SIEMENS

SIMATIC

PCS 7 Process Control System CPU 410-5H Process Automation/CPU 410 SMART

System Manual

10/2013

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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.

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1.1 Preface

Purpose of this manual

This manual represents a useful reference and contains information on operations, descriptions of functions, and technical specifications of the CPU 410-5H Process Automation and the CPU 410 SMART.

For information on installing and wiring this and other modules in order to set up an automation system, refer to Manual *Automation System S7-400, Hardware and Installation*.

Basic knowledge required

This manual requires general knowledge of automation engineering.

Moreover, it is assumed that the readership has sufficient knowledge of computers or equipment similar to a PC, such as programming devices, running under the Windows XP, Windows Server or Windows 7 operating system. The PCS7 Readme includes information on which operating system is suitable for your PCS7 configuration. The CPU 410-5H is configured using the PCS 7 software, and you should thus be familiar in the handling of this software.

In particular when operating a CPU 410-5H system in potentially explosive atmospheres, you should always observe the information on the safety of electronic control systems provided in the appendix of Manual *Automation System S7-400, Hardware and Installation*.

Scope of the manual

The manual is relevant to the following components:

- CPU 410–5H Process Automation; 6ES7 410-5HX08-0AB0 firmware version V8.0 and higher
- CPU 410 SMART; 6ES7 410-5HN08-0AB0 as of firmware version V8.0

Note

CPU 410-5H and CPU 410 SMART

Except for the special features described in the section Properties and technical specifications of CPU 410 SMART (Page 203), the CPU 410 SMART behaves like a CPU 410-5H. Taking this section into consideration, the statements made in this manual about the CPU 410-5H also apply to the CPU 410 SMART.

Approvals

For details on certifications and standards, refer to Manual *S7-400 Automation System, Module Data*, section 1.1, Standards and Certifications. Here you will also find the technical specification for the entire S7-400.

Online help

In addition to the manual, you will find detailed support on how to use the software in the integrated online help system of the software.

The help system can be accessed using various interfaces:

- The **Help** menu contains several commands: **Contents** opens the Help index. You will find help on fault-tolerant systems in **Configuring fault-tolerant systems**.
- **Using Help** provides detailed instructions on using the online help system.
- The context-sensitive help system provides information on the current context, for example, on an open dialog or active window. You can call this help by clicking "Help" or using the F1 key.
- The status bar provides a further form of context-sensitive help. It shows a short description of each menu command when you position the mouse pointer over a command.
- A short info text is also shown for the toolbar buttons when you hold the mouse pointer briefly over a button.

If you prefer to read the information of the online help in printed form, you can print individual topics, books or the entire help system.

Recycling and disposal

The CPU 410-5H contains environmentally compatible materials and can be recycled. For ecologically compatible recycling and disposal of your old device, contact a certificated disposal service for electronic scrap.

Additional support

If you have any questions relating to the products described in this manual, and do not find the answers in this documentation, please contact your Siemens partner at our local offices.

You will find information on who to contact at:

Contact partners (http://www.siemens.com/automation/partner)

A guide to the technical documents for the various SIMATIC products and systems is available at:

Documentation (http://www.automation.siemens.com/simatic/portal/html_76/techdoku.htm)

You can find the online catalog and order system under:

Catalog (http://mall.automation.siemens.com/)

Functional Safety Services

Siemens Functional Safety Services is a comprehensive performance package that supports you in risk assessment and verification all the way to plant commissioning and modernization. We also offer consulting services for the application of fail-safe and fault-tolerant SIMATIC S7 automation systems.

Additional information is available at:

Functional Safety Services (http://www.siemens.com/safety-services)

Submit your requests to:

Mail Functional Safety Services (mailto:safety-services.industry@siemens.com)

Training center

We offer a range of relevant courses to help you to get started with the SIMATIC S7 automation system. Please contact your local training center or the central training center.

Training (http://www.sitrain.com/index_en.html)

Technical Support

For technical support of all Industry Automation products, fill in and submit the online Support Request:

Support Request (http://www.siemens.de/automation/support-request)

Service & Support on the Internet

In addition to our documentation, we offer a comprehensive online knowledge base on the Internet at:

Service & Support (http://www.siemens.com/automation/service&support)

There you will find:

- The newsletter containing the latest information on your products.
- The latest documents via our search function in Service & Support.
- A forum for global information exchange by users and specialists.
- Your local Automation representative.
- Information on field service, repairs and spare parts. Much more can be found under "Services".

1.2 Security information

Siemens provides automation and drive products with industrial security functions that support the secure operation of plants or machines. They are an important component in a holistic industrial security concept. With this in mind, our products undergo continuous development. We therefore recommend that you keep yourself informed with respect to our product updates. Please find further information and newsletters on this subject at: http://support.automation.siemens.com.

To ensure the secure operation of a plant or machine it is also necessary to take suitable preventive action (e.g. cell protection concept) and to integrate the automation and drive components into a state-of-the-art holistic industrial security concept for the entire plant or machine. Any third-party products that may be in use must also be taken into account. Please find further information at: http://www.siemens.com/industrialsecurity

1.3 Documentation

User documentation

The table below provides an overview of the descriptions of the various components and options in the S7-400 automation system.

Topic	Documentation	See also
Setting up an automation system	S7-400, Hardware and Installation	S7-400 Automation System Hardware and Installation (http://support.automation.siemens.com/WW/view/en/1117849)
Data of the standard modules of an automation system	S7-400 Module Data	SIMATIC S7-400 S7-400 Automation System Module Data (http://support.automation.siemens.com/WW/view/en/1117740)
IM 153-2 IM 153-4 PN	ET 200M Distributed I/O Device	SIMATIC ET 200M Distributed I/O Device, HART Analog Modules (http://support.automation.siemens.com/WW/view/en/22063748)
IM 157 IM 153-2 FF	DP/PA Link and Y Link bus links FF Link bus links	SIMATIC Bus Links DP/PA Coupler, Active Field Distributors, DP/PA Link and Y Link (http://support.automation.siemens.com/WW/view/en/1142696)
Configuring, commissioning, and operation of a PROFINET IO system	PROFINET IO System Description	PROFINET system description (http://support.automation.siemens.com/WW/view/en/19292127)

Topic	Documentation	See also
Fail-safe systems Configuring and programming of fail-safe systems Working with S7 F-Systems V 6.1	S7 F/FH Systems	SIMATIC Industrial Software S7 F/FH Systems - Configuring and Programming (http://support.automation.siemens.com/WW/view/en/2201072)
Solution concepts Function mechanisms Configurations of PCS 7	PCS 7 technical documentation	SIMATIC Process Control System PCS 7 (V8.0) (http://www.automation.siemens.com/mcms/industrial-automation-systems-simatic/en/handbuchuebersicht/tech-dok-pcs7/Seiten/Default.aspx)
Configuring hardware	Configuring Hardware and Communication Connections with STEP 7	Configuring Hardware and Communication Connections with STEP 7 (http://support.automation.siemens.com/WW/view/en/18652631)
System Modifications during Stand-Alone Operation	Modifying the System during Operation via CiR	Modifying the System during Operation via CiR (http://support.automation.siemens.com/WW/view/en/14044916)

Introduction to CPU 410-5H 2

2.1 Scope of application of PCS 7

PCS 7 and CPU 410-5H Process Automation

SIMATIC PCS 7 uses selected standard hardware and software components from the TIA building block system for the process control system in the company-wide automation network called Totally Integrated Automation. It offers an open basis for automation solutions with its consistent data management, communication and configuration.

You can use PCS 7 to create customized and project-specific solutions tailored to specific requirements. Further information about these customized solutions can be found in the configuration manuals.

The CPU 410-5H Process Automation is a controller of the latest generation. This controller is specifically designed for the SIMATIC PCS 7 control system. As with previous controllers of the SIMATIC PCS 7 system, the CPU 410-5H Process Automation can be used in all Process Automation industries. The very flexible scalability based on PCS 7 process objects makes it possible to cover the entire performance range from the smallest to the largest controller, in standard, fault-tolerant and fail-safe applications with only one hardware.

The CPU 410-5H can be used for PCS 7 V8.0 SP1 + HUP CPU 410-5H and higher. It is available under ID 68627630 at this address:

AS 410 modular systems
(http://support.automation.siemens.com/WW/view/en/77430465/130000)

To use a CPU410-5H you must create a new configuration. The parameters of a CPU 410-5H are set to PCS7 default values when a new configuration is created. Some parameters that were previously freely assignable cannot be changed in the CPU 410-5H. You can transfer charts from existing PCS7 projects.

The PCS 7 project

Among the objects of a PCS 7 project are the following:

- Hardware configuration
- Blocks
- CFCs and SFCs

These objects are always present - regardless of the number of operator stations and modules and their networking.

PCS 7 applications

You create a PCS 7 project on an engineering station (ES for short). A variety of applications are available on the ES:

- SIMATIC Manager – the central application of PCS 7. From here you open all other applications in which you must enter settings for the PCS 7 project. You will set up your entire project from SIMATIC Manager.
- HW Config – configuration of all hardware of a system, e.g., CPUs, power supply, communications processors.
- CFC editor and SFC editor - creation of continuous function charts (CFC) and sequential control systems.
- PCS 7 OS in conjunction with various editors - Implementation of OS configuration.

Every application has a graphic user interface for easy operation and clear representation of your configuration data.

Important information on configuration

> **WARNING**
>
> **Open equipment**
>
> Risk of death or serious injury.
>
> S7–400 modules are classified as open equipment, meaning you must install the S7–400 in an enclosure, cabinet, or switch room that can only be accessed by means of a key or tool. Only instructed or authorized personnel are permitted to access these enclosures, cabinets, or switch rooms.

Additional information

The components of the standard S7-400 system, e.g., power supplies, I/O modules, CPs, and FMs, are also used in the high availability S7-400H automation system. For a detailed description of all hardware components for S7-400, refer to Reference Manual *S7-400 Automation System, Module Data*.

The rules governing the design of the user program and the use of function blocks laid down for the S7-400 standard system also apply to the fault-tolerant S7-400H automation system. Refer to the descriptions in Manual *Programming with STEP 7* and Reference Manual *System Software for S7-300/400; Standard and System Functions*.

See also

Overview of the parameters for the CPU 410-5H (Page 44)

2.2 Possible applications

Important information on configuration

> **WARNING**
>
> **Open equipment**
>
> S7–400 modules are classified as open equipment, meaning you must install the S7–400 in an enclosure, cabinet, or switch room that can only be accessed by means of a key or tool. Only instructed or authorized personnel are permitted to access these enclosures, cabinets, or switch rooms.

The following figure shows an example of an S7–400H configuration with shared distributed I/O and connection to a redundant plant bus. The next pages deal with the hardware and software components required for the installation and operation of the S7–400H.

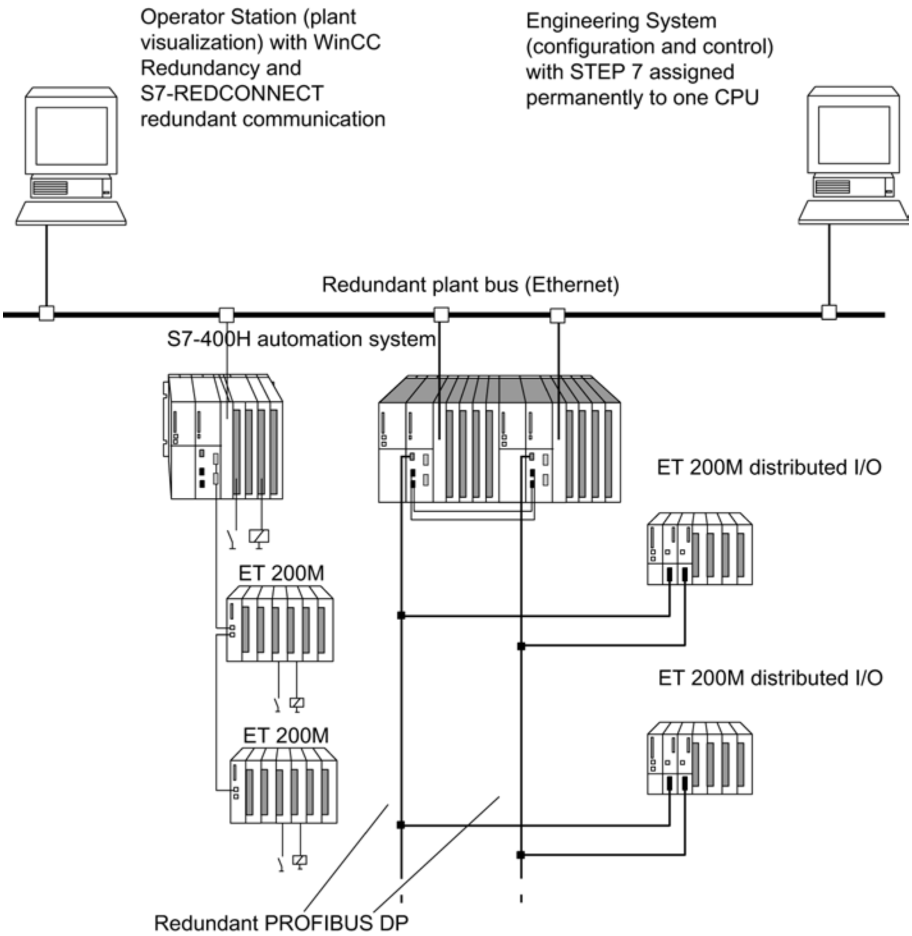


Figure 2-1 Overview

Additional information

The components of the S7–400 standard system are also used in connection with the CPU 410-5H Process Automation. For a detailed description of all hardware components for S7-400, refer to Reference Manual *S7-400 Automation System; Module Specifications*.

2.3 The basic system of the CPU 410-5H for stand-alone operation

Definition

Stand-alone operation refers to the use of a CPU 410-5H Process Automation in a standard SIMATIC-400 station.

Hardware of the basic system

The basic system consists of the hardware components required for a controller. The following figure shows the components in the configuration.

The basic system can be expanded with standard modules of the S7-400. There are restrictions for the function modules and communication processors. See Appendix Function and communication modules that can be used in a redundant configuration (Page 305).

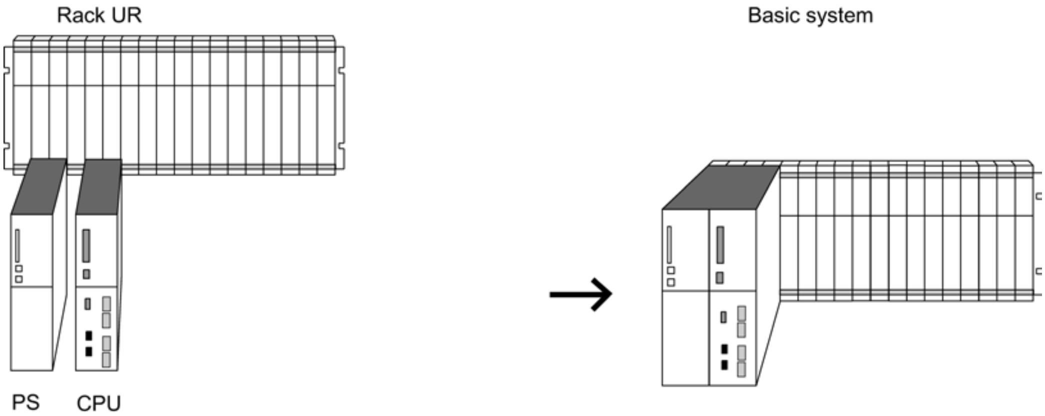


Figure 2-2 Hardware of the S7-400H basic system

Central controller and expansion units

The rack containing the CPU is called the central controller (CC). The racks in the system that are equipped with modules and connected to the CC are the expansion units (EU).

Note

The rack number must be set to "0" on the CPU.

Power supply

You require a power supply module from the standard system range of the S7-400.

To increase availability of the power supply, you can also use two redundant power supplies. In this case, you use the power supply modules PS 405 R / PS 407 R.

A combination of these can also be used in redundant configurations (PS 405 R with PS 407 R).

Operation

The operation of a CPU 410-5H requires a system expansion card. The system expansion card specifies the maximum number of process objects that can be loaded to the CPU and saves the license information in case of a system expansion. The system expansion card forms a hardware unit with the CPU 410-5H.

2.4 The basic system for redundant operation

Hardware of the basic system

The basic system consists of the hardware components required for a fault-tolerant controller. The following figure shows the components in the configuration.

The basic system can be expanded with standard modules of the S7-400. There are restrictions for the function modules and communication processors. See Appendix Function and communication modules that can be used in a redundant configuration (Page 305).

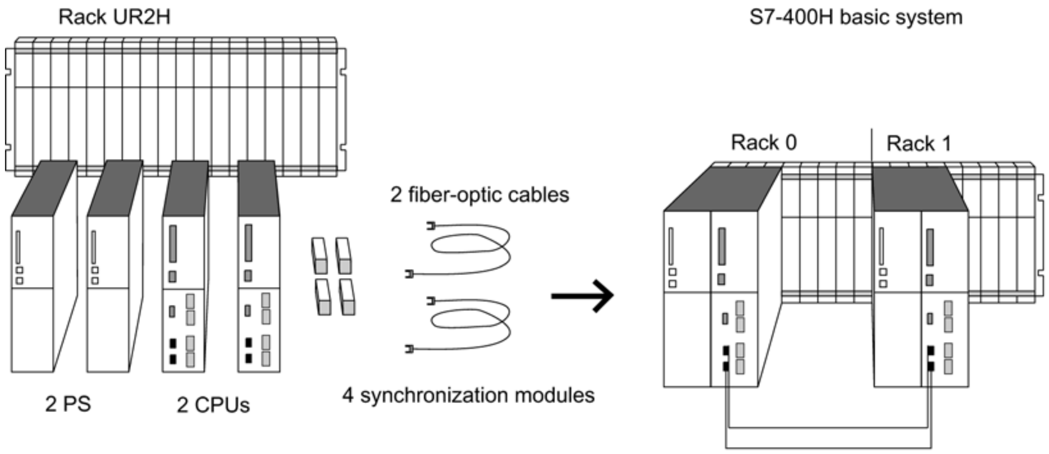


Figure 2-3 Hardware of the S7-400H basic system

Central processing units

The two CPUs are the heart of the S7-400H. Use the switch **on the rear** of the CPU to set the rack numbers. In the following sections, we will refer to the CPU in rack 0 as CPU 0, and to the CPU in rack 1 as CPU 1.

Rack for S7-400H

The UR2-H rack supports the installation of two separate subsystems with nine slots each, and is suitable for installation in 19" cabinets.

You can also set up the S7-400H in two separate racks. The racks UR1, UR2, and CR3 are available for this purpose.

Power supply

You require a power supply module from the standard system range of the S7-400 for each of the two subsystems of the S7-400H.

To increase availability of the power supply, you can also use two redundant power supplies in each subsystem. In this case, you use the power supply modules PS 405 R / PS 407 R.

A combination of these can also be used in redundant configurations (PS 405 R with PS 407 R).

Synchronization modules

The synchronization modules are used to link the two CPUs. They are installed in the CPUs and interconnected by means of fiber-optic cables.

Two types of synchronization modules are available:

- Synchronization modules for synchronization cables up to 10 meters long
- Synchronization modules for synchronization cables up to 10 kilometers long

You must use 4 synchronization modules of the same type in a fault-tolerant system. For a description of the synchronization modules, refer to the section Synchronization modules for the CPU 410-5H (Page 181).

Fiber-optic cable

The fiber-optic cables are used to interconnect the synchronization modules for the redundant link between the two CPUs. They interconnect the upper and lower synchronization modules in pairs.

You will find the specification of the fiber-optic cables you can use in an S7-400H in the section Selecting fiber-optic cables (Page 187).

Operation

The operation of a CPU 410-5H requires a system expansion card. The system expansion card specifies the maximum number of process objects that can be loaded to the CPU and saves the license information in case of a system expansion. The system expansion card forms a hardware unit with the CPU 410-5H. In redundant operation, two CPUs 410-5H must have system expansion cards with the same number of POs.

2.5 Rules for the assembly of fault-tolerant stations

The following rules have to be complied with for a fault-tolerant station, in addition to the rules that generally apply to the arrangement of modules in the S7-400:

- The CPUs have to be inserted in the same slots.
- Redundantly used external DP master interface modules or communication processors must be inserted in the same slots in each case.
- External DP master interface modules for redundant DP master systems may only be inserted in central controllers and not in expansion units.
- Redundantly used modules (e.g., CPU 410-5H, DP slave interface module IM 153-2) must be identical. This means that they must have the same order number and the same product or firmware version.
- Two CPUs 410-5H must have system expansion cards with the same number of POs.

2.6 I/O for CPU 410-5H

You can use the input/output modules of the SIMATIC S7 with the CPU 410-5H Process Automation. The I/O modules can be used in the following devices:

- Central controllers
- Expansion units
- Distributed via PROFIBUS DP
- Distributed via PROFINET IO

You will find the function modules (FM) and communication processors (CP) that can be used with the CPU 410-5H in Appendix Auto-Hotspot.

2.7 I/O configuration variants of the fault-tolerant system

I/O configuration variants

The following configuration variants are available for the input/output modules:

- In stand-alone operation: single-sided configuration.

  In the single-sided configuration, there is a single set of the input/output modules (single-channel) that are addressed by the CPU.
- In redundant operation: Single-channel switched configuration with enhanced availability.

  In the single-channel switched distributed configuration, there is a single set of the I/O modules, but they can be addressed by both subsystems.
- In redundant operation: two-channel redundant configuration with maximum availability.

  In the two-channel redundant configuration there are two sets of the I/O modules that can be addressed by both subsystems.

2.8 Tools for configuring (STEP 7 - HW Config, PCS 7)

Like the S7-400, the CPU 410-5H Process Automation is also configured with STEP 7.

Restrictions for the configuration of the CPUs and the fault-tolerant system can be found in the STEP 7 online help.

Detailed information on this can be found in the online help.

Optional software

You can use PCS 7 and all the optional packages available there.

2.9 PCS 7 project

STEP 7

STEP 7 is the basis for configuring the PCS 7 process control system.

STEP 7 supports the various tasks involved in creating a project with the following project views:

- Component view (HW Config)
- Process object view
- Technological perspective

The hardware that you need in a SIMATIC project, such as automation systems, communication components, and process I/O, is stored in an electronic catalog. You configure this hardware and assign the hardware parameters with HW Config.

You can protect function blocks (FBs) and functions (FCs) against unauthorized access using the S7 Block Privacy application. You can no longer edit protected blocks in STEP 7. Only the interfaces of the blocks are then visible.

You can load selective configuration changes online to the corresponding system components. This can result in extended loading and startup times.

Continuous Function Chart (CFC)

The CFC editor is the tool for graphical configuration and commissioning. You use the CFC editor to place and interconnect instances of function block types and assign their parameters. In addition, the CFC editor is the tool for loading user programs.

The CFC editor supports the following types of standardized software modules:

- Function block type
- Process tag type
- Control module type

Sequential Function Chart (SFC)

The SFC editor is the tool for the graphical configuration and commissioning of sequential control systems for batch production processes. You use a sequential control system to control and process basic automation functions created in CFC by means of operating mode and system status changes. Depending on the subsequent use, you create the sequential control systems either as a SFC chart or SFC type.

SFC chart

You use an SFC chart to implement a single-use sequential control system that controls multiple sub-areas of a production plant. Each SFC plan contains standardized inputs and outputs for status information and for control by the user program or the user. You can place and interconnect the SFC chart in the CFC as a block.

SFC type

SFC types are standardized multi-use sequential control systems that control one sub-area of the production plant. You can select the SFC types from a catalog and then place and interconnect them and assign their parameters as an instance in a CFC. An SFC type may contain up to 32 sequencers.

Organization blocks, system functions, system and standard function blocks

Organization blocks (OB), system functions (SFC), and system and standard function blocks (SFB) are integrated in the operating system of the CPU. The PCS 7 blocks are called in the OBs. PCS 7 blocks can call SFCs or SFBs or form interfaces to SFCs and SFBs.

2.10 Scaling and licensing (scaling concept)

License management

License objects are process objects (PO) and their associated runtime licenses (RT-PO). When a PCS 7 application is created, the PCS 7 system determines the number of POs that corresponds to the scope of this application. A PCS 7 application requires a certain number of POs and the system expansion cards of the associated CPU 410-5H must have the same (or greater) number of POs. To run the PCS 7 application, a quantity of runtime licenses corresponding to the PO quantity must also be available.

The CPU is scaled by means of the system expansion card, which means the system expansion card determines the maximum quantity of POs. The CFC counts and manages the POs used in the application. The number of POs that can be loaded to the CPU is limited to the amount specified by the system expansion card.

Expansion of a PCS 7 project

When you expand a PCS 7 project and load it in the CPU, a check is made to determine whether the project can run in the CPU with the current number of POs.

Use of the system expansion card

The number of POs of a CPU 410-5H is stored on a system expansion card (SEC). You insert the SEC in a slot on the back of the CPU before commissioning the CPU. The SEC contains information that specifies the performance class of the CPU in terms of the amount of POs it supports. The system expansion card is an essential part of the CPU hardware. Without a system expansion card, the CPU cannot be operated. If an SEC is not detected, the corresponding CPU goes to STOP. A loss of synchronization is triggered in the fault-tolerant system, in which a start-up block prevents automatic reconnection.

Boundary conditions for the use of an SEC

- The CPU 410-5H cannot be operated without an SEC.
- You cannot operate two CPUs 410-5H redundantly with two different SECs.
- To replace the SEC, the CPU must be removed, which also results in the deletion of the user program on the CPU.

Structure of the CPU 410-5H

3

3.1 Operator controls and display elements on the CPU 410-5H

Operator controls and display elements on the CPU 410-5H

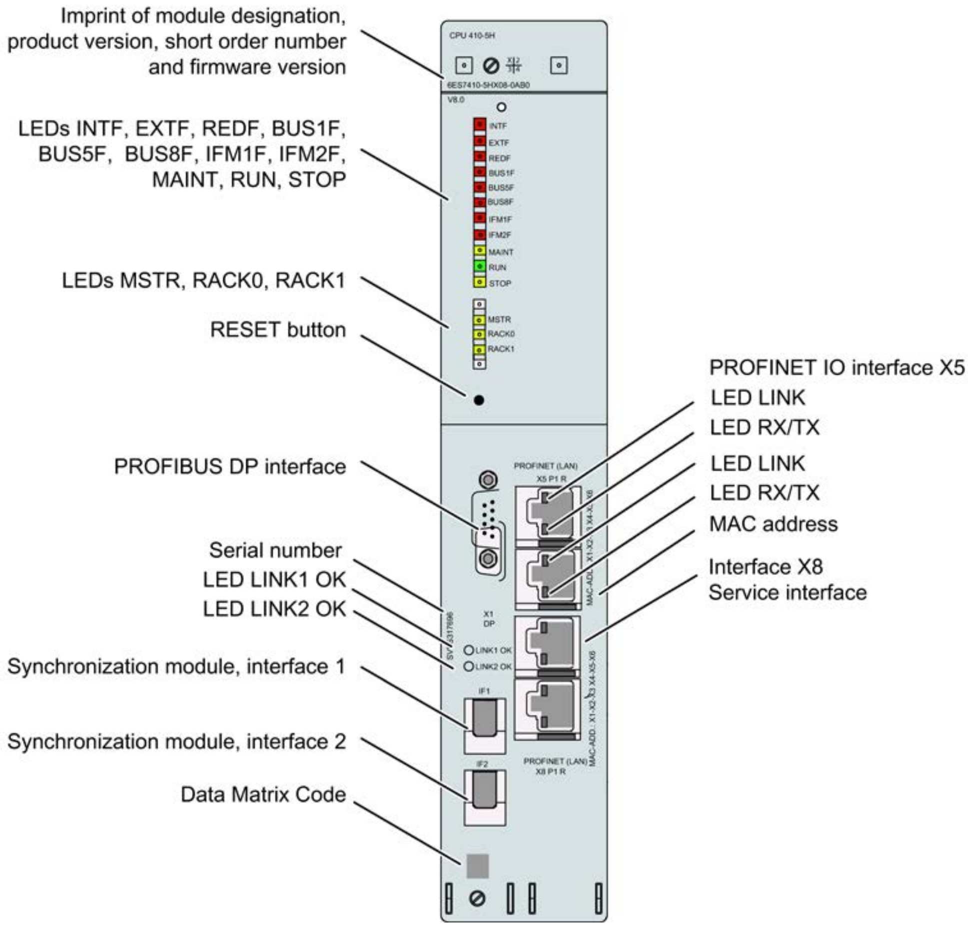


Figure 3-1 Arrangement of the control and display elements on CPU 410-5H

LED displays

The following table shows an overview of the LED displays on the individual CPUs.

Sections Monitoring functions of the CPU 410-5H (Page 35) and Status and error displays (Page 37) describe the states and errors/faults indicated by these LEDs.

Table 3- 1 LED displays on the CPUs

LED	Color	Meaning
Top bar		
INTF	red	Internal error
EXTF	red	External error
REDF	red	Loss of redundancy/Redundancy fault
BUS1F	red	Bus fault at the PROFIBUS interface
BUS5F	red	Bus fault at the first PROFINET IO interface
BUS8F	red	Bus fault at the service interface
IFM1F	red	Error in synchronization module 1
IFM2F	red	Error in synchronization module 2
MAINT	yellow	Maintenance request pending
RUN	green	RUN mode
STOP	yellow	STOP mode
Bottom bar		
MSTR	yellow	CPU controls the process
RACK0	yellow	CPU in rack 0
RACK1	yellow	CPU in rack 1
For the interfaces		
LINK	green	Connection at the PROFINET IO interface is active
RX/TX	orange	Receiving or sending data at the PROFINET IO interface.
LINK 1 OK	green	Connection via synchronization module 1 is active and OK
LINK 2 OK	green	Connection via synchronization module 2 is active and OK

Reset button

You operate the reset button in the following cases:

- You want to reset the CPU to the factory state, see section Resetting the CPU410-5H to factory settings (Page 126)
- You want to reset the CPU during operation (Forced reset), see section Reset during operation (Page 127)

The reset button is on the front of the CPU directly below the LED strip. Use an appropriately narrow object to press the reset button.

Slot for synchronization modules

You can insert one synchronization module into this slot. See section Synchronization modules (Page 181).

PROFIBUS DP interface

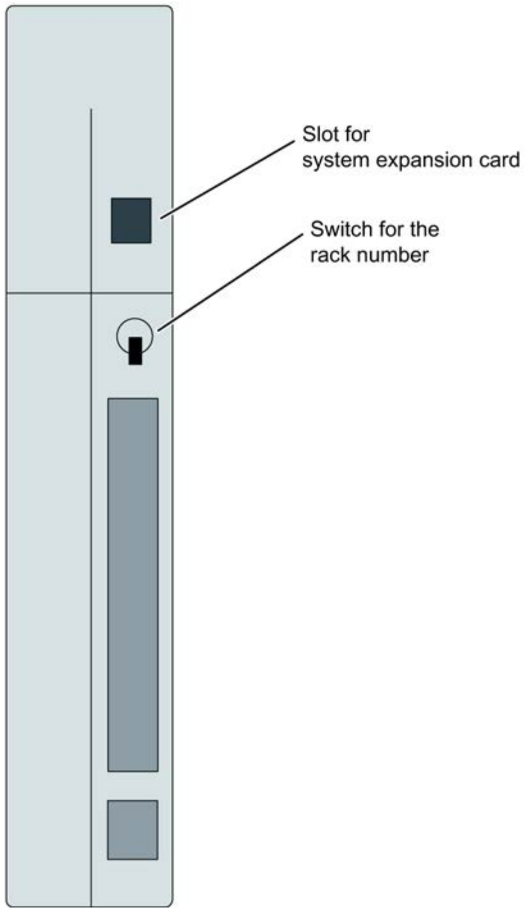
You can connect the distributed I/O to the PROFIBUS DP interface.

PROFINET IO interface

The PROFINET IO interfaces establish the connection to Industrial Ethernet. The PROFINET IO interfaces also serve as the access point for the engineering system. The PROFINET IO interfaces feature two switched ports with external connectors (RJ 45). You can connect IO devices to the first PROFINET IO interface X5. The interface X8 is designed as service interface and cannot be used as PROFINET IO interface. You will find additional information about PROFINET IO in the sections PROFINET IO systems (Page 89).

NOTICE
Connecting only to Ethernet LAN These interfaces only allow connection to an Ethernet LAN. You cannot connect them to the public telecommunication network, for example. You may only connect PROFINET IO-compliant network components to this interface.

Rear panel of the CPU 410-5H



Setting the rack number

Use the switch on the rear panel of the CPU to set the rack number. The switch has two positions: 1 (up) and 0 (down). One CPU is allocated rack number 0, and the partner CPU is assigned rack number 1. The default setting of all CPUs is rack number 0.

Slot for system expansion card

The back of the CPU has a slot in which you insert the system expansion card (SEC) before commissioning the CPU. The SEC contains information that specifies the performance class of the CPU in terms of the amount of POs it supports. The SEC is an essential part of the CPU hardware. The CPU cannot be operated without an SEC. If an SEC is not detected, the corresponding CPU goes to STOP and requests a memory reset. "STOP by CPU memory management" is also entered in the diagnostics buffer.
You need a small screwdriver to remove the SEC. Place the screwdriver at the top of the SEC slot and lift out the SEC with the screwdriver.

3.2 Monitoring functions of the CPU 410-5H

Monitoring functions and error messages

The hardware of the CPU and operating system provide monitoring functions to ensure proper operation and defined reactions to errors. Various errors may also trigger a reaction in the user program.

The table below provides an overview of possible errors and their causes, and the corresponding responses of the CPU.

Additional test and information functions are available in each CPU; they can be initiated in STEP 7.

Type of error	Cause of error	Error LED
Access error	Module failure (SM, FM, CP)	EXTF
Time error	• The user program execution time (OB 1 and all interrupts and error OBs) exceeds the specified maximum cycle time. • OB request error • Overflow of the start information buffer • Time-of-day error interrupt	INTF
Power supply module(s) fault (not power failure)	In the central or S7-400 expansion rack • at least one backup battery of the power supply module is completely discharged. • the backup battery voltage is missing. • the 24 V supply to the power supply module has failed.	EXTF
Diagnostic interrupt	An I/O module with interrupt capability reports a diagnostic interrupt The synchronization module signals a diagnostic interrupt; see Chapter Synchronization modules for the CPU 410-5H (Page 181) The LED EXTF lights up with the first incoming diagnostic interrupt and goes out with the outgoing diagnostic interrupt. The LED does not light up when only an outgoing diagnostic interrupt is reported.	EXTF
Swapping interrupt	Removal or insertion of an SM, and insertion of a wrong module type. Removing a synchronization module. The LED EXTF does not light up when a correct module is inserted.	EXTF
Redundancy error interrupt	• Loss of redundancy on the CPUs • Standby-master changeover • Synchronization error • Error in a synchronization module • Cancellation of the update process • Comparison error (e.g., RAM, PIQ)	EXTF REDF
CPU hardware fault	• A memory error was detected and eliminated	INTF

Type of error	Cause of error	Error LED
Program execution error	• Priority class is called, but the corresponding OB is not available. • In the case of an SFB call: Missing or faulty instance DB • Process image update error	INTF EXTF
Failure of a rack/station	• Power failure in an S7-400 expansion unit • Failure of a DP/PN segment • Failure of a coupling segment: Missing or defective IM, interrupted cable	EXTF BUSF for PN and DP REDF for redundant segments
Communication error	Communication error: • Time synchronization • Access to DB when exchanging data via communications function blocks	INTF
Execution canceled	The execution of a program block was canceled. Possible reasons for the cancellation are: • Nesting depth of nesting levels too great • Nesting depth of master control relay too great • Nesting depth of synchronization errors too great • Nesting depth of block call commands (U stack) too great • Nesting depth of block call commands (B stack) too great • Error during allocation of local data	INTF
Missing license for Runtime software	Internal error due to missing licenses for Runtime software.	INTF
Programming error	User program error: • BCD conversion error • Range length error • Range error • Alignment error • Write error • Timer number error • Counter number error • Block number error • Block not loaded	INTF
MC7 code error	Error in the compiled user program, for example, illegal OP code or a jump beyond block end	INTF

3.3 Status and error displays

RUN and STOP LEDs

The RUN and STOP LEDs provide information about the currently active CPU operating state.

LED		Meaning
RUN	**STOP**	
Lit	Dark	The CPU is in RUN mode.
Dark	Lit	The CPU is in STOP mode. The user program is not being executed. Cold restart/restart is possible. If the STOP status was triggered by an error, the error indicator (INTF or EXTF) is also set.
Flashes 2 Hz	Flashes 2 Hz	The CPU has detected a serious error that is blocking startup. All other LEDs also flash at 2 Hz.
Flashes 0.5 Hz	Lit	HOLD status has been triggered by a test function.
Flashes 2 Hz	Lit	A cold restart/restart was initiated. The cold restart/warm start may take a minute or longer, depending on the length of the called OB. If the CPU still does not change to RUN, there might be an error in the system configuration, for example.
Dark	Flashes 2 Hz	A high-quality RAM test (self-test) is executed after POWER ON. The self-test takes at least 15 minutes. Memory is being reset
Dark	Flashes 0.5 Hz	The CPU requests a memory reset.
Flashes 0.5 Hz	Flashes 0.5 Hz	Troubleshooting mode This display also indicates that internal processes are busy on the CPU and prevent access to the CPU until completed. This status can be triggered by the following routines: • Startup (POWER ON) of a CPU on which a large number of blocks is loaded. If encrypted blocks are loaded, startup may take a longer time depending on the number of such blocks.

MSTR, RACK0, and RACK1 LEDs

The three LEDs MSTR, RACK0, and RACK1 provide information about the rack number set on the CPU and show which CPU controls the switched I/O.

LED			Meaning
MSTR	RACK0	RACK1	
Lit	Irrelevant	Irrelevant	CPU controls switched I/O
Irrelevant	Lit	Dark	CPU on rack number 0
Irrelevant	Dark	Lit	CPU on rack number 1

INTF and EXTF LEDs

The two INTF and EXTF LEDs provide information about errors and other particular things that happen during user program execution.

LED		Meaning
INTF	EXTF	
Lit	Irrelevant	An internal error was detected (programming, parameter assignment, or license error).
Irrelevant	Lit	An external error was detected (i.e., an error whose cause is not in the CPU module).

BUS1F, BUS5F, and BUS8F LEDs

The BUS1F, BUS5F and BUS8F LEDs indicate errors associated with the PROFIBUS DP and PROFINET IO interfaces.

Table 3- 2 Possible states of the BUS1F, BUS5F, and BUS8F LEDs

LED			Meaning
BUS1F	BUS5F	BUS8F	
Lit	Irrelevant	Irrelevant	An error was detected at the PROFIBUS DP interface.
Irrelevant	Lit	Irrelevant	An error was detected at the PROFINET IO interface. A PROFINET IO system is configured but not connected.
Irrelevant	Flashes	Irrelevant	One or several devices on the PROFINET IO interface are not responding.
Flashes	Irrelevant	Irrelevant	One of more slaves on the PROFIBUS DP interface are not responding.
Irrelevant	Flashes	Irrelevant	One or more IO devices on the PROFINET IO interface are not responding.

IFM1F and IFM2F LEDs

The IFM1F and IFM2F LEDs indicate errors on the first or second synchronization module.

LED		Meaning
IFM1F	IFM2F	
Lit	Irrelevant	An error was detected on synchronization module 1.
Irrelevant	Lit	An error was detected on synchronization module 2

LINK and RX/TX LEDs

The LINK and RX/TX LEDs indicate the current state of the PROFINET IO interface.

Table 3- 3 Possible states of the LINK and RX/TX LEDs

LED		Meaning
LINK	RX/TX	
Lit	Irrelevant	Connection at the PROFINET IO interface is active
Irrelevant	Flashes 6 Hz	Receiving or sending data at the PROFINET IO interface.

Note

The LINK and RX/TX LEDs are located directly next to the PROFINET IO interface sockets. They are not labeled.

REDF LED

The REDF LED indicates specific system states and redundancy errors.

REDF LED	System state	Basic requirements
Flashes 0.5 Hz	Link-up	-
Flashes 2 Hz	Update	-
Dark	Redundant (CPUs are redundant)	No redundancy error
Lit	Redundant (CPUs are redundant)	There is an I/O redundancy error: • Failure of a DP master, or partial or total failure of a DP master system • Failure of a PN IO subsystem • Loss of redundancy on the DP slave • Loss of redundancy at the PN IO device

LEDs LINK1 OK and LINK2 OK

When commissioning the fault-tolerant system, you can use the LINK1 OK and LINK2 OK LEDs to check the quality of the connection between the CPUs.

LED LINKx OK	Meaning
Lit	The connection is OK
Flashes	The connection is not reliable, and the signal is disrupted Check the connectors and cables Ensure that the fiber-optic cables are installed in accordance with the guidelines in Chapter Installation of fiber-optic cables (Page 185). Check whether the synchronization module works in another CPU.
Dark	The connection is interrupted, or there is insufficient light intensity Check the connectors and cables Ensure that the fiber-optic cables are installed in accordance with the guidelines in Chapter Installation of fiber-optic cables (Page 185). Check whether the synchronization module works in another CPU.

LED MAINT

This LED indicates that maintenance is required. Maintenance is required when there are problems with the synchronization modules or if maintenance is demanded by one of the PN devices. For more information, refer to the STEP 7 Online Help.

Diagnostics buffer

In STEP 7, you can select "PLC -> Module Information" to read the cause of an error from the diagnostics buffer.

3.4 PROFIBUS DP interface (X1)

Connectable devices

The PROFIBUS DP interface can be used to set up a PROFIBUS master system, or to connect PROFIBUS I/O devices.

You can connect any standard-compliant DP slaves to the PROFIBUS DP interface.

You can connect the PROFIBUS DP I/O to the PROFIBUS DP interface in redundant or single-channel switched configuration.

Here, the CPU represents the DP master, and is connected to the passive slave stations or, in stand-alone operation, to other DP masters via the PROFIBUS DP fieldbus.

Various compatible devices take the 24 V supply from the interface. This voltage provided at the PROFIBUS DP interface is non-isolated.

Connectors

Always use bus connectors for PROFIBUS DP and PROFIBUS cables to connect devices to the PROFIBUS DP interface (*refer to the Installation Manual*).

Redundant operation

In redundant operation, the PROFIBUS DP interfaces have the same baud rate.

3.5 PROFINET IO interface (X5, X8)

Note

The second PROFINET IO interface X8 serves as service interface. It is disabled in version 8.0 and cannot be used.

Assigning an IP address

You have the following options of assigning an IP address to an Ethernet interface:

- By editing the CPU properties in HW Config. Download the modified configuration to the CPU.

You can also set up the IP address parameters and the station name (NameOfStation, NoS) locally without having to modify the configuration data.

- Using the "PLC -> Edit Ethernet Node" command in SIMATIC Manager.

Devices that can be connected via PROFINET IO (PN)

- PG/PC with Ethernet card or CP16xx communication processor
- Active network components, e.g., Scalance X200
- S7-300/S7-400, e.g., CPU 417-5H or communication processor CP443-1
- PROFINET IO devices, e.g., ET 200M

Connectors

Always use RJ45 connectors to hook up devices to the PROFINET interface.

Properties of the PROFINET IO interface

Protocols and communication functions	
PROFINET IO	
In accordance with IEC 61784-2 , Conformance Class A and BC	
Open block communication over • TCP • UDP • ISO-on-TCP	
S7 communication	
PG functions	
Port statistics of PN IO devices (SNMP)	
Detection of the network topology (LLDP)	
Media redundancy (MRP)	
Time synchronization using the NTP method as a client, or the SIMATIC method	

For more information on the properties of the PROFINET IO interface, refer to the technical specifications of the respective CPU. In Chapter Technical data (Page 195).

Connection	
Version	2 x RJ45
	Switch with 2 ports
Media	Twisted pair Cat5
Transmission rate	10/100 Mbps
	Autosensing Autocrossing Autonegotiation

Note

Networking of PROFINET IO components

The PROFINET IO interfaces of our devices are set to "automatic setting" (autonegotiation) by default. Verify that all devices connected to the PROFINET IO interface of the CPU are also set to the "Autonegotiation" mode. This is the default setting of standard PROFINET IO/Ethernet components.

If you connect a device to the PROFINET IO interface of the CPU that does not support the "automatic setting" (Autonegotiation) operating mode or you choose a setting other than the "automatic setting" (Autonegotiation) for this device, note the following:

- PROFINET IO requires 100 Mbps full-duplex operation, which means if the PROFINET IO interface of the CPU is used simultaneously for PROFINET IO communication and Ethernet communication, operation of the PROFINET IO interface is permissible only in 100 Mbps full-duplex mode.
- If the PROFINET IO interface(s) of the CPU are used for Ethernet communication only, 100 Mbps full-duplex mode is possible. Half-duplex mode is not allowed in any situation.

Background: If a switch that is permanently set to 10 Mbps half-duplex is connected to the interface of the CPU, the "Autonegotiation" setting forces the CPU to adapt itself to the settings of the partner device, i.e., the communication operates de facto at "10 Mbps half-duplex". However, this would not be a valid operating mode because PROFINET IO demands operation at 100 Mbps full-duplex.

Reference

- For details about PROFINET, refer to PROFINET System Description (http://support.automation.siemens.com/WW/view/en/19292127)
- For detailed information about Ethernet networks, network configuration and network components refer to SIMATIC NET Manual: Twisted-Pair and Fiber-Optic Networks (http://support.automation.siemens.com/WW/view/en/8763736).
- For additional information about PROFINET IO, refer to: PROFINET (http://www.profibus.com/)

3.6 Overview of the parameters for the CPU 410-5H

Default values

All parameters are set to factory defaults. These defaults are suitable for a wide range of standard applications and can be used to operate the CPU 410-5H directly without having to make any additional settings.

You can define the defaults using the "Configuring Hardware" tool in STEP 7.

Parameter blocks

The responses and properties of the CPU are defined in parameters. The CPU 410-5H has a defined default setting. You can modify these default setting by editing the parameters in the hardware configuration.

The list below provides an overview of the assignable system properties of the CPUs.

- General properties such as the CPU name
- Watchdog interrupts, e.g., priority, interval duration
- Diagnostics/clock, e.g., time-of-day synchronization
- Security levels
- H parameters, e.g., duration of a test cycle

Parameter assignment tool

You can set the individual CPU parameters using "HW Config" in STEP 7.

Further settings

- The rack number of a CPU 410-5H, 0 or 1

  Use the selector switch on the rear panel of the CPU to change the rack number.
- The operating mode of a CPU 410-5H, stand-alone operation or redundant operation

I/O configuration variants 4

4.1 Stand-alone operation

Overview

This chapter provides you with the necessary information for stand-alone operation of the CPU 410. You will learn:

- how stand-alone operation is defined
- when stand-alone operation is required
- what you have to take into account for stand-alone operation
- how the fault tolerance-specific LEDs react in stand-alone operation
- how to configure stand-alone operation of a CPU 410
- how you can expand a CPU 410 to form a fault-tolerant system
- which system modifications are possible during stand-alone operation and which hardware requirements must be met

Definition

By stand-alone operation, we mean the use of a CPU 410 in a standard SIMATIC-400 station.

Reasons for stand-alone operation

- No requirements for increased availability
- Use of fault-tolerant connections
- Configuration of the S7-400F fail-safe automation system

  A fail-safe user program can only be compiled for execution on the CPU 410 with a F-runtime license (for more details refer to Manual *S7-400F and S7-400FH Automation Systems*).

Note

The self-test of the CPU 410 is also performed in stand-alone operation.

What you have to take into account for stand-alone operation of a CPU 410

Note

In stand-alone operation of a CPU 410, no synchronization modules may be connected. The rack number must be set to "0".

The table below lists the differences between the operation of a CPU 410 in stand-alone mode and redundant mode.

Table B-1 Differences between stand-alone and redundant operation

Function	CPU 410 in stand-alone operation	CPU 410 in redundant system state
Multi-DP master mode	Yes	No
System modifications during operation	Yes, as described in Manual "Modifying the System during Operation via CIR".	Yes, as described in Chapter Failure and replacement of components during redundant operation (Page 167) for redundant operation.

Fault tolerance-specific LEDs

The REDF, IFM1F, IFM2F, MSTR, RACK0 and RACK1 LEDs show the reaction specified in the table below in stand-alone operation.

LED	Behavior
REDF	Dark
IFM1F	Dark
IFM2F	Dark
MSTR	Lit
RACK0	Lit
RACK1	Dark

Configuring stand-alone operation

Requirement: No synchronization module may be inserted in the CPU 410.

Procedure:

1. Insert a **SIMATIC-400** station in your project.
2. Configure the station with the CPU 410 according to your hardware configuration. For stand-alone operation, insert the CPU 410 in a standard rack (Insert > Station > S7-400 station in SIMATIC Manager).
3. Assign the parameters of the CPU 410. Use the default values, or customize the necessary parameters.
4. Configure the necessary networks and connections. For stand-alone operation you can also configure "fault-tolerant S7 connections".

For help on procedure refer to the Help topics in SIMATIC Manager.

Expanding the configuration to a fault-tolerant system

Note

You can only expand your system to a fault-tolerant system if you have not assigned any odd numbers to expansion units in stand-alone operation.

To expand the CPU 410 to a fault-tolerant system later, follow these steps:

1. Open a new project and insert a fault-tolerant station.
2. Copy the entire rack from the standard SIMATIC-400 station and insert it twice into the fault-tolerant station.
3. Insert the subnets as required.
4. Copy the DP slaves from the old stand-alone operation project to the fault-tolerant station as required.
5. Reconfigure the communication connections.
6. Carry out all changes required, such as the insertion of one-sided I/Os.

For information on how to configure the project refer to the Online Help.

Changing the operating mode of a CPU 410

The procedure for changing the operating mode of a CPU 410 differs depending on the operating mode you want to switch to and the rack number configured for the CPU:

Change from stand-alone to redundant operation, rack number 0

1. Insert the synchronization modules into the CPU.
2. Insert the synchronization cables into the synchronization modules.
3. Run an power cycle without battery backup, for example, by removing and inserting the CPU after power off, or download a project to the CPU in which it is configured for redundant operation.

Change from stand-alone mode to redundant operation, rack number 1

1. Set rack number 1 on the CPU.
2. Install the CPU.
3. Insert the synchronization modules into the CPU.
4. Insert the synchronization cables into the synchronization modules.

Changing from redundant to stand-alone operation

1. Remove the CPU.
2. Remove the synchronization modules
3. Set rack number 0 on the CPU.
4. Install the CPU.
5. Download a project to the CPU in which the CPU is configured for stand-alone operation.

System modification during operation in stand-alone operation

With a system modification during operation, it is also possible to make certain configuration changes in RUN in stand-alone operation of a CPU 410. The procedure corresponds to that for standard CPUs. Processing is halted during this, but for no more than 2.5 seconds (can be assigned). During this time, the process outputs retain their current values. In process control systems in particular, this has virtually no effect on the process. See also Manual *"Modifying the System during Operation via CiR"*.

System modifications during operation are only supported with distributed I/O. They require a configuration as shown in the figure below. To give you a clear overview, this shows only one DP master system and one PA master system.

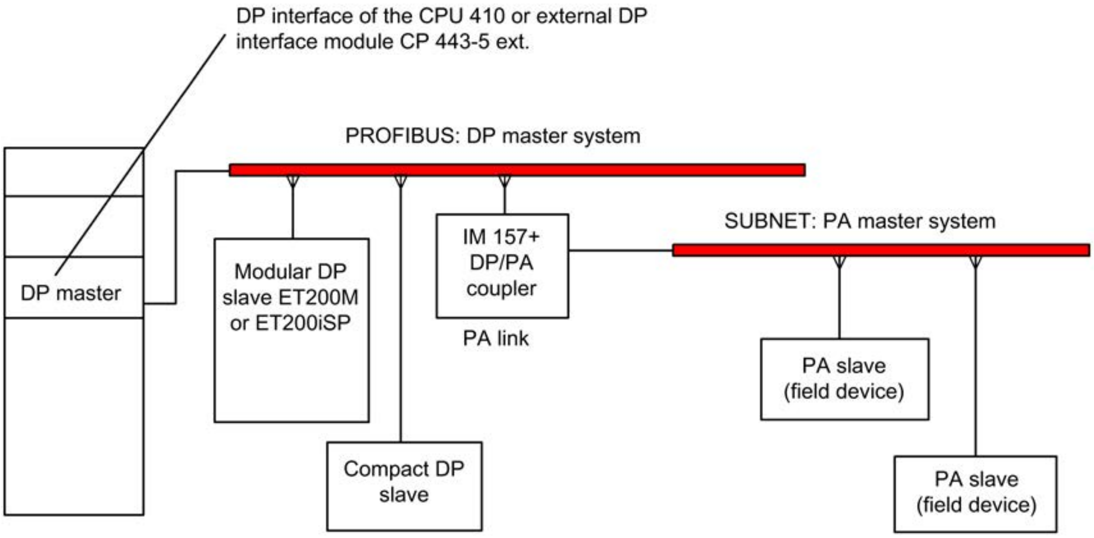


Figure 4-1 Overview: System structure for system modifications during operation

Hardware requirements for system modifications during operation

To modify a system during operation, the following hardware requirements must be met at the commissioning stage:

- CPU 410 in stand-alone operation
- If you use a CP 443-5 Extended, this must have a firmware V5.0 or higher.
- To add modules to an ET 200M: Use an IM 153-2, MLFB 6ES7 153-2BA00-0XB0 or higher, or an IM 153-2FO, MLFB 6ES7 153-2BB00-0XB0 or higher.
- If you want to add entire stations: Make sure that you have the required connectors, repeaters, etc.
- If you want to add PA slaves (field devices): Use IM 157, MLFB 6ES7 157-0AA82-0XA00 or higher, in the corresponding DP/PA link.

- The ET200M, ET200iSP and the PA-Link have to be connected with unassigned bus modules.
- RESERVE submodules have to be inserted in the free slots on the ET200iSP.

Note

You can freely combine components which support system modifications during operation with those that do not. Depending on your selected configuration, there may be restrictions affecting the components on which you can make system modifications during operation.

Permitted system modifications: Overview

During operation, you can make the following system modifications:

- Add modules or submodules with the modular DP slaves ET 200M or ET 200iS
- Use of previously unused channels in a module or submodule of the modular slaves ET 200M or ET 200iS
- Add DP slaves to an existing DP master system
- Add PA slaves (field devices) to an existing PA master system
- Add DP/PA couplers downstream of a PA link
- Add PA-Links (including PA master systems) to an existing DP master system
- Assign added modules to a process image partition
- Change parameter settings for I/O modules, for example selecting different interrupt limits
- Undo changes: Modules, submodules, DP slaves and PA slaves (field devices) you added earlier can be removed again

4.2 Fail-safe operation

Ensuring functional safety

A safety-related system encompasses sensors for signal acquisition, an evaluation unit for processing the signals, and actuators for signal output.

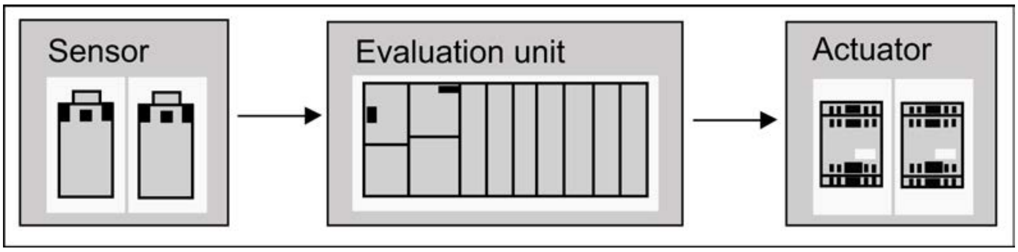


Figure 4-2 Processing chain: acquire, process, output

All of the components contribute to the functional safety of the system, in order, when a dangerous event occurs, to put the system into a safe state or to keep it in a safe state.

Safety of fail-safe SIMATIC Safety Integrated systems

For SIMATIC Safety Integrated systems, the evaluation unit consists, for example, of fail-safe single-channel CPUs and fail-safe dual-channel I/O modules. The fail-safe communications take place via the safety-related PROFIsafe profile.

Functions of a fail-safe CPU

A fail-safe CPU has the following functions:

- Comprehensive self-tests and self-diagnostics check the fail-safe state of the CPU.
- Simultaneous execution of standard and safety programs on one CPU. When there are changes to the standard user program, there are no unwanted effects on the safety program.

Fail-safe I/O modules (F-modules)

F-modules have all of the required hardware and software components for safe processing in accordance with the required safety class. This includes wire tests for short-circuit and cross-circuit. You only program the user safety functions.

Safety-related input and output signals form the interface to the process. This enables, for example, direct connection of single-channel and two-channel I/O signals from devices such as EMERGENCY STOP buttons or light barriers.

Safety-related communication with PROFIsafe profile

PROFIsafe was the first communication standard according to the IEC 61508 safety standard that permits both standard and safety-related communication on one bus line. This not only results in an enormous savings potential with regard to cabling and part variety, but also the advantage of retrofit ability.

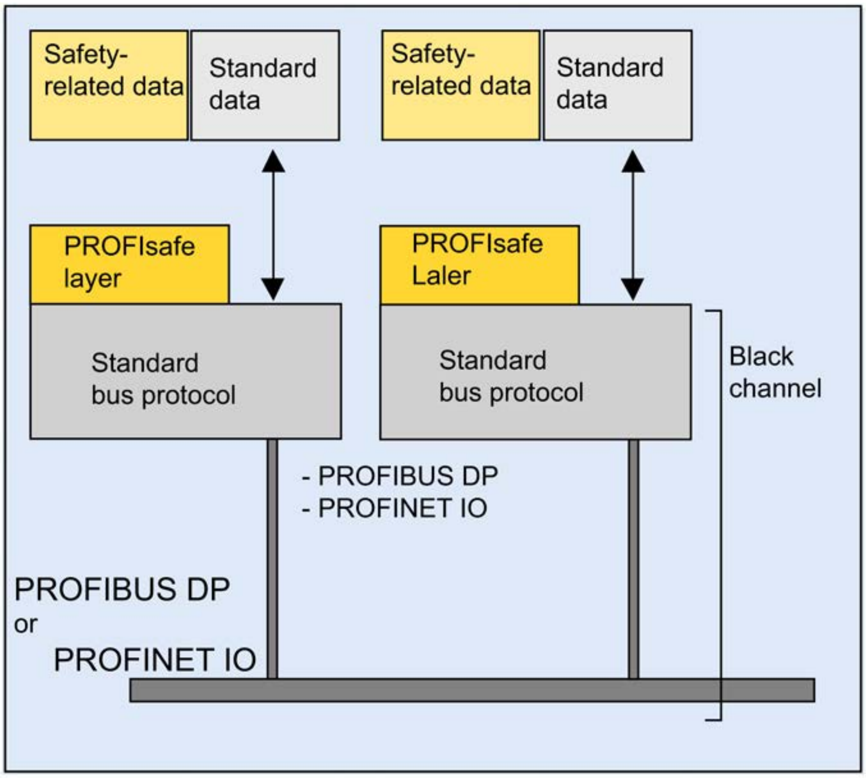


Figure 4-3 Safety-related communication

Safety-related and standard data are transmitted with PROFIsafe over the same bus line. Black channel means that collision-free communication via a bus system with media-independent network components (also wireless) is possible.

PROFIsafe is an open solution for safety-related communication via standard fieldbuses. Numerous manufacturers of safety components and end users of safety technology have helped to develop this vendor-neutral and open standard for PROFIBUS International (PI).

The PROFIsafe profile supports safe communication for the open PROFIBUS and PROFINET standard buses. An IE/PB Link ensures integrated, safety-related communication between PROFIBUS DP and PROFINET IO.

As a component of SIMATIC Safety Integrated, PROFIsafe is certified according to IEC 61508 (up to SIL 3), EN 954 (up to Category 4), NFPA 79-2002, NFPA 85, and thus meets the most stringent requirements for the production and process industries.

PROFIBUS is the global standard for fieldbuses with approximately 13 million installed nodes. Its market acceptance is so high because a large number of manufacturers offer many products for PROFIBUS. With the PA transmission variant (IEC 1158-2), PROFIBUS extends the unified system concept of distributed automation to the process world.

PROFINET IO is the innovative and open Industrial Ethernet standard for automation. It enables fast reaction times and transmission of large data quantities.

PROFIsafe uses the PROFIBUS or PROFINET IO services for safe communication. A fail-safe CPU 410 and a fail-safe slave (F-slave) exchange both user data as well as status and control information; no additional hardware is required for this.

PROFIsafe takes the following measures to counteract the various possible errors when transferring messages.

Table 4- 1 Measures in PROFIsafe for error avoidance

Measure/ Error	Consecutive number	Time expectation with acknowledgment	Identifier for sender and receiver	Data backup CRC
Repetition	✓			
Loss	✓	✓		
Insertion	✓	✓	✓	
Incorrect sequence	✓			
Data falsification				✓
Delay		✓		
Coupling of safety-related messages and standard messages (masquerade)		✓	✓	✓
FIFO errors (first-in-first-out data register for maintaining the sequence)		✓		

4.3 Fault-tolerant automation systems (redundancy operation)

4.3.1 Redundant SIMATIC automation systems

Operating objectives of redundant automation systems

Redundant automation systems are used in practice with the aim of achieving a higher degree of availability or fault tolerance.

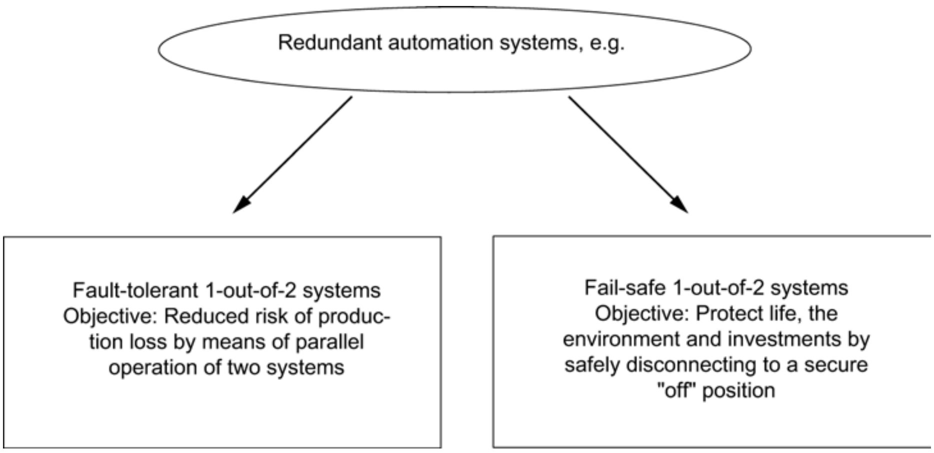


Figure 4-4 Operating objectives of redundant automation systems

Note the difference between fault-tolerant and fail-safe systems.
The S7-400H is a fault-tolerant automation system. You may only use the S7-400H to control safety-related processes if you have programmed it and assigned its parameters in accordance with the rules for F-systems. You can find details in the following manual:
SIMATIC Industrial Software S7 F/FH Systems
(http://support.automation.siemens.com/WW/view/en/2201072)

Why fault-tolerant automation systems?

The purpose of using fault-tolerant automation systems is to reduce production downtimes, regardless of whether the failures are caused by an error/fault or are due to maintenance work.

The higher the costs of production stops, the greater the need to use a fault-tolerant system. The generally higher investment costs of fault-tolerant systems are soon recovered since production stops are avoided.

Redundant I/O

Input/output modules are termed redundant when they exist twice and they are configured and operated as redundant pairs. The use of redundant I/O provides the highest degree of availability, because the system tolerates the failure of a CPU or of a signal module.

See also

Connecting redundant I/O to the PROFIBUS DP interface (Page 68)

4.3.2 Increase of plant availability, reaction to errors

The CPU 410 satisfies the high demands on availability, intelligence, and decentralization placed on modern automation systems. It also provides all functions required for the acquisition and preparation of process data, including functions for the open-loop control, closed-loop control, and monitoring of assemblies and plants.

System-wide integration

The CPU 410 and all other SIMATIC components, such as the SIMATIC PCS 7 control system, are matched to one another. The system-wide integration, ranging from the control room to the sensors and actuators, is implemented as a matter of course and ensures maximum system performance.

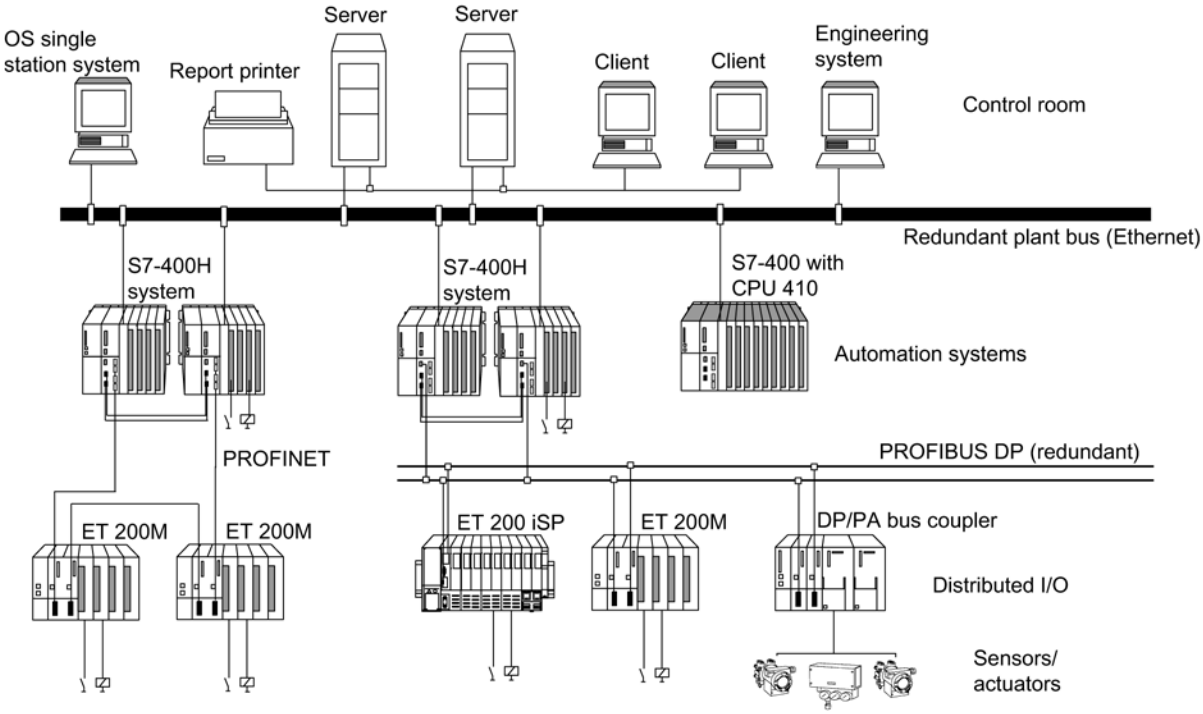


Figure 4-5 Integrated automation solutions with SIMATIC

Graduated availability by duplicating components

The redundant structure of the S7-400H ensures requirements to reliability at all times. This means: all essential components are duplicated.

This redundant structure includes the CPU, the power supply, and the hardware for linking the two CPUs.

You yourself decide on any other components you want to duplicate to increase availability depending on the specific process you are automating.

Redundancy nodes

Redundant nodes represent the fail safety of systems with redundant components. A redundant node can be considered as independent when the failure of a component within the node does not result in reliability constraints in other nodes or in the overall system.

The availability of the overall system can be illustrated simply in a block diagram. With a 1-out-of-2 system, **one** component of the redundant node may fail without impairing the operability of the overall system. The weakest link in the chain of redundant nodes determines the availability of the overall system

No error/fault

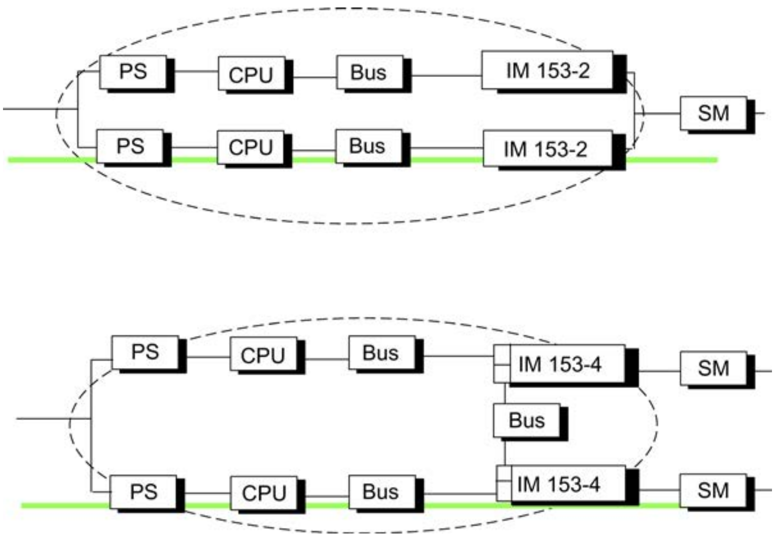


Figure 4-6 Example of redundancy in a network without error

With error/fault

The following figure shows how a component may fail without impairing the functionality of the overall system.

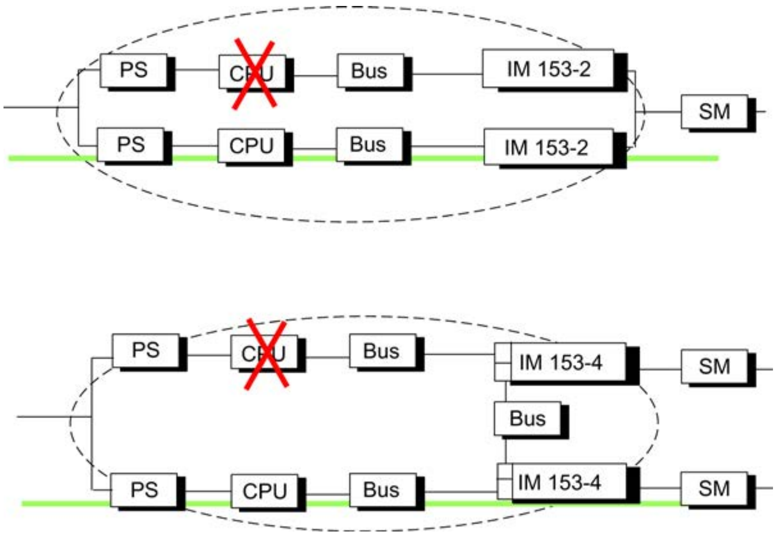


Figure 4-7 Example of redundancy in a 1-out-of-2 system with error

Failure of a redundancy node (total failure)

The following figure shows that the overall system is no longer operable, because both subunits have failed in a 1-out-of-2 redundancy node (total failure).

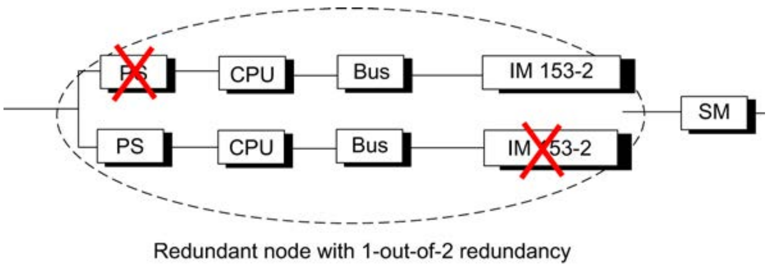


Figure 4-8 Example of redundancy in a 1-out-of-2 system with total failure

4.4 Introduction to the I/O link to fault-tolerant system

I/O installation types

In addition to the power supply module and CPUs, which are always redundant, the operating system supports the following I/O installation types. You specify the I/O installation types in the configuration with HW Config.

Configuration	Availability
Single-channel switched	Increased
System-redundant	Increased
Two-channel redundant	High

Addressing

If you are using switched I/O, you always use the same address when addressing the I/O.

Further I/O expansion

If there are insufficient slots in the central controllers, you can expand the installation of a fault-tolerant system with expansion units.

You can assign racks with even numbers only to central controller 0, and racks with odd numbers only to central controller 1.

For use of distributed I/O, you can connect a DP master system in each of the two subsystems. Connect a DP master to the integrated interface of the CPU and others by means of external DP master systems.

Note

PROFIBUS DP and PROFINET IO in combination

You can use PROFINET IO devices as well as PROFIBUS DP stations on a CPU 410.

Distributed I/O over PNIO

You can also operate distributed PROFINET I/O on the integrated PROFINET IO interface.

4.5 Using single-channel switched I/O

What is single-channel switched I/O?

In the single-channel switched configuration, the input/output modules are present singly (single-channel).

In redundant operation, these can addressed by both subsystems.

In solo operation, the master subsystem can always address **all switched I/Os** (in contrast to one-sided I/O).

The single-channel switched I/O configuration is recommended for system components which tolerate the failure of individual modules within the ET 200M or ET 200iSP.

Single-channel switched I/O configuration at the PROFIBUS DP interface

The system supports single-channel switched I/O configurations containing an ET 200M distributed I/O module with active backplane bus and a redundant PROFIBUS DP slave interface module and with the ET 200iSP distributed I/O module.

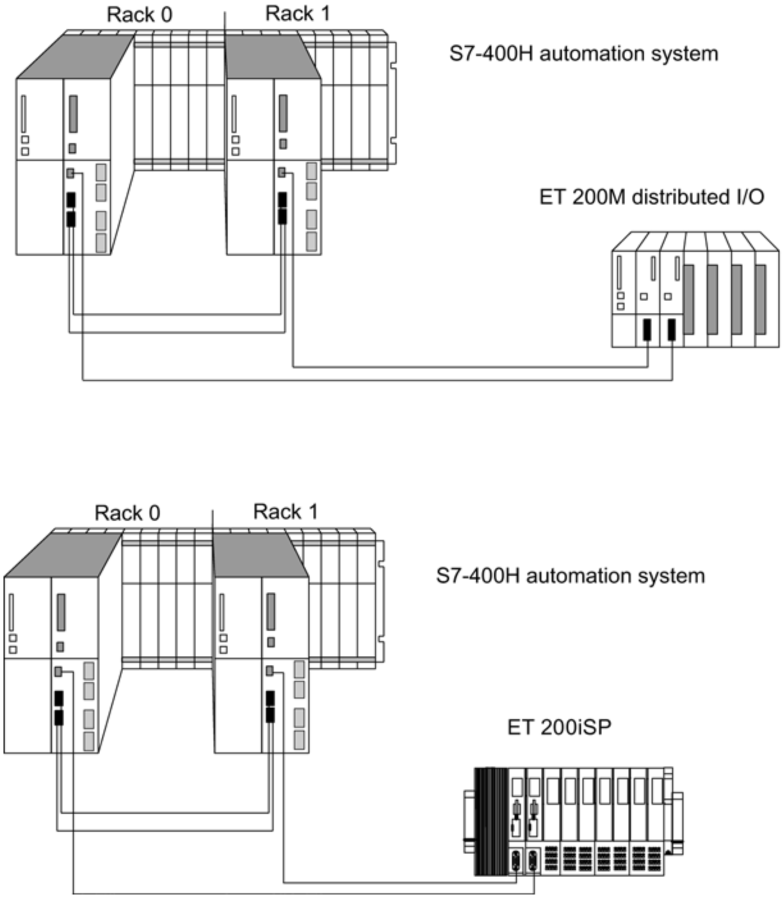


Figure 4-9 Single-channel switched distributed I/O configuration at the PROFIBUS DP interface

You can use the following interface modules for the I/O configuration at the PROFIBUS DP interface:

Table 4- 2 Interface modules for use of single-channel switched I/O configuration at the PROFIBUS DP interface

Interface module	Order number
IM 152 for ET 200iSP	6ES7152-1AA00-0AB0
IM 153–2 for ET 200M	6ES7 153–2BA82–0XB0 6ES7 153–2BA81–0XB0 6ES7 153–2BA02–0XB0 6ES7 153–2BA01–0XB0 6ES7 153–2BA00–0XB0
IM 153–2FO for ET 200M	6ES7 153–2AB02–0XB0 6ES7 153–2AB01–0XB0 6ES7 153–2AB00–0XB0

Each S7-400H subsystem is interconnected with one of the two DP slave interfaces of the ET 200M via a DP master interface.

DP/PA link

The DP/PA link consists of one or two IM 153-2 interface modules, and one to five DP/PA couplers that are either connected with one another via passive bus couplers or via bus modules.
The DP/PA link creates a gateway from a PROFIBUS DP master system to PROFIBUS PA. In this case the two bus systems are non-interacting through the IM 153-2 both physically (galvanically) and in terms of protocols and time.

PROFIBUS PA can be connected to a redundant system via a DP/PA link. The following IM 157 PA coupler is supported: 6ES7 157-0AC83-0XA0

You can use the following DP/PA links:

DP/PA link	Order number
ET 200M as DP/PA link with	6ES7 153–2BA82–0XB0 6ES7 153–2BA81–0XB0 6ES7 153–2BA02–0XB0 6ES7 153–2BA01–0XB0

Y Link

The Y Link consists of two IM 153-2 interface modules and one Y coupler that are connected with one another by bus modules.
The Y Link creates a gateway from the redundant DP master system of an S7-400H to a non-redundant DP master system. This means that devices with only one PROFIBUS DP interface can be connected to a S7-400H as switched I/Os.

A single-channel DP master system can be connected to a redundant system via a Y coupler.
The following IM 157 Y coupler is permissible: 6ES7 197-1LB00 0XA0.

You can use the following Y Links:

Y Link	Order number
ET 200M as Y Link with	6ES7 153–2BA82–0XB0 6ES7 153–2BA81–0XB0 6ES7 153–2BA02–0XB0 6ES7 153–2BA01–0XB0

Rule for PROFIBUS DP

A single-channel switched I/O configuration must always be symmetrical.

- This means, the fault-tolerant CPU and other DP masters must be installed in the same slots in both subsystems (e.g., slot 4 in both subsystems)
- The DP slaves must be connected to the same DP interface in both subsystems (e.g., to the PROFIBUS DP interfaces of both fault-tolerant CPUs).

Single-channel switched I/O configuration at the PROFINET IO interface

The system supports single-channel switched I/O configurations containing the ET 200M distributed I/O station with active backplane bus and a redundant PROFINET IO interface module.

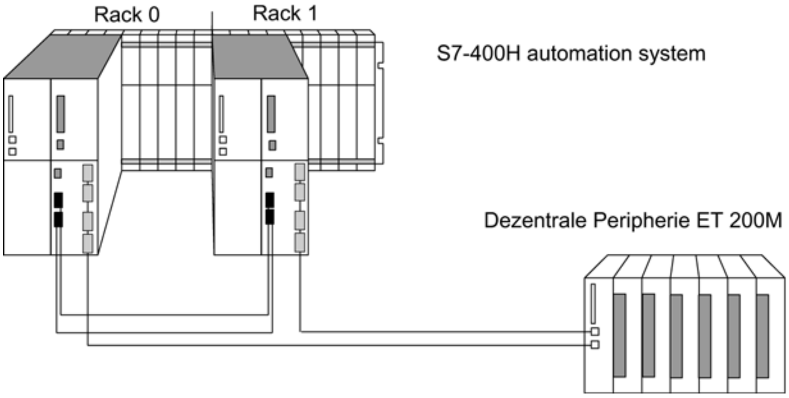


Figure 4-10 Single-channel switched distributed I/O configuration at the PROFINET IO interface

Each S7-400H subsystem is connected separately (via a PROFINET IO interface) to the PROFINET IO interface of the ET 200M. See Chapter System redundancy (Page 63).

You can use the following interface module for the I/O configuration at the PROFINET IO interface:

Table 4- 3 Interface module for use of single-channel switched I/O configuration at the PROFINET IO interface

Interface module	Order number
IM 153-4 PN V4.0 and higher	6ES7153-4BA00-0XB0

Single-channel switched I/O and user program

In redundant operation, in principle any subsystem can access single-channel switched I/O. The data is automatically transferred via the synchronization link and compared. An identical value is available to the two subsystems at all times owing to the synchronized access.

The fault-tolerant system uses only one of the DP interface or PROFINET IO interface at any given time. The active DP interface is indicated by the ACT LED on the corresponding IM 153–2.

The path via the currently active DP interface or PROFINET IO interface is called the **active channel**, while the path via the other interface is called the **passive channel**. The DP or PNIO cycle is always active on both channels. However, only the input and output values of the active channel are processed in the user program or output to the I/O. The same applies to asynchronous activities, such as interrupt processing and the exchange of data records.

Failure of the single-channel switched I/O

The fault-tolerant system with single-channel switched I/O responds to errors as follows:

- The faulty I/O is no longer available if an input/output module or a connected device fails.
- In certain failure situations (such as the failure of a subsystem, DP master system, or DP slave interface module IM153-2), the single-channel switched I/O remains available to the process.
  This is achieved by a switchover between the active and passive channels. This switchover takes place separately for each DP or PNIO station. A distinction is made between the following two types of failure:
  - Failures affecting only one station (such as failure of the DP slave interface of the currently active channel)
  - Failures affecting all stations of a DP master system or PNIO system.

    This includes unplugging of the connector at the DP master interface or at the PNIO interface, shutdown of the DP master system (e.g. RUN-STOP transition on a CP 443-5), and a short-circuit at the cable harness of a DP master system or PNIO system.

The following applies to each station affected by a failure: If both DP slave interfaces or PNIO connections are currently functional and the active channel fails, the previously passive channel automatically becomes active. A redundancy loss is reported to the user program when OB 70 starts (event W#16#73A3).

Once the problem is eliminated, redundancy is restored. This also starts OB 70 (event W#16#72A3). In this situation, there is no changeover between the active and passive channel.

If one channel has already failed, and the remaining (active) channel also fails, then there is a complete station failure. This starts OB 86 (event W#16#39C4).

Note

If the DP master interface module can detect failure of the entire DP master system (due to short-circuit, for example), it reports only this event ("Master system failure entering state" W#16#39C3). The operating system no longer reports individual station failures. This feature can be used to accelerate the changeover between the active and passive channel.

Duration of a changeover of the active channel

The maximum changeover time is

DP error detection time + DP changeover time + changeover time of the DP slave interface

You can determine the first two values from the bus parameters of your DP master system in STEP 7. You can obtain the last value from the manuals of the relevant DP slave interface module *(distributed I/O device ET 200M* or *DP/PA bus link*).

Note

When using fail-safe modules, always set a monitoring time for each fail-safe module that is longer than the changeover time of the active channel in the fault-tolerant system. If you ignore this rule, you risk passivation of the fail-safe modules during the changeover of the active channel.

Note

Note that the CPU can only detect a signal change if the signal duration is greater than the specified changeover time.
When there is a changeover of the entire DP master system, the changeover time of the slowest DP component applies to all DP components. A DP/PA link or Y link usually determines the changeover time and the associated minimum signal duration. We therefore recommend that you connect DP/PA and Y links to a separate DP master system.

Changeover of the active channel during link-up and updating

During link-up and updating with master/standby changeover (see Chapter Link-up sequence (Page 261)), a changeover between the active and passive channels occurs for all stations of the switched I/O. At the same time OB 72 is called.

Bumpless changeover of the active channel

To prevent the I/O failing temporarily or outputting substitute values during the changeover between the active and passive channel, the DP or PNIO stations of the switched I/O put their outputs on hold until the changeover is completed and the new active channel has taken over.

To ensure that total failure of a DP or PNIO station is also detected during the changeover, the changeover is monitored by the various DP/PN IO stations and by the DP master system.

System configuration and project engineering

You should allocate switched I/O with different changeover times to separate chains. This, for example, simplifies the calculation of monitoring times.

See also

Time monitoring (Page 110)

4.6 System and media redundancy at the PROFINET IO interface

4.6.1 System redundancy

System redundancy is a connection of IO devices via PROFINET IO in which a communication connection exists between each IO device and each of the two fault-tolerant CPUs. This communication connection can be set up using any topological interconnection. The topology of a system alone does not indicate if an IO device is integrated in system redundancy.

Contrary to a one-sided connection of IO devices, the failure of a CPU does not result in the failure of the IO devices connected with this CPU.

Configuration

The figure below shows a configuration with two IO devices connected in system redundancy.

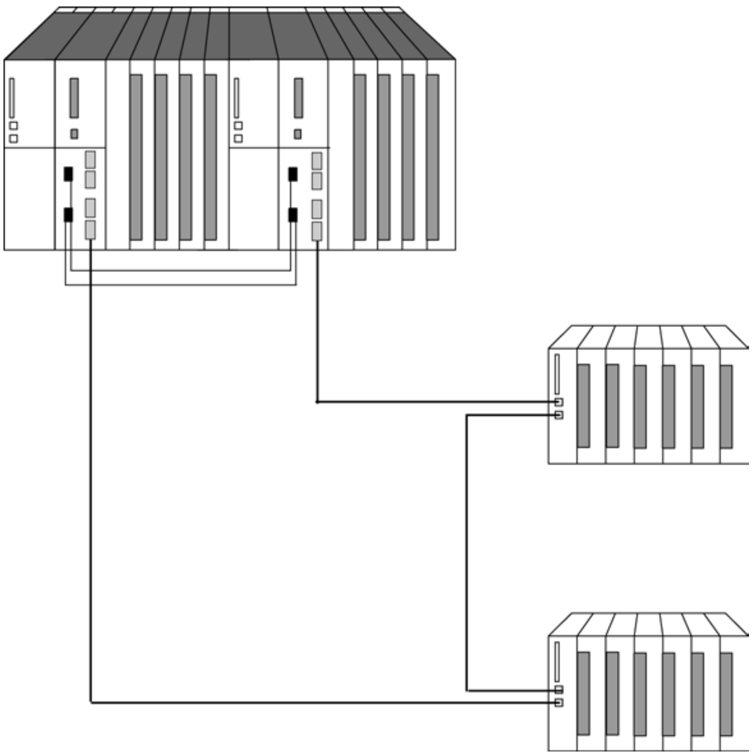


Figure 4-11 S7-400H system with IO devices connected in system redundancy

This topology has the following advantage: The entire system can continue to operate in case of an interrupted connection, no matter where it occurs. One of the two communication connections of the IO devices will always remain intact. The IO devices that were redundant until now will continue operating as one-sided IO devices.

The figure below shows the view in STEP 7, the logical view and the physical view of the configuration with two integrated IO devices in system redundancy. Note that the view in STEP 7 does not exactly match the physical view.

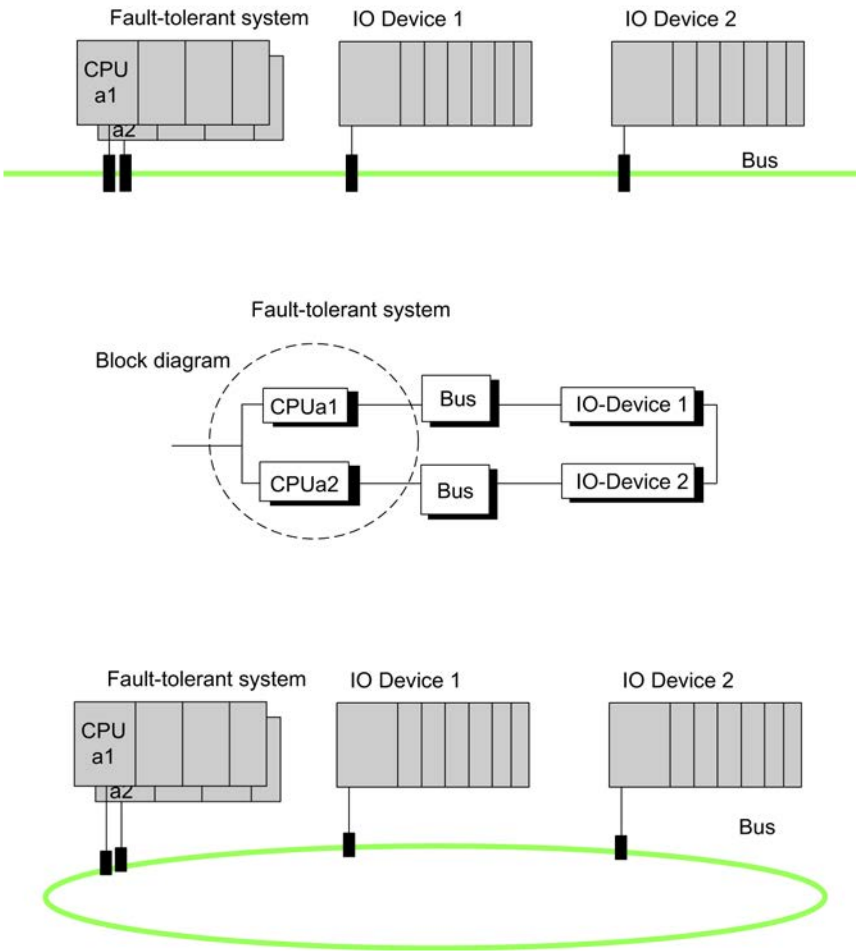


Figure 4-12 System redundancy in different views

Commissioning a system-redundant configuration

It is imperative that you assign unique names during commissioning.

Proceed as follows when you change or reload a project:

1. Set the fault-tolerant system to STOP on both sides.
2. Reset the standby CPU memory.

3. Download the new project to the master CPU.
4. Start the fault-tolerant system.

Note

Using the topology editor

Use the topology editor in HW Config.

Station numbers

The IO devices can be configured as one-sided or redundant. The station numbers must be unique across both PROFINET IO interfaces and between 1 and 256.

PN/IO with system redundancy

The figure below shows the system-redundant connection of three IO devices using one switch. Two additional IO devices are also connected in system redundancy.

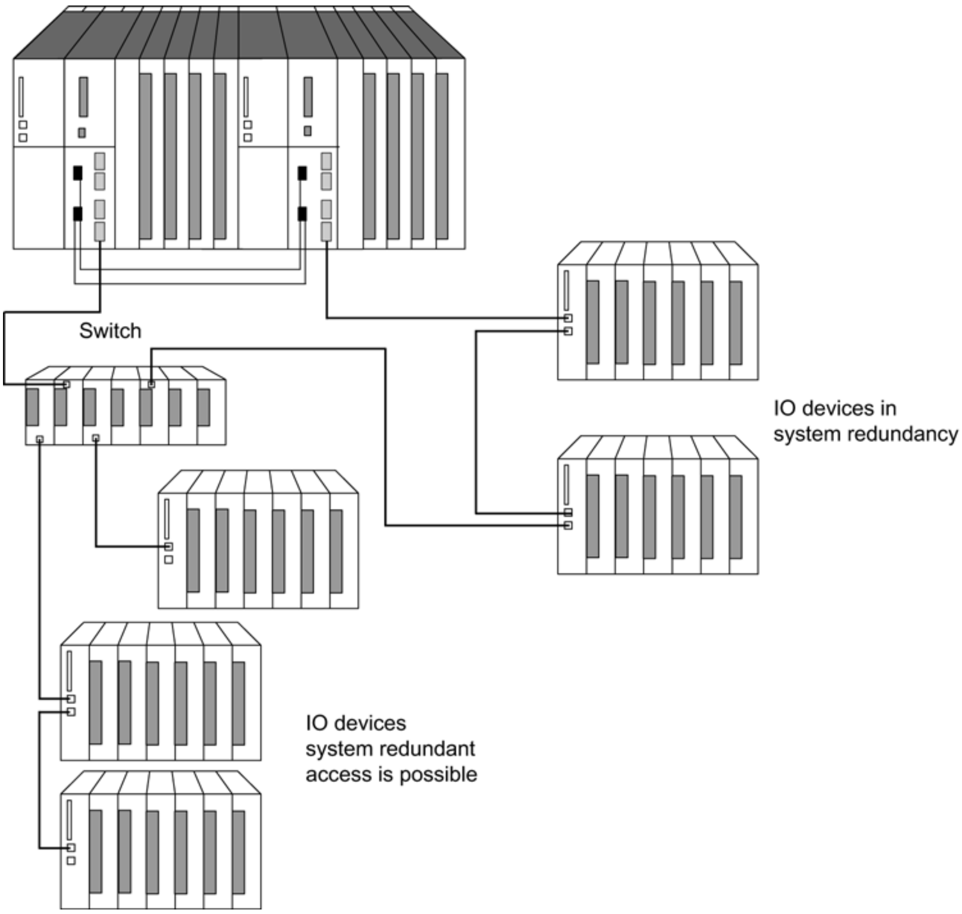


Figure 4-13 PN/IO with system redundancy

The figure below shows the system-redundant connection of nine IO devices using three switches. This configuration, for example, allows you to arrange IO devices in several cabinets.

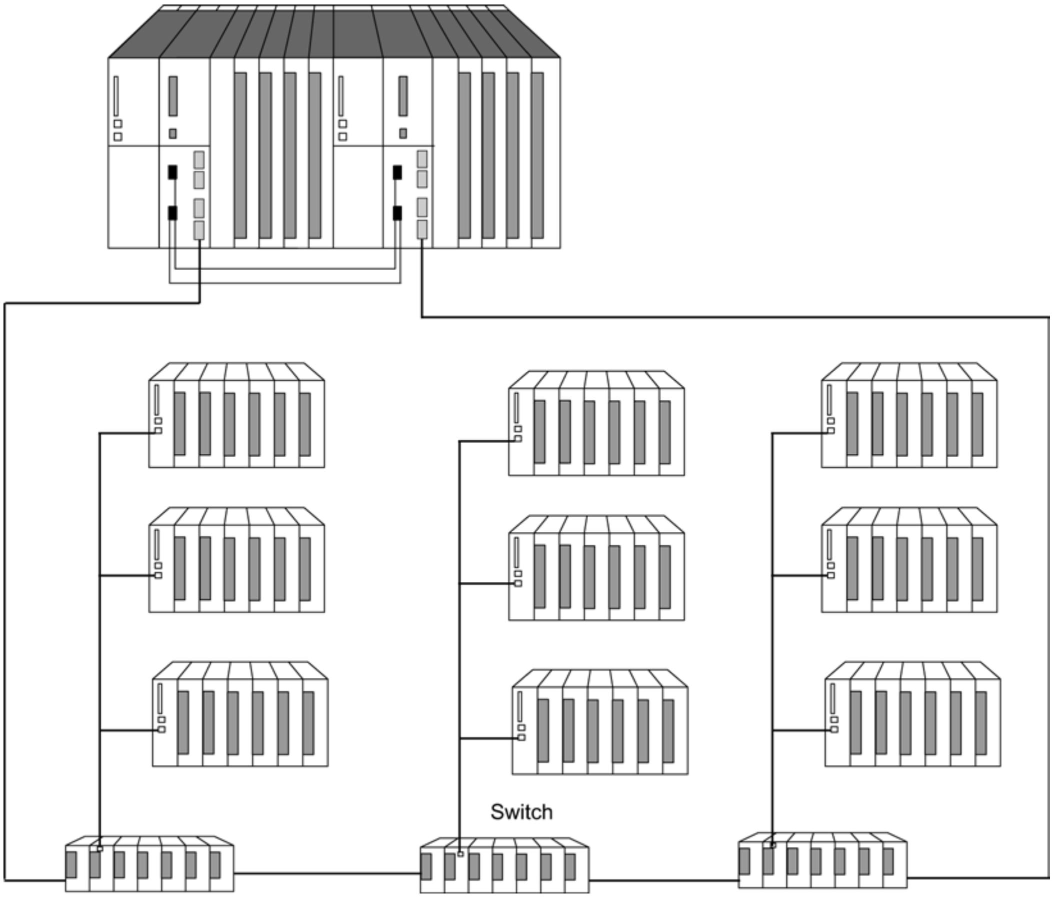


Figure 4-14 PN/IO with system redundancy

Note

Logical structure and topology

The topology itself does not determine if IO devices are connected one-sided or in a configuration with system redundancy. This is determined in the course of configuration. You can configure the IO devices in the first figure, for example, as one-sided instead of the system-redundant setup.

4.6.2 Media redundancy

Media redundancy is a function for ensuring network availability and thus contributes to increasing the plant availability. Redundant transmission links in a ring topology ensure that an alternative communication path is always available if a transmission link fails.

You can enable the media redundancy protocol (MRP) for IO devices, switches, and CPUs with PROFINET IO interface V8.0 or higher in STEP 7 -> HW Config. MRP is a component of the PROFINET IO standardization according to IEC 61158.

In media redundancy with MRP, one device is the media redundancy manager (MRM), and all other devices are redundancy clients.

Installing a ring topology

To set up a ring topology with media redundancy, you must join both free ends of a line network topology in the same device. You join the line topology to form a ring via two ports (ring ports, port ID "R") of a device connected to the ring. Specify the ring ports in the configuration data of the relevant device.

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.

Topology

You can also combine media redundancy under PROFINET IO with other PROFINET IO functions.

Media redundancy

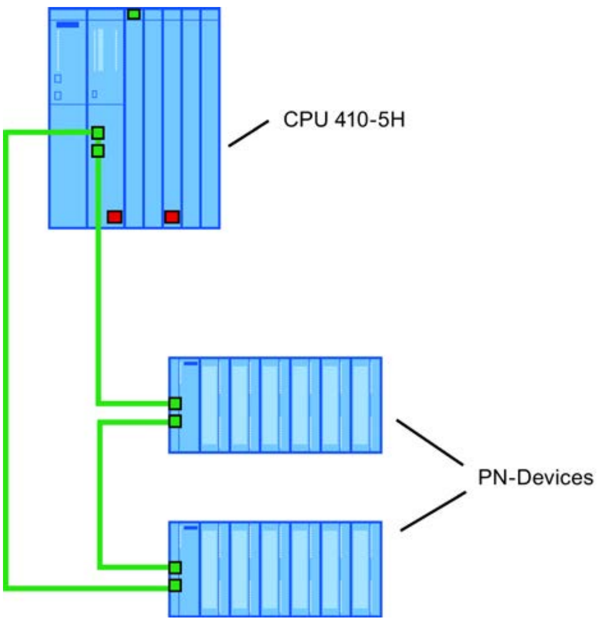


Figure 4-15 Configuration example of media redundancy

RT communication (real-time communication)

The transmission of real-time data with PROFINET IO is based on the cyclic data exchanges with a provider-consumer model. To better scale the communication options and therefor the determinism for PROFINET IO, real-time classes have been defined for data exchange. These are unsynchronized and synchronized communication. The details are handled independently in the field devices. Real-time automatically includes an increase in priority with PROFINET compared to UDP/IP frames. This is necessary to prioritize the transmission of data in the switches so that RT frames are not delayed by UDP/IP frames.

Note

RT communication is interrupted (station failure) if the reconfiguration time of the ring is greater than the selected response monitoring time of the IO device. The same applies to IO devices configured with MRP outside the ring.

Additional information

For additional information, refer to the STEP 7 Online Help and to Manual PROFINET System Description (http://support.automation.siemens.com/WW/view/en/19292127).

4.7 Connecting redundant I/O to the PROFIBUS DP interface

4.7.1 Signal modules for redundancy

Signal modules as redundant I/O

The signal modules listed below can be used distributed as redundant I/O. Take into account the latest information on the use of modules in the Readme and in the following SIMATIC FAQ : S7-400H Systems Redundant I/O (http://support.automation.siemens.com/WW/view/en/9275191)

Note

The statements on the individual signal modules in this section refer exclusively to their use in redundant operation. Restrictions and special features listed here especially do not apply to the use of the corresponding module in stand-alone operation.

Take into account that you can only use modules of the same product version and same firmware version as redundant pairs.

Note

PROFINET

The use of redundant I/O at the PROFINET interface is not possible.

A complete list of all modules approved for PCS7 V8.0 SP1 is available at the following address: SIMATIC Process Control System PCS 7 Approved Modules (V8.0 SP1) (http://support.automation.siemens.com/WW/view/de/68157377/0/en)

Table 4- 4 Signal modules for redundancy

Module	Order number
Redundant DI dual-channel	
DI16xDC 24 V, interrupt	6ES7 321-7BH00-0AB0
DI16xDC 24 V	6ES7 321–7BH01–0AB0
In the event of an error on one channel, the entire group (2 channels) is passivated. When using the module with HF index, only the faulty channel is passivated in the event of a channel error. Use with non-redundant encoder • This module supports the "wire break" diagnostic function. To implement this function, make sure that a total current between 2.4 mA and 4.9 mA flows even at signal state "0" when you use an encoder that is evaluated at two inputs in parallel. You achieve this by connecting a resistor across the encoder. Its value depends on the type of switch and usually ranges between 6800 and 8200 ohms for contacts. For BEROS, calculate the resistance based on this formula: (30 V/(4.9 mA – I_R_Bero) < R < (20 V/(2.4 mA – I_R_Bero)	
DI16xDC 24 V	6ES7 321-1BH02-0AA0
In some system states, it is possible that an incorrect value of the first module is read in briefly when the front connector of the second module is removed. This is prevented by using series diodes like those shown in figure C-3.	
DI32xDC 24 V	6ES7 321-1BL00-0AA0
In some system states, it is possible that an incorrect value of the first module is read in briefly when the front connector of the second module is removed. This is prevented by using series diodes like those shown in figure C-4.	
DI 8xAC 120/230V	6ES7 321-1FF01-0AA0
DI 4xNamur [EEx ib]	6ES7 321-7RD00-0AB0
You cannot use the module in redundant operation for applications in hazardous areas. Use with non-redundant encoder • You can only connect 2-wire NAMUR encoders or contact makers. • Equipotential bonding of the encoder circuit should always be at one point only (preferably encoder negative). • When selecting encoders, compare their properties with the specified input characteristics. Remember that this function must always be available, regardless of whether you are using one or two inputs. Example of valid values for NAMUR encoders: for "0" current > 0.2 mA; for "1" current > 4.2 mA.	

Module	Order number
DI 16xNamur	6ES7321-7TH00-0AB0
Use with non-redundant encoder • Equipotential bonding of the encoder circuit should always be at one point only (preferably encoder negative). • Operate the two redundant modules on a common load power supply. • When selecting encoders, compare their properties with the specified input characteristics. Remember that this function must always be available, regardless of whether you are using one or two inputs. Example of valid values for NAMUR encoders: for "0" current > 0.7 mA; for "1" current > 4.2 mA.	
DI 24xDC 24 V	6ES7326–1BK01–0AB0 6ES7326–1BK02–0AB0
F-module in fail-safe and standard mode	
DI 8xNAMUR [EEx ib]	6ES7326-1RF00-0AB0
F-module in standard mode	
Redundant DO dual-channel	
DO8xDC 24 V/0.5 A	6ES7322-8BF00-0AB0
A definite evaluation of the diagnostics information "P short-circuit" and "wire break" is not possible. Deselect these individually in your configuration.	
DO8xDC 24 V/2 A	6ES7322-1BF01-0AA0
DO32xDC 24 V/0.5 A	6ES7322-1BL00-0AA0
DO8xAC 120/230 V/2 A	6ES7322-1FF01-0AA0
DO 4x24 V/10 mA [EEx ib]	6ES7322-5SD00-0AB0
You cannot use the module in redundant operation for applications in hazardous areas.	
DO 4x15 V/20 mA [EEx ib]	6ES7322-5RD00-0AB0
You cannot use the module in redundant operation for applications in hazardous areas.	
DO 16xDC 24 V/0.5 A	6ES7322-8BH01-0AB0
• The equipotential bonding of the load circuit should always take place from one point only (preferably load minus). • Diagnostics of the channels is not possible.	
DO 16xDC 24 V/0.5 A	6ES7322-8BH10-0AB0
• The equipotential bonding of the load circuit should always take place from one point only (preferably load minus).	
DO 10xDC 24 V/2 A	6ES7326–2BF10–0AB0
F-module in fail-safe mode	
Redundant AI dual-channel	
AI6x0/4...20mA HART	6ES7336-4GE00-0AB0
F-module in fail-safe mode	

Module	Order number
AI8x12Bit	6ES7331-7KF02-0AB0
Use in voltage measurement • The "wire break" diagnostics function in HW Config must not be activated, neither when operating the modules with transmitters nor when thermocouples are connected. Use for indirect current measurement • When determining the measuring error, observe the following: The total input resistance in measuring ranges > 2.5 V is reduced from a nominal 100 kilohm to 50 kilohm when operating two inputs connected in parallel. • The "wire break" diagnostics function in HW Config must not be activated, neither when operating the modules with transmitters nor when thermocouples are connected. • Use a 50 ohm resistor (measuring range +/- 1 V) or 250 ohm resistor (measuring range 1 - 5 V) to map the current on a voltage, see figure 11-4. The tolerance of the resistor must be added on to the module error. • This module is not suitable for direct current measurement. Use of redundant encoders: • You can use a redundant encoder with the following voltage settings: +/- 80 mV (only without wire break monitoring) +/- 250 mV (only without wire break monitoring) +/- 500 mV (wire break monitoring not configurable) +/- 1 V (wire break monitoring not configurable) +/- 2.5 V (wire break monitoring not configurable) +/- 5 V (wire break monitoring not configurable) +/- 10 V (wire break monitoring not configurable) 1...5 V (wire break monitoring not configurable)	
AI 8x16Bit	6ES7 331-7NF00-0AB0
Use in voltage measurement • The "wire break" diagnostics function in HW Config must not be activated when operating the modules with transmitters. Use in indirect current measurement • When using indirect current measurement, ensure a reliable connection between the sensor resistances and the actual inputs, because a reliable wire break detection cannot be guaranteed in the case of a wire break of individual cables of this connection. • Use a 250 ohm resistor (measuring range 1 - 5 V) to map the current on a voltage; see figure 11-4. Use in direct current measurement • Suitable Zener diode: BZX85C8v2 • Circuit-specific additional error: If one module fails, the other may suddenly show an additional error of approx. 0.1%. • Load capability of 4-wire transmitters: R_B > 610 ohms (determined for worst case: 1 input + 1 Zener diode at an S7 overload value 24 mA to $R_B = (R_E * I_{max} + U_{z\,max})/I_{max}$) • Input voltage in the circuit when operating with a 2-wire transmitter: $U_{e\text{-}2w} < 15$ V (determined for worst case: 1 input + 1 Zener diode at an S7 overload value 24 mA to $U_{e\text{-}2w} = R_E * I_{max} + U_{z\,max}$)	

Module	Order number
AI 8x16Bit	6ES7 331-7NF10-0AB0
Use in voltage measurement • The "wire break" diagnostics function in HW Config must not be activated, neither when operating the modules with transmitters nor when thermocouples are connected. Use in indirect current measurement • Use a 250 ohm resistor (measuring range 1 - 5 V) to map the current on a voltage; see figure 11-4. Use in direct current measurement • Suitable Zener diode: BZX85C8v2 • Load capability of 4-wire transmitters: R_B > 610 ohms (determined for worst case: 1 input + 1 Zener diode at an S7 overload value 24 mA to $R_B = (R_E * I_{max} + U_{z\ max})/I_{max}$) • Input voltage in the circuit when operating with a 2-wire transmitter: $U_{e\text{-}2w}$ < 15 V (determined for worst case: 1 input + 1 Zener diode at an S7 overload value 24 mA to $U_{e\text{-}2w} = R_E * I_{max} + U_{z\ max}$)	
AI 6xTC 16Bit iso, 6ES7331-7PE10-0AB0	6ES7331-7PE10-0AB0
Notice: These modules must only be used with redundant encoders. You can use this module with Version 3.5 or higher of FB 450 "RED_IN" in the library "Redundant IO MGP" and Version 5.8 or higher of FB 450 "RED_IN" in the library "Redundant IO CGP" V50. Observe the following when measuring temperatures by means of thermocouples and assigned redundancy: The value specified in "Redundancy" under "Tolerance window" is always based on 2764.8 °C. For example, a tolerance of 27 °C is checked if "1" is entered, or a tolerance of 138 °C is checked if "5" is entered. A firmware update is not possible in redundant operation. Online calibration is not possible in redundant operation. Use in voltage measurement • The "wire break" diagnostics function in HW Config must not be activated when operating the modules with thermocouples. Use in indirect current measurement • Due to the maximum voltage range +/- 1 V, the indirect current measurement can be carried out exclusively via a 50 ohm resistor. Mapping that conforms to the system is only possible for the area +/- 20 mA.	
AI 4x15Bit [EEx ib]	6ES7331-7RD00-0AB0
You cannot use the module in redundant operation for applications in hazardous areas. It is not suitable for indirect current measurement. Use in direct current measurement • Suitable Zener diode: BZX85C6v2 • Load capability of 4-wire transmitters: RB > 325 ohms determined for worst case: 1 input + 1 Zener diode at an S7 overload value 24 mA to RB = (RE * $I_{max} + U_{z\ max})/I_{max}$ • Input voltage for 2-wire transmitters: Ue–2w < 8 V determined for worst case: 1 input + 1 Zener diode at an S7 overload value 24 mA to Ue–2w = RE * $I_{max} + U_{z\ max}$ **Note:** You can only connect 2-wire transmitters with a 24 V external supply or 4-wire transmitters. The internal power supply for transmitters cannot be used in the circuit shown in figure 11-4 because it outputs only 13 V, which means in the worst case it would supply only 5 V to the transmitter.	
AI 6x13Bit	6ES7 336-1HE00-0AB0
F-module in standard mode	

Module	Order number
AI 8x0/4...20mA HART	6ES7 331-7TF01-0AB0
A firmware update is not possible in redundant operation. Online calibration is not possible in redundant operation. See Manual *ET 200M Distributed I/O Device; HART Analog Modules* manual	
Redundant AO dual-channel	
AO4x12 Bit	6ES7332-5HD01-0AB0
AO8x12 Bit	6ES7332-5HF00-0AB0
AO4x0/4...20 mA [EEx ib]	6ES7332-5RD00-0AB0
You cannot use the module in redundant operation for applications in hazardous areas.	
AO 8x0/4...20mA HART	6ES7 332-8TF01-0AB0
A firmware update is not possible in redundant operation. Online calibration is not possible in redundant operation. See Manual *ET 200M Distributed I/O Device; HART Analog Modules*	

Note

You need to install the F-ConfigurationPack for F-modules.
The F ConfigurationPack can be downloaded free of charge from the Internet.
You can get it from Customer Support at Download of F Configuration Pack (http://support.automation.siemens.com/WW/view/en/15208817)

Quality levels in the redundant configuration of signal modules

The availability of modules in the case of an error depends on their diagnostics possibilities and the fine granularity of the channels.

Using digital input modules as redundant I/O

The following parameters were set to configure digital input modules for redundant operation:

- Discrepancy time (maximum permitted time in which the redundant input signals may differ). The specified discrepancy time must be a multiple of the update time of the process image and therefore also the basic conversion time of the channels.
  When there is still a discrepancy in the input values after the configured discrepancy time has expired, an error has occurred.
- Response to a discrepancy in the input values

First, the input signals of the paired redundant modules are checked for consistency. If the values match, the uniform value is written to the lower memory area of the process input image. If there is a discrepancy and it is the first, it is marked accordingly and the discrepancy time is started.

During the discrepancy time, the most recent matching (non-discrepant) value is written to the process image of the module with the lower address. This procedure is repeated until the values once again match within the discrepancy time or until the discrepancy time of a bit has expired.

If the discrepancy continues past the expiration of the configured discrepancy time, an error has occurred.

The defective side is localized according to the following strategy:

1. During the discrepancy time, the most recent matching value is retained as the result.
2. Once the discrepancy time has expired, the following error message is displayed: Error code 7960: "Redundant I/O: discrepancy time at digital input expired, error not yet localized". Passivation is not performed and no entry is made in the static error image. Until the next signal change occurs, the configured response is performed after the discrepancy time expires.
3. If another signal change now occurs, the channel in which the signal change occurred is the intact channel and the other channel is passivated.

Note

The time that the system actually needs to determine a discrepancy depends on various factors: bus runtimes, cycle and call times of the user program, conversion times, etc. Redundant input signals can therefore be different for a longer period than the configured discrepancy time.

Modules with diagnostics capability are also passivated by calling OB 82.

MTA Terminal Modules

MTA terminal modules (Marshalled Termination Assemblies) can be used to connect field devices, sensors and actuators to the I/O modules of the ET 200M remote I/O stations simply, quickly and reliably. They can be used to significantly reduce the costs and required work for cabling and commissioning, and prevent wiring errors.

The individual MTA terminal modules are each tailored to specific I/O modules from the ET 200M range. MTA versions for standard I/O modules are also available, as for redundant and safety-related I/O modules. The MTA terminal modules are connected to the I/O modules using 3 m or 8 m long preassembled cables.

Details on combinable ET 200M modules and suitable connection cables as well as the current MTA product range are available at this address: Update and expansion of the MTA terminal modules (http://support.automation.siemens.com/WW/view/en/29289048)

Using redundant digital input modules with non-redundant encoders

With non-redundant encoders, you use digital input modules in a 1-out-of-2 configuration:

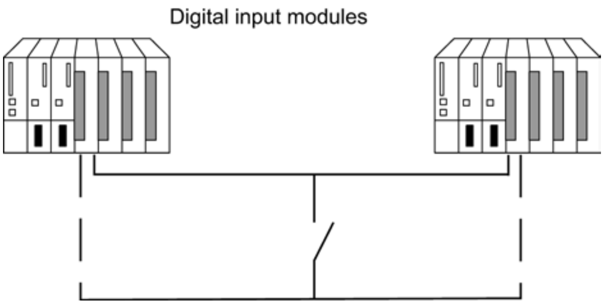


Figure 4-16 Fault-tolerant digital input module in 1-out-of-2 configuration with one encoder

The use of redundant digital input modules increases their availability.

Discrepancy analysis detects "Continuous 1" and "Continuous 0" errors of the digital input modules. A "Continuous 1" error means the value 1 is applied permanently at the input, a "Continuous 0" error means that the input is not energized. This can be caused, for example, by a short-circuit to L+ or M.

The current flow over the chassis ground connection between the modules and the encoder should be the minimum possible.

When connecting an encoder to several digital input modules, the redundant modules must operate at the same reference potential.

If you want to replace a module during operation and are not using redundant encoders, you will need to use decoupling diodes.

If you do not use terminal modules, see the interconnection examples in the Appendix Connection examples for redundant I/Os (Page 307).

Note

Remember that the proximity switches (Beros) must provide the current for the channels of both digital input modules. The technical data of the respective modules, however, specify only the required current per input.

Using redundant digital input modules with redundant encoders

With redundant encoders you use digital input modules in a 1-out-of-2 configuration:

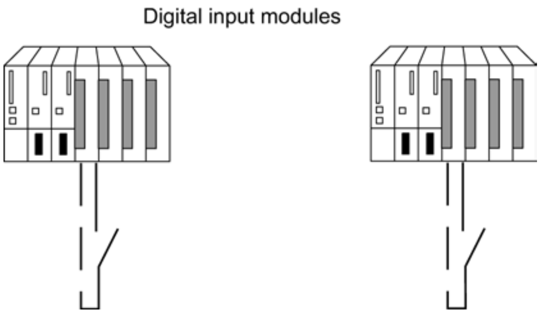


Figure 4-17 Fault-tolerant digital input modules in 1-out-of-2 configuration with two encoders

The use of redundant encoders also increases their availability. A discrepancy analysis detects all errors, except for the failure of a non-redundant load voltage supply. You can enhance availability by installing redundant load power supplies.

You will find interconnection examples in Appendix Connection examples for redundant I/Os (Page 307).

Redundant digital output modules

Fault-tolerant control of a final controlling element can be achieved by connecting two outputs of two digital output modules or fail-safe digital output modules in parallel (1-out-of-2 configuration).

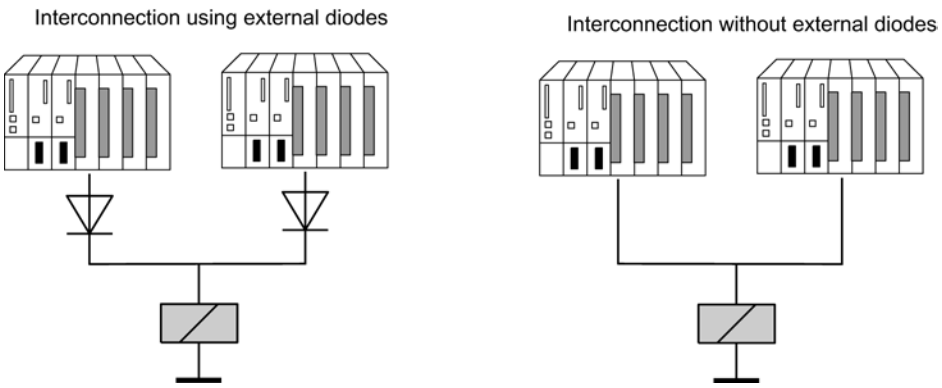


Figure 4-18 Fault-tolerant digital output modules in 1-out-of-2 configuration

The digital output modules must be connected to a common load voltage supply.

If you do not use terminal modules, see the interconnection examples in the Appendix Connection examples for redundant I/Os (Page 307).

Using analog input modules as redundant I/O

You specified the following parameters when you configured the analog input modules for redundant operation:

- Tolerance window (configured as a percentage of the end value of the measuring range)
  Two analog values are considered equal if they are within the tolerance window.
- Discrepancy time (maximum permitted time in which the redundant input signals can be outside the tolerance window). The specified discrepancy time must be a multiple of the update time of the process image and therefore also the basic conversion time of the channels.
  An error is generated when there is an input value discrepancy after the configured discrepancy time has expired.
  If you connect identical sensors to both analog input modules, the default value for the discrepancy time is usually sufficient. If you use different sensors, in particular temperature sensors, you will have to increase the discrepancy time.
- Applied value
  The applied value represents the value of the two analog input values that is applied to the user program.

The system verifies that the two read-in analog values are within the configured tolerance window. If they are, the applied value is written to the lower data memory area of the process input image. If there is a discrepancy and it is the first, it is marked accordingly and the discrepancy time is started.

When the discrepancy time is running, the most recent valid value is written to the process image of the module with the lower address and made available to the current process. If the discrepancy time expires, the channel with the configured standard value is declared as valid and the other channel is passivated. If the maximum value from both modules is configured as the standard value, this value is then taken for further program execution and the other channel is passivated. If the minimum value is set, this channel supplies the data to the process and the channel with the maximum value is passivated. Whichever is the case, the passivated channels are entered in the diagnostic buffer.

If the discrepancy is eliminated within the discrepancy time, analysis of the redundant input signals is still carried out.

Note

The time that the system actually needs to determine a discrepancy depends on various factors: bus runtimes, cycle and call times of the user program, conversion times, etc. Redundant input signals can therefore be different for a longer period than the configured discrepancy time.

Note

There is no discrepancy analysis when a channel reports an overflow with 16#7FFF or an underflow with 16#8000. The relevant channel is passivated immediately.

You should therefore disable all unused inputs in HW Config using the "Measurement type" parameter.

Redundant analog input modules with non-redundant encoder

With non-redundant encoders, analog input modules are used in a 1-out-of-2 configuration:

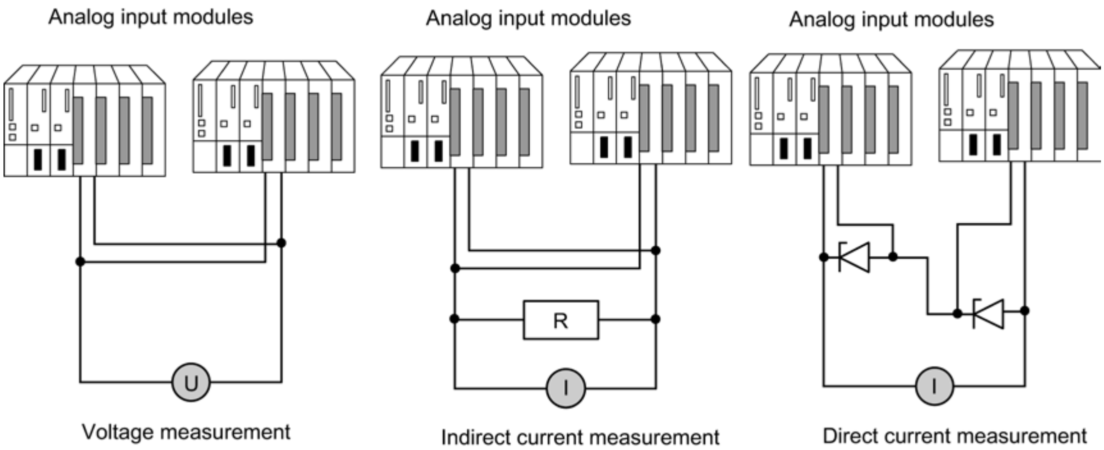


Figure 4-19 Fault-tolerant analog input modules in 1-out-of-2 configuration with one encoder

Remember the following when connecting an encoder to multiple analog input modules:

- Connect the analog input modules in parallel for voltage sensors (left in figure).
- You can convert a current into voltage using an external load to be able to use voltage analog input modules connected in parallel (center in the figure).
- 2-wire transmitters are powered externally to allow you to repair the module online.

The redundancy of the fail-safe analog input modules enhances their availability.

If you do not use terminal modules, see the interconnection examples in the Appendix Connection examples for redundant I/Os (Page 307).

Redundant analog input modules for indirect current measurement

The following applies to the wiring of analog input modules:

- Suitable encoders for this circuit are active transmitters with voltage output and thermocouples.
- The "wire break" diagnostics function in HW Config must not be activated, neither when operating the modules with transmitters nor when thermocouples are connected.
- Suitable encoder types are active 4-wire and passive 2-wire transmitters with output ranges +/-20 mA, 0...20 mA, and 4...20 mA. 2-wire transmitters are powered by an external auxiliary voltage.
- Criteria for the selection of resistance and input voltage range are the measurement accuracy, number format, maximum resolution and possible diagnostics.
- In addition to the options listed, other input resistance and voltage combinations according to Ohm’s law are also possible. Note, however, that such combinations may lead to loss of the number format, diagnostics function and resolution. The measurement error also depends largely on the size of the measure resistance of certain modules.
- Use a measure resistance with a tolerance of +/- 0.1% and TC 15 ppm.

Additional conditions for specific modules

AI 8x12bit 6ES7 331-7K..02-0AB0

- Use a 50 ohm or 250 ohm resistor to map the current on a voltage:

Resistor	50 ohms	250 ohms	
Current measuring range	+/-20 mA	+/-20 mA *)	4...20 mA
Input range to be assigned	+/-1 V	+/-5 V	1...5 V
Measuring range cube position	"A"	"B"	
Resolution	12 bits + sign	12 bits + sign	12 bits
S7 number format	x	x	
Circuit-specific measuring error - 2 parallel inputs - 1 input	- -	0.5% 0.25%	
"Wire break" diagnostics	-	-	x *)
Load for 4-wire transmitters	50 ohms	250 ohms	
Input voltage for 2-wire transmitters	> 1.2 V	> 6 V	
*) The AI 8x12bit outputs diagnostic interrupt and measured value "7FFF" in the event of wire break.			

The listed measuring error results solely from the interconnection of one or two voltage inputs with a measure resistance. Allowance has neither been made here for the tolerance nor for the basic/operational limits of the modules.

The measuring error for one or two inputs shows the difference in the measurement result depending on whether two inputs or, in case of error, only one input acquires the current of the transmitter.

AI 8x16bit 6ES7 331-7NF00-0AB0

- Use a 250 ohm resistor to map the current on a voltage:

Resistor	250 ohms *)	
Current measuring range	+/-20 mA	4...20 mA
Input range to be assigned	+/-5 V	1...5 V
Resolution	15 bits + sign	15 bits
S7 number format	x	
Circuit-specific measuring error - 2 parallel inputs - 1 input	- -	
"Wire break" diagnostics	-	x
Load for 4-wire transmitters	250 ohms	
Input voltage for 2-wire transmitters	> 6 V	
*) It may be possible to use the freely connectable internal 250 ohm resistors of the module		

Redundant analog input modules for direct current measurement

Requirements for wiring analog input modules according to Figure 11-4:

- Suitable encoder types are active 4-wire and passive 2-wire transmitters with output ranges +/-20 mA, 0...20 mA, and 4...20 mA. 2-wire transmitters are powered by an external auxiliary voltage.
- The "wire break" diagnostics function supports only the 4...20 mA input range. All other unipolar or bipolar ranges are excluded in this case.
- Suitable diodes include the types of the BZX85 or 1N47..A series (Zener diodes 1.3 W) with the voltages specified for the modules. When selecting other elements, make sure that the reverse current is as low as possible.
- A fundamental measuring error of max. 1 µA results from this type of circuit and the specified diodes due to the reverse current. In the 20 mA range and at a resolution of 16 bits, this value leads to an error of < 2 bits. Individual analog inputs in the circuit above lead to an additional error, which may be listed in the constraints. The errors specified in the manual must be added to these errors for all modules.
- The 4-wire transmitters used must be capable of driving the load resulting from the circuit above. You will find details in the technical specifications of the individual modules.
- When connecting up 2-wire transmitters, note that the Zener diode circuit weighs heavily in the power budget of the transmitter. The required input voltages are therefore included in the technical specifications of the individual modules. Together with the inherent supply specified on the transmitter data sheet, the minimum supply voltage is calculated to L+ > U_{e-2w} + U_{IS-TR}

Redundant analog input modules with redundant encoders

With double-redundant encoders, it is better to use fail-safe analog input modules in a 1-out-of-2 configuration:

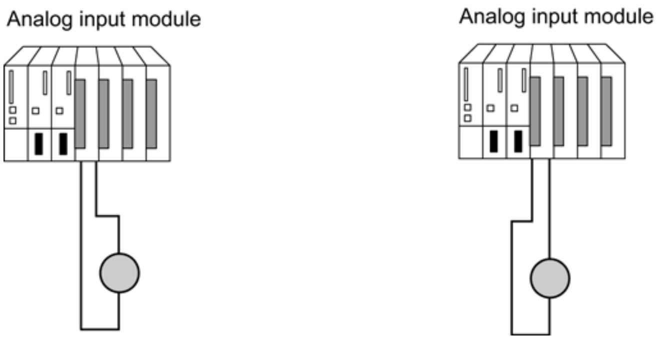


Figure 4-20 Fault-tolerant analog input modules in 1-out-of-2 configuration with two encoders

The use of redundant encoders also increases their availability.

A discrepancy analysis also detects external errors, except for the failure of a non-redundant load voltage supply.

You will find interconnection examples in Appendix Connection examples for redundant I/Os (Page 307).

The general comments made at the beginning of this documentation apply.

Redundant encoders <-> non-redundant encoders

The table below shows you which analog input modules you can use in redundant operation with redundant or non-redundant encoders:

Table 4- 5 Analog input modules and encoders

Module	Redundant encoders	Non-redundant encoders
6ES7 336-4GE00-0AB0	X	X
6ES7 331-7KF02-0AB0	X	X
6ES7 331-7NF00-0AB0	X	X
6ES7 331-7RD00-0AB0	X	X

Redundant analog output modules

You implement fault-tolerant control of a final controlling element by wiring two outputs of two analog output modules in parallel (1-out-of-2 structure).

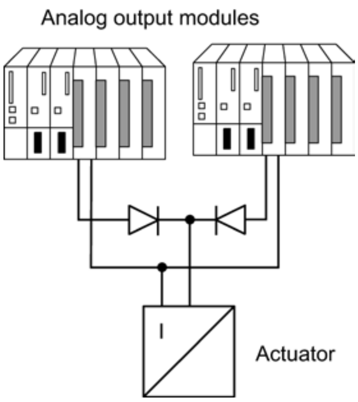


Figure 4-21 Fault-tolerant analog output modules in 1-out-of-2 configuration

The following applies to the wiring of analog output modules:

- Wire the ground connections in a star structure to avoid output errors (limited common-mode suppression of the analog output module).

If you do not use terminal modules, see the interconnection examples in the Appendix Connection examples for redundant I/Os (Page 307)

Analog output signals

Only analog output modules with current outputs (0 to 20 mA, 4 to 20 mA) can be operated redundantly.

The output value is divided by 2, and each of the two modules outputs half. If one of the modules fails, the failure is detected and the remaining module outputs the full value. As a result, the surge at the output module in the event of an error is not as high.

Note

The output value drops briefly to half, and after the reaction in the program it is returned to the proper value. The duration of the output value drop is determined by the following time intervals:

- Time interval between the initial occurrence of an interrupt and the interrupt report reaching the CPU.
- Time interval until the next RED_OUT (FB 451) call.
- Time interval until the intact analog output module has doubled the output value.

In the case of passivation or a CPU STOP, redundant analog outputs output an assignable minimum current of approximately 120-1000 µA per module (or 240-1000 µA for HART analog output modules), i.e., a total of approximately 240-2000 µA (or 480-2000 µA for HART analog output modules). Considering the tolerance, this means that the output value is always positive.

A configured substitute value of 0 mA will produce at least these output values. In a redundant configuration of analog outputs, the substitute value of the current outputs is automatically set permanently to "zero current and zero voltage". You can also specify a configurable compensation current of 0-400 µA for an output range of 4-20 mA.

This means you have the option of matching the minimum/compensation current to the connected I/O.

To minimize the error of the total current at the summing point in case of one-sided passivation, the assigned compensation current is subtracted in this case from the current of the depassivated (i.e., active) channel with a pre-set value of 4 mA (range +-20 µA).

Note

If both channels of a channel pair were passivated (e.g., by OB 85), the respective half of the current value is still output to both storage locations in the process image of outputs. If one channel is depassivated, then the full value is output on the available channel. If this is not required, a substitute value must be written to the lower channels of both modules prior to executing FB 451 "RED_OUT".

Depassivation of modules

Passivated modules are depassivated by the following events:

- When the fault-tolerant system starts up
- When the fault-tolerant system changes over to "redundant" operating state
- After system modifications during operation
- If you call FC 451 "RED_DEPA" and at least one redundant channel or module is passivated.

The depassivation is executed in FB 450 "RED IN" after one of these events has occurred. Completion of the depassivation of all modules is logged in the diagnostics buffer.

Note

When a redundant module is assigned a process image partition and the corresponding OB is not available on the CPU, the complete passivation process may take approximately 1 minute.

4.7.2 Evaluating the passivation status

Procedure

First, determine the passivation status by evaluating the status byte in the status/control word "FB_RED_IN.STATUS_CONTROL_W". If you see that one or more modules have been passivated, determine the status of the respective module pairs in MODUL_STATUS_WORD.

Evaluating the passivation status using the status byte

The status word "FB_RED_IN.STATUS_CONTROL_W" is located in the instance DB of FB 450 "RED_IN". The status byte returns information on the status of the redundant I/Os. The assignment of the status byte is described in the online help for the respective block library.

Evaluating the passivation status of individual module pairs by means of MODUL_STATUS_WORD

MODUL_STATUS_WORD is an output parameter of FB 453 and can be interconnected accordingly. It returns information on the status of individual module pairs.

The assignment of the MODUL_STATUS_WORD status byte is described in the online help for the respective function block library.

PROFIBUS DP 5

5.1 CPU 410-5H as PROFIBUS DP master

Startup of the DP master system

You use the following parameters to set startup monitoring of the DP master:

- Ready message from module
- Transfer of parameters to modules

This means that the DP slaves must be started up and their parameters assigned by the CPU (as DP master) within the set time.

PROFIBUS address of the DP master

PROFIBUS addresses 0 to 126 are permissible.

5.2 DP address ranges of the CPU 410-5H

Address ranges of the CPU 410-5H

Table 5- 1 CPU 410-5H

Address range	CPU 410-5H
DP interface as PROFIBUS DP, both inputs and outputs (bytes)	6144
Inputs and outputs up to x bytes each can be set in the process image	0 to 16384

In the address range for the inputs, each DP diagnostic address occupies at least 1 byte for the DP master and each DP slave. For example, the DP standard diagnostics for each node can be called at these addresses using the LADDR parameter of SFC 13. You specify the DP diagnostic addresses when configuring. If you do not specify DP diagnostic addresses, STEP 7 assigns the addresses as DP diagnostic addresses in descending order starting at the highest byte address.

5.3 Diagnostics of the CPU 410-5H as PROFIBUS DP master

Diagnostics using LED displays

The following table explains the meaning of the BUS1F LED.

Table 5- 2 Meaning of the "BUSF" LED of the CPU 410-5H as DP master

BUS1F	Meaning	Remedy
Off	Configuration correct; all configured slaves are addressable	-
Lit	• Bus fault (physical fault)	• Check whether the bus cable has a short-circuit or a break.
	• DP interface fault • Different baud rates in multi-DP master operation (only in stand-alone operation)	• Analyze the diagnostic data. Reconfigure or correct the configuration.
Flashes	• Station failure • At least one of the assigned slaves cannot be addressed	• Check whether the bus cable is connected to the CPU 410-5H or the bus is interrupted. • Wait until the CPU 410-5H has started up. If the LED does not stop flashing, check the DP slaves or analyze the diagnostics data of the DP slaves.

Diagnostic addresses for DP master and I-slave

You assign diagnostic addresses for PROFIBUS DP for the CPU 410-5H. Pay attention during configuring that DP diagnostic addresses are assigned once to the DP master and once to the I-slave.

Specify 2 diagnostic addresses when configuring

Diagnostic address

During configuration of the DP master, specify (in the associated project of the DP master) a diagnostic address for the DP slave.

This diagnostic address is used by DP master to obtain information about the status of DP slave or a bus interruption.

Diagnostic address

During configuration of the I-slave, also specify (in the associated project of the I-slave) a diagnostic address that is assigned to the I-slave
.
This diagnostic address is used by the I-slave to obtain information on the status of the DP master
or on a bus interruption.

PROFINET IO 6

6.1 Introduction

What is PROFINET IO?

PROFINET IO is the open, cross-vendor Industrial Ethernet standard for automation. It enables continuous communication from the business management level down to the field level.

PROFINET IO meets the stringent requirements of industry, for example:

- Industry-compatible installation technology
- Real-time capability
- Cross-vendor engineering

There are a wide range of products available for PROFINET IO, including active and passive network components, controllers, distributed field devices, and components for industrial wireless LAN and industrial security.

Information about the use of I/O connected to the PROFINET interface is available in Chapter System redundancy (Page 63).

With PROFINET IO a switching technology is implemented that allows all stations to access the network at any time. In this way, the network can be used much more efficiently through simultaneous data transmission of multiple nodes. Simultaneous sending and receiving is enabled through the full-duplex operation of Switched Ethernet.

PROFINET IO is based on Switched Ethernet full-duplex operation and a bandwidth of 100 Mbit/s.

In PROFINET IO communication, a portion of the transmission time is reserved for cyclic, deterministic data transmission. This allows you to split the communication cycle into a deterministic and an open part. Communication takes place in real-time.

The direct connection of distributed field devices (IO devices, such as signal modules) to PROFINET IO supports a consistent diagnostics concept for efficient localization and elimination of any errors.

Note

No changes to the PROFINET IO interface during operation

I/O components that are connected to a PROFINET IO interface as well as parameters of the PROFINET IO interface cannot be modified during operation.

Documentation on the Internet

Comprehensive information about PROFINET (http://www.profibus.com/) is available on the Internet.

Also observe the following documents:

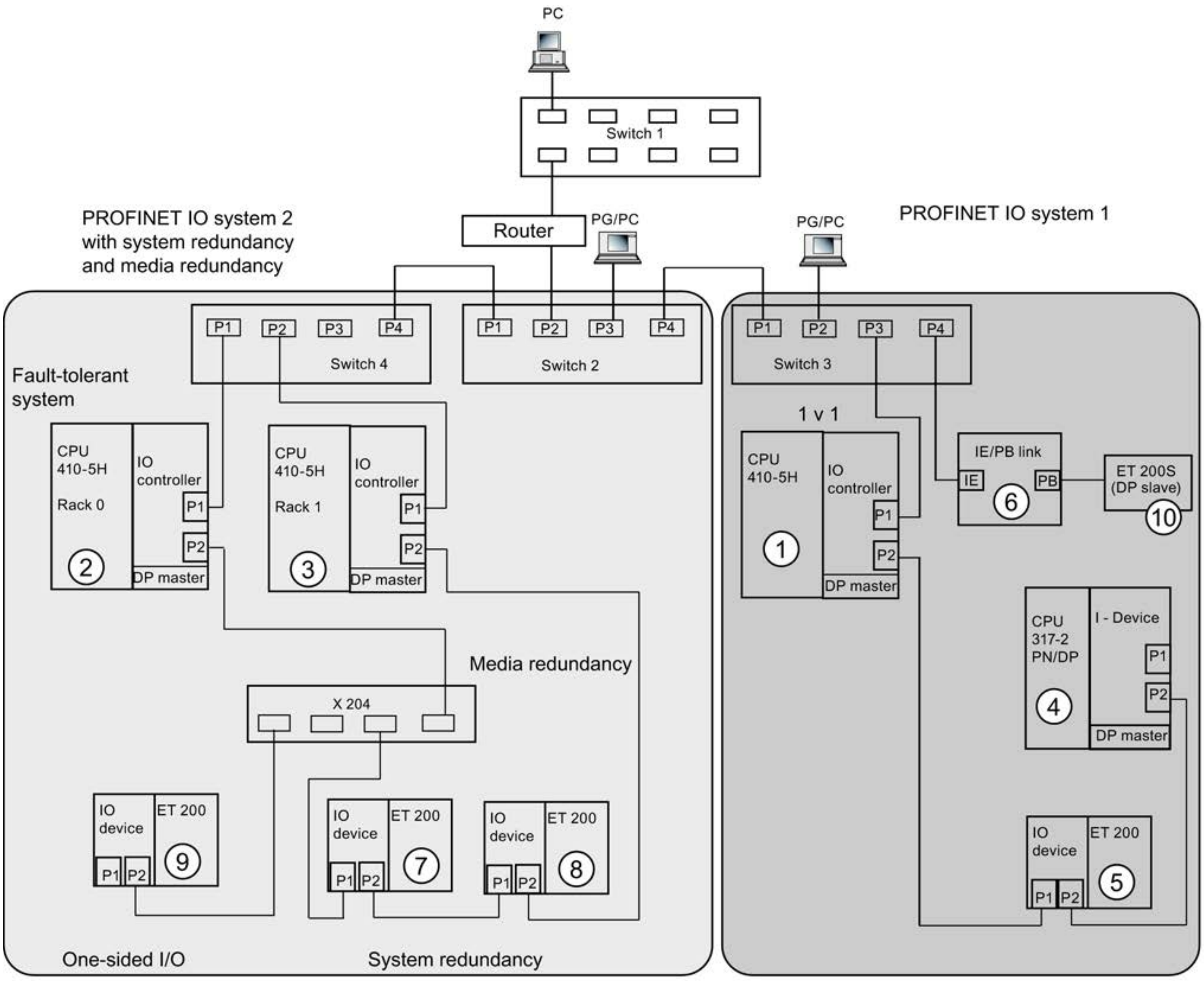
- Installation guideline
- Assembly guideline
- PROFINET_Guideline_Assembly

Additional information on the use of PROFINET IO in automation engineering is available at the following Internet address (http://www.siemens.com/profinet/).

6.2 PROFINET IO systems

Functions of PROFINET IO

The following graphic shows the new functions in PROFINET IO:



The graphic shows	Examples of connection paths
The connection of company network and field level	You can access devices at the field level from PCs in your company network • Example: PC - Firewall - Switch 1 - Router - Switch 2 - CPU 410-5H ①.
Connections between the automation system and field level	You can also access other areas on the Industrial Ethernet from a programming device at the field level. Example: • Programming device - integrated Switch 3 - Switch 2 - Switch 4 - integrated Switch CPU 410-5H ③ - on IO device ET 200⑧.

The graphic shows	Examples of connection paths
The IO controller of CPU 410-5H ① spans PROFINET IO system 1 and directly controls devices on the Industrial Ethernet and PROFIBUS.	At this point, you see the IO features between the IO controller, intelligent device, and the IO device(s) on Industrial Ethernet: • The CPU 410-5H ① is the IO controller for the IO device ET 200 ⑤, Switch 3, and the intelligent device CPU 317-2 PN/DP ④. • The CPU 410-5H ① is also the master for the DP slave ⑩ via the IE/PB Link.
The fault-tolerant system, consisting of CPU 410-5H ② + ③, spans the PROFINET IO system 2 as IO controller. This IO controller operates IO devices in system redundancy as well as a one-sided IO device.	The fault-tolerant system, consisting of CPU 410-5H ② + ③, spans the PROFINET IO system 2 as IO controller. This IO controller operates IO devices in system redundancy as well as a one-sided IO device. Here you see that a fault-tolerant system can operate system-redundant IO devices as well as a one-sided IO device: • The fault-tolerant system is the IO controller for both system-redundant IO devices ET 200 ⑦ + ⑧ as well as the one-sided IO device ⑨.

Further information

You will find further information about PROFINET IO in the documents listed below:

- In manual PROFINET system description (http://support.automation.siemens.com/WW/view/en/19292127)
- In Programming Manual *From PROFIBUS DP to PROFINET IO.*

6.3 Device replacement without removable medium/programming device

IO devices having this function can be replaced in a simple manner:

- A removable medium (e.g. SIMATIC Micro Memory Card) with stored device name is not required.
- The PN-IO topology must be configured in STEP 7.
- The device name does not have to be assigned with the programming device.

  The replacement IO device is now assigned a device name from the IO controller. It is no longer assigned using a removable medium or programming device. The IO controller uses the configured topology and the relations determined by the IO devices. The configured target topology must match the actual topology.

Before reusing IO devices that you already had in operation, reset these to factory settings.

Additional information

For additional information, refer to the STEP 7 Online Help and to the PROFINET System Description (http://support.automation.siemens.com/WW/view/en/19292127) manual.

Operator controls and operating modes of the CPU 410-5H 7

7.1 Operating modes of the CPU 410-5H

7.1.1 RUN mode

Reaction of the CPU

If there is no startup problem or error and the CPU was able to switch to RUN, the CPU either executes the user program or remains idle. The I/O can be accessed.

- You can upload programs from the CPU to the programming device (CPU -> Programming device).
- You can download programs from the programming device to the CPU (Programming device -> CPU).

The user program is executed by at least one CPU in the following system states:

- Stand-alone operation
- Single mode
- Link-up, update
- Redundant

Single mode, link-up, update

In the system states standalone mode, link-up and update, the master CPU is in RUN and executes the user program in standalone mode.

Redundant system mode

The master CPU and standby CPU are always in RUN when operating in redundant system mode. Both CPUs execute the user program in synchronism, and perform mutual checks.

In redundant system mode it is not possible to test the user program with breakpoints.

The redundant system state is only supported with CPUs of the same version and firmware version. Redundancy will be lost if one of the errors listed in the following table occurs.

Table 7- 1 Causes of error leading to redundancy loss

Cause of error	Reaction
Failure of one CPU	Failure and replacement of a CPU during redundant operation (Page 167)
Failure of the redundant link (synchronization module or fiber-optic cable)	Failure and replacement of a synchronization module or fiber-optic cable (Page 172)
RAM comparison error	ERROR-SEARCH mode (Page 95)

Redundant use of modules

Modules interconnected in redundant mode (e.g. DP slave interface module IM 153-2) must be in identical pairs, i.e. the two redundant linked modules have the same order number and product or firmware version.

7.1.2 STOP mode

Reaction of the CPU

The CPU does not execute the user program. The digital signal modules are disabled. The output modules are disabled in the default parameter settings.

- You can upload programs from the CPU to the programming device (CPU -> Programming device).
- You can download programs from the programming device to the CPU (Programming device -> CPU).

Special features in redundant mode

When you download a configuration to one of the CPUs while both are in STOP operating state, observe the points below:

- Start the CPU to which you downloaded the configuration first in order to set it up for master mode.
- If the system startup is requested from the ES, the CPU to which an active connection exists is started first, regardless of the master or standby status. Then the second CPU starts up and will become the standby CPU after link-up and update operations.

Note

A system startup may trigger a master–standby changeover.

A CPU 410 can only exit the STOP operating state with a loaded configuration.

Memory reset

The memory reset function affects only the selected CPU. To reset both CPUs, you must reset one and then the other.

7.1.3 STARTUP mode

Startup types

The CPU 410 distinguishes between two startup types: cold restart and warm restart.

Cold restart

- During a cold restart, all data (process image, bit memory, timers, counters and data blocks) is reset to the start values stored in the program (load memory), regardless of whether they were configured as retentive or non-retentive.
- The associated startup OB is OB 102
- Program execution is restarted from the beginning (OB 102 or OB 1).

Warm restart

- A warm restart resets the process image and the non-retentive bit memories, timers, times, and counters.

  Retentive flags, times and counters retain their last valid value.

  All data blocks assigned the "Non Retain" attribute are reset to the downloaded values. The other data blocks retain their last valid value.
- The associated startup OB is OB 100
- Program execution is restarted from the beginning (OB 100 or OB 1).
- If the power supply is interrupted, the warm restart function is only available in backup mode.

Special features in redundant mode

The special features described below apply to startup when you operate two CPUs 410 redundantly.

Startup processing by the master CPU

The startup system state is always processed by the master CPU in redundant mode.

During STARTUP, the master CPU compares the existing I/O configuration with the hardware configuration that you created in STEP 7. The master CPU reacts as described above if there is a discrepancy.

The master CPU checks and assigns parameters for the following:

- the switched I/O devices
- its assigned one-sided I/O devices

Startup of the standby CPU

The standby CPU startup routine does not call an OB 100 or OB 102.

The standby CPU checks and assigns parameters for the following:

- its assigned one-sided I/O devices

Special features at startup

During a Power On with battery backup of a CPU 410 with large configurations containing many CPs and/or external DP masters, it may take up to 2 minutes until a requested warm restart is executed. During this time, the LEDs on the CPU light up successively as follows:

1. All LEDs light up
2. The STOP LED flashes for about 75 seconds as it does during a memory reset
3. The RUN and STOP LEDs flash for about 2 seconds
4. The RUN LED flashes briefly 2 to 3 times
5. The STOP LED lights up for about 25 seconds
6. The RUN LED starts flashing again.

This begins the start up.

Additional information

For detailed information on STARTUP operating state, refer to Manual *Programming with STEP 7*.

7.1.4 HOLD mode

The HOLD mode is for test purposes. You need to have set respective breakpoints in the user program for this purpose. It can only be reached from the RUN mode.

Special features in redundant mode

The HOLD mode can only be reached in redundant operation from STARTUP mode and from the RUN in single mode. It is not possible to set breakpoints when the fault-tolerant system is in redundant system mode. Link-up and update operations are not available while the CPU is in HOLD mode; the standby CPU remains in STOP and outputs a diagnostics message.

7.1.5 LINK-UP and UPDATE modes

The master CPU checks and updates the memory content of the standby CPU before the fault-tolerant system assumes redundant system mode. This is implemented in two successive phases: link-up and update.

The master CPU is always in RUN mode and the reserve CPU is in LINK-UP or UPDATE mode during the link-up and update phases.

In addition to the link-up and update functions, which are carried out to establish redundant system mode, the system also supports linking and updating in combination with master/reserve changeover.

For detailed information on connect and updating, refer to section Link-up and update (Page 109).

7.1.6 ERROR-SEARCH mode

The ERROR-SEARCH operating state can only be reached from the redundant system state. During troubleshooting, the redundant system state is exited, the other CPU becomes master, if necessary, and continues running in solo operation.

Note

If the master CPU changes to STOP during troubleshooting, the troubleshooting is continued on the standby CPU. However, once troubleshooting is completed, the standby CPU does not start up again.

The following events will trigger the ERROR-SEARCH operating state:

1. If a one-sided call of OB 121 (on only one CPU) occurs in redundant operation, the CPU assumes a hardware fault and switches to ERROR-SEARCH operating state. The other CPU becomes master, if necessary, and continues running in solo operation.
2. If a checksum error occurs on only one CPU in redundant operation, that CPU switches to ERROR-SEARCH operating state. The other CPU becomes master, if necessary, and continues running in solo operation.
3. If a RAM/PIQ comparison error is detected in redundant operation, the standby CPU switches to ERROR-SEARCH operating state (default response), and the master CPU continues running in solo operation.

   The response to RAM/PIQ comparison errors can be modified in the configuration (for example, the standby CPU switches to STOP).
4. If a multiple-bit error occurs on a CPU in redundant operation, that CPU will switch to ERROR-SEARCH operating state. The other CPU becomes master, if necessary, and continues running in solo operation.

   But: OB 84 is called if 2 single-bit errors occur on a CPU in redundant operation within 6 months. The CPU does not change to ERROR-SEARCH operating state.
5. If synchronization is lost during redundant operation, the standby CPU changes to ERROR-SEARCH operating state. The other CPU remains master and continues running in solo operation.

The purpose of ERROR-SEARCH operating state is to find a faulty CPU. The standby CPU runs the full self-test, while the master CPU remains in RUN. If a hardware fault is detected, the CPU changes to DEFECTIVE state. If no fault is detected the CPU is linked up again. The fault-tolerant system resumes the redundant system state. An automatic master-standby changeover then takes place. This ensures that when the next error is detected in error-search mode, the hardware of the previous master CPU is tested.

No communication is possible, e.g., by means of access from a programming device, while the CPU is in ERROR-SEARCH operating state. The ERROR-SEARCH operating state is indicated by the RUN and STOP LEDs, see Chapter Status and error displays (Page 37).

For additional information on the self-test, refer to Chapter Self-test (Page 104)

7.1.7 DEFECTIVE state

The CPU enters the DEFECTIVE state when an error occurred that cannot be automatically eliminated by the operating system.

Reaction of the CPU

The reaction of the CPU in the DEFECTIVE state is intended to leave this state, if possible, and to restart.

The CPU reacts as follows in DEFECTIVE state:

1. The CPU writes the cause of the defect into the diagnostic buffer.
2. The CPU performs a memory dump.
3. The CPU backs up the extended diagnostic data.
4. The CPU checks the consistency of the user data.

   The CPU cannot leave the DEFECTIVE state independently if the user data show inconsistencies.
5. The CPU checks the time stamp of the last automatic reboot.

   If an entire day has not passed since the last automatic reboot, the CPU cannot leave the DEFECTIVE state independently any longer.
6. The CPU checks the event that has caused the transition to the DEFECTIVE state.

   The CPU cannot leave the DEFECTIVE state independently if the event prevents an automatic reboot.
7. The CPU saves the current user data retentively.
8. The CPU saves the time stamp of the current reboot retentively.
9. The CPU writes an event 0x4x09 ("Memory reset started automatically") to the diagnostic buffer.
10. The CPU performs an automatic reboot.

11. The CPU starts up without battery backup until STOP.
12. In stand-alone operation and in single mode, the CPU loads the backed up user program and performs a warm restart.
    In redundant mode, the standby CPU links up to the running master.

7.2 System states of the redundant CPU 410-5H

7.2.1 Introduction

The S7-400H consists of two redundantly configured subsystems that are synchronized via fiber-optic cables.

The two subsystems form a fault-tolerant automation system that operates with a two-channel (1-out-of-2) structure based on the "active redundancy" principle.

What does active redundancy mean?

Active redundancy means that all redundant resources are constantly in operation and simultaneously involved in the execution of the control task.

For the S7-400H this means that the user programs in both CPUs are identical and executed synchronously by the CPUs.

Convention

To identify the two subsystems, we use the traditional expressions of "master" and "standby" for dual-channel fault-tolerant systems in this description. However, the standby runs event-synchronized with the master at all times and not just when an error occurs.

The differentiation between the master and standard CPUs is primarily important for ensuring reproducible fault reactions. The standby goes into troubleshooting mode when RAM/PIQ errors are detected, for example, while the master CPU remains in RUN.

Master-standby assignment

When the S7-400H is initially switched on, the CPU that started up first becomes the master CPU, and the other CPU becomes the standby CPU.

The preset master-standby assignment is retained when both CPUs power up simultaneously.

The master-standby assignment changes when:

1. The standby CPU starts up before the master CPU (interval of at least 3 s)
2. The master CPU fails or goes to STOP in redundant system state

3. No error was found in ERROR-SEARCH operating state (see Chapter ERROR-SEARCH mode (Page 95))
4. Programmed master-standby switchover with SFC 90 "H_CTRL"

Synchronizing the subsystems

The master and standby CPUs are linked by fiber-optic cables. Both CPUs maintain event-synchronous program execution via this connection.

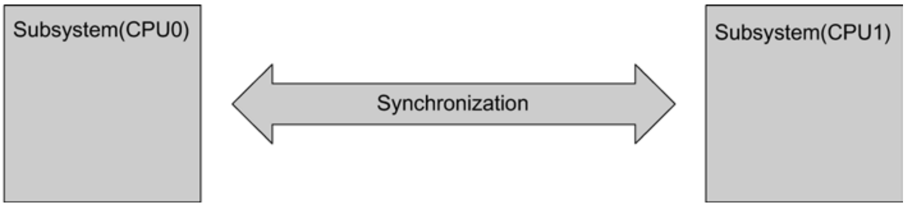


Figure 7-1 Synchronizing the subsystems

Synchronization is performed automatically by the operating system and has no effect on the user program. You create your program in the same way as for standard S7-400 CPUs.

Event-driven synchronization procedure

The "event-driven synchronization" procedure patented by Siemens was used for the S7-400H.

Event-driven synchronization means that the master and standby always synchronize their data when an event occurs which may lead to different internal states of the subsystems.

The master and standby CPUs are synchronized when:

- There is direct access to the I/O
- Interrupts occur
- User timers (e.g., S7 timers) are updated
- Data is modified by communication functions

Continued bumpless operation even if redundancy of a CPU is lost

The event-driven synchronization method ensures bumpless continuation of operation by the standby CPU even if the master CPU fails. The inputs and outputs do not lose their values during the master-standby switchover.

Self-test

Malfunctions or errors must be detected, localized and reported as quickly as possible. Consequently, extensive self-test functions have been implemented in the S7-400H that run automatically and entirely in the background.

The following components and functions are tested:

- Coupling of the central controllers
- Processor
- Internal memory of the CPU
- I/O bus

If the self-test detects an error, the fault-tolerant system tries to eliminate it or to suppress its effects.

For detailed information on the self-test, refer to Chapter Self-test (Page 104).

System operation without Stop

To best meet the requirements of the process industry for system operation without Stop, PCS 7 intercepts as many possible stop causes as possible. The PA-CPU 410 has been enhanced such that, as a redundant system, it reaches the Run Redundant operating state automatically on every occasion if possible. A change in the operating state is only possible through an engineering system command. In addition, the Stop command is password-protected. The diagnostic information always indicates the RUN switch position.

7.2.2 The system states of the fault-tolerant system

The system states of the fault-tolerant system result from the operating states of the two CPUs. The term "system state" is used as a simplified term which identifies the concurrent operating states of the two CPUs.

Example: Instead of "the master CPU is in RUN and the standby CPU is in LINK-UP mode" we say "the fault-tolerant system is in link-up mode".

Overview of system states

The table below provides an overview of the possible states of the fault-tolerant system.

Table 7- 2 Overview of system states of the fault-tolerant system

System states of the fault-tolerant system	Operating states of the two CPUs	
	Master	**Reserve**
Stop	STOP	STOP, power off, DEFECTIVE
Startup	STARTUP	STOP, power off, DEFECTIVE, no synchronization
Single mode	RUN	STOP, ERROR-SEARCH, power off, DEFECTIVE, no synchronization
Link-up	RUN	STARTUP, LINK-UP
Update	RUN	UPDATE

System states of the fault-tolerant system	Operating states of the two CPUs	
	Master	Reserve
Redundant	RUN	RUN
Hold	HOLD	STOP, ERROR-SEARCH, power off, DEFECTIVE, no synchronization

7.2.3 Displaying and changing the system state of a fault-tolerant system

Procedure:

1. Select a CPU in SIMATIC Manager.
2. Select the PLC > Operating state menu command.

Note

Stop is only possible with authorization.

Result:

The "Operating state" dialog box shows the current system state of the fault-tolerant system and the operating states of the individual central processing units.

The CPU that was selected in SIMATIC Manager when the menu command was executed is the first one displayed in the table.

Changing the system state:

The options of changing the system state depend on the current system state of the fault-tolerant system.

7.2.4 System status change from the STOP system state

Requirement

You have selected one of the two CPUs in SIMATIC Manager and opened the "Operating mode" dialog using the PLC > Operating state menu command.

Changing to redundant system mode (starting the fault-tolerant system)

1. Select the fault-tolerant system in the table.
2. Select the Restart button (warm restart).

Result:

The CPU displayed first in the table starts up as master CPU. Then the second CPU starts up and will become the standby CPU after link-up and update operations.

Changing to standalone mode (starting only one CPU)

1. In the table, select the CPU you want to start up.
2. Select the *Restart (warm restart)* button.

7.2.5 System status change from the standalone mode system status

Requirements:

- For CPU access protection with password: You have entered the CPU access password with the menu command PLC > Access Rights > Setup in SIMATIC Manager.
- You have opened the "Operating state" dialog using the PLC > Operating state menu command in SIMATIC Manager.
- The standby CPU is not in ERROR-SEARCH operating state.

Changing to redundant system state (starting the standby CPU)

1. In the table, select the CPU that is in STOP, or the fault-tolerant system.
2. Select the Restart button (warm restart).

Changing to system status STOP (stopping the running CPU)

1. In the table, select the CPU that is in RUN, or the fault-tolerant system.
2. Select the Stop button.

Note

Any set up access right is not canceled until you stop the SIMATIC Manager. You should reset the access right once again to prevent unauthorized access. You reset the access right in the SIMATIC Manager with the menu command PLC > Access Rights > Cancel.

7.2.6 System status change from the redundant system state

Requirement:

- For CPU access protection with password: You have entered the CPU access password with the menu command PLC > Access Rights > Setup in SIMATIC Manager.
- You have opened the "Operating state" dialog using the PLC > Operating state menu command in SIMATIC Manager.

Changing to STOP system state (stopping the fault-tolerant system)

1. Select the fault-tolerant system in the table.
2. Select the Stop button.

Result

Both CPUs switch to STOP.

Changing to standalone mode (stop of one CPU)

1. In the table, select the CPU that you want to stop.
2. Select the Stop button.

Result:

The selected CPU goes into the STOP state, while the other CPU remains in RUN state; the fault-tolerant system continues operating in standalone mode.

Note

Any set up access right is not canceled until you stop the SIMATIC Manager. You should reset the access right once again to prevent unauthorized access. You reset the access right in the SIMATIC Manager with the menu command PLC > Access Rights > Cancel.

7.2.7 System diagnostics of a fault-tolerant system

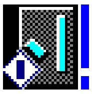
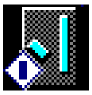
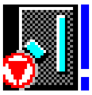
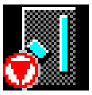
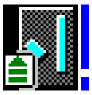
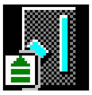
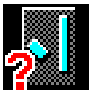
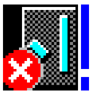
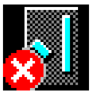
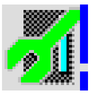
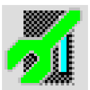
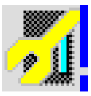
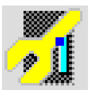
The diagnose hardware function identifies the state of the entire fault-tolerant system.

Procedure:

1. Select the fault-tolerant station in SIMATIC Manager.
2. Right-click and select the PLC > *Diagnose hardware* command.
3. In the "Select CPU" dialog, select the CPU and confirm with OK.

Result:

The operating state of the selected CPU can be identified based on the display of the selected CPU in the "Diagnose hardware" dialog:

CPU icon	Operating state of the respective CPU
	Master CPU is in RUN operating state
	Standby CPU is in RUN operating state
	Master CPU is in STOP operating state
	Standby CPU is in STOP operating state
	Master CPU is in STARTUP operating state
	Standby CPU is in LINK-UP or UPDATE operating state
	Standby CPU is in ERROR-SEARCH operating state
	Master CPU or a module whose parameters it assigned is faulty.
	Standby CPU or a module whose parameters it assigned is faulty
	Maintenance required on master CPU
	Maintenance required on standby CPU
	Maintenance request on master CPU
	Maintenance request on standby CPU

Note

The view is not updated automatically in the Online view. Use the F5 function key to view the current operating state.

7.3 Self-test

Processing the self-test

The CPU executes the complete self-test program after an unbuffered POWER ON, e.g., POWER ON after initial insertion of the CPU or POWER ON without backup battery, and in the ERROR-SEARCH operating state.

The self-test takes at least 15 minutes.

When the CPU of a fault-tolerant system requests a memory reset and then undergoes a OFF/ON cycle with battery backup, it performs a self-test in spite of the battery backup.

In RUN the operating system splits the self-test routine into several small program sections ("test slices") which are processed in multiple successive cycles. The cyclic self-test is organized to perform a single, complete pass in a certain time. The default time of 90 minutes can be modified in the configuration.

Response to errors during the self-test

If the self-test returns an error, the following happens:

Table 7- 3 Response to errors during the self-test

Type of error	System response
Hardware fault without one-sided call of OB 121	The faulty CPU switches to DEFECTIVE state. The fault-tolerant system switches to solo operation. The cause of the error is written to the diagnostics buffer.
Hardware fault with one-sided call of OB 121	The CPU with the one-sided OB 121 switches to ERROR-SEARCH. The fault-tolerant system switches to solo operation (see below).
RAM/PIQ comparison error	The cause of the error is written to the diagnostics buffer. The CPU switches to the configured system or operating state (see below).
Checksum errors	The response depends on the error situation (see below).
Multiple-bit errors	The faulty CPU switches to ERROR-SEARCH operating state.

Hardware fault with one-sided call of OB 121

If a hardware fault occurs with a one-sided OB 121 call for the first time since the previous POWER ON without battery backup, the faulty CPU switches to ERROR-SEARCH operating state. The fault-tolerant system switches to solo operation. The cause of the error is written to the diagnostics buffer.

RAM/PIQ comparison error

If the self-test returns a RAM/PIQ comparison error, the fault-tolerant system exits the redundant operating state and the standby CPU switches to ERROR-SEARCH operating state (in default configuration). The cause of the error is written to the diagnostics buffer.

The response to a recurring RAM/PIQ comparison error depends on whether the error occurs in the subsequent self-test cycle after troubleshooting or not until later.

Table 7- 4 Response to a recurring comparison error

Comparison error recurs ...	Reaction
in the first self-test cycle after troubleshooting	The standby CPU first switches to ERROR-SEARCH and then to STOP. The fault-tolerant system switches to solo operation.
after two or more self-test cycles after troubleshooting	Standby CPU switches to ERROR-SEARCH. The fault-tolerant system switches to solo operation.

Checksum errors

When a checksum error occurs for the first time since the last POWER ON without battery backup, the system reacts as follows:

Table 7- 5 Reaction to checksum errors

Time of detection	System response
During the startup test after POWER ON	The faulty CPU switches to DEFECTIVE state. The fault-tolerant system switches to solo operation.
In the cyclic self-test (STOP or solo operation)	The error is corrected. The CPU remains in STOP operating state or in solo operation.
In the cyclic self-test (redundant system state)	The error is corrected. The faulty CPU switches to ERROR-SEARCH operating state. The fault-tolerant system switches to solo operation.
In the ERROR-SEARCH operating state	The faulty CPU switches to DEFECTIVE state.
Single-bit errors	The CPU calls OB 84 after detection and elimination of the error.

The cause of the error is written to the diagnostics buffer.

In an F-system, the F-program is informed that the self-test has detected an error the first time a checksum error occurs in STOP or in solo operation. The reaction of the F-program to this is described in Manual *S7-400F and S7-400FH Automation Systems*.

Hardware fault with one-sided call of OB 121, checksum error, second occurrence

A CPU 410–5H reacts to a second occurrence of a hardware fault with a one-sided call of OB 121 and to checksum errors as set out in the table below, based on the various operating modes of the CPU 410.

Table 7- 6 Hardware fault with one-sided call of OB 121, checksum error, second occurrence

Error	CPU in solo operation	CPU in stand-alone operation	CPU in redundant operation
Hardware fault with one-sided call of OB 121	OB 121 is executed	OB 121 is executed	The faulty CPU switches to ERROR-SEARCH operating state. The fault-tolerant system switches to solo operation.
Checksum errors	The CPU enters the DEFECTIVE state if two errors occur within two successive test cycles (configure the length of the test cycle in HW Config).	The CPU enters the DEFECTIVE state if two errors occur within two successive test cycles (configure the length of the test cycle in HW Config).	The CPU enters the DEFECTIVE state if a second error triggered by the first error event occurs in ERROR-SEARCH mode.

If a second checksum error occurs in solo or stand-alone operation after twice the test cycle time has expired, the CPU reacts as it did on the first occurrence of the error. If a second error (hardware fault with one-sided call of OB 121, checksum error) occurs in redundant operation when troubleshooting is finished, the CPU reacts as it did on the first occurrence of the error.

Multiple-bit errors

If a multiple-bit error is detected during redundant operation of a fault-tolerant system, the CPU switches to ERROR-SEARCH operating state. When troubleshooting is finished, the CPU can be linked up and updated again, and resume redundant operation. At the transition to error-search mode, the address of the errors is reported in the diagnostics buffer.

Single-bit errors

The CPU calls OB 84 after detection and elimination of the error.

Influencing the cyclic self-test

SFC 90 "H_CTRL" allows you to influence the scope and execution of the cyclic self-test. For example, you can remove various test components from the overall test and re-introduce them. In addition, you can explicitly call and process specific test components.

For detailed information on SFC 90 "H_CTRL", refer to Manual *System Software for S7-300/400, System and Standard Functions*.

Note

In a fail-safe system, you are not allowed to disable and then re-enable the cyclic self-tests. For more details, refer to Manual *S7-400F and S7-400FH Automation Systems*.

Link-up and update 8

8.1 Effects of link-up and updating

Link-up and updating are indicated by the REDF LEDs on the two CPUs. During link-up, the LEDs flash at a frequency of 0.5 Hz, and when updating at a frequency of 2 Hz.

Link-up and update have various effects on user program execution and on communication functions.

Table 8- 1 Properties of link-up and update functions

Process	Link-up	Update
Execution of the user program	All priority classes (OBs) are processed.	Processing of the priority classes is delayed section by section. All requests are caught up with after the update. For details, refer to the sections below.
Deleting, loading, generating, and compressing of blocks	Blocks cannot be deleted, loaded, created or compressed. When such actions are busy, link-up and update operations are inhibited.	Blocks cannot be deleted, loaded, created or compressed.
Execution of communication functions, PG operation	Communication functions are executed.	Execution of the functions is restricted section by section and delayed. All the delayed functions are caught up with after the update. For details, refer to the sections below.
CPU self-test	Not performed	Not performed
Test and commissioning functions, such as "Monitor and modify variable", "Monitor (On/Off)"	Test and commissioning functions are disabled. When such actions are busy, link-up and update operations are inhibited.	Test and commissioning functions are disabled.
Handling of the connections on the master CPU	All connections are retained; no new connections can be made.	All connections are retained; no new connections can be made. Interrupted connections are not restored until the update is completed
Handling of the connections on the reserve CPU	All the connections are cancelled; no new connections can be made.	All connections are already down. They were cancelled during link-up.

8.2 Conditions for link-up and update

Which commands you can use on the programming device to initiate a link-up and update operation is determined by the current conditions on the master and standby CPU. The table below shows the correlation between those conditions and available programming device commands for link-up and update operations.

Table 8- 2 Conditions for link-up and update

Link-up and update as PG command:	FW version in the master and standby CPUs	Available sync connections	Hardware version on master and standby CPU
Restart of the standby	Are identical	2	Are identical
Switch to CPU with modified configuration	Are identical	2	Are identical
Switching to CPU with modified operating system	Are different	2	Are identical
CPUs with changed hardware version	Are identical	2	Are different
Only one synchronization link-up is available over only one intact redundant link	Are identical	1	Are identical

8.3 Time monitoring

Program execution is interrupted for a certain time during updating. This section is relevant to you if this period is critical in your process. If this is the case, configure one of the monitoring times described below.

During updating, the fault-tolerant system monitors the cycle time extension, communication delay and inhibit time for priority classes > 15 in order to ensure that their configured maximum values are not exceeded, and that the configured minimum I/O retention time is maintained.

Note

If you have not defined any default values for the monitoring times, make allowance for the update in the scan cycle monitoring time. If in this case the update is cancelled, the fault-tolerant system switches to standalone mode: The previous master CPU remains in RUN, and the standby CPU goes into STOP.

You can either configure all the monitoring times or none at all.

You made allowances for the technological requirements in your configuration of monitoring times.

The monitoring times are described in detail below.

- Maximum cycle time extension
  - Cycle time extension: The time during the update in which neither OB 1 nor any other OBs up to priority class 15 are executed. "Normal" cycle time monitoring is disabled within this time span.
  - Max. cycle time extension: The maximum permissible cycle time extension configured by the user.
- Maximum communication delay
  - Communication delay: The time span during the update during which no communication functions are processed. Note: The master CPU, however, maintains all existing communication links.
  - Maximum communication delay: The maximum permissible communication delay configured by the user.
- Maximum inhibit time for priority classes > 15
  - Inhibit time for priority classes > 15: The time span during an update during which no OBs (and thus no user program) are executed nor any I/O updates are implemented.
  - Maximum inhibit time for priority classes > 15: The maximum permissible inhibit time for priority classes > 15 configured by the user.
- Minimum I/O retention time:

  This represents the interval between copying of the outputs from the master CPU to the standby CPU, and the time of the master/standby changeover (time at which the previous master CPU goes into STOP and the new master CPU goes into RUN). Both CPUs control the outputs within this period, in order to prevent the I/O from going down when the system performs an update with master/standby changeover.
  The minimum I/O retention time is of particular importance when updating with master/standby changeover. If you set the minimum I/O retention time to 0, the outputs could possibly shut down when you modify the system during operation.

The monitoring start times are indicated in the highlighted boxes in Figure 12-2. These times expire when the system enters the redundant system mode or when there is a master/standby changeover, i.e. on the transition of the new master to RUN when the update is completed.

The figure below provides an overview of the relevant update times.

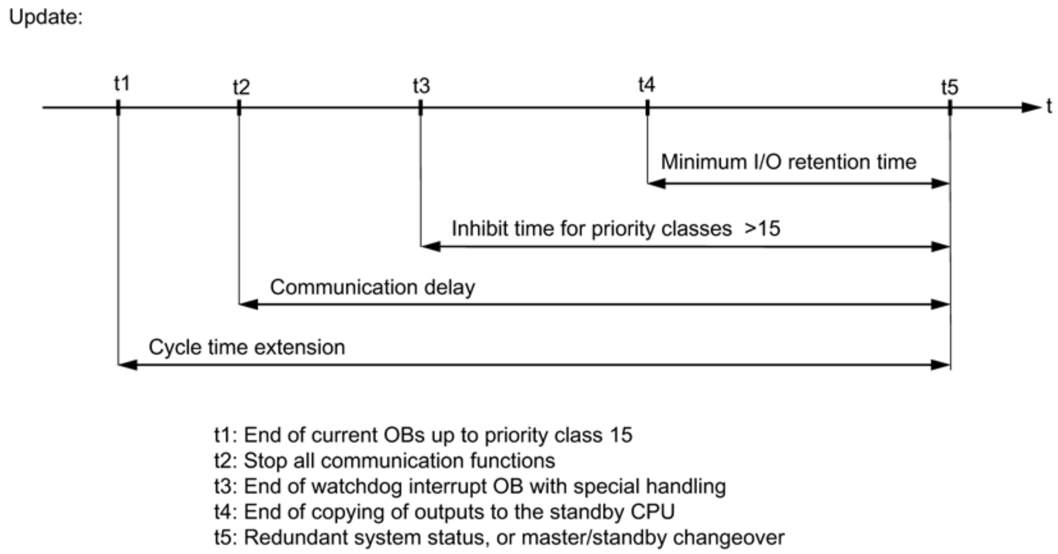


Figure 8-1 Meanings of the times relevant for updates

Response to time-outs

If one of the times monitored exceeds the configured maximum value, the following procedure is started:

1. Cancel update
2. Fault-tolerant system remains in standalone mode, with the previous master CPU in RUN
3. Cause of cancelation is entered in diagnostic buffer
4. Call OB 72 (with corresponding start information)

The standby CPU then reevaluates its system data blocks.
Following this, after at least one minute, the CPU tries again to perform the link-up and update. If still unsuccessful after a total of 10 retries, the CPU abandons the attempt. You yourself will then need to start the link-up and update again.

A monitoring timeout can be caused by:

- High interrupt load (e.g. from I/O modules)
- High communication load causing prolonged execution times for active functions
- In the final update phase, the system needs to copy large amounts of data to the standby CPU.

8.3.1 Time response

Time response during link-up

The influence of link-up operations on your plant's control system should be kept to an absolute minimum. The current load on your automation system is therefore a decisive factor in the increase of link-up times. The time required for link-up is in particular determined by

- the communication load
- the cycle time

Link-up takes about 2 minutes for automation systems without load.

It can take more than one hour when there is a high load on your automation system.

Time response during updating

The update transfer time is determined by the number and overall length of modified data blocks, rather than by the modified volume of data within a block. It is also dependent on the current process status and communication load.

As a simple approximation, we can interpret the maximum inhibit time to be configured for priority classes > 15 as a function of the data volume in the work memory. The volume of code in the work memory is irrelevant.

8.3.2 Determining the monitoring times

Calculation using STEP 7 or formulas

STEP 7 automatically calculates the monitoring times listed below for each new configuration. You can also calculate these times using the formulas and procedures described below. They are equivalent to the formulas provided in STEP 7.

- Maximum cycle time extension
- Maximum communication delay
- Maximum inhibit time for priority classes
- Minimum I/O retention time

You can also start automatic calculation of monitoring times with Properties CPU > H Parameters in HW Config.

Monitoring time accuracy

Note

The monitoring times determined by STEP 7 or by using formulas merely represent recommended values.

These times are based on a fault-tolerant system with two communication peers and an average communication load.

Your system profile may differ considerably from those scenarios, therefore the following rules must be observed.

- The cycle time extension factor may increase sharply at a high communication load.
- Any modification of the system in operation may lead to a significant increase in cycle times.
- Any increase in the number of programs executed in priority classes > 15 (in particular processing of communication blocks) automatically increases the communication delay and cycle time extension.
- You can even undercut the calculated monitoring times in small plants with high-performance requirements.

Configuration of the monitoring times

When configuring monitoring times, always make allowances for the following dependencies; conformity is checked by STEP 7:

Maximum cycle time extension
> maximum communication delay
> (maximum inhibit time for priority classes > 15)
> minimum I/O retention time

If you have configured different monitoring times in the CPUs and perform a link-up and update operation with master/standby changeover, the system always applies the higher of the two values.

Calculating the minimum I/O retention time (T_{PH})

The following applies to the calculation of the minimum I/O retention time:

- With central I/O: T_{PH} = 30 ms
- For distributed I/O (PROFIBUS DP): $T_{PH} = 3 \times T_{TRmax}$

  Where T_{TRmax} = maximum target rotation time of all DP master systems of the fault-tolerant station
- For distributed I/O (PROFINET IO): $T_{PH} = T_{wd\_max}$

  with T_{wd_max} = maximum cyclic interrupt time (product of WD factor and update time) of a switched device in all IO subsystems of the fault-tolerant station

When using central and distributed I/O, the resultant minimum I/O retention time is:

$T_{PH} = MAX(30\ ms, 3 \times T_{TRmax}, T_{wd\_max})$

The following figure shows the correlation between the minimum I/O retention time and the maximum inhibit time for priority classes > 15.

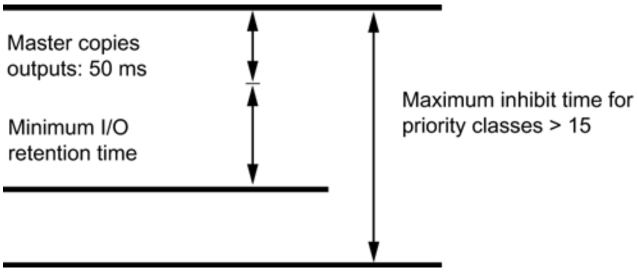


Figure 8-2 Correlation between the minimum I/O retention time and the maximum inhibit time for priority classes > 15

Note the following condition:

50 ms + minimum I/O retention time ≤
(maximum inhibit time for priority classes > 15)

It follows that a high minimum I/O retention time can determine the maximum inhibit time for priority classes > 15.

Calculating the maximum inhibit time for priority classes > 15 (T_{P15})

The maximum inhibit time for priority classes > 15 is determined by 4 main factors:

- As shown in Figure 12-2, all the contents of data blocks modified since last copied to the standby CPU are once again transferred to the standby CPU on completion of the update. **The number and structure of the DBs** you write to in the high-priority classes is a decisive factor in the duration of this operation, and thus in the maximum inhibit time for priority classes > 15. Relevant information is available in the remedies described below.
- In the final update phase, all OBs are either delayed or inhibited. To avoid any unnecessary extension of the maximum inhibit time for priority classes > 15 due to unfavorable programming, you should always process the time-critical I/O components in a **selected cyclic interrupt**. This is particularly relevant in fail-safe user programs. You can define this cyclic interrupt in your configuration. It is then executed again right after the start of the maximum inhibit time for priority classes > 15, provided you have assigned it a priority class > 15.

- In link-up and update operations with master/standby changeover (see section Link-up sequence (Page 261)), you also need to changeover the active communication channel on the switched DP slaves and switched IO devices on completion of the update. This operation prolongs the time within which valid values can neither be read nor output. How long this process takes is determined by your **hardware configuration**.
- The **technological conditions in your process** also decide how long an I/O update can be delayed. This is particularly important in time-monitored processes in fail-safe systems.

Note

For details, refer to Manual *S7-400F and S7-400FH Automation Systems* and Manual *S7-300 Automation Systems, Fail-safe Signal Modules*. This applies in particular to the internal execution times of fail-safe modules.

---

1. Based on the bus parameters in STEP 7, determine the following for each DP master system:
   – T_{TR} for the DP master system
   – DP changeover time (referred to below as T_{DP_UM})
2. From the STEP 7 configuration, determine the following for each IO subsystem:
   – Maximum update time of the IO subsystem (referred to below as T_{max_Akt})
   – PN changeover time (referred to below as T_{PN_UM})
3. Based on the technical data of the switched DP slaves, determine the following for each DP master system:
   – The maximum changeover time of the active communication channel (referred to below as T_{SLAVE_UM}).
4. Based on the technical specifications of the switched PN devices, determine the following for each IO subsystem:
   – Maximum changeover time of the active communication channel (referred to below as T_{Device_UM}).
5. Based on the technological specifications of your system, determine the following:
   – Maximum permissible time during which there is no update of your I/O modules (referred to below as T_{PTO}).
6. Based on your user program, determine the following:
   – Cycle time of the highest-priority or selected (see above) cyclic interrupt (T_{WA})
   – Execution time of your program in this cyclic interrupt (T_{PROG})
7. For each DP master system this results in:

   T_{P15} (DP master system) = $T_{PTO} - (2 \times T_{TR} + T_{WA} + T_{PROG} + T_{DP\_UM} + T_{SLAVE\_UM})$ [1]

8. For for each IO subsystem, this results in:

   T_{P15} (IO subsystem) = T_{PTO} - (2 x T_{max_Akt} + T_{WA} + T_{PROG} + T_{PN_UM} + T_{Device_UM}) [1]

   Note

   If T_{P15}(DP master system) < 0 or T_{P15}(IO subsystem) < 0, stop the calculation here. Possible remedies are shown below the following example calculation. Make appropriate changes and then restart the calculation at 1.

9. Select the minimum of all T_{P15} (DP master system) values.

   This time is referred to below as TP15_HW.

10. Determine the share of the maximum inhibit time for I/O classes > 15 that is required by the minimum I/O retention time (T_{P15_OD}):

    T_{P15_OD} = 50 ms + min. I/O retention time [2]

    Note

    If T_{P15_OD} > T_{P15_HW}, stop the calculation here. Possible remedies are shown below the following example calculation. Make appropriate changes and then restart the calculation at 1.

11. Using the information in Chapter Performance values for link-up and update (Page 120), calculate the share of the maximum inhibit time for priority classes > 15 that is required by the user program (T_{P15_AWP}).

    Note

    If T_{P15_AWP} > T_{P15_HW}, stop the calculation here. Possible remedies are shown below the following example calculation. Make appropriate changes and then restart the calculation at 1.

12. The recommended value for the maximum inhibit time for priority classes > 15 is now obtained from:

    T_{P15} = MAX (T_{P15_AWP}, T_{P15_OD}) [3]

Example of the calculation of T_{P15}

In the next steps, we take an existing system configuration and define the maximum permitted time span of an update, during which the operating system does not execute any programs or I/O updates.

There are two DP master systems and one IO subsystem: DP master system_1 is connected via the DP interface of the CPU, and DP master system_2 is connected to the CPU via an external DP master interface. The IO subsystem is connected via the integrated Ethernet interface.

1. Based on the bus parameters in STEP 7:

   T_{TR_1} = 25 ms

   T_{TR_2} = 30 ms

   $T_{DP\_UM\_1}$ = 100 ms

   $T_{DP\_UM\_2}$ = 80 ms
2. Based on the configuration in STEP 7:

   T_{max_Akt} = 8 ms

   T_{PN_UM} = 110 ms
3. Based on the technical data of the DP slaves used:

   $T_{SLAVE\_UM\_1}$ = 30 ms

   $T_{SLAVE\_UM\_2}$ = 50 ms
4. Based on the technical specifications of the PN devices used:

   T_{Device_UM} = 20 ms
5. Based on the technological settings of your system:

   T_{PTO_1} = 1250 ms

   T_{PTO_2} = 1200 ms

   T_{PTO_PN} = 1000 ms
6. Based on the user program:

   T_{WA} = 300 ms

   T_{PROG} = 50 ms
7. Based on the formula [1]:

   T_{P15} (DP master system_1)

   = 1250 ms - (2 x 25 ms + 300 ms + 50 ms + 100 ms + 30 ms) = 720 ms

   T_{P15} (DP master system_2)

   = 1200 ms - (2 x 30 ms + 300 ms + 50 ms + 80 ms + 50 ms) = 660 ms
8. Based on the formula [1]:

   T_{P15} (IO subsystem)

   = 1200 ms - (2 x 8 ms + 300 ms + 50 ms + 110 ms + 20 ms) = 704 ms

Check: Since T_{P15} > 0, continue with

1. T_{P15_HW} = MIN (720 ms, 660 ms, 704 ms) = 660 ms
2. Based on the formula [2]:

T_{P15_OD} = 50 ms + T_{PH} = 50 ms + 90 ms = 140 ms

Check: Since T_{P15_OD} = 140 ms < T_{P15_HW} = 660 ms, continue with

1. Based on section Performance values for link-up and update (Page 120) with 170 Kbytes of user program data:

   T_{P15_AWP} = 194 ms

Check: Since T_{P15_AWP} = 194 ms < T_{P15_HW} = 660 ms, continue with

1. Based on formula [3], we obtain the recommended max. inhibit time for priority classes > 15:

T_{P15} = MAX (194 ms, 140 ms)

T_{P15} = 194 ms

This means that by setting a maximum inhibit time of 194 ms for priority classes > 15 in STEP 7, you ensure that any signal changes during the update are detected with a signal duration of 1250 ms or 1200 ms.

Remedies if it is not possible to calculate T_{P15}

If no recommendation results from calculating the maximum inhibit time for priority classes > 15, you can remedy this by taking various measures:

- Reduce the cyclic interrupt cycle of the configured cyclic interrupt.
- If T_{TR} times are particularly high, distribute the slaves across several DP master systems.
- If possible, reduce the maximum update time of switched devices on the IO subsystem.
- Increase the baud rate on the affected DP master systems.
- Configure the DP/PA links and Y links in separate DP master systems.
- If there is a great difference in changeover times on the DP slaves, and thus (generally) great differences in T_{PTO}, distribute the slaves involved across several DP master systems.
- If you do not expect any significant load caused by interrupts or parameter assignments in the various DP master systems, you can also reduce the calculated T_{TR} times by around 20% to 30%. However, this increases the risk of a station failure in the distributed I/O.
- The time value T_{P15_AWP} represents a guideline and depends on your program structure. You can reduce it by taking the following measures, for example:
  - Save data that changes often in different DBs than data that does not change as often.
  - Specify a smaller DB sizes in the work memory.

If you reduce the time T_{P15_AWP} without taking the measures described, you run the risk that the update operation will be canceled due to a monitoring timeout.

Calculation of the maximum communication delay

Use the following formula:

Maximum communication delay =
4 x (maximum inhibit time for priority classes > 15)

Decisive factors for determining this time are the process status and the communication load in your system. This can be understood as the absolute load or as the load relative to the size of your user program. You may have to adjust this time.

Calculation of the maximum cycle time extension

Use the following formula:

Maximum cycle time extension =
10 x (maximum inhibit time for priority classes > 15)

Decisive factors for determining this time are the process status and the communication load in your system. This can be understood as the absolute load or as the load relative to the size of your user program. You may have to adjust this time.

8.3.3 Performance values for link-up and update

User program share T_{P15_AWP} of the maximum inhibit time for priority classes > 15

The user program share T_{P15_AWP} of the maximum inhibit time for priority classes > 15 can be calculated using the following formula:

T_{P15_AWP} in ms = 0.7 x size of DBs in work memory in KB + 75

The table below shows the derived times for some typical values in work memory data.

Table 8- 3 Typical values for the user program part

Work memory data	T_{P15_AWP}
500 KB	220 ms
1 MB	400 ms
2 MB	0.8 s
5 MB	1.8 s
10 MB	3.6 s

The following assumptions were made for this formula:

- 80% of the data blocks are modified prior to delaying the interrupts of priority classes > 15.
  In particular for fail-safe systems, this calculated value must be more precise to avoid any timeout of driver blocks (see section Determining the monitoring times (Page 113)).
- For active or queued communication functions, allowance is made for an update time of approximately 100 ms per MB in the work memory occupied by data blocks.
  Depending on the communication load of your automation system, you will need to add or deduct a value when you set T_{P15_AWP}.

8.3.4 Influences on time response

The period during which no I/O updates take place is primarily determined by the following influencing factors:

- The number and size of data blocks modified during the update
- The number of instances of SFBs in S7 communication and of SFBs for generating block-specific messages
- System modifications during operation
- Settings by means of dynamic quantity structures
- Expansion of distributed I/Os with PROFIBUS DP (a lower baud rate and higher number of slaves increases the time it takes for I/O updates).
- Expansion of distributed I/Os with PROFINET IO (a higher update time and higher number of devices increases the time it takes for I/O updates).

In the worst case, this period is extended by the following amounts:

- Maximum cyclic interrupt used
- Duration of all cyclic interrupt OBs
- Duration of high-priority interrupt OBs executed until the start of interrupt delays

8.4 Special features in link-up and update operations

Requirement for input signals during the update

Any process signals read previously are retained and not included in the update. The CPU only recognizes changes of process signals during the update if the changed signal state remains after the update is completed.

The CPU does not detect pulses (signal transitions "0 → 1 → 0" or "1 → 0 →1") which are generated during the update.

You should therefore ensure that the interval between two signal transitions (pulse period) is always greater than the required update period.

Communication links and functions

Connections on the master CPU are not be shut down. However, associated communication jobs are not executed during updates. They are queued for execution as soon as one of the following cases occurs:

- The update is completed, and the system is in the redundant state.
- The update and master/standby changeover are completed, the system is in solo operation.
- The update was canceled (e.g., due to timeout), and the system has returned to solo operation.

An initial call of communication blocks is not possible during the update.

Memory reset request on cancelation of link-up

If the link-up operation is canceled while the content of load memory is being copied from the master to the standby CPU, the standby CPU requests a memory reset. This indicated in the diagnostics buffer by event ID W#16#6523.

9 Special functions of the CPU 410-5H

9.1 Security levels

You can define a protection level for your project in order to prevent unauthorized access to the CPU programs. The objective of these protection level settings is to grant a user access to specific programming device functions which are not protected by password, and to allow that user to execute those functions on the CPU.

Setting protection levels

You can set the CPU protection levels 1 to 3 under "STEP 7/Configure Hardware".

The following table shows the protection levels of a CPU.

Table 9- 1 Protection levels of a CPU

CPU function	Protection level 1	Protection level 2	Protection level 3
Display of list of blocks	Access granted	Access granted	Access granted
Monitor variables	Access granted	Access granted	Access granted
Module status STACKS	Access granted	Access granted	Access granted
Operator control and monitoring functions	Access granted	Access granted	Access granted
S7 communication	Access granted	Access granted	Access granted
Read time of day	Access granted	Access granted	Access granted
Set time of day	Access granted	Access granted	Access granted
Block status	Access granted	Access granted	Password required
Load in PG	Access granted	Access granted	Password required
Stop a CPU or the system	Access granted	Password required	Password required
Load in CPU	Access granted	Password required	Password required
Delete blocks	Access granted	Password required	Password required
Compress memory	Access granted	Password required	Password required
Controlling selection	Access granted	Password required	Password required
Modify variable	Access granted	Password required	Password required
Breakpoint	Access granted	Password required	Password required
Clear breakpoint	Access granted	Password required	Password required
Memory reset	Access granted	Password required	Password required

Setting the protection level with SFC 109 "PROTECT"

You can set the following protection levels on your CPU with SFC 109:

- SFC 109 call with MODE=0: Setting of protection level 1. The SFC 109 call with MODE=0 overrides any existing lock of password legitimization.
- SFC 109 call with MODE=1: Setting of protection level 2 with password legitimization. This means you can cancel the write protection set with SFC 109 if you know the valid password. The SFC 109 call with MODE=1 overrides any existing lock of password legitimization.
- SFC 109 call with MODE=12: Setting of protection level 3 without password legitimization. This means you cannot cancel the write and read protection set with SFC 109 even if you know the valid password. If a legitimate connection exists when you call SFC-109 with MODE=12, the SFC-109 call has no effect on this connection.

Note

Setting a lower protection level

You can use SFC 109 "PROTECT" to set a lower protection level than the one you configured with STEP 7 "Configure hardware".

Additional aspects

- Both fault-tolerant CPUs of a fault-tolerant system can have different protection levels in STOP.
- The protection level is transferred from the master to the standby during link-up/update operations.
- The set protection levels of both fault-tolerant CPUs are retained if you make modifications to the plant during operation.
- The protection level is transferred to the target CPU in the following cases:
  – Switching to a CPU with modified configuration
  – Switching to a CPU with expanded memory capacity/modified system expansion card
  – Switching to a CPU with modified operating system
  – Switching to a CPU using only one intact redundant link

9.2 Access-protected blocks

S7-Block Privacy

The STEP 7 add-on package S7-Block Privacy can be used to protect the functions and function blocks against unauthorized access.

Observe the following information when using S7-Block Privacy:

- S7-Block Privacy is operated by means of shortcut menus. To view a specific menu help, press the "F1" function key.
- You can no longer edit protected blocks in STEP 7. Moreover, testing and commissioning functions such as "Monitor blocks" or breakpoints are no longer available. Only the interfaces of the protected block remain visible.
- Protected blocks can only be released again for editing if you have the correct key and the corresponding decompilation information included in your package. Make sure that the key is always kept in a safe place.
- The loading of protected blocks is only supported on CPUs as of version 6.0.
- If your project contains sources, you can use these to restore the protected blocks by means of compilation. The S7-Block Privacy sources can be removed from the project.

Note

Memory requirements

Each protected block with decompilation information occupies 232 additional bytes in load memory.

Each protected block without decompilation information occupies 160 additional bytes in load memory.

Note

Extended runtimes

The startup time of the CPU at power on, the loading time of blocks and the startup after a system modification at runtime may be significantly prolonged.

To optimize additional time requirements, it is best practice to protect one large block instead of many small blocks.

If you have many protected blocks and change one of the following parameters, the error "Unable to load system data..." could occur during the loading process.

- Size of the process image
- Size of the diagnostic buffer
- Maximum number of communication jobs
- Total amount of local data

Download the system data once again in this case.

Additional information

For additional information, refer to "S7 block privacy" in the STEP 7 Online Help.

9.3 Resetting the CPU410-5H to factory settings

CPU factory settings

A general memory reset is performed when you reset the CPU to its factory settings and the properties of the CPU are set to the following values:

Table 9- 2 CPU properties in the factory settings

Properties	Value
Contents of the diagnostics buffer	Empty
IP parameters	None
SNMP parameters	Default values
Operating hours counter	0 without battery backup
Date and time	01.01.94, 00:00:00 without battery backup

Procedure

Proceed as follows to reset a CPU to its factory settings:

1. Switch off the line voltage.
2. Switch on the line voltage while pressing and holding down the Reset button for 5 seconds.
3. Wait until LED pattern 1 from the following overview is displayed. In this lamp pattern, INTF flashes at 0.5 Hz. EXTF, BUSxF, MAINT, IFMxF, RUN, and STOP remain unlit.
4. Wait until LED pattern 2 from the following overview is displayed. In this LED pattern, INTF is lit. EXTF, BUSxF, MAINT, IFMxF, RUN, and STOP remain unlit.

The CPU is now reset to its factory settings. It starts up and switches to STOP operating state or links up. The event "Reset to factory setting" is entered in the diagnostics buffer.

Note

Canceling the operation

If the described operation is canceled prematurely and the CPU remains in an undefined state, you can bring it back to a defined state by cycling the power off and on.

LED patterns during CPU reset

While you are resetting the CPU to its factory settings, the LEDs light up consecutively in the following LED patterns:

Table 9- 3 LED patterns

LED	LED pattern 1	LED pattern 2
INTF	Flashes at 0.5 Hz	Lit
EXTF	Dark	Dark
BUSxF	Dark	Dark
MAINT	Dark	Dark
IFMxF	Dark	Dark
RUN	Dark	Dark
STOP	Dark	Dark

9.4 Reset during operation

CPU operating state

The following procedure references the RED or RUN RED operating state.

Note

The CPU should not be reset after an automatic reboot. The memory dump associated with the reset will destroy the error information saved during the reboot and a detailed search for the cause of the error is no longer possible.

Reset procedure during operation

Press and hold down the Reset button for 5 seconds.

1. The CPU performs a memory dump and documents it with the event 0x4x08 ("Memory reset started by switch operation") in the diagnostic buffer.
2. The CPU performs a memory reset and then switches to STOP or links up.

Automatic reset in stand-alone operation with warm restart

Note

During Power On with battery backup of a fault-tolerant system with large configurations, many CPs and/or external DP masters, it may take up to 30 seconds until a requested restart is executed. During this time, the LEDs on the CPU light up successively as follows:

1. All LEDs light up
2. The STOP LED flashes as it does during a memory reset
3. The RUN and STOP LEDs flash for about 2 seconds
4. The RUN LED flashes briefly 2 to 3 times
5. The STOP LED lights up for about 25 seconds
6. The RUN LED starts flashing again.
   This begins the start up.

9.5 Updating firmware

Basic procedure

To update the firmware of a CPU, you will receive several files (*.UPD) containing the current firmware. You download these files to the CPU.

Requirement

The CPU whose firmware you want to update must be accessible online, e.g., via PROFIBUS or Industrial Ethernet. The files containing the current firmware versions must be downloaded into the programming device/PC file system. A folder may contain only the files of one firmware version. If the CPU is protected with a password, you need the respective password for the update.

Note any information posted in the firmware download area.

Procedure in HW Config

Proceed as follows to update the firmware of a CPU:

1. Open the station containing the CPU you want to update in HW Config.
2. Select the CPU.
3. Select the "PLC -> Update Firmware" menu command.

4. In the "Update Firmware" dialog, select the path to the firmware update files (*.UPD) using the "Browse" button.

   After you have selected a file, the information in the bottom boxes of the "Update Firmware" dialog box indicate the modules for which the file is suitable and from which firmware version.
5. Click on "Run".

STEP 7 verifies that the selected file can be interpreted by the CPU and then downloads the file to the CPU. If this requires changing the operating state of the CPU, you will be prompted to do this in the relevant dialog boxes.

Procedure in SIMATIC Manager

The procedure corresponds to that in HW Config; the menu command here is also "PLC > Update firmware". However, STEP 7 checks whether the module supports the function only at the time of execution.

Note

Protecting the update

In order to protect the firmware update, there is a digital signature that is checked by the CPU during the update. If an error is detected, the old firmware remains active and the new firmware is rejected.

Values retained after a firmware update

The following values are retained after a CPU memory reset:

- IP address of the CPU
- Device name (NameOfStation)
- Subnet mask
- Static SNMP parameters

9.6 Firmware update in RUN mode

Requirement

You operate the CPU 410-5H in a fault-tolerant system. Both Sync links exist and are working. There are no I/O bus errors, such as a faulty IM153-2.

Note any information posted in the firmware download area.

Procedure for automatic firmware update

Initial situation: Both CPUs are in redundant operation.

1. For CPU access protection with password: In SIMATIC Manager, select a CPU of the fault-tolerant system, then select
   "PLC > Access Rights > Setup" from the menu. Enter the CPU access password.
2. Select one of the two CPUs using either SIMATIC Manager -> Project, or HW Config.

   Do not use the "Accessible nodes" menu command in SIMATIC Manager.
3. Select the "PLC > Update Firmware" menu command.

   A wizard is started that can automatically update the firmware on both CPUs.

Alternative procedure for progressive firmware update

Follow the steps below to update the firmware of the CPUs of a fault-tolerant system in RUN:

1. For CPU access protection with password: In SIMATIC Manager, select a CPU of the fault-tolerant system, then select
   "PLC > Access Rights > Setup" from the menu. Enter the CPU access password.
2. Set one of the CPUs to STOP using the ES.
3. Select this CPU in HW Config or in SIMATIC Manager in your STEP 7 project.
4. Select the "PLC -> Update Firmware" menu command.

   The "Update Firmware" dialog box opens. Select the firmware file from which the current firmware will be downloaded to the selected CPU.
5. In SIMATIC Manager or HW Config, select the "PLC > Operating Mode > Switch to" and select the "With altered operating system" check box.

   The fault-tolerant system switches the master/standby roles, after which the CPU will be in RUN again.
6. Repeat steps 1 to 3 for the other CPU.
7. Restart the CPU. The fault-tolerant system will return to redundant operating state.

Both CPUs have updated firmware (operating system) and are in redundant operating state.

Note

Only the third number of the firmware versions of the master and standby CPU may differ by 1. You can only update to the newer version.

The constraints described in Chapter Operator controls and operating modes of the CPU 410-5H (Page 91) also apply to a firmware update in RUN.

Any set up access right is not canceled until you stop the SIMATIC Manager. You should reset the access right once again to prevent unauthorized access. You reset the access right in the SIMATIC Manager with the menu command PLC > Access Rights > Cancel.

9.7 Reading service data

Application case

If you need to contact Customer Support due to a service event, the department may require specific diagnostic information on the CPU status of your system. This information is stored in the diagnostic buffer and in the service data.

Select the "PLC -> Save service data" command to read this information and save the data to two files. You can then send these to Customer Support.

Note the following:

- If possible, save the service data immediately after the CPU goes into STOP or the synchronization of a fault-tolerant system has been lost.
- Always save the service data of both CPUs in an H system.

Procedure

1. Select the "PLC > Save service data" command.

   In the dialog box that opens up, select the file path and the file names.
2. Save the files.
3. Forward these files to Customer Support on request.

9.8 Response to fault detection

Response to fault detection

In order to ensure a high level of reliability, in particular, of the fault tolerant system, the CPU 410 has many self diagnostics. Faults can thus be detected and eliminated at an early stage. In the rare instance that a fault occurs that cannot be eliminated by the firmware, the current status data can be saved internally (memory dump) for further evaluation by SIEMENS specialists. An automatic reboot is then started. This behavior minimizes the down time of the CPU and guarantees the fastest possible restoration of access to the process.

Automatic reboot in the event of a one-sided defect in the fault-tolerant system

The defective CPU performs the complete self-test. The other CPU remains in RUN. If a hardware error is detected, the CPU remains in DEFECTIVE. If no fault is detected, the CPU links up again. The fault-tolerant system switches back to the redundant system state.

The necessary defect information can be read out immediately afterwards during operation with the function Read out service data.

9.9 Time synchronization

Introduction

The CPU 410-5H has a powerful timer system. You can synchronize this timer system using a higher-level time generator, which will allow you to synchronize, trace, record, and archive sequences.

Interfaces

Time synchronization is possible via every interface of the CPU 410-5H:

- PROFIBUS DP interface

  You can configure the CPU as a time master or a time slave.
- PROFINET IO interface via Industrial Ethernet

  Time synchronization using the NTP method; the CPU is the client.

  Time synchronization using the SIMATIC method as master or slave
- Via the S7-400 backplane bus

  You can configure the CPU as a time master or a time slave.

Time synchronization via the PROFINET IO interface

With the PROFINET IO interface, time synchronization is possible using the NTP method and the SIMATIC method. The PROFINET IO CPU is a client in this process.

You may configure up to four NTP servers. You can set the update interval between 10 seconds and 1 day. For times greater than 90 minutes, an NTP request of the PROFINET IO CPU always occurs every 90 minutes.

If you synchronize the PROFINET IO CPU in the NTP method, you should use SICLOCK or an NTP server on the OS.

Time synchronization is also possible via Ethernet MMS (Simatic method on Ethernet) as master or slave. The combination NTP with SIMATIC method is allowed in this case.

CPU as a time slave

If the CPU is a time slave on the S7-400 backplane bus, synchronization is carried out via the CP by a central clock connected to the LAN.

You can use a CP to forward the time to the S7-400 station. If the CP supports a direction filter, the CP must be configured for time forwarding with the "from LAN to station" option.

CPU as a time master

If you configure the CPU as a time master, you must specify a synchronization interval. You can select any interval between 1 second and 24 hours.

Select a synchronization interval of 10 s if the CPU is the time master on the S7-400 backplane bus.

The time master sends its first message frame via SFC 0 "SET_CLK" or via a programming device function once the time has been set for the first time. If another interface was configured as a time slave or as an NTP client, the time starts once the first time message frame has been received.

Reference

Information about time synchronization for PCS 7 is available in the manual SIMATIC Process Control System PCS 7, time synchronization (V8.0) (http://support.automation.siemens.com/WW/view/en/61189664).

System modifications during redundant operation 10

10.1 System modifications during operation

In addition to the options described in the chapter Failure and replacement of components during redundant operation (Page 167) to replace failed components during operation, you can also make a system modification with the CPU 410-5H without interrupting the running program.

The procedure and scope depend on the operating mode of the CPU.

- Modifications to the Profibus I/O can be made to a limited extent in stand-alone operation. The procedure is described in a separate manual, see Modifying the System during Operation via CiR (http://support.automation.siemens.com/WW/view/en/14044916)
- More extensive modifications to the I/O and the CPU parameters are possible in redundant mode. Detailed information is available in the chapters below.

The procedures described below for making changes during operation are each created in such a way that they start from the redundant system state (see Chapter The system states of the fault-tolerant system (Page 99)) and have as their objective a return to redundant system state.

Note

Keep strictly to the rules described in this section with regard to modifications of the system in runtime. If you contravene one or more rules, the response of the fault-tolerant system can result in its availability being restricted or even failure of the entire automation system.

Only perform a system change in runtime when there is no redundancy error, i.e., when the REDF LED is not lit. The automation system may otherwise fail.

The cause of a redundancy error is listed in the diagnostics buffer.

Safety-related components are not taken into account in this description. For more information on dealing with fail-safe systems refer to Manual *S7-400F and S7-400FH Automation Systems*.

What should I consider during system planning?

For switched I/O to be expanded during operation, the following points must be taken into account already at the system planning stage:

- In both cables of a redundant DP master system, sufficient numbers of branching points are to be provided for spur lines or isolating points (spur lines are not permitted for transmission rates of 12 Mbit/s). These branching points can be spaced or implemented at any points that can be accessed easily.
- Both cables must be uniquely identified so that the line which is currently active is not accidentally cut off. This identification should be visible not only at the end points of a line, but also at each possible new connection point. Different colored cables are especially suitable for this.
- Modular DP slave stations (ET 200M), DP/PA links and Y links must always be installed with an active backplane bus and fitted with all the bus modules required wherever possible, because the bus modules cannot be installed and removed during operation.
- The removal of the terminal modules with the ET200iSP should have sufficient reserves and be fitted with unconfigured reserve modules.
- Always terminate both ends of PROFIBUS DP and PROFIBUS PA bus cables using active bus terminating elements in order to ensure proper termination of the cables while you are reconfiguring the system.
- PROFIBUS PA bus systems should be built up using components from the SpliTConnect product range (see interactive catalog CA01) so that separation of the lines is not required.

Modification of the hardware configuration

With a few exceptions, all elements of the configuration can be modified during operation. Usually configuration changes will also affect the user program.

The following must not be changed by means of system modifications during operation:

- Certain CPU parameters (for details refer to the relevant sections)
- PN configurations
- The transmission rate (baud rate) of redundant DP master systems
- S7 and S7 H connections

Modifications to the user program and the connection configuration

The modifications to the user program and connection configuration are loaded into the target system in redundant system state. More detailed information can be found in Manuals *PCS 7, Configuration Manual*.

10.2 Possible hardware modifications

How is a hardware modification made?

If the hardware components concerned are suitable for unplugging or plugging in live, the hardware modification can be carried out in redundant system state. However, the fault-tolerant system must be switched temporarily to solo operation, because the download of a modified hardware configuration in redundant system state would cause the fault-tolerant system to stop. In solo operation, the process is then controlled by only one CPU while the desired configuration changes are made to the other CPU.

Note

During a hardware modification, you can either remove or add modules. If you want to alter your fault-tolerant system such that you remove modules and add others, you have to make two hardware changes.

Note

Always download configuration changes to the CPU using the "Configure hardware" function.

Synchronization link

Whenever you make hardware modifications, make sure that the synchronization link between the two CPUs is established **before** you start or turn on the standby CPU. If the power supply to the CPUs is on, the LEDs IFM1F and IFM2F that indicate errors on the module interfaces on the two CPUs should **go off**.

If one of the IFM LEDs continues to be lit even after you have replaced the relevant synchronization modules, the synchronization cables and even the standby CPU, there is an error in the master CPU. In this case, you can, however, switch to the standby CPU by selecting the "via only one intact redundancy link" option in the "Switch" STEP 7 dialog box.

Which components can be modified?

The following modifications can be made to the hardware configuration during operation:

- Adding or removing modules in the central controllers or expansion units (e.g., one-sided I/O module).

Note

IM 460, IM 461 and CP 443-5 Extended

Adding or removing IM460 and IM461 interface modules, external CP443-5 Extended DP master interface modules and their cables is only permitted in a de-energized state.

Note

Signal modules capable of generating substitute values in the central controller

The minimum I/O retention time is ineffective in case of a plant change for signal modules capable of generating substitute values in a central controller. This means there is no bumpless switchover of these modules, for example, with configured module redundancy. There is always going to be a gap of 3 to 50 ms.

- Adding or removing components of the distributed I/O such as
  - DP slaves with a redundant interface module (e.g., ET 200M, ET200iSP, DP/PA link, or Y Link)
  - One-sided DP slaves (in any DP master system)
  - Modules in modular DP slaves (ET200M and ET200iSP)
  - DP/PA couplers
  - PA devices
- Changing specific CPU parameters
- Reassigning the module parameters
- Assigning a module to another process image partition
- Upgrading the CPU version
- Upgrading to a higher product version or a current version of used components, such as DP-IMs or external DP interface modules.
- Changing the master with only one available redundant link

Note

No changes to the PROFINET IO interface during operation

I/O components that are connected to a PROFINET IO interface as well as parameters of the PROFINET IO interface cannot be modified during operation.

Follow the rules for assembling a fault-tolerant station when making any modifications (see section Rules for the assembly of fault-tolerant stations (Page 27)).

Special features

- Keep changes to a manageable extent. We recommend that you modify only one DP master and/or a few DP slaves (e.g., no more than 5) per reconfiguration run.
- When using an IM 153-2, active bus modules can only be plugged in if the power supply is off.

Note

When using redundant I/O that you have implemented as one-sided I/O at the user level (see section Other options for connecting redundant I/Os (Page 268)), you must take the following into consideration:

Due to the link-up and update process carried out after a system modification, the I/O data of the previous master CPU may be temporarily deleted from the process image until all (changed) I/Os of the "new" master CPU are written to the process image.

During the first update of the process image after a system modification, you may (incorrectly) have the impression that the redundant I/O has failed completely or that a redundant I/O exists. So correct evaluation of the redundancy status is not possible until the process image has been fully updated.

This does not apply for modules that have been enabled for redundant operation (see section Connecting redundant I/O to the PROFIBUS DP interface (Page 68)).

Preparations

To minimize the time during which the fault-tolerant system has to run in single operation, perform the following steps **before** making the hardware change:

- Check whether the CPUs provide sufficient memory capacity for the new configuration data and user program.
- Always ensure that plugged modules which are not configured yet do not have any unwanted influence on the process.

10.3 Adding components

Starting situation

You have verified that the CPU parameters (e.g., monitoring times) match the planned new program. Adapt the CPU parameters first, if necessary (see Chapter Editing CPU parameters (Page 155)).

The fault-tolerant system is operating in redundant system state.

Procedure

Carry out the steps listed below to add hardware components to a fault-tolerant system in PCS 7. Details of each step are described in a section.

Step	What has to be done?	See Chapter
1	Modify hardware	Step 1: Modify hardware (Page 140)
2	Modify the hardware configuration offline	Step 2: Modify the hardware configuration offline (Page 141)
3	Stop the standby CPU	Step 3: Stop the standby CPU (Page 142)
4	Download new hardware configuration to the standby CPU	Step 4: Download new hardware configuration to the standby CPU (Page 142)
5	Switch to CPU with modified configuration	Step 5: Switch to CPU with modified configuration (Page 143)
6	Transition to redundant system state	Step 6: Transition to redundant system state (Page 144)
7	Modify and download the user program	Step 7: Modify and download the user program (Page 145)

Exceptions

This overall sequence for system modification does not apply in the following cases:

- For use of free channels on an existing module
- For adding of interface modules (see Chapter Addition of interface modules (Page 147))

Note

After changing the hardware configuration, you can have the download operation run essentially automatically. You then no longer have to perform the steps described in Chapters Step 3: Stop the standby CPU (Page 142) to Step 6: Transition to redundant system state (Page 144). The system behavior remains unchanged as already described.

You will find more information in the HW Config online help, "Download to module -> Download station configuration in RUN operating state".

10.3.1 Step 1: Modify hardware

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

1. Add the new components to the system.
   - Plug new central modules into the racks.
   - Plug new module into existing modular DP stations
   - Add new DP stations to existing DP master systems.

   Note

   With switched I/O: Always complete all changes on **one** segment of the redundant DP master system before you modify the next segment.

   ---

2. Connect the required sensors and actuators to the new components.

Result

The insertion of non-configured modules will have no effect on the user program. The same applies to adding DP stations.

The fault-tolerant system continues to operate in redundant system mode.

New components are not yet addressed.

10.3.2 Step 2: Modify the hardware configuration offline

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

1. Perform all the modifications to the hardware configuration relating to the added hardware offline. Assign appropriate icons to the new channels to be used.
2. Compile the new hardware configuration, but do **not** load it into the target system just yet.

Result

The modified hardware configuration is in the PG/ES. The target system continues operation with the old configuration in redundant system mode.

Configuring connections

The interconnections with added CPs must be configured on both connection partners **after** you complete the HW modification.

10.3.3 Step 3: Stop the standby CPU

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

1. For CPU access protection with password: In SIMATIC Manager, select a CPU of the fault-tolerant system, then select
   "PLC > Access Rights > Setup" from the menu. Enter the CPU access password.
2. In SIMATIC Manager, select a CPU of the fault-tolerant system, then select "PLC > Operating Mode" from the menu.
3. In the "Operating Mode" dialog box, select the standby CPU and click "Stop".

Result

The standby CPU switches to STOP mode, the master CPU remains in RUN mode, the fault-tolerant system works in single mode. The one-sided I/O of the standby CPU is no longer addressed.

Although I/O access errors of the one-sided I/O will result in OB 85 being called, due to the higher-priority CPU redundancy loss (OB 72) they will not be reported. OB 70 (I/O redundancy loss) is not called.

10.3.4 Step 4: Download new hardware configuration to the standby CPU

Starting situation

The fault-tolerant system is operating in single mode.

Procedure

Load the compiled hardware configuration in the reserve CPU that is in STOP mode.

Note

The user program and connection configuration cannot be downloaded in single mode.

Result

The new hardware configuration of the reserve CPU does not yet have an effect on ongoing operation.

10.3.5 Step 5: Switch to CPU with modified configuration

Starting situation

The modified hardware configuration is downloaded to the reserve CPU.

Procedure

1. In SIMATIC Manager, select a CPU of the fault-tolerant system, then choose "PLC > Operating Mode" from the menu.
2. In the "Operating Mode" dialog box, click the "Switch to..." button.

   In the "Switch" dialog box, select the "with altered configuration" option and click the "Switch" button.
3. Acknowledge the prompt for confirmation with "OK".

Result

The reserve CPU connects, is updated (see section Link-up and update (Page 109)) and becomes the master. The previous master CPU switches to STOP mode, the fault-tolerant system operates with the new hardware configuration in single mode.

Reaction of the I/O

<table>
<tr><th>Type of I/O</th><th>One-sided I/O of previous master CPU</th><th>One-sided I/O of new master CPU</th><th>Switched I/O</th></tr>
<tr><td>Added I/O modules</td><td>are not addressed by the CPU.</td><td colspan="2">are given new parameter settings and updated by the CPU.
Driver blocks are not yet present. Process or diagnostic interrupts are detected, but are not reported.</td></tr>
<tr><td>I/O modules still present</td><td>are no longer addressed by the CPU.
Output modules output the configured substitute or holding values.</td><td>are given new parameter settings[1)] and updated by the CPU.</td><td>continue operation without interruption.</td></tr>
<tr><td>Added DP stations</td><td>are not addressed by the CPU.</td><td colspan="2">as for added I/O modules (see above)</td></tr>
<tr><td colspan="4">[1)] The central modules are first reset. Output modules briefly output 0 during this time (instead of the configured substitute or hold values).</td></tr>
</table>

Reaction to monitoring timeout

The update is canceled and no change of master takes place if one of the monitored times exceeds the configured maximum. The fault-tolerant system remains in single mode with the previous master CPU and, assuming certain conditions are met, attempts the master changeover later. For additional information, refer to the section Time monitoring (Page 110).

10.3.6 Step 6: Transition to redundant system state

Starting situation

The fault-tolerant system is operating with the new hardware configuration in single mode.

Procedure

1. In SIMATIC Manager, select a CPU of the fault-tolerant system, then select "PLC > Operating Mode" from the menu.
2. From the "Operating Mode" dialog box, select the reserve CPU, then click "Warm Restart".

Result

The reserve CPU links up and is updated. The fault-tolerant system is operating with the new hardware configuration in redundant system mode.

Note

Any set up access right is not canceled until you stop the SIMATIC Manager. You should reset the access right once again to prevent unauthorized access. You reset the access right in the SIMATIC Manager with the menu command PLC > Access Rights > Cancel.

Reaction of the I/O

Type of I/O	One-sided I/O of the standby CPU	One-sided I/O of the master CPU	Switched I/O
Added I/O modules	are given new parameter settings and updated by the CPU. Driver blocks are not yet present. Any interrupts occurring are not reported.	are updated by the CPU. Driver blocks are not yet present. Process or diagnostic interrupts are detected, but are not reported.	
I/O modules still present	are given new parameter settings1) and updated by the CPU.	continue operation without interruption.	
Added DP stations	as for added I/O modules (see above)	Driver blocks are not yet present. Any interrupts occurring are not reported.	
1) Central modules are first reset. Output modules briefly output 0 during this time (instead of the configured substitute or hold values).			

Reaction to monitoring timeout

If one of the monitored times exceeds the configured maximum, the update is canceled. The fault-tolerant system remains in single mode with the previous master CPU and, assuming certain conditions are met, attempts the link-up and update later. For additional information, refer to section Time monitoring (Page 110).

10.3.7 Step 7: Modify and download the user program

Starting situation

The fault-tolerant system is operating with the new hardware configuration in redundant system mode.

CAUTION

The following program modifications are not possible in redundant system mode and result in the system mode Stop (both CPUs in STOP mode):

- Structural modifications to an FB interface or the FB instance data.
- Structural modifications to global DBs.
- Compression of the CFC user program.

Before the entire program is recompiled and reloaded due to such modifications the parameter values must be read back into the CFC, otherwise the modifications to the block parameters could be lost. You will find more detailed information on this topic in the *CFC for S7, Continuous Function Chart* manual.

Procedure

1. Adapt the program to the new hardware configuration. You can add the following components:
   – CFCs and SFCs
   – Blocks in existing charts
   – Connections and parameter settings
2. Assign parameters for the added channel drivers and interconnect them with the newly assigned icons (see section Step 2: Modify the hardware configuration offline (Page 141)).
3. In SIMATIC Manager, select the charts folder and choose the "Options > Charts > Generate Module Drivers" menu command.
4. Compile only the modifications in the charts and download them to the target system.
5. Configure the interconnections for the new CPs on both communication partners and download them to the target system.

Result

The fault-tolerant system processes the entire system hardware with the new user program in redundant system mode.

10.3.8 Use of free channels on an existing module

The use of previously free channels of an I/O module depends mainly on the fact if the module can be configured or not.

Non-configurable modules

Free channels can be switched and used in the user program at any time in case of non-configurable modules.

Configurable modules

The hardware configuration first has to be matched to the used sensors or actuators for configurable modules. This step usually requires a new configuration of the entire module in most cases.

This means an uninterrupted operation of the respective modules is no longer possible:

- One-sided output modules briefly output 0 during this time (instead of the configured substitute or hold values).
- Modules in switched DP stations are not reconfigured when you switch over to the CPU with the modified configuration.

Proceed as follows to change the channel use:

- In steps 1 to 5, you completely remove the respective module from the hardware configuration and the user program. But it can remain inserted in the DP station. The module drivers must not be removed.
- In steps 2 to 7, you add the module with the modified use once again to the hardware configuration and the user program.

Note

The respective modules are not addressed between the two changeover steps (step 5); respective output modules output the value 0. The existing channel drivers in the user program hold their signals.

If this behavior is unacceptable for the process to be controlled, there is no other way to use previously free channels. In this case you must install additional modules to expand the system.

10.3.9 Addition of interface modules

Always switch off power before you install the IM460 and IM461 interface modules, external CP443-5 Extended DP master interface module and their connecting cables.

Always switch off power to an entire subsystem. To ensure that this does not influence the process, always set the subsystem to STOP before you do so.

Procedure

1. Change the hardware configuration offline (see section Step 2: Modify the hardware configuration offline (Page 141))
2. Stop the reserve CPU (see section Step 3: Stop the standby CPU (Page 142))
3. Download the new hardware configuration to the reserve CPU (see section Step 4: Download new hardware configuration to the standby CPU (Page 142))
4. Proceed as follows to expand the subsystem of the present reserve CPU:
   – Switch off the power supply of the reserve subsystem.
   – Insert the new IM460 into the central unit, then establish the link to a new expansion unit.

     or
   – Add a new expansion unit to an existing chain.

     or
   – Plug in the new external DP master interface, and set up a new DP master system.
   – Switch on the power supply of the reserve subsystem again.
5. Switch to CPU with altered configuration (see section Step 5: Switch to CPU with modified configuration (Page 143))
6. Proceed as follows to expand the subsystem of the original master CPU (currently in STOP mode):
   – Switch off the power supply of the reserve subsystem.
   – Insert the new IM460 into the central unit, then establish the link to a new expansion unit.

     or
   – Add a new expansion unit to an existing chain.

     or
   – Plug in the new external DP master interface, and set up a new DP master system.
   – Switch on the power supply of the reserve subsystem again.
7. Change to redundant system mode (see section Step 6: Transition to redundant system state (Page 144))
8. Modify and download the user program (see section Step 7: Modify and download the user program (Page 145))

10.4 Removal of components

Starting situation

You have verified that the CPU parameters (e.g. monitoring times) match the planned new program. Adapt the CPU parameters first, if necessary (see section Editing CPU parameters (Page 155)).

The modules to be removed and their connected sensors and actuators are no longer of any significance to the process being controlled. The fault-tolerant system is operating in redundant system mode.

Procedure

Carry out the steps listed below to remove hardware components from a fault-tolerant system in PCS 7. Details of each step are described in a subsection.

Step	What to do?	See section
1	Offline modification of the hardware configuration	Step 1: Modify the hardware configuration offline (Page 149)
2	Editing and downloading the user program	Step 2: Modify and download the user program (Page 149)
3	Stopping the reserve CPU	Step 3: Stop the standby CPU (Page 150)
4	Loading a new hardware configuration in the reserve CPU	Step 4: Download new hardware configuration to the standby CPU (Page 151)
5	Switch to CPU with modified configuration	Step 5: Switch to CPU with modified configuration (Page 151)
6	Transition to redundant system mode	Step 6: Transition to redundant system state (Page 152)
7	Modification of hardware	Step 7: Modify hardware (Page 153)

Exceptions

This general procedure for system modifications does not apply to removing interface modules (see section Removal of interface modules (Page 154)).

Note

After changing the hardware configuration, download takes place practically automatically. This means that you no longer need to perform the steps described in sections Step 3: Stop the standby CPU (Page 150) to Step 6: Transition to redundant system state (Page 152). The system behavior remains as described.

You will find more information in the HW Config online help, "Download to module -> Download station configuration in RUN mode".

10.4.1 Step 1: Modify the hardware configuration offline

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

1. Perform offline only the configuration modifications relating to the hardware being removed. As you do, delete the icons to the channels that are no longer used.
2. Compile the new hardware configuration, but do **not** load it into the target system just yet.

Result

The modified hardware configuration is in the PG/ES. The target system continues operation with the old configuration in redundant system mode.

10.4.2 Step 2: Modify and download the user program

Starting situation

The fault-tolerant system is operating in redundant system mode.

> **CAUTION**
>
> The following program modifications are not possible in redundant system mode and result in the system mode Stop (both CPUs in STOP mode):
>
> - Structural modifications to an FB interface or the FB instance data.
> - Structural modifications to global DBs.
> - Compression of the CFC user program.
>
> Before the entire program is recompiled and reloaded due to such modifications the parameter values must be read back into the CFC, otherwise the modifications to the block parameters could be lost. You will find more detailed information on this topic in the *CFC for S7, Continuous Function Chart* manual.

Procedure

1. Edit only the program elements related to the hardware removal. You can delete the following components:
   – CFCs and SFCs
   – Blocks in existing charts
   – Channel drivers, interconnections and parameter settings
2. In SIMATIC Manager, select the charts folder and choose the "Options > Charts > Generate Module Drivers" menu command.

   This removes the driver blocks that are no longer required.
3. Compile only the modifications in the charts and download them to the target system.

Note

Until an FC is called the first time, the value of its output is undefined. This must be taken into account in the interconnection of the FC outputs.

Result

The fault-tolerant system continues to operate in redundant system mode. The modified user program will no longer attempt to access the hardware being removed.

10.4.3 Step 3: Stop the standby CPU

Starting situation

The fault-tolerant system is operating in redundant system mode. The user program will no longer attempt to access the hardware being removed.

Procedure

1. For CPU access protection with password: In SIMATIC Manager, select a CPU of the fault-tolerant system, then select
   "PLC > Access Rights > Setup" from the menu. Enter the CPU access password.
2. In SIMATIC Manager, select a CPU of the fault-tolerant system, then select "PLC > Operating Mode" from the menu.
3. In the "Operating Mode" dialog box, select the standby CPU and click "Stop".

Result

The standby CPU switches to STOP mode, the master CPU remains in RUN mode, the fault-tolerant system works in single mode. The one-sided I/O of the standby CPU is no longer addressed.

10.4.4 Step 4: Download new hardware configuration to the standby CPU

Starting situation

The fault-tolerant system is operating in single mode.

Procedure

Load the compiled hardware configuration in the reserve CPU that is in STOP mode.

Note

The user program and connection configuration cannot be downloaded in single mode.

Result

The new hardware configuration of the reserve CPU does not yet have an effect on ongoing operation.

10.4.5 Step 5: Switch to CPU with modified configuration

Starting situation

The modified hardware configuration is downloaded to the reserve CPU.

Procedure

1. In SIMATIC Manager, select a CPU of the fault-tolerant system, then choose "PLC > Operating Mode" from the menu.
2. In the "Operating Mode" dialog box, click the "Switch to..." button.
3. In the "Switch" dialog box, select the "with altered configuration" option and click the "Switch" button.
4. Acknowledge the prompt for confirmation with "OK".

Result

The reserve CPU links up, is updated (see section Link-up and update (Page 109)) and becomes the master. The previous master CPU switches to STOP mode, the fault-tolerant system operates with the new hardware configuration in single mode.

Reaction of the I/O

Type of I/O	One-sided I/O of previous master CPU	One-sided I/O of new master CPU	Switched I/O
I/O modules to be removed[1)]	are no longer addressed by the CPU. Driver blocks are no longer present.		
I/O modules still present	are no longer addressed by the CPU. Output modules output the configured substitute or holding values.	are given new parameter settings[2)] and updated by the CPU.	continue operation without interruption.
DP stations to be removed	as for I/O modules to be removed (see above)		
1) No longer included in the hardware configuration, but still plugged in 2) Central modules are first reset. Output modules briefly output 0 during this time (instead of the configured substitute or hold values).			

Reaction to monitoring timeout

The update is canceled and no change of master takes place if one of the monitored times exceeds the configured maximum. The fault-tolerant system remains in single mode with the previous master CPU and, assuming certain conditions are met, attempts the master changeover later. For additional information, refer to section Time monitoring (Page 110).

10.4.6 Step 6: Transition to redundant system state

Starting situation

The fault-tolerant system is operating with the new hardware configuration in single mode.

Procedure

1. In SIMATIC Manager, select a CPU of the fault-tolerant system, then select "PLC > Operating Mode" from the menu.
2. From the "Operating Mode" dialog box, select the reserve CPU, then click "Warm Restart".

Result

The reserve CPU links up and is updated. The fault-tolerant system is operating with the new hardware configuration in redundant system mode.

Note

Any set up access right is not canceled until you stop the SIMATIC Manager. You should reset the access right once again to prevent unauthorized access. You reset the access right in the SIMATIC Manager with the menu command PLC > Access Rights > Cancel.

Reaction of the I/O

Type of I/O	One-sided I/O of the standby CPU	One-sided I/O of the master CPU	Switched I/O
I/O modules to be removed[1)]	are no longer addressed by the CPU. Driver blocks are no longer present.		
I/O modules still present	are given new parameter settings[2)] and updated by the CPU.	continue operation without interruption.	
DP stations to be removed	as for I/O modules to be removed (see above)		
1) No longer included in the hardware configuration, but still plugged in 2) Central modules are first reset. Output modules briefly output 0 during this time (instead of the configured substitute or hold values).			

Reaction to monitoring timeout

If one of the monitored times exceeds the configured maximum, the update is canceled. The fault-tolerant system remains in single mode with the previous master CPU and, assuming certain conditions are met, attempts the link-up and update later. For additional information, refer to section Time monitoring (Page 110).

10.4.7 Step 7: Modify hardware

Starting situation

The fault-tolerant system is operating with the new hardware configuration in redundant system mode.

Procedure

1. Disconnect all the sensors and actuators from the components you want to remove.
2. Unplug modules of the one-sided I/Os that are no longer required from the racks.

3. Unplug components that are no longer required from the modular DP stations.
4. Remove DP stations that are no longer required from the DP master systems.

Note

With switched I/O: Always complete all changes on **one** segment of the redundant DP master system before you modify the next segment.

Result

The removal of non-configured modules does not influence the user program. The same applies to removing DP stations.

The fault-tolerant system continues to operate in redundant system mode.

10.4.8 Removal of interface modules

Always switch off the power before you remove the IM460 and IM461 interface modules, external CP 443-5 Extended DP master interface module, and their connecting cables.

Always switch off power to an entire subsystem. To ensure that this does not influence the process, always set the subsystem to STOP before you do so.

Procedure

1. Change the hardware configuration offline (see section Step 1: Modify the hardware configuration offline (Page 149))
2. Modify and download the user program (see section Step 2: Modify and download the user program (Page 149))
3. Stop the reserve CPU (see section Step 3: Stop the standby CPU (Page 150))
4. Download the new hardware configuration to the reserve CPU (see section Step 4: Download new hardware configuration to the standby CPU (Page 151))
5. Follow the steps below to remove an interface module from the subsystem of the reserve CPU:
   - Switch off the power supply of the reserve subsystem.
   - Remove an IM460 from the central unit.

     or
   - Remove an expansion unit from an existing chain.

     or
   - Remove an external DP master interface module.
   - Switch on the power supply of the reserve subsystem again.
6. Switch to CPU with altered configuration (see section Step 5: Switch to CPU with modified configuration (Page 151))

7. Proceed as follows to remove an interface module from the subsystem of the original master CPU (currently in STOP mode):
   – Switch off the power supply of the reserve subsystem.
   – Remove an IM460 from the central unit.

     or

   – Remove an expansion unit from an existing chain.

     or

   – Remove an external DP master interface module.
   – Switch on the power supply of the reserve subsystem again.
8. Change to redundant system mode (see section Step 6: Transition to redundant system state (Page 152))

10.5 Editing CPU parameters

10.5.1 Editing CPU parameters

Only certain CPU parameters (object properties) can be edited in operation. These are highlighted in the screen forms by blue text. If you have set blue as the color for dialog box text on the Windows Control Panel, the editable parameters are indicated in black characters.

Note

If you edit any protected parameters, the system will reject any attempt to changeover to the CPU containing those modified parameters. The event W#16#5966 is written to the diagnostic buffer. and you will then have to restore the wrongly changed parameters in the parameter configuration to their last valid values.

Table 10- 1 Modifiable CPU parameters

Tab	Editable parameter
Start-up	Monitoring time for signaling readiness by modules
	Monitoring time for transferring parameters to modules
Cycle/clock memory	Cycle load due to communication
Memory	Local data for the various priority classes *)
	Communication resources: Maximum number of communication jobs.You may only increase the configured value of this parameter *).
Time-of-day interrupts (for each time-of-day interrupt OB)	"Active" checkbox
	"Execution" list box

Tab	Editable parameter
	Starting date
	Time
Watchdog interrupt (for each watchdog interrupt OB)	Execution
	Phase offset
Diagnostics/clock	Correction factor
Security	Security level and password
H parameter	Test cycle time
	Maximum cycle time extension
	Maximum communication delay
	Maximum inhibit time for priority classes > 15
	Minimum I/O retention time
*) Modifying these parameters also modifies the memory content.	

The selected new values should match both the currently loaded and the planned new user program.

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

To edit the CPU parameters of a fault-tolerant system, follow the steps outlined below. Details of each step are described in a subsection.

Step	What to do?	See section
1	Editing CPU parameters offline	Step 1: Editing CPU parameters offline (Page 157)
2	Stopping the reserve CPU	Step 2: Stopping the reserve CPU (Page 157)
3	Downloading modified CPU parameters to the reserve CPU	Step 3: Downloading a new hardware configuration to the reserve CPU (Page 158)
4	Switching to a CPU with modified configuration	Step 4: Switching to CPU with modified configuration (Page 158)
5	Transition to redundant system mode	Step 5: Transition to redundant system mode (Page 159)

Note

After changing the hardware configuration, download takes place practically automatically. You then no longer have to perform the steps described in sections Step 2: Stopping the reserve CPU (Page 157) to Step 5: Transition to redundant system mode (Page 159). The system behavior remains as described.

You will find more information in the HW Config online help "Download to module -> Download station configuration in RUN mode". You will find more information in the HW Config online help "Download to module -> Download station configuration in RUN mode".

10.5.2 Step 1: Editing CPU parameters offline

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

1. Edit the relevant CPU properties offline in HW Config.
2. Compile the new hardware configuration, but do **not** load it into the target system just yet.

Result

The modified hardware configuration is in the PG/ES. The target system continues operation with the old configuration in redundant system mode.

10.5.3 Step 2: Stopping the reserve CPU

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

1. For CPU access protection with password: In SIMATIC Manager, select a CPU of the fault-tolerant system, then select
"PLC > Access Rights > Setup" from the menu. Enter the CPU access password.
2. In SIMATIC Manager, select a CPU of the fault-tolerant system, then select "PLC > Operating Mode" from the menu.
3. In the "Operating Mode" dialog box, select the standby CPU and click "Stop".

Result

The standby CPU switches to STOP mode, the master CPU remains in RUN mode, the fault-tolerant system works in single mode. The one-sided I/O of the standby CPU is no longer addressed.

10.5.4 Step 3: Downloading a new hardware configuration to the reserve CPU

Starting situation

The fault-tolerant system is operating in single mode.

Procedure

Load the compiled hardware configuration in the reserve CPU that is in STOP mode.

Note

The user program and connection configuration cannot be downloaded in single mode.

Result

The modified CPU parameters in the new hardware configuration of the standby CPU do not yet have an effect on ongoing operation.

10.5.5 Step 4: Switching to CPU with modified configuration

Starting situation

The modified hardware configuration is downloaded to the reserve CPU.

Procedure

1. In SIMATIC Manager, select a CPU of the fault-tolerant system, then choose "PLC > Operating Mode" from the menu.
2. In the "Operating Mode" dialog box, click the "Switch to..." button.
3. In the "Switch" dialog box, select the "with altered configuration" option and click the "Switch" button.
4. Acknowledge the prompt for confirmation with "OK".

Result

The reserve CPU links up, is updated and becomes the master. The previous master CPU switches to STOP mode, the fault-tolerant system continues operating in single mode.

Reaction of the I/O

Type of I/O	One-sided I/O of previous master CPU	One-sided I/O of new master CPU	Switched I/O
I/O modules	are no longer addressed by the CPU. Output modules output the configured substitute or holding values.	are given new parameter settings[1)] and updated by the CPU.	continue operation without interruption.
1) Central modules are first reset. Output modules briefly output 0 during this time (instead of the configured substitute or hold values).			

Reaction to monitoring timeout

The update is canceled and no change of master takes place if one of the monitored times exceeds the configured maximum. The fault-tolerant system remains in single mode with the previous master CPU and, assuming certain conditions are met, attempts the master changeover later. For additional information, refer to section Time monitoring (Page 110).

Where the values for the monitoring times in the CPUs differ, the higher values always apply.

10.5.6 Step 5: Transition to redundant system mode

Starting situation

The fault-tolerant system operates with the modified CPU parameters in single mode.

Procedure

1. In SIMATIC Manager, select a CPU of the fault-tolerant system, then select "PLC > Operating Mode" from the menu.
2. From the "Operating Mode" dialog box, select the reserve CPU, then click "Warm Restart".

Result

The reserve CPU links up and is updated. The fault-tolerant system is operating in redundant system mode.

Note

Any set up access right is not canceled until you stop the SIMATIC Manager. You should reset the access right once again to prevent unauthorized access. You reset the access right in the SIMATIC Manager with the menu command PLC > Access Rights > Cancel.

Reaction of the I/O

Type of I/O	One-sided I/O of the standby CPU	One-sided I/O of the master CPU	Switched I/O
I/O modules	are given new parameter settings[1)] and updated by the CPU.	continue operation without interruption.	
1) Central modules are also reset first. Output modules briefly output 0 during this time (instead of the configured substitute or hold values).			

Reaction to monitoring timeout

If one of the monitored times exceeds the configured maximum, the update is canceled. The fault-tolerant system remains in single mode with the previous master CPU and, assuming certain conditions are met, attempts the link-up and update later. For additional information, refer to section Time monitoring (Page 110).

Where the values for the monitoring times in the CPUs differ, the higher values always apply.

10.6 Re-parameterization of a module

10.6.1 Re-parameterization of a module

Refer to the information text in the "Hardware Catalog" window to determine which modules (signal modules and function modules) can be reconfigured during ongoing operation. The specific reactions of individual modules are described in the respective technical documentation.

Note

If you edit any protected parameters, the system will reject any attempt to changeover to the CPU containing those modified parameters. The event W#16#5966 is written to the diagnostic buffer. and you will then have to restore the wrongly changed parameters in the parameter configuration to their last valid values.

The selected new values must match the current and the planned user program.

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

To edit the parameters of modules in a fault-tolerant system, perform the steps outlined below. Details of each step are described in a subsection.

Step	What to do?	See section
1	Editing parameters offline	Step 1: Editing parameters offline (Page 162)
2	Stopping the reserve CPU	Step 2: Stopping the reserve CPU (Page 162)
3	Downloading modified CPU parameters to the reserve CPU	Step 3: Downloading a new hardware configuration to the reserve CPU (Page 163)
4	Switching to CPU with modified configuration	Step 4: Switching to CPU with modified configuration (Page 163)
5	Transition to redundant system mode	Step 5: Transition to redundant system mode (Page 164)

Note

After changing the hardware configuration, download takes place practically automatically. This means that you no longer need to perform the steps described in sections Step 2: Stopping the reserve CPU (Page 162) to Step 5: Transition to redundant system mode (Page 164). The system behavior remains as described.

You will find more information in the HW Config online help "Download to module -> Download station configuration in RUN mode".

10.6.2 Step 1: Editing parameters offline

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

1. Edit the module parameters offline in HW Config.
2. Compile the new hardware configuration, but do **not** load it into the target system just yet.

Result

The modified hardware configuration is in the PG/ES. The target system continues operation with the old configuration in redundant system mode.

10.6.3 Step 2: Stopping the reserve CPU

Starting situation

The fault-tolerant system is operating in redundant system mode.

Procedure

1. For CPU access protection with password: In SIMATIC Manager, select a CPU of the fault-tolerant system, then select
   "PLC > Access Rights > Setup" from the menu. Enter the CPU access password.
2. In SIMATIC Manager, select a CPU of the fault-tolerant system, then select "PLC > Operating Mode" from the menu.
3. In the "Operating Mode" dialog box, select the standby CPU and click "Stop".

Result

The standby CPU switches to STOP mode, the master CPU remains in RUN mode, the fault-tolerant system works in single mode. The one-sided I/O of the standby CPU is no longer addressed.

10.6.4 Step 3: Downloading a new hardware configuration to the reserve CPU

Starting situation

The fault-tolerant system is operating in single mode.

Procedure

Load the compiled hardware configuration in the reserve CPU that is in STOP mode.

Note

The user program and connection configuration cannot be downloaded in single mode.

Result

The modified parameters in the new hardware configuration of the reserve CPU do not yet have an effect on ongoing operation.

10.6.5 Step 4: Switching to CPU with modified configuration

Starting situation

The modified hardware configuration is downloaded to the reserve CPU.

Procedure

1. In SIMATIC Manager, select a CPU of the fault-tolerant system, then select "PLC > Operating Mode" from the menu.
2. In the "Operating Mode" dialog box, click the "Switch to..." button.
3. In the "Switch" dialog box, select the "with altered configuration" option and click the "Switch" button.
4. Acknowledge the prompt for confirmation with "OK".

Result

The reserve CPU links up, is updated and becomes the master. The previous master CPU switches to STOP mode, the fault-tolerant system continues operating in single mode.

Reaction of the I/O

Type of I/O	One-sided I/O of previous master CPU	One-sided I/O of new master CPU	Switched I/O
I/O modules	are no longer addressed by the CPU. Output modules output the configured substitute or holding values.	are given new parameter settings1) and updated by the CPU.	continue operation without interruption.
1) Central modules are also reset first. Output modules briefly output 0 during this time (instead of the configured substitute or hold values).			

Reaction to monitoring timeout

The update is canceled and no change of master takes place if one of the monitored times exceeds the configured maximum. The fault-tolerant system remains in single mode with the previous master CPU and, assuming certain conditions are met, attempts the master changeover later. For additional information, refer to section Time monitoring (Page 110).

Where the values for the monitoring times in the CPUs differ, the higher values always apply.

10.6.6 Step 5: Transition to redundant system mode

Starting situation

The fault-tolerant system operates with the modified parameters in single mode.

Procedure

1. In SIMATIC Manager, select a CPU of the fault-tolerant system, then select "PLC > Operating Mode" from the menu.
2. From the "Operating Mode" dialog box, select the reserve CPU, then click "Warm Restart".

Result

The reserve CPU links up and is updated. The fault-tolerant system is operating in redundant system mode.

Note

Any set up access right is not canceled until you stop the SIMATIC Manager. You should reset the access right once again to prevent unauthorized access. You reset the access right in the SIMATIC Manager with the menu command PLC > Access Rights > Cancel.

Reaction of the I/O

Type of I/O	One-sided I/O of the standby CPU	One-sided I/O of the master CPU	Switched I/O
I/O modules	are given new parameter settings1) and updated by the CPU.	continue operation without interruption.	
1) Central modules are also reset first. Output modules briefly output 0 during this time (instead of the configured substitute or hold values).			

Reaction to monitoring timeout

If one of the monitored times exceeds the configured maximum, the update is canceled. The fault-tolerant system remains in single mode with the previous master CPU and, assuming certain conditions are met, attempts the link-up and update later. For additional information, refer to section Time monitoring (Page 110).

Where the values for the monitoring times in the CPUs differ, the higher values always apply.

Failure and replacement of components during redundant operation 11

> **Note**
>
> **Components in redundant mode**
>
> Only components with the same product version, the same order number and the same version can be operated redundantly.
> If a component is no longer available as spare part, you must replace both components so that this condition is met once again.

11.1 Failure and replacement of central components

11.1.1 Failure and replacement of a CPU during redundant operation

Starting situation for replacement of the CPU

Failure	How does the system react?
The S7-400H is in redundant system mode and a **CPU** fails.	• The partner CPU switches to single mode. • The partner CPU reports the event in the diagnostic buffer and in OB 72.

Requirements for replacement

The module replacement described below is possible only if the "new" CPU

- has the same operating system version as the failed CPU and
- if it is equipped with the same system expansion card as the failed CPU.

> **Note**
>
> New CPUs are always shipped with the latest operating system version. If this differs from the version of the operating system of the remaining CPU, you will have to equip the new CPU with the same version of the operating system. Download the required operating system via HW Config with "PLC -> Update Firmware", see chapter Updating firmware (Page 128).

Procedure

Follow the steps below to **replace a CPU**:

Step	What has to be done?	How does the system react?
1	Turn off the power supply module.	• The entire subsystem is switched off (system operates in single mode).
2	Replace the CPU. Make sure the rack number is set correctly on the CPU.	–
3	Insert the synchronization modules.	–
4	Plug in the fiber-optic cable connections of the synchronization modules.	–
5	Switch the power supply module on again.	• CPU runs the self-tests and changes to STOP.
6	Perform a CPU memory reset on the replaced CPU.	–
7	Start the replaced CPU (for example, STOP-RUN or Start using the PG).	• The CPU performs an automatic LINK-UP and UPDATE. • The CPU changes to RUN and operates as the reserve CPU.

11.1.2 Failure and replacement of a power supply module

Starting situation

Both CPUs are in RUN.

Failure	How does the system react?
The S7-400H is in redundant system mode and a power supply module fails.	• The partner CPU switches to single mode. • The partner CPU reports the event in the diagnostic buffer and in OB 72.

Procedure

Proceed as follows to replace a power supply module in the central rack:

Step	What has to be done?	How does the system react?
1	Turn off the power supply (24 V DC for PS 405 or 120/230 V AC for PS 407).	• The entire subsystem is switched off (system operates in single mode).
2	Replace the module.	–
3	Switch the power supply module on again.	• The CPU executes the self-tests. • The CPU performs an automatic LINK-UP and UPDATE. • The CPU changes to RUN (redundant system mode) and operates as reserve CPU.

Note

Redundant power supply

If you use a redundant power supply (PS 407 10A R), two power supply modules are assigned to one fault-tolerant CPU. If a part of the redundant PS 407 10A R power supply module fails, the associated CPU keeps on running. The defective part can be replaced during operation.

Other power supply modules

If the failure concerns a power supply module outside the central rack (e.g. in the expansion rack or in the I/O device), the failure is reported as a rack failure (central) or station failure (remote). In this case, simply switch off the power supply to the power supply module concerned.

11.1.3 Failure and replacement of an input/output or function module

Starting situation

Failure	How does the system react?
The CPU 410-5H is in redundant system mode and an input/output or function module fails.	• Both CPUs report the event in the diagnostic buffer and via appropriate OBs.

Procedure

> **CAUTION**
>
> **Note the different procedures.**
>
> Minor injury or damage to equipment is possible.
>
> The procedure for replacing and input/output or function module differs for modules of the S7-300 and S7-400.
>
> Use the correct procedure when replacing a module. The correct procedure is described below for the S7-300 and the S7-400.

To replace signal and function modules of an S7-300, perform the following steps:

Step	What has to be done?	How does the system react?
1	Disconnect the module from its peripheral power supply, if necessary.	
2	Remove the failed module (in RUN mode).	• Both CPUs generate a remove/insert interrupt and enter the event in the diagnostic buffer and the system status list.
3	Disconnect the front connector and wiring.	-
4	Plug the front connector into the new module.	-
5	Insert the new module.	• Both CPUs generate a remove/insert interrupt and enter the event in the diagnostic buffer and the system status list. • Parameters are assigned automatically to the module by the CPU concerned and the module is addressed again.

To replace signal and function modules of an S7-400, perform the following steps:

Step	What has to be done?	How does the system react?
1	Disconnect the module from its peripheral power supply, if necessary.	
2	Disconnect the front connector and wiring.	• If the affected module can generate diagnostic interrupts and if diagnostic interrupts are enabled as per configuration, a diagnostic interrupt is generated. • Call OB 122 if you are accessing the module by direct access • Call OB 85 if you are accessing the module using the process image
3	Remove the failed module (in RUN mode).	• Both CPUs generate a remove/insert interrupt and enter the event in the diagnostic buffer and the system status list.
4	Insert the new module.	• Both CPUs generate a remove/insert interrupt and enter the event in the diagnostic buffer and the system status list. • Parameters are assigned automatically to the module by the CPU concerned and the module is addressed again.
5	Plug the front connector into the new module.	• If the affected module can generate diagnostic interrupts and if diagnostic interrupts are enabled as per configuration, a diagnostic interrupt is generated.

11.1.4 Failure and replacement of a communication module

This section describes the failure and replacement of communication modules for PROFIBUS and Industrial Ethernet.

The failure and replacement of communication modules for PROFIBUS DP are described in section Failure and replacement of a PROFIBUS DP master (Page 176).

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system mode and a communication module fails.	• Both CPUs report the event in the diagnostic buffer and via appropriate OBs. • In communication via standard connections: Connection failed • In communication via redundant connections: Communication is maintained without interruption over an alternate channel.

Procedure

If you want to use a communication module that is already being used by another system, you have to ensure that there are no parameter data saved in the module's integrated FLASH-EPROM before you swap it.

Proceed as follows to replace a communication module for PROFIBUS or Industrial Ethernet:

Step	What has to be done?	How does the system react?
1	Remove the module.	• Both CPUs process the swapping interrupt OB 83 synchronized with each other.
2	Insert the new module.	• Both CPUs process the swapping interrupt OB 83 synchronized with each other. • The module is automatically configured by the appropriate CPU.
3	Turn the module back on.	• The module resumes communication (system establishes communication connection automatically).

11.1.5 Failure and replacement of a synchronization module or fiber-optic cable

In this section, you will see three different error scenarios:

- Failure of a synchronization module or fiber-optic cable
- Successive failure of both synchronization modules or fiber-optic cables
- Simultaneous failure of both synchronization modules or fiber-optic cables

The CPU indicates by means of LEDs and diagnostics whether the lower or upper redundant link has failed. After the defective parts (fiber-optic cable or synchronization module) have been replaced, LEDs IFM1F and IFM2F must go out.

Starting situation

Failure	How does the system react?
Failure of a fiber-optic cable or synchronization module: The S7-400H is in redundant system mode and a fiber-optic cable or synchronization module fails. See also chapter Synchronization modules for the CPU 410-5H (Page 181).	• The master CPU reports the event in the diagnostic buffer and with OB 72 of OB 82. • The reserve CPU changes to ERROR-SEARCH mode for some minutes. If the error is eliminated during this time, the reserve CPU switches to redundant system mode, otherwise it switches to STOP. • The LED Link1 OK or Link2 OK on the synchronization module is lit.

Procedure

Follow the steps below to replace a synchronization module or fiber-optic cable:

Step	What has to be done?	How does the system react?
1	First, check the fiber-optic cable.	–
2	Start the reserve CPU (for example, STOP-RUN or Start using the programming device).	The following responses are possible: 1. CPU changes to RUN mode. 2. CPU changes to STOP mode. In this case continue at step 3.
3	Remove the faulty synchronization module from the reserve CPU.	–
4	Insert the new synchronization module in the reserve CPU.	–
5	Plug in the fiber-optic cable connections of the synchronization modules.	• The LED Link1 OK or Link2 OK on the synchronization module goes out. • Both CPUs report the event in the diagnostic buffer
6	Start the reserve CPU (for example, STOP-RUN or Start using the programming device).	The following responses are possible: 1. CPU changes to RUN mode. 2. CPU changes to STOP mode. In this case continue at step 7.
7	If the reserve CPU changed to STOP in step 6: Remove the synchronization module from the master CPU.	• The master CPU processes swapping interrupt OB 83 and redundancy error OB 72 (entering state).
8	Insert the new synchronization module into the master CPU.	• The master CPU processes swapping interrupt OB 83 and redundancy error OB 72 (exiting state).

Step	What has to be done?	How does the system react?
9	Plug in the fiber-optic cable connections of the synchronization modules.	–
10	Start the reserve CPU (for example, STOP-RUN or Start using the programming device).	• The CPU performs an automatic LINK-UP and UPDATE. • The CPU changes to RUN (redundant system mode) and operates as reserve CPU.

Note

If both fiber-optic cables or synchronization modules are damaged or replaced one after the other, the system responses are the same as described above.

The only exception is that the reserve CPU does not change to STOP but instead requests a memory reset.

Starting situation

Failure	How does the system react?
Failure of both fiber-optic cables or synchronization modules: The S7-400H is in redundant system mode and **both** fiber-optic cables or synchronization modules fail.	• Both CPUs report the event in the diagnostic buffer and via OB 72. • Both CPUs become the master CPU and remain in RUN mode. • The LED Link1 OK or Link2 OK on the synchronization module is lit.

Procedure

The double error described results in loss of redundancy. In this event proceed as follows:

Step	What has to be done?	How does the system react?
1	Switch off one subsystem.	–
2	Replace the faulty components.	–
3	Turn the subsystem back on.	• LEDs IFM1F and IFMF2F go off. The LED MSTR of the switched on subsystem goes out.
4	Start the CPU (for example Start from programming device or STOP - RUN).	• The CPU performs an automatic LINK-UP and UPDATE. • The CPU changes to RUN (redundant system mode) and operates as reserve CPU.

11.1.6 Failure and replacement of an IM 460 and IM 461 interface module

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system mode and an interface module fails.	• The connected expansion unit is turned off. • Both CPUs report the event in the diagnostic buffer and via OB 86.

Procedure

Follow the steps below to replace an interface module:

Step	What has to be done?	How does the system react?
1	Turn off the power supply of the central rack.	• The partner CPU switches to single mode.
2	Turn off the power supply of the expansion unit in which you want to replace the interface module.	–
3	Remove the interface module.	–
4	Insert the new interface module and turn the power supply of the expansion unit back on.	–
5	Switch the power supply of the central unit back on and start the CPU.	• The CPU performs an automatic LINK-UP and UPDATE. • The CPU changes to RUN and operates as the reserve CPU.

11.2 Failure and replacement of components of the distributed I/Os

Which components can be replaced?

The following components of the distributed I/Os can be replaced during operation:

- PROFIBUS DP master
- PROFIBUS DP interface module (IM 153-2 or IM 157)

- PROFIBUS DP slave
- PROFIBUS DP cable

Note

Replacing I/O and function modules located in a distributed station is described in section Failure and replacement of an input/output or function module (Page 169).

11.2.1 Failure and replacement of a PROFIBUS DP master

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system mode and a DP master module fails.	• With single-channel one-sided I/O: The DP master can no longer process connected DP slaves. • With switched I/O: DP slaves are addressed via the DP master of the partner.

Procedure

Proceed as follows to replace a PROFIBUS DP master:

Step	What has to be done?	How does the system react?
1	Turn off the power supply of the central rack.	The fault-tolerant system switches to single mode.
2	Unplug the Profibus DP cable of the affected DP master module.	–
3	Replace the module.	–
4	Plug the Profibus DP back in.	–
5	Turn on the power supply of the central rack.	• The CPU performs an automatic LINK-UP and UPDATE. • The CPU changes to RUN and operates as the reserve CPU.

11.2.2 Failure and replacement of a redundant PROFIBUS DP interface module

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system mode and a PROFIBUS DP interface module (IM 153–2, IM 157) fails.	Both CPUs report the event in the diagnostic buffer and via OB 70.

Replacement procedure

Proceed as follows to replace the PROFIBUS DP interface module:

Step	What has to be done?	How does the system react?
1	Turn off the supply for the affected DP interface module.	–
2	Remove the bus connector.	–
3	Insert the new PROFIBUS DP interface module and turn the power supply back on.	–
4	Plug the bus connector back in.	• The CPUs process the I/O redundancy error OB 70 (outgoing event) synchronized with each other. • Redundant access to the station by the system is now possible again.

11.2.3 Failure and replacement of a PROFIBUS DP slave

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system state and a DP slave fails.	Both CPUs signal the event in the diagnostics buffer and via a corresponding OB 86.

Procedure

Proceed as follows to replace an IO device:

Step	What has to be done?	How does the system react?
1	Switch off the power supply for the IO device.	–
2	Remove the bus connector.	–

Step	What has to be done?	How does the system react?
3	Replace the IO device.	–
4	Plug the bus connector back in and turn the power supply back on.	• The CPUs process the rack failure OB 86 synchronously (outgoing event) • The IO device can be addressed by the respective DP master system.

11.2.4 Failure and replacement of PROFIBUS DP cables

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system mode and the PROFIBUS DP cable is defective.	• With single-channel one-sided I/O: Rack failure OB (OB 86) is started (incoming event). The DP master can no longer process connected DP slaves (station failure). • With switched I/O: I/O redundancy error OB (OB 70) is started (incoming event). DP slaves are addressed via the DP master of the partner.

Replacement procedure

Proceed as follows to replace PROFIBUS DP cables:

Step	What has to be done?	How does the system react?
1	Check the cabling and localize the interrupted PROFIBUS DP cable.	–
2	Replace the defective cable.	–
3	Switch the failed modules to RUN mode.	The CPUs process the error OBs synchronized with each other • With one-sided I/O: Rack failure OB 86 (outgoing event) The DP slaves can be addressed via the DP master system. • With switched I/O: I/O redundancy error OB 70 (outgoing event). The DP slaves can be addressed via both DP master systems.

11.3 Failure and replacement of components of PROFINET IO

11.3.1 Failure and replacement of a PROFINET IO device

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system state and an IO device fails.	Both CPUs signal the event in the diagnostics buffer and via a corresponding OB.

Procedure

Proceed as follows to replace an IO device:

Step	What has to be done?	How does the system react?
1	Switch off the power supply for the IO device.	–
2	Remove the bus connector.	–
3	Replace the IO device.	–
4	Plug the bus connector back in and turn the power supply back on.	• The CPUs process the rack failure OB 86 synchronously (outgoing event) • The IO device can be addressed by the respective IO system.

11.3.2 Failure and replacement of PROFIBUS IO cables

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system state and the PROFINET IO cable is defective.	• With single-channel one-sided I/O: Rack failure OB (OB 86) is started (incoming event). The IO controller can no longer process connected IO cables (station failure). • With switched I/O: I/O redundancy error OB (OB 70) is started (incoming event). The IO cables are addressed via the IO controller of the partner.

Replacement procedure

Proceed as follows to replace PROFINET IO cables:

Step	What has to be done?	How does the system react?
1	Check the cabling and localize the interrupted PROFINET IO cable.	–
2	Replace the defective cable.	–
3	Switch the failed modules to RUN mode.	The CPUs process the error OBs synchronized with each other • With one-sided I/O: Rack failure OB 86 (outgoing event) The IO cables can be addressed via the IO controller. • With switched I/O: I/O redundancy error OB 70 (outgoing event). The IO cables can be addressed via both IO controllers.

Synchronization modules 12

12.1 Synchronization modules for the CPU 410-5H

Function of the synchronization modules

Synchronization modules are used for communication between two redundant CPU 410-5H. You require two synchronization modules per CPU, connected in pairs by fiber-optic cable.

The system supports hot-swapping of synchronization modules, and so allows you to influence the repair response of the fault-tolerant systems and to control the failure of the redundant connection without stopping the plant.

The diagnostics of synchronization modules is based on the known extended maintenance concept of PROFINET IO.

If you remove a synchronization module in redundant system mode, there is a loss of synchronization. The standby CPU switches to ERROR-SEARCH operating state for a few minutes. If the new synchronization module is inserted and the redundant link is reestablished during this time, the standby CPU switches to redundant system state, otherwise it switches to STOP.

Once you have inserted the new synchronization module and reestablished the redundant link, you must restart the standby CPU.

Distance between the S7–400H CPUs

Two types of synchronization module are available:

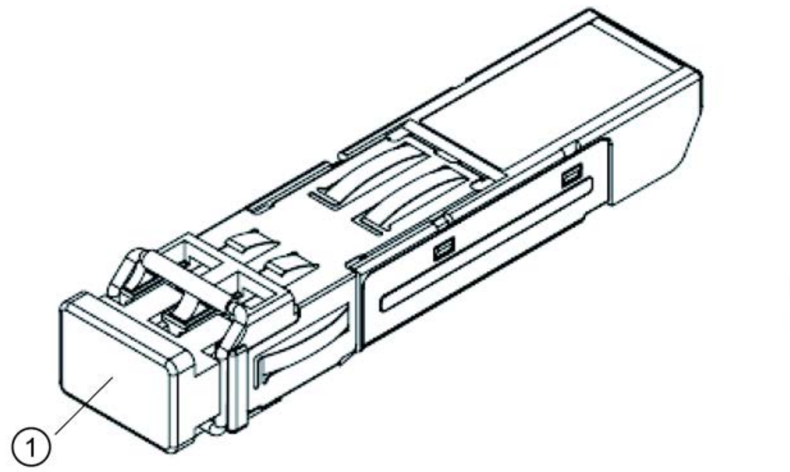
Order number	Maximum distance between the CPUs
6ES7 960–1AA06–0XA0	10 m
6ES7 960–1AB06–0XA0	10 km

Long synchronization cables may increase cycle times. This extension can have the factor 2 - 5 with a cable length of 10 km.

Note

You must use 4 synchronization modules of the same type in a fault-tolerant system. You can configure the synchronization modules as another type. For example, modules for a distance of 10 meters between the CPUs can be configured as modules for a distance of 10 km between the CPUs, but all 4 modules can still be identical. Startup of the system is only possible in this case if "Startup if preset configuration does not match actual configuration" is configured.

Mechanical configuration



① Dummy plugs

Figure 12-1 Synchronization module

⚠ CAUTION
Risk of injury. The synchronization module is equipped with a laser system and is classified as a "CLASS 1 LASER PRODUCT" according to IEC 60825–1. Avoid direct contact with the laser beam. Do not open the housing. Always observe the information provided in this manual, and keep the manual to hand as a reference.

CLASS 1 LASER PRODUCT
LASER KLASSE 1 PRODUKT
TO EN 60825

OB 82

In redundant mode, the operating system of the CPU calls OB82 in case of a Snyc link fault.

The cause of the fault can be found in the "Sync module diagnostics" tab in HW Config -> PLC -> Module state.

Diagnostics of the synchronization module

You can display the following channel-specific diagnostic data in the Module state tab dialog for the selected synchronization module:

- Overtemperature

  The synchronization module is too hot.
- Fiber-optic error

  The sender of the electro-optical component has reached the end of its service life.
- Violation of lower limit

  The sent or received optical performance is low or too low.
- Violation of upper limit

  The sent or received optical performance is high or too high.
- Functional error of the network component

  The quality of the redundancy link between the CPUs (transmission distance including synchronization modules and fiber-optic cables) is reduced so that transmission errors are occurring frequently.

Fiber-optic interfaces of unused modules

Fiber-optic interfaces of unused modules must be blanked off during storage to protect the optical equipment. The plugs are in the synchronization module when shipped.

Wiring and inserting the synchronization module

1. Remove the dummy plug of the synchronization module.
2. Fold back the clip completely against the synchronization module.
3. Insert the synchronization module into the IF1 interface of the first fault-tolerant CPU until it snaps into place.
4. Insert the end of the fiber-optic cable into the synchronization module until it snaps into place.

5. Repeat steps 1 to 4 for the second synchronization module.
6. Repeat the process for the second fault-tolerant CPU.

   Connect the IF1 interface of the first CPU with the IF1 interface of the second CPU and the IF2 interface of the first CPU with the IF2 interface of the second CPU.

Note

Wiring synchronization modules crosswise

If you wire synchronization modules crosswise, i.e., the IF1 interface of the first CPU with the IF2 interface of the second CPU and vice versa, the two CPUs take over the master role and the system will now function properly. The LEDs IFM 1 and IFM 2 are lit on both CPUs.

Make sure that you connect the IF1 interface of the first CPU with the IF1 interface of the second CPU and the IF2 interface of the first CPU with the IF2 interface of the second CPU.

Removing the synchronization module

1. Slightly press the release of the fiber-optic cable and remove it from the synchronization module.
2. Fold the clip of the synchronization module to the front and remove the synchronization module from the fault-tolerant CPU interface.
3. Place the dummy plug on the synchronization module.
4. Repeat this procedure for all interfaces and both fault-tolerant CPUs.

Technical data

Technical data	6ES7 960–1AA06–0XA0	6ES7 960–1AB06–0XA0
Maximum distance between the CPUs	10 m	10 km
Power supply	3.3 V, supplied by the CPU	3.3 V, supplied by the CPU
Current consumption	220 mA	240 mA
Power loss Wavelength of the optical transceivers	0.77 W 850 nm	0.83 W 1310 nm
Maximal permitted attenuation of the fiber-optic cable	7.5 dB	9.5 dB
Maximum permitted difference in cable lengths	9 m	50 m
Dimensions W x H x D (mm)	13 x 14 x 58	13 x 14 x 58
Weight	0.014 kg	0.014 kg

See also

Installation of fiber-optic cables (Page 185)

12.2 Installation of fiber-optic cables

Introduction

Fiber-optic cables may only be installed by trained and qualified personnel. Always observe the applicable rules and statutory regulations. The installation must be carried out with meticulous care, because faulty installations represent the most common source of error. Causes are:

- Kinking of the fiber-optic cable due to an insufficient bending radius.
- Crushing of the cable as a result of excess forces caused by persons treading on the cable, or by pinching, or by the load of other heavy cables.
- Overstretching due to high tensile forces.
- Damage on sharp edges etc.

Permitted bending radius for prefabricated cables

You may not go below the following bending radius when laying the cable:

- Next to connector: 55 mm
- During installation: 60 mm (repeated)
- After installation: 40 mm (one-time)

Points to observe when installing the fiber-optic cables for the S7-400H synchronization link

Always route the two fiber-optic cables separately. This increases availability and protects the fiber-optic cables from potential double errors caused, for example, by interrupting both cables at the same time.

Always make sure the fiber-optic cables are connected to both CPUs before switching on the power supply or the system, otherwise the CPUs may process the user program as the master CPU.

Local quality assurance

Check the points outlined below before you install the fiber-optic cables:

- Does the delivered package contain the correct fiber-optic cables?
- Any visible transport damage to the product?
- Have you organized a suitable intermediate on-site storage for the fiber-optic cables?
- Does the category of the cables match the connecting components?

Check the attenuation of the fiber-optic cables after installation.

Storage of the fiber-optic cables

if you do not install the fiber-optic cable immediately after you received the package, it is advisable to store it in a dry location where it is protected from mechanical and thermal influences. Observe the permitted storage temperatures specified in the data sheet of the fiber-optic cable. You should not remove the fiber-optic cables from the original packaging until you are going to install them.

Open installation, wall breakthroughs, cable ducts:

Note the points outlined below when you install fiber-optic cables:

- The fiber-optic cables may be installed in open locations, provided you can safely exclude any damage in those areas (vertical risers, connecting shafts, telecommunications switchboard rooms, etc.).
- Fiber-optic cables should be mounted on mounting rails (cable trays, wire mesh ducts) using cable ties. Take care not to crush the cable when you fasten it (see Pressure).
- Always deburr or round the edges of the breakthrough before you install the fiber-optic cable, in order to prevent damage to the sheathing when you pull in and fasten the cable.
- The bending radii must not be smaller than the value specified in the manufacturer's data sheet.
- The branching radii of the cable ducts must correspond to the specified bending radius of the fiber-optic cable.

Cable pull-in

Note the points below when pulling-in fiber-optic cables:

- Always observe the information on pull forces in the data sheet of the corresponding fiber-optic cable.
- Do not reel off any greater lengths when you pull in the cables.
- Install the fiber-optic cable directly from the cable drum wherever possible.
- Do not spool the fiber-optic cable sideways off the drum flange (risk of twisting).
- You should use a cable pulling sleeve to pull in the fiber-optic cable.
- Always observe the specified bending radii.
- Do not use any grease or oil-based lubricants.
  You may use the lubricants listed below to support the pulling-in of fiber-optic cables.
  - Yellow compound (Wire-Pulling, lubricant from Klein Tools; 51000)
  - Soft soap
  - Dishwashing liquid
  - Talcum powder
  - Detergent

Pressure

Do not exert any pressure on the cable, for example, by the inappropriate use of clamps (cable quick-mount) or cable ties. Your installation should also prevent anyone from stepping onto the cable.

Influence of heat

Fiber-optic cables are highly sensitive to direct heat, which means the cables must not be worked on using hot-air guns or gas burners as used in heat-shrink tubing technology.

12.3 Selecting fiber-optic cables

Check or make allowance for the following conditions and situations when selecting a suitable fiber-optic cable:

- Required cable lengths
- Indoor or outdoor installation
- Any particular protection against mechanical stress required?
- Any particular protection against rodents required?
- Can an outside cable be routed directly underground?
- Does the fiber-optic cable need to be water-proof?
- Which temperatures influence the installed fiber-optic cable?

Cable length up to 10 m

The synchronization module 6ES7 960–1AA06–0XA0 can be operated in pairs with fiber-optic cables up to a length of 10 m.

Select cables with the following specification for lengths up to 10 m:

- Multimode fiber 50/125 µ or 62.5/125 µ
- Patch cable for indoor applications
- 2 x duplex cables per fault-tolerant system, cross-over
- Connector type LC–LC

Such cables are available in the following length as accessories for fault-tolerant systems:

Table 12- 1 Accessory fiber-optic cable

Length	Order number
1 m	6ES7960–1AA04–5AA0
2 m	6ES7960–1AA04–5BA0
10 m	6ES7960–1AA04–5KA0

Cable length up to 10 km

The synchronization module 6ES7 960-1AB06-0XA0 can be operated in pairs with fiber-optic cables up to a length of 10 km.

The following rules apply:

- Make sure of adequate strain relief on the modules if you use fiber-optic cables longer than 10 m.
- Keep to the specified environmental conditions of the fiber-optic cables used (bending radii, pressure, temperature...)
- Observe the technical specifications of the fiber-optic cable (attenuation, bandwidth...)

Fiber-optic cables with lengths above 10 m usually have to be custom-made. First, select the following specification:

- Single-mode fiber (mono-mode fiber) 9/125 µ

  In exceptional situations, you may also use the lengths up to 10 m available as accessories for short distances when testing and commissioning. However, only the use of specified cables with single-mode fibers is allowed for continuous operation.

Note

Cable up to 10 m lenght on the synchronization module 6ES7 960-1AB06-0XA0

Cables up to a length of 10 m are available on order as accessories. If you use one of these cables on the synchronization module 6ES7 960-1AB06-0XA0 , you may see the error message "Optical performmance too high" at the call of OB 82.

The table below shows the further specifications, based on your application:

Table 12- 2 Specification of fiber-optic cables for indoor applications

Cabling	Components required	Specification
The entire cabling is routed within a building No cable junction is required between the indoor and outdoor area The necessary cable length is available in one piece. There is no need to connect several cable segments by means of distribution boxes. Convenient and complete installation using patch cables	Patch cables	2 x duplex cables per system Connector type LC–LC Crossed cores Further specifications you may need to observe for your plant, e.g.: UL approval Halogen-free materials
	Assembled patch cable	Multicore cables, 4 cores per system Connector type LC–LC Crossed cores Further specifications you may need to observe for your plant, e.g.: UL approval Halogen-free materials

Cabling	Components required	Specification
The entire cabling is routed within a building No cable junction is required between the indoor and outdoor area The necessary cable length is available in one piece. There is no need to connect several cable segments by means of distribution boxes. Convenient and complete installation using patch cables	including patch cables for indoor applications as required	1 cable with 4 cores per fault-tolerant system Both interfaces in one cable 1 or 2 cables with several shared cores Separate installation of the interfaces in order to increase availability (reduction of common cause factor) Connector type ST or SC, for example, to match other components; see below Further specifications you may need to observe for your plant: UL approval Halogen-free materials Avoid splicing cables in the field. Use prefabricated cables with pulling protection/aids in whiplash or breakout design, including measuring log.
	Patch cable for indoor applications	Connector type LC on ST or SC, for example, to match other components
Installation using distribution boxes, see Fig. 12-2	One distribution/junction box per branch Installation and patch cables are connected via the distribution box. Either ST or SC plug-in connections can be used, for example. Check the cross-over installation when you wire the CPUs.	Connector type ST or SC, for example, to match other components

Table 12- 3 Specification of fiber-optic cables for outdoor applications

Cabling	Components required	Specification
A cable junction is required between the indoor and outdoor area see Figure 12-2	• Installation cables for outdoor applications	Installation cables for outdoor applications • 1 cable with 4 cores per fault-tolerant system Both interfaces in one cable • 1 or 2 cables with several shared cores Separate installation of the interfaces in order to increase availability (reduction of common cause factor) • Connector type ST or SC, for example, to match other components; see below Further specifications you may need to observe for your plant: • UL approval • Halogen-free materials Further specifications you may need to observe for your plant: • Protection against increased mechanical stress • Protection against rodents • Water-proofing • Suitable for direct underground installation • Suitable for the given temperature ranges Avoid splicing cables in the field. Use prefabricated cables with pulling protection/aids in whiplash design, including measuring log.
	• including patch cables for indoor applications as required	• 1 cable with 4 cores per fault-tolerant system Both interfaces in one cable • 1 or 2 cables with several shared cores Separate installation of the interfaces in order to increase availability (reduction of common cause factor) • Connector type ST or SC, for example, to match other components; see below Further specifications you may need to observe for your plant: • UL approval • Halogen-free materials Avoid splicing cables in the field. Use prefabricated cables with pulling protection/aids in whiplash or breakout design, including measuring log.
	• Patch cable for indoor applications	• Connector type LC on ST or SC, for example, to match other components

Cabling	Components required	Specification
A cable junction is required between the indoor and outdoor area see Figure 12-2	• One distribution/junction box per branch Installation and patch cables are connected via the distribution box. Either ST or SC plug-in connections can be used, for example Check the cross-over installation when you wire the CPUs.	• Connector type ST or SC, for example, to match other components

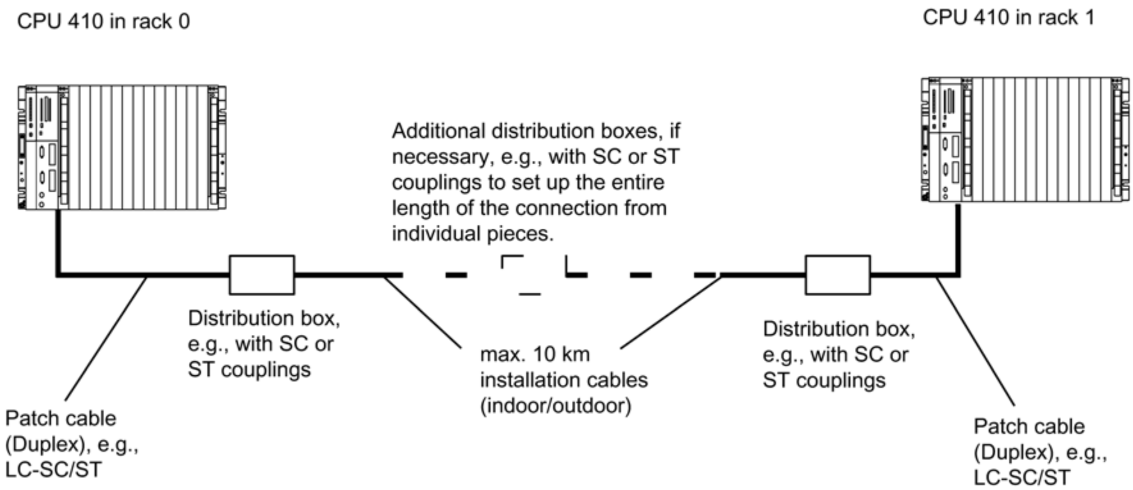


Figure 12-2 Fiber-optic cables, installation using distribution boxes

System expansion card 13

13.1 Variants of the system expansion card

Use of the system expansion card

The system expansion card (SEC) is inserted in a slot at the back of the CPU.

With the SEC, the CPU 410-5H is scaled according to the maximum number of loadable process objects. More detailed information about the scaling concept can be found in the section Scaling and licensing (scaling concept) (Page 30).

The CPU cannot be operated without the SEC.

SECs are available with the following number of POs:

- 100
- 500
- 1000
- 1600
- 2k+ (unlimited)

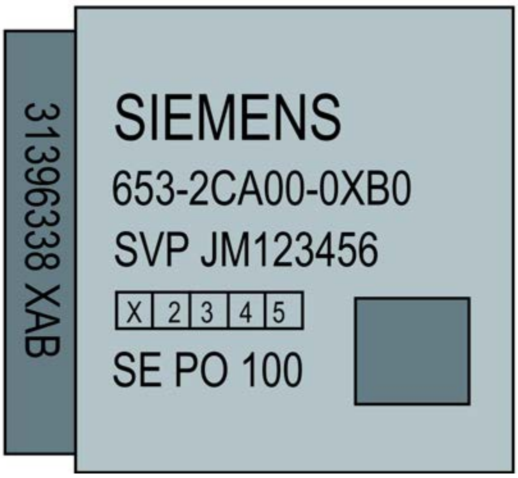


Figure 13-1 SEC

14 Technical data

14.1 Technical specifications of the CPU 410-5H; (6ES7 410-5HX08-0AB0)

	6ES7410-5HX08-0AB0
Product type designation	CPU 410-5H Process Automation
General information	
Hardware product version	1
Firmware version	V8.0.1
Model	with Conformal Coating (ISA-S71.04 severity level G1; G2; G3)
Engineering with	
Programming package	as of PCS 7 V8.0 SP1 + HUP CPU 410-5H
CiR – Configuration in RUN	
CiR synchronization time, base load	60 ms
CiR synchronization time, time per I/O slave	0 μs
Input current	
From backplane bus 5 V DC, typ.	2.0 A
From backplane bus 5 V DC, max.	2.4 A
From backplane bus 24 V DC, max.	150 mA; DP interface
From interface 5 V DC, max.	90 mA at the DP Interface
Power loss	
Power loss, typ.	10 W
Memory	
Main memory	
integrated	32 MB
Integrated (for program)	16 MB
Integrated (for data)	16 MB
Expandable	No
Load memory	
Expandable FEPROM	No
Integrated RAM, max.	48 MB
Expandable RAM	No
Battery backup	
Available	Yes
With battery	Yes; all data
Without battery	No

	6ES7410-5HX08-0AB0
Battery	
Backup battery	
Battery operation	
• Backup battery current, typ.	370 µA; valid to 40 °C
• Backup battery current, max.	2.1 mA
• Backup battery time, max.	Covered with the conditions and effects described in the Module Data manual
• Feed of external backup voltage to the CPU	No
CPU processing times	
CPU speed	450 MHz; multiprocessor system
PCS 7 process objects	100 ... approx. 2600 can be set with system expansion card
Average processing time of PCS 7 typicals	46 µs; with APL typicals
Process tasks, max.	9; can be set individually from 10 ms to 5 s
CPU blocks	
DB	
Number, max.	16000; number range: 1 to 16 000 (= instances)
FB	
Number, max.	8000; number range: 0 to 7999
FC	
Number, max.	8000; number range: 0 to 7999
OB	
Number of free-cycle OBs	1; OB 1
Number of time-of-day interrupt OBs	8; OB 10-17
Number of time-delay interrupt OBs	4; OB 20-23
Number of cyclic interrupt OBs	9; OB 30-38 (= Process tasks)
Number of process interrupt OBs	8; OB 40-47
Number of DPV1 interrupt OBs	3; OB 55-57
Number of restart OBs	2; OB 100, 102
Number of asynchronous error OBs	9; OB 80-88
Number of synchronous error OBs	2; OB 121, 122
Data areas and their retentivity	
Retentive data area, total	Total work and load memory (with backup battery)
Address range	
I/O address range	
Inputs	16 Kbyte; up to 7500 IO
Outputs	16 Kbyte; up to 7500 IO
of those distributed	
• DP interface, inputs	8 Kbyte; up to 3800 IO
• DP interface, outputs	8 Kbyte; up to 3800 IO
• PN interface, inputs	8 Kbyte; up to 3800 IO
• PN interface, outputs	8 Kbyte; up to 3800 IO

	6ES7410-5HX08-0AB0
Digital channels	
Inputs	131072, max.
Outputs	131072, max.
Analog channels	
Inputs	8192, max.
Outputs	8192, max.
Hardware configuration	
Expansion units, max.	21) S7-400 expansion units
connectable OP	119
Multicomputing	No
Interface modules	
Number of plug-in IMs (total), max.	6
Number of plug-in IM 460s, max.	6
Number of plug-in IM 463s, max.	4; only in stand-alone operation
Number of DP masters	
integrated	1
Via CP	10; CP 443-5 Extended
Number of IO controllers	
integrated	1
Via CP	0
Number of usable FMs and CPs (recommendation)	
PROFIBUS and Ethernet CPs	11; max. 10 CPs as DP masters
Time	
Clock	
Hardware clock (real-time clock)	Yes
With battery backup, can be synchronized	Yes
Resolution	1 ms
Deviation per day (with battery backup), max.	1.7 s; Power Off
Deviation per day (without battery backup), max.	8.6 s; Power On
Time synchronization	
Supported	Yes
On DP, master	Yes
On DP, slave	Yes
On the AS, master	Yes
On the AS, slave	Yes
On Ethernet using NTP	Yes; as client
Time difference in the system with synchronization via	
Ethernet, max.	10 ms
Interfaces	
Number of RS 485 interfaces	1; PROFIBUS DP
Number of other interfaces	3; 2x Synchronization, 1x Service
PROFINET IO	
Number of PROFINET interfaces	1

	6ES7410-5HX08-0AB0
1. Interface	
Type of interface	integrated
Physics	RS 485/PROFIBUS
Electrically isolated	Yes
Power supply at interface (15 to 30 V DC), max.	150 mA
Number of connection resources	32
Functionality	
DP master	Yes
DP slave	No
DP master	
Number of connections, max.	32
Transmission rate, max.	12 Mbps
Number of DP slaves, max.	96
Services	
• PG/OP communication	Yes
• Routing	Yes
• Global data communication	No
• S7 communication	Yes
• S7 communication, as client	Yes
• S7 communication, as server	Yes
• Support for constant bus cycle time	No
• Isochronous mode	No
• SYNC/FREEZE	No
• Activation/deactivation of DP slaves	No
• Direct data exchange (cross-traffic)	No
• DPV1	Yes
Address range	
• Inputs, max.	8 Kbyte; up to 3800 IO
• Outputs, max.	8 Kbyte; up to 3800 IO
User data per DP slave	
• User data per DP slave, max.	244 bytes
• Inputs, max.	244 bytes
• Outputs, max.	244 bytes
• Slots, max.	244
• Per slot, max.	128 bytes
2. Interface	
Type of interface	PROFINET
Physics	Ethernet RJ45

	6ES7410-5HX08-0AB0
Electrically isolated	Yes
Integrated switch	Yes
Number of ports	2
Automatic determination of transmission rate	Yes; Autosensing
Autonegotiation	Yes
Autocrossing	Yes
Change of the IP address at runtime, supported	No
Number of connection resources	120
Media redundancy	
Supported	Yes
Changeover time at line interruption, typ.	200 ms
Number of nodes on the ring, max.	50
Functionality	
PROFINET IO controller	Yes
PROFINET IO device	No
Open IE communication	Yes
Web server	No
PROFINET IO controller	
Transmission rate, max.	100 Mbps
Number of connectable IO devices, max.	250
Number of connectable IO devices for RT, max.	250
• of which in line, max.	250
Shared device, supported	No; but can be used in S7 framework
Prioritized startup supported	No
Device replacement without removable medium	Yes
Send clocks	250 μs, 500 μs, 1 ms, 2 ms, 4 ms
Update time	250 μs to 512 ms, minimum value depends on the amount of configured user data and the configured operating mode or redundancy mode
Services	
• PG/OP communication	Yes
• S7 routing	Yes
• S7 communication	Yes
• Open IE communication	Yes
Address range	
• Inputs, max.	8 Kbyte; up to 3800 IO
• Outputs, max.	8 Kbyte; up to 3800 IO
• User data consistency, max.	1024 bytes
Open IE communication	
Open IE communication, supported	Yes
Number of connections, max.	118

	6ES7410-5HX08-0AB0
Local port numbers used by the system	0, 20, 21, 25, 102, 135, 161, 34962, 34963, 34964, 65532, 65533, 65534, 65535
Keep Alive function supported	Yes
3. Interface	
Type of interface	integrated
Physics	RJ45 (only for service)
4. Interface	
Type of interface	Plug-in synchronization module (FOC)
Plug-in interface modules	Synchronization module 6ES7960-1AA06-0XA0 or 6ES7960-1AB06-0XA0
5. Interface	
Type of interface	Plug-in synchronization module (FOC)
Plug-in interface modules	Synchronization module 6ES7960-1AA06-0XA0 or 6ES7960-1AB06-0XA0
Protocols	
PROFINET IO	Yes
PROFINET CBA	No
PROFIsafe	Yes
PROFIBUS	Yes
Protocols (Ethernet)	
TCP/IP	Yes
Other protocols	
AS-i	Yes; via add-on
MODBUS	Yes; via add-on
Foundation Fieldbus	Yes; via DP/FF link
Communication functions	
PG/OP communication	Yes
• Number of connectable OPs without message processing	119
• Number of connectable OPs with message processing	119; when using Alarm_S/SQ and Alarm_D/DQ
Data record routing	Yes
S7 routing	Yes
S7 communication	
Supported	Yes
As server	Yes
As client	Yes
User data per job, max.	64 KB
User data per job (consistent), max.	462 bytes; 1 variable
Open IE communication	
TCP/IP	Yes; via integrated PROFINET interface and loadable FBs
• Number of connections, max.	118
• Data length, max.	32 KB
• Several passive connections per port, supported	Yes

	6ES7410-5HX08-0AB0
ISO-on-TCP (RFC1006)	Yes; via integrated PROFINET interface or CP 443-1 and loadable FBs
• Number of connections, max.	118
• Data length, max.	32 KB; 1452 bytes via CP 443-1 Adv.
UDP	Yes; via integrated PROFINET interface and loadable FBs
• Number of connections, max.	118
• Data length, max.	1472 bytes
Number of connections	
Total	120
S7 message functions	
Number of stations that can be logged on for message functions, max.	119; max. 119 with Alarm_S and Alarm_D (OPs); max 12 wit Alarm_8 and Alarm_P (e.g., WinCC)
Alarm_8 blocks	Yes
• Number of instances for Alarm_8 and S7 communication blocks, max.	10000
• Pre-assigned, max.	10000
Process control messages	Yes
Test and commissioning functions	
Block status	Yes
Single-step	Yes
Number of breakpoints	4
Monitor/modify	
Status/modify tag	Yes
Tags	Inputs/outputs, bit memory, DB, I/O inputs/outputs, timers, counters
Number of tags, max.	70
Diagnostics buffer	
Available	Yes
Number of entries, max.	3200
Service data	
Readable	Yes
EMC	
Emission of radio interference according to EN 55 011	
Limit class A, for use in industrial areas	Yes
Limit class B, for use in residential areas	No
Configuration	
Know-how protection	
User program/password security	Yes
Block encryption	Yes; using S7-Block Privacy

	6ES7410-5HX08-0AB0
Dimensions	
Width	50 mm
Height	290 mm
Depth	219 mm
Slots required	2
Weights	
Weight, approx.	1.1 kg

Properties and technical specifications of CPU 410 SMART 15

15.1 CPU 410 SMART

CPU 410-5H and CPU 410 SMART

Note

Except for the special features described in this section, the CPU 410 SMART behaves like a CPU 410-5H. Taking this section into consideration, the statements made in this manual about the CPU 410-5H also apply to the CPU 410 SMART.

Hardware Upgrade Package

You need the associated Hardware Upgrade Package PCS 7 HUP 247 for configuration of the CPU 410 SMART with PCS7. It is available under ID 82142878 at this address: AS 410 modular systems (http://support.automation.siemens.com/WW/view/en/77430465/130000)

You can only operate the CPU 410 SMART with the PCS 7 SYSTEM EXPANSION CARD PO 800. Operation with a different SEC is not possible.

DP master interface

You cannot use external DP master interfaces with the CPU 410 SMART. Only the integrated DP interface is available.

The CPU 410 SMART supports 48 DP slaves. The number of slots is limited to 816.

The DP interface of the CPU 410 SMART supports 1536 byte inputs and 1536 byte outputs.

The address range is from 0 to 16 KB.

PN/IO controller

You cannot use an external IO controller with the CPU 410 SMART. Only the integrated PN/IO interface is available.

The CPU 410 SMART supports 48 PNIO devices. The number of slots is limited to 1536.

The PN/IO interface of the CPU 410 SMART supports 1536 byte inputs and 1536 byte outputs.

The address range is from 0 to 16 KB.

Fail-safe operation

You cannot use the CPU 410 SMART as fail-safe CPU. Fail-safe operation is not supported.

Memory configuration

The integrated main memory of the CPU 410 SMART is 8 MB; 4 MB for programs and 4 MB for data. This size of the load memory is 48 MB.

Time-delay interrupt OBs

The CPU 410 SMART does not support time-delay interrupt OBs (OB 2x) and no associated SFC 32, 33 and 34. If you open one of these SFCs in the user program, it is not executed. An error message is created instead and OB 121 is called.

If a SFC is assigned to a time-delay interrupt and downloaded to the CPU 410 SMART, the SFC is not executed. An OB request error is reported when the configured time has elapsed.

Cyclic interrupts

The CPU 410 SMART supports the following cyclic interrupt OBs:

- OB 32 with a default run time of 2000ms
- OB 33 with a default run time of 1000ms
- OB 34 with a default run time of 500ms
- OB 35 with a default run time of 200ms

The lowest value to which you can set the run time of cyclic interrupts is 200ms. You cannot set a phase offset.

Hardware interrupt OBs

The CPU 410 SMART does not support hardware interrupt OBs (OB 4x). If you assign a SFC to a hardware interrupt and download it to the CPU 410 SMART, the SFC is ignored.

If you have nevertheless enabled hardware interrupts on I/O modules with interrupt capability and a hardware interrupt is generated, it is merely entered in the diagnostics buffer and the SFC is not executed.

Minimum cycle time of OB1

The minimum cycle time is permanently set to 200 ms and cannot be changed.

Ethernet interface X8

The second Ethernet interface X8 is designed as service interface and cannot be used as PROFINET IO interface.

15.2 Technical specifications of the CPU 410 SMART; (6ES7 410-5HN08-0AB0)

	6ES7410-5HN08-0AB0
Product type designation	CPU 410 SMART Process Automation
General information	
Hardware product version	1
Firmware version	V8.0.1
Model	with Conformal Coating (ISA-S71.04 severity level G1; G2; G3)
Engineering with	
Programming package	as of PCS 7 V8.0 SP1 + HUP 247
CiR – Configuration in RUN	
CiR synchronization time, base load	60 ms
CiR synchronization time, time per I/O slave	0 µs
Input current	
From backplane bus 5 V DC, typ.	2.0 A
From backplane bus 5 V DC, max.	2.4 A
From backplane bus 24 V DC, max.	150 mA; DP interface
From interface 5 V DC, max.	90 mA at the DP Interface
Power loss	
Power loss, typ.	10 W
Memory	
Main memory	
integrated	8 MB
Integrated (for program)	4 MB
Integrated (for data)	4 MB
Expandable	No
Load memory	
Expandable FEPROM	No
Integrated RAM, max.	48 MB
Expandable RAM	No
Battery backup	
Available	Yes
With battery	Yes; all data
Without battery	No
Battery	
Backup battery	
Battery operation	
• Backup battery current, typ.	370 µA; valid to 40 °C
• Backup battery current, max.	2.1 mA

	6ES7410-5HN08-0AB0
• Backup battery time, max.	Covered with the conditions and effects described in the Module Data manual
• Feed of external backup voltage to the CPU	No
CPU processing times	
CPU speed	450 MHz; multiprocessor system
PCS 7 process objects	800; only System Expansion Card PO800 can be used
Average processing time of PCS 7 typicals	110 μs; with APL typicals
Process tasks, max.	4; can be set individually from 200 ms to 5 s
CPU blocks	
DB	
Number, max.	16000; number range: 1 to 16 000 (= instances)
FB	
Number, max.	8000; number range: 0 to 7999
FC	
Number, max.	8000; number range: 0 to 7999
OB	
Number of free-cycle OBs	1; OB 1
Number of time-of-day interrupt OBs	8; OB 10-17
Number of cyclic interrupt OBs	4; OB 32-35
Number of DPV1 interrupt OBs	3; OB 55-57
Number of restart OBs	2; OB 100, 102
Number of asynchronous error OBs	9; OB 80-88
Number of synchronous error OBs	2; OB 121, 122
Data areas and their retentivity	
Retentive data area, total	Total work and load memory (with backup battery)
Address range	
I/O address range	
Inputs	16 KB
Outputs	16 KB
of those distributed	
• DP interface, inputs	1536 bytes; up to 1500 IO
• DP interface, outputs	1536 bytes; up to 1500 IO
• PN interface, inputs	1536 bytes; up to 1500 IO
• PN interface, outputs	1536 bytes; up to 1500 IO
Digital channels	
Inputs	36864, max.
Outputs	36864, max.
Analog channels	
Inputs	2304, max.
Outputs	2304, max.

	6ES7410-5HN08-0AB0
Hardware configuration	
connectable OP	119
Multicomputing	No
Number of DP masters	
integrated	1
Via IM 467	0
Via CP	0
Number of IO controllers	
integrated	1
Via CP	0
Number of usable FMs and CPs (recommendation)	
CP, LAN	2
Time	
Clock	
Hardware clock (real-time clock)	Yes
With battery backup, can be synchronized	Yes
Resolution	1 ms
Deviation per day (with battery backup), max.	1.7 ms; Power Off
Deviation per day (without battery backup), max.	8.6 ms; Power On
Time synchronization	
Supported	Yes
On DP, master	Yes
On DP, slave	Yes
On the AS, master	Yes
On the AS, slave	Yes
On Ethernet using NTP	Yes; as client
Time difference in the system with synchronization via	
Ethernet, max.	10 ms
Interfaces	
Number of RS 485 interfaces	1; PROFIBUS DP
Number of other interfaces	3; 2x Synchronization, 1x Service
PROFINET IO	
Number of PROFINET interfaces	1
1. Interface	
Type of interface	integrated
Physics	RS 485/PROFIBUS
Electrically isolated	Yes
Power supply at interface (15 to 30 V DC), max.	150 mA
Number of connection resources	32
Functionality	
DP master	Yes
DP slave	No

	6ES7410-5HN08-0AB0
DP master	
Number of connections, max.	32
Transmission rate, max.	12 Mbps
Number of DP slaves, max.	48
Services	
• PG/OP communication	Yes
• Routing	Yes
• Global data communication	No
• S7 basic communication	No
• S7 communication	Yes
• S7 communication, as client	Yes
• S7 communication, as server	Yes
• Support for constant bus cycle time	No
• Isochronous mode	No
• SYNC/FREEZE	No
• Activation/deactivation of DP slaves	No
• Direct data exchange (cross-traffic)	No
• DPV1	Yes
Address range	
• Inputs, max.	1536 bytes; up to 1500 IO
• Outputs, max.	1536 bytes; up to 1500 IO
User data per DP slave	
• User data per DP slave, max.	244 bytes
• Inputs, max.	244 bytes
• Outputs, max.	244 bytes
• Slots, max.	244
• Per slot, max.	128 bytes
2. Interface	
Type of interface	PROFINET
Physics	Ethernet RJ45
Electrically isolated	Yes
Integrated switch	Yes
Number of ports	2
Automatic determination of transmission rate	Yes; Autosensing
Autonegotiation	Yes
Autocrossing	Yes
Change of the IP address at runtime, supported	No
Number of connection resources	120

	6ES7410-5HN08-0AB0
Media redundancy	
Supported	Yes
Changeover time at line interruption, typ.	200 ms
Number of nodes on the ring, max.	50
Functionality	
PROFINET IO controller	Yes
PROFINET IO device	No
PROFINET CBA	No
Open IE communication	Yes
Web server	No
PROFINET IO controller	
Transmission rate, max.	100 Mbps; full duplex
Number of connectable IO devices, max.	48
Number of connectable IO devices for RT, max.	48
• of which in line, max.	48
Shared device, supported	No; but can be used in S7 framework
Prioritized startup supported	No
Enabling/disabling of IO devices	No
Hot swapping of IO devices (partner ports), supported	No
Device replacement without removable medium	Yes
Send clocks	250 µs, 500 µs, 1 ms, 2 ms, 4 ms
Update time	250 µs to 512 ms, minimum value depends on the amount of configured user data and the configured operating mode or redundancy mode
Services	
• PG/OP communication	Yes
• S7 routing	Yes
• S7 communication	Yes
• Open IE communication	Yes
Address range	
• Inputs, max.	1536 bytes; up to 1500 IO
• Outputs, max.	1536 bytes; up to 1500 IO
• User data consistency, max.	1024 bytes
Open IE communication	
Open IE communication, supported	Yes
Number of connections, max.	118
Local port numbers used by the system	0, 20, 21, 25, 102, 135, 161, 34962, 34963, 34964, 65532, 65533, 65534, 65535
Keep Alive function supported	Yes
3. Interface	
Type of interface	integrated
Physics	RJ45 (only for service)

	6ES7410-5HN08-0AB0
4. Interface	
Type of interface	Plug-in synchronization module (FOC)
Plug-in interface modules	Synchronization module 6ES7960-1AA06-0XA0 or 6ES7960-1AB06-0XA0
5. Interface	
Type of interface	Plug-in synchronization module (FOC)
Plug-in interface modules	Synchronization module 6ES7960-1AA06-0XA0 or 6ES7960-1AB06-0XA0
Protocols	
PROFINET IO	Yes
PROFINET CBA	No
PROFIsafe	No
PROFIBUS	Yes
Protocols (Ethernet)	
TCP/IP	Yes
Other protocols	
AS-i	Yes; via add-on
MODBUS	Yes; via add-on
Foundation Fieldbus	Yes; via DP/FF link
Communication functions	
PG/OP communication	Yes
• Number of connectable OPs without message processing	119
• Number of connectable OPs with message processing	119; when using Alarm_S/SQ and Alarm_D/DQ
Data record routing	Yes
S7 routing	Yes
S7 communication	
Supported	Yes
As server	Yes
As client	Yes
User data per job, max.	64 KB
User data per job (consistent), max.	462 bytes; 1 variable
Open IE communication	
TCP/IP	Yes; via integrated PROFINET interface and loadable FBs
• Number of connections, max.	118
• Data length, max.	32 KB
• Several passive connections per port, supported	Yes
ISO-on-TCP (RFC1006)	Yes; via integrated PROFINET interface or CP 443-1 and loadable FBs
• Number of connections, max.	118
• Data length, max.	32 KB; 1452 bytes via CP 443-1 Adv.

	6ES7410-5HN08-0AB0
UDP	Yes; via integrated PROFINET interface and loadable FBs
• Number of connections, max.	118
• Data length, max.	1472 bytes
Number of connections	
Total	120
S7 message functions	
Number of stations that can be logged on for message functions, max.	119; max. 119 with Alarm_S and Alarm_D (OPs); max 12 wit Alarm_8 and Alarm_P (e.g., WinCC)
Alarm_8 blocks	Yes
• Number of instances for Alarm_8 and S7 communication blocks, max.	10000
• Pre-assigned, max.	10000
Process control messages	Yes
Test and commissioning functions	
Block status	Yes
Single-step	Yes
Number of breakpoints	4
Monitor/modify	
Status/modify tag	Yes
Tags	Inputs/outputs, bit memory, DB, I/O inputs/outputs, timers, counters
Number of tags, max.	70
Diagnostics buffer	
Available	Yes
Number of entries, max.	3200
Service data	
Readable	Yes
EMC	
Emission of radio interference according to EN 55 011	
Limit class A, for use in industrial areas	Yes
Limit class B, for use in residential areas	No
Configuration	
Know-how protection	
User program/password security	Yes
Block encryption	Yes; using S7-Block Privacy
Dimensions	
Width	50 mm
Height	290 mm
Depth	219 mm
Slots required	2
Weights	
Weight, approx.	1.1 kg

Supplementary information 16

16.1 Supplementary information on PROFIBUS DP

Monitor/Modify, programming via PROFIBUS

You can use the PROFIBUS DP interface to program the CPU or execute the programming device functions Monitor and Modify.

Note

The "Programming" or "Monitor/Modify" applications prolong the DP cycle if executed via the PROFIBUS DP interface.

Determining the bus topology in a DP master system using SFC 103 "DP_TOPOL"

The diagnostic repeater is available to improve the ability to locate faulty modules or an interruption on the DP cable when failures occur in ongoing operation. This module is a slave that recognizes the topology of a DP segment and detects any problems caused by it.

You use SFC 103 "DP_TOPOL" to trigger the identification of the bus topology of a DP master system by the diagnostic repeater. For information on SFC 103, refer to the related online help and to Manual *System and Standard Functions*. The diagnostic repeater is described in Manual *Diagnostic Repeater for PROFIBUS DP*, order number 6ES7972-0AB00-8BA0.

Adding modules with ET 200M at a later time

If you want to add modules with the ET 200M while using IM 153-2, MLFB 6ES7 153-2BA00-0XB0 or higher, or an IM 153-2FO, MLFB 6ES7 153-2BB00-0XB0 or higher, note the following: The ET 200M must be equipped with an active backplane bus with sufficient free space
for the planned expansion. Include the ET 200M so that it complies with IEC 61158.

Adding modules with ET 200iSP at a later time

If you want to add modules with the ET200iSP, the expansion of the terminal modules should have sufficient reserves from the start and be fitted with unconfigured reserve modules.

16.2 Supplementary information on diagnostics of CPU 410-5H as PROFIBUS DP master

Reading the diagnostics data with STEP 7

Table 16- 1 Reading the diagnostics data with STEP 7

DP master	Block or tab in STEP 7	Application	See ...
CPU 41x	"DP Slave Diagnostics" tab	Show slave diagnostics in plain text on the *STEP 7* user interface	See "Hardware diagnostics" in the *STEP 7* online help and in Manual *Configuring Hardware and Communication Connections with STEP 7*
	SFC 13 "DPNRM_DG"	Read slave diagnostics data, i.e., save them to the data area of the user program It is possible that the busy bit will not be set to "0" if an error occurs while SFC 13 is being processed. You should therefore check the RET_VAL parameter after every execution of SFC 13.	see *System and Standard Functions* reference manual. For the structure of other slaves, refer to their descriptions.
	SFC 59 "RD_REC"	Read data records of S7 diagnostics (store in the data area of the user program)	See *System and Standard Functions* reference manual
	SFC 51 "RDSYSST"	Read SSL partial lists. Call SFC 51 in the diagnostic interrupt with SSL ID W#16#00B3 and read the SSL of the slave CPU.	
	SFB 52 "RDREC"	For DPV1 slaves Read the data records of S7 diagnostics, i.e., store in the data area of the user program	
	SFB 54 "RALRM"	For DPV1 slaves: Read interrupt information within the associated interrupt OB	

Evaluating diagnostics data in the user program

The figure below shows how to evaluate the diagnostics data in the user program.

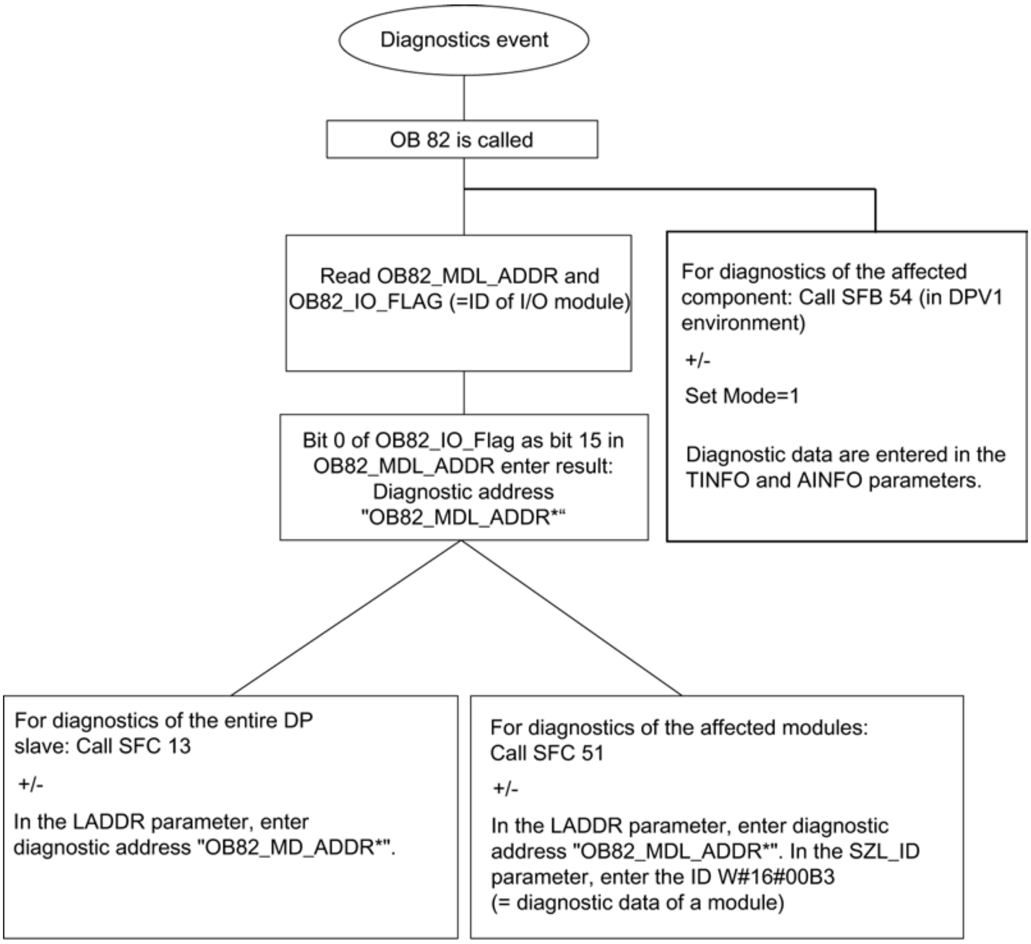


Figure 16-1 Diagnostics with CPU 410

Event detection

The following table shows how the CPU 41xH in DP master mode detects operating state changes on a DP slave or interruptions of the data transfer.

Table 16- 2 Event detection of the CPU 41xH as a DP master

Event	What happens in the DP master?
Bus interruption due to short-circuit or disconnection of the connector	• OB 86 is called with the message **Station failure** as an incoming event; diagnostics address of the DP slave assigned to the DP master • With I/O access: Call of OB 122, I/O area access error
DP slave: RUN → STOP	• OB 82 is called with the message **Module error** as incoming event; diagnostic address of the DP slave assigned to the DP master; variable OB82_MDL_STOP=1
DP slave: STOP → RUN	• OB 82 is called with the message **Module OK** as incoming event; diagnostic address of the DP slave assigned to the DP master; variable OB82_MDL_STOP=0

Evaluation in the user program

The table below shows you how to evaluate RUN-STOP changes of the DP slave on the DP master. Also refer to the previous table.

On the DP master	On the DP slave (CPU 41x)
• Example of diagnostic addresses: Master diagnostics address=1023 Slave diagnostics address in master system=1022	• Example of diagnostic addresses: Slave diagnostics address=422 Master diagnostics address=irrelevant
The CPU calls OB 82 with the following information, for example: • OB 82_MDL_ADDR:=1022 • OB82_EV_CLASS:=B#16#39 As incoming event • OB82_MDL_DEFECT:=module error The CPU diagnostic buffer also contains this information. Your user program should also be set up to read the diagnostic data of the DP slave using SFC 13 "DPNRM_DG". Use SFB 54 in the DPV1 environment. It outputs the full interrupt information.	CPU: RUN → STOP CPU generates a DP slave diagnostics frame.

16.3 System status lists for PROFINET IO

Introduction

The CPU makes certain information available and stores this information in the "System status list".

The system status list describes the current status of the automation system. It provides an overview of the configuration, the current parameter assignment, the current statuses and sequences in the CPU, and the assigned modules.

The system status list data can only be read, but not be changed. The system status list is a virtual list that is compiled only on request.

From a system status list you receive the following information about the PROFINET IO system:

- System data
- Module status information in the CPU
- Diagnostic data from a module
- Diagnostics buffer

Compatibility of system status lists

System status lists are available for PROFINET IO that support PROFINET IO configuration sizes and can also be used for PROFIBUS.

You can use a previously known PROFIBUS system status list that is also supported by PROFINET IO as usual. If you use a system status list in PROFINET IO that PROFINET IO does not support, an error code is returned in RET_VAL (8083: Index wrong or not permitted).

Comparison of the system status lists of PROFINET IO and PROFIBUS DP

Table 16- 3 Comparison of the system status lists of PROFINET IO and PROFIBUS DP

SSL-ID	PROFINET IO	PROFIBUS DP	Applicability
W#16#0C75	Yes, parameter adr1 changed	Yes	Communication status between the fault-tolerant system and a switched DP slave/PN device
W#16#0C91	Yes, internal interface Parameter adr1/adr2 and set/actual type identifier changed No, external interface	Yes, internal interface No, external interface	Module status information of a module in a central configuration or at an integrated DP or PROFIBUS interface, or at an integrated DP interface using the logical address of the module.
W#16#4C91	No	No, internal interface Yes, external interface	Module status information of a module attached to an external DP or PROFIBUS interface using the start address.

SSL-ID	PROFINET IO	PROFIBUS DP	Applicability
W#16#0D91	Yes Parameter adr1 changed No, external interface	Yes	Module status information of all modules in the specified rack/station
W#16#xy92	No Replacement: SSL-ID W#16#0x94	Yes	Rack/station status information Replace this system status list with the system status list with ID W#16#xy94 in PROFIBUS DP, as well.
W#16#0x94	Yes, internal interface No, external interface	Yes, internal interface No, external interface	Rack/station status information
W#16#0C96	Yes, internal interface No, external interface	Yes, internal interface No, external interface	Module status information of a submodule using the logical address of this submodule
W#16#0591	Yes Parameter adr1 changed	Yes	Module status information for the interfaces of a module
W#16#0696	Yes, internal interface No, external interface	No	Module status information of all submodules on an internal interface of a module using the logical address of the module, not possible for submodule 0 (= module)

Detailed information

For detailed descriptions of the individual system status lists, refer to Manual *System Software for S7-300/400 System and Standard Functions*.

16.4 Configuring with STEP 7

16.4.1 Rules for arranging fault-tolerant station components

The following rules have to be complied with for a fault-tolerant station, in addition to the rules that generally apply to the arrangement of modules in the S7-400:

- Insert the CPUs into the same slots.
- Redundantly used external DP master interfaces or communication modules must be inserted in the same slots in each case.
- Insert an external DP master interface for redundant DP master systems only in the central controllers and not in the expansion units.
- Redundantly used modules (for example, CPU 410-5H, DP slave interface module IM 153-2, external DP interface module CP443-5, communication module CP 443-1) must be identical, which means they must have the same order number and the same product or firmware version.

Layout rules

- A fault-tolerant station may contain up to 20 expansion units.
- Assign racks with even numbers only to central controller 0, and racks with odd numbers only to central controller 1.
- FMs and CPs can be operated only in racks 0 through 6.
- FMs and CPs are not permitted in switched I/O.
- Pay attention to the rack numbers for operation of CPs for fault-tolerant communication in expansion units:

  The numbers must be directly sequential and begin with the even number, e.g., rack numbers 2 and 3, but not rack numbers 3 and 4.
- A rack number is also assigned for DP master no. 9 onwards if the central controller contains DP master modules. The number of possible expansion units is reduced as a result.

Compliance with the rules is monitored automatically by STEP 7 and considered accordingly during configuration.

16.4.2 Configuring hardware

You can create the AS bundle configurations with the PCS 7 wizard.

Another way of achieving a redundant hardware configuration is to initially assemble **one** rack with all components to be implemented redundantly and to assign parameters to them. The entire rack must then be copied and inserted. You adjust the network parameters appropriately in the subsequent dialogs.

Special features in presenting the hardware configuration

In order to enable quick recognition of a redundant DP master system or PN/IO system, each of them is represented by two parallel cables.

16.4.3 Assigning parameters to modules in a fault-tolerant station

Procedure

Assign all parameters of the redundant components identically, with the exception of communication addresses.

The special case of CPUs

You can only set the CPU0 parameters (CPU on rack 0). Any values that you specify are automatically allocated to CPU1 (CPU on rack 1). You can set the following values for CPU1:

- Parameters of the DP interface (X1)
- Addresses of sync modules
- Parameters of the PROFINET IO interface

16.4.4 Recommendations for setting CPU parameters, fixed settings

Monitoring time for transferring parameters to modules

You specify this monitoring time on the "Startup" tab. It depends on the configuration of the fault-tolerant station. If the monitoring time is too short, the CPU enters the W#16#6547 event in the diagnostics buffer.

For some slaves (e.g., IM 153-2) these parameters are packed in system data blocks. The transmission time of the parameters depends on the following factors:

- Baud rate of the bus system (high baud rate => short transmission time)
- Size of the parameters and the system data blocks (long parameter => long transmission time)
- Load on the bus system (many slaves => slow transmission rate);
  Note: The bus load is at its peak during restart of the DP master, for example, following Power OFF/ON

Recommended setting (default setting of the CPU 410): 600 corresponds to 60 s.

Note

The fault-tolerant-specific CPU parameters, and thus also the monitoring times, are calculated automatically. The work memory allocation of all data blocks is based on a CPU-specific default value. If your fault-tolerant system does not link up, check the data memory allocation (HW Config > CPU Properties > H Parameters > Work memory used for all data blocks).

See also

Service & Support (http://www.siemens.com/automation/service&support)

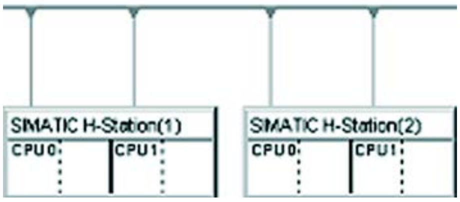
16.4.5 Networking configuration

The fault-tolerant S7 connection is a separate connection type of the "Configure Networks" application. It permits that the following communication peers can communicate with each other:

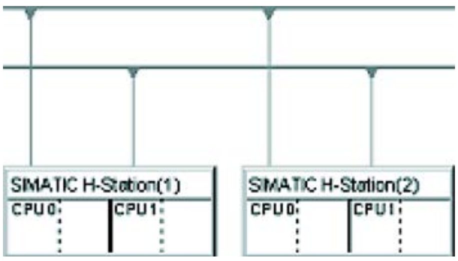
- S7–400 fault-tolerant station (with 2 fault-tolerant CPUs)->S7–400 fault-tolerant station (with 2 fault-tolerant CPUs)
- S7–400 station (with 1 fault-tolerant CPU)->S7–400 fault-tolerant station (with 2 fault-tolerant CPUs)
- S7–400 station (with 1 fault-tolerant CPU)->S7–400 station (with 1 fault-tolerant CPU)
- SIMATIC PC stations > S7–400 fault-tolerant station (with 2 fault-tolerant CPUs)

When this connection type is configured, the application automatically determines the number of possible connecting paths:

- If two independent but identical subnets are available and they are suitable for an S7 connection, two connecting paths are used. In practice, they are usually electrical power systems, one CP in each subnet:



- If only one subnet is available, four connecting paths are used for a connection between two fault-tolerant stations. All CPs are in this subnet:



Downloading the network configuration into a fault-tolerant station

The complete network configuration can be downloaded into the fault-tolerant station in one operation. The same requirements that apply for downloads into standard stations must be met.

16.5 Programming device functions in STEP 7

Display in SIMATIC Manager

In order to do justice to the special features of a fault-tolerant station, the way in which the system is visualized and edited in SIMATIC Manager differs from that of a S7-400 standard station as follows:

- In the offline view, the S7 program appears only under CPU0 of the fault-tolerant station. No S7 program is visible under CPU1.
- In the online view, the S7 program appears under both CPUs and can be selected in both locations.

Communication functions

For programming device (PG) functions that establish online connections (e.g., downloading charts), one of the two CPUs has to be selected even if the function affects the entire system over the redundant link.

- Data which is modified in one of the central processing units in redundant operation affect the other CPUs over the redundant link.
- Data which is modified when there is no redundant link (i.e. in single mode) initially affects only the processed CPU. The blocks are applied by the master CPU to the reserve CPU during the next link-up and update. Exception: No new blocks are applied after changing the configuration. Loading the blocks is then the responsibility of the user.

16.6 Communication services

16.6.1 Overview of communication services

Overview

Table 16- 4 Communication services of the CPUs

Communication service	Functionality	Allocation of S7 connection resources	Via DP	Via PN/IE
PG communication	Commissioning, testing, diagnostics	Yes	Yes	Yes
OP communication	Operator control and monitoring	Yes	Yes	Yes
S7 communication	Data exchange via configured connections	Yes	Yes	Yes
Routing of PG functions	For example, testing, diagnostics beyond network boundaries	Yes	Yes	Yes
PROFIBUS DP	Data exchange between master and slave	No	Yes	No

Communication service	Functionality	Allocation of S7 connection resources	Via DP	Via PN/IE
PROFINET IO	Data exchange between I/O controllers and I/O devices	No	No	Yes
SNMP (Simple Network Management Protocol)	Standard protocol for network diagnostics and parameter assignment	No	No	Yes
Open communication over TCP/IP	Data exchange over Industrial Ethernet with TCP/IP protocol (with loadable FBs)	Yes	No	Yes
Open communication over ISO on TCP	Data exchange over Industrial Ethernet with ISO on TCP protocol (with loadable FBs)	Yes	No	Yes
Open communication over UDP	Data exchange over Industrial Ethernet with UDP protocol (with loadable FBs)	Yes	No	Yes
Data record routing	For example, parameter assignment and diagnostics of field devices on PROFIBUS DP with PDM.	Yes	Yes	Yes

Note

Communication via the PNIO interface

If you want to use the PNIO interface of the module for communication in plant operation, you must also network this in Step 7 / HW Config / NetPro.

Connection resources in the S7-400 H

S7-400 H components provide a module-specific number of connection resources.

Availability of connection resources

Table 16- 5 Availability of connection resources

CPU	Total number of connection resources	Can be used for S7-H connections	Reserved from the total number for	
			PG communication	OP communication
CPU 410-5H	120	62	1	1

Free S7 connections can be used for any of the above communication services.

Note

Communication service via the PROFIBUS DP interface

A fixed default timeout of 40 s is specified for communication services using S7 connection resources. If you operate those communication services via a PROFIBUS DP interface at a low baud rate, operation in configurations with a Ttr (Target Rotation Time) < 20 s is ensured.

16.6.2 PG communication

Properties

Programming device communication is used to exchange data between engineering stations (PG, PC, for example) and SIMATIC modules which are capable of communication. This service is available via PROFIBUS and Industrial Ethernet subnets. Routing between subnets is also supported.

You can use the programming device communication for the following actions:

- Loading programs and configuration data
- Performing tests
- Evaluating diagnostic information

These functions are integrated in the operating system of SIMATIC S7 modules.

A CPU can maintain several simultaneous online connections to one or multiple programming devices.

16.6.3 OP communication

Properties

OP communication is used to exchange data between HMI stations, such as WinCC, OP, TP and SIMATIC modules which are capable of communication. This service is available via PROFIBUS and Industrial Ethernet subnets.

You can use the OP communication for operator control, monitoring and alarms. These functions are integrated in the operating system of SIMATIC S7 modules. A CPU can maintain several simultaneous connections to one or several OPs.

16.6.4 S7 communication

Properties

A CPU can always act as a server or client in S7 Communication. A connection is configured permanently. The following connections are possible:

- One-sided configured connections (for PUT/GET only)
- Two-side configured connections (for USEND, URCV, BSEND, BRCV, PUT, GET)

You can use the S7 communication via integrated PROFIBUS DP or PROFINET IO interfaces. If required, S7 communication can be used via additional communication processors: CP 443-1 for Industrial Ethernet or CP 443-5 for PROFIBUS.

The S7-400 features integrated S7 communication services that allow the user program in the controller to initiate reading and writing of data. The S7 communication functions are called in the user program using SFBs. These functions are independent of specific networks, allowing you to program S7 communication via PROFINET, Industrial Ethernet, or PROFIBUS.

S7 communication services provide the following options:

- During system configuration, you configure the connections used by the S7 communication. These connections remain configured until you download a new configuration.
- You can establish several connections to the same partner. The number of communication partners accessible at any time is restricted to the number of connection resources available.
- You can configure fault-tolerant S7 connections using the integrated PROFINET IO interface.

Note

Downloading the connection configuration during operation

When you load a modified connection configuration during operation, connections which have been set up which are not affected by changes in the connection configuration may also be aborted.

S7 communication allows you to transfer a block of up to 64 Kbytes per call to the SFB. An S7-400 transfers a maximum of 4 tags per block call.

SFBs for S7 Communication

The following SFBs are integrated in the operating system of the S7-400 CPUs:

Table 16- 6 SFBs for S7 Communication

Block	Block name	Brief description
SFB 8 SFB 9	USEND URCV	Send data to a remote partner SFB of type "URCV" Receive asynchronous data from a remote partner SFB of type "USEND"
SFB 12 SFB 13	BSEND BRCV	Send data to a remote partner SFB of type "BRCV" Receive data from a remote partner SFB of type "BSEND" With this data transfer, a larger amount of data can be transported between the communication partners than is possible with all other communications SFBs for the configured S7 connections.
SFB 14	GET	Read data from a remote CPU
SFB 15	PUT	Write data to a remote CPU
SFB 16	PRINT	Send data via a CP 441 to a printer
SFB 19	START	Carry out a reboot (warm restart) or cold restart in a remote station
SFB 20	STOP	Set a remote station to STOP operating state
SFB 22	STATUS	Query the device status of a remote partner
SFB 23	USTATUS	Uncoordinated receiving of a remote device status

Integration into STEP 7

S7 communication offers communication functions through configured S7 connections. You use STEP 7 to configure the connections.

S7 connections with an S7-400 are established when the connection data is downloaded.

16.6.5 S7 routing

Properties

You can access your S7 stations beyond subnet boundaries using the programming device / PC. You can use them for the following actions:

- Downloading user programs
- Downloading a hardware configurations
- Performing test and diagnostic functions

Requirements

- The network configuration does not exceed project limits.
- The modules have loaded the configuration data containing the latest "knowledge" of the entire network configuration of the project.

  Reason: All modules connected to the network gateway must receive routing information which defines the paths to other subnets.
- In your network configuration, the PG/PC you want to use to set up a connection via gateway must be assigned to the network to which it is physically connected.
- The CPU must be configured as the master.

S7 routing gateways: PN - DP

Gateways between subnets are routed in a SIMATIC station that is equipped with interfaces to the respective subnets. The following figure shows CPU 1 (DP master) acting as router for subnets 1 and 2.

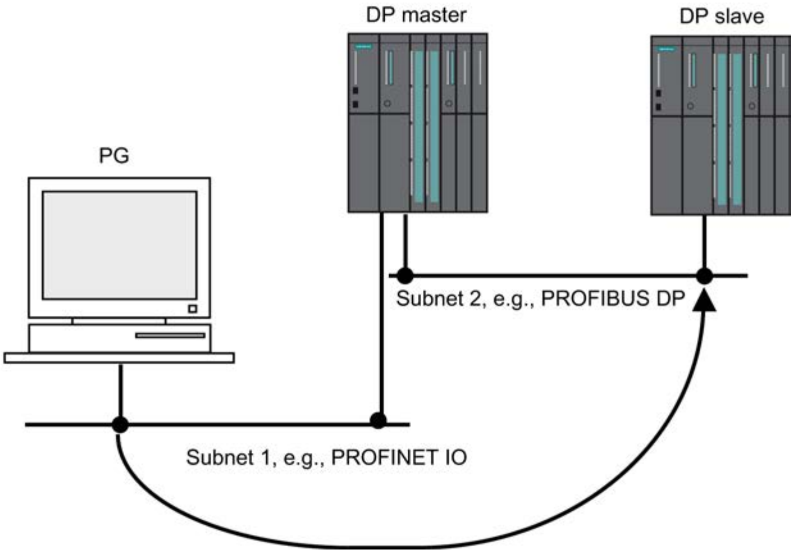


Figure 16-2 S7 routing

S7 routing gateways: PROFINET IO - DP - PROFINET IO

The following figure shows the access from PROFINET IO to PROFIBUS to PROFINET IO. CPU 1 is the router between subnet 1 and subnet 2; CPU 2 is the router between subnet 2 and subnet 3.

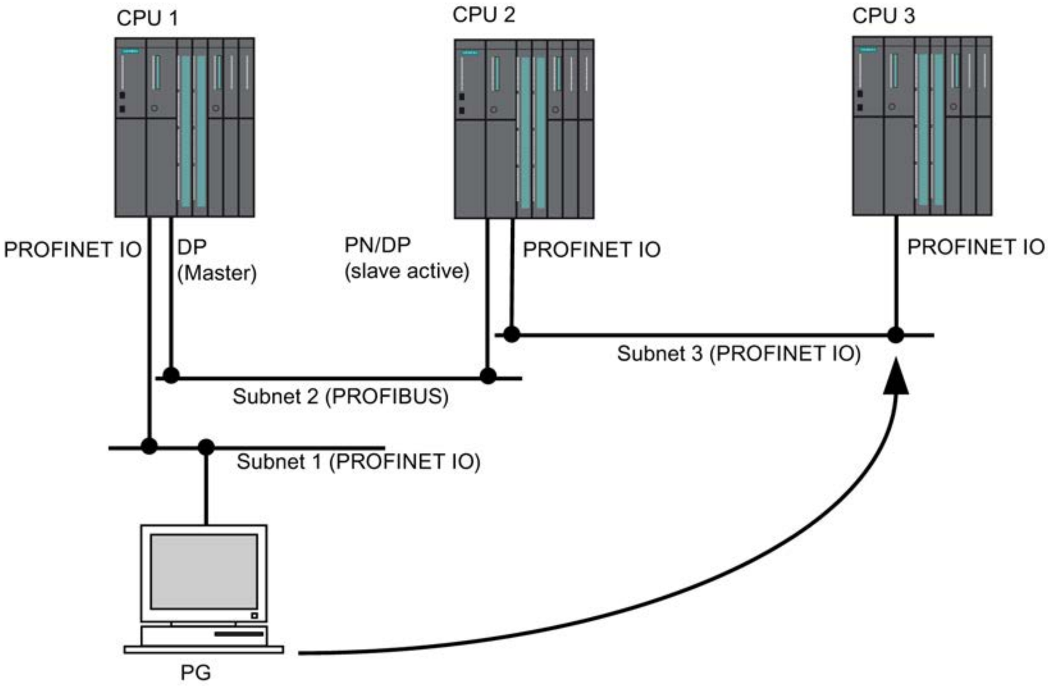


Figure 16-3 S7 routing gateways: PROFINET IO - DP - PROFINET IO

S7 routing: TeleService application example

The following figure shows an application example of the remote maintenance of an S7 station using a PG. The connection to other subnets is set up via modem.

The bottom of the figure shows how this can be configured in STEP 7.

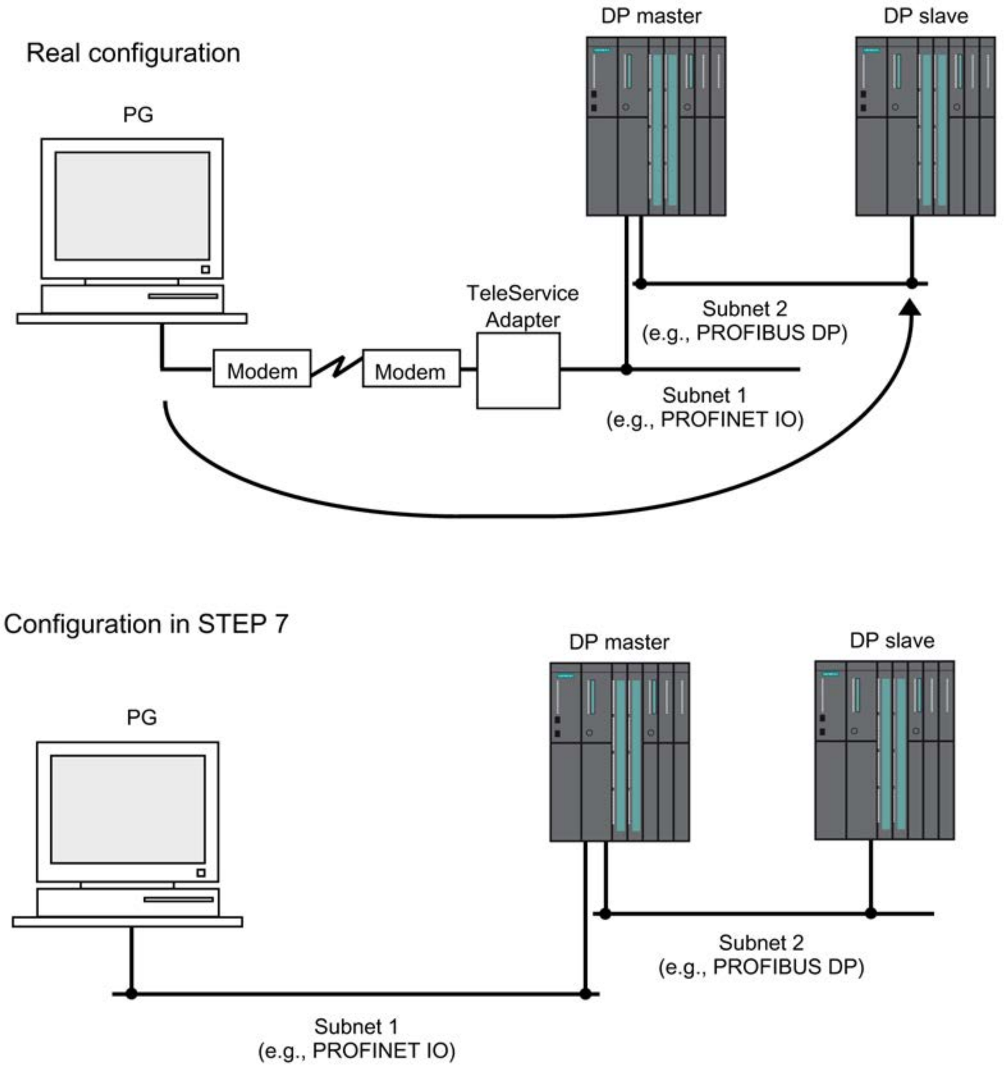


Figure 16-4 S7 routing: TeleService application example

Reference

- Further information on configuration with STEP 7 can be found in Manual Configuring hardware and communication connections with STEP 7 (http://support.automation.siemens.com/WW/view/en/45531110).
- More basic information is available in Manual Communication with SIMATIC (http://support.automation.siemens.com/WW/view/en/1254686).
- For more information about the TeleService adapter, refer to Manual TS Adapter (http://support.automation.siemens.com/WW/view/en/20983182)
- For additional information about SFCs, refer to the Instructions list. (http://support.automation.siemens.com/WW/view/en/44395684)
  For a detailed description, refer to the *STEP 7 online help* or Manual System and Standard Functions (http://support.automation.siemens.com/WW/view/de/44240604/0/en).

16.6.6 Data set routing

Routing and data set routing

Routing is the transfer of data beyond network boundaries. You can send information from a transmitter to a receiver across several networks.
Data set routing is an expansion of S7 routing and is used, for example, in SIMATIC PDM. The data sent through data record routing include the parameter assignments of the participating communication devices and device-specific information (for example, setpoint values, limit values, etc.). The structure of the destination address for data set routing depends on the data content, in other words, it is determined by the device for which the data is intended.
The field device itself does not have to support data set routing, since these devices do not forward the received information.

Data set routing

The following figure shows the engineering station accessing a variety of field devices. The engineering station is connected to the CPU via Industrial Ethernet in this scenario. The CPU communicates with the field devices via the PROFIBUS.

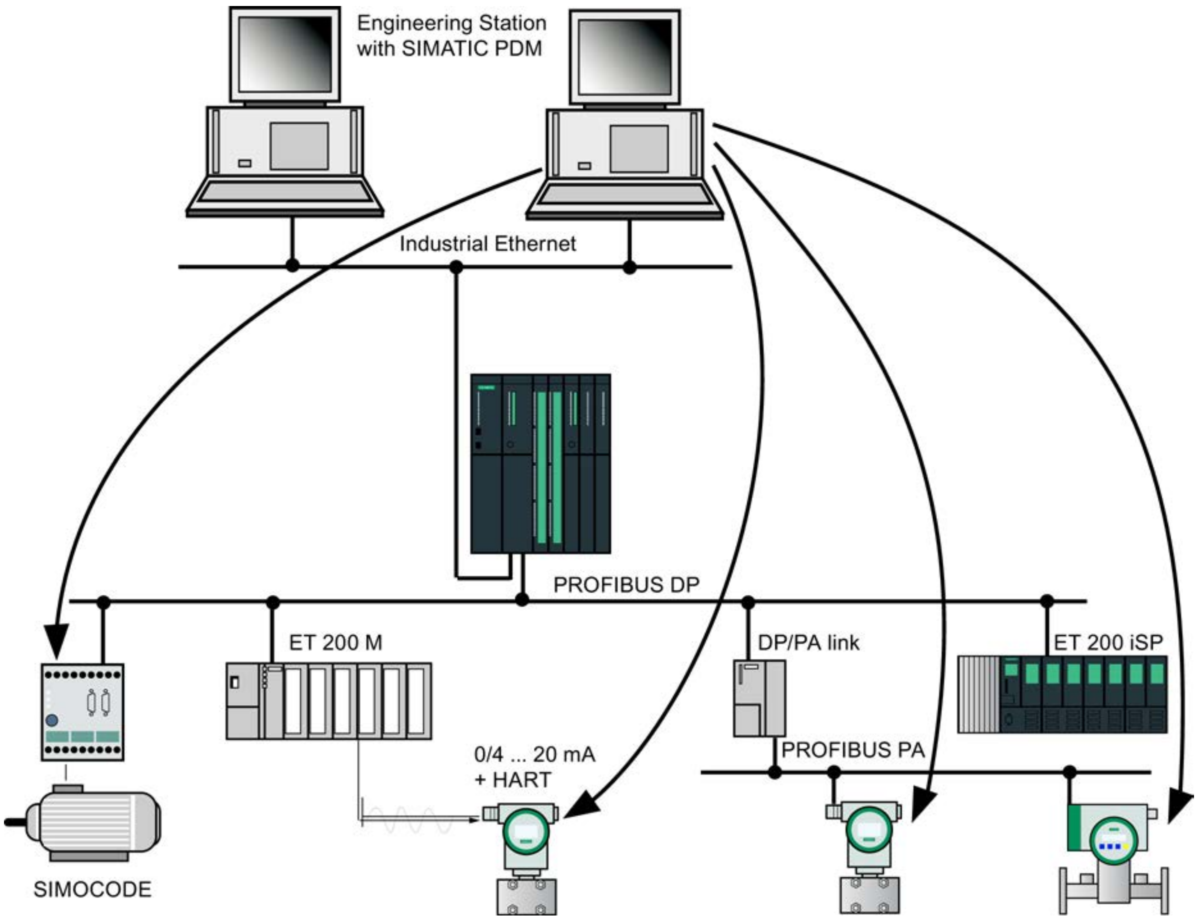


Figure 16-5 Data set routing

See also

For more information on SIMATIC PDM, refer to Manual *The Process Device Manager*.

16.6.7 SNMP network protocol

Properties

SNMP (Simple Network Management Protocol) is the standardized protocol for diagnostics of the Ethernet network infrastructure. In the office setting and in automation engineering, devices from many different manufacturers support SNMP on the Ethernet. SNMP-based applications can be operated on the same network in parallel to applications with PROFINET IO.

Configuration of the SNMP OPC server is integrated in the STEP 7 Hardware Configuration application. Already configured S7 modules from the STEP 7 project can be transferred directly. As an alternative to STEP 7, you can also perform the configuration with the NCM PC (included on the SIMATIC NET CD). All Ethernet devices can be detected by means of their IP address and/or the SNMP protocol (SNMP V1) and transferred to the configuration.

Use the profile MIB_II_V10.

SNMP-based applications can be operated on the same network parallel to applications with PROFINET IO.

Note

MAC addresses

During SNMP diagnostics, the following MAC addresses are shown for the ifPhysAddress parameter:

Interface 1 (PN interface) = MAC address (specified on the front panel of the CPU)

Interface 2 (port 1) = MAC address + 1

Interface 3 (port 2) = MAC address + 2

Diagnostics with SNMP OPC Server in SIMATIC NET

The SNMP OPC server software enables diagnostics and parameter assignment of any SNMP devices. The OPC server uses the SNMP protocol to perform data exchange with SNMP devices.

All information can be integrated in OPC-compatible systems, such as the WinCC HMI system. This enables process and network diagnostics to be combined in the HMI system.

Reference

For further information on the SNMP communication service and diagnostics with SNMP, refer to the *PROFINET System Description.*

16.6.8 Open Communication Via Industrial Ethernet

Functionality

The following services are available for open IE communication:

- Connection-oriented protocols:

  Prior to data transmission connection-oriented protocols establish a logical connection to the communication partner and close this again, if necessary, after transmission is complete. Connection-oriented protocols are used when security is especially important in data transmission. A physical cable can generally accommodate several logical connections. The maximum job length is 32 Kbytes.

  The following connection-oriented protocols are supported for the FBs for open IE communication:

  – TCP to RFC 793

  – ISO on TCP according to RFC 1006

  Note

  ISOonTCP

  For data communication with third-party systems via RFC1006, the connection partner must adhere to the maximum TPDU size (TPDU = Transfer Protocol Data Unit) negotiated in the ISOonTCP connection establishment.

- Connectionless protocols:

  Connectionless protocols operate without a logical connection. There is also no establishing or terminating a connection to remote partner. Connectionless protocols transfer the data unacknowledged and thus unsecured to the remote partner. The maximum message frame length is 1472 bytes.
  The following connectionless protocols are supported for the FBs for open communication via Industrial Ethernet:

  – UDP according to RFC 768

    The single-cast and broadcast modes are supported.

How to use open IE communication

You can exchange data with other communication partners via the user program. The following FBs and UDTs are available for this in the "Standard Library" of STEP 7 under "Communication Blocks".

- Connection-oriented protocols: TCP, ISO on TCP
  - FB 63 "TSEND" for sending data
  - FB 64 "TRCV" for receiving data
  - FB 65 "TCON", for connection setup
  - FB 66 "TDISCON", for disconnecting
  - UDT 65 "TCON_PAR" with the data structure for the configuration of the connection
- Connectionless protocol: UDP
  - FB 67 "TUSEND" for sending data
  - FB 68 "TURCV" for receiving data
  - FB 65 "TCON" for setting up the local communication access point
  - FB 66 "TDISCON" for resolving the local communication access point
  - UDT 65 "TCON_PAR" with the data structure for configuring the local communication access point
  - UDT 66 "TCON_ADR" with the data structure of the addressing parameters of the remote partner

Data blocks for parameter assignment

- Data blocks for parameter assignment of communication connections for TCP and ISO on TCP

  In order to assign parameters for the communication connections for TCP and ISO on TCP, you must create a DB that contains the data structure from UDT 65 "TCON_PAR". This data structure contains all parameters you need to set up the connection. For each connection you need this type of data structure, which you can also group within a global data range.

  Connection parameter CONNECT of FB 65 "TCON" reports the address of the corresponding connection description to the user program (for example, P#DB100.DBX0.0 byte 64).
- Data blocks for the configuration the local UDP communication access point

  To assign parameters to the local communication access point, create a DB containing the data structure from the UDT 65 "TCON_PAR". This data structure contains the necessary parameters you need to set up the connection between the user program and the communication layer of the operating system. You also need UDT 66 "TCON_ADDR" for UDP. You can also store this UDT in the DB .

  The CONNECT parameter of the FB 65 "TCON" contains a reference to the address of the corresponding connection description (for example, P#DB100.DBX0.0 Byte 64).

Job lengths and parameters for the different types of connection

Table 16- 7 Job lengths and "local_device_id" parameter

Message frame	CPU 410-5H	CPU 410-5H with CP 443-1
TCP	32 Kbytes	-
ISO on TCP	32 Kbytes	1452 bytes
UDP	1472 bytes	-
"local_device_id" parameter for the connection description		
Dev. ID	16#5 for CPU 0 16#15 for CPU1	16#0 for CPU 0 16#10 for CPU1

Establishing a communication connection

- Use with TCP and ISO on TCP

  Both communication partners call FB 65 "TCON" to establish the connection. In the configuration, you specify which communication partner activates the connection, and which one responds to the request with a passive connection. To determine the number of possible connections, refer to your CPU's technical specifications.

  The CPU automatically monitors and holds the active connection.

  If the connection is broken, for example by line interruption or by the remote communication partner, the active partner tries to reestablish the connection. You do not have to call FB 65 "TCON" again.

  When FB 66 "TDISCON" is called or the CPU is in STOP operating state, an existing connection will be terminated. To reestablish the connection you must call FB65 "TCON" again.

- Use with UDP

  Both communication partners call FB 65 "TCON" to set up their local communication access point. This establishes a connection between the user program and operating system's communication layer. No connection is established to the remote partner.

  The local access point is used to send and receive UDP message frames.

Terminating a communication connection

- Use with TCP and ISO on TCP

  FB 66 "TDISCON" disconnects the communication connection between the CPU and a communication partner.

- Use with UDP

  FB 66 "TDISCON" disconnects the local communication access point. This means that the connection between the user program and communication layer of the operating system is terminated.

Options for terminating the communication connection

The following events are available for terminating communication connections:

- You program the termination of the communication connection with FB 66 "TDISCON".
- The CPU state changes from RUN to STOP.
- At POWER OFF / POWER ON

Connection diagnostics

In Step 7, you can read detailed information on the configured connections by selecting "Module state -> Communication -> Open communication over Industrial Ethernet".

Reference

For detailed information on the blocks described above, refer to the *STEP 7 Online Help.*

16.7 Basics and terminology of fault-tolerant communication

Overview

When more stringent requirements for overall plant availability exist, it is necessary to increase the reliability of the communication, i.e., by configuring the communication redundantly as well.

Below you will find an overview of the fundamentals and basic concepts which you ought to know with regard to using fault-tolerant communications.

Redundant communication system

The availability of the communication system can be increased by duplicating subcomponents, duplicating all bus components, or using a fiber-optic ring.

On failure of a component, the various monitoring and synchronization mechanisms ensure that the communication functions are taken over by the standby components during operation.

A redundant communication system is essential if you want to use fault-tolerant S7 connections.

Fault-tolerant communication

Fault-tolerant communication is the deployment of S7 communication SFBs over fault-tolerant S7 connections.

Fault-tolerant S7 connections need a redundant communication system.

Redundancy nodes

Redundancy nodes represent extreme reliability of communication between two fault-tolerant systems. A system with multi-channel components is represented by redundancy nodes. Redundancy nodes are independent when the failure of a component within the node does not result in any reliability impairment in other nodes.

Even with fault-tolerant communication, only single errors/faults can be tolerated. If more than one error occurs between two communication end points, communication can no longer be guaranteed.

Connection (S7 connection)

A connection represents the logical assignment of two communication peers for executing a communication service. Every connection has two end points containing the information required for addressing the communication peer as well as other attributes for establishing the connection.

An S7 connection is the communication link between two standard CPUs or from a standard CPU to a CPU in a fault-tolerant system.

In contrast to a fault-tolerant S7 connection, which contains at least two partial connections, an S7 connection actually consists of just one connection. If that connection fails, communication is terminated.

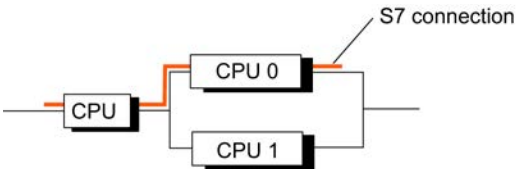


Figure 16-6 Example of an S7 connection

Note

Generally speaking, "connection" in this manual means a "configured S7 connection". For other types of connection, refer to Manuals *SIMATIC NET NCM S7 for PROFIBUS* and *SIMATIC NET NCM S7 for Industrial Ethernet*.

Fault-tolerant S7 connections

The requirement for higher availability with communication components (for example CPs and buses) means that redundant communication connections are necessary between the systems involved.

Unlike an S7 connection, a fault-tolerant S7 connection consists of at least two underlying subconnections. From the perspective of the user program, configuration, and connection diagnostics, the fault-tolerant S7 connection with its underlying subconnections is represented by exactly one ID (just like a standard S7 connection). Depending on the configuration, it can consist of a maximum of four subconnections. To maintain communication in the event of an error, two of the four subconnections are always connected (active) at any given time. The number of subconnections depends on the possible alternative paths (see figure below) and is determined automatically. Within an S7-H connection, only subconnections over CP or over the integrated CPU interface are used in the configuration.

The following examples and the possible configurations in STEP 7 are based on a maximum of two subnets and a maximum of 4 CPs in the redundant fault-tolerant system. Configurations with a higher number of CPs or networks are not supported in STEP 7.

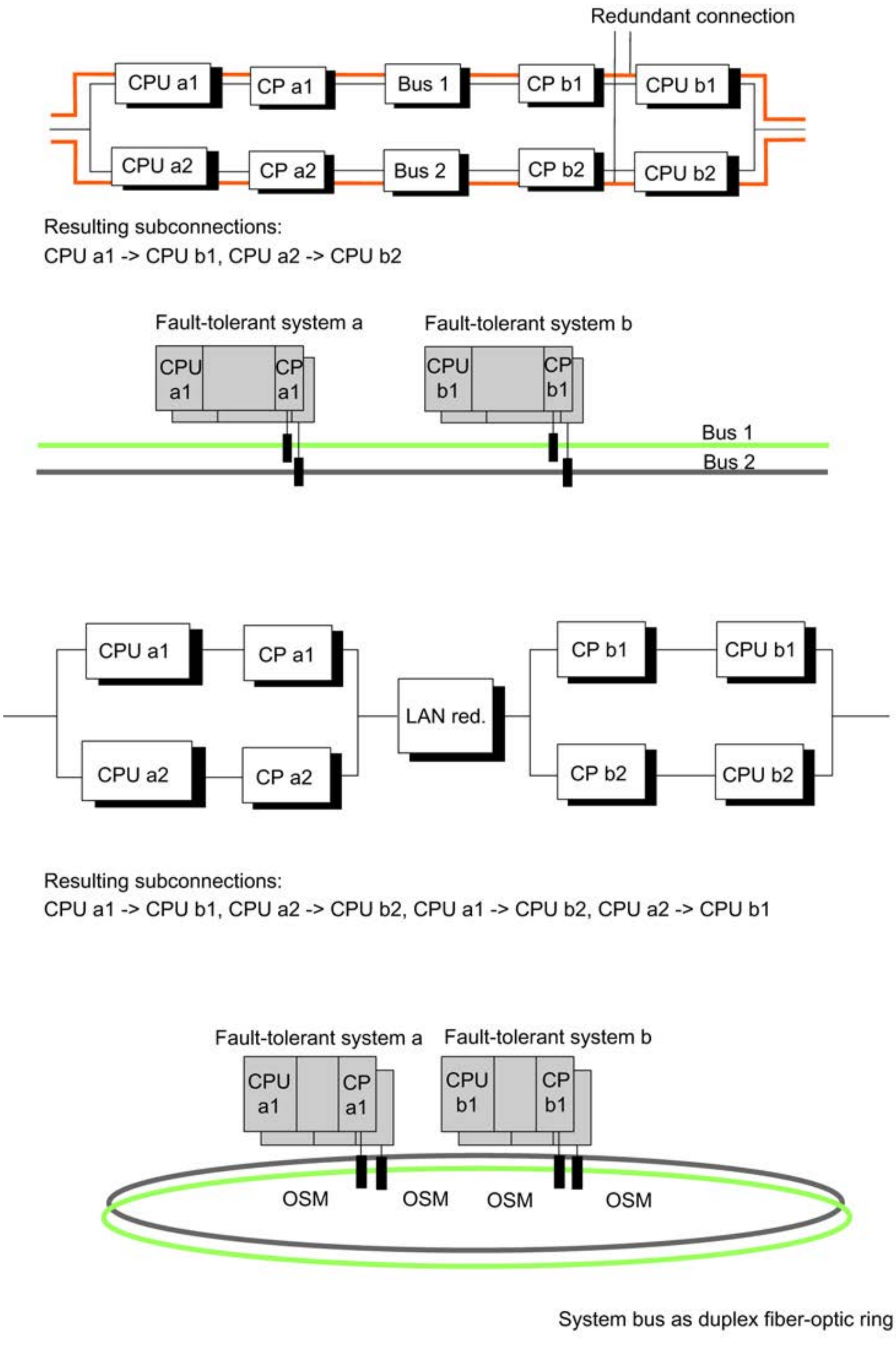


Figure 16-7 Example that shows that the number of resulting partial connections depends on the configuration

If the active subconnection fails, the already established second subconnection automatically takes over communication.

Resource requirements of fault-tolerant S7 connections

The fault-tolerant CPU supports operation of 62 fault-tolerant S7 connections (see technical specifications). Each connection needs a connection resource on the CPU; subconnections do not need any additional connection resources. On the CP, on the other hand, each subconnection needs a connection resource.

Note

If you have configured several fault-tolerant S7 connections for a fault-tolerant station, establishing them may take a considerable time. If the configured maximum communication delay was set too short, link-up and updating is canceled and the redundant system state is no longer achieved (see Chapter Time monitoring (Page 110)).

16.8 Usable networks

Your choice of the physical transmission medium depends on the required expansion, targeted fault tolerance, and transfer rate. The following bus systems are used for communication with fault-tolerant systems:

- Industrial Ethernet
- PROFIBUS

Additional information on the networks that can be used is available in the relevant SIMATIC NET documentation on PROFIBUS and Ethernet.

16.9 Communication via S7 connections

Communication with standard systems

There is no fault-tolerant communication between a fault-tolerant system and a standard CPU. The following examples illustrate the actual availability of the communicating systems.

Configuration

S7 connections are configured in STEP 7.

Programming

If S7 communication is used on a fault-tolerant system, all communication functions can be used for this.

The communication SFBs are used in STEP 7 to program communication.

Note

The START and STOP communication functions act on exactly one CPU or on all CPUs of the fault-tolerant system. More detailed information is available in Reference Manual *System Software for S7-300/400 System and Standard Functions*.

Note

Downloading the connection configuration during operation

If you download a connection configuration during operation, established connections may be terminated.

16.9.1 Communication via S7 connections - one-sided mode

Availability

Availability for communication between a fault-tolerant system and a standard system is also increased by using a redundant plant bus instead of a single bus (see figure below).

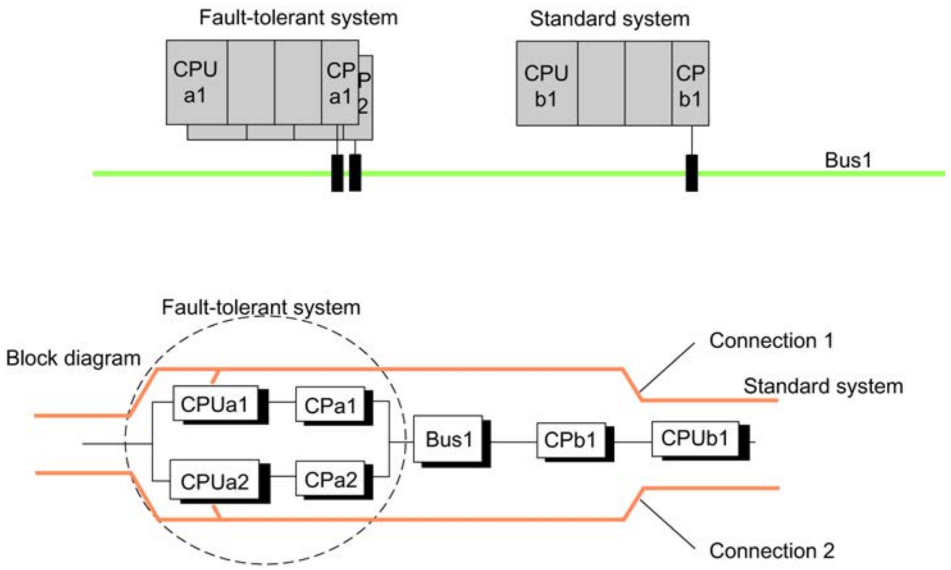


Figure 16-8 Example of linking standard and fault-tolerant systems in a simple bus system

With this configuration and redundant operation, the fault-tolerant system is connected to the standard system via bus1. This applies no matter which CPU is the master CPU.

For linked fault-tolerant and standard systems, the availability of communication cannot be improved by means of a dual electrical bus system. To be able to use the second bus system as redundancy, a second S7 connection must be used and managed accordingly in the user program (see next figure).

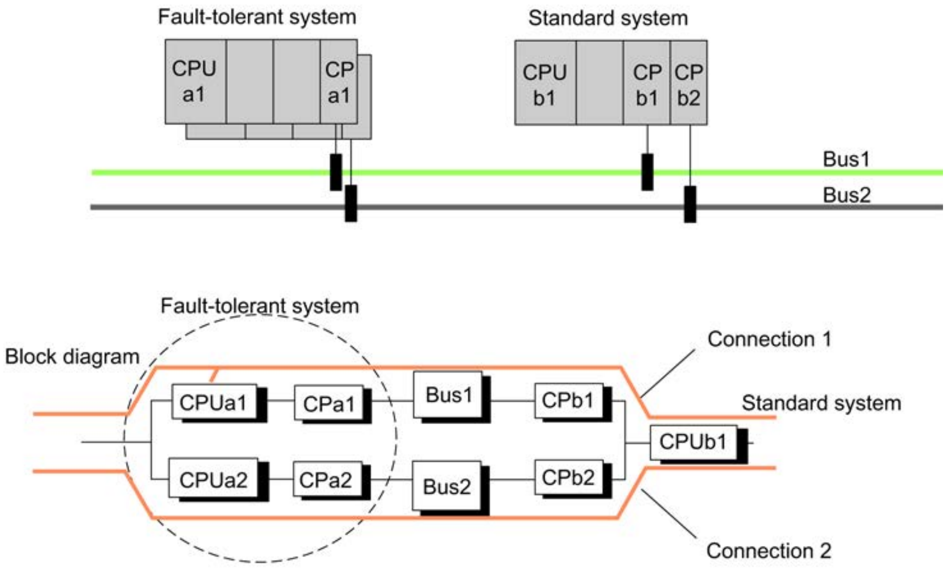


Figure 16-9 Example of linking standard and fault-tolerant systems in a redundant bus system

If the plant bus is configured as a duplex fiber-optic ring, the communication of the systems involved is maintained if a break of the two-fiber fiber-optic cable occurs. The systems then communicate as if they were connected to a bus system (linear structure); see following figure.

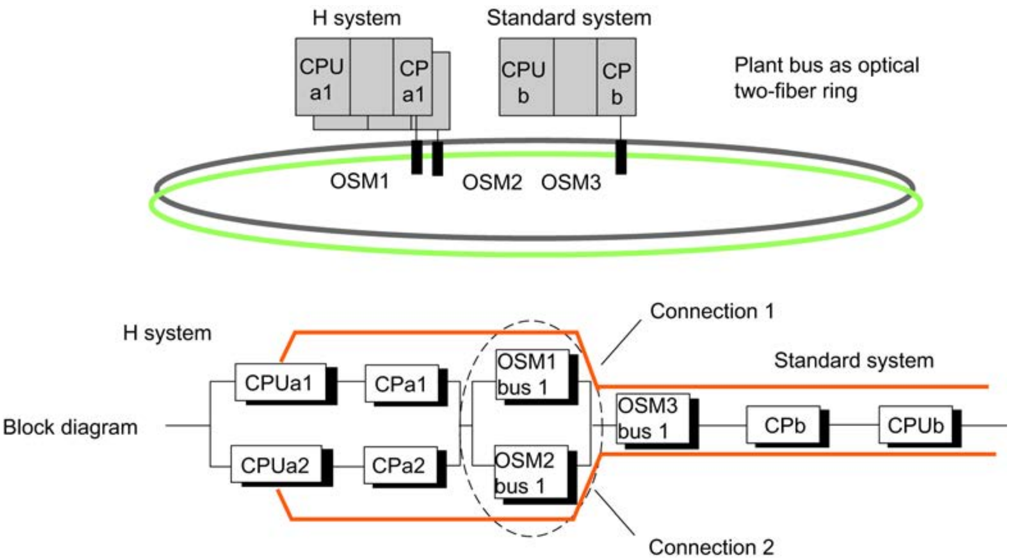


Figure 16-10 Example of linking of standard and fault-tolerant systems in a redundant ring

Response to failure

Duplex fiber-optic ring and bus system

S7 connections are used here in which the connection ends on the CPU of the subsystem, here CPUa1. For this reason, an error in the fault-tolerant system, e.g., CPUa1 or CPa1, as well as an error in system b, e.g., CP b, will result in a total failure of the communication between the two systems involved. This can be seen in the preceding figures.

There are no bus system-specific differences in the response to failure.

Linking standard and fault-tolerant systems

Driver block "S7H4_BSR": You can link a fault-tolerant system to an S7-400 / S7-300 using the "S7H4_BSR" driver block. For more information, contact Siemens by e–mail: function.blocks.industry @siemens.com

Alternative: SFB 15 "PUT" and SFB 14 "GET" in the fault-tolerant system: As an alternative, use two SFB 15 "PUT" blocks over two standard connections. First call the first block. If there was no error message when the block executed, the transmission is considered to have been successful. If there was an error message, the data transmission is repeated via the second block. If a connection cancelation is detected later, the data is also transferred again to exclude possible information losses. You can use the same method with an SFB 14 "GET".

If possible, use the mechanisms of S7 communication for communication.

16.9.2 Communication via redundant S7 connections

Availability

Availability can be enhanced by using a redundant plant bus and two separate CPs in a standard system.

Redundant communication can also be operated with standard connections. For this two separate S7 connections must be configured in the program in order to implement connection redundancy. In the user program, both connections require the implementation of monitoring functions in order to allow the detection of failures and to change over to the standby connection.

The following figure shows such a configuration.

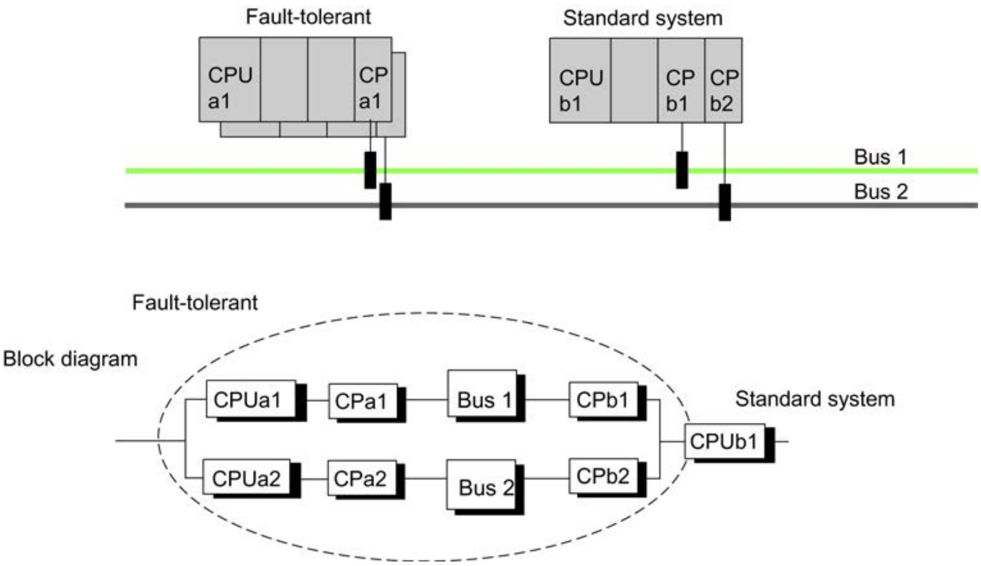


Figure 16-11 Example of redundancy with fault-tolerant systems and a redundant bus system with redundant standard connections

Response to failure

Double errors in the fault-tolerant system (i.e., CPUa1 and CPa 2) or in the standard system (CPb1 and CPb2), and single errors in the standard system (CPUb1) lead to a total failure of communication between the systems involved (see previous figure).

16.9.3 Communication via point-to-point CP on the ET 200M

Connection via ET 200M

Links from fault-tolerant systems to single-channel systems are often possible only by way of point-to-point connections, as many systems offer no other connection options.

In order to make the data of a single-channel system available to CPUs of the fault-tolerant system as well, the point-to-point CP, i.e., CP 341, must be installed in a distributed rack along with two IM 153-2 modules.

Configuring connections

Redundant connections between the point-to-point CP and the fault-tolerant system are not necessary.

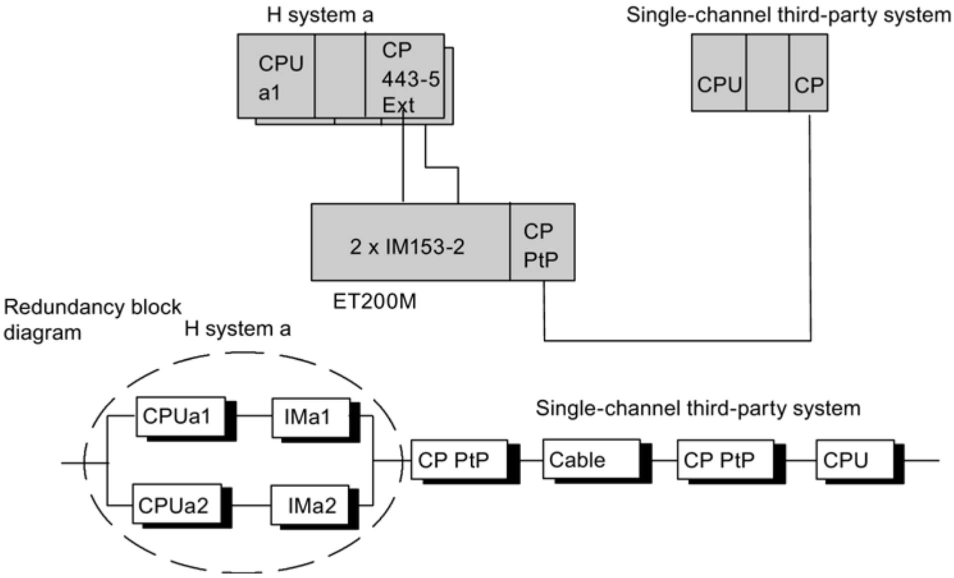


Figure 16-12 Example of connecting a fault-tolerant system to a single-channel third-party system via switched PROFIBUS DP

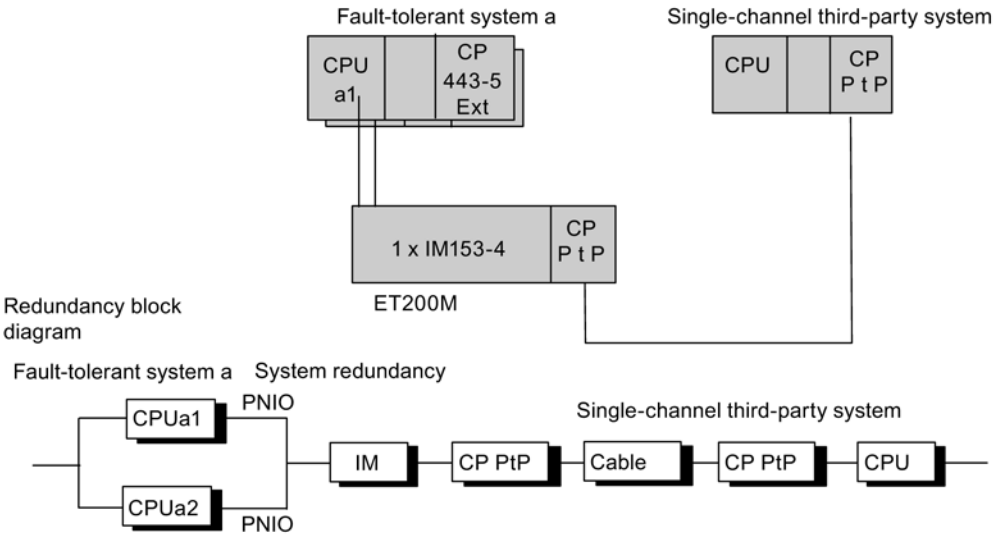


Figure 16-13 Example of connecting a fault-tolerant system to a single-channel third-party system via PROFINET IO with system redundancy

Response to failure

Double errors in the fault-tolerant system (i.e., CPUa1 and IM 153) and a single fault in the third-party system lead to a total failure of communication between the systems involved. This can be seen in the previous figure.

The point-to-point CP can also be inserted centrally in "Fault-tolerant system a". However, in this configuration even the failure of the CPU, for example, will cause a total failure of communication.

16.9.4 Custom connection to single-channel systems

Connection via PC as gateway

Fault-tolerant systems and single-channel systems can also be via a gateway (no connection redundancy). The gateway is connected to the system bus by one or two CPs, depending on availability requirements. Fault-tolerant connections can be configured between the gateway and the fault-tolerant systems. The gateway allows you to link any type of single-channel system (e.g., TCP/IP with a manufacturer-specific protocol).

A user-programmed software instance in the gateway implements the single-channel transition to the fault-tolerant systems, and so allows any single-channel systems to be linked to a fault-tolerant system.

Configuring connections

Redundant connections between the gateway CP and the single-channel system are not required.

The gateway CP is located on a PC system which has fault-tolerant connections to the fault-tolerant system.

To configure fault-tolerant S7 connections between fault-tolerant system A and the gateway, you first need to install S7-REDCONNECT on the gateway. The functions for preparing data for their transfer via the single-channel link must be implemented in the user program.

For additional information, refer to the "*Industrial Communications IK10*" Catalog.

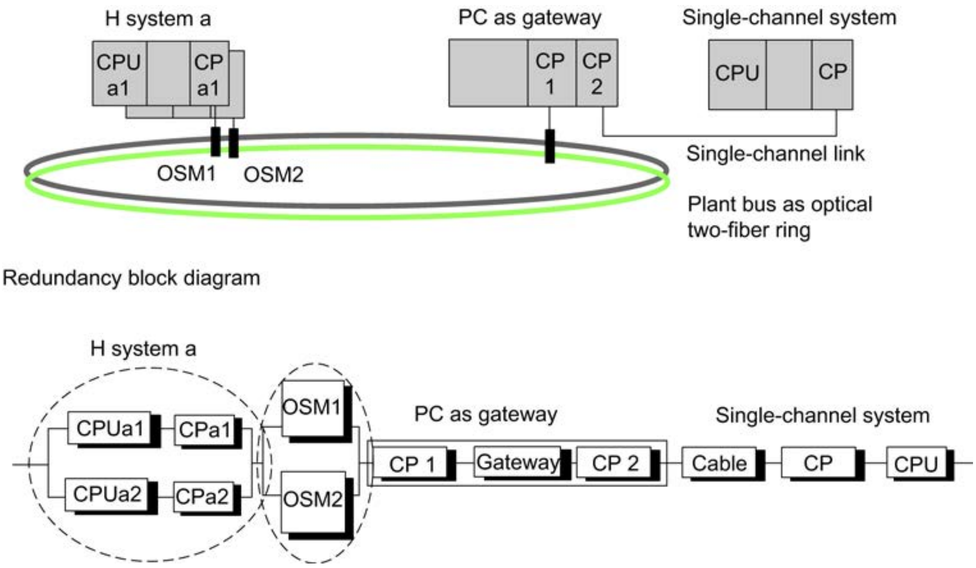


Figure 16-14 Example of linking a fault-tolerant system to a single-channel third-party system

16.10 Communication via fault-tolerant S7 connections

Availability of communicating systems

Fault-tolerant communication expands the overall SIMATIC system by additional, redundant communication components such as CPs and bus cables. To illustrate the actual availability of communicating systems when using an optical or electrical network, a description is given below of the possibilities for communication redundancy.

Requirement

The essential requirement for the configuration of fault-tolerant connections with STEP 7 is a configured hardware installation.

The hardware configuration in both subsystems of a fault-tolerant system **must** be identical. This applies in particular to the slots.

Depending on the network used, CPs can be used for fault-tolerant and fail-safe communication, see Appendix Function and communication modules that can be used in a redundant configuration (Page 305)
Industrial Ethernet with ISO protocol or PROFIBUS without distributed I/O and, as of Version 6.0, ISO on TCP is supported. Fault-tolerant S7 connections via Industrial Ethernet with ISO on TCP are supported by the integrated PN interface and corresponding CPs. You require a suitable CP for fault-tolerant S7 connections via Industrial Ethernet with ISO protocol or via PROFIBUS. These connections are not possible via the internal PROFIBUS-DP interface.

Only Industrial Ethernet is supported for connecting to PC stations using fault-tolerant S7 connections. To be able to use fault-tolerant S7 connections between a fault-tolerant system and a PC, you must install the "S7-REDCONNECT" software package on the PC. The software is part of the SIMATIC Net CD. Communication via ISO on TCP is also supported as of version 8.1.2. Please refer to the product information on the SIMATIC NET PC software to learn more about the CPs you can use at the PC end.

Communication combinations

The following table shows the possible combinations of fault-tolerant connections via Industrial Ethernet.

Local connection end point	Local network connection	Used network protocol	Remote network connection		Remote connection end point	
CPU 410	CPU-PN interface CP443-1 (EX 20/30) CP443-1 (EX20/30)	TCP TCP TCP	CPU-PN interface CPU-PN interface CP443-1 (EX 30)	TCP TCP TCP	CPU 410 CPU 41xH V6/CPU 410 CPU 41xH V4.5 and higher/CPU 410	S7 fault tolerant connection via ISOonTCP
CPU 410	CP443-1 (EX 20/30)	ISO	CP443-1	ISO	CPU 41xH /CPU 410	S7 fault tolerant connection via ISO
PC station with Simatic Net CD	CP1623 as of V8.1.2	TCP TCP	CPU-PN interface CP443-1 (EX 30)	TCP TCP	CPU 41xH V6/CPU 410 CPU 41xH V4.5 and higher/CPU 410	S7 fault tolerant connection via ISOonTCP
PC station with Simatic Net CD	CP1623 as of V8.1.2	ISO	CP443-1	ISO	CPU 41xH /CPU 410	S7 fault tolerant connection via ISO
PC station with Simatic Net CD	CP1623 up to V7.x	ISO	CP443-1	ISO	CPU 41xH /CPU 410	S7 fault tolerant connection via ISO

Configuration

The availability of the system, including the communication, is set during configuration. Refer to the STEP 7 documentation to find out how to configure connections.

Only S7 communication is used for fault-tolerant S7 connections. To set this up, open the "New Connection" dialog box, then select "S7 Connection Fault-Tolerant" as the type.

The number of required redundant subconnections is determined by STEP 7 as a function of the redundancy nodes. Up to four redundant connections can be generated, if supported by the network. Higher redundancy cannot be achieved even by using more CPs.

In the "Properties - Connection" dialog box you can also modify specific properties of a fault-tolerant connection if necessary. When using more than one CP, you can also route the connections in this dialog box. This may be practical, because by default all connections are routed initially through the first CP. If all the connections are busy there, any further connections are routed via the second CP, etc.

You have to extend the monitoring time of the connection when you use long synchronization cables.

Example: If you are operating 5 fault-tolerant S7 connections with a monitoring time of 500 ms and short synchronization cables up to 10 m and you want to change these to long synchronization cables with a length of 10 km, you must increase the monitoring time to 1000 ms.

To ensure CIR capability of the fault tolerant system, you must activate the "Save connections prior to loading" option in Step 7 NetPro.

Programming

Fault-tolerant communication is supported on the fault-tolerant CPU and is implemented using S7 communication.

This is possible only within an S7 project/multiproject.

You program the fault-tolerant communication with STEP 7 using communication SFBs. These communication blocks can be used to transmit data over subnets (Industrial Ethernet, PROFIBUS). The communication SFBs integrated in the operating system enable an acknowledged data transmission. In addition to data transfer, you can also use other communication functions for controlling and monitoring the communication peer.

User programs written for S7 connections can also be used for fault-tolerant S7 connections without program modification. Cable and connection redundancy has no effect on the user program.

Note

For information on programming the communication, refer to the STEP 7 documentation (e.g., *Programming with STEP 7*).

The START and STOP communication functions act on exactly one CPU or on all CPUs of the fault-tolerant system (for more details refer to Reference Manual *System Software for S7-300/400, System and Standard Functions*).

Disruptions of a subconnection while communication jobs are active over fault-tolerant S7 connections can extend the runtime of these jobs.

Note

Downloading the connection configuration during operation

If you download a connection configuration during operation, established connections may be terminated.

16.10.1 Communication between fault-tolerant systems

Availability

The easiest way to increase the availability between linked systems is to use a redundant plant bus. This is set up with a duplex fiber-optic ring or a dual electrical bus system. The connected nodes may consist of simple standard components.

Availability can best be enhanced using a duplex fiber-optic ring. If a break of the two-fiber fiber-optic cable occurs, communication is maintained between the systems involved. The systems then communicate as if they were connected to a bus system (line). A ring topology basically contains two redundant components and automatically forms a 1-out-of-2 redundancy node. The fiber-optic network can also be set up in star topology as redundant bus.

If one electrical cable segment fails, communication between the participating systems is also upheld (1-out-of-2 redundancy).

The following examples illustrate the differences between a duplex fiber-optic ring and a dual electrical bus system.

Note

The number of connection resources required on the CPs depends on the network used.

If you implement a duplex fiber-optic ring (see figure below), two connection resources are required per CP. In contrast, only one connection resource is required per CP if a double electrical network (see figure after next) is used.

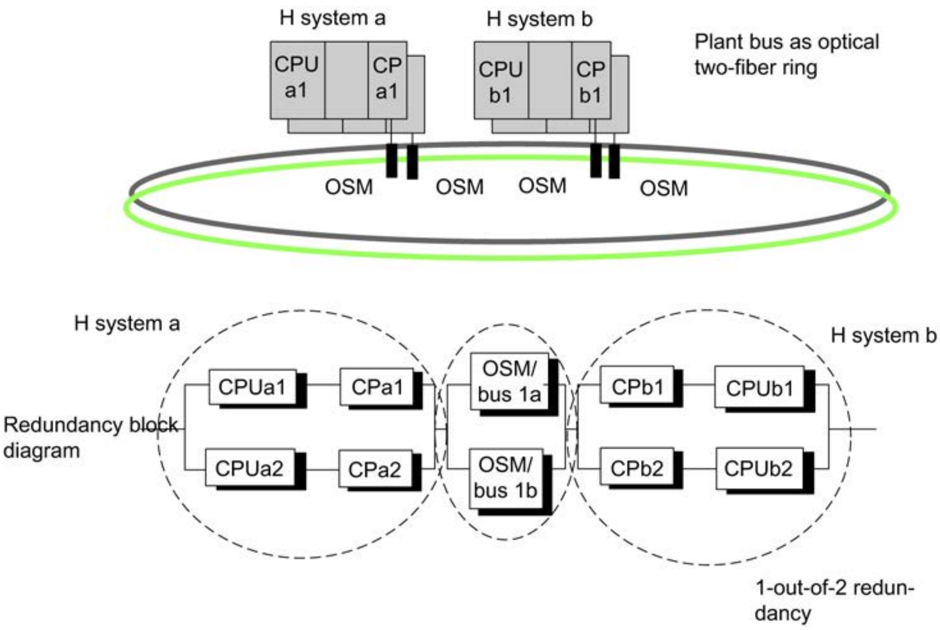


Figure 16-15 Example of redundancy with fault-tolerant system and redundant ring

Configuration view ≠ Physical view

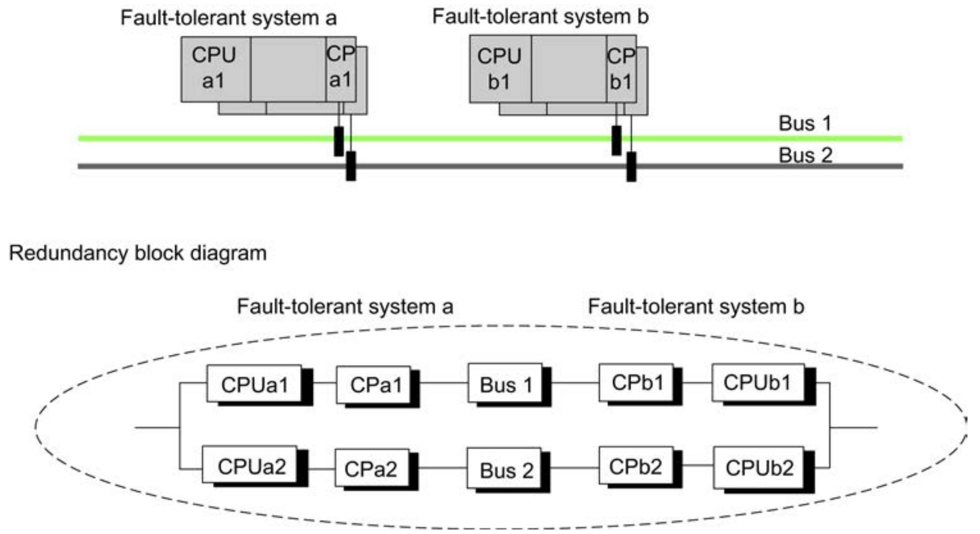


Figure 16-16 Example of redundancy with fault-tolerant system and redundant bus system

Configuration view = Physical view

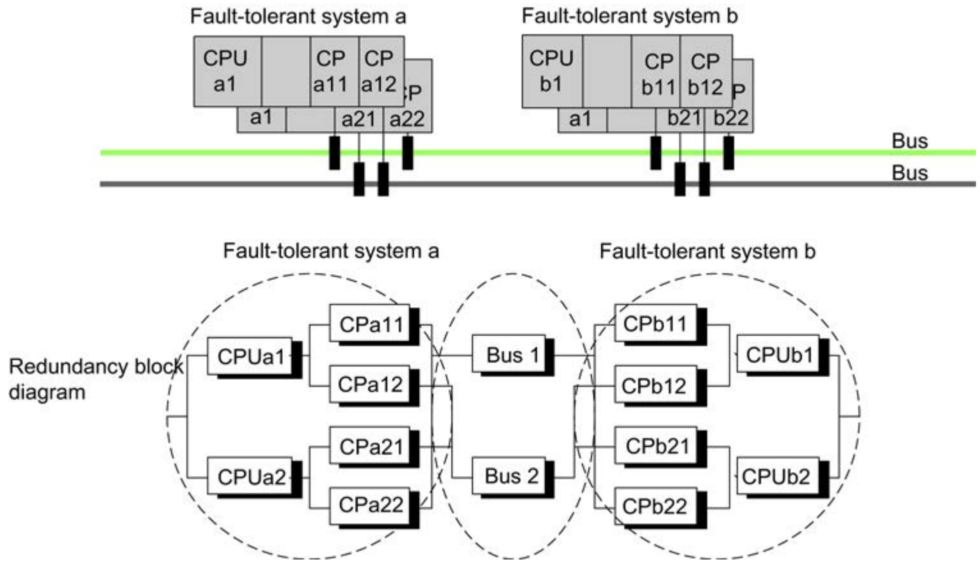


Figure 16-17 Example of fault-tolerant system with additional CP redundancy

Configuration view = Physical view

You decide during configuration if the additional CPs are used to increase resources or availability. This configuration is typically used to increase availability.

Note

Internal and external interface

Communication between fault-tolerant systems may only take place between internal interfaces or external interfaces (CP). Communication between internal interface and CP is not possible.

Response to failure

With a duplex optic-fiber ring, only a double error within a fault-tolerant system, e.g., CPUa1 and CPa2 in one system, leads to total failure of communication between the systems involved (see Figure 11-14).

If a double error, e.g., CPUa1 and CPb2, occurs in the first case of a redundant electrical bus system (see Figure 11-15), this results in a total failure of communication between the systems involved.

In the case of a redundant electrical bus system with CP redundancy (see Figure 11-16), only a double error within a fault-tolerant system, e.g., CPUa1 and CPa2, or a triple error, e.g., CPUa1, CPa22, and bus2, will result in a total failure of communication between the systems involved.

Fault-tolerant S7 connections

Any disruption of subconnections while communication jobs are active over fault-tolerant S7 connections leads to extended delay times.

16.10.2 Communication between fault-tolerant systems and a fault-tolerant CPU

Availability

Availability can be enhanced by using a redundant plant bus and by using a fault-tolerant CPU in a standard system.

If the communication peer is a fault-tolerant CPU, redundant connections can also be configured, in contrast to systems with a standard CPU.

Note

Fault-tolerant connections use two connection resources on CP b1 for the redundant connections. One connection resource each is occupied on CP a1 and CP a2 respectively. In this case, the use of further CPs in the standard system only serves to increase the resources.

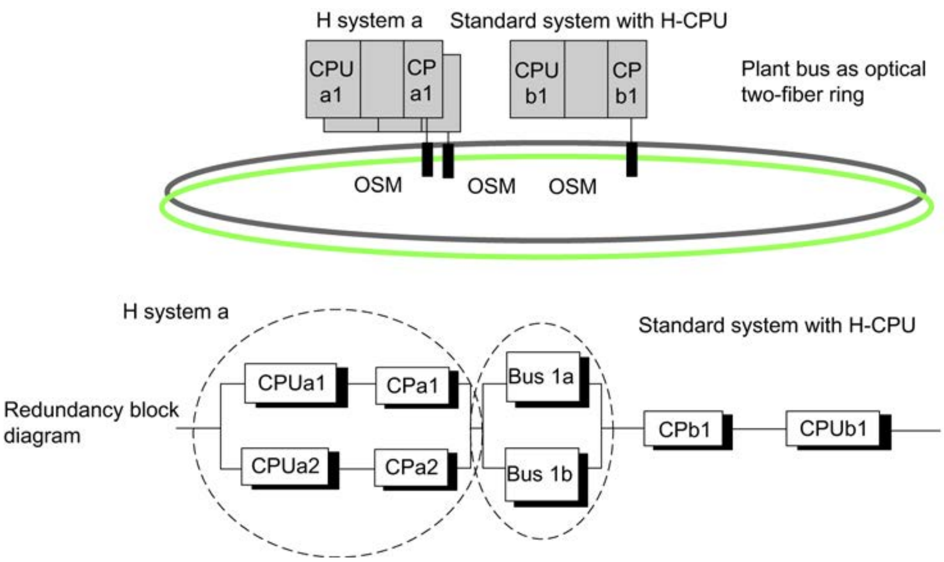


Figure 16-18 Example of redundancy with fault-tolerant system and fault-tolerant CPU

Response to failure

Double errors in the fault-tolerant system, i.e., CPUa1 and CPa2, or single errors in the standard system, i.e., CPUb1, lead to a total failure of communication between the systems involved. This can be seen in the previous figure.

16.10.3 Communication between fault-tolerant systems and PCs

Availability

When fault-tolerant systems are linked to a PC, the availability of the overall system is concentrated not only on the PCs (OS) and their data management, but also on data acquisition in the automation systems.

PCs are not fault-tolerant due to their hardware and software characteristics. They can be arranged redundantly within a system, however. The availability of such a PC (OS) system and its data management is ensured by means of suitable software such as WinCC Redundancy.

Communication takes place via fault-tolerant S7 connections.

The "S7-REDCONNECT" software package is required for fault-tolerant communication on a PC. S7-REDCONNECT supports the connection of a PC to a fiber-optic network with one CP, or to a redundant bus system with 2 CPs. Always use the latest version of this software.

Only Industrial Ethernet is supported for connecting PC systems. The SIMATIC Net software V 8.1.2 is required for connection via ISOonTCP. This corresponds to the configuration TCP/RFC1006 at the PC end.

Note

The PROFINET IO MRP (Media Redundancy Protocol) for PROFINET IO ring topologies is not supported by SIMATIC NET PC modules. Plant buses as duplex fiber-optic rings cannot be operated with MRP.

Configuring connections

The PC must be engineered and configured as a SIMATIC PC station. Additional configuration of fault-tolerant communication is not necessary at the PC end. The connection configuration is uploaded from the STEP 7 project to the PC station.

You can find out how to use STEP 7 to integrate fault-tolerant S7 communication for a PC into your OS system in the WinCC documentation.

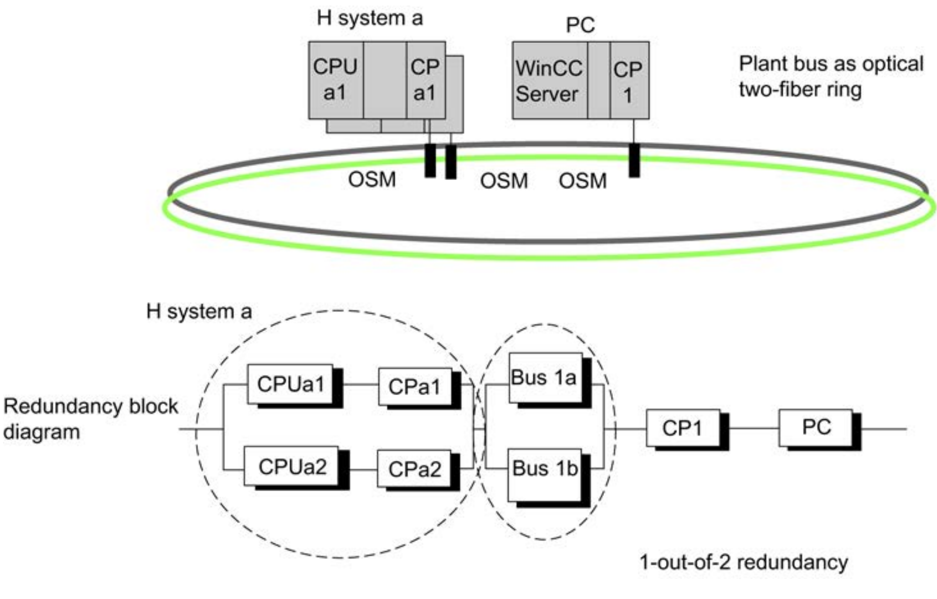


Figure 16-19 Example of redundancy with fault-tolerant system and redundant bus system

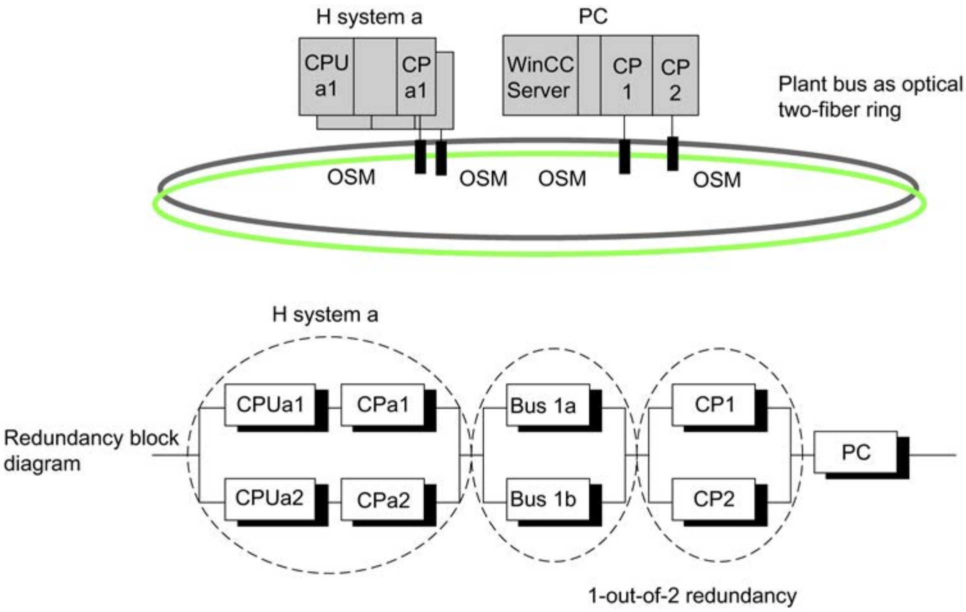


Figure 16-20 Example of redundancy with a fault-tolerant system, redundant bus system, and CP redundancy on PC.

Response to failure

Double errors in the fault-tolerant system, e.g., CPUa1 and CPa2, and failure of the PC result in a total failure of communication between the systems involved; see previous figures.

PC/PG as Engineering System (ES)

To be able to use a PC as Engineering System, you need to configure it under its name as a PC station in HW Config. The ES is assigned to a CPU and is capable of executing STEP 7 functions on that CPU.

If this CPU fails, communication between the ES and the fault-tolerant system is no longer possible.

16.11 Consistent data

16.11.1 Consistency of communication blocks and functions

On the S7-400H, communication jobs are not processed in the cycle control point but rather in fixed time slices during the program cycle.

The byte, word and double word data formats can always be processed consistently in the system, in other words, the transmission or processing of 1 byte, 1 word = 2 bytes or 1 double word = 4 bytes cannot be interrupted.

If the user program calls communication blocks, such as SFB 12 "BSEND" and SFB 13 "BRCV", which are only used in pairs and access shared data, access to this data area can be coordinated by the user by means of the "DONE" parameter, for example. The consistency of data transmitted locally with these communication blocks can thus be ensured in the user program.

In contrast, S7 communication functions do not require a block such as SFB 14 "GET", SFB 15 "PUT", in the user program of the target device. Here, you must make allowance for the volume of consistent data in the programming phase.

Access to work memory of the CPU

The communication functions of the operating system access the CPU's work memory in fixed block lengths. Blocks for S7-400H CPUs have a variable length of up to 472 bytes.

This ensures that the interrupt response time is not prolonged due to communication load. Because this access is performed asynchronously to the user program, you cannot transmit an unlimited number of bytes of consistent data.

The rules to ensure data consistency are described below.

16.11.2 Consistency rules for SFB 14 "GET" or read variable, and SFB 15 "PUT" or write variable

SFB 14

The data are received consistently if you observe the following points:

Evaluate the entire, currently used part of the receive area RD_i before you activate a new request.

SFB 15

When a send operation is initiated (rising edge at REQ), the data to be sent from the send areas SD_i are copied from the user program. You can write new data to these areas after the block call command without corrupting the current send data.

Note

Completion of transfer

The send operation is not completed until the status parameter DONE assumes value 1.

16.11.3 Consistent reading and writing of data from and to DP standard slaves/IO devices

Reading data consistently from a DP standard slave using SFC 14 "DPRD_DAT"

Using SFC 14 "DPRD_DAT" (read consistent data of a DP standard slave), you can consistently read the data of a DP standard slave of IO device.

if no error occurred during the data transmission, the data read is entered into the destination area defined by RECORD.

The destination area must have the same length as the one you have configured for the selected module with STEP 7.

By calling SFC 14 you can only access the data of one module/DP identifier at the configured start address.

For information on SFC 14, refer to the corresponding online help and to Manual "System and Standard Functions".

Note

Evaluate the entire currently used part of the receive area RD_i before you activate a new job.

Writing data consistently to a DP standard slave using SFC 15 "DPWR_DAT"

Using SFC 15 "DPWR_DAT" (write consistent data to a DP standard slave), you transmit the data in RECORD consistently to the addressed DP standard slave or IO device.

The source area must have the same length as the one you configured for the selected module with STEP 7.

For information on SFC 15, refer to the corresponding online help and Manual "System and Standard Functions".

Note

When a send operation is activated (positive edge at REQ), the data to be transmitted from the send areas SD_i is copied from the user program. You can write new data to these areas after the block call command without corrupting the current send data.

Upper limits for the transfer of consistent user data to a DP slave

The PROFIBUS DP standard defines upper limits for the transfer of consistent user data to a DP slave. For this reason a maximum of 64 words = 128 bytes of user data can be consistently transferred in a block to the DP standard slave.

You can define the length of the consistent area in your configuration. In the special identification format (SIF), you can define a maximum length of consistent data of 64 words = 128 bytes: 128 bytes for inputs and 128 bytes for outputs. A greater length is not possible.

This upper limit applies only to pure user data. Diagnostics and parameter data are grouped to form complete data records, and are thus always transferred consistently.

In the general identification format (GIF), you can define a maximum length of consistent data of 16 words = 32 bytes; 32 bytes for inputs, and 32 bytes for outputs. A greater length is not possible.

In this context, consider that a CPU 41x operating as DP slave generally has to support its configuration at an external master (implementation by means of GSD file) using the general identification format. A CPU 41x operated as DP slave thus supports only a maximum length of 16 words = 32 bytes in its transfer memory for PROFIBUS DP.

Note

The PROFIBUS DP standard defines the upper limits for transmission of consistent user data. Typical DP standard slaves adhere to this upper limit. Older CPUs (<1999) had CPU-specific restrictions in terms of the transmission of consistent user data. The maximum length of data this CPU can consistently read and write to and from a DP standard slave is specified in your technical specifications, keyword "DP Master – User data per DP slave". With this value, newer CPUs exceed the length of data that a DP standard slave provides or receives.

Upper limits of the length of consistent user data transmitted to an IO Device

The length of consistent user data that you can transmit to an IO device is limited to 1025 bytes (= 1024 bytes user data + 1 byte secondary value). Irrespective of whether you can transmit more than 1024 bytes to an IO device, the transmission of consistent data is still limited to 1024 bytes.

When operating in PN-IO mode, the length of data transmission via CP 443-1 is limited to 240 bytes.

16.12 Link-up and update sequence

There are two types of link-up and update operation:

- Within a "normal" link-up and update operation, the fault-tolerant system will change over from solo operation to redundant system state. The two CPUs then process the same program synchronously.
- When a link up and update operation takes place with master/standby changeover, the second CPU with modified components can assume control over the process. Either the hardware configuration or the operating system may have been modified.

  In order to return to redundant system state, a "normal" link-up and update operation must be performed subsequently.

How to start the link-up and update operation?

Initial situation: Solo operation, i.e., only one of the CPUs of a fault-tolerant system connected via fiber-optic cables is in RUN operating state.

You can initiate the link-up and update operation for achieving the redundant system state as follows:

- POWER ON the standby if prior to POWER OFF the CPU was not in STOP operating state.
- Operator input on the PG/ES.

You can only start a link-up and update operation with master/standby changeover by an operator input on the PG/ES.

Note

If a link-up and update operation is interrupted on the standby CPU (for example due to POWER OFF, STOP), this may cause data inconsistency and lead to a memory reset request on this CPU.

The link-up and update functions are possible again after a memory reset on the standby.

Flow chart of the link-up and update operation

The figure below outlines the general sequence of the link-up and update. In the initial situation, the master is in solo operation. In the figure, CPU 0 is assumed to be the master CPU.

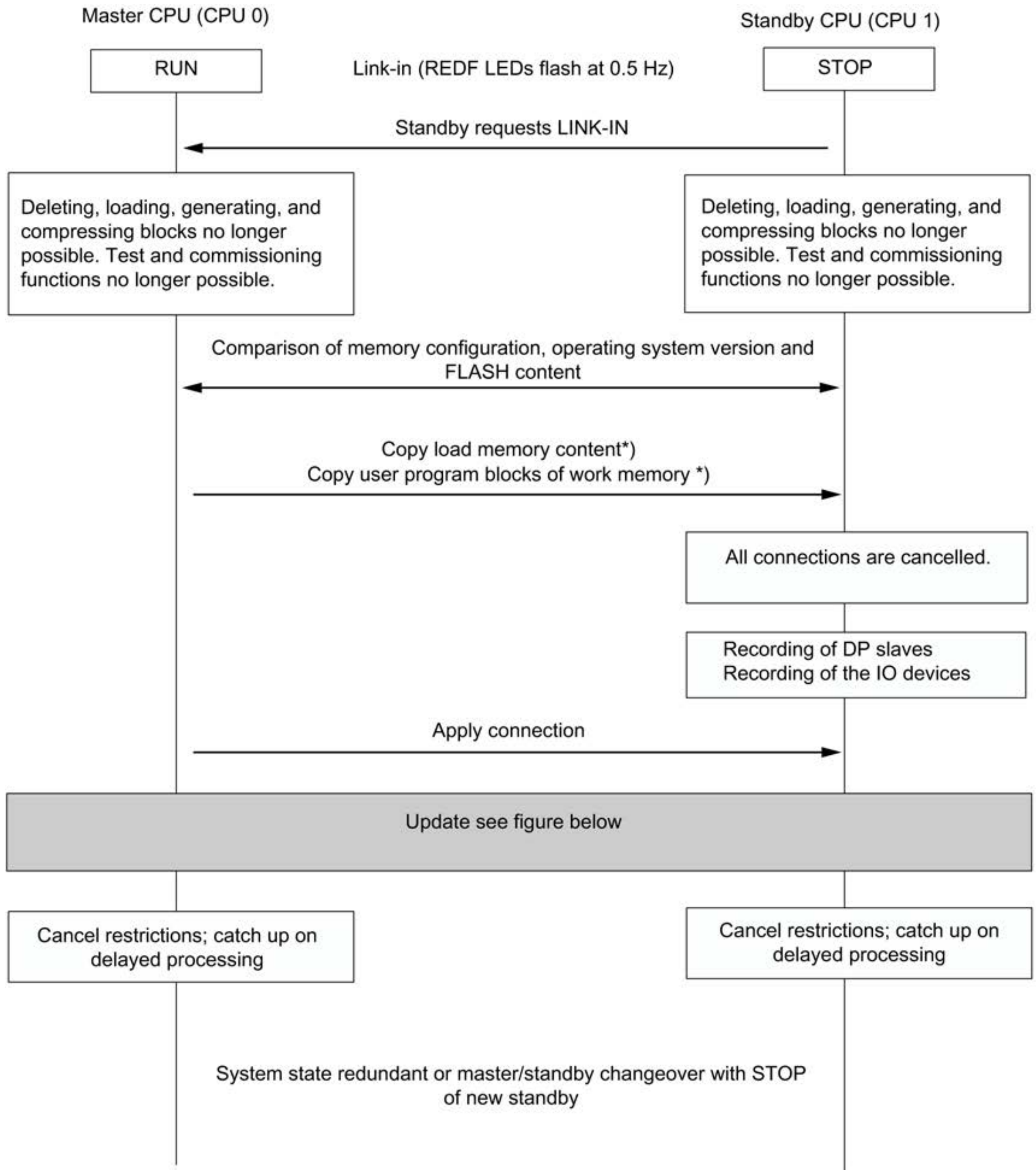


Figure 16-21 Sequence of link-up and update

*) If the "Switchover to CPU with modified configuration" option is set, the content of the load memory is not copied; what is copied from the user program blocks of the work memory (OBs, FCs, FBs, DBs, SDBs) of the master CPU is listed in Chapter Switch to CPU with modified configuration or expanded memory configuration (Page 265)

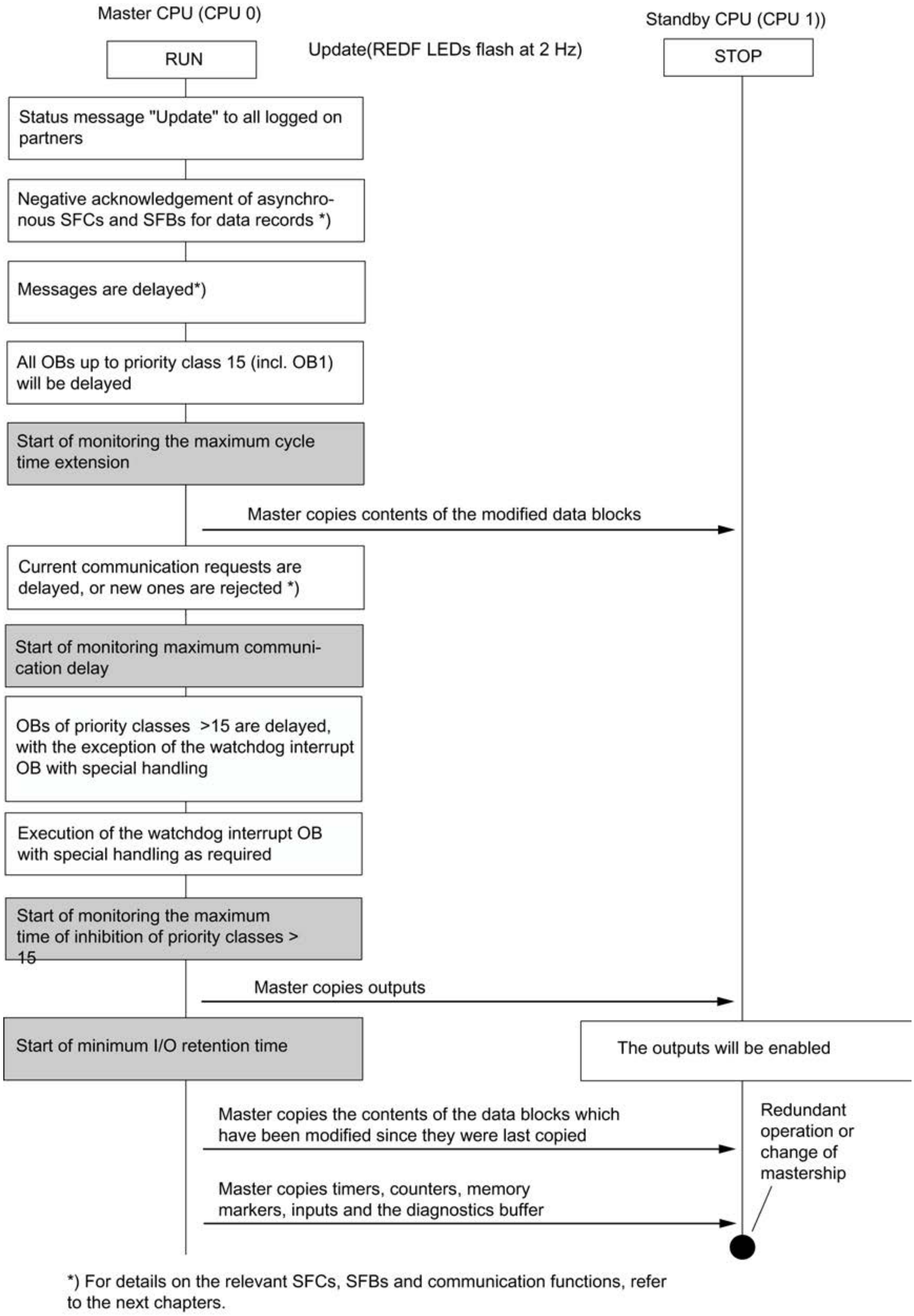


Figure 16-22 Update sequence

Minimum duration of input signals during update

Program execution is stopped for a certain time during the update (the sections below describe this in greater detail). To ensure that the CPU can reliably detect changes to input signals during the update, the following condition must be satisfied:

Minimum signal duration > 2 × time required for I/O update (DP and PNIO only)
+ call interval of the priority class
+ execution time for the program of the priority class
+ update time
+ execution time for programs of higher-priority classes

Example:

Minimum signal duration of an input signal that is evaluated in a priority class > 15 (e.g., OB 40).

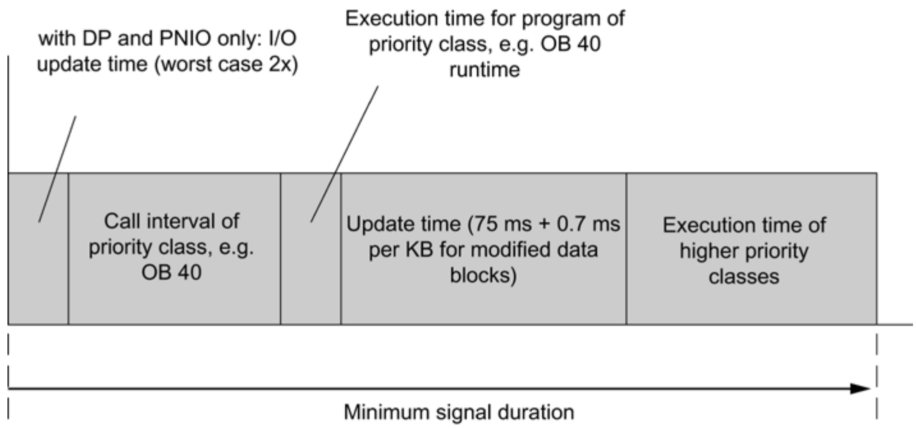


Figure 16-23 Example of minimum signal duration of an input signal during the update

16.12.1 Link-up sequence

For the link-up sequence, you need to decide whether to carry out a master/standby changeover, or whether the redundant system state is to be achieved after that.

Link-up with the objective of achieving the redundant system state

To exclude differences in the two subsystems, the master and the standby CPU run the following comparisons.

The following are compared:

1. Consistency of the memory configuration
2. Consistency of the operating system version
3. Consistency of the contents in load memory

If 1. or 2. are inconsistent, the standby CPU switches to STOP and outputs an error message.

If 3. is inconsistent, the user program in the load memory in RAM is copied from the master CPU to the standby CPU.

Link-up with master/standby changeover

In STEP 7 you can select one of the following options:

- "Switch to CPU with modified configuration"
- "Switchover to CPU with expanded memory configuration"
- "Switchover to CPU with modified operating system"
- "Switchover to CPU with modified hardware version"
- "Switchover to CPU via only one intact redundant link"

Switch to CPU with modified configuration

You may have modified the following elements on the standby CPU:

- The hardware configuration

No blocks are transferred from the master to the standby during the link-up. The exact circumstances are described in Chapter Switch to CPU with modified configuration or expanded memory configuration (Page 265).

The steps to be performed for the scenarios indicated above (modification of hardware configuration, changing of the load memory type) are described in Chapter Failure and replacement of components during redundant operation (Page 167).

Note

Even though you have not modified the hardware configuration on the standby CPU, there is nevertheless a master/standby changeover and the previous master CPU switches to STOP.

16.12.2 Update sequence

What happens during updating?

The execution of communication functions and OBs is restricted section by section during updating. Likewise, all the dynamic data (content of the data blocks, timers, counters, and bit memories) are transferred to the standby CPU.

Update procedure:

1. Until the update is completed, all asynchronous SFCs and SFBs which access data records of I/O modules (SFCs 13, 51, 52, 53, 55 to 59, SFB 52 and 53) are acknowledged as "negative" with the return values W#16#80C3 (SFCs 13, 55 to 59, SFB 52 and 53) or W#16#8085 (SFC 51). When these values are returned, the jobs should be repeated by the user program.
2. Message functions are delayed until the update is completed (see list below).

3. The execution of OB 1 and of all OBs up to priority class 15 is delayed.

   In the case of cyclic interrupts, the generation of new OB requests is disabled, so no new cyclic interrupts are stored and as a result no new request errors occur.

   The system waits until the update is completed, and then generates and processes a maximum of one request per cyclic interrupt OB. The time stamp of delayed cyclic interrupts cannot be evaluated.
4. Transfer of all data block contents modified since link-up.
5. The following communication jobs are acknowledged negatively:
   – Reading/writing of data records using HMI functions
   – Reading diagnostic information using STEP 7
   – Disabling and enabling messages
   – Logon and logoff for messages
   – Acknowledgement of messages
6. Initial calls of communication functions are acknowledged negatively. These calls manipulate the work memory, see also *System Software for S7-300/400, System and Standard Functions*. All remaining communication functions are executed with delay, after the update is completed.
7. The system disables the generation of new OB requests for all OBs of priority class > 15, so new interrupts are not saved and as a result do not generate any request errors.

   Queued interrupts are not requested again and processed until the update is completed. The time stamp of delayed interrupts cannot be evaluated.

   The user program is no longer processed and there are no more I/O updates.
8. Generating the start event for the cyclic interrupt OB with special handling.

Note

The cyclic interrupt OB with special handling is particularly important in situations where you need to address certain modules or program parts within a specific time. This is a typical scenario in fail-safe systems. For details, refer to the *S7-400F and S7-400FH Automation Systems* and *S7-300 Automation Systems, Fail-safe Signal Modules* manuals.

To prevent an extension of the special cyclic interrupt, the cyclic alarm OB with special handling must be assigned top priority.

---

9. Transfer of outputs and of all data block contents modified again. Transfer of timers, counters, bit memories, and inputs. Transfer of the diagnostic buffer.

   During this data synchronization, the system interrupts the clock pulse for cyclic interrupts, time-delay interrupts and S7 timers. This results in the loss of any synchronism between cyclic and time-of-day interrupts.

10. Cancel all restrictions. Delayed interrupts and communication functions are executed. All OBs are executed again.

   A constant bus cycle time compared with previous calls can no longer be guaranteed for delayed cyclic interrupt OBs.

   Note

   Process interrupts and diagnostic interrupts are stored by the I/O devices. Such interrupt requests issued by distributed I/O modules are executed when the block is re-enabled. Any such requests by central I/O modules can only be executed provided the same interrupt request did not occur repeatedly while the status was disabled.

If the PG/ES requested a master/standby changeover, the previous standby CPU assumes master mode and the previous master CPU goes into STOP when the update is completed. Both CPUs will otherwise go into RUN (redundant system mode) and execute the user program in synchronism.

When there is a master/standby changeover, in the first cycle after the update OB 1 is assigned a separate identifier (see *System Software for S7-300/400, System and Standard Functions* Reference Manual). For information on other aspects resulting from modifying the configuration, refer to section Switch to CPU with modified configuration or expanded memory configuration (Page 265).

Delayed message functions

The listed SFCs, SFBs and operating system services trigger the output of messages to all logged-on partners. These functions are delayed after the start of the update:

- SFC 17 "ALARM_SQ", SFC 18 "ALARM_S", SFC 107 "ALARM_DQ", SFC 108 "ALARM_D"
- SFC 52 "WR_USMSG"
- SFB 31 "NOTIFY_8P", SFB 33 "ALARM", SFB 34 "ALARM_8", SFB 35 "ALARM_8P", SFB 36 "NOTIFY", SFB 37 "AR_SEND"
- Process control alarms
- System diagnostics messages

From this time on, any requests to enable and disable messages by SFC 9 "EN_MSG" and SFC 10 "DIS_MSG" are rejected with a negative return value.

Communication functions and resulting jobs

After it has received one of the jobs specified below, the CPU must in turn generate communication jobs and output them to other modules. These include, for example, jobs for reading or writing parameterization data records from/to distributed I/O modules. These jobs are rejected until the update is completed.

- Reading/writing of data records using HMI functions
- Reading data records using SSL information
- Disabling and enabling messages
- Logon and logoff for messages
- Acknowledgement of messages

Note

The last three of the functions listed are registered by a WinCC system, and automatically repeated when the update is completed.

16.12.3 Switch to CPU with modified configuration or expanded memory configuration

Switchover to CPU with modified configuration

You may have modified the following elements on the standby CPU:

- The hardware configuration
  The steps to be performed for this scenario are described in Chapter Failure and replacement of components during redundant operation (Page 167).

Note

Even though you have not modified the hardware configuration on the standby CPU, there is nevertheless a master/standby changeover and the former master CPU switches to STOP.

When you initiate the link-up and update operation from STEP 7 with the "Switch to CPU with modified configuration" option, the system reacts as follows with respect to handling of the memory contents.

Load memory

The contents of the load memory are not copied from the master to the standby CPU.

Work memory

The following components are transferred from the work memory of the master CPU to the standby CPU:

- Contents of all data blocks assigned the same interface time stamp in both load memories and whose attributes "read only" and "unlinked" are not set.
- Data blocks generated in the master CPU by SFCs.

  The DBs generated in the standby CPU by means of SFC are deleted.

  If a data block with the same number is also contained in the load memory of the standby CPU, the link-up operation is cancelled with an entry in the diagnostics buffer.
- Process images, timers, counters, and bit memories

If there is insufficient memory, link-up is cancelled with an entry in the diagnostics buffer.

The status of SFB instances of S7 communication contained in modified data blocks is restored to the status prior to their initial call.

Note

When changing over to a CPU with modified configuration, the size of load memories in the master and reserve may be different.

RAM and load memory

During the link-up, the user program blocks (OBs, FCs, FBs, DBs, SDBs) of the master are transferred from the load memory and work memory to the reserve.

16.12.4 Disabling of link-up and update

Link-up and update entails a cycle time extension. This includes a period during which no I/O updates are performed; see Chapter Time monitoring (Page 110). You must pay special attention to this if you are using distributed I/O and a master/standby changeover occurs after the update (thus, when the configuration is modified during operation).

⚠ CAUTION
Always perform link-up and update operations when the process is not in a critical state.

You can set specific start times for link-up and update operations at SFC 90 "H_CTRL". For detailed information on this SFC, refer to Manual *System Software for S7-300/400, System and Standard Functions*.

Note

If the process tolerates cycle time extensions at any time, you do not need to call SFC 90 "H_CTRL".

The CPU does not perform a self-test during link-up and updating. If you use a fail-safe user program, you should avoid any excessive delay for the update operation. For more details, refer to Manual *S7-400F and S7-400FH Automation Systems*.

Example of a time-critical process

A slide block with a 50 mm cam moves on an axis at a constant velocity
v = 10 km/h = 2.78 m/s = 2.78 mm/ms. A switch is located on the axis. So the switch is actuated by the cam for the duration of Δt = 18 ms.

For the CPU to detect the actuation of the switch, the inhibit time for priority classes > 15 (see below for definition) must be significantly below 18 ms.

With respect to maximum inhibit times for operations of priority class > 15, STEP 7 only supports settings of 0 ms or between 100 and 60000 ms, so you need to work around this by taking one of the following measures:

- Shift the start time of link-up and updating to a time at which the process state is non-critical . Use SFC 90 "H_CTRL" to set this time (see above).
- Use a considerably longer cam and/or substantially reduce the approach velocity of the slide block to the switch.

16.13 The user program

The rules of developing and programming the user program for the standard S7-400 system also apply to the S7-400H.

In terms of user program execution, the S7-400H behaves in the same manner as a standard system. The synchronization functions are integrated in the operating system and are executed automatically in the background. You do not need to consider these functions in your user program.

In redundant operation, the user programs are stored identically on both CPUs and are executed in event-synchronous mode.

However, we offer you several specific blocks for optimizing your user program, e.g., in order to improve its response to the extension of cycle times due to updates.

Specific blocks for S7–400H

In addition to the blocks that can be used both in S7-400 and in S7-400H, there are additional blocks for S7-400H. You can use these blocks to influence redundancy functions.

You can react to redundancy errors of the S7-400H using the following organization blocks:

- OB 70, I/O redundancy errors
- OB 72, CPU redundancy errors

SFC 90 "H_CTRL" can be used to influence fault-tolerant systems as follows:

- You can disable interfacing in the master CPU.
- You can disable updating in the master CPU.
- You can remove, resume or immediately start a test component of the cyclic self-test.
- You can execute a programmed master-standby changeover. The following changeovers are possible:
  – The current standby CPU becomes the master CPU.
  – The CPU in rack 0 becomes a master CPU.
  – The CPU in rack 1 becomes a master CPU.

Additional information

For detailed information on programming the blocks described above, refer to the STEP 7 Online Help.

16.14 Other options for connecting redundant I/Os

Redundant I/O at user level

If you cannot use the redundant I/O supported by the system (Chapter Connecting redundant I/O to the PROFIBUS DP interface (Page 68)), for example, because the module to be used redundantly is not in the list of supported components, you can also implement the use of redundant I/O at the user level.

Configurations

The following redundant I/O configurations are supported:

1. Redundant configuration with one-sided central and/or distributed I/O.

   For this purpose, one signal module each is inserted into the CPU 0 and CPU 1 subsystems.

2. Redundant configuration with switched I/O

   One signal module each is inserted into two ET 200M distributed I/O devices with active backplane bus.

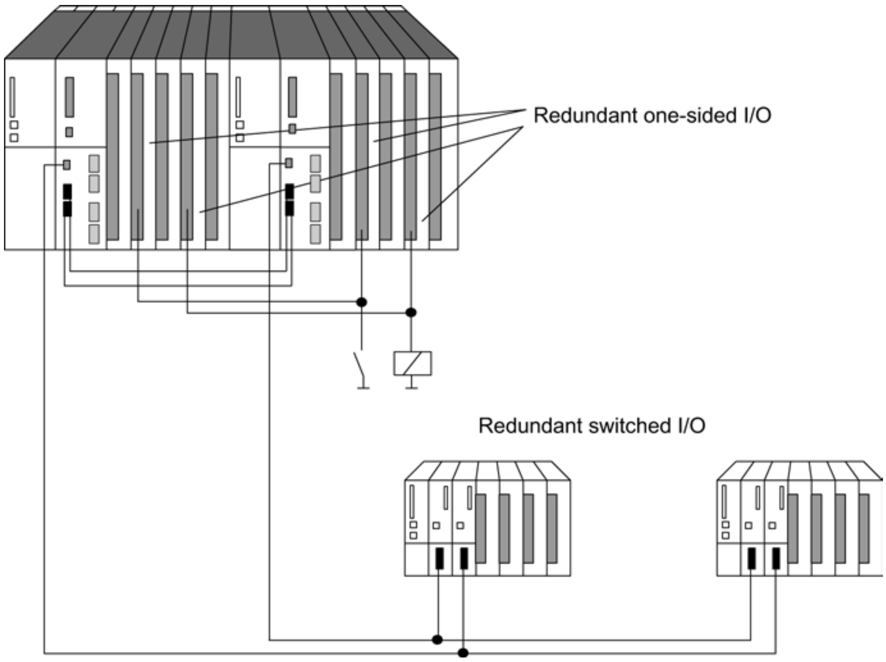


Figure 16-24 Redundant one-sided and switched I/O

Note

When using redundant I/O, you may need to add time to the calculated monitoring times; see Chapter Determining the monitoring times (Page 113)

Hardware configuration and project engineering of the redundant I/O

Strategy recommended for use of redundant I/O:

1. Use the I/O as follows:
   – in a one-sided configuration, one signal module in each subsystem
   – in a switched configuration, one signal module each in two ET 200M distributed I/O devices.
2. Wire the I/O in such a way that it can be addressed by both subsystems.
3. Configure the signal modules so that they have different logical addresses.

Note

It is not advisable to configure the input and output modules with the same logical addresses. Otherwise, in addition to the logical address, you will also need to query the type (input or output) of the defective module in OB 122.

The user program must update the process image for redundant one-sided output modules even in solo operation (e.g., direct accesses). If you use process image partitions, the user program must update them (SFC 27 "UPDAT_PO") in OB 72 (recovery of redundancy). The system would otherwise first output old values to the single-channel one-sided output modules of the standby CPU on the transition to redundant system state.

Redundant I/O in the user program

The sample program below shows the use of two redundant digital input modules:

- Module A in rack 0 with logical start address 8 and
- module B in rack 1 with logical start address 12.

One of the two modules is read in OB 1 by direct access. For the following it is generally assumed that the module in question is A (value of variable MODA is TRUE). If no error occurred, processing continues with the value read.

If an I/O area access error has occurred, module B is read by direct access ("second try" in OB 1). If no error occurred, processing of module B continues with the value read. However, if an error has also occurred here, both modules are currently defective, and operation continues with a substitute value.

The sample program is based on the fact that following an access error on module A and its replacement, module B is always processed first in OB 1. Module A is not processed first again in OB 1 until an access error occurs on module B.

Note

The MODA and IOAE_BIT variables must also be valid outside OB 1 and OB 122. The ATTEMPT2 variable, however, is used only in OB 1.

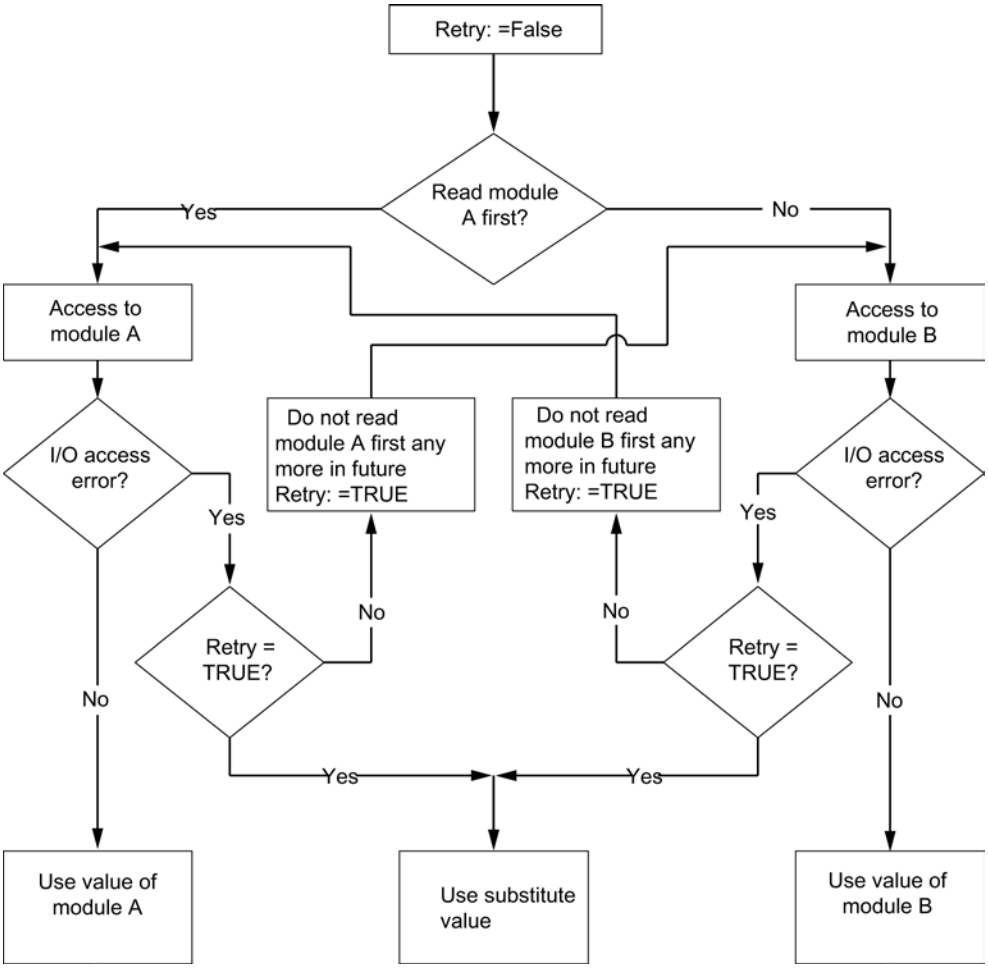


Figure 16-25 Flow chart for OB 1

Monitoring times during link-up and update

Note

If you have made I/O modules redundant and have taken account of this in your program, you may need to add an overhead to the calculated monitoring times so that no bumps occur at output modules (in HW Config -> Properties CPU -> H Parameter).

An overhead is only required if you operate modules from the following table as redundant modules.

Table 16- 8 For the monitoring times with redundant I/O

Module type	Overhead in ms
ET200M: Standard output modules	2
ET200M: HART output modules	10
ET200M: F-output modules	50

Follow the steps below:

- Calculate the overhead from the table. If you use several module types from the table redundantly, apply the largest overhead.
- Add this to all of the monitoring times calculated so far.

16.15 Cycle and response times of the CPU 410-5H

16.15.1 Cycle time

This chapter describes the decisive factors in the cycle time, and how to calculate it.

Definition of cycle time

The cycle time represents the time that the operating system needs to execute a program, that is, one OB 1 cycle, including all program sections and system activities interrupting this cycle.

This time is monitored. The CPU 410-5H has a fixed cycle monitoring of 6 seconds.

Time slice model

Cyclic program processing, and therefore also user program processing, is based on time slices. To demonstrate the processes, let us presume a global time slice length of exactly 1 ms.

Process image

During cyclic program execution, the CPU requires a consistent image of the process signals. To ensure this, the process signals are read/written prior to program execution. During the subsequent program execution, the CPU does not access the signal modules directly when addressing the input (I) and output (O) address areas. It accesses the CPU's system memory area containing the image of the inputs and outputs.

Sequence of cyclic program processing

The table below shows the various phases in cyclic program execution.

Table 16- 9 Cyclic program processing

Step	Sequence
1	The operating system initiates the scan cycle monitoring time.
2	The CPU copies the values from the process output images to the output modules.
3	The CPU reads the status of inputs of the input modules, and then updates the process image of the inputs.
4	The CPU processes the user program in time slices and executes the instructions specified in the program.
5	At the end of a cycle, the operating system executes pending tasks, e.g., loading and deleting of blocks.
6	Finally, on expiration of any given minimum cycle time, the CPU returns to the start of the cycle and restarts cycle monitoring.

Elements of the cycle time

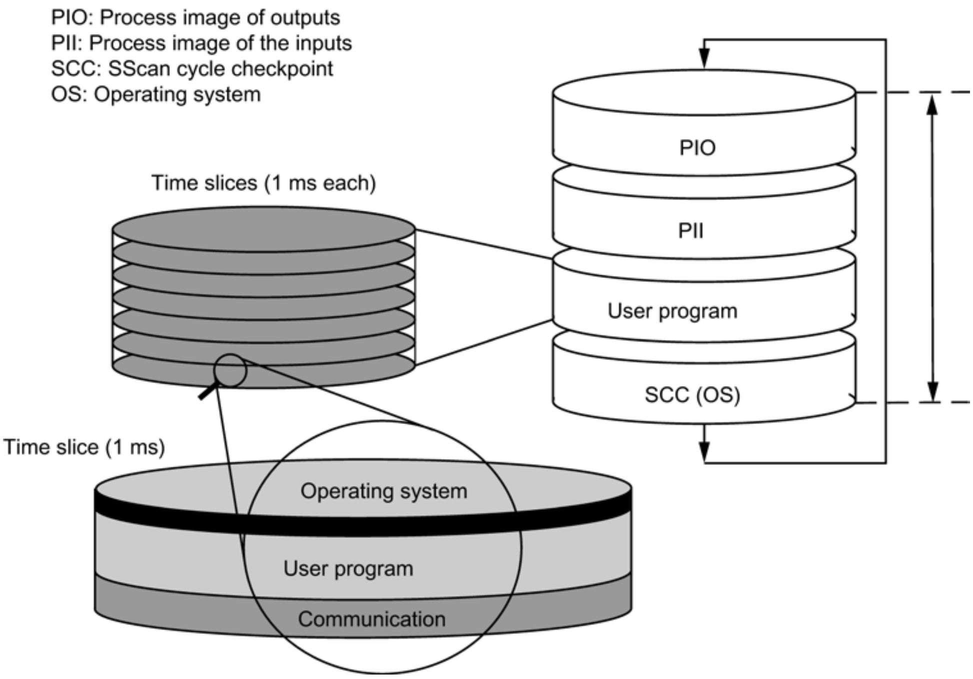


Figure 16-26 Elements and composition of the cycle time

16.15.2 Calculating the cycle time

Extending the cycle time

The cycle time of a user program is extended by the factors outlined below:

- Time-based interrupt processing
- Hardware interrupt processing (see also Chapter Interrupt response time (Page 288))
- Diagnostics and error processing (see also Chapter Example of calculation of the interrupt response time (Page 290))
- Communication via the integrated PROFINET IO interface and CPs connected by means of the communication bus
  (e.g.: Ethernet, Profibus, DP) as a factor in communication load
- Special functions such as monitoring and modifying variables
  or the block status
- Transfer and deletion of blocks, compressing of the user program memory
- Runtime of signals using the synchronization cable

Influencing factors

The table below shows the factors influencing the cycle time.

Table 16- 10 Factors influencing cycle time

Factors	Remark
Transfer time for the process output image (POI) and process input image (PII)	See tables from 19-3 onwards
User program execution time	This value is calculated based on the execution times of the various statements (see the *S7-400 statement list*).
Operating system execution time at the cycle control point	See Table 19-7
Extension of cycle time due to communication load	You configure the maximum permitted communication load on the cycle as a percentage in **STEP 7** (Manual *Programming with STEP 7*). See Chapter Communication load (Page 277).
Load on cycle times due to interrupts	Interrupt requests can always stop user program execution. See Table 19-8

Process image update

The table below shows the time a CPU requires to update the process image (process image transfer time). The specified times only represent "ideal values", and may be extended accordingly by any interrupts or communication of the CPU.

Calculation of the transfer time for process image update:

K+ portion in the central controller (from row A in the following table)
+ portion in the expansion device with local connection (from row B)
+ portion in the expansion device with remote connection (from row C)
+ portion via integrated DP interface (from row D1)
+ portion via external DP interface (from row D2)
portion of consistent data via integrated DP interface (from row E1)
+ portion of consistent data via external DP interface (from row E2)
+ portion in PN/IO area for the integrated PROFINET IO interface (from row F)
+ portion for each submodule with 32 byte of consistent data for the integrated PROFINET IO interface (from row G)

= Transfer time for process image update

The tables below show the various portions of the transfer time for a process image update (process image transfer time). The specified times only represent "ideal values", and may be extended accordingly by any interrupts or communication of the CPU.

Table 16- 11 Portion of the process image transfer time, CPU 410-5H

	Portions	CPU 410-5H stand-alone mode	CPU 410-5H redundant
K	Base load	2 μs	3 μs
A *)	In the central controller Read/write byte/word/double word	7.3 μs	15 μs
B *)	In the expansion unit with local link Read/write byte/word/double word	20 μs	26 μs
C *)**)	In the expansion unit with remote link Read/write byte/word/double word	45 μs	50 μs
D1	In the DP area for the integrated DP interface Read byte/word/double word	0.4 μs	10 μs
D2 ***)	In the DP area for the external DP interfaces Read/write byte/word/double word	5 μs	15 μs
E1	Consistent data in the process image for the integrated DP interface Read/write data	8 μs	30 μs
E2	Consistent data in the process image for the external DP interface (CP 443–5 extended) Read write	80 μs 60 μs	100 μs 70 μs
F	In the PNIO area for the integrated PROFINET IO interface Read/write for each byte/word/double word	2 μs	15 μs
G	Per submodule with 32 bytes of consistent data for the integrated PROFINET IO interface	8 μs	30 μs
*) In the case of I/O inserted into the central controller or expansion device, the specified value includes the execution time for the I/O module The module data is updated with the minimum number of accesses. (example: 8 bytes result in 2 double word accesses; 16 bytes in 4 double word accesses.)			
**) Measured with IM460-3 and IM461-3 at a link length of 100 m			
***) Measured with modules with 1 byte of user data, e.g., DI 16.			

Extending the cycle time

The calculated cycle time of a S7-400H CPU must be multiplied by a CPU-specific factor. The table below lists these factors:

Table 16- 12 Extending the cycle time

Startup	CPU 410-5H stand-alone mode	CPU 410-5H redundant
Factor	1.05	1.2

Long synchronization cables may increase cycle times. This extension can have the factor 2 - 5 with a cable length of 10 km.

Operating system execution time at the cycle control point

The table below shows the operating system execution time at the cycle checkpoint of the CPUs.

Table 16- 13 Operating system execution time at the cycle control point

Sequence	CPU 410-5H stand-alone mode	CPU 410-5H redundant
Cycle control at the SCCP	25 - 330 µs ∅ 30 µs	120 - 600 µs ∅ 135 µs

Extended cycle time due to nested interrupts

Table 16- 14 Extended cycle time due to nested interrupts

CPU	Hardware interrupt	Diagnostic interrupt	Time-of-day interrupt	Delay interrupt	Cyclic interrupt	Programming error	I/O access error	Asynchro-nous error
CPU 410-5H stand-alone mode	75 µs	40 µs	50 µs	40 µs	40 µs	20 µs	20 µs	55 µs
CPU 410-5H redundant	180 µs	70 µs	200 µs	120 µs	120 µs	90 µs	45 µs	130 µs

The program runtime at interrupt level must be added to this time extension.

If several interrupts are nested, their times must be added together.

16.15.3 Communication load

The operating system of the CPU provides the configured percentage of the overall CPU processing capacity to the communication on a continuous basis (time slice technique). If this processing capacity is not required for communication, it is made available to the other processing.

In the hardware configuration you can specify a communication load value between 5% and 50%. The default value is 20%.

This percentage is to be interpreted as a mean value, i.e., within one time slice, the communication portion may be significantly greater than 20%. The communication portion is then only a few % or 0% in the next time slice.

The formula below describes the influence of communication load on the cycle time:

$$\text{Actual cycle time} = \text{Cycle time} \times \frac{100}{100 - \text{"Configured communication load in \%"}}$$

Round the result up to the next highest integer !

Figure 16-27 Formula: Influence of communication load

Data consistency

The user program is interrupted to process communications. This interruption can be triggered after any command. These communication jobs may lead to a change in user data. As a result, data consistency cannot be ensured over several accesses.
How to ensure data consistency in operations comprising more than one command is described in Chapter "Consistent data".

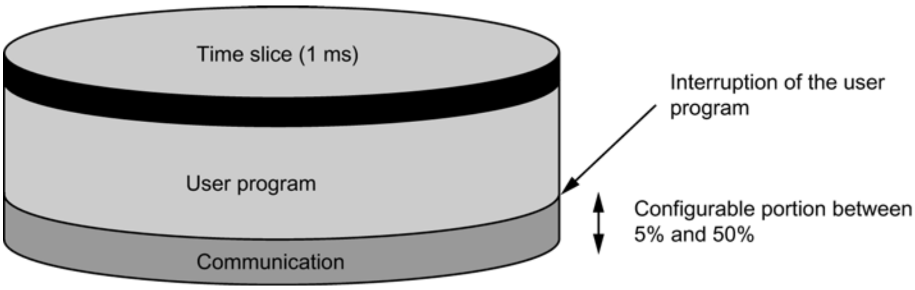


Figure 16-28 Distribution of a time slice

The operating system takes a certain portion of the remaining time slice for internal tasks. This portion is included in the factor defined in the tables starting at 16-3.

Example: 20% communication load

In the hardware configuration you have set a communication load of 20%.

The calculated cycle time is 10 ms.

This means that a setting of 20% communication load allocates an average of 200 μs to communication and 800 μs to the user program in each time slice. So the CPU requires 10 ms / 800 μs = 13 time slices to execute one cycle. This means the physical cycle time is equivalent to 13 times 1-ms time slice = 13 ms, if the CPU fully utilizes the configured communication load.

That is to say, 20% communication does not extend the cycle by a linear amount of 2 ms, but by 3 ms.

Example: 50% communication load

You configured a communication load of 50% in the hardware configuration.

The calculated cycle time is 10 ms.

This means that 500 μs remain in each time slice for the cycle. Therefore, the CPU requires 10 ms / 500 μs = 20 time slices to execute one cycle. This means the physical cycle time is 20 ms if the CPU fully utilizes the configured communication load.

So a setting of 50% communication load allocates 500 μs to communication and 500 μs to the user program in each time slice. Therefore, the CPU requires 10 ms / 500 μs = 20 time slices to execute one cycle. This means the physical cycle time is equivalent to 20 times 1-ms time slice = 20 ms, if the CPU fully utilizes the configured communication load.

This means that 50% communication does not extend the cycle by a linear amount of 5 ms, but by 10 ms (= doubling the calculated cycle time).

Dependency of the actual cycle time on communication load

The figure below describes the non-linear dependency of the actual cycle time on communication load. In our example we have chosen a cycle time of 10 ms.

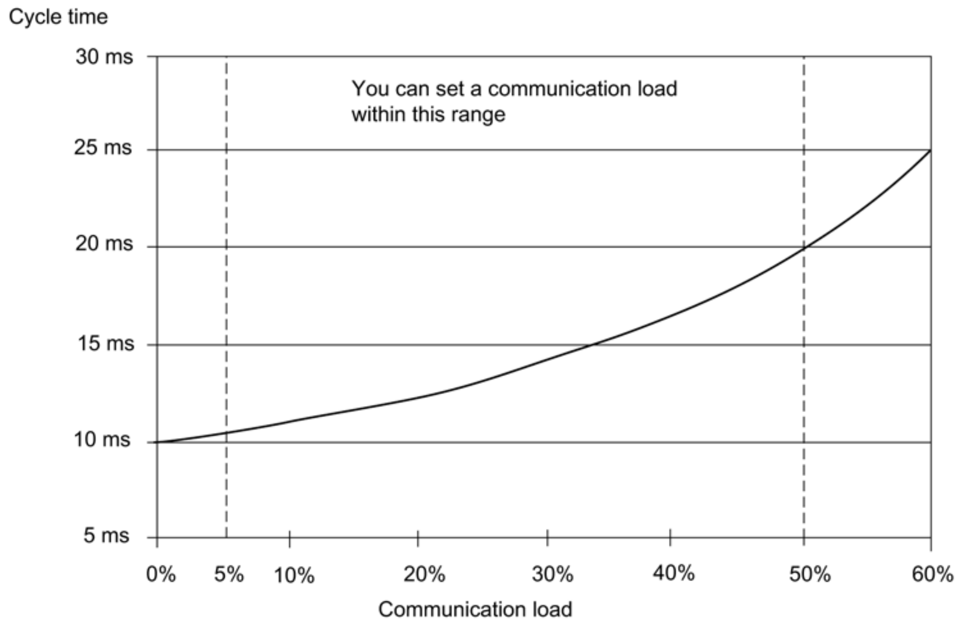


Figure 16-29 Dependency of the cycle time on communication load

Further effects on the actual cycle time

Seen statistically, the extension of cycle times due to communication load leads to more asynchronous events occurring within an OB 1 cycle, for example interrupts. This further extends the OB 1 cycle. How much it is extended depends on the number of events per OB 1 cycle and the time required for processing these events.

Remarks

- Change the value of the "communication load" parameter to check the effects on the cycle time during system runtime.
- Always take the communication load into account when you set the maximum cycle time, otherwise you risk timeouts.

16.15.4 Response time

Definition of response time

The response time is the time from detecting an input signal to changing the output signal associated with it.

Fluctuation range

The actual response time lies between the shortest and the longest response time. You must always assume the longest response time when configuring your system.

The shortest and longest response times are analyzed below so that you can gain an impression of the variation of the response time.

Factors

The response time depends on the cycle time and the following factors:

- Delay of the inputs and outputs
- Additional DP cycle times on the PROFIBUS DP network
- Execution in the user program

Delay of inputs/outputs

Make allowances for the following module-specific delay times:

- For digital inputs: the input delay time
- For interrupt-capable digital inputs: the input delay time + internal preparation time
- For digital outputs: negligible delay times

- For relay outputs: typical delay times of 10 ms to 20 ms.
  The delay of relay outputs depends on
  the temperature and voltage, among other things.
- For analog inputs: cycle time for analog input
- For analog outputs: response time at analog outputs

For information on delay times, refer to the technical specifications of the signal modules.

DP cycle times on the PROFIBUS DP network

If you configured your PROFIBUS DP network in **STEP 7**, **STEP 7** calculates the typical DP cycle time to be expected. You can then view the DP cycle time of your configuration on the PG in the bus parameters section.

The figure below provides an overview of the DP cycle time. In this example, we assume an average value for each DP slave of 4 bytes of data.

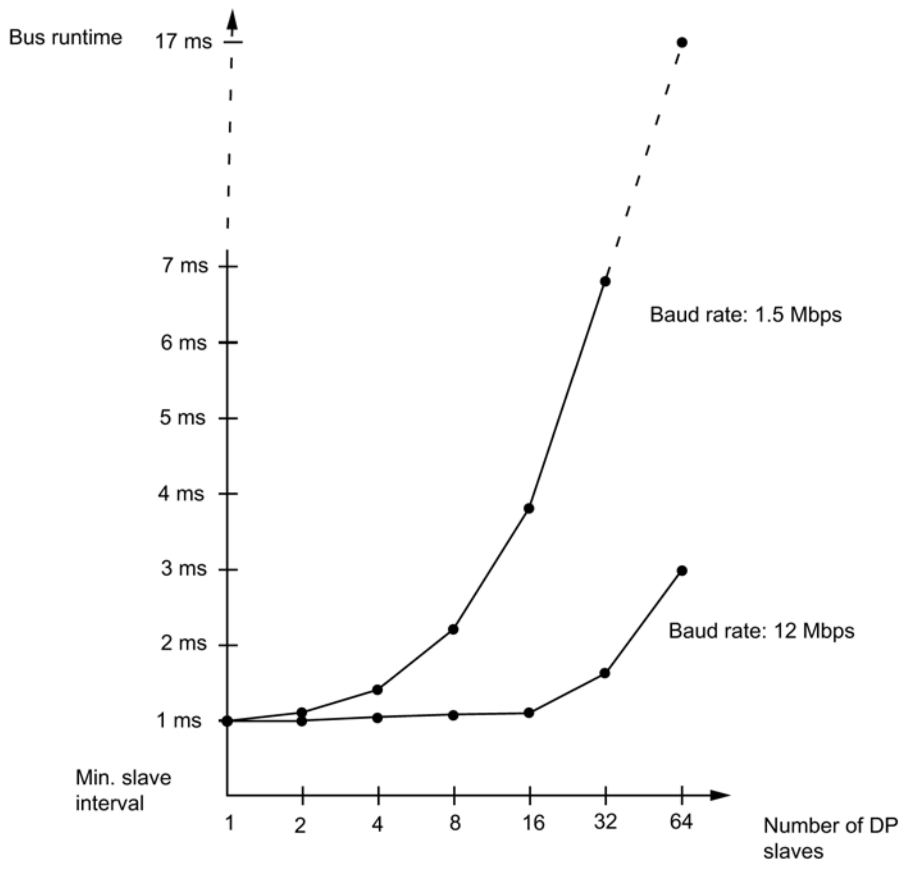


Figure 16-30 DP cycle times on the PROFIBUS DP network

If you are operating a PROFIBUS DP network with more than one master, you will need to take the DP cycle time into account for each master. In other words, perform a separate calculation for each master and add the results together.

Shortest response time

The figure below shows the conditions under which the shortest response time is achieved.

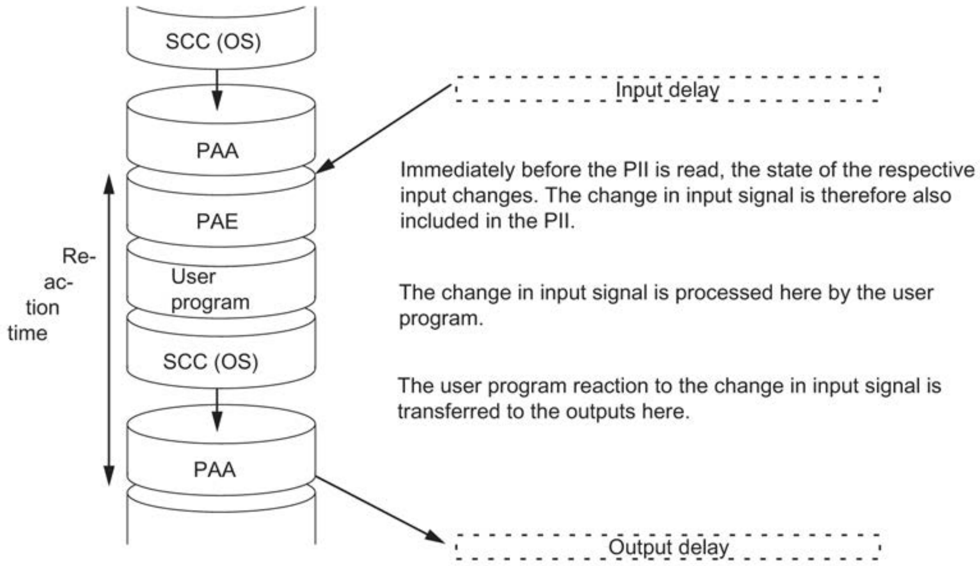


Figure 16-31 Shortest response time

Calculation

The (shortest) response time is calculated as follows:

- 1 x process image transfer time of the inputs +
- 1 x process image transfer time of the outputs +
- 1 x program processing time +
- 1 x operating system processing time at the SCCP +
- Delay of the inputs and outputs

The result is equivalent to the sum of the cycle time plus the I/O delay times.

Note

If the CPU and signal module are not in the central controller, you must add twice the runtime of the DP slave frame (including processing in the DP master).

Longest response time

The figure below shows the conditions under which the longest response time is achieved.

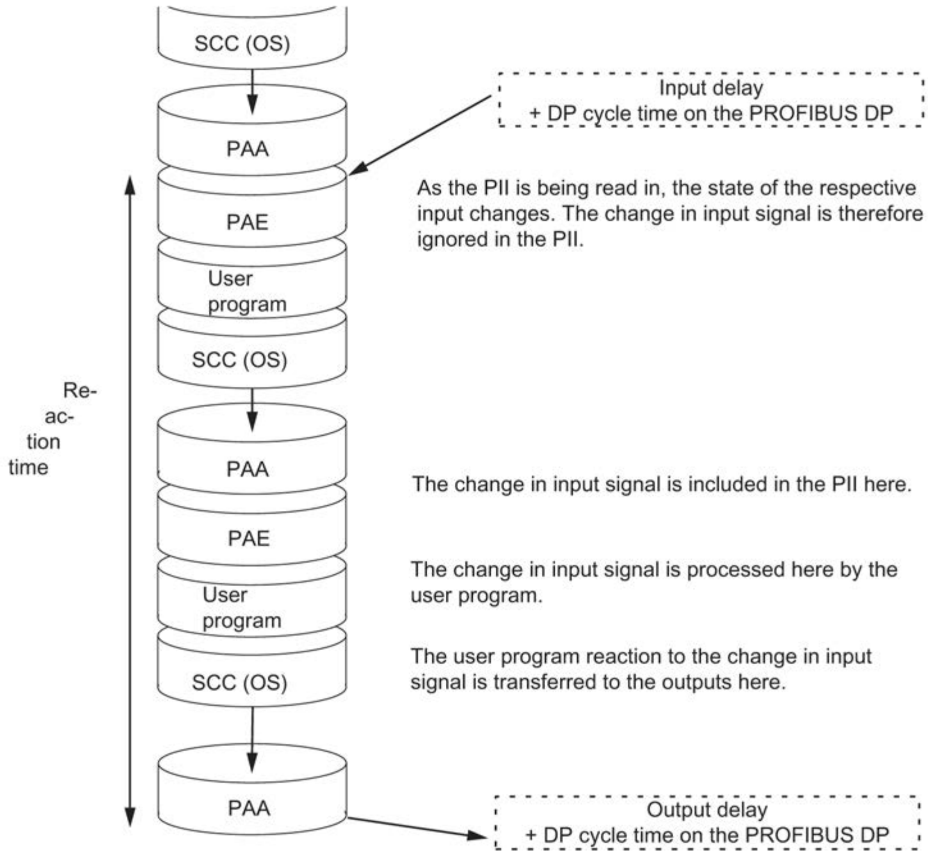


Figure 16-32 Longest response time

Calculation

The (longest) response time is calculated as follows:

- 2 x process image transfer time of the inputs +
- 2 x process image transfer time of the outputs +
- 2 x operating system processing time +
- 2 x program processing time +
- 2 x delay of the DP slave frame (including processing in the DP master) +
- Delay of the inputs and outputs

This is equivalent to the sum of twice the cycle time and the delay in the inputs and outputs plus twice the DP cycle time.

Processing direct I/O access

You can achieve faster response times by directly accessing the I/O in your user program, e.g., with the following instructions:

- L PIB
- T PQW

However, note that any I/O access requires a synchronization of the two units and thus extends the cycle time.

Reducing the response time

This reduces the maximum response time to

- Delay of the inputs and outputs
- Runtime of the user program (can be interrupted by higher-priority interrupt processing)
- Runtime of direct access
- 2x bus runtime of DP

The following table lists the execution times of direct access by the CPU to I/O modules. The specified times are pure CPU processing times and do not include the processing times of the signal modules.

Table 16- 15 Direct access of the CPUs to I/O modules in the central controller

Access type	CPU 410-5H stand-alone mode	CPU 410-5H redundant
Read byte	2.2 µs	11.0 µs
Read word	3.7 µs	11.1 µs
Read double word	6.8 µs	14.2 µs
Write byte	2.2 µs	10.8 µs
Write word	3.8 µs	11.2 µs
Write double word	7.0 µs	14.4 µs

Table 16- 16 Direct access of the CPUs to I/O modules in the expansion unit with local link

Access type	CPU 410-5H stand-alone mode	CPU 410-5H redundant
Read byte	5.5 µs	13.0 µs
Read word	10.5 µs	17.9 µs
Read double word	19.9 µs	27.4 µs
Write byte	5.3 µs	12.7 µs
Write word	10.2 µs	17.6 µs
Write double word	19.8 µs	27.3 µs

Table 16- 17 Direct access of the CPUs to I/O modules in the expansion unit with remote link, setting 100 m

Access type	CPU 410-5H stand-alone mode	CPU 410-5H redundant
Read byte	11.3 μs	16.6 μs
Read word	22.8 μs	28.1 μs
Read double word	44.1 μs	49.8 μs
Write byte	10.8 μs	16.2 μs
Write word	21.9 μs	27.3 μs
Write double word	44.0 μs	49.4 ms

Note

You can also achieve fast response times by using hardware interrupts; see Chapter Interrupt response time (Page 288).

16.15.5 Calculating cycle and response times

Cycle time

1. Determine the user program runtime with the help of the instruction list.
2. Calculate and add the process image transfer time. You will find guide values for this in the tables starting at 16-3.
3. Add the processing time at the scan cycle checkpoint. You will find guide values for this in Table 16-8.
4. Multiply the calculated value by the factor in Table 16-7.

The final result is the **cycle time**.

Extension of the cycle time due to communication and interrupts

1. Multiply the result by the following factor:

   100 / (100 – "configured communication load in %")
2. Using the instruction list, calculate the runtime of the program elements processing the interrupts. To do so, add the relevant value from Table 16-9.
   Multiply this value by the factor from step 4.
   Add this value to the theoretical cycle time as often as the interrupt is triggered or is expected to be triggered during the cycle time.

The result is an approximated **actual cycle time**. Note down the result.

Table 16- 18 Example of calculating the response time

Shortest response time	Longest response time
3. Next, calculate the delays in the inputs and outputs and, if applicable, the cycle times on the PROFIBUS DP network.	3. Multiply the actual cycle time by factor 2.
	4. Next, calculate the delays in the inputs and outputs and the DP cycle times on the PROFIBUS DP network.
4. The result you obtain is the **shortest response time**.	5. The result you obtain is the **longest response time**.

16.15.6 Examples of calculating the cycle and response times

Example I

You have installed an S7-400 with the following modules in the central controller:

- a CPU 410–5H in redundant mode
- 2 digital input modules SM 421; DI 32xDC 24 V (each with 4 bytes in the PI)
- 2 digital output modules SM 422; DO 32xDC 24 V/0.5 (each with 4 bytes in the PI)

User program

According to the instruction list, the user program runtime is 15 ms.

Calculating the cycle time

The cycle time for the example results from the following times:

- As the CPU-specific factor is 1.2, the user program execution time is:
  approx. 18.0 ms
- Process image transfer time (4 double-word accesses)

  Process image: 9 μs + 4 ×25 μs = approx. 0.109 ms
- OS execution time at the scan cycle checkpoint:
  approx. 0.31 ms

The total of the listed times is equivalent to the cycle time:

Cycle time = 18.0 ms + 0.109 ms + 0.31 ms **= 18.419 ms**.

Calculation of the actual cycle time

- Allowance for communication load (default value: 20%):
  18.419 ms * 100 / (100–20) **= 23.024 ms**.
- There is no interrupt processing.

So the actual, cycle time is approx. **23 ms**.

Calculating the longest response time

- Longest response time
  23.024 ms * 2 **= 46.048 ms**.
- The delay of the inputs and outputs is negligible.
- All the components are plugged into the central controller; DP cycle times do not therefore have to be taken into account.
- There is no interrupt processing.

So the longest, rounded up response time is **= 46.1 ms**.

Example II

You have installed an S7-400 with the following modules:

- a CPU 410–5H in redundant mode
- 4 digital input modules SM 421; DI 32×DC 24 V (each with 4 bytes in the PI)
- 3 digital output modules SM 422; DO 16xDC 24 V /2 (each with 2 bytes in the PI)
- 2 analog input modules SM 431; AI 8x13 bit (not in the PI)
- 2 analog output modules SM 432; AO 8x13 bit (not in the PI)

CPU parameters

The CPU parameters were assigned as follows:

- Cycle load due to communication: 40%

User program

According to the instruction list, the user program runtime is 10.0 ms.

Calculating the cycle time

The theoretical cycle time for the example is derived from the following times:

- As the CPU-specific factor is 1.2, the user program execution time is:
  approx. 12.0 ms
- Process image transfer time (4 x double-word access and 3 x word access)

  Process image: 9 μs + 7 ×25 μs = approx. 0.184 ms
- Operating system runtime at scan cycle checkpoint:
  approx. 0.31 ms

The total of the listed times is equivalent to the cycle time:

Cycle time = 12.0 ms + 0.184 ms + 0.31 ms **= 12.494 ms**.

Calculation of the actual cycle time

- Allowance for communication load:
  12.494 ms * 100 / (100–40) **= 20.823 ms**.
- A time-of-day interrupt with a runtime of 0.5 ms is triggered every 100 ms.
  The interrupt can be triggered a maximum of one time during a cycle:
  0.5 ms + 0.490 ms (from table 16-9) **= 0.99 ms.**
  Allowing for communication load:
  0.99 ms * 100 / (100–40) **= 1.65 ms**.
- 20.823 ms + 1.65 ms **= 22.473 ms**.

Taking into account the time slices, the actual rounded up cycle time is **22.5 ms**.

Calculating the longest response time

- Longest response time
  22.5 ms * 2 **= 45 ms**.
- Delay of inputs and outputs
  - The maximum input delay of the digital input module SM 421; DI 32×DC 24 V is 4.8 ms per channel
  - The output delay of the digital output module SM 422; DO 16×DC 24 V/2A is negligible.
  - An interference frequency suppression of 50 Hz was assigned for the analog input module SM 431; AI 8×13Bit. The result is a conversion time of 25 ms per channel. As 8 channels are active, a cycle time of the analog input module of 200 ms results.
  - Analog output module SM 432; AO 8×13Bit was assigned for measuring range 0 ... 10 V. This results in a conversion time of 0.3 ms per channel. Since 8 channels are active, the result is a cycle time of 2.4 ms. The transient time for a resistive load of 0.1 ms must be added to this. The result is an analog output response time of 2.5 ms.
- All components are installed in the central controller, so DP cycle times can be ignored.
- Case 1: The system sets an output channel of the digital output module after a digital input signal is read in. The result is as follows:

  Response time = 45 ms + 4.8 ms = 49.8 ms.
- Case 2: The system reads in and outputs an analog value. The result is as follows:

  Response time = 45 ms + 200 ms + 2.5 ms = 247.5 ms.

16.15.7 Interrupt response time

Definition of interrupt response time

The interrupt response time is the time from the first occurrence of an interrupt signal to the call of the first instruction in the interrupt OB.

General rule: Higher priority interrupts are handled first. This means the interrupt response time is increased by the program execution time of the higher-priority interrupt OBs, and by previous interrupt OBs of the same priority which have not yet been processed (queue).

Note that any update of the standby CPU extends the interrupt response time.

Calculating the interrupt response time

Minimum interrupt response time of the CPU
+ minimum interrupt response time of the signal modules
+ cycle time on PROFIBUS DP or PROFINET IO

= Shortest interrupt response time

Minimum interrupt response time of the CPU
+ maximum interrupt response time of the signal modules
+ 2 * cycle time on PROFIBUS DP or PROFINET IO

= Longest interrupt response time

Hardware and diagnostic interrupt response times of the CPUs

Table 16- 19 Hardware and interrupt response times; maximum interrupt response time without communication

CPU	Hardware interrupt response times		Diagnostic interrupt response times	
	min.	max.	min.	max.
CPU 410-5H stand-alone mode	60 µs	90 µs	60 µs	90 µs
CPU 410-5H redundant	140 µs	310 µs	120 µs	250 µs

Increasing the maximum interrupt response time with communication

The maximum interrupt response time is extended when the communication functions are active. The additional time is calculated using the following formula:

CPU 410-5H t_v = 100 µs + 1000 µs × n%, significant extension possible

where n = cycle load due to communication

Signal modules

The hardware interrupt response time of signal modules is made up as follows:

- Digital input modules

  Hardware interrupt response time = internal interrupt processing time + input delay

  You will find these times in the data sheet for the respective digital input module.

- Analog input modules

  Hardware interrupt response time = internal interrupt processing time + conversion time

  The internal interrupt processing time for analog input modules can be neglected. The conversion times can be found in the data sheet for the individual analog input modules.

The diagnostic interrupt response time of the signal modules is the time from detection of a diagnostic event by the signal module to the triggering of the diagnostic interrupt by the signal module. This short time can be neglected.

Hardware interrupt processing

Hardware interrupt processing begins when the hardware interrupt OB 4x is called. Higher-priority interrupts stop hardware interrupt processing. Direct access to I/O modules is executed during the execution time of the operation. After the hardware interrupt has been processed, the system either resumes cyclic program processing, or calls and processes interrupt OBs of the same or lower priority.

16.15.8 Example of calculation of the interrupt response time

Elements of the interrupt response time

As a reminder: The hardware interrupt response time is made up of the following:

- Hardware interrupt response time of the CPU
- Hardware interrupt response time of the signal module
- 2 × DP cycle time on PROFIBUS DP

Example

You have installed a CPU 410-5H and four digital modules in the central controller. One digital input module is the SM 421; DI 16×UC 24/60 V; with hardware and diagnostic interrupts. You have enabled only the hardware interrupt in your CPU and SM parameter assignment. You decided not to use time-driven processing, diagnostics or error handling. You have assigned an input delay of 0.5 ms for the digital input modules. No activities are required at the scan cycle checkpoint. You have set the communication load of the cycle as 20%.

Calculation

In this example, the hardware interrupt response time is based on following time factors:

- Process interrupt response time of CPU 410-5H: Approx. 0.3 ms (mean value in redundant operation)
- Extension due to communication according to the description in Chapter Interrupt response time (Page 288):

100 μs + 1000 μs × 20% = 300 μs = 0.3 ms

- Hardware interrupt response time of SM 421; DI 16×UC 24/60 V:
  - Internal interrupt processing time: 0.5 ms
  - Input delay: 0.5 ms
- The DP cycle time on the PROFIBUS DP is irrelevant, because the signal modules are installed in the central controller.

The hardware interrupt response time is equivalent to the sum of the listed time factors:

Hardware interrupt response time = 0.3 ms + 0.3 ms + 0.5 ms + 0.5 ms = **approx. 1.6 ms**.

This calculated hardware interrupt response time is the time between detection of a signal at the digital input and the call of the first instruction in OB 4x.

16.15.9 Reproducibility of delay and watchdog interrupts

Definition of "reproducibility"

Time-delay interrupt:

The period that expires between the call of the first operation in the interrupt OB and the programmed time of interrupt.

Cyclic interrupt:

The fluctuation range of the interval between two successive calls, measured between the respective initial operations of the interrupt OB.

Reproducibility

The following table contains the reproducibility of time-delay and cyclic interrupts of the CPUs.

Table 16- 20 Reproducibility of time-delay and cyclic interrupts of the CPUs

Module	Reproducibility	
	Time-delay interrupt	Cyclic interrupt
CPU 410-5H stand-alone mode	± 120 μs	± 160 μs
CPU 410-5H redundant	± 200 μs	± 180 μs

These times only apply if the interrupt can actually be executed at this time and if it is not delayed, for example, by higher-priority interrupts or queued interrupts of equal priority.

16.16 Runtimes of the FCs and FBs for redundant I/Os

Table 16- 21 Runtimes of the blocks for redundant I/Os

Block	Runtime in stand-alone/single mode	Runtime in redundant mode
FC 450 RED_INIT Specifications are based on the startup	2 ms + 300 µs / configured module pairs The specification for a module pair is a mean value. The runtime may be < 300 µs for a few modules. For a large number of redundant modules the value may be > 300 µs.	-
FC 451 RED_DEPA	160 µs	360 µs
FB 450 RED_IN Called from the corresponding sequence level.	750 µs + 60 µs / module pair of the current TPA The specification for a module pair is a mean value. The runtime may be additionally increased if discrepancies occur resulting in passivation and logging to the diagnostic buffer. The runtime may also be increased by a depassivation carried out at the individual sequence levels of FB RED_IN. Depending on the number of modules in the sequence level, the depassivation may increase the runtime of the FB RED_IN by 0.4 ... 8 ms. An 8 ms increase can be expected in redundant operation of modules totaling more than 370 pairs of modules at a sequence level.	1000 µs + 70 µs / module pair of the current TPA The specification for a module pair is a mean value. The runtime may be additionally increased if discrepancies occur resulting in passivation and logging to the diagnostic buffer. The runtime may also be increased by a depassivation carried out at the individual sequence levels of FB RED_IN. Depending on the number of modules in the sequence level, the depassivation may increase the runtime of the FB RED_IN by 0.4 ... 8 ms. An 8 ms increase can be expected in redundant operation of modules totaling more than 370 pairs of modules at a sequence level.
FB 451 RED_OUT Called from the corresponding sequence level.	650 µs + 2 µs / module pair of the current TPA The specification for a module pair is a mean value. The runtime may be < 2 µs for a few modules. For a large number of redundant modules the value may be > 2 µs.	860 µs + 2 µs / module pair of the current TPA The specification for a module pair is a mean value. The runtime may be < 2 µs for a few modules. For a large number of redundant modules the value may be > 2 µs.

Block	Runtime in stand-alone/single mode	Runtime in redundant mode
FB 452 RED_DIAG	Called in OB 72: 160 µs Called in OB 82, 83, 85: 250 µs + 5 µs / configured module pairs Under extreme conditions the runtime of FB RED_DIAG is increased up to 1.5 ms. . This is the case when the working DB is 60 KB or larger and if there are interrupt trigger addresses that do not belong to the redundant I/O.	Called in OB 72: 360 µs Called in OB 82, 83, 85: 430 µs (basic load) + 6 µs / configured module pairs Under extreme conditions the runtime of FB RED_DIAG is increased up to 1.5 ms. . This is the case when the working DB is 60 KB or larger and if there are interrupt trigger addresses that do not belong to the redundant I/O.
FB 453 RED_STATUS	160 µs 4 µs/ configured module pairs * number of module pairs) The runtime depends on the random position of the module being searched for in the working DB. When a module address is not redundant, the entire working DB is searched. This results in the longest runtime of FB RED_STATUS. The number of module pairs is based either on all inputs (DI/AI) or all outputs (DO/AO).	350 µs + 5 µs / configured module pairs * number of module pairs) The runtime depends on the random position of the module being searched for in the working DB. When a module address is not redundant, the entire working DB is searched. This results in the longest runtime of FB RED_STATUS. The number of module pairs is based either on all inputs (DI/AI) or all outputs (DO/AO).

Note

These are guide values, not absolute values. The actual value may deviate from these specifications in some cases. This overview is intended as a guide and should help you estimate how use of the Redundant IO CGP V52 library may change the cycle time.

Characteristic values of redundant automation systems

A

This appendix provides a brief introduction to the characteristic values of redundant automation systems, and shows the practical effects of redundant configurations, based on a selection of configurations.

You will find an overview of the MTBF of various SIMATIC products in the SIMATIC FAQs in the following entry: Mean Time Between Failures (MTBF) list for SIMATIC Products (http://support.automation.siemens.com/WW/view/en/16818490)

A.1 Basic concepts

The quantitative assessment of redundant automation systems is usually based on their reliability and availability parameters. These are described in detail below.

Reliability

Reliability refers to the capability of technical equipment to fulfill its function during its operating period. This is usually no longer the case if any of its components fails.

So a commonly used measure for reliability is the **MTBF** (**M**ean **T**ime **B**etween **F**ailure). This can be analyzed statistically based on the parameters of running systems, or by calculating the failure rates of the components used.

Reliability of modules

The reliability of SIMATIC components is extremely high as a consequence of extensive quality assurance measures in design and production.

Reliability of automation systems

The use of redundant modules considerably prolongs the MTBF of a system. The combination of integrated high-quality self-tests and error detection mechanisms of the S7-400H CPUs allows the detection and localization of virtually all errors.

The MTBF of an S7-400H is determined by the **MDT** (**M**ean **D**own **T**ime) of a system unit. This time is derived in essence from the error detection time plus the time required to repair or replace defective modules.

In addition to other measures, a CPU provides a self-test function with an adjustable test cycle time. The default test cycle time is 90 minutes. This time has an influence on the error detection time. The repair time usually required for a modular system such as the S7-400H is 4 hours.

Mean Down Time (MDT)

The MDT of a system is determined by the times outlined below:

- Time required to detect an error
- Time required to find the cause of an error
- Time required for troubleshooting and to restart the system

The system MDT is calculated based on the MDT of the individual system components. The structure in which the components make up the system also forms part of the calculation.

Correlation between MDT and MTBF: MDT << MTBF

The MDT value is of the highest significance for the quality of system maintenance. The most important factors are:

- Qualified personnel
- Efficient logistics
- High-performance tools for diagnostics and error recognition
- A sound repair strategy

The figure below shows the dependency of the MDT on the times and factors mentioned above.

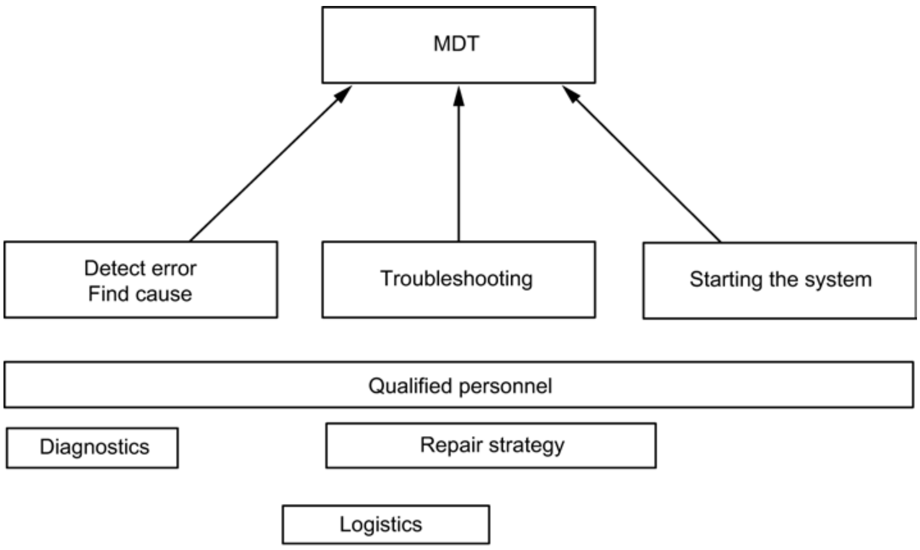


Figure A-1 MDT

The figure below shows the parameters included in the calculation of the MTBF of a system.

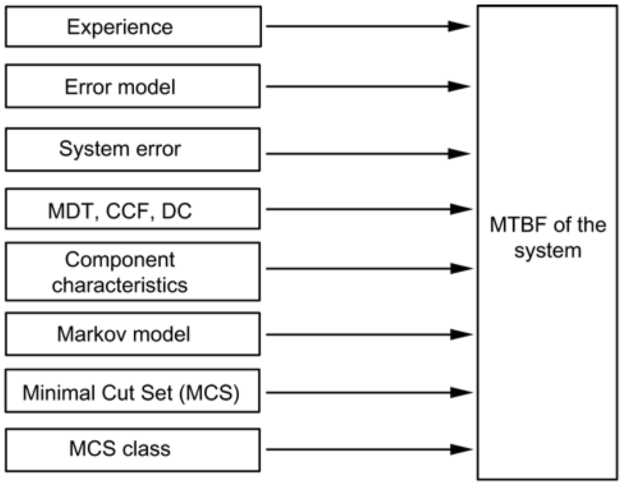


Figure A-2 MTBF

Requirements

This analysis assumes the following conditions:

- The failure rate of all components and all calculations is based on an average temperature of 40 °C.
- The system installation and configuration is free of errors.
- All replacement parts are available locally, in order to prevent extended repair times due to missing spare parts. This keeps the component MDT down to a minimum.
- The MDT of individual components is 4 h. The system's MDT is calculated based on the MDT of the individual components plus the system structure.
- The MTBF of the components meets the following standards:
  - SN 29500

    This standard is compliant with MIL–HDBK 217–F.
  - IEC 60050
  - IEC 61709
- The calculations are made using the diagnostic coverage of each component.
- A CCF factor between 0.2% and 2% is assumed, depending on the system configuration.

Common Cause Failure (CCF)

The Common Cause Failure (CCF) is an error which is caused by one or more events which also lead to an error state on two or more separate channels or components in a system. A CCF leads to a system failure.

The CCF may be caused by one of the following factors:

- Temperature
- Humidity

- Corrosion
- Vibration and shock
- Electromagnetic interference
- Electrostatic discharge
- RF interference
- Unexpected sequence of events
- Operating errors

The CCF factor defines the ratio between the probability of the occurrence of a CCF and the probability of the occurrence of any other error.

Typical CCF factors range from 2% to 0.2% in a system with identical components, and between 1% and 0.1% in a system containing different components.

Within the range stipulated in IEC 61508, a CCF factor between 0.02% and 5% is used to calculate the MTBF.

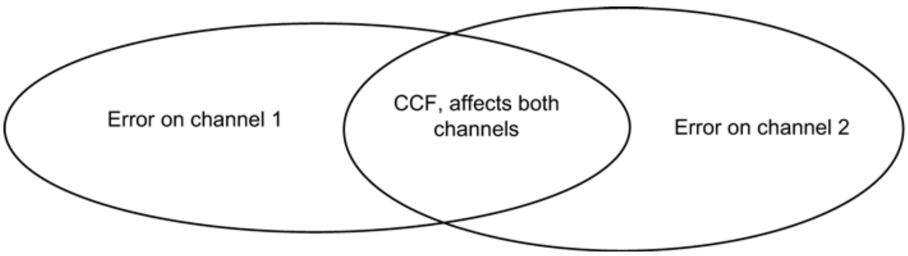


Figure A-3 Common Cause Failure (CCF)

Reliability of an S7-400H

The use of redundant modules prolongs the system MTBF by a large factor. The integrated high-grade self-test and the test/message functions of the S7-400H CPUs enable the detection and localization of virtually all errors. The calculated diagnostic coverage is around 90%.

The reliability in stand-alone mode is described by the corresponding failure rate. The failure rate for all S7 components is calculated according to the SN29500 standard.

The reliability in redundant mode is described by the failure rate of the components involved. This is termed "MTBF" below. Those combinations of failed components which cause a system failure are described and calculated using Markov models. Calculations of the system MTBF take account of the diagnostic coverage and the common cause factor.

Availability

Availability is the probability that a system is operable at a given point of time. This can be enhanced by means of redundancy, for example by using redundant I/O modules or multiple encoders at the same sampling point. Redundant components are arranged such that system operability is not affected by the failure of a single component. Here, again, an important element of availability is a detailed diagnostics display.

The availability of a system is expressed as a percentage. It is defined by the mean time between failure (MTBF) and the mean time to repair MTTR (MDT). The availability of a two-channel (1-out-of-2) fault-tolerant system can be calculated using the following formula:

$$V = \frac{MTBF_{1v2}}{MTBF_{1v2} + MDT} 100\%$$

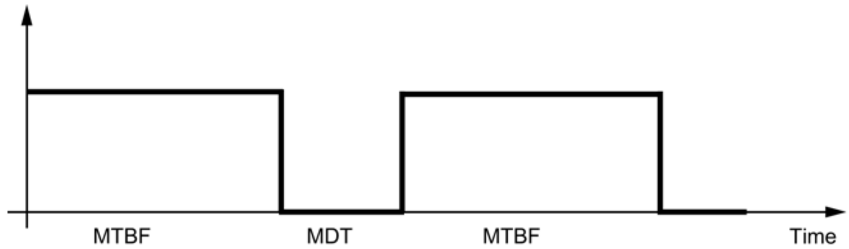


Figure A-4 Availability

A.2 Comparison of MTBF for selected configurations

The following sections compare systems with a centralized and distributed I/Os.

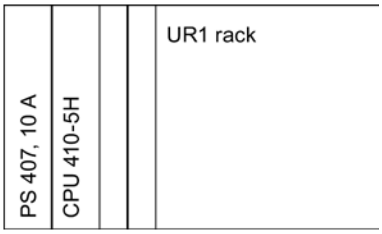
The following framework conditions are set for the calculation.

- MDT (Mean Down Time) 4 hours
- Ambient temperature 40 degrees
- Buffer voltage is safeguarded

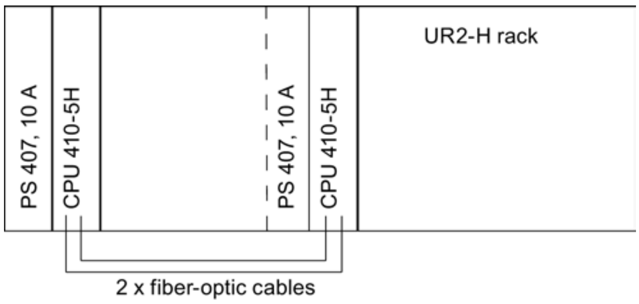
A.2.1 System configurations with redundant CPU 410-5H

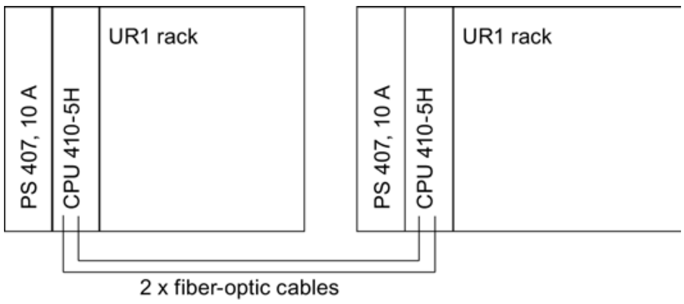
The following system with one CPU (e.g., CPU 410-5H PN/DP) in stand-alone operation serves as the basis for calculating a reference factor that defines the multiple of the system MTBF of other systems with centralized I/O compared with the base line.

Fault-tolerant CPU in stand-alone operation

Fault-tolerant CPU 410-5H in stand-alone mode	Factor
	1

Redundant CPUs in different racks

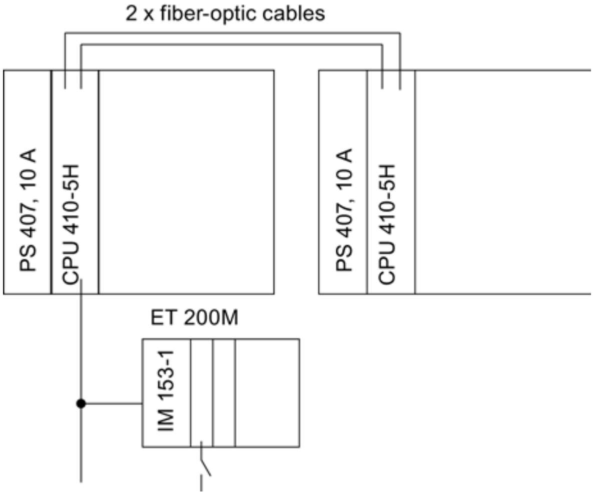
Redundant CPU 410-5H in divided rack, CCF = 2%	Factor
	approx. 20

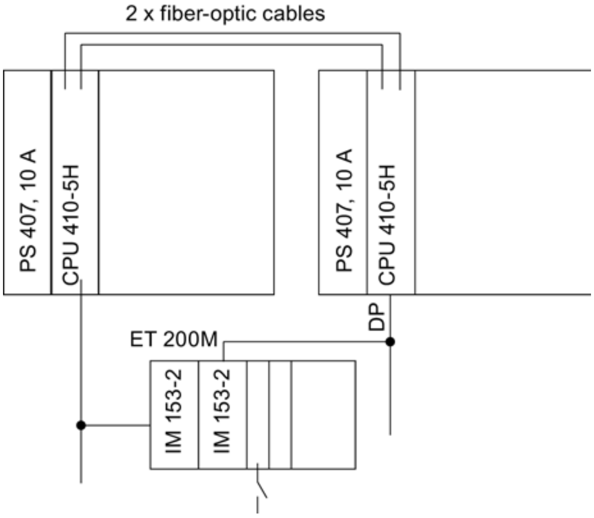
Redundant CPU 410-5H in two separate racks, CCF = 1 %	Factor
	approx. 38

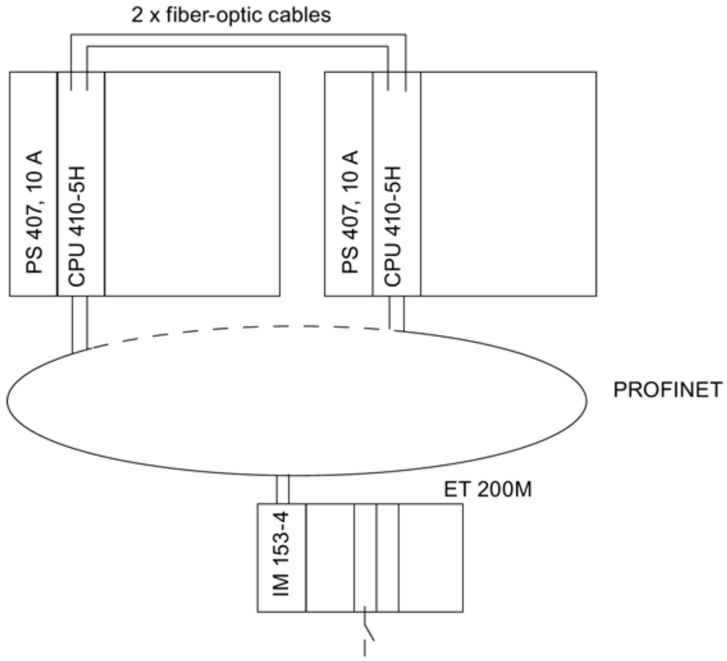
A.2.2 System configurations with distributed I/Os

The system with two fault-tolerant CPUs 410-5H and one-sided I/Os described below is taken as a basis for calculating a reference factor which specifies the multiple of the availability of the other systems with distributed I/Os compared with the base line.

Redundant CPUs with single-channel one-sided or switched I/O

One-sided distributed I/O	Base line
	1

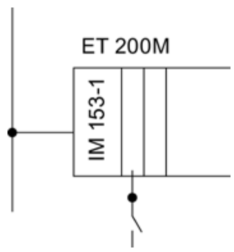
Switched distributed I/O, PROFIBUS DP, CCF = 2 %	Factor
	approx. 15

Switched distributed I/O, PROFINET, CCF = 2 %	Factor
	approx. 10

The estimate applies if the process allows for any device to fail.

Redundant CPUs with redundant I/O

The comparison only took account of the I/O modules.

Single-channel one-sided I/O	MTBF factor
	1

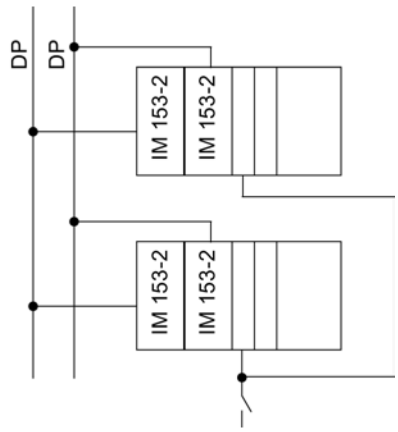
Redundant I/O	MTBF factor
	See following table

Table A-1 MTBF factors of the redundant I/O

Module	MLFB	MTBF factor CCF = 1%
Digital input modules, distributed		
DI 24xDC24V	6ES7 326–1BK02–0AB0	approx. 5
DI 8xNAMUR [EEx ib]	6ES7 326-1RF00-0AB0	approx. 5
DI16xDC24V, Alarm	6ES7 321–7BH01–0AB0	approx. 4
Analog input modules, distributed		
AI 6x13Bit	6ES7 336-1HE00-0AB0	approx. 5
AI8x12Bit	6ES7 331-7KF02-0AB0	approx. 5
Digital output modules, distributed		
DO 10xDC24V/2A	6ES7 326–2BF01–0AB0	approx. 5
DO8xDC24V/2A	6ES7 322-1BF01-0AA0	approx. 3
DO32xDC24V/0.5A	6ES7 322–1BL00–0AA0	approx. 3

Summary

Several thousand redundant automation systems are in use in different configurations. To calculate the MTBF, we assumed an average configuration.

Based on experience in the field, an assumption of MTBF of 3000 years is 95% reliable.

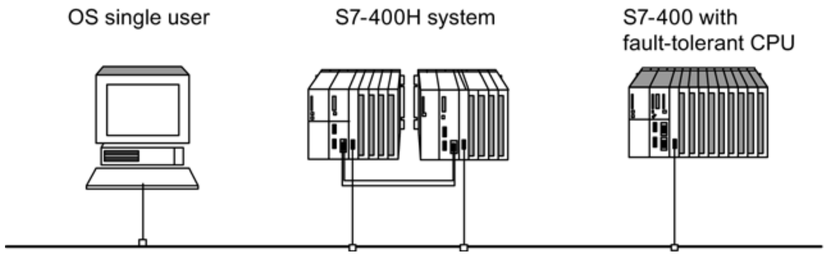
The system MTBF value calculated is about 230 years for a system configuration with redundant CPU 410-5H.

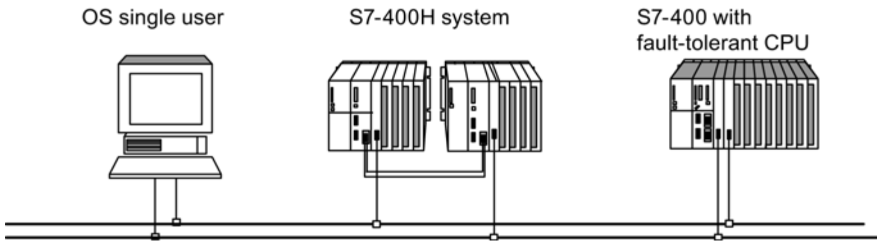
A.2.3 Comparison of system configurations with standard and fault-tolerant communication

The next section shows a comparison between standard and fault-tolerant communication for a configuration consisting of a fault-tolerant system, a fault-tolerant CPU operating in stand-alone mode, and a single-channel OS.

The comparison only took account of the CP and cable communication components.

Systems with standard and fault-tolerant communication

Standard communication	Base line
	1

Fault-tolerant communication	Factor
	Approx. 80

Function and communication modules that can be used in a redundant configuration B

A complete list of all modules approved for PCS7 V8.0 SP1 is available at the following address: SIMATIC Process Control System PCS 7 Approved Modules (V8.0 SP1) (http://support.automation.siemens.com/WW/view/de/68157377/0/en)

In **redundant configuration** you can use the following function modules (FM) and communication processors (CP) with a CPU 410-5H.

Note

There may be further restriction for individual modules. Refer to the information in the corresponding product information and FAQ, or in SIMATIC NET News.

FMs and CPs which can be used centrally

Module	Order No.	Release	One-sided	Redundant
Function module FM 458-1 DP	6DD 1607-0AA2	As of firmware 2.0.0	Yes	No
Communication processor CP 443-1 Multi (Industrial Ethernet ISO and TCP/IP, 2-port switch) Without PROFINET IO and PROFINET CBA	6GK7 443-1EX20-0XE0	As of product version 1 As of firmware V2.1	Yes	Yes
	6GK7 443–1EX30–0XE0	As of product version 1 As of firmware V1.0	Yes	Yes
Communication processor CP 443-1 Multi (Industrial Ethernet ISO and TCP/IP, 4-port switch, gigabit port)	6GK7 443–1GX30–0XE0	As of product version 1 as of firmware V3.0	Yes	Yes
Communication processor CP 443-5 Extended (PROFIBUS DPV1) [1) 2)]	6GK7 443-5DX04-0XE0	As of product version 1 As of firmware V6.0	Yes	Yes
	6GK7 443-5DX05-0XE0	As of product version 1 As of firmware V7.1	Yes	Yes

[1)] Only these modules should be used as external master interfaces on the PROFIBUS DP.

[2)] These modules support DPV1 as external DP master interface module (complying with IEC 61158/EN 50170).

FMs and CPs usable for distributed switched use

Module	Order No.	Release
Communication processor CP 341-1 (point-to-point link)		
	6ES7 341-1AH01-0AE0 6ES7 341-1BH01-0AE0 6ES7 341-1CH01-0AE0	As of product version 1 As of firmware V1.0.0
	6ES7 341-1AH02-0AE0 6ES7 341-1BH02-0AE0 6ES7 341-1CH02-0AE0	As of product version 1 As of firmware V2.0.0
Communication processor CP 342-2 (ASI bus interface module)	6GK7 342-2AH01-0XA0	As of product version 1 As of firmware V1.10
Communication processor CP 343-2 (ASI bus interface module)	6GK7 343-2AH00-0XA0	As of product version 2 As of firmware V2.03
Counter module FM 350-2	6ES7 350-2AH00-0AE0	As of product version 2
Control module FM 355 C	6ES7 355-0VH10-0AE0	As of product version 4
Control module FM 355 S	6ES7 355-1VH10-0AE0	As of product version 3

Note

One-sided or switched function modules and communication processors are **not** synchronized in the fault-tolerant system if they exist in pairs.

Connection examples for redundant I/Os C

C.1 MTA terminal modules (Marshalled Termination Assemblies)

MTA Terminal Modules

MTA terminal modules (Marshalled Termination Assemblies) can be used to connect field devices, sensors and actuators to the I/O modules of the ET 200M remote I/O stations simply, quickly and reliably. They can be used to significantly reduce the costs and required work for cabling and commissioning, and prevent wiring errors.

The individual MTA terminal modules are each tailored to specific I/O modules from the ET 200M range. MTA versions for standard I/O modules are also available, as for redundant and safety-related I/O modules. The MTA terminal modules are connected to the I/O modules using 3 m or 8 m long preassembled cables.

Details on combinable ET 200M modules and suitable connection cables as well as the current MTA product range are available at this address: Update and expansion of the MTA terminal modules (http://support.automation.siemens.com/WW/view/en/29289048)

C.2 Interconnection of output modules

Interconnection of digital output modules using external diodes <-> without external diodes

The table below lists the redundant digital output modules which in redundant operation you should interconnect using external diodes:

Table C- 1 Interconnecting digital output modules with/without diodes

Module	with diodes	without diodes
6ES7 326–2BF01–0AB0	X	X
6ES7 322–1BL00–0AA0	X	-
6ES7 322-1BF01-0AA0	X	-
6ES7 322-8BF00-0AB0	X	X
6ES7 322–1FF01–0AA0	-	X
6ES7 322-8BH01-0AB0	-	X
6ES7 322-8BH10-0AB0	-	X
6ES7 322-5RD00-0AB0	X	-
6ES7 322-5SD00-0AB0	X	-

Information on connecting digital output modules via diodes

- Suitable diodes are diodes with U_r >=200 V and I_F >= 1 A (e.g., types from the series 1N4003 ... 1N4007).
- It is advisable to separate the ground of the module and the ground of the load. There must be equipotential bonding between both.

Information on connecting analog output modules via diodes

- Suitable diodes are diodes with U_r >=200 V and I_F >= 1 A (e.g., types from the series 1N4003 ... 1N4007).
- A separate load supply is advisable. There must be equipotential bonding between both load supplies.

C.3 8-channel HART analog input MTA

The following figure shows the connection of an encoder to two SM 331; AI 8 x 0/4...20mA HART via an 8-channel HART analog input MTA.

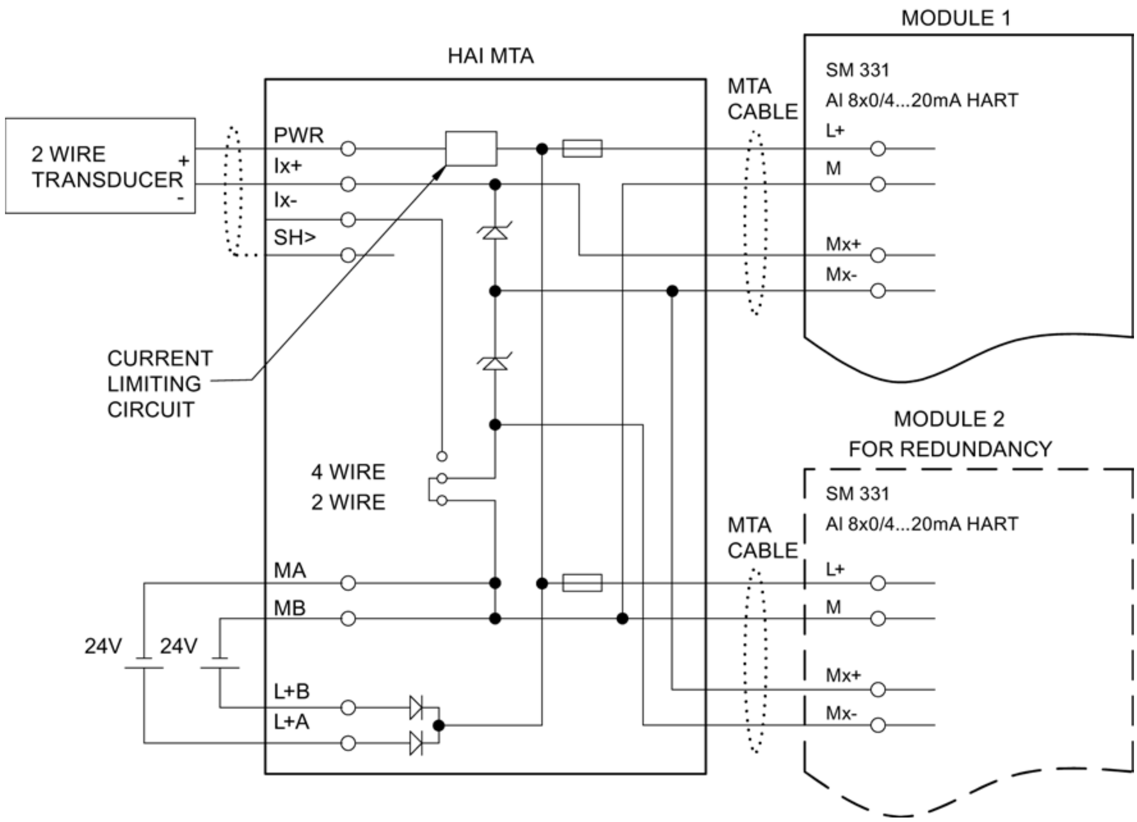


Figure C-1 Interconnection example for SM 331, AI 8 x 0/4...20mA HART

C.4 8-channel HART analog output MTA

The following figure shows the connection of an encoder to two redundant SM 322; AI 8 x 0/4...20mA HART via an 8-channel HART analog output MTA.

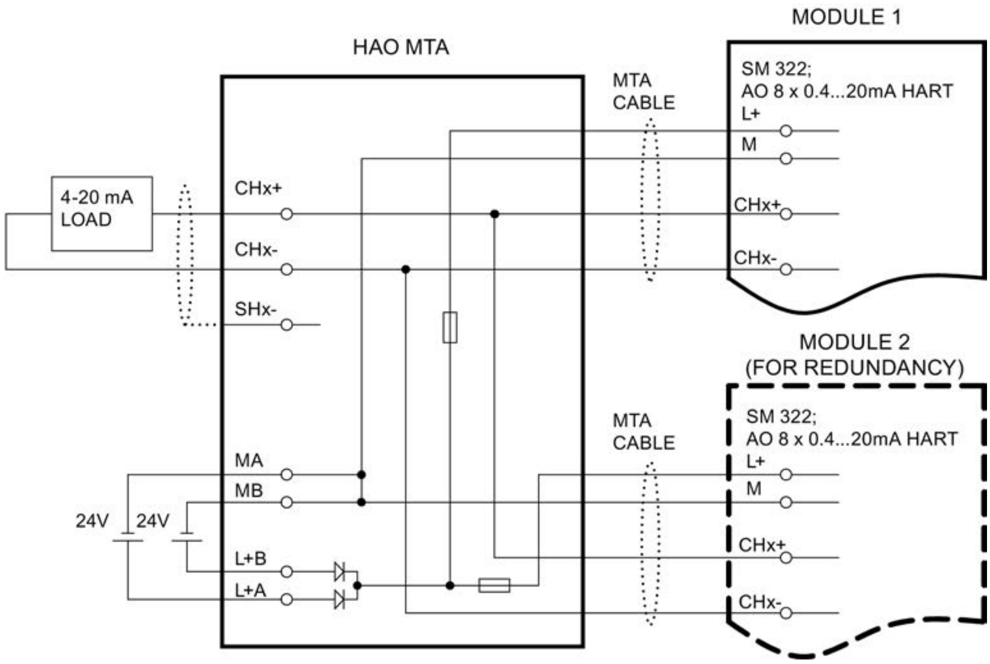


Figure C-2 Interconnection example for SM 322, AI 8 x 0/4...20mA HART

C.5 SM 321; DI 16 x DC 24 V, 6ES7 321–1BH02–0AA0

The diagram below shows the connection of two redundant encoders to two SM 321; DI 16 x DC 24 V. The encoders are connected to channel 0.

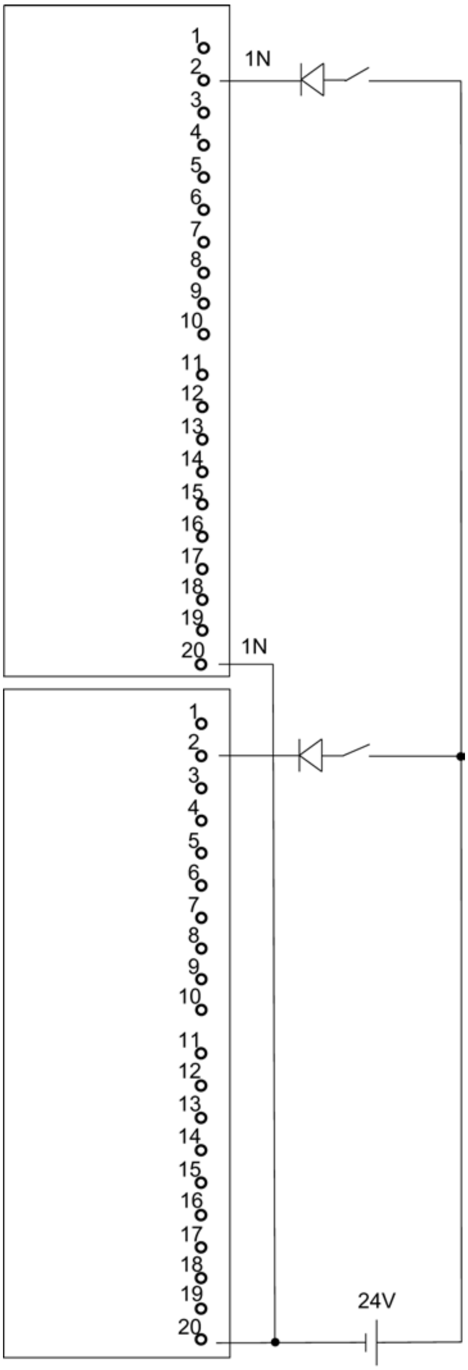


Figure C-3 Example of an interconnection with SM 321; DI 16 x DC 24 V

C.6 SM 321; DI 32 x DC 24 V, 6ES7 321–1BL00–0AA0

The diagram below shows the connection of two redundant encoder pairs to two redundant SM 321; DI 32 x DC 24 V. The encoders are connected to channel 0 and channel 16 respectively.

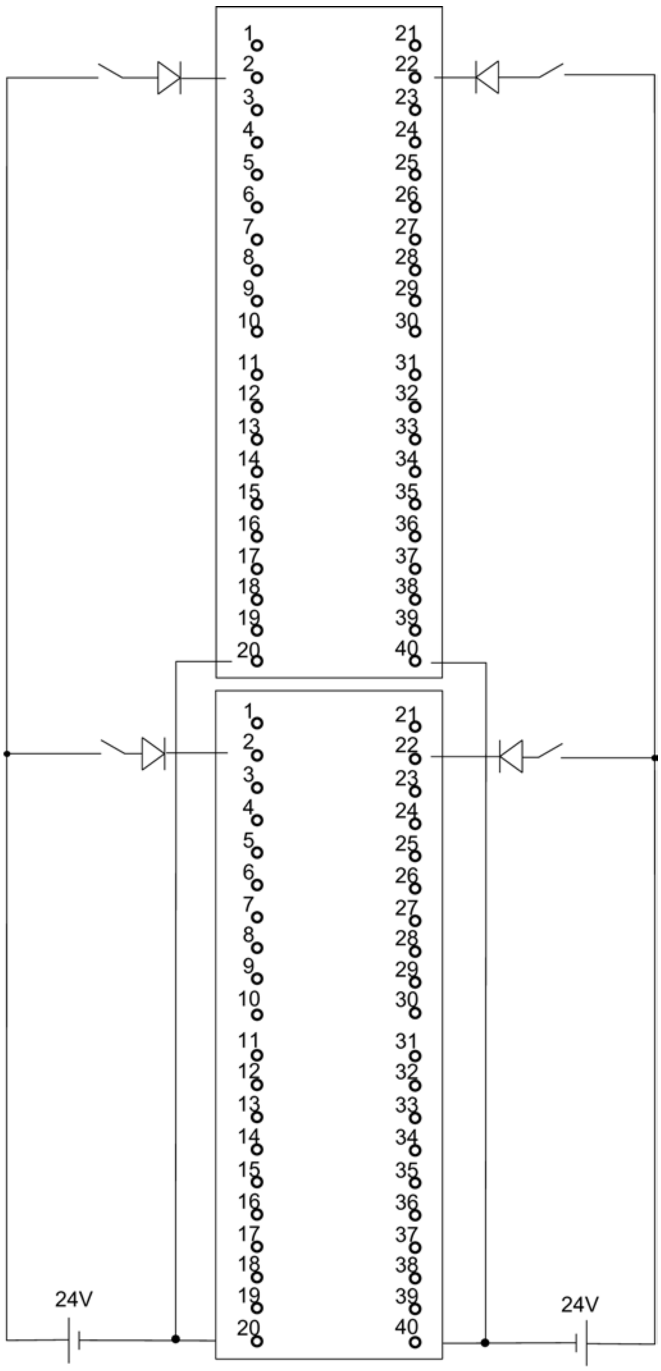


Figure C-4 Example of an interconnection with SM 321; DI 32 x DC 24 V

C.7 SM 321; DI 16 x AC 120/230V, 6ES7 321–1FH00–0AA0

The diagram below shows the connection of two redundant encoders to two SM 321; DI 16 x AC 120/230 V. The encoders are connected to channel 0.

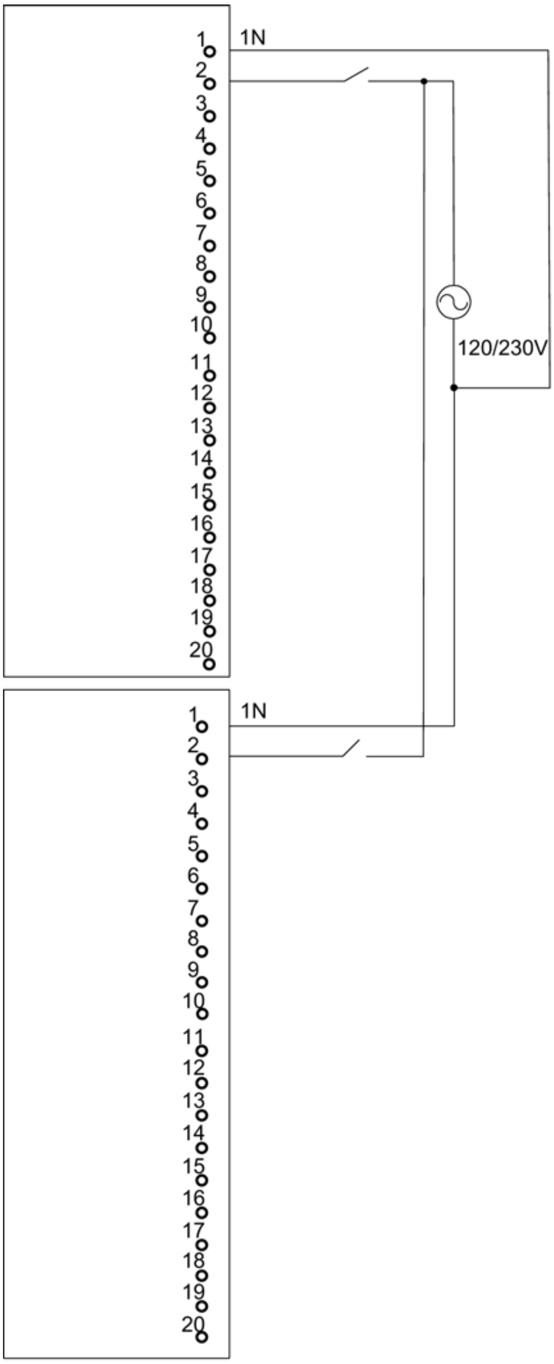


Figure C-5 Example of an interconnection with SM 321; DI 16 x AC 120/230 V

C.8 SM 321; DI 8 x AC 120/230 V, 6ES7 321–1FF01–0AA0

The diagram below shows the connection of two redundant encoders to two SM 321; DI 8 AC 120/230 V. The encoders are connected to channel 0.

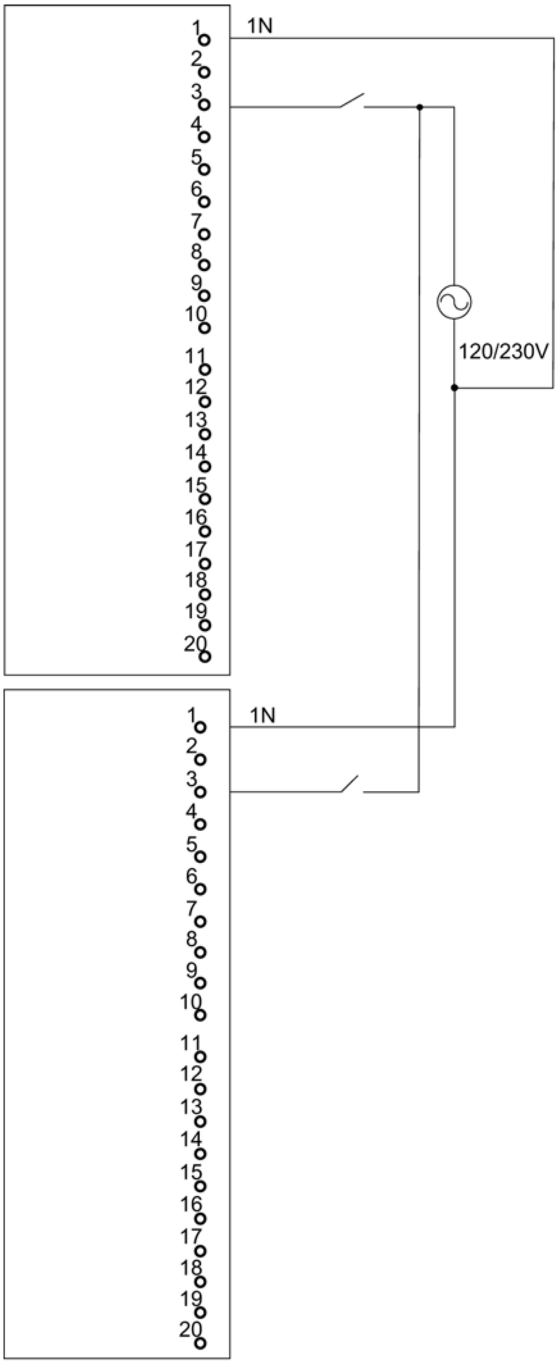


Figure C-6 Example of an interconnection with SM 321; DI 8 x AC 120/230 V

C.9 SM 321; DI 16 x DC 24V, 6ES7 321–7BH00–0AB0

The diagram below shows the connection of two redundant encoder pairs to two SM 321; DI 16 x DC 24V. The encoders are connected to channels 0 and 8.

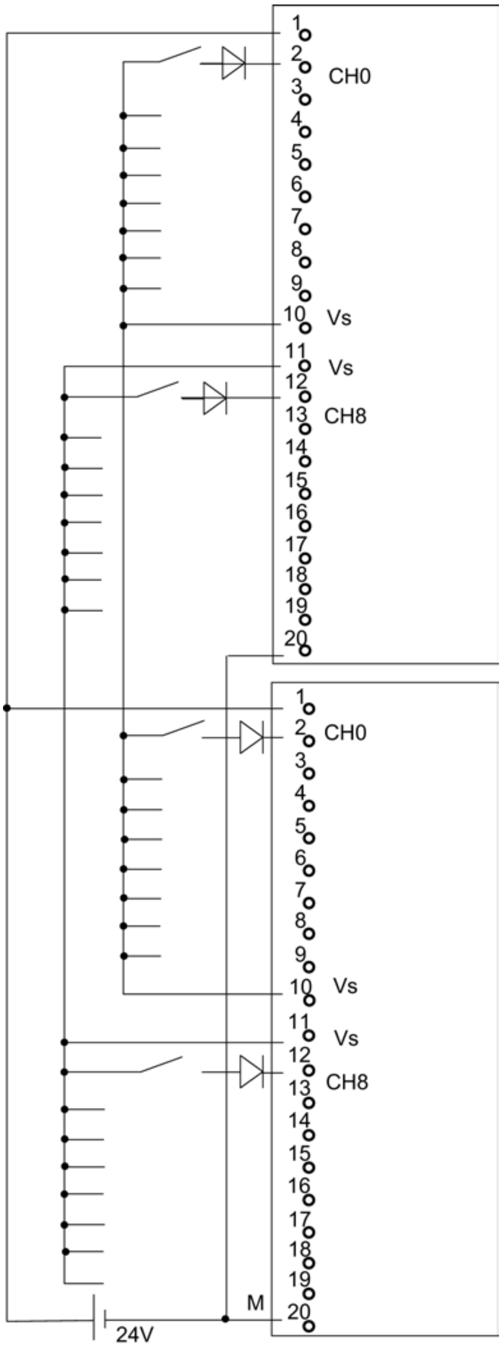


Figure C-7 Example of an interconnection with SM 321; DI 16 x DC 24V

C.10 SM 321; DI 16 x DC 24V, 6ES7 321–7BH01–0AB0

The diagram below shows the connection of two redundant encoder pairs to two SM 321; DI 16 x DC 24V. The encoders are connected to channels 0 and 8.

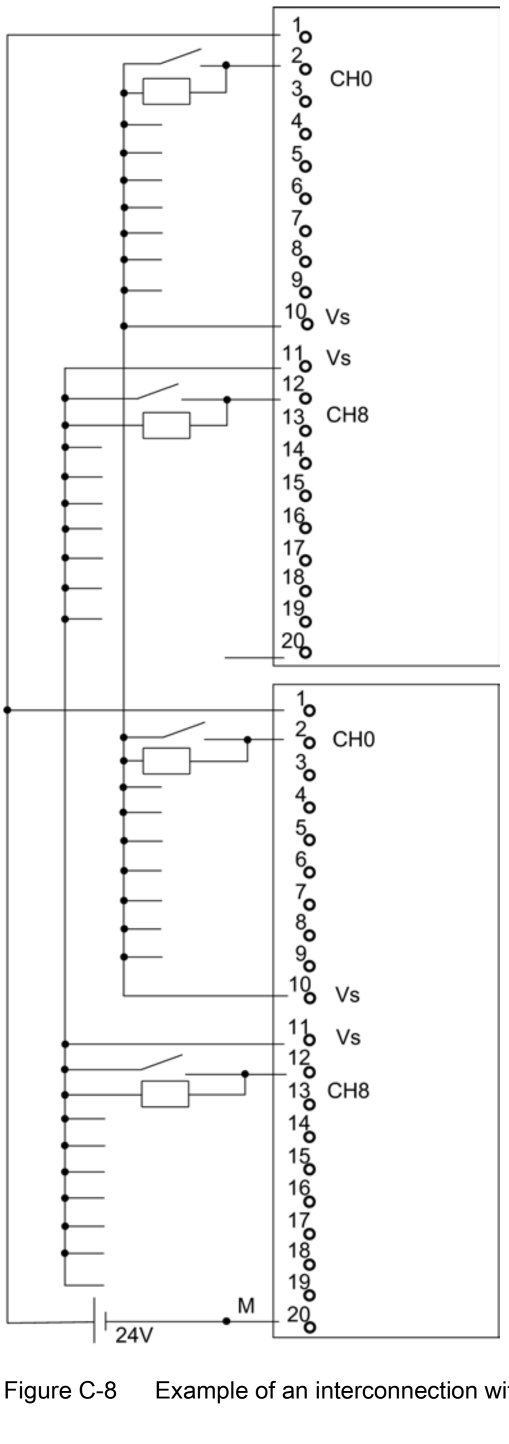


Figure C-8 Example of an interconnection with SM 321; DI 16 x DC 24V

C.11 SM 326; DO 10 x DC 24V/2A, 6ES7 326–2BF01–0AB0

The diagram below shows the connection of an actuator to two redundant SM 326; DO 10 x DC 24V/2A. The actuator is connected to channel 1.

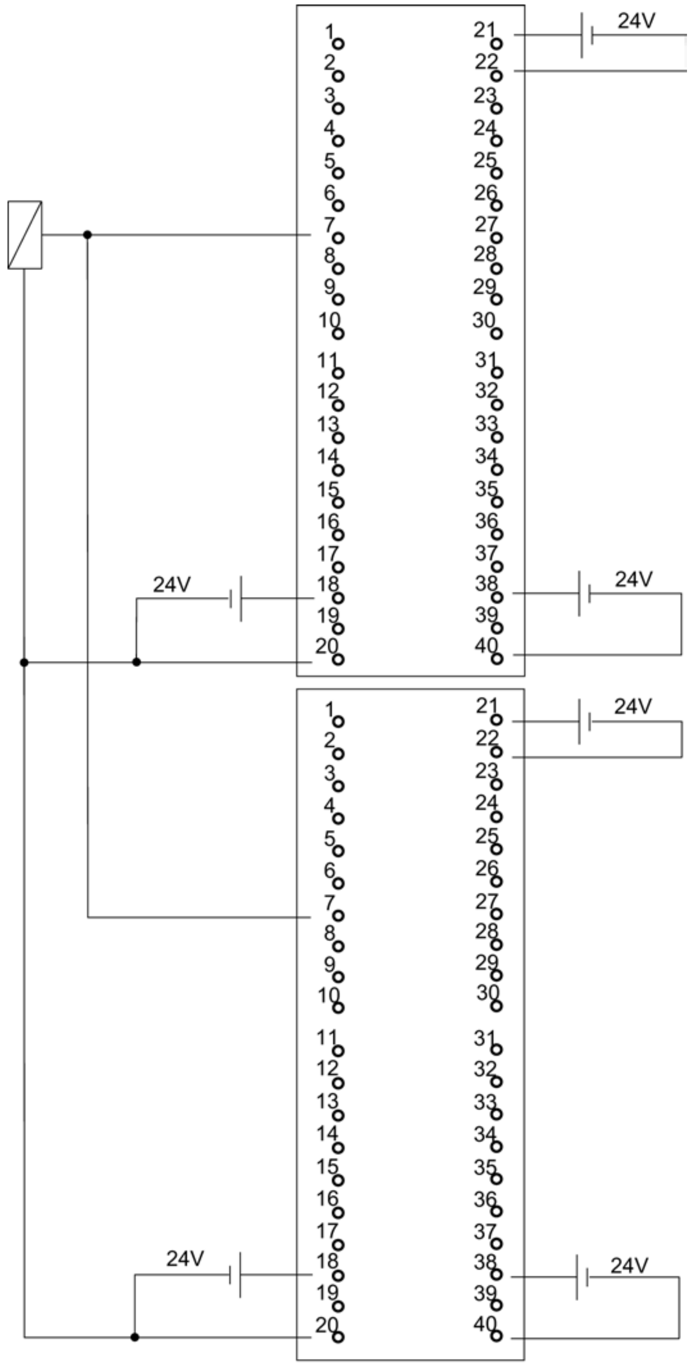


Figure C-9 Example of an interconnection with SM 326; DO 10 x DC 24V/2A

C.12 SM 326; DI 8 x NAMUR, 6ES7 326–1RF00–0AB0

The diagram below shows the connection of two redundant encoders to two redundant SM 326; DI 8 x NAMUR . The encoders are connected to channel 4.

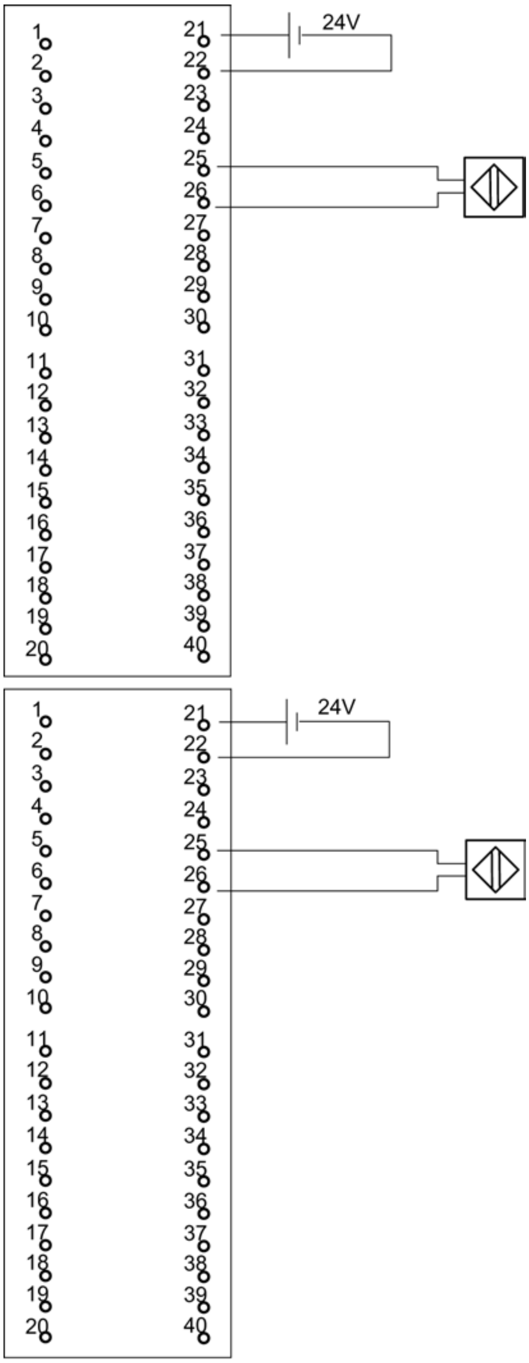


Figure C-10 Example of an interconnection with SM 326; DI 8 x NAMUR

C.13 SM 326; DI 24 x DC 24 V, 6ES7 326–1BK00–0AB0

The diagram below shows the connection of one encoder to two redundant SM 326; DI 24 x DC 24 V. The encoder is connected to channel 13.

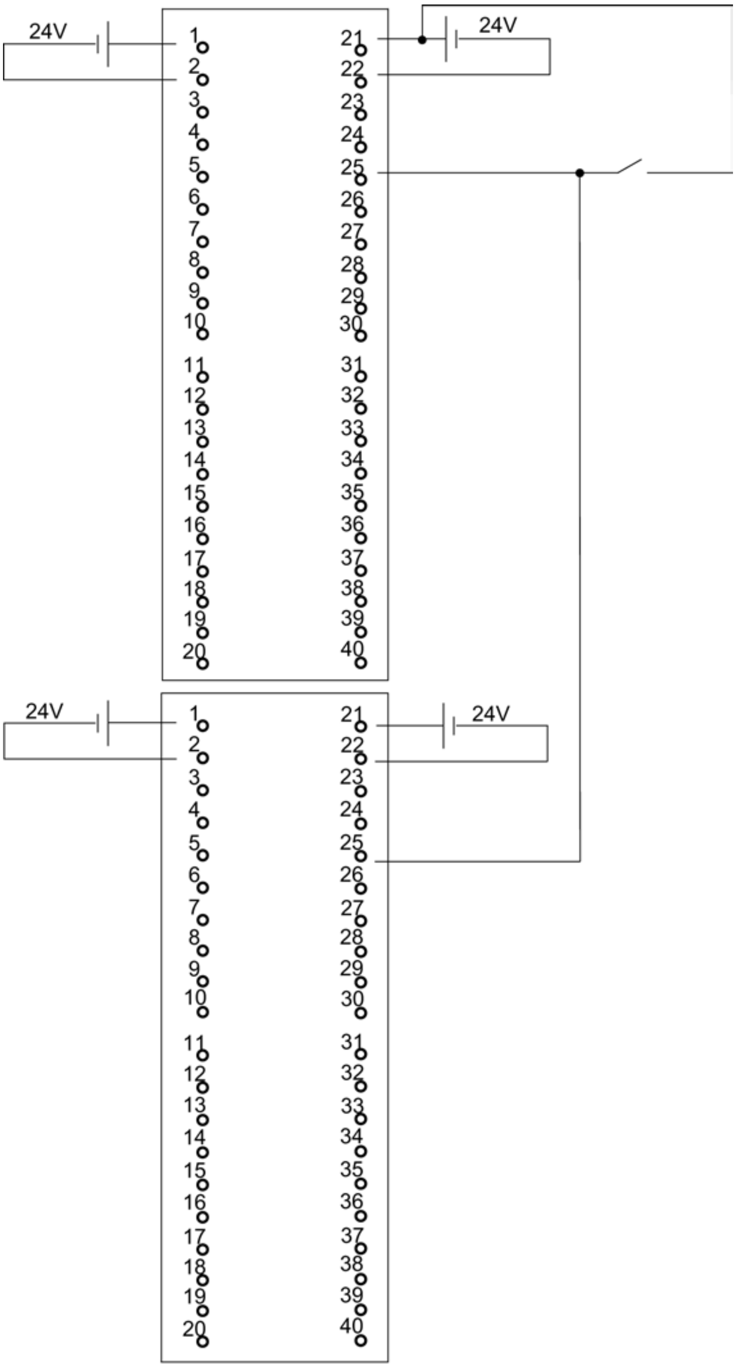


Figure C-11 Example of an interconnection with SM 326; DI 24 x DC 24 V

C.14 SM 421; DI 32 x UC 120 V, 6ES7 421–1EL00–0AA0

The diagram below shows the connection of a redundant encoder to two SM 421; DI 32 x UC 120 V. The encoder is connected to channel 0.

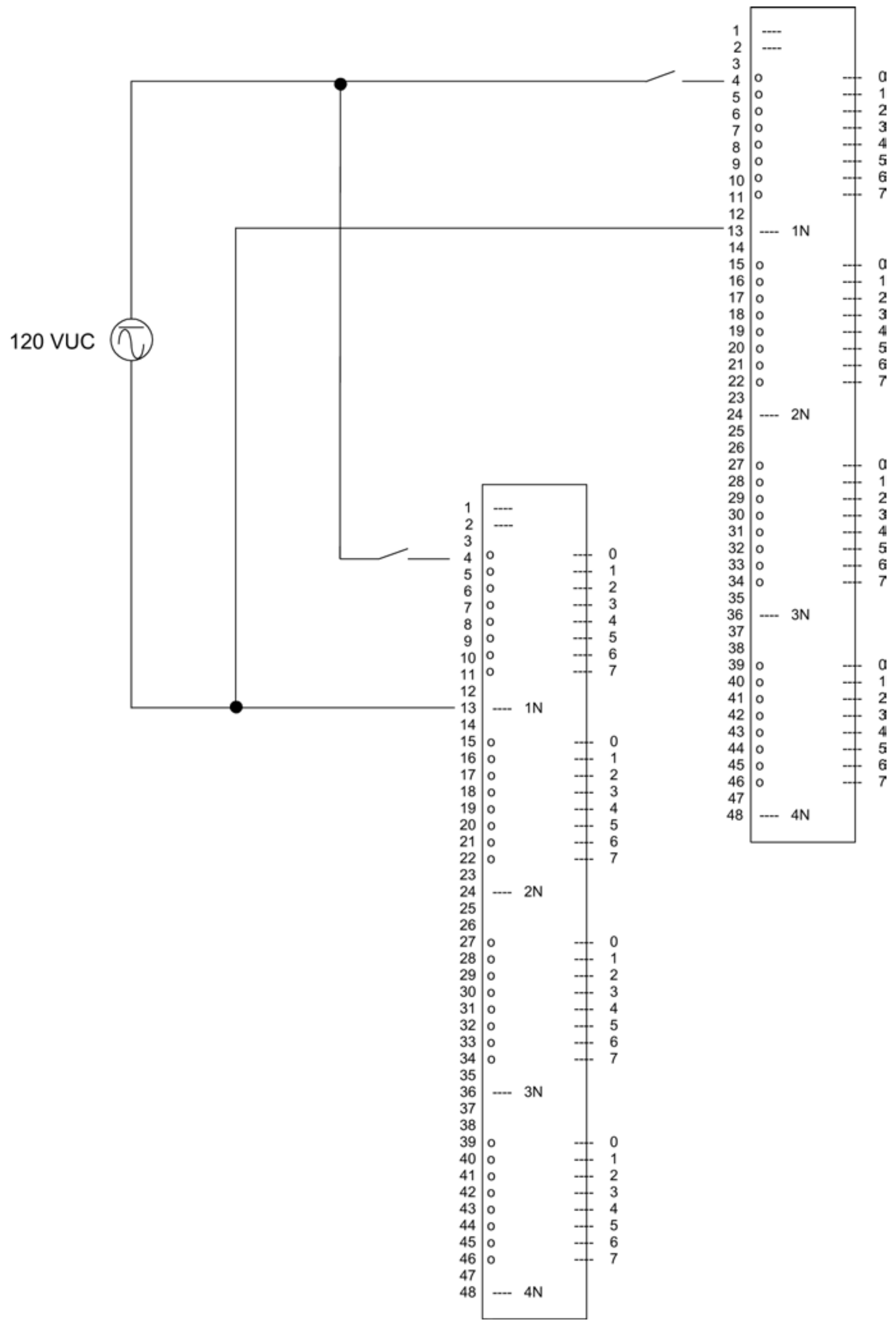


Figure C-12 Example of an interconnection with SM 421; DI 32 x UC 120 V

C.15 SM 421; DI 16 x DC 24 V, 6ES7 421–7BH01–0AB0

The diagram below shows the connection of two redundant encoders pairs to two SM 421; D1 16 x 24 V. The encoders are connected to channel 0 and 8.

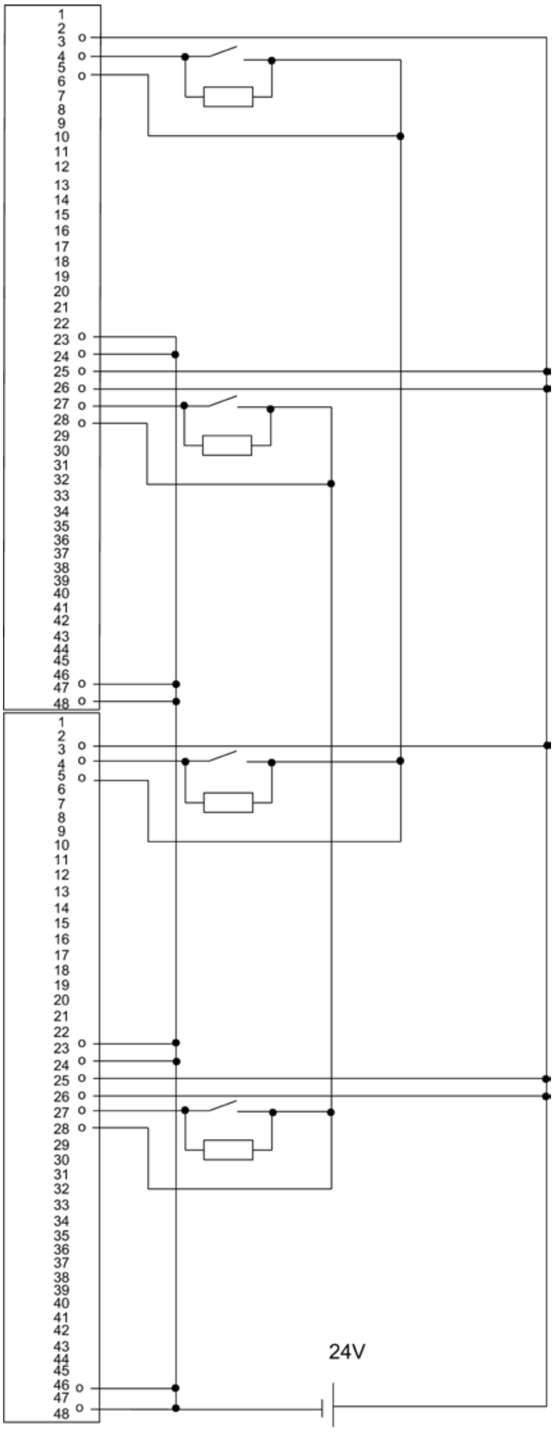


Figure C-13 Example of an interconnection with SM 421; DI 16 x 24 V

C.16 SM 421; DI 32 x DC 24 V, 6ES7 421–1BL00–0AB0

The diagram below shows the connection of two redundant encoders to two SM 421; D1 32 x 24 V. The encoders are connected to channel 0.

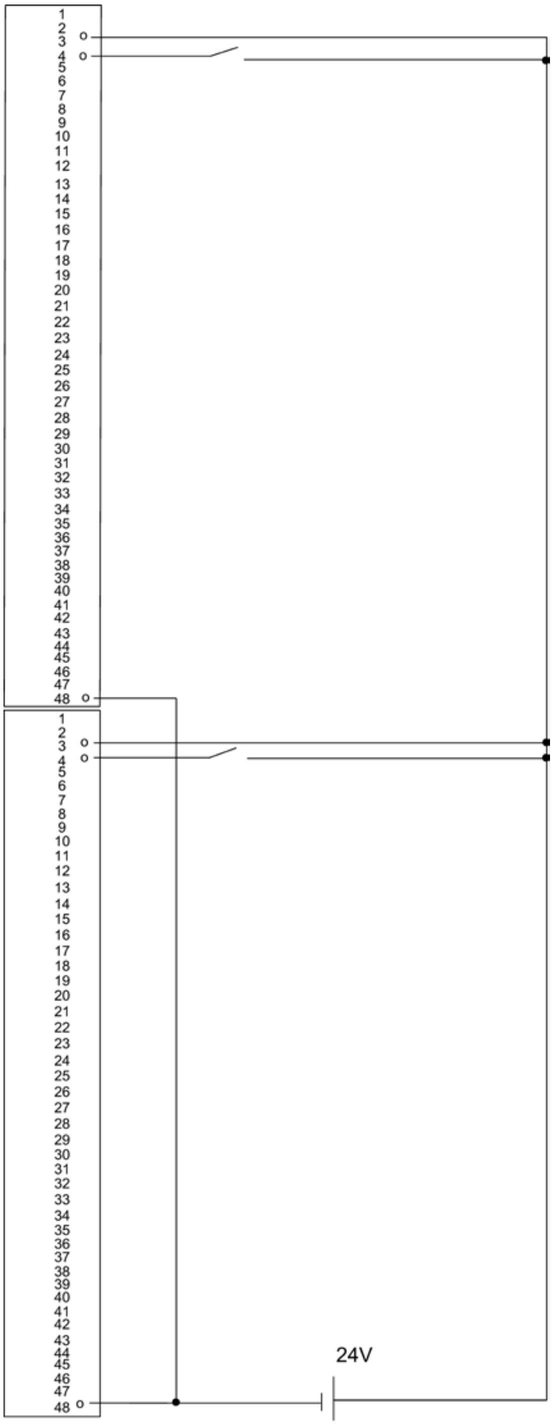


Figure C-14 Example of an interconnection with SM 421; DI 32 x 24 V

C.17 SM 421; DI 32 x DC 24 V, 6ES7 421–1BL01–0AB0

The diagram below shows the connection of two redundant encoders to two SM 421; D1 32 x 24 V. The encoders are connected to channel 0.

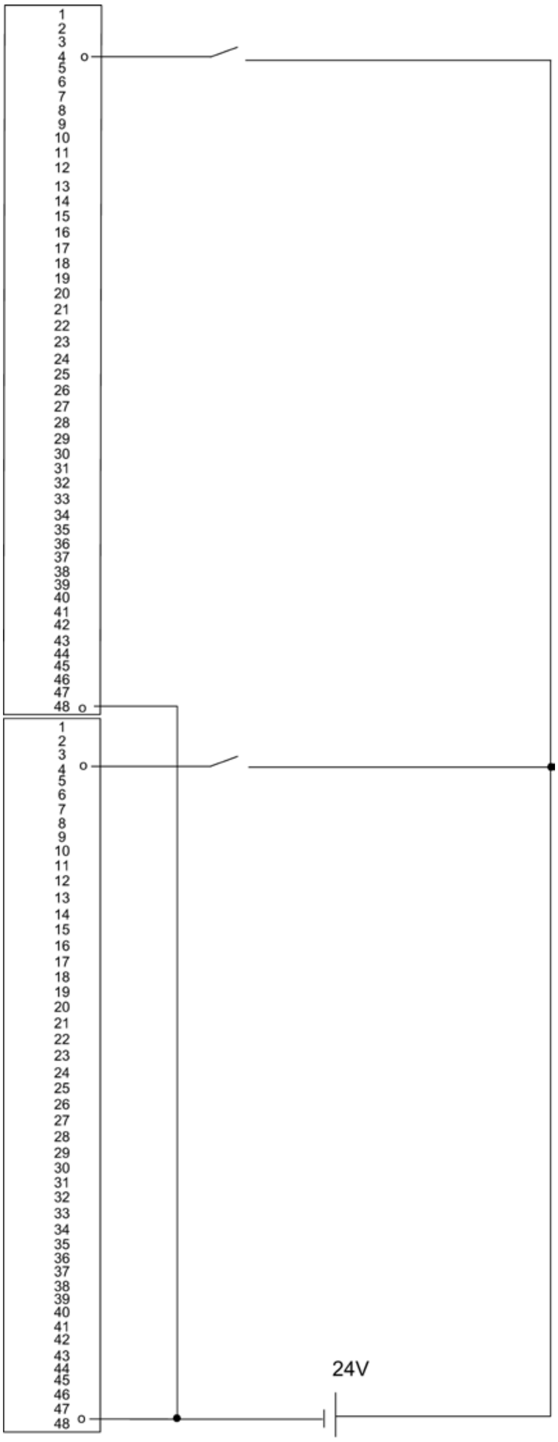


Figure C-15 Example of an interconnection with SM 421; DI 32 x 24 V

C.18 SM 322; DO 8 x DC 24 V/2 A, 6ES7 322–1BF01–0AA0

The diagram below shows the connection of an actuator to two redundant SM 322; DO 8 x DC 24 V. The actuator is connected to channel 0.

Types with U_r >=200 V and I_F >= 2 A are suitable as diodes

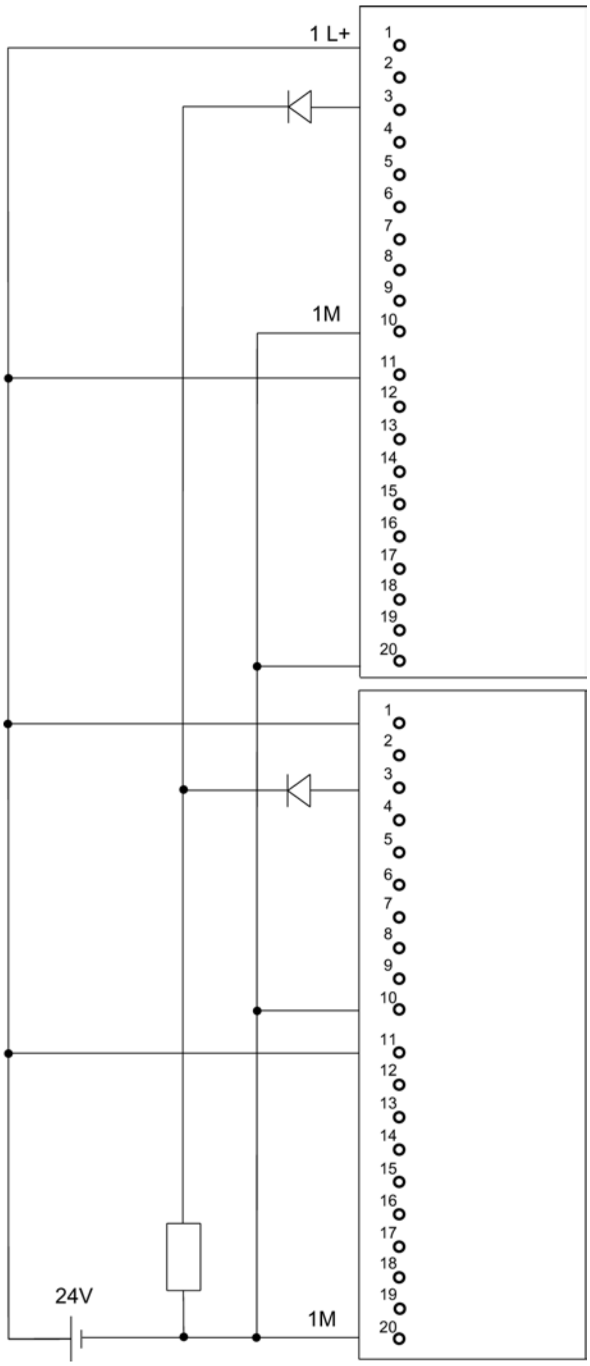


Figure C-16 Example of an interconnection with SM 322; DO 8 x DC 24 V/2 A

C.19 SM 322; DO 32 x DC 24 V/0,5 A, 6ES7 322–1BL00–0AA0

The diagram below shows the connection of an actuator to two redundant SM 322; DO 32 x DC 24 V. The actuator is connected to channel 1.

Suitable diodes are, for example, those of the series 1N4003 ... 1N4007, or any other diode with U_r >=200 V and I_F >= 1 A

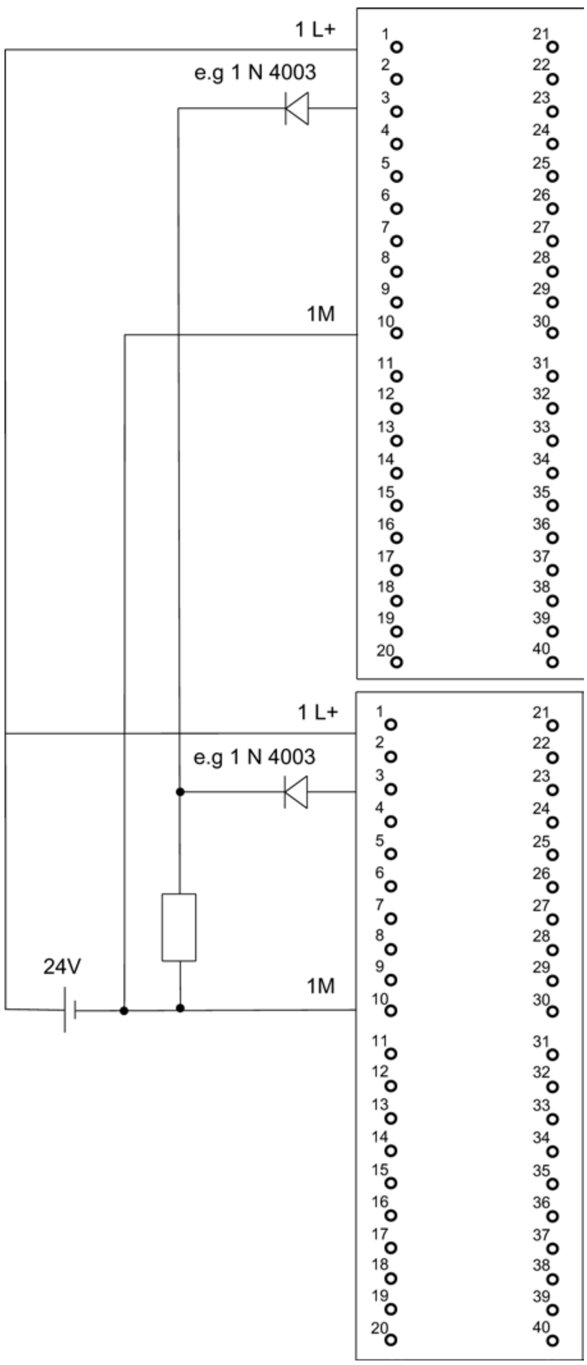


Figure C-17 Example of an interconnection with SM 322; DO 32 x DC 24 V/0.5 A

C.20 SM 322; DO 8 x AC 230 V/2 A, 6ES7 322–1FF01–0AA0

The diagram below shows the connection of an actuator to two SM 322; DO 8 x AC 230 V/2 A. The actuator is connected to channel 0.

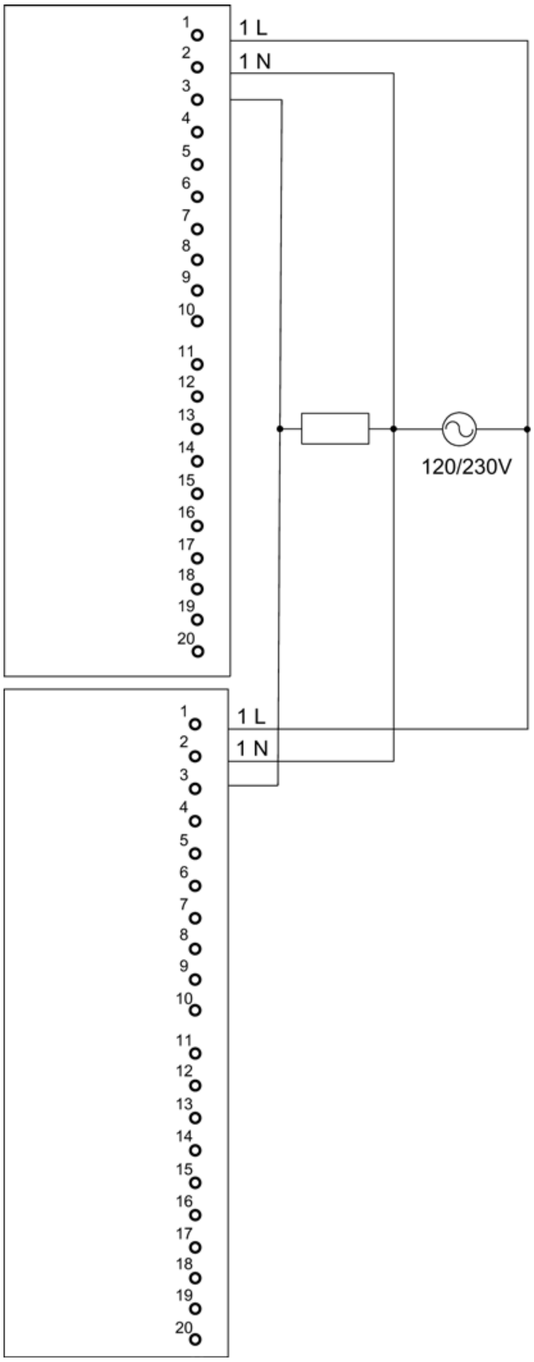


Figure C-18 Example of an interconnection with SM 322; DO 8 x AC 230 V/2 A

C.21 SM 322; DO 4 x DC 24 V/10 mA [EEx ib], 6ES7 322–5SD00–0AB0

The diagram below shows the connection of an actuator to two SM 322; DO 16 x DC 24 V/10 mA [EEx ib]. The actuator is connected to channel 0. Suitable diodes are, for example, those of the series 1N4003 ... 1N4007, or any other diode with U_r >=200 V and I_F >= 1 A

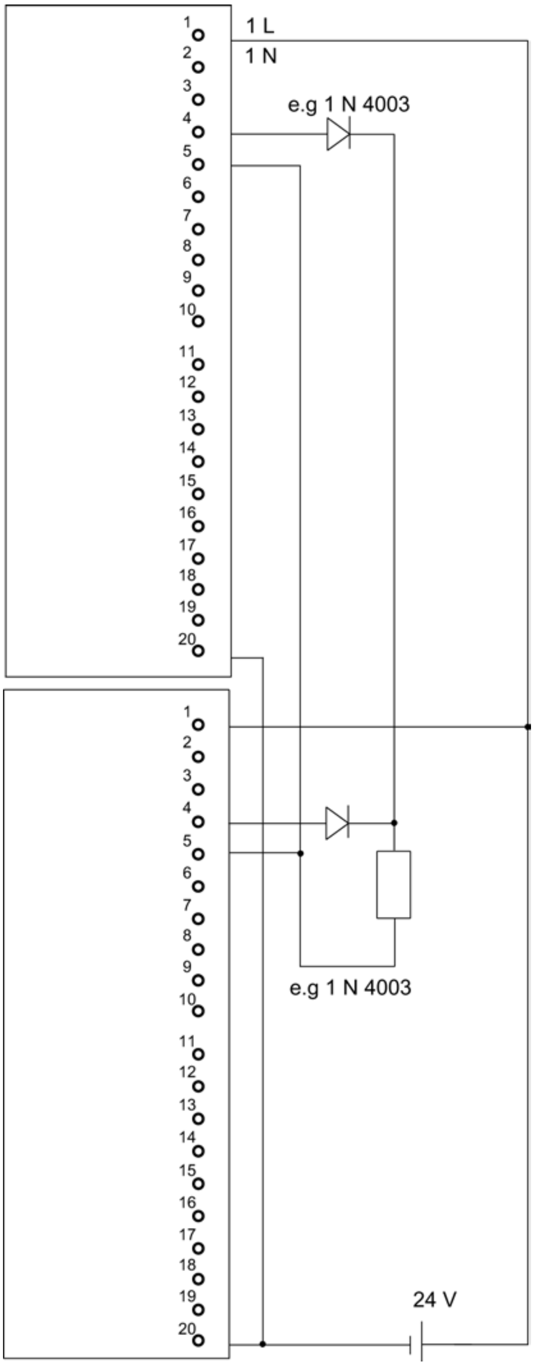


Figure C-19 Example of an interconnection with SM 322; DO 16 x DC 24 V/10 mA [EEx ib]

C.22 SM 322; DO 4 x DC 15 V/20 mA [EEx ib], 6ES7 322–5RD00–0AB0

The diagram below shows the connection of an actuator to two SM 322; DO 16 x DC 15 V/20 mA [EEx ib]. The actuator is connected to channel 0. Suitable diodes are, for example, those of the series 1N4003 ... 1N4007, or any other diode with U_r >=200 V and I_F >= 1 A

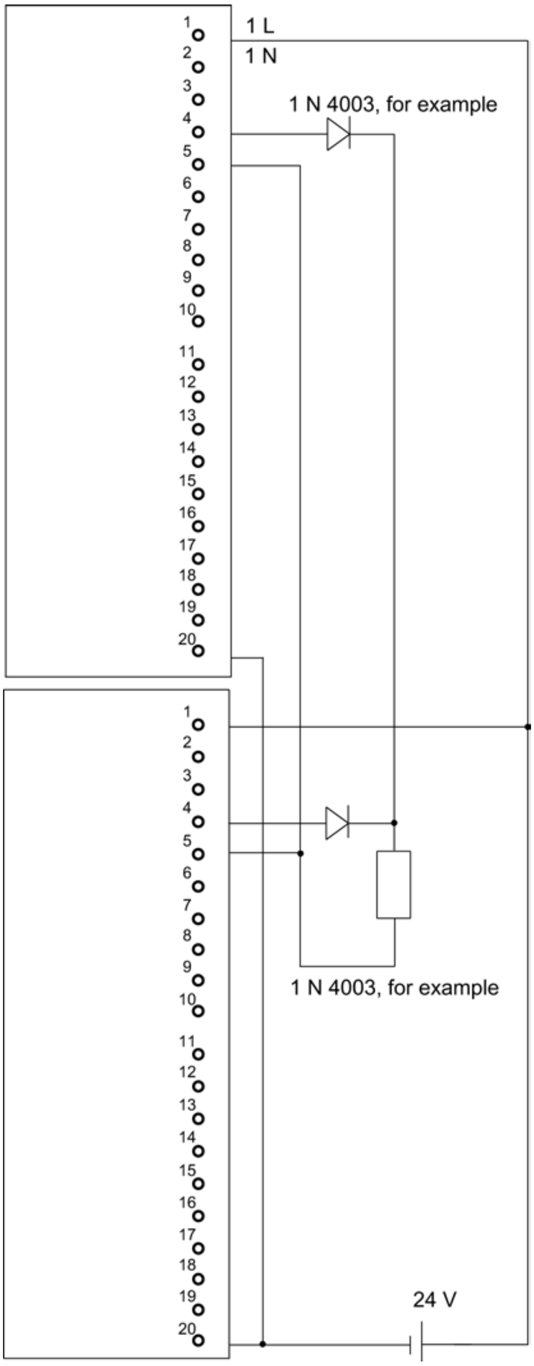


Figure C-20 Example of an interconnection with SM 322; DO 16 x DC 15 V/20 mA [EEx ib]

C.23 SM 322; DO 8 x DC 24 V/0.5 A, 6ES7 322–8BF00–0AB0

The diagram below shows the connection of an actuator to two redundant SM 322; DO 8 x DC 24 V/0.5 A. The actuator is connected to channel 0.

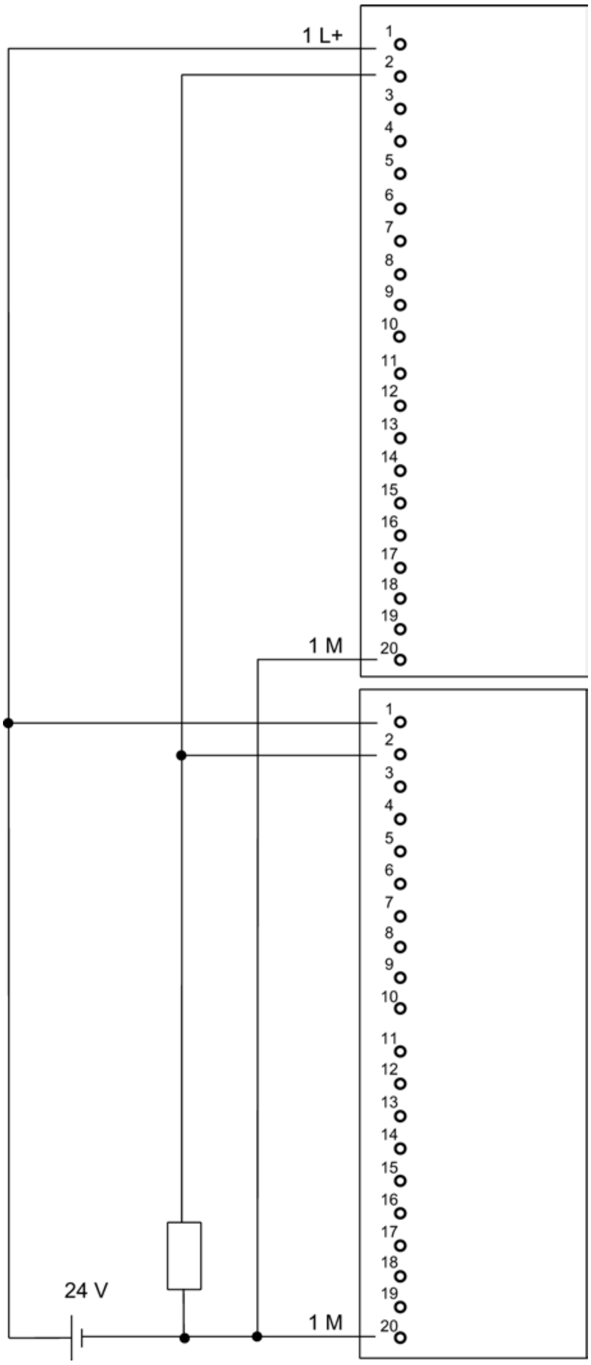


Figure C-21 Example of an interconnection with SM 322; DO 8 x DC 24 V/0.5 A

C.24 SM 322; DO 16 x DC 24 V/0.5 A, 6ES7 322–8BH01–0AB0

The diagram below shows the connection of an actuator to two redundant SM 322; DO 16 x DC 24 V/0.5 A. The actuator is connected to channel 8.

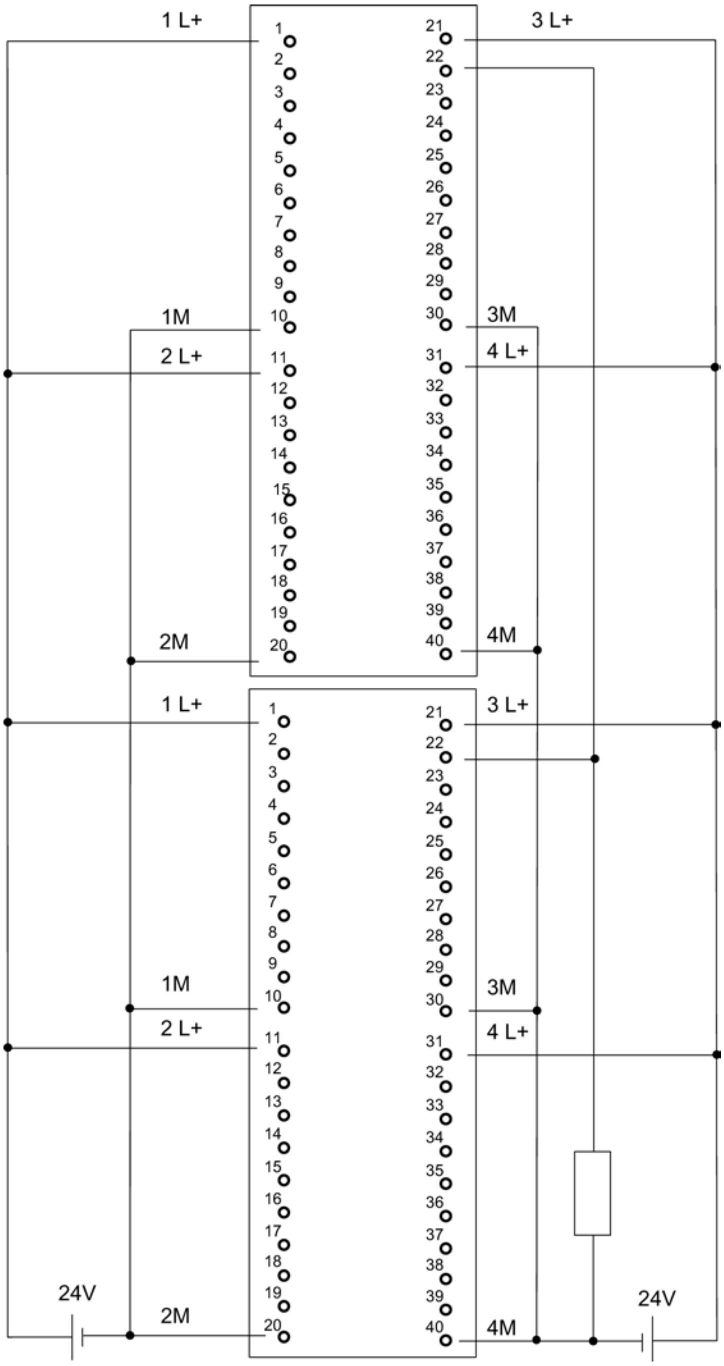


Figure C-22 Example of an interconnection with SM 322; DO 16 x DC 24 V/0.5 A

C.25 SM 332; AO 8 x 12 Bit, 6ES7 332–5HF00–0AB0

The diagram below shows the connection of two actuators to two redundant SM 332; AO 8 x 12 Bit. The actuators are connected to channels 0 and 4. Suitable diodes are, for example, those of the series 1N4003 ... 1N4007, or any other diode with U_r >=200 V and I_F >= 1 A

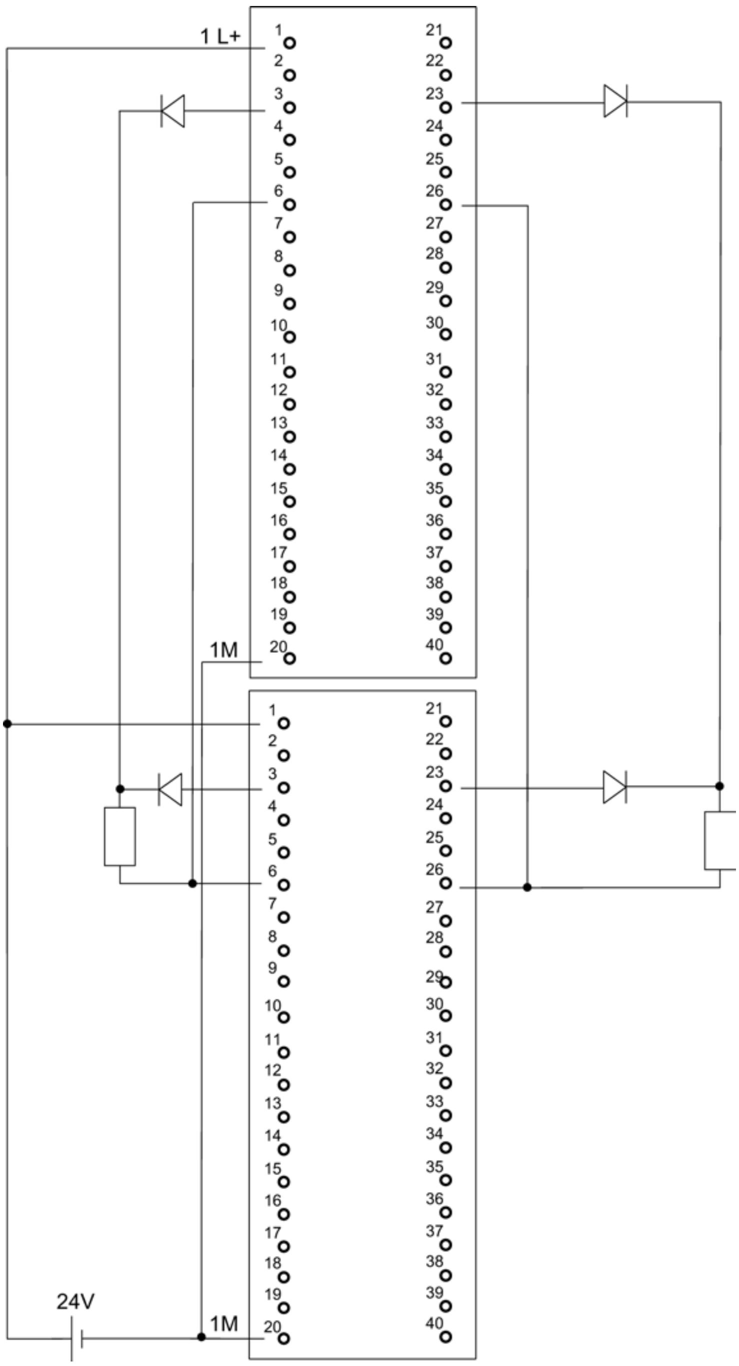


Figure C-23 Example of an interconnection with SM 332, AO 8 x 12 Bit

C.26 SM 332; AO 4 x 0/4...20 mA [EEx ib], 6ES7 332–5RD00–0AB0

The diagram below shows the connection of an actuator to two SM 332; AO 4 x 0/4...20 mA [EEx ib]. The actuator is connected to channel 0.
Suitable diodes are, for example, types from the series 1N4003 ... 1N4007 or any other diode with U_r >=200 V and I_F >= 1 A

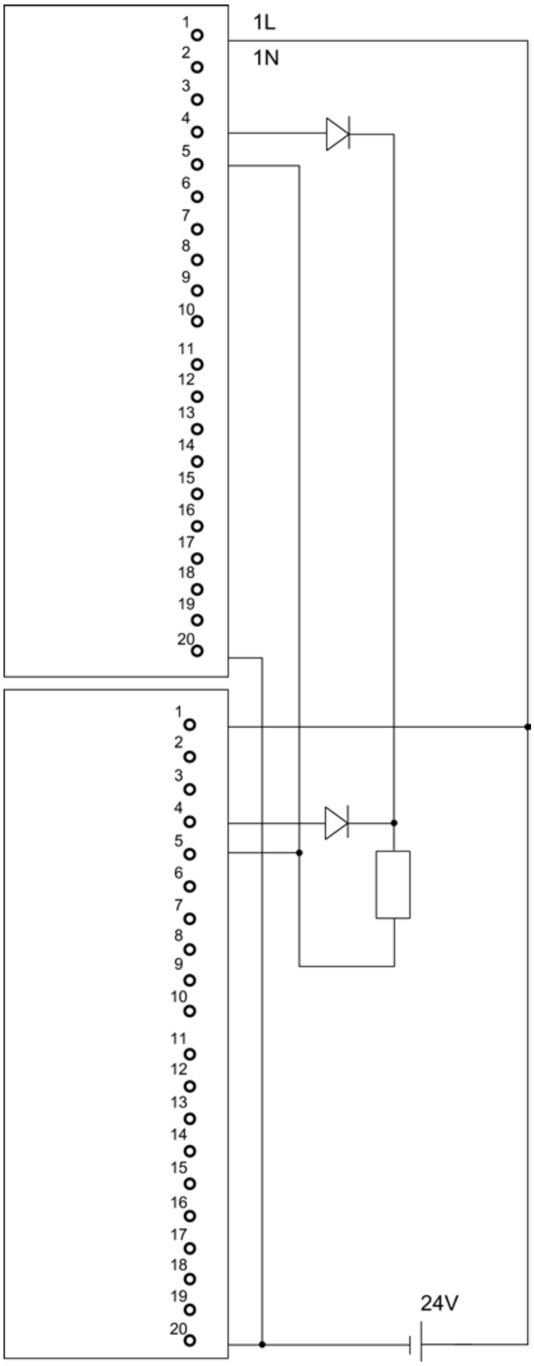


Figure C-24 Example of an interconnection with SM 332; AO 4 x 0/4...20 mA [EEx ib]

C.27 SM 422; DO 16 x AC 120/230 V/2 A, 6ES7 422–1FH00–0AA0

The diagram below shows the connection of an actuator to two SM 422; DO 16 x 120/230 V/2 A. The actuator is connected to channel 0.

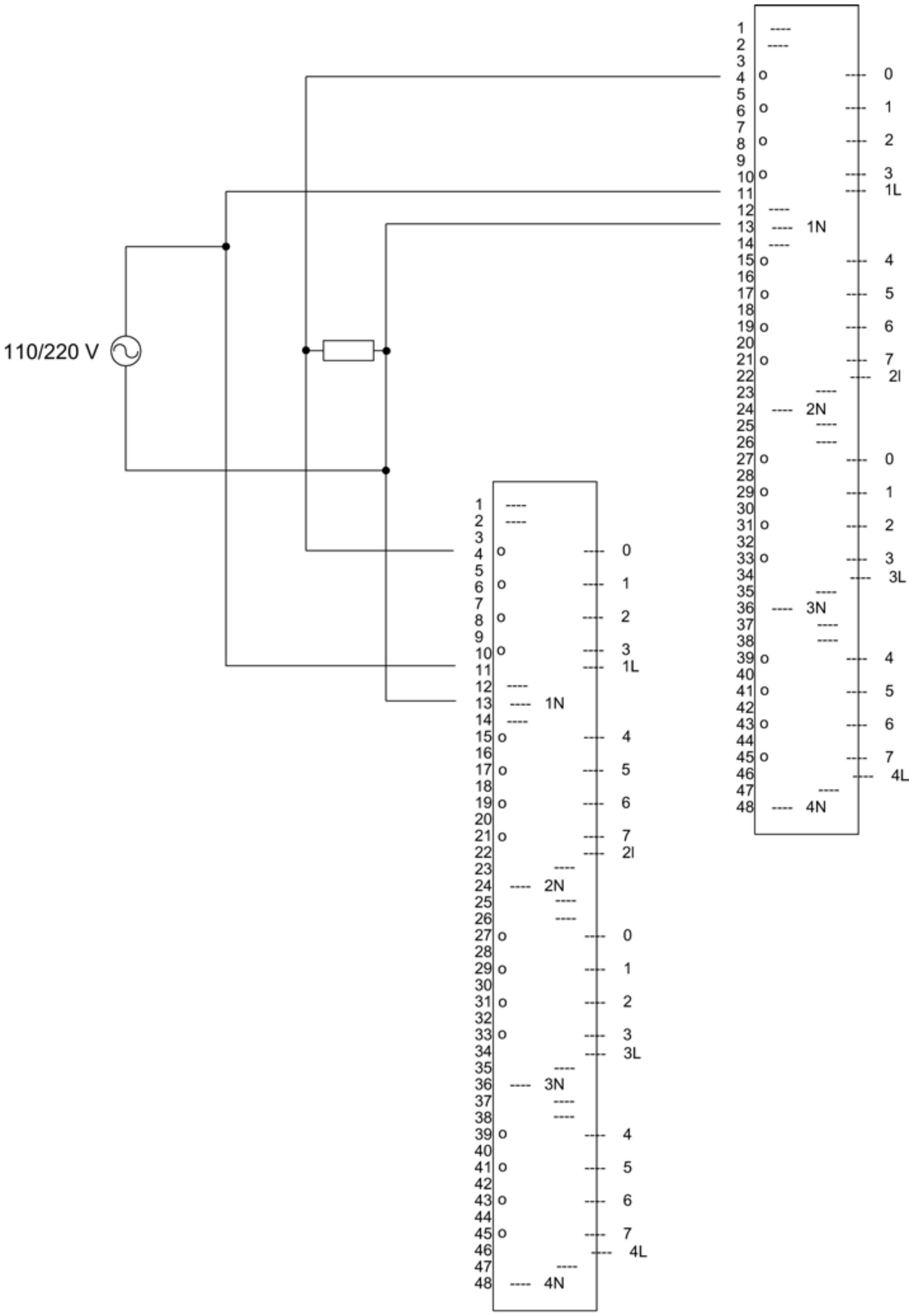


Figure C-25 Example of an interconnection with SM 422; DO 16 x 120/230 V/2 A

C.28 SM 422; DO 32 x DC 24 V/0.5 A, 6ES7 422–7BL00–0AB0

The diagram below shows the connection of an actuator to two SM 422; DO 32 x 24 V/0.5 A. The actuator is connected to channel 0. Suitable diodes are, for example, those of the series 1N4003 ... 1N4007, or any other diode with U_r >=200 V and I_F >= 1 A

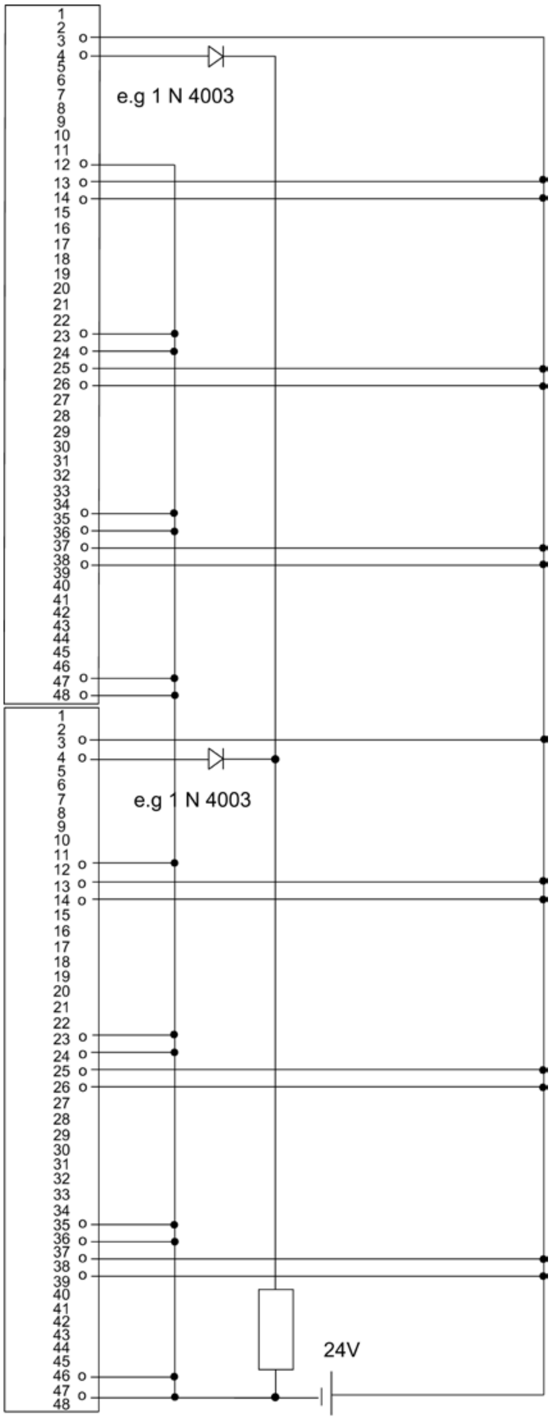


Figure C-26 Example of an interconnection with SM 422; DO 32 x DC 24 V/0.5 A

C.29 SM 331; AI 4 x 15 Bit [EEx ib]; 6ES7 331–7RD00–0AB0

The diagram below shows the connection of a 2-wire transmitter to two SM 331; AI 4 x 15 Bit [EEx ib]. The transmitter is connected to channel 1. Suitable Zener diode: BZX85C6v2.

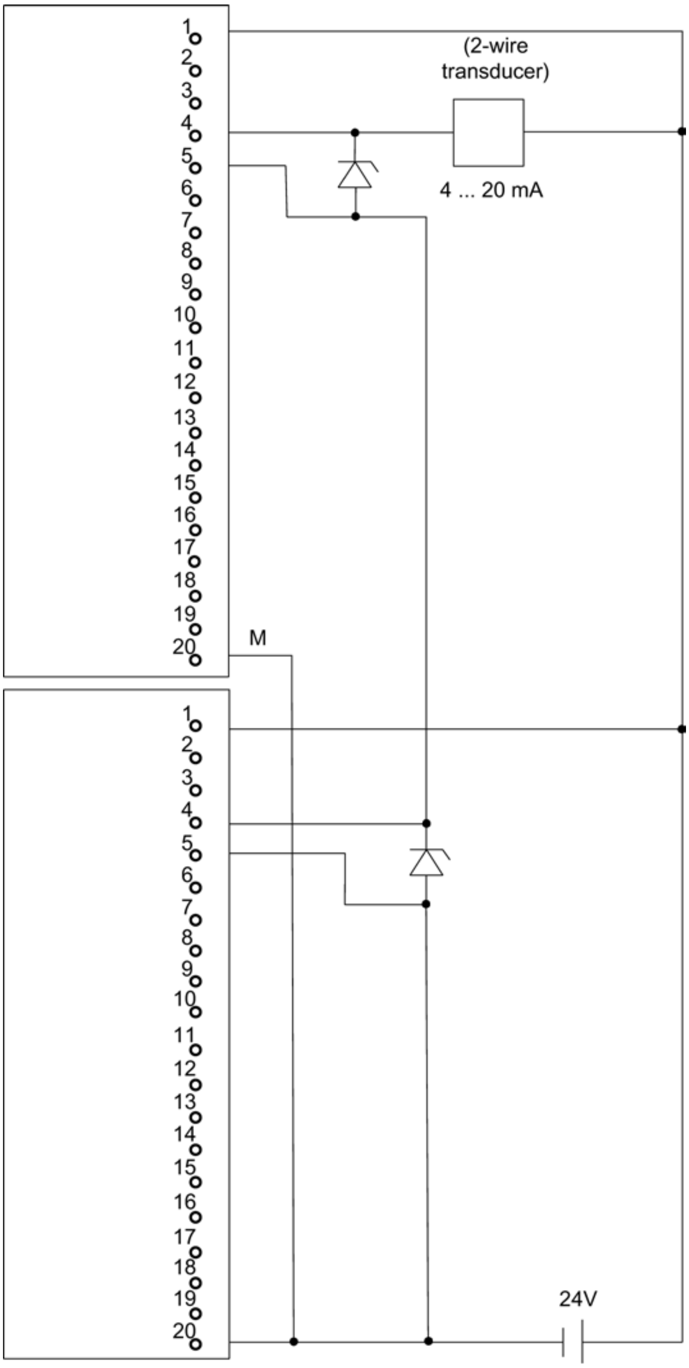


Figure C-27 Example of an interconnection with SM 331, AI 4 x 15 Bit [EEx ib]

C.30 SM 331; AI 8 x 12 Bit, 6ES7 331–7KF02–0AB0

The diagram below shows the connection of a transmitter to two SM 331; AI 8 x 12 Bit. The transmitter is connected to channel 0.

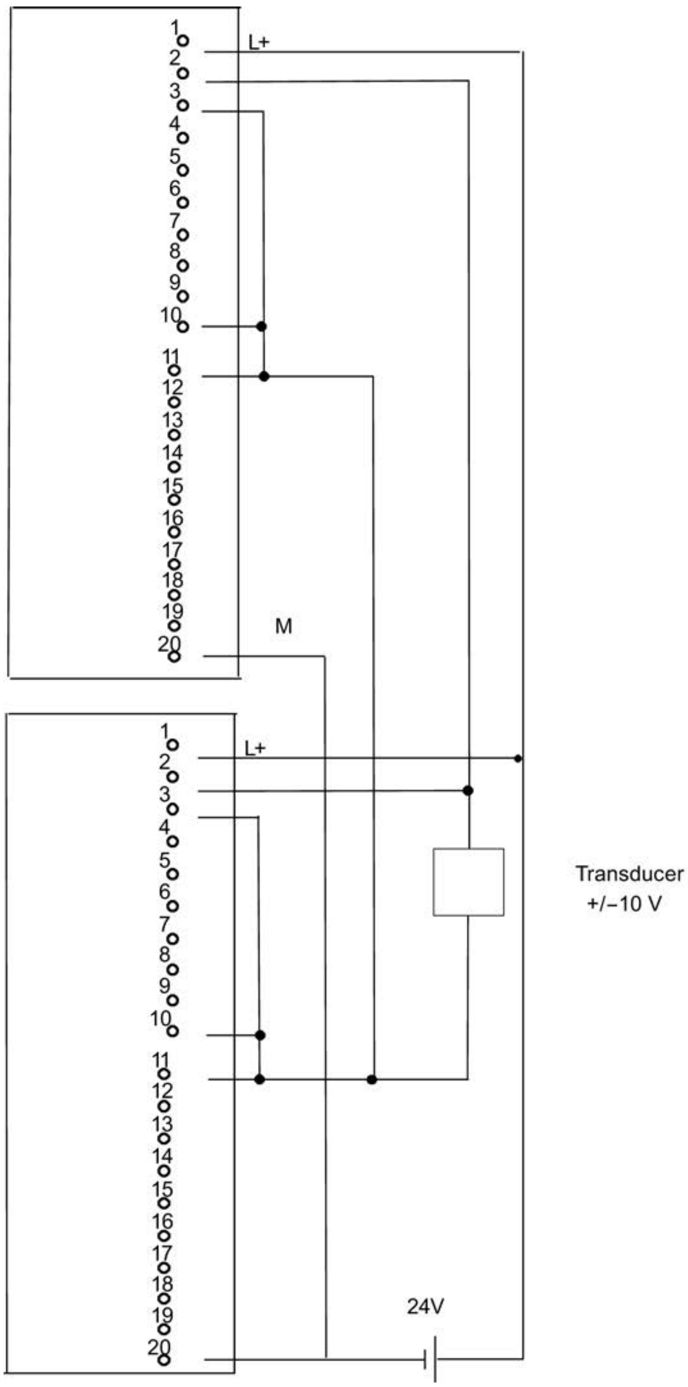


Figure C-28 Example of an interconnection with SM 331; AI 8 x 12 Bit

C.31 SM 331; AI 8 x 16 Bit; 6ES7 331–7NF00–0AB0

The figure below shows the connection of a transmitter to two redundant SM 331; AI 8 x 16 Bit. The transmitter is connected to channel 0 and 7 respectively.

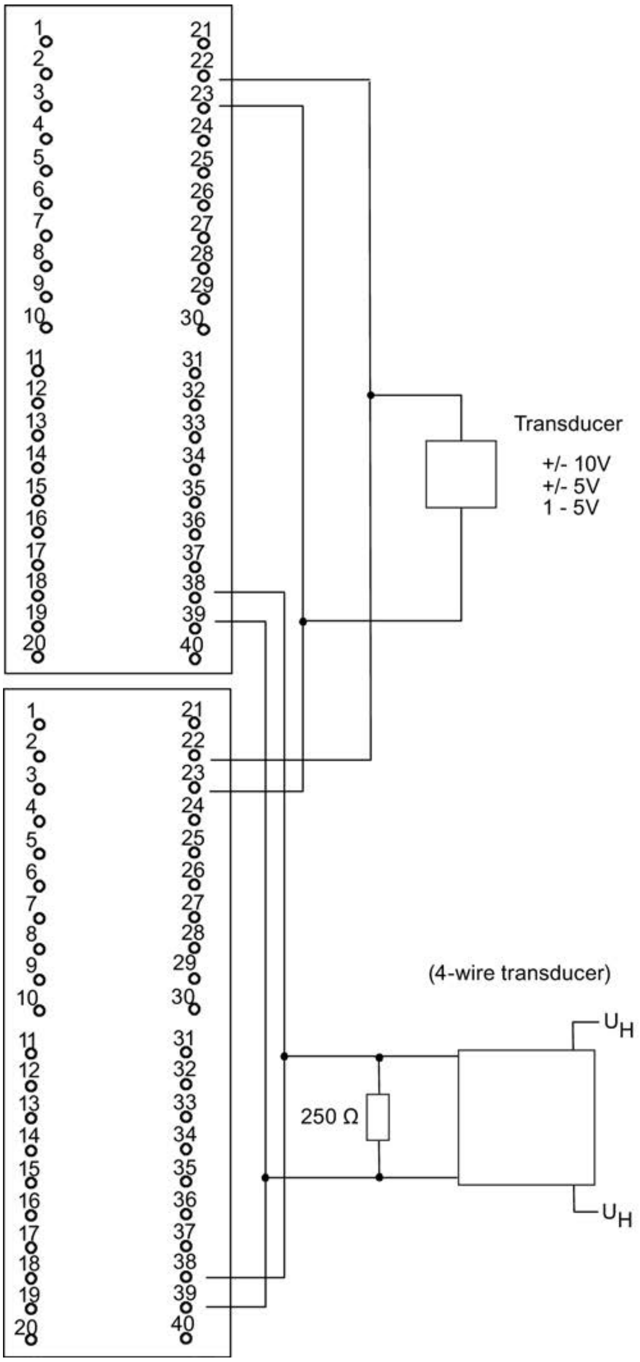


Figure C-29 Example of an interconnection with SM 331; AI 8 x 16 Bit

C.32 SM 331; AI 8 x 16 Bit; 6ES7 331–7NF10–0AB0

The figure below shows the connection of a transmitter to two redundant SM 331; AI 8 x 16 Bit. The transmitter is connected to channel 0 and 3 respectively.

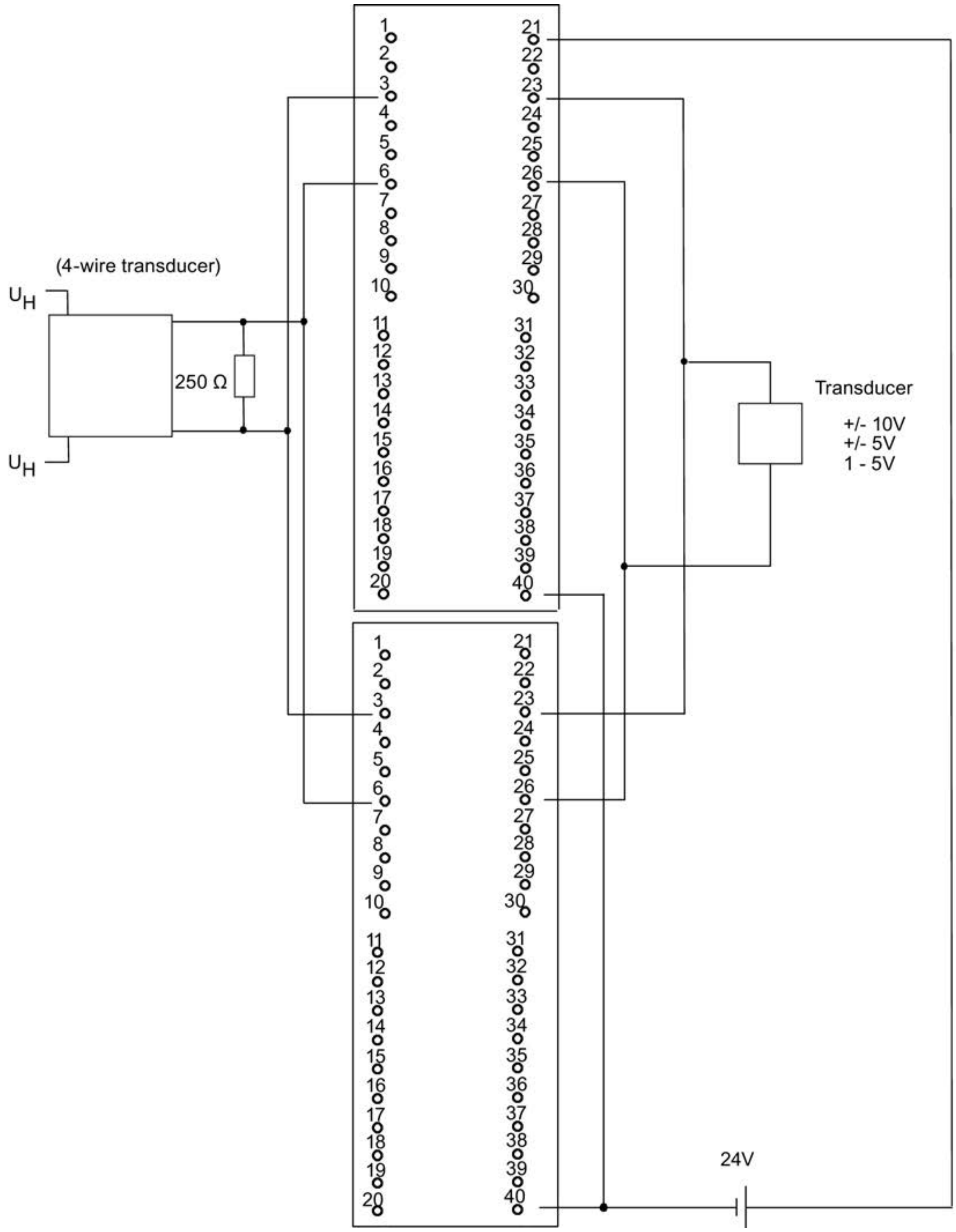


Figure C-30 Example of an interconnection with SM 331; AI 8 x 16 Bit

C.33 AI 6xTC 16Bit iso, 6ES7331-7PE10-0AB0

The figure below shows the connection of a thermocouple to two redundant SM 331 AI 6xTC 16Bit iso.

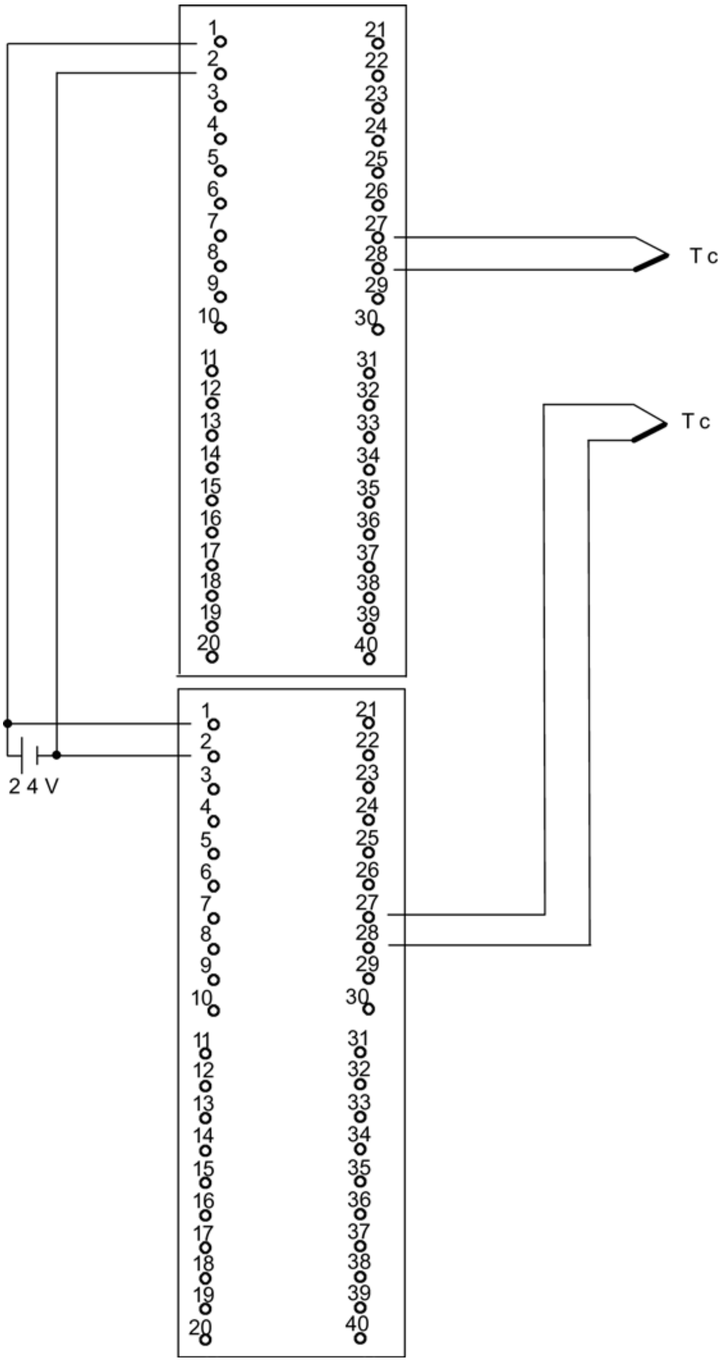


Figure C-31 Example of an interconnection AI 6xTC 16Bit iso

C.34 SM331; AI 8 x 0/4...20mA HART, 6ES7 331-7TF01-0AB0

The diagram below shows the connection of a 4-wire transmitter to two redundant SM 331; AI 8 x 0/4...20mA HART.

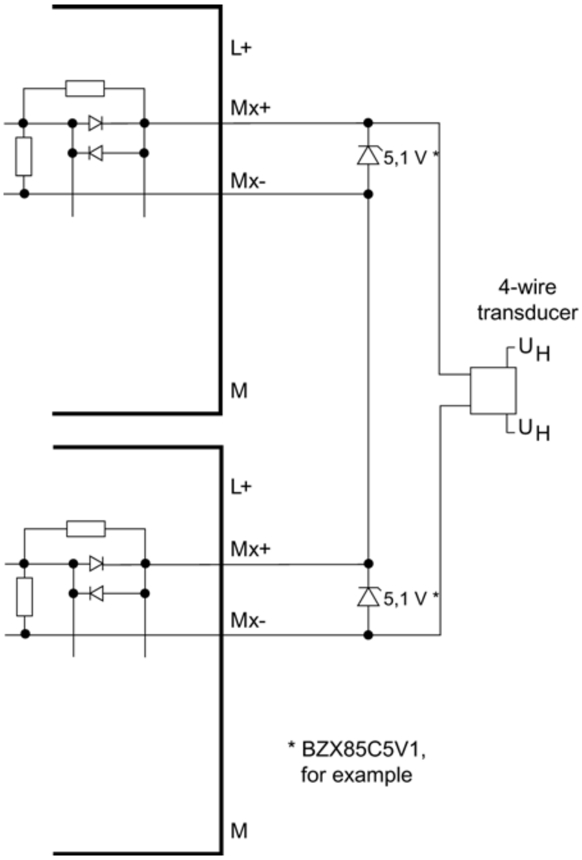


Figure C-32 Interconnection example 1 SM 331; AI 8 x 0/4...20mA HART

The diagram below shows the connection of a 2-wire transmitter to two redundant SM 331; AI 8 x 0/4...20mA HART.

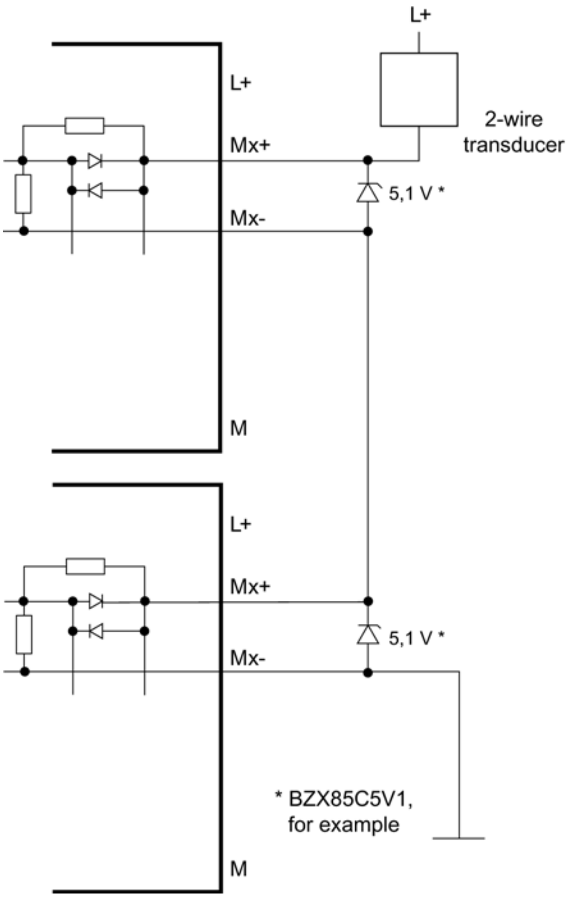


Figure C-33 Interconnection example 2 SM 331; AI 8 x 0/4...20mA HART

C.35 SM 332; AO 4 x 12 Bit; 6ES7 332–5HD01–0AB0

The diagram below shows the connection of an actuator to two
SM 332; AO 4 x 12 Bit. The actuator is connected to channel 0. Suitable diodes are, for example, those of the series 1N4003 ... 1N4007, or any other diode with U_r >=200 V and I_F >= 1 A

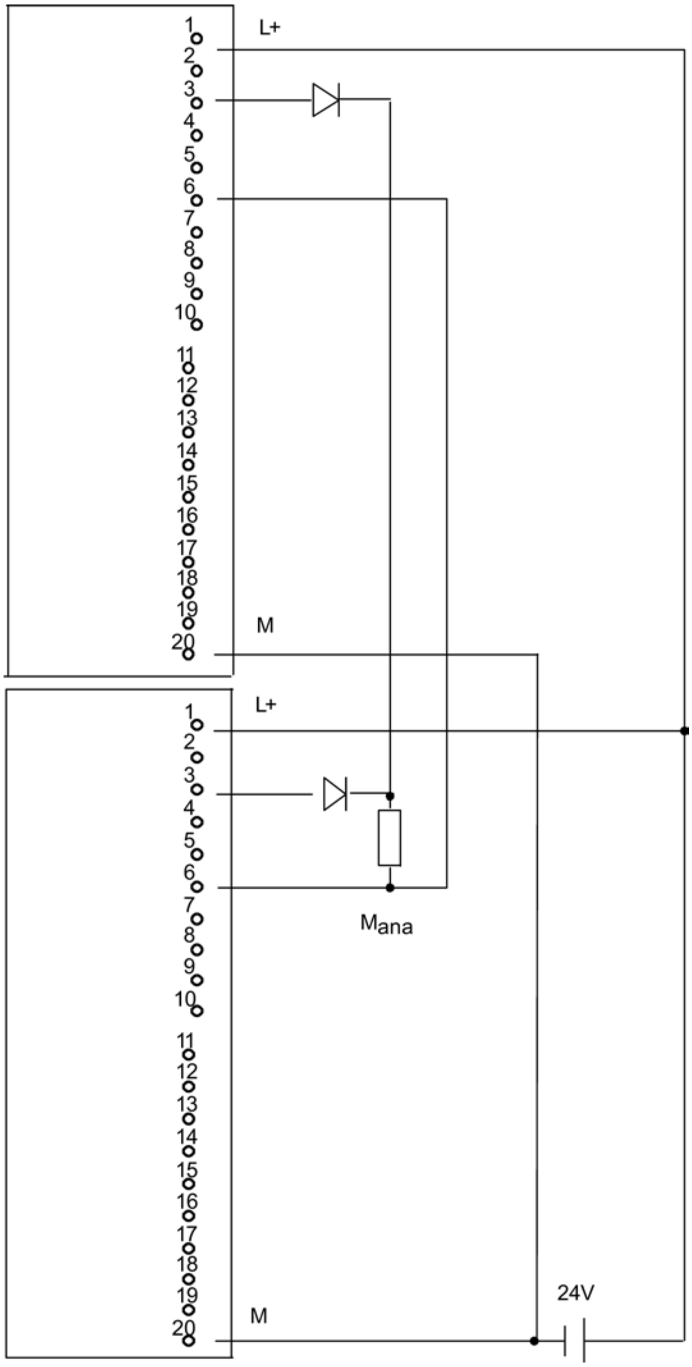


Figure C-34 Example of an interconnection with SM 332, AO 4 x 12 Bit

C.36 SM332; AO 8 x 0/4...20mA HART, 6ES7 332-8TF01-0AB0

The diagram below shows the connection of an actuator to two SM 332; AO 8 x 0/4...20 mA HART.

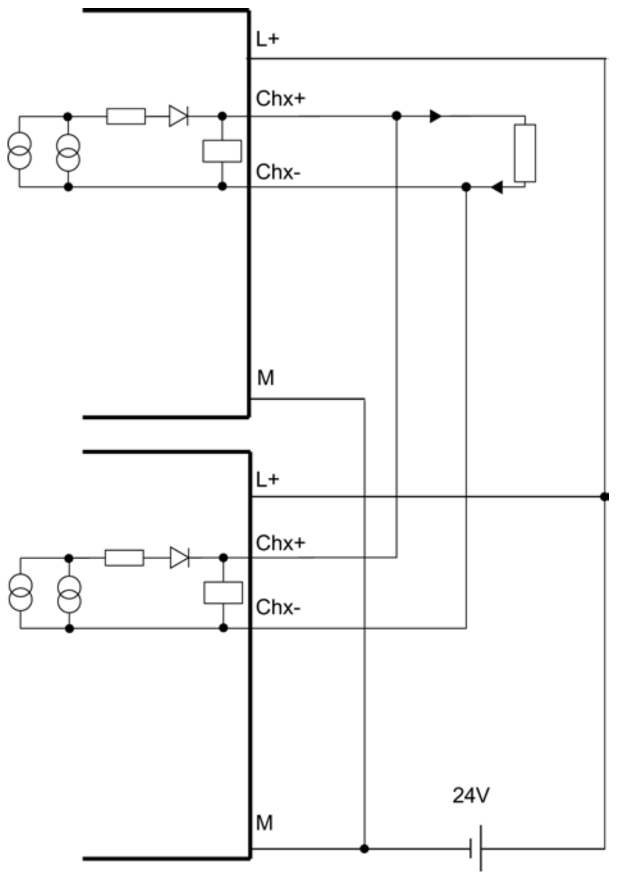


Figure C-35 Interconnection example 3 SM 332; AO 8 x 0/4...20mA HART

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