access control.

GSD file

As a Generic Station Description, this file contains all properties of a PROFINET device that are necessary for its configuration in XML format.

H-Sync Forwarding

H-Sync Forwarding enables a PROFINET device with MRP to forward synchronization data (synchronization frames) of a S7-1500R redundant system only within the PROFINET ring.

In addition, H-Sync Forwarding forwards the synchronization data even during reconfiguration of the PROFINET ring. H-Sync Forwarding avoids a cycle time increase if the PROFINET ring is interrupted.

S7-1500R: H-Sync Forwarding is recommended for all PROFINET devices with only two ports in the PROFINET ring. All PROFINET devices with more than two ports (e.g. switch) in the PROFINET ring must support H-Sync forwarding.

S7-1500H: H-Sync Forwarding is not relevant for redundant S7-1500H systems.

I-device

The "I-device" (intelligent IO device) functionality of a CPU facilitates data exchange with an IO controller, for example, as intelligent preprocessing unit of sub-processes. In its role as an IO device, the I-device is accordingly integrated into a "higher-level" IO controller.

Industrial Ethernet

Industrial Ethernet is a guideline for installing an Ethernet in an industrial environment. The biggest difference from standard Ethernet is the mechanical current carrying capacity and noise immunity of the individual components.

Interrupt

An interrupt is an event that causes the operating system of an S7-CPU to automatically call an assigned organization block (interrupt OB) in which the user can program the desired reaction.

Interrupt, diagnostics

→ *Diagnostics error interrupt*

IP address

To allow a PROFINET device to be addressed as a device on Industrial Ethernet, this device also requires an IP address that is unique within the network. Example: An IPv4 address consists of 4 decimal numbers with the value range 0 to 255. The decimal numbers are separated by periods.

The IP address is made up of the following components:

- Address of the network
- Address of the device (generally called the host or network node).

IRT

IRT is a synchronized communication protocol for cyclic exchange of IRT data between PROFINET devices. A reserved bandwidth is available in the send cycle for IRT data. The reserved bandwidth ensures that the IRT data can be transferred at reserved synchronized intervals, without being influenced also by higher other network loads (such as TCP/IP communication, or additional real-time communication).

LAN

Local Area Network - a local network to which multiple computers within a company are connected. The LAN therefore has a limited geographical span and is only available to the company or institution.

Line depth

Designates the number of external switches or integrated switches interconnected in series.

MAC address

Worldwide unique device identification for all Ethernet devices. It is assigned by the manufacturer and has a 3-byte vendor ID and 3-byte device ID as a consecutive number.

Every PROFINET device is assigned a worldwide unique device identifier at the factory. This 6-byte long device identifier is the MAC address.

Maintenance Required / Maintenance Demanded

A "Maintenance required" system message can be defined for different wear parameters and an inspection of a component can be recommended, for example, when a certain number of operating hours has elapsed.

The "Maintenance demanded" alarm is sent when the part involved needs to be replaced within a foreseeable period.

(Example printer: The maintenance demanded alarm is sent when the ink/printer cartridges have to be replaced immediately.)

Master

Higher-level, active participant in the communication/on a PROFIBUS subnet. It has rights to access the bus (token), sends data and requests it.

Media redundancy

The so-called **Media Redundancy Protocol (MRP)** enables the configuration of redundant networks. Redundant transmission links (ring topology) ensure that an alternating communication path is made available if a transmission link fails. The PROFINET devices that are a part of this redundant network form an MRP domain.

Micro Memory Card (MMC)

Micro Memory Cards are memory media for CPUs and CPs. Their only difference to the SIMATIC memory card is the smaller size. S7-1500 and ET 200SP-CPU use SIMATIC memory cards.

MPI

The multipoint interface (**M**ulti **P**oint Interface, MPI) represents the programming device interface of SIMATIC S7. It enables multiple devices (programming devices, text-based displays, OPs) to be operated simultaneously by one or more CPUs. Each device is identified by its unique (MPI) address.

MRPD

MRPD (**M**edia **R**edundancy with **P**lanned **D**uplication of **F**rames) based on IRT and MRP. To realize media redundancy with short update times, the PROFINET devices participating in the ring send their data in both directions. The devices receive this data at both ring ports so that there is no reconfiguration time.

Network

A network consists of one or more interconnected subnets with any number of devices. Several networks can exist alongside each other.

OB

→ *Organization block*

OPC

OPC (OLE for Process Control) refers to a standard interface for communication in automation technology.

Operating states

Operating states describe the behavior of a single CPU at a specific time.

The CPUs of the SIMATIC standard systems feature the STOP, STARTUP and RUN operating states.

The primary CPU of the S7-1500R/H redundant system has the operating states STOP, STARTUP, RUN, RUN-Syncup and RUN-Redundant. The backup CPU has the operating states STOP, SYNCUP and RUN-Redundant.

Organization block

Organization blocks (OBs) form the interface between the CPU operating system and the user program. The order in which the user program is executed is defined in the organization blocks.

Parameter

1. Tag of a STEP 7 code block:
2. Tag used to set one or several characteristics of a module

In delivery state, every module has practical basic settings, which can be modified by configuration in STEP 7.

There are static and dynamic parameters

PG

→ *Programming device*

PLC

→ *Programmable logic controller*

Primary AR

The primary AR is the system redundancy AR between an IO device with system redundancy S2 and the primary CPU of the redundant S7-1500R/H system.

Primary CPU

If at least one R/H CPU is in RUN state, the primary CPU is the controlling CPU. The primary CPU controls the process (productive data).

The user program is executed identically in the primary CPU and the backup CPU.

Prioritized startup

Prioritized startup denotes the PROFINET functionality for accelerating the startup of IO devices operated on a PROFINET IO system with RT and IRT communication. It reduces the time that the correspondingly configured IO devices require in order to return to cyclic user data exchange in the following cases:

- After the power supply has returned
- After a station has returned
- After activation of IO devices

Process image (I/O)

The CPU transfers the values from the input and output modules to this memory area. At the start of the cyclic program, the CPU transfers the process image output as a signal state to the output modules. The CPU then transfers the signal states of the input modules to the process image of the inputs. Then the CPU executes the user program.

PROFIBUS

Process Field Bus - European Fieldbus standard.

PROFIBUS device

A PROFIBUS device has at least one PROFIBUS interface with an electrical (RS485) or optical (polymer optical fiber, POF) interface.

PROFIBUS DP

A PROFIBUS with DP protocol that complies with EN 50170. DP stands for distributed I/O (fast, real-time capable, cyclic data exchange). From the perspective of the user program, the distributed I/Os are addressed in exactly the same way as the centralized I/Os.

PROFIBUS Users Organization

Technical committee dedicated to the definition and development of the PROFIBUS and PROFINET standard. Additional information can be found on the Internet (Page).

PROFInergy

Function for energy saving in the process, for example, during pause times by briefly switching off the entire system via standardized PROFInergy commands.

PROFINET

Open component-based industrial communication system based on Ethernet for distributed automation systems. Communication technology promoted by the PROFIBUS Users Organization.

PROFINET device

A PROFINET device always has a PROFINET interface (electrical, optical, wireless). A lot of devices also have a PROFIBUS DP interface to connect PROFIBUS devices.

PROFINET IO

Communication concept for the realization of modular, distributed applications within the scope of PROFINET.

PROFINET IO is based on switched Ethernet with full-duplex operation and a bandwidth of 100 Mbps.

PROFINET IO Controller

Device used to address the connected IO devices. This means that the IO controller exchanges input and output signals with assigned field devices. The IO controller is often the controller on which the automation program runs.

PROFINET IO Device

A distributed field device that is assigned to one of the IO controllers (e.g. remote IO, valve terminals, frequency converters, switches)

PROFINET IO System

PROFINET IO controller with assigned PROFINET IO devices.

PROFINET ring

Structure of a network. Common structures include:

- Linear bus topology
- Ring topology
- Star topology
- Tree topology

Programmable logic controller

Programmable logic controllers (PLCs) are electronic controllers whose function is stored as a program in the control unit. The structure and wiring of the device does not therefore depend on the controller's function. A programmable logic controller is structured like a computer. It consists of a CPU with memory, input/output modules and an internal bus system. The IOs and the programming language are oriented to the requirements of the control technology.

Programming device

Programming devices are essentially compact and portable PCs which are suitable for industrial applications. They are identified by a special hardware and software configuration for programmable logic controllers.

Proxy

The PROFINET device with proxy functionality is the substitute for a PROFIBUS device on Ethernet. The proxy functionality allows a PROFIBUS device to communicate not only with its master but also with all devices on PROFINET.

With PROFINET, existing PROFIBUS systems can be integrated into the PROFINET communication with the aid of an IE/PB link, for example. The IE/PB Link PN IO then handles communication via PROFINET on behalf of the PROFIBUS components.

In this way, you can link both DPV0 and DPV1 slaves to PROFINET.

Real-time

Real-time means that a system processes external events within a defined time.

Real-time communication

Group error for RT and IRT.

PROFINET uses its own real-time channel (RT) rather than TCP/IP for communication of time-critical IO user data.

Redundant systems

Redundant systems are characterized by the fact that important automation components are present multiple times (redundantly). Process control is maintained if a redundant component fails.

Router

A router interconnects two subnets. A router works in a similar way to a switch. With a router, however, you can also specify which communication devices may communicate via the router and which may not. The communication devices on various sides of a router can only communicate with one another if you have explicitly enabled communication between these devices via the router. Real-time data cannot be exchanged beyond subnet boundaries.

RT

PROFINET IO with Real Time communication (RT) is the optimal transmission method for time-critical applications in factory automation. PROFINET IO frames are prioritized over standard frames in accordance with IEEE802.1Q. This ensures the required determinism in the automation technology.

Security

Generic term for all the measures taken to protect against

- Loss of confidentiality due to unauthorized access to data
- Loss of integrity due to manipulation of data
- Loss of availability due to the destruction of data

Send clock

Period between two consecutive intervals for IRT or RT communication. The send clock is the shortest possible transmit interval for exchanging data.

SIMATIC

The term denotes Siemens AG products and systems for industrial automation.

SIMATIC NET

Siemens Industrial Communication division for Networks and Network Components.

SIMATIC PC Station

A "PC station" is a PC with communication modules and software components within a SIMATIC automation solution.

SIMATIC Memory Card (SMC)

→ *Micro Memory Card (MMC)*

Slave

A slave can only exchange data after being requested to do so by the master.

→ *See also DP slave*

SNMP

The network management protocol SNMP (**S**imple **N**etwork **M**anagement **P**rotocol) uses the wireless UDP transport protocol. It consists of two network components, similar to the client/server model. The SNMP manager monitors the network nodes and the SNMP agents collect the various network-specific information in the individual network nodes and stores it in a structured form in the MIB (**M**anagement **I**nformation **B**ase). This information allows a network management system to run detailed network diagnostics.

STEP 7

STEP 7 is an engineering system and contains programming software for the creation of user programs for SIMATIC S7 controllers.

Subnet

All the devices interconnected by switches are nodes of the same network or subnet. All the devices in a subnet can communicate directly with each other.

All devices in the same subnet have the same subnet mask.

A subnet is physically restricted by a router.

Subnet mask

The bits set in the subnet mask decide the part of the IP address that contains the address of the network.

In general, the following applies:

- The network address is obtained from the AND operation of the IP address and subnet mask.
- The device address is obtained from the AND NOT operation of the IP address and subnet mask.

Switch

Network components used to connect several terminal devices or network segments in a local network (LAN).

Switched S1 device

The "Switched S1 device" function of the CPU enables operation of standard IO devices on the S7-1500R/H redundant system.

PROFINET communication runs on an AR between the primary CPU and the standard IO device. When replacing the primary CPU, the standard IO device is briefly disconnected from the S7-1500R/H redundant system until the new primary CPU has set up an AR to the standard IO device.

Sync domain

All PROFINET devices to be synchronized with IRT via PROFINET IO must belong to a sync domain.

The sync domain consists of exactly one sync master and at least one sync slave. An IO controller or switch generally handles the role of the sync master.

Non-synchronized PROFINET devices are not part of a sync domain.

System diagnostics

System diagnostics refers to the detection, evaluation, and signaling of errors that occur within the automation system, for example, programming errors or module failures. System errors can be indicated by LEDs or in STEP 7.

System redundancy AR

In a redundant system, an IO device with system redundancy S2 has a system redundancy AR with each of the two CPUs (IO controllers).

System states

The system states of the redundant S7-1500R/H system result from the operating states of the primary and backup CPUs. The concept of the system state is used to obtain a simplified expression that characterizes the simultaneously occurring operating states of the two CPUs. The following system states are available for the redundant S7-1500R/H system: STOP, STARTUP, RUN-Solo, SYNCUP and RUN-Redundant.

TCP/IP

The Ethernet itself is only a transport system for data - similar to a highway, which is a transport system for people and goods. The actual data transport is performed by so-called protocols - similar to cars and trucks, which transport people and goods on the highway.

The two basic protocols TCP (Transmission Control Protocol) and IP (Internet Protocol) - TCP/IP for short - perform the following tasks:

1. The data is broken down into packets at the sender.
2. The packets are transported over the Ethernet to the correct recipient.
3. At the recipient, the packets are reassembled in the correct order.
4. Corrupt packets continue to be sent until they are received correctly.

Most higher-level protocols use TCP/IP to perform their duties. Hyper Text Transfer Protocol (HTTP), for example transfers documents written in Hyper Text Markup Language (HTML) in the World Wide Web (WWW). This technique is what enables you to view web pages in your Internet browser in the first place.

Topology configuration

All the interconnected ports of the PROFINET devices in the STEP 7 project and their relationships to each other.

Twisted-pair

Fast Ethernet via twisted-pair cables is based on the IEEE 802.3u standard (100 Base-TX). The transmission medium is a shielded 2x2 twisted-pair cable with an impedance of 100 Ω (AWG 22). The transmission characteristics of this cable must meet the requirements of category 5.

The maximum length of the connection between the terminal and the network component must not exceed 100 m. The connectors are designed according to the 100Base-TX standard with the RJ45 connector system.

Update time

An IO device / IO controller in the PROFINET IO system is supplied cyclically with new data from the IO controller / IO device within this time interval. The update time can be configured separately for each IO device and determines the interval at which data is sent from the IO controller to the IO device (outputs) as well as from the IO device to the IO controller (inputs).

User program

In SIMATIC, we distinguish between the CPU operating system and user programs. The user program contains all instructions, declarations and data by which a plant or process can be controlled. The user program is assigned to a programmable module (for example, CPU, CM) and can be structured in smaller units.

WAN

A network that extends beyond LAN boundaries and enables, for example, intercontinental network communication. Legal rights do not belong to the user but to the provider of the communication network.

XML

XML (**Extensible Markup Language**) is a flexible, easy to understand and easy to learn data description language. Information is exchanged using readable XML documents. These include continuous text supplemented by structure information.

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SIEMENS

SIMATIC

PROFIBUS PROFIBUS with STEP 7 V13

Function Manual

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Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

Trademarks

All names identified by ® are registered trademarks of Siemens AG. The remaining trademarks in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owner.

Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the manual

This function manual provides an overview of the PROFIBUS communication system with SIMATIC STEP 7 V13.

STEP 7 V13 is integrated into the powerful graphic Totally Integrated Automation Portal (TIA Portal), the new integration platform for all automation software tools.

This function manual supports you in planning a PROFIBUS system. The manual is structured into the following subject areas:

- PROFIBUS basics
- PROFIBUS diagnostics
- PROFIBUS functions

Basic knowledge required

The following knowledge is required in order to understand the manual:

- General knowledge of automation technology
- Knowledge of the industrial automation system SIMATIC
- Knowledge about the use of Windows-based computers
- Proficiency with STEP 7

Scope

This function manual is the basic documentation for all SIMATIC products from the PROFIBUS environment. The product documentation is based on this documentation.

The examples are based on the functionality of the S7-1500 automation system.

Changes compared to previous version

As compared to the previous version (version 07/2014), this manual contains the following amendments/changes:

- Extension of the documentation to STEP 7 (TIA Portal) V13 SP1
- Addition of the function Intelligent DP slaves (I-slaves)
- New guide

Conventions

STEP 7: We refer to "STEP 7" in this documentation as a synonym for the configuration and programming software "STEP 7 as of V12 (TIA Portal)" and subsequent versions.

This documentation contains figures of the devices described. The figures may differ slightly from the device supplied.

You should also pay particular attention to notes such as the one shown below:

Note

A note contains important information on the product described in the documentation, on the handling of the product or on the section of the documentation to which particular attention should be paid.

Additional support

You will find information about available technical support in the appendix Service & Support (Page 91).

The technical documentation for the individual SIMATIC products and systems is available on the Internet (<http://www.siemens.com/simatic-tech-doku-portal>).

The online catalog and the ordering system are available on the Internet (<http://mall.industry.siemens.com>).

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (<http://www.siemens.com/industrialsecurity>).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (<http://support.automation.siemens.com>).

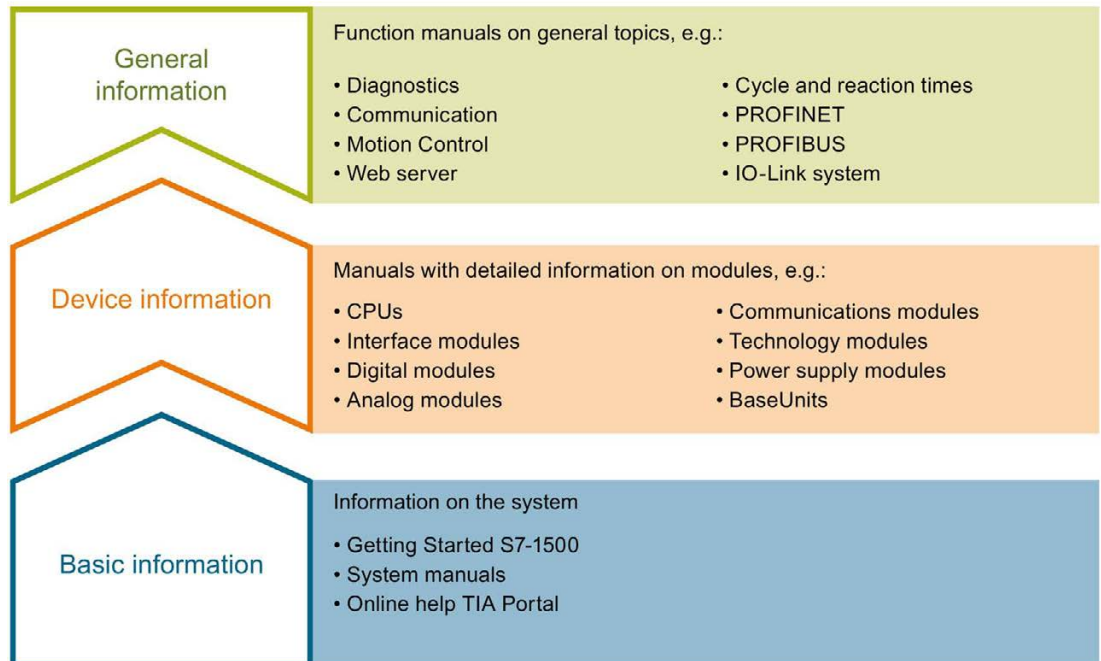
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Documentation guide

The documentation for the SIMATIC S7-1500 automation system and the SIMATIC ET 200MP, ET 200SP and ET 200AL distributed I/O systems is divided into three areas. This division allows you easier access to the specific information you require.



Basic information

System manuals and Getting Started describe in detail the configuration, installation, wiring and commissioning of the SIMATIC S7-1500, ET 200MP, ET 200SP and ET 200AL systems. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics such as diagnostics, communication, Motion Control, Web server.

You can download the documentation free of charge from the Internet (<http://w3.siemens.com/mcms/industrial-automation-systems-simatic/en/manual-overview/Pages/Default.aspx>).

Changes and additions to the manuals are documented in product information sheets.

Manual Collections

The Manual Collections contain the complete documentation of the systems put together in one file.

You will find the Manual Collections on the Internet:

- S7-1500/ET 200MP (<http://support.automation.siemens.com/WW/view/en/86140384>)
- ET 200SP (<http://support.automation.siemens.com/WW/view/en/84133942>)
- ET 200AL (<http://support.automation.siemens.com/WW/view/en/95242965>)

My Documentation Manager

The My Documentation Manager is used to combine entire manuals or only parts of these to your own manual.

You can export the manual as PDF file or in a format that can be edited later.

You can find the My Documentation Manager on the Internet (<http://support.automation.siemens.com/WW/view/en/38715968>).

Applications & Tools

Applications & Tools supports you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus in individual products.

You can find Applications & Tools on the Internet (<http://support.automation.siemens.com/WW/view/en/20208582>).

CAX Download Manager

The CAX Download Manager is used to access the current product data for your CAX or CAE systems.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find the CAX Download Manager on the Internet (<http://support.automation.siemens.com/WW/view/en/42455541>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet

(<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

Description

2.1 Introduction to PROFIBUS

What is PROFIBUS?

PROFIBUS is a bus system that networks automation systems and field devices that are compatible with PROFIBUS. As communication medium for the field level, PROFIBUS is an important part of Totally Integrated Automation (TIA).

The different communication networks can be used independent of one another or they can be combined with each other.

PROFIBUS protocols

PROFIBUS DP (distributed I/O) is a communication network for the field level according to IEC 61158-2 / EN 61158-2 with the hybrid access protocols token bus and master-slave. The networking takes place by means of two-wire lines or fiber-optic cables. Data transmission rates of 9.6 kbps to 12 Mbps are possible.

PROFIBUS PA is the PROFIBUS for process automation (PA). It connects the PROFIBUS DP communication protocol with the MBP (Manchester Bus Powered) transmission technology to IEC 61158-2.

PROFIBUS PA networks can be designed based on shielded, twisted two-wire lines intrinsically safe and are therefore suitable for hazardous areas (Ex zones 0 and 1). The data transmission rate is 31.25 kbps.

2.1.1 Applications of PROFIBUS DP

Introduction

The efficiency of control systems is not determined by automation devices alone, but depends to a large extent on the overall configuration of an automation solution. This includes a powerful communication system in addition to plant visualization and operator control and monitoring.

The STEP 7 engineering tool supports you during the engineering and configuration of an automation solution.

Applications of PROFIBUS DP

The PROFIBUS network offers wireless connection of several controllers, components and subnets as electrical network, optical network or by using links. Sensors and actuators are controlled centrally by means of PROFIBUS DP.

The following figure shows connection options to PROFIBUS DP:

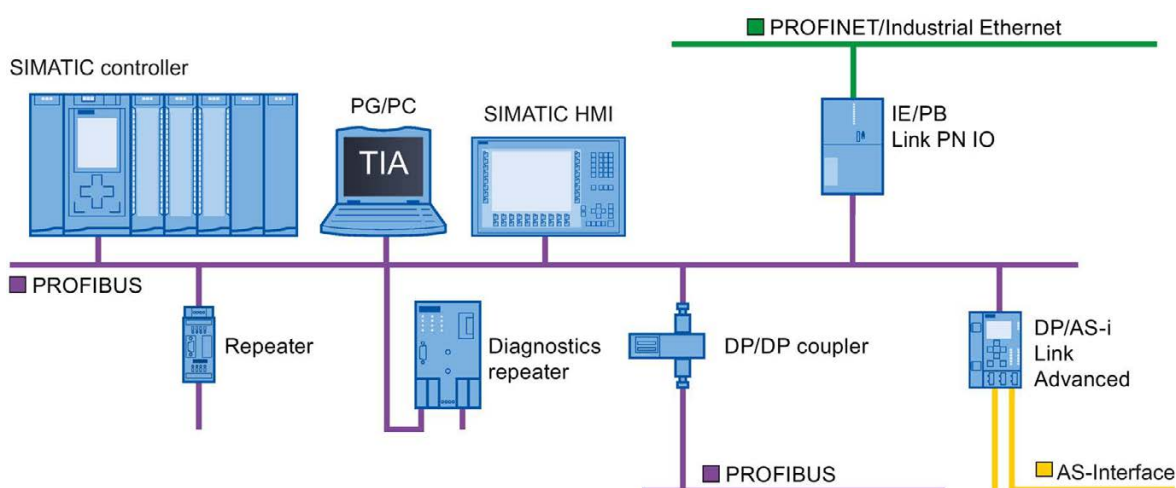


Figure 2-1 Connection options to PROFIBUS DP

Objectives of PROFIBUS DP

Distributed automation systems are increasingly used in production and process automation. This means a complex control task is divided up into smaller, more transparent subtasks with distributed control systems. This creates a high demand for communication between the distributed systems.

Distributed systems offer the following benefits:

- Independent and simultaneous commissioning of individual devices is possible
- Small, manageable programs
- Parallel processing due to distributed automation systems
- Reduced response times
- Higher-level structures can take on additional diagnostics and logging functions.
- Increased plant availability because the rest of the overall system can continue to work when a subordinate station fails.

2.1.2 PROFIBUS terminology

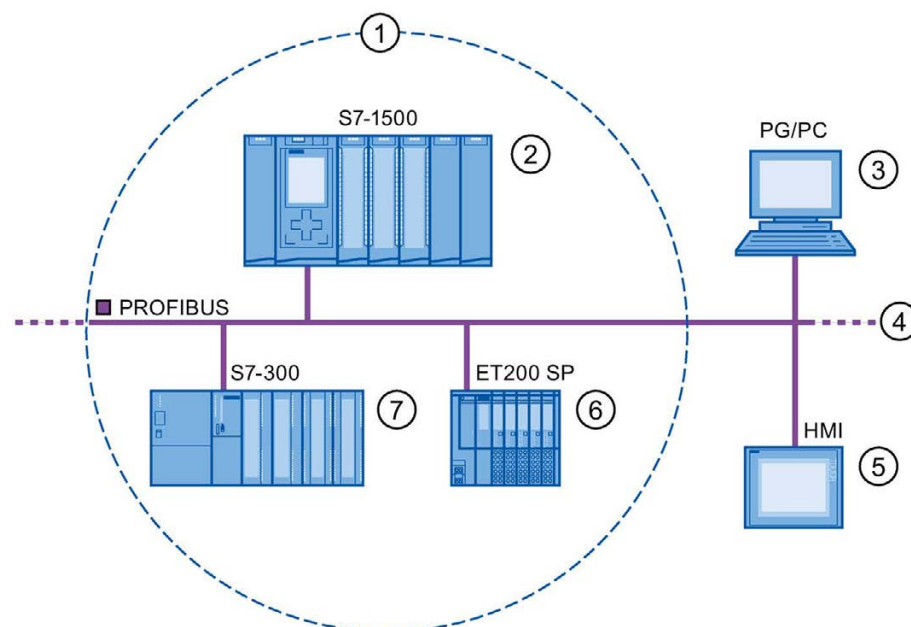
Definition: Devices in the PROFIBUS environment

In the PROFIBUS environment, "device" is the generic term for:

- Automation systems (for example, PLC, PC)
- Distributed I/O systems
- Field devices (for example, hydraulic devices, pneumatic devices)
- Active network components (e.g., diagnostic repeater, optical link module)
- Gateways to AS interface or other fieldbus systems

Devices with PROFIBUS DP

The figure below shows the most important components with PROFIBUS DP. The table below lists the designations of the individual components.



Number	PROFIBUS	Note
①	DP master system	
②	DP master	Device used to address the connected DP slaves. The DP master exchanges input and output signals with field devices. The DP master is often the controller on which the automation program runs.
③	PG/PC	PG/PC/HMI device for commissioning and diagnostics DP master of class 2
④	PROFIBUS	Network infrastructure
⑤	HMI	Device for operating and monitoring functions
⑥	DP slave	Distributed field device assigned to the DP master, e.g., valve terminals, frequency converters.
⑦	I-slave	Intelligent DP slave

Figure 2-2 Devices with PROFIBUS

Overview of I/O communication

I/O communication is the reading or writing of inputs/outputs of the distributed I/O. The figure below gives you an overview of I/O communication using PROFIBUS DP:

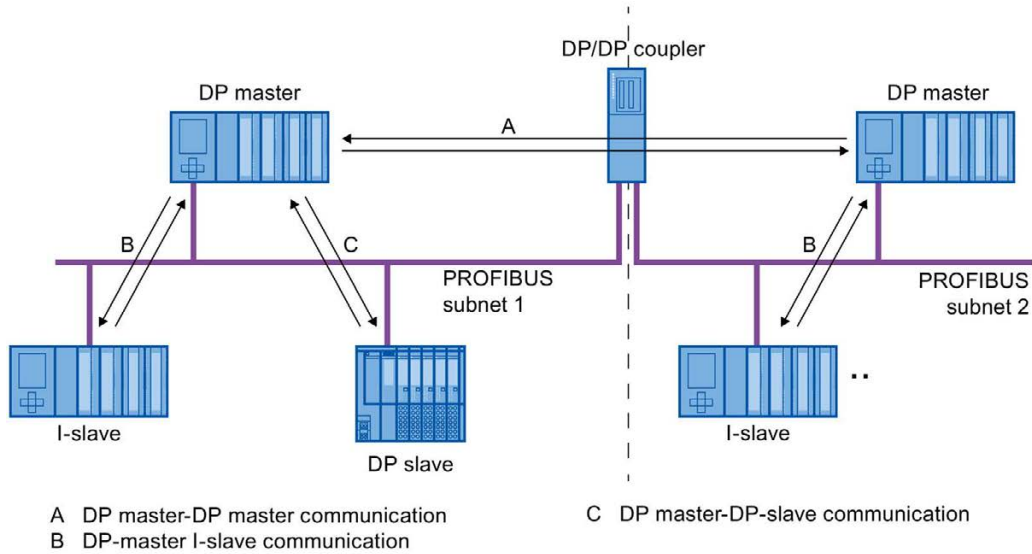


Figure 2-3 I/O communication using PROFIBUS DP

I/O communication is also available with the communication module (CM) or the interface module (IM) with integrated DP interface. These DP interfaces behave like integrated DP interfaces of the CPU.

I/O communication using PROFIBUS DP

Table 2- 1 I/O communication using PROFIBUS DP

Communication between ...	Explanation
DP master and DP slave	The data exchange between a DP master and DP slaves with I/O modules takes place as follows: The DP master queries the DP slaves of its master system one after the other, receives input values from the DP slaves, and transmits output data to the DP slaves (master-slave principle).
DP master and I-slave	<p>A fixed amount of data is transmitted cyclically between the user programs in CPUs of DP masters and I-slaves.</p> <p>The DP master does not access the I/O modules of the I-slave, but instead accesses configured address areas, called transfer areas, that can be inside or outside the process image of the I-slave CPU. If parts of the process image are used as transfer areas, these may not be used for actual I/O modules.</p> <p>Data transmission takes place with load and transfer operations using the process image or by direct access.</p>
DP master and DP master	<p>A fixed amount of data is transmitted cyclically between the user programs in CPUs of DP masters. A DP/DP coupler is required as additional hardware.</p> <p>The DP masters mutually access configured address areas, called transfer areas, inside or outside the process image of the CPUs. If parts of the process image are used as transfer areas, these may not be used for actual I/O modules.</p> <p>Data transmission takes place with load and transfer operations using the process image or by direct access.</p>

Additional information

You can find additional information on the hardware configuration in the STEP 7 online help.

2.1.3 PROFIBUS DP interface

Properties

A PROFIBUS device has at least one PROFIBUS interface with an electrical (RS 485) interface or optical (Polymer Optical Fiber, POF) interface.

Table 2- 2 Properties of the PROFIBUS DP interface

Standard	PROFIBUS: IEC 61158/61784
Physical bus/media	PROFIBUS cables (twisted two-wire lines RS 485 or fiber-optic cables)
Transmission rate	9.6 kbps to 12 Mbps

Representation of the PROFIBUS DP interface in STEP 7

In the device view of STEP 7, the PROFIBUS DP interfaces for a DP master and a DP slave are highlighted by a purple rectangle:



Figure 2-4 PROFIBUS DP interfaces

2.2 Structure of PROFIBUS networks

Contents of this chapter

The following chapter provides background information on building your communication network.

- Overview of the most important passive network components: These are network components that forward a signal without the possibility of actively influencing it, for example, cables, connectors.
- Overview of the most important active network components: These are network components that actively affect a signal, for example, repeaters, diagnostic repeaters.
- Overview of the most common network structures (topologies)

Physical connections of industrial networks

PROFIBUS devices can be networked in industrial plants in two different physical ways:

- By means of electrical signals via copper cables
- By means of optical signals via fiber-optic cables

Selection criteria for networking

The table below includes selection criteria for electrical and optical networking of PROFIBUS devices:

Table 2- 3 Selection criteria for electrical and optical networking

Criteria		Electrical PROFIBUS	Optical network with OLM	Optical network with OBT
Transmission medium	Shielded two-wire line	•	–	–
	POF	–	•	•
	PCF	–	•	•
	Glass	–	•	–
Distances	Max. network span	PROFIBUS DP: 9.6 km PROFIBUS PA: 1.9 km	90 km	9.6 km
	Between two devices	up to 1 km ¹⁾	up to 15 km ²⁾	up to 300 m ²⁾
Topology	Bus	•	–	–
	Linear	–	•	•
	Tree	•	•	•
	Ring	–	•	•
Transmission protocols		DP, PA	DP, PA	DP
Connection of devices by means of	OLM	–	•	–
	Integrated interfaces	•	–	•
	Bus terminal	•	–	•
	Bus connector	•	–	–
Electrical network segments can be connected		•	•	–

• Suitable

– Not relevant for this application

1) Depending on data rate and type of service used

2) Depending on cable type used

Installation guideline for PROFIBUS networks

A PROFIBUS segment must be terminated at the start and end; passively with a connector or actively with a bus terminating resistor.

The same principles apply to the installation of a PROFIBUS network as described in the SIMATIC NET PROFIBUS networks

(<http://support.automation.siemens.com/WW/view/en/35222591>) manual.

2.2.1 Passive network components for RS 485 networks

2.2.1.1 RS 485 cables

Introduction

The following applies to all RS 485 cables for PROFIBUS from Siemens:

- Their double shielding makes them especially suited for laying in industrial environments with electromagnetic interference.
- A continuous grounding concept can be implemented by means of the outer shield of the bus cable and the ground terminals of the bus terminals.
- The imprinted meter marking makes it easier to determine the length (accuracy $\pm 5\%$).

RS 485 cables for PROFIBUS

SIMATIC NET PROFIBUS cables are available in different versions which allow optimum adaptation to different areas of application:

- FC Standard Cable GP (bus cable for fixed laying inside buildings)
- FC Standard Cable IS GP (bus cable for hazardous area)
- FC-FRNC Cable GP (bus cable with halogen-free protective jacket for use inside buildings)
- FC Food Cable (bus cable with PE jacket for use in the food and beverage industry)
- FC Robust Cable (bus cable with PUR jacket for environments subject to chemical and mechanical stress)
- FC Ground Cable (ground cable with PE jacket)
- PROFIBUS FC Trailing Cable (trailing cable for tow chains)
- PROFIBUS Festoon Cable (bus cable for festoon mounting)
- PROFIBUS Torsion Cable (torsion-free bus cable for networking movable plant parts, for example, robots)
- PROFIBUS FC Flexible Cable (bus cable for machine parts that are moved infrequently or cabinet doors)
- SIENOPYR-FR ship cable (for permanent laying on ships and off-shore units in all rooms and on open deck)
- PROFIBUS Hybrid Standard Cable (hybrid cable with 2 power wires (1.5 mm²) for data and power supply of the ET 200pro)
- PROFIBUS Hybrid Robust Cable (trailable hybrid cable with 2 power wires (1.5 mm²) for data and power supply of the ET 200pro)

Maximum cable lengths

When using copper cables, the maximum size of a PROFIBUS segment depends on the transmission rate.

If these lengths are not sufficient for your application, you can expand the network by using repeaters. You can achieve a maximum size by cascading up to nine repeaters.

Table 2- 4 Maximum cable lengths

Transmission rate	Maximum cable length of a bus segment	Maximum distance between two stations
9.6 to 187.5 kbps	1000 m	10000 m
500 kbps	400 m	4000 m
1.5 Mbps	200 m	2000 m
3 to 12 Mbps	100 m	1000 m

2.2.1.2 PROFIBUS FastConnect system

PROFIBUS FastConnect (FC)

PROFIBUS FastConnect is a system for fast and easy fabrication of PROFIBUS copper cables.

The system consists of three components:

- FastConnect bus cables for quick mounting
- FastConnect stripping tool
- FastConnect bus connector for PROFIBUS with insulation displacement method

FastConnect bus cables and stripping tool

The special design of the FastConnect bus cables allows for the use of the FastConnect stripping tool to accurately strip away the protective jacket and the braided shield in one step. The connection of the prepared cables takes place in the FastConnect bus connectors using the insulation displacement method.

All PROFIBUS FastConnect bus cables can also be connected to the conventional bus connectors with screw-type terminals.

Area of application

You need FastConnect bus connectors for PROFIBUS for the following applications:

- Connect devices with an electrical 9-pin D-Sub interface to IEC 61158-2 directly with SIMATIC NET PROFIBUS cables.
- Connect electrical segments or individual devices to the Optical Link Module (OLM) and Optical Bus Terminal (OBT).
- Connect devices or programming devices to the repeater.

Versions

The FastConnect bus connector in degree of protection IP20 is available in the following versions:

- with integrated terminating resistor and isolating function
- with or without PG socket
- with a cable outlet of 35°, 90° or 180°
- with device category 3G suitable for zone 2 hazardous area

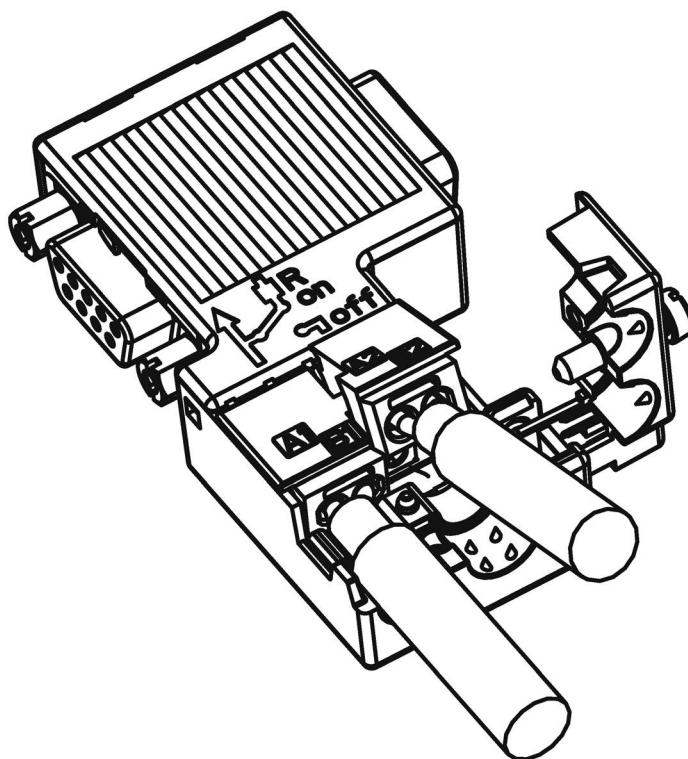


Figure 2-5 Example for PROFIBUS FastConnect bus connector with PG socket, cable outlet 90°

Additional information

For additional information on the available components visit the Siemens Mall (<http://mall.industry.siemens.com>).

2.2.1.3 PROFIBUS bus connector

Area of application

You need PROFIBUS bus connectors for the following applications:

- Connect devices with a 9-pin D-Sub interface to IEC 61158-2 directly with the SIMATIC NET PROFIBUS cables.
- Connect electrical segments or individual devices to the Optical Link Module (OLM) and Optical Bus Terminal (OBT).
- Connect devices or programming devices to the repeater.

Versions

The PROFIBUS bus connector in degree of protection IP20 is available in the following versions:

- with integrated terminating resistor and isolating function
- with or without PG socket
- with a cable outlet of 35°, 90° or 180°
- with device category 3G suitable for zone 2 hazardous area

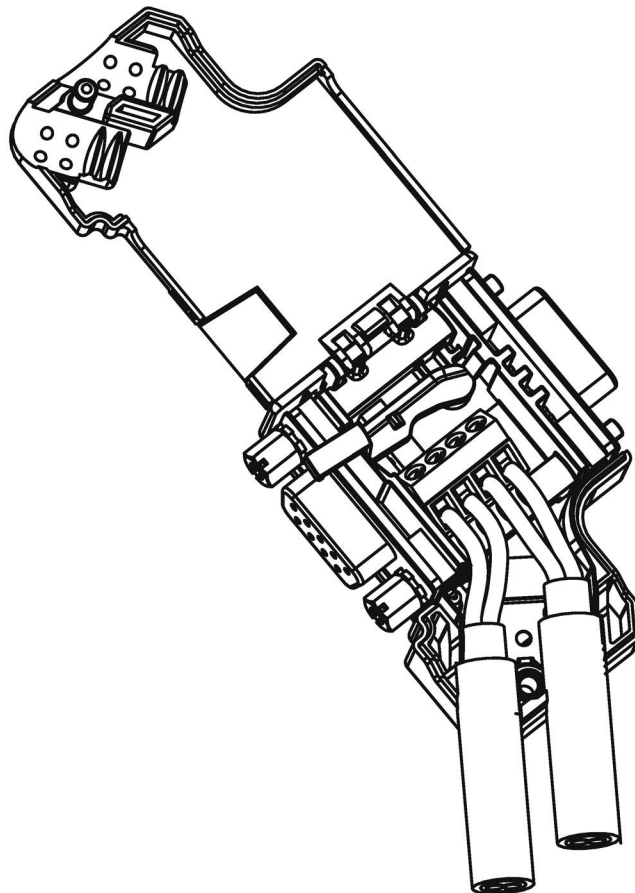


Figure 2-6 Example for PROFIBUS bus connector with PG socket, cable outlet 35°

Additional information

For additional information on the available components visit the Siemens Mall (<http://mall.industry.siemens.com>).

2.2.1.4 M12 bus connector

Area of application

Devices with an electrical M12 interface can use the M12 bus connector for SIMATIC NET PROFIBUS for direct connection with the SIMATIC NET PROFIBUS cables.

The M12 bus connector in degree of protection IP65 is available in the following versions:

- with screw-type terminals
- with insulation displacement termination
- with a cable outlet of 180°

2.2.1.5 Bus terminals for RS 485 networks

Bus terminal RS 485 and bus terminal M12

A bus terminal is used for the connection of an individual PROFIBUS station with RS485 interface to the PROFIBUS bus cable.

Bus terminals in degree of protection IP20 are available in the following versions:

- Bus terminal RS 485 with or without PG interface, transmission rate 9.6 kbps to 1.5 Mbps, integrated terminating resistor combination (connectible), with 1.5 m and 3 m connecting cable
- Bus terminal M12, transmission rate 9.6 kbps to 12 Mbps, integrated terminating resistor combination with isolating function, with 1.5 m connecting cable

2.2.1.6 M12 bus terminating resistor

Terminating segment with terminating resistor

If there is a station with M12 connection system at the beginning or end of a PROFIBUS segment, you need an M12 bus terminating resistor.

The M12 PROFIBUS connection of a device consists of an M12 socket for the infeed and an M12 male connector to loop-through the bus signal.

This means you need one bus terminating resistor with male contacts (6GK1905-0EC00) and with female contacts (6GK1905-0ED00) for each M12 bus cable.

2.2.2 Passive components for optical networks

2.2.2.1 Fiber-optic cables

Types of fiber-optic cables

Data transmission with fiber-optic cables takes place through modulation of electromagnetic waves in the range of visible and invisible light. These cables are made of high-quality plastic fibers and glass fibers:

- Plastic and PCF fiber-optic cables (Page 26)
- Glass fiber-optic cables (Page 27)

The different types of fiber-optic cables provide solutions matched to the operating and environmental conditions for the connection of components with each other.

Benefits

Fiber-optic cables offer the following benefits when compared with electrical cables:

- Galvanic isolation of the devices and segments
- No potential equalization currents
- No impact on transmission path through external electromagnetic interference
- No lightning protection elements required
- No noise radiation along the transmission route
- Low weight
- Depending on the type of fiber you can implement cable lengths up to few kilometers at even higher transmission rates.
- No dependency of the maximum permitted distances on the transmission rate

Additional information

Additional information of the properties and technical specifications of the passive components and connectors for fiber-optic cables is available in the PROFIBUS network manual (<http://support.automation.siemens.com/WW/view/en/35222591>).

2.2.2.2 Plastic and PCF fiber-optic cables

Plastic and PCF fiber-optic cables

Plastic (POF) and PCF fiber-optic cables are used for the connection of Optical Link modules with connections for plastic fiber-optic cables (OLM/P), Optical Bus Terminal (OBT) and devices with integrated optical interfaces. Under certain conditions, they are an inexpensive alternative to conventional glass fiber-optic cables.

Plastic Fiber Optic duplex core

The plastic fiber-optic duplex core is a flat dual core with PVC inner jacket without protective jacket. The cable can be easily assembled on-site.

The cable is intended for indoor applications with low mechanical loads or inside cabinets. For OLM connections and with integrated optical interfaces you cover a length of up to 50 m between two devices with this cable.

Plastic Fiber Optic standard cable

The plastic fiber optic standard cable consists of two plastic fibers with robust polyamide inner jacket surrounded by Kevlar tensile elements and a purple PVC protective jacket. The cable can be easily assembled on-site.

The robust round cable is suited for indoor applications. The maximum distance that can be covered is 80 m for OLM/P connections and 50 m with integrated optical interfaces and OBT.

PCF Standard Cable

The pre-assembled PCF Standard Cable consists of two PCF fibers surrounded by Kevlar tensile elements and a purple PVC protective jacket. It is always supplied with a pulling aid installed on one end to pull in the cable channels.

The robust round cable is suited for indoor applications with cable lengths up to 400 m (OLM) or 300 m (integrated optical interfaces, OBT) between two devices.

PCF Standard Cable GP

The PCF Standard Cable GP consists of two PCF fibers surrounded by Aramid tensile elements and a green PVC protective jacket. The cable is pre-assembled and can be ordered by the meter. It is supplied with a pulling aid installed on one end to pull in the cable channels.

The robust round cable is suited for indoor and outdoor applications with cable lengths up to 400 m (OLM) or 300 m (integrated optical interfaces, OBT) between two devices.

PCF Trailing Cable

The PCF Trailing Cable consists of two PCF fibers surrounded by Aramid tensile elements and a green PUR protective jacket. The cable is pre-assembled and can be ordered by the meter. It is supplied with a pulling aid installed on one end to pull in the cable channels.

The robust round cable is suited for moving indoor and outdoor applications with cable lengths up to 400 m (OLM) or 300 m (integrated optical interfaces, OBT) between two devices.

PCF Trailing Cable GP

The PCF Trailing Cable GP consists of two PCF fibers surrounded by Aramid tensile elements and a green PVC protective jacket. The cable is pre-assembled and can be ordered by the meter. It is supplied with a pulling aid installed on one end to pull in the cable channels.

The robust round cable is suited for moving indoor and outdoor applications with cable lengths up to 400 m (OLM) or 300 m (integrated optical interfaces, OBT) between two devices.

2.2.2.3 Glass fiber-optic cables

Glass fiber-optic cables

Glass fiber-optic cables are suitable for connection of optical interfaces that work in the wavelength range around 850 nm and around 1300 nm. They include two graded-index multimode fibers of the type 62.5/125 μm .

The glass fiber-optic cables are available in different versions which makes for an optimum adaptation to different areas of application:

- Fiber Optic standard cable
- INDOOR Fiber Optic indoor cable
- Flexible Fiber Optic trailing cable

Fiber Optic standard cable

The standard cable is the universal cable for indoor and outdoor use.

INDOOR Fiber Optic indoor cable

The indoor cable is intended for weather-proof indoor use. It is halogen-free, non-crush and flame-retardant.

Flexible Fiber Optic trailing cable

The trailing cable was designed for the special application of forced movement, for example, for constantly moved machine parts such as trailing chains. It is mechanically designed for 100,000 bending cycles by $\pm 90^\circ$ (with the specified minimum radius). Integrated dummy elements ensure a round cross-section of the cable. The trailing cable can be used indoors and outdoors.

Maximum distances between two optical link modules

The following distances may not be exceeded between two OLMs regardless of the optical power budget:

- OLM/P11, OLM/P12: 400 m
- OLM/G11, OLM/G12, OLM/G12-EEC: 3 km
- OLM/G11-1300, OLM/G12-1300: 15 km

Additional information

All operating instructions (<http://support.automation.siemens.com/WW/view/en/10805951/133300>) of the SIMATIC NET bus components include information on distances that can be covered with the SIMATIC NET glass fiber-optic cables. You can configure your optical network without any calculations using simple limits.

2.2.3 Active network components

2.2.3.1 Network components in electrical networks

Active network components

The following active network components are available for PROFIBUS in electrical networks:

- Repeater RS485
- Diagnostics repeater
- PROFIBUS Terminator
- DP/DP coupler
- IE/PB Link PN IO
- IWLAN/PB Link PN IO
- Active components for the connection of CAN
- Active components for the gateway between PROFIBUS and AS-Interface
 - DP/AS-i LINK Advanced
 - DP/AS-Interface Link 20E
 - DP/AS-i F-Link

RS485 repeater

The RS485 IP20 repeater connects two PROFIBUS bus segments in RS485 technology with up to 32 devices. It provides transmission rates from 9.6 kbps to 12 Mbps.

The RS485 repeater refreshes a signal regarding amplitude, signal width and edge steepness between two segments. It is used when more than 32 stations are connected to the bus or the maximum cable length of a segment is exceeded.

Bus segments can be operated ungrounded (galvanic isolation of segments) with an RS485 repeater.

Diagnostics repeater

The diagnostic repeater connects three PROFIBUS segments in RS485 technology, two of which are diagnostics-capable segments with 31 devices each. It is designed as DP slave to send diagnostics alarms to the DP master.

The diagnostic function provides the location and the cause of cable faults, such as wire break or missing terminating resistors. The fault location is indicated relative to the existing devices.

The diagnostics repeater refreshes a signal regarding amplitude, signal width and edge steepness between the segments. The cascading depth between any two PROFIBUS devices is limited to nine diagnostics repeaters.

PROFIBUS Terminator

The PROFIBUS Terminator forms an active bus termination. Bus devices can be switched off, removed or replaced without affecting data transmission. This is particularly true for bus devices on both ends of the bus cable at which terminating resistors must be connected or supplied. The PROFIBUS Terminator can be mounted on a standard mounting rail.

IE/PB Link PN for the connection of a PROFIBUS segment to an Industrial Ethernet network

The IE/PB Link PN IO as independent component provides the seamless transition between Industrial Ethernet and PROFIBUS. Through the use of IE/PB Link PN IO as substitute on the Ethernet, the existing PROFIBUS devices can continue to be used and can be integrated into a PROFINET application.

A PROFINET IO controller is required for this configuration. The IE/PB Link PN acts as master on the PROFIBUS end.

IWLAN/PB Link PN IO as gateway between LAN and PROFIBUS

PROFIBUS devices can be coupled to PROFINET IO by means of IWLAN/PB Link PN IO. This means you can integrate existing PROFIBUS configurations into PROFINET.

The IWLAN/PB Link PN IO supports the use of IWLAN and WLAN antennas for wireless data transmission, for example, in suspended monorail systems or conveyor systems. Because of the PROFINET support, the numerous PROFIBUS system services, for example, diagnostics by bus, can continue to be used.

A PROFINET IO controller is required for this configuration. The IWLAN/PB Link PN IO acts as master on the PROFIBUS end.

CANopen module for connection to CAN

You can use the CANopen module to easily connect CANopen applications to PROFIBUS.

Typical areas of application:

- Control of hydraulic valves/hydraulic axes in vehicles
- Control of motors in packaging machines and on conveyor belts
- Use in wind turbines for detection of angular encoders
- Detection of HMI devices on machines, e.g., joysticks
- Detection of measured data from displacement transducers, inclination sensors or angle encoders on tower cranes or gantry cranes

DP/DP coupler for connection of two PROFIBUS networks

The PROFIBUS DP/DP coupler is used to connect two PROFIBUS DP networks. Data (0 to 244 bytes) is transmitted from the DP master of the first network to the DP master of another network and vice versa.

The DP/DP coupler comes equipped with two independent DP interfaces that establish the connection to the two DP networks. There is one slave at each DP network. The data exchange between the two DP networks takes place by internal copying in the coupler.

DP/PA bus link for connection of PROFIBUS PA

The DP/PA bus link is the connection between PROFIBUS DP and PROFIBUS PA. This means it connects the process control systems with the field devices of the process automation.

The following components are available for a DP/PA bus link:

- DP/PA coupler Ex [ia]
- DP/PA coupler FDC 157-0
- Interface module IM 153-2 for establishing a DP/PA link.
- Active field distributor AFDiS for hazardous areas

Active components for the gateway between PROFIBUS and AS-Interface

- **DP/AS-i LINK Advanced:**

The **DP/AS-i LINK Advanced** is PROFIBUS DPV1 slave (according to IEC 61158-2/EN 61158-2) and AS-Interface master (according to AS-Interface specification V3.0 according to EN 50295) and provides transparent data access to AS-Interface from PROFIBUS DP.

PROFIBUS DP masters can cyclically exchange I/O data with the AS-Interface; DP masters with acyclic services can also make AS-Interface master calls. The **DP/AS-i LINK Advanced** is particularly suited for distributed configurations and for the connection of a subordinate AS-Interface network.

The DP/AS-i LINK Advanced in the version as AS-Interface single master is completely sufficient for applications with typical configuration limits.

For applications with high configuration limits, the DP/AS-i LINK Advanced is used as AS-Interface double master. In this case, the duplicate configuration limits can be used on two independently running AS-Interface strands.

- **DP/AS-Interface Link 20E:**

The DP/AS-Interface Link 20E is PROFIBUS DP slave (in accordance with EN 61158) and AS-Interface master (in accordance with AS-Interface specification V3.0 according to EN 50295) and supports operation of the AS-Interface on PROFIBUS DP.

Single PROFIBUS masters can cyclically exchange I/O data with the AS-Interface; masters with acyclic services can exchange I/O data and make master calls.

- **DP/AS-i F-Link:**

The DP/AS-i F-Link is PROFIBUS DP-V1 slave (according to EN 61158) and AS-i master (according to AS-Interface specification V3.0 to EN 50295) and provides transparent data access to AS-Interface from PROFIBUS DP. The DP/AS-i F-Link is also the only AS-i master that can forward safety-oriented input data of ASIsafe slaves to a fail-safe CPU with PROFIBUS DP master by means of the PROFIsafe protocol. Additional safety cabling or monitoring is not required (in particular, no AS-Interface safety monitor). Depending on the slave type, you can transmit binary values or analog values. All slaves according to AS-Interface specification V2.0, V2.1 or V3.0 can be operated as AS-i slaves.

As fully-featured AS-i master according to specification V3.0, you can use higher configuration limits on the AS-i network (496 inputs and outputs each, up to 62 digital or analog slaves).

Additional information

Information on the components is available in the Siemens Mall (<http://mall.industry.siemens.com>).

Additional information is available in these manuals:

- PROFIBUS Network Manual (<http://support.automation.siemens.com/WW/view/en/35222591>)
- Diagnostic repeater (<http://support.automation.siemens.com/WW/view/en/7915183>)
- DP/DP Coupler (<http://support.automation.siemens.com/WW/view/en/1179382>)
- SIMATIC NET Twisted-Pair and Fiber-Optic Networks (<http://support.automation.siemens.com/WW/view/en/8763736>)
- Basics on Setting up an Industrial Wireless LAN (<http://support.automation.siemens.com/WW/view/en/9975764>)
- SIMATIC bus links, DP/PA coupler, active field distributors, DP/PA Link and Y Link (<http://support.automation.siemens.com/WW/view/en/1142696>)
- Information on the CANopen module is available on the Internet (<http://www.hms-networks.com/can-for-et200s>).
- DP/AS-interface LINK Advanced (<http://support.automation.siemens.com/WW/view/en/22502958/133300>) manual
- DP/AS-i F-Link (<http://support.automation.siemens.com/WW/view/en/24196041>) manual

See also

Topology with RS485 repeater (Page 35)

OLM topology (Page 40)

WLAN topology (Page 40)

Connecting PROFIBUS to PROFINET (Page 41)

2.2.3.2 Network components in optical networks

Active network components

The following active network components are available for PROFIBUS in optical networks:

- Optical Link Module OLM
- Optical Bus Terminal OBT

Optical Link Module OLM

You can use the PROFIBUS Optical Link Modul OLM to install PROFIBUS networks in line, star structure and redundant ring structure.

The transmission rate of a fiber-optic cable line does not depend on the distance and can be 9.6 kbps to 12 Mbps.

Applications for OLM include, for example, plant buses on PROFIBUS base, networking across buildings using glass fiber-optic cables, mixed networks with electrical and optical segments, large networks (road tunnels, traffic guidance systems) and networks with high demands on availability (redundant ring networks).

Optical Link modules can be combined by means of an RS485 interface and individual devices or entire electrical segments can be integrated into the optical PROFIBUS network.

The following distances may not be exceeded between two OLMs regardless of the optical power budget:

- OLM/P11, OLM/P12: 400 m
- OLM/G11, OLM/G12, OLM/G12-EEC: 3 km
- OLM/G11-1300, OLM/G12-1300: 15 km

Optical Bus Terminal OBT (optical bus terminal)

The Optical Bus Terminal connects an individual PROFIBUS device without integrated optical interface or a PROFIBUS RS 485 segment with up to 31 devices to an optical PROFIBUS.

An individual PROFIBUS DP device is connected with its RS 485 interface by means of a PROFIBUS cable with integrated terminating resistor, for example, connecting cable 830-1T, to the RS 485 interface of the OBT. The OBT is integrated into the optical line by means of two optical interfaces.

The following optical transmission media can be connected to the OBT:

- Plastic fiber-optic cable up to 50 m single distance length. They can be assembled on-site with two 2x2 Simplex connectors.
- PCF fiber-optic cable up to 300 m single distance length. The cables are delivered pre-assembled.

Additional information

Information on the components is available in the Siemens Mall (<http://mall.industry.siemens.com>).

Additional information is available in these manuals:

- PROFIBUS network manual (<http://support.automation.siemens.com/WW/view/en/35222591>)
- SIMATIC NET PROFIBUS, Optical Link Module (<http://support.automation.siemens.com/WW/view/de/56606534/0/en>)
- SIMATC NET Twisted-Pair and Fiber-Optic Networks (<http://support.automation.siemens.com/WW/view/en/8763736>)

2.2.4 Examples for topology

2.2.4.1 Topology with RS485 repeater

Configuration options with the RS485 repeater

You can operate the RS485 repeater in the following configurations:

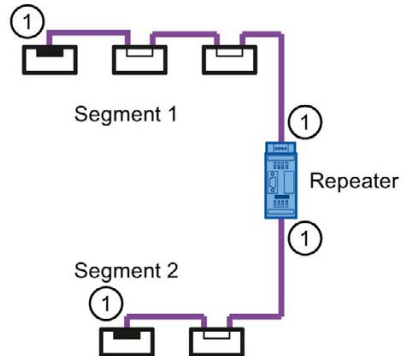


Figure 2-7 Segment 1 and segment 2 connected to RS485 repeater

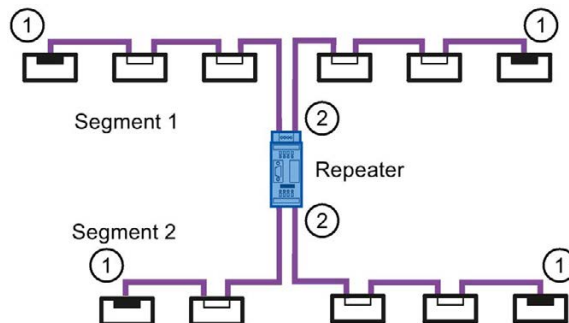


Figure 2-8 Segment 1 and segment 2 looped-through to RS485 repeater

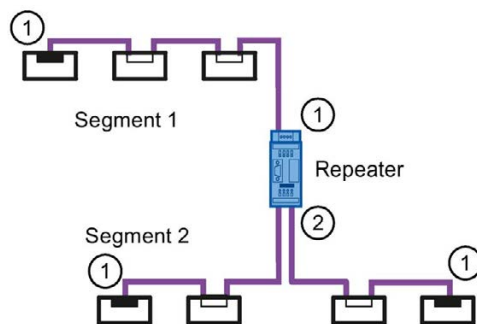


Figure 2-9 Segment 1 connected to RS485 repeater and segment 2 looped-through to RS485 repeater

- ① Connect terminating resistor
- ② Do not connect terminating resistor

Configuration example

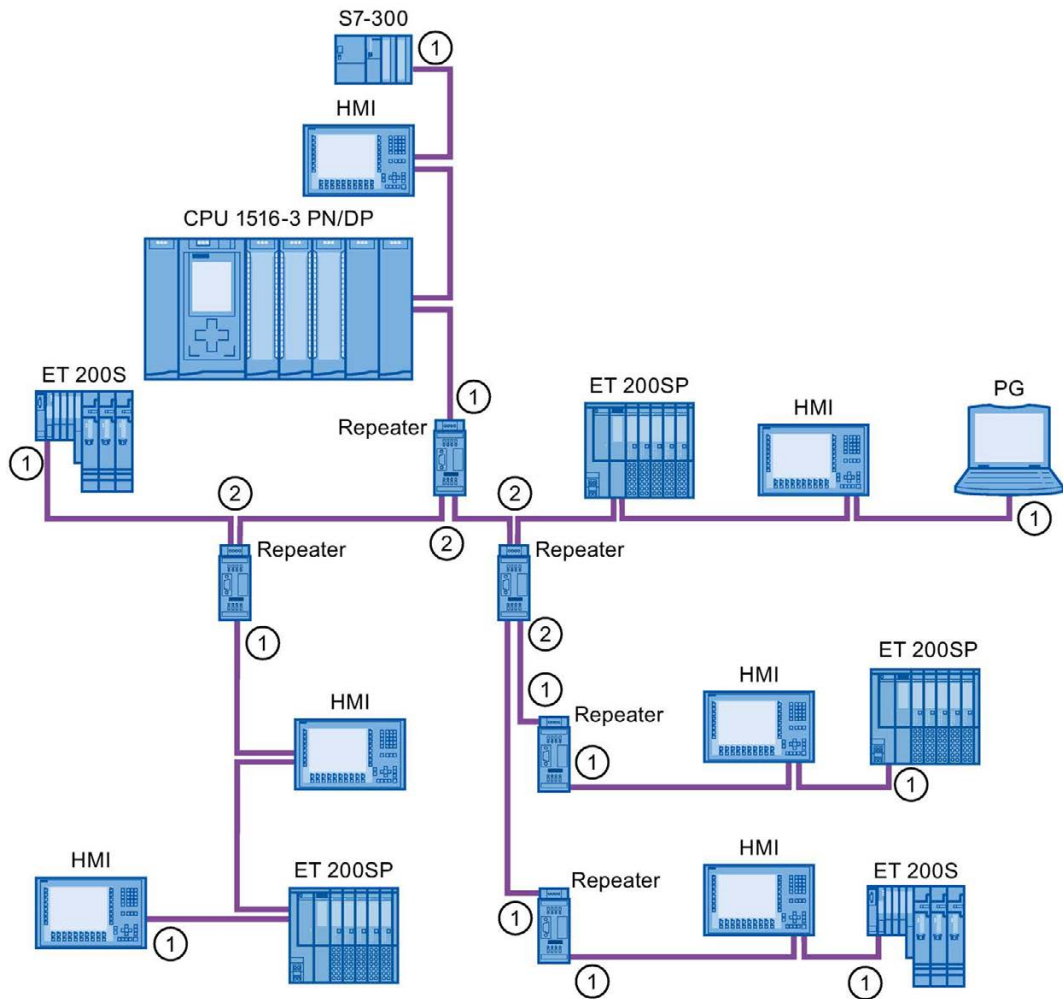


Figure 2-10 Configuration example with five RS485 repeaters

- ① Connect terminating resistor
- ② Do not connect terminating resistor

Maximum configuration

If you install a PROFIBUS network with RS485 repeaters, you may not connect more than nine RS485 repeaters in series.

2.2.4.2 Topology with diagnostic repeater

Diagnostic repeater with three segments

You may not exceed the maximum permitted cable length of 100 m per segment that can be monitored for the diagnostic repeater. The segments connected to DP2 and DP3 are diagnostics-capable. The cable length that can be monitored is limited for some cable types.

Maximum cascade depth

You can connect up to nine diagnostic repeaters in series between any two PROFIBUS stations.

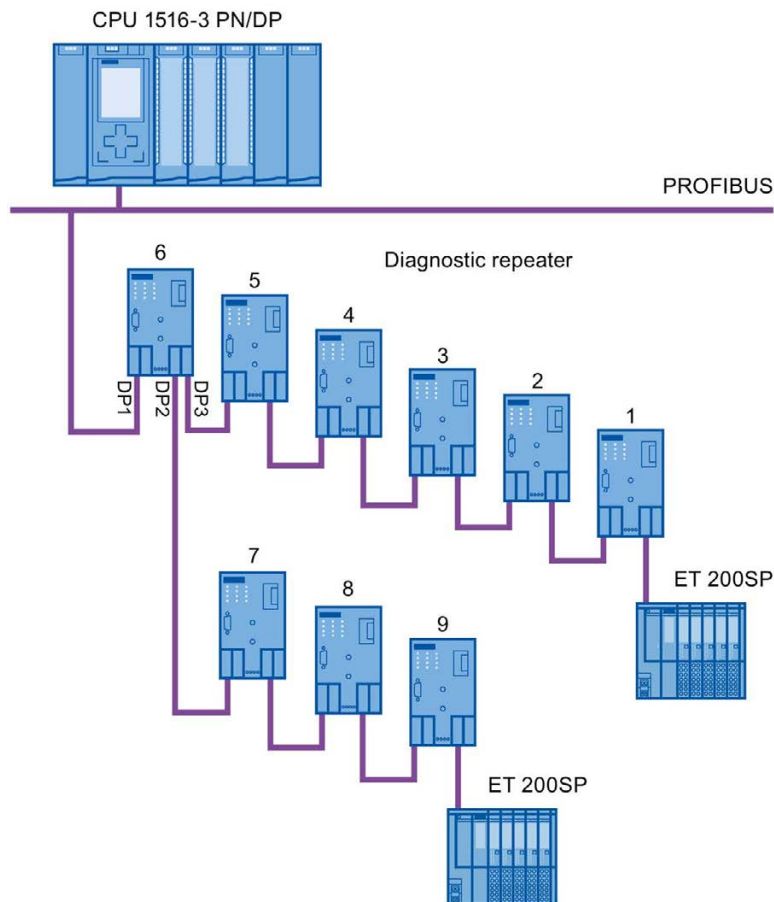


Figure 2-11 Schematic layout of a PROFIBUS network with maximum possible cascade depth at diagnostic repeaters

Example: Maximum cascade depth exceeded

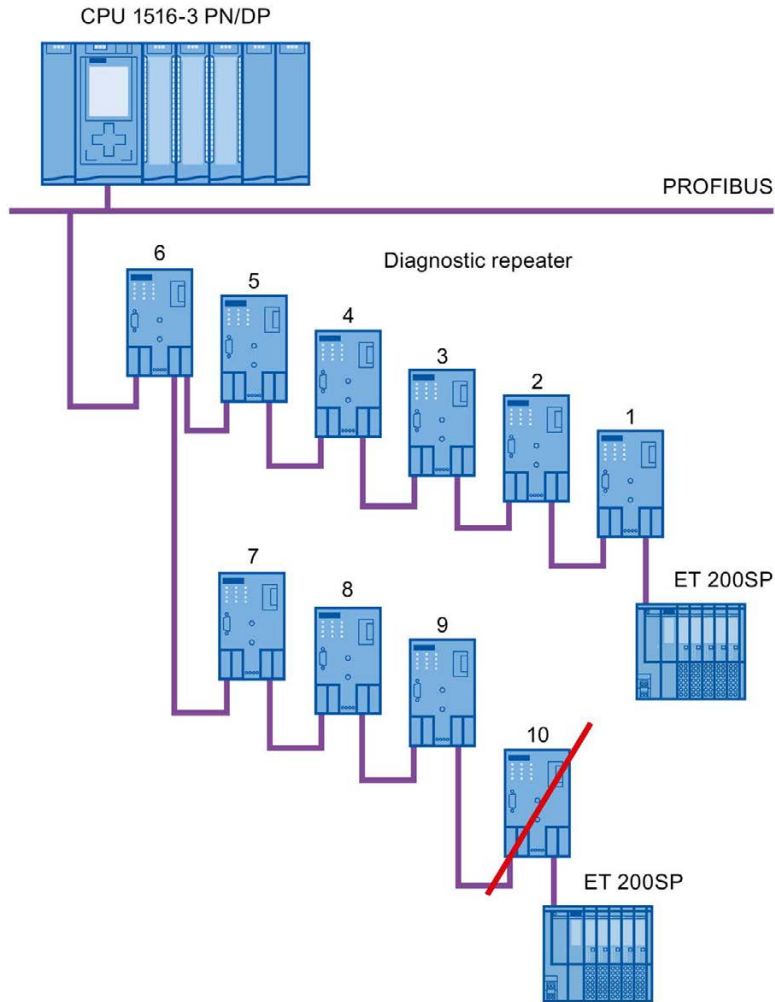


Figure 2-12 Maximum cascade depth exceeded

Layout with several segments

You can increase the number of used diagnostic repeaters by using several segments. The example shows a layout in which the maximum cascade depth is exceeded at two segments.

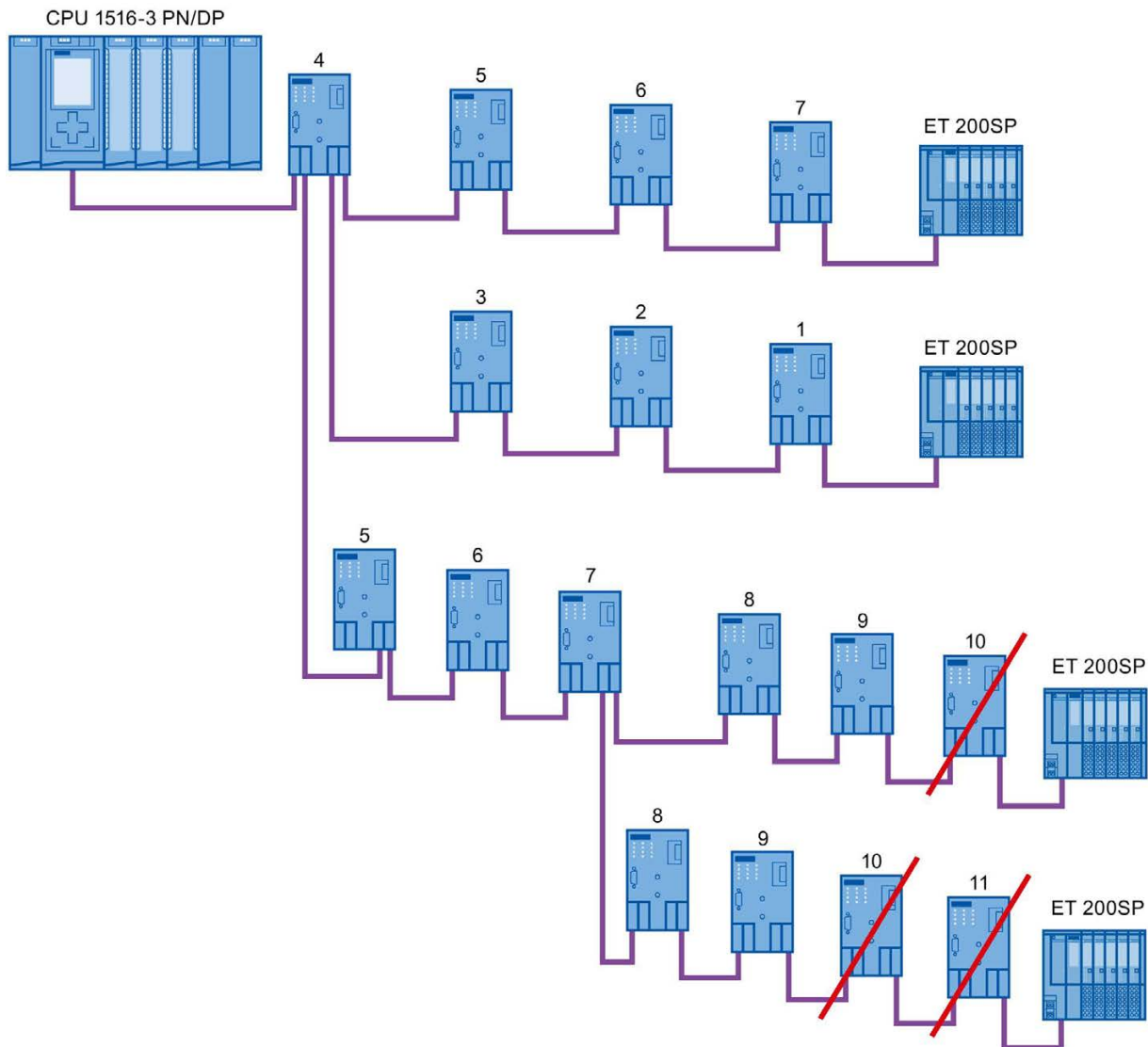


Figure 2-13 Layout with several segments, maximum cascade depth exceeded

Additional information

Additional information is available in the Diagnostic Repeater (<http://support.automation.siemens.com/WW/view/en/7915183>) manual.

2.2.4.3 OLM topology

Combination of electrical and optical networks with OLM

Additional distances can be covered by means of the Optical Link Module.

Because bus cables across several buildings are particularly vulnerable to damage caused by overvoltage (effect of lightning), the devices in the connected bus segment must be protected against overvoltage.

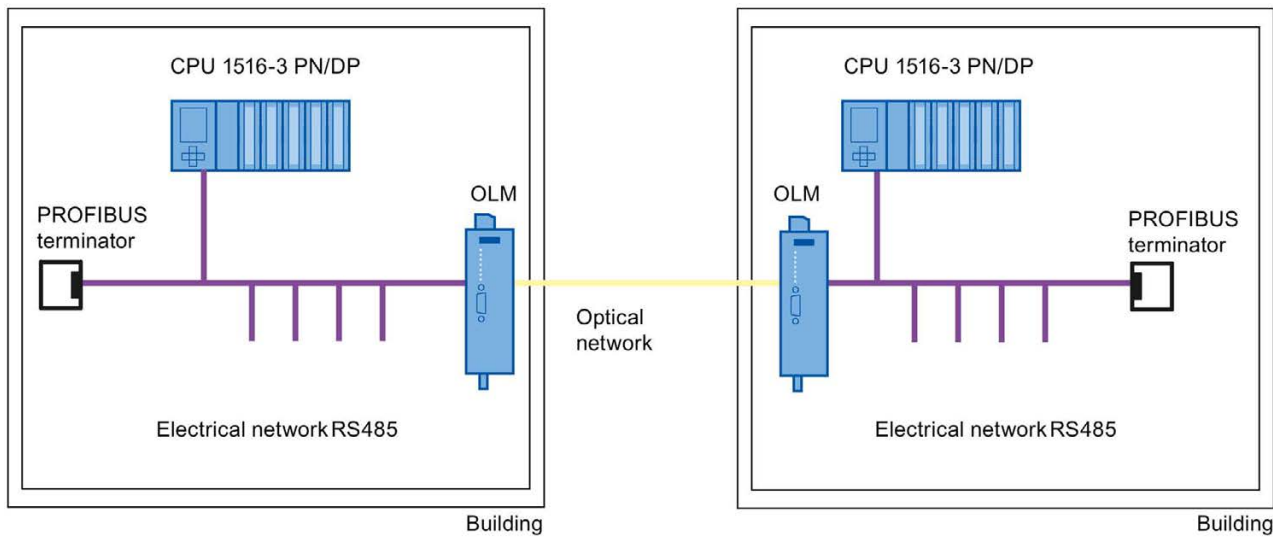


Figure 2-14 Combination of electrical and optical networks

2.2.4.4 WLAN topology

IWLAN/PB Link PN IO as gateway between Industrial Wireless LAN and PROFIBUS

The IWLAN/PB Link PN IO supports the use of IWLAN and WLAN antennas for wireless data transmission. This means the numerous PROFIBUS system services, for example, diagnostic by bus, can be used throughout.

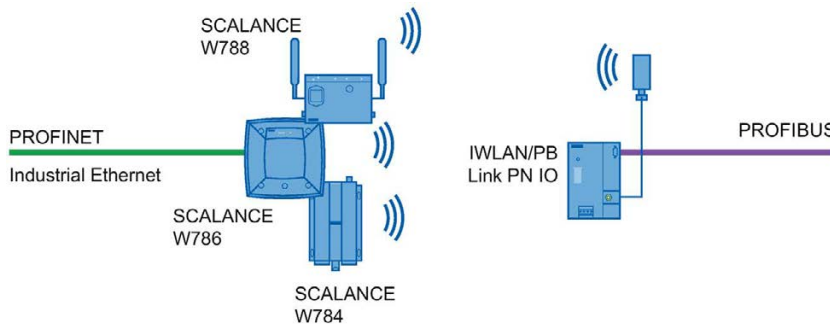


Figure 2-15 PROFIBUS and WLAN

2.2.4.5 Connecting PROFIBUS to PROFINET

PROFIBUS can be integrated in PROFINET. In this way, you can set up any hybrid systems consisting of fieldbus and Ethernet-based subsystems. This provides a continuous data exchange.

Coupling of PROFIBUS and PROFINET

With a proxy-capable PROFINET device that is equipped with a PROFIBUS interface in addition to a PROFINET interface, you can integrate existing PROFIBUS configurations into the PROFINET configuration.

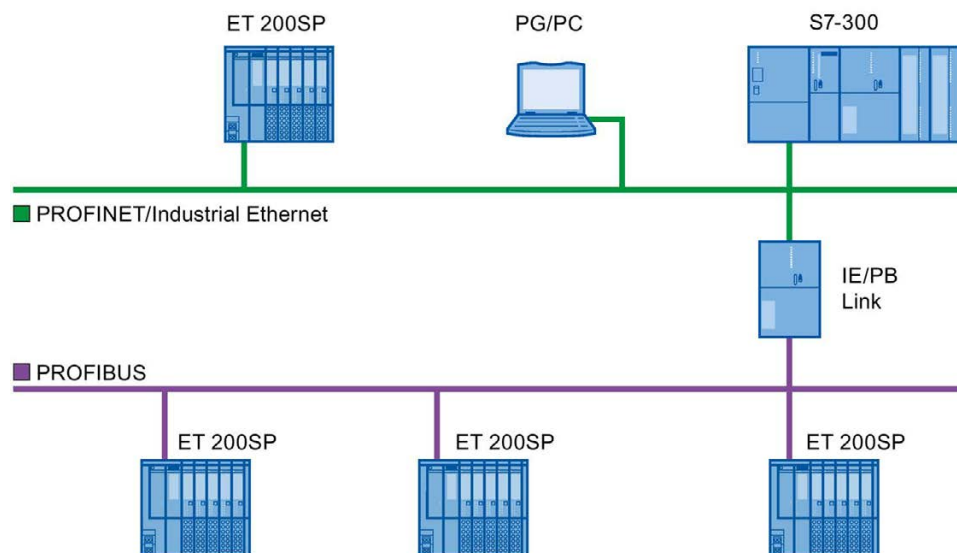


Figure 2-16 Connection of PROFIBUS and PROFINET with IE/PB link

PROFINET device with proxy functionality

The PROFINET device with proxy functionality is the substitute for a PROFIBUS device on Ethernet. The proxy functionality allows a PROFIBUS device to communicate not only with its master but also with all devices on PROFINET.

With PROFINET, existing PROFIBUS systems can be integrated into the PROFINET communication with the aid of an IE/PB link. The IE/PB link PN IO then handles communication via PROFINET on behalf of the PROFIBUS components.

Parameter assignment/addressing

To set up an automation system, you will need to configure, assign parameters and link the individual hardware components. The work needed for this is undertaken in the STEP 7 device, topology and network view.

Configuration

"Configuring" is understood to mean arranging, setting and networking devices and modules within the device or network view.

A PROFIBUS address is automatically assigned to each module. The addresses can be subsequently modified.

The CPU compares the preset configuration created in STEP 7 with the actual configuration of the plant. Errors can be detected and signaled immediately this way.

The exact procedure for configuring devices is described in detail in the STEP 7 online help.

Parameter assignment

"Parameter assignment" is understood to mean setting the properties of the components used. The settings for the hardware components and for data exchange are assigned, for example, activating diagnostics, input delay with DI.

The parameters are downloaded into the CPU and transferred to the corresponding modules when the CPU starts up. Modules can be replaced with ease because with SIMATIC CPUs the set parameters are automatically downloaded into the new module during each startup.

Adjusting the hardware to the project requirements

You need to adapt the hardware if you want to set up, expand or change an automation project. To do this, add hardware components to your layout, link them with existing components, and adapt the hardware properties to the tasks.

The properties of the automation systems and modules are preset so that in many cases you do not have to assign parameters again.

But parameter assignment is required in the following cases:

- You want to change the preset parameters of a module.
- You want to use special functions.
- You want to configure communication connections.

Basic procedure for creating a PROFIBUS DP system

- Configuration
 - Creating PROFIBUS devices and modules in STEP 7
 - Assigning the DP slave to a DP master (Page 43)
- Optional: Parameter assignment
 - Assigning the PROFIBUS address (Page 45)
 - Making network settings (Page 46)
 - Considering cable configuration (Page 49)
 - Considering additional network devices (Page 51)
 - Bus parameters – creating a user-defined profile (Page 52)
 - Configuring constant bus cycle time (Page 55)

3.1 Assigning the DP slave to a DP master

PROFIBUS DP system

A PROFIBUS DP system consists of a PROFIBUS DP master and its assigned PROFIBUS DP slaves. Once the devices have been placed in the network view or device view, STEP 7 assigns default parameter values to them. Initially, you only have to assign the DP slaves to one DP master.

Requirement

- The network view of STEP 7 is open.
- A CPU has been placed (e.g., CPU 1516-3 PN/DP).
- A DP slave has been placed (e.g., IM151-1 HF).

Procedure

To assign DP slaves to a DP master, follow these steps:

1. On the DP slave, use the left mouse button to click on the "Not assigned" link. The "Select DP master" menu opens.
2. Select the DP master in the menu to which you want to assign the DP slave.

Result: A subnet with a DP system is created on the CPU. The CPU is now the PROFIBUS DP master. The DP slave is assigned to the DP master.

3. Repeat steps 1 and 2 for all other DP slaves that you want to assign to the DP master.

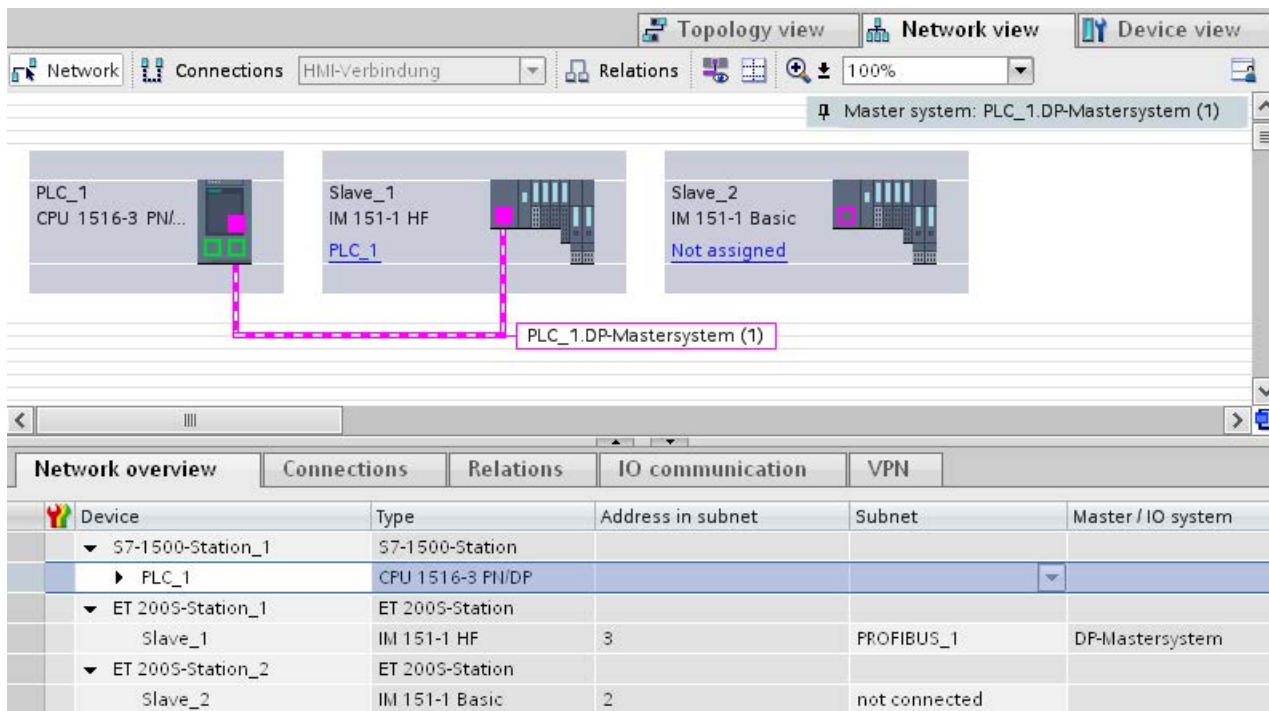


Figure 3-1 Assigning the DP slave to a DP master

Network overview

You can check the communication relationships of the activated interface in the network overview. The network overview is context-sensitive for selection in the network view:

- The selection of the CPU shows the DP communication of the CPU.
- The selection of the station shows the communication of the entire station.
- The selection of the interface shows the DP communication of the interface.

3.2 PROFIBUS address

Devices can be connected to the PROFIBUS subnet that communicate by means of configured connections or that are part of a PROFIBUS DP master system.

If the DP slave has already been assigned to a DP master, the PROFIBUS subnet to which the device is connected is automatically displayed under "Interface linked with".

In the Inspector window under "PROFIBUS", select the subnet to which the interface is linked or add a new subnet.

All devices of a subnet must have different PROFIBUS addresses.

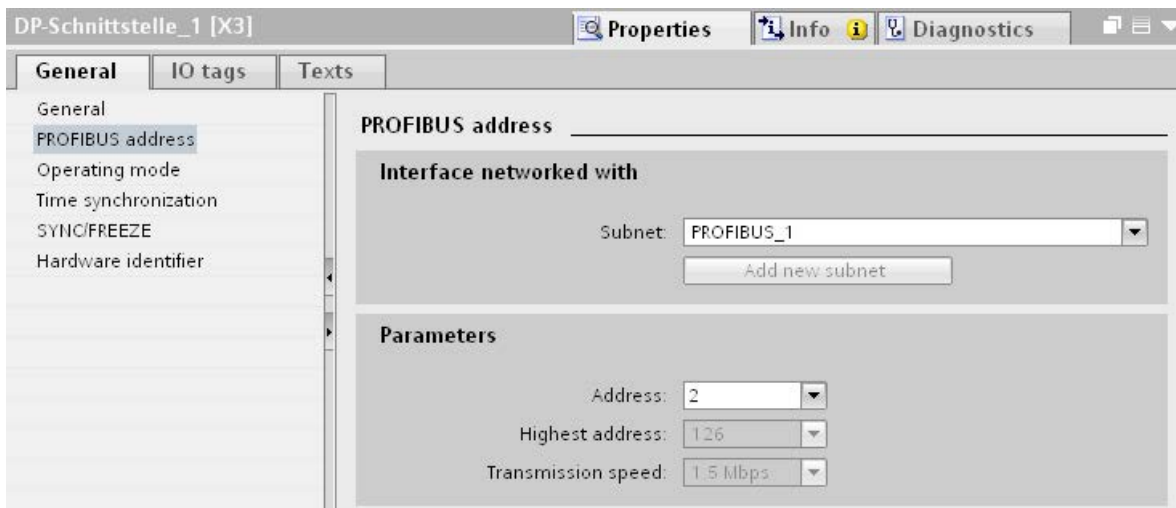


Figure 3-2 PROFIBUS address

Rules for address assignment

STEP 7 automatically assigns device addresses.

You can change the addresses if you observe the following points:

- Assign a unique PROFIBUS address to each device in the PROFIBUS network, each DP master and each DP slave in the PROFIBUS network.
- Depending on the DP slave, not all permitted PROFIBUS addresses are supported. For devices with BCD switches, it is often the case that only the PROFIBUS addresses 1 to 99 are supported.

Changing the PROFIBUS address

You change the PROFIBUS address under "Parameter".

3.3 Network settings

Highest PROFIBUS address (HSA)

Outputs the highest PROFIBUS address of an active device. PROFIBUS addresses greater than HSA are permitted for passive devices, but only up to 126.

Profile

Depending on the connected device types and the protocols used, different profiles are available on the PROFIBUS. The profiles differ with respect to their setting options and calculation of the bus parameters.

The PROFIBUS subnet will only work properly if the bus parameters of all devices have the same values.

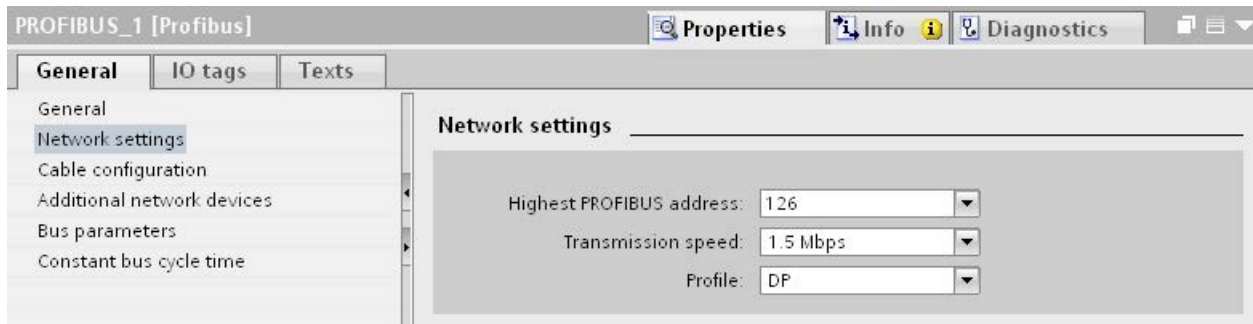


Figure 3-3 Network settings

Profiles and transmission rates

Table 3- 1 Profiles and transmission rates

Profiles	Supported transmission rates
DP	9.6 kbps to 12 Mbps
Standard	9.6 kbps to 12 Mbps
Universal (DP/FMS) (FMS is not supported)	9.6 kbps to 1.5 Mbps
User-defined	9.6 kbps to 12 Mbps

DP (recommended profile)

Select the "DP" profile if only devices meeting the requirements of the standard EN 61158-6-3 are connected to the PROFIBUS subnet. The setting of the bus parameters has been optimized for these devices. These include devices with DP master and DP slave interfaces of SIMATIC S7 as well as distributed I/O devices from third parties.

Note

Profile for constant bus cycle time and isochronous mode

DP is the recommended profile for the configuration of constant bus cycle time and isochronous mode.

Standard

Compared with the "DP" profile, the "Standard" profile gives you the option to take into consideration devices of another project or devices that have not been configured here for calculation of the bus parameters. The bus parameters are then calculated with a simple algorithm that was not optimized.

Universal (DP/FMS) (FMS is not supported)

Select the "Universal (DP/FMS)" profile if individual devices in the PROFIBUS subnet use the FMS service (e.g., CP 343-5, PROFIBUS FMS devices).

As with the "Standard" profile, here, too, you have the option to take additional devices into consideration for calculation of the bus parameters.

User-defined

The PROFIBUS subnet will only work properly if the parameters for the profile have been synchronized. Select the "User-defined" profile if none of the other profiles "match" for operation of a PROFIBUS device and if you have to adapt the bus parameters for your special layout.

You cannot configure all theoretically possible combinations with the user-defined profile either. The PROFIBUS standard prescribes some parameter limits depending on other parameters. It is, for example, not permitted that a responder responds (Min Tsdr) before the initiator is able to receive the frame (Trdy). These standard specifications are also checked in the "User-defined" profile.

Note

User-defined settings

Use user-defined settings only if you are familiar with the PROFIBUS parameters. It is usually better to work with the "DP" profile.

Contact Customer Support (Page 91) if you have any questions.

The bus parameters that were last valid on the PROFIBUS subnet are automatically set as user-defined. If the "DP" bus profile was valid for the subnet, for example, the bus parameters for "DP" are set in the "User-defined" bus profile. You can modify the parameters based on these settings.

The monitoring times are not automatically recalculated in the "User-defined settings" setting so that the uniformity of the set values is not changed without your knowledge, for example, to configure other configuration tools.

You can calculate the monitoring times Ttr and watchdog based on the parameters you have set. To do so, click on the "Recalculate" button.

See also

Additional network stations (Page 51)

3.4 Cable configuration

Considering cable configuration

Information on the cable configuration can be taken into consideration for calculation of the bus parameters. To do so, select the check box "Take into account the following cable configuration" in the properties of the PROFIBUS subnet.

The other information depends on the type of cable used.

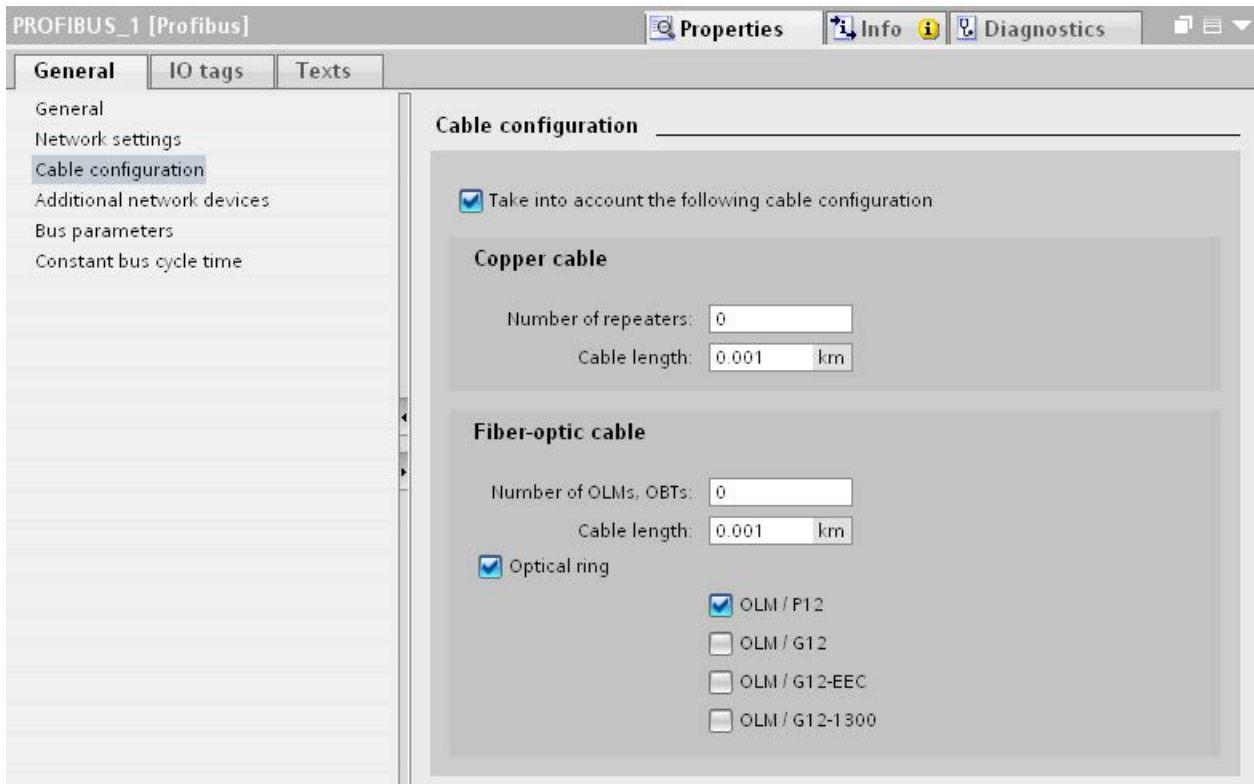


Figure 3-4 Cable configuration

Cable configuration: Fiber-optic cables/optical ring

The calculation depends on the used OLM types. Select the corresponding check box. Multiple selections are possible.

Adapting bus parameters in the optical ring

With the layout as ring, there is a kind of redundancy because you have the option to address all devices using the ring structure even if the connection between two devices is interrupted.

The following configuration conditions must be met in the optical ring:

- A free address below HSA (Highest Station Address)

- Increase of the retry value to at least 3

(Network settings: user-defined profile)

- Checking and adapting of the slot time

(Network settings: user-defined profile; bus parameters: Tslot parameter:

You need short slot time values for OLM / P12, medium slot time values for OLM / G12 and OLM / G12-EEC and high slot time values for OLM / G12-1300. This results in a high performance for small networks and a medium to low performance with medium to large networks.

Additional information

Additional information on adaptation of the retry value and the slot time is available in the PROFIBUS Network Manual

(<http://support.automation.siemens.com/WW/view/en/35222591>).

3.5 Additional network stations

Communication load - considering additional network stations

The bus parameters depend on the communication volume of the active network stations. There are differences between cyclical communication (DP) and connection-oriented, acyclical communication (S7 communication, Send/Receive (FDL)). Contrary to DP, the number and size of the communication jobs (communication load) depends on the user program. This means the communication load cannot always be determined automatically.

If you select the check box "Consider the following network stations", you can consider network stations in the calculation of the bus times that were not configured in the project.

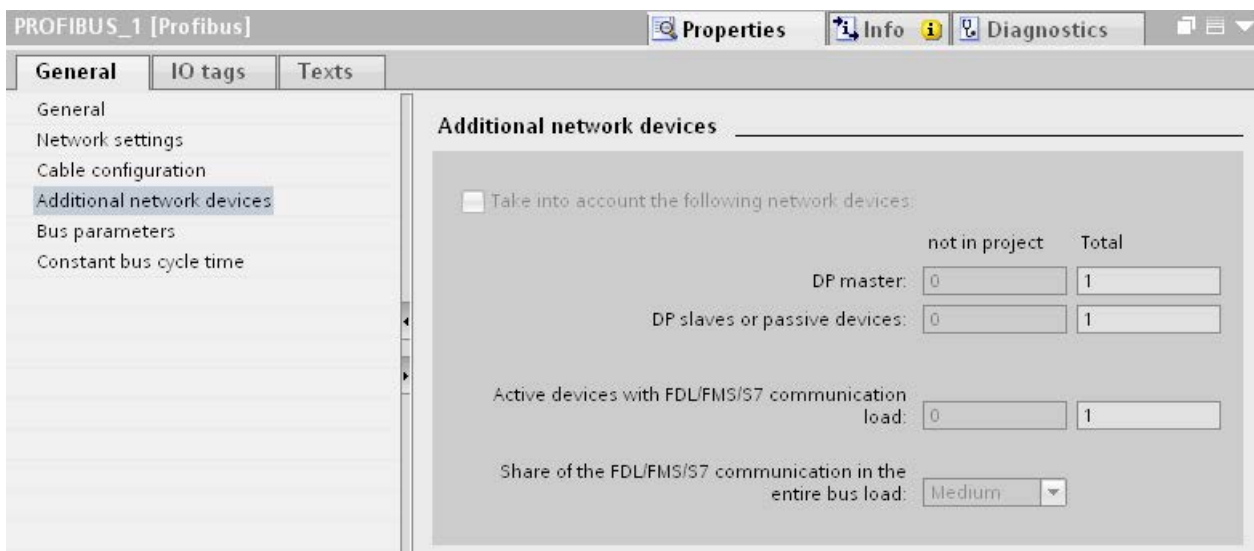


Figure 3-5 Additional network stations

Calculating the bus times

You can specify a network configuration in the parameter group "Additional network stations" for calculation of the bus times that deviates from the configured network configuration.

The network configuration is available for the following profiles:

- Standard
- Universal (DP/FMS)
- User-defined

3.6 Bus parameters

Quantification of the communication load

The following settings are possible to take the communication load into consideration:

- Number of network stations that are not configured
- Information on the communication load from the user programs for FDL or S7 communication. You can choose from the following levels:
 - Low: Typical for DP, no larger data communication except DP.
 - Medium: Typical for mixed operation of DP and other communication services (e.g., S7 communication), if DP has high time requirements and with medium, acyclical communication volume.
 - High: For mixed operation of DP and other communication services (e.g., S7 communication), if DP has low time requirements and with high, acyclical communication volume.

3.6 Bus parameters

Introduction

Bus parameters control the transmission behavior on the bus. Each device on the bus must correspond with the bus parameters of other devices.

Note

The PROFIBUS subnet will only work properly if the parameters for the bus profile have been synchronized. Change the preset values only if you are familiar with the parameter assignment of the bus profile for PROFIBUS.

Cyclical distribution of the bus parameters

If the check box "Activate cyclical distribution of bus parameters" is selected under "Bus parameters" with the selected PROFIBUS subnet in the Inspector window, the bus parameters are sent cyclically during operation by the modules that support this function. This way you can, for example, connect a programming device to the PROFIBUS during operation.

Disable this function in the following cases:

- In constant bus cycle time mode to minimize the bus cycle.
- If third-party devices are connected in the PROFIBUS subnet whose protocol uses the DSAP 63 (Destination Service Access Point) for multicast.

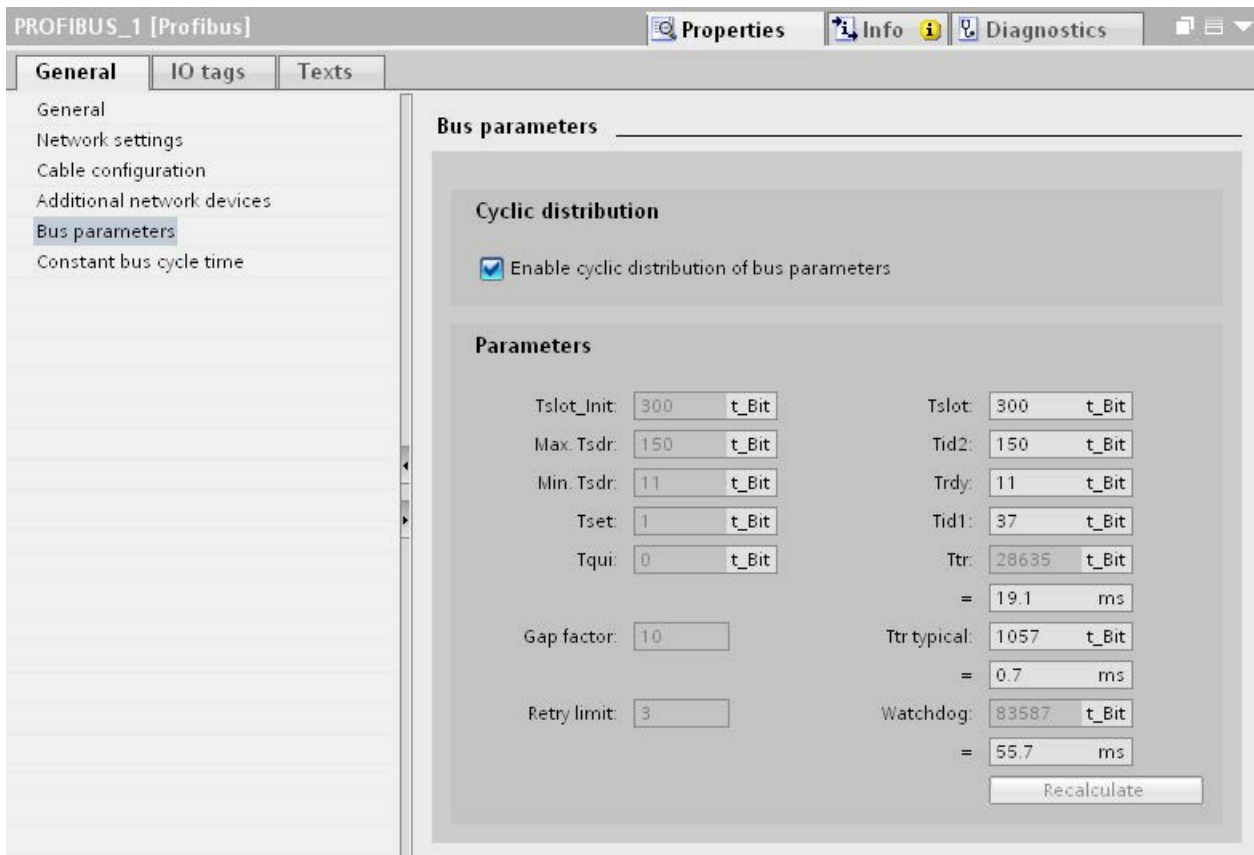


Figure 3-6 Bus parameters

Bus parameters for the bus profile of PROFIBUS subnets

Note

Display of offline values

The offline values of the bus parameters are always displayed even if they are connected online with the target system.

Table 3-2 Bus parameters - value ranges

Bus parameters	Adjustable ¹	Limit values
Tslot_Init	Yes	Max. Tsdr + 15 <= Tslot_Init <= 16.383 t_Bit
Max. Tsdr	Yes	35 + 2*Tset + Tqui <= Max. Tsdr <= 1,023 t_Bit
Min. Tsdr	Yes	11 t_Bit <= Min. Tsdr <= MIN(255 t_Bit, Max. Tsdr - 1, 34 + 2*Tset + Tqui)
Tset	Yes	1 t_bit <= Tset <= 494 t_bit
Tqui	Yes	0 t_bit <= Tqui <= MIN(31 t_bit, Min. Tsdr - 1)
GAP factor	Yes	1 <= GAP factor <= 100
Retry limit	Yes	1 <= Retry limit <= 15
Tslot (slot time)	No	-
Tid2	No	Tid2 = Max. Tsdr
Trdy	No	Trdy = Min. Tsdr
Tid1	No	Tid1 = 35 + 2*Tset + Tqui
Ttr (Target Rotation Time)	Yes	256 t_Bit <= Ttr <= 16,777,960 t_bit
Ttr typical	No	This time is for information only and is not transmitted to the devices.
Watchdog		10 ms <= Watchdog <= 650 s

¹ depending on bus profile

User-defined bus profile

Use the following settings to create a user-defined bus profile:

- minimum Target Rotation Time (Ttr) = 5000x HSA (highest PROFIBUS address of an active device)
- minimum watchdog (Watchdog) = 6250x HSA

Recalculate

Use the button "Recalculate" to recalculate the parameters.

3.7 Constant bus cycle time

Constant bus cycle time

The DP master addresses its assigned DP slaves cyclically. S7 communication may cause the intervals to vary. You can enable a "bus cycle with constant bus cycle time" to achieve identical intervals. This ensures data transmission at the same (constant bus cycle time) intervals.

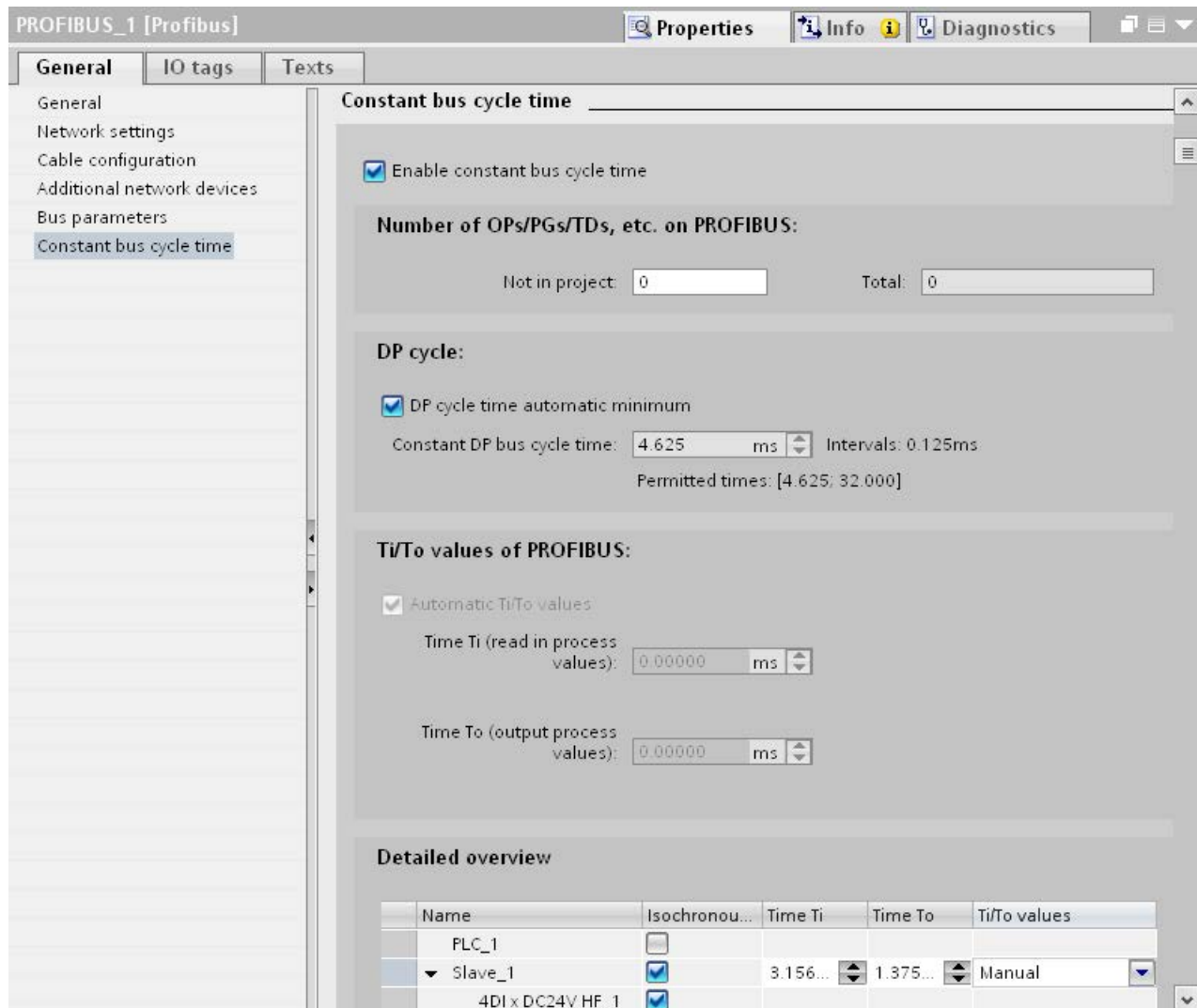


Figure 3-7 Enabling a bus cycle with constant bus cycle time

Number of OPs/PGs/TDs at the PROFIBUS

Here you enter the number of devices that are not configured.

Increasing DP cycle time manually

The following situation can occur especially with very short DP cycle times:
The runtime of the user program is greater than the shortest cycle (see Technical specifications of the CPU, section "Isochronous mode"). You have to manually increase the automatically calculated DP cycle time in this case.

See also

Configuring isochronous mode (Page 67)

Diagnostics

4.1 Overview

Diagnostics options

In case of an error you can determine the current status of your automation system and react specifically by using the event-related diagnostics and the evaluation of interrupts.

You can use the following options for diagnostics of the PROFIBUS components:

- Determine the status of the system using the Lifelist in STEP 7.
- Evaluate the module status, error and message texts by using the display of the S7-1500 CPU.
- Run cable diagnostics during operation by means of the diagnostics repeater.
- Evaluate the diagnostics and interrupt behavior in isochronous mode. (Page 70)
- Determine status information for fault localization and fault rectification by using the DP/PA coupler FDC 157-0 configured as PROFIBUS diagnostics slave.

Additional information

Additional information on diagnostics is available in these manuals:

- In the Diagnostics repeater for PROFIBUS-DP (<http://support.automation.siemens.com/WW/view/en/7915183>) manual for diagnostics with STEP 7, diagnostics in the user program, monitoring function isochronous PROFIBUS, topology display in STEP 7.
- In the Diagnostics (<http://support.automation.siemens.com/WW/view/en/59192926>) function manual for diagnostics options that are available for the SIMATIC systems S7-1500, ET 200MP, ET 200SP and ET 200AL.
- In the PROFIBUS Network Manual (<http://support.automation.siemens.com/WW/view/en/35222591>) system manual for diagnostics of fiber-optic cables.
- In the DP/PA Coupler, Active Field Distributors, DP/PA Link and Y Link (<http://support.automation.siemens.com/WW/view/en/1142696>) operating instructions.
- In the Web Server (<http://support.automation.siemens.com/WW/view/en/59193560>) function manual for diagnostics options (based on the functionality of the CPU).

4.2 Diagnostics using the display of the S7-1500

Displays

Each CPU in the S7-1500 automation system has a front cover with a display and operating buttons. Control and status information is displayed in different menus on the display. You use the operating buttons to navigate through the menus.

The following states can be evaluated on the display:

- Module status for central and distributed modules
- Error and alarm texts (system diagnostics, user-defined alarms)

Module status

From the station overview you go to the module status for a distributed module via the module overview.

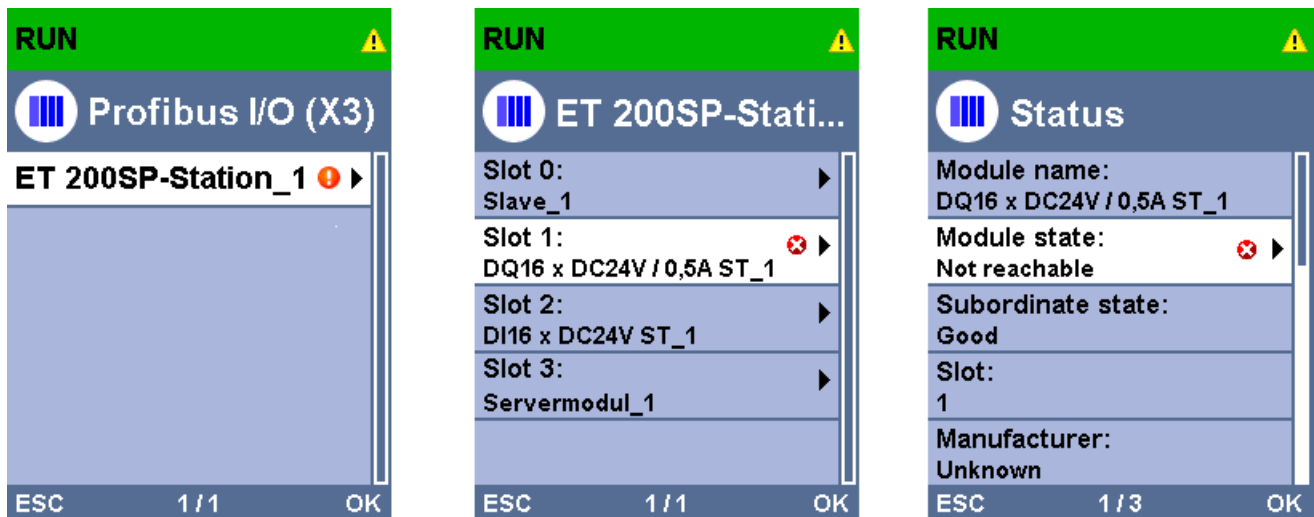


Figure 4-1 Example: Station overview, module overview, module status

Error and alarm texts

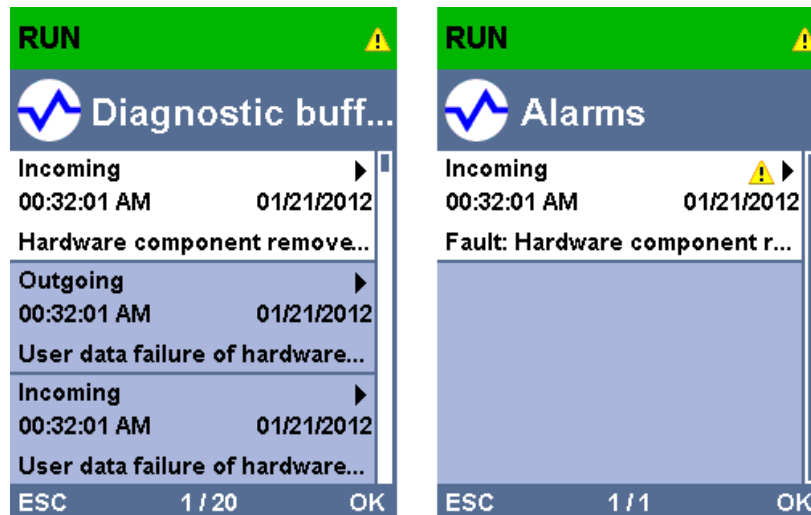


Figure 4-2 Example: Diagnostic buffer, alarms

Additional information

Additional information on the topic "Functions and operation of the display" is available in the documentation for the S7-1500 automation system on the Internet (<http://support.automation.siemens.com/WW/view/en/59191792>).

4.3 Diagnostics with the diagnostic repeater

Introduction

The diagnostic repeater is a repeater that can monitor two segments of a RS485-PROFIBUS subnet (copper cable) during operation and signal cable faults to the DP master by sending a diagnostic frame. Fault location and the cause of the fault can be displayed in plain text by means of STEP 7 as well as operator control and monitoring devices (SIMATIC HMI).

With its cable diagnostics during operation, the diagnostic repeater allows you to detect and localize cable faults early on. This means plant faults are detected early and plant downtimes can be prevented.

Diagnostic functions

- The diagnostic function provides the location and the cause of cable faults, such as wire break or missing terminating resistors. The fault location is specified relative to the devices present, for example "Break on signal line A and/or B".
- Reading out the saved diagnostic and statistical information.
- Monitoring of the isochronous PROFIBUS, e.g., violation of cycle time.
- Providing identification data.

Additional information

Additional information on diagnostics with STEP 7 and for reading out the diagnostics with the user program is available in the Diagnostic repeater for PROFIBUS DP (<http://support.automation.siemens.com/WW/view/en/7915183>) manual.

4.4 I&M data (Identification and Maintenance)

Definition and properties

Identification and maintenance data (I&M) is information saved in a module to provide support when:

- Checking the plant configuration
- Locating hardware changes in a plant

Identification data (I data) is module information (some of which may be printed on the module housing) such as the order and serial number. I data is read-only, vendor-specific module information.

Maintenance data (M data) is system-specific information such as the installation location and date. M data is generated in the course of configuration and is written to the module memory.

The modules can be uniquely identified in online mode by means of the I&M data.

Additional information

Information if and to what extent a DP device supports I&M data is available in the respective device manual of the device.

Functions

5.1 Isochronous mode

5.1.1 What is isochronous mode?

Why isochronous mode?

Assuming public transport were to operate at maximum speed while reducing stop times at the passenger terminals to absolute minimum, the last thing many potential passengers would notice of the departing contraption are its red tail lights. The overall travel time is, however, decided by the train, bus or underground clock, because well adjusted timing is essential to a good service. This also applies to distributed automation engineering. Not only fast cycles but also the adaptation and synchronization of the individual cycles result in optimum throughput.

Just-In-Time

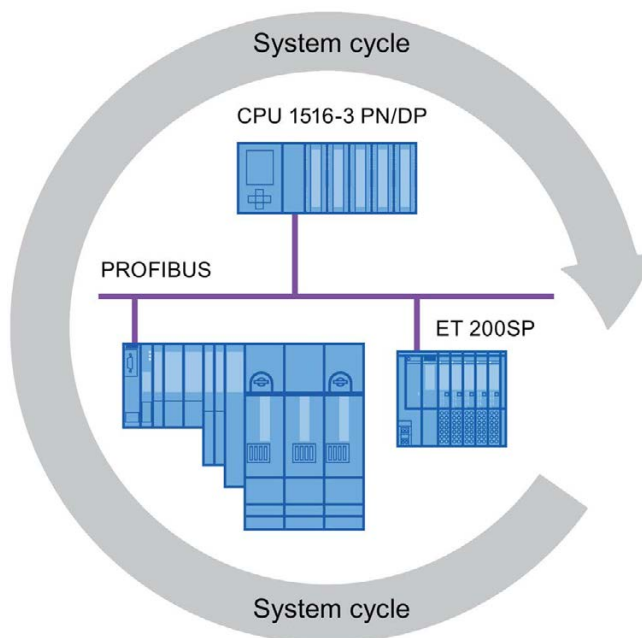


Figure 5-1 System cycle

The high speed and reliable reaction time of a system operating in isochronous mode is based on the fact that all data is provided just-in-time. The constant bus cycle time PROFIBUS DP cycle beats the time here.

Advantages of isochronous mode

The use of isochronous mode provides:

- Optimized controls
- Determinism
- Consistent (simultaneous) reading of input data
- Consistent (simultaneous) output of output data

5.1.2 Use of isochronous mode

The system property "isochronous mode" enables recording of measured values and process data in a defined system cycle. Signal processing takes place in the same system cycle all the way to switching to the "output terminal". This means isochronous mode improves the control quality and provides greater manufacturing precision. Isochronous mode drastically reduces the possible fluctuations of process response times. The time-assured processing can be used for a higher machine cycle.

Isochronous mode is basically always the choice when acquisition of measured values needs to be synchronized, movements need to be coordinated and process reactions need to be defined and take place simultaneously. This means the areas of applications for isochronous mode are manifold.

5.1.3 Isochronous applications

Example: Isochronous measurement at several measuring points

QC requires precise measurement of dimensions within a camshaft production process.

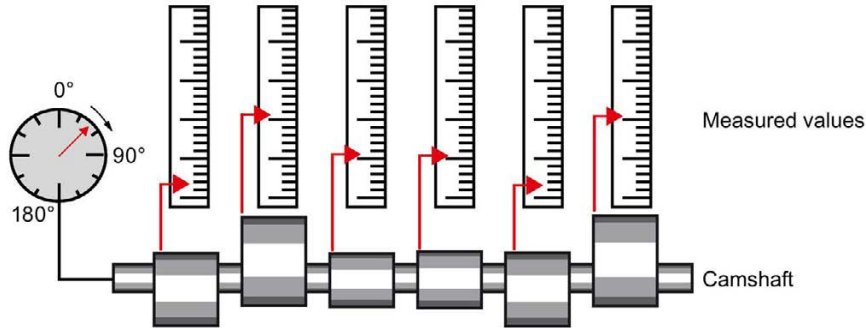


Figure 5-2 Measuring of camshafts

Isochronous workflow

By using the system property "isochronous mode" and the associated simultaneous measured value acquisition, measurement can be performed continuously and the time required for measurement is reduced. Resultant workflow:

- Continuous turning of the camshaft.
- During the continuous turning, measure the positions and cam excursion synchronously.
- Process the next camshaft.

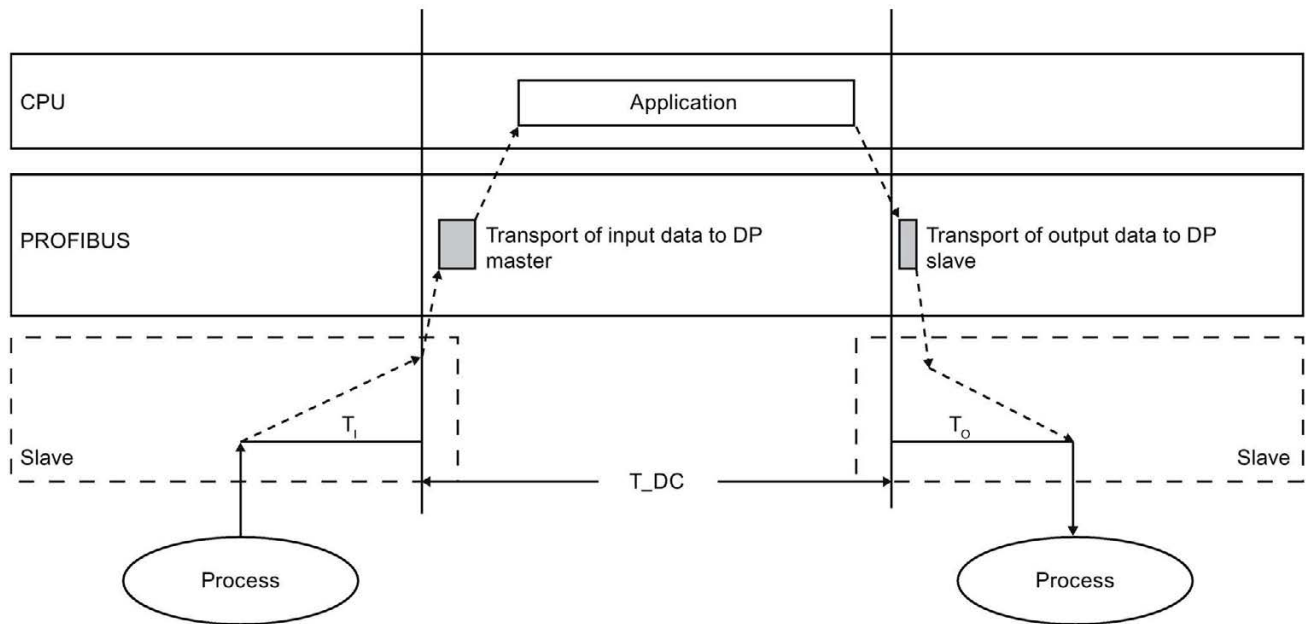
All camshaft positions and the corresponding measured values (red) are measured synchronously within a single rotation of the camshaft. This increases machine output and maintains or enhances precision of the measurement.

5.1.4 Sequence of synchronization

From reading of input data to output of output data

The sequence of all components involved in the synchronization is explained in the paragraphs below:

- Isochronous reading of input data
- Transport of input data by means of the PROFIBUS subnet to the DP master (CPU)
- Further processing in the isochronous application of the CPU
- Transport of output data by means of the PROFIBUS subnet to the output DP slave
- Isochronous output of output data



- T_DC Date cycle
- T_I Time for reading the input data
- T_O Time for output of output data

Figure 5-3 Time sequence of synchronization

To ensure that all input data is ready for transportation via the PROFIBUS DP line when the next PROFIBUS DP cycle begins, the I/O read cycle has a lead time T_I so that it starts earlier. The T_I is the "flash gun" for all inputs. This T_I is necessary to compensate for analog to digital conversion, backplane bus times, etc. The lead time T_I can be configured by STEP 7 or by the user. We recommend that you have T_I assigned automatically by STEP 7 .

The PROFIBUS DP line transports the input data to the DP master. The synchronous cycle interrupt OB SynchronousCycle is called. The user program in the synchronous cycle interrupt OB decides the process reaction and provides the output data in time for the start of the next data cycle. The length of the data cycle is always configured by the user.

T_0 is the compensation from the backplane bus and the digital to analog conversion within the slave. The T_0 is the "flash gun" for all outputs. The time T_0 can be configured by STEP 7 or by the user. We recommend that you have T_0 assigned automatically by STEP 7.

Without isochronous mode, application, data transmission and field devices have their own, unsynchronized processing cycles; these result in a higher total cycle time with high jitter. With isochronous mode, application, data transmission and field device are synchronized resulting in a minimum total cycle with minimum jitter.

Isochronous mode and non isochronous mode distributed I/O

It is possible to combine isochronous mode distributed I/O with non isochronous mode distributed I/O on one DP master.

5.1.5 Requirements for configuration

Note the following requirements for configuration of isochronous mode:

- Isochronous mode cannot be used in optical PROFIBUS networks.
- Constant bus cycle time and isochronous mode are only possible with the bus profiles "DP" and "User-defined".
- Isochronous mode is only possible with the DP interfaces integrated in the CPU. Isochronous mode with CPs for PROFIBUS is not possible.
- Only the constant bus cycle time master is permitted as active station on the isochronous PROFIBUS DP. OPs and PGs (for example, PCs with PG functionality) influence the time behavior of the isochronous DP cycle and are therefore not permitted.
- Isochronous mode is not permitted across lines.
- Isochronous I/O can only be processed in process image partitions. Isochronous consistent data transmission is not possible without the use of process image partitions. The adherence to quantity structures is monitored because the number of slaves and bytes on the DP master system is limited for each process image partition.
- The addresses of isochronous modules must be located in a process image partition.
- Full isochronous mode from "terminal" to "terminal" is only possible if all components involved in the chain support the system property "isochronous mode".

Make sure you look for the entry "Isochronous mode" or "Isochronous processing" in the information box of the module when you select it in the catalog.

- When you configure isochronous mode, you may not assign a SYNC/FREEZE group to the slave.

5.1.6 Configuring isochronous mode

Introduction

A SIMATIC automation solution can be connected to the isochronous PROFIBUS with the isochronous mode function. Isochronous mode guarantees the synchronous reading of input data, the processing and output of output data at the same (isochronous) intervals.

Basic procedure for configuration of isochronous mode

1. Setting the properties for isochronous mode on the DP slave:
 - Isochronous DP cycle
 - Isochronous mode of the modules
2. Setting the properties for isochronous mode on the modules:
 - Synchronous cycle interrupt (SynchronousCycle)
 - Process image partition
 - Input delay
3. Create user program with access to isochronous I/O

Requirement

- The network view in STEP 7 is open.
- A CPU has been placed (e.g., CPU 1516-3 PN/DP).
- An interface module has been placed and networked with the CPU (e.g., IM 151-1 HF).
- I/O modules have been placed (e.g., 2DI x DC24V HF and 2DO x DC24V/0,5A HF).

Configuring isochronous mode on the DP slave

1. Select the DP slave in the network view and navigate to the "isochronous mode" area in the Inspector window.
2. Enable the option for synchronization to the DP cycle for the DP slave.
Default: The DP slaves get the Ti/To values from the subnet which means the values are automatically the same for all DP slaves of the DP master system.
3. Enable the "Isochronous mode" option the the "Detail view" for all I/O modules you want to operate in isochronous mode.
4. Repeat steps 1 and 3 for all DP slaves that you want to operate in isochronous mode.

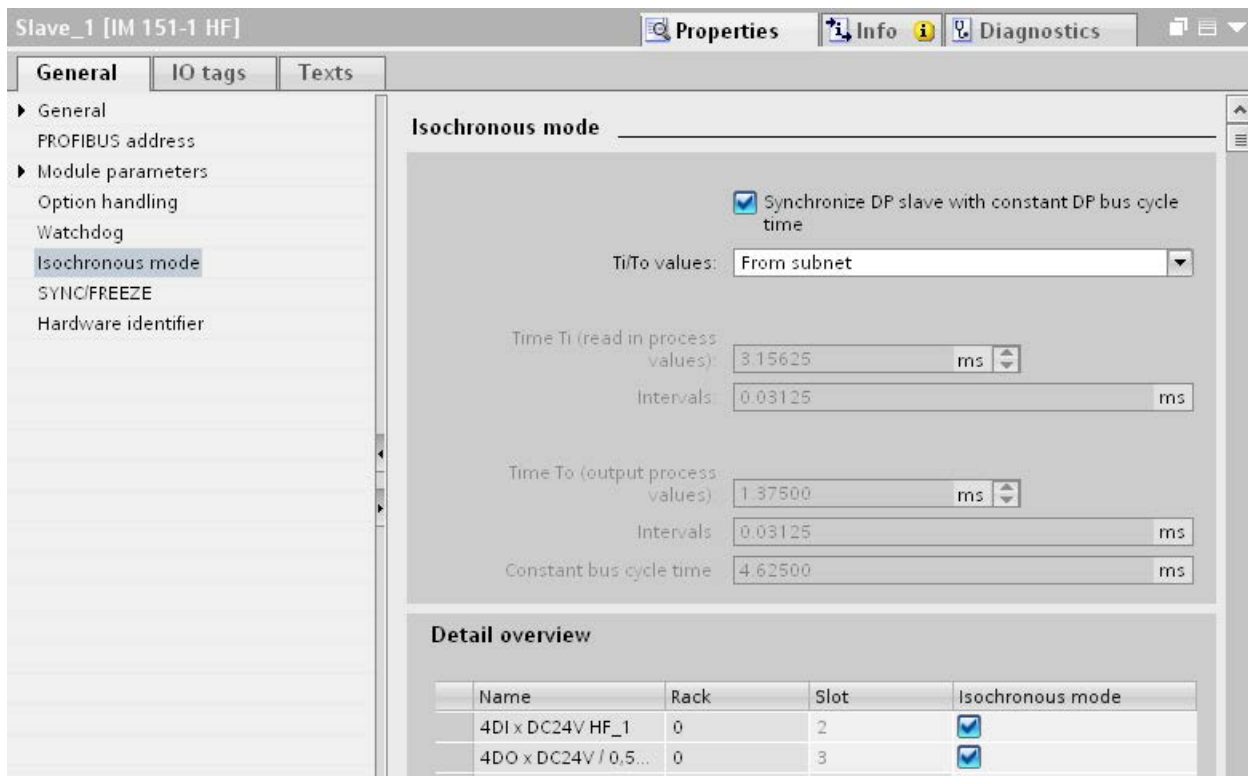


Figure 5-4 Configuring isochronous mode on the DP slave

Configuring synchronous cycle interrupt on the I/O module

1. Select an I/O module in the device view and navigate to the "I/O addresses" area in the Inspector window.
 - The option for isochronous mode is selected.
2. Select the synchronous cycle interrupt in the drop-down list.

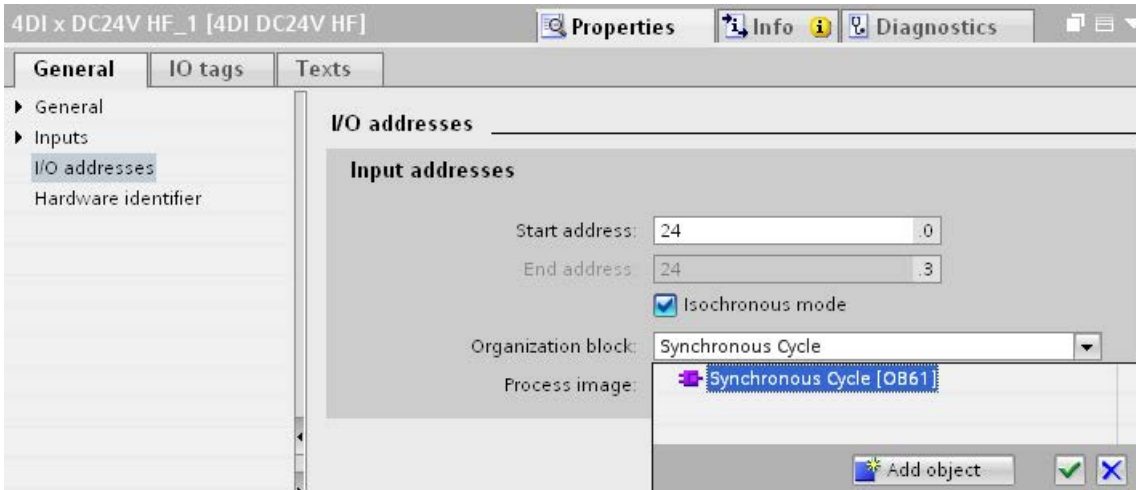


Figure 5-5 I/O addresses - creating the synchronous cycle interrupt OB

3. Assign the process image partition configured in the CPU.

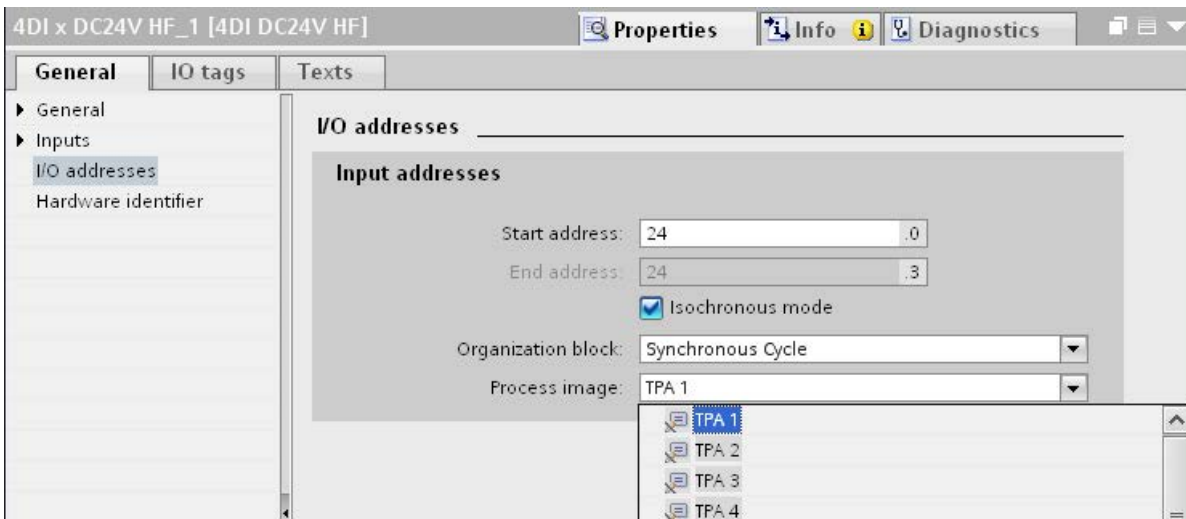


Figure 5-6 I/O addresses - assigning process image partitions

4. Repeat steps 1 and 3 for all I/O modules that you want to operate in isochronous mode.

Programming isochronous mode

To operate your plant in isochronous mode, the user program must be structured accordingly. This means you have to add a synchronous cycle interrupt in the STEP 7 project tree.

You access the isochronous I/O by means of a process image partition, which means the addresses of the isochronous modules must be located in a process image partition. You program access to isochronous I/O with the "SYNC_PI" instructions (updating the process image partitions of the inputs) and "SYNC_PO" (updating the process image partition of the outputs) in the synchronous cycle interrupt OB.

You call the "SYNC_PI" instruction at the start of the synchronous cycle interrupt OB, provided you have selected the automatic setting for the delay time. You call the "SYNC_PO" instruction at the end of the synchronous cycle interrupt OB.

5.1.7 Diagnostics and interrupt functions

The diagnostic and interrupt functions of STEP 7 are available for isochronous mode. These reduce downtimes and simplify localization and elimination of faults.

Events, causes of errors and remedies

Below, you will find the events for diagnostic and interrupt functions and remedies for the problem.

Table 5- 1 Events, causes of errors and remedies

Event	Cause of the error	Remedy
<ul style="list-style-type: none"> • Synchronous cycle interrupt OB is started with the input parameter EventCount > 0 (number of lost OB calls since last OB call) <p>If configured:</p> <ul style="list-style-type: none"> • Call of the time error OB • Diagnostic buffer entry "Buffer overflow for OB6x events" 	<p>The synchronous cycle interrupt OB takes too long.</p>	<ul style="list-style-type: none"> • Shorten the synchronous cycle interrupt OB. • Increase the DP cycle. • Reduce the delay time setting (setting with isochronous mode at synchronous cycle interrupt OB).
<p>Error (negative RetVals) when updating the isochronous process image partition with SYNC_PI / SYNC_PO:</p> <ul style="list-style-type: none"> • Consistency warning • Update time is after / before the permitted access window. 	<p>SYNC_PI / SYNC_PO are not called in the permitted access window in the synchronous cycle interrupt OB, which means they are called or processed during the I/O data transfer on PROFIBUS.</p>	<ul style="list-style-type: none"> • Increase the delay time. • Increase the DP cycle. • Adapt the program.
<p>Error when updating the isochronous process image partition with SYNC_PI / SYNC_PO:</p> <ul style="list-style-type: none"> • Access error 	<p>DP slave / module does not respond / is not available.</p>	

5.1.8 Parameter settings for isochronous mode

Parameter changes as task of the field service technician

The task of a field service technician is to maintain the production process.

In this context the technician has to detect, localize and eliminate errors and performance losses of isochronous mode.

All parameters which influence isochronous mode can be checked and configured using the "Isochronous mode" dialog box.

Parameters should only be changed by experienced users or service technicians.

5.1.8.1 Viewing isochronous mode parameters

"Isochronous mode" dialog box

1. Select "Properties > Isochronous mode" in the Inspector window.

The "isochronous mode" dialog box opens with an overview of parameters which influence isochronous mode.

Information on the individual parameters is available under "Detail overview".

2. Compare the values shown with the values in the documentation, or with the value specified by a technician.

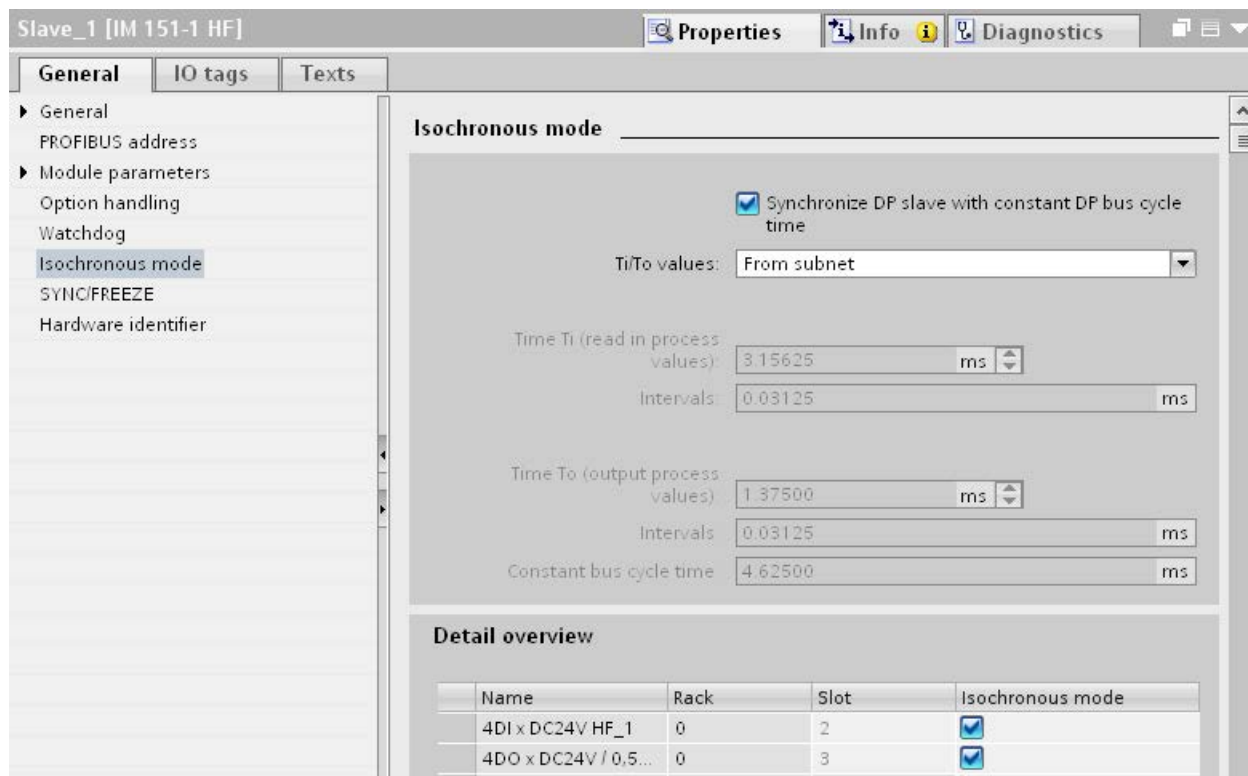


Figure 5-7 Viewing parameters for isochronous mode

5.1.8.2 Change parameters

Changing parameters for the DP master system

You can change the parameters for isochronous mode in the "Constant bus cycle time" dialog box.

1. Select the DP master system in the network view.
2. Select the section "Constant bus cycle time" in the Inspector window.
3. Change the parameters according to the received instructions.

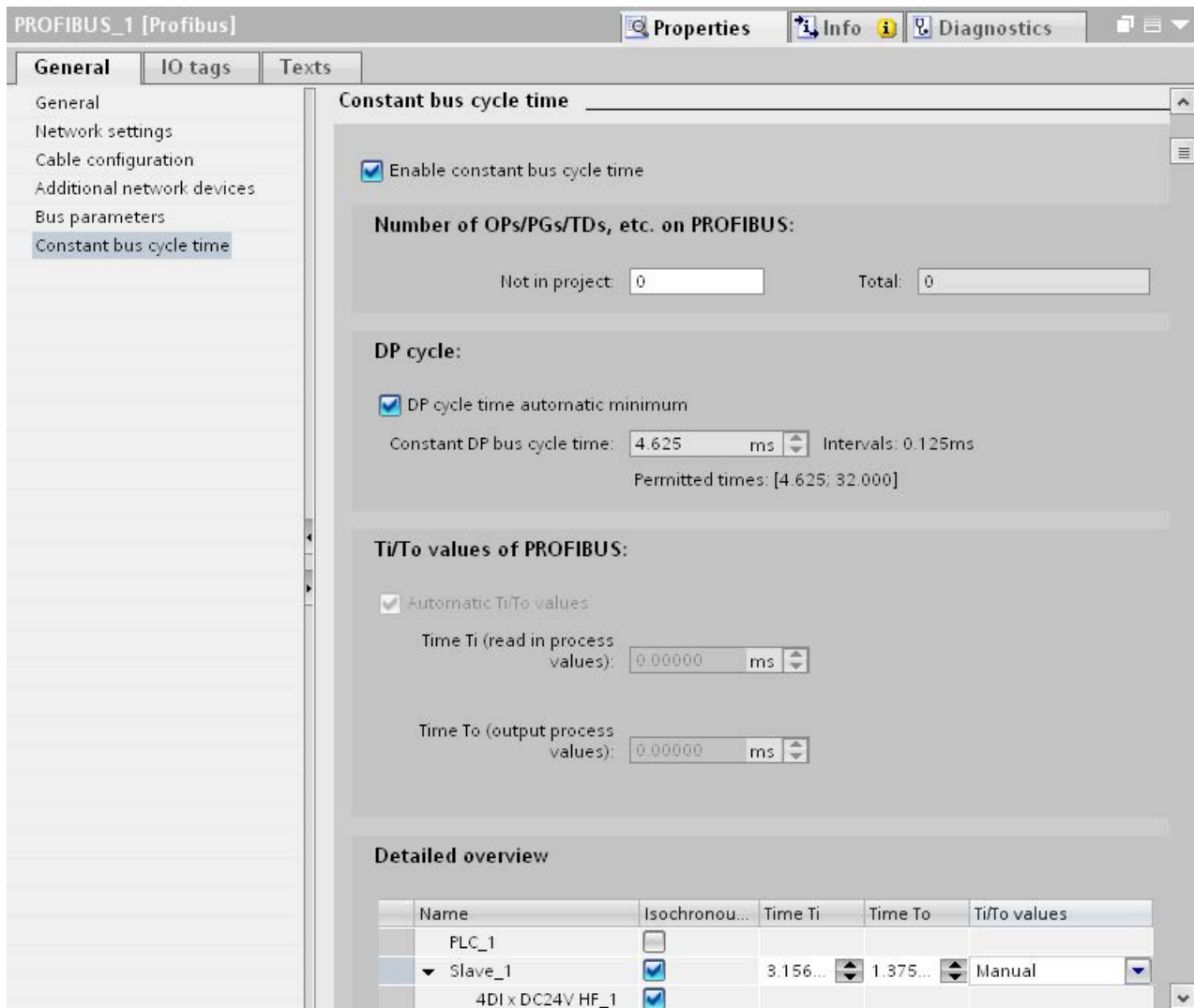


Figure 5-8 Changing parameters for the DP master system

Adapting the input delay

1. Select the input module in the device view.
2. Select the section "Inputs" in the Inspector window.
3. Adapt the input delay.

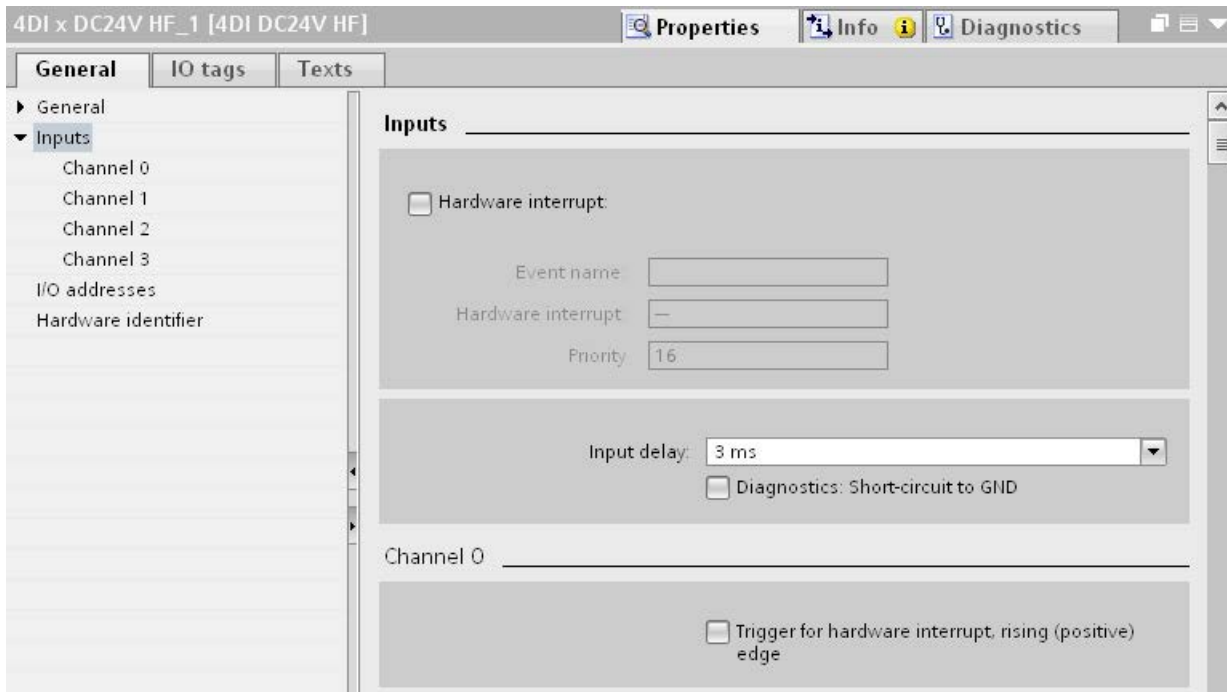


Figure 5-9 Adapting the input delay

Compile, load and save the changed configuration

1. Put the plant out of operation.
2. Select the CPU in the project navigator.
3. Select "Compile > Hardware" in the shortcut menu.
4. Select "Download to device" in the shortcut menu.
5. Save the project.

5.2 Acyclical data exchange

Additional functionality with DPV1 devices (DP master/DP slaves)

DP masters and DP slaves that support DPV1 have the following additional functions compared to the devices that support only DPV0:

- The acyclic data exchange between master and slave is supported.
- Interrupts can be set by a DPV1 slave which ensure handling of the interrupt-triggering event in the master CPU.

Acyclic data exchange

Read/write data record, for example, to change the parameters of a slave during operation. The data records of a module and the structure of these data records is available in the documentation for the respective module.

The table below contains the instructions with their functions for access to DPV1 slaves. Detailed information is available in the STEP 7 online help.

Table 5- 2 Instructions for access to DPV1 slaves

Instructions	Function (DPV1)
RDREC	Read data record
WRREC	Write data record
RALRM	Receive interrupt from a DP slave. (The instruction must be called in the OB that triggers the interrupt.)

5.3 SYNC/FREEZE groups

Assigning the SYNC/FREEZE group to the DP slave

A DP master with the corresponding functionality can send the control commands SYNC and/or FREEZE for synchronization of the DP slaves simultaneously to a group of DP slaves. You must assign SYNC/FREEZE groups to the DP slaves for this purpose.

Requirement: A DP master system has been created in the project.

Procedure

To assign a DP slave to a SYNC/FREEZE group, follow these steps:

1. Select the DP interface of the DP slave you want to assign to a group in the device view or network view.
2. Select the check boxes for the required SYNC/FREEZE groups under the group "SYNC/FREEZE" in the Inspector window.

You can assign each DP slave to only one SYNC/FREEZE group.

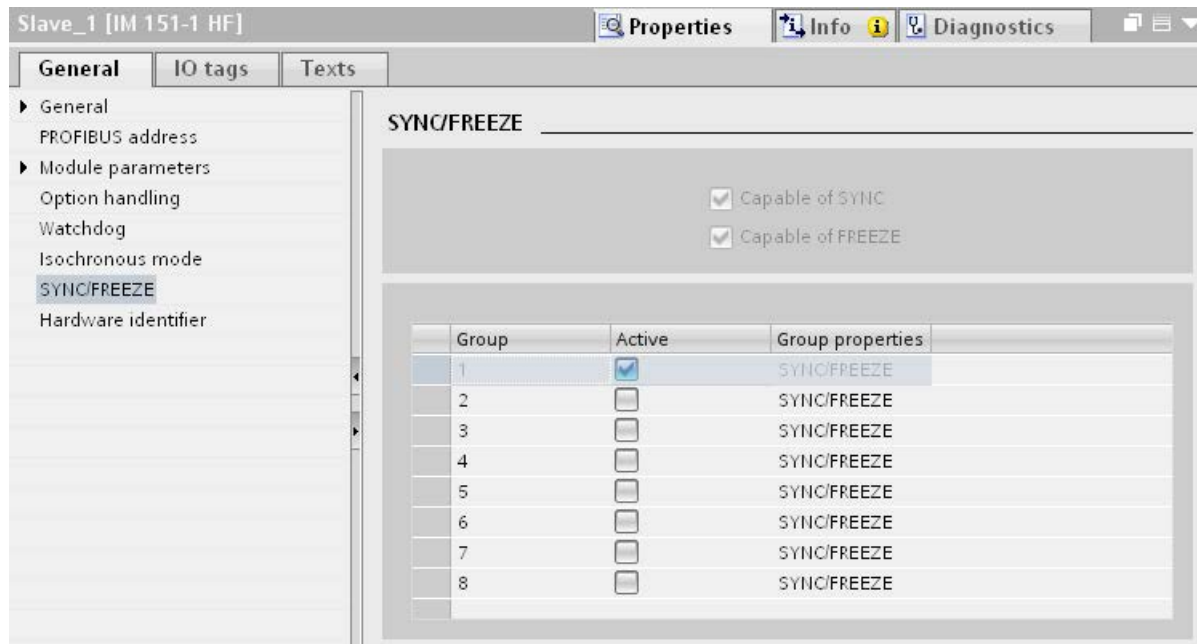


Figure 5-10 Assigning the DP slave to a SYNC/FREEZE group

Important information on the control commands SYNC and FREEZE

You can use the control commands SYNC and FREEZE in the DP master to synchronize the DP slaves event-controlled. The DP master sends the control commands simultaneously to a group of DP slaves in its master system. It does not take into consideration DP slaves that have failed or are currently sending diagnostic information.

Requirement for synchronization using control commands is that you have assigned the DP slaves to SYNC/FREEZE groups.

For a S7 CPU use the instruction DPSYC_FR (SFC 11) to synchronize the DP slaves.

When you select the DP master, you see a list of the eight SYNC/FREEZE groups under "Properties > DP interface > SYNC/FREEZE" in the Inspector window.

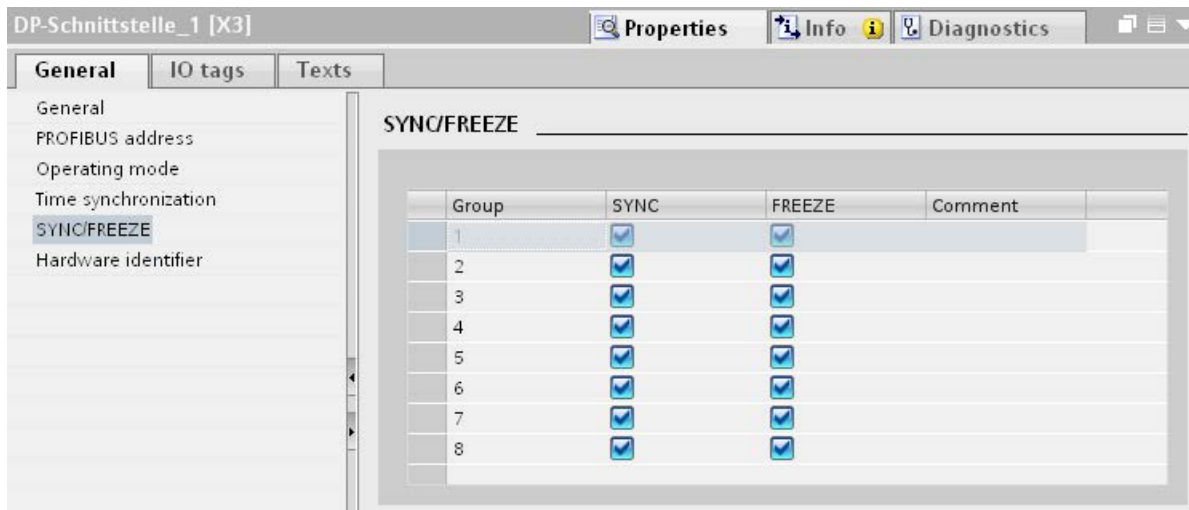


Figure 5-11 SYNC/FREEZE groups on DP master

SYNC control command

The DP master uses the SYNC control command to cause a group of DP slaves to freeze the states of their outputs to the current value.

The DP slaves save the output data of the DP master for the following frames. But the states of the DP slave outputs remain unchanged.

Only after each new SYNC control command does the DP slave set its outputs to the values that it has saved as the output data of the DP master.

The outputs are not updated cyclically again until the DP master has sent a UNSYNC control command.

FREEZE control command

After receiving the FREEZE control command from the DP master, the DP slaves of a group freeze the current status of their inputs. The DP slaves send these frozen input data to the DP master with the following cyclical frames.

The DP slaves freeze the current state of their inputs again after each new FREEZE control command.

The state of the DP slave inputs is only send to the DP master cyclically again when the DP master sends the UNFREEZE control command.

5.4 Interrupts

Interrupts and interrupt OBs for DPV1

Interrupts can be set by a DPV1 slave which ensure handling of the interrupt-triggering event in the master CPU. The interrupt data is evaluated in the CPU and the diagnostics buffer and the module state are updated even in the "STOP" operating mode. The OB is not processed in STOP.

The following DPV1 interrupts are supported:

- Status interrupt
- Update interrupt
- Vendor-specific interrupt

Detailed information is available in the descriptions on the OBs. You can use the corresponding OBs that are provided by the operating system of the S7 CPUs for diagnostic interrupts, hardware interrupts, and pull/plug interrupts.

OB 55 interrupt - Status interrupt

The status interrupt can be triggered when the operating mode of a device or module changes, for example, from RUN to STOP.

OB 56 interrupt - Update interrupt

An update interrupt can be triggered if the parameters of a slot were changed. This may be caused by local access or partner access to the parameters.

OB 57 interrupt - Vendor-specific interrupt

The event that triggers the vendor-specific interrupt can be specified by the manufacturer of a DPV1 slave.

Additional information

A detailed description of the events at which interrupts are triggered is available in the documentation of the respective manufacturer of the DPV1 slave.

5.5 Intelligent DP slaves (I-slaves)

5.5.1 I-slave functionality

I-slave functionality

The "I-slave" (intelligent DP slave) functionality of a CPU supports the exchange of data with a DP master and thus allows the CPU to be used, for example, as intelligent preprocessing unit of subprocesses. The I-slave is connected in its role as DP slave to a "higher-level" DP master.

The preprocessing is handled by the user program in the I-slave. The process values acquired by the I/O modules are preprocessed by the user program and made available to the DP master.

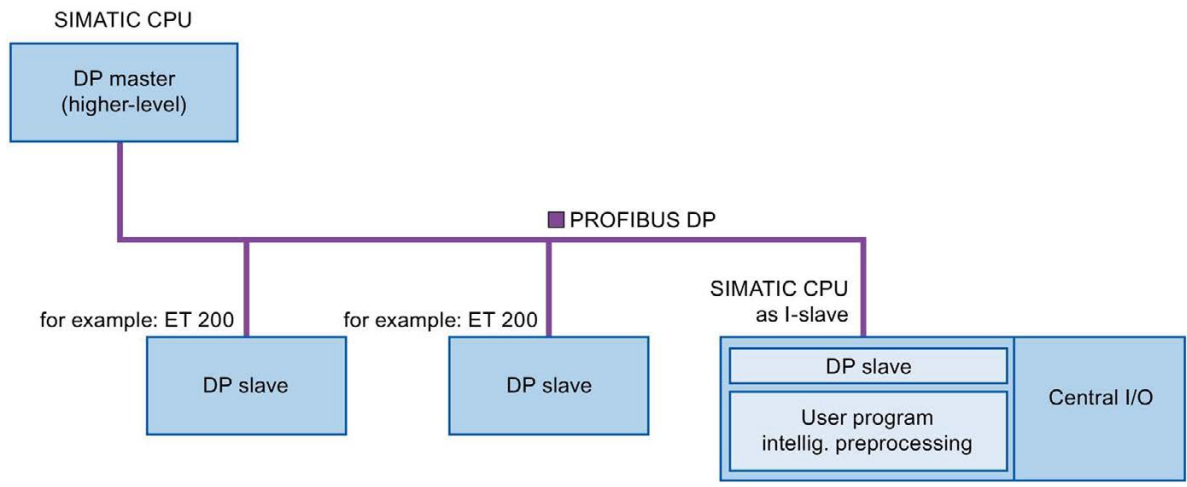


Figure 5-12 I-slave functionality

"I-slave" naming convention

In the remainder of this description, a CPU or a CP with I-slave functionality is simply called an "I-slave".

Advantages of configurations with I-slaves

The I-slave offers the following advantages:

- Simple coupling of CPUs with PROFIBUS interface
- Real-time communication between CPUs and PROFIBUS interface
- Distributed processing

A complex automation task can be divided into smaller units/subprocesses. This results in manageable processes which lead to simplified subtasks.

- Relieving the DP master by distributing the computing capacity to I-devices
- Lower communication load by processing process data locally
- Separating subprocesses

Complicated, widely distributed and extensive processes can be subdivided into several subprocesses with manageable interfaces by using I-slaves. These subprocesses can be stored in individual STEP 7 projects if necessary, which can later be merged to form one master project.

- Separating STEP 7 projects

Creators and users of an I-device can have completely separated STEP 7 projects. The GSD file together with the configuration of the transfer areas of the I-slave form the interface between the STEP 7 projects. This allows coupling to standard DP masters via a standardized interface.

- Know-how protection

Plant units can now only be delivered with a GSD file and the configuration of the transfer areas instead of with a STEP 7 project for the I-slave interface description. This means that you no longer have to disclose the user program know-how.

Difference: DP slave - I-slave

In the case of a DP slave, the DP master accesses the distributed inputs/outputs directly.

In the case of an I-slave, the DP master accesses a transfer area in the I/O address space of the preprocessing CPU instead of accessing the connected inputs/outputs of the I-slave. The user program running on the preprocessing CPU is responsible for ensuring data exchange between the operand area and inputs/outputs.

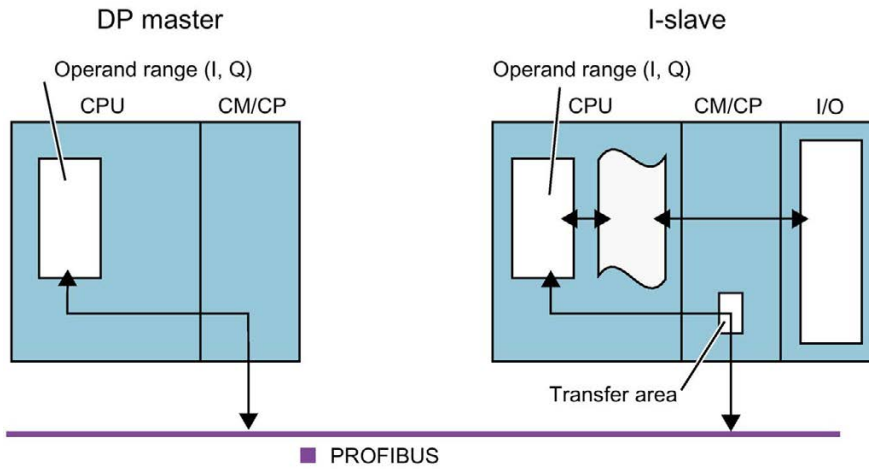


Figure 5-13 Data access to an I-slave

Note

DP master or DP slave

Note: The communication modules of the S7-1500 CPUs/ET 200SP CPUs, for example the CP 1542-5, support the operation as DP master or DP slave only as alternative.

Note

The I/O areas configured for data exchange between the DP master and DP slaves must not be used by I/O modules.

5.5.2 Data exchange with higher-level DP master

Introduction

The following section describes the data exchange between the I-slave and the higher-level DP master.

Transfer areas

Transfer areas are an interface to the user program of the I-slave CPU. Inputs are processed in the user program and outputs are the result of the processing in the user program.

The data for communication between DP master and I-slave is made available in the transfer areas. A transfer area contains an information unit that is exchanged consistently, in terms of bytes, words or overall, between DP master and I-slave. You can find more information on configuration and use of transfer areas in the section Configuring transfer areas (Page 84).

The following figure shows the data exchange between the I-slave and the higher-level DP master. The individual communication relations are explained below based on the numbers.

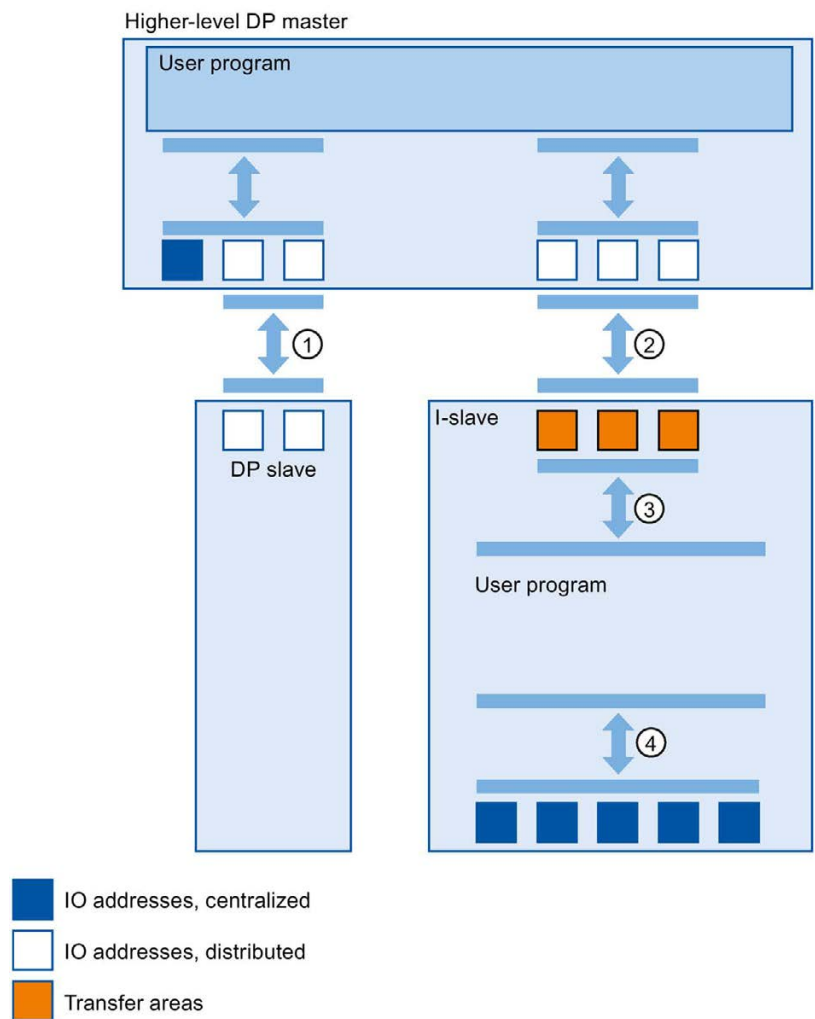


Figure 5-14 Data exchange with the DP master

① Data exchange between higher-level DP master and normal DP slave

In this way, the DP master and the DP slave exchange data through PROFIBUS.

② Data exchange between higher-level DP master and I-slave

In this way, the DP master and the slave exchange data through PROFIBUS.

The data exchange between a higher-level DP master and an I-slave is based on the conventional DP master/DP slave relationship.

For the higher-level DP master, the transfer areas of the I-slave represent submodules of a DP slave.

The output data of the DP master is the input data of the I-slave. Analogously, the input data of the DP master is the output data of the I-slave.

③ Transfer relationship between the user program and the transfer area

In this way, the user program and the transfer area exchange input and output data.

④ Data exchange between the user program and the I/O of the I-slave

In this way, the user program and the centralized I/O of the I-slave exchange input and output data.

5.5.3 Configuring an I-slave

Requirements for configuring an I-slave

The I-slave consists of:

- A CPU from S7-1500 and a communications module CM 1542-5/CP 1542-5 (STEP 7 as of V12)
- A CPU from ET 200SP and a communications module CM DP (STEP 7 as of V13 SP1)

Procedure for configuring an I-slave

This section shows how to configure an I-slave in STEP 7 based on the example of a CPU 1512SP-1 PN. The procedure for the CPUs from S7-1500 with CM 1542-5/CP 1542-5 and for the CPU 1510SP-1 PN with CM DP is the same.

To configure an I-slave, follow these steps:

1. Drag a CPU 1512SP-1 PN from the hardware catalog to the network view.
2. Open the device view of the CPU.
3. Double-click on the CM DP communications module in the hardware catalog. STEP 7 creates the CM DP in the device view.
4. Select the PROFIBUS interface of the CM DP communications module.
5. In the Inspector window in the area navigation, select the "Operating mode" entry and enable the "DP slave" check box.
6. Now you can select the DP master in the "Assigned DP Master" drop-down list.

Once you have selected the DP master, the networking and the DP master system between both devices are displayed in the network view.

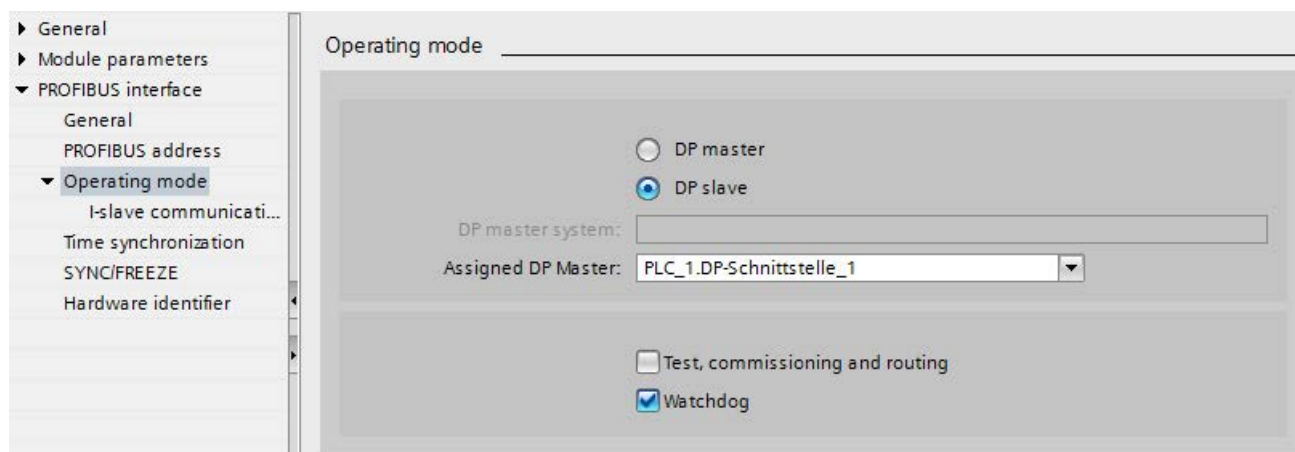


Figure 5-15 Configuring an I-slave

Note

Operation using a GSD file

If you operate an I-slave using a GSD file, you should not select the "Test, commissioning and routing" check box.

Create a DP subnet on the PROFIBUS interface of the I-slave.

Result

You have configured an I-slave.

5.5.4 Configuring transfer areas

Requirements for configuring transfer areas

- You have configured an I-slave in STEP 7.
- You are in the device view of the I-device and have selected the PROFIBUS interface of the communications module.

Procedure for configuring transfer areas

To configure transfer areas for an I-slave in STEP 7, follow these steps:

1. In the area navigation, go to the section "Operating mode" > "I-slave communication" > "Transfer areas".
2. Create transfer areas. Set the properties of the created transfer areas.

	①	②	③		④	⑤
...	Transfer area	Type	Master address	↔ Slave address	Length	Consistency
1	Transferbereich_1	MS	Q 0	→ I 0	1 byte	Unit
2	<Add new>					

- ① Click in the first cell of the "Transfer area" column. STEP 7 assigns a default name that you can change.
- ② Select the type of communication relation: Currently, you can only select MS for "master-slave communication relation".
- ③ STEP 7 assigns the addresses for the transfer area automatically. Correct the addresses if necessary.
- ④ Set the length of the transfer area. Specify the length of the transfer area in the cell in the following format: [1...64] Byte/Word.
Examples: "32 Byte", "64 Word"
- ⑤ Specify whether the transfer area is exchanged in units of bytes or words or consistently over the entire length between the DP master and I-slave.

Figure 5-16 Configuring transfer areas

A separate entry is created in the area navigation for each transfer area. If you select one of these entries, you can adjust the details of the transfer area, or correct them and comment on them.

5.5.5 Sample program

Introduction

This simple sample program shows how you use the transfer areas of an I-slave.

Requirement

You have configured an I-slave.

Task

The result of an "AND logic operation" of two inputs (preprocessing) in the I-slave is to be provided to the higher-level DP master. This result is to be assigned to a local output in the DP master (further processing).

Use a transfer area with the following addresses for this purpose:

- Address in the I-slave: Q568
- Address in the DP master: I68

Required steps

The following steps are necessary to solve the task:

1. Configuring the transfer area
2. Programming the I-slave
3. Programming the DP master


Configuring the transfer area


Configure a transfer area with the following properties in the I-slave:

Details of the transfer area

Transfer area:

Type of transfer area:

Partner: 

Local: 

Data exchange between: and

Slot:

Address type:

Start address:

Organization block:

Process image:

Length:

Unit:

Consistency:

Comment:

Figure 5-17 Transfer area, I-slave sample program

Programming the I-slave

To program the sample program for the I-slave, follow these steps:

1. Using the SCL programming language, create a new function with the name "preprocessing" in the project tree under "Program blocks" > "Add new block". Open the function.
2. In the interface of the function "preprocessing", create the following tags:

Name	Data type	Input/output type
input 1	bool	Input
input 2	bool	Input
result	bool	Output

3. In the instruction window of the function "preprocessing", write the following program code:
`#result:=#input 1&#input 2;`
4. Call the function "preprocessing" in a cycle OB, for example, in OB1.
5. Wire the function "preprocessing" in the cycle OB as follows:

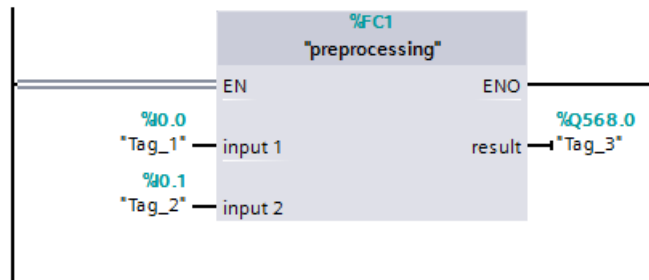


Figure 5-18 I-slave sample program

Programming the DP master

To program the sample program for the DP master, follow these steps:

1. Using the SCL programming language, create a new function with the name "further processing" in the project tree under "Program blocks" > "Add new block". Open the function.
2. In the interface of the function "further processing", create the following tags:

Name	Data type	Input/output type
result	bool	Input
output	bool	Output

3. In the instruction window of the function "further processing", write the following program code:
#output:=#result;
4. Call the function "further processing" in a cycle OB, for example, in OB1.
5. Wire the function "further processing" in the cycle OB as follows:

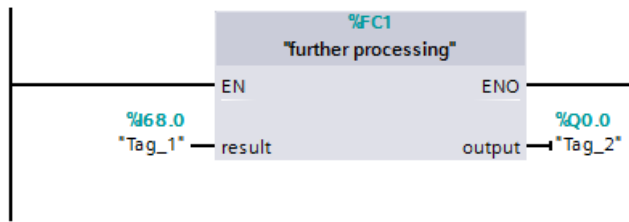


Figure 5-19 DP master sample program

Result

You mastered the task successfully.

5.5.6 Diagnostics and interrupt behavior

Diagnostics and interrupt behavior

S7 CPUs have numerous diagnostics and interrupt functions that can, for example, report errors/faults or failures of underlying DP systems. These diagnostics alarms reduce downtimes and simplify localization and elimination of problems.

Diagnostics options in the higher-level DP master and in the I-slave

The following diagnostics mechanisms are available to the higher-level DP master and the I-slave:

- OB 82 (diagnostic interrupt)

When the I-slave changes mode, the DP master calls OB 82 (diagnostic interrupt).

When the DP master changes mode, the I-slave calls OB 82 (diagnostic interrupt).

- OB 86 (rack failure)

If the bus connection to the I-slave is interrupted, the DP master calls OB 86 (rack failure).

If the bus connection to the DP master is interrupted, the I-slave calls OB 86 (rack failure).

- OB 122 (I/O access error)

If you have not set the attribute "Handle errors within block" for OB 122, the following applies:

- If the bus connection to the I-slave is interrupted, the DP master calls OB 122 (I/O access error) if there is direct access to the relevant transfer areas.
- If the bus connection to the DP master is interrupted, the I-slave calls OB 122 (I/O access error) if there is direct access to the relevant transfer areas.

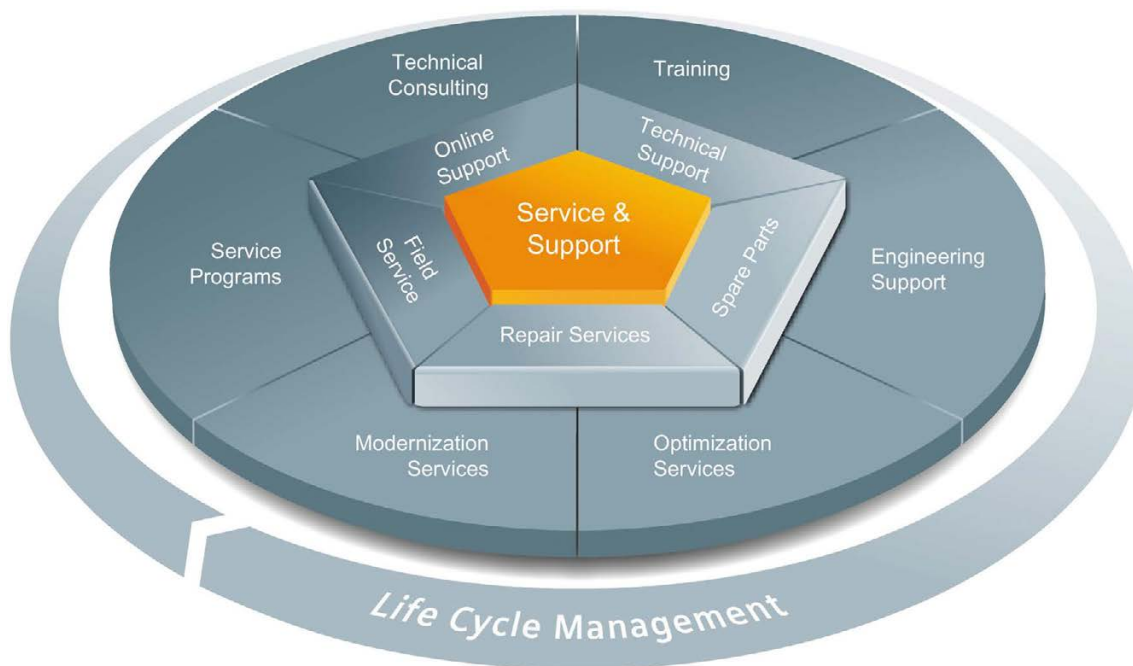
Reaction of the transfer areas to mode changes

Table 5- 3 Reaction of the transfer areas to mode changes

DP master	I-slave	Reaction of DP master input transfer areas	Reaction of I-slave input transfer areas
RUN→STOP	RUN	No updating of the process image	The input transfer areas retain their current values. (no access error)
STOP→RUN	RUN	The input transfer areas are updated by the cyclic user program via the process image.	The input transfer areas are updated via the process image.
RUN	RUN→STOP	The I-slave sets the input transfer areas on the DP master to "0".	No updating of the process image
RUN	STOP→RUN	The I-slave sets the input transfer areas on the DP master to "0". After the startup program of the I-slave, the input transfer areas of the DP master are updated via the process image.	Prior to processing of the startup program, the input transfer areas are updated via the process image.

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A



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Glossary

Automation system

Programmable logic controller for the open-loop and closed-loop control of process chains of the process engineering industry and manufacturing technology. The automation system consists of different components and integrated system functions according to the automation task.

Bus

A common transfer route to which all nodes are connected; it has two defined ends. In the case of PROFIBUS, the bus is a two-wire line or a fiber-optic cable.

Bus connector

Physical connection between the node and bus cable.

Bus system

All stations physically connected to a bus cable form a bus system.

Device

In the PROFIBUS environment, "device" is the generic term for:

- Automation systems (for example, PLC, PC)
- Distributed I/O systems
- Field devices (for example, hydraulic devices, pneumatic devices)
- Active network components
- Gateways to AS interface or other fieldbus systems

Device that can send, receive or amplify data via the bus, for example, a DP slave by means of PROFIBUS DP.

Device

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- Automation systems (for example, PLC, PC)
- Distributed I/O systems
- Field devices (for example, hydraulic devices, pneumatic devices)
- Active network components
- Gateways to AS interface or other fieldbus systems

Device that can send, receive or amplify data via the bus, for example, a DP slave by means of PROFIBUS DP.

Diagnostics

Monitoring functions for the recognition, localization, classification, display and further evaluation of errors, faults and alarms. They run automatically during plant operation. This increases the availability of systems/plants by reducing commissioning times and downtimes.

DP master

CPU or device that conducts the communication with the DP slaves according to a defined algorithm. To do this, the DP master uses the functions for communication with the DP slaves which are defined by PROFIBUS DP. It acts according to standard EN 50170, Part 3.

→ *Master*

DP slave

Slave in the distributed I/O that is operated on the PROFIBUS with PROFIBUS DP protocol and acts according to standard EN 50170, Part 3. The DP slave is addressed by the DP master and provides it with specified functions (I/O data, diagnostics, etc.).

→ *Slave*

DPV1

The designation DPV1 refers to the functional extension of acyclic services (to include new interrupts, for example) provided by the DP protocol. The DPV1 functionality is integrated in IEC 61158/EN 50170, Volume 2, PROFIBUS.

FDL

Fieldbus Data Link (bus access protocol). Step 2 with PROFIBUS.

HMI device

Human Machine Interface, device for visualization and control of automation processes.

HSA

Highest Station Address. A bus parameter for PROFIBUS. Outputs the highest PROFIBUS address of an active device. PROFIBUS addresses greater than HSA are permitted for passive devices, up to 126.

Industrial Ethernet

Guideline for setting up Ethernet in an industrial environment. The main difference to the standard Ethernet is the mechanical current carrying capacity and interference immunity of the individual components.

I-slave

The "I-slave" functionality of a CPU supports the exchange of data with a DP master and can thus be used, for example, as intelligent preprocessing unit of partial processes. The I-slave is connected in its role as DP slave to a "higher-level" DP master.

Master

A master device that is in possession of the token can send data to other devices and request data from them (= active device).

PCF

Polymer Cladded Fiber (plastic-covered glass fiber)

POF

Polymer Optical Fiber (plastic fiber-optic cable made of light-conducting plastics)

Process image

Address area in the system memory of the DP master. At the start of the cyclic program the signal states of the input modules are transmitted to the process image of the inputs. And the end of cyclic program execution, the process image of the outputs is transmitted to the DP slave as signal state.

PROFIBUS

PROcess Field BUS, in IEC 61158-2 as "Type 3" standardized, bit-serial fieldbus system. The standard specifies functional, electrical and mechanical properties.

PROFIBUS is a bus system that networks automation systems and field devices compatible with PROFIBUS at the cell and field level. PROFIBUS is available with the protocols DP (= distributed I/O), FMS (= fieldbus message specification) or PA (process automation).

PROFIBUS address

Unique identification of a device connected to PROFIBUS. The PROFIBUS address is transmitted in the frame for addressing a device. A PC or programming device has the PROFIBUS address "0". DP masters and DP slaves have a PROFIBUS address in the range from 1 to 125.

PROFIBUS device

A PROFIBUS device has at least one PROFIBUS interface with an electrical (RS 485) or optical (Polymer Optical Fiber, POF) interface.

PROFIBUS DP

A PROFIBUS with DP protocol that complies with EN 50170. DP stands for distributed I/O (fast, real-time capable, cyclic data exchange). From the perspective of the user program, the distributed I/Os are addressed in exactly the same way as the centralized I/Os.

PROFINET

Open component-based industrial communication system based on Ethernet for distributed automation systems. Communication technology promoted by the PROFIBUS Users Organization.

RS 485

Asynchronous data transmission process for PROFIBUS DP to ANSI TIA/EIA-RS485-A.

RS 485 repeater

Equipment for amplifying bus signals and for coupling segments over long distances.

Segment

The bus line between two terminating resistors forms a bus segment.

A bus segment can contain up to 32 bus nodes. Segments can be coupled, for example, by means of RS 485 repeaters or diagnostics repeaters.

Slave

Distributed device in a fieldbus system that may exchange data with a master after being requested to do so by the master. Slaves are all DP slaves, for example, such as ET 200SP, ET 200MP, ET 200AL.

Standard mounting rail

Standardized metal profile to EN 50022.

The standard mounting rail is used for quick snap-on installation of network components, such as OLM, repeaters, etc.

Subnet

Part of a network whose parameters must be synchronized with the devices (e.g., with PROFIBUS). A subnet includes the bus components and all connected stations.

SynchronousCycle

Name for synchronous cycle interrupt OB in STEP 7.

Target-Rotation-Time (Ttr)

Bus parameter for PROFIBUS. The token is the send permission for a device on PROFIBUS. A device compares a token rotation time it has measured with the Target-Rotation-Time and controls the sending of frames with high priority or low priority based on this comparison.

Terminating resistor

Component that terminates the ends of a data transmission line to prevent reflections in the transmission medium.

Terminator

Terminating resistor of bus segments with transmission rates of 9.6 kbps to 12 Mbps. The power supply is separate from the bus nodes.

TIA Portal

Totally Integrated Automation Portal

Topology

Structure of a network. Common structures are line topology, ring topology, star topology and tree topology.

Transmission rate

Specifies the number of bits transmitted per second.

Watchdog

Mechanism for monitoring the readiness for operation.

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SIEMENS

SIMATIC

IO-Link system

Function Manual

Preface

Guide

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Integration into the
automation system

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

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We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This function manual provides a general overview of the IO-Link communication system. It shows the interaction of the various components of an IO-Link system and will help you improve your general understanding of IO-Link.

Basic knowledge required

The following knowledge is required in order to understand the documentation:

- General knowledge of automation technology
- Knowledge of the industrial automation system SIMATIC
- Proficiency with STEP 7

Scope of the documentation

This documentation is the basic documentation for IO-Link systems at Siemens. The product documentation is based on this documentation.

Conventions

In this documentation, "STEP 7" is used as a synonym for all versions of the configuration and programming software "STEP 7 (TIA Portal)".

Please also observe notes marked as follows:

Note

A note contains important information on the product described in the documentation, on the handling of the product or on the section of the documentation to which particular attention should be paid.

Additional support

- Information about Technical Support is available in section Siemens Industry Online Support (Page 4).
- The range of technical documentation for the individual SIMATIC products and systems can be found on the Internet.
- Information about the online catalog and online order system is available in section Industry Mall (Page 5).

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions constitute one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

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Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customers' exposure to cyber threats.

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- **Product support**

All the information and extensive know-how on your product, technical specifications, FAQs, certificates, downloads, and manuals.

- **Application examples**

Tools and examples to solve your automation tasks – as well as function blocks, performance information and videos.

- **Services**

Information about Industry Services, Field Services, Technical Support, spare parts and training offers.

- **Forums**

For answers and solutions concerning automation technology.

- **mySupport**

Your personal working area in Industry Online Support for messages, support queries, and configurable documents.

This information is provided by the Siemens Industry Online Support in the Internet (<http://www.siemens.com/automation/service&support>).

Industry Mall

The Industry Mall is the catalog and order system of Siemens AG for automation and drive solutions on the basis of Totally Integrated Automation (TIA) and Totally Integrated Power (TIP).

You can find catalogs for all automation and drive products on the Internet (<https://mall.industry.siemens.com>).

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Documentation

Various IO-Link products are available from Siemens. Each of these products has a separate documentation. The IO-Link products are embedded in systems, e.g. ET 200SP. The documentation for the system consists of the respective system manual, function manuals and manuals. In addition, the STEP 7 online help and the Port Configuration Tool - S7-PCT online help assist you in configuring and programming your automation system with IO-Link.

IO-Link components from Siemens

Siemens offers a wide range of products and support for IO-Link:

- Master
- Device, I/O modules
- Device, industrial switchgear
- Device, RFID systems (RFID = radio-frequency identification)
- Port Configuration Tool - S7-PCT
(<https://support.industry.siemens.com/cs/ww/en/view/32469496>)
- IO-Link library (<https://support.industry.siemens.com/cs/ww/en/view/82981502>) with the blocks "IO_LINK_MASTER" and "IO_LINK_DEVICE"
- Overview of the topic IO-Link
(<https://support.industry.siemens.com/cs/ww/en/view/109737170>)

Additional information on the products can be found on the Internet (<http://www.siemens.com/io-link>).

Additional documentation for IO-Link

You can find a free download of the latest documentation on the IO-Link products on the Internet (<https://support.industry.siemens.com/cs/ww/en/ps/15818/man>).

System overview

Introduction

A continuous communication down to the lowest field level ensures enhanced use of the functions and performance capability of sensors and actuators. Enhanced use of sensors and actuators allows you to operate your machines and plants more productively.

No data other than the actual process value can be exchanged via the standard interfaces (digital, analog) used at the sensor/actuator level. Sensors and actuators with integrated intelligence are now used for increasingly complex functions and require a communication interface tailored to these requirements.

Definition

IO-Link is an innovative, point-to-point communication interface for the sensor/actuator area that is specified in IEC 61131-9.

IO-Link consists of the following system components:

- IO-Link master
- IO-Link device
- Unshielded 3-wire or 5-wire standard cable
- Engineering tool for configuring and assigning parameters of IO-Link

2.1 Advantages of IO-Link

The IO-Link system offers significant advantages as digital interface when connecting sensors/actuators:

- Open standard in accordance with IEC 61131-9
 - Devices can be integrated in the same way in all conventional fieldbus systems and automation systems
- Tool supported parameter setting and central data management
 - Fast configuration and commissioning
 - Simple creation of current plant documentation even for sensors/actuators
- Single, uniform wiring and far fewer different interfaces at the sensors/actors
 - Standardized, uniform interface for sensors and actuators independent of their complexity (switching, measuring, multi-channel, binary, mixed signals, etc.)
 - Reduction in the variety of types and inventory
 - Fast commissioning
 - Any combination of IO-Link devices and sensors/actuators without IO-Link at IO-Link master
- Continuous communication between sensors/actuators and the CPU
 - Access to all process data, diagnostic data and device information
 - Access to device-specific data, such as energy data
 - Remote diagnostics can be performed
- Continuous diagnostic information down to sensor/actuator level
 - Reduction in troubleshooting effort
 - Minimizing risk of failure
 - Preventive maintenance and optimization of service and maintenance planning
- Dynamic change of sensor/actuators parameters by the controller or the operator at the HMI
 - Reduction in downtimes during product change
 - Increased variability of the machine
- Automatic reassignment of parameters when devices are replaced during operation
 - Minimization of downtimes
 - Device replacement by untrained personnel without additional aids
 - Avoidance of incorrect settings
- Integrated device identification
 - Identification of the installed devices
 - Ensure quality of result in production and manufacturing when replacing the device

2.2 Overview of IO-Link system

Components

An IO-Link system consists of the following components:

- IO-Link master
- IO-Link device, for example:
 - Sensors/actuators
 - RFID readers
 - I/O modules
 - Valves
- Unshielded 3-wire or 5-wire standard cables
- Engineering tool for configuring and assigning parameters of IO-Link

Example plant with IO-Link

The figure below shows an example of plant architecture with IO-Link.

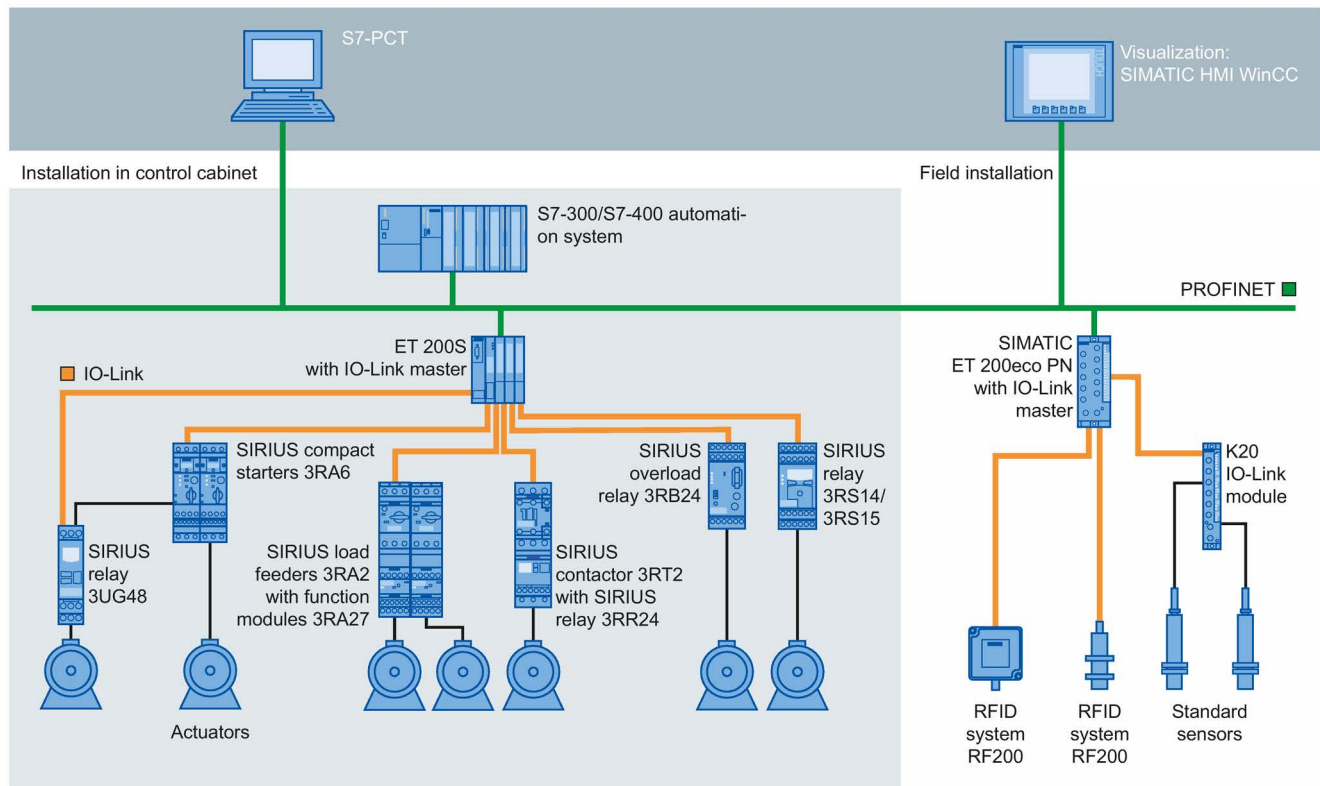


Figure 2-1 Plant architecture with IO-Link

The IO-Link master establishes the connection between the IO-Link devices and the automation system. If the IO-Link master is a component of the I/O system, it is installed either in the control cabinet or directly in the field as remote I/O in degree of protection IP65/67. The IO-Link master communicates by means of various fieldbuses or product-specific backplane buses. An IO-Link master can have multiple IO-Link ports (channels). An IO-Link device can be connected (point-to-point communication) to each port.

Engineering

The IO-Link system is engineered parallel to the overall automation system and can be embedded in it and intermeshed with it.

2.3 IO-Link interface

Introduction

The IO-Link is a serial, bidirectional point-to-point connection for signal transmission and power distribution under any network, fieldbus or backplane bus.

Connection system in IP65/67

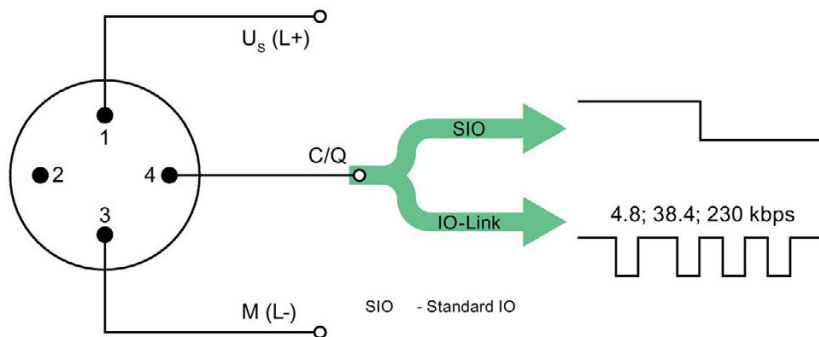
M12 connectors and other connectors are defined for the connection system in IP65/67; sensors have a 4-pin connector, actuators a 5-pin connector. IO-Link masters are always equipped with a 5-pin M12 socket.

The pin assignment according to IEC 60974-5-2 is specified as follows:

- Pin 1: 24 V
- Pin 3: 0 V
- Pin 4: Switching and communication cable (C/Q)

In addition to IO Link communication, these three pins also implement the power supply of the device.

Detailed information about the power supply can be found in the documentation of the utilized IO-Link master.



Pin	Signal	Definition	Standard
1	$U_s (L+)$	24 V	IEC 61131-2
2	-	not defined	-
3	$M (L-)$	0 V	IEC 61131-2
4	Q	Switching signal DI, DQ (SIO)	IEC 61131-2
4	C	"coded switching signal" (IO-Link)	IEC 61131-9

Figure 2-2 Pin assignment IO-Link device

Port types in IP65/67

Two types of ports are distinguished in the specifications for IO-Link masters:

- Port Class A (Type A)
With this type, the functions of pins 2 and 5 are not assigned. The manufacturer defines this function. Generally, an additional digital channel is assigned to pin 2.

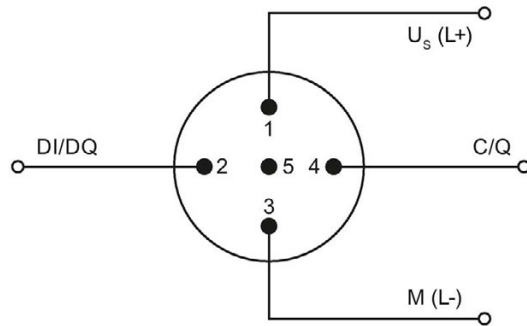


Figure 2-3 Pin assignment Port Class A

- Port Class B (Type B)
This type offers an additional supply voltage and is suitable for the connection of devices that have an increased power requirement. In this case an additional (galvanically isolated) supply voltage is made available by pins 2 and 5. A 5-wire standard cable is required to use this additional supply voltage.

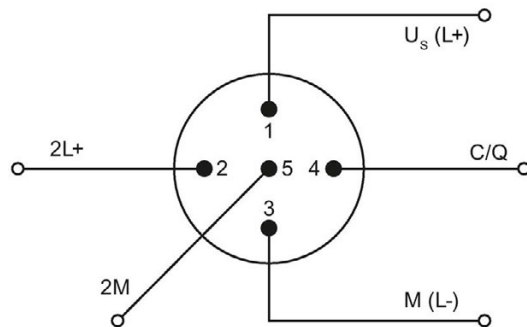


Figure 2-4 Pin assignment Port Class B

Connecting cables

The devices are connected to the master with unshielded 3-wire or 5-wire standard cables with a maximum length of 20 m. Standard cables can be used to wire the sensors. No shielding or compliance with specific regulations is necessary for the installation of the cables.

2.4 IO-Link protocol

Operating modes

The IO-Link port of the master can be operated in the following modes:

- IO-Link:
The port is located in the IO-Link communication.
- DI:
The port behaves like a digital input.
- DQ:
The port behaves like a digital output.
- Disabled:
The port is disabled.

Transmission rate

In the IO-Link specification V1.1, three data transmission rates (baud rates) are specified for the IO-Link operating mode:

- COM 1 = 4.8 kBaud
- COM 2 = 38.4 kBaud
- COM 3 = 230.4 kBaud (optional according to Specification V1.0)

The IO-Link device only supports one of the defined data transmission rates. The IO-Link master to Specification V1.1 supports all data transmission rates and adjusts automatically to the data transmission rate supported by the device.

Response time of the IO-Link system

The response time of the IO-Link system provides information about the frequency and speed of the data transmission between device and master. The response time depends on various factors.

A value for the minimum cycle time of the device is stored in the device description file IODD of the device (Page 17). This value indicates in which time intervals the master may address the device. The value has a big influence on the response time. The master also has an internal processing time that is factored into the calculation of the response time.

Devices with different minimum cycle time can be configured on a master. The response time for these devices differs accordingly. In other words, the response time for various devices connected to a master can vary greatly.

When you configure the master you can specify a fixed cycle time in addition to the device-specific minimum cycle time stored in the IODD. The master then addresses the device according to this specification.

The typical response time for a device thus results from the effective cycle time of the device and the typical internal processing time of the master.

Transmission performance

IO-Link is a very robust communication system. This communication system operates with a 24V level. If transmissions fail, the frame is repeated two more times. The IO-Link master only detects a break in communication after the failure of the second repeat attempt and reports this to the higher-level CPU.

Data types

Four data types are available:

- Process data → Cyclic data
- PQI → Cyclic data
- Device data → Acyclic data
- Events → Acyclic data

Process data

The process data of the devices is transferred cyclically in a data frame with the process data size being determined by the device. Process data from 0 to 32 bytes is possible per device (input and output, respectively).

Port Qualifier Information (PQI)

Each port has a Port Qualifier Information (PQI). This PQI provides information on the device status of the port and IO-Link (value status). The PQI is transmitted cyclically with the process data. The PQI is disabled by default.

Device data

Device data can be parameters, identification data or diagnostic information. The data is exchanged cyclically and at the request of the IO-Link master. Device data can be written to the device and also read from the device.

Events

When an event occurs, the device signals to the master that an event is present. The master then reads the event. Events can be error messages (for example, short-circuit) and warning/maintenance data (for example, dirt, overheating).

Error messages are transferred from the device to the CPU or the HMI by the IO-Link master.

The IO-Link master can also transfer events and states. Such events are, for example, wire break, break in communication or overload.

Device parameters or events are transmitted independently of the cyclic transmission of process data. The transmissions do not influence or impair each other.

Startup of the IO system

If the port of the master is set to IO-Link mode, the IO-Link master attempts to communicate with the connected IO-Link device. For this purpose the IO-Link master sends a defined signal and waits for the reply of the IO-Link device.

The IO-Link master first attempts a communication with the highest defined data transmission rate. If this transmission attempt fails the IO-Link master attempts a communication with the lowest data transmission rate. The device always supports only one defined data transmission rate.

If the master receives a reply, communication starts. First they exchange communication parameters. If necessary the parameters stored in the system are transferred to the device.

Then the cyclic data exchange of process data and value status starts.

2.5 Device profiles

Introduction

Device profiles are defined for IO-Link to standardize access of the CPU user program to the devices.

Data structure, data contents and basic functionality are defined in the device profiles. A standard user view and an identical program access is thus achieved for a number of different devices that have the same device profile.

IO-Link profiles

The device profile "Smart Sensor Profile" is currently defined for IO-Link. This profile is especially suited for measurement sensors. In other words, measured values are transmitted in addition to switching points.

In addition, the switchgear (for example, contactors) support the LVSG (Low Voltage Switchgear) profile defined in IEC 61915-2.

2.6 IODD and Port Configuration Tool - S7-PCT

Device description IODD

An electronic device description, the IODD file (IO Device Description) is available for each device. The IODD provides a wealth of information for system integration:

- Communication properties
- Device parameters with value range and default value
- Identification, process and diagnostic data
- Device data
- Text description
- Image of the device
- Manufacturer logo

The structure of the IODD is identical for all devices from all manufacturers. The structure of the IODD is always represented in the identical manner by the IO-Link Configuration Tool of the master manufacturer (for Siemens, S7-PCT). This ensures that the handling is the same for all IO-Link devices regardless of the manufacturer.

Two different IODD versions are available for devices that support both V1.0 and V1.1 functionality.

IODDfinder

The IODDfinder is a cross-vendor, central IO-Link database.

This database provides you with the latest IODDs of the device manufacturers and offers an information and download platform.

The IODDfinder is available on the Internet (<https://ioddfinder.io-link.com>).

IO-Link configuration tool

Configuration tools are required to configure the entire IO-Link system. The IO-Link configuration tools of the master manufacturers are able to read IODDs.

The main tasks of the IO-Link configuration tool include:

- Assigning the devices to the ports of the master
- Address assignment of ports within the address area of the master
- Assigning parameters for the IO-Link device

Diagnostics can also be carried out on the connected devices.

This means the IO-Link configuration tool supports the transparent representation of the IO-Link system down to field level.

Siemens provides S7-PCT for engineering of the IO-Link system.

S7-PCT with IODD of a device

The following figure shows a section from S7-PCT with IODD of a device and the device information contained therein.

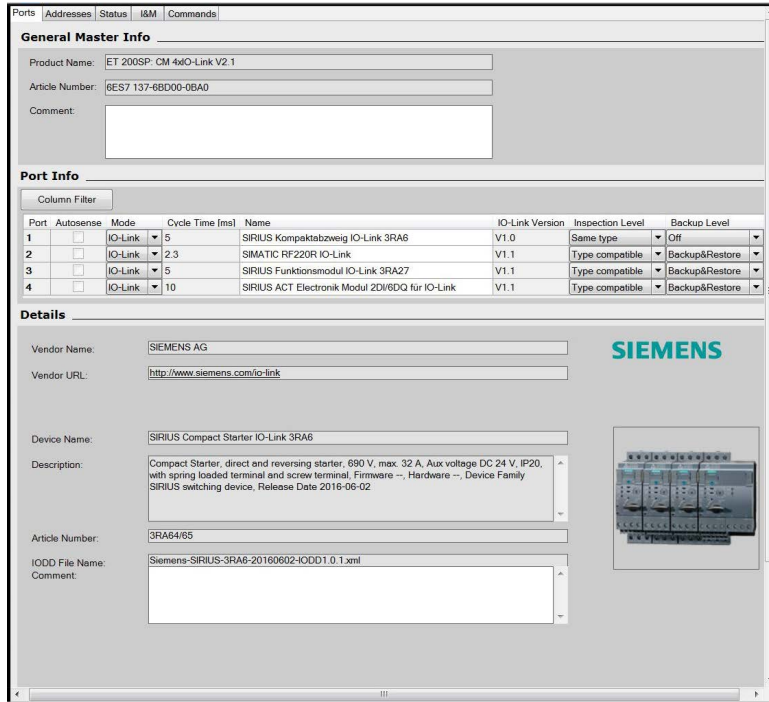


Figure 2-5 S7-PCT with IODD of a device and the device information contained therein

2.7 Differences between IO-Link specifications V1.0 and V1.1

Specification

The technical definition of the IO-Link system is described in a specification of the IO-Link consortium. The first step was the creation of specification version 1.0. The further development and added functions of the IO-Link system led to version 1.1.

The main enhancements of version 1.1 are:

- Data backup for device replacement during operation (Backup&Restore)
- Data transmission rate 230.4 kBaud is mandatory for the IO-Link master

Combination of IO-Link devices

Note the following when combining IO-Link devices:

- Only IO-Link devices that comply with V1.0 can be operated on the IO-Link master to V1.0.
- IO-Link devices that comply with V1.0 and V1.1 can be operated on the IO-Link master to V1.1.
- Data backup and a data transmission rate of 230.4 kBaud of the IO-Link master after V1.1 can only be used when these functions are also supported by the IO-Link device.

Integration into the automation system

3.1 Configuration of the IO-Link system

Introduction

An IO-Link system is configured in several steps. In the first step, the master is integrated in the automation system and configured. In the second step, the IO-Link devices are configured.

Integration in the automation system

When using a SIMATIC S7 CPU, use the engineering tool STEP 7, V5.x or STEP 7 (TIA Portal) for configuration.

The IO-Link system is represented by the IO-Link master in the configuration of the automation system or the fieldbus and integrated with STEP 7 or a GSD file.

The IO-Link master itself can be a field bus node (e.g. ET 200eco PN IO-Link master) or a part of the modular IO system that is connected to the field bus (e.g. ET 200SP IO-Link master). In both cases, the number of ports, the address range and the module properties are described in STEP 7 or in the GSD file.

Example configuration in STEP 7 (TIA Portal)

The figure below shows a PROFINET configuration with integrated PROFINET devices ET 200SP and ET 200ecoPN with IO-Link masters.

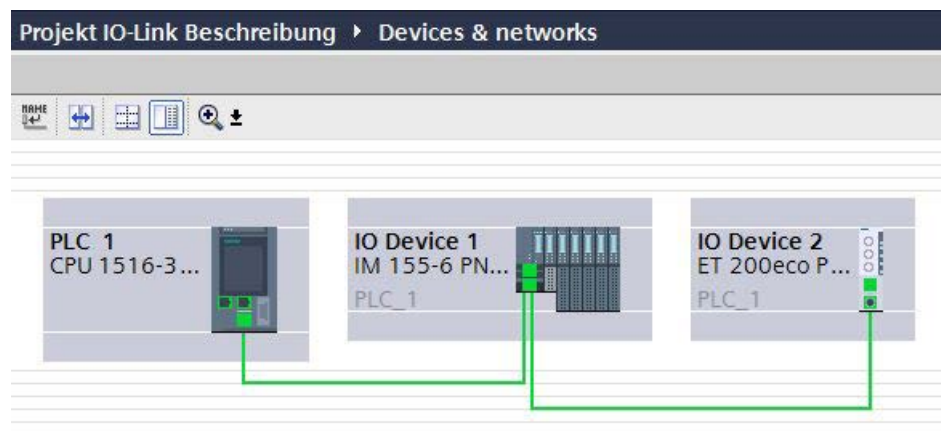


Figure 3-1 Configuration of a PROFINET network with lower-level IO-Link masters

In the device view of the PROFINET device, you can:

- Parameterize the ports
- Specify the input and output address ranges of IO-Link for exchange of cyclic data (process values).

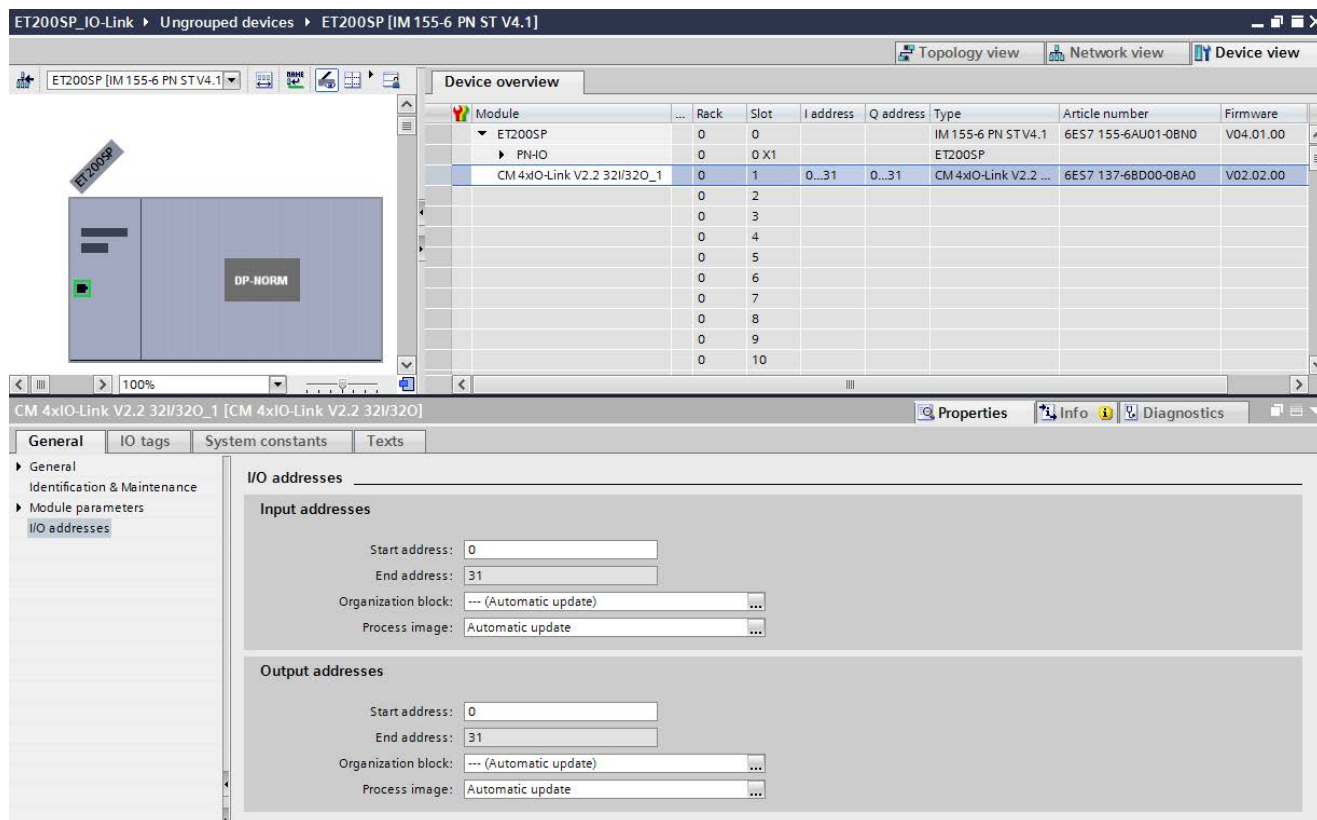


Figure 3-2 Device view with setting of the IO-Link address range

In addition, you can set in the module properties of the IO-Link master how the IO-Link system is to be configured and parameterized.

In doing so, you can select whether or not you also want to work with the S7-PCT configuration tool.

Note

IO data length

To ensure smooth operation, select an IO data length during configuration of the IO-Link master that corresponds at least to the IO data length of all connected IO-Link devices.

3.1.1 Configuration with S7-PCT

Introduction

The following sections describe how you configure your IO-Link master with the S7-Port Configuration Tool (S7-PCT).

You need S7-PCT to display the system architecture completely and transparently all the way to the IO-Link device and to configure and parameterize the IO-Link system in detail.

With S7-PCT you can easily configure the IO-Link devices with the help of the IODD (IO-Link Device Description) supplied by the device manufacturer.

In the S7-PCT online view you can display the diagnostics states and process values of the IO-Link devices in detail.

Configuration with S7-PCT

When you have selected the option "Configuration with S7-PCT", you are also making the settings of the IO-Link master ports with S7-PCT.

These settings include:

- Specification of the address range for each port
- Behavior when replacing an IO-Link device
- Setting the identification data for checking the connected IO-Link device type

Start S7-PCT from HW Config in STEP 7.

S7-PCT shows you all Siemens IO-Link masters you have configured in your automation system.

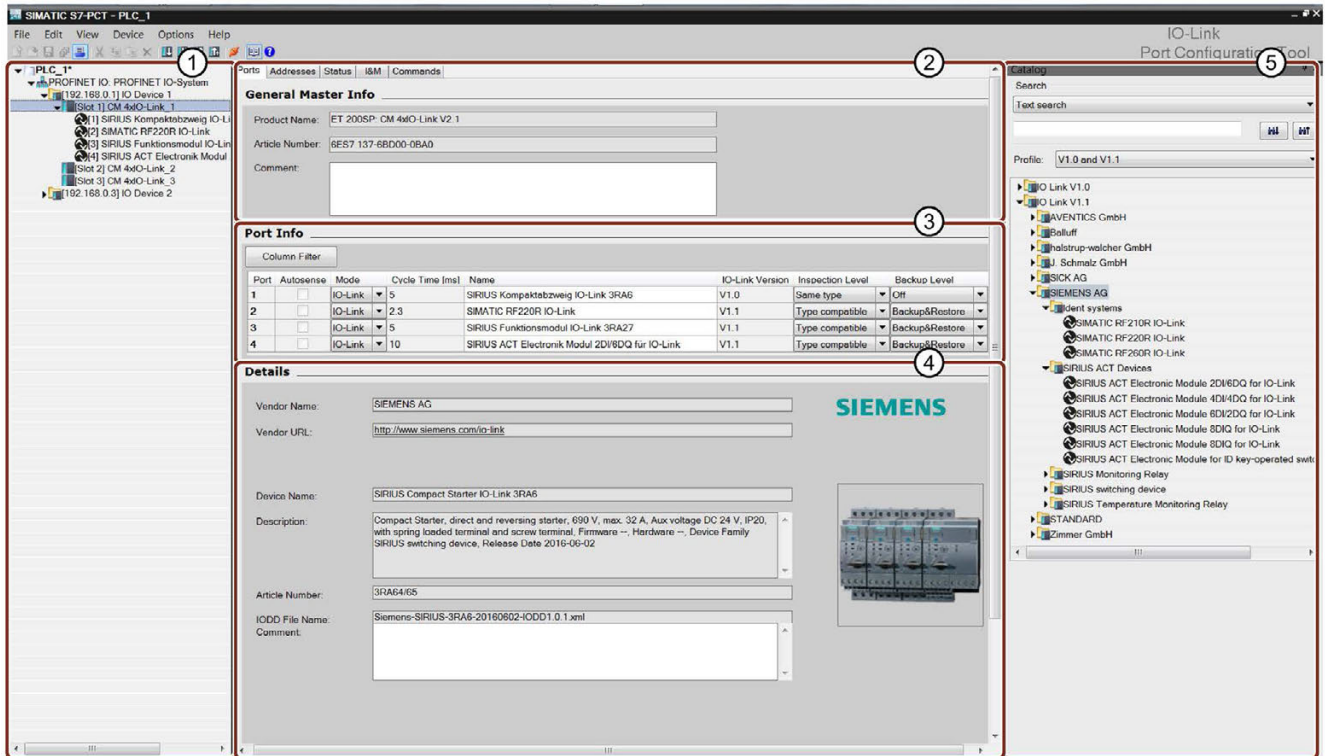
After selecting an IO-Link master, you can assign its IO-Link ports to the desired IO-Link devices.

To do so, select the corresponding IO-Link devices (or their IODDs) from the device catalog and drag them to the port of the IO-Link master.

Example configuration in S7-PCT

The following figure shows the configuration of an IO-Link master in S7-PCT.

This S7-PCT view shows you a wide variety of information:



- ① Higher-level field bus and overview or structure of the lower-level IO-Link master
- ② Detailed information on the selected IO-Link master
- ③ Current configuration of the IO-Link ports of the selected IO-Link master
- ④ Detailed information on the selected IO-Link device
- ⑤ Device catalog with the IODDS of the IO-Link devices from different manufacturers

Figure 3-3 Configuration of an IO-Link master in S7-PCT

Address range of the ports

In addition to the assignment of the IO-Link devices to the IO-Link master ports, the default address ranges of the ports can be changed. The IO-Link master transfers the process values that it receives from the IO-Link device in these address ranges and makes the process values available to the higher-level automation system.

To set the address range, select the "Addresses" tab.

Setting device parameters

Specific parameter settings are required to adjust the device to the respective application task. The possible parameters and set values are contained in the IODD of each device. You set the device parameters directly in S7-PCT.

After selecting the corresponding device in the project tree (left tree), set the device parameters in the "Parameters" tab.

The figure below shows you an example of the parameter assignment of an IO-Link device:

Identification	Parameters	Monitoring	Diagnostics	Connection	
Column Filter					
Parameter	Value	Icon	Unit	Status	Help
Parameters					
Parameter Data					
System command					
Device Reset	Device Reset				
Restore Factory Setting	Restore Factory Setting				
Device access locks					
Parameter (write) Access	Locked			changed	
Data Storage	Unlocked				
Operating system functions					
index131 - Group diagnostics	enabled				enable/disable automatic signaling to PLC
index131 - Group error diagnostics	enabled				enable/disable automatic signaling of error messages to PLC
index131 - Local threshold change	enabled				enable/disable local threshold changing via buttons
index131 - Local parameter change	enabled				enable/disable local parameter changing via buttons
index131 - Local reset	enabled				enable/disable local reset via buttons
index131 - Retentive error memory	disabled				enable/disable remanent saving of error messages in the event of a power fa...
index131 - Analog value coding	Tmax [°C] (5)				choose the analog value trasmitted cyclically in the process image
Temperature monitoring					
index131 - Temperature monitoring mode	Range monitoring			changed	set the value of temperature monitoring mode
index131 - Temperature unit	°C				choose the temperature unit for display and monitoring (°C or °F)
index131 - ON-delay time (at Power ON)	enabled				enable/disable starting of delay time at Power-ON
index131 - ON-delay time (at manual reset)	enabled				enable/disable starting of delay time at manual reset of the device
index131 - ON-delay time	0.0		s		set the value of ON-delay time
index131 - Tripping delay time (if the temperat...	0.0		s		set the value of tripping delay time (temperature overshoot or undershoot)
index131 - Temperature sensor type	PT100				choose the type of the connected temperature sensor(s)
index131 - Hysteresis	3			changed	set the value of hysteresis for automatic reset after overshoot or undershoot
index131 - Relay switching response	Closed-circuit principle (NC)				choose the circuit principle of relay switching
Thresholds					
index131 - Threshold #1	30			changed	set temperature threshold 1 for tripping (overshoot or undershoot depends o...
index131 - Threshold #2	20			changed	set temperature threshold 2 for tripping (overshoot or undershoot depends o...
index131 - Warning threshold for #1	28			changed	set temperature warning threshold 1 (overshoot or undershoot depends on ...
index131 - Warning threshold for #2	22			changed	set temperature warning threshold 2 (overshoot or undershoot depends on ...

Figure 3-4 Setting the parameter values of the IO-Link device

Starting from the displayed defaults, you can edit and save the values in the defined value range.

The configuration of the IO-Link system and the parameters of the devices are available to the IO-Link system and the entire automation project. You have the option of saving and printing the configuration and the parameters.

3.1.2 Configuration without S7-PCT

Introduction

The following sections describe how you configure your IO-Link master without the S7-Port Configuration Tool (S7-PCT).

Your options for configuration of the IO-Link system without S7-PCT are limited.

You can configure the port of the IO-Link master using STEP 7 or the GSD file, but you cannot set any parameters of the lower-level IO-Link devices.

Configuration without S7-PCT

You can activate the following parameters in STEP 7 or the GSD file during port configuration:

- Port Qualifier Information (PQI):
provides information on the status, such as process data of the IO-Link port; is transmitted with the input data of the IO-Link device.
- Operating mode
 - IO-Link Autostart:
The IO-Link master accepts each connected IO-Link device and starts it automatically.
 - IO-Link Manual:
The IO-Link master only accepts IO-Link devices that match the Vendor ID and Device ID set below.
The connected IO-Link device is **not** started automatically.
 - DI:
The port is operating as a standard digital input.
 - DQ:
The port is operating as a standard digital output.
 - Disabled:
The port is disabled.
- Input Data Length:
Process data length of the input data
- Output Data Length:
Process data length of the output data
- Vendor ID
ID number of the device manufacturer. You can find the Vendor ID on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109748852>).

3.1 Configuration of the IO-Link system

- Device ID
ID number of the device. You can find the Device ID on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109748852>).
- Inspection level for data backup:
 - Identical type (V1.0) without Backup&Restore
 - Type-compatible (V1.1) without Backup&Restore
 - Type-compatible (V1.1) with Backup&Restore
 - Type-compatible (V1.1) with Restore

The figure below shows you an example of the settings of a port configuration in STEP 7 or with GSD file:

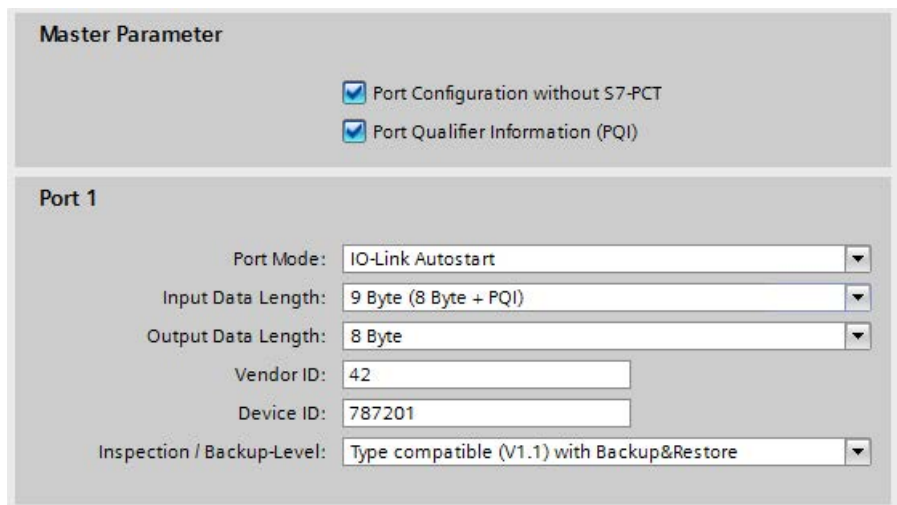


Figure 3-5 Settings of the port configuration in STEP 7 or with GSD file

3.1.3 Overview of configuration options

Introduction

The tables below show the configuration options offered by the SIMATIC IO-Link master with or without S7-PCT and which FW versions of the IO-Link master support the individual configurations.

Comparison of the configuration options

The following table provides an overview of the available options for configuration with and without S7-PCT:

Requirement	Configuration with S7-PCT	Configuration without S7-PCT	
		IO-Link Autostart	IO-Link Manual
Use of the IO-Link device description IODD	Yes	No	No
Setting the length of input and output data (per port)	Automatic	Manual	Manual
Assignment of the Vendor ID and Device ID	Automatic	-	Manual (see FAQ (https://support.industry.siemens.com/cs/ww/en/view/109748852))
Behavior during IO-Link device replacement	Programmable	-	Programmable
Adjustable IO-Link cycle time	Yes	No	No
Adjustable IO-Link device parameters	Yes	No	No
Display of the IO-Link process data structure	Yes	No	No
Monitoring of IO-Link process data	Yes	No	No
Display of IO-Link device diagnostics messages	Yes	No	No

Configuration options of the SIMATIC IO-Link masters

The following table provides an overview of the configuration options supported by the individual IO-Link masters:

Device designation	Article number	As of FW version	Configuration...	
			...with S7-PCT	...without S7-PCT
ET 200SP				
Communications module IO-Link Master CM 4xIO-Link	6ES7137-6BD00-0BA0	V1.0.0	x	-
		V2.2.0	x	x
ET 200AL				
Communications module CM 4xIO-Link 4xM12	6ES7147-5JD00-0BA0	V1.0.0	x	-
		V1.1.0	x	x
ET 200ecoPN				
IO-Link master 4 IO-L + 8 DI + 4 DO DC 24V/1,3A 8xM12	6ES7148-6JA00-0AB0	V6.1.0	x	-
IO-Link master 4 IO-L 4xM12	6ES7148-6JD00-0AB0	V1.0.0	x	x (Autostart only)
ET 200pro				
Electronic module EM 4 IO-LINK HF	6ES7147-4JD00-0AB0	V1.0.0	x	-
ET 200S				
Electronic module 4SI IO-Link	6ES7138-4GA50-0AB0	V1.0.0	x	-
S7-1200				
SM1278 4xIO-LINK MASTER	6ES7278-4BD32-0XB0	V1.0.0	x	-

3.2 Data access of the automation system and the HMI device

Cyclic data exchange

To exchange cyclic process data between an IO-Link device and a CPU, the IO-Link data is assigned by the IO-Link master to the previously set address ranges. The user program of the CPU accesses and processes the process values by using these addresses. The cyclic data from the CPU to the IO-Link device (for example, IO-Link actuator) takes place in reverse order.

Acyclic data exchange

Acyclic data, such as device parameters or events, is exchanged by means of a fixed index and subindex area. The CPU accesses the data using system mechanisms (for example, for online functions such as reading the status). You can use the index and subindex area to access specific device information (for example, to re-assign parameters of the device or master during operation).

Function blocks "IO_LINK_MASTER" and "IO_LINK_DEVICE"

The programming of the CPU user program is another task in addition to the configuration and parameterization of the IO-Link system and its integration into the overall automation system.

For acyclic data exchange, you can use the function blocks "IO_LINK_MASTER" and "IO_LINK_DEVICE" for controllers of the S7-300, S7-400, S7-1200 and S7-1500 product lines.

The function block "IO_LINK_MASTER" reads all relevant functions and accesses to the IO-Link master, the function block "IO_LINK_DEVICE" reads all accesses to the IO-Link devices.

You can use the function block "IO_LINK_MASTER" to restore all parameters saved in the IO-Link master. A typical application is the replacement of the IO-Link master.

Note

Function blocks "IO_LINK_MASTER" and "IO_LINK_DEVICE"

The function blocks "IO_LINK_MASTER" and "IO_LINK_DEVICE" replace the functions of the previously available block "IOL_CALL".

Reference

The IO-Link block library with a description of the integration is available on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/82981502>).

You can find an application example of using the block library with HMI devices on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/90529409>).

3.3 Changing and saving device parameters during plant operation

Changing device parameters

You can adjust the device parameters during operation. The changed parameters will become effective on the device in the process and are retentively saved in the device.

The parameters can be adapted during operation with:

- the engineering tool used (e.g. during plant commissioning)
- the CPU user program (program-controlled)
- HMI (through plant operator during batch change, process optimization)
- Locally through operation on the device (local operating unit on the device)

Saving device parameters (backup)

You can also save the parameters set in the device during commissioning or changed during operation of the plant in the IO-Link master.

This data backup takes place depending on the set behavior of the IO-Link master ports.

You can set the following data backup levels:

- None
No data backup in the IO-Link master.
- Backup&Restore
Every time the device parameters are changed, the changed data is automatically saved in the IO-Link master (see section "Triggering a backup").
- Restore
No automatic data backup in the IO-Link master.

IO-Link Version	Inspection Level	Backup Level
V1.0	No check	Off
V1.1	Type compatible	Backup&Restore
V1.1	Type compatible	Backup&Restore
V1.1	Type compatible	Backup&Restore

Figure 3-6 Overview of data backup level in S7-PCT

Note

IO-Link Specification V1.0

IO-Link master and devices to IO-Link specification V1.0 do not offer this function; a data backup cannot be set (Data backup: None).

Note that the behavior of the IO-Link master and the IO-Link devices during device replacement depends directly on the set data backup level. You can find additional information on this dependency in the section Replacing a master or device during operation (Page 32).

Triggering a backup

Requirements

- You have set the correct data backup level.
- The IO-Link master and the IO-Link devices you are using support this function (IO-Link Specification V1.1).

Procedure

There are several ways to trigger a backup:

- In the engineering tool:
After you have downloaded the engineering settings to the device, the IO-Link device immediately triggers a backup.
- In the CPU user program:
IO-Link device parameters can be changed successively by the user program.
A backup is only triggered by a system command. The system command must be triggered by the user program after the parameter changes.
You can implement the parameter changes and the system command for triggering the backup with function blocks of the CPU.
- Using the HMI:
You proceed as with triggering by the user program.
The plant operator then triggers the necessary system command on the HMI device.
- Locally by operating the IO-Link device:
After confirming the input on the IO-Link device, the IO-Link device initiates the backup.

3.4 Replacing a master or device during operation

Replacing a device

Replacing a device during operation is a scenario that occurs again and again and has to be completed without longer plant downtimes. Replace a device quickly and avoid incorrect settings. Devices can also be replaced by operators without special knowledge and aids.

When you use the backup function of the master, the master automatically supplies the saved parameters to the new device during device replacement.

You have the following setting options for device replacement:

- Backup&Restore

You have set the master port to Backup&Restore. The new device behaves as the replaced device because the master has saved the last parameter change with the backup function.

- Restore

You have set the master port to Restore. The new device applies the parameter settings that were saved in the master at the time of the last backup.

If you have made parameter changes since the last backup, these are not saved in the master and are not available to the new device.

The behavior of the new device can deviate from the behavior of the replaced device.

This may be useful if you want to make short-term plant optimizations but do not want to save them in the plant backup.

Note

Field calibration of sensors

When you are using sensors that must be adapted to specific rated conditions on site (field calibration), you must repeat this calibration after replacing the device.

The backup does not include the data of the field calibration. After repeating the field calibration, the new device works just like the replaced device.

Replacing a master

Replacing a master during operation is a rather rare scenario. Here, too, longer plant downtimes are to be avoided. Replace a device quickly and avoid incorrect settings. Devices can also be replaced by operators without special knowledge and aids.

You can save the configuration and parameter data of the master and the devices connected to the master in the CPU and download this information to the new master after the replacement.

When using an S7-CPU, you can use function blocks for this purpose.

You can find additional information on function blocks in the section Data access of the automation system and the HMI device (Page 29).

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SIEMENS

SIMATIC

S7-1500, ET 200MP, ET 200SP, ET 200AL, ET 200pro, ET 200eco PN Analog value processing

Function Manual

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This documentation covers general topics applicable to all products.

In addition to introductory information about analog value processing, this manual covers the following topics:

- Wiring transducers to analog inputs
- Wiring actuators/loads to analog outputs
- Compensating for reference junction temperatures
- Calibrating analog modules
- Diagnostics options of an analog module
- High-speed analog modules

Basic knowledge required

The following knowledge is required in order to understand the documentation:

- General knowledge of automation technology
- Knowledge of analog value processing (analog technology)
- Knowledge of the industrial automation system SIMATIC
- Knowledge about how to use STEP 7 (TIA Portal)

Scope of the documentation

This manual is considered the basic documentation for all analog input and analog output modules of the S7-1500, ET 200MP, ET 200SP, ET 200AL, ET 200pro and ET 200eco PN product series.

Changes compared to previous version

Changes / enhancements described in this manual, compared to the previous version (version 12/2013):

- Extension of the scope of validity to the distributed I/O system ET 200AL

Conventions

STEP 7: In this documentation, "STEP 7" is used as a synonym for "STEP 7 as of V12 (TIA Portal)" and subsequent versions of the configuration and programming software. This documentation includes images of the products it describes. The products supplied may differ slightly from these images.

Please observe notes labeled as follows:

Note

Notes contain important information on a point in the documentation of particular importance.

Additional support

Additional information on SIMATIC products is available on the Internet. The associated documentation is also available on the Internet.

- The portfolio of technical documentation for SIMATIC products and systems can be accessed on the Internet (<http://www.siemens.com/simatic-tech-doku-portal>).
- The online catalog and the ordering system are available on the Internet (<http://mall.automation.siemens.com>).

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (<http://www.siemens.com/industrialsecurity>).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (<http://support.automation.siemens.com>).

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Documentation guide

Introduction

The documentation of the SIMATIC products has a modular structure and covers diverse topics concerning your automation system.

The complete documentation for the S7-1500, ET 200MP, ET 200SP, ET 200AL, ET 200pro and ET 200eco PN systems consists of the respective system manuals, function manuals and product manuals.

Overview of additional documents related to analog value processing

The following table lists further references that supplement this description of analog value processing.

Table 1- 1 References for analog value processing

Topic	Documentation	Most important contents
System description	System manual S7-1500 Automation System (http://support.automation.siemens.com/WW/view/en/59191792)	<ul style="list-style-type: none"> • Application planning • Installation • Connecting • Commissioning
	System manual ET 200SP distributed I/O system (http://support.automation.siemens.com/WW/view/en/58649293)	
	System Manual ET 200MP Distributed I/O System (http://support.automation.siemens.com/WW/view/en/59193214)	
	System manual Distributed I/O System ET 200AL (http://support.automation.siemens.com/WW/view/en/89254965)	
	Operating instructions ET 200pro Distributed I/O System (http://support.automation.siemens.com/WW/view/en/21210852)	
	Operating instructions ET 200eco PN Distributed I/O System (http://support.automation.siemens.com/WW/view/en/29999018)	

Topic	Documentation	Most important contents
Configuring interference-free controllers	Function manual Configuring Interference-Free Controllers (http://support.automation.siemens.com/WW/view/en/59193566)	<ul style="list-style-type: none">• Basics• Electromagnetic compatibility• Lightning protection
Analog module	Product manual of the respective analog module	<ul style="list-style-type: none">• Connecting• Parameters• Technical specifications• Parameter data record• Tables of analog values

SIMATIC manuals

All current manuals for SIMATIC products are available for download free of charge from the Internet (<http://www.siemens.com/automation/service&support>).

What you should know about analog technology

2.1 Overview

Introduction

This chapter is intended to familiarize you with the essential parameters of analog input modules and analog output modules based on the fundamentals of analog technology. The descriptions and examples provided on the following pages serve as a reference to the manuals for the respective analog module and are intended to facilitate the handling of these manuals.

Analog and binary signals

Binary signals can assume only 2 signal states: signal state 1 (voltage present) and signal state 0 (no voltage present). In control engineering, it is frequently necessary to read, process and output analog signals in addition to binary signals. In contrast to binary signals, analog signals take on any number of values within a specific range. Possible analog variables include:

- Temperature
- Pressure
- Speed
- Fill level
- pH value

Transducers

Controllers are only capable of processing analog values in the form of bit patterns. For this purpose, transducers which can be connected to the analog module measure physical variables such as pressure or temperature. The analog input module reads this analog value in the form of current, voltage or resistance. To enable the CPU to process the current or voltage measured, an integrated analog-to-digital converter in the analog input module converts the value into a 16-bit integer value. Depending on the type of measurement, you can use the following transducers:

- Voltage transducers
- Current transducers
 - 2-wire transducers
 - 4-wire transducers
- Resistance transducers
 - 4-wire connection
 - 3-wire connection
 - 2-wire connection
- Thermocouples

Additional information on wiring various types of transducers to analog inputs can be found in Wiring transducers (Page 65).

Example

Speed is acquired using a transducer which converts the speed range of 0 to 1500 rpm to a voltage range of 1 to 5 V. At a measured speed of 865 rpm, the transducer outputs a value of 3.3 V.

The resulting voltage value is calculated as follows:

$$U = \frac{5\text{ V} - 1\text{ V}}{1500 \frac{\text{rpm}}{\text{min}}} * 865 \frac{\text{rpm}}{\text{min}} + 1\text{ V} = 3.3\text{ V}$$

The graph below illustrates voltage acquisition:

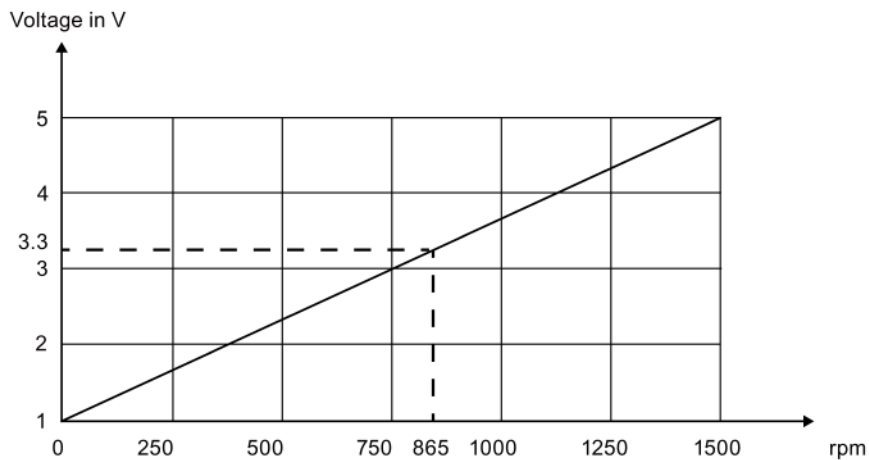


Figure 2-1 Speed measurement

Analog-to-digital conversion

A CPU processes information exclusively in digital format. The analog value is therefore converted into a bit pattern. Conversion is done using an integrated ADC (analog-to-digital converter) in the analog input module. For the CPU, this conversion always returns a 16-bit word for SIMATIC products. The ADC used digitalizes the analog signal and approximates its value with a stepped curve. Resolution and conversion speed are the most important ADC parameters.

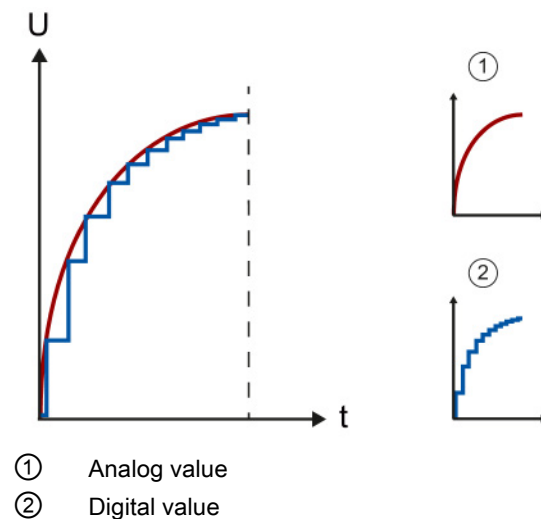


Figure 2-2 Approximation of an analog graph with low- and high-resolution stepped curves

Digital-to-analog conversion

Once the CPU has processed the digital signal, an integrated DAC (digital-to-analog converter) in the analog output module converts the output signal to an analog current or voltage value. The resulting value of the output signal corresponds to the output value used to control the analog actuators. Such actuators include, for example, small servo drives or proportional valves. You will find more information on wiring actuators in Wiring loads/actuators (Page 103).

Important parameters of analog modules

Alongside the type and range of measurement, the precision, resolution and conversion time are the main points to consider when selecting an analog module. For some applications such as systems which cover a large area, common mode or channel isolation are also important. The parameters listed here are examined in more detail in the following pages.

Processing analog signals

The following figure demonstrates analog signal processing in a PLC.

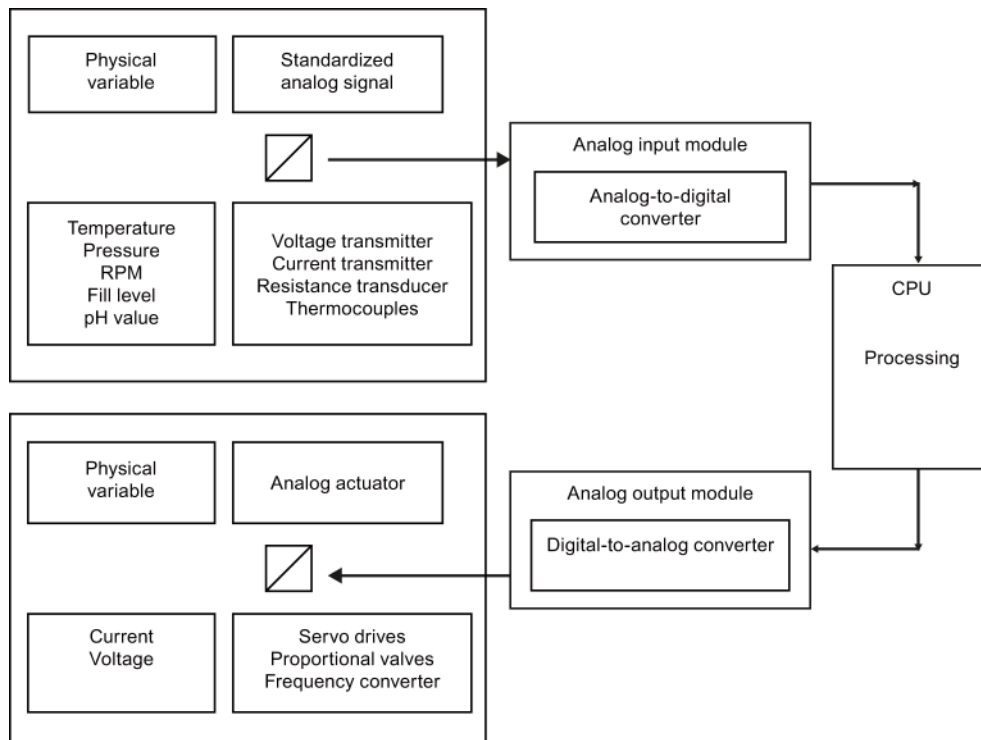


Figure 2-3 Analog value processing

2.2 Precision/resolution

The resolution of an analog module depends on the converter and its external circuitry. An approximation of the analog signal to be acquired/output is returned by a stepped curve. The resolution determines the number of increments of the analog value along this stepped curve. A higher module resolution reduces the length of increments and adds precision to the digitization of the analog signal.

Approximation of an analog value

The figures below show the approximation of an analog value by means of a stepped curve. A low resolution only returns a rough approximation of the actual curve (left figure), while the approximation is more precise at higher resolutions (right figure).

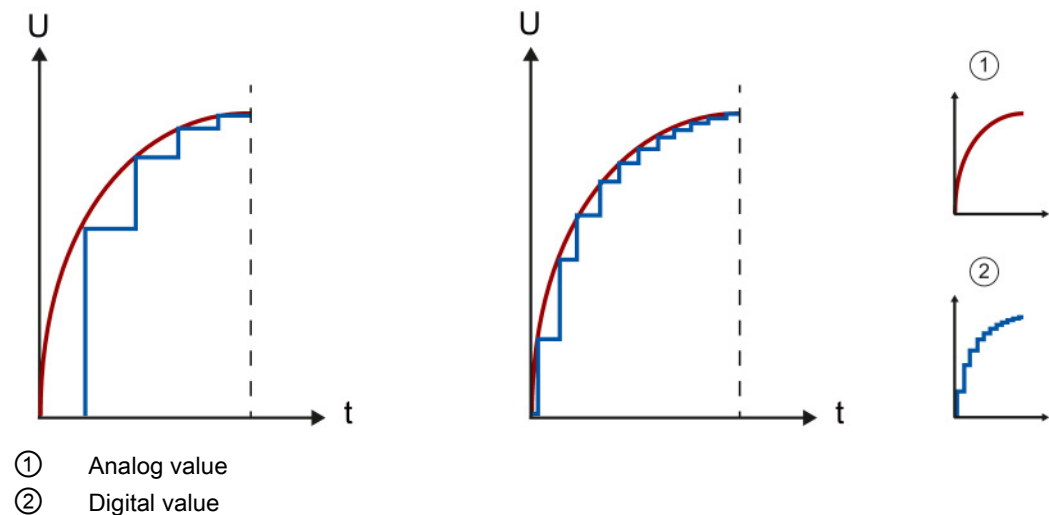


Figure 2-4 Approximation of an analog curve with a stepped curve

Visualization of the measuring range at a resolution of 13 bits and 16 bits

The unipolar measured value from a module having a resolution of 13 bits (= 12 bits + S) is segmented into a total of $2^{12} = 4096$ increments. The smallest increment in a measuring range of 0 to 10 V is $10 \text{ V}/4096$, equal to 2.4 mV.

A module with 16-bit (= 15 bits + S) resolution thus provides an increment of 0.3 mV. If the resolution increases by one bit, the number of increments doubles and the width of an increment halves.

If the resolution increases from 13 bits to 16 bits, the number of increments increases eightfold from 4096 to 32768. With a resolution of 13 bits, the smallest value that can be displayed is therefore 2.4 mV. By contrast, this value is approximately 0.3 mV at a resolution of 16 bits.

Measuring ranges

For the display of the measuring range, SIMATIC S7 distinguishes between the rated range, the overrange and underrange, and the overflow or underflow. This distinction allows you to recognize whether the measured value is actually in the measuring range determined in the technical specifications. The overflow and underflow ranges are reserved for error detection.

At a resolution of 16 bits the theoretically possible 32768 increments are distributed across a voltage range of 11.852 V, which means that only 27648 increments are actually available for the resolution of a measuring range of 10 V. The minimum value which can be represented is therefore 0.3617 mV (see table).

Table 2- 1 Example of resolution for the 0 to 10 V measuring range of a SIMATIC S7 module

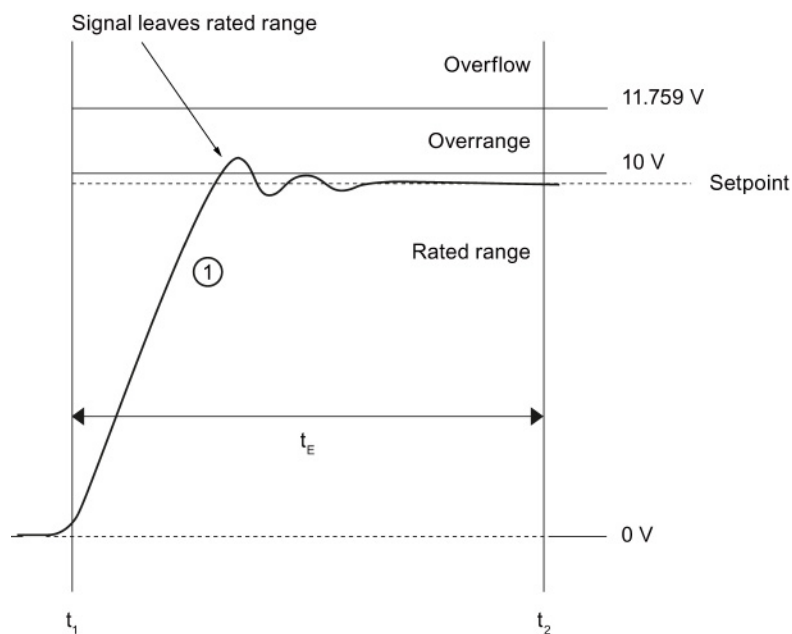
Value (increments)	Voltage measuring range	
	0 to 10 V	Range
32767	11.852 V	Overflow
32512		
32511	11.759 V	Overrange
27649		
27648	10.0 V	Rated range
20736	7.5 V	
1	361.7 μ V	
0	0 V	
not relevant for this example as negative values are not possible		
		Underflow

The digitized visualization of the input ranges, separated into bipolar and unipolar input ranges, is shown in the section Visualization of the input ranges (Page 62). The digitized visualization of the output ranges, separated into bipolar and unipolar output ranges, is shown in the section Visualization of the output ranges (Page 63). You will find a summary of all measuring ranges which you can use with your analog module in the corresponding device manual.

Over and underrange

It may happen for control processes with high signal jumps that the settling curve of the signal briefly leaves the rated range until it reaches the setpoint. The over and underrange ensures that no error is reported while the signal is not in the rated range. If the signal exceeds the over or underrange, however, and reaches the overflow or underflow range, the error state "Overflow" or "Underflow" is diagnosed. This means the over or underrange correspond to a tolerance range between the rated range and the overflow or underflow. Additional information on the settling time is available in the section Settling and response times of analog output modules (Page 52).

The figure below shows the rated range, the overrange and overflow of a unipolar measuring range. The signal leaves the rated range briefly during the settling phase.



① Analog output signal

t_E Settling time of the signal to the setpoint

t_1 Module ends conversion at the terminal of the analog output channel and outputs the signal

t_2 Signal has settled and the specified analog output value has been reached

Analog module precision

The precision of an analog module is specified as a percentage value or absolute value, for example, in K or °C. This characterizes the total error of measured value acquisition. The basic error limit at 25 °C, as well as the operational limit, are specified in accordance with international standard IEC 61131, which also forms the basis for European Standard EN 61131. For more information on the operational/basic error limits, refer to the Operational and basic error limits (Page 23) section.

Relation between resolution and precision

A certain resolution must be given to reach a specific precision (operational error).

Example

Measuring error as a result of digitization at a resolution of 8 bits and 14 bits

An analog module has a measuring range of 0 V to 10 V. A resolution of 8 bits represents a total of 256 values. This is equivalent to a minimum possible voltage step of 39 mV or 0.4% of the measuring range end value. A resolution of 14 bits represents a total of 16384 values. This is equivalent to a minimum possible voltage step of 0.61 mV or 0.006% of the measuring range end value.

The percentages derived in this way also represent the theoretical best-case values for the operational limit. With a resolution of 8 bits and a measuring range of 0 to 10 V, it is therefore impossible to achieve a precision of more than 0.4 %. In practical life, this value would be clearly worse, depending on the implemented circuitry.

Calculating the maximum measuring error

The maximum measuring error of a 0 to 10 V analog module with an operational limit of $\pm 0.5\%$ across the entire temperature range is calculated as follows:

$$10 \text{ V} \times 0.5/100 = 50 \text{ mV}$$

This means the maximum measuring error is approximately ± 50 mV. This also means that each analog voltage input is subject to a distortion of ± 50 mV across the entire input range. A voltage of 3.5 V that is to be measured can therefore be visualized by any value between 3.45 V and 3.55 V.

For more information on the operational/basic error limits, refer to the Operational and basic error limits (Page 23) section.

2.3 Scaling analog values

Scaling

It is often necessary to calculate the actual process value rather than increments (e.g., 10 V = 27648 increments) for further processing of digitalized analog values. The conversion of a value range (e.g., -27648 to +27648 increments) to the original physical quantity (e.g., 0 to 500 liters) is referred to as scaling.

Scaling blocks

STEP 7 offers the suitable program block for scaling of analog values. The SCALE block is included in the STEP 7 scope of delivery and permits input of a high and low limit (e.g., 0 to 500 liters).

Example

In the example below the fill level of a tank with a capacity of 500 liters is to be measured. The transducer used measures a voltage of -10 V with an empty tank and a voltage of +10 V with a full tank. The analog module converts the voltage range from -10 V to +10 V into the value range -27648 to +27648 and converts this range into the original quantity of 0 to 500 liters with the SCALE program block.

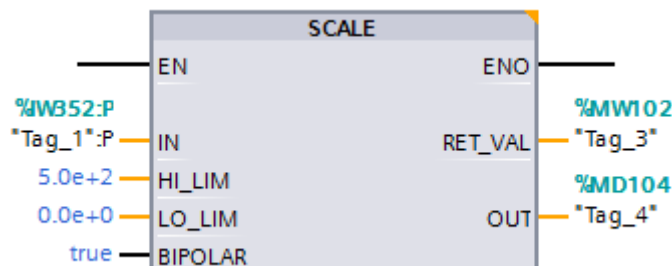


Figure 2-5 Scaling in the SCALE program block

The analog value at input **IN** is read directly by the module or is transferred by a data interface in INT format. The input **LO_LIM** is used to determine the low limit (0 liters) and **HI_LIM** to determine the high limit (500 liters) of the physical quantity. The output **OUT** outputs the scaled value (physical quantity) as floating-point number ($LO_LIM \leq OUT \leq HI_LIM$). You can assign parameters via the input **BIPOLAR** to specify if only positive or only negative values are to be converted. If the parameter receives an operand with the state '0', there is a unipolar scaling. An operand with the state '1' results in a bipolar scaling. The output **RET_VAL** outputs an error code in case of an error (e.g., overflow) and the value '0' in case of an error-free execution.

Additional information on the SCALE block can be found in the STEP 7 online help.

Unipolar and bipolar measuring ranges

The measurement of the fill level in our example took place within a bipolar measuring range. In addition to the positive voltage the transducer also provides negative voltage. Because the tank volume is mapped to the range from -27648 to +27648 increments, the measurement of the fill level takes place with twice the resolution (Δ) as in the unipolar measuring range.

Note

Transducers

The prerequisite for a measurement within a bipolar measuring range is that the used transducer supports bipolar measuring ranges.

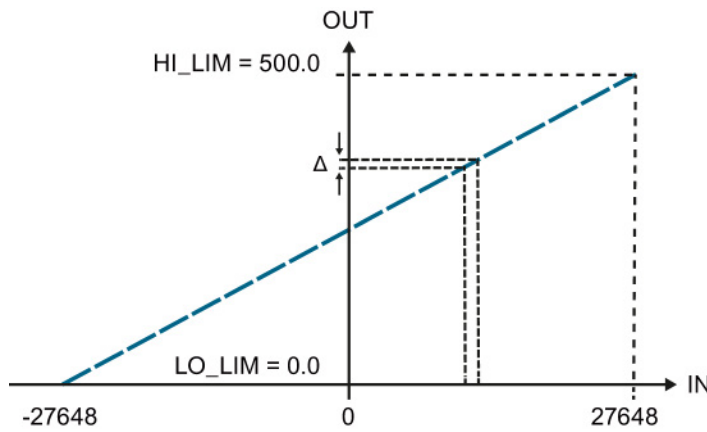


Figure 2-6 Bipolar measuring range

The measurement of the fill level in the bipolar measuring range takes place with twice the resolution (Δ) as in the unipolar measuring range.

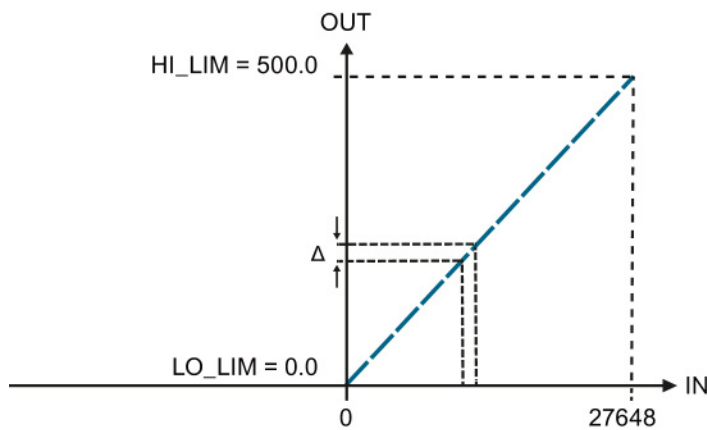


Figure 2-7 Unipolar measuring range

2.4 Unscaling analog values

Unscaling

The output of scaled analog values often requires conversion of the analog value calculated by the user program into the value range of the analog output module. This conversion is referred to as unscaling.

Unscaling blocks

STEP 7 offers the suitable program block for unscaling of analog values. The UNSCALE block is included in the STEP 7 scope of delivery and permits the input of a high and low limit that defines the range of the program value.

Example

An analog value from 0.0 to 100.0% calculated by the user program is to be converted with the UNSCALE block to the value range -27648 to +27648. When the unscaled value is output to an analog output module, this module addresses an analog actuator (e.g., modulating valve). The actuator is to be addressed at a program value of 0% with the minimum value (-10 V or -20 mA) and at 100% with the maximum value (+10 V or +20 mA).

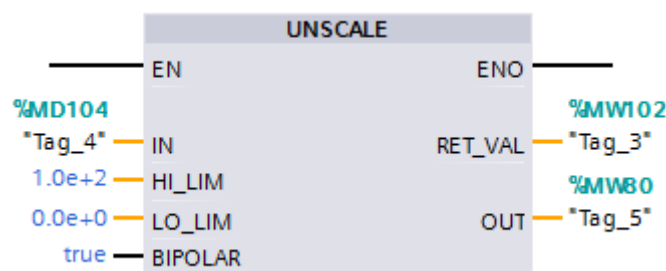


Figure 2-8 Unscaling in the UNSCALE program block

The value calculated by the program must be transferred in the REAL format (**IN**). You use the input **LO_LIM** to determine the low limit (0.0%) and **HI_LIM** to determine the high limit (100.0%) within which the program value moves. The unscaled value is output in INT format at the **OUT** output. You can assign parameters via the input **BIPOLAR** to specify if only positive or only negative values are to be converted. If the parameter receives an operand with the state '0', there is a unipolar scaling. An operand with the state '1' results in a bipolar scaling. The output **RET_VAL** outputs an error code in case of an error and the value '0' in case of an error-free execution.

Additional information on the UNSCALE block can be found in the STEP 7 online help.

Unipolar and bipolar measuring ranges

The figure below shows the scaling for an actuator that is to be addressed at a program value of 0% with the minimum value 0 (0 V or 0 mA) and at 100% (+27648) with the maximum value (10 V or 20 mA).

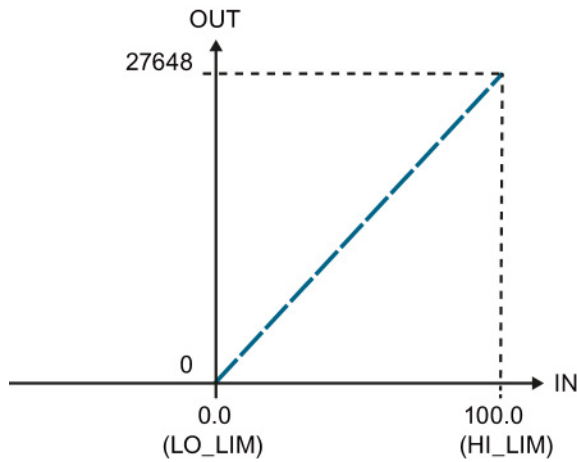


Figure 2-9 Unipolar measuring range

The figure below shows the scaling for an actuator that is to be addressed at a program value of 0% (-27648) with the minimum value 0 (-10 V or -20 mA) and at 100% (+27648) with the maximum value (+10 V or +20 mA).

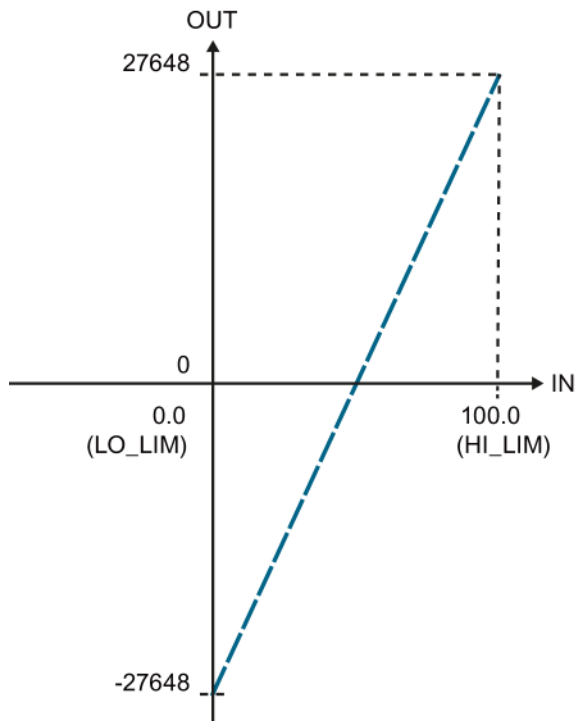


Figure 2-10 Bipolar measuring range

2.5 Linearity errors

Definition

Linearity denotes the deviation of the actual A/D or D/A conversion from the ideal lines within a specified measuring range. The linearity error therefore represents the deviation of the real transmission function from the ideal straight line. The error is given in the technical data as a percentage of the rated range of the analog module.

The figure below shows the linearity error of an ADC, magnified for better visibility.

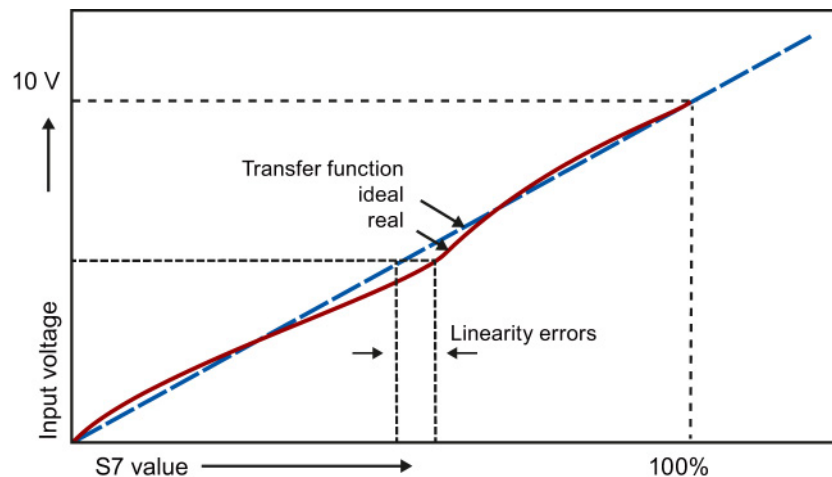


Figure 2-11 Linearity errors

Example

An error of ± 1 mV is returned at an input range of ± 10 V and a linearity error of $\pm 0.01\%$. The error is calculated as follows: $10 \text{ V} \cdot 0.01\% = 1 \text{ mV}$

The linearity error information given in the technical specifications is taken into account in the operational limit. You will find a detailed description of the operational limit in Operational and basic error limits (Page 23).

2.6 Repeat accuracy

Definition

The repeat accuracy is the maximum deviation in measured/output value for the same input signal or output value after another value has been created or output. Other parameters, e.g. the Temperature parameter, remain unchanged. The repeat accuracy refers to the rated range of the module and applies in a steady temperature state.

Measured value variance

The repeat accuracy provides information on the variance of individual measurements. The smaller the variance, the greater the repeat accuracy. The repeat accuracy is therefore one of the most important properties of measuring devices. In the technical data, the repeat accuracy is given as a percentage of the input or output range at 25°C in the steady state.

Example

The specified repeat accuracy for an analog input module as a percentage of the measuring range end value is $\pm 0.02\%$. This corresponds to a repeat accuracy of 2 mV for any value within the measuring range of $\pm 10\text{ V}$. If you change the measured value from 10 V to -10 V, for example, and then measure with 10 V again, the measured value deviation may not exceed $\pm 2\text{ mV}$.

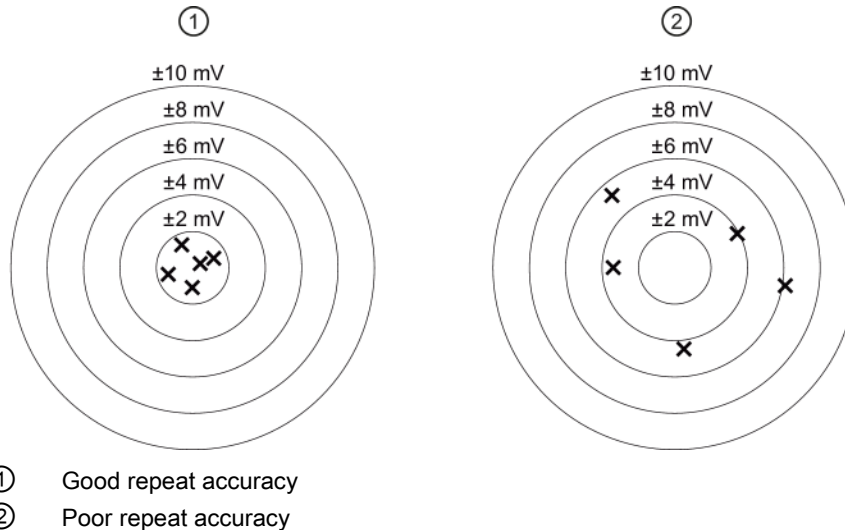


Figure 2-12 Repeat accuracy of measured values output

2.7 Operational and basic error limits

Introduction

The following section shows you how to determine the operational or basic error limits and thus the measurement error or output error with the help of the technical specification. The worst-case configuration ensures that the module will not exceed the specified value within the valid operational range.

The precision of analog input or output modules is only part of the precision of the entire measurement section. A measurement section usually consists of transducer, transmitter, transmission line as well as input / output module.

Operational limit

The operational limit is the entire measurement or output error rate of the analog module in the rated range in temperature-settled state within the approved temperature range.

Basic error limit

The basic error limit is the entire measurement or output error rate in the rated range at an ambient temperature of 25 °C and temperature-settled state.

The basic error limit of the module is more or less a theoretical value, because a constant ambient temperature of 25 °C is rarely maintained in plants. For this reason, the operational limit always takes priority in terms of the practical selection and assessment of a module.

Note

The operational limit and basic error limit percentages listed in the technical specifications always relate to the **maximum possible** I/O value (the measuring range end value) in the rated range of the module.

The following image shows an example of operational and basic error limits in comparison with the ideal curve.

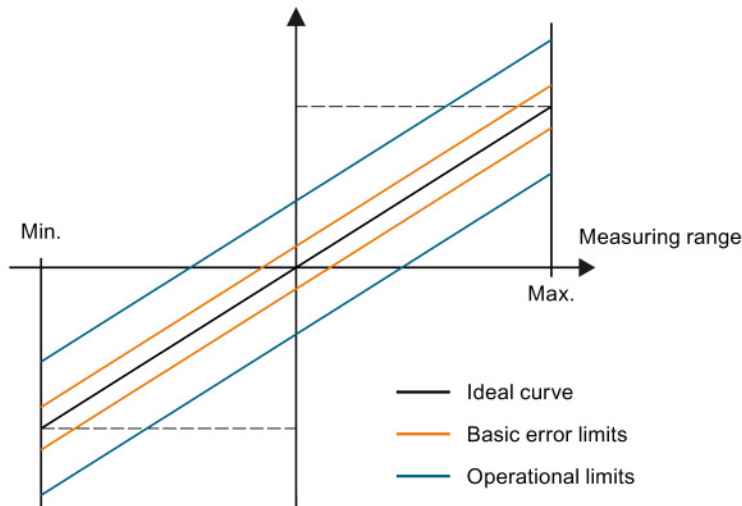


Figure 2-13 Operational and basic error limits

Example of output error calculation

An analog output module is used for voltage output in a range of 0 to 10 V. The module is operating at an ambient temperature of 30 °C, which means that the operational limit applies. Technical specifications of the module:

- Operational limit for the voltage output: $\pm 0.1\%$

The result is an output error of approximately ± 10 mV ($\pm 0.1\%$ of 10 V) across the rated range of the module.

For example, the output value may range from 2.49 V to 2.51 V at an actual voltage of 2.50 V.

Note

Bipolar measuring ranges

The calculation also applies to bipolar measuring ranges.

An error of ± 10 mV is also returned at an input range of ± 10 V and a linearity error of $\pm 0.1\%$.

2.8 Temperature error

Introduction

Analog modules are exposed to operational conditions that have an impact on their precision and on the measurement results they return. Temperature errors develop, for example, if the operating temperature of the module deviates from the ambient temperature of 25 °C. These temperature errors within the approved temperature range are taken into account in the operational limit.

Definition

The temperature error identifies the maximum drift of measuring/output values caused by fluctuation of the ambient temperature at the analog module. The maximum drift can occur at any ambient temperature. The temperature error is specified depending on the module used in percent per degree Celsius and/or percent per Kelvin, e.g. $\pm 0.005\%/K$, and relates to the measuring range end value of the analog module.

Operational limits of compensation

The temperature error of the reference junction temperature compensation function only occurs with thermocouple measurements. The temperature error of compensation is added to the actual temperature error if "Internal reference junction" operating mode is selected. The temperature error of compensation is defined in the technical specifications as a percentage of the physical rated range of the analog module or as an absolute value in °C.

Note

Calculating the error in thermocouple measurements

Add the error of a thermocouple measurement to the error of the compensation measurement to determine the total error of a thermocouple measurement. These errors are defined in the respective manual.

Example

In this example, the total error of the temperature measurement is determined with the help of a type K thermocouple. The type K thermocouple takes measurements at a temperature range from -270 °C to +1372 °C.

The technical specifications state an operational limit of $>-200\text{ °C} \pm 2.4\text{ K}$ for the type K thermocouple. The temperature error of compensation amounts to $\pm 6\text{ °C}$. The total temperature error is measured as follows at a temperature of $>-200\text{ °C}$:

Operational error ($\pm 2.4\text{ K}$) + temperature error of compensation ($\pm 6\text{ °C}$) = $\pm 8.4\text{ °C}$.

2.9 Interference frequency suppression

Definition

The interference frequency suppression function is applied to analog input modules to suppress the noise caused by the frequency of the AC voltage supply used.

The frequency of the AC voltage supply is likely to have a negative effect particularly on the values returned by measurements in the low voltage range and on thermocouples.

Parameter assignment

The line frequency at which the system is operated can be set by means of module parameters, for example, in STEP 7.

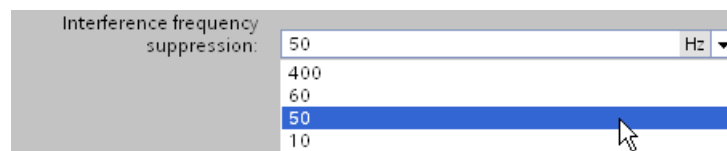


Figure 2-14 Interference frequency suppression

The conversion time changes depending on the set interference frequency suppression. The data sheets of the respective module define this dependency.

Please note the following when selecting interference frequency suppression:

The higher the frequency setting, the shorter the conversion time.

Note

Line frequency

Always select the interference frequency based on the line frequency used. Mismatch errors must be expected if a frequency that deviates from this line frequency is set, for example, to reduce the conversion time. In this case, the specified technical data and, in particular, precision are possibly outside the specified range.

Smoothing

By smoothing analog values, you achieve an additional improvement for the suppression of interference frequencies. For more information on the smoothing of analog values, refer to the section Smoothing (Page 54).

Line frequencies used

The line frequency is the frequency used in an electricity network for AC supply. It is measured in hertz and indicates the number of oscillations per second in a periodic signal. A line frequency of 50 Hz, for example, means 50 oscillations per second.

Europe, Australia and most countries in Asia and Africa use a line frequency of 50 Hz. North and Central America and most countries in South America have electricity networks with a line frequency of 60 Hz.

Frequencies of 400 Hz are most commonly used in on-board networks for airplanes, in the aerospace sector and for military applications. One reason for this is that engines with a line frequency of 400 Hz can usually be made smaller and lighter. As, however, it is not economic to transport such high frequencies over large distances, 400 Hz applications are usually subject to significant spatial limits.

A frequency of $16 \frac{2}{3}$ Hz is used for the traction power supply in Germany, Austria and Switzerland. Some modules of the SIMATIC S7 product range also support the interference frequency suppression of this line frequency. The configurable interference frequency suppression in these cases is 16.6 Hz.

2.10 Common mode interference (UCM)

Definition

Common mode interference denotes interference voltages and currents in the lines connecting electrical devices and system components. They affect both the positive and negative line with the same phase angle and amplitude. The interference signal needs an additional current path to affect the utility signal. This current path is usually provided by common reference potential, e.g. earth or ground connection, of the utility signal and interference source.

Common mode interference in analog modules

Common mode interference occurs in analog input and output modules if their reference potential is different from the reference potential of the connected sensor or actuator.

Common mode interference is most likely to occur when analog modules are operated with grounded sensors. The size of the overall system means that voltage differences may develop between machine components with grounded sensors and the analog module reference. These voltage differences affect both the positive and negative signal path equally, which is why they are termed common mode interference.

In operation with non-grounded sensors, the occurrence of common mode interference is not as obvious as in grounded operation. Nevertheless, capacitive or inductive coupling can also create voltage differences in such cases which have the effect of common mode interference. Depending on the conditions in grounded and non-grounded operation, common mode voltage can occur as direct or as alternating voltage.

Example

The following figure of an analog module with two inputs (Ch₁/Ch₂) shows the coupled interference voltages at the inputs (U_{CM1}/U_{CM2}) as well as an interference voltage coupled between these inputs (U_{CM3}). Common mode rejection indicates the extent to which these interference signals can be suppressed. It is calculated using the following equation:
CMR [dB] = 20 · log (U_{CM} / U_a)

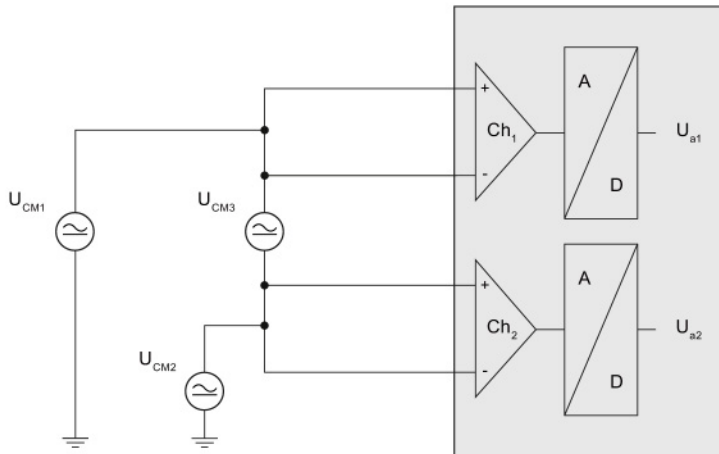


Figure 2-15 Common mode voltage coupled between two inputs

If there is common-mode voltage (U_{CM}), the equation is solved for U_a to calculate the measuring error (U_a):

$$U_a = U_{CM} * 10^{-\frac{CMR}{20}}$$

Note

The common mode rejection (CMR) is detailed in "Common mode interference" in the technical data of the device manual for your analog module.

2.11 Series mode interference (USM)

Definition

Series mode interference is interference voltages and currents affecting the connection lines in opposite directions. They have opposite polarity in the positive and negative directions. Series mode interference currents cause a voltage drop at the input impedance that has the effect of an interference voltage.

Causes

Series mode interference is caused by capacitive or inductive coupling. Inductive coupling generates a magnetic flow that is radiated between adjacent current-carrying conductors. This induces an interference voltage in the conductor. Galvanic coupling is given where different circuits influence each other due to common conductor sections, e.g. common ground connection.

The diagram below shows series mode interference as a voltage source (U_{SM}) connected in series to the actual measuring signal (U_M). The index "SM" stands for "Series Mode". Series Mode rejection indicates the extent to which these interference signals are suppressed. It is calculated using the following equation: $SMR [dB] = 20 \cdot \log (U_{SM} / U_a)$

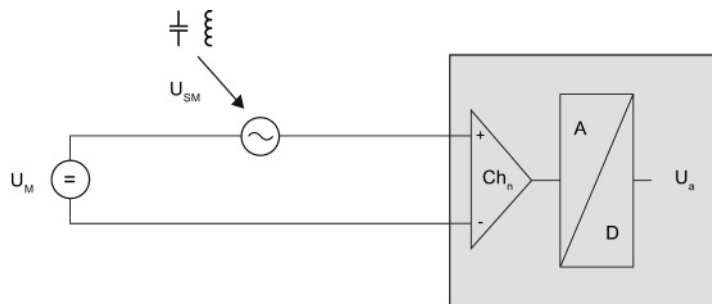


Figure 2-16 Capacitive or inductive interference coupling to the signal cable

The voltage (U_a) measurement error is calculated by solving the equation for U_a .

$$U_a = U_{SM} * 10^{-\frac{SMR}{20}}$$

The following equation shows the calculation of current (I_a) measuring errors using a current input.

$$I_a = \frac{U_{SM}}{R_{ein}} * 10^{-\frac{SMR}{20}}$$

Note

The series mode rejection (SMR) is detailed in "Series mode interference" in the technical data of the device manual for your analog module. The level of input resistance (R_{ein}) is also specified in the technical data.

2.12 Interference voltage suppression

Definition

Interference voltage suppression gives the factor by which the interference signal is suppressed in measurement value acquisition. Higher values reduce the effect of interference on the measurement signal. The technical data differentiates between "Common mode interference" and "Series mode interference". Interference voltage suppression is specified in decibels.

Example

The diagram below shows the measuring error for interference voltages in volts and interference voltage suppression of 0 to 120 dB.

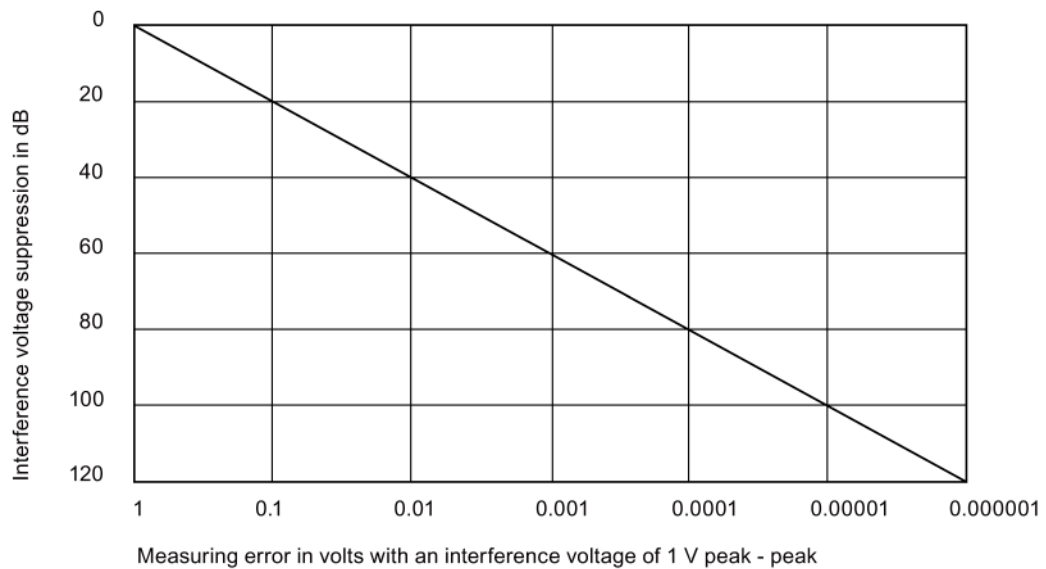


Figure 2-17 Interference voltage suppression

With an interference voltage suppression of 40 dB and an interference voltage of 1 V, the measured value is only distorted by 0.01 V.

Note

Interference-free design

Disturbance variables can be substantially reduced by means of appropriate grounding and shielding to increase interference immunity of the configuration. You will find a detailed description of how to avoid interference in the Configuring interference-free controllers (<http://support.automation.siemens.com/WW/view/en/59193566>) function manual.

Common mode rejection

The table below sets out the possible common mode rejection specifications in the technical data of an analog input module:

Interference voltage suppression for $f = n \times (f_1 \pm 1 \%)$, ($f_1 =$ interference frequency), $n = 1, 2, \dots$	
Common mode interference	> 100 dB
Common mode voltage, max.	10 V

If the interference frequency is configured as 50 Hz, the specified interference voltage suppression for common mode interference will only apply for the frequencies 50 Hz $\pm 1 \%$, 100 Hz $\pm 1 \%$, 150 Hz $\pm 1 \%$, etc. Immunity is lower for all other frequencies. Interferences caused by the line voltage distort the measured utility signal in the ratio of 100,000 : 1. An interference voltage amplitude of 1 V, for example, will affect the utility signal by 10 μ V.

The Common Mode voltage (U_{CM}) defines the maximum permitted deviation of the potential between two channels and between one channel and analog ground. The interference voltage suppression defined in the technical specifications must not be exceeded. If the maximum common mode voltage specified, for example, 10 V, is exceeded, the analog signal is processed incorrectly. Depending on the module used, this error may be diagnosed and an error message output. The maximum common mode voltage may be exceeded as a result of varying input or overly long lines.

Series mode rejection

The table below sets out the possible series mode rejection specifications in the technical data of an analog module:

Interference voltage suppression for $f = n \times (f_1 \pm 1 \%)$, ($f_1 =$ interference frequency), $n = 1, 2, \dots$	
Series mode interference	> 60 dB

If the interference frequency is configured as 50 Hz, the specified interference voltage suppression for series mode interference will only apply for the frequencies 50 Hz $\pm 1 \%$, 100 Hz $\pm 1 \%$, 150 Hz $\pm 1 \%$, etc. Immunity is lower for all other frequencies. Overall, interference caused by the line voltage distorts the utility signal measured by 1000 : 1. For example, an interference voltage amplitude of 1 V will affect the utility signal by 1 mV.

2.13 Crosstalk between channels

Origin of the term

The term crosstalk/XT was originally used in the field of telecommunication to denote unwanted coupling of voice signals between two cable conductors of different subscribers.

Definition

Crosstalk between signal channels denotes the interactive influence between two independent channels as a result of leakage currents and capacitive or inductive coupling. Crosstalk between the channels changes the signal by the value of the amplitude of the crosstalk signal.

Causes

Technically, it is not feasible to totally isolate the module channels from environmental conditions. This means that it is always possible for leakage currents or disturbance coupling having an interactive effect.

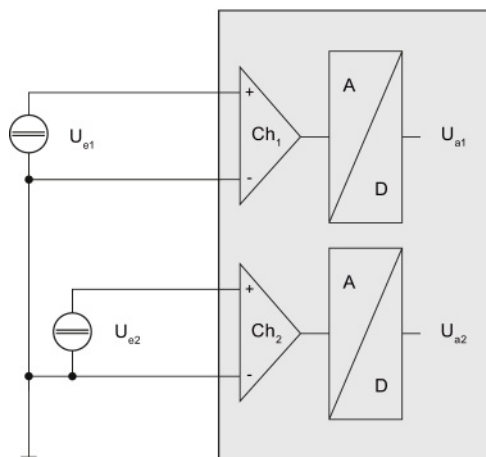


Figure 2-18 Crosstalk between two channels

The diagram shows the effects of crosstalk for the user with two channels (Ch₁/Ch₂) of an analog module. The crosstalk value is the factor by which the utility signal at a second channel U_{a2} is affected by the signal at the first channel U_{e1}. The measuring error (U_{a1}) can be calculated using the following equation:

$$U_{a1} = U_{e2} * 10^{\frac{XT [dB]}{20}}$$

Example of crosstalk attenuation

The "crosstalk between inputs" value in the technical specifications is defined as a value of >-100 dB at a measuring range of -10 V to +10 V on channel 1 of an eight-channel analog input module. The voltage at the input has an amplitude of 10 V. What is the error caused by crosstalk at channel 0 (measuring range ±10 V) and channel 2 (measuring range ±80 mV)?

100 dB are equal to a factor of 100,000. The measured values at channels 0 and 2 to 7 are therefore affected by $10 \text{ V} / 100,000 = 100 \text{ } \mu\text{V}$. This distortion is added to or subtracted from the pending measuring signal and its effect depends on the selected measuring range.

- Channel 0: $100 \text{ } \mu\text{V} / 10 \text{ V} = 0.001 \%$
- Channel 2: $100 \text{ } \mu\text{V} / 80 \text{ mV} = 0.125 \%$

A voltage of 10 V set at channel 1 distorts the measured value at channel 0 by 0.001% and the measured value at channel 2 by 0.125%. The measuring error resulting from crosstalk in this example is therefore 0.001 % or 0.125 %. The basic error limit already includes the error generated as a result of crosstalk between the channels.

Calculating measuring error

You calculate the measurement error at channel 1 in this example based on a change in the measurement voltage of 10 V at channel 2. The crosstalk (XT [dB]) value is defined in the technical specifications in the manual of the analog module that you are using.

$$\text{Measured value error channel 1 [in V]} = \text{measured value change at channel 2 [in V]} * 10^{\frac{\text{XT [dB]}}{20}}$$

$$\text{Measured value error channel 1 [in V]} = 10 \text{ V} * 10^{\frac{-80 \text{ dB}}{20}} = 0.001 \text{ V}$$

A change in the measurement voltage of 10 V at channel 2 causes a measurement deviation of 0.001 V at channel 1.

2.14 Diagnostics

Diagnostics for analog modules

SIMATIC analog modules can diagnose errors. A number of different types of diagnostics are available for analog modules in STEP 7. Please note that the parameter assignment options vary depending on the analog module and product family used. More detailed information on the types of diagnostics can be found in the device manual for your analog input or analog output module.

Proceed as follows to select the diagnostics types of the analog module used:

1. Open STEP 7.
2. Select the analog module in the Device view.
3. Select the "Properties" tab.
4. Select the inputs or the required channel of the analog module in the Inspector window.

Table 2- 2 Overview of diagnosable errors

Type of diagnostics	Analog input module	Analog output module
Wire break	✓	✓
No supply voltage L+	✓	✓
Overflow	✓	✓
Underflow	✓	✓
Common mode error	✓	-
Short-circuit	✓	✓
Overload	-	✓
Reference junction	✓	-

Diagnostics of the analog module are carried out while the system is in operation, on the basis of the current output variables such as current or voltage. If the output current or output voltage is no longer sufficient, the module will not be able to run reliable diagnostics. The limits within which diagnostics are possible are specified in the technical data for each module.

The module reports the diagnosed state to the CPU using a diagnostics error interrupt. If several diagnostics are pending at the same time, the diagnostics with the highest priority is reported to the CPU first. Diagnostics are output on LED displays on the affected module, on the CPU display, on the Web server or on an HMI device.

The configurable diagnostics types depend on the respective selected measuring type or output type. The following tables shows the relationship between the diagnostics types, measuring types or output types of an analog input module or analog output module.

Diagnostics Analog input modules

Table 2- 3 **Diagnostics types of an analog input module to be configured depending on the measurement type "Voltage"**

	No supply voltage L+	Wire break (1 to 5 V)	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	✓	✓	✓	✓	✓	-	-
ET 200MP	✓	✓	✓	✓	✓	-	-
ET 200SP	✓	-	✓	✓	-	-	✓
ET 200AL	-	✓	✓	✓	-	-	✓
ET 200eco PN	✓	✓	✓	✓	-	-	-
ET 200pro	-	✓	✓*	✓*	-	-	✓

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

Table 2- 4 **Diagnostics types of an analog input module to be configured depending on the measurement type "Current (4-wire transducer)"**

	No supply voltage L+	Wire break (4 to 20 mA)	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	✓	✓	✓	✓	✓	-	-
ET 200MP	✓	✓	✓	✓	✓	-	-
ET 200SP	✓	✓	✓	✓	-	-	✓**
ET 200AL	-	✓	✓	✓	-	-	✓**
ET 200eco PN	✓	✓	✓	✓	-	-	-
ET 200pro	-	✓	✓*	✓*	-	-	✓

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

** Diagnostics for encoder supply only

Table 2- 5 **Diagnostics types of an analog input module to be configured depending on the measurement type "Current (2-wire transducer)"**

	No supply voltage L+	Wire break (4 to 20 mA)	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	✓	✓	✓	✓	✓	-	-
ET 200MP	✓	✓	✓	✓	✓	-	-
ET 200SP	✓	✓	✓	-	-	-	✓**
ET 200AL	-	✓	✓	✓	-	-	✓**
ET 200eco PN	✓	✓	✓	✓	-	-	-
ET 200pro	-	✓	✓*	✓*	-	-	✓

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

** Diagnostics for encoder supply only

2.14 Diagnostics

Table 2- 6 Configurable diagnostics types of an analog input module depending on the measurement type "Resistor (4-wire connection)"

	No supply voltage L+	Wire break	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	✓	✓	✓	✓	-	-	-
ET 200MP	✓	✓	✓	✓	-	-	-
ET 200SP	✓	✓	✓	✓	-	-	-
ET 200eco PN	✓	✓	✓	-	-	-	-
ET 200pro	-	✓	✓*	✓*	-	-	-

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

Table 2- 7 Configurable diagnostics types of an analog input module depending on the measurement type "Resistor (3-wire connection)"

	No supply voltage L+	Wire break	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	✓	✓	✓	✓	-	-	-
ET 200MP	✓	✓	✓	✓	-	-	-
ET 200SP	✓	✓	✓	✓	-	-	-
ET 200AL	-	✓	✓	-	-	-	-
ET 200eco PN	✓	✓	✓	-	-	-	-
ET 200pro	-	✓	✓*	✓*	-	-	-

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

Table 2- 8 Configurable diagnostics types of an analog input module depending on the measurement type "Resistor (2-wire connection)"

	No supply voltage L+	Wire break	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	✓	-	-	✓	-	-	-
ET 200MP	✓	-	-	✓	-	-	-
ET 200SP	✓	✓	✓	✓	-	-	-
ET 200AL	-	✓	✓	-	-	-	-
ET 200eco PN	✓	✓	✓	-	-	-	-
ET 200pro	-	✓	✓*	✓*	-	-	-

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

Table 2- 9 Configurable diagnostics types of an analog input module depending on the measurement type "Thermal resistor (4-wire connection)"

	No supply voltage L+	Wire break	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	✓	✓	✓	✓	-	-	-
ET 200MP	✓	✓	✓	✓	-	-	-
ET 200SP	✓	✓	✓	✓	-	-	-
ET 200eco PN	✓	✓	✓	✓	-	-	-
ET 200pro	-	✓	✓*	✓*	-	-	-

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

Table 2- 10 Configurable diagnostics types of an analog input module depending on the measurement type "Thermal resistor (3-wire connection)"

	No supply voltage L+	Wire break	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	✓	✓	✓	✓	-	-	-
ET 200MP	✓	✓	✓	✓	-	-	-
ET 200SP	✓	✓	✓	✓	-	-	-
ET 200AL	-	✓	✓	✓	-	-	-
ET 200eco PN	✓	✓	✓	✓	-	-	-
ET 200pro	-	✓	✓*	✓*	-	-	-

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

Table 2- 11 Configurable diagnostics types of an analog input module depending on the measurement type "Thermal resistor (2-wire connection)"

	No supply voltage L+	Wire break	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	-	-	-	✓	-	-	-
ET 200MP	-	-	-	✓	-	-	-
ET 200SP	✓	✓	✓	✓	-	-	-
ET 200AL	-	✓	✓	✓	-	-	-
ET 200eco PN	✓	✓	✓	✓	-	-	-
ET 200pro	-	✓	✓*	✓*	-	-	-

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

Table 2- 12 Diagnostics types of an analog input module to be configured depending on the measurement type "Thermocouple"

	No supply voltage L+	Wire break	Overflow	Underflow	Common mode error	Reference junction	Short-circuit
S7-1500	✓	✓	✓	✓	✓	✓	-
ET 200MP	✓	✓	✓	✓	✓	✓	-
ET 200SP	✓	✓	✓	✓	-	✓	-
ET 200eco PN	✓	-	✓	✓	-	✓	-
ET 200pro	-	-	✓*	✓*	-	✓	-

* For ET 200pro, the parameters "Overflow" and "Underflow" are combined to the parameter "Overflow/Underflow"

Diagnostics for analog output modules

Table 2- 13 Diagnostics types of an analog output module to be configured depending on the measurement type "Voltage"

	No supply voltage L+	Wire break	Overflow	Underflow	Short-circuit	Overload
S7-1500	✓	-	✓	✓	✓	-
ET 200MP	✓	-	✓	✓	✓	-
ET 200SP	✓	-	✓	✓	✓	-
ET 200eco PN	✓	-	-	-	✓	✓
ET 200pro	-	-	-	-	✓	-

Table 2- 14 Diagnostics types of an analog output module to be configured depending on the measurement type "Current"

	No supply voltage L+	Wire break	Overflow	Underflow	Short-circuit	Overload
S7-1500	✓	✓	✓	✓	-	-
ET 200MP	✓	✓	✓	✓	-	-
ET 200SP	✓	✓	✓	✓	-	-
ET 200eco PN	✓	✓	-	-	-	✓
ET 200pro	-	✓	-	-	-	-

Note

Measuring ranges

Note that the diagnostics types that can be parameterized depend on the selected measurement/output type as well as on the respective measuring range.

Note

Minimum output values

Certain errors such as wire break and short circuit cannot be diagnosed below a given current or voltage value. Diagnostics are only possible again once the output returns to above this minimum value.

No supply voltage L+

You can diagnose a missing or low supply voltage L+ at the analog module by activating the "No supply voltage L+" checkbox. If the supply voltage is missing or too low, the status and error display on the analog module will provide the relevant information. The entry in the diagnostics buffer also makes this information available to the CPU.

If there is no supply voltage, no other types of diagnostics available are possible either.

Wire break

The term wire break denotes a failure state that is triggered by the interruption of a usually closed electrical circuit.

Wire break in analog input modules

The "Wire break" diagnostics function facilitates the detection of errors during system operation. In STEP 7 you define the module properties by setting various parameters. Depending on the module used, you may, for example, be able to set a current limit parameter at which a wire break is to be reported.

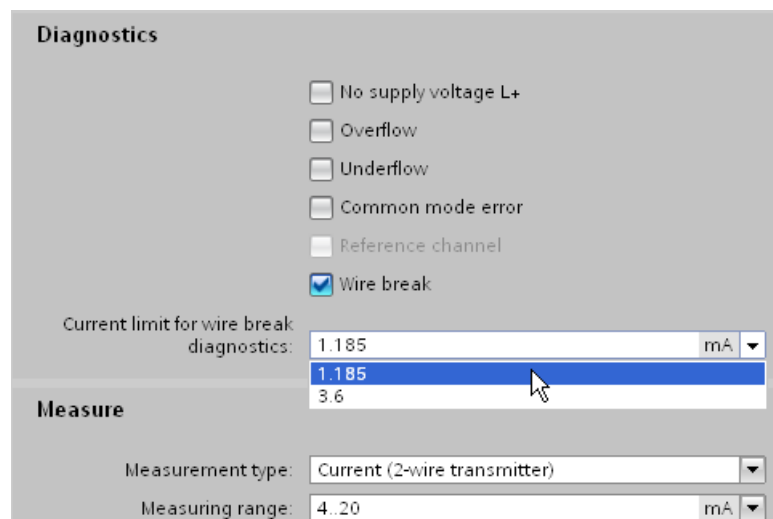


Figure 2-19 Configuring the wire break current limit for an analog input module in STEP 7

Usually, the live zero technique is deployed to detect wire breaks. The start of the measuring range for the standard live zero signal of 4 to 20 mA is assigned the 4 mA signal value. A wire break between the input and sensor can therefore be detected based on the missing current flow. Instead of a current signal, you may also use a voltage signal from 1 to 5 V to detect a wire break. The "Wire break" diagnostics function can therefore only be configured for a range of 4 to 20 mA or 1 to 5 V.

For "Resistor", "Thermal resistor" and "Thermocouple" measurements, a current is impressed into the line. If a wire break occurs, the flow of current is interrupted and the analog module therefore detects the wire break.

Wire break in analog output modules

The analog signal output is used for wire break detection. Reliable wire break diagnostics is not possible if the voltage is too low. In this case, the diagnostics function is deactivated without triggering a change of the diagnostics status.

The current limit up to which the module will diagnose wire break can be found in the technical data for the module.

Overflow/underflow

The resolution of the measuring range of an analog input module distinguishes between the rated range, the overrange or underrange, and the overflow or underflow. The following table assign the number of increments into which the measured signal is divided to the various voltage measuring ranges.

Table 2- 15 Voltage measuring range ± 10 V of an analog input module

Value (increments)	Voltage measuring range	Range
Decimal	± 10 V	
32767	> 11.759 V	Overflow
32511	11.759 V	Overrange
27649		
27648	10.0 V	Rated range
0	0 V	
-27648	-10 V	
-27649		Underrange
-32512	-11.759 V	
-32768	< -11.759 V	Underflow

As of a decimal value of 32512, the value acquired is beyond the overrange and is no longer valid. If this is the case, the error status "Overflow" is diagnosed. The overrange is a tolerance range before overflow is reached.

As of a decimal value of -32513, the value acquired is below the configured measuring range and is no longer valid. If this is the case, the error status "Underflow" is diagnosed. The underrange is the equivalent of the overrange, but for negative values.

An "Overflow" or "Underflow" diagnostics may be caused, for example, by a wire break, an incorrect measuring range or incorrect wiring.

Note

Accuracy

The accuracy specified in the technical data of the relevant module is only guaranteed within the rated range.

Common mode error

Activating the "Common mode" checkbox diagnoses a violation of the maximum potential difference U_{CM} . A violation of the permitted potential difference U_{CM} has occurred, for example, between the reference point of the measuring inputs and the analog ground M_{ANA} .

Possible causes:

- Wiring error
- Environments with EMC disturbance
- Incorrectly grounded transducers
- Long line lengths
- Sensor not connected
- 2-wire transducer connected to M_{ANA}

Note

With 4-wire transducers, a current meter connected in series will result in too great a drop in voltage.

Potential differences U_{CM} beyond the valid limits may lead to measurement errors and malfunctions. If you want to ensure that the maximum value is not exceeded, interconnect the measuring inputs and analog ground M_{ANA} with an equipotential bonding cable. More detailed information can be found in *Wiring transducers*.

Short-circuit

Activating the "Short circuit" checkbox activates short-circuit diagnostics for an analog channel. The diagnostics function is triggered by channel overload.

Possible causes:

- Wiring error (e.g. short circuit between conductors at the connections or in the cable)
- Use of faulty or incorrect actuators (e.g. internal short circuit or low input resistance as a result of actuator failure)

The analog signal output is used for short circuit detection. If the voltage is too low, reliable short-circuit diagnostics are not possible. In this case, the diagnostics function is deactivated without triggering a change of the diagnostics status. The voltage limit up to which the module will diagnose a short circuit can be found in the technical data for the module.

SIMATIC modules have a special protective circuit to prevent short circuit. The short circuit current is limited internally in the module. The level of short circuit current is specified in the technical data of your analog module.

Note

Overload

Please note that overload exposes the modules are exposed to a greater thermal load. This can affect the output channels. You should therefore avoid continuously running analog output modules in overload.

Reference junction

This type of diagnostics can only be selected for analog input modules for "Thermocouple" measuring. Selecting the "Reference junction" check box diagnoses an error on the reference channel for compensating the reference junction temperature.

The temperature at the reference junction of a thermocouple is measured at the reference channel of the module using an external thermal resistor (RTD). If an error occurs, for example as a result of a wire break, the temperature measured at the reference junction of the thermocouple will no longer be compensated. The reference temperature may then be outside the valid range.

Additional information on connecting thermocouples and thermal resistors and on how they operate can be found in Thermocouples and Wiring transducers.

Overload

Activating the "Overload" checkbox activates the diagnostics of the thermal monitoring of the output level. The "Overload" diagnostics is triggered when the maximum temperature is exceeded at the output and is detected channel by channel.

The maximum temperature may be exceeded for the following reasons:

- Ambient temperature is too high
- Output is being operated outside the specification

Note

Overload

Please note that overload exposes the modules to a high thermal load. This can affect the output channels. You should therefore avoid continuously running analog output modules in overload.

2.15 Value status

Value status

In case of a faulty analog value, the analog module outputs the error values 0x7FFF (error value for overflow and all other error states) or 0x8000 (error value for underflow) for the affected channel. The user program is now able to detect and evaluate a channel error. The user also has the option to evaluate the system diagnostics event-driven by means of diagnostics alarms.

In addition to the error values 0x7FFF or 0x8000 and the configured diagnostic types, analog input and output modules provide diagnostics information by means of the Process image input (PII). It is referred to as Value status and transferred synchronously with the user data. The value status (Quality Information = QI) provides a statement regarding the validity of the input signal. A distinction is made between the quality level "Good" (signal valid = 1) and "Bad" (signal invalid = 0).

Note

For analog input modules, the use of the value status is an alternative to the evaluation of the channels by the error values 0x7FFF or 0x8000. Compared to the error values, the binary evaluation of the value status (0 or 1) in the user program is simpler and more clearly arranged.

For analog output modules, the value status informs you as to whether the written value can be output by the respective channel. Using the value status you can respond to this information without having to evaluate the diagnostics of the module in the first place.

Example

Enabling the value status of an analog input module

To enable the value status of an analog input module, follow these steps:

- Select the required analog module in STEP 7.
- Select "AI configuration" in the "Properties" tab of the analog module.
- Click the "Value status" button.

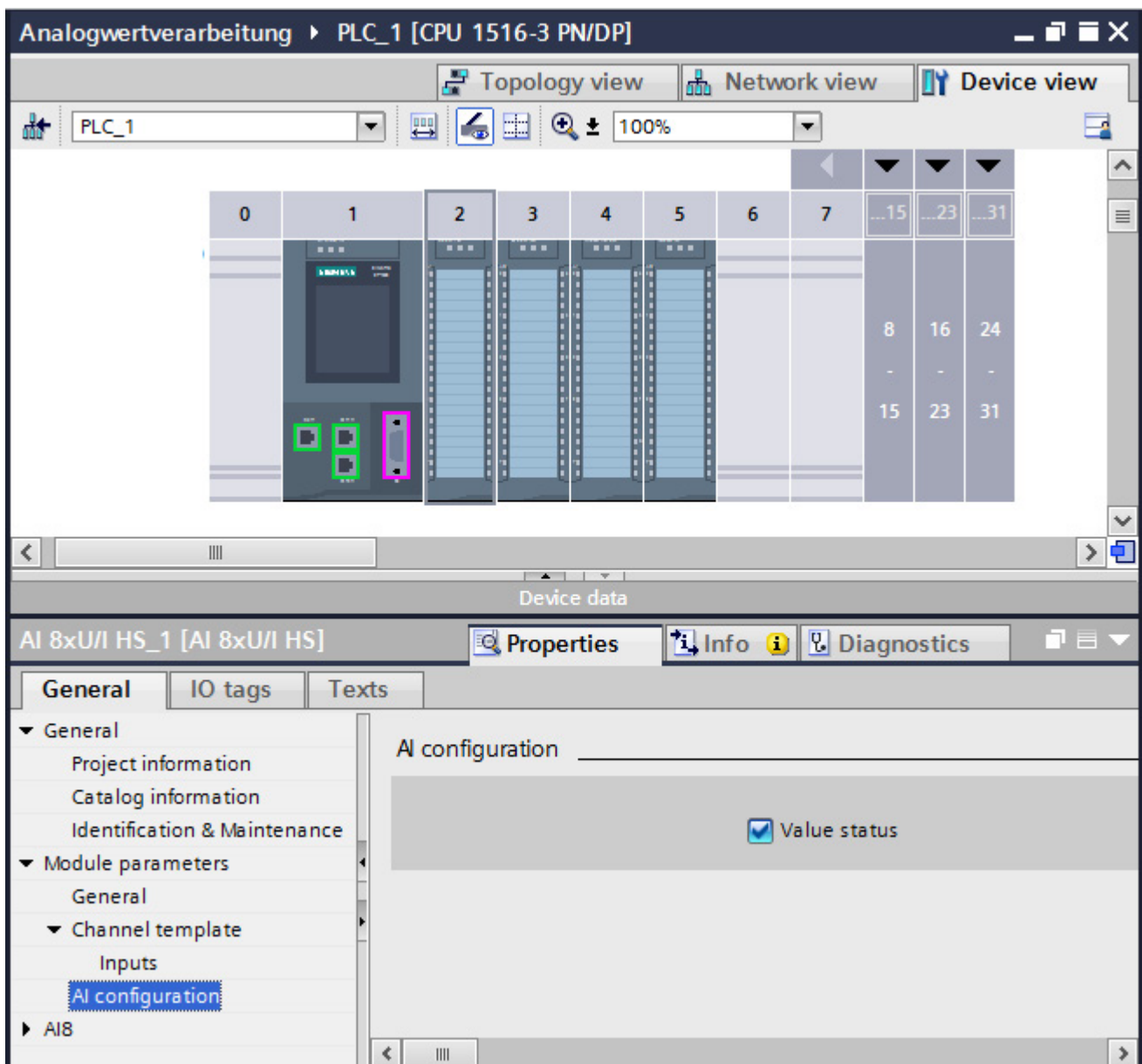


Figure 2-20 Enabling the value status in STEP 7

2.15 Value status

An additional byte is occupied in the input address space of the respective module when you enable the value status. Each bit in this byte is assigned to a channel and provides information on, for example, whether the output value specified by the user program is actually queued at the module terminal (0= value is invalid; 1= value is valid).

Error occurrence

If a wire break occurs at an analog input module, for example, the current signal state is entered in the process image and the value status of the signal is set to "invalid". To trigger an indicator light in case of an error, for example, evaluate the value status in the user program.

Diagnostics alarms and value status

If you configure analog modules in a third-party product with the help of a GSD file and the diagnostics alarms are not evaluated event-driven, it is best to use the value status.

Note

The Value status represents a group diagnostics which only gives the user a Good or Bad information. The Value status is not suitable for a more specific identification of the cause of the error (e.g., wire break, short circuit in the encoder cable or load voltage failure).

2.16 Conversion time of an analog module

Basic conversion time and conversion time of an analog input channel

The basic conversion time is the minimum time required by one single channel to convert analog values. The actual conversion time comprises both the basic conversion time and, depending on the analog input module used:

- Processing time for measuring resistance
- Processing time for wire break monitoring
- Processing time for overflow/underflow monitoring
- Processing time for checking common mode errors

Example

This example shows channel 6 of an analog input module for resistance measurement in the range of 6000 Ω , a configured integration time of 20 ms, and activated wire break monitoring.

The conversion time of the channel is derived from the total of the following measurement variables:

Measurement variable	Time in ms
Basic conversion time	27
Processing time for RTD/resistance (6000 Ω)	4
Processing time for wire break monitoring in the RTD/resistance and thermocouple areas	9
Conversion time of the channel	40

Conversion time of the analog output channels

The conversion time of an output channel starts with the transfer of the digital value from the internal memory of the module and ends with the digital-to-analog conversion.

The conversion time does not include the settling time for the analog signal at the module terminal. Detailed information on the settling time can be found in Settling and response times of analog output modules (Page 52).

Note

Relationship between diagnostics and conversion time

While some diagnostics run parallel to the conversion and do not extend the conversion time, other diagnostics types can lead to an extension of the conversion time, as demonstrated in the example above.

Conversion time for high-speed analog modules

High-Speed analog modules (HS modules) are designed for faster processing of signals. HS modules offer fewer diagnostics and measurement types than standard modules (ST modules). You can find more information on HS modules in the section High-Speed analog modules (Page 113).

2.17 Cycle time of an analog module

Definition

The cycle time of an analog module represents the time that the module needs to process all channels used. The cycle time depends on the form of measured value acquisition used, e.g. multiplex or parallel measured value acquisition.

Sequential measured value processing

This procedure processes the analog channels in the module one after another (sequentially). For analog inputs, the values are connected to a converter, for example using a multiplexer, and sequentially converted.

The cycle time of the analog module is derived from the total conversion time of all activated analog channels of the module. STEP 7 provides the option of deactivating unused analog channels. to reduce the cycle time.

The figure below gives an overview of the factors that determine the cycle time of an n-channel analog module.

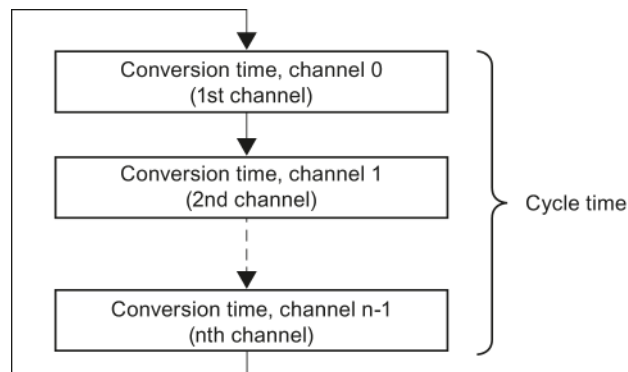


Figure 2-21 Cycle time of an analog module with multiplex conversion

Parallel measured value acquisition

This procedure processes the analog channels of a module at the same time (in parallel) rather than one after another. In parallel measured value processing, the cycle time of the module is usually constant and does not depend on the number of channels used. The goal of parallel measured value acquisition as it is applied by high-speed analog modules, for example, is a shorter cycle time. You can find more information on HS modules in the section High-Speed analog modules (Page 113).

2.18 Settling and response times of analog output modules

Settling and response times provide information on the delay of the output of a specified analog output variable and its availability to the process.

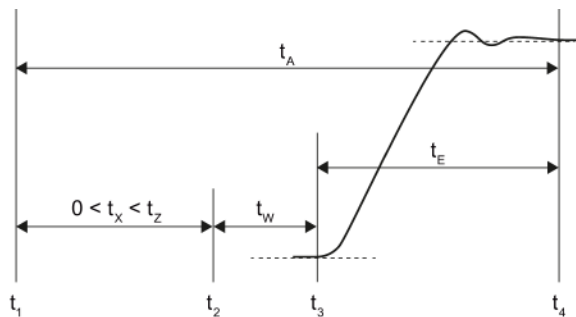
Response time

The response time for a new output value is defined as the time between the input of a digital output value to the internal memory of the module and the value to be output at the analog output being reached (with a residual error of 1 %).

The response time (t_A) is the sum of application time (t_x), conversion time (t_w) and settling time (t_E):

$$t_A = t_x + t_w + t_E$$

Settling and response times of analog output modules



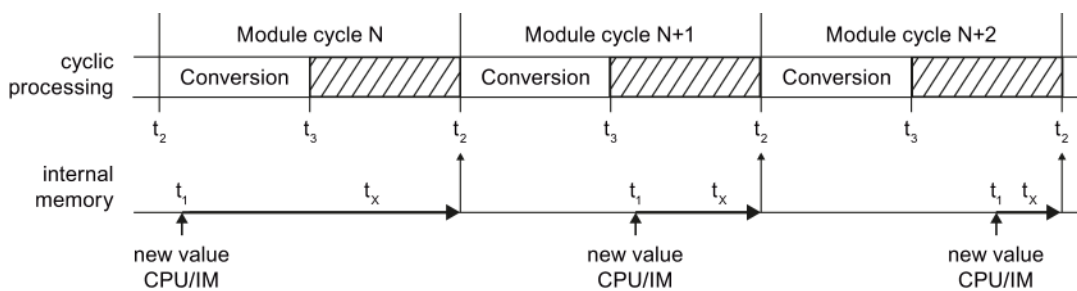
- t_A Response time
- t_x Application time
- t_z Module cycle time
- t_w Conversion time
- t_E Settling time
- t_1 New digital output value is available in the internal memory of the module
- t_2 Module activates the digital output value and starts conversion
- t_3 Module ends conversion at the terminal of the analog output channel and outputs the analog signal
- t_4 Signal has settled and the specified analog output value has been reached (residual error 1 %)

Figure 2-22 Settling and response time of an output channel

Application time

The CPU/IM (interface module) writes new output values to the internal memory of the analog output module. The time required for this is not determined by the CPU/IM. These output values are converted asynchronously to their entry in buffer memory. The worst-case application time (t_x) may be equal to the cycle time (t_z). This situation develops if the CPU writes a new value to the internal memory of the module immediately after the transfer of the value for conversion. This new value will not be processed until the next conversion.

The figure below shows acyclic access of the analog output module to output values from the internal memory in non-isochronous mode. You can find more information on isochronous mode in the paragraph on isochronous mode of the section High-Speed analog modules (Page 113).



- t_x Application time
- t_1 New digital output value is available in the internal memory of the module
- t_2 Module activates the digital output value and starts conversion
- t_3 Module ends conversion at the terminal of the analog output channel and outputs the analog signal

Figure 2-23 Application of the output values

Conversion time

The conversion time of an output channel starts with the transfer of the digital value from the internal memory of the module (t_2) and ends with the digital-to-analog conversion (t_3).

Settling time

The settling time starts when the analog signal is output to the module (t_3) terminals and ends when the output value (t_4) is reached. The output value is reached as soon as the output signal has settled at its final value, taking into account a residual error of 1%.

The settling time depends on the type of output for the module, and on the connected load. The load for the analog output consists of connecting line and connected actuator. When the output is "Current", the settling time increases with high ohmic resistance. Inductive loads cause subsequent fluctuation in the output value. When the output is "Voltage", the capacitive load causes subsequent fluctuation.

2.19 Smoothing

Using the smoothing functions

Most analog input modules allow you to configure smoothing for the measuring signal in STEP 7. Smoothing analog values reduces the effect of interference signals. Smoothing is useful with slow changes in measured values, for example in temperature measurements.

Smoothing principle

The measured values are smoothed by means of filtering. The module forms mean values from a specified number of converted (digitalized) analog values. Smoothing should not be confused with the integration of measured values over a defined period of time. It is therefore not possible to smooth measured signals to filter out a specific interference frequency. However, this smoothing returns more "stable" data values because it suppresses peaks which overlay the measured signal.

4 (none, weak, medium, strong) or more levels of smoothing can be configured by the user depending on the module used. The level determines the number of analog values from which the mean value is generated. The greater the smoothing factor, the better the filtering.

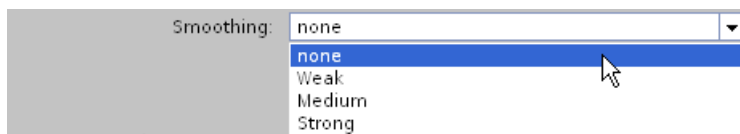


Figure 2-24 Selecting the smoothing level in STEP 7

Smoothing method

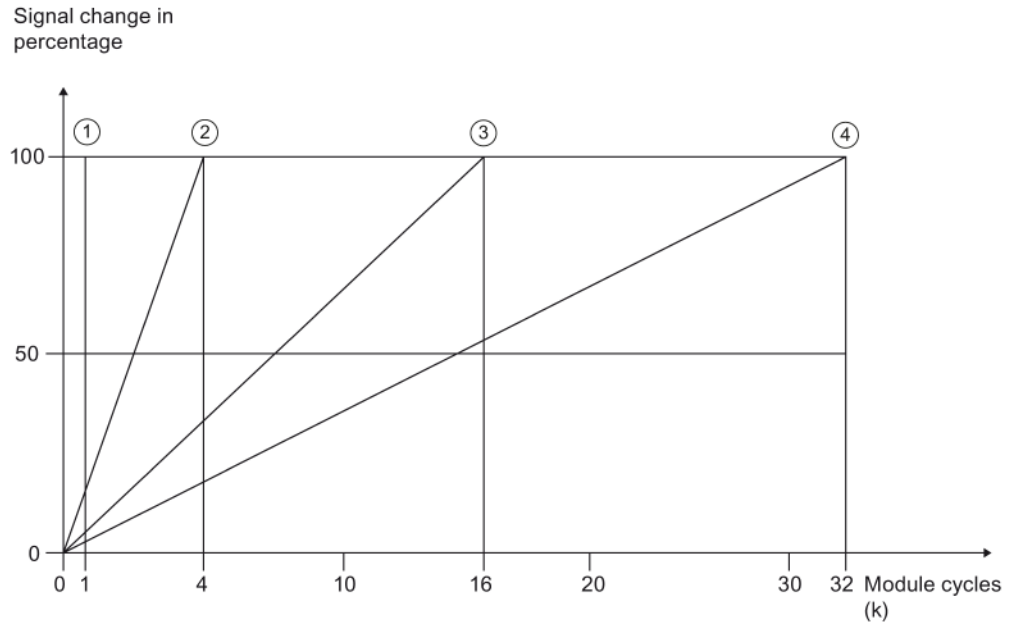
A smoothing algorithm is applied to a configurable number of measured values (e.g. 4, 8, 32) in line with the moving average. Each new measured value is factored in, and the oldest measured value then ignored. This mechanism suppresses interference peaks which overlay the measured signal. Utility signal jumps only become evident in the data after some time (see examples below).

The modules of the various product ranges use different smoothing algorithms. Smoothing is either linear or exponential. The differences are apparent particularly with strong smoothing and lead to a faster or slower rate of rise depending on the product used.

For information on whether or not a specific module supports customization of the smoothing function, please refer to the manual of the analog input module.

Example 1: Linear smoothing

The diagram below shows the number of module cycles (k) it takes for each smoothing level setting for the smoothed analog value to reach approximately 100 % after a step response. This specification is valid for all signal changes at the analog input.



- ① No smoothing (k = 1)
- ② Weak smoothing (k = 4)
- ③ Medium smoothing (k = 16)
- ④ Strong smoothing (k = 32)

Figure 2-25 Linear smoothing with four smoothing levels

Example 2: Exponential smoothing

The diagram below shows the step response of the smoothing factor for different numbers of module cycles.

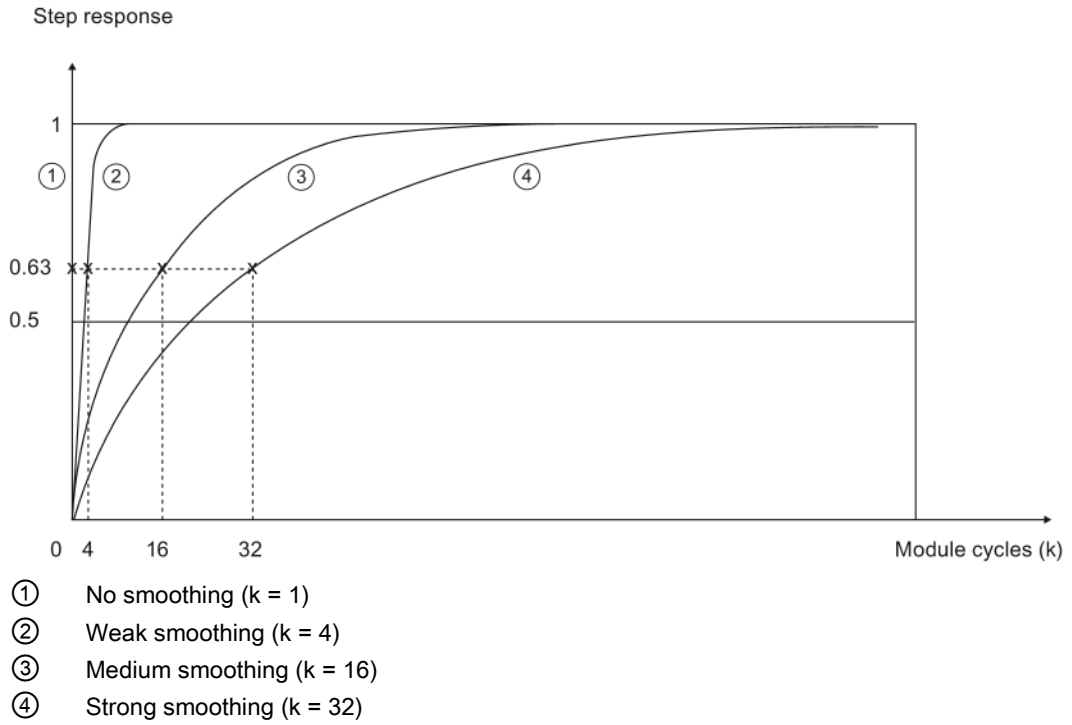


Figure 2-26 Exponential smoothing with four smoothing levels

2.20 Burden with 2-wire transducers

2-wire transducers

2-wire transducers are current transducers which convert the process variable into a current signal of between 4 and 20 mA. Two connection lines supply the transducer with an output current of at least 4 mA. Additional information on connecting 2-wire transducers to analog input modules can be found in the section Wiring current transducers (Page 72).

Burden

The burden indicates how great the external resistance in a current loop may be. If the external resistance is greater than the specified burden, the 2-wire transducer supply voltage is too low. The burden consists of the resistance of the transducer and all other resistances connected to the current loop.

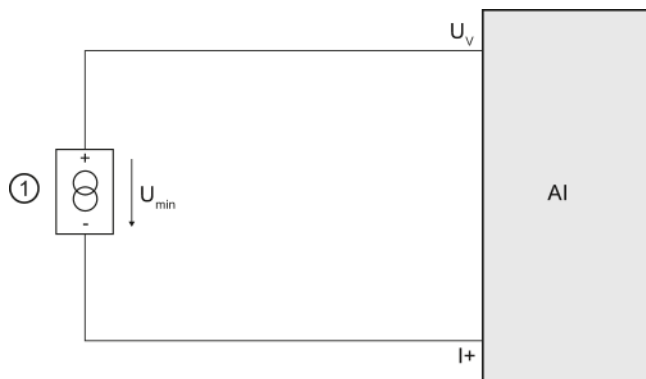
The maximum admissible burden of the transducer, e.g. 820 Ω , is specified in the technical data of the analog module.

Example 1: Connecting a transducer to the electrical circuit

In accordance with the technical data of the 2-wire transducer used, it requires a supply voltage (U_{min}) of at least 8.5 V. Using Ohm's Law, you can calculate the resistance of the transducer used (R_{2DMU}) for a current of 20 mA.

$$R_{2DMU} = \frac{U_{min}}{I} = \frac{8.5 \text{ V}}{0.020 \text{ A}} = 425 \Omega$$

With a supply voltage of at least 8.5 V, the transducer has a resistance of 425 Ω . The resistance is less than 820 Ω . You can therefore connect the transducer to the analog input module (AI) without exceeding the maximum burden.



- ① 2-wire transducers
- U_v Terminal for feed voltage at the channel
- $I+$ Terminal for current input
- U_{min} Voltage drop at 2-wire transducer

Figure 2-27 Connecting a transducer to the electrical circuit

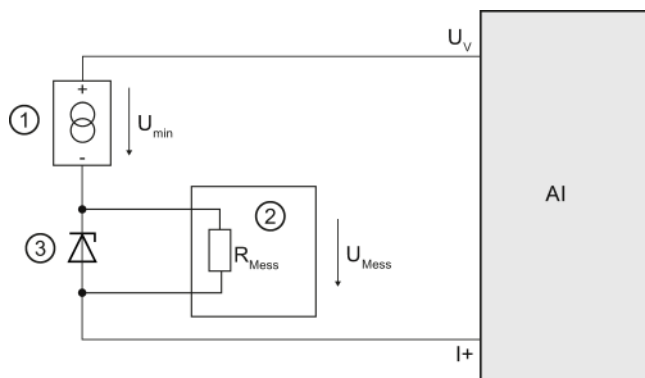
Example 2: Connecting a transducer and other devices

If multiple measuring devices are connected in series, the sum of all connected resistances may not exceed the value of the maximum burden.

If you have connected a 2-wire transducer to a supply voltage of 8.5 V, you will need to allow for the resistance of the measuring device connected ②.

Maximum transducer burden:	820 Ω
Transducer resistance upon a voltage drop of 8.5 V:	425 Ω
Maximum resistance of additional devices connected:	395 Ω

The resistance of the measuring instrument may therefore not exceed 395 Ω.



- ① 2-wire transducers
- ② Digital multimeter
- ③ Zener diode
- U_v Terminal for feed voltage at the channel
- $I+$ Terminal for current input
- U_{min} Voltage drop at 2-wire transducer
- R_{Mess} Resistance at measuring instrument
- U_{Mess} Voltage drop at the measuring instrument

Figure 2-28 Connecting a transducer and other devices to the circuit

Calculating admissible voltage drop

The maximum additional resistance in the current loop may not exceed 395 Ω at a maximum current of 20 mA. You can calculate the voltage drop at the connected measuring instrument (U_{Mess}) as follows using Ohm's Law:

$$U_{Mess} = R_{Mess} * I = 395 \Omega * 0.020 \text{ A} = 7.9 \text{ V}$$

The voltage drop at the measuring instrument should therefore not exceed 7.9 V.

Representation of analog values

3.1 Overview

Conversion of analog values

The CPU only processes analog values in digitalized format.

Analog input modules convert the analog signal into a digital value for further processing by the CPU.

Analog output modules convert the digital output value from the CPU into an analog signal.

Analog value representation at 16-bit resolution

The digitized analog value is the same for all I/O values at the same rated range. The analog values are represented as fixed point numbers in twos complement. This leads to the following conditions:

Table 3- 1 Representation of analog values

Resolution	Analog value															
Bit number	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Significance of the bits	S	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Sign

The sign (S) of the analog value is always set in bit 15:

- "0" → +
- "1" → -

Resolution less than 16 bits

The analog value is left-aligned in the memory of analog modules with a resolution of less than 16 bits. The unused least significant digits are padded with "0" values.

This reduces the number of measured values that can be represented. Modules occupy a range of values of between +32767 and -32768 regardless of the resolution. The scaling between two successive values depends on the resolution of the module.

Example

The following example shows how the least significant digits are padded with "0" values:

- The module with 16-bit resolution is capable of incrementing the values in steps of one unit ($2^0 = 1$).
- The module with 13-bit resolution is capable of incrementing the values in steps of 8 units ($2^3 = 8$).

Table 3- 2 Example: Bit pattern of a 16-bit and 13-bit analog value

Resolution	Analog value															
Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
16-bit	S	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
13-bit	S	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	0	0	0

S = sign

Note

For information on the resolution supported by each analog module, please refer to the technical data for the relevant module.

3.2 Representation of input ranges

The tables below set out the digitalized representation of the input ranges by bipolar and unipolar input ranges. The resolution is 16 bits.

Please see the device manuals for each analog input module for assignment of the values to the specific measured values in each measuring range.

Table 3- 3 Bipolar input ranges

Dec. value	Measured value in %	Data word																Range
		2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	
32767	>117.589	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Overflow
32511	117.589	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	Over range
27649	100.004	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	
27648	100.000	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	Rated range
1	0.003617	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
0	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-1	-0.003617	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
-27648	-100.000	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	
-27649	-100.004	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	Under range
-32512	-117.593	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	
-32768	<-117.593	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Underflow

Table 3- 4 Unipolar input ranges

Dec. value	Measured value in %	Data word																Range
		2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	
32767	>117.589	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Overflow
32511	117.589	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	Over range
27649	100.004	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	
27648	100.000	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	Rated range
1	0.003617	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
0	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-1	-0.003617	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Under range
-4864	-17.593	1	1	1	0	1	1	0	1	0	0	0	0	0	0	0	0	
-32768	<-17.593	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Underflow

3.3 Representation of output ranges

The tables below set out the digitalized representation of the output ranges by bipolar and unipolar range. The resolution is 16 bits.

Please see the device manuals for each analog output module for assignment of the values to the specific output values in each measuring range.

Table 3- 5 Bipolar output ranges

Dec. value	Output value in %	Data word																Range
		2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	
32511	117.589	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	Maximum output value*
32511	117.589	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	Over range
27649	100.004	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	
27648	100.000	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	Rated range
1	0.003617	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
0	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-1	-0.003617	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
-27648	-100.000	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	
-27649	100.004	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	Under range
-32512	-117.593	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	
-32512	-117.593	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	Minimum output value**

* When values > 32511 are specified, the output value is limited to 117.589 % or 0 % (0.0 V / 0.0 mA), depending on the module used.

** When values < -32512 are specified, the output value is limited to -117.593 % or 0 % (0.0 V / 0.0 mA), depending on the module used.

Representation of analog values

3.3 Representation of output ranges

Table 3- 6 Unipolar output ranges

Dec. value	Output value in %	Data word																Range
		2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	
32511	117.589	0	1	1	1	1	1	1	1	x	x	x	x	x	x	x	x	Maximum output value*
32511	117.589	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	Over range
27649	100.004	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	
27648	100.000	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	Rated range
1	0.003617	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
0	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Minimum output value**

* When values > 32511 are specified, the output value is limited to 117.589 % or 0 % (0.0 V / 0.0 mA), depending on the module used.

** When values < 0 are specified, the output value is limited to 0% (0.0 V / 0.0 mA).

Connecting transducers

4.1 Overview

Introduction

This chapter describes the basic procedure for wiring transducers to analog inputs. Information on specific wiring options is available in the manual of each module.

For more information, e.g. on cable routing and shielding or potential equalization, etc., refer to the function manual for Configuring interference-free controllers (<http://support.automation.siemens.com/WW/view/en/59193566>).

Transducers that can be wired to analog inputs

You can wire the following transducers to the analog input modules, depending on the type of measurement:

- Voltage transducers
- Current transducers
 - 2-wire transducers
 - 4-wire transducers
- Resistance transducers
 - 4-wire connection
 - 3-wire connection
 - 2-wire connection
- Thermocouples

Isolated transducers and non-isolated transducers

Transducers are available in various models:

- Isolated transducers are **not connected** locally to the ground potential. Floating operation is possible.
- Non-isolated transducers are **connected** locally to the ground potential.

Non-isolated transducer connections are connected to the conductive enclosure.

Note: All non-isolated transducers must have a galvanic connection to each other and be locally connected to the ground potential.

Abbreviations used in the figures

Key to the abbreviations in the figures below:

AI	Analog input module
M	Ground connection
L+	Supply voltage connection
M_n^+/M_n^-	Measuring input, channel n
I_{Cn}^+/I_{Cn}^-	Current output to thermal resistor (RTD) channel n
U_n^+/U_n^-	Voltage input channel n
I_n^+/I_n^-	Current input channel n
COMP+/COMP-	Compensation input
I_{Comp}^+/I_{Comp}^-	Current output for compensation
U_V	Feed voltage at channel (the connection can be used for 2-wire transducer (2DMU) or with ET 200eco PN and ET 200pro for 2/4-wire transducer).
U_{CM}	Potential difference between the reference points of the measuring inputs / the analog ground M_{ANA}
U_{ISO}	Potential difference between the reference points of the measuring inputs and the central ground
M_{ANA}	Reference point of the analog ground

Lines for analog signals

Always use shielded twisted-pair cables to wire the analog signals. This improves immunity.

4.2 Wiring analog inputs with MANA connection

The reference potentials of the measuring inputs and the central ground are electrically isolated in analog input modules with MANA connection.

Limited potential difference U_{ISO} (insulation voltage)

Always verify that the admissible potential difference U_{ISO} between the reference point of the analog ground M_{ANA} and the central ground is not exceeded.

Potential difference U_{ISO} may be caused by: Maximum line lengths exceeded.

If you want to ensure that the permitted value U_{ISO} is not exceeded, install an equipotential bonding cable between the terminal M_{ANA} and the central grounding point.

Limited potential difference U_{CM} (common mode)

Always verify that the admissible potential difference U_{CM} between the reference point of the measuring inputs and the analog ground M_{ANA} is not exceeded.

Potential differences U_{CM} may be caused by:

- Environments with EMC disturbance
- Use of grounded transducers
- Use of long cable lengths

Measuring errors / malfunctions can occur if the admissible potential difference U_{CM} is exceeded.

Some modules can detect an invalid potential difference U_{CM} and report this error with an entry in the diagnostics buffer of the CPU.

If you want to ensure that the maximum value U_{CM} is not exceeded, interconnect the reference points of the measuring inputs and the analog ground M_{ANA} with an equipotential bonding cable.

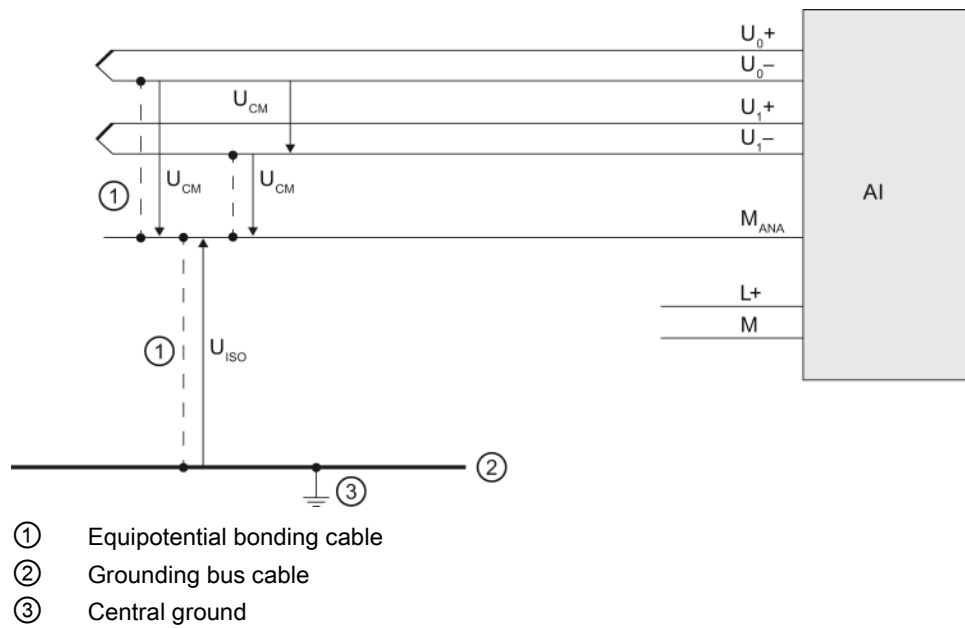


Figure 4-1 Example: Reference potential for analog input modules with M_{ANA} connection

4.3 Wiring analog inputs without MANA connection

The reference potentials of the measuring inputs and the central ground are electrically isolated from each other in analog input modules without an MANA connection.

Limited potential difference U_{ISO} (insulation voltage)

Always verify that the maximum potential difference U_{ISO} between the reference points of the measuring inputs and central ground is not exceeded.

Potential difference U_{ISO} may be caused by: Maximum line lengths exceeded.

If you want to ensure that the permitted value U_{ISO} is not exceeded, install an equipotential bonding cable between the reference points of the measuring inputs and the central grounding point.

Limited potential difference U_{CM} (common mode)

Always ensure that the permitted potential difference U_{CM} between the reference points of the measuring inputs is not exceeded.

Potential differences U_{CM} may be caused by:

- Environments with EMC disturbance
- Use of grounded transducers
- Use of long cable lengths

Measuring errors / malfunctions can occur if the admissible potential difference U_{CM} is exceeded.

Some modules can detect an invalid potential difference U_{CM} and report this error with an entry in the diagnostics buffer of the CPU.

If you want to ensure that the permitted value U_{CM} is not exceeded, install equipotential bonding cables between the reference points of the measuring inputs or, with the ET 200eco PN and ET 200pro, between the reference points of the measuring inputs and ground.

4.3 Wiring analog inputs without MANA connection

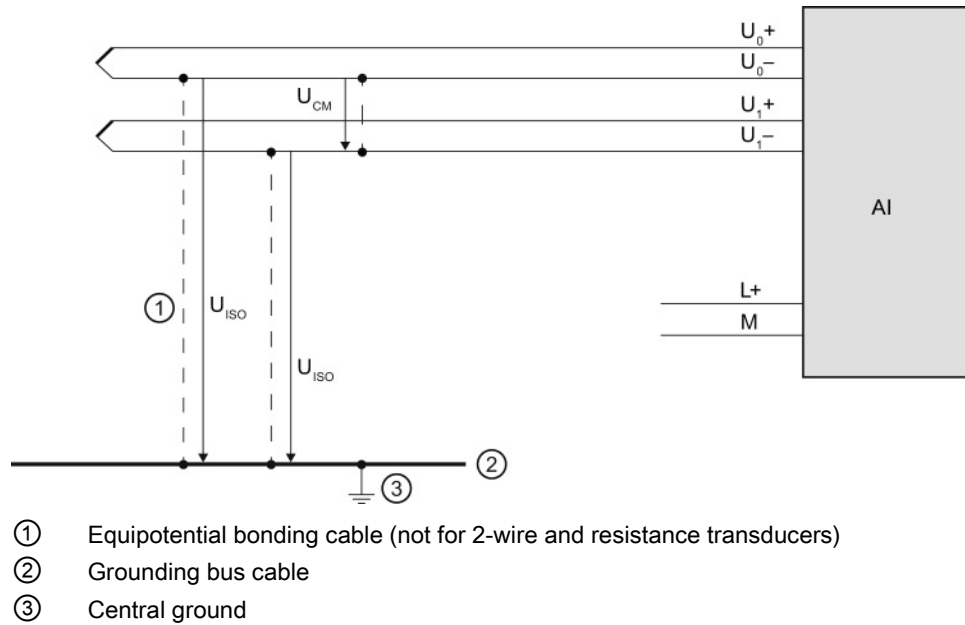
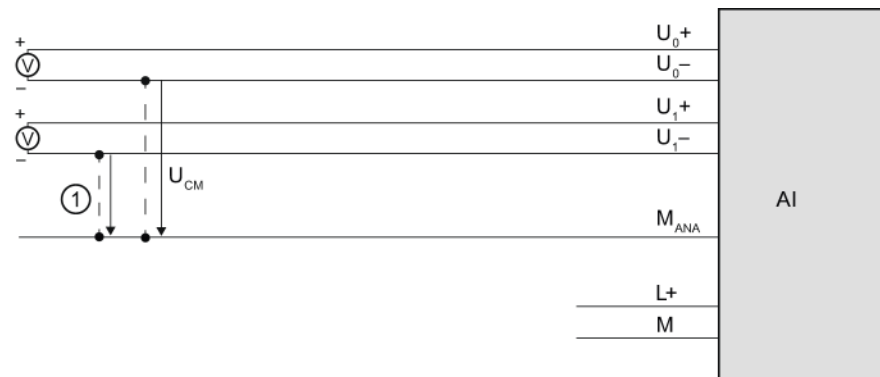


Figure 4-2 Example: Reference potential for analog input modules without MANA connection

4.4 Wiring voltage transducers

The figure below shows how to connect voltage transducers. If you want to ensure that the permitted value U_{CM} is not exceeded, install equipotential bonding cables to connect the reference points of the measuring inputs to the analog ground M_{ANA} , or with ET 200eco PN and ET 200pro the reference points of the measuring inputs to the ground.



① Equipotential bonding cable (only relevant to modules with M_{ANA} connection)

Figure 4-3 Example: Wiring voltage transducers to an analog input module

4.5 Wiring current transducers

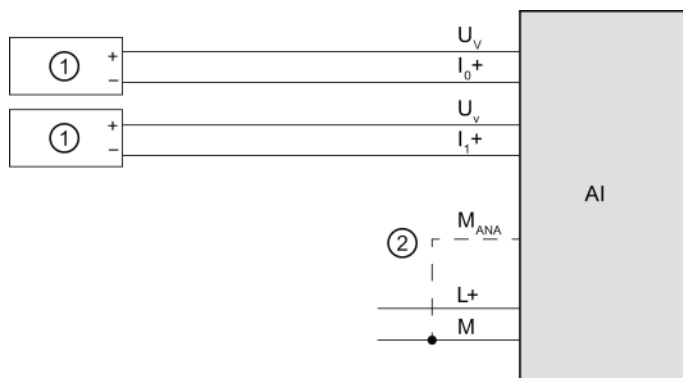
Current transducers are available as 2-wire transducers and 4-wire transducers. Below are a number of ways to supply current transducers with voltage.

Wiring 2-wire transducers with power supply from the module

The 2-wire transducer converts the process variable into a current. The 2-wire transducer is wired to the short circuit-proof supply voltage at the terminals of the analog input module. The transducer is therefore frequently also called a "passive transducer". Its simple wiring means that the 2-wire transducer is frequently used in industrial environments. If you use this type of connection, you will need to set the "Current (2-wire transducer)" measurement type in STEP 7.

Note

2-wire transducers must be electrically isolated.



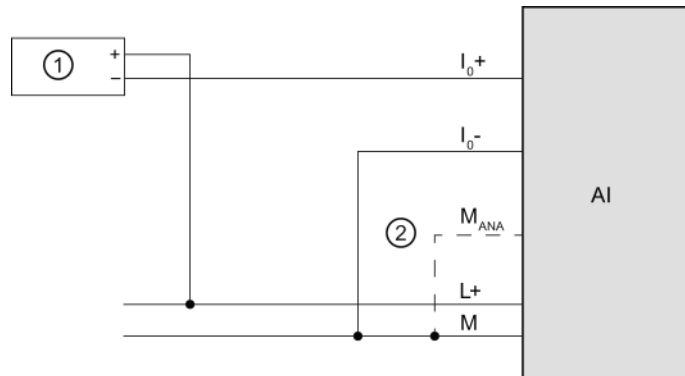
- ① 2-wire transducers (2WT)
- ② Equipotential bonding cable (only relevant to modules with M_{ANA} connection)

Figure 4-4 Example: Wiring 2-wire transducers to an analog input module

Wiring 2-wire transducers to an analog input for 4-wire transducers

The figure below shows an alternative to the above connection: supplying the 2-wire transducer from supply line L+ of the module. If you use this type of connection, you will need to set the "Current (**4-wire transducer**)" measurement type in STEP 7.

In this type of connection, galvanic isolation between the supply voltage L+ and the analog circuit will be removed.

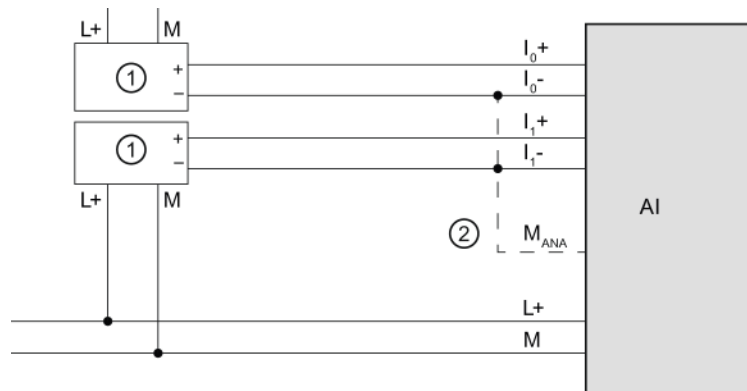


- ① 2-wire transducers (2WT)
- ② Equipotential bonding cable (only relevant to modules with M_{ANA} connection)

Figure 4-5 Example: Wiring 2-wire transducers to an analog input for 4-wire transducers

Wiring and connecting 4-wire transducers

4-wire transducers provide terminals for connecting a separate supply voltage. They are powered with an external supply and are frequently called "active transducers". If you use this type of connection, you will need to set the "Current (**4-wire transducer**)" measurement type in STEP 7.



- ① 4-wire transducers (4WT)
- ② Equipotential bonding cable (only relevant to modules with M_{ANA} connection)

Figure 4-6 Example: Wiring 4-wire transducers to an analog input module

4.6 Wiring thermal resistors and resistors

The module provides a constant current at terminals I_{C+} and I_{C-} for resistance measurements. The constant current is fed to the resistance to be measured where it is measured as voltage drop. It is important to wire the connected constant current cables directly to the thermal resistor/resistor.

Measurements with 4-wire or 3-wire connection compensate for line resistance and therefore achieve greater accuracy compared to measurements with 2-wire connection.

Measurements with two-wire connection always acquire line resistance in addition to the actual resistance; you must therefore allow for a significant loss of precision in the measuring results.

The figures below give some connection examples.

4-wire connection of a thermal resistor

The voltage at the thermal resistor is acquired using high-impedance measurement via the M_0+ and M_0- terminals. Make sure the wiring is correctly poled (I_{C0+} and M_0+ , and I_{C0-} and M_0- at the thermal resistor).

Always wire the I_{C0+} and M_0+ lines, and the I_{C0-} and M_0- lines directly to the thermal resistor.

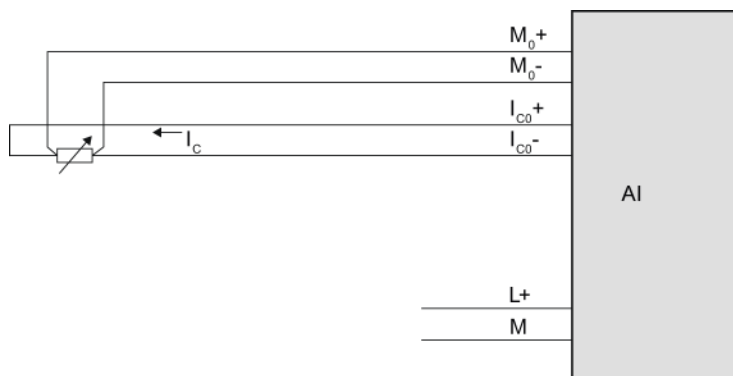


Figure 4-7 Example: 4-wire connection of thermal resistor to an analog input module

3-wire connection of a thermal resistor

Depending on the module, for a 3-wire connection to modules with 4 terminals (per channel), you may need to insert a bridge between **M₀₋** and **I_{C0-}** (see figure below) or between **M₀₊** and **I_{C0+}**. Always wire the **I_{C0+}** and **M₀₊** lines directly to the thermal resistor. Use cable with wires with identical cross-section.

For ET 200AL, ET 200eco PN and ET 200pro, no bridge is required as all necessary connections are implemented internally.

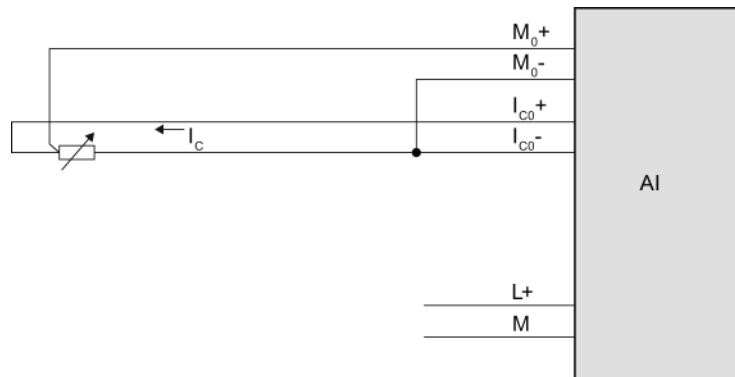


Figure 4-8 Example: 3-wire connection of thermal resistor to an analog input module

2-wire connection of a thermal resistor

When installing a 2-wire device on modules with 4 terminals (per channel), you will need to insert bridges at the module between **M₀₊** and **I_{C0+}** and between **M₀₋** and **I_{C0-}** as shown in the figure below. The line resistance is measured, but not compensated. As a result of physical limitations, this measurement type is less accurate than measurement with 3-wire or 4-wire connections. The wiring for this type of measurement is, however, simple as the bridges required can be wired in the plug, saving line.

For ET 200AL, ET 200eco PN and ET 200pro, no bridge is required as all necessary connections are implemented internally.

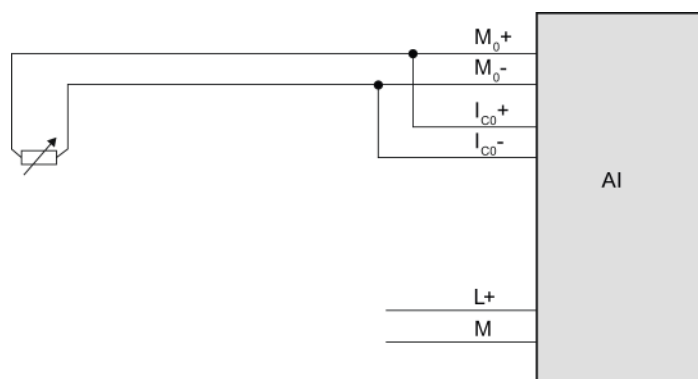


Figure 4-9 Example: 2-wire connection of thermal resistor to an analog input module

4.7 Wiring thermocouples

Introduction

Thermocouples are generally supplied ready-to-use. Protective casing prevents the thermocouples from being destroyed by mechanical force, for example.

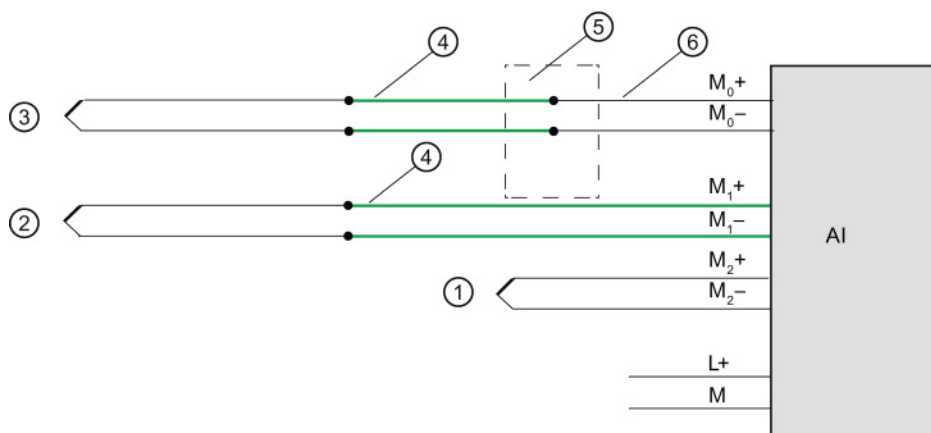
Compensating lines

The compensating lines belonging to the respective thermocouples are identified by a special color code, because only the compensating line that is made of the material matching the thermocouple may be used. The standardized compensating lines are specified in DIN EN 60584. Observe the maximum temperatures in the manufacturer's specifications.

Thermocouple connection options

There are various different ways to wire thermocouples to an analog input module:

- Directly ①.
- Using compensating lines ②.
- With a compensating line to the reference junction, connected with a supply line, e.g. copper ③.



- ① Thermocouple without compensating line
- ② Thermocouple with compensating line
- ③ Thermocouple with compensating line and supply line
- ④ Compensating line (same material as thermocouple)
- ⑤ External reference junction
- ⑥ Copper supply cable, for example

Figure 4-10 Example: Wiring thermocouples to an analog input module

Further information

Further information, such as the selection of thermocouples and how they operate, can be found in the section Thermocouples (Page 77).

Thermocouples

5.1 Selecting thermocouples

Introduction

Thermocouples are electrical devices for precise temperature measurement. They consist of two different metals connected at one point. Temperature affecting this point generates a voltage difference from which the temperature can be calculated.

Thermocouples can measure a wide range of temperatures and come in extremely robust models. They are therefore frequently used in industrial applications. Below are some of the criteria to consider when selecting the right thermocouple:

- Temperature range
- Atmospheric conditions
- Price

Grounded thermocouples

In grounded thermocouples, a conductive thermocouple wire is attached to the inside of the sensor housing. This results in good heat transfer from the sensor housing to the thermocouple measuring tip.

Non-grounded thermocouples

In non-grounded thermocouples, the thermocouple is not connected to the sensor housing. The response time following temperature changes is longer than with grounded thermocouples. The measuring point is galvanically isolated.

Type and temperature range

The different thermocouple types are derived from different material compositions.

Note

Due to physical conditions, thermocouples are extremely inaccurate outside the specified temperature range. Only use thermocouple in the temperature range specified by the manufacturer.

The following table lists the types and material compositions, as well as the temperature measuring range of different thermocouples:

Type	Material composition	Temperature range
B	PtRh-PtRh	250 to 1820 °C
C	W-Re	0 to 2315 °C
E	NiCr-CuNi	-270 to 1000 °C
J	Fe-CuNi	-210 to 1200 °C
K	NiCr-Ni	-270 to 1372 °C
L	Fe-CuNi	-200 to 900 °C
N	NiCrSi-NiSi	-270 to 1300 °C
R	PtRh-Pt (Pt 13%)	- 50 to 1769 °C
S	PtRh-Pt (Pt 10%)	-50 to 1769 °C
T	Cu-CuNi	-270 to 400 °C
U	Cu-CuNi	-200 to 600 °C
TXK/XKL	NiCr-CuCr	-200 to 800 °C

5.2 Structure and operating principle of thermocouples

Thermocouple structure

A thermocouple consists of a pair of thermal sensors and the respective installation and wiring elements. Two wires made of different metals/alloys are welded together at their ends (hot end). The welding point forms the so-called measuring point, while the free ends of the thermocouple form the reference junction.

The free ends are interconnected with the evaluation device (e.g. analog input module) via insulated wires or cables.

The different thermocouple types, e.g. K/J/N, are derived from different material composition; the same measuring principle is applied to all thermocouples, independent on their type.

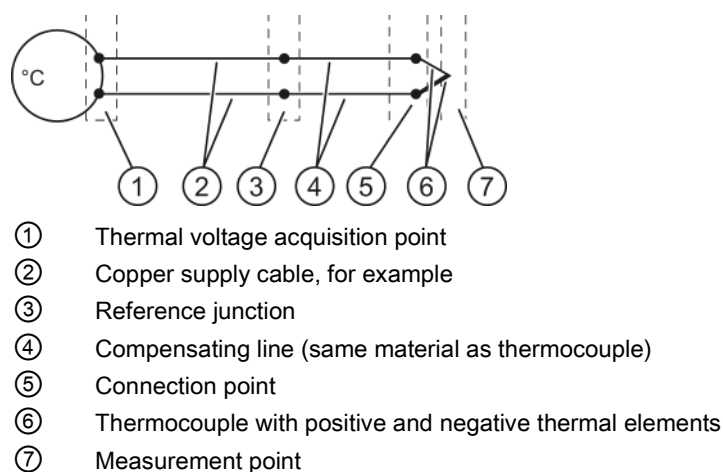


Figure 5-1 Thermocouple

Operating principle of thermocouples

Temperature differences between the measuring point and the free ends of the pair of thermal sensors (connection point) generate a thermal voltage at the reference junction. The value of the thermal voltage is determined by the temperature difference between the measuring point and the free ends, as well as by the material composition of the pair of thermal sensors.

Thermocouples always acquire a differential temperature, which means that the temperature at their free ends (reference junction) must be known to determine the temperature at the measuring point.

The thermocouple can be extended with compensating lines from the connection point. This allows the reference junction to be located at a specific point, for example, where the temperature can be kept constant or the temperature sensor is easy to install. The compensating lines and thermocouple wires are made of the same material. Copper cables are used to connect the reference junction to the module.

Note

Always observe the polarity, as incorrect wiring will result in unacceptable measuring errors.

5.3 Compensation for the reference junction temperature

5.3.1 Overview

Introduction

You have several options for measuring the reference junction temperature in order to obtain a correct temperature value as a function of the temperature difference between the reference junction and the measuring point.

You have various compensation options to suit requirements at the location of the reference junction.

The compensation options supported by the analog module used are specified in the manual of the respective module.

Options of compensating for the reference junction temperature

Table 5- 1 Compensation options: Explanation and use case

Compensation options	Explanation	Use case / special feature
Internal reference junction	<p>Function principle</p> <p>With this type of compensation, the temperature of the reference junction is measured using an integrated sensor in the analog module.</p> <p>Procedure</p> <p>Connect the thermocouple to the I/O module directly, or with compensating lines; see chapter Compensation with internal reference junction (Page 84).</p>	<ul style="list-style-type: none"> • For the connection, use compensating lines that match the thermocouple material. • If the reference junction temperature and the module temperature are identical in your system, you may also use lines made from a different material. • Advantages: <ul style="list-style-type: none"> – Inexpensive – No external reference junction required – No additional wiring required

5.3 Compensation for the reference junction temperature

Compensation options	Explanation	Use case / special feature
Reference channel of the module	<p>Properties With this type of compensation, the reference junction temperature is determined using an external thermal resistor (RTD).</p> <p>Procedure Connect the thermocouple to the supply lines directly at the reference junction, or indirectly using compensating lines. Wire the supply lines to the corresponding terminals of the module. Wire the thermal resistor (RTD) to the reference channel of the module. The thermal resistor (RTD) must be positioned in the area of the reference junction; see chapter Compensation with reference channel of the module (Page 86).</p>	<ul style="list-style-type: none"> • They acquire the temperature directly at the reference junction. • The measured temperatures of all channels that you have configured for this compensation type will be corrected automatically by the temperature value of the reference junction. • Advantages: <ul style="list-style-type: none"> – More precise compared to compensation with internal reference junction; however, you need to install and wire an additional thermal resistor.
Reference channel of group 0	<p>Properties With the "TC" (thermocouple...) setting, the channel acts as receiver for the reference junction temperature of group 0. The associated transmitter of group 0 is set up to for the RTD channel.</p> <p>Procedure Connect the thermocouple to the supply lines directly at the reference junction, or indirectly using compensating lines. Wire the supply lines to the corresponding terminals of the module. Wire the thermal resistor (RTD) to the configured reference channel for group 0 of the module. The thermal resistor (RTD) must be positioned in the area of the reference junction; see chapter Compensation, reference channel of Group 0 (Page 88).</p>	<ul style="list-style-type: none"> • They acquire the temperature directly at the reference junction. • The measured temperatures of all channels that you have configured for this compensation type will be corrected automatically by the temperature value of the reference junction (transmitter).
Fixed reference temperature	<p>Properties With this type of compensation, the reference junction temperature is stored in the module as fixed value.</p> <p>Procedure Connect the thermocouple to the supply lines directly at the reference junction, or indirectly using compensating lines. Wire the supply lines to the corresponding terminals of the module. Depending on the module, you can enter a fixed reference junction temperature in the configuration data (e.g. 20 °C), or use the fixed reference junction temperature of the module (0 °C); see chapter Compensation with fixed reference temperature (Page 91).</p>	<ul style="list-style-type: none"> • You keep the reference junction temperature constant and know the temperature value. • To ensure high precision, you must ensure that the temperature remains constant (this can be complicated, depending on the application).

5.3 Compensation for the reference junction temperature

Compensation options	Explanation	Use case / special feature
Dynamic reference temperature	<p>Properties With this type of compensation, the reference junction temperature is determined using a module. Transfer this temperature value to other modules in the user program by means of a data record.</p> <p>Procedure Wire the thermal resistor (RTD) for the reference junction to any channel. The reference junction temperature is transferred with a function block by means of data records from the CPU or IM to the module, see section Compensation by means of dynamic reference temperature (Page 94).</p>	<ul style="list-style-type: none"> You are using multiple modules at the reference junction and can therefore compensate for all channels using a common temperature value. You only need a thermal resistor (RTD) or a thermocouple to measure the temperature value.
No/external compensation	<p>Properties With this type of compensation, the reference junction temperature is measured outside the analog input module. You can, for example, connect a compensating box to the thermocouple for this purpose.</p> <p>Procedure Connect the compensating box with the connection module of the analog input module with copper cables, see section "None" or external compensation (Page 98).</p>	<ul style="list-style-type: none"> The temperature of the reference junction for this type of compensation is specified as 0 °C. This can be achieved by using a compensating box. A separate compensating box is required for each thermocouple. Thermocouples of type B do not require a compensating box.
RTD (0)	<p>Properties This compensation is based on a measurement of the resistance value of a Pt1000 at the clamping unit of a compensation connector or of an external resistance value Pt1000.</p> <p>Procedure Additional information about the connection options with and without compensation connector is available in the section Type of compensation RTD (0) (Page 100).</p>	<ul style="list-style-type: none"> The reference junction temperature is determined with resistance value of the Pt1000. All channels of the analog input module that you select for this type of compensation receive the same reference junction temperature.

5.3.2 Compensation with internal reference junction

Function principle

The reference junction for compensation via internal reference junction is at the terminals of the analog input module. Wire the thermocouples or compensating lines directly to the module inputs. The internal temperature sensor acquires the module temperature and returns a compensating voltage.

Note that compensation via internal reference junction will not always reach the precision of external compensation!

Procedure

Configuration steps:

1. Open the project in STEP 7.
2. In the device view, select the required analog module and the corresponding channel.
3. Select the "General" tab in the Inspector window of the selected module.
4. Select the "Inputs/Measuring" area.
5. Select the "Thermocouple" value as "Measurement type".
6. As "Reference junction", select the value "Internal reference junction".

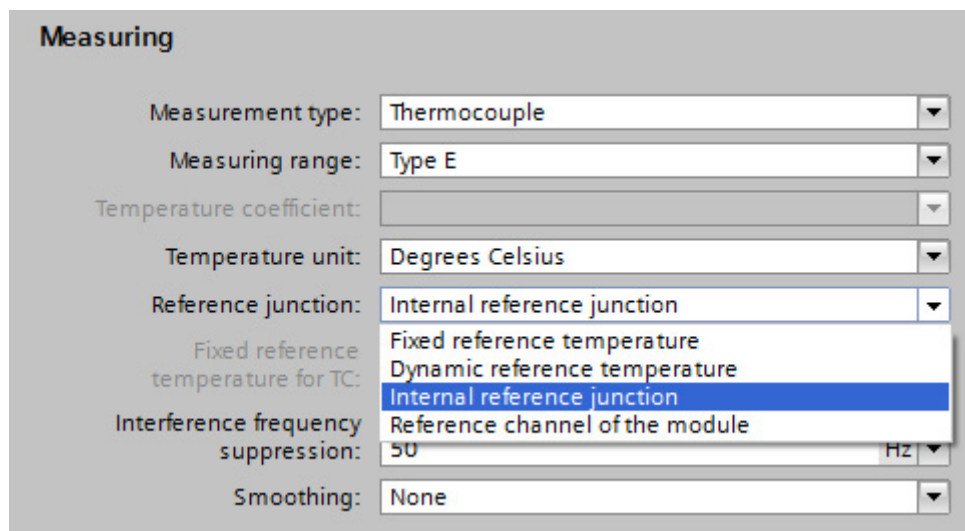


Figure 5-2 Internal reference junction

Wiring thermocouples

Wire the thermocouples directly or indirectly via compensating lines to the module inputs.

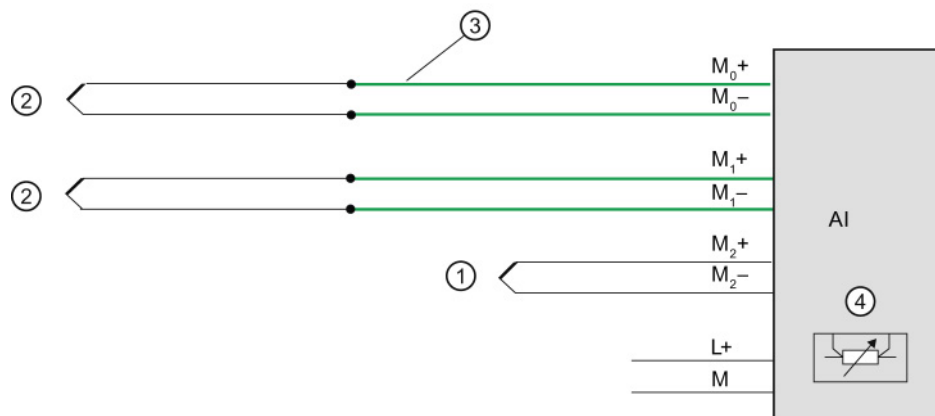


Figure 5-3 Example: Wiring thermocouples for compensation via internal reference junction

5.3.3 Compensation with reference channel of the module

Function principle

With this type of compensation, the reference junction temperature is determined using an external thermal resistor (RTD). Certain modules provide an internal reference channel.

Procedure

Configuration steps:

1. Open the project in STEP 7.
2. In the device view, select the required analog module and the corresponding channel.
3. Select the "General" tab in the Inspector window of the selected module.
4. Select the "Inputs/Measuring" area.
5. Select the "Thermocouple" value as "Measurement type".
6. As "Reference junction", select the value "Reference channel of the module".

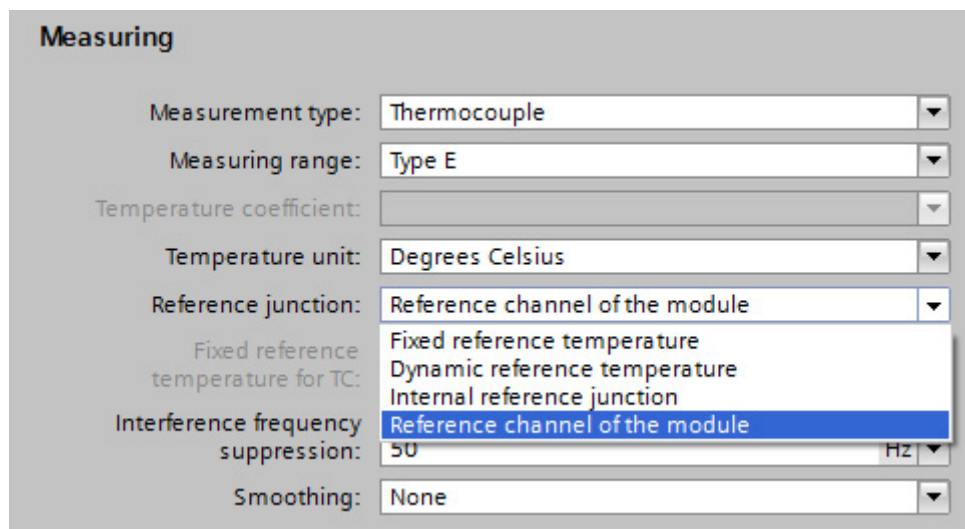
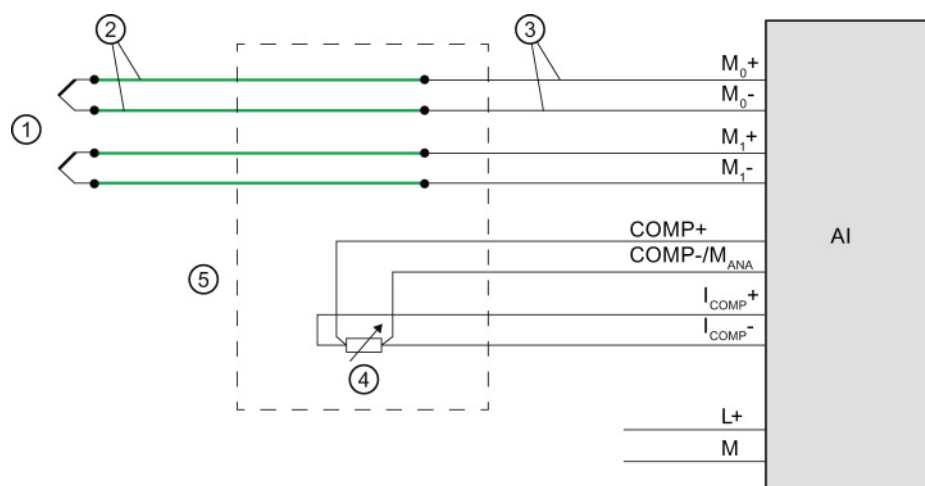


Figure 5-4 Reference channel of the module

Wiring thermocouples and thermal resistors

Connect the thermocouple to the supply lines directly at the reference junction, or indirectly using compensating lines. Wire the supply lines to the corresponding terminals of the module.

You may use cables made of any material to wire the thermal resistor to the module terminals.



- ① Thermocouple
- ② Compensating line (same material as thermocouple)
- ③ Copper supply cable, for example
- ④ Thermal resistor (RTD)
- ⑤ Reference junction

Figure 5-5 Example: Wiring thermocouples/thermal resistors for compensation by means of reference channel of the module

5.3.4 Compensation, reference channel of Group 0

Function principle

For this compensation, a module channel with a connected thermal resistor (RTD) acts as "Reference temperature transmitter". Other channels (reference temperature receivers) with connected thermocouples can be compensated using this reference temperature. The measured temperatures of all channels (receivers) that you have configured for this compensation type will be compensated automatically by the temperature value of the reference junction (transmitter).

The reference junction temperature is determined by means of an external thermal resistor (RTD).

Procedure

Configuration steps:

1. Open the project in STEP 7.
2. In the device view, select the required analog module and the corresponding channel.
3. Select the "General" tab in the Inspector window of the selected module.
4. Select the area "Inputs/measurement".
5. For the channel of the relevant module, specify as transmitter:

As "Measurement type" select, for example, "Thermal resistor (4-wire)".

As "Reference junction", select the value "Reference channel of group 0".

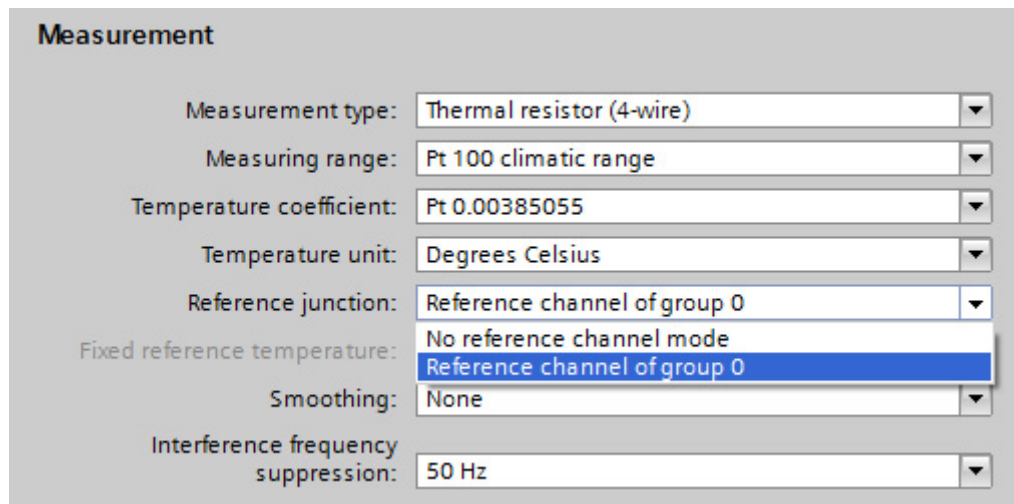


Figure 5-6 Transmitter: Reference channel of group 0

6. For the channels you specify as receivers:

Select the "Thermocouple" value as "Measurement type".

As "Reference junction", select the value "Reference channel of group 0".

The screenshot shows a configuration window titled "Measurement" with the following settings:

- Measurement type: Thermocouple
- Measuring range: Type E
- Temperature coefficient: (empty)
- Temperature unit: Degrees Celsius
- Reference junction: Reference channel of group 0
- Fixed reference temperature: Reference channel of the module, Internal reference junction, Reference channel of group 0 (highlighted), Fixed reference temperature
- Smoothing: Reference channel of group 0 (highlighted), Fixed reference temperature
- Interference frequency suppression: 50 Hz

Figure 5-7 Receivers: Reference channel of group 0

Connecting thermocouples and thermal resistors

The example below shows:

- An analog module with thermal resistor as reference temperature transmitter and
- Two analog modules with thermocouple as reference temperature receivers.

Connect the thermocouples to the supply lines at the reference junction, either directly or with compensating lines. Wire the supply lines to the corresponding terminals of the module.

You may use cables made of any material to wire the thermal resistor to the module terminals.

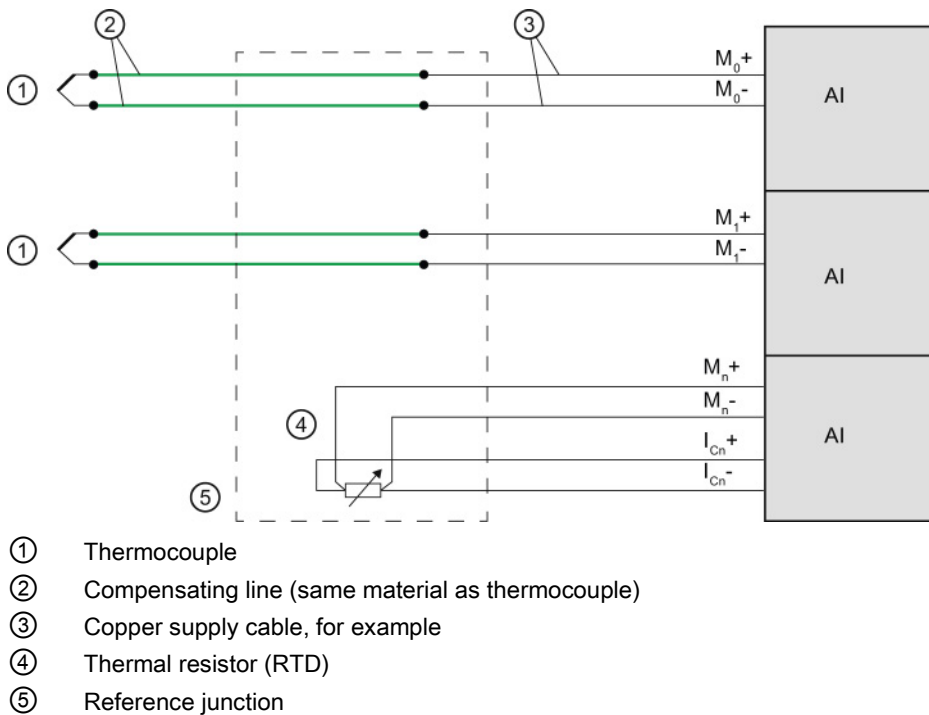


Figure 5-8 Example: Connecting thermocouples/thermal resistors for group 0 compensation

5.3.5 Compensation with fixed reference temperature

Function principle

With this type of compensation, the reference junction temperature is stored in the module as fixed value.

Procedure

Configuration steps:

1. Open the project in STEP 7.
2. Select the required analog module in the Device view.
3. Select the "General" tab in the Inspector window of the selected module.
4. Select the "Inputs/Measuring" area.
5. Select the "Thermocouple" value as "Measurement type".
6. As "Reference junction", select the value "Fixed reference temperature".
7. Specify the temperature of the reference junction in the "Fixed reference temperature" area, for example, 20 °C.

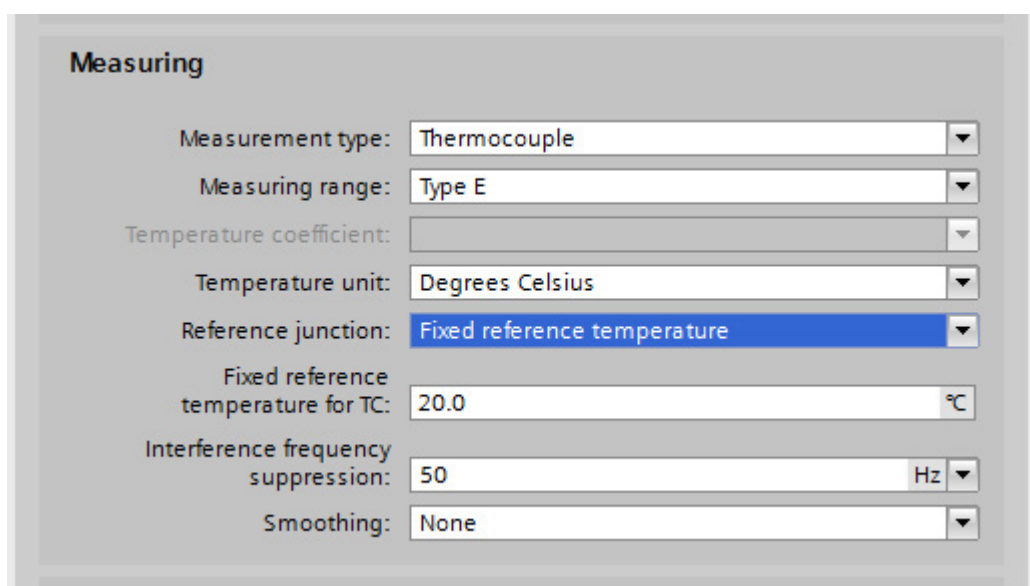
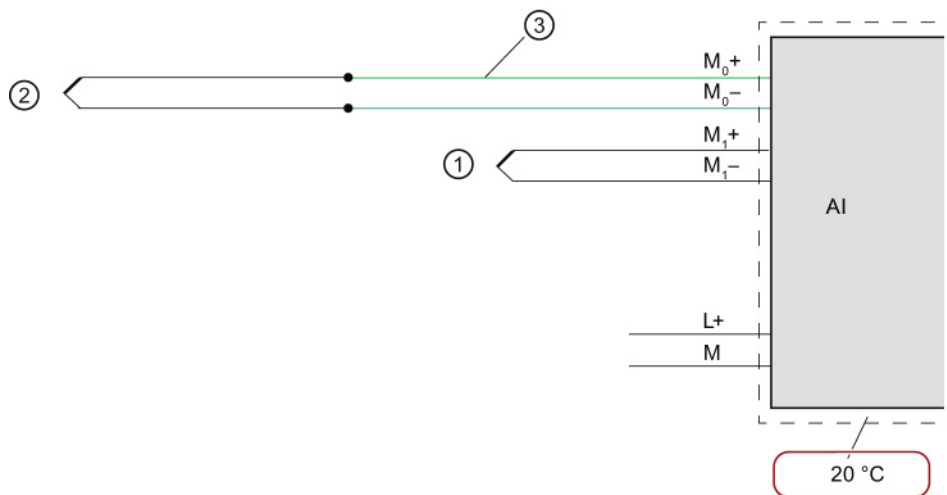


Figure 5-9 Fixed reference temperature

Temperature condition with "Fixed reference temperature" setting

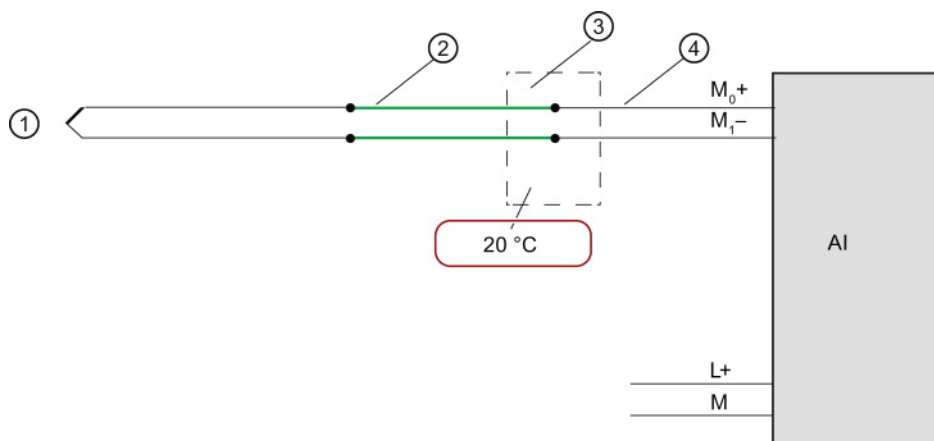
The figure below shows the connection options for thermocouples provided the temperature of the module is kept at a fixed reference temperature (20 °C), for example by installing it in an air-conditioned switch cabinet. The reference junction is in the module.



- ① Thermocouple without compensating line
- ② Thermocouple via compensating line
- ③ Compensating line (same material as thermocouple)

Figure 5-10 Example 1: Connecting a thermocouple to an analog module for compensation with "fixed reference temperature"

The figure below shows the connection options for thermocouples provided the temperature of the reference junction (outside the module) is kept at a fixed reference temperature (20 °C).



- ① Thermocouple with compensating line and supply line
- ② Compensating line (same material as thermocouple)
- ③ Reference junction
- ④ Copper supply cable, for example

Figure 5-11 Example 2: Connecting a thermocouple to an analog module for compensation with "fixed reference temperature"

5.3.6 Compensation by means of dynamic reference temperature

Function principle

This compensation type allows you to handle the reference junction temperature for temperature compensation in the user program. You can derive the temperature value from any other module of the station. The reference junction temperature is transferred via data records using the instruction **WRREC** (SFB 53).

The structure of the data records is detailed in the device manual for each module.

Requirement

STEP 7 project with the following contents:

- User program with WRREC (SFB 53) instruction for transferring the data records with reference temperature
- Analog module for acquisition of the process temperature using thermocouple (TC)
- Analog module for measuring the process temperature using thermal resistor (RTD)

Analog module for acquisition of the process temperature using thermocouple (TC)

Configuration steps:

1. Open the project in STEP 7.
2. In the device view, select the required analog module and the corresponding channel.
3. Select the "General" tab in the Inspector window of the selected module.
4. Select the "Inputs/Measuring" area.
5. Select the "Thermocouple" value as "Measurement type".
6. As "Reference junction", select the value "Dynamic reference temperature".

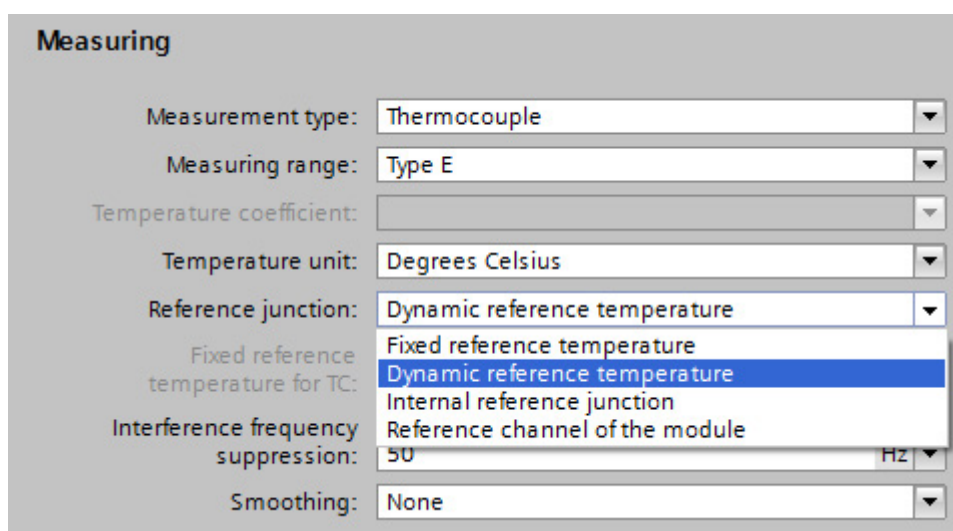


Figure 5-12 Dynamic reference temperature

Analog module for measuring the process temperature using thermal resistor (RTD)

Configuration steps:

1. Open the project in STEP 7.
2. In the device view, select the required analog module and the corresponding channel.
3. Select the "General" tab in the Inspector window of the selected module.
4. Select the "Inputs/Measuring" area.
5. Select the "Thermal resistor (4-wire connection)" value as "Measurement type".

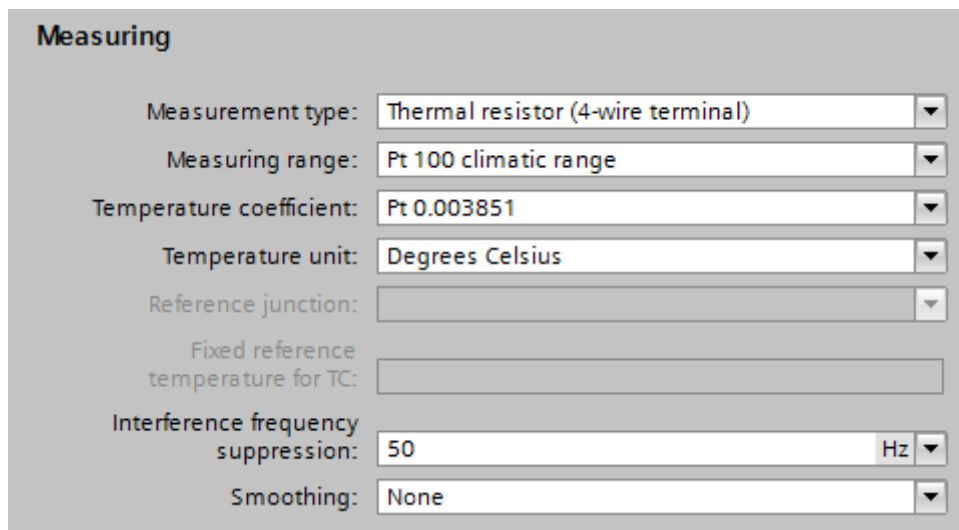
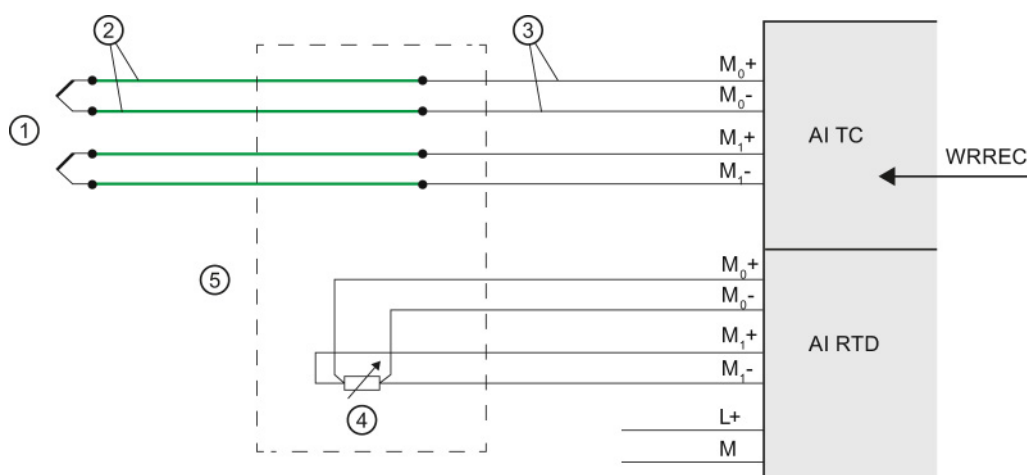


Figure 5-13 Settings for thermal resistor (RTD) type of measurement

Connecting thermocouples and thermal resistors

Connect the thermocouples, for example, to the module inputs using supply lines for temperature compensation with dynamic reference temperature. In this case, the temperature is acquired at the reference junction by means of a thermal resistor (RTD). This reference junction temperature determined in this way is transferred to the analog module with thermocouple via data records with the WRREC instruction.



- ① Thermocouple
- ② Compensating line (same material as thermocouple)
- ③ Copper supply cable, for example
- ④ Thermal resistor (RTD)
- ⑤ Reference junction

Figure 5-14 Example: Connecting thermocouples/thermal resistors for compensation by means of dynamic reference temperature

5.3.7 "None" or external compensation

Function principle

The reference junction temperature of the thermocouples is measured outside the analog input module, e.g., by means of a compensating box on the thermocouple. The temperature of the reference junction for this type of compensation is specified as 0° C.

The compensating box includes a bridge circuit that is calibrated for a specific reference junction temperature (compensation temperature). The connectors for the ends of the compensating line of the thermocouple form the reference junction. If the actual comparison temperature deviates from the compensation temperature, the temperature-dependent bridge resistor changes. A positive or negative compensation voltage is generated and added to the thermal voltage.

Note

Thermocouples of type B do not require a compensating box.

Procedure

Configuration steps:

1. Open the project in STEP 7.
2. Select the required analog module in the Device view.
3. Select the "Inputs" tab in the Inspector window of the selected module and the respective channel.
4. Select the "Thermocouple" value as "Measurement type" in the "Measuring" area.
5. As "Reference junction", select the value "None" or "External compensation" depending on the used module.

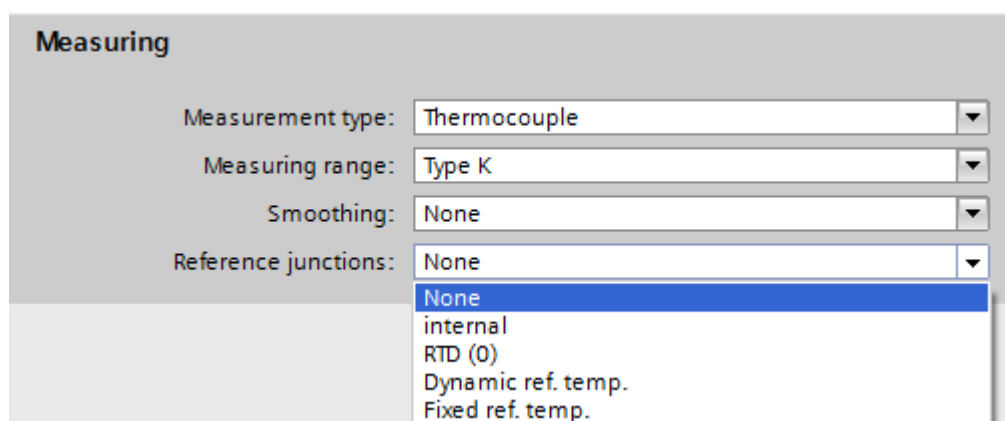


Figure 5-15 No reference junction

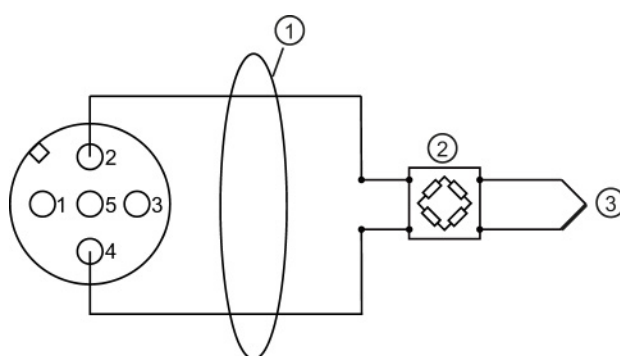
Connection of the compensating box

The compensating box is looped into the supply lines of an individual thermocouple. The compensating box must be supplied isolated. The power supply unit must have a sufficient noise filter, e.g., by means of a grounded shielding winding.

Each channel can use its own thermocouple type supported by the analog module regardless of the other channels. A separate compensating box is required for each channel.

Connection example "None" or external compensation

Connect the compensating box with the connection module of the analog input module using copper cables.



- ① Copper cables
- ② Compensating box (per channel), for example; thermocouple type B does not require a compensating box
- ③ Thermocouple

Figure 5-16 Connection example "No" compensation as reference junction

5.3.8 Compensation type RTD (0)

Function principle

The reference junction temperature is determined by means of the resistance value of a Pt 1000 at the clamping unit of the M12 compensation connector. The resistance measurement is only permitted at the X1 circular socket (channel 0). All of the module's channels with this type of compensation receive the same reference junction temperature.

Procedure

Configuration steps:

1. Open the project in STEP 7.
2. Select the required analog module in the Device view.
3. Select the "Inputs" tab in the Inspector window of the selected module.
4. Select the "Thermocouple" value as "Measurement type" in the "Measuring" area.
5. As "Reference junction", select the value "RTD (0)".

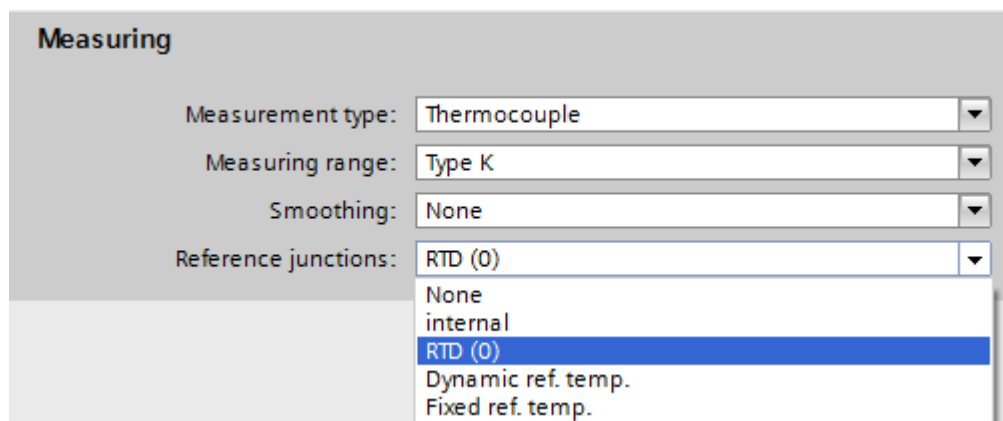


Figure 5-17 Compensation type RTD (0)

Connection example

Connection with M12 compensation connector

Connect the thermocouple to the M12 compensation connector directly or with compensating lines. Install the M12 compensation connector to the X1 circular socket (channel 0) of the CM IO 4 x M12 at the 4 AI TC High Feature.

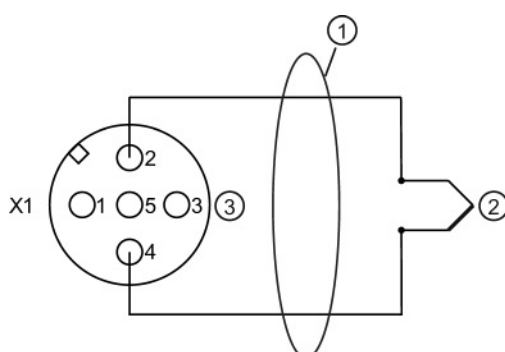
Connection without M12 compensation connector

To measure the referent junction temperature, connect an external Pt1000 (with $\alpha = 003851$) to terminals 1 and 3 using copper cables. The thermal resistor Pt1000 must be positioned in the area of the reference junction. Connect the thermocouples to terminals 2 and 4 from the reference junction with copper cables.

Connecting additional thermocouples

You can connect additional thermocouples to the circular sockets X2 to X4 on the CM IO 4 x M12 of the 4 AI TC High Feature. The temperature of reference junction collected by measuring the resistance value at the X1 circular socket applies to all channels of the module that you have selected for this type of compensation.

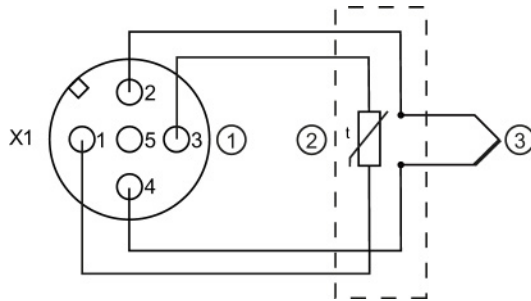
The figure below shows a connection example "RTD (0)" as reference junction with M12 compensation connector and integrated thermal resistor Pt1000:



- ① Direct connection of the thermocouple or with compensating lines
- ② Thermocouple
- ③ M12 compensation connector (terminals 1 and 3 with internal Pt1000) only at X1 circular socket. The comparison value of the M12 compensation connector at circular socket X1 also applies to thermocouples at X2, X3 and X4.

Figure 5-18 Connection example "RTD (0)" as reference junction in the M12 compensation connector

The figure below shows a connection example "RTD (0)" as reference junction with external thermal resistor Pt1000:



- ① M12 connector only at X1 circular socket
- ② External Pt1000 ($\alpha = 0.003851$) in the area of the reference junction with copper cables at terminals 1 and 3. The comparison value of the external Pt1000 at circular socket X1 also applies to thermocouples at X2, X3 and X4.
- ③ Thermocouple

Figure 5-19 Connection example "RTD (0)" as reference junction with external Pt1000

Wiring loads/actuators

6.1 Overview

Introduction

This chapter describes the basic procedure for wiring loads/actuators to analog outputs. Information on specific wiring options is available in the manual of each module.

For detailed information on cable routing and shielding, potential equalization, etc. please refer to the function manual *Configuring interference-free controllers* (<http://support.automation.siemens.com/WW/view/en/59193566>).

Abbreviations used in the figures

Key to the abbreviations in the figures below:

AQ	Analog output module
M	Ground connection
L+	Supply voltage connection
S _n +/S _n -	Sense line channel n
QV _n +/QV _n -	Voltage output channel n
QI _n +/QI _n -	Current output channel n
M _{ANA}	Reference point of the analog ground
U _{ISO}	Insulation voltage

Lines for analog signals

Always use shielded twisted-pair cables to wire the analog signals. This improves immunity.

6.2 Wiring loads/actuators

Reference potential for analog output modules with M_{ANA} connection

Analog output modules have no galvanic connection between the reference point of the analog ground M_{ANA} and the central ground.

Always verify that the admissible potential difference U_{ISO} between the reference point of the analog ground M_{ANA} and the central ground is not exceeded.

Potential difference U_{ISO} may be caused by: Maximum line lengths exceeded.

If you want to ensure the maximum value U_{ISO} is not exceeded, wire terminal M_{ANA} and the central ground with an equipotential bonding cable.

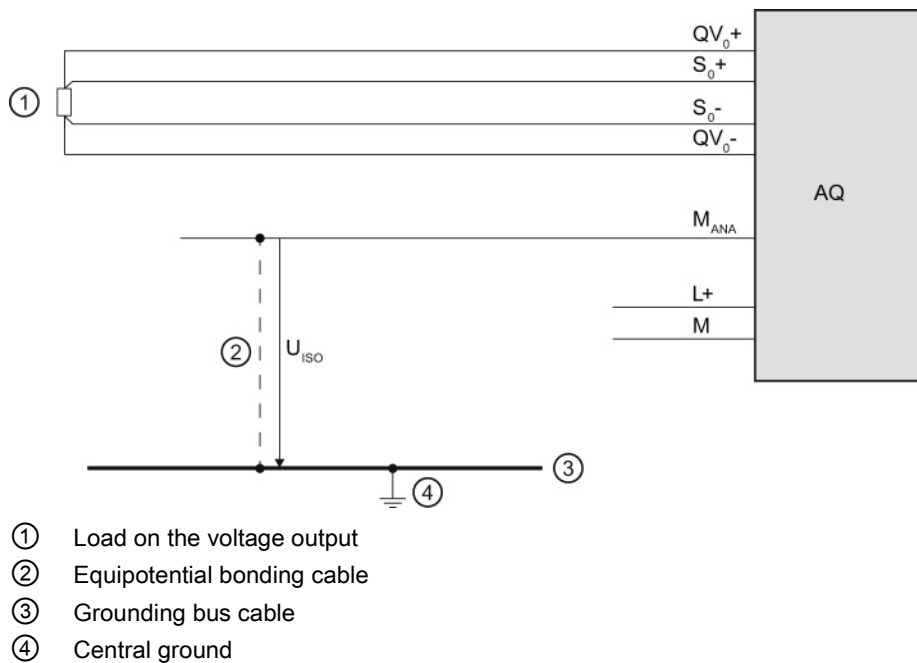


Figure 6-1 Example: Reference potential for an analog output module with M_{ANA} connection

Reference potential for analog output modules without M_{ANA} connection

Analog output modules have no galvanic connection between the reference potential of the analog output circuits and central ground.

Always verify that the maximum potential difference U_{ISO} between the reference points of the analog output circuits and the central ground is not exceeded.

Potential difference U_{ISO} may be caused by: Maximum line lengths exceeded.

If you want to ensure the maximum value U_{ISO} is not exceeded, interconnect each analog output circuit with the central ground using an equipotential bonding cable.

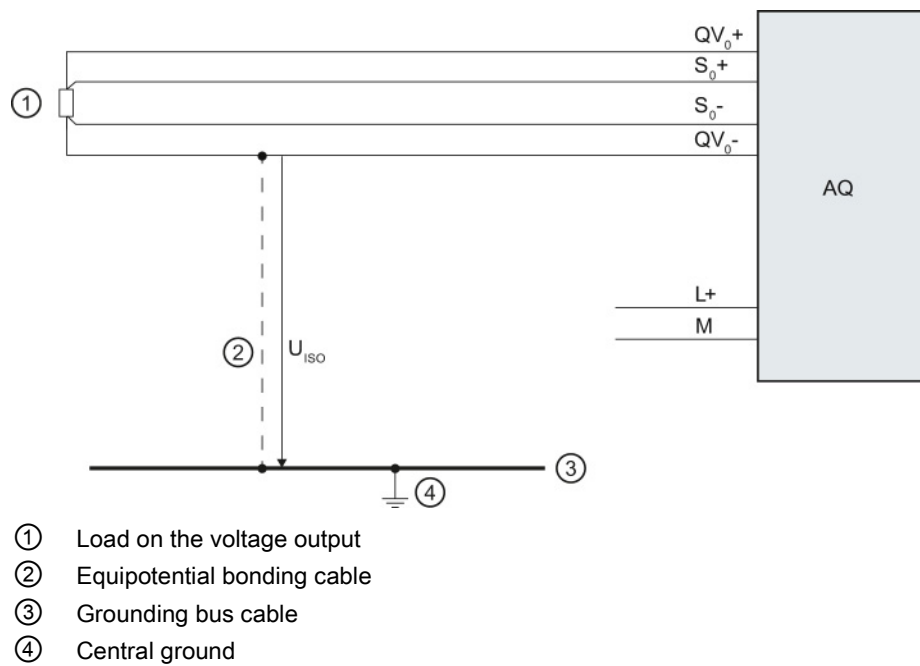


Figure 6-2 Example: Reference potential for an analog output module without M_{ANA} connection

Supported functions

7.1 Calibrating analog modules

7.1.1 Overview

Calibration

A calibration checks the process values measured by the analog input module and the process values output by the analog output module, determines the deviation from the actual values and compensates for any measurement and output errors.

Calibrating analog modules

The SIMATIC analog modules were calibrated before being shipped and have excellent long-term stability; calibration is therefore not required during runtime.

But certain regulations and directives, for example from the Food and Drug Administration (FDA), require regular calibration for all components in a measuring circuit. These components include analog input and output modules.

A calibration makes sense especially for plants in which sensors detect and process relatively small voltages or currents. The calibration compensates for influences on the measuring result by cables and/or temperature.

The calibration collects the new values and saves them retentively on the module. But the calibration values determined prior to delivery at the plant are not lost. You can return to these original calibration values at any time.

Note

The calibration saves the calibration values of each channel for the specific measuring range retentively on the module, which means the values apply to the same measuring range in which the user calibration took place.

If you reconfigure a channel with effective user calibration values to another type of measuring mode, the calibration values saved at the plant for this channel and for this measuring range will become effective.

But the user calibration values are not deleted. They are not overwritten until there is a new user calibration of the channel. If you set the original measuring range for this channel once again without new user calibration, the previously determined user calibration values will become effective.

The respective manual will include information whether or not your analog module supports the "Calibration" functionality.

Scope of functions

The "Calibration" group offers the following functions:

- Specifying the current calibration of all channels
- Calibrating a channel
- Canceling a running calibration
- Resetting the calibration of a channel to the factory settings

7.1.2 Calibrating analog modules

Manual calibration

The following requirements must be met to start manual calibration:

- An online connection exists between STEP 7, the respective CPU and the analog module to be calibrated.
- You have opened the "Online & Diagnostics" view for the selected analog module from the shortcut menu of the project and you are now in the "Functions > Calibration" area.
- The configuration reflects the actual structure of the station.
- No calibration process is busy on the module (if you want to launch calibration).
- A 24 V load voltage must be present at each module for the calibration.
- The last step was successfully completed (if you want to continue or conclude calibration).

Procedure

The basic mask for calibration opens once you start the "Calibration" function. The module reads the following general information data and calibration values after each new selection of a channel:

- **Calibration:** Indicates whether or not the currently effective calibration values are factory calibration values or user calibration values.
- **Measurement type:** Information about the selected measurement type
- **Measuring range:** Currently configured measuring range of the selected channel
- **Gain:** Currently effective gain correction of the analog-digital converter
- **Offset:** Currently effective offset correction of the analog-digital converter

Overview

Channel..	Calibration	Measuring typ	Measuring r..	Gain:	Offset:	Date	
0	Factory	Voltage	+/- 10 V	1	0	12/1...	▲
1	Factory	Voltage	+/- 10 V	1.001	0	12/1...	☰
2	Factory	Voltage	+/- 10 V	1	0	12/1...	
3	Factory	Voltage	+/- 10 V	1.001	0	12/1...	
4	Factory	Voltage	+/- 10 V	1.001	0	12/1...	
5	Factory	Voltage	+/- 10 V	1	0	12/1...	
6	Factory	Voltage	+/- 10 V	1.001	0	12/1...	
7	Factory	Voltage	+/- 10 V	1	0	12/1...	▼

Start manual calibration Set to factory settings

Figure 7-1 Calibration table

To start the calibration, follow these steps:

1. Select the line associated with the channel to be calibrated in the overview table.
2. Click the "Start manual calibration" button.
3. Now go through the steps in the "Manual calibration" section.
4. Follow the instructions in the "Command" field.
5. Click ""Next".

The required calibration values of the selected channel according to the measuring range configured for this channel are specified once again during the user calibration.

Note

The calibration can take place in RUN mode as well as STOP mode of the CPU. If the CPU is in RUN, the calibration value that was last collected prior to the start of the calibration is supplied for the duration of the calibration.

The module channel to be calibrated cannot process any new process values during the user calibration. All analog input values of the module are set to 0x7FFF ("Invalid analog value") until the end of the calibration. When the value status is enabled, the value status of the signal is set to "invalid" for the duration of the calibration.

You must provide a voltage and/or temperature during a user calibration. To do so, use the corresponding external wiring and an external voltage/temperature transducer. The field "Command" includes numbers of pins to which you can connect the calibration stimulus. The first pin number identifies the positive connector, the second pin number the negative connector. The accuracy of the calibration depends on the accuracy of the provided voltage/temperature.

Note

To ensure that the module retains the specified measuring accuracy after the user calibration, the provided voltage/temperature must be twice as accurate as specified for the module. Inaccurate voltages or temperature result in a faulty calibration.

The figure below shows an example of channel calibration with "Voltage" measurement, measuring range "+/- 10 V".

Manual calibration

Step 1 of 2

Command: Please apply a voltage of 10000 mV to terminal 3.
Please apply the ground to terminal 4.

Status: Calibration started without errors.

Measured value: 10000

Next Cancel

Figure 7-2 Manual calibration

7.1 Calibrating analog modules

- **Command:** The field "Command" indicates which actions the user has to execute during the current calibration step. Here you execute the specified actions and confirm them with the "Next" button. The module now executes all actions required for the current calibration step. If the calibration step was error-free, the next calibration step takes place.
The instructions in the "Command" field are to be performed additively. For example, after you have applied the voltage/ground to the terminals 3/4, these connections must remain in place during the execution of the next calibration step.
- **Status:** Depending on the set type of measurement, several calibration steps are required for calibration of a channel. The field "Status" indicates whether or not the last calibration step included errors. If an error occurs during processing of a calibration step, the error is displayed here and calibration of the channel is aborted. All calibration values recorded up to this point are deleted. The calibration values that were in effect prior to the start of the user calibration are effective once again.

Note

Calibrators

If the "Wire break" diagnostics is activated for analog input modules, a test current is applied to the line for the measuring types "Resistance", "Thermistor" and "Thermocouple". This applied test current can result in inaccurate measured values in some calibrators. The wire break monitoring is therefore automatically disabled in some analog modules during the calibration.

To avoid the risk of inaccurate measured values, we recommend you disable the "Wire break" diagnostics during the calibration of analog input modules.

Result

Calibration sets new settings for the channel.

Error occurrence

If an error occurs during the calibration, the module cancels the calibration. All calibration values recorded up to this point are lost. The channel to be calibrated will then have the same settings as before the start of calibration.

7.1.3 Canceling a calibration

Requirement

- You have opened the "Online & Diagnostics" view for the selected analog module from the shortcut menu of the project and you are now in the "Functions > Calibration" area.
- The associated CPU is online.
- A calibration is currently running on the analog module.

Procedure

Click the "Cancel" button to cancel an ongoing calibration.

Result

The active calibration is canceled. The channel to be calibrated will then have the same settings as before the start of calibration.

7.1.4 Resetting analog modules to factory settings

Requirement

- You have opened the "Online & Diagnostics" view for the selected analog module from the shortcut menu of the project and you are now in the "Functions > Calibration" area.
- The associated CPU is online.

Procedure

Proceed as follows to reset the channel of an analog module to factory settings:

1. In the overview table, select the line of the channel to be calibrated.
2. Click the "Set to factory settings" button.

Result

The factory settings of the channel are restored.

Note

When you reset the current channel to the factory settings, the original calibration values that were saved in the delivery state of the module become effective once again. Any existing user calibration values of this channel are lost. You cannot restore these user calibration values.

High-speed analog modules

8.1 Basics

High-Speed analog modules (HS) are available for users with high demands regarding performance and speed. The main characteristics of these HS analog modules compared to Standard analog modules (ST) is their shorter cycle times. To achieve this goal, the input and output modules are equipped with components with extremely short throughput and conversion times. In addition, the entire architecture of the modules is designed for faster signal processing.

HS analog modules convert the output of measured values and output values at the same time. Each channel within the module has its own A/D or D/A converter. This means the cycle time is basically the conversion time and independent of the number of activated channels. This is true for analog input modules as well as analog output modules. This means HS modules can be used in fast isochronous mode.

Apart from isochronous mode, the HS analog modules also provide benefits in non-isochronous (free-running) mode. Due to the fast processing of the process signals, HS analog modules are able to detect changes in the process values more quickly and to respond to these events with the appropriate program blocks (for example, hardware interrupt or cyclic interrupt organization blocks). Additional information on the various organizational blocks can be found in the STEP 7 online help.

Isochronous mode

Isochronous mode refers to synchronous coupling:

- Of signal acquisition and output via the distributed I/O
- Of signal transmission via PROFIBUS or PROFINET
- Of program processing with the constant bus cycle time of PROFIBUS or PROFINET.

The result is a system that acquires its input signals in constant time intervals, processes them and outputs the output signals. Isochronous mode guarantees reproducible and defined process reaction times as well as equidistant and synchronous signal processing with distributed I/O.

The bus system and the I/O modules work synchronously with configured isochronous mode. The transmitted input and output data are linked to an "isochronous task" in the CPU. As a result, the data of a cycle are always consistent. All data of a process image belong together logically and in time. Jitter in the user program caused by the acquisition of outdated values is therefore almost impossible.

Even fast processes can be perfectly controlled by the exact timing reproducibility of all processes. Isochronous mode thus contributes to high control quality and hence to greater manufacturing precision. While possible fluctuations of the process reaction times are drastically reduced. The time-assured processing can be utilized to improve machine cycle times. Shorter cycle times increase the processing speed and help to lower production costs.

Send clocks

When you configure isochronous mode, the input and output data is synchronized within a send clock (cycle). The data of the input modules is acquired in cycle n and simultaneously transferred to the IM. The data is available in cycle n+1 in the CPU and can be processed. The CPU copies the data to the IM in the next cycle n+2. The output modules then output the data simultaneously in the same send clock. The acquisition – processing – output therefore takes place in three cycles. You can find more information on the configuration of isochronous mode in the STEP 7 online help.

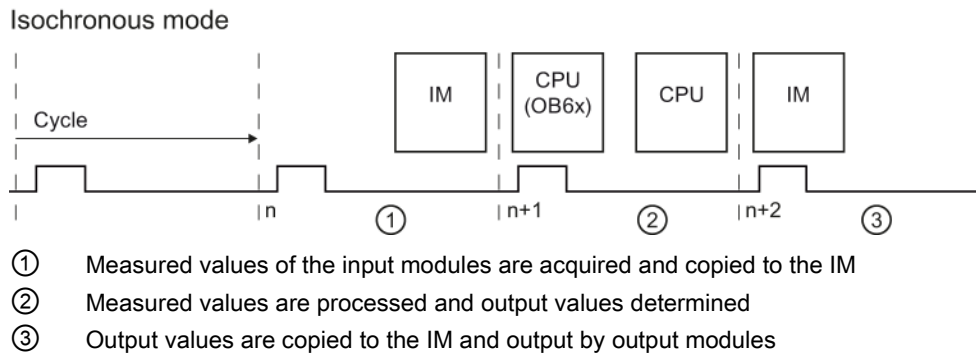


Figure 8-1 3-cycle model

Oversampling

The use of the oversampling function in analog input or analog output modules requires an isochronous configuration.

With analog input modules, the set send clock is divided into time-equidistant sub-cycles. The send clocks can be subdivided into 2 to 16 sub-cycles. Each sub-cycle reads in a measured value. The read-in measured values of a data cycle are copied to the IM in the next send clock and are then available to the processing CPU one send clock later.

With analog output modules, the set send clock is also divided into time-equidistant sub-cycles. The send clocks can be subdivided into 2 to 16 sub-cycles. Each sub-cycle returns an output value. The output values are copied to the IM by the CPU within the same send clock and are written to the process one send clock later.

The read-in and output values are transmitted in the user data of the analog module. This way, the address space of the module is extended from 2 bytes of user data per channel to 16 x 2 bytes of user data per channel. If you subdivide the send clock into less than 16 sub-cycles, the unused addresses are assigned the error value 0x7FFF during input. For output, the values of the unused addresses are ignored.

Because the sub-cycles have to be within a send clock, oversampling needs an additional send clock to copy the data to the IM, unlike the 3-cycle model of isochronous mode. The result is a 5-cycle model.

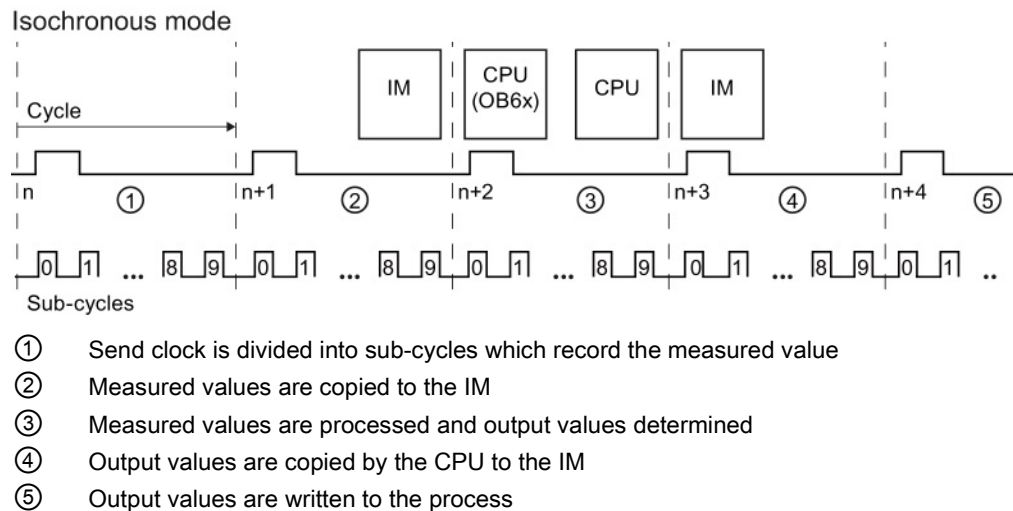


Figure 8-2 5-cycle model

Due to the configured modules, the send clock of an IO device has a minimum possible update time, which means the time interval within which an IO device/IO controller of the PROFINET IO system is supplied with new data. Modules with oversampling functionality, however, offer the option of further reducing the update time for their channels without having to shorten the send clock for the entire S7 station at the same time. The subdivision of the send clock into time-equidistant sub-cycles therefore enables an even faster signal processing speed.

Example

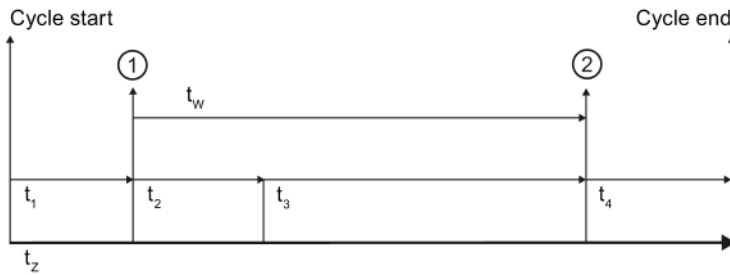
In practice, the use of oversampling makes sense when the isochronous system works with only one specific send clock (for example, 1 ms) due to the modules used and when faster sampling of the process values is required. By using oversampling and a subdivision of the send clock into 4 sub-cycles, for example, you can sample the process values in intervals of 250 μ s.

Configuring oversampling

Enable the option "Isochronous mode" in the IO device used and set the corresponding parameters ("Send clock", etc.). You define the number of sub-cycles in the relevant distributed analog module with the "Sampling rate" parameter for analog input modules and the "Output rate" parameter for analog output modules. If, for example, you configure a "Sampling rate" of 4 "Values/cycle" for a "Send clock" of 1 ms, the send clock is subdivided into 4 sub-cycles and the process values are sampled in intervals of 250 μ s.

Cycle time of an analog input module

If you have configured the system property "Isochronous mode" for HS modules, all analog input modules are synchronized to a shared time within the send clock (cycle) ①. The cycle time is made up of the following time intervals: $t_z = t_1 + t_2 + t_3 + t_4$

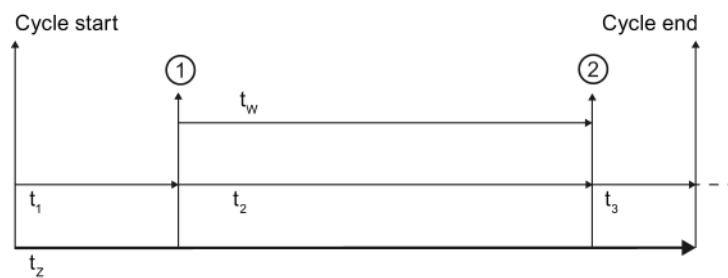


- ① Synchronization time for all analog input modules in isochronous mode and simultaneously time of the converted input signal at the terminal in this cycle
- ② Digitalized input signal is transferred to the backplane bus
- t_z Cycle time
- t_1 Time between cycle start and synchronization
- t_2 Hardware-related runtime up to the analog-digital converter
- t_3 Processing time of digitalized input data in the module
- t_4 Transfer time of the backplane bus
- t_w Conversion time of the module

Figure 8-3 Cycle time of the analog input module

Cycle time of an analog output module

The synchronization time for analog output modules refers to the output of the digital-analog converter ②. Because the impedance of the connected actuator including connection cable is unknown in output modules but has a significant impact on the signal run time, the settling time cannot be added as a fixed value. The respective manuals of the output modules specify the typical load settling times as reference point. But in practice, a measurement with an oscilloscope is required for a precise measurement of the settling time. The settling time may exceed the actual end of the cycle due to very short cycle times and very high capacitive loads. The cycle time is made up of the following time intervals: $t_z = t_1 + t_2 + t_3$



- ① Output data is available in digital form in the module
- ② Synchronization time for all analog output modules in isochronous mode and simultaneously output time of data in the digital-analog converter

t_z Cycle time

t_1 Transfer time of the backplane bus

t_2 Processing time of data in the module until output at digital-analog converter

t_3 Settling time of hardware until setpoint of output value

t_w Conversion time of the module

Figure 8-4 Cycle time of the analog output module

Typical applications

In principle, isochronous mode is worthwhile whenever measured values must be acquired synchronously, movements must be coordinated, and process reactions must be defined and executed at the same time. There are thus numerous areas in which isochronous mode can be used.

Typical applications include, for example, the acquisition of binary signals for quality assurance at specific times and positions. But hydraulic applications with position and pressure control can benefit as well from the equidistant and isochronous data transmission.

The following example shows the use of isochronous mode within the production process of camshafts. Precise measurements must be made at several measuring points for quality assurance.

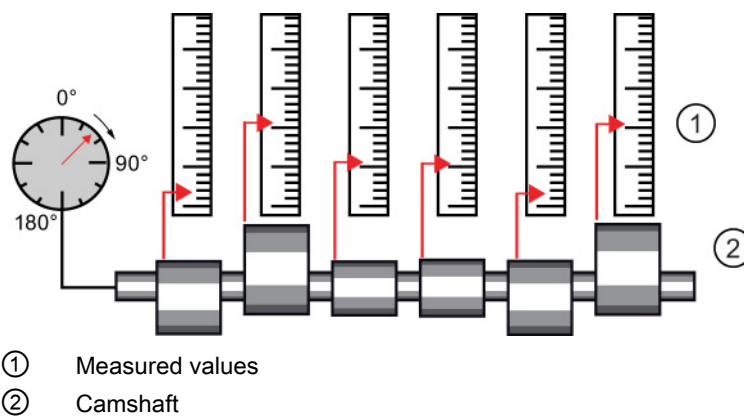


Figure 8-5 Measuring of camshafts

By using the system property "isochronous mode" and the associated simultaneous measured value acquisition, measurement can be performed continuously. The time required for measurement is reduced. Resultant workflow:

- Continuous machining of the camshaft
- During the continuous turning, measure the positions and cam excursion synchronously
- Process the next cam shaft

All camshaft positions and the corresponding measured values are measured synchronously within a single rotation of the camshaft. This increases machine output and maintains or enhances precision of the measurement.

8.2 ST modules vs HS modules

This section gives you an overview of other important distinctions between standard and high-speed analog modules. The specified numerical values are examples of selected modules. Keep in mind that the information can vary from module to module. The exact information of specific used analog module is available in the corresponding manual.

Conversion method

Instantaneous value conversion

Instantaneous value conversion is often used to convert analog signal into digital information in HS modules. In this type of conversion a very short sample is taken from the measured signal and converted into digital data. This digital information therefore represents an instantaneous value of the measured signal. Instantaneous value conversion is used to acquire fast changes of process values, such as in the area of motion control. The quickly changing physical quantities in this case must be acquired and processed quickly in cooperation with suitable transducers. Input areas are primarily voltage, current and resistance, the latter especially for position potentiometers.

Because the measured signal is converted within a short time, there is a risk of incorrect measurements in case of faulty signals. The analog inputs working with the instantaneous value conversion method cannot detect if the sampled signal value is the target signal or an overlaying disturbing pulse. They always convert the "instantaneously" detected value. This means the pending measurement task should be carefully examined with regard to time constraints.

Integrating conversion

ST modules usually work according to the integrating conversion principle. The integrating conversion involves the sampling of a measured signal across a specified time period (integration time). Although this method is slower than instantaneous value conversion, it returns a conversion with higher immunity to interference. When you select the time interval for the conversion so that it corresponds to one or several periods of the surrounding network frequency, the omnipresent interference that is possibly also overlaying the signal is basically suppressed. SIMATIC modules give you the option to set the network frequency at which the plant is operated by means of parameter assignment. The resolution and conversion times may change depending on the interference frequency suppression that is set. The technical specifications of the respective module define these dependencies.

Analog inputs with integrating methods can be used universally. Even though the cabling must also be carefully designed with these analog inputs, the requirements are much less than those for analog inputs with instantaneous value conversion due to their slower signal acquisition that is basically immune to interference.

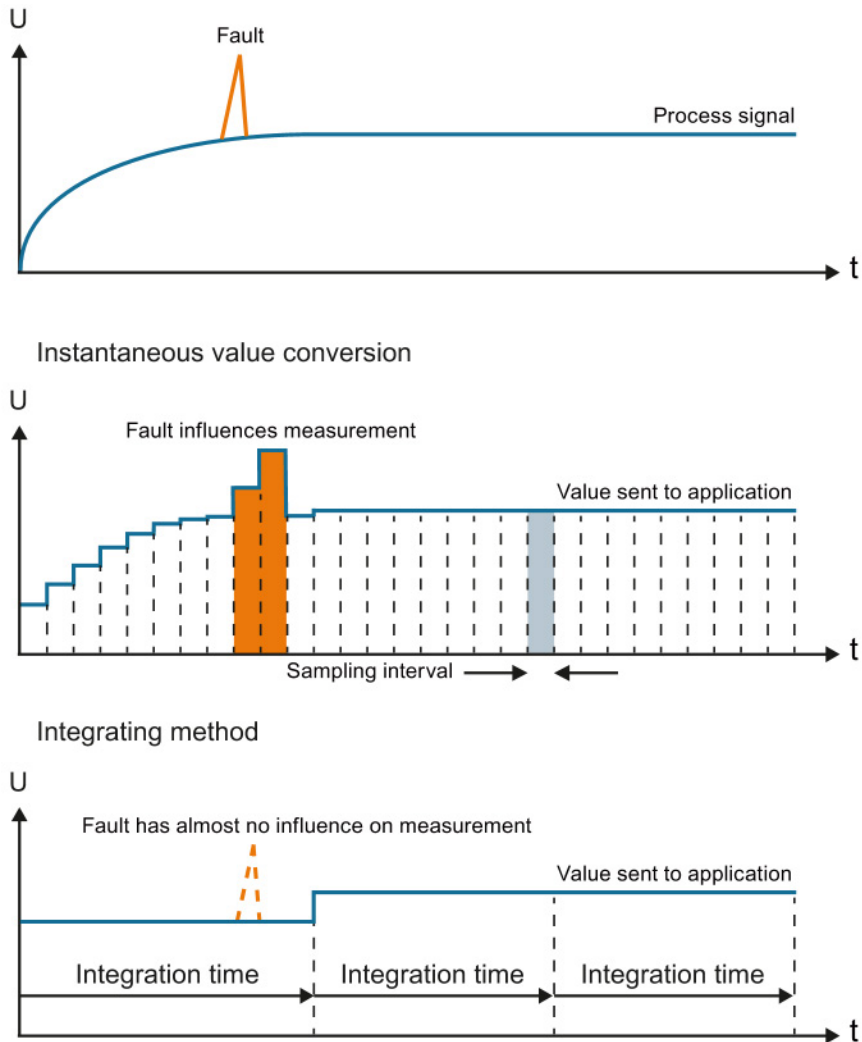


Figure 8-6 While an interference directly influences the value that is supplied to the application with instantaneous value encryption, its influence is negligible for the integrating method.

Electromagnetic compatibility

The entire architecture of HS modules is designed for fast processing of the signals. An interference-free design is therefore critical when using HS modules.

The following rules apply to the wiring of HS modules with sensors and actuators:

- Keep the cables as short as possible
- Use shielded and twisted pair cables
- Low-impedance connection of the cable shield at the respective shield supports
- Short cable loop between shield support and terminal connection

Note

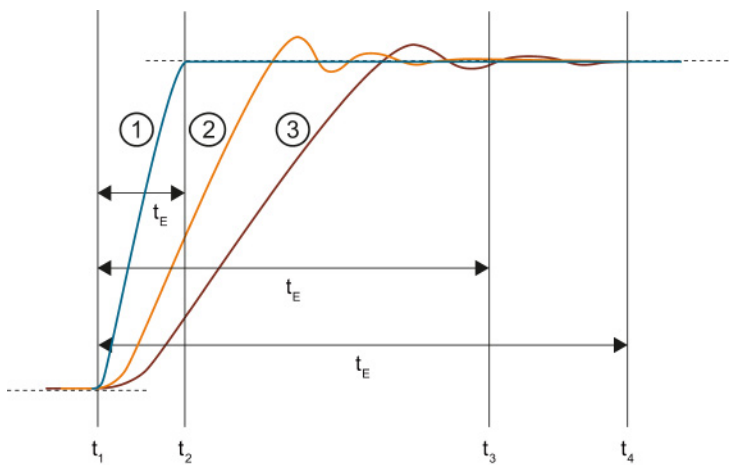
Interference-free design

Make sure that you pay close attention to the notes listed in the function manual Configuring interference-free controllers (<http://support.automation.siemens.com/WW/view/en/59193566>) when using HS modules.

Effect of load on the settling time

The settling times to the setpoint achieved with analog output modules depend on the applied load, among other things. To take advantage of the faster conversion times, only small loads (e.g., max. 47 nF) are permitted in HS modules as specified in the technical specifications.

The type of load has an effect on the form of settling to the setpoint when using output modules. Capacitive loads reduce the rise time due to the charging process and can cause the output signal to overshoot. Inductive loads result in a delayed current increase due to remagnetization and therefore also a shorter rise time. The figure below shows the output signal with no/small ①, medium ② and high ③ capacitive load.



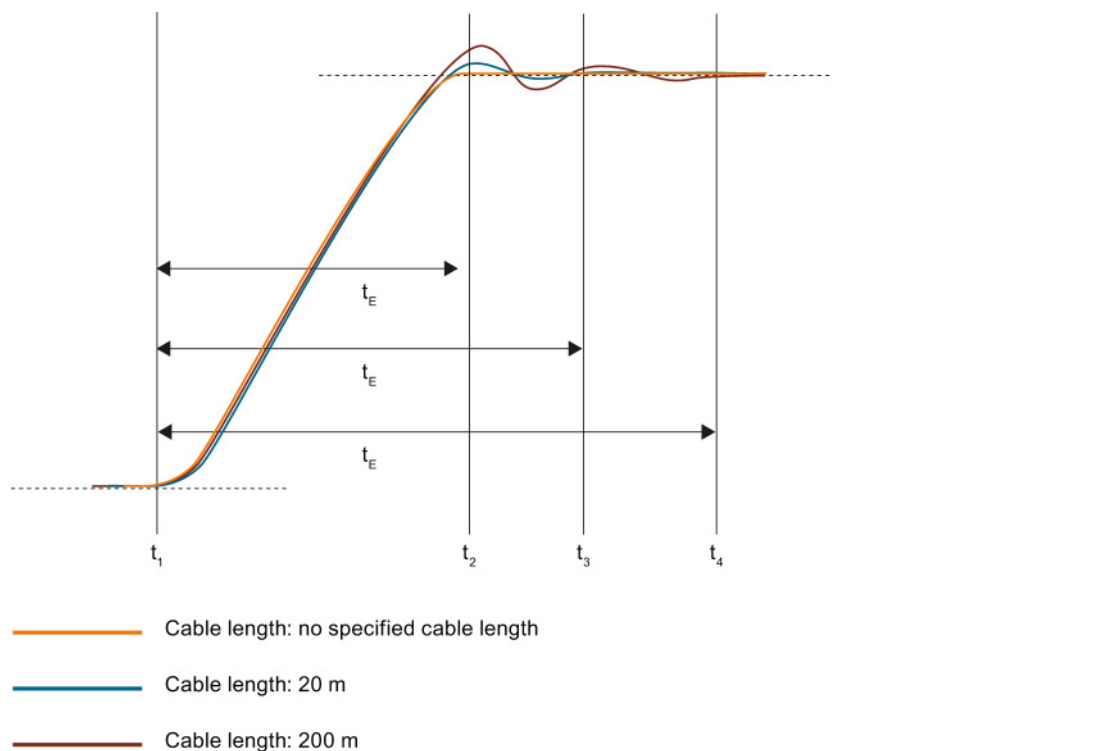
- ① Reference curve of a signal with no/small load capacity
- ② Signal with a load capacity of 47 nF
- ③ Signal with a load capacity of 100 nF
- t_E Settling time
- t_1 Module ends conversion at the terminal of the analog output channel and outputs the analog signal
- t_2 Signal ① has settled and the specified analog output value has been reached (residual error 1 %)
- t_3 Signal ② has settled and the specified analog output value has been reached (residual error 1 %)
- t_4 Signal ③ has settled and the specified analog output value has been reached (residual error 1 %)

Figure 8-7 Effect of different loads on the settling time

Effect of the cable length on the settling time

Long cables between signal source and module are a target for interferences. You should therefore keep the cables as short as possible especially for HS modules. Cables have a capacitive and inductive component and therefore have an effect on the settling behavior of the signal.

The example below shows the jump of the output voltage of an HS output module with small, medium and long cable length. The overshoot of the input signal increases with the length of the cable and therefore the time until it reaches the setpoint.



- t_E Settling time
- t_1 Module ends conversion at the terminal of the analog output channel and outputs the analog signal
- t_2 The signal running through a cable with short length has settled and the specified analog output value has been reached (residual error 1 %)
- t_3 The signal running through a 20 m cable has settled and the specified analog output value has been reached (residual error 1 %)
- t_4 The signal running through a 200 m cable has settled and the specified analog output value has been reached (residual error 1 %)

Figure 8-8 Effect of different cable lengths on the settling time

Effect of the value jump on the settling time

The figure below shows the effect of the height of the value jump between different output values on the settling time for analog output modules. The dotted line indicates the time when the signal has reached the setpoint. The higher the value jump, the later the signal reaches the setpoint.

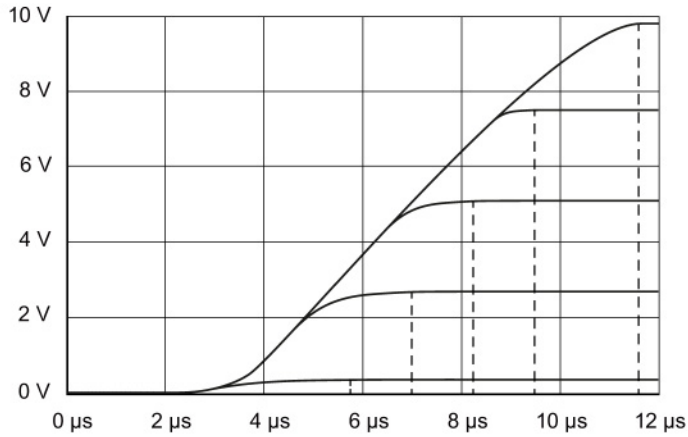


Figure 8-9 Settling time of five different analog signals with different value jumps

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SIEMENS

SIMATIC

High-precision input/output with Time-based IO

Function Manual



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Configuring and parameter
assignment

3




Programming

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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

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Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

Trademarks

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This function manual will support you when you use "Time-based IO" technology with the S7-1500, ET 200MP, and ET 200SP systems.

The documentation deals with the following topics:

- Using "Time-based IO" technology
- Functions of the "Time-based IO" technology
- Hardware and software requirements for "Time-based IO"
- Configuring the "Time-based IO" function with STEP 7 (TIA Portal)

Basic knowledge required

The following knowledge is required in order to understand the Function manual:

- General knowledge of automation technology
- Knowledge of the industrial automation system SIMATIC
- Proficiency with STEP 7 (TIA Portal)
- Knowledge about isochronous mode

Scope of the documentation

The following documentation is valid for all components of the S7-1500, ET 200MP and ET 200SP systems that support the "Time-based IO" technology.

Conventions

The following terms are used as synonyms in this documentation:

- **TIO module:** This term is used as synonym for I/O modules of the type:
 - ET 200MP TM Timer DIDQ 16x24V
 - ET 200SP TM Timer DIDQ 10x24V
- **TIO_Time:** This term is used as synonym for the shared time base (relative time) of the TIO modules.
- **Jitter:** This is a general term that includes various time influences affecting accuracy. This means that:
 - for input data: Deviation of the measured time from the actual event.
 - for output data: Deviation of the actual switching time from the specified time.

You should also pay particular attention to notes such as the one shown below:

Note

The notes contain important information on the product, handling the product or on part of the documentation to which particular attention should be paid.

Additional support

The range of technical documentation for the individual SIMATIC products and systems can be found on the Internet (<http://www.siemens.com/simatic-tech-doku-portal>).

For more information about configuration of Time-based IO, see the following FAQs in the Siemens Industry Online Support:

- Entry ID 109738186 (<https://support.industry.siemens.com/cs/ww/en/view/109738186>)
- Entry ID 109736374 (<https://support.industry.siemens.com/cs/ww/en/view/109736374>)

Additional information on isochronous mode is available in the Isochronous mode (<http://support.automation.siemens.com/WW/view/en/49948856>) and PROFINET with STEP 7 (<https://support.industry.siemens.com/cs/ww/en/view/109755401>) manuals.

Siemens Industry Online Support

You can find current information on the following topics quickly and easily here:

- **Product support**

All the information and extensive know-how on your product, technical specifications, FAQs, certificates, downloads, and manuals.

- **Application examples**

Tools and examples to solve your automation tasks – as well as function blocks, performance information and videos.

- **Services**

Information about Industry Services, Field Services, Technical Support, spare parts and training offers.

- **Forums**

For answers and solutions concerning automation technology.

- **mySupport**

Your personal working area in Industry Online Support for messages, support queries, and configurable documents.

This information is provided by the Siemens Industry Online Support in the Internet (<https://support.industry.siemens.com>).

Industry Mall

The Industry Mall is the catalog and order system of Siemens AG for automation and drive solutions on the basis of Totally Integrated Automation (TIA) and Totally Integrated Power (TIP).

You can find catalogs for all automation and drive products on the Internet (<https://mall.industry.siemens.com>) and in the Information and Download Center (<https://www.siemens.com/automation/infocenter>).

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions only form one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For additional information on industrial security measures that may be implemented, please visit (<http://www.siemens.com/industrialsecurity>).

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply latest updates may increase customer's exposure to cyber threats.

To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed under (<http://www.siemens.com/industrialsecurity>).

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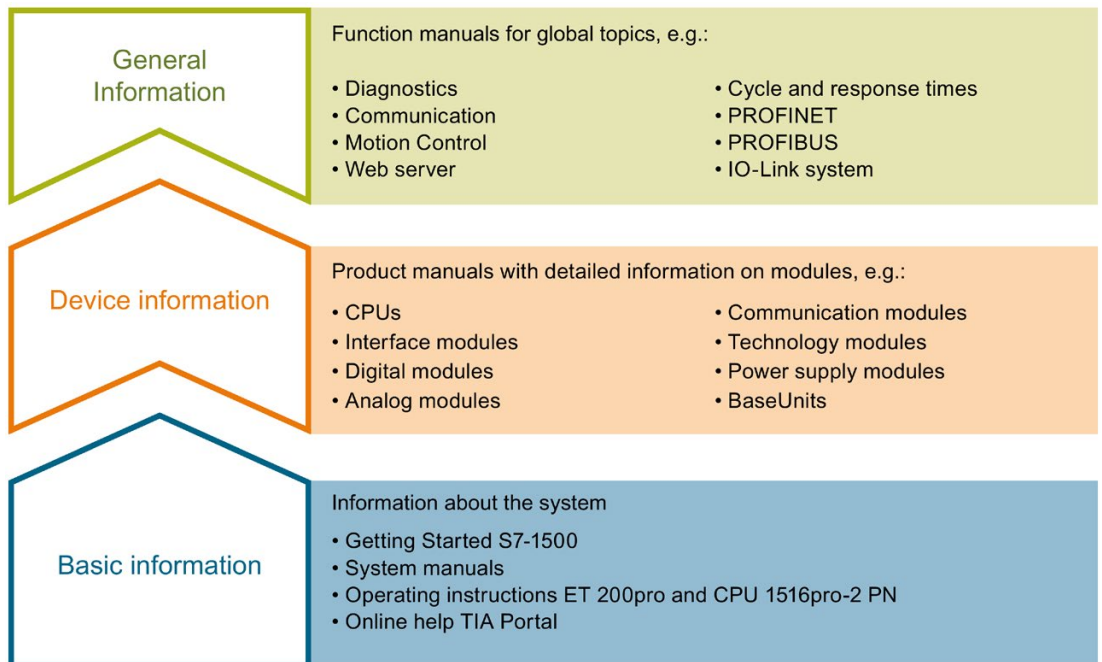
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Documentation guide

1.1 Guide to documentation function manuals

The documentation for the SIMATIC S7-1500 automation system, the CPUs 1513/1516pro-2 PN based on SIMATIC S7-1500, and the distributed I/O systems SIMATIC ET 200MP, ET 200SP and ET 200AL is divided into three areas.

This division allows you easier access to the specific information you require.



Basic information

System manuals and Getting Started manuals describe in detail the configuration, installation, wiring and commissioning of the SIMATIC S7-1500, ET 200MP, ET 200SP and ET 200AL systems. Use the corresponding operating instructions for the CPUs 1513/1516pro-2 PN. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, terminal diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics such as diagnostics, communication, Motion Control, Web server, OPC UA.

You can download the documentation free of charge from the Internet (<https://support.industry.siemens.com/cs/ww/en/view/109742705>).

Changes and additions to the manuals are documented in product information sheets.

You will find the product information on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/us/en/view/68052815>)
- ET 200SP (<https://support.industry.siemens.com/cs/us/en/view/73021864>)
- ET 200AL (<https://support.industry.siemens.com/cs/us/en/view/99494757>)

Manual Collections

The Manual Collections contain the complete documentation of the systems put together in one file.

You will find the Manual Collections on the Internet:

- S7-1500/ET 200MP (<https://support.industry.siemens.com/cs/ww/en/view/86140384>)
- ET 200SP (<https://support.industry.siemens.com/cs/ww/en/view/84133942>)
- ET 200AL (<https://support.industry.siemens.com/cs/ww/en/view/95242965>)

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In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

You must register once to use the full functionality of "mySupport".

You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en>).

"mySupport" - Documentation

With "mySupport", your personal workspace, you make the best out of your Industry Online Support.

In "mySupport", you can save filters, favorites and tags, request CAx data and compile your personal library in the Documentation area. In addition, your data is already filled out in support requests and you can get an overview of your current requests at any time.

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You can find "mySupport" on the Internet (<https://support.industry.siemens.com/My/ww/en/documentation>).

"mySupport" - CAx data

In the CAx data area of "mySupport", you can access the latest product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx data on the Internet (<http://support.industry.siemens.com/my/ww/en/CAxOnline>).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet (<https://support.industry.siemens.com/sc/ww/en/sc/2054>).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).

This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.

With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet (<http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool>).

SIMATIC Automation Tool

You can use the SIMATIC Automation Tool to perform commissioning and maintenance activities simultaneously on various SIMATIC S7 stations as a bulk operation independent of TIA Portal.

The SIMATIC Automation Tool provides a multitude of functions:

- Scanning of a PROFINET/Ethernet system network and identification of all connected CPUs
- Address assignment (IP, subnet, gateway) and station name (PROFINET device) to a CPU
- Transfer of the date and the programming device/PC time converted to UTC time to the module
- Program download to CPU

- RUN/STOP mode switchover
- CPU localization by means of LED flashing
- Reading out of CPU error information
- Reading of the CPU diagnostics buffer
- Reset to factory settings
- Firmware update of the CPU and connected modules

You can find the SIMATIC Automation Tool on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/98161300>).

PRONETA

SIEMENS PRONETA (PROFINET network analysis) allows you to analyze the plant network during commissioning. PRONETA features two core functions:

- The topology overview automatically scans the PROFINET and all connected components.
- The IO check is a fast test of the wiring and the module configuration of a plant.

You can find SIEMENS PRONETA on the Internet (<https://support.industry.siemens.com/cs/ww/en/view/67460624>).

SINETPLAN

SINETPLAN, the Siemens Network Planner, supports you in planning automation systems and networks based on PROFINET. The tool facilitates professional and predictive dimensioning of your PROFINET installation as early as in the planning stage. In addition, SINETPLAN supports you during network optimization and helps you to exploit network resources optimally and to plan reserves. This helps to prevent problems in commissioning or failures during productive operation even in advance of a planned operation. This increases the availability of the production plant and helps improve operational safety.

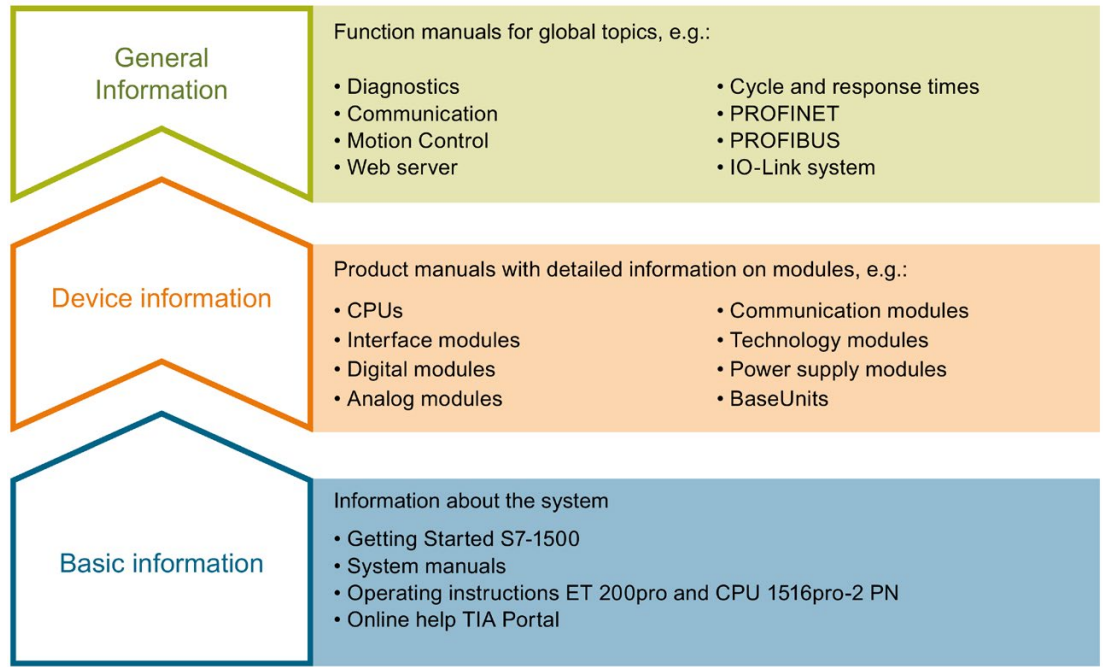
The advantages at a glance

- Network optimization thanks to port-specific calculation of the network load
- Increased production availability thanks to online scan and verification of existing systems
- Transparency before commissioning through importing and simulation of existing STEP 7 projects
- Efficiency through securing existing investments in the long term and the optimal use of resources

You can find SINETPLAN on the Internet (<https://www.siemens.com/sinetplan>).

The documentation for the SIMATIC S7-1500 automation system, for CPU 1516pro-2 PN based on SIMATIC S7-1500, and for the distributed I/O systems SIMATIC ET 200MP, ET 200SP and ET 200AL is divided into three areas.

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- S7-1500/ET 200MP
- ET 200SP
- ET 200AL

Manual Collections

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- S7-1500/ET 200MP
- ET 200SP
- ET 200AL

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You can find "mySupport" on the Internet.

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus on individual products.

You will find the application examples on the Internet.

Time-based IO basics

2.1 Using Time-based IO

Many processes in a plant require a relatively precise reproducibility as far as time is concerned. The reproducibility can be optimized to a limited extent by shorter CPU cycle times. The use of high-precision input/output with Time-based IO provides a more accurate reproducibility than the one that can be achieved by optimizing the CPU cycle time. An additional advantage of Time-based IO is the independence from the time scale of the application cycle.

Below is a selection of typical areas of application that can benefit from this technology.

Defined response times

An output signal that responds with a precise delay time that is independent of the application cycle can be output by adding a specified time to the time stamp of an edge at the digital input.

Length measurement

The length of a product passing by can be determined by the difference between two input time stamps and an associated travel speed.

Cam controller

The ongoing movement can be extrapolated from a synchronous position information (for example, from a counter module or an axis). Based on this result, the time of a switching position (cam position) is calculated and transferred to the TIO module (output). This way the switch event takes place at the required position.

Dosing

By specifying a switch-on and a switch-off edge to a time-controlled digital output, a valve can be opened for a specific time and the amount of liquid can be dosed accordingly.

2.2 Time behavior of Time-based IO

2.2.1 Time behavior of standard technology

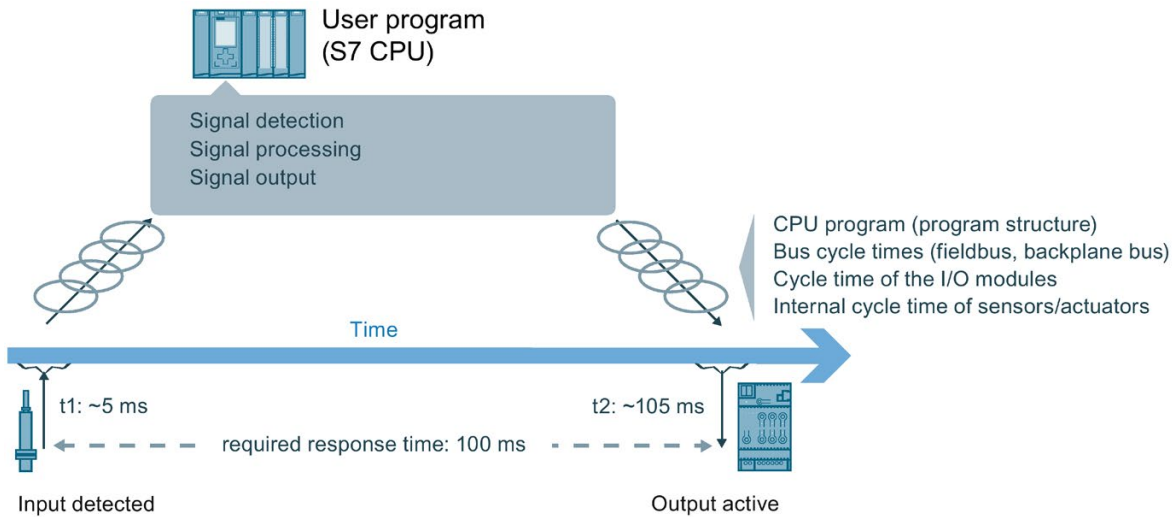
The time behavior of the inputs/outputs depends on the following factors for standard technology:

- CPU program (program structure)
- Bus cycle times (fieldbus, backplane bus)
- Cycle time of the I/O modules
- Internal cycle time of sensors/actuators

A deterministic statement as to

- when an input event (e.g., sensor signal) has taken place
- when the output event has an effect on the input event (e.g., output switches)

will become inaccurate due to the time factors listed above.

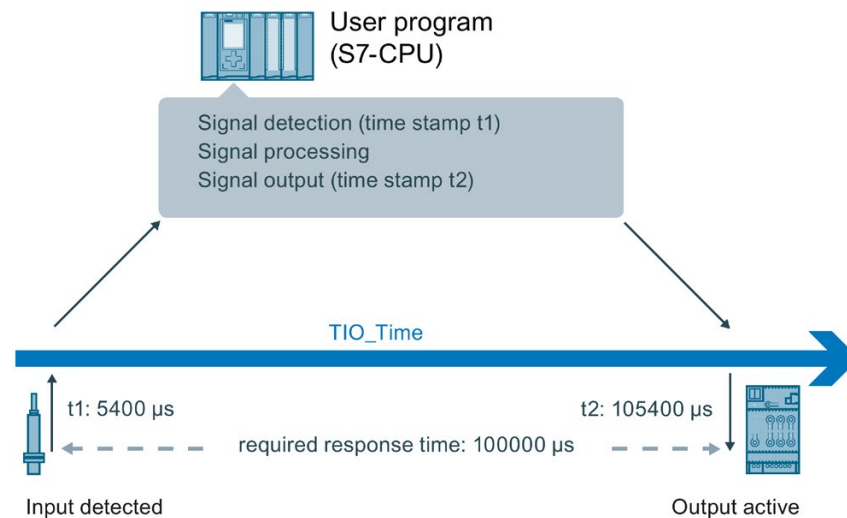


2.2.2 Time-based IO properties

Time-controlled I/O functionality

Time-based IO stands for time-based processing of I/O signals. All input signals are referred to one time (TIO_Time). The input signals receive the time stamp t_1 . After signal processing, the output event can also be linked with the TIO_Time and output at the required time. Output takes place at time t_2 .

Here an example for Time-based IO:



Independence and focus of Time-based IO

The shared time basis (TIO_Time) of all components involved is the basis for Time-based IO. By using TIO_Time, the accuracy of the output with Time-based IO does not depend on:

- CPU program (program structure)
- Bus cycle times (fieldbus, backplane bus)
- Cycle time of the I/O modules

The focus of Time-based IO is not on the I/O response time but on the predictability (determinism) of I/O signals. With Time-based IO, it is possible to respond to an input signal with an output signal within a defined time. Keep in mind the system-dependent minimum response time when using Time-based IO.

Time-based IO stands for:

- I/O functionalities executed with high precision
- I/O processes with time stamp

Accuracy

Accuracy is crucial for the performance capability of Time-based IO.

The accuracy is a property of the TIO modules and indicates the deviation with which the required response is achieved. For Time-based IO, the accuracy and reproducibility of the response is in the millisecond range.

Response time

In addition to a very high accuracy, a minimum response time to an input event can result depending on the configuration.

The response time is the time between the input event and the required output event.

For the minimum response time:

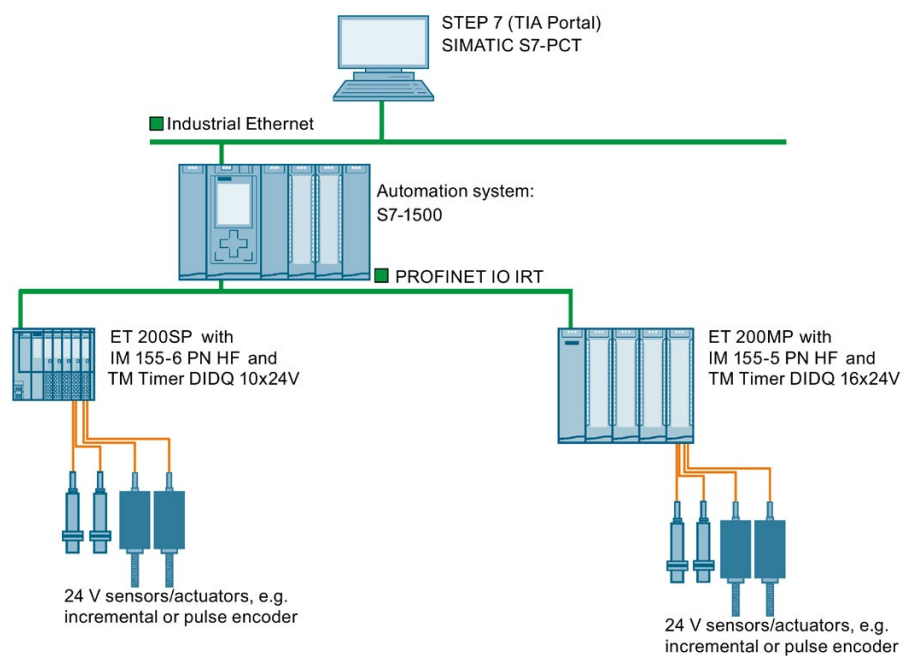
$3 \times \text{application cycle } T_{APP}$

2.3 System environment

Introduction

Possible system configurations with PROFINET for the use of Time-based IO are shown below.

Use with STEP 7 (TIA Portal)



2.4 Hardware requirements

Introduction

The properties of the hardware components required for Time-based IO are listed below. You will also find specific modules as an example.

Requirements

Component	Properties	Examples
CPU	Isochronous mode/ PROFINET IO IRT: provides defines response time and high-precision plant behavior.	<ul style="list-style-type: none"> • CPU 1511-1 PN
ET 200 interface module	Supports isochronous mode	<ul style="list-style-type: none"> • ET 200SP with IM 155-6 PN HF (as of firmware V2.1) • ET 200MP with IM 155-5 PN HF
I/O module	TIO module	<ul style="list-style-type: none"> • ET 200SP: TM Timer DIDQ 10x24V • ET 200MP: TM Timer DIDQ 16x24V (as of firmware V1.0.1)

2.5 Configuration software requirements

Introduction

Below is a list of the software versions which support the "Time-based IO" function.

Requirements

Configuration software	Requirements	Supported hardware components	Additional information
STEP 7 (TIA Portal) V16 and above	PROFINET IO IRT or isochronous mode on the backplane bus	<ul style="list-style-type: none"> • S7-1500 automation system • ET 200SP and ET 200MP distributed I/O systems • TM Timer DIDQ 16x24V • TM Timer DIDQ 10x24V 	STEP 7 (TIA Portal) online help

Additional information on isochronous mode is available in the Isochronous mode (<http://support.automation.siemens.com/WW/view/en/49948856>) and PROFINET with STEP 7 (<https://support.industry.siemens.com/cs/ww/en/view/109755401>) manuals.

TIO instructions

The TIO instructions are specific function blocks for use of Time-based IO. The following TIO instructions (Page 27) are available:

- TIO_SYNC
- TIO_DI
- TIO_DI_ONCE
- TIO_DQ

2.6 Technical implementation

Introduction

The information below will help you better understand the core aspects of Time-based IO and find out which SIMATIC functions are used to implement the described aspects.

Synchronization of involved modules (shared time basis)

The Time-based IO technology uses isochronous mode for all involved stations.

Isochronous mode enables multiple TIO modules to be synchronized to a shared time basis. The basis of the shared time basis for the TIO modules is the relative time TIO_Time.

Additional information on isochronous mode is available in the Isochronous mode (<http://support.automation.siemens.com/WW/view/en/49948856>) and PROFINET with STEP 7 (<https://support.industry.siemens.com/cs/ww/en/view/109755401>) manuals.

TIO_Time

The TIO_Time is the central time basis to which all time stamps refer.

TIO_Time has the following properties:

- Shared time basis for all TIO modules which are synchronized with the TIO instruction TIO_SYNC.
- The time starts counting again with each CPU startup.
- The TIO_Time has data type LTime (e.g. LT#14s830ms652us315ns).
- All valid time stamps refer to TIO_Time:
 - Input time stamps of the TIO modules are converted to the TIO_Time in the TIO instructions TIO_DI and TIO_DI_ONCE.
 - In the TIO instruction TIO_DQ, output time stamps are converted to the output time stamp of the TIO modules.
- The value of TIO_TIME corresponds to the current time with respect to TIO instructions and is updated with the call of TIO_SYNC. If you want an output to relate not to a previous input time stamp but to the current time, you can use the value of TIO_TIME as basis for the output time stamp. Example: Output of an edge in 20 ms:
TIO_DQ.TimeStampRE=TIO_SYNC_DATA.TIO_TIME+LT#20ms)

TIO instructions in the isochronous OB

The TIO instructions must be called in a "Synchronous Cycle" or "MC-PostServo" OB.
You can find additional information in the chapter Programming (Page 27).

Note

The TIO instructions also support geared down isochronous mode. With a clock reduction ratio, the application cycle is longer than the send clock.

Note

The TIO instructions must be called in an "MC-PreServo" OB.

If you use an OB of the "MC-PostServo" type, you can decide separately for each TIO model whether it is used with Motion Control technology objects or with TIO instructions.

If you call the TIO instructions in an "MC-PostServo" type OB, you need to use the IPO model and also cannot use any reduction ratio.

Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.

Modes for updating the process image

In isochronous mode, you can influence the order of the update of the process image partition of the input and output data. In doing so, you can select the following program execution models:

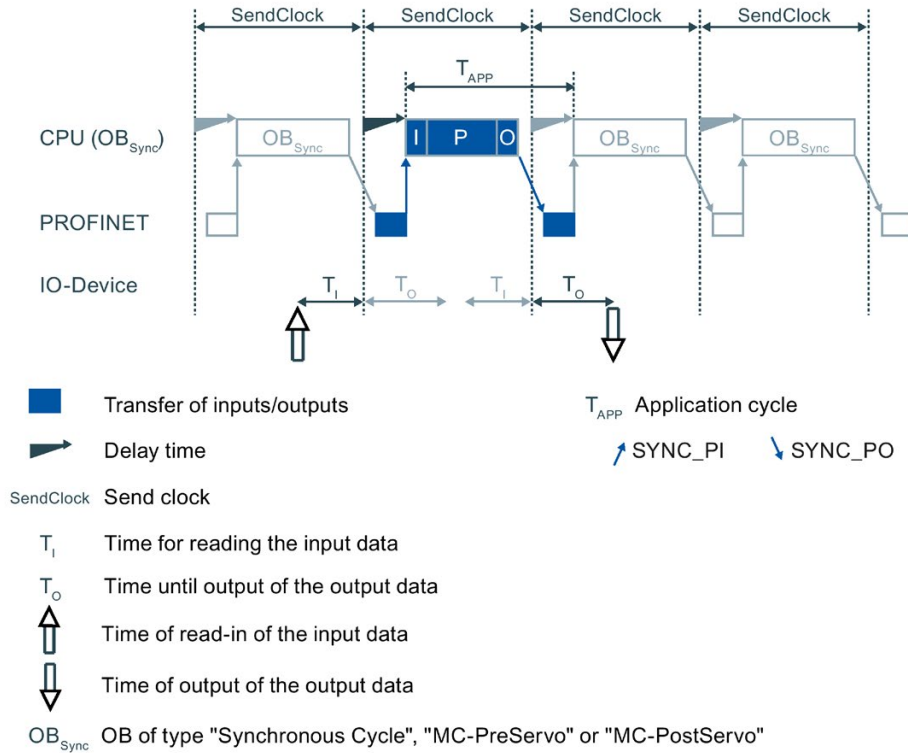
- IPO model (application cycle factor = 1)
- OIP model (application cycle factor ≥ 1)

The abbreviations I, P, O stand for the following processes: I = Input, P= Processing, O = Output.

Additional information on the application cycle factor is available in the PROFINET with STEP 7 (<http://support.automation.siemens.com/WW/view/en/49948856>) Manual.

IPO model (application cycle factor = 1)

The user program is started after the delay time. Start by updating the corresponding process image partition of the inputs in the user program by calling the SYNC_PI system instruction. Processing is started next (for example, calculation of the time stamps). The corresponding process image partition of the outputs is updated at the end of the user program in the CPU by SYNC_PO.

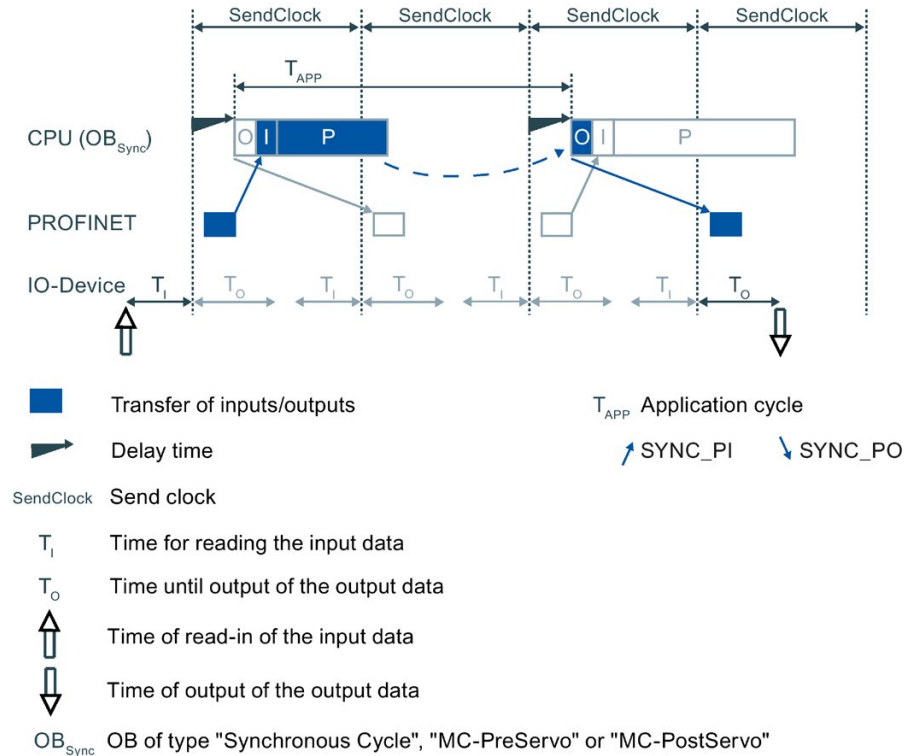


Properties of the IPO model:

- Supports shorter response times
- The application cycle must not be greater than the send clock. This gives the application less time than with the OIP model.

OIP model (application cycle factor ≥ 1)

The user program is started after the delay time. In PIP_Mode 0, the TIO_SYNC instruction updates the process image. In the other modes, you start by updating the corresponding process image partition of the outputs in the user program by calling the SYNC_PO system instruction. As a result, the output data that was calculated in the previous network cycle will become active during the next network cycle (T_o). Next the corresponding process image partition of the inputs is updated in the CPU by SYNC_PI. Processing starts after the data is transmitted (for example, calculation of the time stamps).



Properties of the OIP model:

- The response time is longer than with the IPO model.
- It is one application cycle longer than permitted by the send clock.
This gives the application more time than with the IPO model.

Influence of accuracy

To estimate the accuracy you need the accuracy of

- TIO module
- Sensor/ actuator

Consult the data sheets of the respective module regarding the accuracy value.

You have to add the individual jitters of the TIO modules and the sensors/actuators. You can neglect any other influencing factors.

See also

Programming of Time-based IO (Page 28)

Configuring and parameter assignment

3.1 Requirements

Introduction

You need additional software components to use Time-based IO. You must also have created the standard configuration for your project.

Below you will learn more about the standard configuration for Time-based IO.

Requirements

In STEP 7 (TIA Portal):

- The project has been created.
- The CPU has been created and the parameters are assigned.
- Automation system and modules have been created and the parameters have been assigned.
- When using an ET 200 station: The connection has been created and the parameters are assigned via PROFINET.
- A "Synchronous Cycle" or "MC-PostServo" type OB has been created.

See also

System environment (Page 17)

Configuration software requirements (Page 19)

3.2 Settings for Time-based IO

Below you will find an overview of which settings have to be made for which components of Time-based IO.

Table 3- 1 Overview of settings for Time-based IO

Component	Where adjustable ¹	Properties to be set	Additional information
When using an ET 200 station: PROFINET subnet	Properties of the PROFINET subnet > sync domain	Create sync domain or edit properties of sync domain	<ul style="list-style-type: none"> PROFINET function manual (http://support.automation.siemens.com/WW/view/en/49948856) Online help in the STEP 7 (TIA Portal) information system
		Specify devices of the sync domain: <ul style="list-style-type: none"> Specify CPU as sync master. Specify ET 200 interface module as sync slave with RT class "IRT". 	
S7-1500 station ET 200 station	Properties of the PROFINET interface > isochronous communication	Enable isochronous mode	<ul style="list-style-type: none"> Function Manual Isochronous Mode (https://support.industry.siemens.com/cs/ww/en/view/109755401)
TIO module	Properties of the TIO module > I/O addresses	Enable isochronous mode	<ul style="list-style-type: none"> PROFINET function manual (http://support.automation.siemens.com/WW/view/en/49948856) Manual Technology Module TM Timer DIDQ 16x24V (http://support.automation.siemens.com/WW/view/en/95153313) Manual Technology Module TM Timer DIDQ 10x24V (http://support.automation.siemens.com/WW/view/en/95153951)
	Properties of the TIO module > I/O addresses	Assign or create a "Synchronous Cycle" or "MC-PostServo" type OB	
	Properties of the TIO module > I/O addresses	Assignment of I/O addresses to the process image partition (e.g., PIP1)	
	Properties of the TIO module > Basic parameters	Configure "Module use from the user program"	
	Properties of the TIO module > Basic parameters/Channel parameters	For TM Timer DIDQ 10x24V: If required, assign parameters for Configuration "Use input/output individually" Parameter assignment for use of Timer DI and Timer DQ	
Isochronous OB (Synchronous Cycle or MC-PostServo)	Properties of the Isochronous OB > Isochronous mode	Adjust application cycle, if necessary	<ul style="list-style-type: none"> Online help in the STEP 7 (TIA Portal) information system

¹ Describes the topic area in the configuration software.

Setting for Time-based IO

If you have no special response time requirements, the following setting is suitable as a starting point:

- Send clock: 2 ms
- Application cycle: 4 ms
- Assignment to the process image partition: PIP1
- PIP_Mode: 0 (OIP model)

FAQ

For more information, see the following FAQs in the Siemens Industry Online Support:

- Entry ID 109738186 (<https://support.industry.siemens.com/cs/ww/en/view/109738186>)
- Entry ID 109736374 (<https://support.industry.siemens.com/cs/ww/en/view/109736374>)

See also

Programming of Time-based IO (Page 28)

Programming

4.1 Overview of instructions

Introduction

Time-based IO is used with special instructions (TIO instructions). The TIO_SYNC TIO instruction is responsible for synchronizing all involved TIO modules and creates a unique time basis (TIO_Time) to which all actions are referenced.

Additional instructions undertake the reading in of process input signals with associated time stamps and/or the time-controlled output of process output signals.

Note

The TIO instructions are helpful for general time-based IO applications. For special applications, such as cam controllers, there are also separate technology objects, for example, TO_CamOutput.

Note

The TIO instructions use the time stamp functions of the TIO modules. The other functions of the TIO modules can be used independently of the TIO instructions in applications.

TIO instructions

Instruction	Short description
TIO_SYNC	Synchronizes the TIO modules and provides the time basis for Time-based IO
TIO_DI	Detects the edges at the digital input (Timer DI) and supplies the associated time stamp
TIO_DI_ONCE	<ul style="list-style-type: none"> • Detects the edges at the digital input (timer DI) once and provides the associated time stamp • Controls a timer DI channel which is configured as an edge-triggered enable for another channel.
TIO_DQ	Outputs time-controlled edges at the digital output (Timer DQ)

4.2 Programming of Time-based IO

Introduction

To use Time-based IO, the TIO instructions must be called in an isochronous OB. The application can also run in another OB. This allows you to shorten the runtime of the isochronous OB.

You need the following TIO instructions according to the required task:

TIO module	TIO instructions
<ul style="list-style-type: none"> TM Timer DIDQ 16x24V TM Timer DIDQ 10x24V 	<ul style="list-style-type: none"> Per digital input, one TIO_DI or TIO_DI_ONCE for read-in Per digital output, one TIO_DQ for output One TIO_SYNC (for up to eight TIO modules)

This section below describes the programming of the CPU for Time-based IO.

Requirements

Hardware configuration in STEP 7 (TIA Portal):

- The TIO modules are assigned to an isochronous network.
- The TIO modules are assigned to a shared process image partition.
- The process image partition is assigned to an isochronous OB.
- The TIO modules are configured for use with instructions from the "Time-based IO" library.

Additional information on configuration of Time-based IO is available in the section Settings for Time-based IO (Page 25).

Procedure

1. Create a TIO instruction, TIO_SYNC, in the isochronous OB.
2. Connect all TIO modules to be synchronized at the TIO_SYNC TIO instruction using parameters HWID_1 to HWID_8.

The HWID can be found in the hardware configuration under "Properties > System constants".

Note

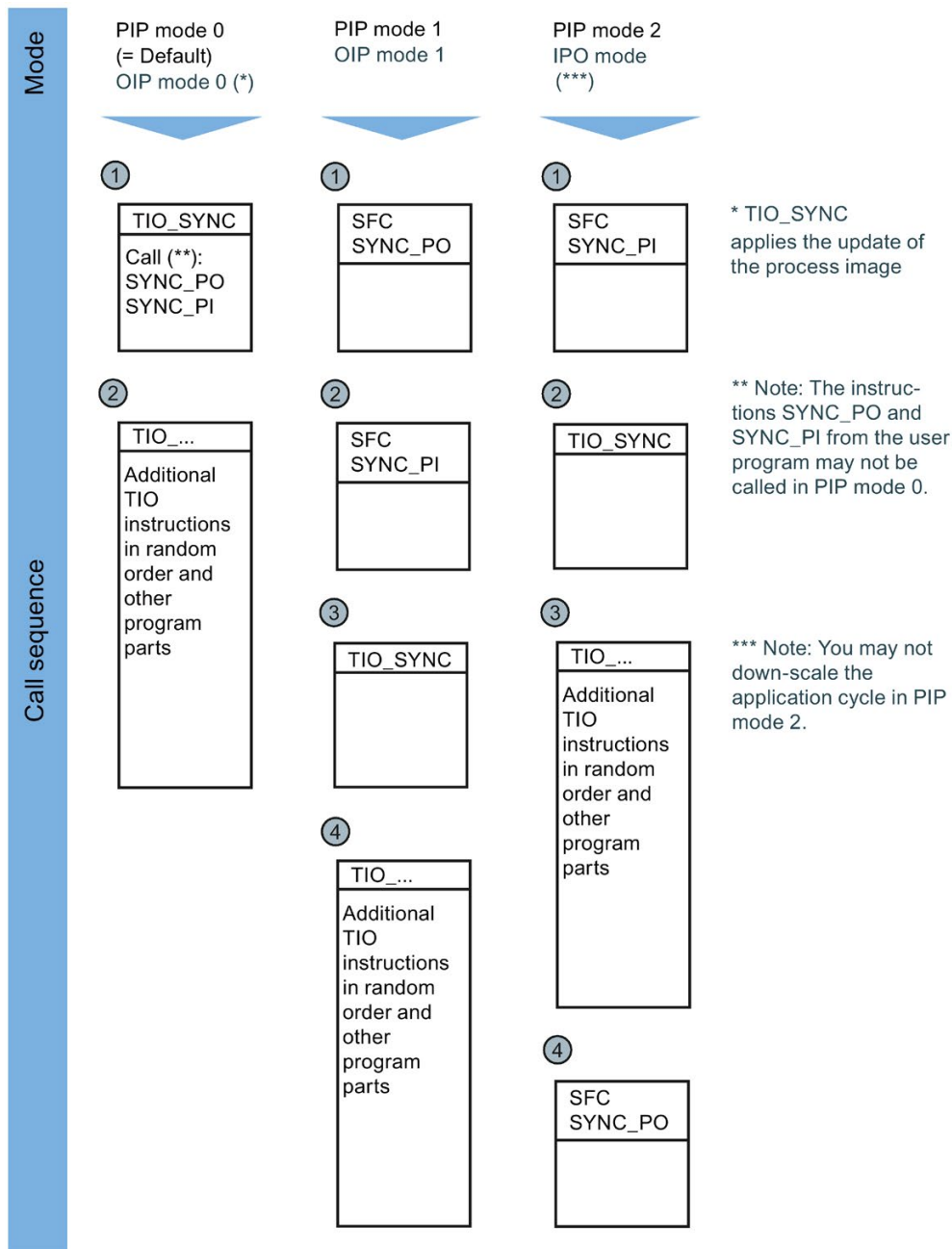
Use of symbolic constants is generally preferred instead of absolute numerical values when interconnecting.

3. Set the data update mode at the TIO_SYNC instruction at the PIP_Mode input parameter.

The description of the modes is available in the chapter Technical implementation (Page 20).

The parameter assignment of the TIO_SYNC TIO instruction is complete.

4. For the following instructions, note the call sequence depending on the selected value for PIP_Mode:



5. Add the TIO instructions for read-in/output required for your application in the isochronous OB.
6. At the TIO instructions for read-in/output, interconnect in each case the input/output TIO_SYNC_Data with the same name output at the TIO_SYNC.
7. At the TIO instructions for read-in/output, assign parameters for the input parameters HWID (see "Properties > System constants" in hardware configuration) and Channel. The Time-based IO functionality is successfully programmed.

8. Interconnect the Time-based IO functionality with your application, such as evaluating the read-in time stamp in a step sequencer in another OB.
9. If TIO_SYNC does not automatically read out the send clock: Define the send clock manually, e.g. in OB100.
10. Compile and download the entire project to the CPU.

Result

You have completed programming the use of Time-based IO.

FAQ

For more information, see the following FAQs in the Siemens Industry Online Support:

- Entry ID 109738186 (<https://support.industry.siemens.com/cs/ww/en/view/109738186>)
- Entry ID 109736374 (<https://support.industry.siemens.com/cs/ww/en/view/109736374>)

4.3 Time-based IO

4.3.1 TIO_SYNC: Synchronizing TIO modules

Description

TIO_SYNC is the basis for all other TIO instructions. TIO_SYNC synchronizes TIO modules to a shared time basis TIO_Time.

You can synchronize up to 8 TIO modules with TIO_SYNC. All TIO modules must be assigned to the same process image partition (PIP). If you select "0" for the input parameter PIP_Mode, you assign the number of the process image partition at the PIP_PART input parameter.

Additional information on configuration of Time-based IO is available in the Configuration and parameter assignment section.

Startup characteristics

At the startup of the CPU, the TIO_SYNC instruction receives and checks the input parameters once and initializes the TIO_Time.

You have several options for handling the optional parameters SendClock, AppCycleFactor and ToTimes:

- SendClock, AppCycleFactor and ToTimes can be read in automatically each time the system is started. This results in a time delay during startup, but the values are always consistent.
- Automatically read in SendClock, AppCycleFactor and ToTimes at each startup and apply the read-in values as set values during commissioning. This results in fast subsequent startups, but is inconsistent after changes in the hardware configuration (repeat commissioning necessary).
- Manually define SendClock, AppCycleFactor and ToTimes before the first call of the instruction, for example, in OB100:

```

1
2 "TIO_SYNC_DB".SendClock := LI#4ms;
3 "TIO_SYNC_DB".AppCycleFactor := 1;
4 "TIO_SYNC_DB".ToTimes[1] := LI#210us;
5 "TIO_SYNC_DB".ToTimes[2] := LI#210us;
6

```

This results in a fast startup, but you need to manually update the values after changes to the hardware configuration.

You will find information about the parameters in the table below.

If startup takes place without errors, the instruction changes to normal operation. In the event of an error, the instruction does not change to normal operation and generates an error message.

Functional description

In normal operation, the instruction ensures synchronization of all TIO modules configured at the HWID input.

The calculated TIO_Time for the instructions of the TIO modules is provided at the TIO_SYNC_Data output.

Reaction to error

The Error output indicates if the instruction was processed correctly. In the event of an error, the cause of the error is displayed at the Status output.

Parameter

The table below shows the parameters of the TIO_SYNC instruction.

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0	S7-1500		
HWID_1 ... HWID_8*	Input		HW_IO	65535	Hardware identifier for TIO module from hardware configuration
PIP_Mode*	Input		PIP	0	Mode for the data update**: <ul style="list-style-type: none"> • 0: OIP model with internal update of the process image by SYNC_PO and SYNC_PI. • 1: OIP model without internal update of the process image • 2: IPO model without internal update of the process image
PIP_PART*	Input		USInt	1	Only relevant if PIP_Mode = 0 Number of the process image partition which is to be updated isochronously.
TIO_SYNC_Data	Output		"TIO_SYNC_Data"		Calculated system time for the TIO instructions of the TIO modules and internal data used for synchronization. See UDT TIO_SYNC_Data (Page 58).
Status	Output		DWord	16#0	Status of the instruction: see description of Status parameter
Error	Output		Bool	False	Error = True: An error has occurred. For detailed information see Status parameter. Error is reset as soon as the error is corrected.

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0	S7-1500		
OperatingState		Static	Int	0	<p>Internal operating state of the instruction:</p> <ul style="list-style-type: none"> • 0: Input parameters are checked • 1: Optional parameters are read out • 2: Read-out parameters are checked • 3: Normal operation (all parameters OK, TIO modules synchronized) <p>As soon as operating state 3 is reached, time stamps can be read in and edges can be output. If you want to repeat the synchronization of the TIO modules and the readout of the optional parameters, you can set the operating state to 0.</p>
SendClock	Input	Static	LTime	LT#0ns	<p>Send clock of the sync domain. Apply the send clock from the PROFINET configuration.</p>
AppCycle-Factor		Static	UInt	0	<p>Application cycle factor:</p> <ul style="list-style-type: none"> • Range of values: $0 \leq \text{AppCycleFactor} \leq 85$ • 0: SendClock, AppCycleFactor and ToTimes are read in automatically <p>The application cycle T_{APP} is calculated as follows: $T_{APP} = \text{AppCycleFactor} \times \text{SendClock}$</p>
ToTimes		Static	LTime array [1...8]	LT#0ns	<p>T_o for each TIO module: Time for output of isochronous output data.</p>

* Checked once at startup of the CPU

** The IPO model (PIP_Mode = 2) provides the shortest response times, but it also places the highest demands on system performance. Processing of all TIO instructions and other program sections must be completed within one send clock. Select the OIP model (PIP_Mode = 0) only if you use only *one* instance of the TIO_SYNC instruction per process image partition so that the SYNC_PI and SYNC_PO instructions are not called more than once in the isochronous OB. In addition, do not call SYNC_PI and SYNC_PO in the other program sections in the OIP model.

Note

The TIO instructions must be called in an "MC-PreServo" OB.

If you use an OB of the "MC-PostServo" type, you can decide separately for each TIO model whether it is used with Motion Control technology objects or with TIO instructions.

If you call TIO_SYNC in an "MC-PostServo" type OB, you need to use PIP_Mode = 2 and also cannot use any reduction ratio.

Status parameter

Error codes or status information is output as double word at the Status output.

The double word is divided as follows:

Error code (DW#16#...)	Meaning
z0yywww	Error of a system function: <ul style="list-style-type: none"> during startup (z = 1) during normal operation (z = 0) System functions with subordinate use are coded in yy: See table with error codes. www specifies the RET_VAL of the system function. The error information is available in the help for the system function.
z0yy0000	An error that does not originate in a system function. This error receives a consecutive error number yy. The error can occur: <ul style="list-style-type: none"> during startup (z = 1) during normal operation (z = 0)

Table with error codes

Error code (DW#16#...)	Meaning	Solution
00000000	No error.	—
1001xxxx	An error has occurred with system function RD_SINFO. The low word xxxx displays the error information of the RET_VAL return value from RD_SINFO.	<ul style="list-style-type: none"> Read the description of the RD_SINFO in the STEP 7 (TIA Portal) information system. Make sure that TIO_SYNC is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10020000	The read cycle time of the isochronous OB is invalid (LT#0ms or negative). The instruction can only be used without errors in an isochronous OB.	<ul style="list-style-type: none"> Correct the value of the cycle time. Make sure that TIO_SYNC is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10030000	The TIO_SYNC instruction is not called in an isochronous OB. The instruction can only be used without errors in an isochronous OB.	Make sure that TIO_SYNC is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10040000	The assigned value at the PIP_Mode input parameter is outside the valid range of 0 to 2.	Correct the value at the PIP_Mode input parameter.
10050000	The configured send clock is outside the permitted range of 0 < SendClock <= 4 ms.	Correct the value of the send clock.
0006xxxx*	An error has occurred during execution of the SYNC_PI system function. The low word xxxx displays the error information of the RET_VAL return value from SYNC_PI.	Read the description of the SYNC_PI in the STEP 7 (TIA Portal) information system.
0007xxxx*	An error has occurred during execution of the SYNC_PO system function. The low word xxxx displays the error information of the return value RET_VAL from SYNC_PO.	Read the description of the SYNC_PO in the STEP 7 (TIA Portal) information system.

Error code (DW#16#...)	Meaning	Solution
10080000	At least one of the hardware identifiers does not belong to a TIO module.	Check the values of input parameters HWID_1 to HWID_8. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration.
10090000	HWID_1 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	Check the value of the respective input parameter. In each case, specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
100A0000	HWID_2 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100B0000	HWID_3 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100C0000	HWID_4 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100D0000	HWID_5 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100E0000	HWID_6 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
100F0000	HWID_7 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
10100000	HWID_8 is not a valid hardware identifier. Possible cause: No module with this hardware identifier available.	
10110000	The value at input parameter PIP_PART is outside the valid range of 1 ... 31.	Correct the value at the PIP_PART input parameter.
10120000	The value "2" is configured at the input parameter PIP_Mode, while the value > 1 (reduction ratio) is configured at the static parameter AppCycleFactor.	Correct the value at the PIP_Mode input parameter. PIP_Mode with the value "2" does not allow a reduction ratio.
x0130000	MC-Servo (OB91) is not isochronous to the bus cycle time.	Correct the value of the cycle time of the MC-Servo to the value of the bus cycle time. Note: Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.
x014xxxx	An error has occurred when reading the data record. The low word xxxx indicates the error information of the instruction RDREC.	Read the description of the instruction RDREC in the STEP 7 (TIA Portal) information system.
x0FF0000	General internal error.	—

* Available only when "0" is selected for the input parameter PIP_Mode.

4.3.2 TIO_DI: Reading in edges at digital input and associated time stamps

Description

TIO_DI continuously detects the edges at a digital input of a TIO module and returns the associated time stamps.

Startup characteristics

During startup of the CPU, the instruction TIO_DI applies the input parameters once and checks the following:

- Checking HWID
- Checking to see if the number of the digital input (Channel) is in the permitted range (depending on addressed module and channel configuration)
- Checking TIO_SYNC_Data.ERROR: Is an error present at TIO_SYNC?
- Checking TIO_SYNC_Data.TO_TIMES for plausibility (0 ms to 4 ms)
- Checking to see whether the OB is isochronous

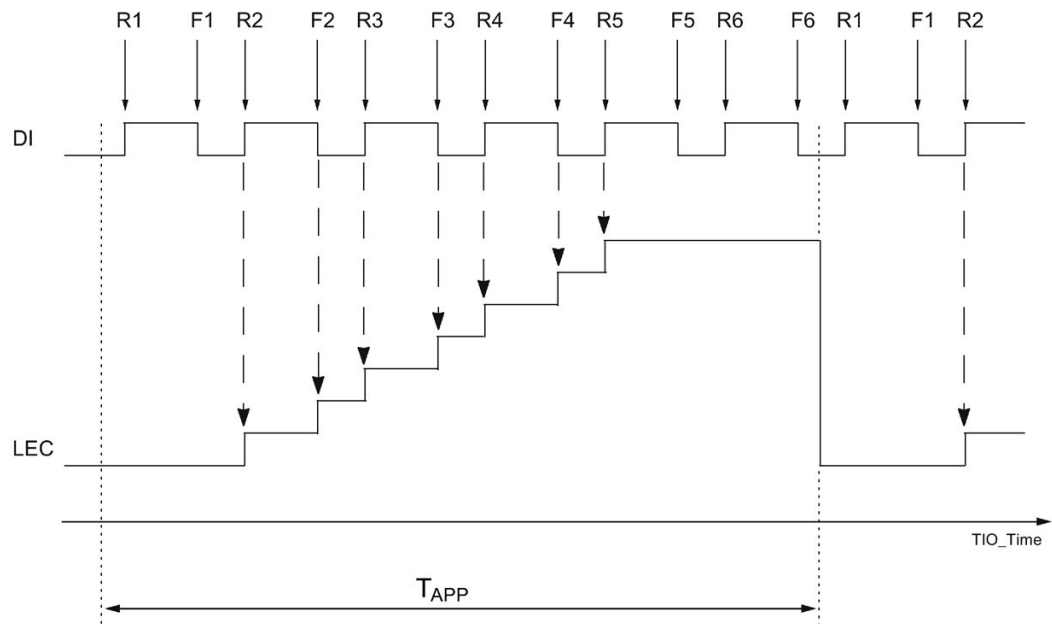
If startup takes place without errors, the instruction changes to normal operation. In the event of an error, the instruction does not change to normal operation and generates an error message.

Functional description

In normal operation, the instruction detects the edges at a digital input and the associated time stamps of the last valid, defined edge pair from the preceding isochronous cycle. Use the input parameter EdgeSel to determine the edges for which time stamps are detected.

You connect the input TIO_SYNC_Data with the output of the same name of the TIO_SYNC instruction. This ensures a shared time basis.

The following figure shows an example of the behavior of LEC when a read-in job is started with EdgeSel = 3 (rising and falling edge, order depending on occurrence).



- T_{APP} Application cycle
- R_n Specified times of a positive DI edge
- F_n Specified times of a falling DI edge

The module can count a maximum of seven edges per application cycle. LEC = 7 means therefore that seven or more edges have been counted.

Reaction to error

The Error output indicates if the instruction was processed correctly. In the event of an error, the cause of the error is displayed at the Status output.

Parameter

The table below shows the parameters of the TIO_DI instruction.

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0			
HWID*	Input		HW_IO	0	Hardware identifier for TIO module from hardware configuration
Channel*	Input		UInt	0	Number (0 ... m) of the digital input of the connected TIO module
EdgeSel	Input		UInt	3	Specify the edges for which time stamps are detected: 0b: Invalid 1: Two rising edges 2: Two falling edges 3: Rising and falling edge (order depending on occurrence) 4: First rising, then falling edge 5: First falling, then rising edge 6 to 255: Invalid EdgeSel can be changed during normal operation.
DI	Output		Bool	False	Status of digital input. If an inversion of the digital input is configured, this parameter is inverted as well.
TimeStampRE	Output		LTime	LT#0ns	Time stamp: Time at which a positive edge was detected. Exception: EdgeSel = 2: Time at which a falling edge has been detected (if <i>multiple</i> falling edges have occurred during the application cycle).
TimeStampFE	Output		LTime	LT#0ns	Time stamp: Time at which a falling edge was detected. Exception: EdgeSel = 1: Time at which a rising edge has been detected (if <i>multiple</i> rising edges have occurred during the application cycle).
EventCountRE	Output		UInt	0	Counter: Is incremented with each new, valid time stamp at a positive edge. The counter is reset with each CPU startup.
EventCountFE	Output		UInt	0	Counter: Is incremented with each new, valid time stamp at a falling edge. The counter is reset with each CPU startup.
LEC	Output		UInt	0	Counter: Number of edges for which no time stamp could be saved. The module can count a maximum of seven edges per application cycle. The counter is reset with each new application cycle.
Status	Output		DWord	16#0	Status of the instruction: see description of Status parameter

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0	S7-1500		
Error	Output		Bool	False	Error = True: An error has occurred. For detailed information see Status parameter. Error is reset as soon as the error is corrected.
TIO_SYNC_Data*	Input	InOut	"TIO_SYNC_Data"		System time provided for the TIO instructions of the TIO modules by the TIO_SYNC instruction. See UDT TIO_SYNC_Data (Page 58). Connect this input parameter with the "TIO_SYNC_Data" output parameter of the TIO_SYNC instruction.

* Checked once at startup of the CPU

Status parameter

Error codes or status information is output as double word at the Status output.

The double word is divided as follows:

Error code (DW#16#...)	Meaning
z0yywww	Error of a system function: <ul style="list-style-type: none"> during startup (z = 1) during normal operation (z = 0) System functions with subordinate use are coded in yy: See table with error codes. www specifies the RET_VAL of the system function. The error information is available in the help for the system function.
z0yy0000	An error that does not originate in a system function. This error receives a consecutive error number yy. The error can occur: <ul style="list-style-type: none"> during startup (z = 1) during normal operation (z = 0)

Table with error codes

Error code (DW#16#...)	Meaning	Solution
00000000	No error.	—
10010000	The assigned number of the digital input at the Channel input parameter is outside the permitted range (depending on addressed module and channel configuration).	Correct the value at the Channel input parameter.
10020000	The TIO_DI instruction is not called in an isochronous OB. The instruction can only be used without errors in an isochronous OB.	Make sure that TIO_DI is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10030000	An error occurred when reading the HWID input parameter.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
x0040000	The data in TIO_SYNC_Data is invalid/incorrect.	Check the TIO_SYNC instruction and the interconnection of its TIO_SYNC_Data output.
1005xxxx	An error has occurred during execution of the RD_SINFO system function. The low word xxxx displays the error information of the RET_VAL return value from RD_SINFO.	<ul style="list-style-type: none"> Read the description of the RD_SINFO in the STEP 7 (TIA Portal) information system. Make sure that TIO_DI is called in a "Synchronous Cycle" or "MC-PostServo" OB.

Error code (DW#16#...)	Meaning	Solution
10060000	No TIO module found. Possible cause: The module configured using the hardware identifier is not a TIO module.	<ul style="list-style-type: none"> Make sure that the configured module is a TIO module. Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration.
10070000	An internal error occurred during the address calculation.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
00080000	TIO module is not synchronized using the TIO_SYNC instruction. The error code can also indicate that: <ul style="list-style-type: none"> A job was already present before the first run of the instruction. The assigned number at the Channel input parameter is not a digital input. 	Check the instruction TIO_SYNC.
10090000	The read cycle time of the isochronous OB is outside the permitted range of $0 < T_{APP} \leq 16$ ms and is therefore invalid. The instruction can only be used without errors in an isochronous OB.	<ul style="list-style-type: none"> Correct the cycle time. Make sure that TIO_DI is called in a "Synchronous Cycle" or "MC-PostServo" OB.
100A0000	The time T_o of the TIO model stored in TIO_SYNC_Data is outside the permissible range of $0 < T_o \leq 4$ ms.	Check the instruction TIO_SYNC.
100Bxxxx	An error has occurred during execution of the RD_ADDR system function. The low word xxxx displays the error information of the RET_VAL return value from RD_ADDR.	Read the description of the RD_ADDR in the STEP 7 (TIA Portal) information system.
000C0000	The converted time stamp is invalid. Possible cause: Communication error	Check the communication with the TIO module.
000D0000	The Quality Information of the digital input indicates that an error has occurred at the digital input.	Check the supply voltage L+/1L+/2L+.
000E0000	The assigned number at the Channel input parameter is not a digital input configured as Timer DI.	<ul style="list-style-type: none"> Check the channel configuration (only for TM Timer DIDQ 16x24V). Check the operating mode of the digital input.
000F0000	The assigned value at the EdgeSel input parameter is outside the valid range of 1 to 5.	Correct the value at the EdgeSel input parameter.

Error code (DW#16#...)	Meaning	Solution
10100000	The send clock is outside the permitted range of 0 < SendClock <= 4 ms and is therefore invalid. The error code can also indicate that <ul style="list-style-type: none"> • The data in TIO_SYNC_Data is invalid or does not exist. • The TIO_DI instruction is not called in an isochronous OB. 	Correct the send clock.
x0130000	MC-Servo (OB91) is not isochronous to the bus cycle time.	Correct the value of the cycle time of the MC-Servo to the value of the bus cycle time. Note: Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.
10140000	The configured value at the HWID input parameter is not present in the structure at the TIO_SYNC_Data parameter. The HWID and TIO_SYNC_Data parameters are not consistent.	Correct the value at the HWID input parameter or the structure at the TIO_SYNC_Data parameter.
x0FF0000	General internal error.	—

4.3.3 TIO_DI_ONCE: Reading in edges once at the digital input and associated time stamps

Description

TIO_DI_ONCE detects the edges at a digital input of a TIO module **once** and returns the associated time stamps. Alternatively, you can use this instruction to control a timer DI channel that is configured as an edge-triggered enable for another channel.

Startup characteristics

During startup of the CPU, the instruction TIO_DI_ONCE applies the input parameters once and checks the following:

- Checking HWID
- Checking to see if the number of the digital input (Channel) is in the permitted range (depending on addressed module and channel configuration)
- Checking TIO_SYNC_Data.ERROR: Is an error present at TIO_SYNC?
- Checking TIO_SYNC_Data.TO_TIMES for plausibility (0 ms to 4 ms)
- Checking to see whether the OB is isochronous

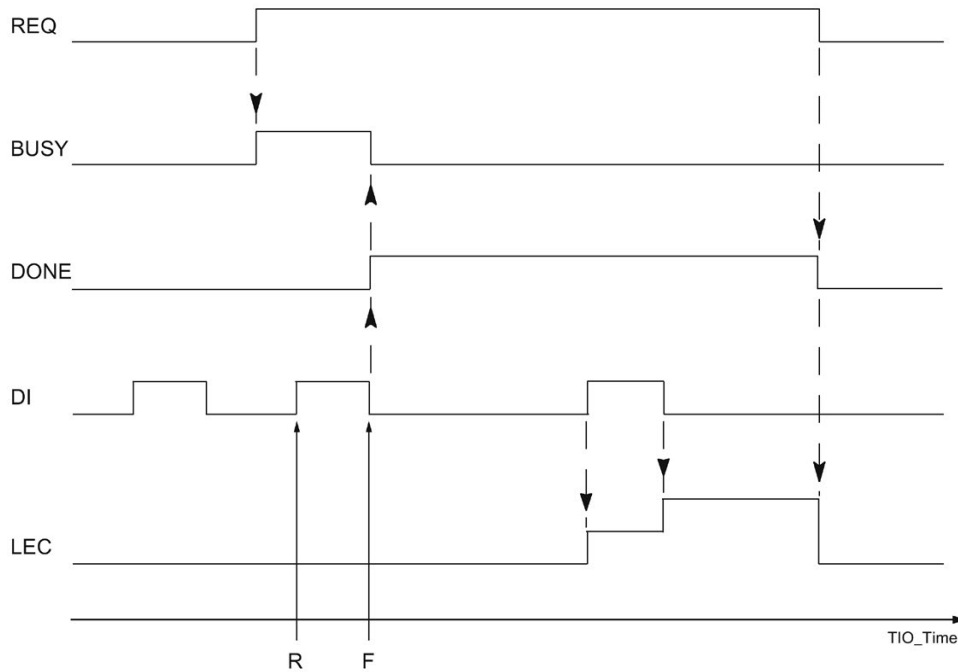
If startup takes place without errors, the instruction changes to normal operation. In the event of an error, the instruction does not change to normal operation and generates an error message.

Functional description: Time stamp detection

In normal operation, the instruction detects the edges at a digital input and the associated time stamps of the **first** valid, defined edge pair after the start of a read-in job. Use the input parameter EdgeSel to determine the edges for which time stamps are detected. To detect a new edge pair, a new positive edge is required at the REQ input parameter of the instruction.

You connect the input TIO_SYNC_Data with the output of the same name of the TIO_SYNC instruction. This ensures a shared time basis.

The figure below shows an example for the reaction of the bits DONE and BUSY at the start of a read-in job (EdgeSel = 4).



R Read-in time of the positive DI edge
 F Read-in time of the falling DI edge

Functional description: edge-triggered enable

You can use this instruction to control a timer DI channel that is configured as an edge-triggered enable for another channel.

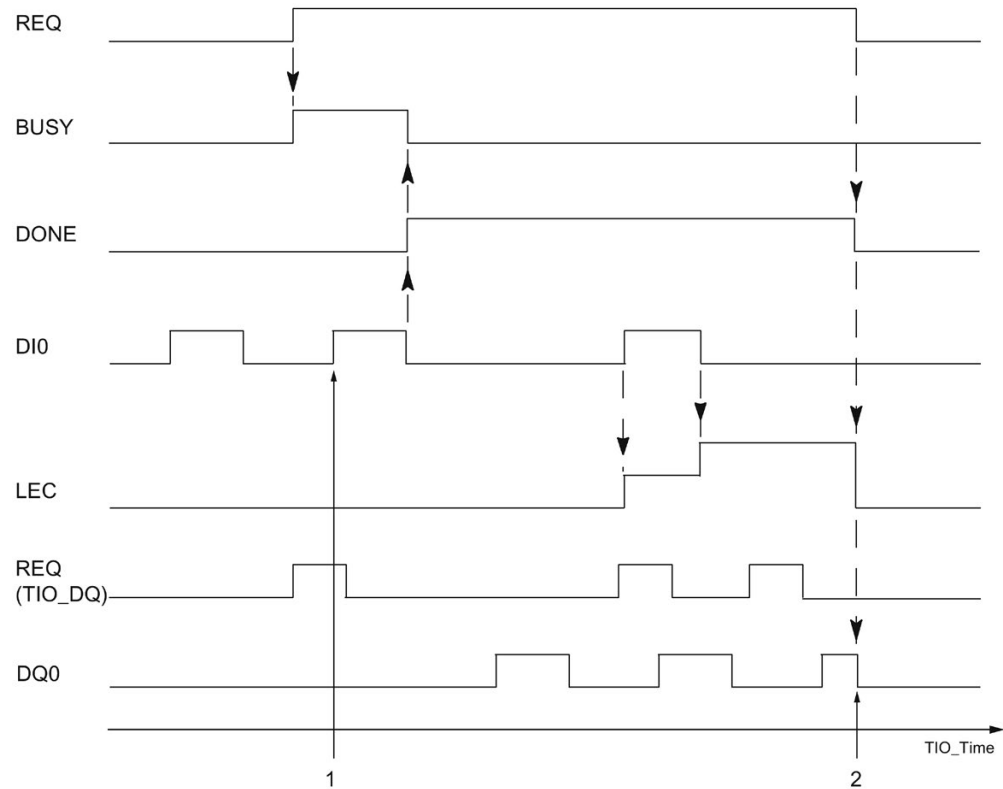
Example:

For a TIO module TM Timer DIDQ 10x24V, the following is configured in the hardware configuration for DQ0/DI0:

- Configuration DQ/DI group = timer DQ with enable
- HW enable by DI0 = edge-triggered
- DQ0 is not inverted

In this case, use the instruction TIO_DQ for DQ0 and the instruction TIO_DI_ONCE for DI0. You can control the enable by means of the input parameters REQ and EdgeSel of TIO_DI_ONCE. As soon as TIO_DI_ONCE has recorded a time stamp according to the value of EdgeSel, the enable is considered granted. You take the enable back by resetting REQ.

The following figure shows an example with EdgeSel = 4n (first positive, then falling edge). In this case the first valid positive edge at DI0 grants the enable for DQ0 after the start of a read-in job.



- 1 Start of enable at positive edge of enable input
- 2 End of enable when falling edge at REQ

If required, you can use the time stamps detected by the instruction for your application.

Reaction to error

The Error output indicates if the instruction was processed correctly. In the event of an error, the cause of the error is displayed at the Status output.

Parameter

The table below shows the parameters of the TIO_DI_ONCE instruction.

Parameter	Declaration	Data type	Default	Description
		S7-1500		
REQ	Input	Bool	False	Starts the job at a positive edge.
HWID*	Input	HW_IO	0	Hardware identifier for TIO module from hardware configuration
Channel*	Input	UInt	0	Number (0 ... m) of the digital input of the connected TIO module
EdgeSel	Input	UInt	3	Specify the edges for which time stamps are detected: 0: Invalid 1: Two rising edges 2: Two falling edges 3: Rising and falling edge (order depending on occurrence) 4: First rising, then falling edge 5: First falling, then rising edge 6 to 255: Invalid If edge-triggered enable is used, the following also applies: 1: Enable at first positive DI edge 2: Enable at first falling DI edge 3: Enable at first DI edge 4: Enable at first positive DI edge 5: Enable at first falling DI edge EdgeSel can be changed during normal operation.
DONE	Output	Bool	False	DONE = True: The job was completed without errors.
BUSY	Output	Bool	False	BUSY = True: The job has not yet been completed.
Error	Output	Bool	False	Error = True: An error has occurred. For detailed information see Status parameter. Error is reset as soon as the error is corrected.
Status	Output	DWord	16#0	Status of the instruction: see description of Status parameter
DI	Output	Bool	False	Status of digital input. If an inversion of the digital input is configured, this parameter is inverted as well.
Time-StampRE	Output	LTime	LT#0ns	Time stamp: EdgeSel = 1: The last but one read-in time at which a positive edge was detected (if <i>multiple</i> positive edges have occurred). EdgeSel = 2: The last read-in time at which a falling edge was detected (if <i>multiple</i> falling edges have occurred). EdgeSel = 3; 4; 5: The last read-in time at which a falling edge was detected.

Parameter	Declaration	Data type	Default	Description
		S7-1500		
Time-StampFE	Output	LTime	LT#0ns	Time stamp: EdgeSel = 1: The last read-in time at which a positive edge was detected (if <i>multiple</i> positive edges have occurred). EdgeSel = 2: The last but one read-in time at which a falling edge was detected (if <i>multiple</i> falling edges have occurred). EdgeSel = 3; 4; 5: The last read-in time at which a positive edge was detected.
LEC	Output	UInt	0	Counter: Number of edges for which no time stamp could be saved. The module can count a maximum of seven edges during REQ. The counter is reset with the falling edge at REQ.
TIO_SYNC_Data*	InOut	"TIO_SYNC_Data"		System time provided for the TIO instructions of the TIO modules by the TIO_SYNC instruction. See UDT TIO_SYNC_Data (Page 58). Connect this input parameter with the "TIO_SYNC_Data" output parameter of the TIO_SYNC instruction.
Initialized	Static	Bool	False	Instruction is initialized and ready

* Checked once at startup of the CPU

Status parameter

Error codes or status information is output as double word at the Status output.

The double word is divided as follows:

Error code (DW#16#...)	Meaning
z0yywww	Error of a system function: <ul style="list-style-type: none"> during startup (z = 1) during normal operation (z = 0) System functions with subordinate use are coded in yy: See table with error codes. www specifies the RET_VAL of the system function. The error information is available in the help for the system function.
z0yy0000	An error that does not originate in a system function. This error receives a consecutive error number yy. The error can occur: <ul style="list-style-type: none"> during startup (z = 1) during normal operation (z = 0)

Table with error codes

Error code (DW#16#...)	Meaning	Solution
00000000	No error.	—
10010000	The assigned number of the digital input at the Channel input parameter is outside the permitted range (depending on addressed module and channel configuration).	Correct the value at the Channel input parameter.
10020000	The TIO_DI_ONCE instruction is not called in an isochronous OB. The instruction can only be used without errors in an isochronous OB.	Make sure that TIO_DI_ONCE is called in a "Synchronous Cycle" or "MC-PostServo" OB.
10030000	An error occurred when reading the HWID input parameter.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
x0040000	The data in TIO_SYNC_Data is invalid/incorrect.	Check the TIO_SYNC instruction and the interconnection of its TIO_SYNC_Data output.
1005xxxx	An error has occurred during execution of the RD_SINFO system function. The low word xxxx displays the error information of the RET_VAL return value from RD_SINFO.	<ul style="list-style-type: none"> Read the description of the RD_SINFO in the STEP 7 (TIA Portal) information system. Make sure that TIO_DI_ONCE is called in a "Synchronous Cycle" or "MC-PostServo" OB.

Error code (DW#16#...)	Meaning	Solution
10060000	No TIO module found. Possible cause: The module configured using the hardware identifier is not a TIO module.	<ul style="list-style-type: none"> Make sure that the configured module is a TIO module. Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration.
10070000	An internal error occurred during the address calculation.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
00080000	TIO module is not synchronized using the TIO_SYNC instruction. The error code can also indicate that: <ul style="list-style-type: none"> A job was already present before the first run of the instruction. The assigned number at the Channel input parameter is not a digital input. 	Check the instruction TIO_SYNC.
10090000	The read cycle time of the isochronous OB is outside the permitted range of $0 < T_{APP} \leq 16$ ms and is therefore invalid. The instruction can only be used without errors in an isochronous OB.	<ul style="list-style-type: none"> Correct the cycle time. Make sure that TIO_DI_ONCE is called in a "Synchronous Cycle" or "MC-PostServo" OB.
100A0000	The time T_o of the TIO model stored in TIO_SYNC_Data is outside the permissible range of $0 < T_o \leq 4$ ms.	Check the instruction TIO_SYNC.
100Bxxxx	An error has occurred during execution of the RD_ADDR system function. The low word xxxx displays the error information of the RET_VAL return value from RD_ADDR.	Read the description of the RD_ADDR in the STEP 7 (TIA Portal) information system.
000C0000	The converted time stamp is invalid. Possible cause: Communication error	Check the communication with the TIO module.
000D0000	The Quality Information of the digital input indicates that an error has occurred at the digital input.	Check the supply voltage L+/1L+/2L+.
000E0000	The assigned number at the Channel input parameter is not a digital input configured as Timer DI.	<ul style="list-style-type: none"> Check the channel configuration (only for TM Timer DIDQ 16x24V). Check the operating mode of the digital input.
000F0000	The assigned value at the EdgeSel input parameter is outside the valid range of 1 to 5.	Correct the value at the EdgeSel input parameter.

Error code (DW#16#...)	Meaning	Solution
10100000	The send clock is outside the permitted range of 0 < SendClock <= 4 ms and is therefore invalid. The error code can also indicate that <ul style="list-style-type: none"> • The data in TIO_SYNC_Data is invalid or does not exist. • The TIO_DI instruction is not called in an isochronous OB. 	Correct the send clock.
x0130000	MC-Servo (OB91) is not isochronous to the bus cycle time.	Correct the value of the cycle time of the MC-Servo to the value of the bus cycle time. Note: Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.
10140000	The configured value at the HWID input parameter is not present in the structure at the TIO_SYNC_Data parameter. The HWID and TIO_SYNC_Data parameters are not consistent.	Correct the value at the HWID input parameter or the structure at the TIO_SYNC_Data parameter.
x0FF0000	General internal error.	—

4.3.4 TIO_DQ: Output edges time-controlled at the digital output

Description

TIO_DQ enables a digital output of a TIO module to be switched at specified times.

Startup characteristics

During startup of the CPU, the instruction TIO_DQ applies the input parameters once and checks the following:

- Checking HWID
- Checking to see if the number of the digital input (Channel) is in the permitted range (depending on addressed module and channel configuration)
- Checking TIO_SYNC_Data.Error: Is an error present at TIO_SYNC?
- Checking TIO_SYNC_Data.TO_TIMES for plausibility (0 ms to 4 ms)
- Checking to see whether the OB is isochronous

If startup takes place without errors, the instruction changes to normal operation. The input parameters REQ, Out_Mode, TimeStampRE and TimeStampFE can be changed during normal operation. In the event of an error, the instruction does not change to normal operation and generates an error message.

Functional description

The instruction outputs edges time-controlled at a digital output during normal operation.

- At the time defined at the TimeStampRE input parameter, a positive edge is output at the digital output.
- At the time defined at the TimeStampFE input parameter, a falling edge is output at the digital output.

Depending on the program execution model, a time stamp must exceed the following value:

Program execution model	TimeStampRE > ... TimeStampFE > ...
IPO model	$TIO_Time + T_{APP} + T_O$
OIP model	$TIO_Time + T_{APP} + SendClock + T_O$

Use the input parameter Out_Mode to determine if only one edge or both edges are output.

You connect the input TIO_SYNC_Data with the output of the same name of the TIO_SYNC instruction. This ensures a shared time basis.

You start an output job with a positive edge at the REQ parameter. You can only start a new job when there is no error pending and no job is active. When the output job is started, the digital output is switched at the times defined with TimeStampRE and TimeStampFE.

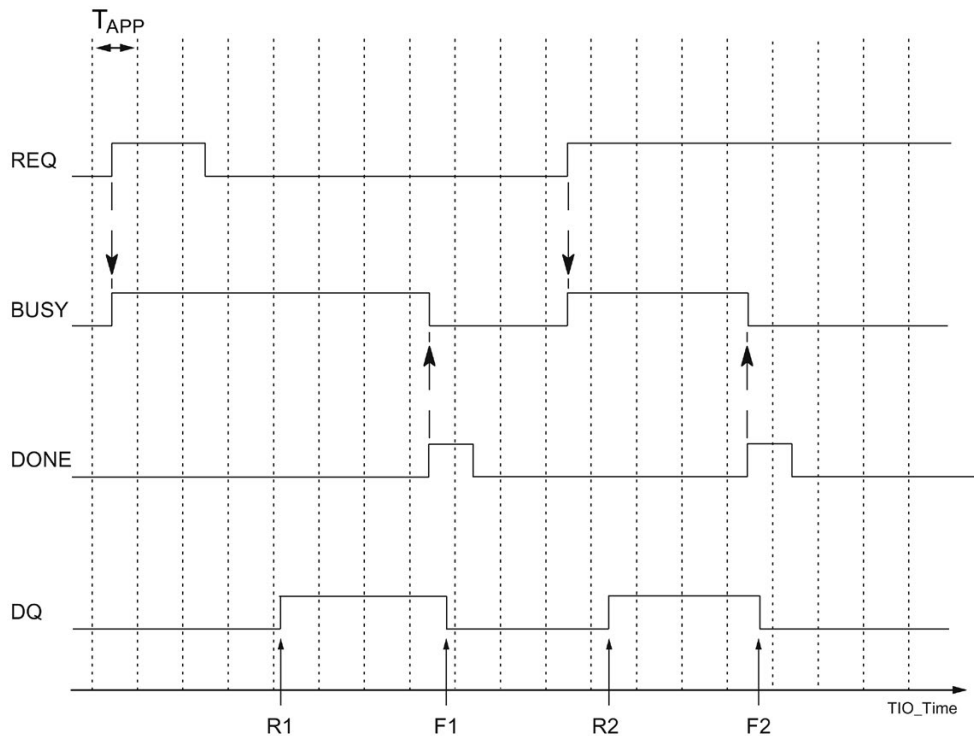
- If the digital output is already set at time TimeStampRE, the output job is not transferred to the module for the positive edge.
- If the digital output is not set at time TimeStampFE, the output job is not transferred to the module for the negative edge.

This means the digital output is not switched in both cases.

The job is done when the last application cycle is executed before the second output time is reached (DONE). Status and Error are constantly being updated during the job runtime. You can cancel an active output job by changing TimeStampRE or TimeStampFE to an invalid time stamp, e.g. LT#5µs.

The figure below shows an example for the reaction of the bits DONE and BUSY at the start of an output job under the following conditions:

- Out_Mode = 2 (both edges are output)
- The two time stamps are not changed between the start of the job and the output.



- T_{APP} Application cycle
- R1, R2 Specified times of a positive DQ edge
- F1, F2 Specified times of a falling DQ edge

Note

Once the job has been started with a positive edge at REQ, you can change the output times with a new input of TimeStampRE and TimeStampFE without having to restart the job.

Constraint:

If a changed time stamp is less than two application cycles before the output time ($\text{TimeStampRE} - \text{TIO_Time} < 2 \cdot T_{\text{APP}}$ or $\text{TimeStampFE} - \text{TIO_Time} < 2 \cdot T_{\text{APP}}$), it is not taken into consideration. In this case, the last valid time stamp is used because it was already transferred to the TIO module.

Note

If you specify the same value for TimeStampRE and TimeStampFE, the instruction ignores the job and does not output an edge.

If you specify the value 0 for TimeStampRE or TimeStampFE, you can output the respective edge directly at the digital output with the input parameter Out_Mode = 3. This gives you the option to implement a direct control from the TIO module without time stamp in manual mode. You can use the direct control to interrupt an ongoing job.

Reaction to error

The Error output indicates if the instruction was processed correctly. In the event of an error, the cause of the error is displayed at the Status output.

Parameter

The table below shows the parameters of the TIO_DQ instruction.

Parameter	Declaration in library version		Data type	Default	Description
	< V2.0	≥ V2.0			
			S7-1500		
REQ	Input		Bool	False	Starts the job at a positive edge.
HWID*	Input		HW_IO	0	Hardware identifier for TIO module from hardware configuration
Channel*	Input		UInt	0	Number (0 ... m) of the digital output of the connected TIO module
Out_Mode	Input		UInt	2	Specify the output mode for the edges at the digital output: 0: Only rising edge is output (TimeStampRE). 1: Only falling edge is output (TimeStampFE). 2: Both edges are output (TimeStampRE and TimeStampFE). 3: Each edge is output directly if TimeStampRE = 0 or TimeStampFE = 0. If both time stamps have the value "0" or if no time stamp has the value "0", no edge is output. 4 to 255: Invalid
TimeStampRE	Input		LTime	LT#0ns	Time stamp: Time when a positive edge is to be output.
TimeStampFE	Input		LTime	LT#0ns	Time stamp: Time when a falling edge is to be output.
StatusDQ	Output		Bool	False	Actual status of the digital output. If an inversion of the digital output is configured, StatusDQ is inverted as well. StatusDQ shows the internal state of the digital output independent of the effect of any configured HW enable.
DONE	Output		Bool	False	DONE = True is displayed for one cycle: The job was completed without errors.
BUSY	Output		Bool	False	BUSY = True: The job has not yet been completed.
Error	Output		Bool	False	Error = True: An error has occurred. In this case, BUSY and DONE are set to False. For detailed information see Status parameter. Error is reset as soon as the error is corrected.
Status	Output		DWord	16#0	Status of the instruction: see description of Status parameter
TIO_SYNC_Data*	Input	InOut	"TIO_SYNC_Data"		System time provided for the TIO instructions of the TIO modules by the TIO_SYNC instruction. See UDT TIO_SYNC_Data (Page 58). Connect this parameter with the TIO_SYNC_Data output parameter of the TIO_SYNC instruction.

* Checked once at startup of the CPU

Status parameter

Error codes or status information is output as double word at the Status output.

The double word is divided as follows:

Error code (DW#16#...)	Meaning
z0yywww	<p>Error of a system function:</p> <ul style="list-style-type: none"> during startup (z = 1) during normal operation (z = 0) <p>System functions with subordinate use are coded in yy: See table with error codes. www specifies the RET_VAL of the system function. The error information is available in the help for the system function.</p>
z0yy0000	<p>An error that does not originate in a system function. This error receives a consecutive error number yy. The error can occur:</p> <ul style="list-style-type: none"> during startup (z = 1) during normal operation (z = 0)

Table with error codes

Error code (DW#16#...)	Meaning	Solution
00000000	No error.	—
10010000	The assigned number of the digital output at the Channel input parameter is outside the permitted range (depending on addressed module and channel configuration).	Correct the value at the Channel input parameter.
10020000	The TIO_DQ instruction is not called in an isochronous OB. The instruction can only be used without errors in an isochronous OB.	Make sure that TIO_DQ is called in an OB of the type "Synchronous Cycle" or "MC-PostServo".
10030000	An error occurred when reading the HWID input parameter.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
x0040000	The data in TIO_SYNC_Data is invalid/incorrect.	Check the TIO_SYNC instruction and the interconnection of its TIO_SYNC_Data output.
1005xxxx	An error has occurred during execution of the RD_SINFO system function. The low word xxxx displays the error information of the RET_VAL return value from RD_SINFO.	<ul style="list-style-type: none"> Read the description of the RD_SINFO in the STEP 7 (TIA Portal) information system. Make sure that TIO_DQ is called in a "Synchronous Cycle" or "MC-PostServo" OB.

4.3 Time-based IO

Error code (DW#16#...)	Meaning	Solution
10060000	No TIO module found. Possible cause: The module configured using the hardware identifier is not a TIO module.	<ul style="list-style-type: none"> Make sure that the configured module is a TIO module. Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration.
10070000	An internal error occurred during the address calculation.	Check the value at the HWID input parameter. Specify the hardware identifier of the TIO module from its module properties in the hardware configuration. An internal system constant of data type Hw_SubModule is available for the symbolic addressing.
x0080000	TIO module is not synchronized using the TIO_SYNC instruction. The error code can also indicate that: <ul style="list-style-type: none"> A job was already present before the first run of the instruction. The assigned number at the Channel input parameter is not a digital output. 	Check the instruction TIO_SYNC.
10090000	The read cycle time of the isochronous OB is LT#0ms or has as negative value and is therefore invalid. Correct the value. The instruction can only be used without errors in an isochronous OB.	<ul style="list-style-type: none"> Correct the cycle time. Make sure that TIO_DQ is called in a "Synchronous Cycle" or "MC-PostServo" OB.
100A0000	The time T_0 of the TIO model stored in TIO_SYNC_Data is outside the permissible range of $0 < T_0 \leq 4$ ms.	Check the instruction TIO_SYNC.
100Bxxxx	An error has occurred during execution of the RD_ADDR system function. The low word xxxx displays the error information of the RET_VAL return value from RD_ADDR.	Read the description of the RD_ADDR in the STEP 7 (TIA Portal) information system.
000C0000	One or both time stamps at the TimeStampRE and TimeStampFE input parameters are invalid. The error is only signaled for the duration of one application cycle.	Check the TimeStampRE and TimeStampFE input parameters.
000D0000	The Quality Information of the digital output indicates that an error has occurred at the digital output.	<ul style="list-style-type: none"> Check the parameter assignment of the digital output. Check the supply voltage L+/1L+/2L+. Check the wiring of the digital output for short-circuit, overload, and overtemperature.
000E0000	The number configured at the Channel input parameter is not a digital output configured as Timer DQ.	<ul style="list-style-type: none"> Check the channel configuration (only for TM Timer DIDQ 16x24V). Check the operating mode of the digital output.
100F0000	The read cycle time of the OB of type "Synchronous Cycle" is too long: $T_{APP} > 16$ ms.	Configure a smaller multiple of the send clock as the cycle time.

Error code (DW#16#...)	Meaning	Solution
10100000	The send clock is outside the permitted range of $0 < \text{SEND_CLOCK} \leq 4$ ms and is therefore invalid. The error code can also indicate that <ul style="list-style-type: none"> The data in TIO_SYNC_Data is invalid or does not exist. The TIO_DQ instruction is not called in an isochronous OB. 	Correct the send clock.
00110000	The assigned value at the Out_Mode input parameter is outside the valid range of 0 to 3.	Correct the value at the Out_Mode input parameter.
x0130000	MC-Servo (OB91) is not isochronous to the bus cycle time.	Correct the value of the cycle time of the MC-Servo to the value of the bus cycle time. Note: Calling TIO instructions in an OB of the type "MC-PostServo" with reduction ratio "MC-Servo" can result in incorrect calculation of time stamps.
10140000	The configured value at the HWID input parameter is not present in the structure at the TIO_SYNC_Data parameter. The HWID and TIO_SYNC_Data parameters are not consistent.	Correct the value at the HWID input parameter or the structure at the TIO_SYNC_Data parameter.
x0FF0000	General internal error.	—

4.3.5 UDT TIO_SYNC_Data

Description

The data type UDT TIO_SYNC_Data contains the central structure and data for synchronization of the modules and passing of the TIO_Time.

Parameter

Parameter	Data type	Description
	S7-1500	
TIO_TIME	LTime	Shared time basis (relative time) of the TIO modules
PIP_MODE	USInt	Mode for data update (is forwarded by the PIP_Mode input parameter of the TIO_SYNC instruction)
APP_CYC	LTime	Application cycle of the "MC-PostServo" or "Synchronous Cycle", "MC-PreServo" OB
SEND_CLOCK	LTime	Send clock of sync domain (is forwarded by the SendClock parameter of the TIO_SYNC instruction)
SYNC_MODULES	HW_IO array [1...8]	Hardware identifiers of the TIO modules from hardware configuration
TO_TIMES	UDInt-Array [1...8]	T _O for each TIO module:
TIO_TIME_BASE	LTime	Internal use
TBASE	LTime	
ERROR	Bool	

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SIEMENS

SIMATIC

S7-1500, ET 200MP, ET 200SP, ET 200AL Designing interference-free controllers

Function Manual




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Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER
indicates that death or severe personal injury will result if proper precautions are not taken.
 WARNING
indicates that death or severe personal injury may result if proper precautions are not taken.
 CAUTION
indicates that minor personal injury can result if proper precautions are not taken.
NOTICE
indicates that property damage can result if proper precautions are not taken.


If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

 WARNING
Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

Trademarks

All names identified by ® are registered trademarks of Siemens AG. The remaining trademarks in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owner.

Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Preface

Purpose of the documentation

This documentation will support you in installing and commissioning programmable controllers.

Correct configuration is essential for fault-free operation of programmable controllers.

Basic knowledge required

The following knowledge is required in order to understand the documentation:

- General knowledge of automation technology
- Knowledge of the industrial automation system SIMATIC
- Knowledge of VDE (German Association for Electrical, Electronic and Information Technologies) and EC regulations
- Knowledge of the rules for installing controllers and switchgear

Conventions

You should also pay particular attention to notes such as the one shown below:

Note

A note contains important information on the product described in the documentation, on the handling of the product or on the section of the documentation to which particular attention should be paid.

Scope of the documentation

This documentation is valid for all products of the product series SIMATIC S7-1500, ET 200MP, ET 200SP and ET 200AL.

The product series SIMATIC S7-1500, ET 200MP and ET 200SP are approved for IP20 degree of protection, i.e. the modules of these product series must be installed in a control cabinet.

The SIMATIC ET 200AL product series is approved for IP65/IP67 degree of protection, i.e. the modules need **not** be installed in a control cabinet.

Changes compared to previous version

Changes / enhancements described in this manual, compared to the previous version (version 01/2013):

- Extension of the scope of validity to the distributed I/O system ET 200AL
- Supplement to the section Connection of the cable shielding for ET 200AL
- Components for lightning protection potential equalization amended

Additional support

Additional information on SIMATIC products is available on the Internet. The associated documentation is also available on the Internet.

- The range of technical documentation for the individual SIMATIC products and automation systems can be found on the Internet (<http://www.siemens.com/simatic-tech-doku-portal>).
- The online catalog and the ordering system are available on the Internet (<http://mall.automation.siemens.com>).

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens' products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates.

For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. You can find more information about industrial security on the Internet (<http://www.siemens.com/industrialsecurity>).

To stay informed about product updates as they occur, sign up for a product-specific newsletter. You can find more information on the Internet (<http://support.automation.siemens.com>).

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Documentation guide

Introduction

The documentation of the SIMATIC products has a modular structure and covers diverse topics concerning your automation system.

The complete documentation for the S7-1500, ET 200SP, ET 200MP and ET 200AL systems consists of the respective system manuals, function manuals and product manuals.

The STEP 7 information system (online help) also supports you when configuring and programming your automation system.

Overview of documentation on the subject of designing interference-free controllers

The following table lists additional documentation which supplements this description of designing interference-free controllers.

Table 1- 1 Documentation on the subject of designing interference-free controllers

Topic	Documentation	Most important contents
System description	System manual S7-1500 Automation System (http://support.automation.siemens.com/WW/view/en/59191792)	<ul style="list-style-type: none"> • Application planning • Installation • Wiring • Commissioning
	System manual ET 200SP Distributed I/O System (http://support.automation.siemens.com/WW/view/en/58649293)	
	System Manual ET 200MP Distributed I/O System (http://support.automation.siemens.com/WW/view/en/59193214)	
	System manual Distributed I/O System ET 200AL (http://support.automation.siemens.com/WW/view/en/89254965)	

SIMATIC manuals

All current manuals for SIMATIC products are available for download free of charge from the Internet (<http://www.siemens.com/automation/service&support>).

Basic information on electromagnetic compatibility

2

2.1 Overview of possible interference

Introduction

SIMATIC products and their components have been developed for use in industrial environment and meet the legal EMC requirements (EMC - Electromagnetic Compatibility). However, you still need to conduct an EMC assessment before installing your controller in order to identify possible sources of interference and to include these in your considerations.

Electromagnetic compatibility

Electromagnetic compatibility describes the ability of an electrical device to function properly in its particular electromagnetic environment. Neither the environment itself nor the electrical device are influenced in an unacceptable manner.

Possible interference

Electromagnetic interference can influence an automation system in various ways. The most significant interferences and their causes are as follows:

- Electromagnetic fields having a direct influence on the system
- Interference coupling caused by bus signals (for example, PROFINET)
- Interference influencing the system via the process wiring
- Interference which reaches the system via the power supply and/or protective ground

The figure below shows the likely paths of electromagnetic interference.

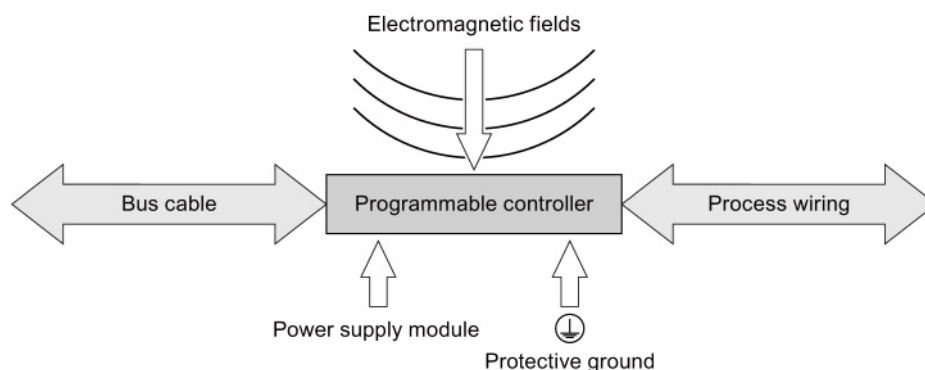


Figure 2-1 Electromagnetic interference

2.2 Coupling mechanisms

Depending on the emitting medium and the distance between the source of interference and the device, interference can reach the automation system via four different coupling mechanisms.

The following table shows possible causes and typical sources of interference for the various coupling mechanisms:

Table 2- 1 Coupling mechanisms

Coupling mechanism	Cause	Typical sources of interference
Galvanic coupling	Two electric circuits share the same cable	<ul style="list-style-type: none"> • Clocked devices (influence on the network due to converters and third-party power supply units) • Starting motors • Potential differences on component enclosures with shared power supply
Capacitive coupling	Potential difference between conductors	<ul style="list-style-type: none"> • Interference coupling due to parallel routing of signal cables • Static discharge of the operator
Inductive coupling	Mutual influencing of current-carrying conductor loops. The magnetic fields caused by the current flow induce interference voltages.	<ul style="list-style-type: none"> • Transformers, motors, electrical welding equipment • Power supply cables routed in parallel • Cables whose currents are switched • High-frequency signal cables • Unwired coils
Radiation coupling	Effect of an electromagnetic wave on a cable configuration. This wave induces currents and voltages.	<ul style="list-style-type: none"> • Neighboring transmitters (for example, walkie-talkies) • Spark gaps (spark plugs, collectors of electrical motors, welding devices)

Interference-free cable routing

This chapter describes the EMC-compatible classification of cables and cable routing for bus, data, signal and supply lines.

3.1 Classifying cables into cable categories

Classify the cables into cable categories according to their sensitivity to interference coupling and interference emission. The further away from one another cables of different cable categories are installed, the lower the mutual influence by capacitive and inductive coupling.

The following table shows the cable categories into which you can classify your cables accordingly.

Table 3- 1 Cable categories

Category A	<ul style="list-style-type: none"> • Signal lines to I/O modules • Bus and data lines (for example, PROFIBUS, PROFINET) • Lines to HMI devices • Supply lines for extra-low voltages (< 24V DC or < 60V AC)
Category B	<ul style="list-style-type: none"> • Supply lines with safe electrical isolation (SELV) • Supply voltages < 400 V
Category C	<ul style="list-style-type: none"> • Supply voltages > 400 V

3.1 Classifying cables into cable categories

The following table shows the minimum clearance you must maintain when installing cables.

Table 3-2 Combination of cable categories

	Category A	Category B	Category C
Category A	<ul style="list-style-type: none"> In common bundles or cable channels 	<ul style="list-style-type: none"> In separate bundles or cable channels (no minimum clearance necessary) 	<ul style="list-style-type: none"> Inside cabinets in separate bundles or cable channels Outside cabinets, but inside buildings, on separate cable racks with at least 10 cm clearance
Category B	<ul style="list-style-type: none"> In separate bundles or cable channels (no minimum clearance necessary) 	<ul style="list-style-type: none"> In common bundles or cable channels 	
Category C	<ul style="list-style-type: none"> Inside cabinets in separate bundles or cable channels Outside cabinets, but inside buildings, on separate cable racks with at least 10 cm clearance 		<ul style="list-style-type: none"> In common bundles or cable channels

If you install different cable categories in the same cable channel, use metallic cable channels with metallic partition.

The following figure show a schematic view of a cable channel with partition.

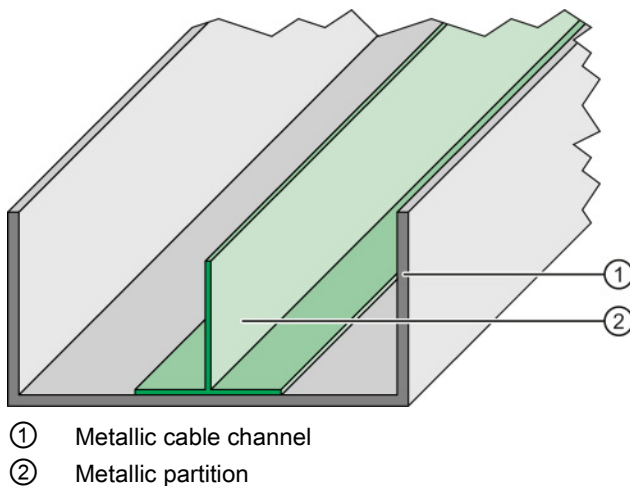


Figure 3-1 Cable channel with partition

3.2 Cable routing inside cabinets in buildings

Rule

Observe the following rules for proper cable routing inside of control cabinets:

- If a crossing of cables is unavoidable, then cross the cables at an angle of 90°, if possible, in order to keep interference from electrical fields as low as possible.
- Do not route cables coming into the cabinet from outside parallel to the shield supports.

3.3 Cable routing outside cabinets and inside buildings

Rule

Observe the following rules for proper cable routing outside control cabinets and inside buildings:

- Read the information in section Assigning cables to cable categories (Page 9).
- If you route the cables in metallic cable channels, you can rearrange the cable channels next to each other.
- Connect metallically conductive cable racks to the potential equalization of the building.
- If a crossing of cables is unavoidable, then cross the cables at an angle of 90°, if possible, in order to keep interference from electrical fields as low as possible.

3.4 Cable routing outside buildings

If possible, lay the cables outside buildings on metallic cable holders. Connect the cable holder joints galvanically to each other and ground the cable holders.

Rule

Observe the following rules when laying cables outside of buildings:

- Use metallic auxiliary terminal boxes to connect cables coming from outside at the junction to cables inside the building. Ground these boxes.
- If a crossing of cables is unavoidable, then cross the cables at an angle of 90°, if possible, in order to keep interference from electrical fields as low as possible.
- Integrate bus cables installed outside of buildings into your lightning and overvoltage concept.

Lightning protection

When you lay cables for SIMATIC devices outside of buildings, you have to take internal and external lightning protection measures.

Reference

For additional information about lightning protection, refer to chapter Lightning protection and overvoltage protection (Page 26).

3.5 Underground cable routing

Rule

Observe the following rules for underground cable routing:

- Lay the cable at least 60 cm below the ground surface.
- Install equipotential bonding approximately 20 cm above the cable. You can use a zinc-plated ground strip, for example. The ground strips also serve as protection against lightning strikes.
- Protect the cable against mechanical damage by, for example, using a plastic pipe and/or a cable warning tape in the ground, approximately 40 cm above the cable.
- Separate the various cable categories in the ground using cable channels, for example.

The following figure shows the arrangement of cable warning tape, equipotential bonding and a cable.

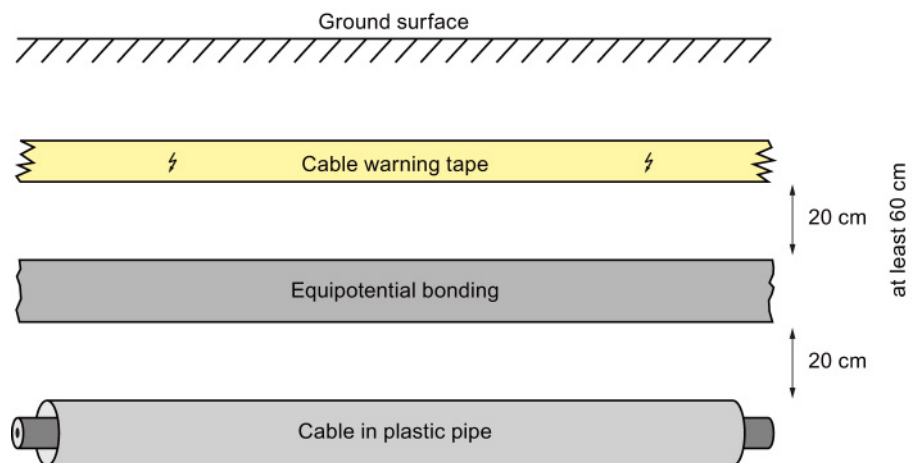


Figure 3-2 Arrangement underground

Lightning protection

When you lay cables for SIMATIC devices outside of buildings, you have to take internal and external lightning protection measures.

Reference

For additional information about lightning protection, refer to chapter Lightning protection and overvoltage protection (Page 26).

3.6 Bending radii and tensile strength of cables

Tensile strain

A high strain on the cables due to tensile forces leads to conductor material flow. The tensile forces thus cause a change in the structure of the material and lower the conductor cross-section. This decrease of the conductor cross-section leads, in turn, to a heating of the conductor and premature wear of the conductor insulation.

Use the supplied cable ties to relieve the terminal points on the plugs for the I/O modules of the product series SIMATIC S7-1500 and SIMATIC ET 200MP.

Bending radius

If you select too small bending radii when laying cables, this will cause the materials to stretch and compress and changes the mechanical structure of the cables. The electrical properties are impaired as a result.

Pay particular attention to the bending radii of fiber-optic cables. If the bending radii are too small, the optical properties of the fiber-optic cable are adversely affected. Reliable transmission is no longer guaranteed.

Cable shielding

Shielding is a measure to attenuate (dampen) magnetic, electrical or electromagnetic interference fields.

Interference currents on cable shields are diverted from the shield connection to ground. To avoid interference as a result of these currents, it is imperative to provide a low-impedance connection to the protective conductor.

Rules

Ideally, you should use cables equipped with a protective braided shield. The shield's contacting must be more than 80% at the contact point. Avoid tensile and compression strain on cables with a foil shield. This type of strain can damage the foil shield very slightly at the fastening point. The result is a reduced shielding effect.

Shield connection with grounding at both ends

Always connect the cable shields to the ground at both ends. Low and high frequency interference can be reduced only by connecting both ends of the shield to the ground.

Note

Laying an additional equipotential bonding cable

Whenever potential differences develop between the grounding points, an equalizing current flows on a shielding that is connected at both ends. In this case, lay an additional equipotential bonding cable. You can find more information on this topic in the chapter Equipotential bonding (Page 23).

Shield connection with capacitive grounding at one end

If you do not have the option of installing equipotential bonding (in plants covering a large area, for example), connect capacitive grounding to one end of your shield. In this case, only high-frequency interference will be reduced.

The following figure shows the capacitive grounding of a cable shield. The values indicated in the figure are indicative and will differ from system to system. The capacity diverts the high-frequency interference. This capacity provides high-impedance protection for the power frequency (50 or 60 Hz), thus preventing equalizing currents via the shield. A parallel switched high-impedance resistance prevents the capacity from loading a direct current.

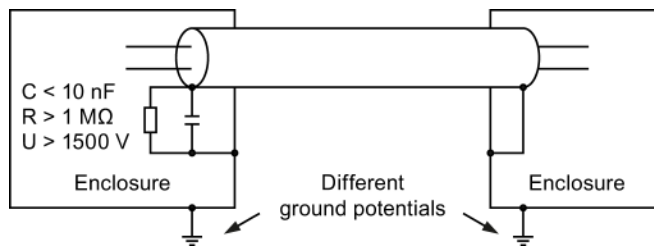


Figure 4-1 Capacitive grounding of the shield

4.1 Connecting the cable shielding for S7-1500 and ET 200MP

A special shield design has been developed for the automation system S7-1500 and the distributed I/O system ET 200MP for the shield connection of the signal lines. The connection element for the cable shield consists of a shield clamp and a shield terminal.

If the front connector is located in the module, the interference currents which occur are diverted by the connection element to the ground via the module and mounting rail.

The shield clamp is a pluggable mount for the analog and technology modules. The shield clamp allows the low-impedance application of cable shields with minimum installation times.

The following figure shows a front connector with mounted shield clamp and associated shield terminal.

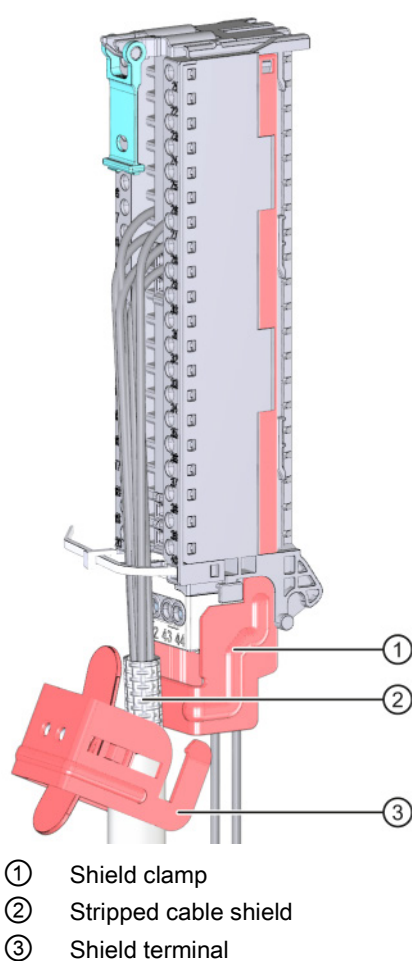


Figure 4-2 Shield clamp and shield terminal on front connector

The shield clamp is inserted from below onto the front connector until the shield clamp latches audibly. The shield terminal is fastened to the shield clamp.

Additional information

For additional information on installing the shield clamp and shield terminal, refer to the "Connecting front connectors" chapter in the S7-1500 automation system (<http://support.automation.siemens.com/WW/view/en/59191792>) or ET 200MP Distributed I/O System (<http://support.automation.siemens.com/WW/view/en/59193214>) system manuals.

4.2 Connecting the cable shielding for ET 200SP

A special shield design has been developed for the shield connection of the signal lines of the ET 200SP distributed I/O system. The connection element for the cable shield consists of a shield terminal.

If the front connector is located in the module, the interference currents that occur are diverted by the connection element via BaseUnit and mounting rail to the ground.

The shield terminal is plugged into a mount of the BaseUnit. The shield terminal allows the low-impedance application of cable shields with minimum installation times. There is no need for the otherwise standard connection of the cable shield at the cabinet entry.

The following figure shows a BaseUnit with shield terminal and shield support.

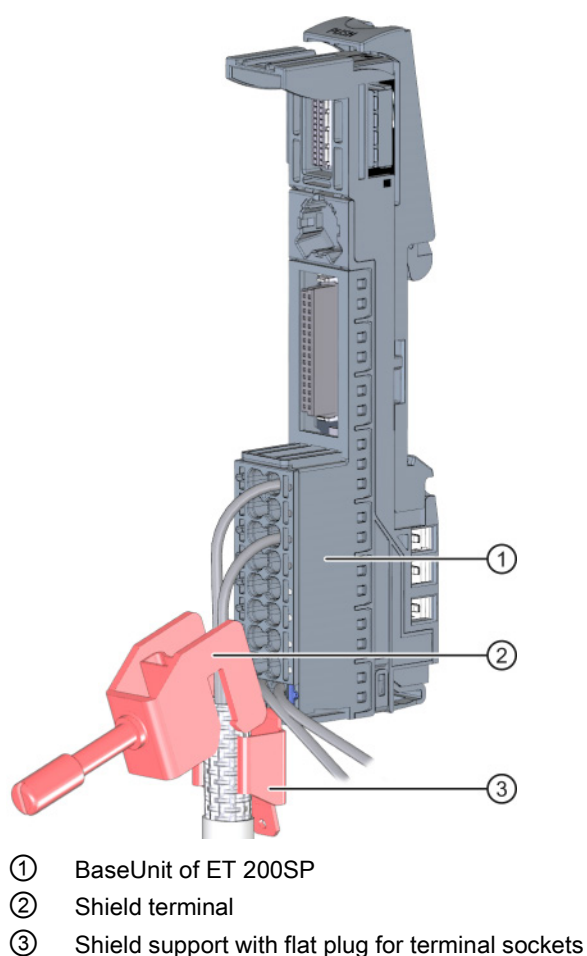


Figure 4-3 BaseUnit with shield terminal

Additional information

For more information on mounting the shield terminal, refer to the "Connecting cable shields" chapter of the system manual ET 200SP Distributed I/O System (<http://support.automation.siemens.com/WW/view/en/58649293>).

4.3 Connecting the cable shielding for ET 200AL

Each module of the ET 200AL distributed I/O system features a functional ground connection.

Use only shielded cables for connection of analog signals, PROFINET and PROFIBUS signals and for the ET-Connection. If you have screwed the plug in correctly, the interference currents that occur are diverted to the metal parts and functional ground.

If you attach an ET 200AL module to a **conductive**, grounded base, the lower mounting bolt establishes a conductive connection to the earth potential.

If you attach an ET 200AL module to a **non-conductive** base, connect the lower mounting bolt to the ground wire at the same time.

The following figure shows how to connect the functional ground via a ground wire, using the IM 157-1 PN interface module as an example.

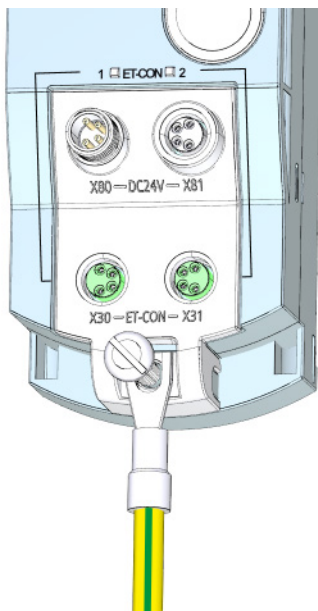


Figure 4-4 Connect functional ground via a ground wire

Additional information

You can find more information on installing ET 200AL modules in the Installing Modules section of the system manual Distributed I/O System ET 200AL (<http://support.automation.siemens.com/WW/view/en/89254965>).

4.4 Connecting the cable shield for bus cables

In the S7-1500, ET 200MP and ET 200SP systems, the cable shields of PROFIBUS and PROFINET cables are connected to the existing bus connection elements. Cable shield and shield support are thus galvanically connected to each other. If the connector is plugged into the module, the coupled interferences are diverted via the module carrier to the ground. There is no need for the otherwise standard connection of the shield at the cabinet entry.

The following figure shows examples of the shield connection for various bus connection elements.

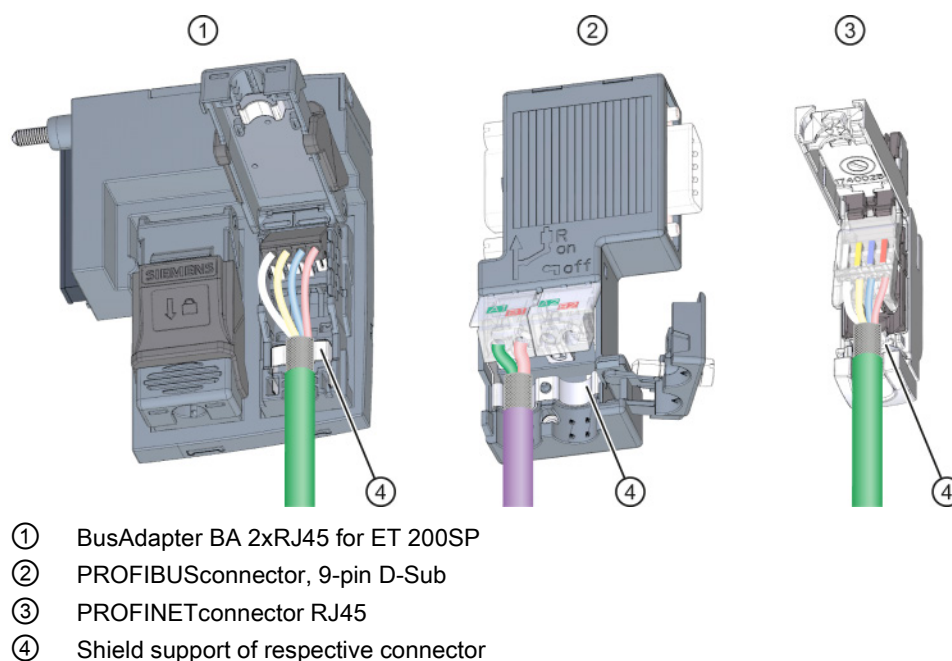


Figure 4-5 Shield connection for bus connection elements

Reference

For more information on installing the connectors, refer to the "Connecting PROFINET IO BusAdapter BA 2xRJ45 to the interface module" chapter of the system manual ET 200SP Distributed I/O System (<http://support.automation.siemens.com/WW/view/en/58649293>) and to the supplied product information.

4.5 Connecting the cable shield for other components

The following procedures for connecting the shield to devices that do not have any special shield terminals have proven themselves in practice.

Rule

Note the following points when handling the shield:

- Always use metal clamps to mount the protective braided shields of the cables. The clamps must cover a large area of the shield and provide appropriate contact force.
- Attach the shield to a shielding bus directly after the point where the cable enters the cabinet. If you route the shield further to the module, do not connect the shield again in front of the module, as this would create ground loops.

The following figure shows standard types of shield fastening.

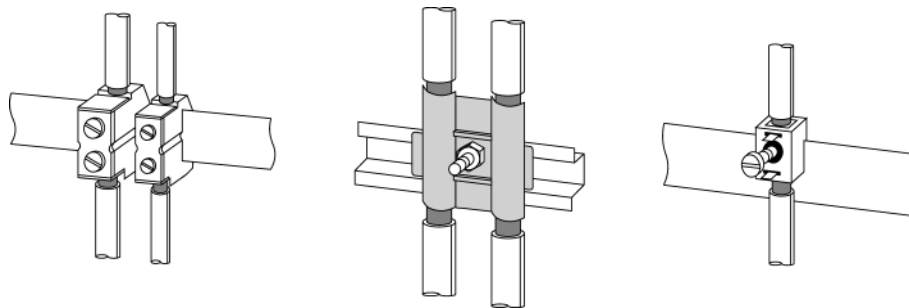


Figure 4-6 Cable shielding

Equipotential bonding

Definition according to DIN VDE 0100

Equipotential bonding is an electrical connection which brings the bodies of electrical equipment and external conductive parts to the same, or nearly the same, potential.

Equipotential bonding is divided into:

- Main equipotential bonding
- Additional local equipotential bonding

Both versions of equipotential bonding are of great importance not only for protection against electric shock, but also for EMC.

Main equipotential bonding

Main equipotential bonding is required by DIN VDE 0100 Part 410 as a protective measure and is mandatory, regardless of other measures for protection against direct and indirect contact.

Additional local equipotential bonding

Additional local equipotential bonding is required if:

- Unfavorable grounding conditions exist between plant parts due to different conductivity of the soil (for example, sandy or stony ground)
- Cables bridge a large distance
- Electrical energy is fed in from various power supplies (for example, in the case of multiple substations)
- Considerable electrical power is used (for example, welding robots, large drives)

Measures

In such cases, an additional equipotential bonding cable between the individual potentials can solve the problem. The equipotential bonding cable must also be able to divert large currents and carry lightning stroke current. The following equipotential bonding systems have proven themselves in practice:

- 16 mm² for copper equipotential bonding cables up to 200 m long
- 25 mm² for copper equipotential bonding cables over 200 m long

To prevent ground loops, equipotential bonding cables are installed in parallel and, whenever possible, near to the signal/bus cable. This allows the area between the two cables to be kept as small as possible.

The following figure shows a schematic view of the installation of an equipotential bonding cable.

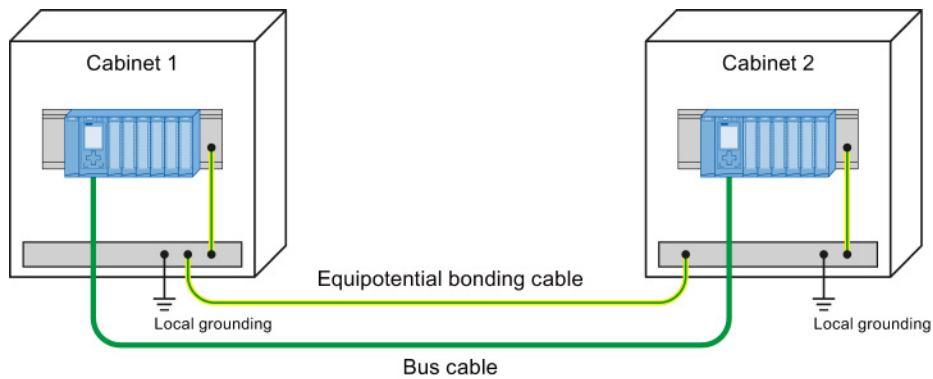


Figure 5-1 Installation of equipotential bonding cables

Rule

Note the following issues regarding equipotential bonding:

- The lower the impedance of an equipotential bonding cable, the more effective is equipotential bonding. The impedance of the additionally installed equipotential bonding cable should not exceed 10% of the shield impedance.
- Connect the equipotential bonding cables to a large area of the grounding system.
- Protect the connection points against corrosion.
- Avoid ground loops.
- Install the equipotential bonding cables in such a way as to minimize the areas enclosed between the equipotential bonding cables and signal lines.

Special measures for interference-free operation

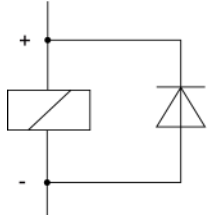
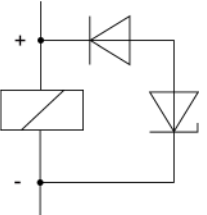
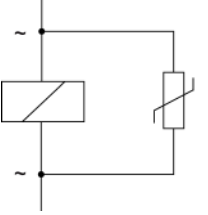
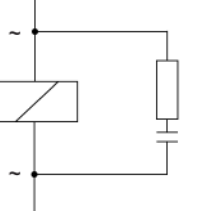
Connecting inductances to quenching elements

Ideally, the inductances (for example, contactor or relay coils) controlled by SIMATIC do not require any wiring to external quenching elements. The required quenching elements are already integrated into the modules.

If the SIMATIC output circuit can also be switched off by built-in contacts (such as relay contacts for EMERGENCY OFF), the module's integrated quenching elements are no longer effective. In this case, the inductances must be wired to quenching elements.

Wire inductances to freewheeling diodes, varistors or RC elements, for example.

Table 6- 1 Wiring inductances

Wiring DC-operated inductances		Wiring AC-operated inductances	
with diode	with Z diode	with varistor	with RC element
			

Programming devices

Provide a socket in each cabinet for the supply of the programming devices. The sockets are supplied from the distribution board to which the protective conductor for the cabinet is also connected.

Observe the following points during the installation of the socket in the control cabinet:

- Include the grounding of the socket in your consideration of the equipotential bonding.
- The common star point of the two ground potentials (cabinet and socket) must be close to the two end points.
- An equipotential bonding cable is not permitted as communication cable between programming device and controller.

Lightning protection and overvoltage protection

7.1 What is lightning and overvoltage protection?

Introduction

The term "Lightning and overvoltage protection" covers both the concept and system for the protection of structural systems (such as buildings or electrical equipment). This concept also includes the protection of people and animals.

Overvoltages are most frequently caused by lightning strikes.

Lightning protection system

The lightning protection system is the complete system used to reduce physical damage to a structural system as a result of direct lightning strikes and overvoltages. The lightning protection system is divided into external and internal lightning protection.

External lightning protection

External lightning protection is part of the lightning protection system and comprises an interception device, an arrester and a grounding system. In the event of a lightning strike, the external lightning protection serves to divert the lightning current safely to the ground. This measure most frequently prevents fire damage.

Internal lightning protection

Internal lightning protection is part of the lightning protection system and comprises lightning protection equipotential bonding and/or electrical isolation with respect to the external lightning protection. In the event of a lightning strike, the internal lightning protection reduces the damage caused by overvoltages resulting from the lightning.

Even at larger distances of up to 1.5 km, lightning strikes can sometimes still cause damage. You obtain effective lightning protection by expanding the external lightning protection into an overall protection system. This system includes equipotential bonding and surge protection devices.

7.2 Lightning protection zone concept

Introduction

Each building requires a coordinated protection zone concept. The grading of the protection is of key importance for this. Sufficient protection can only be guaranteed if this grading requirement is satisfied.

The lightning protection zone concept described in the standards IEC 62305-4 and DIN EN 62305-4 is used for this purpose. The lightning protection zone concept groups devices and areas that have the same risk potential and can be wired to arresters of the same type.

Use overvoltage protection devices at the transitions of the lightning protection zones based on the requirements. Install the overvoltage protection devices at an appropriate location such as the main or sub-distribution board.

Principle of the lightning protection zone concept

The principle behind the lightning protection zone concept is the division of the areas to be protected from overvoltages, for example buildings, into lightning protection zones based on EMC considerations.

Schematic diagram of the lightning protection zone concept

The following is a schematic diagram of the lightning protection zone concept in a physical structure.

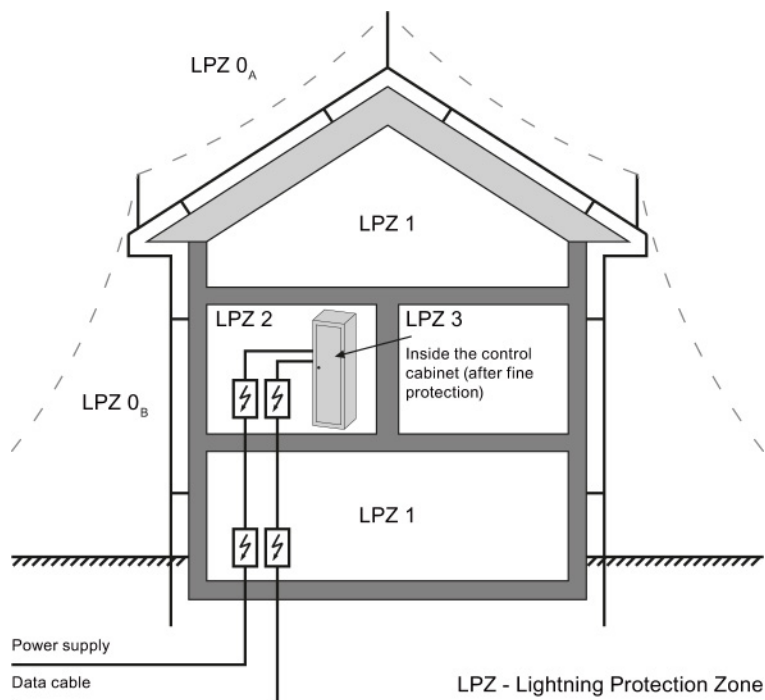


Figure 7-1 Division of a structural system into lightning protection zones

Division of lightning protection zones

The various lightning protection zones (LPZ - Lightning Protection Zone) are limited spatially as follows and not necessarily by physical boundaries, such as walls or floors.

The following table explains the division into various lightning protection zones.

Table 7- 1 External and internal lightning protection zones

Lightning protection zones	
External lightning protection zones:	
LPZ 0 _A	<ul style="list-style-type: none">• Risk from direct lightning strikes• Risk from the full electromagnetic field of the lightning
LPZ 0 _B	<ul style="list-style-type: none">• Protected against direct lightning strike• Risk from the full electromagnetic field of the lightning
Internal lightning protection zones:	
LPZ 1	<ul style="list-style-type: none">• Protected against direct lightning strike• Attenuated electromagnetic field of the lightning
LPZ 2	<ul style="list-style-type: none">• Protected against direct lightning strike• Reduced leakage currents and electromagnetic fields compared to LPZ 1• Protected terminal devices
LPZ 3	<ul style="list-style-type: none">• Protected against direct lightning strike• Protected area inside the terminal device• Local equipotential bonding

Effects of the lightning strike

Direct lightning strikes occur in the lightning protection zone LPZ 0_A. Effects of the lightning strike are high-energy lightning currents and strong electromagnetic fields. These effects are reduced from one lightning protection zone to the next through suitable lightning current or overvoltage arrester/shielding measures.

Frequent damage caused by lightning strikes includes:

- Injury to people and animals, which may in worst cases lead to death
- Damage to buildings
- Fire caused by strong heat development of a lightning strike

Overvoltages

Electromagnetic fields of the lightning channel can be reduced with appropriate shielding measures. Overvoltages due to inductions can be reduced to a safe level starting in lightning protection zone LPZ 0_B with overvoltage arresters.

7.3 Rules and components for the transitions between lightning protection zones

Introduction

This chapter provides you with information on the rules for transitions between lightning protection zones. Measures must be taken to reduce the surge current load and the magnetic fields at the transitions between the lightning protection zones.

Each zone-penetrating metallic/electrical system is incorporated into the equipotential bonding at the zone transition.

The metallic systems include channels, structural parts, and pipes (for water, gas, and heat, for example).

Electrical systems include power and IT cables and wires (for example, power cables and bus cables).

Transitions between lightning protection zones

Overvoltage protection must be provided at the transitions between lightning protection zones (LPZ - Lightning Protection Zone) in accordance with DIN EN 62305. The protection levels are defined at the transitions and implemented by means of overvoltage protection devices (SPD - Surge Protective Device).

- SPD Type 1 - Coarse protection for the transition from LPZ 0 to LPZ 1
- SPD Type 2 - Medium protection for the transition from LPZ 1 to LPZ 2
- SPD Type 3 - Fine protection for the transition from LPZ 2 to LPZ 3

The following figure illustrates the lightning protection zones and the type classes from the supply line to the consumer.

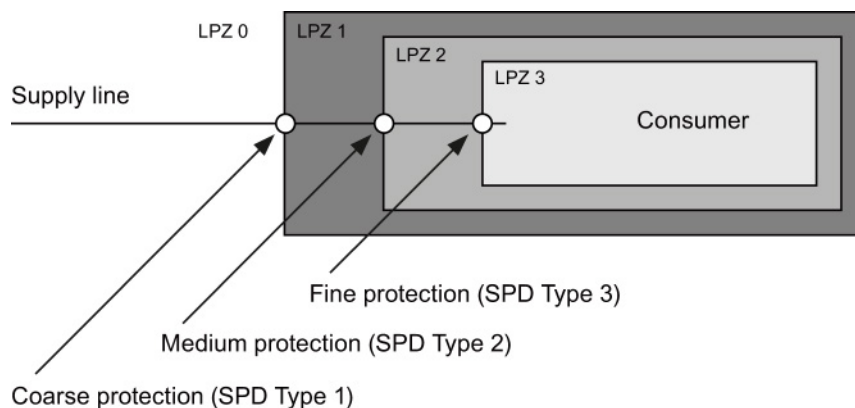


Figure 7-2 Lightning protection zone transitions

Rule for transition from lightning protection zone 0_A to 1

Lightning protection equipotential bonding is required at the transition from lightning protection zone 0_A to 1. The following applies to the transition at the interface of lightning protection zone 0_A to 1:

- Use of lightning arresters prevents introduction of partial lightning currents into structural systems
- Creation of local equipotential bonding at the transition of lightning protection zones, with incorporation of metallic supply systems (for example, pipes, air ducts, cable channels or cable ducts)

Components for lightning protection equipotential bonding from lightning protection zone 0_A to 1

The following table shows components for lightning protection equipotential bonding from lightning protection zone 0_A to 1.

Table 7-2 Components for transition from lightning protection zone 0_A to 1

Seq. no.	Cables for ...	Connection at the 0 _A interface to 1 with:	
		S7-1500/ET 200MP/ET 200SP/ET 200AL	Article number
1	Three-phase TN-C system	DEHNventil® DV M TNC 255	951 300
		DEHNventil® DV M TNC 255 FM *	951 305 *
2	Three-phase TN-S system	DEHNventil® DV M TNS 255	951 400
		DEHNventil® DV M TNS 255 FM *	951 405 *
3	Three-phase TT system	DEHNventil® DV M TT 255	951 310
		DEHNventil® DV M TT 255 FM *	951 315 *
4	AC TN-S system	DEHNventil® DV M TN 255	951 200
		DEHNventil® DV M TN 255 FM *	951 205 *
5	AC TT system	DEHNventil® DV M TT 2P 255	951 110
		DEHNventil® DV M TT 2P 255 FM *	951 115 *
6	Supply U _N = 24 V DC	BLITZDUCTOR® XT, base section BXT BAS	920 300
		BLITZDUCTOR® XT, module BXT ML2 B 180 (I _L = 1.2 A) (2-wire)	920 211
7	Supply U _N = 24 V DC	DEHNbloc® M, DB M 1 150	961 110
		DEHNbloc® M, DB M 1 150 FM * (2 pieces required)	961 115 *
8	Bus cable MPI RS 485, RS 232 (V.24)	BLITZDUCTOR® XT, base section BXT BAS	920 300
		BLITZDUCTOR® XT, module BXT ML2 B 180 (2-wire)	920 211
9	Inputs/outputs of digital modules U _N = 24 V DC	BLITZDUCTOR® XT, base section BXT BAS	920 300
		BLITZDUCTOR® XT, module BXT ML4 B 180 (I _L = 1.2 A) (4-wire)	920 310
10	Inputs/outputs of digital modules U _N = 230 V AC	DEHNbloc® M, DB M 1 255	961 120
		DEHNbloc® M, DB M 1 255 * (2 pieces required)	961 125 *

Seq. no.	Cables for ...	Connection at the 0 _A interface to 1 with:	
		S7-1500/ET 200MP/ET 200SP/ET 200AL	Article number
11	Inputs/outputs of analog modules (e.g., 4-20 mA, 1-10 V)	BLITZDUCTOR® XT, base section BXT BAS	920 300
		BLITZDUCTOR® XT, module (I _L = 1.2 A) (4-wire)	920 310
<p>* Version with remote indication contact</p> <p>Components of the series BLITZDUCTOR® XT can be remotely monitored with the appropriate accessories. Additional information is available on the Internet (http://www.dehn.de)</p> <p>Components can be ordered directly from: DEHN+SÖHNE GMBH+CO.KG. Hans-Dehn-Straße 1 D-92318 Neumarkt</p>			

Rule for the transition from lightning protection zone 0_B to 1, 1 to 2, or 2 to 3

The transition from lightning protection zone 0_B to 1, 1 to 2, or 2 to 3 prevents strong electromagnetic coupling and serves as overvoltage protection. The following applies to the transition at the interface from lightning protection zone 0_B to 1, 1 to 2, or 2 to 3:

- Use of power cables with surge current-carrying cable shields or twisted-pair IT cables
- Laying cables and lines
 - In continuous, surge current-carrying metal pipes that are grounded at both ends
 - In reinforced concrete channels capable of carrying surge current with grounding at both ends
 - On closed metal cable racks that are grounded at the beginning and end
- Use of fiber-optic cables without a metal shield if such a transmission is intended
- Creation of local equipotential bonding at the transition of lightning protection zones, with incorporation of metallic supply systems (for example, pipes, air ducts, cable channels or cable ducts)

Additional measures

If the actions listed above cannot be implemented, protection by means of overvoltage arresters must be provided. The following sections contain tables with overvoltage arresters that are very suitable for protecting the plant.

Components for lightning protection equipotential bonding from lightning protection zone 0_B to 1 and 1 to 2

The following table shows components for lightning protection equipotential bonding from lightning protection zone 0_B to 1 and 1 to 2.

Table 7- 3 Components for transition from lightning protection zone 0_B to 1 and 1 to 2

Seq. no.	Cables for ...	Connection at the 0 _B interface to 1 with:	
		S7-1500/ET 200MP/ET 200SP/ET 200AL	Article number
1	Three-phase TN-C system	DEHNguard® DG M TNC 275	952 300
		DEHNguard® DG M TNC 275 FM *	952 305 *
2	Three-phase TN-S system	DEHNguard® DG M TNS 275	952 400
		DEHNguard® DG M TNS 275 FM *	952 405 *
3	Three-phase TT system	DEHNguard® DG M TT 275	952 310
		DEHNguard® DG M TT 275 FM *	952 315 *
4	AC TN-S system	DEHNguard® DG M TN 275	952 200
		DEHNguard® DG M TN 275 FM *	952 205 *
5	AC TT system	DEHNguard® DG M TT 2P 275	952 110
		DEHNguard® DG M TT 2P 275 FM *	952 115 *
6	Supply U _N = 24 V DC	BLITZDUCTOR® VT, BVT AVD 24	918422
7	Bus cable MPI/DP RS 485	BLITZDUCTOR® XT, base section BXT BAS	920 300
		BLITZDUCTOR® XT, module BXT ML2 BD HFS 5	920 271
8	Bus cable RS 232 (V.24)	BLITZDUCTOR® XT, base section BXT BAS	920 300
		BLITZDUCTOR® XT, module BXT ML2 BE S 12	920 222
9	Industrial Ethernet	DEHNpatch® DPA M CLE RJ45B 48	929 121
10	Inputs of digital modules U _N = 24 V DC	DEHNconnect® RK, DCO RK E 60 (I _L = 0.5 A)	919 990
11	Outputs of digital modules U _N = 24 V DC	DEHNconnect® RK, DCO RK D 5 24 (I _L = 10.0 A)	919 986
12	Inputs/outputs of digital modules U _N = 230 V AC	DEHNguard® DG S 275	952 070
		DEHNguard® DG S 275 FM *	952 090 *
		N-PE arrester in the TT system	
		DEHNgap® C S, DGP C S	952 030
		DEHNgap® C S, DGP C S FM *	952 035 *
13	Inputs/outputs of analog modules (e.g., 4-20 mA, 1-10 V)	DEHNconnect® RK, DCO RK E 60 (I _L = 0.5 A)	919 990

Seq. no.	Cables for ...	Connection at the 0 _B interface to 1 with:	
		S7-1500/ET 200MP/ET 200SP/ET 200AL	Article number
14	Inputs/outputs of the fail-safe modules (24 V DC)	DEHNconnect® RK, DCO RK D 5 24	919 986
<p>* Version with remote indication contact</p> <p>Components of the series BLITZDUCTOR® XT can be remotely monitored with the appropriate accessories. Additional information is available on the Internet (http://www.dehn.de)</p> <p>Components can be ordered directly from: DEHN+SÖHNE GMBH+CO.KG. Hans-Dehn-Straße 1 D-92318 Neumarkt</p>			

Components for lightning protection equipotential bonding from lightning protection zone 2 to 3

The following table shows components for lightning protection equipotential bonding from lightning protection zone 2 to 3 that you can use for S7-1500/ET 200MP and ET 200SP.

Table 7- 4 Components for transition from lightning protection zone 2 to 3 (for S7-1500/ET 200MP and ET 200SP)

Seq. no.	Cables for ...	Connection at the interface 2 to 3 with:			
		S7-1500/ET 200MP	Article number	ET 200SP	Article number
1	Three-phase TN-S, TT system	DEHNrail® DR M 4P 255	953 400	DEHNguard® DG M TNS 275	952 400
				DEHNguard® DG MOD 275	952 010
		DEHNrail® DR M 4P 255 FM * (I _L = 25.0 A)	953 405 *	DEHNguard® DG M TT 275	952 310
				DEHNguard® DG MOD 275	952 010
DEHNguard® DG MOD NPE	952 050				
2	AC TN-S, TT system	DEHNrail® DR M 2P 255	953 200	DEHNguard® DG M TN 275	952 200
				DEHNguard® DG MOD 275	952 010
		DEHNrail® DR M 2P 255 FM * (I _L = 25.0 A)	953 205 *	DEHNguard® DG M TT 2P 275	952 110
				DEHNguard® DG MOD 275	952 010
DEHNguard® DG MOD NPE	952 050				
3	Supply U _N = 24 V DC	BLITZDUCTOR® VT, BVT AVD 24	918 422	BLITZDUCTOR® VT, BVT AVD 24 ® VT	918 422
4	Bus cable MPI/DP RS 485	BLITZDUCTOR® XT, base section BXT BAS	920 300	---	---
		BLITZDUCTOR® XT, module BXT ML2 BD HFS 5	920 271	---	---
5	Bus cable RS 232 (V.24)	BLITZDUCTOR® XT, base section BXT BAS	920 300	---	---
		BLITZDUCTOR® XT, module BXT ML2 BE S 12	920 222	---	---
6	Industrial Ethernet	DEHNpatch® DPA M CLE RJ45B 48	929 121	---	---
7	Inputs of digital modules U _N = 24 V DC	DEHNconnect® RK, DCO RK E60 (I _L = 0.5 A)	919 990	BLITZDUCTOR® XT, BXT ML4 BD 24 (I _L < 1 A)	920 344

Seq. no.	Cables for ...	Connection at the interface 2 to 3 with:			
		S7-1500/ET 200MP	Article number	ET 200SP	Article number
				BLITZDUCTOR® XT, base section BXT BAS (I _L < 1 A)	920 300
8	Outputs of digital modules U _N = 24 V DC	DEHNconnect® RK, DCO RK D 5 24 (I _L = 10.0 A)	919 986	BLITZDUCTOR® XT, BXT ML4 BD 24 (I _L < 1 A)	920 344
				BLITZDUCTOR® XT, base section BXT BAS (I _L < 1 A)	920 300
				DEHNconnect® SD2, DCO SD2 E 48 (I _L < 10 A)	917 989
9	Inputs/outputs of digital modules U _N = 230 V AC	DEHNguard® DG S 275	952 070	DEHNguard® DG S 275	952 070
				DEHNguard® DG MOD 275	952 010
		DEHNguard® DG S 275 FM *	952 090 *	---	---
		N-PE arrester in the TT system			
		DEHNgap® C S, DGP C S	952 030	---	---
		DEHNgap® C S, DGP C S FM *	952 035 *	---	---
10	Inputs/outputs of analog modules (e.g., 4-20 mA, 1-10 V)	DEHNconnect® RK, DCO RK E 60 (I _L = 0.5 A)	919 990	BLITZDUCTOR® XT, BXT ML4 BD 24 (I _L < 1 A)	920 344
				BLITZDUCTOR® XT, base section BXT BAS (I _L < 1 A)	920 300
11	Inputs/outputs of the fail-safe modules (24 V DC)	---	---	DEHNconnect® RK, DCO RK D 5 24	919 986
				DEHNconnect® RK, DCO RK E 60	919 990
<p>* Version with remote indication contact</p> <p>Components of the series BLITZDUCTOR® XT can be remotely monitored with the appropriate accessories. Additional information is available on the Internet (http://www.dehn.de)</p> <p>Components can be ordered directly from: DEHN+SÖHNE GMBH+CO.KG. Hans-Dehn-Straße 1 D-92318 Neumarkt</p>					

7.3 Rules and components for the transitions between lightning protection zones

The following table shows components for lightning protection equipotential bonding from lightning protection zone 2 to 3 that you can use for ET 200AL.

Table 7- 5 Components for transition from lightning protection zone 2 to 3 (for ET 200AL)

Seq. no.	Cables for ...	Connection at the interface 2 to 3 with:	
		ET 200AL	Article number
1	Supply U _N = 24 V DC	BLITZDUCTOR® VT, BVT AVD 24 ® VT	918 422
<p>Components of the series BLITZDUCTOR® XT can be remotely monitored with the appropriate accessories. Additional information is available on the Internet (http://www.dehn.de)</p> <p>Components can be ordered directly from: DEHN+SÖHNE GMBH+CO.KG. Hans-Dehn-Straße 1 D-92318 Neumarkt</p>			

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