SIEMENS

SIMATIC

Fault-tolerant systems CPU S7-400H (V6.0)

System Manual

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Fault-tolerant systems CPU S7-400H (V6.0)

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Preface

1

1.1 Preface

Purpose of this manual

This manual represents a useful reference and contains information on operator inputs, descriptions of functions, and technical specifications of the S7-400H CPUs.

For information on installing and wiring these and other modules in order to set up an S7-400H system, refer to the *S7-400 Automation System, Installation* manual.

Changes compared to the previous version

The following are the changes as compared to the predecessor version of this manual SIMATIC, High-Availability Systems, Edition 07/2014 (A5E00267693-13):

- Adapted procedure for expanding the load memory

Differences in system behavior between versions 4.5 and 6.0

- A user program that uses SFC 87 to read out the current connection status and that was written for a H-CPU V4.x does not return any data on an H-CPU V6.0. The reason is that the quantity Framework expanded to 120 connections also requires a larger target range in the program. You must adapt the program accordingly.
- A reserve CPU can take over the role of master at startup, see section STARTUP mode (Page 115).
- In large configurations with many CPs and/or external DP masters it may take up to 30 seconds until a requested restart is performed in the buffered POWER ON mode of the H-CPU V 6.0, see section STARTUP mode (Page 115)
- In contrast to OB 84, the cause of the call is not entered in the start information of OB 82, see the Synchronization Modules manual (https://support.industry.siemens.com/cs/ww/en/view/109779483).
- Extension of the cycle time for long synchronization lines, see the System Synchronization Modules manual (https://support.industry.siemens.com/cs/ww/en/view/109779483).
- If you use long synchronization lines, you have to extend the monitoring time of the connection at an H-CPU V6.0, see section Communication via fault-tolerant S7 connections (Page 216).
- The startup time of the CPU at power on, the loading time of blocks, as well as the startup after a plant modification at runtime can be significantly prolonged by encrypted blocks; see section Access-protected blocks (Page 67).
- The following applies to PROFINET in the fault-tolerant system: The job must be repeated if it is rejected with return value W#16#80BA when using SFB 52/53/54.

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 Vista or Windows 7 operating system. An S7-400H is configured using the STEP 7 basic software, and you should thus be familiar in the handling of this basic software. This knowledge is provided in the *Programming with STEP 7* manual.

In particular when operating an S7-400H system in potentially explosive atmospheres, you should always observe the information on the safety of electronic control systems provided in the appendix of the *S7-400 Automation System, Installation* manual.

Scope of the manual

The manual is relevant to the following components:

- CPU 412–5H; 6ES7 412–5HK06–0AB0 as of firmware V6.0
- CPU 414–5H; 6ES7 414–5HM06–0AB0 as of firmware V6.0
- CPU 416–5H; 6ES7 416–5HS06–0AB0 as of firmware V6.0
- CPU 417–5H; 6ES7 417–5HT06–0AB0 as of firmware V6.0

Approvals

For details on certifications and standards, refer to the *S7-400 Automation System, Module Data* manual, section 1.1, Standards and Certifications.

Further information

For more information on the topics covered in this manual, refer to the following manuals:

Programming with STEP 7 (https://support.industry.siemens.com/cs/ww/en/view/18652056)

Configuring Hardware and Communication Connections with STEP 7 (https://support.industry.siemens.com/cs/ww/en/view/18652631)

System and Standard Functions (https://support.industry.siemens.com/cs/ww/en/view/44240604)

PROFINET System Description (https://support.industry.siemens.com/cs/ww/en/view/19292127)

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: **Table of contents** opens the Help index. You will find help on H systems in **Configuring H-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 S7-400H system 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 (https://www.siemens.com/automation/partner)

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

Documentation (https://new.siemens.com/global/en/products/automation/process-control/simatic-pcs-7/technical-documentation.html)

You can find the online catalog and order system under:

Catalog (https://mall.industry.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 (https://www.siemens.com/processsafety)

Submit your requests to:

Mail Functional Safety Services (mailto:team-ec.industry@siemens.com)

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 (https://www.sitrain-learning.siemens.com/)

Technical Support

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

Support Request (https://support.industry.siemens.com/cs/ww/en/my)

Service & Support on the Internet

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

Service & Support (https://support.industry.siemens.com/cs/ww/en/)

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 Cybersecurity information

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

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

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For additional information on industrial cybersecurity measures that may be implemented, please visit
https://www.siemens.com/cybersecurity-industry.

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

To stay informed about product updates, subscribe to the Siemens Industrial Cybersecurity RSS Feed under
https://new.siemens.com/cert.

1.3 Information on configuration

The SIMATIC range offers additional products for individual controllers or whole automation cells that increase protection from unauthorized access. These products add components for protection of communication connections to your system.

Note

Network security

To secure communication on the plant network, you should use a SCALANCE SC. See PCS 7 Compendium Part F Industrial Security and SIEMENS Cyber Security Guidelines.

Security measures include:

- Firewall
- NAT/NAPT router
- VPN (Virtual Private Network)

Fault-tolerant automation systems

2

2.1 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.

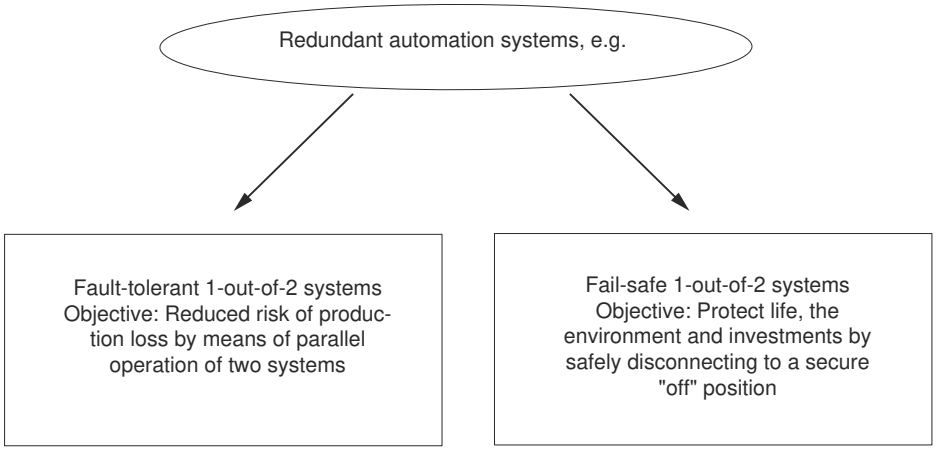


Figure 2-1 Operating objectives of redundant automation systems

Note the difference between fault-tolerant and fail-safe systems.
The S7–400H is a fault-tolerant automation system. You may only use it to control safety-related processes if you have programmed and configured it in accordance with the rules for F systems. You can find details in the following manual: SIMATIC Industrial Software S7 F/FH Systems (https://support.industry.siemens.com/cs/ww/en/view/109773062)

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. If you require a redundant I/O, you use the blocks of the "Functional I/O Redundancy" function block library, see section Connecting redundant I/O to the PROFIBUS DP interface (Page 157).

2.2 Increasing the availability of plants

The S7-400H automation system 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 S7-400H automation system and all other SIMATIC components such as the SIMATIC PCS7 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.

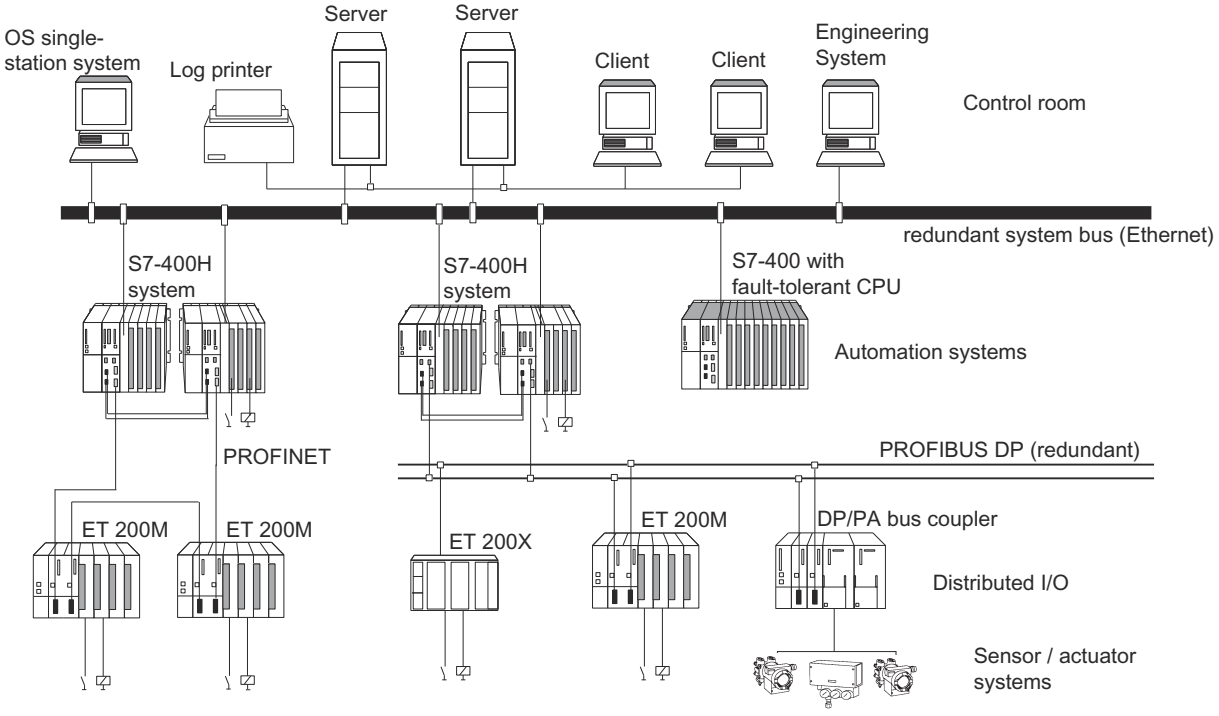


Figure 2-2 Integrated automation solutions with SIMATIC

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.

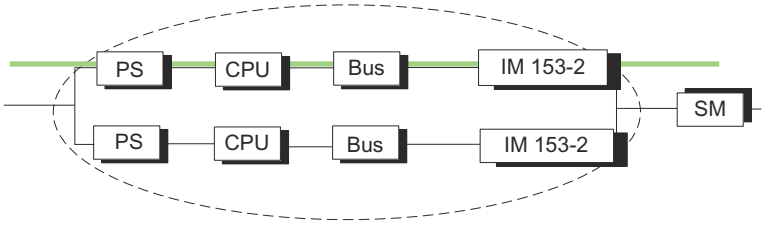
You yourself decide on any other components you want to duplicate to increase availability depending on the specific process you are automating.

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



Redundancy node with 1oo2 redundancy

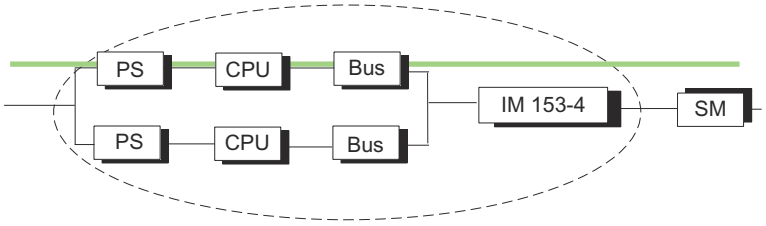
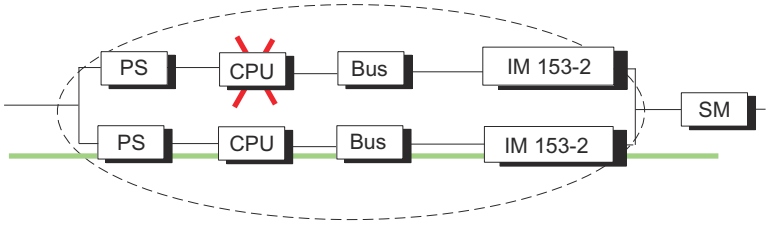


Figure 2-3 Example of redundancy in a network without error

With error/fault

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



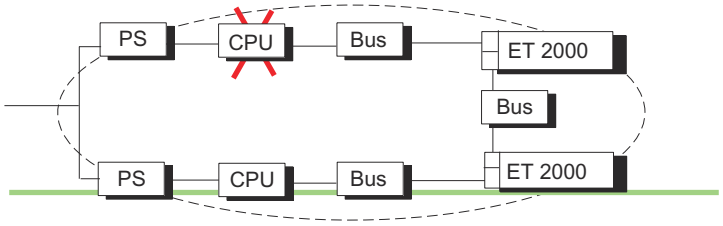


Figure 2-4 Example of redundancy in a 1-out-of-2 system with error

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).

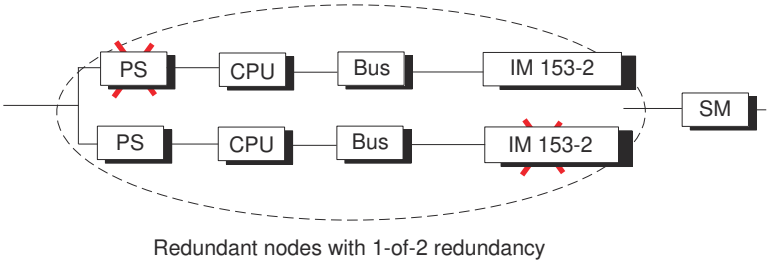


Figure 2-5 Example of redundancy in a 1-out-of-2 system with total failure

S7-400H setup options

3

3.1 S7-400H setup options

The first part of the description deals with the basic setup of the fault-tolerant S7-400H automation system, and with the components of an S7-400H basic system. We then describe the hardware components with which you can expand this basic system.

The second part deals with the software tools required for configuring and programming the S7-400H. Also included is a description of the extensions and functional expansions available for the S7-400 standard system which you need to create your user program to utilize all properties of your S7-400H in order to increase availability.

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 which can only be accessed by means of a key or tool. Such enclosures, cabinets, or switch rooms may only be accessed by instructed or authorized personnel.

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.

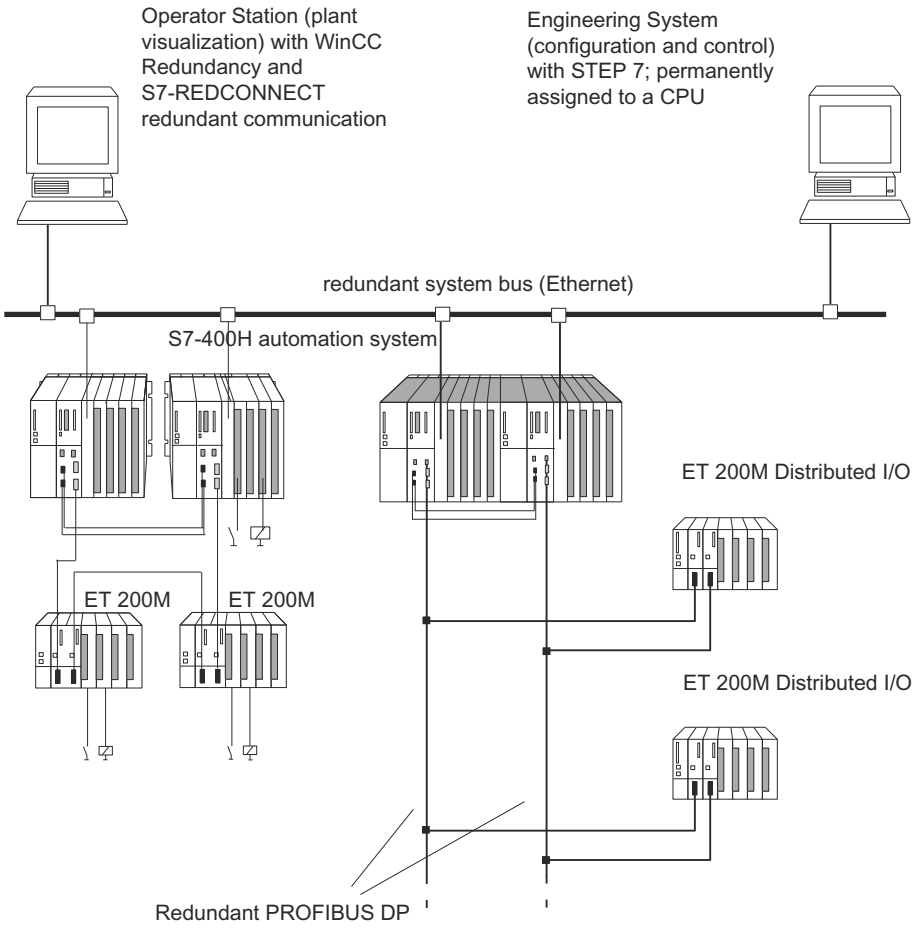


Figure 3-1 Overview

Additional information

The components of the S7-400 standard system are also used in the fault-tolerant S7–400H automation system. For a detailed description of all hardware components for S7–400, refer to the Reference Manual *S7-400 Automation System; Module Specifications*.

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 the *Programming with STEP 7* manual, and to the *System Software for S7-300/400; Standard and System Functions* Reference Manual.

3.2 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 interfaces or communication modules must be inserted in the same slots in each case.
- External DP master interfaces for redundant DP master systems must only be inserted in central units rather than in expansion devices.
- Redundantly used CPUs must be identical, i.e. they must have the same article number, product version and firmware version. It is not the marking on the front side that is decisive for the product version, but the revision of the "Hardware" component ("Module status" dialog mask) to be read using Step 7.
- Redundantly used other modules must be identical, i.e. they must have the same article number, product version and - if available - firmware version.

3.3 The S7–400H basic system

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 S7–400 standard modules. There are limitations in the case of function and communications modules, see appendix Function modules and communication processors supported by the S7-400H (Page 395).

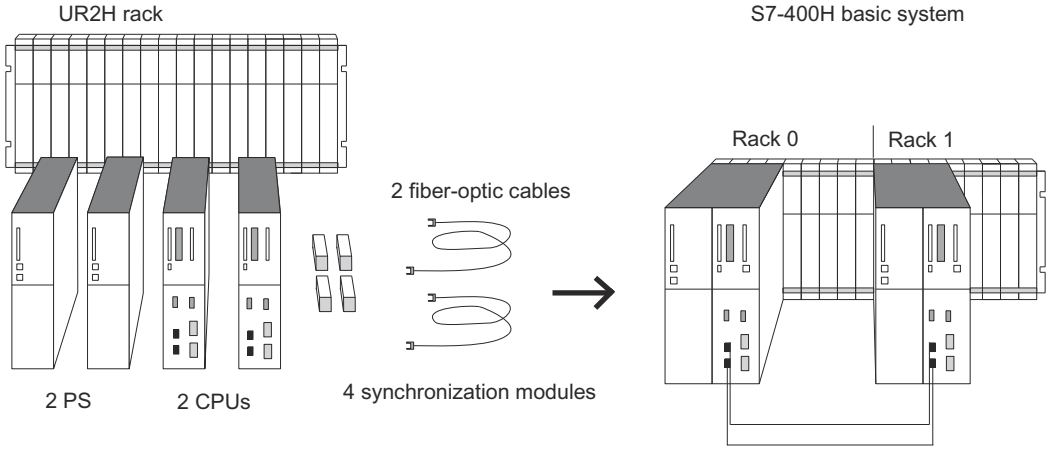


Figure 3-2 Hardware of the S7–400H basic system

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 one power supply module from the standard range of the S7-400 for each H-CPU, or to be more precise, 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. Use the power supply modules PS 405 R / PS 407 R for this purpose.

They can also be used together 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.

There are two types of synchronization modules: one for distances up to 10 meters, and one for distances up to 10 km between the CPUs.

A fault-tolerant system requires 4 synchronization modules of the same type. You can find a description of the synchronization modules in under https://support.industry.siemens.com/cs/ww/en/view/109779483 (https://support.industry.siemens.com/cs/ww/en/view/109779483) in the manual "Synchronization Modules for S7–400H".

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 can the specification of the fiber-optic cables you can use in an S7-400H under https://support.industry.siemens.com/cs/ww/en/view/109779483 (https://support.industry.siemens.com/cs/ww/en/view/109779483) in the manual "Synchronization Modules for S7–400H".

3.4 I/O modules for S7–400H

I/O modules of the SIMATIC S7 series can be used for the S7-400H. The I/O modules can be used in the following devices:

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

You will find the function modules (FMs) and communications modules (CPs) suitable for use in the S7-400H in Appendix Function modules and communication processors supported by the S7-400H (Page 395).

I/O design versions

The following I/O module design versions are available:

- Single-channel, one-sided configuration with standard availability
  With the single-channel, one-sided design, single input/output modules are available. The I/O modules are located in only one subsystem, and are only addressed by this subsystem. However, in redundant mode, both CPUs are interconnected via the redundant link and thus execute the user program identically.
- Single-channel, switched configuration with enhanced availability
  Switched single-channel distributed configurations contain only single I/O modules, but they can be addressed by both subsystems.
- Redundant dual-channel configuration with maximum availability
  A redundant dual-channel configuration contains two sets of the I/O modules which can be addressed by both subsystems.

Additional information

For detailed information on using the I/O, refer to section Using I/Os in S7–400H (Page 149).

3.5 Communication

The S7-400H supports the following communication methods and mechanisms:

- Plant buses with Industrial Ethernet
- Point-to-point connection

This equally applies to the central and distributed components. Suitable communication modules are listed in Appendix Function modules and communication processors supported by the S7-400H (Page 395).

Communication availability

You can vary the availability of communication with the S7-400H. The S7-400H supports various solutions to meet your communication requirements. These range from a simple linear network structure to a redundant optical two-fiber loop.

Fault-tolerant communication via PROFIBUS or Industrial Ethernet is supported only by the S7 communication functions.

Programming and configuring

Apart from the use of additional hardware components, there are basically no differences with regard to configuration and programming compared to standard systems. Fault-tolerant connections only have to be configured; specific programming is not necessary.

All communication functions required for fault-tolerant communication are integrated in the operating system of the fault-tolerant CPU. These functions run automatically in the background, for example, to monitor the communication connection, or to automatically change over to a redundant connection in the event of error.

Additional information

For detailed information on communication with the S7-400H, refer to section Communication (Page 189).

3.6 Tools for configuration and programming

Like the S7-400, the S7-400H is also configured and programmed using STEP 7.

You only need to make allowances for slight restrictions when you write the user program. However, there are some additional details specific to the fault-tolerant configuration. The operating system automatically monitors the redundant components and switches over to the standby components when an error occurs. You have already configured the relevant information and communicated it to the system in your STEP 7 program.

Detailed information can be found in the online help, section Configuring with STEP 7 (Page 229), and Appendix Differences between fault-tolerant systems and standard systems (Page 391).

Optional software

All standard tools, engineering tools and runtime software used in the S7-400 system are also supported by the S7-400H system. Any restrictions in the functional scope are described in the respective Online Help.

3.7 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 exactly the same manner as a standard system. The integral synchronization functions of the operating system 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 supported both in the S7-400 and S7-400H systems, the S7-400H software provides further blocks which you can use to influence the 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 to standby changeover. The following changeovers are possible:
  - The current standby CPU becomes a master CPU.
  - The CPU in rack 0 becomes a master CPU.
  - The CPU in rack 1 becomes a master CPU.

Note

Required OBs

Always download these error OBs to the S7-400H CPU: OB 80, OB 82, OB 83, OB 85, OB 86, OB 88, OB 121 and OB 122. If you do not download these OBs, the fault-tolerant system goes into STOP when an error occurs.

Additional information

For detailed information on programming the blocks described above, refer to the STEP 7 Online Help.

3.8 Documentation

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

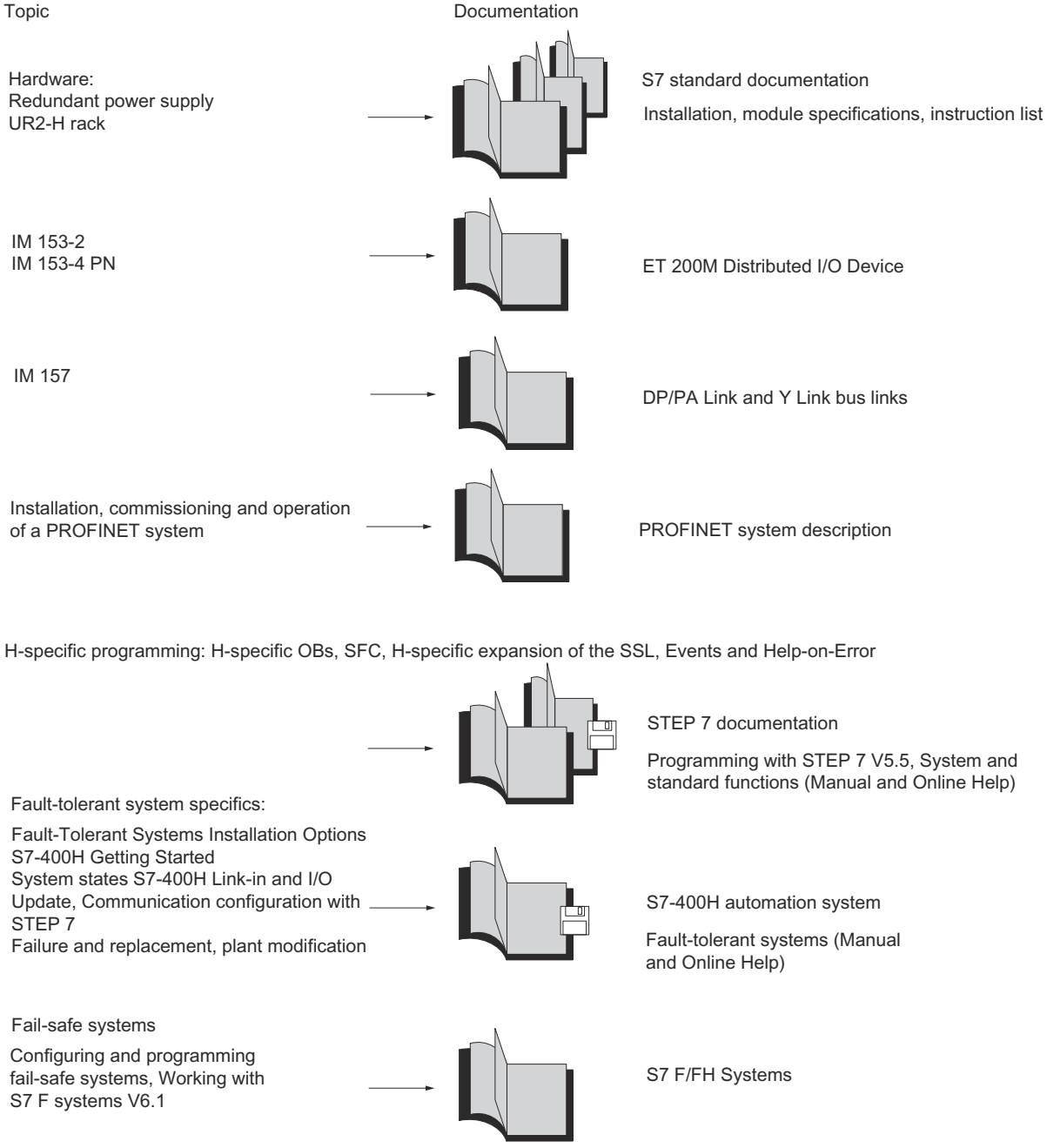


Figure 3-3 User documentation for fault-tolerant systems

Getting Started

4

4.1 Getting Started

Based on a specific example, these instructions guide you through the steps to implement commission all the way to a functional application. You will learn how an S7-400H automation system operates and become familiar with its response to a fault.

It takes about 1 to 2 hours to work through this example, depending on your previous experience.

4.2 Requirements

The following requirements must be met:

A correctly installed and valid version of the STEP 7 basic software on your programming device; see section Configuring with STEP 7 (Page 229). Any necessary hardware updates are installed.

The modules required for the hardware setup available:

- An S7-400H automation system consisting of:
  - 1 UR2–H rack
  - 2 PS 407 10 A power supply units
  - 2 H–CPUs
  - 4 synchronization modules
  - 2 fiber-optic cables
- An ET 200M distributed I/O device with active backplane bus with
  - 2 IM 153–2
  - 1 digital input module, SM321 DI 16 x DC24V
  - 1 digital output module, SM322 DO 16 x DC24V
- All necessary accessories such as PROFIBUS cables, etc.

4.3 Hardware assembly and commissioning of the S7–400H

Assembly of the hardware

Follow the steps below to assemble the S7-400H as shown in the following figure:

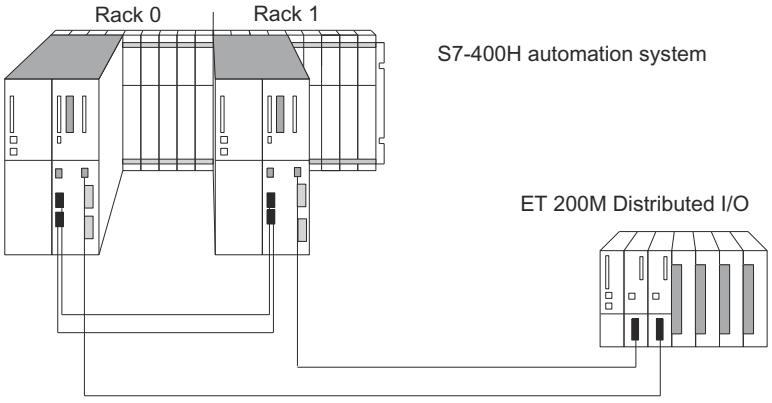


Figure 4-1 Hardware assembly

1. Assemble both modules of the S7-400H automation system as described in the *S7-400 Automation Systems, Installation* and *Module Specifications* manuals.
2. Set the rack numbers using the switch on the rear of the CPUs.
   An incorrectly set rack number prevents online access and the CPU might not start up.
3. Install the synchronization modules in the CPU. You can obtain information in the Service and Support Portal in the manual Synchronization Modules (https://support.industry.siemens.com/cs/ww/en/view/109779483).
4. Connect the fiber-optic cables.
   Always interconnect the two upper and two lower synchronization modules of the CPUs.
   Route your fiber-optic cables so that they are reliably protected against any damage.
   You should also always make sure that the two fiber-optic cables are routed 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.
   Furthermore, always connect at least one fiber-optic cable to both CPUs before you switch on the power supply or the system. Otherwise both CPUs may execute the user program as master CPU.
5. Configure the distributed I/O as described in the *ET 200M Distributed I/O Device* manual.
6. Connect the programming device to the first fault-tolerant CPU (CPU0). This CPU will be the master of your S7-400H.
7. A high-quality RAM test (self-test) is executed after POWER ON. The self-test takes at least 10 minutes.
   The CPU cannot be accessed and the STOP LED flashes for the duration of this test. If you use a backup battery, this test is no longer performed when you power up in future.

Commissioning the S7–400H

Follow the steps outlined below to commission the S7–400H:

1. In SIMATIC Manager, open the sample project "HProject". The configuration corresponds to the hardware configuration described in "Requirements".
2. Open the hardware configuration of the project by selecting the "Hardware" object, then by right-clicking and selecting the shortcut menu command "Object -> Open". If your configuration matches, continue with step 6.
3. If your hardware configuration does not match the project, e.g. there are different module types, MPI addresses or DP addresses, edit and save the project accordingly. For additional information, refer to the basic help of SIMATIC Manager.
4. Open the user program in the "S7 program" folder.
   In the offline view, this "S7 program" folder is only assigned to CPU0. The user program is executable with the described hardware configuration. It activates the LEDs on the digital output module (running light).
5. Edit the user program as necessary to adapt it to your hardware configuration, and then save it.
6. Select "PLC -> Download" to download the user program to CPU0.
7. Start up the S7-400H automation system by setting the mode switch of CPU0 to RUN and then the switch on CPU1. The CPU performs a restart and calls OB 100.
   Result: CPU0 starts up as the master CPU and CPU1 as the reserve CPU. After the reserve CPU is linked and updated, the S7-400H assumes redundant mode and executes the user program. It activates the LEDs on the digital output module (running light).

Note

You can also start and stop the S7-400H automation system using STEP 7.

For additional information, refer to the online help.

You can only initiate a cold restart using the programming device command "Cold restart". For this purpose, the CPU must be in STOP mode and the mode switch must be set to RUN. OB 102 is called in the cold restart routine.

4.4 Examples of the response of the fault-tolerant system to faults

Example 1: Failure of a CPU or power supply unit

Initial situation: The S7-400H is in redundant system mode.

1. Simulate a CPU0 failure by switching off the power supply.
   Result: The LEDs REDF, IFM1F and IFM2F light up on CPU1. CPU1 goes into single mode and the user program continues to run.
2. Switch the power supply back on again.
   Result:
   - CPU0 performs an automatic LINK-UP and UPDATE.
   - CPU0 changes to RUN and now operates as standby CPU.
   - The S7-400H is now in redundant system mode.

Example 2: Failure of a fiber-optic cable

Initial situation: The S7-400H is in redundant system mode. The mode selector switch of each CPU is set to RUN.

1. Disconnect one of the fiber-optic cables.
   Result: The LEDs REDF, IFM1F and IFM2F now light up on both CPUs. The standby CPU changes to ERROR-SEARCH mode. The other CPU remains master and continues running in single mode.
2. Reconnect the fiber-optic cable.
   Result: The standby CPU performs a LINK-UP and UPDATE. The S7–400H system resumes redundant system mode.

4.5 Special layout features of SIMATIC Manager

In order to do justice to the special features of a fault-tolerant system, 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. 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.

- In the online view, the CPUs are represented by symbols that reflect the respective operating states of the CPUs.
- For programming device (PG) functions that set up online connections, one of the two CPUs has to be selected (even if the function affects the entire fault-tolerant system by means of the redundant link).

Note

You should preferably process CPU0, because information that is only available offline will be missing otherwise (e.g. comments or parameter names).

Assembly of a CPU 41x–H

5

5.1 Operator controls and display elements of the CPUs

Controls and display elements of CPU 41x-5H PN/DP

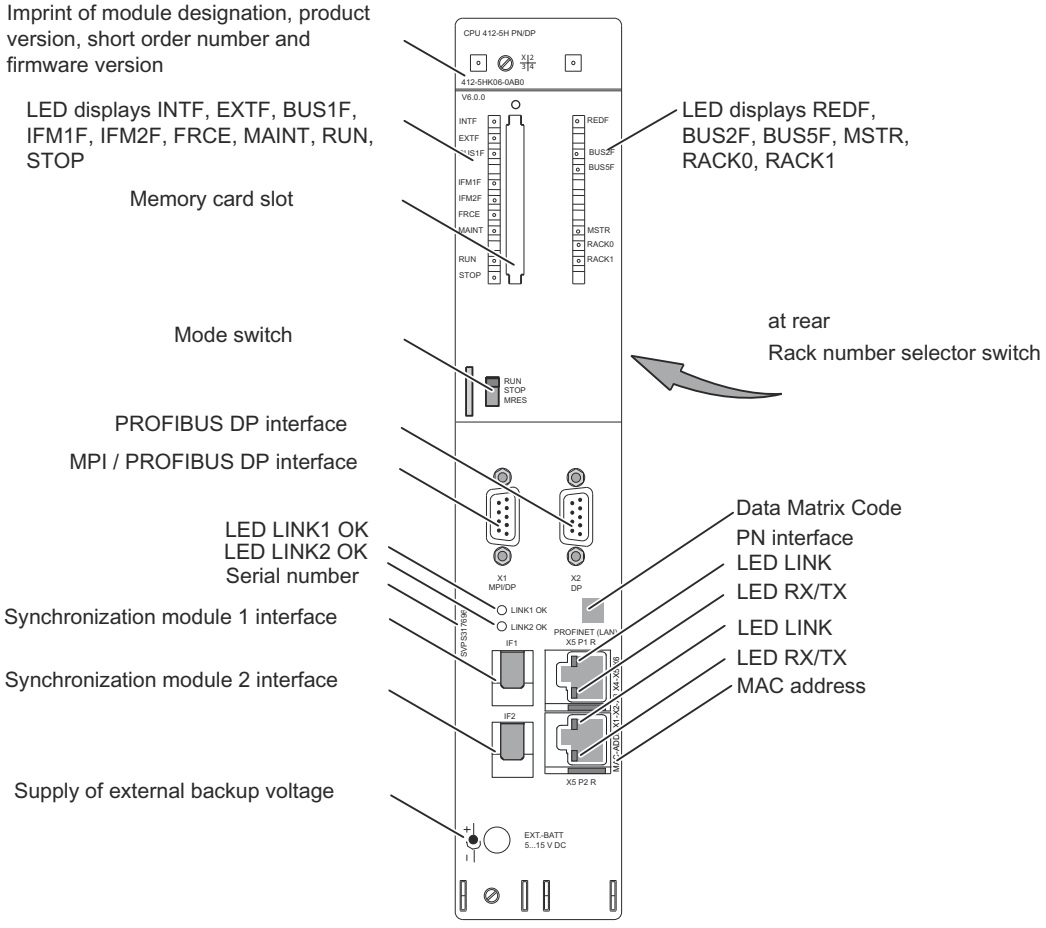


Figure 5-1 Arrangement of the control and display elements on CPU 41x-5H PN/DP

LED displays

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

Sections Monitoring functions of the CPU (Page 43) and Status and error displays (Page 46) describe the states and errors/faults indicated by these LEDs.

Table 5-1 LED displays on the CPUs

LED	Color	Meaning
INTF	red	Internal error
EXTF	red	External error
BUS1F	red	Bus fault on MPI/PROFIBUS DP interface 1
IFM1F	red	Error in synchronization module 1
IFM2F	red	Error in synchronization module 2
FRCE	yellow	Active force request
MAINT	yellow	Maintenance request pending
RUN	green	RUN mode
STOP	yellow	STOP mode
REDF	red	Loss of redundancy/Redundancy fault
BUS2F	red	Bus error at the PROFIBUS interface
BUS5F	red	Bus error at the PROFINET interface
MSTR	yellow	CPU controls the process
RACK0	yellow	CPU in rack 0
RACK1	yellow	CPU in rack 1
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
LINK	green	Connection at the PROFINET interface is active
RX/TX	orange	Receiving or sending data at the PROFINET interface.

Mode switch

You can use the mode switch to set the current operating mode of the CPU. The mode switch is a toggle switch with three switching positions.

Section Function of the mode switch (Page 49) describes the functions of the mode selector.

Memory card slot

You can insert a memory card into this slot.

There are two types of memory card:

- RAM cards
  You can expand the CPU load memory with a RAM card.
- FLASH cards
  A FLASH card can be used for fail-safe backup of the user program and data without a backup battery. You can program the FLASH card either on the programming device or in the CPU. The FLASH card also expands the load memory of the CPU.
  You can find a more detailed description of the memory cards in the section Design and function of the memory cards (Page 54).

Slot for synchronization modules

You can insert one synchronization module into this slot. You can obtain information in the Service and Support Portal in the manual Synchronization Modules (https://support.industry.siemens.com/cs/ww/en/view/109779483).

MPI/DP interface

You can, for example, connect the following devices to the MPI of the CPU:

- Programming devices
- Operator control and monitoring devices
- Additional S7-400 or S7-300 controllers, see section Multi Point Interface MPI/DP (X1) (Page 59).

Use bus connectors with angled cable outlet, see manual *Automation System S7-400, Hardware and Installation*.

You can also configure the MPI interface as a DP primary and, thus, as a PROFIBUS DP interface with up to 32 DP secondaries.

PROFIBUS DP interface

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

PROFINET interface

You can connect PROFINET IO devices to the PROFINET interface. The PROFINET interface features two switched ports with external connectors (RJ 45). The PROFINET interface provides the interconnection with Industrial Ethernet.

⚠ CAUTION
Use of the PROFINET interface This interface only allows connection to an Ethernet LAN. You cannot connect it to the public telecommunication network, for example.

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.

Connecting an external backup voltage to the "EXT. BATT." socket

You can use two backup batteries for the power supply modules of the S7-400H to achieve the following:

- Back up the user program stored in RAM.
- Retain bit memories, timers, counters, system data and data in variable data blocks.
- Back up the internal clock.

You can achieve the same backup by connecting a DC voltage between 5 V DC and 15 V DC to the "EXT. BATT." socket of the CPU.

Properties of the "EXT. BATT." input:

- Reverse polarity protection
- Short-circuit current limiting to 20 mA

For incoming supply at the "EXT. BATT" socket, you require a connecting cable with a 2.5 mm Ø jack connector as shown in the figure below. Observe the polarity of the jack connector.

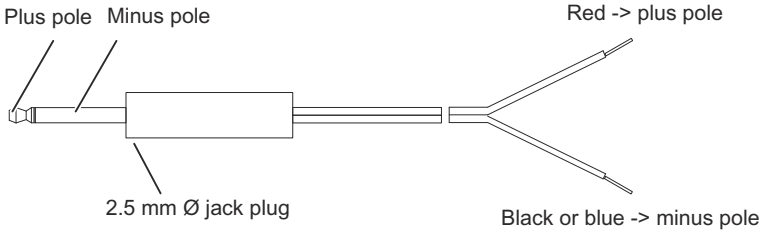


Figure 5-2 Jack connector

You can order an assembled jack connector and cable with the order number A5E00728552A.

Note

If you replace a power supply module and want to backup the user program and the data (as described above) in an RAM while doing so, you must connect an auxiliary power supply to the "EXT. BATT." socket.

Do not interconnect the cables of different CPUs. Interconnecting the cables of different CPUs may lead to problems with regard to EMC conditions and different voltage potentials.

5.2 Monitoring functions of the CPU

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	Response of the operating system	Error LED
Access error	Module failure (SM, FM, CP)	LED "EXTF" remains lit until the error is eliminated. In SMs: • Call of OB 122 with direct access, call of OB 85 in the event of a process image update • Entry in the diagnostic buffer • In the case of input modules: Entry of "null" as date in the accumulator or the process image In the case of other modules: • Call of OB 122 with direct access, call of OB 85 in the event of a process image update	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	LED "INTF" remains lit until the error is eliminated. Call of OB 80. If the OB is not loaded: CPU changes to STOP mode.	INTF
Power supply module(s) fault (not power failure)	In the central or expansion rack: • at least one backup battery in the power supply module is flat. • the backup voltage is missing. • the 24 V supply to the power supply module has failed.	Call of OB 81 If the OB is not loaded: The CPU remains in RUN.	EXTF
Diagnostic interrupt	An I/O module with interrupt capability reports a diagnostic interrupt In a configuration as of V6.0: The synchronization module reports a diagnostic interrupt, see the manual "Synchronization Modules for S7-400H (https://support.industry.siemens.com/cs/ww/en/view/109779483)".	Call of OB 82 If the OB is not loaded: CPU changes to STOP mode.	EXTF

Type of error	Cause of error	Response of the operating system	Error LED
Swapping interrupt	Removal or insertion of an SM, and insertion of a wrong module type. Removing a synchronization module.	Call of OB 83 If the OB is not loaded: CPU changes to STOP mode.	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, PAA)	Call of OB 72 If the OB is not loaded: The CPU remains in RUN.	EXTF
CPU hardware fault	• A memory error was detected and eliminated • In a configuration older than V6.0: Data transmission error at the redundant link.	Call of OB 84 If the OB is not loaded: The CPU remains in RUN.	INTF
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	Call of OB 85 If the OB is not loaded: CPU changes to STOP mode.	INTF EXTF
Failure of a rack/ station	• Power failure in an expansion rack • Failure of a DP/PN segment • Failure of a coupling segment: Missing or defective IM, interrupted cable	Call of OB 86 If the OB is not loaded: CPU changes to STOP mode.	EXTF
Communication error	Communication error: • Time synchronization • Access to DB when exchanging data via communications function blocks	Call of OB 87 If the OB is not loaded: CPU does not change to STOP mode.	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	Call of OB 88 If the OB is not loaded: CPU changes to STOP mode.	INTF

Type of error	Cause of error	Response of the operating system	Error LED
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	Call of OB 121 If the OB is not loaded: CPU changes to STOP mode.	INTF
MC7 code error	Error in the compiled user program, for example, illegal OP code or a jump beyond block end	CPU changes to STOP mode. Restart or memory reset required.	INTF

5.3 Status and error displays

RUN and STOP LEDs

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

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	CPU is DEFECTIVE. 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 10 minutes. Memory is being reset
Irrelevant	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. • Memory reset after you have inserted a large Memory Card, or if there are encrypted 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, EXTF, and FRCE LEDs

The three LEDs INTF, EXTF, and FRCE provide information about errors and special events in the user program execution.

LED			Meaning
INTF	**EXTF**	**FRCE**	
Lit	Irrelevant	Irrelevant	An internal error was detected (programming or parameter assignment error).
Irrelevant	Lit	Irrelevant	An external error was detected (i.e. an error whose cause is not in the CPU module).
Irrelevant	Irrelevant	Lit	A force request is active.

BUSF1 BUSF2 and BUS5F LEDs

The BUS1F, BUS2F and BUS5F LEDs indicate errors associated with the MPI/DP, PROFIBUS DP and PROFINET interfaces.

Table 5-2 Possible states of the BUS1F, BUS2F and BUS5F LEDs

LED			Meaning	
BUS1F	**BUS2F**	**BUS5F**		
Lit	Irrelevant	Irrelevant	An error was detected at the MPI/DP interface.	
Irrelevant	Lit	Irrelevant	An error was detected at the PROFIBUS DP interface.	
Irrelevant	Irrelevant	Lit	An error was detected at the PROFINET IO interface. A PROFINET IO system is configured but not connected.	
Irrelevant	Irrelevant	Flashes	One or more devices at the PROFINET IO interface is not responding.	
Flashes	Irrelevant	Irrelevant	CPU is DP primary:	One or more secondaries at the PROFIBUS DP interface 1 are not responding.
			CPU is DP secondary:	CPU is not being addressed by the DP primary.
Irrelevant	Flashes	Irrelevant	CPU is DP primary:	One or more secondaries at the PROFIBUS DP interface 2 are not responding.
			CPU is DP secondary:	CPU is not being addressed by the DP primary.

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 interface.

Table 5-3 Possible states of the LINK and RX/TX LEDs

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

Note

The LINK and RX/TX LEDs are located directly next to the PROFINET 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 primary or partial or total failure of a DP primary system • Loss of redundancy at the DP secondary • Loss of redundancy at the PN IO device

LEDs LINK1 OK and LINK2 OK

During commissioning of an H-system, you can check the quality of the connection between the CPUs with the LINK1 OK and LINK2 OK LEDs.

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 the manual "Synchronization Modules for S7-400H (https://support.industry.siemens.com/cs/ww/en/view/109779483)". 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 the manual "Synchronization Modules for S7-400H (https://support.industry.siemens.com/cs/ww/en/view/109779483)". Check whether the synchronization module works in another CPU.

LED MAINT

This LED indicates that maintenance is required. For more information, refer to the STEP 7 Online Help.

Diagnostic buffer

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

5.4 Mode switch

5.4.1 Function of the mode switch

Function of the mode switch

The mode switch can be used to set the CPU to RUN mode or STOP mode, or to reset the CPU memory. STEP 7 offers further options of changing the mode.

Positions

The mode switch is designed as toggle switch. The following figure shows all possible positions of the mode switch.

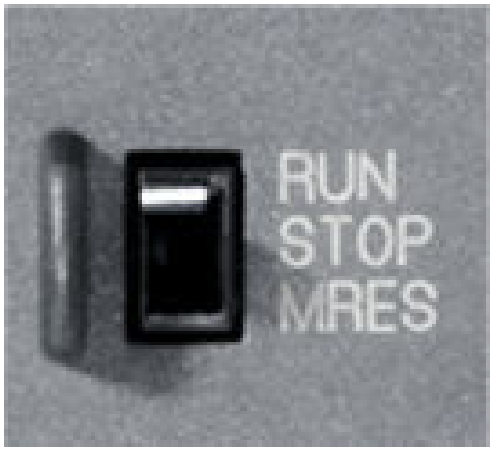


Figure 5-3 Mode switch positions

The following table explains the positions of the mode switch. If an error or a startup problem occurs, the CPU will either change to or stay in STOP mode regardless of the position of the mode switch.

Table 5-4 Mode switch positions

Position	Explanations
RUN	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).
STOP	The CPU does not execute the user program. The digital signal modules are disabled. The output modules are disabled. • 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).
MRES (Memory reset; Master Reset)	Momentary-on position of the toggle switch for CPU memory reset; see chapter Performing a memory reset (Page 51). Momentary-on position for the "Reset CPU to factory state" function; see chapter Resetting the CPU to the factory state (Page 69)

5.4.2 Performing a memory reset

Case A: You want to download a new user program to the CPU.

1. Set the switch to the STOP position.
   Result: The STOP LED is lit.
2. Toggle the switch to MRES, and hold it in that position. In this position the mode switch acts as pushbutton.
   Result: The STOP LED is off for one second, then on for one second, then again off for one second, and then it remains lit.
3. Then release the switch, return it to MRES within the next 3 seconds, and then release it again.
   Result: The STOP LED flashes for at least 3 seconds at 2 Hz (memory is reset) and then remains lit.

Case B: The STOP LED is flashing slowly at 0.5 Hz. This indicates that the CPU is requesting a memory reset (memory reset requested by system, e.g. after a memory card has been removed or inserted).

Toggle the switch to MRES, and then release it again.

Result: The STOP LED flashes for at least 3 seconds at 2 Hz, the memory reset is executed, and the LED then remains lit.

Memory reset process in the CPU

During a memory reset, the following process occurs on the CPU:

- The CPU deletes the entire user program in the main memory.
- The CPU deletes the user program from the load memory. This process deletes the program from the integrated RAM and from any inserted RAM Card. The user program elements stored on a FLASH card will not be deleted if you have expanded the load memory with such a card.
- The CPU deletes all counters, bit memories, and timers, but not the time of day.
- The CPU tests its hardware.
- The CPU sets its parameters to default settings.
- If a FLASH card is inserted, the CPU copies the user program and the system parameters stored on the FLASH card into main memory after the memory reset.

Data retained after a memory reset...

The following values are retained after a memory reset:

- The content of the diagnostic buffer
  If no FLASH card was inserted during memory reset, the CPU resets the capacity of the diagnostic buffer to its default setting of 120 entries, i.e. the most recent 120 entries will be retained in the diagnostic buffer.
  You can read out the content of the diagnostic buffer using STEP 7.
- The MPI/DP interface parameters. Note the special features shown in the table below.
  - MPI address
  - Highest MPI address
  - Baud rate.
- Parameters of the PN interface. Note the special features shown in the table below.
  - Name (NameOfStation)
  - IP address of CPU
  - Subnet mask
  - Static SNMP parameters
- The time of day
- The status and value of the operating hours counter

Special feature

A special situation is presented for the MPI/DP and PN interface parameters when a memory reset is preformed. The following parameters are valid after a memory reset:

- Memory reset with inserted FLASH card:
  The parameters stored on the FLASH card are valid
- Memory reset without inserted FLASH card:
  The parameters in the CPU are retained and valid.

5.4.3 Cold restart / Warm restart

Cold restart

- A cold restart resets the process image, all bit memories, timers, counters, and data blocks to the initial values stored in the load memory, regardless of whether these data were parameterized as being retentive or not.
- Program execution resumes with OB 1, or with OB 102 if available.

Restart (warm restart)

- A warm restart resets the process image and the non-retentive bit memories, timers, times, and counters.
  Retentive bit memories, timers, counters, and all data blocks retain their last valid value.
- The associated startup OB is OB 100
- Program execution resumes with OB 1, or with OB 100 if available.
- If the power supply is interrupted, the warm restart function is only available in backup mode.

Note

Restart in buffered Power On mode

In buffered PowerOn mode 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.

Operating sequence for warm restart

1. Set the switch to the STOP position.
   Result: The STOP LED lights up.
2. Set the switch to RUN.
   Result: The STOP LED goes dark, the RUN LED is lit.

Operating sequence for cold restart

You can only initiate a cold restart using the programming device command "Cold restart". For this purpose, the CPU must be in STOP mode and the mode switch must be set to RUN.

5.5 Design and function of the memory cards

Order numbers

The order numbers for memory cards are listed in the technical specifications, see section Technical data of memory cards (Page 371).

Design of a memory card

The memory card is slightly larger than a credit card and is protected by a strong metal casing. It is inserted into one of the slots on the front of the CPU. The memory card is designed so that it can only be inserted one way.

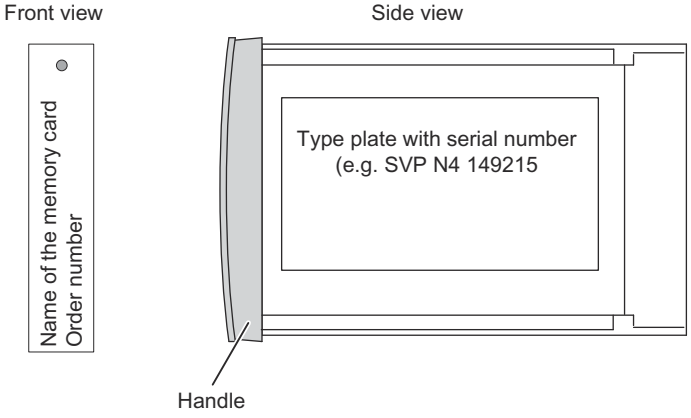


Figure 5-4 Design of the memory card

Function of the memory card

The memory card and an integrated memory area on the CPU together form the load memory of the CPU. During operation, the load memory contains the complete user program, including comments, symbols, and special additional information that enables decompilation of the user program, as well as all module parameters.

Data stored on the memory card

The following data can be stored on the memory card:

- The user program, i.e. OBs, FBs, FCs, DBs, and system data
- Parameters that determine the behavior of the CPU
- Parameters that determine the behavior of I/O modules
- The full set of project files on suitable memory cards.

Serial number

In version 5 or later, all memory cards have a serial number. This serial number is listed in INDEX 8 of the SSL Parts List W#16#xy1C. The parts list can be read using SFC 51 "RDSYSST".

You can determine the following when you read the serial number in your user program: The user program can only be executed when a specific memory card is inserted into the CPU. This protects against unauthorized copying of the user program, similar to a dongle.

5.6 Using memory cards

Types of memory cards for the S7–400

Two types of memory cards are used for S7–400H:

- RAM cards
- FLASH cards

What type of memory card should I use?

Whether you use a RAM card or a FLASH card depends on your application.

Table 5-5 Types of memory card

If you ...	then ...
want to be able to edit your program in RUN mode,	use a **RAM card**
want to keep a permanent backup of your user program on the memory card, even when power is off, i.e. without backup or outside the CPU,	use a **FLASH card**

RAM card

Insert the RAM card to load the user program in the CPU. Load the user program in STEP 7 by selecting "Target system > Download".

You can load the entire user program or individual elements such as FBs, FCs, OBs, DBs, or SDBs in the load memory in STOP or RUN mode.

When you remove the RAM card from the CPU, the information stored on it will be lost. The RAM card is not equipped with an integrated backup battery.

If the power supply is equipped with an operational backup battery, or the CPU is supplied with an external backup voltage at the "EXT. BATT." socket, the RAM card memory contents are retained when power is switched off, provided the RAM card remains inserted in the CPU and the CPU remains inserted in the rack.

FLASH card

If you use a FLASH card, there are two ways of loading the user program:

- Use the mode switch to set the CPU to STOP, insert the FLASH card into the CPU, and then download the user program to the FLASH card in STEP 7 by selecting "Target system > Download user program to memory card".
- You download the user program to the FLASH card in offline mode on the programming device/programming adapter, and then insert the FLASH card into the CPU.

The FLASH card is a non-volatile memory, i.e. its data are retained when it is removed from the CPU or your S7-400 is being operated without backup voltage (without a backup battery in the power supply module or external backup voltage at the "EXT. BATT." input of the CPU).

Automatic restart or cold restart without backup

If you operate your CPU without a backup battery, CPU memory reset followed by restart or cold restart, as configured, will automatically be carried out after switch-on or voltage recovery after power off. The user program must be available on the FLASH card and the battery indicator switch on the power supply module may not be set to battery monitoring.

If battery monitoring is set, you must carry out a restart or cold restart either with the mode switch or via a programming device after CPU switch on or voltage recovery following power off. The absence of or a defective backup battery is reported as an external fault and the LED EXTF lights up.

Downloading a user program

You can only download the full user program to a FLASH card.

Downloading additional user program elements

You can download further elements of the user program from the programming device to the integrated load memory of the CPU. Note that the content of this integrated RAM will be deleted if the CPU performs a memory reset, i.e. the load memory is updated with the user program stored on the FLASH card after a memory reset.

What memory card capacity should I use?

The capacity of your memory card is determined by the scope of the user program.

Determining memory requirements using SIMATIC Manager

You can view the block lengths offline in the "Properties - Block folder offline" dialog box (Blocks > Object Properties > Blocks tab).

The offline view shows the following lengths:

- Size (sum of all blocks, without system data) in the load memory of the target system
- Size (sum of all blocks, without system data) in the work memory of the target system

Block lengths on the programming device (PG/PC) are not shown in the properties of the block container.

Block lengths are shown in "byte" units.

The following values are shown in the properties of a block:

- Required local data volume: Length of local data in bytes
- MC7: Length of MC7 code in bytes
- Length of DB user data
- Length in load memory of the target system
- Length in work memory of the target system (only if hardware assignment is known)

The views always show these block data, regardless whether it is located in the window of an online view or of an offline view.

When a block container is opened and "View Details" is set, the project window always indicates work memory requirements, regardless of whether the block container appears in the window of an online or offline view.

You can add up the block lengths by selecting all relevant blocks. SIMATIC Manager outputs the total length of the selected blocks in its status bar.

Lengths of blocks (VATs, for example) which can not be downloaded to the target system are not shown.

Block lengths on the programming device (PG/PC) are not shown in the Details view.

See also

Technical data of memory cards (Page 371)

5.7 Multi Point Interface MPI/DP (X1)

Connectable devices

You can, for example, connect the following devices to the MPI:

- Programming devices (PG/PC)
- Operating and monitoring devices (OPs and TDs)
- Additional SIMATIC S7 controllers

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

PG/OP–CPU communication

A CPU is capable of handling several online connections to PGs/OPs in parallel. By default, however, one of these connections is always reserved for a PG, and one for an OP/HMI device.

CPU–CPU communication

CPUs exchange data by means of S7 communication.

For additional information, refer to the *Programming with STEP 7* manual.

Connectors

Use only bus connectors with angled cable outlet for PROFIBUS DP or PG cables to connect devices to the MPI (see *installation manual*).

MPI interface as DP interface

You can also configure the MPI interface as a DP interface. To do so, you can re-configure the MPI interface in SIMATIC Manager of STEP 7. This allows you to configure a DP line with a maximum of 32 secondaries.

5.8 PROFIBUS DP interface (X2)

Connectable devices

The PROFIBUS DP interface is used to configure a PROFIBUS primary system, or to connect PROFIBUS I/O.

You can connect redundant I/O to the PROFIBUS DP interfaces.

You can connect all DP secondaries that conform to the standard to the PROFIBUS DP interface.

In this case, the CPU is the DP primary, which is connected to the passive secondary stations or, in stand-alone operation, to other DP primaries via the PROFIBUS DP fieldbus.

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

Connectors

Use only bus connectors for PROFIBUS DP or PROFIBUS cables to connect devices to the PROFIBUS DP interface (*see installation manual*).

Redundant mode

In redundant mode, the PROFIBUS DP interfaces have the same parameters.

5.9 PROFINET interface (X5)

Assigning an IP address

You have the following options of assigning an IP address to the 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 which can be connected via PROFINET (PN)

- Programming device/PC with Ethernet adapter and TCP protocol
- Active network components, e.g. Scalance X200
- S7-300/S7-400, e.g. CPU 417-5H PN/DP
- PROFINET IO devices, e.g. IM 153-4 PN in an ET 200M

Connectors

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

Properties of the PROFINET interface

Protocols and communication functions

- PROFINET IO
- In accordance with IEC61784-2 , 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 interface, refer to the technical specifications of the respective CPU. In Chapter Technical data (Page 331).

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

Note

Networking PROFINET components

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

If connecting a device to the on-board PROFINET interface of the CPU that does not support the "automatic setting" (Autonegotiation) operating mode, or selecting a setting other than the "automatic setting" (Autonegotiation), note the following:

- PROFINET IO needs to be operated at 100 Mbps in full-duplex mode, which means if the on-board PROFINET interface of the CPU for PROFINET IO communication and Ethernet communication is used at the same time, the PROFINET interface may only be operated at 100 Mbps in full-duplex mode.
- Operation at 100 Mbps full-duplex is possible if the on-board PROFINET interface(s) of the CPU is(are) used for Ethernet communication only. 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 additional information on PROFINET, refer to PROFINET System Description (https://support.industry.siemens.com/cs/ww/en/view/19292127)
- For detailed information about Ethernet networks, network configuration and network components refer to the SIMATIC NET manual: Twisted-pair and fiber-optic networks (https://support.industry.siemens.com/cs/ww/en/view/8763736) manual.
- For additional information about PROFINET, refer to: PROFINET (https://www.profibus.com/)

5.10 Overview of the parameters for the S7-400H CPUs

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 S7-400H directly without having to make any additional settings.

You can determine the CPU-specific default values by selecting "Configuring Hardware" in STEP 7.

Parameter blocks

The responses and properties of the CPU are defined in parameters which are stored in system data blocks. The CPUs have 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 parameterizable system properties of the CPUs.

- General properties such as the CPU name
- Start-up
- Cycle/clock memory, e.g. the scan cycle monitoring time
- Retentivity, i.e., the number of bit memories, timers, and counters that are retained after restart
- Memory, e.g. local data
  Note: If you change the work memory allocation by modifying parameters, this work memory is reorganized when you download system data to the CPU. As a consequence, the data blocks generated by means of SFC are deleted and the remaining data blocks are initialized with values from load memory.
  If you change the following parameters, the work memory area available for logic blocks and data blocks will be modified when loading the system data:
  - Size of the process image, byte-oriented in the "Cycle/Clock memory" tab
  - Communication resources in the "Memory" tab
  - Size of the diagnostic buffer in the "Diagnostics/Clock" tab
  - Number of local data for all priority classes in the "Memory" tab
- Assignment of interrupts (hardware interrupts, time delay interrupts, asynchronous error interrupts) to the priority classes
- Time-of-day interrupts such as start, interval duration, priority
- Watchdog interrupts, e.g. priority, interval duration
- Diagnostics/clock, e.g. time-of-day synchronization

- Security levels
- Fault tolerance parameters

Note

16 bit memory bytes and 8 counters are set by default in retentive memory, i.e., they are not deleted at a CPU restart.

Parameter assignment tool

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

Note

If you modify the parameters listed below, the operating system initializes the following:

- Size of the process input image
- Size of the process output image
- Size of the local data
- Number of diagnostic buffer entries
- Communication resources

This involves the following initialization actions:

- Data blocks are initialized with the load values
- Bit memories, timers, counters, inputs and outputs are deleted, regardless of their retentivity setting (0).
- DBs generated by SFC will be deleted
- Permanently configured, basic communication connections are shut down
- All run levels are initialized.

Further settings

- The rack number of a fault-tolerant CPU, 0 or 1
  Use the selector switch on the rear panel of the CPU to change the rack number.
- The operating mode of a fault-tolerant CPU: Stand-alone or redundant mode
  For information on how to change the operating mode of a fault-tolerant CPU, refer to Appendix Stand-alone operation (Page 385).

Special functions of a CPU 41x-H

6

6.1 Security levels

You can define a security level for your project in order to prevent unauthorized access to the CPU programs. The objective of these security 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. When logged on with a password, the user may execute all PG functions.

Setting security levels

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

If you do not know the password, you can clear the set security level by means of a manual memory reset using the mode selector. No flash card may be inserted in the CPU.

The following table shows the protection levels of a CPU of S7-400.

Table 6-1 Security levels of a CPU

CPU function	Security level 1	Security level 2	Security 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
Reading the time	Access granted	Access granted	Access granted
Setting the time	Access granted	Access granted	Access granted
Block status	Access granted	Access granted	Password required
Load in PG	Access granted	Access granted	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
Stop a CPU or the system	Access granted *	Access granted *	Access granted *
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
Memory reset	Access granted *	Password required	Password required
Firmware update	Access granted *	Password required	Password required

* A password is required if the CPU has a safety program.

Note

Cancel access rights

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.

Note

Select a higher protection level

You should set the protection level to at least level 2.

Setting the security level with SFC 109 "PROTECT"

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

- SFC 109 call with MODE=0: Setting the protection level 1. If the password legitimization is locked, the lock is canceled by calling SFC 109 with MODE=0.
- SFC 109 call with MODE=1: Setting of security 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 security 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 security level

You can use SFC 109 "PROTECT" to set a lower security 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 security levels in STOP.
- The security level is transferred from the master to the standby during link-up/update operations.
- The set security levels of both fault-tolerant CPUs are retained if you make modifications to the plant during operation.
- The security level is transferred to the target CPU in the following cases:
  - Switching to CPU with modified configuration
  - Switching to a CPU with expanded memory configuration
  - Switching to a CPU with modified operating system
  - Switching to a CPU using only one intact redundant link

6.2 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.

Operation with FlashCard can significantly prolong the time for memory reset.

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.

6.3 Resetting the CPU to the factory state

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 6-2 CPU properties in the factory settings

Properties	Value
MPI address	2
MPI transmission rate	187.5 Kbps
Contents of the diagnostic buffer	Empty
IP parameters	None
IP parameters	Default values
Operating hours counter	0
Date and time	01.01.94, 00:00:00

Procedure

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

1. Switch off the mains voltage.
2. If a memory card is inserted in the CPU, always remove the memory card.
3. Hold the toggle switch in the MRES setting and switch the mains voltage on again.
4. Wait until LED pattern 1 from the following overview is displayed.
5. Release the toggle switch, set it back to MRES within 3 seconds and hold it in this position. After approx. 4 seconds all the LEDs light up.
6. Wait until LED pattern 2 from the following overview is displayed.
   This LED pattern lights up for approximately 5 seconds. During this period you can abort the resetting procedure by releasing the toggle switch.
7. Wait until LED pattern 3 from the following overview is displayed, and release the toggle switch again.

The CPU is now reset to its factory settings. It starts without buffering and goes to STOP mode. The event "Reset to factory setting" is entered in the diagnostic buffer.

Note

Canceling the operation

If the described operation is canceled prematurely and the CPU remains in an undefined state, you can once again set it to a defined state by cycling 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 6-3 LED patterns

LED	LED pattern 1	LED pattern 2	LED pattern 3
INTF	Flashes at 0.5 Hz	Flashes at 0.5 Hz	Lit
EXTF	Dark	Dark	Dark
BUSxF	Dark	Dark	Dark
FORCE	Flashes at 0.5 Hz	Dark	Dark
MAINT	Dark	Dark	Dark
IFMxF	Dark	Dark	Dark
RUN	Flashes at 0.5 Hz	Dark	Dark
STOP	Flashes at 0.5 Hz	Dark	Dark

6.4 Updating the firmware without a memory card

Basic procedure

To update the firmware of a CPU, you will receive several files (*.UPD) containing the current firmware. Download these files to the CPU. You do not need a memory card to perform an online update. However, it is still possible to update the firmware using a memory card.

Requirement

The CPU whose firmware you want to update must be accessible online, e.g. via PROFIBUS, MPI, or Industrial Ethernet. The files containing the current firmware versions must be available in the programming device/PC file system. A folder may contain only the files of one firmware version. If security level 2 or 3 is set for the CPU, you require the password to update the firmware.

Note

You can update the firmware of the fault-tolerant CPUs via Industrial Ethernet. Updating the firmware over a MPI can take a long time if the transfer rate is low (e.g. approximately 10 minutes at 187.5 Kbit/s).

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 command procedure is the same as in HW Config, i.e. "PLC > Update firmware". However, STEP 7 waits until the command is executed before it verifies that the module supports this function.

Note

Update security

For reasons of firmware security, the CPU validates a digital signature before it runs the firmware update. If it detects an error, it retains the current firmware version and rejects the new one.

Values retained after a firmware update

The following values are retained after a CPU memory reset:

- The parameters of the MPI interface (MPI address and highest MPI address)
- IP address of the CPU
- Device name (NameOfStation)
- Subnet mask
- Subnet mask

6.5 Firmware update in RUN mode

Requirement

The size of the load memory on the master and reserve CPU is the same. Both Sync links exist and are working.

Procedure for automatic firmware update

Initial situation: Both CPUs are in redundant operation.

1. 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.
2. 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 an H system in RUN:

1. Set one of the CPUs to STOP using the programming device
2. Select this CPU in HW Config or in SIMATIC Manager in your STEP 7 project.
3. 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.
4. In SIMATIC Manager or HW Config, select the "PLC -> Operating Mode -> Switch to CPU 41x-H" 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.
5. Repeat steps 1 to 3 for the other CPU.
6. Restart the CPU. The fault-tolerant system will return to redundant mode.

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

Note

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

Example: From V6.0.0 to V6.0.1

Please take note of any information posted in the firmware download area.

The constraints described in section System and operating states of the S7–400H (Page 107) also apply to a firmware update in RUN

6.6 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.

PROFIBUS DP

7

7.1 CPU 41x-H as PROFIBUS DP primary

Introduction

This section describes how to use the CPU as DP master and configure it for direct data exchange.

Further references

The STEP 7 Online Help provides descriptions and information on the following topics:

- Planning of a PROFIBUS subnet
- Configuration of a PROFIBUS subnet
- Diagnostics in the PROFIBUS subnet

Additional information

You can find descriptions and information on switching from PROFIBUS DP to PROFIBUS DPV1 on the Internet (https://support.industry.siemens.com/cs/ww/en/view/7027576).

7.1.1 DP address ranges of CPUs 41x-H

Address ranges of CPUs 41x-H

Table 7-1 CPUs 41x-H, MPI/DP interface as PROFIBUS DP interface

Address range	412-5H	414-5H	416-5H	417–5H
MPI as PROFIBUS DP, inputs and outputs (bytes) in each case	2048	2048	2048	2048
DP interface as PROFIBUS DP, inputs and outputs (bytes) in each case	4096	6144	8192	8192
Of those addresses you can configure up to x bytes for each I/O in the process image	0 to 8192	0 to 8192	0 to 16384	0 to 16384

DP diagnostic addresses occupy at least 1 byte for the DP primary and each DP secondary in the address range for inputs. At these addresses, for example, the DP standard diagnostics of the relevant node can be called using parameter LADDR of SFC 13. You specify the DP diagnostic addresses when configuring. If you do not specify DP diagnostic addresses, STEP 7 assigns the addresses starting from the highest byte address down as DP diagnostic addresses.

7.1.2 CPU 41x-H as PROFIBUS DP primary

Requirement

You must configure the corresponding CPU interface as the PROFIBUS DP primary. This means you must make the following settings in **STEP 7**:

- Assign a network
- Configure the CPU as PROFIBUS DP primary
- Assign a PROFIBUS address
- Change the operating mode, if necessary. Default setting is DPV1
- Connect DP secondaries to the DP primary system

Note

Is one of the PROFIBUS DP secondaries a CPU 31x or a CPU 41x?

If yes, you will find this DP secondary in the PROFIBUS DP catalog as an "already configured station". You assign a secondary diagnostic address to this DP secondary CPU in the PROFIBUS DP primary. You must connect the PROFIBUS DP primary to the DP secondary CPU and specify the address ranges for the data exchange with the DP secondary CPU.

Monitor/Modify, programming via PROFIBUS

As an alternative to the MPI interface, you can program the CPU or execute the PG functions Status and Modify via the PROFIBUS DP interface.

Note

The "Programming" or "Monitor/Modify" applications prolong the DP cycle if executed via the PROFIBUS DP interface.

Startup of the DP primary system

You use the following parameters to set the startup time monitoring of the PROFIBUS DP primary:

- Ready message from module
- Transfer of parameters to modules

That is, the DP secondaries must start up and be parameterized by the CPU (as PROFIBUS DP primary) within the set time.

PROFIBUS address of the PROFIBUS DP primary

All PROFIBUS addresses are permissible.

From IEC 61158 to DPV1

The IEC 61158 standard for distributed I/Os has been enhanced. The enhancements were incorporated into IEC 61158/IEC 61784–1:2002 Ed1 CP 3/1. The SIMATIC documentation uses the term "DPV1" in this context. The new version features various expansions and simplifications.

SIEMENS automation components feature DPV1 functionality. In order to be able to use these new features, you first have to make some modifications to your system. A full description of the migration from IEC 61158 to DPV1 is available in the FAQ section titled "Migrating from IEC 61158 to DPV1", FAQ entry ID 7027576, on the Customer Support Internet site.

Components supporting PROFIBUS DPV1 functionality

DPV1 primary

- The S7-400 CPUs with integrated DP interface.
- CP 443-5 with order number 6GK7 443–5DX03–0XE0, 6GK7 443–5DX04–0XE0, 6GK7 443-5DX05-0XE0.

DPV1 secondaries (default setting in SIMATIC)

- You can see if DP secondaries listed in the hardware catalog of STEP 7 under their family name are DPV1 secondaries in the information text.
- DP secondaries that are introduced in STEP 7 through GSD files, GSD revision 3 or higher.

What operating modes are there for DPV1 components?

- S7-compatible mode
  In this mode, the component is compatible with IEC 61158. However, you cannot use the full DPV1 functionality.
- DPV1 mode
  In this mode the component can make full use of DPV1 functionality. Automation components in the station that do not support DPV1 can be used as before. The DPV1 mode is set by default in SIMATIC.

Compatibility between DPV1 and IEC 61158?

You can continue to use all existing secondaries after the conversion to DPV1. These do not, however, support the enhanced functions of DPV1.

You can also use the DPV1 secondaries without conversion to DPV1. These secondaries then behave like conventional secondaries. You can operate DPV1 secondaries from SIEMENS in S7-compatible mode. For DPV1 secondaries from other manufacturers, you need an IEC 61158-compliant GSD file, revision 2 or earlier.

Determining the bus topology in a DP primary system with SFC 103 "DP_TOPOL"

A diagnostic repeater is available to make it easier to localize disrupted modules or DP cable breaks when failures occur during operation. This module is a secondary that can determine the topology of a DP line and detect faults originating from it.

With SFC 103 "DP_TOPOL", you initiate the determination of the bus topology of a DP primary system by the diagnostic repeater. SFC 103 is described in the corresponding online help and in the *"System and Standard Functions* manual. For information on the diagnostic repeater refer to the *"Diagnostic Repeater for PROFIBUS DP* manual, order number 6ES7972–0AB00–8BA0.

7.1.3 Diagnostics of the CPU 41x-H as PROFIBUS DP primary

Diagnostics using LEDs

The following table explains the meaning of the BUSF LED. In the event of a display, it is always the BUSF LED assigned to the interface configured as the PROFIBUS DP interface that lights up or flashes.

Table 7-2 Meaning of the "BUSF" LED of the CPU 41x as DP primary

BUSF	Meaning	What to do
Off	Configuration correct; all configured secondaries can be addressed	-
Lit	• DP interface error • Different baud rates in multi-DP primary operation (only in stand-alone operation)	• Evaluate the diagnosis. Reconfigure or correct the configuration.
Flashes	• Station failure • At least one of the assigned secondaries cannot be addressed • Bus fault (physical fault)	• Check whether the bus cable is connected to the CPU 41x or whether the bus is interrupted. • Wait until the CPU 41x has powered up. If the LED continues to flash, check the DP secondaries or evaluate the diagnostics of the DP secondaries. • Check whether the bus cable has a short-circuit or a break.

Reading out the diagnostics information with STEP 7

Table 7-3 Reading out the diagnostics information with STEP 7

DP primary	Block or tab in STEP 7	Application	See ...
CPU 41x	Tab "DP secondary diagnostics"	Display secondary diagnostics as plain text in the **STEP 7** user interface	See "Hardware diagnostics" in the **STEP 7** Online Help, and *Configuring hardware and connections with* **STEP 7** in the manual
	SFC 13 "DPNRM_DG"	Read out device diagnostics i.e. store in data area of the user program The busy bit may not be set to "0" if an error occurs while SFC 13 is being processed. You should therefore check the RET_VAL parameter whenever SFC 13 was processed.	Structure for CPU 41x, see *CPU Data Reference Manual*; SFC, see *System and Standard Functions Reference Manual* Structure for other secondaries, see their description
	SFC 59 "RD_REC"	Readout of data records of the S7 diagnosis (saving them to the data area of the user program)	Refer to the *System and Standard Functions Reference Manual*
	SFC 51 "RDSYSST"	Readout of system status lists (SSL). In the diagnostic interrupt with SSL ID W#16#00B3, call SFC 51 and read out SSL of secondary CPU.	

DP primary	Block or tab in STEP 7	Application	See ...
	SFB 52 "RDREC"	Reading data records of S7 diagnostics, i.e. saving them to the data area of the user program	
	SFB 54 "RALRM"	Readout of 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.

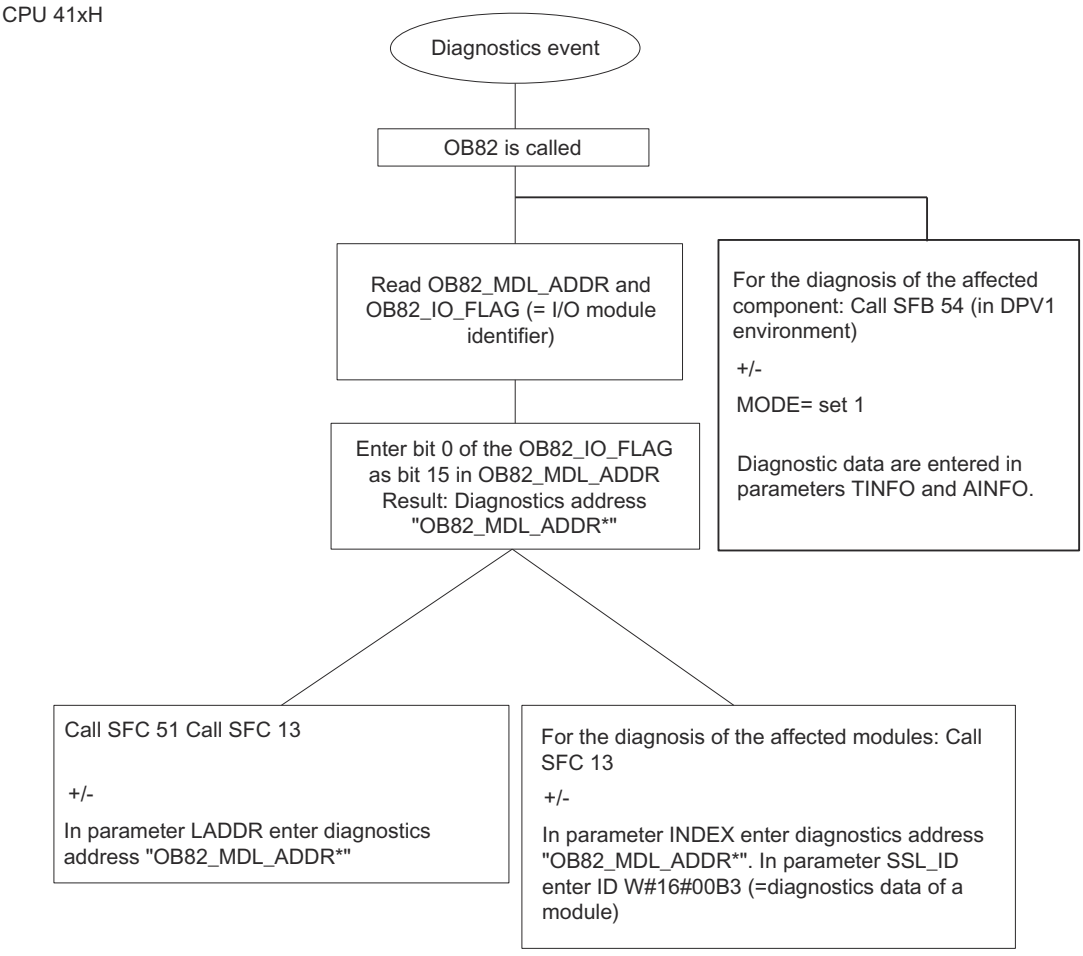


Figure 7-1 Diagnostics with CPU 41xH

Diagnostic addresses in connection with DP secondary functionality

Assign the diagnostics addresses for PROFIBUS DP at the CPU 41xH. Pay attention when configuring that DP diagnostic addresses are assigned once to the DP primary and once to the DP secondary.

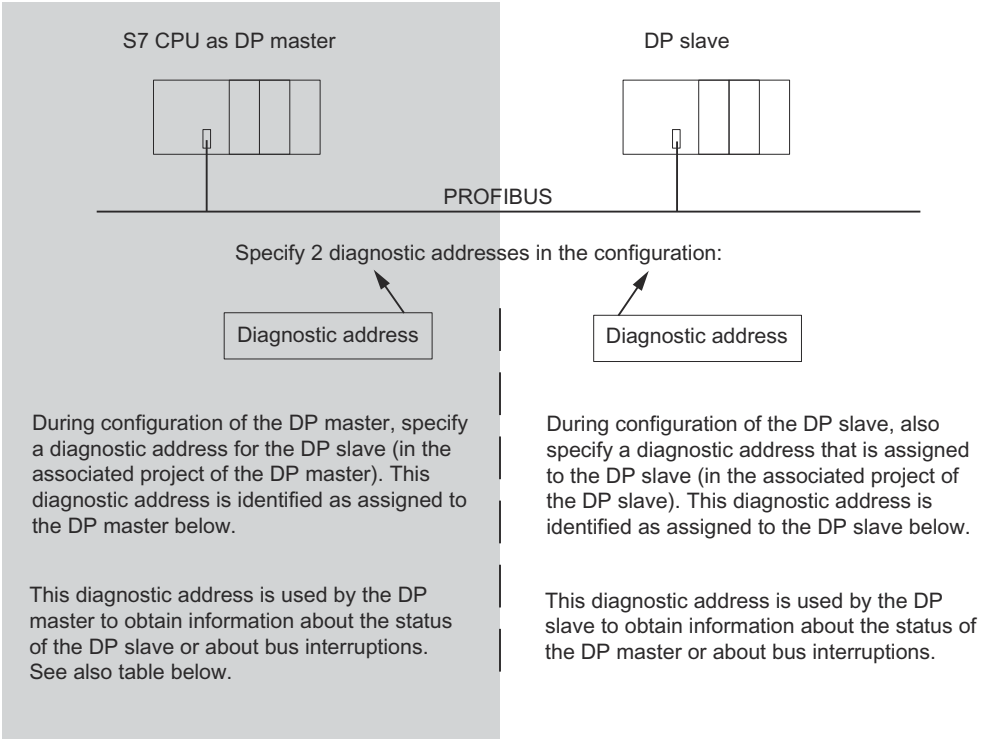


Figure 7-2 Diagnostic addresses for DP primary and DP secondary

Event detection

The following table shows how the CPU 41xH as DP primary detects operating state changes of an i-secondary or interruptions of the data transfer.

Table 7-4 Event detection of the CPUs 41xH as DP primary

Event	What happens in the DP primary
Bus interruption due to short-circuit or disconnection of the connector	• Call of OB 86 with message **Station failure** as incoming event; diagnostic address of the DP secondary/i-secondary assigned to the DP primary • With I/O access: Call of OB 122, I/O area access error
Time-outs when the system updates the process image	• Call of OB 85
i-secondary: RUN → STOP	• Call of OB 82 with message **Faulty module** as incoming event; diagnostic address of the i-secondary assigned to the DP primary; variable OB82_MDL_STOP=1
i-secondary: STOP → RUN	• Call of OB 82 with message **Module ok** as outgoing event; diagnostic address of the i-secondary assigned to the DP primary; variable OB82_MDL_STOP=0

Evaluation in the user program

The following table shows how you can evaluate, for example, RUN-STOP transitions of the i-secondary in the DP primary. Also refer to previous table.

In DP primary	In i-secondary (CPU 41x)
• Example of diagnostics addresses: Primary diagnostic address=1023 Secondary diagnostic address in primary system=1022	• Example of diagnostics addresses: Secondary diagnostic address=422 Primary diagnostic address=not relevant
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 Also program SFC 13 "DPNRM_DG" in the user program to read out the i-secondary diagnostics data. Use SFB 54 in the DPV1 environment. This outputs the full interrupt information.	CPU: RUN → STOP CPU generates an i-secondary diagnostic message frame.

PROFINET

8

8.1 Introduction

What is PROFINET?

PROFINET is the open, non-proprietary Industrial Ethernet standard for automation. It enables comprehensive communication from the business management level down to the field level.

PROFINET fulfills the high demands of industry, for example:

- Industrial-compliant installation engineering
- Real-time capability
- Non-proprietary engineering

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

Information about the use of I/Os at the PROFINET interface is available in the chapter System redundancy (Page 93).

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 the simultaneous data transfer of several 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 slice 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.

Direct connection of distributed field devices (IO devices, such as signal modules) to Industrial Ethernet. PROFINET IO supports a consistent diagnostics concept for efficient error localization and troubleshooting.

Note

No changes to the PROFINET interface at runtime

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

Documentation on the Internet

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

Also observe the following documents:

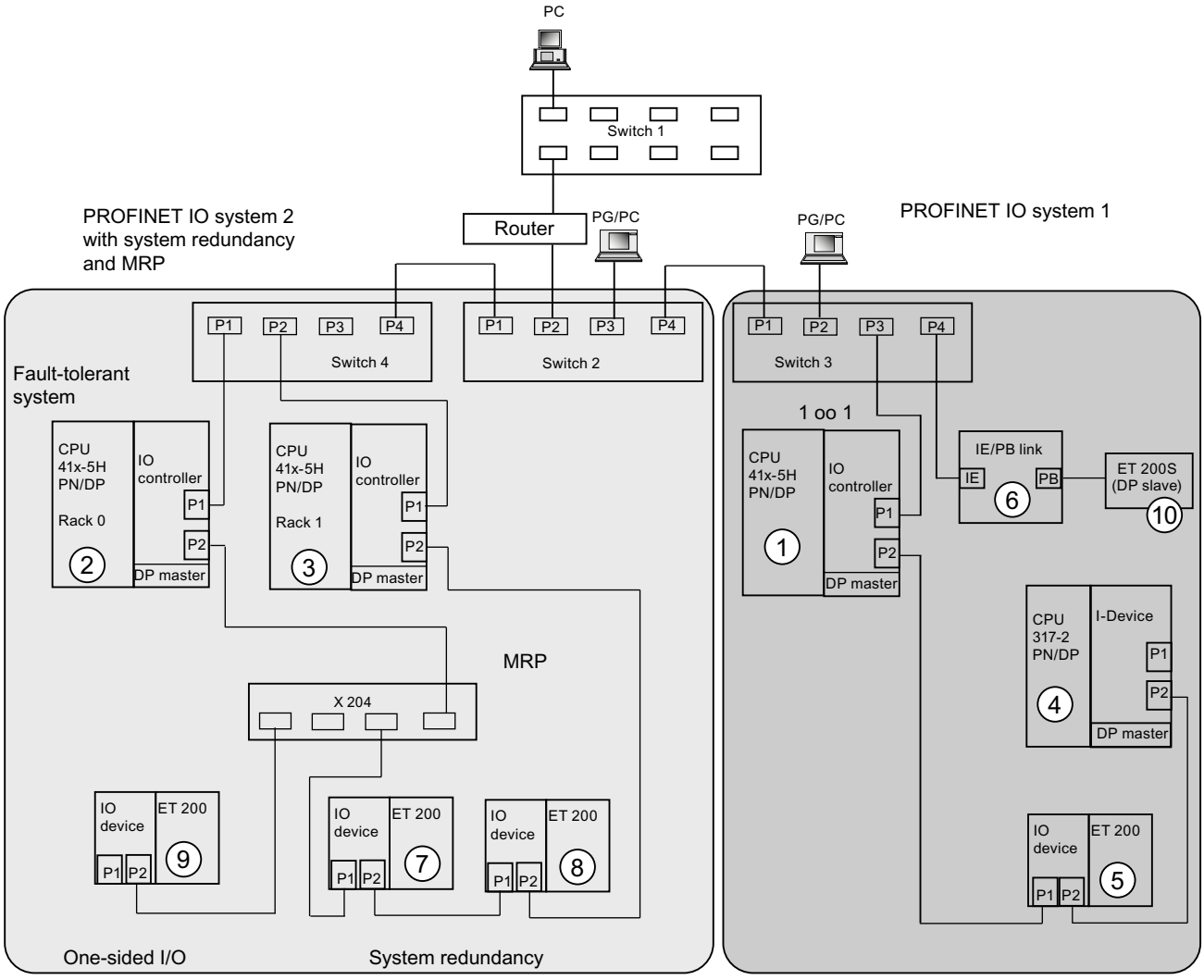
- Installation guideline
- Assembly guideline
- PROFINET_Guideline_Assembly

Additional information on the use of PROFINET in automation engineering is available at the following Internet address (https://new.siemens.com/global/en/products/automation/industrial-communication/profinet.html).

8.2 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 - Switch 1 - Router - Switch 2 - CPU 41x-5H PN/DP 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 41x-5H PN/DP ③ - on IO device ET 200⑧.

The graphic shows	Examples of connection paths
The IO controller of CPU 41x5 PN/DP ① sets up PROFINET IO system 1 and directly controls devices on Industrial Ethernet and PROFIBUS.	At this point, you can see the IO feature between the IO controller, intelligent device, and the IO devices on Industrial Ethernet: • The CPU 41x-5 PN/DP ① is the IO controller for the IO device ET 200 ⑤, for Switch 3 and for the intelligent device CPU 317-2 PN/DP ④. • By means of the IE/PB Link, the CPU 41x-5H PN/DP ① is also the primary for the DP secondary ⑩.
The H-system, consisting of CPU 41x-5H PN/DP ② + ③, spans the PROFINET system 2 as IO controller. This IO controller operates IO devices in system redundancy as well as a one-sided IO device.	The H-system, consisting of CPU 41x-5H PN/DP ② + ③, spans the PROFINET 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 H-system is the IO controller for the two 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 in the documents listed below:

- In manual PROFINET system description (https://support.industry.siemens.com/cs/ww/en/view/19292127)
- In the *From PROFIBUS DP to PROFINET IO programming manual*.
  This manual also provides a clear overview of the new PROFINET blocks and system status lists.

8.3 Blocks in PROFINET IO

Compatibility of the New Blocks

For PROFINET IO, some new blocks were created, among other things, because larger configurations are now possible with PROFINET. You can also use the new blocks with PROFIBUS.

Comparison of the system and standard functions of PROFINET IO and PROFIBUS DP

For CPUs with an integrated PROFINET interface, the table below provides you with an overview of the following functions:

- System and standard functions for SIMATIC that you may need to replace when migrating from PROFIBUS DP to PROFINET IO.
- New system and standard functions

Table 8-1 System and standard functions that are new or have to be replaced

Blocks	PROFINET IO	PROFIBUS DP
SFC 13"DPNRM_DG" Reading diagnostics data of a DP secondary	No Replacement: • Event-related: SFB 54 • Status-related: SFB 52	Yes
SFC 58 "WR_REC" SFC 59 "RD_REC" Write/read record in the I/O devices	No Replacement: SFB 53/52	Yes, if you will have not already replaced these SFBs under DPV 1 by SFB 53/52.
SFB 52 "RDREC" SFB 53 "WRREC" Read/write record	Yes	Yes
SFB 54 "RALRM" Evaluating alarms	Yes	Yes
SFB 81 "RD_DPAR" Reading predefined parameters	Yes	Yes
SFC 5 "GADR_LGC" Determining the start address of a module	No Replacement: SFC 70	Yes
SFC 70 "GEO_LOG" Determining the start address of a module	Yes	Yes
SFC 49 "LGC_GADR" Determining the slot that belongs to a logical address	No Replacement: SFC 71	Yes
SFC 71 "LOG_GEO" Determining the slot that belongs to a logical address	Yes	Yes

The following table provides an overview of the system and standard functions for SIMATIC, whose functionality must be implemented by other functions when converting from PROFIBUS DP to PROFINET IO.

Table 8-2 System and standard functions of PROFIBUS DP that can be emulated in PROFINET IO

Blocks	PROFINET IO	PROFIBUS DP
SFC 54 "RD_DPARM" Reading predefined parameters	No Replacement: SFB 81 "RD_DPAR"	Yes
SFC 55 "WR_PARM" Writing dynamic parameters	No Emulation by means of SFB 53	Yes
SFC 56 "WR_DPARM" Writing predefined parameters	No Emulation by means of SFB 81 and SFB 53	Yes
SFC 57 "PARM_MOD" Assigning module parameters	No Emulation by means of SFB 81 and SFB 53	Yes

The following SIMATIC system function is not supported for PROFINET IO:

- SFC 103 "DP_TOPOL" Determine bus topology in a DP primary

Comparison of the Organization Blocks of PROFINET IO and PROFIBUS DP

The following table lists the changes to OBs 83 und OB 86:

Table 8-3 OBs in PROFINET IO and PROFIBUS DP

Blocks	PROFINET IO	PROFIBUS DP
OB 70 I/O redundancy error, for fault-tolerant systems only	New	Unchanged
OB 83 Removing and inserting modules at runtime	New error information	Unchanged
OB 86 Rack failure	New error information	Unchanged

Detailed information

For more information about the blocks, refer to the manual *System Software for S7-300/400 System and Standard Functions*.

8.4 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 via the PROFINET IO system:

- System data
- Module status information in the CPU
- Diagnostic data from a module
- Diagnostic buffer

Compatibility of the new system status lists

For PROFINET IO, some new system status lists were created, among other things, because larger configurations are now possible with PROFINET.

You can also use these new system status lists with PROFIBUS.

You can continue to use a known PROFIBUS system status list that is also supported by PROFINET. If you use a system status list in PROFINET that PROFINET 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 8-4 Comparison of the system status lists of PROFINET IO and PROFIBUS DP

SSL-ID	PROFINET IO	PROFIBUS DP	Applicability
W#16#0591	Yes Parameter adr1 changed	Yes	Module status information for the interfaces of a module
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.
W#16#0D91	Yes Parameter adr1 changed No, external interface	Yes	Module status information of all modules in the specified rack/station
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)
W#16#0C75	Yes, parameter adr1 changed	Yes	Communication status between the H-system and switched DP secondary/PN device
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#xy92	No Replacement: SSL-ID W#16#0x94	Yes	Rack/stations 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

Detailed information

For detailed descriptions of the individual system status lists, refer to the manual *System Software for S7-300/400 System and Standard Functions*.

8.5 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 (https://support.industry.siemens.com/cs/ww/en/view/19292127) manual.

8.6 Shared Device

The "Shared Device" functionality enables distribution of the submodules of an IO device between different IO controllers. An intelligent I-device can also be operated as shared device.

Prerequisite for using the "Shared Device" function is that the IO controller and shared device are located on the same Ethernet subnet.

The IO controllers can be located in the same or different STEP 7 projects. If they are located in the same STEP 7 project, a consistency check is initiated automatically.

Note

Note that the power modules and electronic modules belonging to the same potential group of a shared IO device (e.g. ET 200S) must be assigned to the same IO controller in order to enable the diagnosis of load voltage failure.

Additional information

You can find more information on the shared device and configuration in the STEP 7 online help and in the manual PROFINET system description (https://support.industry.siemens.com/cs/ww/en/view/19292127).

8.7 Media redundancy

Media redundancy is a function that ensures network and system 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 interface V6.0 or higher. MRP is a component of PROFINET standardization to IEC 61158.

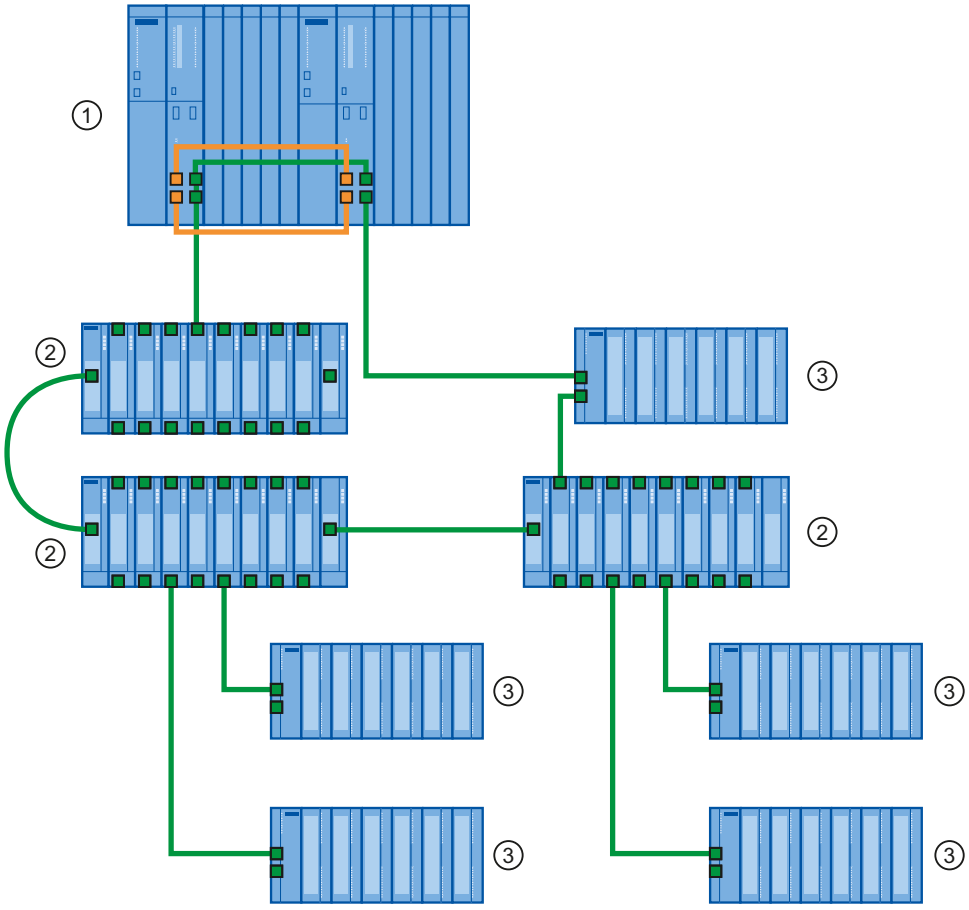
Installing a ring topology

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.

Topology

You can also combine system redundancy under PROFINET with other PROFINET functions.

System redundancy with media redundancy



① S7-400H system
② SCALANCE X400 (one-sided I/Os)
③ ET200M (one-sided/system-redundant I/Os)

Figure 8-1 Configuration example of system redundancy with media redundancy

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. This means that you should select a response monitoring time of the IO device of sufficient length. 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 the PROFINET System Description (https://support.industry.siemens.com/cs/ww/en/view/19292127) manual.

8.8 System redundancy

System redundancy is the connection of IO devices via PROFINET with a communication connection 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.

Requirement

You need the following component versions to set up a fault-tolerant system with system-redundant I/Os:

- CPU 41x-5H PN/DP as of version 6.0
- IM 153-4BA00 as of version 4.0
- STEP7 as of V5.5, SP2 HF1

Configuration

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

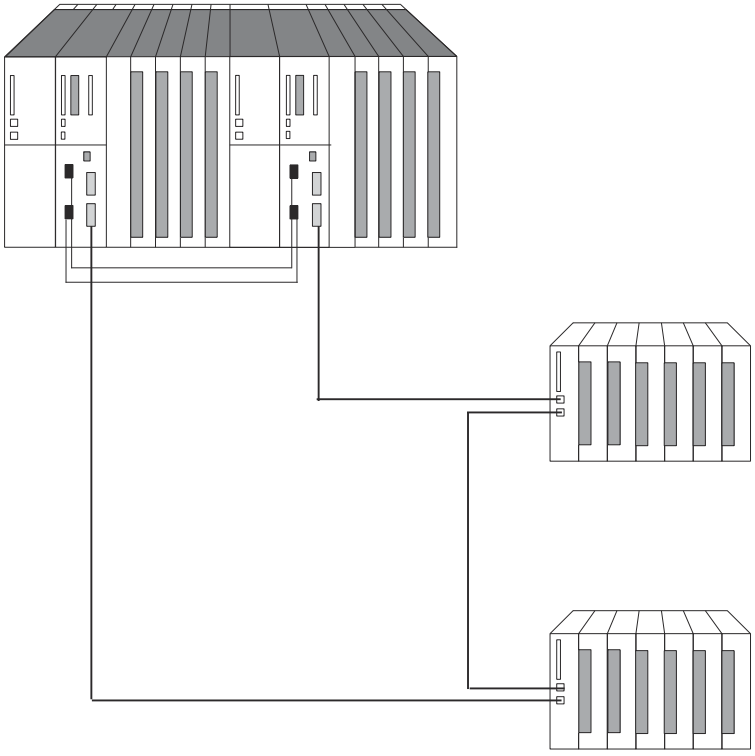


Figure 8-2 S7-400H system with IO devices connected in system redundancy

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 STEP7, the logical view and the physical view of the configuration with two integrated IO devices in system redundancy. Note that the view in STEP7 does not exactly match the physical view.

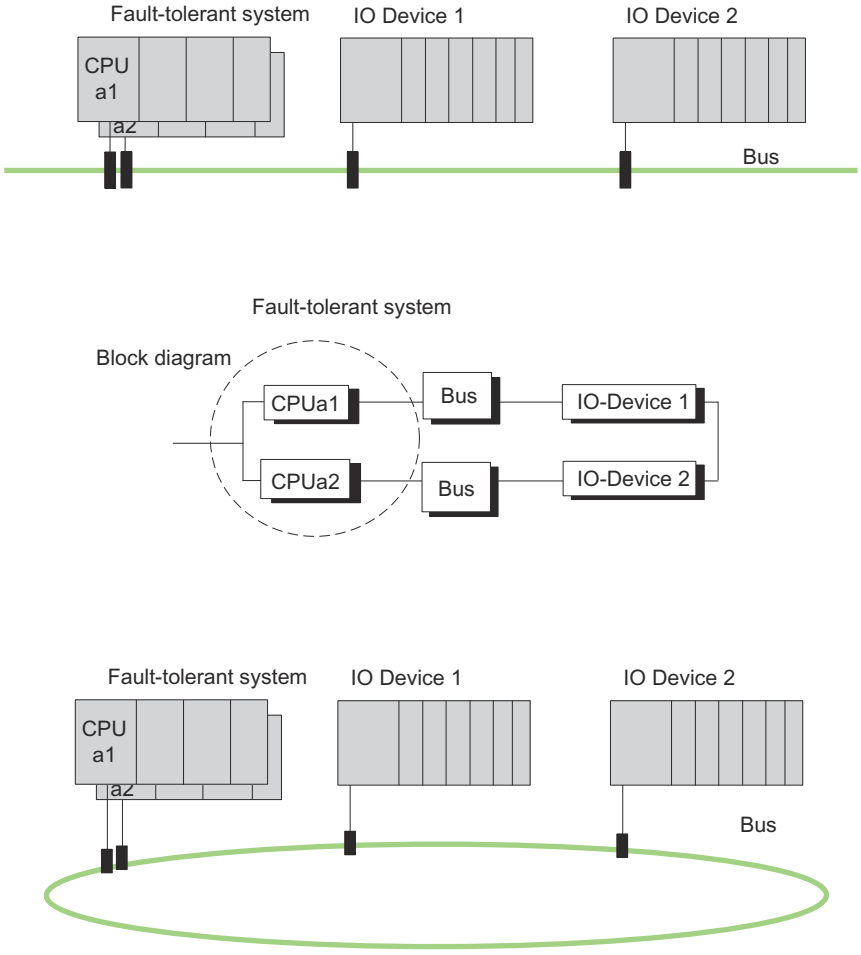


Figure 8-3 System redundancy in different views

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.

Maximum number of IO devices

You can connect up to 256 IO devices to both integrated PROFINET interfaces. These can be configured for one-sided or redundant mode. The station numbers must be unique for both PROFINET 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.

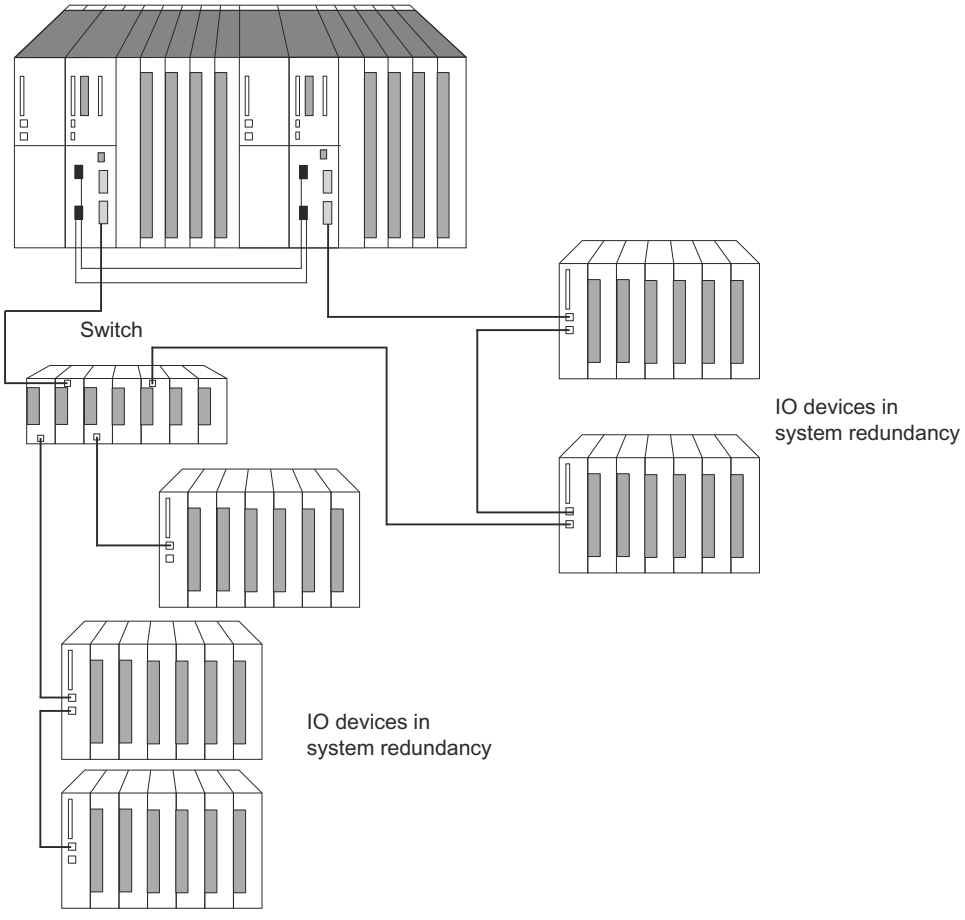


Figure 8-4 PN/IO with system redundancy

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.

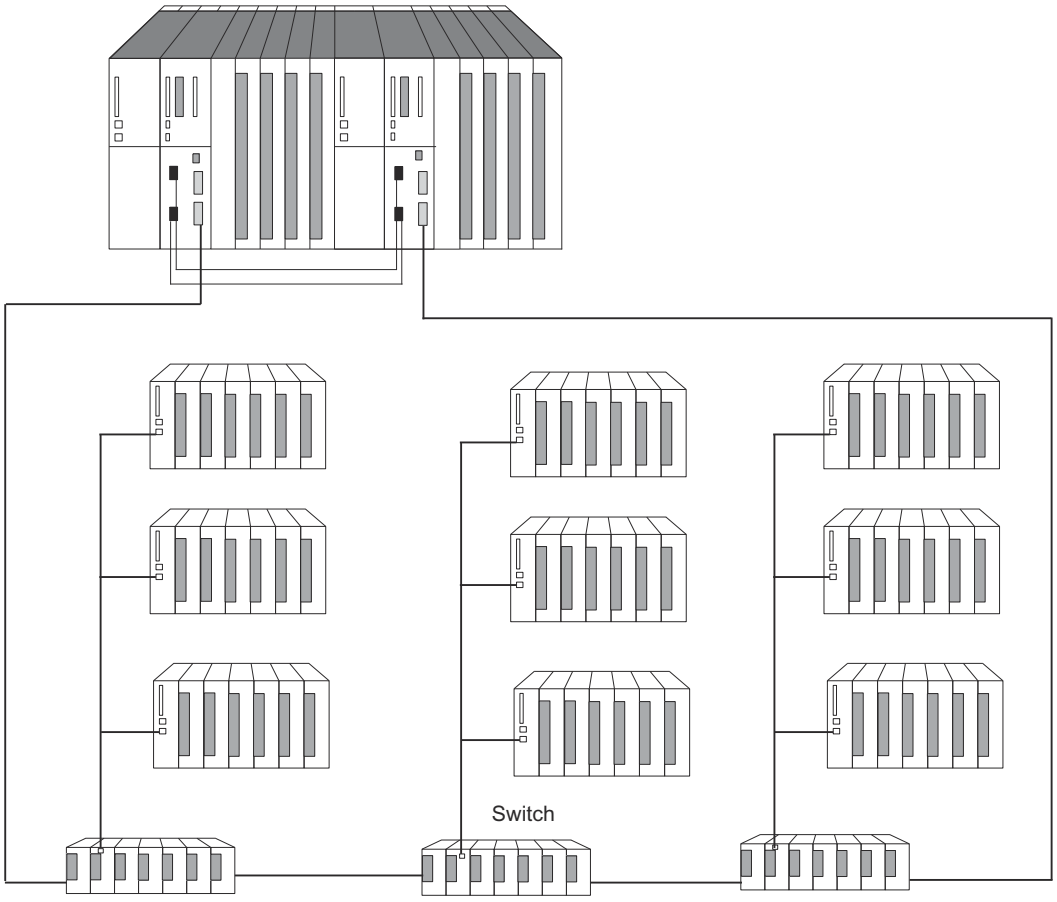


Figure 8-5 PN/IO with system redundancy

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 thje course of configuration. You can configure the IO devices in the first figure as one-sided instead of the system-redundant setup.

Consistent data

9

Overview

Data that belongs together in terms of its content and describe a process state at a specific point in time is known as consistent data. In order to maintain data consistency, do not modify or update the data during their transfer.

Example 1:

In order to provide a consistent image of the process signals to the CPU for the duration of cyclic program processing, the process signals are written to the process image of inputs prior to program execution, or the processing results are written to the process image of outputs after program execution. Subsequently, during program processing when the inputs (I) and outputs (O) operand areas are addressed, the user program addresses the internal memory area of the CPU on which the process image is located instead of directly accessing the signal modules.

Example 2:

Inconsistency may develop when a communication block, such as SFB 14 "GET" or SFB 15 "PUT", is interrupted by a process alarm OB of higher priority. If the user program modifies any data of this process alarm OB which in part have already been processed by the communication block, certain parts of the transferred data will have retained their original status which was valid prior to process alarm processing, while others represent data from after process alarm processing.

This results in inconsistent data, i.e. data which are no longer associated.

SFC 81 "UBLKMOV"

Use SFC 81 "UBLKMOV" to copy the content of a memory range, the source area, consistently to another memory range, the target range. The copy operation cannot be interrupted by other operating system activities.

SFC 81 "UBLKMOV" enables you to copy the following memory areas:

- Bit memory
- DB contents
- Process input image
- Process output image

The maximum amount of data you can copy is 512 bytes. Make allowances for the CPU-specific restrictions listed in the instruction list.

Since copying cannot be interrupted, the alarm response times of your CPU may increase when using SFC 81 "UBLKMOV".

The source and destination areas must not overlap. If the specified destination area is larger than the source area, the function only copies the amount of data contained in the source area to the destination area. If the specified destination area is smaller than the source area, the function only copies as much data as can be written to the destination area.

For information on SFC 81, refer to the corresponding online help and to the "System and Standard Functions" manual.

9.1 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.

9.2 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.

9.3 Consistent reading and writing of data from and to a DP standard secondary/IO device

Reading data consistently from a DP standard secondary with SFC 14 "DPRD_DAT"

With SFC 14 "DPRD_DAT" "Read consistent data of a DP standard secondary", you read out the data of a DP standard secondary or IO device consistently.

The data read is entered into the destination area defined by RECORD if no error occurs during data transfer.

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 the "System and Standard Functions" manual.

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 secondary with SFC 15 "DPWR_DAT"

With SFC 15 "DPWR_DAT" "Write consistent data to a DP standard secondary", you transfer the data in RECORD to the addressed DP standard secondary or IO device consistently.

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 to the "System and Standard Functions" manual.

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 transfer of consistent user data to a DP secondary

The PROFIBUS DP standard defines upper limits for the transfer of consistent user data to a DP secondary. For this reason, a maximum of 64 words = 128 bytes of user data can be transferred to a DP standard secondary consistently in a single block.

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.

Note also in this regard that a CPU 41x as DP secondary must be able to be configured generally on a third-party primary (connection via GSD) using the general identification format. For this reason, the transfer memory of a CPU 41x as DP secondary to PROFIBUS DP has a maximum size of 16 words = 32 bytes.

Note

The PROFIBUS DP standard defines upper limits for the transfer of consistent user data. Common DP standard secondaries adhere to these upper limits. Older CPUs (<1999) had CPU-specific restrictions in terms of the transmission of consistent user data. For these CPUs, you can find the maximum length of data that the CPU can read consistently from a DP standard secondary or write consistently to a DP standard secondary in technical specifications of the CPU under keyword "DP primary – User data per DP secondary". For newer CPUs, this value surpasses the length of data that a DP standard secondary provides or accommodates.

Upper limits for the transfer of consistent user data to an IO device

For the transfer of consistent user data to an IO device, the upper limit of 1025 bytes applies (1024 bytes user data + 1 byte associated value). Even if more than 1024 bytes can be transferred to an IO device, only a maximum of 1024 bytes can be transferred consistently.

For the transfer via a CP 443-1 in PN-IO mode, an upper limit of 240 bytes applies.

Consistent data access without using SFC 14 or SFC 15

Consistent data access > 4 bytes is also possible without using SFC 14 or SFC 15. The data area of a DP secondary or IO device that is to be transferred consistently is transferred to a process image partition. The data in this area are thus always consistent. You can then access the process image partition using the load/transfer commands (L EW 1, for example). This provides a particularly convenient and efficient (low runtime load) method of accessing consistent data. This enables efficient integration and parameterization of drives, for example, or other DP secondaries.

Any direct access to a consistently configured data area,
e.g. L PEW or T PAW, does **not** result in an I/O area access error.

Important aspects in the conversion from the SFC14/15 solution to the process image solution are:

- SFC 50 "RD_LGADR" outputs different address areas with the SFC 14/15 method as with the process image method.
- PROFIBUS DP via internal interface:
  When converting from the SFC14/15 method to the process image method, it is not advisable to use the system functions and the process image concurrently. Although the process image is updated when writing with system function SFC15, this is not the case when reading. In other words, consistency between the values of the process image and of the system function SFC14 is not ensured.
- PROFIBUS DP via CP 443-5 ext:
  If you use a CP 443–5 ext, the parallel use of system functions and process image causes the following errors: Read/write access to the process image is blocked, and/or SFC 14/15 is no longer able to perform any read/write access operations.

Note

Forcing variables

The forcing of variables that lie in the I/O or process image area of a DP secondary or I/O device and do not belong to a consistent area is not allowed. The user program may overwrite these variables in spite of the force job.

Example:

The following example for process image partition 3 "PIP 3" shows a possible configuration in HW Config. Requirement: The process image was previously updated by means of SFC 26/27 call, or the update of the process image was linked to an OB.

- PIP 3 at output: Those 50 bytes are stored consistently in process image partition 3 (drop down list box "Consistent over > Total length"), and can thus be read by means of standard "Load input xy" commands.
- Selecting "Process image -> ---" under Input in the drop down list box means: no storage in a process image. You must work with the system functions SFC14/15.

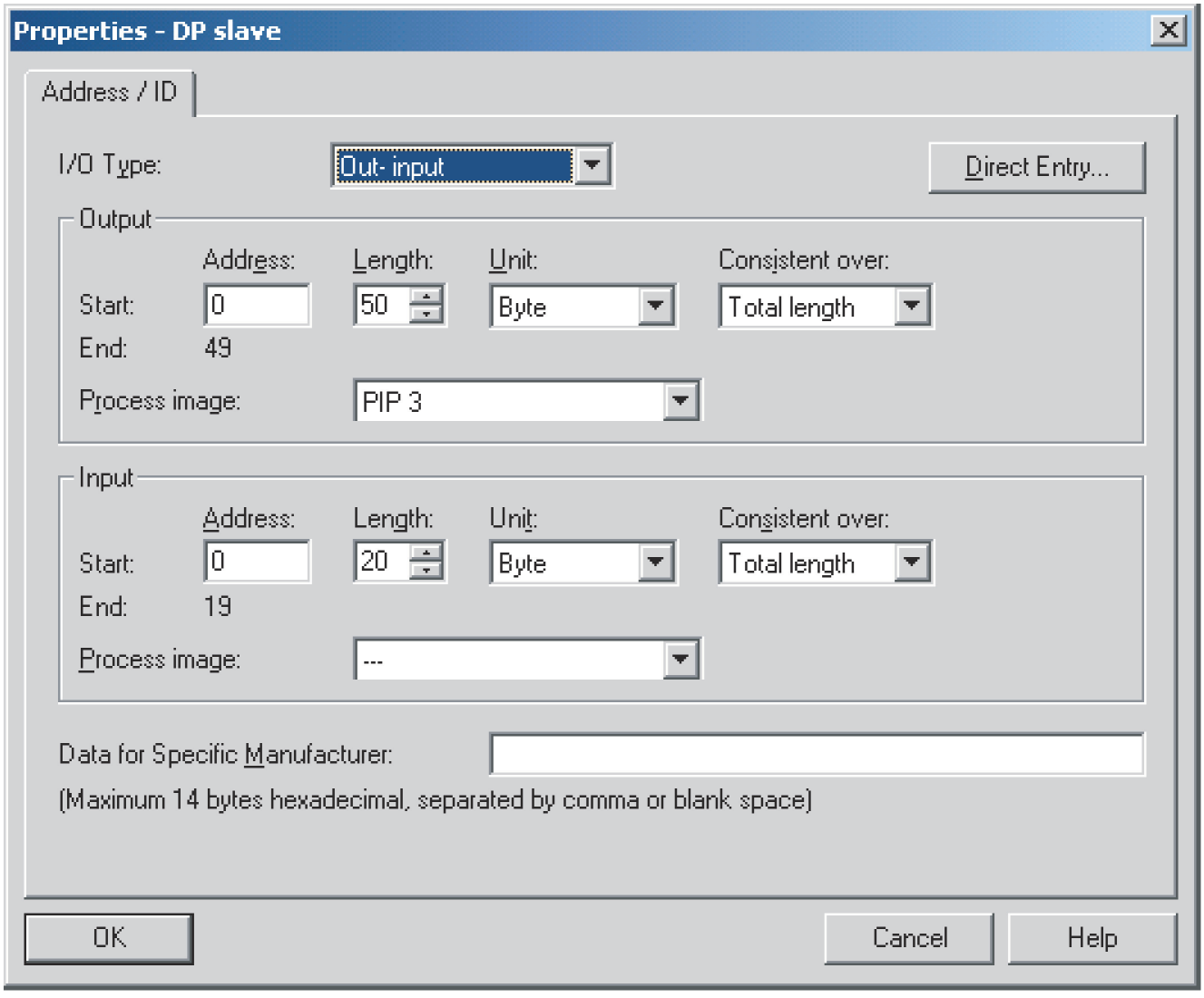


Figure 9-1 Properties - DP secondary

Memory concept

10

10.1 Overview of the memory concept of S7-400H CPUs

Organization of Memory Areas

The memory of the S7-400H CPUs can be divided into the following areas:

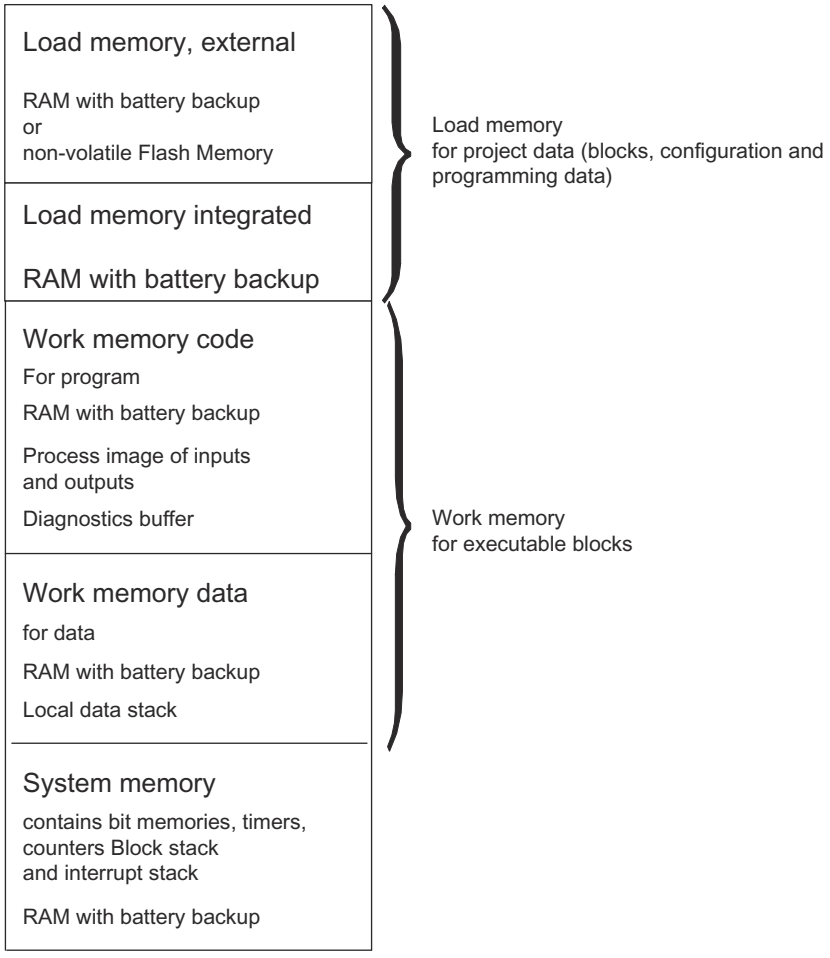


Figure 10-1 Memory areas of the S7-400H CPUs

Memory types of the S7-400H CPUs

- Load memory for the project data, e.g. blocks, configuration, and parameter settings.
- Work memory for the runtime-relevant blocks (logic blocks and data blocks).

- System memory (RAM) contains the memory elements that each CPU makes available to the user program, such as bit memories, timers and counters. System memory also contains the block stack and interrupt stack.
- System memory of the CPU also provides a temporary memory area (local data stack, diagnostics buffer, and communication resources) that is assigned to the program for the temporary data of a called block. This data is only valid as long as the block is active.
  By changing the default values for the process image, local data, diagnostics buffer, and communication resources (see object properties of the CPU in HW Config), you can influence the work memory available to the runtime-relevant blocks.

Note

Please note the following if you expand the process image of a CPU. Reconfigure the modules whose addresses have to be above the highest address of the process image so that the new addresses are still above the highest address of the expanded process image.

Important note for CPUs after the parameter settings for the allocation of RAM have been changed

If you change the work memory allocation by modifying parameters, this work memory is reorganized when you load system data into the CPU. As a consequence, the data blocks generated by means of SFC are deleted and the remaining data blocks are initialized with values from load memory.

The amount of work memory that is made available for logic or data blocks during the download of system data is adapted if you modify the following parameters:

- Size of the process image (byte-oriented; in the "Cycle/Clock Memory" tab)
- Communication resources (in the "Memory" tab)
- Size of the diagnostics buffer ("Diagnostics/Clock" tab)
- Number of local data for all priority classes ("Memory" tab)

Basis for Calculating the Required Working Memory

To ensure that you do not exceed the available amount of working memory on the CPU, you must take into consideration the following memory requirements when assigning parameters:

Table 10-1 Memory requirements

Parameter	Required working memory	In code/data memory
Size of the process image (inputs)	20 bytes per byte in the process image of inputs	Code memory
Size of the process image (outputs)	20 bytes per byte in the process image of inputs	Code memory
Communication resources (communication jobs)	72 bytes per communication job	Code memory
Size of the diagnostics buffer	32 bytes per entry in the diagnostics buffer	Code memory
Quantity of local data	1 byte per byte of local data	Data memory

Flexible memory space

- Work memory:
  The capacity of the work memory is determined by selecting the appropriate CPU from the graded range of CPUs.
- Load memory:
  The integrated load memory is sufficient for small and medium-sized programs.
  The load memory can be increased for larger programs by inserting the RAM memory card. Flash memory cards are also available to ensure that programs are retained in the event of a power failure even without a backup battery. Flash memory cards (8 MB or more) are also suitable for sending and carrying out operating system updates.

Backup

- The backup battery provides backup power for the integrated and external part of the load memory, the data section of the working memory and the code section.

System and operating states of the S7–400H 11

This chapter features an introduction to the subject of S7-400H fault-tolerant systems.

You will learn the basic terms that are used in describing how fault-tolerant systems operate.

Following that, you will receive information on fault-tolerant system states. They depend on the operating states of the different fault-tolerant CPUs, which will be described in the next section.

In describing these operating states, this section concentrates on the behavior that differs from a standard CPU. You will find a description of the standard behavior of a CPU in the corresponding operating mode in the *Programming with STEP 7* manual.

The final section provides details on the modified time response of fault-tolerant CPUs.

11.1 Introduction

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

Both subsystems create a fault-tolerant automation system operating 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 "reserve" for dual-channel fault-tolerant systems in this description. The reserve always processes events in synchronism with the master, and does not explicitly wait for any errors before doing so.

The distinction made between the master and reserve CPUs is primarily important for ensuring reproducible error reactions. For example, the reserve CPU may go into STOP when the redundant link fails, while the master CPU remains in RUN.

Master/reserve assignment

When the S7-400H is initially switched on, the CPU that started up first assumes master mode, and the partner CPU assumes reserve mode.

The preset master/reserve assignment is retained when both CPUs power up simultaneously.

The master/reserve assignment changes when:

1. The reserve CPU starts up before the master CPU (interval of at least 3 s)
2. The master CPU fails or goes into STOP in redundant system mode
3. No error was found in ERROR-SEARCH mode (see also section ERROR-SEARCH mode (Page 119))
4. Programmed master-standby switchover with SFC 90 "H_CTRL"

Synchronizing the subsystems

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

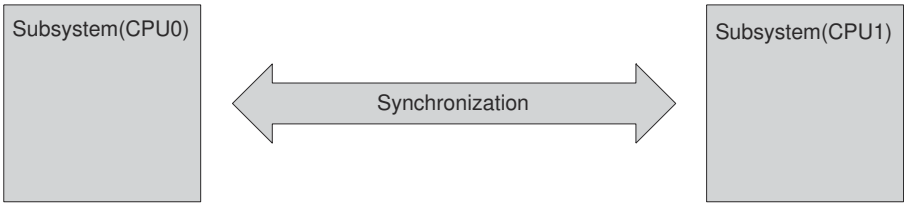


Figure 11-1 Synchronizing the subsystems

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. This procedure has proved itself in practice and has already been used for the S5-115H and S5-155H controllers.

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

The master and reserve 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 reserve CPU even if the master CPU fails.

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 racks
- 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 section Self-test (Page 120).

11.2 System states of the S7–400H

11.2.1 The system states of the S7-400H

The system states of the S7-400H 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 reserve CPU is in LINK-UP mode" we say "the S7-400H system is in link-up mode".

Overview of system states

The table below provides an overview of the possible states of the S7-400H system.

Table 11-1 Overview of S7-400H system states

System states of the S7–400H	Operating states of the two CPUs	
	Master	**Reserve**
Stop	STOP	STOP, power off, DEFECTIVE
Start-up	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
Redundant	RUN	RUN
Hold	HOLD	STOP, ERROR-SEARCH, power off, DEFECTIVE, no synchronization

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

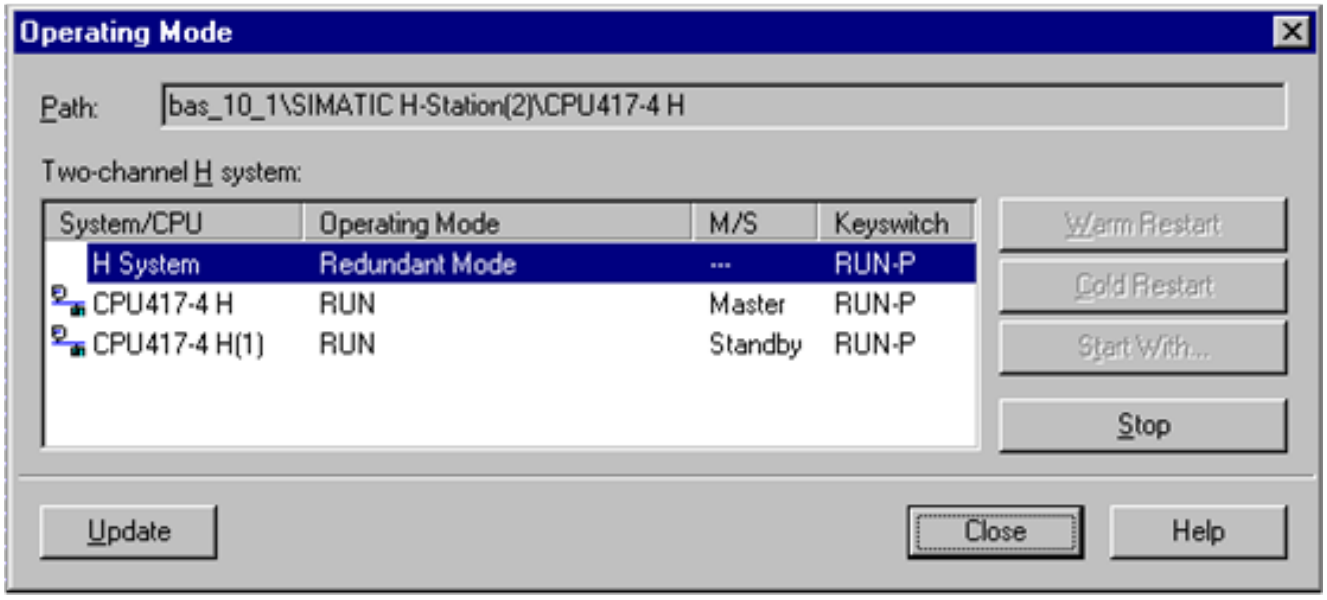
Procedure:

1. In SIMATIC Manager, select a CPU with existing MPI connection.
2. Select the PLC > Operating mode menu command.

Result:

The "Operating mode" dialog shows the current system state of the fault-tolerant system, the operating states of the individual CPUs, as well as the current position of the mode switches on the modules.

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.

11.2.3 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.

11.2.4 System status change from the standalone mode system status

Requirements:

- 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.

11.2.5 System status change from the redundant system state

Requirement:

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.

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.

11.2.6 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. Select the PLC > *Diagnose hardware* menu 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 state
	Standby CPU is in RUN state

CPU icon	Operating state of the respective CPU
	Master CPU is in STOP state
	Standby CPU is in STOP state
	Master CPU is in STARTUP state
	Standby CPU is in LINK-IN or UPDATE state
	Standby CPU is in ERROR-SEARCH operating state
	Malfunction of the master CPU or of a module parameterized by it.
	Malfunction of the standby CPU, or of a module parameterized by it.
	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 mode.

11.3 The operating states of the CPUs

Operating states describe the behavior of the CPUs at any given point in time. Knowledge of the operating states of the CPUs is useful for programming the startup, test, and error diagnostics.

Operating states from POWER ON to redundant system state

Generally speaking, the two CPUs enjoy equal rights so that either can be the master or the standby CPU. For reasons of legibility, the illustration presumes that the master CPU (CPU 0) is started up before the standby CPU (CPU 1) is switched on.

The following figure shows the operating states of the two CPUs, from POWER ON to redundant system state. The HOLD HOLD mode (Page 118) and ERROR-SEARCH ERROR-SEARCH mode (Page 119) states are a special feature and are not shown.

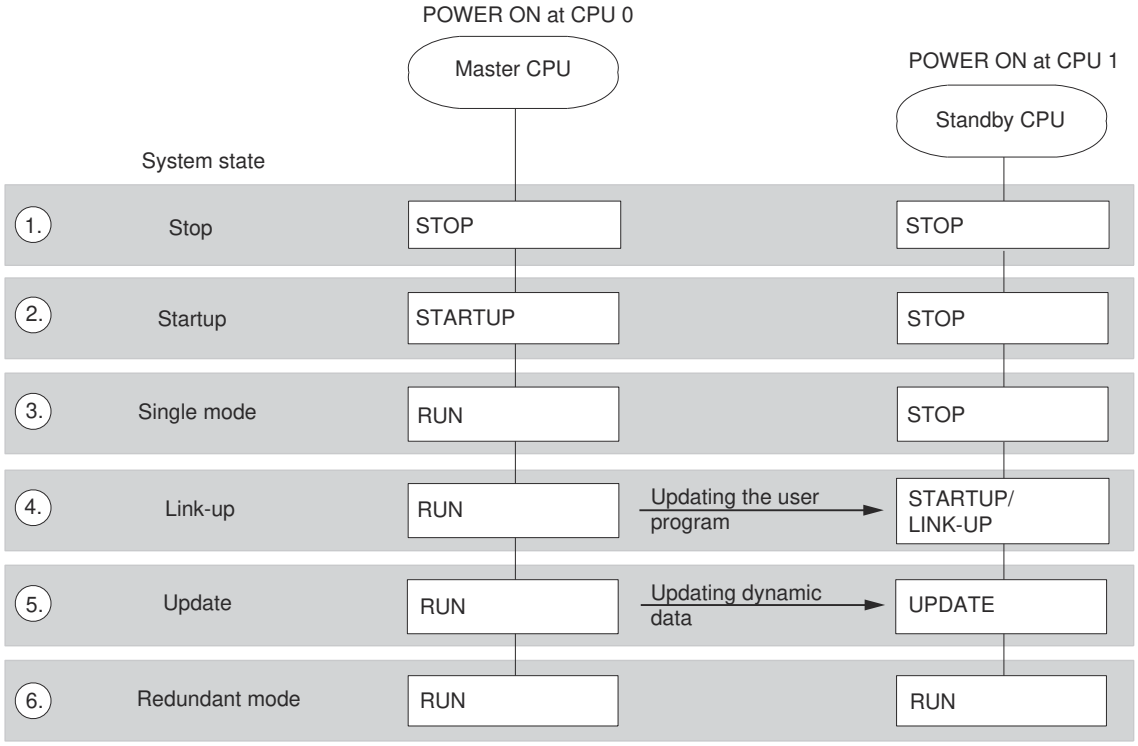


Figure 11-2 System and operating states of the fault-tolerant system

Explanation of the figure

Point	Description
1.	After the power supply has been turned on, the two CPUs (CPU 0 and CPU 1) are in STOP state.
2.	CPU 0 changes to the STARTUP state and executes OB 100 or OB 102 according to the startup mode; see also section STARTUP mode (Page 115).

Point	Description
3.	If startup is successful, the master CPU (CPU 0) changes to standalone mode. The master CPU executes the user program alone. At the transition to the LINK-UP system state, no block may be opened by the "Monitor" option, and no tag table may be active.
4.	If the standby CPU (CPU 1) requests LINK-UP, the master and standby CPUs compare their user programs. If any differences are found, the master CPU updates the user program of the standby CPU, see also section LINK-UP and UPDATE modes (Page 117).
5.	After a successful link-up, updating is started, see section Update sequence (Page 132). The master CPU updates the dynamic data of the standby CPU. Dynamic data includes inputs, outputs, timers, counters, bit memories and data blocks. Following the update, the memories of both CPUs have the same content; see also section LINK-UP and UPDATE modes (Page 117).
6.	The master and standby CPUs are in RUN after the update. Both CPUs process the user program in synchronous mode. Exception: Master/standby changeover for configuration/program modifications. The redundant system state is only supported with CPUs of the same version and firmware version.

11.3.1 STOP mode

Except for the additions described below, the behavior of S7-400H CPUs in STOP state corresponds to that of standard S7-400 CPUs.

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

- Start the CPU to which you downloaded the configuration first in order to set it up for master mode.
- By initiating the system startup request on the programming device, you first start the CPU to which an active connection exists, regardless of the master or standby status.

Note

A system startup may trigger a master–standby changeover.

A fault-tolerant CPU can only exit the STOP 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.

11.3.2 STARTUP mode

Except for the additions described below, the behavior of S7-400H CPUs in STARTUP mode corresponds to that of standard S7-400 CPUs.

Startup modes

The fault-tolerant CPUs distinguish between cold restart and warm restart.

Fault-tolerant CPUs do not support warm restarts.

Startup processing by the master CPU

The startup system mode of an S7-400H is always processed by the master CPU.

During STARTUP, the master CPU compares the existing I/O configuration with the hardware configuration that you created in STEP 7. If any differences are found, the master CPU reacts in the same way as a standard S7-400 CPU.

The master CPU checks and parameterizes 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 parameterizes the following:

- its assigned one-sided I/O devices

Special features at startup

If the master CPU returns to STOP immediately after transition to RUN during startup of a fault-tolerant system, the standby CPU takes over the master role and continues to start up.

In buffered PowerOn mode 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 restarts flashing

Start up is about to begin.

Additional information

For detailed information on STARTUP mode, refer to the *Programming with STEP 7* manual.

11.3.3 LINK-UP and UPDATE modes

The master CPU checks and updates the memory content of the reserve 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 link-up and updating, refer to section Link-up and update (Page 125).

11.3.4 RUN mode

Except for the additions described below, the behavior of S7-400H CPUs in RUN mode corresponds to that of standard S7-400 CPUs.

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

- Single mode
- Link-up, update
- Redundant

Single mode, link-up, update

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

In RUN, the CPU rejects all DCP commands.

Recommendation:

The PROFINET protocol can transmit DCP commands in the STOP of the CPU. To prevent unauthorized changes via DCP commands, the CPU should always be in "RUN" state. Examples of changes via DCP commands (changing and resetting of device parameters):

- DCP-Set (NameOfStation)
- DCP-Set (Reset-to-Factory)

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 11-2 Causes of error leading to redundancy loss

Cause of error	Reaction
Failure of one CPU	Failure and replacement of a CPU (Page 235)
Failure of the redundant link (synchronization module or fiber-optic cable)	Failure and replacement of a synchronization module or fiber-optic cable (Page 240)
RAM comparison error	ERROR-SEARCH mode (Page 119)

Redundant use of modules

The following rule applies to the redundant system mode:

The redundant module pairs used (e.g. DP interface module IM 153–2) must be identical, i.e. the two modules that are redundant to each other must have the same order number and the same product version and firmware version.

11.3.5 HOLD mode

Except for the additions described below, the behavior of the S7-400H CPU in HOLD mode corresponds to that of a standard S7-400 CPU.

The HOLD mode has an exceptional role, as it is used only for test purposes.

When is the HOLD mode possible?

A transition to HOLD is only available during STARTUP and in RUN in single mode.

Properties

- Link-up and update operations are not available while the fault-tolerant CPU is in HOLD mode; the reserve CPU remains in STOP and outputs a diagnostics message.
- It is not possible to set breakpoints when the fault-tolerant system is in redundant system mode.

11.3.6 ERROR-SEARCH mode

The ERROR-SEARCH mode can only be adopted from the redundant system mode. During troubleshooting, the redundant system state is exited, the other CPU becomes master and continues running in Solo mode.

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 ERROR-SEARCH mode:

1. If a one-sided call of OB 121 (on only one CPU) occurs in redundant mode, the CPU assumes a hardware fault and enters ERROR-SEARCH mode. The partner CPU assumes master mode as required, and continues operation in standalone mode.
2. If a checksum error occurs on only one CPU in redundant mode, that CPU enters ERROR-SEARCH mode. The partner CPU assumes master mode as required, and continues operation in standalone mode.
3. If a RAM/POI comparison error is detected in redundant mode, the standby CPU enters ERROR-SEARCH mode (default response), and the master CPU continues operation in standalone mode.
   The response to RAM/POI comparison errors can be modified in the configuration (for example, the standby CPU goes into STOP).
4. If a multiple-bit error occurs on a CPU in redundant mode, that CPU will enter ERROR-SEARCH mode. The partner CPU assumes master mode as required, and continues operation in standalone mode.
   But: OB 84 is called if 2 or more single-bit errors occur on a CPU in redundant operation within 6 months. The CPU does not change to ERROR-SEARCH mode.
5. If synchronization is lost during redundant mode, the standby CPU changes to ERROR-SEARCH mode. The other CPU remains master and continues operation in standalone mode.

The purpose of ERROR-SEARCH mode 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.

For CPU memories extended with FLASH Memory Cards, the following special condition applies: A general reset request is set if the CPU exits the ERROR-SEARCH operating state and is not able to establish a connection to the master CPU, e.g. when both synchronization lines are interrupted. This prevents that the stand-by CPU starts up as second master CPU using the configuration on the FLASH memory card.

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 46).

For additional information on the self-test, refer to Chapter Self-test (Page 120)

11.4 Self-test

Processing the self-test

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

The self-test takes at least 10 minutes. The larger the load memory used (e.g. the size of the inserted RAM memory card), the longer the self-test.

When the CPU of a fault-tolerant system requests a memory reset and is then shut down with backup power, it performs a self-test even though it was backed up. A memory reset is requested when you remove the memory card, for example.

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 11-3 Response to errors during the self-test

Type of error	System response
Hardware fault without one-sided call of OB 121	The faulty CPU enters the DEFECTIVE state. The fault-tolerant system switches to standalone mode. The cause of the error is written to the diagnostic buffer.
Hardware fault with one-sided call of OB 121	The CPU with the one-sided OB 121 enters ERROR-SEARCH mode. The fault-tolerant system switches to standalone mode (see below).
RAM/POI comparison error	The cause of the error is written to the diagnostic buffer. The CPU enters 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 enters ERROR-SEARCH mode.

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 backup, the faulty CPU enters ERROR-SEARCH mode. The fault-tolerant system switches to standalone mode. The cause of the error is written to the diagnostic buffer.

RAM/POI comparison error

If the self-test returns a RAM/POI comparison error, the fault-tolerant system quits redundant mode and the standby CPU enters ERROR-SEARCH mode (in default configuration). The cause of the error is written to the diagnostic buffer.

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

Table 11-4 Response to a recurring comparison error

Comparison error recurs ...	Reaction
in the first self-test cycle after troubleshooting	The standby CPU first enters ERROR-SEARCH mode, and then goes into STOP. The fault-tolerant system switches to standalone mode.
after two or more self-test cycles after trouble-shooting	Standby CPU enters ERROR-SEARCH mode. The fault-tolerant system switches to standalone mode.

Checksum errors

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

Table 11-5 Reaction to checksum errors

Time of detection	System response
During the startup test after POWER ON	The faulty CPU enters the DEFECTIVE state. The fault-tolerant system switches to standalone mode.
In the cyclic self-test (STOP or standalone mode)	The error is corrected. The CPU remains in STOP or in standalone mode.
In the cyclic self-test (redundant system mode)	The error is corrected. The faulty CPU enters ERROR-SEARCH mode. The fault-tolerant system switches to standalone mode.
In the ERROR-SEARCH mode	The faulty CPU enters the 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 diagnostic 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 standalone mode. The reaction of the F program to this is described in the *S7-400F and S7-400FH Automation Systems* manual.

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

A CPU 41x–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 41x–5H.

Table 11-6 Hardware fault with one-sided call of OB 121, checksum error, second occurrence

Error	CPU in standalone mode	CPU in stand-alone mode	CPU in redundant mode
Hardware fault with one-sided call of OB 121	OB 121 is executed	OB 121 is executed	The faulty CPU enters ERROR-SEARCH mode. The fault-tolerant system switches to standalone mode.
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 single/stand-alone mode 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 mode when troubleshooting is finished, the CPU reacts as it did on the first occurrence of the error.

Multiple-bit errors

The CPU changes to ERROR-SEARCH mode when a multiple-bit error is detected while the fault-tolerant system is operating in redundant mode. When troubleshooting is finished, the CPU can automatically connect and update itself, and resume redundant operation. At the transition to error-search mode, the address of the errors is reported in the diagnostic 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 the *System Software for S7-300/400, System and Standard Functions* manual.

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 the *S7-400F and S7-400FH Automation Systems* manual.

11.5 Evaluation of hardware interrupts in the S7-400H system

When using a hardware interrupt-triggering module in the S7-400H system, it is possible that the process values which can be read from the hardware interrupt OB by direct access do not match the process values valid at the time of the interrupt. Evaluate the temporary variables (start information) in the hardware interrupt OB instead.

When using the process interrupt-triggering module SM 321-7BH00, it is not advisable to have different responses to rising or falling edges at the same input, because this would require direct access to the I/O. If you want to respond differently to the two edge changes in your user program, assign the signal to two inputs from different channel groups and parameterize one input for the rising edge and the other for the falling edge.

Link-up and update

12

12.1 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 12-1 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 tag", "Monitor (On/Off)" and "Force"	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.

12.2 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 reserve CPU. The table below shows the correlation between those conditions and available programming device commands for link-up and update operations.

Table 12-2 Conditions for link-up and update

Link-up and update as PG command:	Size and type of load memory in the master and reserve CPUs	FW version in the master and reserve CPUs	Available sync connections	Hardware version on master and reserve CPU
Restart of the reserve	Are identical	Are identical	2	Are identical
Switch to CPU with modified configuration	RAM and EPROM mixed	Are identical	2	Are identical
Switchover to CPU with expanded memory configuration	Size of load memory in the reserve CPU is larger than that of the master	Are identical	2	Are identical
Switchover to CPU with modified operating system	Are identical	Are different	2	Are identical
CPUs with changed hardware version	Are identical	Are identical	2	Are different
Only one synchronization link-up is available over only one intact redundant link	Are identical	Are identical	1	Are identical

12.3 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 should change over from standalone mode to redundant mode. The two CPUs then process the same program synchronized with each other.
- When the CPUs link up and update with master/standby changeover, the second CPU with modified components can assume control over the process. Either the hardware configuration, or the memory configuration, or the operating system may have been modified.
  In order to return to redundant system mode, a "normal" link-up and update operation must be performed subsequently.

How to start the link-up and update operation?

Initial situation: Single mode, i.e. only one of the CPUs of a fault-tolerant system connected via fiber-optic cables is in RUN.

To establish system redundancy, initiate the link-up and update operation as follows:

- Toggle the mode selector switch of the standby CPU from STOP to RUN.
- POWER ON the standby (mode selector in RUN position) if prior to POWER OFF the CPU was not in STOP mode.
- Operator input on the PG/ES.

A link-up and update operation with master/standby changeover is always started 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 operating in standalone mode. In the figure, CPU 0 is assumed to be the master.

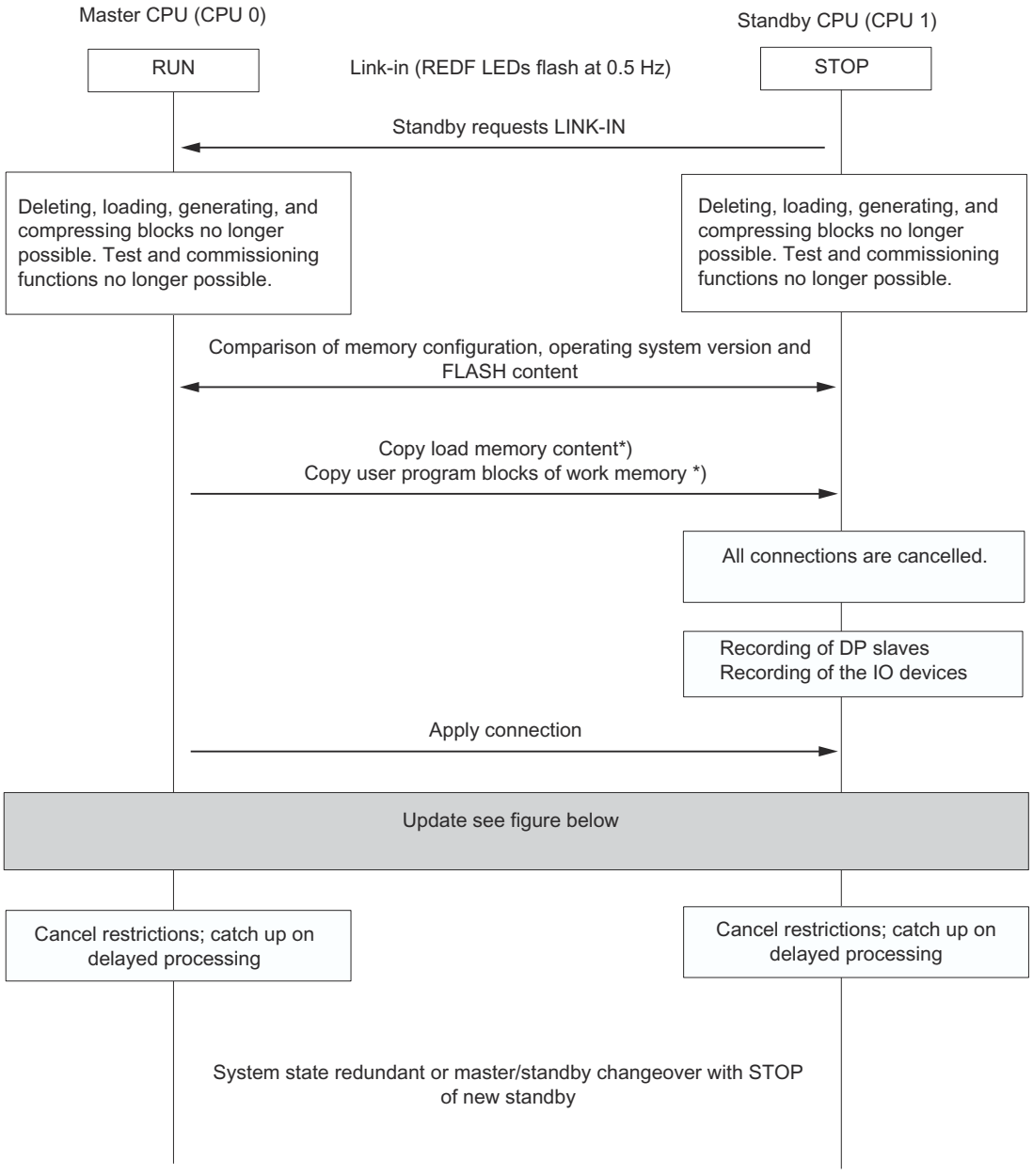


Figure 12-1 Sequence of link-up and update

*) If the "Switchover to CPU with altered 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 section Switch to CPU with modified configuration or expanded memory configuration (Page 135)

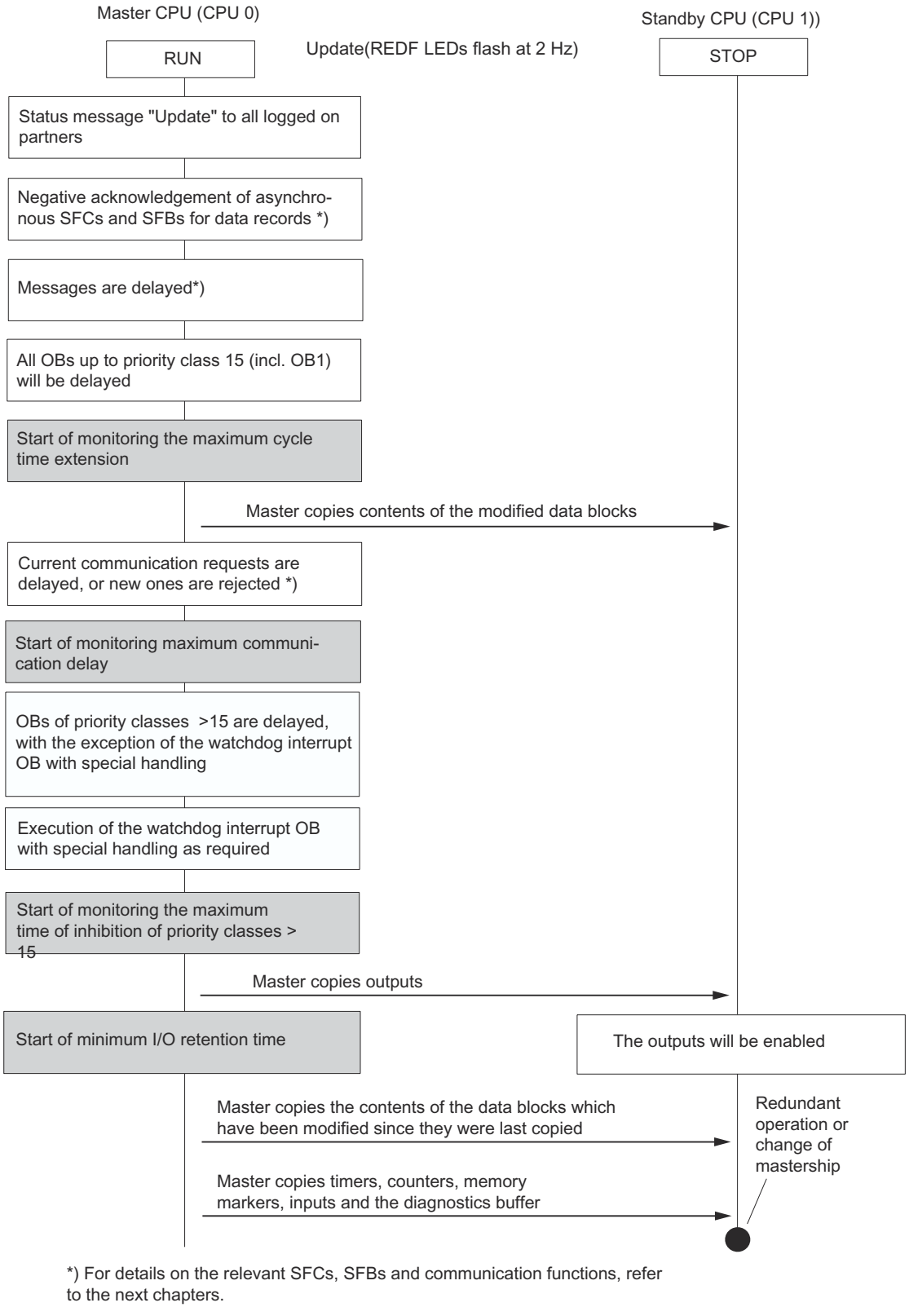


Figure 12-2 Update sequence

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:

Min. signal duration > 2 x the time required for I/O update (DP and PNIO only)
+ call interval of the priority class
+ program execution time 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).

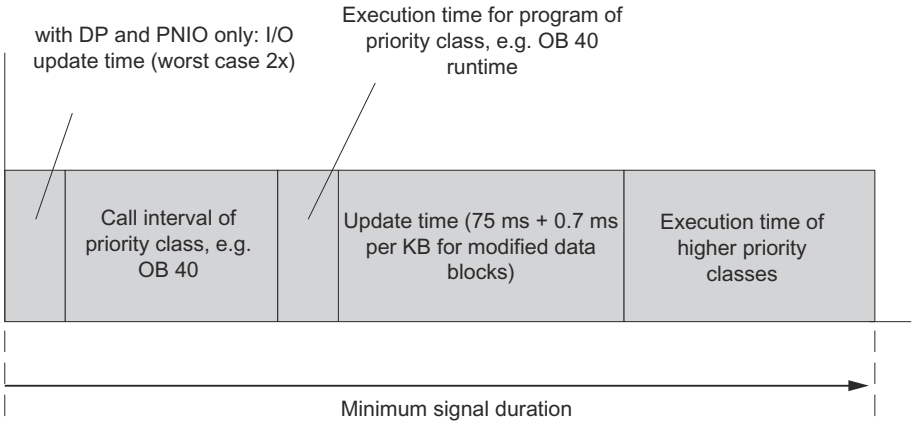


Figure 12-3 Example of minimum signal duration of an input signal during the update

12.3.1 Link-up sequence

For the link-up sequence, you need to decide whether to carry out a master/reserve changeover, or whether redundant system mode is to be achieved after that.

Link-up with the objective of setting up system redundancy

To exclude differences in the two subsystems, the master and the reserve 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 load memory (FLASH card) content
4. Consistency of load memory (integrated RAM and RAM card) content

If 1., 2., or 3. are inconsistent, the reserve CPU changes to STOP mode and outputs an error message.

If 4. is inconsistent, the master CPU copies the user program from its load memory in RAM to the reserve CPU.

The user program stored in load memory on the FLASH card is not transferred.
It must be identical before initiating link-up.

Link-up with master/reserve 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 reserve CPU:

- The hardware configuration
- The type of load memory (for example, you have replaced a RAM card with a FLASH card). The new load memory may be larger or smaller than the old one.

The master does not transfer any blocks to the reserve during the link-up. For detailed information, refer to section Switch to CPU with modified configuration or expanded memory configuration (Page 135).

For information on the required steps based on the scenarios described above (alteration of the hardware configuration, or of the type of load memory), refer to section Failure and replacement of components during operation (Page 235).

Note

Even though you have not modified the hardware configuration or the type of load memory on the reserve CPU, there is nevertheless a master/reserve changeover and the previous master CPU changes to STOP.

Switchover to CPU with expanded memory configuration

You may have expanded the load memory on the reserve CPU. The memory media for storing load memory must be identical, i.e. either RAM cards or FLASH cards. The contents of FLASH cards must be identical.

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. Exception: If the load memory modules are FLASH cards, the system only transfers the blocks from work memory.

For information on changing the type of memory or on load memory expansions, refer to section Changing the CPU memory configuration (Page 292).

Note

Assuming you have implemented a different type of load memory or operating system on the reserve CPU, this CPU does not go into RUN, but rather returns to STOP and writes a corresponding message to the diagnostic buffer.
Assuming you have not expanded load memory on the reserve CPU, this CPU does not go into RUN, but rather returns to STOP and writes a corresponding message to the diagnostic buffer. The system does not perform a master/reserve changeover, and the previous master CPU remains in RUN.

12.3.2 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 135).

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.

12.3.3 Switch to CPU with modified configuration or expanded memory configuration

Switch to CPU with modified configuration

You may have modified the following elements on the reserve CPU:

- The hardware configuration
- The type of load memory. You may have replaced a RAM card with a FLASH card, for example. The new load memory may be larger or smaller than the old one.

For information on steps required in the scenarios mentioned above, refer to section Failure and replacement of components during operation (Page 235).

Note

Even though you have not modified the hardware configuration or the type of load memory on the reserve CPU, there is nevertheless a master/reserve changeover and the previous master CPU changes to STOP.

Note

If you have downloaded connections using NETPRO, you can no longer change the memory type of the load memory from RAM to FLASH.

When you initiate a link-up and update operation with the "Switch to CPU with modified configuration" option in STEP 7, 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 reserve CPU.

Work memory

The following components are transferred from the work memory of the master CPU to the reserve 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 reserve CPU by means of SFC are deleted.
  If a data block with the same number is also found in the load memory of the reserve CPU, link-up is cancelled with an entry in the diagnostic buffer.
- Process images, timers, counters, and bit memories

If there is insufficient memory, link-up is cancelled with an entry in the diagnostic 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.

Switchover to CPU with expanded memory configuration

You may have expanded the load memory on the reserve CPU. The memory media for storing load memory must be identical, i.e. either RAM cards or FLASH cards. The contents of FLASH cards must be identical.

Note

Assuming you have implemented a different type of load memory or operating system on the reserve CPU, this CPU does not go into RUN, but rather returns to STOP and writes a corresponding message to the diagnostic buffer.
Assuming you have not expanded load memory on the reserve CPU, this CPU does not go into RUN, but rather returns to STOP and writes a corresponding message to the diagnostic buffer. The system does not perform a master/reserve changeover, and the previous master CPU remains in RUN.

For information on changing the type of memory or on load memory expansions, refer to section Failure and replacement of components during operation (Page 235).

When you initiate a link-up and update with the "Switchover to CPU with expanded memory configuration" option in STEP 7, the system reacts as follows with respect to the handling of memory contents.

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. Exception: If the load memory modules are FLASH cards, the system only transfers the blocks from work memory.

12.3.4 Disabling of link-up and update

Link-up and update entails a cycle time extension. This includes a period during which the I/O is not updated; see section Time monitoring (Page 137). Make allowances for this feature in particular when using distributed I/Os and on master/reserve changeover after updating (that is, when modifying the configuration 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 the *System Software for S7-300/400, System and Standard Functions* manual.

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 the *S7-400F and S7-400FH Automation Systems* manual.

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.

12.4 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.

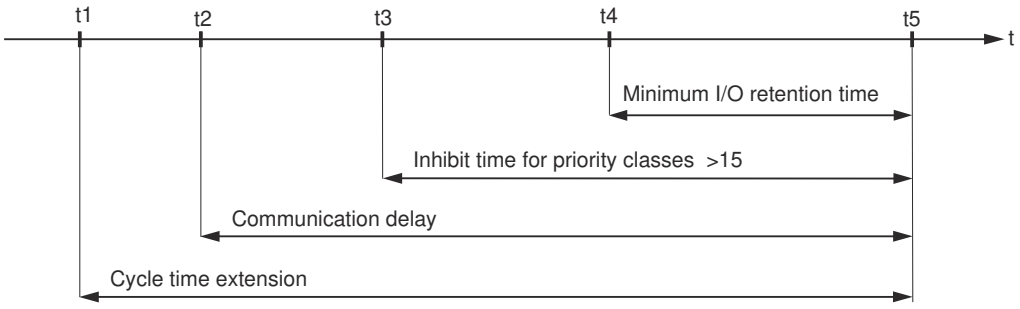
The monitoring times are described in detail below.

- 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 transition to the redundant system mode or 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.

Update:



t1: End of current OBs up to priority class 15
t2: Stop all communication functions
t3: End of watchdog interrupt OB with special handling
t4: End of copying of outputs to the standby CPU
t5: Redundant system status, or master/standby changeover

Figure 12-4 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.
Then, but 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.

12.4.1 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

The following applies to no-load operation of the automation system:

Link-up runtime = size of load memory and work memory in MB × 1 s + base load

The base load is a few seconds.

Whenever your automation system is subject to high load, the memory-specific share may increase up to 1 minute per MB.

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 determined by 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.

12.4.2 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 disabling 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 disabling 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 primary/reserve 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 primary systems of the H-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/Os, 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 relationship between the minimum I/O retention time and the maximum disabling time for priority classes > 15.

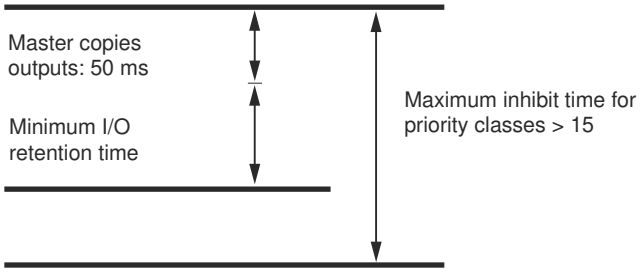


Figure 12-5 Relationship between the minimum I/O retention time and the maximum disabling time for priority classes > 15

Note the following condition:

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

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

Calculation of the maximum disabling time for priority classes > 15 (T_{P15})

The maximum disabling 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. **Number and structure of the data blocks** that you write in the high-priority priority classes determine the duration of this operation and thus the maximum disabling time for priority classes > 15. You receive a notice when using the remedies specified below.
- In the last phase of the update, all OBs are delayed or disabled. To prevent the maximum disabling time for priority classes > 15 from being extended unnecessarily due to unfavorable programming, you should process the most time-critical I/O components in a **selected cyclic interrupt**. This is particularly relevant in fail-safe user programs. You define this cyclic interrupt in your configuration. It is then executed again right after the start of the maximum disabling time for priority classes > 15, provided you have assigned it a priority class > 15.

- In the case of link-up and update with primary/reserve changeover (see section Link-up sequence (Page 130)), after conclusion of the update, the active communication channel of the switched DP secondaries and the switched IO devices must be changed over. 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 the *S7-400F and S7-400FH Automation Systems* and *S7-300 Automation Systems, Fail-safe Signal Modules* manuals. This applies in particular to the internal execution times of fail-safe modules.

1. From the bus parameters in STEP 7, determine the following for each DP primary system:
   - T_{TR} for the DP primary system
   - DP changeover time (referred to below as T_{DP_UM})
2. From the configuration in STEP 7, determine the following for each IO subsystem:
   - Maximum update time of the IO subsystem (referred to below as T_{max_Akt})
   - PN switchover time (referred to below as T_{PN_UM})
3. From the technical specifications for the switched DP secondaries, determine the following for each DP primary system:
   - Maximum changeover time for the active communication channel (referred to below as $T_{Secondary_UM}$).
4. From the technical specifications for the switched PN devices, determine the following for each IO subsystem:
   - Maximum changeover time for the active communication channel (referred to below as T_{Device_UM}).
5. From the technological requirements of your system, determine the following:
   - Maximum permissible time during which there is no update to your I/O modules (referred to below as T_{PTO}).
6. From your user program, determine the following:
   - The cycle time of the highest-priority or selected (see above) cyclic interrupt (T_{WA})
   - The execution time of your program in this cyclic interrupt (T_{PROG})
7. For each DP primary system, this results in:
   T_{P15} (DP primary system) = T_{PTO} - (2 x T_{TR} + T_{WA} + T_{PROG} + T_{DP_UM} + $T_{Secondary_UM}$) [1]
8. 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

For T_{P15}(DP primary system) < 0 or T_{P15}(IO subsystem) < 0, the calculation must be stopped here. Possible remedies are given after the following example calculation. Make appropriate changes and then restart the calculation at 1.

9. Select the minimum of the T_{P15} values (DP primary system, IO subsystem).
   This time is referred to below as TP15_HW.
10. Determine the proportion of the maximum disabling time for priority classes > 15 that is due to the minimum I/O retention time (T_{P15_OD}):
    T_{P15_OD} = 50 ms + min. I/O retention time [2]

    Note

    For $T_{P15_OD} > T_{P15_HW}$, the calculation must be stopped here. Possible remedies are given after the following example calculation. Make appropriate changes and then restart the calculation at 1.

11. Using information from section Performance values for link-up and update (Page 147), calculate the proportion of the maximum disabling time for priority classes > 15 that is due to the user program (T_{P15_AWP}).

    Note

    For $T_{P15_AWP} > T_{P15_HW}$, the calculation must be stopped here. Possible remedies are given after the following example calculation. Make appropriate changes and then restart the calculation at 1.

12. The recommended value for the maximum disabling 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 following, the maximum permitted time during the update in which the operating system does not process the program or update the I/O is determined for a given system configuration.

Assume two DP primary systems and one IO subsystem are present: DP primary system_1 is connected via the MPI/DP interface of the CPU, and DP primary system_2 is connected via an external DP primary interface module. 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 specifications of the DP secondary used:
   $T_{Secondary_UM_1}$ = 30 ms
   $T_{Secondary_UM_2}$ = 50 ms
4. Based on the technical specifications of the PN devices used:
   T_{Device_UM} = 20 ms

5. Based on the technological requirements 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 primary system_1)
   = 1250 ms - (2 x 25 ms + 300 ms + 50 ms + 100 ms + 30 ms) = 720 ms
   T_{P15} (DP primary 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]:

$T_{P15_OD} = 50 \text{ ms} + T_{PH} = 50 \text{ ms} + 90 \text{ ms} = 140 \text{ ms}$

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

1. Based on section Performance values for link-up and update (Page 147) with 170 KB of user program data:
   T_{P15_AWP} = 194 ms

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

1. Using formula [3], the recommended max. disabling time for priority classes > 15 is:

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

T_{P15} = 194 ms

Thus, if you enter 194 ms for the maximum disabling time for priority classes > 15 in STEP 7, it is guaranteed that a signal change during the update with a signal duration of 1250 ms or 1200 ms is always detected.

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

If the calculation of the maximum disabling time for priority classes > 15 does not yield a recommendation, 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 secondaries among several DP primary systems.
- If possible, reduce the maximum update time of switched devices on the IO subsystem.
- Increase the baud rate on the DP primary systems involved.
- Configure DP/PA links and Y links in separate DP primary systems.

- If you have DP secondaries with significantly different switchover times, typically resulting in significantly different T_{PTO} values, distribute these secondaries among several DP primary systems.
- If only minor loads due to interrupts or parameter settings are expected in the individual DP primary systems, you can also reduce the calculated T_{TR} times by approximately 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.

12.4.3 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 12-3 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 141)).
- 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}.

12.4.4 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
- Configuration of the distributed I/O with PROFIBUS DP (As the baud rate is decreased and the number of secondaries is increased, the time required for the I/O update increases.)
- Configuration of the distributed I/O with PROFINET IO (As the update time and the number of devices is increased, the time required for the I/O update increases.)

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

Explicit delay of the update

Delay the update using SFC 90 "H_CTRL", and re-enable it only when the system state shows less communication or interrupt load.

⚠ CAUTION
Delay of update
The update delay increases the time of standalone mode operation of the fault-tolerant system.

12.5 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/reserve changeover are completed, the system is in single mode.
- The update was canceled (e.g. due to timeout), and the system has returned to single mode.

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 reserve CPU, the reserve CPU requests a memory reset. This indicated in the diagnostic buffer by event ID W#16#6523.

Using I/Os in S7–400H

13

This section provides an overview of the different I/O installations in the S7-400H automation system and their availability. It also provides information on configuration and programming of the selected I/O installation.

13.1 Introduction

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 installations:

Configuration	Availability
Single-channel one-sided	normal
Single-channel switched	enhanced
System redundant	enhanced
Dual-channel redundant	high

A dual-channel redundant configuration at user level is also possible. You nevertheless need to implement the high availability in the user program (see chapter Other options for connecting redundant I/Os (Page 184)).

Addressing

No matter whether you are using a single-channel one-sided or switched I/O, you always access the I/O via the same address.

Limits of I/O configuration

If there are insufficient slots in the central racks, you can add up to 20 expansion units to the S7-400H configuration.

Module racks with even numbers are always assigned to central rack 0, and racks with odd numbers are always assigned to central rack 1.

For use of distributed I/O, you can connect up to 12 DP primary systems in each of the two subsystems (2 DP primary systems to the integrated interfaces of the CPU and 10 others via external DP primary systems).

You can operate up to 32 secondaries at the integrated MPI/DP interface. You can connect up to 125 distributed I/O devices to the integrated DP primary interface and to the external DP primary systems.

You can connect up to 256 IO devices to both integrated PROFINET interfaces.

Note

PROFIBUS and PROFINET together

You can use both PROFINET IO devices and PROFIBUS DP stations on an H-CPU.

Distributed I/O over PNIO

You can also operate distributed I/O on the integrated PROFINET interface. Refer to chapter System redundancy (Page 93)

Note

Fail-safe signal modules

If you want to operate fail-safe modules redundantly at the PNIO interface, you require the optional package S7 F Systems as of V6.1 SP1.

13.2 Using single-channel, one-sided I/Os

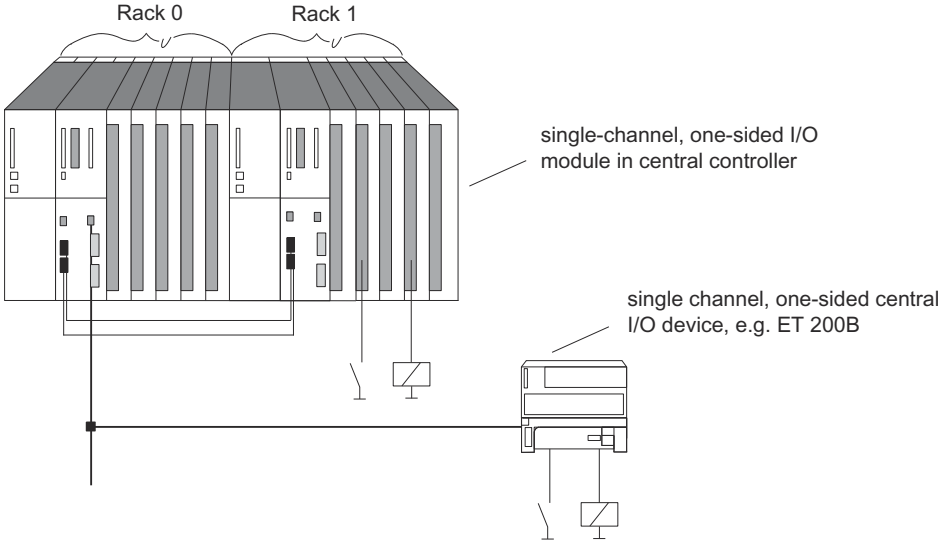
What is single-channel one-sided I/O?

In the single-channel one-sided configuration, the input/output modules exist only once (single-channel). The I/O modules are located in only one subsystem, and are only addressed by this subsystem.

A single-channel one-sided I/O configuration is possible in the following devices:

- Central and expansion devices
- Distributed I/O devices at the PROFIBUS DP interface
- Distributed I/O devices at the PROFINET interface

A configuration with single-channel one-sided I/O is useful for single I/O channels up to system components which only require standard availability.



Single-channel one-sided I/O configuration

Single-channel one-sided I/O and user program

In redundant system mode, the data read from one-sided components (such as digital inputs) is transferred automatically to the second subsystem.

When the transfer is completed, the data read from the single-channel one-sided I/O is available on both subsystems and can be evaluated in their identical user programs. For data processing in the redundant system mode, it is therefore irrelevant whether the I/O is connected to the master or to the standby CPU.

In standalone mode, access to one-sided I/O assigned to the partner subsystem is not possible. This must be considered as follows when programming: Assign functions to the single-channel one-sided I/O that can only be executed conditionally. This ensures that specific I/O access functions are only called in redundant system mode and when the relevant subsystem is in standalone mode.

Note

The user program also has to update the process image for single-channel, one-sided output modules when the system is in standalone mode (direct access, for example). 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 on the single-channel one-sided output modules of the standby CPU when the system changes to redundant mode.

Failure of the single-channel one-sided I/O

The fault-tolerant system with single-channel one-sided I/O responds to errors just like a standard S7-400 system.

- The I/O is no longer available after it fails.
- If the subsystem to which the I/O is connected fails, the entire process I/O of this subsystem is no longer available.

13.3 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 mode, these can addressed by both subsystems.

In solo mode, the primary subsystem always addresses **all switched I/O** (in contrast to one-sided I/O).

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

The configuration with single-channel switched I/O is possible with the ET 200M distributed I/O device with active backplane bus and redundant PROFIBUS DP secondary interface module.

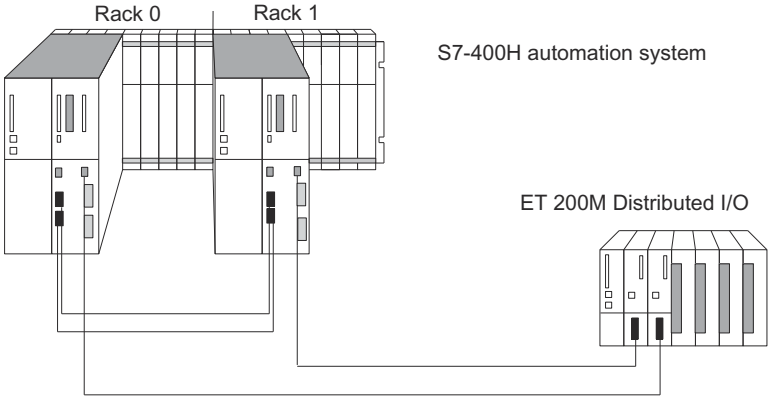


Figure 13-1 Single-channel switched distributed I/O configuration at the PROFIBUS DP interface

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

Table 13-1 Interface modules for use of single-channel switched I/O at the PROFIBUS DP interface

Interface module	Order number
IM 153–2	6ES7 153–2BA81–0XB0 6ES7 153–2BA02–0XB0 6ES7 153–2BA01–0XB0 6ES7 153–2BA00–0XB0
IM 153–2FO	6ES7 153–2AB02–0XB0 6ES7 153–2AB01–0XB0 6ES7 153–2AB00–0XB0 6ES7 153–2AA02–0XB0

Each S7-400H subsystem is connected (via a DP primary interface) to one of the two DP secondary interfaces of the ET 200M.

PROFIBUS PA can be connected to a redundant system via a DP/PA link.

You can use the following DP/PA links:

DP/PA link	Order number
IM 157	6ES7 157–0BA82–0XA0 6ES7 157–0AA82–0XA0 6ES7 157–0AA81–0XA0 6ES7 157–0AA80–0XA0
ET 200M as DP/PA link with	6ES7 153–2BA02–0XB0 6ES7 153–2BA01–0XB0 6ES7 153–2BA81–0XB0

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

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

Rule

If you use single-channel switched I/O, the configuration must always be symmetrical, that is:

- The H-CPU and other DP primaries must be in the same slots in both subsystems (e.g. in slot 4 in both subsystems), or
- The DP primaries must be connected to the same integrated interface in both subsystems (e.g. to the PROFIBUS DP interfaces of both H-CPUs).

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

The configuration with single-channel switched I/O is possible with the ET 200M distributed I/O device with active backplane bus and redundant PROFINET interface module.

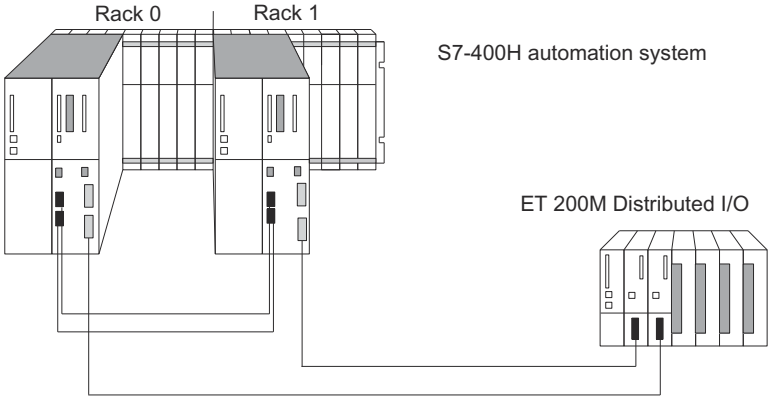


Figure 13-2 Single-channel switched distributed I/O configuration at the PROFINET interface

Each S7-400H subsystem is connected (via a PROFINET interface) to the PROFINET interface of the ET 200M using one connection each. Refer to chapter System redundancy (Page 93).

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

Table 13-2 Interface module for use of single-channel switched I/O at the PROFINET interface

Interface module	Order number
IM 153-4 PN	6ES7153-4BA00-0XB0

Single-channel switched I/O and user program

In redundant mode, 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 interfaces or PROFINET interface at any given time. The active DP interface is indicated by the ACT LED on the corresponding IM 153–2 or IM 157.

The path via the currently active DP interface or PROFINET 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 I/O is no longer available after it fails.
- In certain failure situations (e.g. failure of a subsystem, a DP primary system or a DP secondary interface module IM 153-2 or IM 157, see section Communication (Page 189)), the single-channel switched I/O continues to be available for the process.
  This is achieved by a changeover between the active and passive channel. This switchover takes place separately for each DP or PNIO station. A distinction is made between the following two types of failure:
  - Failures that affect only one station (e.g. failure of the DP secondary interface module of the currently active channel)
  - Failures affecting all stations of a DP primary system or PNIO system
    These include unplugging of the connector at the DP primary interface module or PNIO interface, shutdown of the DP primary system (e.g. RUN-STOP transition on a CP 443-5) and a short-circuit on the cable harness of a DP primary system or PNIO system.

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

Once the problem is eliminated, redundant mode 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 external DP primary interface module can detect the failure of the entire DP primary system (e.g. due to a short-circuit), only this event is reported ("Primary system failure incoming" 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 secondary interface module

You can determine the first two values from the bus parameters of your DP primary system in STEP 7. You determine the last value from the manuals of the relevant DP secondary interface modules (*ET 200M distributed I/O device* 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 failure of the fail-safe modules during the changeover of the active channel.

Note

The above calculation also includes the processing time in OB 70 or OB 86. Make sure that the processing time for a DP or PNIO station is **no longer than 1 ms**. In situations requiring extensive processing, exclude this processing from direct execution of the OBs mentioned.

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 primary 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 links and Y links to a separate DP primary system.

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, you risk failure of the fail-safe modules during the changeover of the active channel.

Changeover of the active channel during link-up and updating

In the case of link-up and update with master/standby changeover (see section Link-up sequence (Page 130)), a changeover between the active and passive channel 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 failures of a DP or PNIO station that occur during the changeover can be detected, the changeover is monitored by the individual DP stations and by the DP primary system.

Provided the minimum I/O retention time is set correctly (see chapter Time monitoring (Page 137)), no interrupts or data records will be lost due to a changeover. There is an automatic repetition when necessary.

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.

13.4 Connecting redundant I/O to the PROFIBUS DP interface

What is 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.

Note

PROFINET

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

Configurations

The following redundant I/O configurations are supported:

1. Redundant signal modules in the central and expansion devices
   For this purpose, the signal modules are installed in pairs in the CPU 0 and CPU 1 subsystems.
   Redundant I/O in central and expansion devices

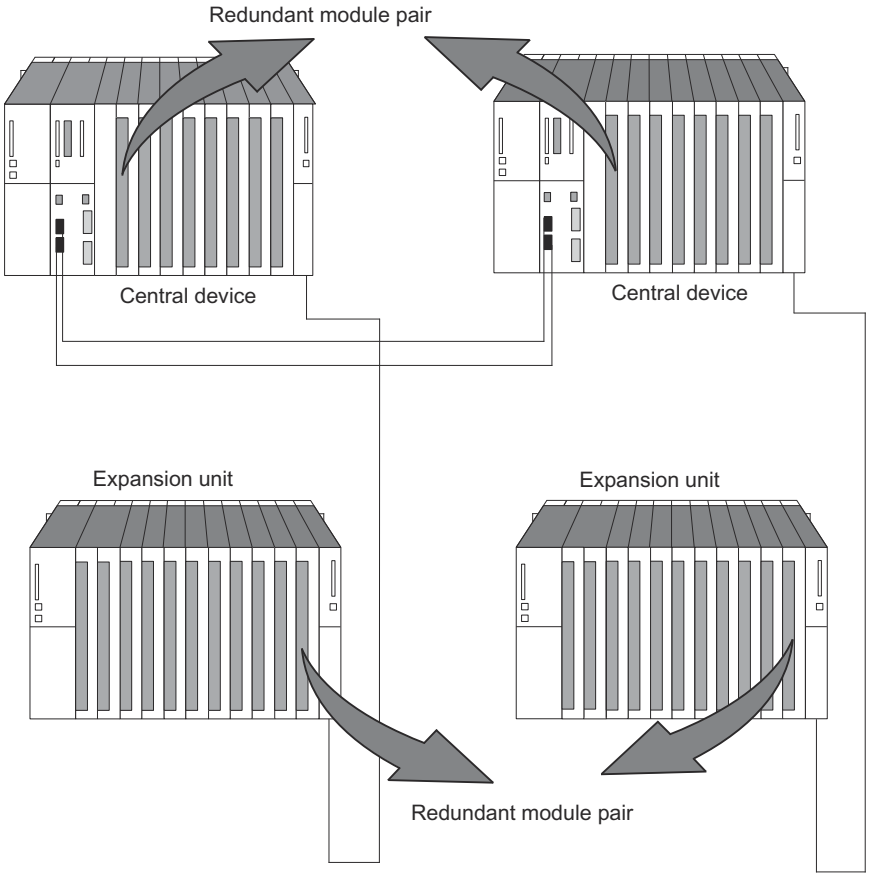


Figure 13-3 Redundant I/O in central and expansion devices

2. Redundant I/O in the one-sided DP secondary
   To achieve this, the signal modules are installed in pairs in ET 200M distributed I/O devices with active backplane bus.

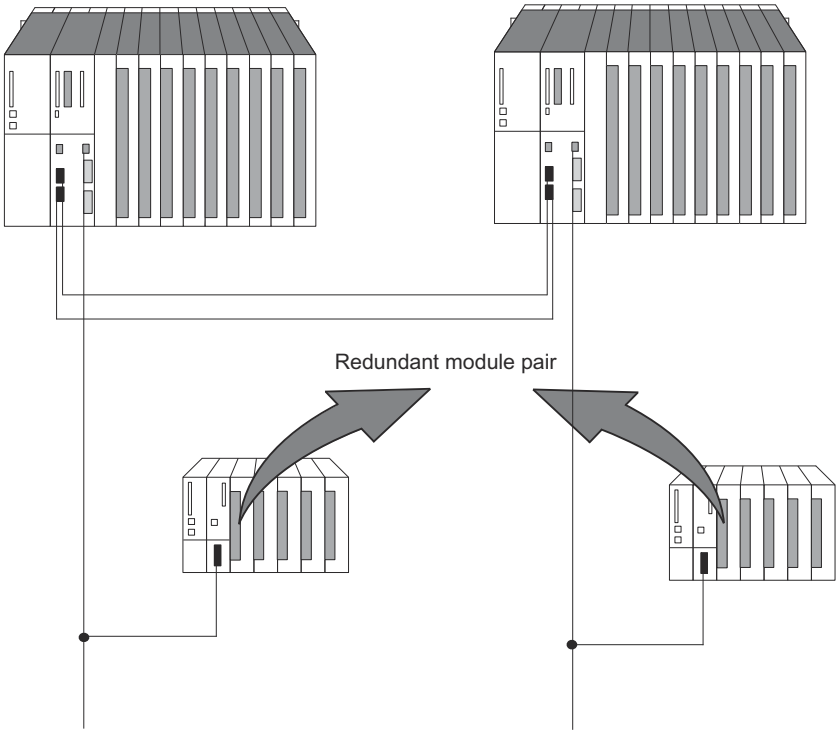


Figure 13-4 Redundant I/O in the one-sided DP secondary

3. Redundant I/O in the switched DP secondary
   To achieve this, the signal modules are installed in pairs in ET 200M distributed I/O devices with active backplane bus.

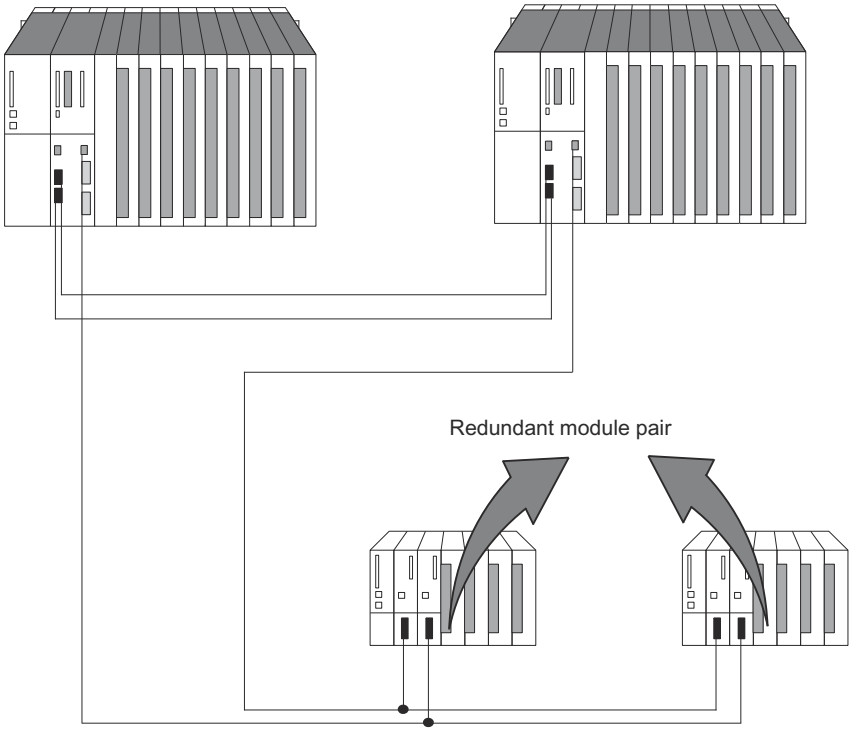


Figure 13-5 Redundant I/O in the switched DP secondary

4. Redundant I/O connected to a fault-tolerant CPU in standalone mode

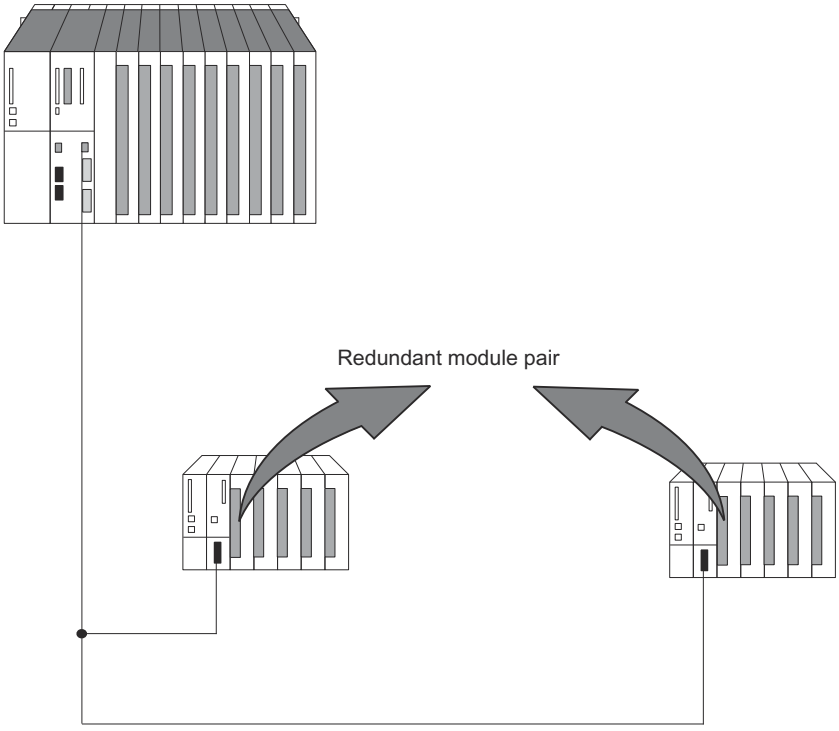


Figure 13-6 Redundant I/O in stand-alone mode

Principle of channel group-specific redundancy

Channel errors due to discrepancy cause the passivation of the respective channel. Channel errors due to diagnostic interrupts (OB82) cause the passivation of the channel group affected. Depassivation depassivates all affected channels as well as the modules passivated due to module errors. Channel group-specific passivation significantly increases availability in the following situations:

- Relatively frequent encoder failures
- Repairs that take a long time
- Multiple channel errors on one module

Note

Channel and channel group

Depending on the module, a channel group contains a single channel, a group of several channels, or all channels of the module. You can therefore operate all modules with redundancy capability in channel group-specific redundancy mode.

You can find an up-to-date list of modules that can be used redundantly in section Signal modules for redundancy (Page 166).

Principle of module-specific redundancy

Redundancy always applies to the entire module, rather than to individual channels. When a channel error occurs in the first redundant module, the entire module and all of its channels are passivated. If an error occurs on another channel on the second module before the first error has been eliminated and the first module has been depassivated, this second error cannot be handled by the system.

You can find an up-to-date list of modules that can be used redundantly in section Signal modules for redundancy (Page 166).

"Functional I/O redundancy" block libraries

The blocks you use for channel group-specific redundancy are located in the "Redundant IO CGP V50" library. The blocks in the library "Redundant IO CGP V40" can also be set for channel group-specific redundancy but only for a limited range of modules.

The blocks you use for module-specific redundancy are located in the "Redundant IO MGP V30" library. Module-specific redundancy is a special form of redundant module operation; see above.

Note

Operating redundant modules

When you are operating signal modules for the first time, use channel group-specific redundancy with the blocks in the "Redundant IO CGP V50" library. This ensures maximum flexibility when using redundant modules.

The "Functional I/O redundancy" block libraries that support the redundant I/O each contain the following blocks:

- FC 450 "RED_INIT": Initialization function
- FC 451 "RED_DEPA": Initiate depassivation
- FB 450 "RED_IN": Function block for reading redundant inputs
- FB 451 "RED_OUT": Function block for controlling redundant outputs
- FB 452 "RED_DIAG": Function block for diagnostics of redundant I/O
- FB 453 "RED_STATUS": Function block for redundancy status information

Configure the numbers of the management data blocks for the redundant I/O in HW Config "Properties CPU -> H Parameter". Assign free DB numbers to these data blocks. The data blocks are created by FC 450 "RED_INIT" during CPU startup. The default setting for the numbers of management data blocks is 1 and 2. These data blocks are not the instance data blocks of FB 450 "RED_IN" or FB 451 "RED_OUT".

You can open the libraries in the SIMATIC Manager with "File -> Open -> Libraries"

The functions and use of the blocks are described in the corresponding online help.

Note

Blocks from different libraries

Always use blocks from a single library. Simultaneous use of blocks from different libraries is not permitted.

If you wish to replace one of the earlier libraries Redundant IO (V1) or Redundant IO CGP with the Redundant IO CGP V5.0, you must first of all edit your user program accordingly. Refer to the context-sensitive block help or the STEP 7 Readme for more information.

Switching to channel group-specific redundancy

To activate channel group-specific passivation, you have to stop the automation system (memory reset and reload user program in STOP).

Observe the following:

Mixing blocks from various libraries in one CPU is not permitted and can lead to unpredictable behavior.

When converting a project, make sure that all library blocks named FB450–453 and FC450–451 have been deleted from the block folder and replaced by the blocks from Red-IO CGP V5.0. Perform this step in every relevant program. Compile and load your project.

Using the blocks

Before you use the blocks, parameterize the redundant modules as redundant in HW Config.

The OBs into which you need to link the various blocks are listed in the table below:

Block	OB
FC 450 "RED_INIT"	• OB 72 "CPU redundancy error" (only with fault-tolerant systems) FC 450 is only executed after the start event B#16#33:"Standby-master changeover by operator" • OB 80 "Timeout error" (only in standalone mode) FC 450 is only executed after the start event "Resume RUN after reconfiguring" • OB 100 "Restart" (the administration DBs are recreated, see the online help) • OB 102 "Cold restart"
FC 451 "RED_DEPA"	• OB 83 "insert/remove module interrupt" or OB 85"Program execution error" If you call FC 451 in OB 83 while inserting modules, or in OB 85 by means of outgoing interrupt, depassivation is delayed by 3 seconds. • OB 1 "Cyclic program" and/or OB 30 to 38 "cyclic interrupt" You must also call FC 451 conditionally in OB1 or OB 30 to 38 after having eliminated the malfunction, for example, with a user acknowledgment. The FC 451 only depassivates modules in the corresponding process image partition. Depassivation is delayed by 10 seconds 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.
FB 450 "RED_IN"	• OB 1 "Cyclic program" • OB 30 to OB 38 "Cyclic interrupt"
FB 451 "RED_OUT"	• OB 1 "Cyclic program" • OB 30 to OB 38 "Cyclic interrupt"
FB 452 "RED_DIAG"	• OB 72 "CPU redundancy error" • OB 82 "Diagnostic interrupt" • OB 83 "Swapping interrupt" • OB 85 "Program execution error"
FB 453 "RED_STATUS"	• OB 1 "Cyclic program" (fault-tolerant systems only) • OB 30 to OB 38 "Cyclic interrupt"

To be able to address redundant modules using process image partitions in cyclic interrupts, the relevant process image partition must be assigned to this pair of modules and to the cyclic interrupt. Call FB 450 "RED_IN" in this cyclic interrupt before you call the user program. Call FB 451 "RED_OUT" in this cyclic interrupt after you call the user program.

The valid values that can be processed by the user program are always located at the lower address of both redundant modules. This means that only the lower address can be used for the application; the values of the higher address are not relevant for the application.

Note

Use of FB 450 "RED_IN" and 451 "RED_OUT" when using process image partitions

For each priority class used (OB 1, OB 30 ... OB 38), you must use a separate process image partition.

Hardware configuration and project engineering of the redundant I/O

Follow the steps below to use redundant I/O:

1. Insert all the modules you want to operate redundantly. Remember the following basic rules for configuration.
2. Configure the module redundancy using HW Config in the object properties of the relevant module.
   Either browse for a partner module for each module, or accept the default settings
   Central configuration: If the module is inserted in slot X in the even-numbered rack, the module is suggested in the same slot in the next odd-numbered rack.
   If the module is inserted in slot X in the odd-numbered rack, the module is suggested in the same slot in the preceding even-numbered rack.
   Distributed in the one-sided DP secondary: If the DP primary system is redundant and the module is inserted in slot X in the secondary, the module is suggested in the same slot X in the secondary of the same PROFIBUS address in the partner DP subsystem.
   Distributed in the switched DP secondary, stand-alone operation: If the module is inserted in slot X in the secondary with a DP address, the module is suggested in slot X in the secondary with the next PROFIBUS address.
3. Enter the remaining redundancy parameters for the input modules.

   Note

   System modifications during operation are also supported with redundant I/O. You are not permitted to change the parameter settings for a redundant module per SFC.

   Note

   Always switch off power to the station or rack before you remove a redundant digital input module that does not support diagnostics functions and is not passivated. You might otherwise passivate the wrong module. This procedure is necessary, for example, when replacing the front connector of a redundant module.

   Redundant modules must be in the process image of the inputs or outputs. Redundant modules are always accessed using the process image.

   When using redundant modules, select the "Cycle/Clock Memory" tab from "HW Config -> Properties CPU 41x-H" and set the following:

   "OB 85 call on I/O area access error > Only incoming and outgoing errors"

13.4.1 Signal modules for redundancy

Signal modules as redundant I/O

The signal modules listed below can be used as redundant I/O. Refer to the latest information on using the modules in the Readme and in the SIMATIC FAQs at Industry Online Support (https://support.industry.siemens.com/cs/ww/en/) under the keyword "Redundant I/O".

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

Table 13-3 Signal modules for redundancy

Library V5.x	Library V4.x	Library V3.x	Module	Order number
Central: Redundant DI dual-channel				
X		X	DI 16xDC 24V interrupt	6ES7 421–7BH0x–0AB0
			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)	
X		X	DI 32xDC 24V	6ES7 421–1BL0x–0AA0
X		X	DI 32xUC 120V	6ES7 421–1EL00–0AA0
Distributed: Redundant DI dual-channel				
X		X	DI16xDC 24 V, interrupt	6ES7 321–7BH00–0AB0
X	X	X	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)	

Library V5.x	Library V4.x	Library V3.x	Module	Order number
X		X	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 F.1.	
X		X	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 F.2.	
X		X	DI 8xAC 120/230V	6ES7 321–1FF01–0AA0
X		X	DI 4xNamur [EEx ib]	6ES7 321–7RD00–0AB0
			You cannot use the module for applications in hazardous areas in redundant mode. 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.	
X		X	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.	
X		X	DI 24xDC 24 V	6ES7326–1BK00–0AB0
			F module in standard mode	
X		X	DI 8xNAMUR [EEx ib]	6ES7326–1RF00–0AB0
			F module in standard mode	
Central: Redundant DO dual-channel				
X		X	DO 32xDC 24V/0.5A	6ES7422–7BL00–0AB0
			A clear evaluation of the diagnostics information "P short-circuit", "M short-circuit" and wire break is not possible. Deselect these individually in your configuration. The minimum I/O retention time remains ineffective in the case of a plant change during operation. As a result, no bumpless switchover of this module is possible, with configured module redundancy, for example. There is always a gap of 3 to 50 ms.	
X		X	DO 16xAC 120/230V/2A	6ES7422–1FH00–0AA0
Distributed: Redundant DO dual-channel				
X		X	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.	

Library V5.x	Library V4.x	Library V3.x	Module	Order number
X		X	DO8xDC 24 V/2 A	6ES7322–1BF01–0AA0
X		X	DO32xDC 24 V/0.5 A	6ES7322–1BL00–0AA0
X		X	DO8xAC 120/230 V/2 A	6ES7322–1FF01–0AA0
X		X	DO 4x24 V/10 mA [EEx ib]	6ES7322–5SD00–0AB0
			You cannot use the module for applications in hazardous areas in redundant mode.	
X		X	DO 4x24 V/10 mA [EEx ib]	6ES7322–5RD00–0AB0
			You cannot use the module for applications in hazardous areas in redundant mode.	
X	X	X	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.	
X	X	X	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).	
X	X	X	DO 10xDC 24 V/2 A, product version 3 or higher	6ES7326–2BF01–0AB0
			F module in standard mode The inputs and outputs must have the same address.	
Central: Redundant AI dual-channel				
X		X	AI 16x16Bit	6ES7431–7QH00–0AB0
			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 50 ohm resistor (measuring range +/- 1 V) or 250 ohm resistor (measuring range 1 to 5 V) to map the current on a voltage, see figure 10-9. The tolerance of the resistor must be added on to the module fault. Use in direct current measurement • Suitable Zener diode: BZX85C6v2 • Load capability of 4-wire transmitters: $R_B > 325$ 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: $U_{e\text{-}2w} < 8$ V (determined for worst case: 1 input + 1 Zener diode at an S7 overload value 24 mA to $U_{e\text{-}2w} = R_E * I_{max} + U_{z\,max}$) **Note:** The circuit shown in figure 10–10 works only with active (4-wire) transmitters or with passive (2-wire) transmitters with external power supply. Always parameterize the module channels for operation as "4-wire transmitter", and set the measuring range cube to position "C". It is not possible to power the transmitters via the module (2DMU).	
Distributed: Redundant AI dual-channel				

Library V5.x	Library V4.x	Library V3.x	Module	Order number
X		X	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 kOhm to 50 kOhm 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 to 5 V) to map the current on a voltage, see figure 10-9. The tolerance of the resistor must be added on to the module fault. • 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)	

Library V5.x	Library V4.x	Library V3.x	Module	Order number
X	X	X	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 10-9. 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 $U_{e\text{-}2w} = R_E * I_{max} + U_{z\,max}$)	
X		X	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 10-9. 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 $U_{e\text{-}2w} = R_E * I_{max} + U_{z\,max}$)	

Library V5.x	Library V4.x	Library V3.x	Module	Order number
X		X	AI 6xTC 16Bit iso, 6ES7331-7PE10-0AB0	6ES7331-7PE10-0AB0
			Notice: You may use this module only 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 parameterized redundancy: The value specified in "Redundancy" under "Tolerance window" is always based on 2764.8 °C. For example, a check is made for a tolerance of 27 degrees when "1" is entered and 138 degrees when "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.	
X		X	AI 4x15Bit [EEx ib]	6ES7331-7RD00-0AB0
			You cannot use the module for applications in hazardous areas in redundant mode. 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 8-10, because this outputs only 13 V, and thus in the worst case it would supply only 5 V to the transmitter.	
X		X	AI 6x13Bit	6ES7 336–1HE00–0AB0
			F module in standard mode	
X	X	X	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 *Distributed I/O Device ET 200M; HART Analog Modules* manual	
Distributed: Redundant AO dual-channel				
X		X	AO4x12 Bit	6ES7332–5HD01–0AB0
X	X	X	AO8x12 Bit	6ES7332–5HF00–0AB0
X		X	AO4x0/4...20 mA [EEx ib]	6ES7332–5RD00–0AB0
			You cannot use the module for applications in hazardous areas in redundant mode.	

Library V5.x	Library V4.x	Library V3.x	Module	Order number
X	X	X	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 find it on the Customer Support site at: Industry Online Support (https://support.industry.siemens.com/cs/ww/en/)

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 occurs, the module/channel in which the signal change occurred is the intact module/channel and the other module/channel is passivated.

Note

The time that the system actually needs to determine a discrepancy depends on various factors: Bus run times, cycle times and call times of the user program, conversion times, etc. For this reason, it is possible for redundant input signals to be different for longer than the configured discrepancy time.

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

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:

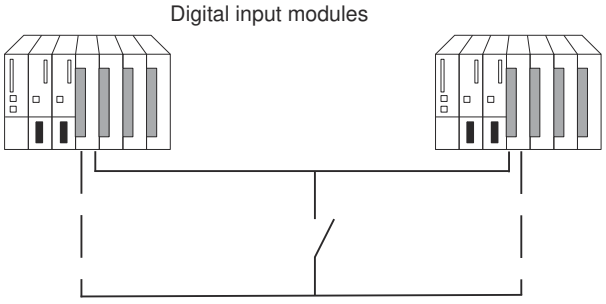


Figure 13-7 Fault-tolerant digital input module in 1-out-of-2 configuration with one encoder

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.

You will find interconnection examples in Appendix Connection examples for redundant I/Os (Page 399).

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:

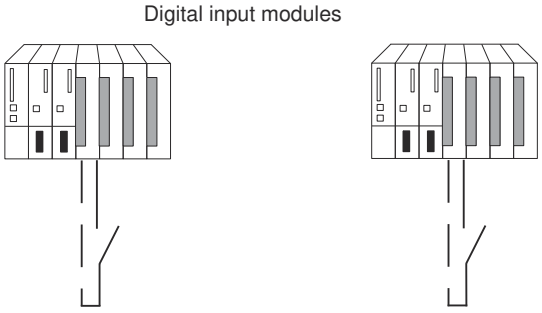


Figure 13-8 Fault-tolerant digital input modules in 1-out-of-2 configuration with two encoders

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 399).

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).

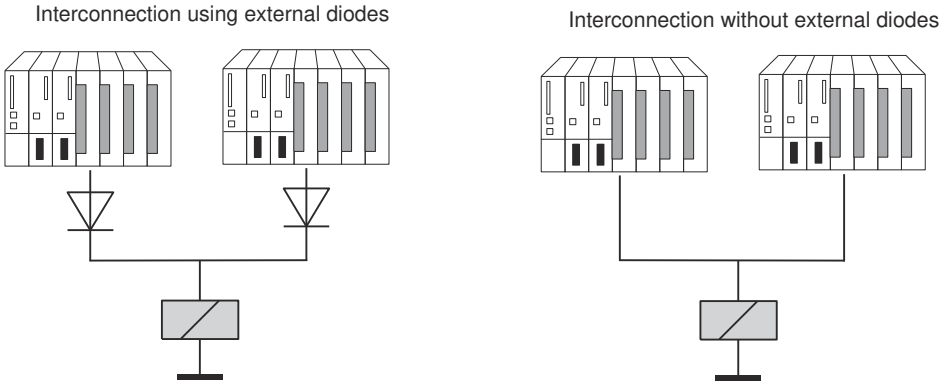


Figure 13-9 Fault-tolerant digital output modules in 1-out-of-2 configuration

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

You will find interconnection examples in Appendix Connection examples for redundant I/Os (Page 399).

Interconnection using external diodes <-> without external diodes

The table below lists the redundant digital output modules which in redundant mode you should interconnect using external diodes:

Table 13-4 Interconnecting digital output modules with/without diodes

Module	with diodes	without diodes
6ES7 422–7BL00–0AB0	X	-
6ES7 422–1FH00–0AA0	-	X
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 with 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.

Using analog input modules as redundant I/O

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

- 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 module/channel with the configured standard value is declared as valid and the other module/channel is passivated. If the maximum value from both modules is parameterized as the standard value, this value is then taken for further program execution and the other module/channel is passivated. If the minimum value is configured, this module/channel supplies the data to the process and the module with the maximum value is passivated. In any case, the passivated modules/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 run times, cycle times and call times of the user program, conversion times, etc. For this reason, it is possible for redundant input signals to be different for longer 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 module/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:

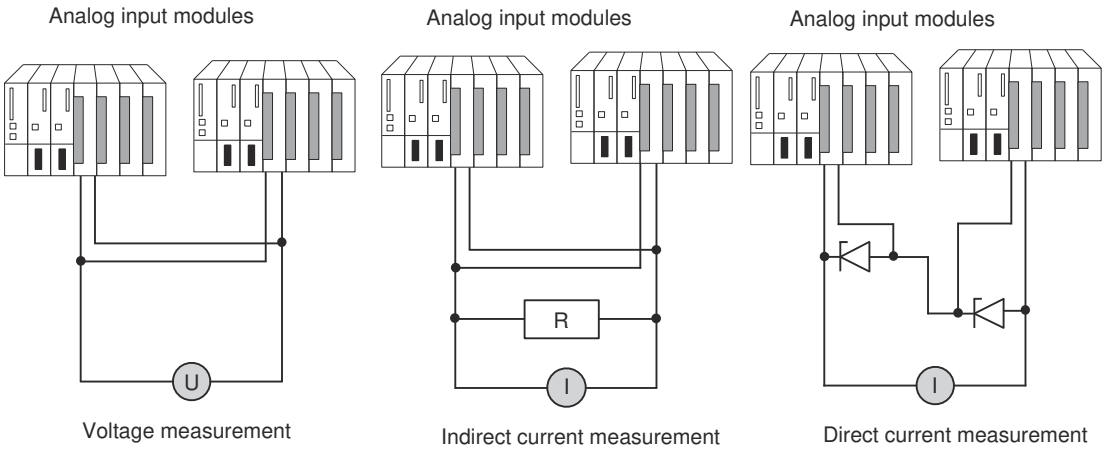


Figure 13-10 Fault-tolerant analog input modules in 1-out-of-2 configuration with one encoder

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.

You will find interconnection examples in Appendix Connection examples for redundant I/Os (Page 399).

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. However, note that the number format, diagnostic capability and resolution may then be lost. 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 parameterized	+/-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 parameterized	+/-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		

AI 16x16bit 6ES7 431–7QH00–0AB0

- 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 configured	+/-1 V	+/-5 V	1...5 V
Measuring range cube position	"A"	"A"	
Resolution	15 bits + sign	15 bits + sign	15 bits
S7 number format	x	x	
Circuit-specific measuring error 1) - 2 parallel inputs - 1 input	- -	- -	
"Wire break" diagnostics	-	-	x
Load for 4-wire transmitters	50 ohms	250 ohms	
Input voltage for 2-wire transmitters	> 1.2 V	> 6 V	

Redundant analog input modules for direct current measurement

Requirements for wiring analog input modules according to Figure 8-10:

- 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:

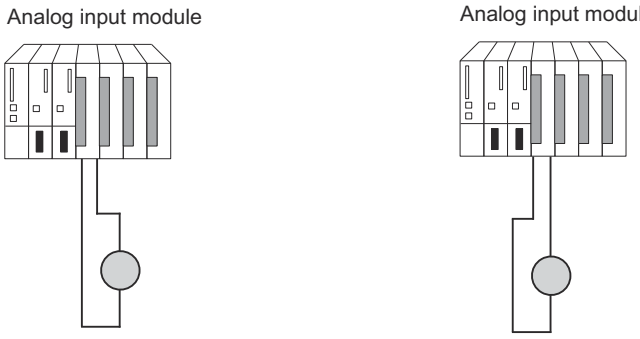


Figure 13-11 Fault-tolerant analog input modules in 1-out-of-2 configuration with two encoders

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 399).

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 operate in redundant mode with redundant or non-redundant encoders:

Table 13-5 Analog input modules and encoders

Module	Redundant encoders	Non-redundant encoders
6ES7 431–7QH00–0AB0	X	X
6ES7 336–1HE00–0AB0	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).

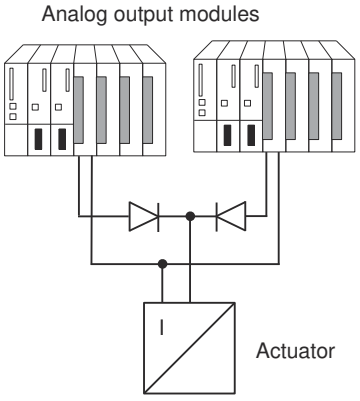


Figure 13-12 Fault-tolerant analog output modules in 1-out-of-2 configuration

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).

Information on connecting with 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.

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 FB 453 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 a parameterizable 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 redundant mode, in the event of a CPU STOP, the response of the current outputs is automatically set to "zero current and zero voltage" in their configuration. 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 parameterized 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" mode
- 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 diagnostic 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.

13.4.2 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.

13.5 Other options for connecting redundant I/Os

Redundant I/O at user level

If you cannot use the redundant I/O supported by your system (section Connecting redundant I/O to the PROFIBUS DP interface (Page 157)), for example because the relevant module may not be listed among the supported components, you can 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.

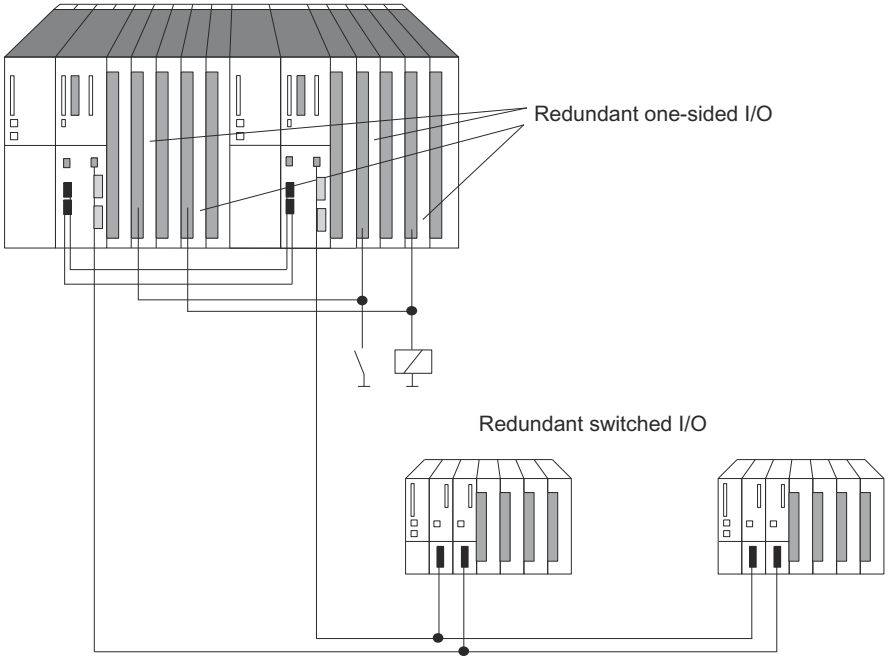


Figure 13-13 Redundant one-sided and switched I/O

Note

When using redundant I/O, you may need to add time to the calculated monitoring times; see section Determining the monitoring times (Page 141)

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 also has to update the process image for redundant one-sided output modules when the system is in single mode (direct access, for example). 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 on the single-channel one-sided output modules of the reserve CPU when the system changes to redundant mode.

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.

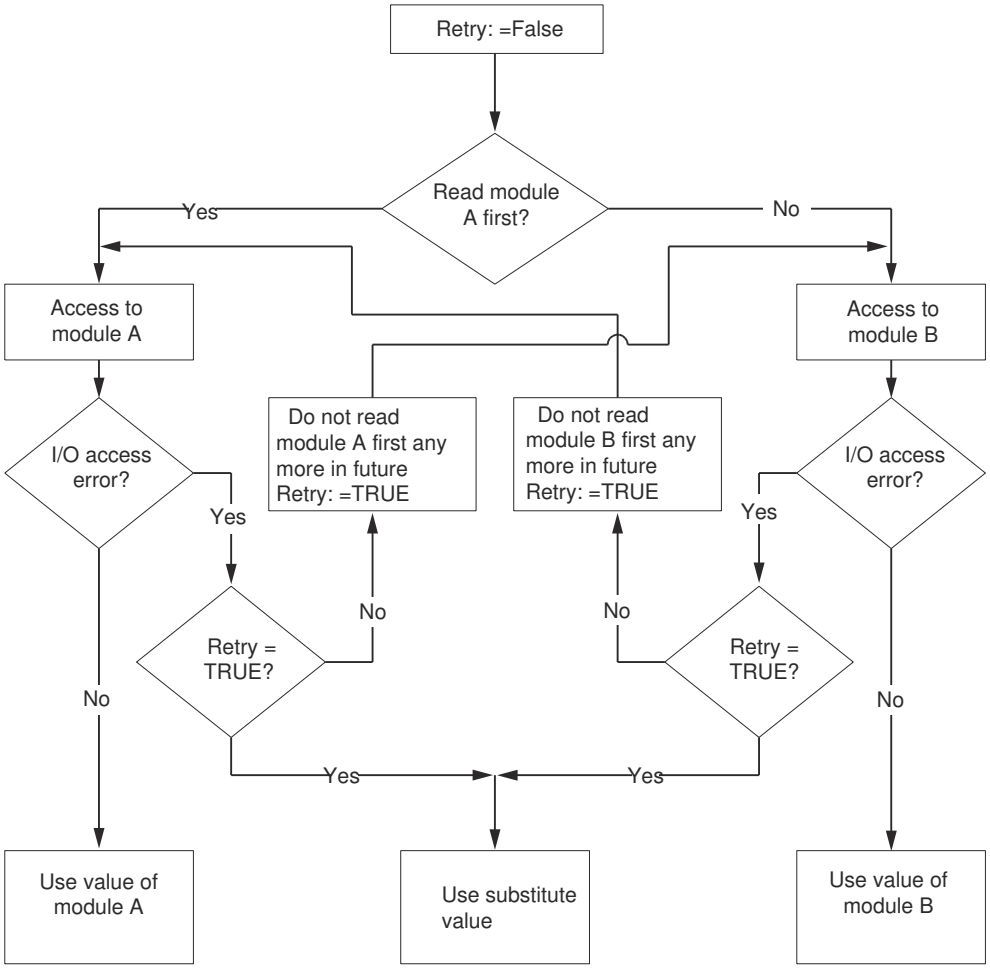


Figure 13-14 Flow chart for OB 1

Example in STL

The required elements of the user program (OB 1, OB 122) are listed below.

Table 13-6 Example of redundant I/O, OB 1 part

STL	Description
NOP 0;	
SET;	
R ATTEMPT2;	//Initialization
A MODA;	//Read module A first?
JCN CMOB;	//If not, continue with module B
CMOA: SET;	
R IOAE_BIT;	//Delete IOAE bit
L PID 8;	//Read from CPU 0
A IOAE_BIT;	//Was IOAE detected in OB 122?

STL	Description
JCN IOOK;	//If not, process access OK
A ATTEMPT2;	//Was this access the second attempt?
JC CMO0;	//If yes, use substitute value
SET;	
R MODA;	//Do not read module A first any more //in future
S ATTEMPT2;	
CMOB: SET;	
R IOAE_BIT;	//Delete IOAE bit
L PID 12;	//Read from CPU 1
A IOAE_BIT;	//Was IOAE detected in OB 122?
JCN IOOK;	//If not, process access OK
A ATTEMPT2;	//Was this access the second attempt?
JC CMO0;	//If yes, use substitute value
SET;	
S MODA;	//Read module A first again in future
S ATTEMPT2;	
JU CMOA;	
CMO0: L SUBS;	//Substitute value
IOOK:	//The value to be used is in ACCU1

Table 13-7 Example of redundant I/O, OB 122 part

STL	Description
	// Does module A cause IOAE?
L OB122_MEM_ADDR;	//Relevant logical base address
L W#16#8;	
== I;	//Module A?
JCN M01;	//If not, continue with M01
	//IOAE during access to module A
SET;	
= IOAE_BIT;	//Set IOAE bit
JU CONT;	
	// Does module B cause an IOAE?
M01: NOP 0;	
L OB122_MEM_ADDR;	//Relevant logical start address
L W#16#C;	
== I;	//Module B?
JCN CONT;	//If not, continue with CONT
	//IOAE during access to module B
SET;	
= IOAE_BIT;	//Set IOAE bit
CONT: NOP 0;	

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 13-8 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
ET200L–SC with analog outputs	≤ 80
ET200S with analog outputs or technology modules	≤ 20

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.

14 Communication

14.1 Communication services

14.1.1 Overview of communication services

Overview

Table 14-1 Communication services of the CPUs

Communication service	Functionality	Allocation of S7 connection resources	via MPI	via DP	via PN/IE
PG communication	Commissioning, testing, diagnostics	Yes	Yes	Yes	Yes
OP communication	Operator control and monitoring	Yes	Yes	Yes	Yes
S7 communication	Data exchange via configured connections	Yes	Yes	Yes	Yes
Routing of PG functions	e.g. testing, diagnostics beyond network boundaries	Yes	Yes	Yes	Yes
PROFIBUS DP	Data exchange between primary and secondary	No	No	Yes	No
PROFINET IO	Data exchange between I/O controllers and I/O devices	No	No	No	Yes
SNMP (Simple Network Management Protocol)	Standard protocol for network diagnostics and parameterization	No	No	No	Yes
Open communication over TCP/IP	Data exchange over Industrial Ethernet with TCP/IP protocol (with loadable FBs)	Yes	No	No	Yes
Open communication over ISO on TCP	Data exchange over Industrial Ethernet with ISO on TCP protocol (with loadable FBs)	Yes	No	No	Yes
Open communication over UDP	Data exchange over Industrial Ethernet with UDP protocol (with loadable FBs)	Yes	No	No	Yes
Data set routing	for example, parameter assignment and diagnostics of field devices on PROFIBUS DP with PDM.	Yes	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 14-2 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
412-5H PN/DP	48	46	1	1
414-5H PN/DP	64	62	1	1
416-5H PN/DP	96	62	1	1
417-5H PN/DP	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. Reliable operation of those communication services at a low baud rate via PROFIBUS DP interface can be ensured in configurations with a Ttr (Target Rotation Time) < 20 s.

14.1.2 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 for MPI, 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.

14.1.3 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 for MPI, 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.

14.1.4 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 S7 communication via integral interfaces (MPI/DP, PROFIBUS-DP, PROFINET) and, if necessary, via additional communication processors (CP443-1 for Industrial Ethernet, CP443-5 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 via SFBs in the user program. These functions are independent of the specific network, allowing you to program S7 communication over PROFINET, Industrial Ethernet, PROFIBUS, or MPI.

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 interface.

Note

Downloading the connection configuration in RUN

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 KB 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 14-3 SFBs for S7 Communication

Block	Block name	Brief description
SFB 8 SFB 9	USEND URCV	Send data to a remote partner SFB with the type "URCV" Receive asynchronous data from a remote partner SFB with the type "USEND"
SFB 12 SFB 13	BSEND BRCV	Send data to a remote partner SFB with the type "BRCV" Receive asynchronous data from a remote partner SFB with the 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 state
SFB 21	RESUME	Carry out a hot restart in a remote station
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.

14.1.5 S7 routing

Properties

You can access your S7 stations beyond subnet boundaries using the PG/PC. You can use this for the following actions:

- Downloading user programs,
- Downloading a hardware configuration
- Performing test and diagnostic functions

Note

If you are using your CPU as an I-secondary, the S7 routing function is only possible with activated DP interface. In STEP 7, activate the check boxes Test, Commissioning, Routing under the Properties of the DP interface. More information can be found in the *Manual of Programming with STEP 7* or directly in the *online help of STEP 7*

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 actually physically connected.
- The CPU must be configured as a primary, or
- If the CPU is configured as a secondary, the check box "Programming, status/modify or other programming device functions" must be selected for DP secondary in the properties of the DP interface in STEP 7.

S7 routing gateways: MPI - DP

The gateways from a subnet to another or to several other subnets are routed in a SIMATIC station that is equipped with interfaces to the respective subnets. In the following figure, CPU 1 (DP primary) is the router between subnet 1 and subnet 2.

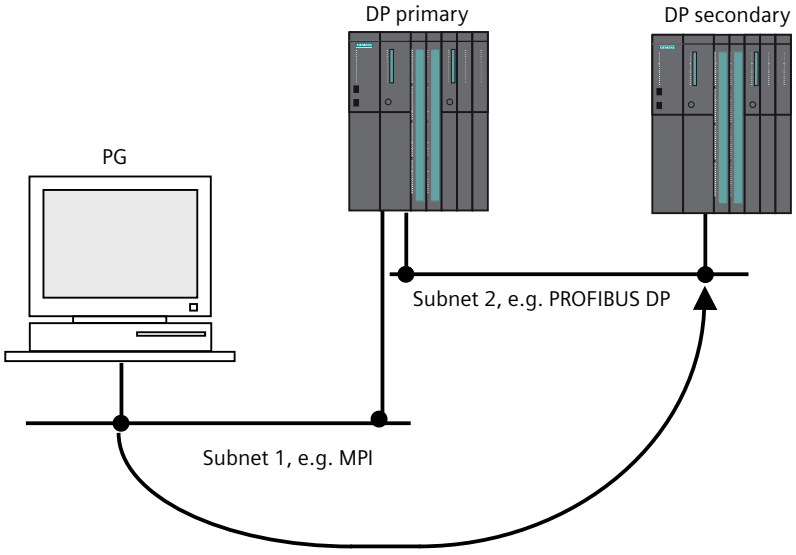


Figure 14-1 S7 routing

S7 routing gateways: MPI-DP-PROFINET

The following figure shows the access from MPI to PROFINET via PROFIBUS. CPU 1, for example, a CPU 416-3, is the router between subnet 1 and subnet 2; CPU 2 is the router between subnet 2 and subnet 3.

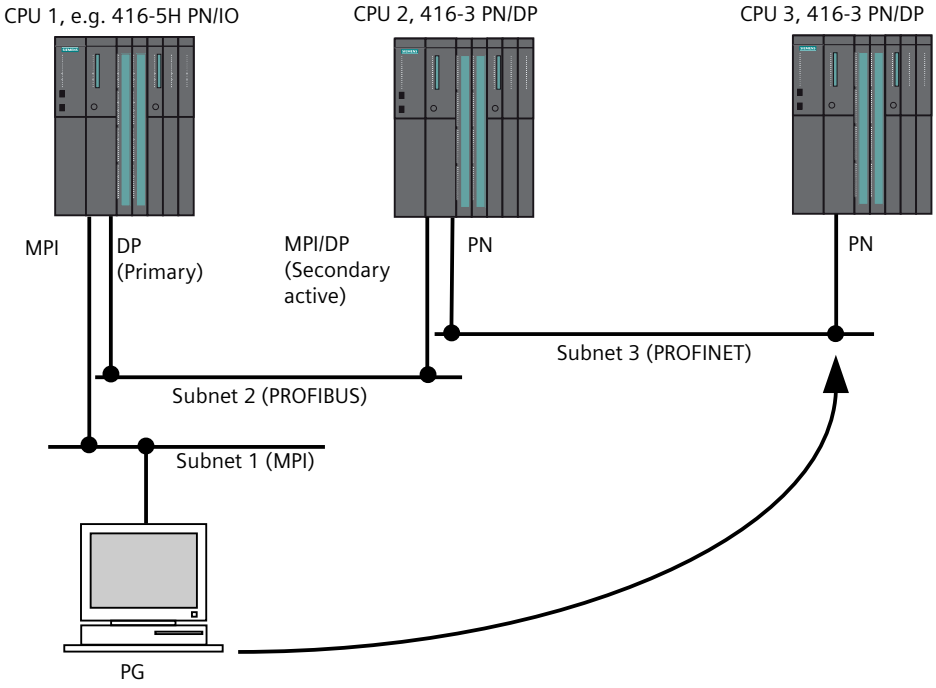


Figure 14-2 S7 routing gateways: MPI-DP-PROFINET

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 is established across subnet boundaries via modem.

The lower part of the figure shows how this can be configured in STEP 7.

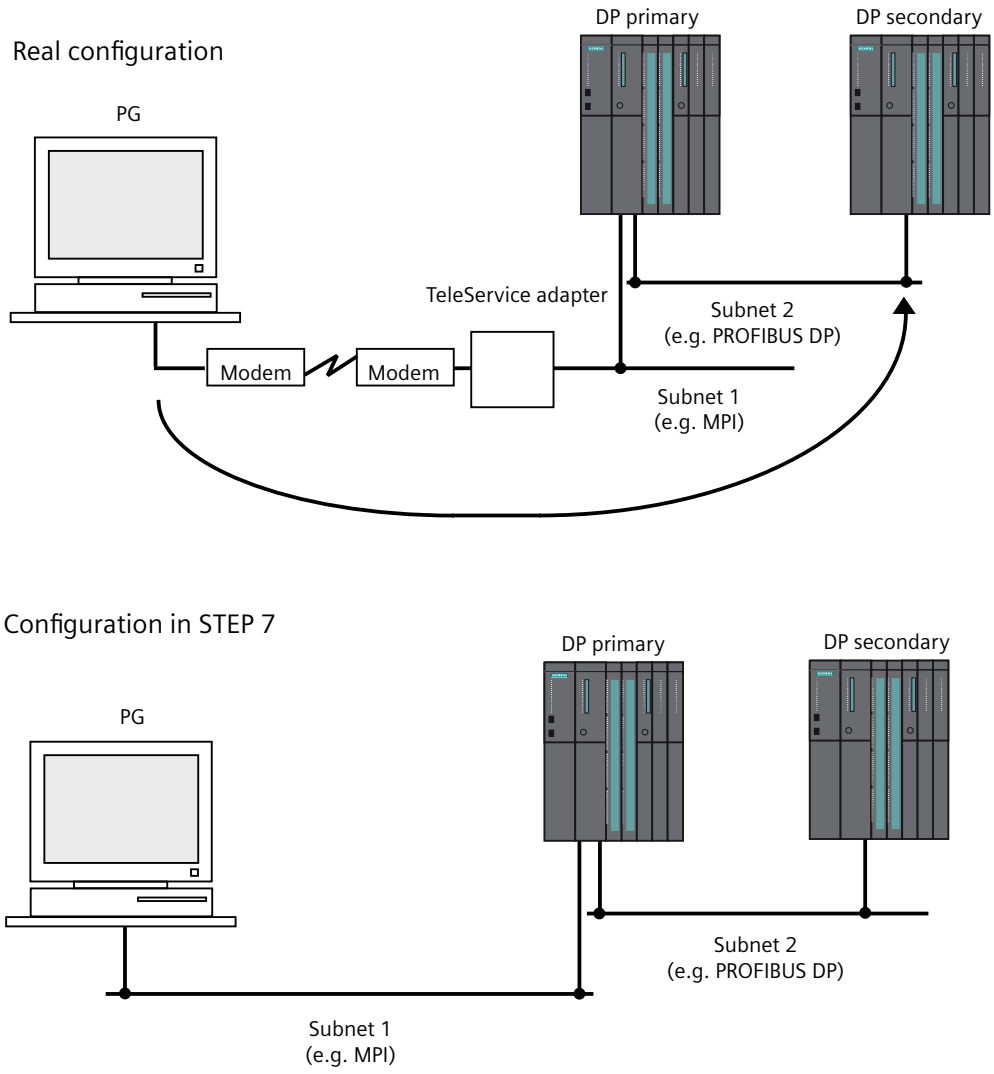


Figure 14-3 S7 routing: TeleService application example

Reference

- More information on configuration with STEP 7 can be found in the manual Configuring hardware and communication connections with STEP 7. (https://support.industry.siemens.com/cs/ww/en/view/18652631)
- For more information about the TeleService adapter, refer to the manual TS Adapter (https://support.industry.siemens.com/cs/ww/en/view/20983182)
- For more information about SFCs, refer to the Instructions list. (https://support.industry.siemens.com/cs/ww/en/view/44395684)
  For a detailed description, refer to the *STEP 7 online help* or the manual System and Standard Functions (https://support.industry.siemens.com/cs/ww/en/view/44240604).

14.1.6 Time synchronization

Introduction

The S7-400 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 S7-400:

- MPI
  You can configure the CPU as time master or time standby.
- PROFIBUS DP interface
  You can configure the CPU as time master or time standby.
- PROFINET interface via Industrial Ethernet
  Time-of-day synchronization using NTP mode; the CPU is the client.
  Time-of-day synchronization using SIMATIC mode as master or standby
- Via the S7-400 backplane bus
  You can configure the CPU as time master or time standby.

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.

If the CPU time master is on the S7-400 backplane bus, you should select a synchronization interval of 10 seconds.

The time master sends its first message frame once the time has been set for the first time (via SFC 0 "SET_CLK" or PG function). If another interface has been configured as time standby or as NTP client, the time starts after the first time frame has been received.

CPU as time standby

If the CPU is a time standby on the S7-400 backplane bus, the time is synchronized by a central clock connected to the LAN or by another CPU.

You can use a CP to forward the time to the S7-400. To do this, the CP (if it supports direction filtering) must be configured with the "from LAN to station" option in order to forward the time.

Time synchronization via the PROFINET interface

Time-of-day synchronization in NTP mode is possible at the PROFINET interface. The PROFINET CPU is client.

You may configure up to four NTP servers. You can set the update interval between 10 seconds and 1 day. If times exceed an interval of 90 minutes, the PROFINET CPU requests an NTP at cyclic intervals of 90 minutes.

Note

If you have configured more than one NTP server address, make sure that the NTP service is also started as a server under the configured IP address.

If you synchronize the PROFINET CPU in NTP mode, you should select "As primary" as the synchronization type and a time interval of 10 seconds for "Synchronization in the PLC" in the "Diagnostics/Clock" tab of the CPU.

Use FB "LT_BT" or FB "BT_LT" from the STEP 7 standard library to make allowances for a time zone or daylight saving/standard time.

Time-of-day synchronization is also possible via Ethernet MMS as master or standby. The combination NTP with SIMATIC method is allowed in this case.

14.1.7 Data set routing

Availability

S7-400H CPUs as of firmware version 6.0 support data set routing. The CPUs must also be configured in this or a higher firmware version for this.

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 need to support data set routing, since these devices do not forward the included 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.

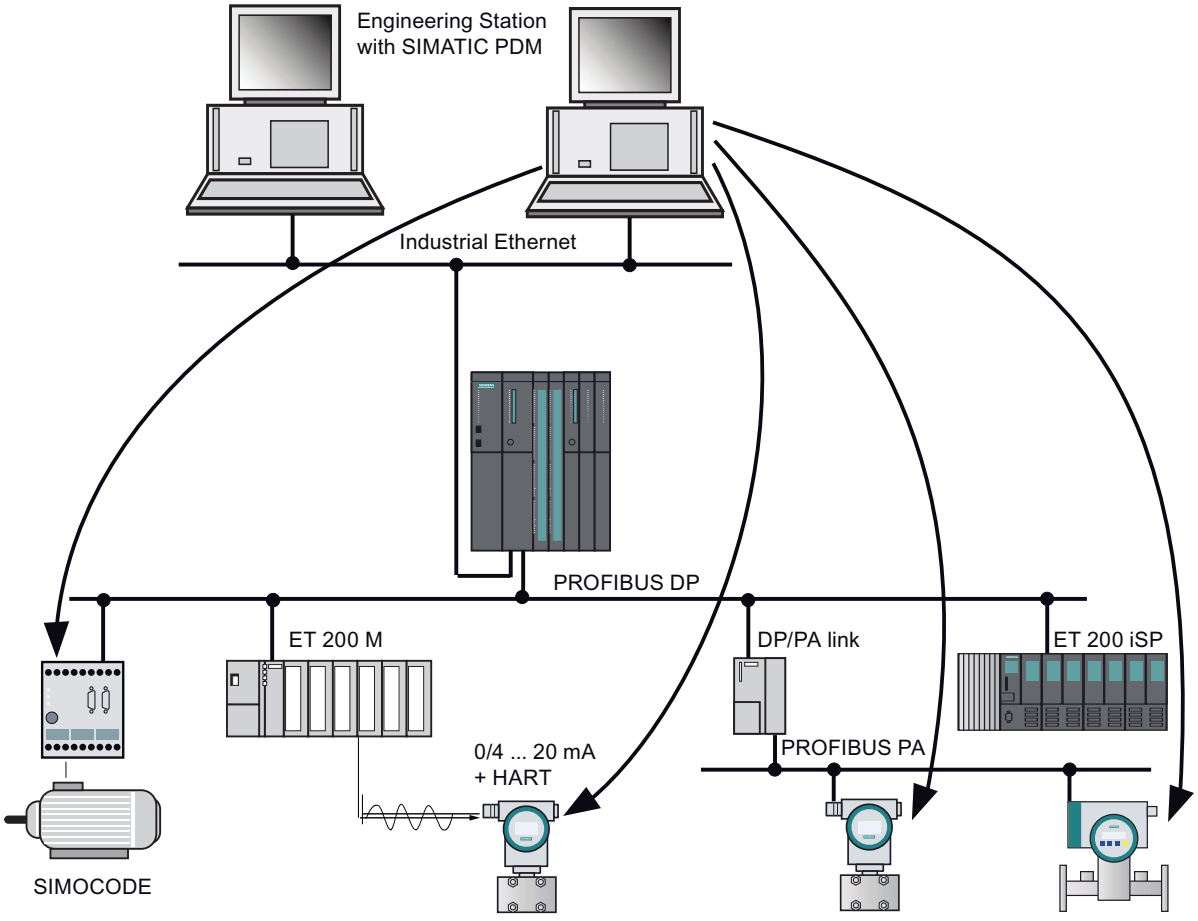


Figure 14-4 Data set routing

See also

For more information on SIMATIC PDM, refer to the *The Process Device Manager* manual.

14.1.8 SNMP network protocol

Availability

S7-400H CPUs as of firmware version 6.0 support the SNMP network protocol. The CPUs must also be configured in this or a higher firmware version for this.

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.

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.

Applications based on SNMP can be operated on the same network at the same time as applications with PROFINET.

Note

MAC addresses

During SNMP diagnostics, the following MAC addresses are shown for the ifPhysAddress parameter as of FW V5.1:

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 provides diagnostics and configuration functions for all 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*.

14.1.9 Open Communication Via Industrial Ethernet

Availability

S7-400H CPUs with firmware version 6.0 support "open communication over Industrial Ethernet" (in short: open IE communication). The CPUs must also be configured accordingly with this or a higher firmware version.

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 completed. 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 KB.
  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 by means of Industrial Ethernet:
  - UDP according to RFC 768
    The single-cast and broadcast modes are supported.

How to use open IE communication

STEP 7 provides the following FBs and UDTs under "Communication Blocks" in the "Standard Library" to allow data to be exchanged with other communication partners:

- 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 parameterization

- Data blocks for parametzerizing TCP and ISO-on-TCP connections
  To be able to parameterize your connection at TCP and ISO-on-TCP, you must create a DB that contains the data structure of UDT 65 "TCON_PAR". This data structure contains all parameters you need to set up the connection. Such a data structure which you can group within a global data range is required for every connection.
  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 14-4 Job lengths and "local_device_id" parameter

Message frame	CPU 41x-5H PN/DP	CPU 41x-5H PN/DP with CP 443-1
TCP	32 KB	-
ISO-on-TCP	32 KB	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. If a subsystem of a fault-tolerance system is switched to STOP, the system retains the connections through the CPU switched to STOP and establishes them again after link-up. You do not have to call FB 65 "TCON" again.
  FB 66 "TDISCON" disconnects the CPU from a communication partner, as does STOP mode. To reestablish the connection to have to 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.

Disconnecting 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, i.e., the interconnection between the user program and the communication layer of the operating system is terminated.

Options for closing the communication connection

The following events cause the communication connection to be closed:

- Program cancellation of the communication connection with FB 66 "TDISCON".
- The CPU state changes from RUN to STOP.
- At POWER OFF / POWER ON

Response in the fault-tolerance system

All connections are terminated when the entire fault-tolerance system switches to STOP. If one CPU in the system is stopped, the CPU's connections are canceled but retained by the fault-tolerant system. Connection termination with FB 66 "TDISCON" for connections available in the system runs asynchronously to program processing (status 7001,7002..7002, 0).

Connection diagnostics

In Step7, 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*.

14.2 Basics and terminology of fault-tolerant communication

Overview

Increased demands on the availability of an overall system require increased reliability of the communication systems, which means implementing redundant communication.

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 enhanced by duplicating component units and all bus components, or by 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 reserve 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 communication endpoints, 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.

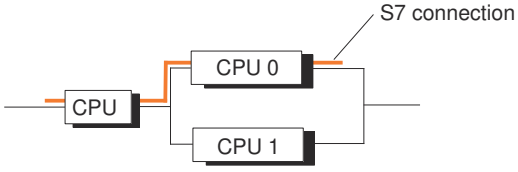


Figure 14-5 Example of an S7 connection

Note

Generally speaking, "connection" in this manual means a "configured S7 connection". For other types of connection, please refer to the *SIMATIC NET NCM S7 for PROFIBUS* and *SIMATIC NET NCM S7 for Industrial Ethernet* manuals.

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 user program, configuration and connection diagnostics perspective, 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 up to four subconnections, of which two are always established (active) to maintain communication in the event of an error. 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.

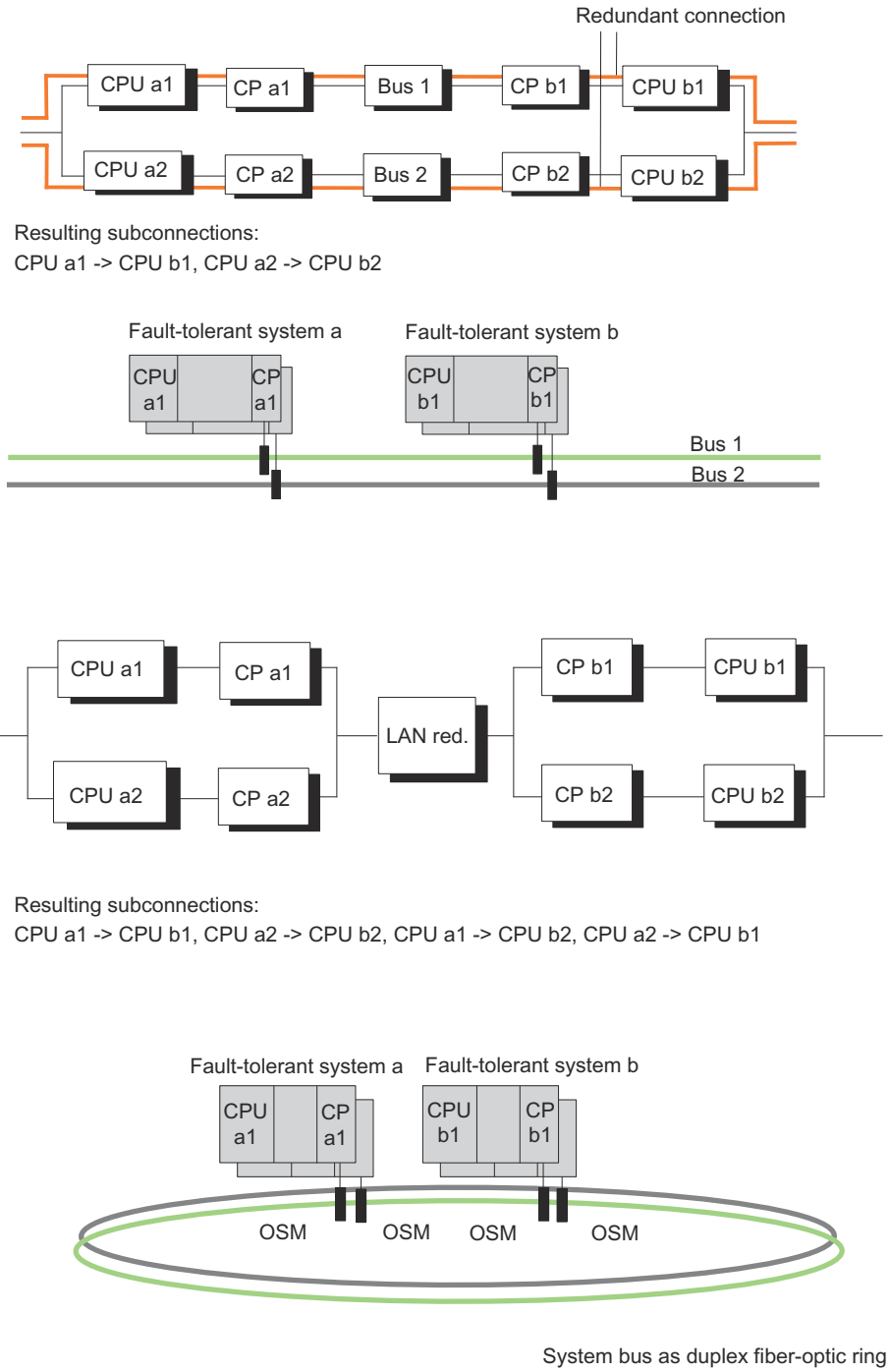


Figure 14-6 Example that shows that the number of resulting partial connections depends on the configuration

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 62/46 (see the technical specifications) fault-tolerant S7 connections. 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 is set too short, link-up and updating is canceled and the redundant system mode is no longer reached (see section Time monitoring (Page 137)).

Each CPU provides the connection resources according to its configuration, which means that a CPU 417-5H that was configured as CPU 412-5H only provides the connection resources of a CPU 412-5H.

14.3 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.

14.4 Usable communication services

The following services can be used:

- S7 communication via fault-tolerant S7 connections:
  - via PROFIBUS
  - Industrial Ethernet (ISO)
    S7 fault-tolerant connections are only possible between SIMATIC-S7-400H stations, or SIMATIC S7-400 stations with CPU41x-5H.
    Fault-tolerant communication with PC stations is only possible over Industrial Ethernet with ISO protocol and with ISO-on-TCP as of version 8.1.2.
  - Via integrated PROFINET interface (ISOonTCP).
- Open communication via Industrial Ethernet
- S7 communication using S7 connections via MPI, PROFIBUS, and Industrial Ethernet
- Standard communication (e.g. FMS) via PROFIBUS
- S5-compatible communication (e.g. SEND and RECEIVE blocks) via PROFIBUS and Industrial Ethernet

The following are not supported:

- S7 basic communication
- Global data communication
- PROFINET CBA

14.5 Communication via S7 connections

Communication with standard systems

Fault-tolerant communication between fault-tolerant and standard systems is not supported. The following examples illustrate the actual availability of the communicating systems.

Configuration

S7 connections are configured in STEP 7.

Programming

All communication functions are supported for S7 communication on a fault-tolerant system.

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 (for more details refer to the *System Software for S7-300/400, System and Standard Functions* Reference Manual).

Note

Downloading the connection configuration in RUN

If you download a connection configuration during operation, any established connections could be canceled.

14.5.1 Communication via S7 connections - one-sided mode

Availability

Availability is also enhanced by using a redundant plant bus instead of a simple bus (see image below) for communication between a fault-tolerant system and a standard system.

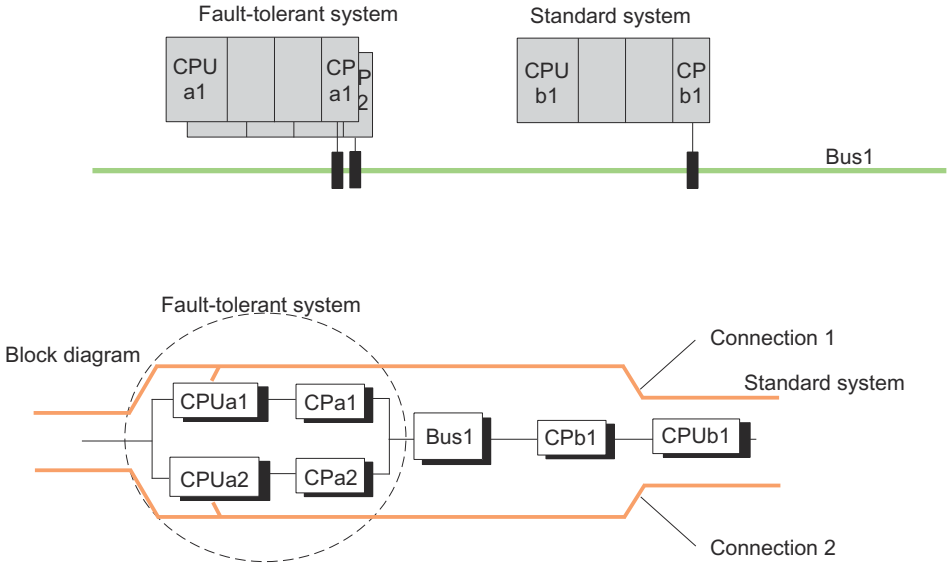


Figure 14-7 Example of linking standard and fault-tolerant systems in a simple bus system

With this configuration and redundant operation, the fault-tolerant system is connected via bus1 with the standard system. 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).

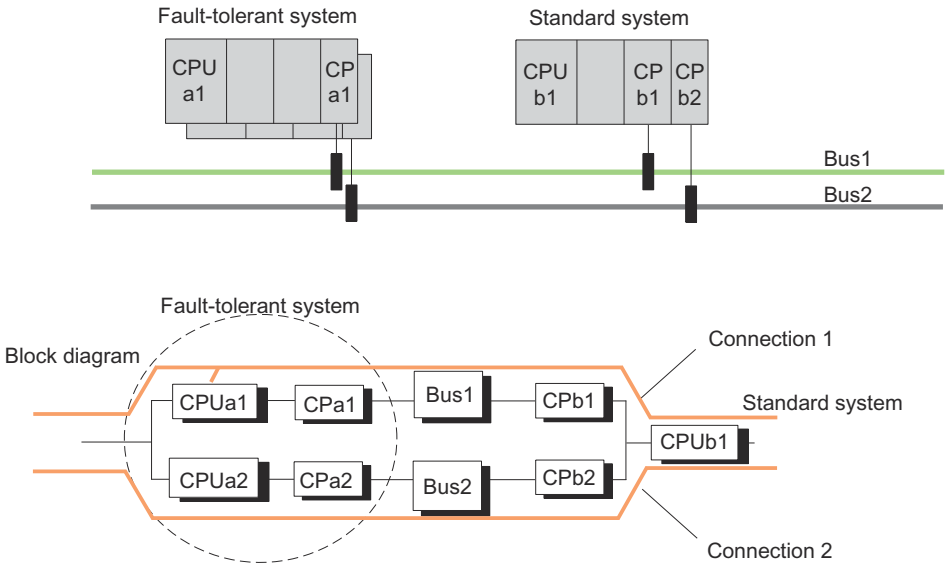


Figure 14-8 Example of linking standard and fault-tolerant systems in a redundant bus system

On a plant bus configured as duplex fiber-optic ring, communication between the partner systems is maintained if the duplex fiber-optic cable breaks. The systems then communicate as if they were connected to a bus system (linear structure); see following figure.

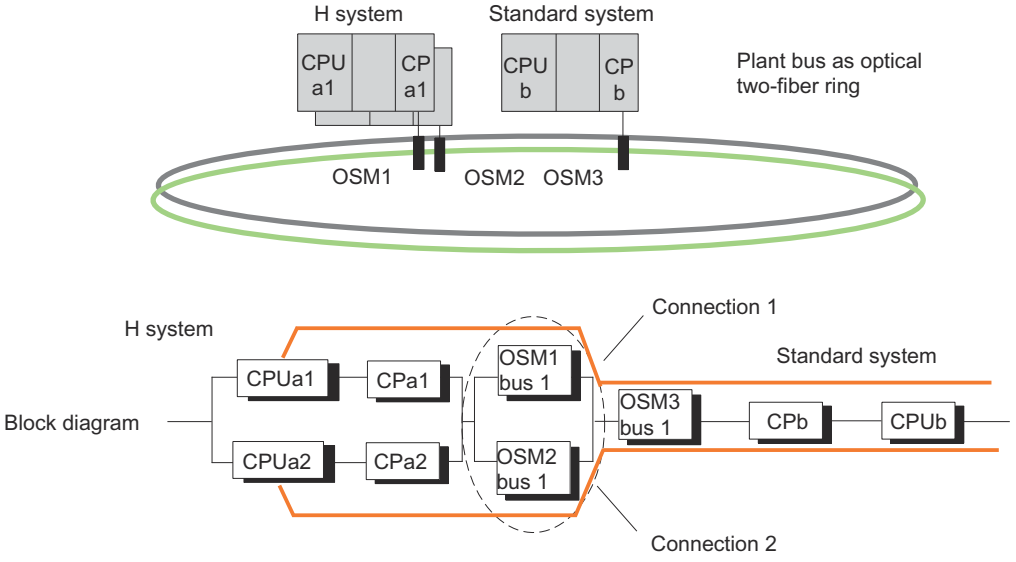


Figure 14-9 Example of linking of standard and fault-tolerant systems in a redundant ring

Response to failure

Duplex fiber-optic ring and bus system

Because S7 connections are used here (the connection ends at the CPU of the subsystem, in this case CPUa1), an error in the fault-tolerant system (e.g. CPUa1 or CPa1) or in system b (e.g. CP b) results in total failure of communication between the participating systems(see previous 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 transfer is assumed to have been successful. If there was an error message, the data transfer 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.

14.5.2 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.

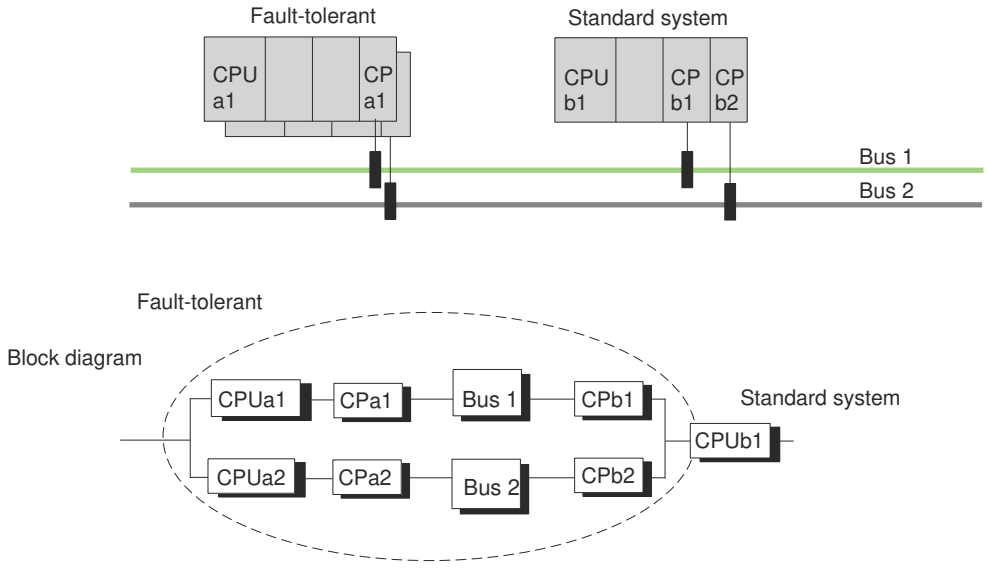


Figure 14-10 Example of redundancy with fault-tolerant systems and a redundant bus system with redundant standard connections

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).

14.5.3 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 (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.

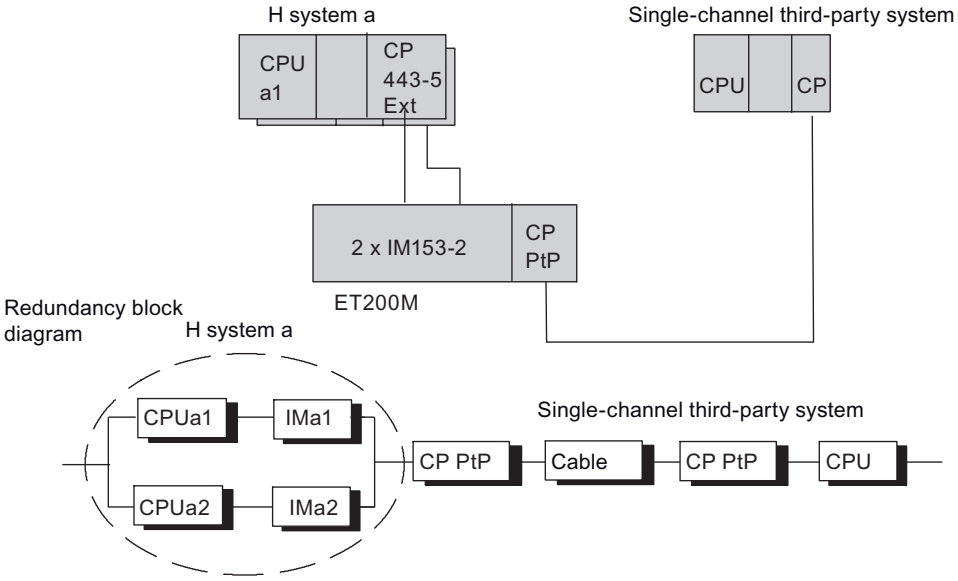


Figure 14-11 Example of connecting a fault-tolerant system to a single-channel third-party system using switched PROFIBUS DP

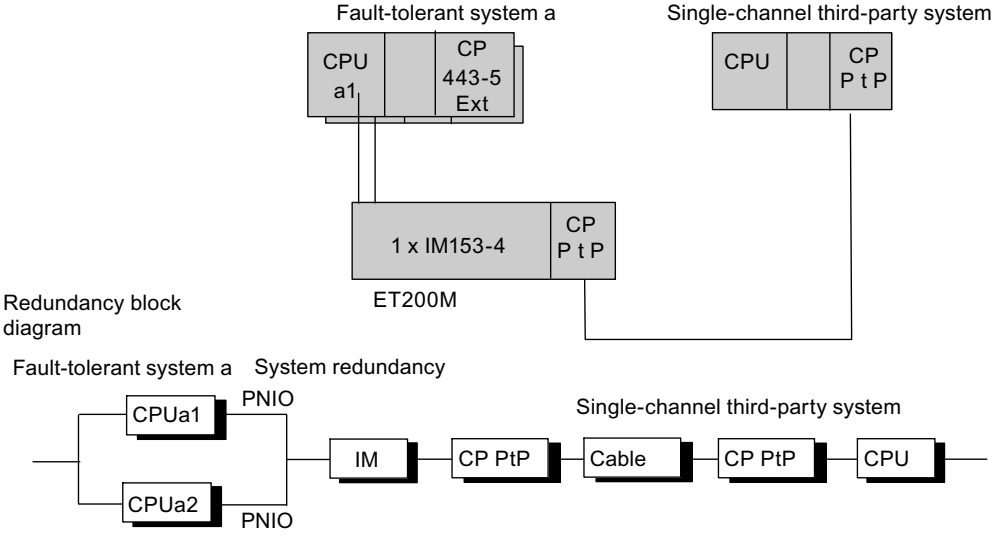


Figure 14-12 Example of connecting a fault-tolerant system to a single-channel third-party system using PROFINET IO with system redundancy

Response to failure

Double errors in the fault-tolerant system (i.e. CPUa1 and IM153) and single errors in the third-party system lead to a total failure of communication between the systems involved (see 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.

14.5.4 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 kinds 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.

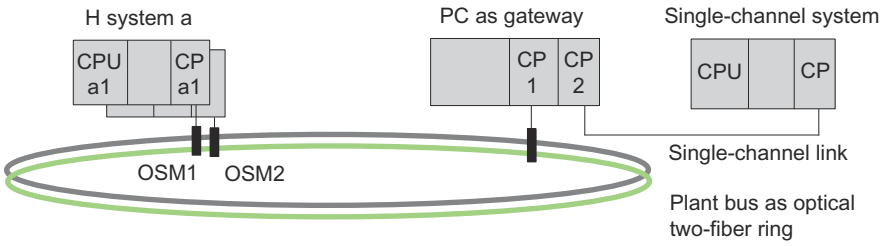
Configuring connections

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.



Redundancy block diagram

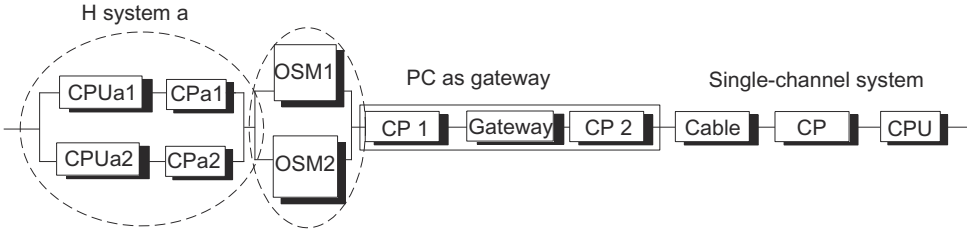


Figure 14-13 Example of linking a fault-tolerant system to a single-channel third-party system

14.6 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 modules and communication processors supported by the S7-400H (Page 395)
Only Industrial Ethernet with the ISO protocol or PROFIBUS without distributed I/O and ISO-on-TCP as of version 6.0 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.

Table 14-5 Possible combinations of high-availability connections via Industrial Ethernet.

Local connection end point	Local network connection	Used network protocol	Remote network connection		Remote connection end point	
CPU 41xH V6	CPU-PN interface CP443-1 (EX11/20) CP443-1 (EX11/20)	TCP TCP TCP	CPU-PN interface CPU-PN interface CP443-1 (EX11/20)	TCP TCP TCP	CPU 41xH V6 CPU 41xH V6 CPU 41xH V6	S7 fault tolerant connection via ISO-onTCP
CPU 41xH V6	CP443-1 (EX11/20)	ISO ISO ISO ISO	CP443-1 (EX11/20) CP443-1 (EX11/20) CP443-1 (EX11) CP443-1 (EX11)	ISO ISO ISO ISO	CPU 41xH V6 CPU 41xH V4.5 CPU 41xH V4.0 CPU 41xH V3.0	S7 fault tolerant connection via ISO
PC station with Simatic Net CD	for example CP1623 with Simatic Net, V8.1.2 or higher	TCP TCP	CPU-PN interface CP443-1 (EX11/20)	TCP TCP	CPU 41xH V6 CPU 41xH V6	S7 fault tolerant connection via ISO-onTCP
PC station with Simatic Net CD	for example CP1623 with Simatic Net, V8.1.2 or higher	ISO ISO ISO ISO	CP443-1 (EX11/20) CP443-1 (EX11/20) CP443-1 (EX11) CP443-1 (EX11)	ISO ISO ISO ISO	CPU 41xH V6 CPU 41xH V4.5 CPU 41xH V4.0 CPU 41xH V3.0	S7 fault tolerant connection via ISO
PC station with Simatic Net CD	for example CP1623 with Simatic Net up to V7.x	ISO ISO ISO ISO	CP443-1 (EX11/20) CP443-1 (EX11/20) CP443-1 (EX11) CP443-1 (EX11)	ISO ISO ISO ISO	CPU 41xH V6 CPU 41xH V4.5 CPU 41xH V4.0 CPU 41xH V3.0	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 10m) and want to convert to long synchronization cables (10km), you must increase the monitoring time to 1000 ms.

To ensure CIR capability of the fault tolerant system, activate the option "Save connections prior to loading" in Step7 Netpro.

Programming

Fault-tolerant communication can be implemented on the fault-tolerant CPU and is implemented by means of S7 communication.

This is possible only within an S7 project/multiproject.

Fault-tolerant communication is programmed in STEP 7 by means of communication SFBs. Those blocks can be used to transfer data on subnets (Industrial Ethernet, PROFIBUS). The standard communication SFBs integrated into the operating system offer you the option of acknowledged data transfer. 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 run 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 the *System Software for S7-300/400, System and Standard Functions* Reference Manual).

Any disruption of subconnections while communication jobs are active over fault-tolerant S7 connections leads to extended delay times.

Note

Downloading the connection configuration in RUN

If you download a connection configuration during operation, any established connections could be canceled.

14.6.1 Communication between fault-tolerant systems

Availability

The easiest way to enhance availability between linked systems is to implement a redundant plant bus, using 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 the one of the multimode fiber-optic cables breaks, communication between the systems involved is maintained. 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. A fiber-optic network can be set up as a line or star topology. However, the line topology does not permit cable redundancy.

If one electrical cable segment fails, communication between the participating systems is also upheld (1-out-of-2 redundancy).

The examples below illustrate the differences between the two variants.

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.

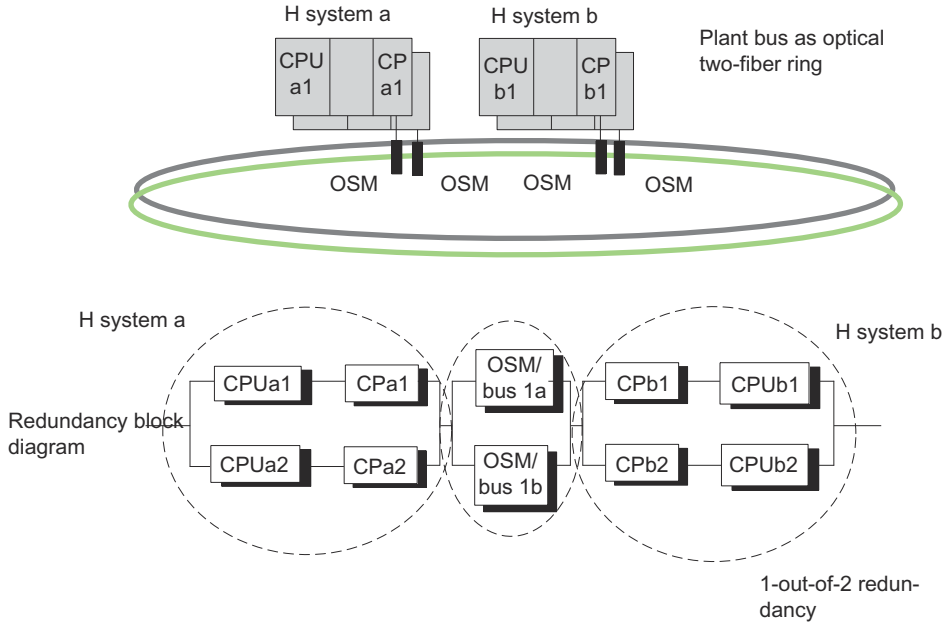


Figure 14-14 Example of redundancy with fault-tolerant system and redundant ring

Configuration view ≠ Physical view

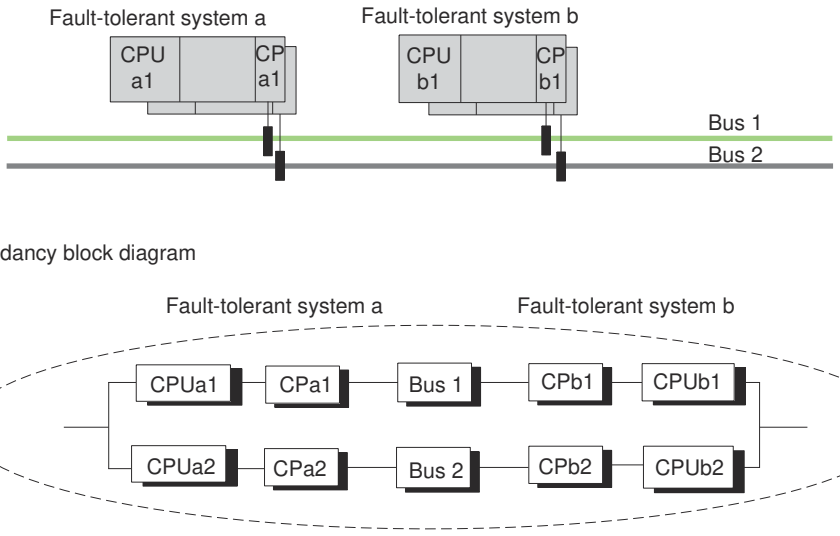


Figure 14-15 Example of redundancy with fault-tolerant system and redundant bus system

Configuration view = Physical view

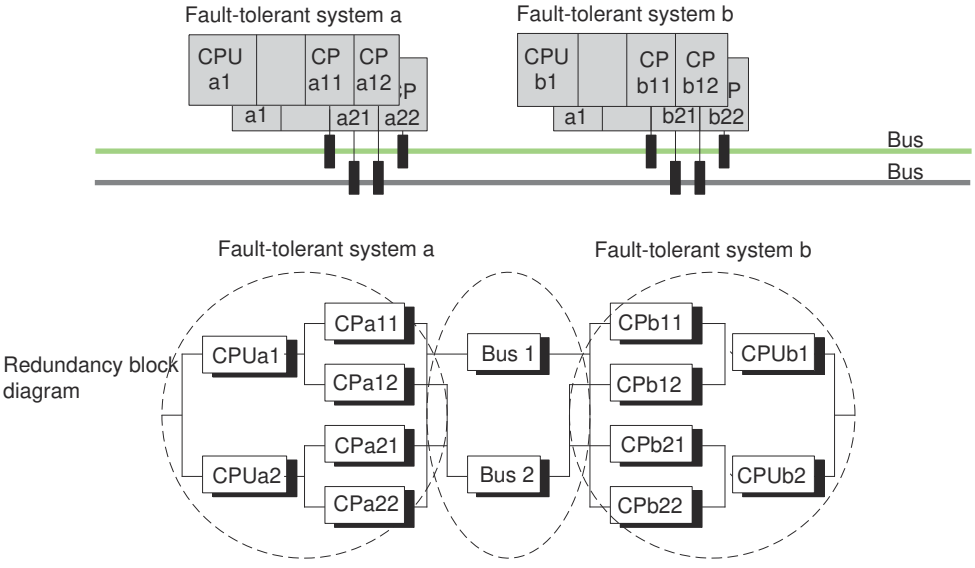


Figure 14-16 Example of fault-tolerant system with additional CP redundancy

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

If a duplex fiber-optic ring is used, 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 first figure).

If a double error (e.g. CPUa1 and CPb2) occurs in the first case of a redundant electrical bus system (see second figure), 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 third figure), only a double error within a fault-tolerant system (e.g. CPUa1 and CPUa2) 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.

14.6.2 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.

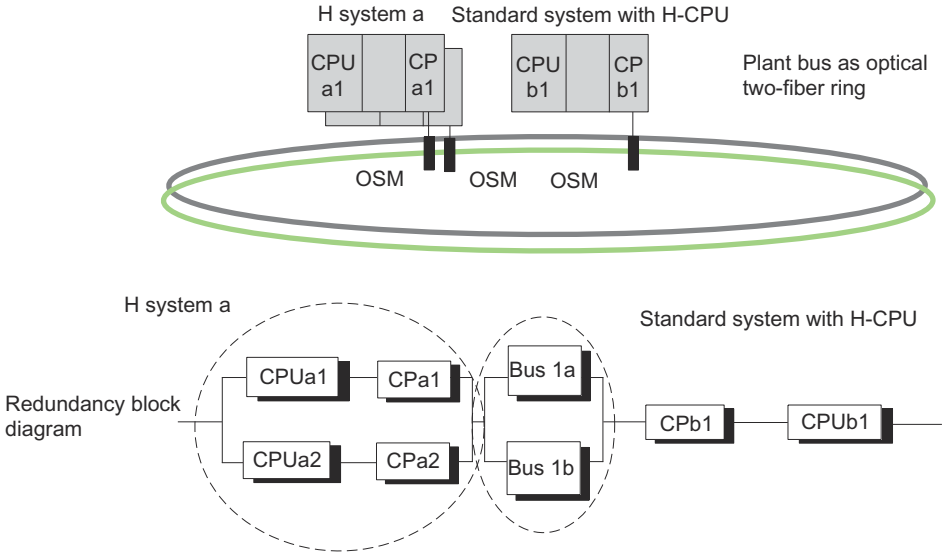


Figure 14-17 Example of redundancy with fault-tolerant system and fault-tolerant CPU

Response to failure

Double errors in the fault-tolerant system (i.e. CPUa1 and CPa2) or single errors in a standard system (CPUb1) lead to a total failure of communication between the systems involved; see previous figure.

14.6.3 Communication between fault-tolerant systems and PCs

Availability

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 is used to connect a PC to a redundant bus system using one or two CPs. The second CP is merely used to redundantly connect the PC to the bus system and does not increase the availability of the PC. 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 MRP (Media Redundancy Protocol) for PROFINET ring topologies is not supported by SIMATIC NET PC modules. System buses as optical two-fiber ring 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.

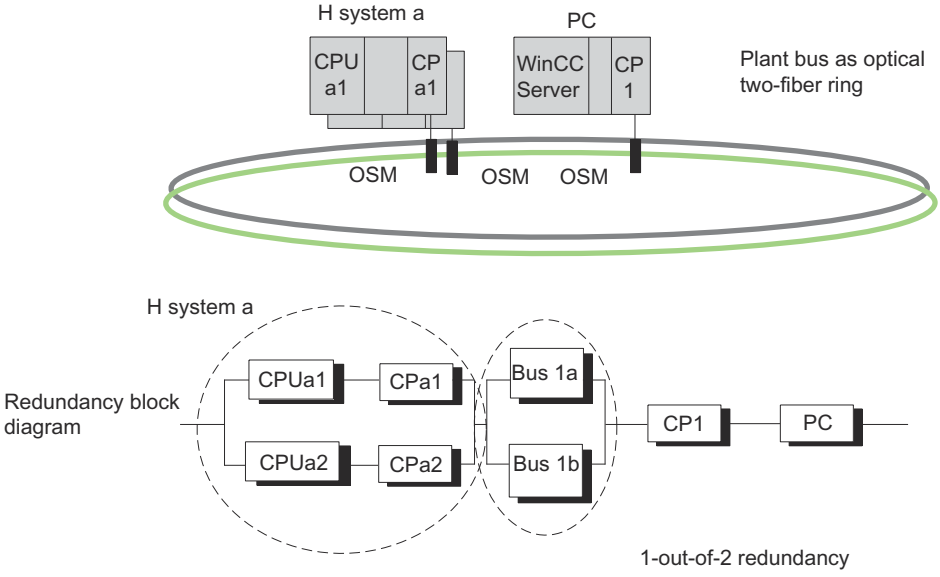


Figure 14-18 Example of redundancy with fault-tolerant system and redundant bus system

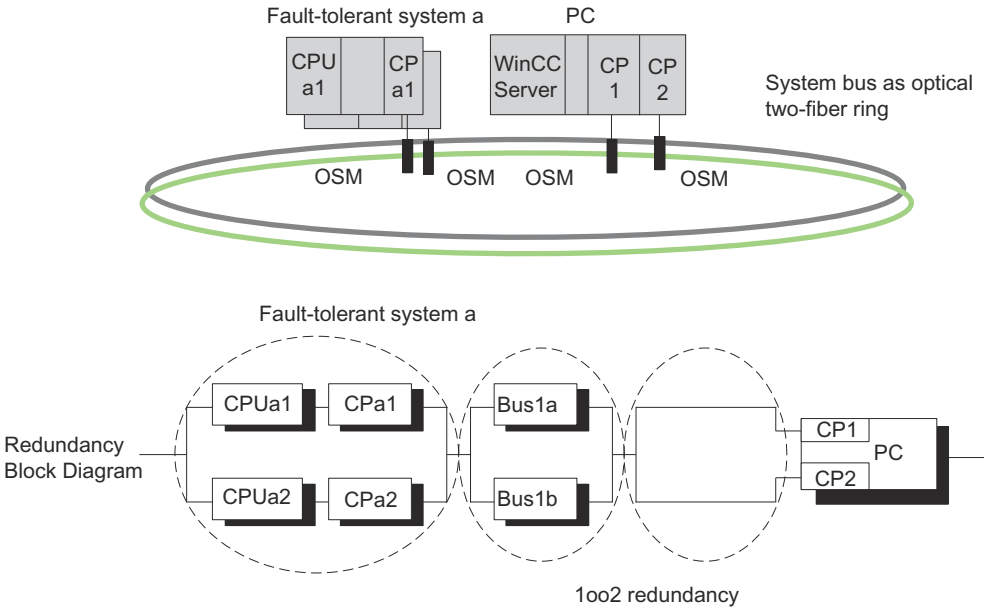


Figure 14-19 Example of redundancy with a fault-tolerant system, redundant bus system, and CP redundancy on PC.

Response to failure

Double errors in the fault-tolerant system, e.g., CPUa1 and CPa2, or 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.

14.7 Communication performance

Compared to a fault-tolerant CPU in stand-alone mode or standard CPU, the communication performance (response time or data throughput) of a fault-tolerant system operating in redundant mode is significantly lower.

The aim of this description is to provide you with criteria which allow you to assess the effects of the various communication mechanisms on communication performance.

You get information on the latest connection statistics of all CPU connections in the "Connection statistics" tab of the "Module state" tab dialog.

Definition of communication load

Communication load is the sum of requests per second issued to the CPU by the communication mechanisms, plus the requests and messages issued by the CPU.

Higher communication load increases the response time of the CPU, meaning the CPU takes more time to respond to a request (such as a read job) or to output requests and messages.

Operating range

In every automation system there is a linear operating range in which an increase in communication load will also lead to an increase in data throughput. This then results in reasonable response times which are acceptable for the automation task at hand.

A further increase in communication load will push data throughput into the saturation range. Under certain conditions, the automation system therefore may no longer be capable of processing the request volume within the response time demanded. Data throughput reaches its maximum, and the reaction time rises exponentially; see the figures below.

Data throughput may even be reduced somewhat due to additional internal loads inside the device.

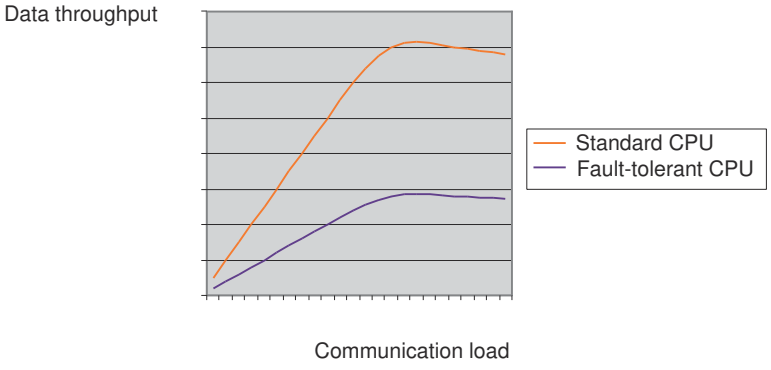


Figure 14-20 Communication load as a variable of data throughput (basic profile)

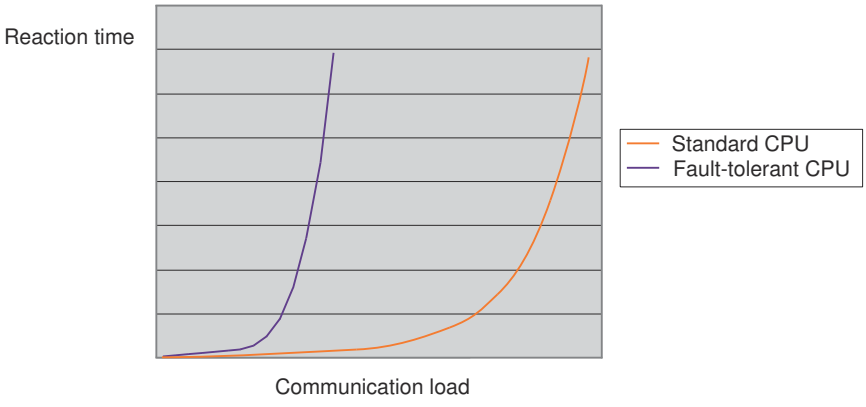


Figure 14-21 Communication load as a variable of response time (basic profile)

Standard and fault-tolerant systems

The information above applies to standard and fault-tolerant systems. Since communication performance in standard systems is clearly higher than that of redundant, fault-tolerant systems, the saturation point is rarely reached in today's plants.

In contrast, fault-tolerant systems require synchronization to maintain synchronous operation. This increases block execution times and reduces communication performance, This means that performance limits are reached earlier. If the redundant, fault-tolerant system is not operating at its performance limits, the performance benchmark compared to the single mode will be lower by the factor 2 to 3.

Communication statistics

You can determine the distribution of the communication load across all connections of a CPU or the redundant fault tolerant system via STEP 7 "Module state -> Communication statistics".

Which variables influence communication load?

The communication load is affected by the following variables:

- Number of connections/connected HMI systems
- Number of tags, or number of tags in screens displayed on OPs or using WinCC.
- Communication type (HMI, S7 communication, S7 message functions, S5-compatible communication, open communication via Industrial Ethernet...)
- The configured maximum cycle time extension as a result of communication load
- The length of the fiber-optic cables of the synchronization connection.
  Data throughput drops by about 5% for each kilometer of cable length.

14.8 General issues regarding communication

Reduce the rate of communication jobs per second as far as possible. Utilize the maximum user data length for communication jobs, for example by grouping several tags or data areas in one read job.

Each request requires a certain processing time, and its status should therefore not be checked before this process is completed.

You can download a tool for the assessment of processing times free of charge from the Internet at:

Service & Support (https://support.industry.siemens.com/cs/ww/en/) ID 1651770

Your calls of communication jobs should allow the event-driven transfer of data. Check the data transfer event only until the job is completed.

Call the communication blocks sequentially and stepped down within the cycle in order to obtain a balanced distribution of communication load.

You can by-pass the block call command by means of a conditional jump if you do not want to transfer any user data.

A significant increase in communication performance between S7 components is achieved by using S7 communication functions, rather than S5-compatible communication functions.

As S5-compatible communication functions (FB "AG_SEND", FB "AG_RECV", AP_RED) generate a significantly higher communication load, you should only deploy these for the communication of S7 components with non-S7 components.

AP_RED software package

When using the "AP_RED" software package, limit the user data length to 240 bytes. If larger data volumes are necessary, transfer those by means of sequential block calls.

The "AP_RED" software package uses the mechanisms of FB "AG_SEND" and FB "AG_RCV". Use AP_RED only to link SIMATIC S5/S5-H controllers or third-party devices which only support S5-compatible communication.

S7 communication (SFB 12 "BSEND" and SFB 13 "BRCV")

Do not call SFB 12 "BSEND" in the user program more often than the associated SFB 13 "BRCV" at the communication peer.

S7 communication (SFB 8 "USEND" and SFB 9 "URCV")

SFB 8 "USEND" should always be event-driven, because this block may generate a high communication load.

Do not call SFB 8 "USEND" in the user program more often than the associated SFB 9 "URCV" at the communication peer.

SIMATIC OPs, SIMATIC MPs

Do not install more than 4 OPs or 4 MPs in a fault-tolerant system. If you do need more OPs/MPs, your automation task may have to be revised. Contact your SIMATIC sales partner for support.

Do not select a screen refresh cycle time of less than 1 s, and increase it to 2 s as required.

Verify that all screen tags are requested within the same cycle time in order to form an optimized group for read jobs.

OPC servers

When OPC is used to connect several HMI devices for your visualization tasks to a fault-tolerant system, you should keep the number of OPC servers accessing the fault-tolerant system as low as possible. OPC clients should address a shared OPC server, which then fetches the data from the fault-tolerant system.

You can optimize data exchange by using WinCC and its client/server concept.

Various HMI devices of third-party vendors support the S7 communication protocol. You should utilize this option.

Configuring with STEP 7

15

This section provides an overview of fundamental issues you must observe when you configure a fault-tolerant system.

The second section covers the PG functions in STEP 7.

For detailed information, refer to *Configuring fault-tolerant systems* in the basic help.

15.1 Configuring with STEP 7

The basic approach to configuring the S7-400H is no different from that used to configure the S7-400.

- Creating projects and stations
- Configuring hardware and networking
- Loading system data onto the target system

Even the individual steps that are required for this are identical for the most part to those familiar from the S7-400.

Note

OBs required

Always download these error OBs to the S7-400H CPU: OB 70, OB 72, OB 80, OB 82, OB 83, OB 85, OB 86, OB 87, OB 88, OB 121 and OB 122. If you do not download these OBs, the fault-tolerant system goes into STOP when an error occurs.

Creating a fault-tolerant station

The SIMATIC fault-tolerant station represents a separate station type in SIMATIC Manager. It allows the configuration of two central units, each having a CPU and therefore a redundant station configuration.

15.1.1 Rules for arranging fault-tolerant station components

Besides the rules that generally apply to the arrangement of modules in S7-400, there are additional rules for an H-station:

- Insert the CPUs in the same slots in each case.
- Insert redundantly used external DP primary interface modules or communication modules in the same slots in each case.

- Insert an external DP primary interface module for redundant DP primary systems only in the central units and not in expansion units.
- Redundantly used CPUs (e.g. CPU 41x-5H PN/DP) must be identical, i.e. they must have the same order number, the same product version and firmware version. It is not the marking on the front side is decisive for the product version, but the revision of the "Hardware" component ("Module status" dialog mask) to be read using step 7.
- Redundantly used modules (e.g. DP secondary interface module IM 153-2) must be identical, i.e. they must have the same order number and product version and, if present, the same firmware version.

Layout rules

- A fault-tolerant station may contain up to 20 expansion devices.
- Assign module racks with even numbers only to central rack 0, and racks with odd numbers only to central rack 1.
- Modules with communication bus interface can be operated only in racks 0 through 6.
- Communication-bus capable modules are not permissible in switched I/O.
- Pay attention to the rack numbers for operation of CPs for fault-tolerant communication in expansion devices:
  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.
- When assembling a central unit with DP primary modules, DP primaries starting from DP primary No. 9 are also assigned a rack number. The number of possible expansion racks is reduced as a result.

Compliance with the rules is monitored automatically by STEP 7 and considered accordingly during configuration.

15.1.2 Configuring hardware

The simplest way of achieving a redundant hardware configuration consists in initially equipping **one** rack with all the redundant components, assigning parameters to them and then copying them.

You can then specify the various addresses (for one-sided I/O only!) and arrange other, non-redundant modules in individual racks.

Special features in presenting the hardware configuration

In order to enable quick recognition of a redundant DP master system, it is represented by two parallel DP cables.

15.1.3 Assigning parameters to modules in a fault-tolerant station

Introduction

Assigning parameters to modules in a fault-tolerant station is no different from assigning parameters to modules in S7-400 standard stations.

Procedure

All parameters of the redundant components (with the exception of MPI and communication addresses) must be identical.

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 MPI/DP interface (X1)
- Parameters of the DP interface (X2)
- Addresses of sync modules
- Parameters of the PROFINET interface

Configuring modules addressed in the I/O address space

Always configure a module that is addressed in the I/O address space so that it is located either entirely in the process image or entirely outside.

Otherwise, consistency cannot be guaranteed, and the data may be corrupted.

I/O access using word or double word operations

The system loads the values to accumulator "0" if the word or double word for I/O access contains only the first or the first three bytes, but not the remaining bytes of the addressed space.

Example: The I/O with address 8 and 9 is available in the S7-400H; addresses 10 and 11 are not used. Access L ID 8 causes the system to load the value DW#16#00000000 into the accumulator.

15.1.4 Recommendations for setting the CPU parameters

CPU parameters that determine cyclic behavior

You specify the CPU parameters that determine the cyclic behavior of the system on the "Cycle/ Clock memory" tab.

Recommended settings:

- As long a scan cycle monitoring time as possible (e.g. 6000 ms)
- OB 85 call when there is an I/O area access error: only with incoming and outgoing errors

Number of messages in the diagnostic buffer

You specify the number of messages in the diagnostic buffer on the "Diagnostics/Clock" tab.

We recommend that you set a large number (3200, for example).

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 diagnostic buffer.

In the case of some secondaries (e.g. IM 157), these parameters are packed into 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 secondaries => slower transmission rate)
  Note: The bus load is at its highest during restart of the DP primary, e.g. after power OFF/ON

Recommended setting: 600 corresponds to 60 s.

Note

The specific fault-tolerant 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).

Note

A CP 443-5 Extended (order number 6GK7443–5DX03) may only be used for transfer rates of up to 1.5 MBaud in an S7–400H or S7–400FH when a DP/PA or Y link is connected (IM157, order number 6ES7157-0AA00-0XA0, 6ES7157-0AA80-0XA0, 6ES7157-0AA81-0XA0). Remedy: see FAQ 11168943 at
Service & Support (https://support.industry.siemens.com/cs/ww/en/)

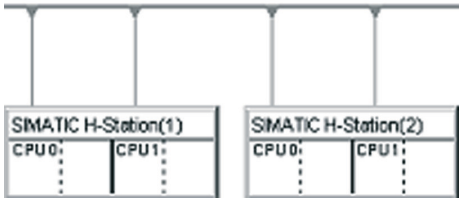
15.1.5 Networking configuration

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:

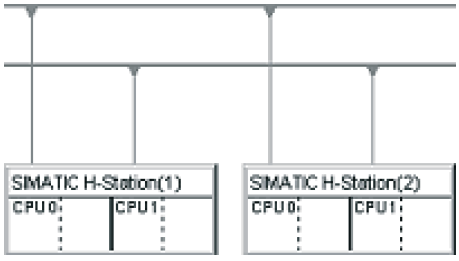
- S7–400 fault-tolerant station (with 2 fault-tolerant CPUs)->S7–400 fault-tolerant station (with 2 fault-tolerant CPUs)
- S7–400 station (with 1 fault-tolerant CPU)->S7–400 fault-tolerant station (with 2 fault-tolerant CPUs)
- S7–400 station (with 1 fault-tolerant CPU)->S7–400 station (with 1 fault-tolerant 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 (DP master systems), two connecting paths are used. In practice, they are usually electrical power systems, one CP in each subnet:



- If only one DP master system is available (in practice usually fiber-optic cables), 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.

15.2 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 and deleting blocks), 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.

Failure and replacement of components during operation

16

16.1 Failure and replacement of components during operation

One factor that is crucial to the uninterrupted operation of the fault-tolerant controller is the replacement of failed components during operation. Quick repairs will recover fault-tolerant redundancy.

We will show you in the following sections how simple and fast it can be to repair and replace components in the S7-400H. Also refer to the tips in the corresponding sections of the manual *S7-400 Automation Systems, Installation*

16.2 Failure and replacement of components during operation

Which components can be replaced?

The following components can be replaced during operation:

- Central processing units (e.g. CPU 417–5H)
- Power supply modules (e.g. PS 405, PS 407)
- Signal and function modules
- Communication processors
- Synchronization modules and fiber-optic cables
- Interface modules (e.g. IM 460, IM 461)

16.2.1 Failure and replacement of a CPU

Complete replacement of the CPU is not always necessary. If only the load memory fails, it is enough to replace the corresponding memory card. Both cases are described below.

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 load memory 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. Either create an operating system update card for the new CPU and use this to load the operating system on the CPU or load the required operating system in HW Config with "PLC -> Update Firmware", see section Updating the firmware without a memory card (Page 71).

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.

Starting situation for replacement of the load memory

Failure	How does the system react?
The S7-400H is in redundant system mode and a **load memory access error** occurs.	• The relevant CPU changes to STOP and requests a memory reset. • The partner CPU switches to single mode.

Procedure

Follow the steps below to **replace the load memory**:

Step	What has to be done?	How does the system react?
1	Replace the memory card on the stopped CPU.	–
2	Perform a memory reset on the CPU with the replaced memory card.	–
3	Start the CPU.	• The CPU performs an automatic LINK-UP and UPDATE. • The CPU changes to RUN and operates as the reserve CPU.

16.2.2 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.

16.2.3 Failure and replacement of an input/output or function module

Starting situation

Failure	How does the system react?
The S7-400H 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 process the swapping interrupt OB 83 synchronized with each other.
3	Disconnect the front connector and wiring.	-
4	Plug the front connector into the new module.	-
5	Insert the new module.	• Both CPUs process the swapping interrupt OB 83 synchronized with each other. • 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.	• Call OB 82 if the module concerned is capable of diagnostic interrupts and diagnostic interrupts are enabled in the configuration. • 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 process the swapping interrupt OB 83 synchronized with each other.
4	Insert the new module.	• Both CPUs process the swapping interrupt OB 83 synchronized with each other. • 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.	• Call OB 82 if the module concerned is capable of diagnostic interrupts and diagnostic interrupts are enabled in the configuration.

16.2.4 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 primary (Page 244).

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).

16.2.5 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 the manual "Synchronization Modules for S7-400H (https://support.industry.siemens.com/cs/ww/en/view/109779483)".	• 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).
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.

16.2.6 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.

16.3 Failure and replacement of components of the distributed I/Os

Which components can be replaced?

The following components of the distributed I/O can be replaced during operation:

- PROFIBUS DP primary
- PROFIBUS DP interface module (IM 153-2 or IM 157)

- PROFIBUS DP secondary
- PROFIBUS DP cable

Note

The replacement of input/output or function modules located in a distributed station has already been described in section Failure and replacement of an input/output or function module (Page 238).

16.3.1 Failure and replacement of a PROFIBUS DP primary

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system state and a DP primary module fails.	• If single-channel one-sided I/O: DP primary can no longer process connected DP secondaries. • If switched I/O: DP secondaries are addressed via the DP primary of the partner.

Procedure

Proceed as follows to replace a PROFIBUS DP primary:

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 from the DP primary module involved.	–
3	Replace the module.	–
4	Plug the PROFIBUS DP cable 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 standby CPU.

Exchanging a CP 443-5 in case of spare part requirement

If a CP 443-5 is replaced by a successor module with a new article number, always both modules must be replaced in the case of redundantly used components.

Redundantly used modules must be identical, i.e. they must have the same article number, product version and firmware version.

Proceed as follows:

Step	What has to be done?	How does the system react?
1	Stop the standby CPU	The fault-tolerant system switches to single mode, see chapter PCS 7, step 3: Stopping the reserve CPU (Page 256) or STEP 7, step 4: Stopping the reserve CPU (Page 272)
2	Turn off the power supply of the central rack.	-
3	Unplug the PROFIBUS DP cable from the DP primary module involved.	–
4	Replace the module.	–
5	Plug the PROFIBUS DP cable back in.	–
6	Turn on the power supply of the central rack.	_
7	Switch to the CPU with the modified configuration.	The standby CPU links up, is updated and becomes the primary. The previous primary CPU switches to STOP and the H-system operates with the new hardware in solo mode. See section PCS 7, step 5: Switch to CPU with modified configuration (Page 257) or section STEP 7, step 6: Switch to CPU with modified configuration (Page 273)
8	Turn off the power supply of the second central rack.	-
9	Unplug the PROFIBUS DP cable from the second DP primary module.	–
10	Replace the module.	–
11	Plug the PROFIBUS DP cable back in.	–
12	Turn on the power supply of the second central rack again.	-
13	Perform a "Warm restart".	CPU performs a LINK-UP and UPDATE and operates as standby CPU, see chapter PCS 7, step 6: Transition to redundant system mode (Page 258) or chapter STEP 7, step 7: Transition to redundant system mode (Page 274)

16.3.2 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.

16.3.3 Failure and replacement of a PROFIBUS DP secondary

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system state and a DP secondary fails.	Both CPUs signal the event in the diagnostic buffer and with a corresponding OB.

Procedure

Proceed as follows to replace a DP secondary:

Step	What has to be done?	How does the system react?
1	Switch off the power supply to the IO device.	–
2	Unplug the connected bus connector.	–
3	Replace the DP secondary.	–
4	Plug the bus connector back in and switch the power supply back on.	• CPUs process the rack failure OB 86 synchronously (outgoing event). • DP secondary can be addressed by the respective DP primary system.

16.3.4 Failure and replacement of PROFIBUS DP cables

Starting situation

Failure	How does the system react?
The S7-400H is in redundant system state and the PROFIBUS DP cable is faulty.	• If single-channel one-sided I/O: Rack failure OB (OB 86) is started (incoming event). DP primary can no longer process connected DP secondaries (station failure). • If switched I/O: I/O redundancy error OB (OB 70) is started (incoming event). DP secondaries are addressed via the DP primary of the partner.

Replacement procedure

Proceed as follows to replace the PROFIBUS DP cables:

Step	What has to be done?	How does the system react?
1	Check the wiring and identify the faulty PROFIBUS DP cable.	–
2	Replace the defective cable.	–
3	Switch the failed modules to RUN.	CPUs process error OBs synchronously • One-sided I/O: Rack failure OB 86 (outgoing event) DP secondaries can be addressed via the DP primary system. • If switched I/O: I/O redundancy error OB 70 (outgoing event). DP secondaries can be addressed via both DP primary systems.

System modifications during operation 17

17.1 System modifications during operation

In addition to the options described in chapter Failure and replacement of components during operation (Page 235) for replacing failed components during operation,

you can also make changes to the system in a fault-tolerant system without interrupting the running program.

The procedure partially depends on whether you are working with your user software in PCS 7 or STEP 7.

The procedures described below for changes during operation are

designed so that you start with the redundant system mode (see chapter The system states of the S7-400H (Page 109)) with the aim of returning to this mode when the procedures are completed.

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 diagnostic buffer.

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

17.2 Possible hardware modifications

How does a hardware modification work?

If the hardware components concerned are suitable for removal or insertion while live, the hardware modification can be carried out in redundant system state. However, because the download of a modified hardware configuration data in redundant system state would lead to the the H-system stopping, it must be put temporarily into solo mode. In solo mode, the process is controlled by only one CPU while the desired configuration changes are being made on the other CPU.

WARNING

Hardware modifications for removing and adding modules

You can either remove or add modules during a hardware change. 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.

Load memory data of both CPUs must be updated several times in the process. It is therefore advisable to expand the integrated load memory with a RAM card (at least temporarily).

You may only change the FLASH card to a RAM card as required for this if the FLASH card has as much maximum storage space as the largest RAM card available. If you cannot obtain a RAM card with a capacity to match the FLASH card memory space, split the relevant configuration and program modifications into several smaller steps in order to provide sufficient space in the integrated load memory.

Synchronization link

In the case of all hardware modifications, ensure that the synchronization link between the two CPUs has been reestablished **before** you start or switch on the standby CPU. When the power supplies of the CPUs are switched on, the IFM1F and IFM2F LEDs, which are used to indicate module interface errors, must **go out** on both CPUs.

If one of the IFM LEDs continues to be lit even after you have replaced the associated synchronization modules, the synchronization cables and even the standby CPU, there is an error in the primary 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 or expansion units (e.g. one-sided I/O module).

  Note

  The addition or removal of the IM460 and IM461 interface modules, the external DP primary interface module CP443-5 Extended and the associated plug-in cables is only permitted in de-energized state.

- Adding or removing components of the distributed I/Os such as
  - DP secondaries with redundant interface module (e.g. ET 200M, DP/PA Link or Y Link)
  - One-sided DP secondaries (in any DP primary system)
  - Modules in modular DP secondaries
  - DP/PA links
  - PA devices
- Changing specific CPU parameters
- Changing the CPU memory configuration
- Re-parameterization of a module
- Assigning a module to another process image partition
- Upgrading to a newer product version of the CPU
- Change from one primary to another with only one redundancy link available

  Note

  No changes to the PROFINET interface at runtime

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

For all changes, observe the rules for assembly of an H-station (see section Rules for the assembly of fault-tolerant stations (Page 25)).

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:

- Provision must be made in both cables of a redundant DP primary system for a sufficient number of branching points for spur lines or isolating points (spur lines are not permitted when using transmission rates of 12 Mbps). 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 secondary stations (ET 200M), DP/PA links and Y links must always be installed with active backplane bus and fitted with all the bus modules required wherever possible, because the bus modules must not be inserted and removed during operation.
- 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.
- Loaded data blocks must not be deleted and created again. In other words, SFC 22 (CREATE_DB) and SFC 23 (DEL_DB) may not be applied to DB numbers occupied by loaded DBs.
- Always ensure that the current status of the user program is available as STEP 7 project in block format at the PG/ES when you modify the system configuration. It is not enough to upload the user program back from one of the CPUs to the PG/ES or to compile it again from an STL source.

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 subsections)
- The transmission rate (baud rate) of redundant DP primary 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 mode. The procedure depends on the software used. For more details refer to the *Programming with STEP 7* manual and the *PCS 7, Configuration Manual*.

Note

After reloading connections/gateways, it is no longer possible to change from a RAM card to a FLASH card.

Special features

- Keep changes to a manageable extent. We recommend changing only one DP primary and/or a few DP secondaries (e.g. no more than 5) in a single reconfiguration operation.
- 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 based on one-sided I/O at the user level (see section Other options for connecting redundant I/Os (Page 184)), you must take the following into consideration:

During link-up and update after a system modification, the I/O of the previous primary CPU may be removed from the process image for a short time before the (modified) I/O of the "new" primary CPU has been fully entered into 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 to modules that have been enabled for redundant operation (see section Connecting redundant I/O to the PROFIBUS DP interface (Page 157)).

Preparations

To minimize the time during which the fault-tolerant system has to run in single mode, 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. If necessary, start by changing the memory configuration (see section Changing the CPU memory configuration (Page 292)).
- Always ensure that plugged modules which are not configured yet do not have any unwanted influence on the process.

17.3 Adding components in PCS 7

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 287)).

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

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 subsection.

Step	What has to be done?	See section
1	Modification of hardware	PCS 7, step 1: Modification of hardware (Page 254)
2	Offline modification of the hardware configuration	PCS 7, step 2: Offline modification of the hardware configuration (Page 255)
3	Stopping the reserve CPU	PCS 7, step 3: Stopping the reserve CPU (Page 256)
4	Loading a new hardware configuration in the reserve CPU	PCS 7, step 4: Loading a new hardware configuration in the reserve CPU (Page 256)
5	Switching to CPU with modified configuration	PCS 7, step 5: Switch to CPU with modified configuration (Page 257)
6	Transition to redundant system mode	PCS 7, step 6: Transition to redundant system mode (Page 258)
7	Editing and downloading the user program	PCS 7, step 7: Editing and downloading the user program (Page 259)

Exceptions

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

- To use free channels on an existing module
- For adding interface modules (see section Adding interface modules in PCS 7 (Page 261))

Note

After changing the hardware configuration, it is downloaded practically automatically. This means that you no longer need to perform the steps described in sections PCS 7, step 3: Stopping the reserve CPU (Page 256) to PCS 7, step 6: Transition to redundant system mode (Page 258). 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 mode".

17.3.1 PCS 7, step 1: Modification of 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.

17.3.2 PCS 7, step 2: Offline modification of the hardware configuration

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.

17.3.3 PCS 7, step 3: Stopping the reserve CPU

Starting situation

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

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, select the reserve CPU, then click "Stop".

Result

The reserve 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 reserve 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.

17.3.4 PCS 7, step 4: Loading a new hardware configuration in 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 new hardware configuration of the reserve CPU does not yet have an effect on ongoing operation.

17.3.5 PCS 7, 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 links up, is updated (see chapter Link-up and update (Page 125)) 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
Added I/O modules	are not addressed by the CPU.	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.	
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[1] and updated by the CPU.	continue operation without interruption.
Added DP stations	are not addressed by the CPU.	as for added I/O modules (see above)	
[1] The 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 chapter Time monitoring (Page 137).

17.3.6 PCS 7, step 6: Transition to redundant system mode

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 choose "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.

Reaction of the I/O

Type of I/O	One-sided I/O of reserve CPU	One-sided I/O of 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 settings[1)] 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 137).

17.3.7 PCS 7, step 7: Editing and downloading 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 PCS 7, step 2: Offline modification of the hardware configuration (Page 255)).
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.

17.3.8 PCS7, Using 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 (steps V and 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.

17.3.9 Adding interface modules in PCS 7

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 PCS 7, step 2: Offline modification of the hardware configuration (Page 255))
2. Stop the reserve CPU (see section PCS 7, step 3: Stopping the reserve CPU (Page 256))
3. Download the new hardware configuration to the reserve CPU (see section PCS 7, step 4: Loading a new hardware configuration in the reserve CPU (Page 256))
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 PCS 7, step 5: Switch to CPU with modified configuration (Page 257))
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 PCS 7, step 6: Transition to redundant system mode (Page 258))
8. Modify and download the user program (see section PCS 7, step 7: Editing and downloading the user program (Page 259))

17.4 Removing components in PCS 7

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 287)).

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	PCS 7, step 1: Editing the hardware configuration offline (Page 263)
2	Editing and downloading the user program	PCS 7, step 2: Editing and downloading the user program (Page 264)
3	Stopping the reserve CPU	PCS 7, step 3: Stopping the reserve CPU (Page 265)
4	Loading a new hardware configuration in the reserve CPU	PCS 7, step 4: Downloading a new hardware configuration to the reserve CPU (Page 265)
5	Switch to CPU with modified configuration	PCS 7, step 5: Switching to CPU with modified configuration (Page 266)
6	Transition to redundant system mode	PCS 7, step 6: Transition to redundant system mode (Page 267)
7	Modification of hardware	PCS 7, step 7: Modification of hardware (Page 267)

Exceptions

This general procedure for system modifications does not apply to removing interface modules (see section Removing interface modules in PCS 7 (Page 269)).

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 PCS 7, step 3: Stopping the reserve CPU (Page 265) to PCS 7, step 6: Transition to redundant system mode (Page 267). 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".

17.4.1 PCS 7, step 1: Editing 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.

17.4.2 PCS 7, step 2: Editing and downloading 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.

17.4.3 PCS 7, step 3: Stopping the reserve 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. 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, select the reserve CPU, then click "Stop".

Result

The reserve 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 reserve CPU is no longer addressed.

17.4.4 PCS 7, step 4: 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 new hardware configuration of the reserve CPU does not yet have an effect on ongoing operation.

17.4.5 PCS 7, step 5: 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 (see section Link-up and update (Page 125)) 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 137).

17.4.6 PCS 7, step 6: Transition to redundant system mode

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 choose "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.

Reaction of the I/O

Type of I/O	One-sided I/O of reserve CPU	One-sided I/O of 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 137).

17.4.7 PCS 7, step 7: Modification of 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.

17.4.8 Removing interface modules in PCS 7

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 PCS 7, step 1: Editing the hardware configuration offline (Page 263))
2. Modify and download the user program (see section PCS 7, step 2: Editing and downloading the user program (Page 264))
3. Stop the reserve CPU (see section PCS 7, step 3: Stopping the reserve CPU (Page 265))
4. Download the new hardware configuration to the reserve CPU (see section PCS 7, step 4: Downloading a new hardware configuration to the reserve CPU (Page 265))
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 PCS 7, step 5: Switching to CPU with modified configuration (Page 266))
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 PCS 7, step 6: Transition to redundant system mode (Page 267))

17.5 Adding components in STEP 7

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 287)).

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

Procedure

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

Step	What to do?	See section
1	Modification of hardware	STEP 7, step 1: Adding hardware (Page 271)
2	Editing the hardware configuration offline	STEP 7, step 2: Offline modification of the hardware configuration (Page 271)
3	Expanding and downloading OBs	STEP 7, step 3: Expanding and downloading OBs (Page 272)
4	Stopping the reserve CPU	STEP 7, step 4: Stopping the reserve CPU (Page 272)
5	Downloading a new hardware configuration to the reserve CPU	STEP 7, step 5: Loading a new hardware configuration in the reserve CPU (Page 273)
6	Switching to CPU with modified configuration	STEP 7, step 6: Switch to CPU with modified configuration (Page 273)
7	Transition to redundant system mode	STEP 7, step 7: Transition to redundant system mode (Page 274)
8	Editing and downloading the user program	STEP 7, step 8: Editing and downloading the user program (Page 275)

Exceptions

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

- To use free channels on an existing module
- For adding interface modules (see section Adding interface modules in STEP 7 (Page 278))

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 7, step 4: Stopping the reserve CPU (Page 272) to STEP 7, step 8: Editing and downloading the user program (Page 275). 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".

17.5.1 STEP 7, step 1: Adding 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.

17.5.2 STEP 7, step 2: Offline modification of the hardware configuration

Starting situation

The fault-tolerant system is operating in redundant system mode. The modules added are not yet addressed.

Procedure

1. Perform all the modifications to the hardware configuration relating to the added hardware offline.
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. 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.

17.5.3 STEP 7, step 3: Expanding and downloading OBs

Starting situation

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

Procedure

1. Verify that the interrupt OBs 4x, 82, 83, 85, 86, OB 88 and 122 react to any interrupts of the new components as intended.
2. Download the modified OBs and the corresponding program elements to the target system.

Result

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

17.5.4 STEP 7, step 4: Stopping the reserve CPU

Starting situation

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

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, select the reserve CPU, then click "Stop".

Result

The reserve 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 reserve CPU is no longer addressed. OB 70 (I/O redundancy loss) is not called due to the higher-priority CPU redundancy loss (OB72).

17.5.5 STEP 7, step 5: Loading a new hardware configuration in 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 new hardware configuration of the reserve CPU does not yet have an effect on ongoing operation.

17.5.6 STEP 7, step 6: 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 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
Added I/O modules	are not addressed by the CPU.	are given new parameter settings and updated by the CPU. The output modules temporarily output the configured substitution values.	
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[1)] and updated by the CPU.	continue operation without interruption.
Added DP stations	are not addressed by the CPU.	as for added I/O modules (see above)	
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 137).

17.5.7 STEP 7, step 7: Transition to redundant system mode

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 choose "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.

Reaction of the I/O

Type of I/O	One-sided I/O of reserve CPU	One-sided I/O of master CPU	Switched I/O
Added I/O modules	are given new parameter settings and updated by the CPU. The output modules temporarily output the configured substitution values.	are updated by the CPU.	are updated by the CPU. Generate insertion interrupt; must be ignored in OB 83.
I/O modules still present	are given new parameter settings[1)] and updated by the CPU.	continue operation without interruption.	
Added DP stations	as for added I/O modules (see above)	are updated by the CPU.	
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 137).

17.5.8 STEP 7, step 8: Editing and downloading the user program

Starting situation

The fault-tolerant system is operating with the new hardware configuration in redundant system mode.

Restrictions

CAUTION

Any attempts to modify the structure of an FB interface or the instance data of an FB in redundant system mode will lead to stop system mode (both CPUs in STOP mode).

Procedure

1. Adapt the program to the new hardware configuration.
   You can add, edit or remove OBs, FBs, FCs and DBs.
2. Download only the program changes to the target system.
3. Configure the interconnections for the new CPs on both communication partners 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 processes the entire system hardware with the new user program in redundant system mode.

17.5.9 STEP7, Using 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.
- In steps 3 to 8, 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 (steps V and 6); respective output modules output the value 0.

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.

17.5.10 Adding interface modules in STEP 7

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 7, step 2: Offline modification of the hardware configuration (Page 271))
2. Expand and download the organization blocks (see section STEP 7, step 3: Expanding and downloading OBs (Page 272))
3. Stop the reserve CPU (see section STEP 7, step 4: Stopping the reserve CPU (Page 272))
4. Download the new hardware configuration to the reserve CPU (see section STEP 7, step 5: Loading a new hardware configuration in the reserve CPU (Page 273))
5. 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.
6. Switch to CPU with altered configuration (see section STEP 7, step 6: Switch to CPU with modified configuration (Page 273))
7. 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.
8. Change to redundant system mode (see section STEP 7, step 7: Transition to redundant system mode (Page 274))
9. Modify and download the user program (see section STEP 7, step 8: Editing and downloading the user program (Page 275))

17.6 Removing components in STEP 7

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 287)).

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 STEP 7. Details of each step are described in a subsection.

Step	What to do?	See section
1	Editing the hardware configuration offline	STEP 7, step 1: Editing the hardware configuration offline (Page 280)
2	Editing and downloading the user program	STEP 7, step 2: Editing and downloading the user program (Page 281)
3	Stopping the reserve CPU	STEP 7, step 3: Stopping the reserve CPU (Page 281)
4	Downloading a new hardware configuration to the reserve CPU	STEP 7, step 4: Downloading a new hardware configuration to the reserve CPU (Page 282)
5	Switching to CPU with modified configuration	STEP 7, step 5: Switching to CPU with modified configuration (Page 282)
6	Transition to redundant system mode	STEP 7, step 6: Transition to redundant system mode (Page 283)
7	Modification of hardware	STEP 7, step 7: Modification of hardware (Page 284)
8	Editing and downloading organization blocks	STEP 7, step 8: Editing and downloading organization blocks (Page 285)

Exceptions

This general procedure for system modifications does not apply to removing interface modules (see section Removing interface modules in STEP 7 (Page 286)).

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 7, step 3: Stopping the reserve CPU (Page 281) to STEP 7, step 6: Transition to redundant system mode (Page 283). 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".

17.6.1 STEP 7, step 1: Editing 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 hardware being removed offline.
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. The target system continues operation with the old configuration in redundant system mode.

17.6.2 STEP 7, step 2: Editing and downloading the user program

Starting situation

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

Restrictions

⚠ CAUTION
Any attempts to modify the structure of an FB interface or the instance data of an FB in redundant system mode will lead to stop system mode (both CPUs in STOP mode).

Procedure

1. Edit only the program elements related to the hardware removal.
   You can add, edit or remove OBs, FBs, FCs and DBs.
2. Download only the program changes to the target system.

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.

17.6.3 STEP 7, step 3: Stopping the reserve 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. 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, select the reserve CPU, then click "Stop".

Result

The reserve 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 reserve CPU is no longer addressed.

17.6.4 STEP 7, step 4: 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 new hardware configuration of the reserve CPU does not yet have an effect on ongoing operation.

17.6.5 STEP 7, step 5: 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 (see section Link-up and update (Page 125)) 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 to be removed[1)]	are no longer addressed by the CPU.		
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 137).

17.6.6 STEP 7, step 6: Transition to redundant system mode

Starting situation

The fault-tolerant system is operating with the new (restricted) hardware configuration in single mode.

Procedure

1. In SIMATIC Manager, select a CPU of the fault-tolerant system, then choose "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.

Reaction of the I/O

Type of I/O	One-sided I/O of reserve CPU	One-sided I/O of master CPU	Switched I/O
I/O modules to be removed[1)]	are no longer addressed by the CPU.		
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 137).

17.6.7 STEP 7, step 7: Modification of 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. Remove the relevant components from the system.
   - Remove the central modules from the rack.
   - Remove the modules from modular DP stations
   - Remove DP stations from 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.

17.6.8 STEP 7, step 8: Editing and downloading organization blocks

Starting situation

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

Procedure

1. Make sure that the interrupt OBs 4x and 82 no longer contain any interrupts of the removed components.
2. Download the modified OBs and the corresponding program elements to the target system.

Result

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

17.6.9 Removing interface modules in STEP 7

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 7, step 1: Editing the hardware configuration offline (Page 280))
2. Modify and download the user program (see section STEP 7, step 2: Editing and downloading the user program (Page 281))
3. Stop the reserve CPU (see section STEP 7, step 3: Stopping the reserve CPU (Page 281))
4. Download the new hardware configuration to the reserve CPU (see section STEP 7, step 4: Downloading a new hardware configuration to the reserve CPU (Page 282))
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 7, step 5: Switching to CPU with modified configuration (Page 282))
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 7, step 6: Transition to redundant system mode (Page 283))
9. Modify and download the user organization blocks (see section STEP 7, step 8: Editing and downloading organization blocks (Page 285))

17.7 Editing CPU parameters

17.7.1 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 17-1 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	Scan cycle monitoring time
	Cycle load due to communication
	Size of the process image of inputs *)
	Size of the process image of outputs *)
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
	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 288)
2	Stopping the reserve CPU	Step 2: Stopping the reserve CPU (Page 289)
3	Downloading modified CPU parameters to the reserve CPU	Step 3: Downloading a new hardware configuration to the reserve CPU (Page 290)
4	Switching to CPU with modified configuration	Step 4: Switching to CPU with modified configuration (Page 290)
5	Transition to redundant system mode	Step 5: Transition to redundant system mode (Page 291)

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 289) to Step 5: Transition to redundant system mode (Page 291). 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".

17.7.2 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.

17.7.3 Step 2: Stopping the reserve CPU

Starting situation

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

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, select the reserve CPU, then click "Stop".

Result

The reserve 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 reserve CPU is no longer addressed.

17.7.4 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.

17.7.5 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 137).

Where the values for the monitoring times in the CPUs differ, the higher values always apply.

17.7.6 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 choose "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.

Reaction of the I/O

Type of I/O	One-sided I/O of reserve CPU	One-sided I/O of 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 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 137).

Where the values for the monitoring times in the CPUs differ, the higher values always apply.

17.8 Changing the CPU memory configuration

17.8.1 Changing the CPU memory configuration

The redundant system state is only possible if both CPUs have the same memory configuration. For this the following condition must be met:

- The size and type of load memory (RAM or FLASH) on both CPUs must match.

The memory configuration of the CPUs can be modified in operation. Possible modifications of S7-400H memory:

- Expanding load memory
- Changing the type of load memory

17.8.2 Expanding load memory

The following methods of memory expansion are possible:

- Upgrade the load memory by inserting a memory card with more memory space
- Upgrade the load memory by inserting a RAM card, if no memory card was previously inserted

With this type of memory change, the entire user program is copied from the master CPU to the backup CPU during coupling (see section Update sequence (Page 132)).

Restrictions

Memory should preferably be expanded using RAM cards, because this will ensure that the user program is copied to load memory of the reserve CPU in the link-up process.

In principle, it is also possible to expand the load memory in the form of flash cards, but it is then your responsibility to load the complete user program and the hardware configuration onto the new flash card (see procedure in section Changing the type of load memory (Page 293)).

Starting situation

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

Procedure

Proceed as follows in the specified sequence:

Step	What to do?	How does the system react?
1	Switch the reserve CPU to STOP using the programming device.	The system is now operating in single mode.
2	Replace the memory card in the CPU with a card which has the required (higher) capacity.	Reserve CPU requests memory reset.
3	Reset the reserve CPU using the programming device.	–
4	Start the reserve CPU with the menu command "PLC > Mode > Switch to CPU ... with expanded memory configuration".	• The reserve CPU links up, is updated and becomes the master. • Previous master CPU changes to STOP. • System operates in single mode.
5	Modify the memory configuration of the second CPU as you did in steps 2 to 3 for the first CPU.	–
6	Start the second CPU with the menu command "Target System > Operating Mode" Select the reserve CPU and click the "Warm restart" button.	• The second CPU is linked up and updated. • The system is now operating again in redundant system mode.

17.8.3 Changing the type of load memory

The following types of memory cards are available for load memory:

- RAM card for the test and commissioning phase
- FLASH Card for permanent storage of the completed user program

The size of the new memory card is irrelevant here.

If you change your memory configuration in this way, the system does not transfer any program parts from the master CPU to the reserve CPU. Instead, it transfers only the contents of the unchanged blocks of the user program (see section Switch to CPU with modified configuration or expanded memory configuration (Page 135)).

It is your responsibility to download the entire user program to the new load memory.

Note

After reloading connections/gateways, it is no longer possible to change from a RAM card to a FLASH card.

Starting situation

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

The current status of the user program is available on the PG/ES as a STEP 7 project in block format.

CAUTION

You cannot deploy a user program you uploaded from the target system here.

It is not permissible to recompile the user program from an STL source file, because this action would set a new time stamp at all blocks and so prevent the block contents from being copied when there is a master-reserve changeover.

Procedure

Proceed as follows in the specified sequence:

Step	What to do?	How does the system react?
1	Switch the reserve CPU to STOP using the programming device.	The system is now operating in single mode.
2	Replace the existing memory card in the reserve CPU with a new one of the required type.	Reserve CPU requests memory reset.
3	Reset the reserve CPU using the programming device.	–
4	Download the program data to the reserve CPU in STEP 7 by selecting the "Download User Program to Memory Card" command. **Notice**: Select the correct CPU from the selection dialog.	–
5	Start the reserve CPU with the menu command "PLC > Mode > Switching to CPU with modified configuration".	• The reserve CPU links up, is updated and becomes the master. • Previous master CPU changes to STOP. • System operates in single mode.
6	Modify the memory configuration of the second CPU as you did for the first CPU in step 2.	–
7	Download the user program and the hardware configuration to the second CPU.	–
8	Start the second CPU from the PG.	• The second CPU is linked up and updated. • The system is now operating again in redundant system mode.

Note

If you want to change to FLASH Cards, you can load them with the user program and hardware configuration in advance without inserting them in the CPU. Steps 4 and 7 can then be omitted.

However, the memory cards in both CPUs must be loaded in the same sequence. Changing the order of blocks in the load memories will lead to termination of the link-up process.

Writing to a FLASH Card in the fault-tolerant system

You can always write to a FLASH Card while the fault-tolerant system is in RUN, without having to stop the fault-tolerant system. This is, however, only possible if the online data of the hardware configuration and the user program in both CPUs and the corresponding offline data in your engineering station match.

Inserting the Flash card

Proceed as follows:

1. Set the reserve CPU to STOP and insert the FLASH Card into the CPU.
2. Reset the CPU using STEP 7.
3. Download the program data with the STEP 7 "Download User Program to Memory Card" command. Note: Select the correct CPU from the selection dialog.
4. Switch to the CPU with the changed configuration using the "Operating Mode" dialog. This changes over the master/reserve roles; the CPU with the Flash Card is now the master CPU. The reserve CPU is now in STOP.
5. Next, insert the Flash Card in the CPU that is in STOP. Reset the CPU using STEP 7.
6. Carry out step 4: Download the program data with the STEP 7 "Download User Program to Memory Card" command. Note: Select the correct CPU from the selection dialog.
7. Execute a warm restart of the reserve CPU using the "Operating Mode" dialog. The system status now changes to "Redundant" mode.

Removing the FLASH card

The online and offline data consistency described earlier also applies when you remove FLASH Cards from a fault-tolerant system. In addition, the available RAM size must not be less than the actual size of the STEP 7 program (STEP 7 Program > Block Container > "Blocks" Properties).

1. Set the reserve CPU to STOP and remove the FLASH Card. Adapt the memory configuration as required.
2. Reset the CPU using STEP 7.
3. Download the block container using STEP 7.
4. Switch to the CPU with the changed configuration using the "Operating Mode" dialog.
5. Remove the FLASH Card from the CPU which is now in STOP. Adapt the RAM configuration as required, and then perform a CPU memory reset.
6. Execute a warm restart of the reserve CPU using the "Operating Mode" dialog. The system status now changes to "Redundant" mode.

17.9 Re-parameterization of a module

17.9.1 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 297)
2	Stopping the reserve CPU	Step 2: Stopping the reserve CPU (Page 298)
3	Downloading modified CPU parameters to the reserve CPU	Step 3: Downloading a new hardware configuration to the reserve CPU (Page 298)
4	Switching to CPU with modified configuration	Step 4: Switching to CPU with modified configuration (Page 298)
5	Transition to redundant system mode	Step 5: Transition to redundant system mode (Page 300)

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 298) to Step 5: Transition to redundant system mode (Page 300). 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".

17.9.2 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.

17.9.3 Step 2: Stopping the reserve CPU

Starting situation

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

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, select the reserve CPU, then click "Stop".

Result

The reserve 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 reserve CPU is no longer addressed.

17.9.4 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.

17.9.5 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 137).

Where the values for the monitoring times in the CPUs differ, the higher values always apply.

Calling OB 83

After transferring the parameter data records to the desired modules, OB 83 is called. The sequence is as follows:

1. After you have made the parameter changes to an module in STEP 7 and loaded them in RUN in the CPU, the OB 83 is started (trigger event W#16#3367). Relevant in the OB start information are the logical start address (OB83_MDL_ADDR) and the module type (OB83_MDL_TYPE). From now on, the input and/or output data of the module might no longer be correct, and no SFCs that send data records to this module may be active.

2. After termination of OB 83, the parameters of the module are reset.

3. After termination of the parameter reset operation, the OB 83 is started again (trigger event W#16#3267 if the parameterization was successful, or W#16#3968 if it was

unsuccessful). The input and output data of the module is the same as after an insertion interrupt, meaning that under certain circumstances may not yet be correct. With immediate effect, you can again call SFCs that send data records to the module.

17.9.6 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 choose "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.

Reaction of the I/O

Type of I/O	One-sided I/O of reserve CPU	One-sided I/O of 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 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 137).

If the values for the monitoring times in the CPUs differ, the higher values apply.

Synchronization modules

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18.1 Synchronization modules

You can obtain information on the available synchronization modules in the Service and Support Portal in the manual https://support.industry.siemens.com/cs/ww/en/view/109779483 (https://support.industry.siemens.com/cs/ww/en/view/109779483).

S7-400 cycle and response times

19

This section describes the decisive factors in the cycle and response times of your of S7-400 station.

You can read out the cycle time of the user program from the relevant CPU using the programming device (refer to the manual *Configuring Hardware and Connections with STEP 7*).

The examples included show you how to calculate the cycle time.

An important aspect of a process is its response time. How to calculate this factor is described in detail in this section. When operating a CPU 41x-H as master on the PROFIBUS DP network, you also need to include the additional DP cycle times in your calculation (see section Response time (Page 315)).

Additional information

For more detailed information on the following execution times, refer to the S7–400H instruction list. This lists all the *STEP 7* instructions that can be executed by the particular CPUs along with their execution times and all the SFCs/SFBs integrated in the CPUs and the IEC functions that can be called in *STEP 7* with their execution times.

19.1 Cycle time

This section describes the decisive factors in the cycle time, and how to calculate it.

Definition of cycle time

The cycle time is the time the operating system requires to execute a program, i.e. to execute OB 1, including all interrupt times required by program parts and for system activities.

This time is monitored.

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 processing, the CPU requires a consistent image of the process signals. To ensure this, the process signals are read/written prior to program execution. Subsequently, during program processing the CPU does not access the signal modules directly when addressing the input (I) and output (O) address areas, but rather it accesses the CPU's internal memory area containing the I/O process image.

Sequence of cyclic program processing

The table below shows the various phases in cyclic program execution.

Table 19-1 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

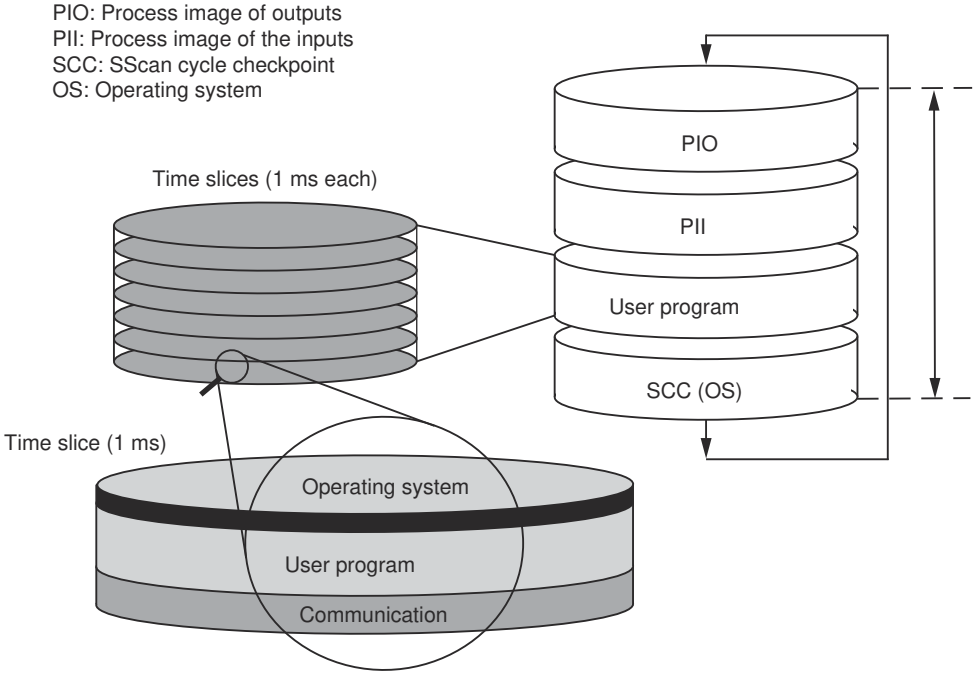


Figure 19-1 Elements and composition of the cycle time

19.2 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 section Interrupt response time (Page 326))
- Diagnostics and error processing (see also section Example of calculation of the interrupt response time (Page 328))
- Communication via MPI or the integrated PROFINET 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 operator control and monitoring of tags
  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 19-2 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** (*Programming with STEP 7* manual). See section Communication load (Page 313).
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 interface (from row F)
+ portion for each submodule with 32 byte of consistent data for the integrated PROFINET 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 19-3 Portion of the process image transfer time, CPU 412-5H

	Portion	**CPU 412–5H stand-alone mode**	**CPU 412–5H redundant**
K	Base load	10 µs	13 µs
A *)	In the central controller Read/write byte/word/double word	 9.5 µs	 35 µs
B *)	In the expansion unit with local link Read/write byte/word/double word	 24 µs	 50 µs
C *)**)	In the expansion unit with remote link Read/write byte/word/double word	 48 µs	 75 µs
D1	In the DP area for the integrated DP interface Read byte/word/double word	 0.75 µs	 35 µs
D2 ***)	In the DP area for the external DP interfaces Read/write byte/word/double word	 6.0 µs	 40 µs
E1	Consistent data in the process image for the integrated DP interface Read/write data	 28 µs	 70 µs
E2	Consistent data in the process image for the external DP interface (CP 443–5 extended) Read write	 250 µs 70 µs	 300 µs 115 µs
F	In the PNIO area for the integrated PROFINET interface Read/write for each byte/word/double word	4 µs	40 µs
G	Per submodule with 32 bytes of consistent data for the integrated PROFINET interface	28 µs	70 µs
*) In the case of I/O inserted into the central controller or expansion device, the specified value contains the execution time of 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.			

Table 19-4 Portion of the process image transfer time, CPU 414-5H

	Portion	CPU 414–5H stand-alone mode	CPU 414–5H redundant
K	Base load	8 µs	9 µs
A *)	In the central controller Read/write byte/word/double word	8.5 µs	25 µs
B *)	In the expansion unit with local link Read/write byte/word/double word	23 µs	40 µs
C *)**)	In the expansion unit with remote link Read/write byte/word/double word	47 µs	64 µs
D1	In the DP area for the integrated DP interface Read byte/word/double word	0.5 µs	21.5 µs
D2 ***)	In the DP area for the external DP interfaces Read/write byte/word/double word	5.2 µs	24.6 µs
E1	Consistent data in the process image for the integrated DP interface Read/write data	15 µs	45 µs
E2	Consistent data in the process image for the external DP interface (CP 443–5 extended) Read write	130 µs 65 µs	170 µs 100 µs
F	In the PNIO area for the integrated PROFINET interface Read/write for each byte/word/double word	3 µs	25 µs
G	Per submodule with 32 bytes of consistent data for the integrated PROFINET interface	15 µs	45 µs
*) In the case of I/O inserted into the central controller or expansion device, the specified value contains the execution time of 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.			

Table 19-5 Portion of the process image transfer time, CPU 416-5H

	Portion	CPU 416–5H stand-alone mode	CPU 416–5H redundant
K	Base load	5 µs	6 µs
A *)	In the central controller Read/write byte/word/double word	8 µs	20 µs
B *)	In the expansion unit with local link Read/write byte/word/double word	22 µs	35 µs
C *)**)	In the expansion unit with remote link Read/write byte/word/double word	46 µs	57 µs
D1	In the DP area for the integrated DP interface Read byte/word/double word	0.45 µs	15 µs

	Portion	CPU 416–5H stand-alone mode	CPU 416–5H redundant
D2 ***)	In the DP area for the external DP interfaces Read/write byte/word/double word	5.1 µs	20 µs
E1	Consistent data in the process image for the integrated DP interface Read/write data	12 µs	35 µs
E2	Consistent data in the process image for the external DP interface (CP 443–5 extended) Read write	127 µs 60 µs	141 µs 80 µs
F	In the PNIO area for the integrated PROFINET interface Read/write for each byte/word/double word	2.5 µs	20 µs
G	Per submodule with 32 bytes of consistent data for the integrated PROFINET interface	12 µs	35 µs
*) In the case of I/O inserted into the central controller or expansion device, the specified value contains the execution time of 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.			

Table 19-6 Portion of the process image transfer time, CPU 417-5H

	Portion	CPU 417–5H stand-alone mode	CPU 417–5H redundant
K	Base load	3 µs	4 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 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 interface	8 µs	30 µs

	Portion	CPU 417–5H stand-alone mode	CPU 417–5H redundant
*) In the case of I/O inserted into the central controller or expansion device, the specified value contains the execution time of 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 19-7 Extending the cycle time

Start-up	412–5H stand-alone mode	412–5H redundant	414–5H stand-alone mode	414–5H redundant	416–5H stand-alone mode	416–5H redundant	417–5H stand-alone mode	417–5H redundant
Factor	1.05	1.2	1.05	1.2	1.05	1.2	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 19-8 Operating system execution time at the cycle control point

Sequence	412-5H stand-alone mode	412–5H redundant	414-5H stand-alone mode	414–5H redundant	416–5H stand-alone mode	416–5H redundant	417-5H stand-alone mode	417–5H redundant
Cycle control at the SCCP	120-700 µs Ø 130 µs	405-2080 µs Ø 505 µs	70-450 µs Ø 80 µs	260-1350 µs Ø 310 µs	50-400 µs Ø 55	180-970 µs Ø 215	30 - 330 µs Ø 35 µs	115 - 650 µs Ø 130 µs

Extended cycle time due to nested interrupts

Table 19-9 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	Asynchronous error
CPU 412-5H stand-alone mode	240 µs	240 µs	230 µs	150 µs	150 µs	80 µs	80 µs	180 µs
CPU 412–5H redundant	680 µs	550 µs	700 µs	580 µs	450 µs	350 µs	179 µs	550 µs
CPU 414–5H stand-alone mode	160 µs	120 µs	150 µs	100 µs	100 µs	60 µs	60 µs	120 µs
CPU 414–5H redundant	420 µs	400 µs	490 µs	360 µs	280 µs	220 µs	120 µs	306 µs
CPU 416–5H stand-alone mode	120 µs	110 µs	100 µs	80 µs	60 µs	40 µs	40 µs	80 µs
CPU 416–5H redundant	300 µs	250 µs	370 µs	220 µs	200 µs	150 µs	90 µs	230 µs
CPU 417–5H stand-alone mode	90 µs	70 µs	70 µs	50 µs	50 µs	30 µs	30 µs	70 µs
CPU 417–5H redundant	200 µs	170 µs	230 µs	150 µs	150 µs	100 µs	45 µs	133 µs

The program runtime at interrupt level must be added to this time extension.

The corresponding times are added together if the program contains nested interrupts.

19.3 Different cycle times

The cycle time (T_{cyc}) length is not the same in every cycle. The figure below shows different cycle times T_{cyc1} and T_{cyc2}. T_{cyc2} is longer than T_{cyc1} because the cyclically executed OB 1 is interrupted by a TOD interrupt OB (here: OB 10).

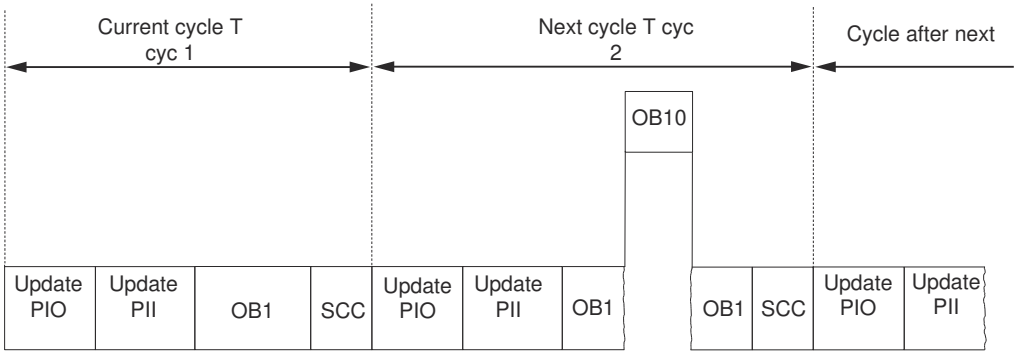


Figure 19-2 Different cycle times

Fluctuation of the block processing time (e.g. OB 1) may also be a factor causing cycle time fluctuation, due to:

- conditional instructions
- conditional block calls
- different program paths
- loops, etc.

Maximum cycle time

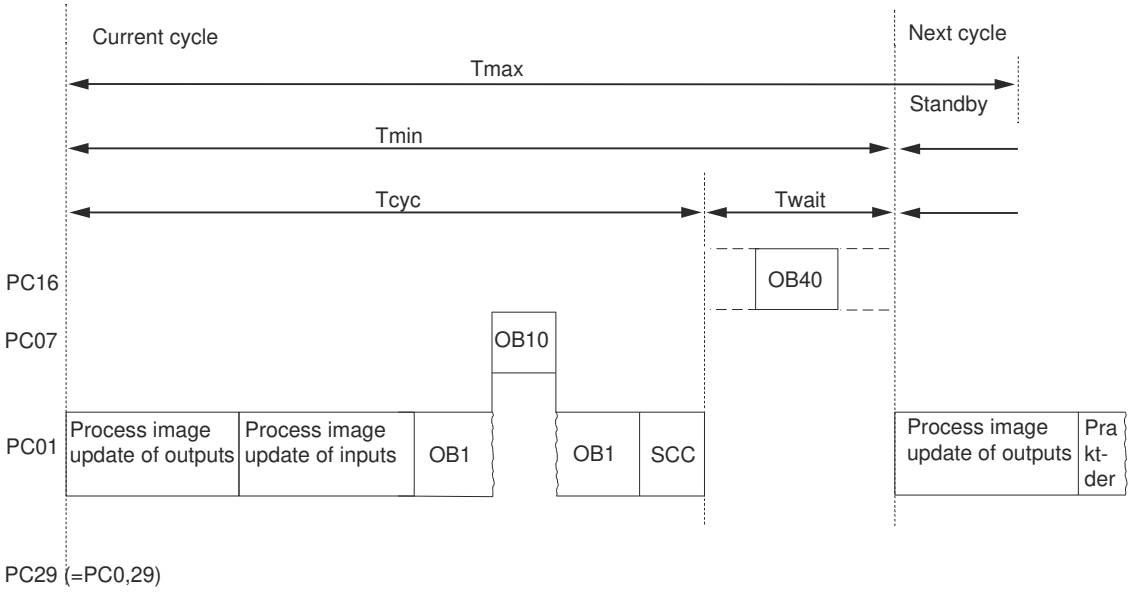
In STEP 7 you can modify the default maximum cycle time (scan cycle monitoring time). OB 80 is called when this time expires. In this block you can specify the CPUs response to this time error. If you do not retrigger the cycle time with SFC 43, OB 80 doubles the cycle time at the first call. In this case the CPU switches to STOP mode when OB 80 is called a second time.

The CPU switches to STOP mode if OB 80 does not exist in its memory.

Minimum cycle time

In STEP 7 you can set a minimum cycle time for a CPU. This is practical if

- the intervals between starting program execution of OB 1 (free cycle) are to be more or less of the same length, or
- the cycle time were too short, the process images would be updated more often than necessary



Tmin = configurable minimum cycle time
Tmax = configurable maximum cycle time
Tcyc = the cycle time
Twait = difference between Tmin and the actual cycle time. Within this time you can process interrupt events or SCC tasks
PC = Priority Class

Figure 19-3 Minimum cycle time

The actual cycle time is the sum of T_{cyc} and T_{wait}. It is thus always longer or equal to T_{min}.

19.4 Communication load

The operating system provides the CPU continuously with the configured time slices as a percentage of the overall CPU processing resources (time slice technique). Processing performance not required for communication is made available to other processes.

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 mean value, i.e. communication resources may take significantly more than 20% of a time slice. 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 19-4 Formula: Influence of communication load

Data consistency

The user program is interrupted to process communications. This interruption can be triggered after any statement. 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 the "Consistent data" section.

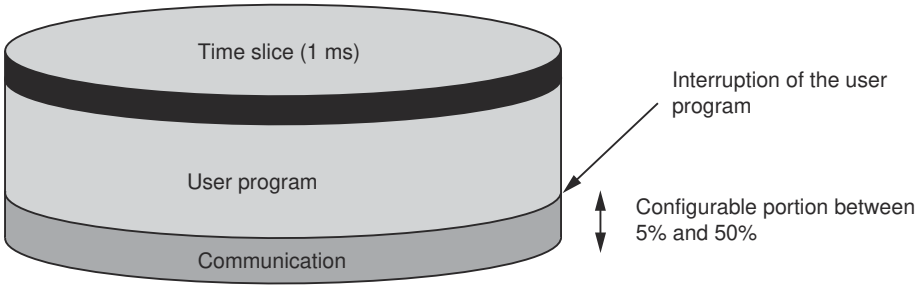


Figure 19-5 Distribution of a time slice

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

In the hardware configuration you have set a communication load of 50 %.

The calculated cycle time is 10 ms.

This means that 500 µs remain in each time slice for the cycle. So 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. So 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.

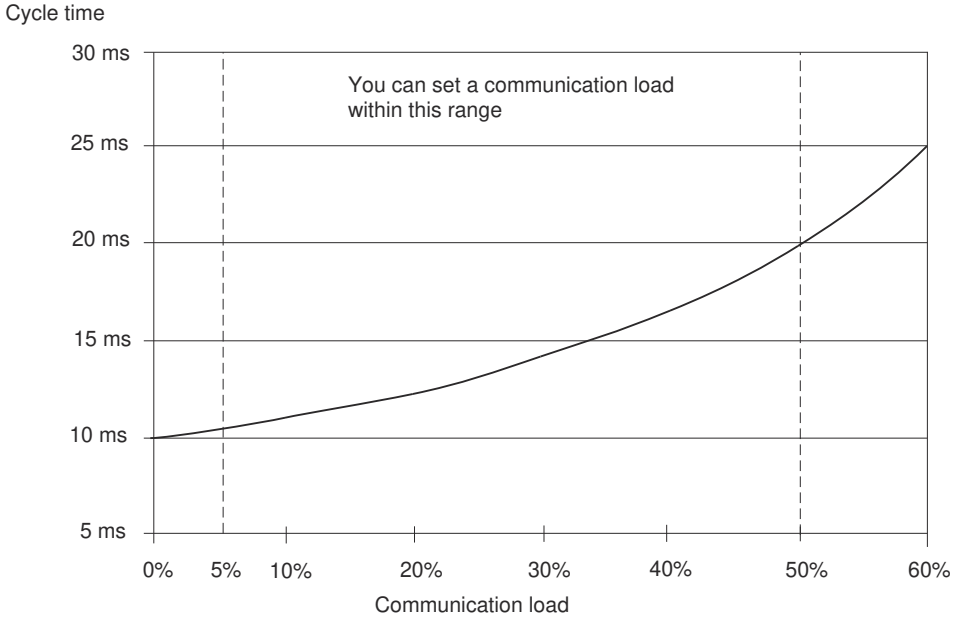


Figure 19-6 Dependency of the cycle time on communication load

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.

Recommendations

- Use the default setting whenever possible.
- Increase this value only if the CPU is used primarily for communication, and if time is not a critical factor for the user program! In all other situations you should only reduce this value!

19.5 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 section below deals with the shortest and longest response times, in order to provide an overview of the fluctuation in the length of response times.

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 the I/Os

Make allowances for the following module-specific delay times:

- For digital inputs: the input delay time
- For digital inputs with interrupt function: the input delay time + internal preparation time
- For digital outputs: negligible delay times
- For relay outputs: typical delay times of 10 to 20 ms.
  The delay of the relay outputs is dependent 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 that, on average, each DP secondary has 4 bytes of data.

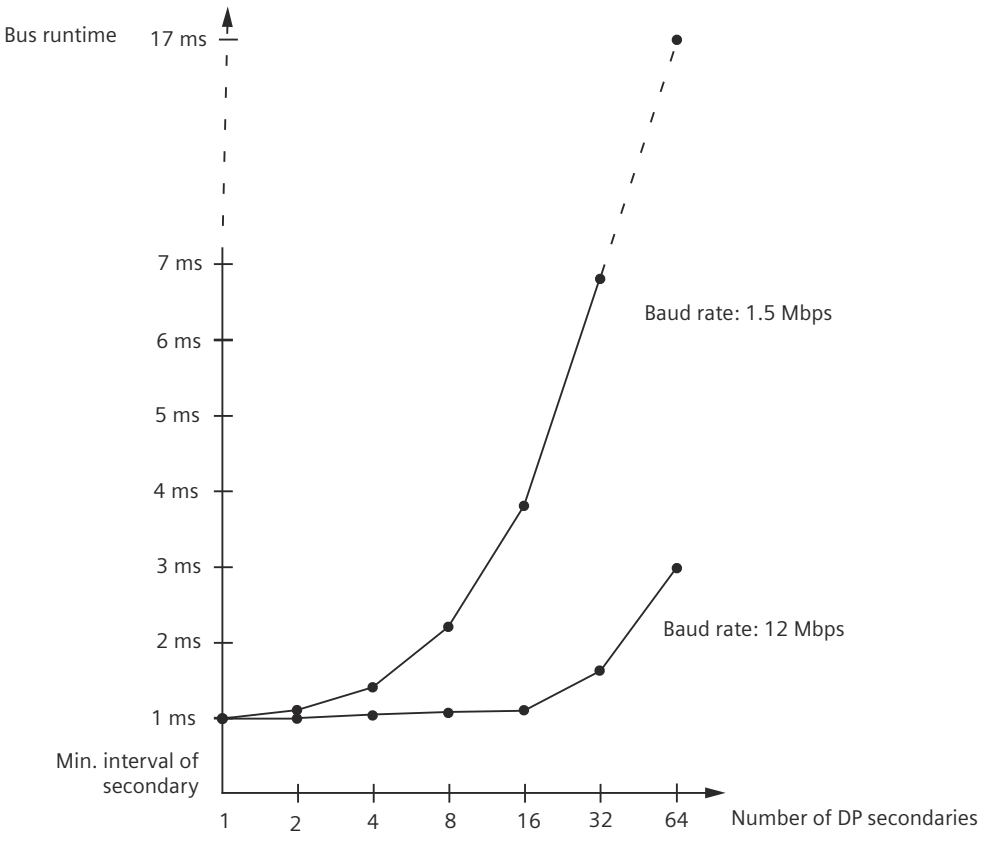


Figure 19-7 DP cycle times on the PROFIBUS DP network

If you operate a PROFIBUS DP network with multiple primaries, you must take the DP cycle time for each primary into account, i.e. create the calculation for each primary separately and add them up.

Shortest response time

The figure below shows the conditions under which the shortest response time is achieved.

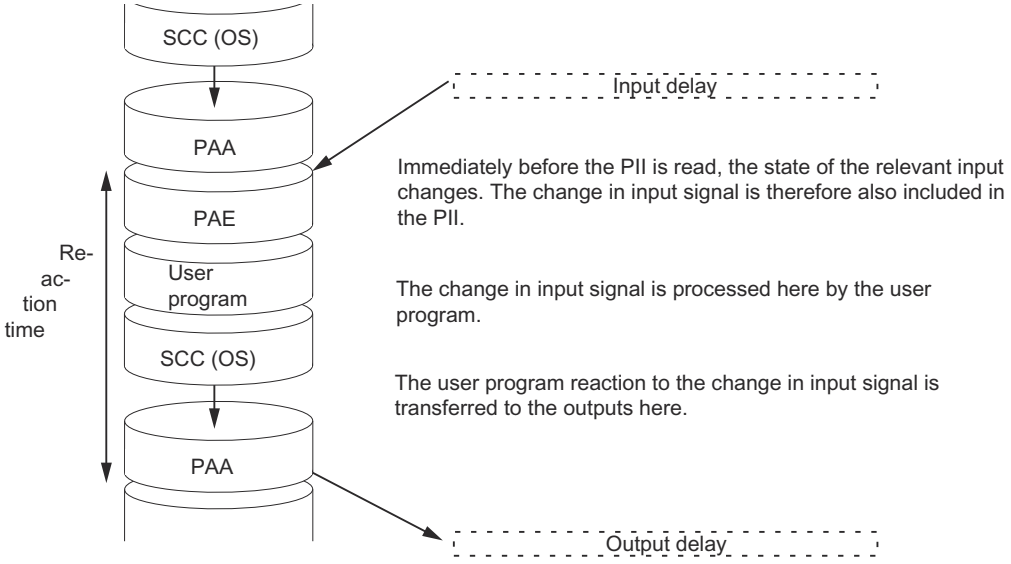


Figure 19-8 Shortest response time

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 unit, you must also add twice the runtime of the DP secondary frame (including processing in the DP primary).

Longest response time

The figure below shows the conditions under which the longest response time is achieved.

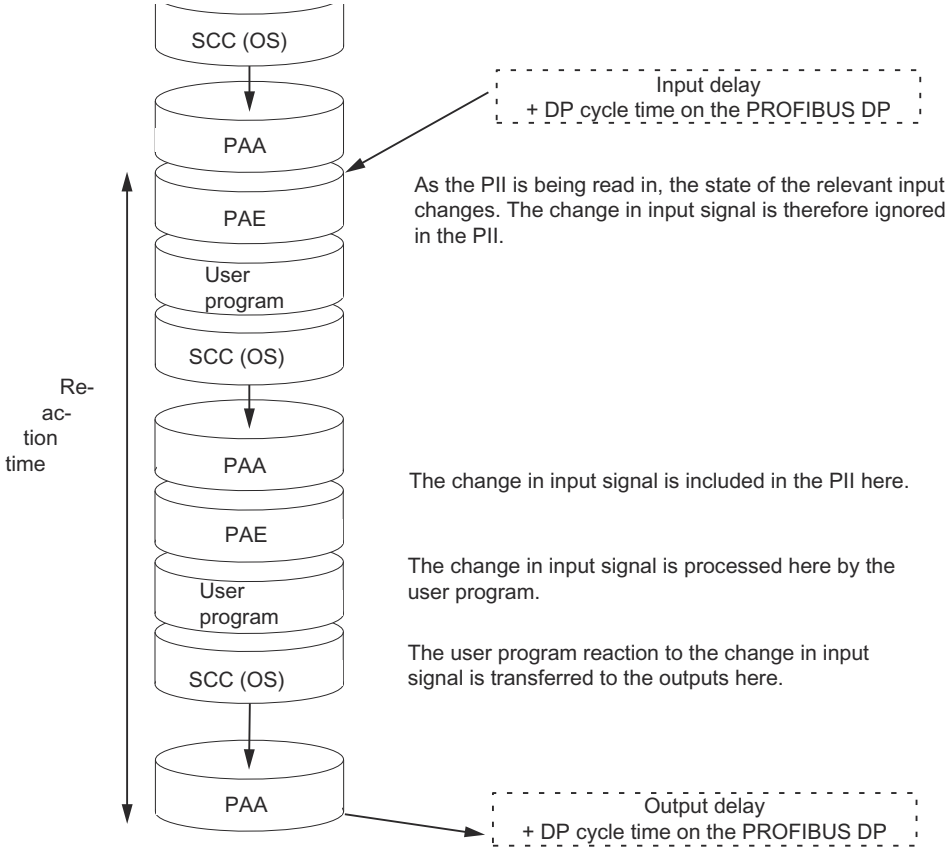


Figure 19-9 Longest response time

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 runtime of DP secondary frame (including processing in DP primary) +
- 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 with direct access to the I/Os in your user program, e.g. with the following operations:

- L PEB
- 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
- User program execution time (can be interrupted by higher-priority interrupt handling)
- Runtime of direct access
- Twice the bus delay time 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 19-10 Direct access of the CPUs to I/O modules in the central rack

Access mode	412-5H stand-alone mode	412-5H redundant	414-5H stand-alone mode	414-5H redundant	416-5H stand-alone mode	416-5H redundant	417-5H stand-alone mode	417-5H redundant
Read byte	3.0 µs	33.9 µs	2.6 µs	21.0 µs	2.3 µs	15.9 µs	2.2 µs	11.2 µs
Read word	4.0 µs	33.9 µs	4.0 µs	24.5 µs	4.0 µs	16.2 µs	3.9 µs	11.7 µs
Read double word	7.0 µs	33.9 µs	7.0 µs	24.5 µs	7.0 µs	17.2 µs	7.0 µs	14.7 µs
Write byte	3.0 µs	33.9 µs	2.6 µs	21.5 µs	2.4 µs	16.0 µs	2.3 µs	11.3 µs
Write word	4.0 µs	33.9 µs	4.0 µs	24.5 µs	4.0 µs	16.2 µs	3.9 µs	11.8 µs
Write double word	7.5 µs	33.9 µs	7.4 µs	24.5 µs	7.3 µs	18.5 µs	7.1 µs	15.0 µs

Table 19-11 Direct access of the CPUs to I/O modules in the expansion unit with local link

Access mode	412-5H stand-alone mode	412-5H redundant	414-5H stand-alone mode	414-5H redundant	416-5H stand-alone mode	416-5H redundant	417-5H stand-alone mode	417-5H redundant
Read byte	6.0 µs	36.0 µs	5.6 µs	24.5 µs	5.6 µs	16.1 µs	5.6 µs	13.4 µs
Read word	11.0 µs	41.3 µs	10.5 µs	32.1 µs	10.5 µs	23.8 µs	10.5 µs	18.6 µs
Read double word	20.0 µs	49.0 µs	19.9 µs	40.0 µs	19.9 µs	31.7 µs	19.9 µs	28.7 µs
Write byte	5.3 µs	35.3 µs	5.3 µs	24.5 µs	5.3 µs	16.1 µs	5.3 µs	13.4 µs
Write word	10.6 µs	41.3 µs	10.2 µs	28.6 µs	10.2 µs	21.5 µs	10.2 µs	18.3 µs
Write double word	19.8 µs	49.0 µs	19.8 µs	39.8 µs	19.8 µs	31.5 µs	19.8 µs	28.0 µs

Table 19-12 Direct access of the CPUs to I/O modules in the expansion unit with remote link, setting 100 m

Access mode	412-5H stand-alone mode	412-5H redundant	414-5H stand-alone mode	414–5H redundant	416-5H stand-alone mode	416-5H redundant	417-5H stand-alone mode	417–5H redundant
Read byte	11.5 µs	41.3 µs	11.5 µs	27.5 µs	11.4 µs	20.3 µs	11.3 µs	17.0 µs
Read word	23.0 µs	49.0 µs	23.0 µs	39.8 µs	22.8 µs	31.5 µs	22.8 µs	28.6 µs
Read double word	46.0 µs	72.1 µs	46.0 µs	62.9 µs	45.9 µs	54.5 µs	45.9 µs	51.7 µs
Write byte	11.0 µs	41.3 µs	11.0 µs	27.0 µs	10.8 µs	20.2 µs	10.8 µs	16.8 µs
Write word	22.0 µs	49.0 µs	22.0 µs	39.8 µs	21.9 µs	31.5 µs	21.9 µs	27.8 µs
Write double word	44.5 µs	72.1 µs	44.5 µs	62.9 µs	44.0 µs	54.5 µs	44.0 µs	50.0 ms

Note

You can also achieve fast response times by using hardware interrupts; see section Interrupt response time (Page 326).

19.6 Calculating cycle and response times

Cycle time

1. Using the Instruction List, determine the runtime of the user program.
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 19-13 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**.

19.7 Examples of calculating the cycle and response times

Example I

You have installed an S7-400 with the following modules in the central unit:

- a CPU 414–5H 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 rack; 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 414–5H 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 was parameterized 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.
  - Analog input module SM 431; AI 8×13Bit was parameterized for 50 Hz interference frequency suppression. 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 parameterized for operation in the 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 of 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 unit, 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.

19.8 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
+ PROFIBUS DP cycle time on PROFINET

= 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

= Longest interrupt response time

Process and diagnostic interrupt response times of the CPUs

Table 19-14 Process and interrupt response times; maximum interrupt response time without communication

CPU	Hardware interrupt response times		Diagnostic interrupt response times	
	min.	max.	min.	max.
412-5H stand-alone mode	190 µs	370 µs	200 µs	390 µs
412–5H redundant	370 µs	850 µs	410 µs	690 µs
414–5H stand-alone mode	140 µs	200 µs	150 µs	330 µs
414–5H redundant	330 µs	620 µs	290 µs	490 µs
416–5H stand-alone mode	90 µs	140 µs	90 µs	200 µs
416–5H redundant	240 µs	500 µs	200 µs	400 µs
417–5H stand-alone mode	80 µs	90 µs	80 µs	90 µs
417–5H redundant	160 µs	310 µs	140 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 41x–5H t_v = 100 µs + 1000 µs × n%, significant extension possible

where n = cycle load due to communication

Signal modules

The process interrupt response time of signal modules is made up as follows:

- Digital input modules
  Process 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
  Process 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 process interrupt OB4x is called. Higher-priority interrupts stop process interrupt processing. Direct access to I/O modules is executed during the execution time of the operation. After the process interrupt has been processed, the system either resumes cyclic program processing, or calls and processes interrupt OBs of the same or lower priority.

19.9 Example of calculation of the interrupt response time

Elements of the interrupt response time

As a reminder: The process interrupt response time is made up of:

- The process interrupt response time of the CPU
- The process interrupt response time of the signal module
- Twice the DP cycle time on PROFIBUS DP

Example: You have installed a 417-5H CPU and four digital modules in the central controller. One digital input module is the SM 421; DI 16×UC 24/60 V; with process and diagnostic interrupts. You have enabled only the process interrupt in your CPU and SM parameterization. You decided not to use time-driven processing, diagnostics or error handling. You have parameterized an input delay of 0.5 ms for the digital input modules. No activities are required at the scan cycle checkpoint. You have set a cycle load of 20% due to communication.

Calculation

In this example, the process interrupt response time is based on following time factors:

- Process interrupt response time of CPU 417-5H: Approx. 0.3 ms (mean value in redundant system mode)
- Extension due to communication according to the description in section Interrupt response time (Page 326):

100 µs + 1000 µs × 20% = 300 µs = 0.3 ms

- Process 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 unit.

The process interrupt response time is equivalent to the sum of the listed time factors:

Process interrupt response time = 0.3 ms + 0.3 ms + 0.5 ms + 0.5 ms = **approx. 1.6 ms**.

This calculated process 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.

19.10 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 19-15 Reproducibility of time-delay and cyclic interrupts of the CPUs

Module	Reproducibility	
	Time-delay interrupt	Cyclic interrupt
CPU 412-5H stand-alone mode	± 230 µs	± 250 µs
CPU 412–5H redundant	± 430 µs	± 520 µs
CPU 414–5H stand-alone mode	± 160 µs	± 240 µs
CPU 414–5H redundant	± 280 µs	± 280 µs
CPU 416–5H stand-alone mode	± 130 µs	± 190 µs
CPU 416–5H redundant	± 230 µs	± 210 µs
CPU 417–5H stand-alone mode	± 120 µs	± 160 µs
CPU 417–5H 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.

Technical data

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20.1 Technical specification of the CPU 412–5H PN/DP; (6ES7 412–5HK06–0AB0)

CPU and firmware version	
Order number	6ES7 412–5HK06–0AB0
• Firmware version	V 6.0
Corresponding programming package	as of STEP7 V 5.5 SP2 HF 1 see also Preface (Page 13)
Memory	
Work memory	
• integrated	512 KB for code 512 KB for data
Load memory	
• integrated	512 KB RAM
• Expandable FEPROM	With memory card (FLASH) 1 MB to 64 MB
• Expandable RAM	With memory card (RAM) 256 KB to 64 MB
Battery backup	Yes, all data
Typical execution times	
Execution times of	
• Bit instructions	31.25 ns
• Word instructions	31.25 ns
• Fixed-point arithmetic	31.25 ns
• Floating-point arithmetic	62.5 ns
Timers/counters and their retentivity	
S7 counters	2048
• Retentivity, configurable	From C 0 to C 2047
• Default	From C 0 to C 7
• Counting range	0 to 999
IEC counters	Yes
• Type	SFB
S7 timers	2048
• Retentivity, configurable	From T 0 to T 2047
• Default	No retentive timers
• Time range	10 ms to 9990 s
IEC timers	Yes
• Type	SFB
Data areas and their retentivity	

Total retentive data area (incl. bit memories, timers, counters)	Total work and load memory (with backup battery)
Bit memory	8 KB
• Retentivity, configurable	From MB 0 to MB 8191
• Preset retentivity	From MB 0 to MB 15
Clock memories	8 (1 bit memory byte)
Data blocks	Maximum 6000 (DB 0 reserved) Number range 1 - 16000
• Size	Maximum 64 KB
Local data (configurable)	Maximum 16 KB
• Default	8 KB
Blocks	
OBs	See *instruction list*
• Size	Maximum 64 KB
Number of free-cycle OBs	OB 1
Number of time-of-day interrupt OBs	OB 10, 11, 12, 13
Number of time-delay interrupt OBs	OB 20, 21, 22, 23
Number of cyclic interrupts	OB 32, 33, 34, 35
Number of process interrupt OBs	OB 40, 41, 42, 43
Number of DPV1 interrupt OBs	OB 55, 56, 57
Number of redundancy error OBs:	OB 70, 72
Number of asynchronous error OBs	OB 80, 81, 82, 83, 84, 85, 86, 87, 88
Number of restart OBs	OB 100, 102
Number of synchronous error OBs	OB 121, 122
Nesting depth	
• Per priority class	24
• Additional ones in an error OB	1
FBs	Maximum 3000 Number range 0 - 7999
• Size	Maximum 64 KB
FCs	Maximum 3000 Number range 0 - 7999
• Size	Maximum 64 KB
SDBs	Maximum 2048
Address ranges (I/O)	
Total I/O address range	8 KB/8 KB
• of those distributed	Including diagnostics addresses, addresses for I/O interfaces, etc.
MPI/DP interface	2 KB/2 KB
DP interface	4 KB/4 KB
PN interface	8 KB/8 KB
Process image	8 KB / 8 KB (configurable)
• Default	256 bytes/256 bytes
• Number of process image partitions	Maximum 15

• Consistent data	Max. 244 bytes
Access to consistent data in the process image	Yes
Consistent data via PROFIBUS Via integrated PROFINET interface	Max. 244 bytes Max. 1024 bytes
Digital channels	Maximum 65536/Maximum 65536
• of those central	Maximum 65536/Maximum 65536
Analog channels	Maximum 4096/Maximum 4096
• of those central	Maximum 4096/Maximum 4096
Configuration	
Central controllers/expansion units	Maximum 2/20
Multicomputing	No
Number of plug-in IMs (total)	Maximum 6
• IM 460	Maximum 6
• IM 463–2	Maximum 4, in stand-alone mode only
Number of DP primaries	
• integrated	2
• Via CP 443–5 Ext.	Maximum 10
Number of plug-in S5 modules via adapter casing (in the central controller)	None
Operable function modules and communication processors	
• FM, CP (point-to-point) see Appendix Function modules and communication processors supported by the S7-400H (Page 395)	Limited by the number of slots and connections
• CP 441	Limited by the number of connections
• PROFIBUS and Ethernet CPs, including CP 443–5 Extended	Maximum 14, of which maximum 10 CPs configured as DP primary
Connectable OPs	47
Time	
Clock (real-time clock)	Yes
• Buffered	Yes
• Resolution	1 ms
Maximum deviation per day	
• Power off (backed up)	1.7 s
• Power on (not backed up)	8.6 s
Operating hours counter	16
• Number/number range	0 to 15
• Range of values	SFC 2, 3 and 4:0 to 32767 hours 0 to 2^{31} -1 hours when SFC 101 is used:
• Granularity	1 hour
• Retentive	Yes
Time synchronization	Yes
• In AS, on MPI, DP and Ethernet MMS	As primary or secondary

• On Ethernet over NTP	As client
Time difference in the system with synchronization via MPI	Max. 200 ms
Time difference in the system with synchronization via Ethernet	Max. 10 ms
S7 alarm functions	
Number of stations that can be logged on	
For block-related alarms with SFC (Alarm_S/SQ and/or Alarm_D/DQ)	47
For block-related alarms with SFB (Notify, Notify_8, Alarm, Alarm_8, Alarm 8P)	8
Block-related alarms with SFC	Yes
• Simultaneously active Alarm_S/SQ blocks or Alarm_D/DQ blocks	Maximum 250
Block-related alarms with SFB	Yes
• Number of communication jobs for block-related alarms with SFC **and** blocks for S7 communication (programmable)	Maximum 600
• Default	300
Process control alarms	Yes
Number of archives that can be logged on simultaneously (SFB 37 AR_SEND)	16
Test and commissioning functions	
Status/modify tag	Yes, maximum 16 tag tables
• Tag	Inputs/outputs, bit memories, DB, distributed inputs/outputs, timers, counters
• Number of tags	Maximum 70
Forcing	Yes
• Tag	Inputs/outputs, bit memories, distributed I/O
• Number of tags	Maximum 256
Status LED	Yes, FRCE-LED
Block status	Yes, maximum 16 blocks at the same time
Single-step	Yes
Number of breakpoints	Maximum 16
Diagnostic buffer	Yes
• Number of entries	Maximum 3200 (configurable)
• Default	120
Communication	
PG/OP communication	Yes
Routing	Yes
S7 communication	Yes
• User data per job	Maximum 64 KB
• of which consistent	1 tag (462 bytes)
S7 basic communication	No
Global data communication	No

S5-compatible communication	Using FC AG_SEND and AG_RECV, max. via 10 CPs 443–1 or 443–5
• User data per job	Maximum 8 KB
• of which consistent	240 bytes
Number of simultaneous AG_SEND/AG_RECV jobs	Maximum 64/64, see CP manual
Standard communication (FMS)	Yes, via CP and loadable FB
Number of connection resources for S7 connections across all interfaces and CPs	48, incl. one each reserved for programming device and OP
Open IE communication over TCP/IP	
Number of connections / access points, total	Maximum 46
Possible port numbers	1 to 49151
Where parameters are assigned without specification of a port number, the system assigns a port from the dynamic port number range between 49152 and 65534	
Reserved port numbers	0 reserved TCP 20, 21 FTP TCP 25 SMTP TCP 102 RFC1006 UDP 135 RPC-DCOM UDP 161 SNMP_REQUEST UDP 34962 PN IO UDP 34963 PN IO UDP 34964 PN IO UDP 65532 NTP UDP 65533 NTP UDP 65534 NTP UDP 65535 NTP
TCP/IP	Yes, via integrated PROFINET interface and loadable FBs
• Maximum number of connections	46
• Data length, max.	32 KB
ISO-on-TCP	Yes (via integrated PROFINET interface or CP 443-1/ EX20/GX 20 and loadable FBs)
• Maximum number of connections	46
• Maximum data length via integrated PROFINET interface	32 KB
• Maximum data length via CP 443-1	1452 bytes
UDP	Yes, via integrated PROFINET interface and loadable blocks
• Maximum number of connections	46
• Data length, max.	1472 bytes
Interfaces	
You must **not** configure the CPU as DP secondary	
1st interface	
Interface designation	X1
Type of interface	integrated
Physics	RS 485/PROFIBUS and MPI
Electrically isolated	Yes

Power supply to interface (15 V DC to 30 V DC)	Max. 150 mA
Number of connection resources	MPI: 32, DP: 16 If a diagnostic repeater is used on the line, the number of connection resources on the line is reduced by 1.
Functionality	
• MPI	Yes
• PROFIBUS DP	DP primary
1st interface in MPI mode	
Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Transmission rates	Maximum 12 Mbps
1st interface in DP primary mode	
Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Constant bus cycle time	No
• Isochronous mode	No
• SYNC/FREEZE	No
• Enabling/disabling of DP secondaries	No
• Direct data exchange (cross-traffic)	No
Transmission rates	Maximum 12 Mbps
Number of DP secondaries	Maximum 32
Number of slots per interface	Maximum 544
Address range	Maximum 2 KB inputs / 2 KB outputs
User data per DP secondary	Maximum 244 Maximum 244 bytes inputs Maximum 244 bytes outputs Maximum 244 slots Maximum 128 bytes per slot
Note: • The total of input bytes across all slots may not exceed 244. • The total of output bytes across all slots may not exceed 244. • The total address range of the interface (maximum 2 KB inputs/2 KB outputs) must not be exceeded across all 32 secondaries.	
2nd interface	
Interface designation	X2

Type of interface	integrated
Physics	RS 485/PROFIBUS
Electrically isolated	Yes
Power supply to interface (15 V DC to 30 V DC)	Max. 150 mA
Number of connection resources	16
Functionality	
• PROFIBUS DP	DP primary
2nd interface in DP primary mode	
Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Constant bus cycle time	No
• SYNC/FREEZE	No
• Enabling/disabling of DP secondaries	No
• Direct data exchange (cross-traffic)	No
• Transmission rates	Up to 12 Mbps
• Number of DP secondaries	Maximum 64
• Number of slots per interface	Maximum 1088
• Address range	Maximum 4 KB inputs/ 4 KB outputs
• User data per DP secondary	Maximum 244 bytes Maximum 244 bytes inputs, Maximum 244 bytes outputs, Maximum 244 slots Maximum 128 bytes per slot
Note: • The total of input bytes across all slots may not exceed 244. • The total of output bytes across all slots may not exceed 244. • The total address range of the interface (maximum 4 KB inputs/4 KB outputs) must not be exceeded across all 96 secondaries.	
3rd interface	
Interface designation	X5
Type of interface	PROFINET
Physics	Ethernet RJ45 2 ports (switch)
Electrically isolated	Yes
Autosensing (10/100 Mbps)	Yes
Autonegotiation	Yes
Auto-crossover	Yes
Media redundancy	Yes
System redundancy	Yes
• Changeover time on line interruption, typical	200 ms (PROFINET MRP)

• Number of nodes on the ring, max.	50
Change of the IP address at runtime, supported	No
Keep Alive function, supported	Yes
Functionality	
• PROFINET	Yes
Utilities	
• PG communication	Yes
• OP communication	Yes
• S7 communication Maximum number of configurable connections Maximum number of instances	Yes 48, one of each reserved for programming device and OP 600
• S7 routing	Yes
• PROFINET IO controller	Yes
• PROFINET I-Device	No
• PROFINET CBA	No
Open IE communication	
• over TCP/IP	Yes
• ISO-on-TCP	Yes
• UDP	Yes
• Time synchronization	Yes
PROFINET IO	
PNO ID (hexadecimal)	Vendor ID: 0x002A Device ID: 0x0102
Number of integrated PROFINET IO controllers	1
Number of PROFINET IO devices that can be connected	256
Number of connectable IO devices for RT of which are in line	256 256
Shared Device, supported	No
Address range	Maximum 8 KB inputs/outputs
Number of submodules	Maximum 8192 Mixed modules count twice
Maximum user data length, including user data qualifiers	1440 bytes
Maximum user data consistency, including user data qualifiers	1024 bytes
Send clock cycles	250 µs, 500 µs, 1 ms, 2 ms, 4 ms
Update Time	250 µs, 0.5 ms, 1 ms, 2 ms, 4 ms, 8 ms, 16 ms, 32 ms, 64 ms, 128 ms, 256 ms, and 512 ms The minimum value depends on the communication slice set for PROFINET IO, the number of IO devices, and the amount of configured user data.
Maximum user data length	1024 bytes per address range
Maximum consistency of user data	1024 bytes per address range

S7 protocol functions	
• PG functions	Yes
• OP functions	Yes
IRT (Isochronous Real Time)	No
Prioritized startup Accelerated (ASU) and Fast Startup Mode (FSU)	No
Tool change	No
Changing an IO device without Micro Memory Card or PG	Yes
4th and 5th interface	
Designation of the interfaces	IF1, IF2
Type of interface	Plug-in synchronization module (FOC)
Usable interface module	Synchronization module IF 960 (only in redundant mode; in stand-alone mode the interface remains free/covered)
Length of the synchronization cable	Max. 10 km
Programming	
Programming language	LAD, FBD, STL, SCL, CFC, Graph, HiGraph®
Instruction set	See instruction list
Nesting levels	7
System functions (SFC)	See instruction list
Number of simultaneously active SFCs per segment	
• SFC 59 "RD_REC"	8
• SFC 58 "WR_REC"	8
• SFC 55 "WR_PARM"	8
• SFC 57 "PARM_MOD"	1
• SFC 56 "WR_DPARM"	2
• SFC 13 "DPNRM_DG"	8
• SFC 51 "RDSYSST"	8
• SFC 103 "DP_TOPOL"	1
The total number of active SFCs on all external segments may be four times more than on one single segment.	
System function blocks (SFB)	See instruction list
Number of simultaneously active SFBs per segment	
• SFB 52 "RDREC"	8
• SFB 53 "WRREC"	8
The total number of active SFBs on all external segments may be four times more than on one single segment.	
User program protection	Password protection
Access-protected blocks	Yes, with S7 Block Privacy
Access to consistent data in the process image	Yes
CiR synchronization time (in stand-alone mode)	
Total load	100 ms
Dimensions	

Mounting dimensions W x H x D (mm)	50 x 290 x 219
Slots required	2
Weight	Approx. 995 g
Voltages and currents	
Current consumption from S7-400 bus (5 V DC)	Typ. 1.6 A Max. 1.9 A
Current consumption from S7-400 bus (24 V DC) The CPU does not consume any current at 24 V, it only makes this voltage available on the MPI/DP interface.	Total current consumption of the components connected to the MPI/DP interfaces, but maximum 150 mA per interface
Current output to DP interface (5 V DC)	Max. 90 mA
Backup current	Typically 180 µA (up to 40 °C) Maximum 1000 µA
Maximum backup time	See *Module Specifications* Reference Manual, chapter 3.3.
Feed of external backup voltage to the CPU	5 V DC to 15 V DC
Power loss	Typ. 7.5 W

20.2 Technical specifications of the CPU 414–5H PN/DP; (6ES7 414–5HM06–0AB0)

CPU and firmware version	
Order number	6ES7 414–5HM06–0AB0
• Firmware version	V 6.0
Corresponding programming package	as of STEP7 V 5.5 SP2 HF 1 see also Preface (Page 13)
Memory	
Work memory	
• integrated	2 MB for code 2 MB for data
Load memory	
• integrated	512 KB RAM
• Expandable FEPROM	With memory card (FLASH) 1 MB to 64 MB
• Expandable RAM	With memory card (RAM) 256 KB to 64 MB
Battery backup	Yes, all data
Typical execution times	
Execution times of	
• Bit instructions	18.75 ns
• Word instructions	18.75 ns
• Fixed-point arithmetic	18.75 ns
• Floating-point arithmetic	37.5 ns
Timers/counters and their retentivity	
S7 counters	2048
• Retentivity, configurable	From C 0 to C 2047
• Default	From C 0 to C 7
• Counting range	0 to 999
IEC counters	Yes
• Type	SFB
S7 timers	2048
• Retentivity, configurable	From T 0 to T 2047
• Default	No retentive timers
• Time range	10 ms to 9990 s
IEC timers	Yes
• Type	SFB
Data areas and their retentivity	
Total retentive data area (incl. bit memories, timers, counters)	Total work and load memory (with backup battery)
Bit memory	8 KB
• Retentivity, configurable	From MB 0 to MB 8191
• Preset retentivity	From MB 0 to MB 15
Clock memories	8 (1 bit memory byte)

Data blocks	Maximum 6000 (DB 0 reserved) Number range 1 - 16000
• Size	Maximum 64 KB
Local data (configurable)	Maximum 16 KB
• Default	8 KB
Blocks	
OBs	See instruction list
• Size	Maximum 64 KB
Number of free-cycle OBs	OB 1
Number of time-of-day interrupt OBs	OB 10, 11, 12, 13
Number of time-delay interrupt OBs	OB 20, 21, 22, 23
Number of cyclic interrupts	OB 32, 33, 34, 35
Number of process interrupt OBs	OB 40, 41, 42, 43
Number of DPV1 interrupt OBs	OB 55, 56, 57
Number of redundancy error OBs:	OB70, 72
Number of asynchronous error OBs	OB 80, 81, 82, 83, 84, 85, 86, 87, 88
Number of restart OBs	OB 100, 102
Number of synchronous error OBs	OB 121, 122
Nesting depth	
• Per priority class	24
• Additional ones in an error OB	1
FBs	Maximum 3000 Number range 0 - 7999
• Size	Maximum 64 KB
FCs	Maximum 3000 Number range 0 - 7999
• Size	Maximum 64 KB
SDBs	Maximum 2048
Address ranges (I/O)	
Total I/O address range	8 KB/8 KB
• of those distributed	Including diagnostic addresses, addresses for I/O interfaces, etc.
MPI/DP interface	2 KB/2 KB
DP interface	6 KB/6 KB
Process image	8 KB / 8 KB (configurable)
• Default	256 bytes/256 bytes
• Number of process image partitions	Maximum 15
Consistent data via PROFIBUS Via integrated PROFINET interface	Max. 244 bytes Max. 1024 bytes
• Consistent data	Max. 244 bytes
Access to consistent data in the process image	Yes
Digital channels	Maximum 65536/ Maximum 65536

• of those central	Maximum 65536/ Maximum 65536
Analog channels	Maximum 4096/ Maximum 4096
• of those central	Maximum 4096/ Maximum 4096
Configuration	
Central controllers/expansion units	Maximum 2/20
Multicomputing	No
Number of plug-in IMs (total)	Maximum 6
• IM 460	Maximum 6
• IM 463–2	Maximum 4, in stand-alone mode only
Number of DP primaries	
• integrated	2
• Via CP 443–5 Ext.	Maximum 10
Number of plug-in S5 modules via adapter casing (in the central controller)	None
Operable function modules and communication processors	
• FM, CP (point-to-point) see Appendix Function modules and communication processors supported by the S7-400H (Page 395)	Limited by the number of slots and connections
• CP 441	Limited by the number of connections
• PROFIBUS and Ethernet CPs, including CP 443–5 Extended	Maximum 14, of which maximum 10 CPs configured as DP primary
Connectable OPs	63
Time	
Clock	Yes
• Buffered	Yes
• Resolution	1 ms
Maximum deviation per day	
• Power off (backed up)	1.7 s
• Power on (not backed up)	8.6 s
Operating hours counter	16
• Number/number range	0 to 15
• Range of values	0 to 32767 hours 0 to 2^{31} -1 hours when SFC 101 is used
• Granularity	1 hour
• Retentive	Yes
Time synchronization	Yes
• In AS, on MPI and DP	As primary or secondary
Time difference in the system with synchronization via MPI	Max. 200 ms

Time difference in the system with synchronization via Ethernet	Max. 10 ms
S7 alarm functions	
Number of stations that can be logged on	
For block-related alarms with SFC (Alarm_S/SQ and/or Alarm_D/DQ)	63
For block-related alarms with SFB (Notify, Notify_8, Alarm, Alarm_8, Alarm 8P)	8
Block-related alarms with SFC	Yes
• Simultaneously active Alarm_S/SQ blocks or Alarm_D/DQ blocks	Maximum 400
Block-related alarms with SFB	Yes
• Number of communication jobs for block-related alarms with SFC **and** blocks for S7 communication (programmable)	Maximum 2500
• Default	900
Process control alarms	Yes
Number of archives that can be logged on simultaneously (SFB 37 AR_SEND)	16
Test and commissioning functions	
Status/modify tag	Yes, maximum 16 tag tables
• Tag	Inputs/outputs, bit memories, DB, distributed inputs/outputs, timers, counters
• Number of tags	Maximum 70
Forcing	Yes
• Tag	Inputs/outputs, bit memories, distributed I/O
• Number of tags	Maximum 256
Status LED	Yes, FRCE-LED
Block status	Yes, maximum 16 blocks at the same time
Single-step	Yes
Number of breakpoints	Maximum 16
Diagnostic buffer	Yes
• Number of entries	Maximum 3200 (configurable)
• Default	120
Communication	
PG/OP communication	Yes
Routing	Yes
S7 communication	Yes
• User data per job	Maximum 64 KB
• of which consistent	1 tag (462 bytes)
S7 basic communication	No
Global data communication	No
S5-compatible communication	Using FC AG_SEND and AG_RECV, max. via 10 CPs 443–1 or 443–5
• User data per job	Maximum 8 KB

• of which consistent	240 bytes
Number of simultaneous AG_SEND/AG_RECV jobs	Maximum 64/64, see CP manual
Standard communication (FMS)	Yes, via CP and loadable FB
Number of connection resources for S7 connections across all interfaces and CPs	64, incl. one each reserved for programming device and OP
Open IE communication over TCP/IP	
Number of connections / access points, total	Maximum 62
Possible port numbers	1 to 49151
Where parameters are assigned without specification of a port number, the system assigns a port from the dynamic port number range between 49152 and 65534	
Reserved port numbers	0 reserved TCP 20, 21 FTP TCP 25 SMTP TCP 102 RFC1006 UDP 135 RPC-DCOM UDP 161 SNMP_REQUEST UDP 34962 PN IO UDP 34963 PN IO UDP 34964 PN IO UDP 65532 NTP UDP 65533 NTP UDP 65534 NTP UDP 65535 NTP
TCP/IP	Yes, via integrated PROFINET interface and loadable FBs
• Maximum number of connections	62
• Data length, max.	32767 bytes
ISO-on-TCP	Yes (via integrated PROFINET interface or CP 443-1/ EX20/GX 20 and loadable FBs)
• Maximum number of connections	62
• Maximum data length via integrated PROFINET interface	32767 bytes
• Maximum data length via CP 443-1	1452 bytes
UDP	Yes, via integrated PROFINET interface and loadable blocks
• Maximum number of connections	62
• Data length, max.	1472 bytes
Interfaces	
You must **not** configure the CPU as DP secondary	
1st interface	
Interface designation	X1
Type of interface	integrated
Physics	RS 485/PROFIBUS
Electrically isolated	Yes
Power supply to interface (15 V DC to 30 V DC)	Max. 150 mA

Number of connection resources	MPI: 32, DP: 16 If a diagnostic repeater is used on the line, the number of connection resources on the line is reduced by 1.
Functionality	
• MPI	Yes
• PROFIBUS DP	DP primary
1st interface in MPI mode	
Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Transmission rates	Maximum 12 Mbps
1st interface in DP primary mode	
• Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Constant bus cycle time	No
• SYNC/FREEZE	No
• Enabling/disabling of DP secondaries	No
• Direct data exchange (cross-traffic)	No
• Transmission rates	Maximum 12 Mbps
• Number of DP secondaries	Maximum 32
• Number of slots per interface	Maximum 544
• Address range	Maximum 2 KB inputs / 2 KB outputs
• User data per DP secondary	Maximum 244 bytes Maximum 244 bytes inputs, Maximum 244 bytes outputs, Maximum 244 slots Maximum 128 bytes per slot
Note: • The total of input bytes across all slots may not exceed 244. • The total of output bytes across all slots may not exceed 244. • The total address range of the interface (maximum 2 KB inputs/2 KB outputs) must not be exceeded across all 32 secondaries.	
2nd interface	
Interface designation	X2
Type of interface	integrated
Physics	RS 485/PROFIBUS

Electrically isolated	Yes
Power supply to interface (15 V DC to 30 V DC)	Max. 150 mA
Number of connection resources	16
Functionality	
• PROFIBUS DP	DP primary
2nd interface in DP primary mode	
Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Constant bus cycle time	No
• SYNC/FREEZE	No
• Enabling/disabling of DP secondaries	No
• Direct data exchange (cross-traffic)	No
• Transmission rates	Up to 12 Mbps
• Number of DP secondaries	Maximum 96
• Number of slots per interface	Maximum 1632
• Address range	Maximum 6 KB inputs / 6 KB outputs
• User data per DP secondary	Maximum 244 bytes Maximum 244 bytes inputs, Maximum 244 bytes outputs, Maximum 244 slots Maximum 128 bytes per slot
Note: • The total of input bytes across all slots may not exceed 244. • The total of output bytes across all slots may not exceed 244. • The total address range of the interface (maximum 6 KB inputs/6 KB outputs) must not be exceeded across all 96 secondaries.	
3rd interface	
Interface designation	X5
Type of interface	PROFINET
Physics	Ethernet RJ45 2 ports (switch)
Electrically isolated	Yes
Autosensing (10/100 Mbps)	Yes
Autonegotiation	Yes
Auto-crossover	Yes
Media redundancy	Yes
System redundancy	Yes
• Changeover time on line interruption, typical	200 ms (PROFINET MRP)
• Number of nodes on the ring, max.	50
Change of the IP address at runtime, supported	No

Keep Alive function, supported	Yes
Functionality	
• PROFINET	Yes
Utilities	
• PG communication	Yes
• OP communication	Yes
• S7 communication Maximum number of configurable connections Maximum number of instances	Yes 64, one of each reserved for programming device and OP 2500
• S7 routing	Yes
• PROFINET IO controller	Yes
• PROFINET I-Device	No
• PROFINET CBA	No
Open IE communication	
• over TCP/IP	Yes
• ISO-on-TCP	Yes
• UDP	Yes
• Time synchronization	Yes
PROFINET IO	
PNO ID (hexadecimal)	Vendor ID: 0x002A Device ID: 0x0102
Number of integrated PROFINET IO controllers	1
Number of PROFINET IO devices that can be connected	256
Number of connectable IO devices for RT of which are in line	256 256
Shared Device, supported	No
Address range	Maximum 8 KB inputs/outputs
Number of submodules	Maximum 8192 Mixed modules count twice
Maximum user data length, including user data qualifiers	1440 bytes
Maximum user data consistency, including user data qualifiers	1024 bytes
Send clock cycles	250 µs, 500 µs, 1 ms, 2 ms, 4 ms
Update Time	250 µs, 0.5 ms, 1 ms, 2 ms, 4 ms, 8 ms, 16 ms, 32 ms, 64 ms, 128 ms, 256 ms, and 512 ms The minimum value depends on the communication slice set for PROFINET IO, the number of IO devices, and the amount of configured user data.
IRT (Isochronous Real Time)	No
S7 protocol functions	
• PG functions	Yes
• OP functions	Yes

Prioritized startup Accelerated (ASU) and Fast Startup Mode (FSU)	No
Tool change	No
Changing an IO device without Micro Memory Card or PG	Yes
4th and 5th interface	
Designation of the interfaces	IF1, IF2
Type of interface	Plug-in synchronization module (FOC)
Usable interface module	Synchronization module IF 960 (only in redundant mode; in stand-alone mode the interface remains free/covered)
Length of the synchronization cable	Maximum 10 km
Programming	
Programming language	LAD, FBD, STL, SCL, CFC, Graph, HiGraph®
Instruction set	See instruction list
Nesting levels	7
System functions (SFC)	See instruction list
Number of simultaneously active SFCs per segment	
• SFC 59 "RD_REC"	8
• SFC 58 "WR_REC"	8
• SFC 55 "WR_PARM"	8
• SFC 57 "PARM_MOD"	1
• SFC 56 "WR_DPARM"	2
• SFC 13 "DPNRM_DG"	8
• SFC 51 "RDSYSST"	8
• SFC 103 "DP_TOPOL"	1
The total number of active SFCs on all external segments may be four times more than on one single segment.	
System function blocks (SFB)	See instruction list
Number of simultaneously active SFBs per segment	
• SFB 52 "RDREC"	8
• SFB 53 "WRREC"	8
The total number of active SFBs on all external segments may be four times more than on one single segment.	
User program protection	Password protection
Access-protected blocks	Yes, with S7 Block Privacy
Access to consistent data in the process image	Yes
CiR synchronization time (in stand-alone mode)	
Total load	100 ms
Dimensions	
Mounting dimensions W x H x D (mm)	50 x 290 x 219
Slots required	2
Weight	Approx. 995 g
Voltages and currents	

Current consumption from S7–400 bus (5 V DC)	Typ. 1.6 A Max. 1.9 A
Current consumption from S7-400 bus (24 V DC) The CPU does not consume any current at 24 V, it only makes this voltage available on the MPI/DP interface.	Total current consumption of the components connected to the MPI/DP interfaces, but maximum 150 mA per interface
Current output to DP interface (5 V DC)	Max. 90 mA
Backup current	Typically 180 µA (up to 40 °C) Maximum 1000 µA
Maximum backup time	See *Module Specifications* Reference Manual, chapter 3.3.
Feed of external backup voltage to the CPU	5 V DC to 15 V DC
Power loss	Typ. 7.5 W

20.3 Technical specifications of the CPU 416–5H PN/DP; (6ES7 416–5HS06–0AB0)

CPU and firmware version	
Order number	6ES7 416–5HS06–0AB0
• Firmware version	V 6.0
Corresponding programming package	as of STEP7 V 5.5 SP2 HF 1 see also Preface (Page 13)
Memory	
Work memory	
• integrated	6 MB for code 10 MB for data
Load memory	
• integrated	1 MB RAM
• Expandable FEPROM	With memory card (FLASH) 1 MB to 64 MB
• Expandable RAM	With memory card (RAM) 256 KB to 64 MB
Battery backup	Yes, all data
Typical execution times	
Execution times of	
• Bit instructions	12.5 ns
• Word instructions	12.5 ns
• Fixed-point arithmetic	12.5 ns
• Floating-point arithmetic	25 ns
Timers/counters and their retentivity	
S7 counters	2048
• Retentivity, configurable	From C 0 to C 2047
• Default	From C 0 to C 7
• Counting range	0 to 999
IEC counters	Yes
• Type	SFB
S7 timers	2048
• Retentivity, configurable	From T 0 to T 2047
• Default	No retentive timers
• Time range	10 ms to 9990 s
IEC timers	Yes
• Type	SFB
Data areas and their retentivity	
Total retentive data area (incl. bit memories, timers, counters)	Total work and load memory (with backup battery)
Bit memory	16 KB
• Retentivity, configurable	From MB 0 to MB 16383
• Preset retentivity	From MB 0 to MB 15
Clock memories	8 (1 bit memory byte)

Data blocks	Maximum 16000 (DB 0 reserved) Number range 1 - 16000
• Size	Maximum 64 KB
Local data (configurable)	Maximum 64 KB
• Default	32 KB
Blocks	
OBs	See instruction list
• Size	Maximum 64 KB
Number of free-cycle OBs	OB 1
Number of time-of-day interrupt OBs	OB 10, 11, 12, 13, 14, 15, 16, 17
Number of time-delay interrupt OBs	OB 20, 21, 22, 23
Number of cyclic interrupts	OB 30, 31, 32, 33, 34, 35, 36, 37, 38
Number of process interrupt OBs	OB 40, 41, 42, 43, 44, 45, 46, 47
Number of DPV1 interrupt OBs	OB 55, 56, 57
Number of redundancy error OBs:	OB70, 72
Number of asynchronous error OBs	OB 80, 81, 82, 83, 84, 85, 86, 87, 88
Number of restart OBs	OB 100, 102
Number of synchronous error OBs	OB 121, 122
Nesting depth	
• Per priority class	24
• Additional ones in an error OB	2
FBs	Maximum 8000 Number range 0 - 7999
• Size	Maximum 64 KB
FCs	Maximum 8000 Number range 0 - 7999
• Size	Maximum 64 KB
SDBs	Maximum 2048
Address ranges (I/O)	
Total I/O address range	16 KB/16 KB
• of those distributed	Including diagnostic addresses, addresses for I/O interfaces, etc.
MPI/DP interface	2 KB/2 KB
DP interface	8 KB/8 KB
Process image	16 KB/16 KB (configurable)
• Default	1024 bytes/1024 bytes
• Number of process image partitions	Maximum 15
Consistent data via PROFIBUS Via integrated PROFINET interface	Max. 244 bytes Max. 1024 bytes
Access to consistent data in the process image	Yes
Digital channels	Maximum 131072/Maximum 131072
• of those central	Maximum 131072/Maximum 131072
Analog channels	Maximum 8192/Maximum 8192
• of those central	Maximum 8192/Maximum 8192

Configuration	
Central controllers/expansion units	Maximum 2/20
Multicomputing	No
Number of plug-in IMs (total)	Maximum 6
• IM 460	Maximum 6
• IM 463–2	Maximum 4, in stand-alone mode only
Number of DP primaries	
• integrated	2
• Via CP 443–5 Ext.	Maximum 10
Number of plug-in S5 modules via adapter casing (in the central controller)	None
Operable function modules and communication processors	
• FM, CP (point-to-point) see Appendix Function modules and communication processors supported by the S7-400H (Page 395)	Limited by the number of slots and connections
• CP 441	Limited by the number of connections
• PROFIBUS and Ethernet CPs, including CP 443–5 Extended	Maximum 14, of which maximum 10 CPs configured as DP primary
Connectable OPs	95
Time	
Clock	Yes
• Buffered	Yes
• Resolution	1 ms
Maximum deviation per day	
• Power off (backed up)	1.7 s
• Power on (not backed up)	8.6 s
Operating hours counter	16
• Number/number range	0 to 15
• Range of values	0 to 32767 hours 0 to 2^{31} -1 hours when SFC 101 is used
• Granularity	1 hour
• Retentive	Yes
Time synchronization	Yes
• In AS, on MPI and DP	As primary or secondary
Time difference in the system with synchronization via MPI	Max. 200 ms
Time difference in the system with synchronization via Ethernet	Max. 10 ms
S7 alarm functions	
Number of stations that can be logged on	
For block-related alarms with SFC (Alarm_S/SQ and/or Alarm_D/DQ)	95

For block-related alarms with SFB (Notify, Notify_8, Alarm, Alarm_8, Alarm 8P)	16
Block-related alarms with SFC	Yes
• Simultaneously active Alarm_S/SQ blocks or Alarm_D/DQ blocks	Maximum 1000
Block-related alarms with SFB	Yes
• Number of communication jobs for block-related alarms with SFC **and** blocks for S7 communication (programmable)	Maximum 10000
• Default	1200
Process control alarms	Yes
Number of archives that can be logged on simultaneously (SFB 37 AR_SEND)	64
Test and commissioning functions	
Status/modify tag	Yes, maximum 16 tag tables
• Tag	Inputs/outputs, bit memories, DB, distributed inputs/outputs, timers, counters
• Number of tags	Maximum 70
Forcing	Yes
• Tag	Inputs/outputs, bit memories, distributed I/O
• Number of tags	Maximum 512
Status LED	Yes, FRCE-LED
Block status	Yes, maximum 16 blocks at the same time
Single-step	Yes
Number of breakpoints	Maximum 16
Diagnostic buffer	Yes
• Number of entries	Maximum 3200 (configurable)
• Default	120
Communication	
PG/OP communication	Yes
Routing	Yes
S7 communication	Yes
• User data per job	Maximum 64 KB
• of which consistent	1 tag (462 bytes)
S7 basic communication	No
Global data communication	No
S5-compatible communication	Using FC AG_SEND and AG_RECV, max. via 10 CPs 443–1 or 443–5
• User data per job	Maximum 8 KB
• of which consistent	240 bytes
Number of simultaneous AG_SEND/AG_RECV jobs	Maximum 64/64, see CP manual
Standard communication (FMS)	Yes, via CP and loadable FB
Number of connection resources for S7 connections across all interfaces and CPs	96, incl. one each reserved for programming device and OP 62 of which fault-tolerant connections

Open IE communication over TCP/IP	
Number of connections / access points, total	Maximum 94
Possible port numbers	1 to 49151
Where parameters are assigned without specification of a port number, the system assigns a port from the dynamic port number range between 49152 and 65534	
Reserved port numbers	0 reserved TCP 20, 21 FTP TCP 25 SMTP TCP 102 RFC1006 UDP 135 RPC-DCOM UDP 161 SNMP_REQUEST UDP 34962 PN IO UDP 34963 PN IO UDP 34964 PN IO UDP 65532 NTP UDP 65533 NTP UDP 65534 NTP UDP 65535 NTP
TCP/IP	Yes, via integrated PROFINET interface and loadable FBs
• Maximum number of connections	94
• Data length, max.	32767 bytes
ISO-on-TCP	Yes (via integrated PROFINET interface or CP 443-1/ EX20/GX 20 and loadable FBs)
• Maximum number of connections	94
• Maximum data length via integrated PROFINET interface	32767 bytes
• Maximum data length via CP 443-1	1452 bytes
UDP	Yes, via integrated PROFINET interface and loadable blocks
• Maximum number of connections	94
• Data length, max.	1472 bytes
Interfaces	
You must **not** configure the CPU as DP secondary	
1st interface	
Interface designation	X1
Type of interface	integrated
Physics	RS 485/PROFIBUS
Electrically isolated	Yes
Power supply to interface (15 V DC to 30 V DC)	Max. 150 mA
Number of connection resources	MPI: 44, DP: 32 If a diagnostic repeater is used on the line, the number of connection resources on the line is reduced by 1.
Functionality	
• MPI	Yes
• PROFIBUS DP	DP primary
1st interface in MPI mode	

Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Transmission rates	Maximum 12 Mbps
1st interface in DP primary mode	
• Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Constant bus cycle time	No
• SYNC/FREEZE	No
• Enabling/disabling of DP secondaries	No
• Direct data exchange (cross-traffic)	No
• Transmission rates	Maximum 12 Mbps
• Number of DP secondaries	Maximum 32
• Number of slots per interface	Maximum 544
• Address range	Maximum 2 KB inputs / 2 KB outputs
• User data per DP secondary	Maximum 244 bytes Maximum 244 bytes inputs, Maximum 244 bytes outputs, Maximum 244 slots Maximum 128 bytes per slot
Note: • The total of input bytes across all slots may not exceed 244. • The total of output bytes across all slots may not exceed 244. • The total address range of the interface (maximum 2 KB inputs/2 KB outputs) must not be exceeded across all 32 secondaries.	
2nd interface	
Interface designation	X2
Type of interface	integrated
Physics	RS 485/PROFIBUS
Electrically isolated	Yes
Power supply to interface (15 V DC to 30 V DC)	Max. 150 mA
Number of connection resources	32
Functionality	
• PROFIBUS DP	DP primary
2nd interface in DP primary mode	
Utilities	

• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Constant bus cycle time	No
• SYNC/FREEZE	No
• Enabling/disabling of DP secondaries	No
• Direct data exchange (cross-traffic)	No
• Transmission rates	Up to 12 Mbps
• Number of DP secondaries	Maximum 125
• Number of slots per interface	Maximum 2173
• Address range	Maximum 8 KB inputs / 8 KB outputs
• User data per DP secondary	Maximum 244 bytes Maximum 244 bytes inputs, Maximum 244 bytes outputs, Maximum 244 slots Maximum 128 bytes per slot
Note: • The total of input bytes across all slots may not exceed 244. • The total of output bytes across all slots may not exceed 244. • The total address range of the interface (maximum 8 KB inputs/8 KB outputs) must not be exceeded across all 125 secondaries.	
3rd interface	
Interface designation	X5
Type of interface	PROFINET
Physics	Ethernet RJ45 2 ports (switch)
Electrically isolated	Yes
Autosensing (10/100 Mbps)	Yes
Autonegotiation	Yes
Auto-crossover	Yes
Media redundancy	Yes
System redundancy	Yes
• Changeover time on line interruption, typical	200 ms (PROFINET MRP)
• Number of nodes on the ring, max.	50
Change of the IP address at runtime, supported	No
Keep Alive function, supported	Yes
Functionality	
• PROFINET	Yes
Utilities	
• PG communication	Yes
• OP communication	Yes

• S7 communication Maximum number of configurable connections Maximum number of instances	Yes 96, one of each reserved for programming device and OP 10000
• S7 routing	Yes
• PROFINET IO controller	Yes
• PROFINET I-Device	No
• PROFINET CBA	No
Open IE communication	
• over TCP/IP	Yes
• ISO-on-TCP	Yes
• UDP	Yes
• Time synchronization	Yes
PROFINET IO	
PNO ID (hexadecimal)	Vendor ID: 0x002A Device ID: 0x0102
Number of integrated PROFINET IO controllers	1
Number of PROFINET IO devices that can be connected	256
Number of connectable IO devices for RT of which are in line	256 256
Shared Device, supported	No
Address range	Maximum 8 KB inputs/outputs
Number of submodules	Maximum 8192 Mixed modules count twice
Maximum user data length, including user data qualifiers	1440 bytes
Maximum user data consistency, including user data qualifiers	1024 bytes
Send clock cycles	250 µs, 500 µs, 1 ms, 2 ms, 4 ms
Update Time	250 µs, 0.5 ms, 1 ms, 2 ms, 4 ms, 8 ms, 16 ms, 32 ms, 64 ms, 128 ms, 256 ms, and 512 ms The minimum value depends on the communication slice set for PROFINET IO, the number of IO devices, and the amount of configured user data.
S7 protocol functions	
• PG functions	Yes
• OP functions	Yes
IRT (Isochronous Real Time)	No
Prioritized startup Accelerated (ASU) and Fast Startup Mode (FSU)	No
Tool change	No
Changing an IO device without Micro Memory Card or PG	Yes
4th and 5th interface	
Designation of the interfaces	IF1, IF2

Type of interface	Plug-in synchronization module (FOC)
Usable interface module	Synchronization module IF 960 (only in redundant mode; in stand-alone mode the interface remains free/covered)
Length of the synchronization cable	Maximum 10 km
Programming	
Programming language	LAD, FBD, STL, SCL, CFC, Graph, HiGraph®
Instruction set	See instruction list
Nesting levels	7
System functions (SFC)	See instruction list
Number of simultaneously active SFCs per segment	
• SFC 59 "RD_REC"	8
• SFC 58 "WR_REC"	8
• SFC 55 "WR_PARM"	8
• SFC 57 "PARM_MOD"	1
• SFC 56 "WR_DPARM"	2
• SFC 13 "DPNRM_DG"	8
• SFC 51 "RDSYSST"	8
• SFC 103 "DP_TOPOL"	1
The total number of active SFCs on all external segments may be four times more than on one single segment.	
System function blocks (SFB)	See instruction list
Number of simultaneously active SFBs per segment	
• SFB 52 "RDREC"	8
• SFB 53 "WRREC"	8
The total number of active SFBs on all external segments may be four times more than on one single segment.	
User program protection	Password protection
Access-protected blocks	Yes, with S7 Block Privacy
Access to consistent data in the process image	Yes
CiR synchronization time (in stand-alone mode)	
Total load	100 ms
Dimensions	
Mounting dimensions W x H x D (mm)	50 x 290 x 219
Slots required	2
Weight	Approx. 995 g
Voltages and currents	
Current consumption from S7–400 bus (5 V DC)	Typ. 1.6 A Max. 1.9 A
Current consumption from S7-400 bus (24 V DC) The CPU does not consume any current at 24 V, it only makes this voltage available on the MPI/DP interface.	Total current consumption of the components connected to the MPI/DP interfaces, but maximum 150 mA per interface
Current output to DP interface (5 V DC)	Max. 90 mA

Backup current	Typically 180 µA (up to 40 °C) Maximum 1000 µA
Maximum backup time	See *Module Specifications* Reference Manual, chapter 3.3.
Feed of external backup voltage to the CPU	5 V DC to 15 V DC
Power loss	Typ. 7.5 W

20.4 Technical specifications of the CPU 417–5H PN/DP; (6ES7 417–5HK06–0AB0)

CPU and firmware version	
Order number	6ES7 417–5HT06–0AB0
• Firmware version	V 6.0
Corresponding programming package	as of STEP7 V 5.5 SP2 HF 1 see also Preface (Page 13)
Memory	
Work memory	
• integrated	16 MB for code 16 MB for data
Load memory	
• integrated	1 MB RAM
• Expandable FEPROM	With memory card (FLASH) 1 MB to 64 MB
• Expandable RAM	With memory card (RAM) 256 KB to 64 MB
Battery backup	Yes, all data
Typical execution times	
Execution times of	
• Bit instructions	7.5 ns
• Word instructions	7.5 ns
• Fixed-point arithmetic	7.5 ns
• Floating-point arithmetic	15 ns
Timers/counters and their retentivity	
S7 counters	2048
• Retentivity, configurable	From C 0 to C 2047
• Default	From C 0 to C 7
• Counting range	0 to 999
IEC counters	Yes
• Type	SFB
S7 timers	2048
• Retentivity, configurable	From T 0 to T 2047
• Default	No retentive timers
• Time range	10 ms to 9990 s
IEC timers	Yes
• Type	SFB
Data areas and their retentivity	
Total retentive data area (incl. bit memories, timers, counters)	Total work and load memory (with backup battery)
Bit memory	16 KB
• Retentivity, configurable	From MB 0 to MB 16383
• Preset retentivity	From MB 0 to MB 15

Clock memories	8 (1 bit memory byte)
Data blocks	Maximum 16000 (DB 0 reserved) Number range 1 to 16000
• Size	Maximum 64 KB
Local data (configurable)	Maximum 64 KB
• Default	32 KB
Blocks	
OBs	See instruction list
• Size	Maximum 64 KB
Number of free-cycle OBs	OB 1
Number of time-of-day interrupt OBs	OB 10, 11, 12, 13, 14, 15, 16, 17
Number of time-delay interrupt OBs	OB 20, 21, 22, 23
Number of cyclic interrupts	OB 30, 31, 32, 33, 34, 35, 36, 37, 38
Number of process interrupt OBs	OB 40, 41, 42, 43, 44, 45, 46, 47
Number of DPV1 interrupt OBs	OB 55, 56, 57
Number of asynchronous error OBs	OB 80, 81, 82, 83, 84, 85, 86, 87, 88
Number of background OBs	OB 90
Number of restart OBs	OB 100, 102
Number of synchronous error OBs	OB 121, 122
Nesting depth	
• Per priority class	24
• Additional ones in an error OB	2
SDBs	Maximum 512
FBs	Maximum 8000 Number range 0 - 7999
• Size	Maximum 64 KB
FCs	Maximum 8000 Number range 0 - 7999
• Size	Maximum 64 KB
SDBs	Maximum 2048
Address ranges (I/O)	
Total I/O address range	16 KB/16 KB
• of those distributed	Including diagnostic addresses, addresses for I/O interfaces, etc.
MPI/DP interface	2 KB/2 KB
DP interface	8 KB/8 KB
Process image	16 KB/16 KB (configurable)
• Default	1024 bytes/1024 bytes
• Number of process image partitions	Maximum 15
Consistent data via PROFIBUS Via integrated PROFINET interface	Max. 244 bytes Max. 1024 bytes
Access to consistent data in the process image	Yes
Digital channels	Maximum 131072/ Maximum 131072

• of those central	Maximum 131072/ Maximum 131072
Analog channels	Maximum 8192/ Maximum 8192
• of those central	Maximum 8192/ Maximum 8192
Configuration	
Central controllers/expansion units	Maximum 2/20
Multicomputing	No
Number of plug-in IMs (total)	Maximum 6
• IM 460	Maximum 6
• IM 463–2	Maximum 4, in stand-alone mode only
Number of DP primaries	
• integrated	2
• Via CP 443–5 Ext.	Maximum 10
Number of plug-in S5 modules via adapter casing (in the central controller)	None
Operable function modules and communication processors	
• FM, CP (point-to-point) see Appendix Function modules and communication processors supported by the S7-400H (Page 395)	Limited by the number of slots and connections
• CP 441	Limited by the number of connections
• PROFIBUS and Ethernet CPs, including CP 443–5 Extended	Maximum 14, of which maximum 10 CPs configured as DP primary
Connectable OPs	63
Time	
Clock	Yes
• Buffered	Yes
• Resolution	1 ms
Maximum deviation per day	
• Power off (backed up)	1.7 s
• Power on (not backed up)	8.6 s
Operating hours counter	16
• Number/number range	0 to 15
• Range of values	0 to 32767 hours 0 to 2^{31} -1 hours when SFC 101 is used
• Granularity	1 hour
• Retentive	Yes
Time synchronization	Yes
• In AS, on MPI and DP	As primary or secondary
Time difference in the system with synchronization via MPI	Max. 200 ms

Time difference in the system with synchronization via Ethernet	Max. 10 ms
S7 alarm functions	
Number of stations that can be logged on	
For block-related alarms with SFC (Alarm_S/SQ and/or Alarm_D/DQ)	119
For block-related alarms with SFB (Notify, Notify_8, Alarm, Alarm_8, Alarm 8P)	16
Block-related alarms with SFC	Yes
• Simultaneously active Alarm_S/SQ blocks or Alarm_D/DQ blocks	Maximum 1000
Block-related alarms with SFB	Yes
• Number of communication jobs for ALARM_8 blocks **and** blocks for S7 communication (selectable)	Maximum 10000
• Default	1200
Process control alarms	Yes
Number of archives that can be logged on simultaneously (SFB 37 AR_SEND)	64
Test and commissioning functions	
Status/modify tag	Yes, maximum 16 tag tables
• Tag	Inputs/outputs, bit memories, DB, distributed inputs/outputs, timers, counters
• Number of tags	Maximum 70
Forcing	Yes
• Tag	Inputs/outputs, bit memories, distributed I/O
• Number of tags	Maximum 512
Status LED	Yes, FRCE-LED
Block status	Yes, maximum 16 blocks at the same time
Single-step	Yes
Number of breakpoints	Maximum 16
Diagnostic buffer	Yes
• Number of entries	Maximum 3200 (configurable)
• Default	120
Communication	
PG/OP communication	Yes
Routing	Yes
Number of connection resources for S7 connections across all interfaces and CPs	120, incl. one each reserved for programming device and OP 62 reserved for fault-tolerant connections
S7 communication	Yes
• User data per job	Maximum 64 KB
• of which consistent	1 tag (462 bytes)
Global data communication	No
S7 basic communication	No

S5-compatible communication	Using FC AG_SEND and AG_RECV, max. via 10 CPs 443–1 or 443–5
• User data per job	Maximum 8 KB
• of which consistent	240 bytes
Number of simultaneous AG_SEND/AG_RECV jobs	Maximum 64/64, see CP manual
Standard communication (FMS)	Yes, via CP and loadable FB
Number of connection resources for S7 connections across all interfaces and CPs	120, incl. one each reserved for programming device and OP 62 of which fault-tolerant connections
Open IE communication over TCP/IP	
Number of connections / access points, total	Maximum 118
Possible port numbers	1 to 49151
Where parameters are assigned without specification of a port number, the system assigns a port from the dynamic port number range between 49152 and 65534	
Reserved port numbers	0 reserved TCP 20, 21 FTP TCP 25 SMTP TCP 102 RFC1006 UDP 135 RPC-DCOM UDP 161 SNMP_REQUEST UDP 34962 PN IO UDP 34963 PN IO UDP 34964 PN IO UDP 65532 NTP UDP 65533 NTP UDP 65534 NTP UDP 65535 NTP
TCP/IP	Yes, via integrated PROFINET interface and loadable FBs
• Maximum number of connections	118
• Data length, max.	32 KB
ISO-on-TCP	Yes (via integrated PROFINET interface or CP 443-1/ EX20/GX 20 and loadable FBs)
• Maximum number of connections	118
• Maximum data length via integrated PROFINET interface	32 KB
• Maximum data length via CP 443-1	1452 bytes
UDP	Yes, via integrated PROFINET interface and loadable blocks
• Maximum number of connections	118
• Data length, max.	1472 bytes
Interfaces	
You must **not** configure the CPU as DP secondary	
1st interface	
Interface designation	X1
Type of interface	integrated
Physics	RS 485/PROFIBUS
Electrically isolated	Yes

Power supply to interface (15 V DC to 30 V DC)	Max. 150 mA
Number of connection resources	MPI: 44, DP: 32 If a diagnostic repeater is used on the line, the number of connection resources on the line is reduced by 1.
Functionality	
• MPI	Yes
• PROFIBUS DP	DP primary
1st interface in MPI mode	
• Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Transmission rates	Maximum 12 Mbps
1st interface in DP primary mode	
Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Constant bus cycle time	No
• SYNC/FREEZE	No
• Enabling/disabling of DP secondaries	No
• Direct data exchange (cross-traffic)	No
Transmission rates	Maximum 12 Mbps
Number of DP secondaries	Maximum 32
Number of slots per interface	Maximum 544
Address range	Maximum 2 KB inputs / 2 KB outputs
User data per DP secondary	Maximum 244 bytes Maximum 244 bytes inputs, Maximum 244 bytes outputs, Maximum 244 slots Maximum 128 bytes per slot
Note: • The total of input bytes across all slots may not exceed 244. • The total of output bytes across all slots may not exceed 244. • The total address range of the interface (maximum 2 KB inputs/2 KB outputs) must not be exceeded across all 32 secondaries.	
2nd interface	
Interface designation	X2
Type of interface	integrated

Physics	RS 485/PROFIBUS
Electrically isolated	Yes
Power supply to interface (15 V DC to 30 V DC)	Max. 150 mA
Number of connection resources	32, if a diagnostic repeater is used on the line, the number of connection resources on the line is reduced by 1
Functionality	
• PROFIBUS DP	DP primary
2nd interface in DP primary mode	
Utilities	
• PG/OP communication	Yes
• Routing	Yes
• S7 communication	Yes
• Global data communication	No
• S7 basic communication	No
• Constant bus cycle time	No
• SYNC/FREEZE	No
• Enabling/disabling of DP secondaries	No
• Direct data exchange (cross-traffic)	No
Transmission rates	Maximum 12 Mbps
Number of DP secondaries	Maximum 125
Number of slots per interface	Maximum 2173
Address range	Maximum 8 KB inputs / 8 KB outputs
User data per DP secondary	Maximum 244 bytes Maximum 244 bytes inputs, Maximum 244 bytes outputs, Maximum 244 slots Maximum 128 bytes per slot
Note: • The total of input bytes across all slots may not exceed 244. • The total of output bytes across all slots may not exceed 244. • The total address range of the interface (maximum 8 KB inputs/8 KB outputs) must not be exceeded across all 125 secondaries.	
3rd interface	
Interface designation	X5
Type of interface	PROFINET
Physics	Ethernet RJ45 2 ports (switch)
Electrically isolated	Yes
Autosensing (10/100 Mbps)	Yes
Autonegotiation	Yes
Auto-crossover	Yes
Media redundancy	Yes
System redundancy	Yes

• Changeover time on line interruption, typical	200 ms (PROFINET MRP)
• Number of nodes on the ring, max.	50
Change of the IP address at runtime, supported	No
Keep Alive function, supported	Yes
Functionality	
• PROFINET	Yes
Utilities	
• PG communication	Yes
• OP communication	Yes
• S7 communication Maximum number of configurable connections Maximum number of instances	Yes 120, one of each reserved for programming device and OP 10000
• S7 routing	Yes
• PROFINET IO controller	Yes
• PROFINET I-Device	No
• PROFINET CBA	No
Open IE communication	
• over TCP/IP	Yes
• ISO-on-TCP	Yes
• UDP	Yes
• Time synchronization	Yes
PROFINET IO	
PNO ID (hexadecimal)	Vendor ID: 0x002A Device ID: 0x0102
Number of integrated PROFINET IO controllers	1
Number of PROFINET IO devices that can be connected	256
Number of connectable IO devices for RT of which are in line	256 256
Shared Device, supported	No
Address range	Maximum 8 KB inputs/outputs
Number of submodules	Maximum 8192 Mixed modules count twice
Maximum user data length, including user data qualifiers	1440 bytes
Maximum user data consistency, including user data qualifiers	1024 bytes
Send clock cycles	250 µs, 500 µs, 1 ms, 2 ms, 4 ms
Update Time	250 µs, 0.5 ms, 1 ms, 2 ms, 4 ms, 8 ms, 16 ms, 32 ms, 64 ms, 128 ms, 256 ms, and 512 ms The minimum value depends on the communication slice set for PROFINET IO, the number of IO devices, and the amount of configured user data.
S7 protocol functions	

• PG functions	Yes
• OP functions	Yes
IRT (Isochronous Real Time)	No
Prioritized startup Accelerated (ASU) and Fast Startup Mode (FSU)	No
Tool change	No
Changing an IO device without Micro Memory Card or PG	Yes
4th and 5th interface	
Designation of the interfaces	IF1, IF2
Type of interface	Plug-in synchronization module (FOC)
Usable interface module	Synchronization module IF 960 (only in redundant mode; in stand-alone mode the interface remains free/covered)
Length of the synchronization cable	Maximum 10 km
Programming	
Programming language	LAD, FBD, STL, SCL, CFC, Graph, HiGraph®
Instruction set	See instruction list
Nesting levels	7
System functions (SFC)	See instruction list
Number of simultaneously active SFCs per segment	
• SFC 59 "RD_REC"	8
• SFC 58 "WR_REC"	8
• SFC 55 "WR_PARM"	8
• SFC 57 "PARM_MOD"	1
• SFC 56 "WR_DPARM"	2
• SFC 13 "DPNRM_DG"	8
• SFC 51 "RDSYSST"	8
• SFC 103 "DP_TOPOL"	1
The total number of active SFCs on all external segments may be four times more than on one single segment.	
System function blocks (SFB)	See instruction list
Number of simultaneously active SFBs per segment	
• SFB 52 "RDREC"	8
• SFB 53 "WRREC"	8
The total number of active SFBs on all external segments may be four times more than on one single segment.	
User program protection	Password protection
Access-protected blocks	Yes, with S7 Block Privacy
Access to consistent data in the process image	Yes
CiR synchronization time (in stand-alone mode)	
Total load	60 ms
Dimensions	
Mounting dimensions W x H x D (mm)	50 x 290 x 219

Slots required	2
Weight	Approx. 995 g
Voltages and currents	
Current consumption from S7–400 bus (5 V DC)	Typ. 1.6 A Max. 1.9 A
Current consumption from S7-400 bus (24 V DC) The CPU does not consume any current at 24 V, it only makes this voltage available on the MPI/DP interface.	Total current consumption of the components connected to the MPI/DP interfaces, but maximum 150 mA per interface
Current output to DP interface (5 V DC)	Max. 90 mA
Backup current	Typically 180 µA (up to 40 °C) Maximum 1000 µA
Maximum backup time	See the Module Specifications reference manual, chapter 3.3.
Feed of external backup voltage to the CPU	5 V DC to 15 V DC
Power loss	Typ. 7.5 W

20.5 Technical data of memory cards

Data

Name	Order number	Current consumption at 5 V	Backup currents
MC 952 / 256 KB / RAM	6ES7952-1AH00-0AA0	typ. 35 mA max. 80 mA	typ. 1 µA max. 40 µA
MC 952 / 1 MB / RAM	6ES7952-1AK00-0AA0	typ. 40 mA max. 90 mA	typ. 3 µA max. 50 µA
MC 952 / 2 MB / RAM	6ES7952-1AL00-0AA0	typ. 45 mA max. 100 mA	typ. 5 µA max. 60 µA
MC 952 / 4 MB / RAM	6ES7952-1AM00-0AA0	typ. 45 mA max. 100 mA	typ. 5 µA max. 60 µA
MC 952 / 8 MB / RAM	6ES7952-1AP00-0AA0	typ. 45 mA max. 100 mA	typ. 5 µA max. 60 µA
MC 952 / 16 MB / RAM	6ES7952-1AS00-0AA0	typ. 100 mA max. 150 mA	typ. 50 µA max. 125 µA
MC 952 / 64 MB / RAM	6ES7952-1AY00-0AA0	typ. 100 mA max. 150 mA	typ. 100 µA max. 500 µA
MC 952 / 1 MB / 5 V FLASH	6ES7952-1KK00-0AA0	typ. 40 mA max. 90 mA	–
MC 952 / 2 MB / 5 V FLASH	6ES7952-1KL00-0AA0	typ. 50 mA max. 100 mA	–
MC 952 / 4 MB / 5 V FLASH	6ES7952-1KM00-0AA0	typ. 40 mA max. 90 mA	–
MC 952 / 8 MB / 5 V FLASH	6ES7952-1KP00-0AA0	typ. 50 mA max. 100 mA	–
MC 952 / 16 MB / 5 V FLASH	6ES7952-1KS00-0AA0	typ. 55 mA max. 110 mA	–
MC 952 / 32 MB / 5 V FLASH	6ES7952-1KT00-0AA0	typ. 55 mA max. 110 mA	–
MC 952 / 64 MB / 5 V FLASH	6ES7952-1KY00-0AA0	typ. 55 mA max. 110 mA	–
Dimensions WxHxD (in mm)		7.5 x 57 x 87	
Weight		Max. 35 g	
EMC protection		Provided by construction	

20.6 Runtimes of the FCs and FBs for redundant I/Os

Table 20-1 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.
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 RED_IO 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 FAQ at:

Service & Support (https://support.industry.siemens.com/cs/ww/en/)

under entry ID 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.

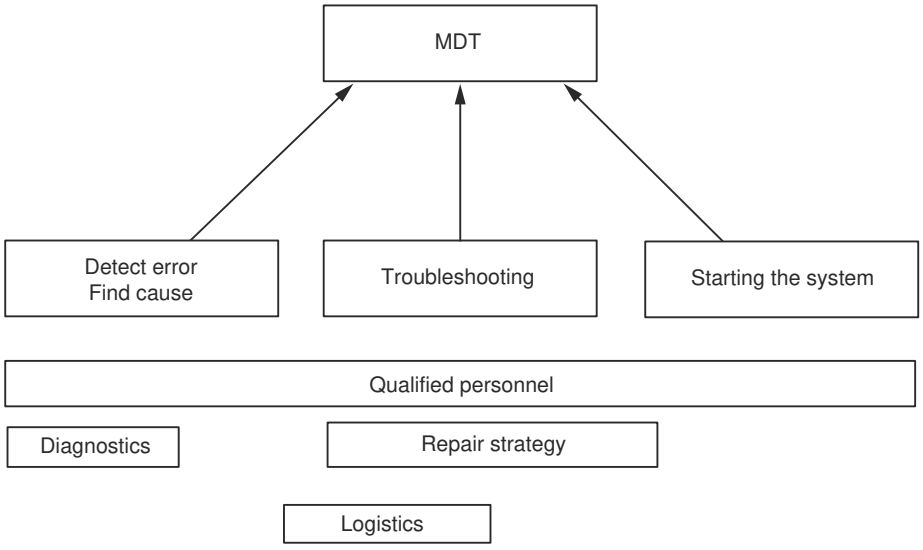


Figure A-1 MDT

The figure below shows the parameters included in the calculation of the MTBF of a system.

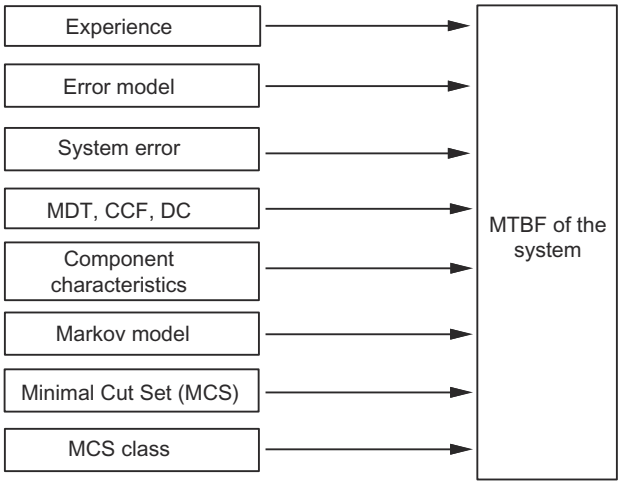


Figure A-2 MTBF

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.

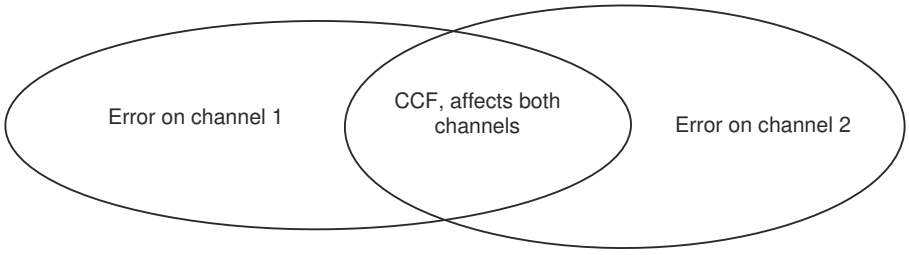


Figure A-3 Common Cause Failure (CCF)

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:

$$V = \frac{MTBF_{1v2}}{MTBF_{1v2} + MDT} 100\%$$

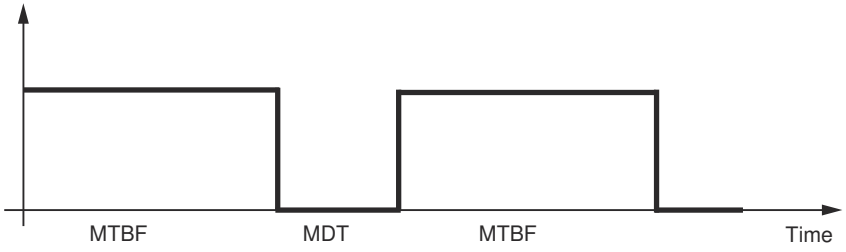


Figure A-4 Availability

A.2 Comparison of MTBF for selected configurations

The following sections compare systems with a centralized and distributed I/Os.

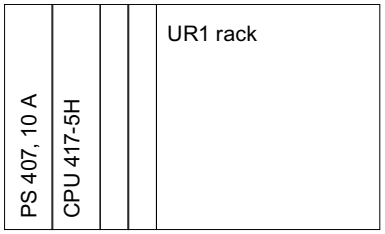
The following framework conditions are set for the calculation.

- MDT (Mean Down Time) 4 hours
- Ambient temperature 40 degrees
- Buffer voltage is safeguarded

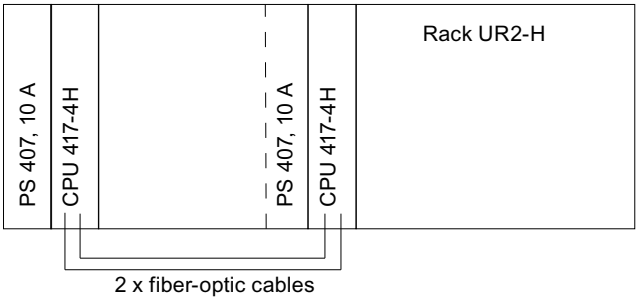
A.2.1 System configurations with redundant CPU 417-5H

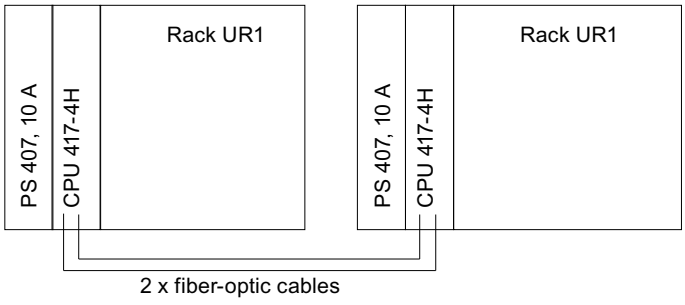
The following system with one CPU (e.g. 417-5H) operating in stand-alone mode forms the basis for calculation of a reference factor, which defines the multiple of the system MTBF of other systems with centralized I/Os compared to the base line.

Fault-tolerant CPU in stand-alone mode

Fault-tolerant CPU in stand-alone mode (e.g. CPU 417–5H)	Factor
	1

Redundant CPUs in different racks

Redundant CPU 417–5H in divided rack, CCF = 2%	Factor
	approx. 20

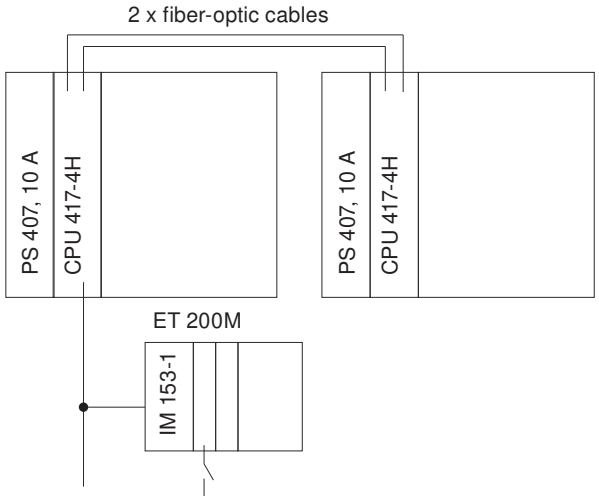
Redundant CPU 417–5H in two separate racks, CCF = 1 %	Factor
	approx. 38

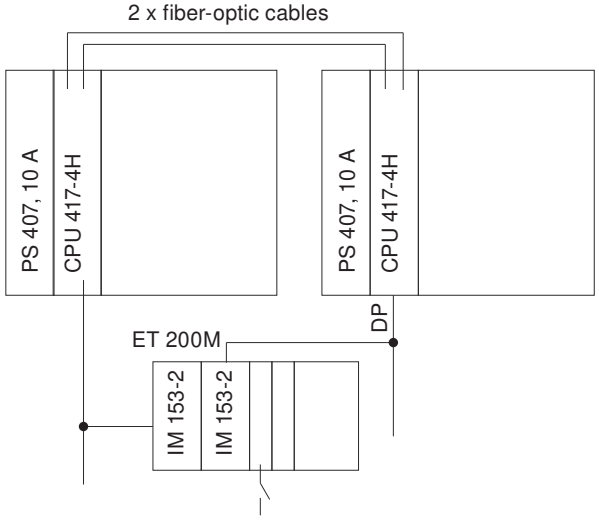
A.2.2 System configurations with distributed I/Os

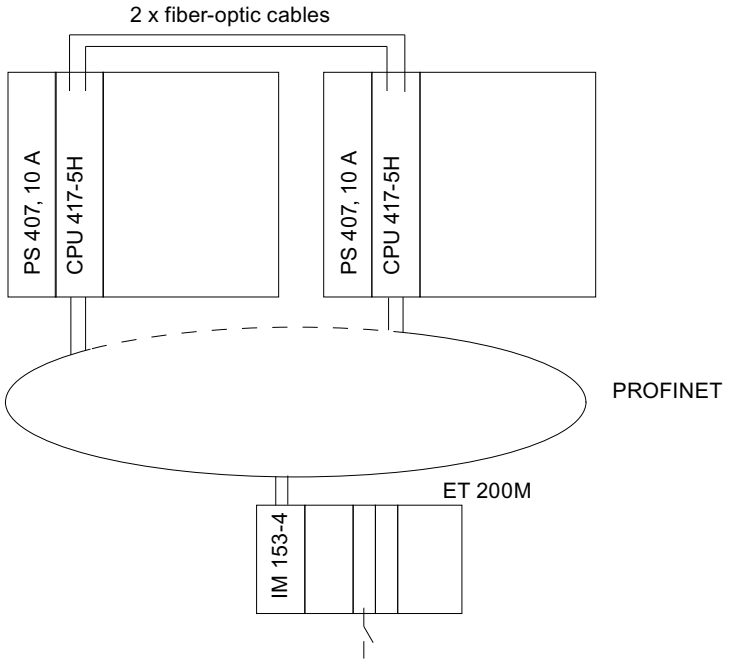
The system with two fault-tolerant CPUs 417-5H and one-sided I/Os described below is taken as a basis for calculating a reference factor which specifies the multiple of the availability of the other systems with distributed I/Os compared with the base line.

You can find the order numbers of the IMs in chapter Using single-channel, one-sided I/Os (Page 151).

Redundant CPUs with single-channel, one-sided or switched I/Os

One-sided distributed I/Os	Base line
	1

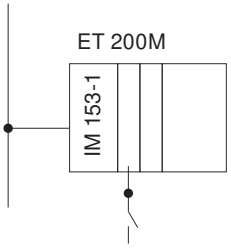
Switched distributed I/O, PROFIBUS DP, CCF = 2 %	Factor
	approx. 15

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/Os

The comparison only took account of the I/O modules.

Single-channel, one-sided I/O	MTBF factor
	1

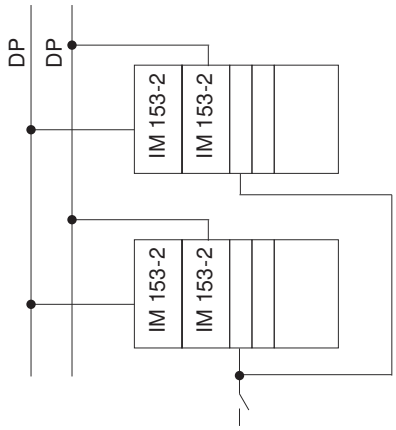
Redundant I/O	MTBF factor
	See following table

Table A-1 MTBF factors of the redundant I/Os

Module	MLFB	MTBF factor CCF = 1%
Digital input modules, distributed		
DI 24xDC24V	6ES7 326–1BK00–0AB0	approx. 5
DI 8xNAMUR [EEx ib]	6ES7 326–1RF00–0AB0	approx. 5
DI16xDC24V, Alarm	6ES7 321–7BH00–0AB0	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 326–2BF00–0AB0	approx. 5
DO8xDC24V/2A	6ES7 322–1BF01–0AA0	approx. 3
DO32xDC24V/0.5A	6ES7 322–1BL00–0AA0	approx. 3

Summary

There are now several thousand applications of redundant automation systems in the field, in various 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.

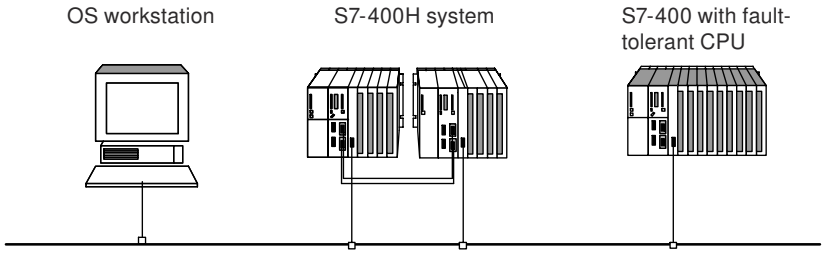
The system MTBF value calculated is about 230 years for a system configuration with redundant CPU 417-5H.

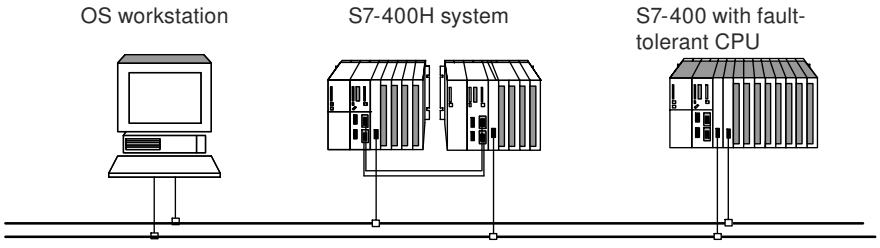
A.2.3 Comparison of system configurations with standard and fault-tolerant communication

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

Stand-alone operation

B

Overview

This appendix provides you with the information for stand-alone operation of a fault-tolerant CPU. You will learn:

- how stand-alone mode is defined
- when stand-alone mode is required
- what you have to take into account for stand-alone operation
- how the fault tolerance-specific LEDs react
- how to configure stand-alone operation of a fault-tolerant CPU
- how you can expand it to form a fault-tolerant system

The differences from a standard S7-400 CPU that you have to take into account when configuring and programming the fault-tolerant CPU are given in appendix Differences between fault-tolerant systems and standard systems (Page 391).

Definition

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

Reasons for stand-alone operation

The applications outlined below are only possible when using a fault-tolerant CPU, so they are not possible with standard S7-400 CPUs.

- 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 a fault-tolerant CPU with a F-runtime license (for more details refer to the *S7-400F and S7-400FH Automation Systems* manuals).

Note

The self-test of the fault-tolerant CPU is also performed in stand-alone mode.

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

Note

When operating a fault-tolerant CPU in stand-alone mode, no synchronization modules may be connected. The rack number must be set to "0".

Although a fault-tolerant CPU has additional functions compared to a standard S7-400 CPU, it does not support specific functions. So particularly when programming your automation system, you need to know the CPU on which you are going to run the user program. A user program written for a standard S7-400 CPU usually will not run on a fault-tolerant CPU in stand-alone mode without adaptations.

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

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

Function	Fault-tolerant CPU in stand-alone mode	Fault-tolerant CPU in redundant system mode
Connection of S5 modules via IM or adapter casing	via IM 463–2	No
Redundancy error OBs (OB 70, OB 72)	Yes, but no calls	Yes
CPU hardware fault (OB 84)	after the detection and elimination of memory errors	after the detection and elimination of memory errors with reduced performance of the redundant link between the two CPUs
SSL ID W#16#0232 index W#16#0004 byte 0 of the "index" word in the data record	W#16#F8	Single mode: W#16#F8 or W#16#F9 Redundant: W#16#F8 and W#16#F1 or W#16#F9 and W#16#F0
Multi-DP primary mode	Yes	No
System modifications during operation	Yes, as described in the "System Modification during Operation Using CIR" manual.	Yes, as described in Chapter Failure and replacement of components during operation (Page 235) for redundant operation.
Shared Device	Yes	No

Fault tolerance-specific LEDs

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

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

Configuring stand-alone mode

Requirement: No synchronization module may be inserted in the fault-tolerant CPU.

Procedure:

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

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

Expansion 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 mode.

To expand the fault-tolerant CPU later to form a fault-tolerant system:

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 secondaries from the old stand-alone operation project to the H-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 fault-tolerant CPU

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

Changing from redundant to stand-alone mode

1. Remove the synchronization modules
2. Remove the CPU.
3. Set rack number 0 on the CPU.

4. Install the CPU.
5. Download a project with the stand-alone configuration to the CPU.

Changing from stand-alone mode to redundant mode, rack number 0

1. Insert the synchronization modules into the CPU.
2. Run an unbuffered power cycle, for example, by removing and inserting the CPU, or download a project to the CPU in which it is configured for redundant mode.

Changing from stand-alone mode to redundant mode, rack number 1

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

System modification during operation in stand-alone mode

With a system modification during operation, it is also possible to make certain configuration changes in RUN on fault-tolerant CPUs. The procedure corresponds to that for standard CPUs. Processing is halted during this, but for no more than 2.5 seconds (parameterizable). 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 the *"Modifying the System during Operation via CiR"* manual.

System modifications during operation are only supported with distributed I/O. They require a configuration as shown in the figure below. For the sake of clarity, only one DP primary system and only one PA primary system is shown.

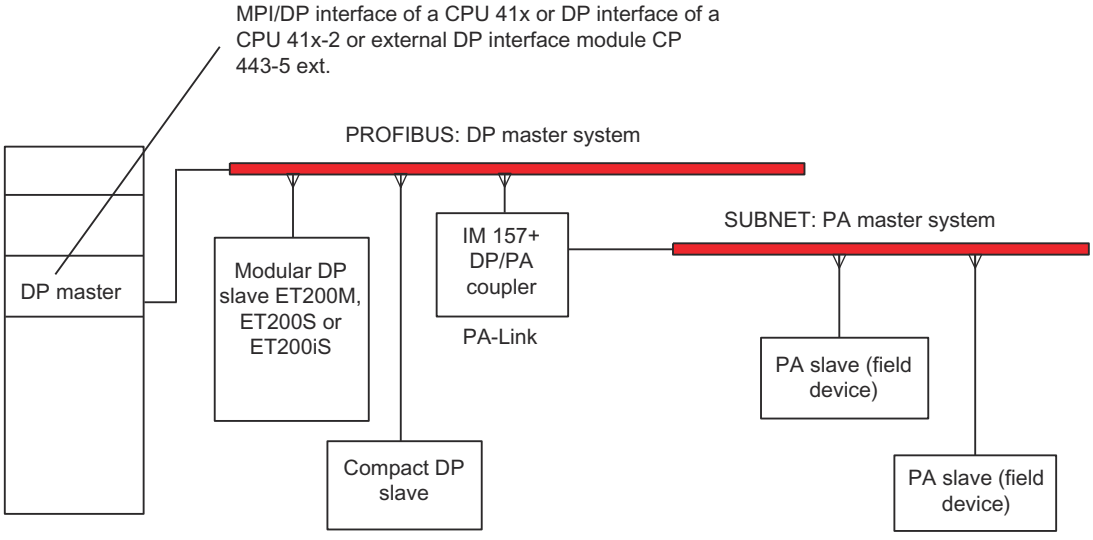


Figure B-1 Overview: System structure for system modifications during operation

Hardware requirements for system modifications during operation

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

- Use of an S7-400 CPU
- S7-400 H-CPU only in stand-alone mode
- 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. The installed ET 200M also requires an active backplane bus with sufficient free space for the planned expansion. Include the ET 200M so that it complies with IEC 61158.
- If you want to add entire stations: Make sure that you have the required connectors, repeaters, etc.
- If you want to add PA secondaries (field devices): Use IM 157, MLFB 6ES7 157-0AA82-0XA00 or higher, in the corresponding DP/PA link.

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.

Software requirements for system modifications during operation

To make modifications during operation, the user program must be written so that station failures or module faults, for example, do not lead to a CPU STOP.

Permitted system modifications: Overview

During operation, you can make the following system modifications:

- Add modules or submodules for modular DP secondaries ET 200M, ET 200S, ET 200iS, provided their behavior complies with IEC 61158
- Use previously unused channels in a module or submodule for the modular secondaries ET 200M, ET 200S, ET 200iS
- Add DP secondaries to an existing DP primary system.
- Add PA secondaries (field devices) to an existing PA primary system
- Add DP/PA couplers downstream of an IM 157
- Add PA links (including PA primary systems) to an existing DP primary system
- Assign added modules to a process image partition
- Change parameter settings for I/O modules, for example selecting different interrupt limits
- Undo changes: Added modules, submodules, DP secondaries and PA secondaries (field devices) can be removed again.

Differences between fault-tolerant systems and standard systems

C

When configuring and programming a fault-tolerant automation system with fault-tolerant CPUs, you must make allowances for a number of differences from the standard S7-400 CPUs. A fault-tolerant CPU has additional functions compared to a standard S7-400 CPU, on the other hand it does not support specific functions. This has to be taken in account particularly if you wish to run a program that was created for a standard S7-400 CPU on a fault-tolerant CPU.

The ways in which the programming of fault-tolerant systems differs from that for standard systems are summarized below. You will find additional differences in appendix Stand-alone operation (Page 385).

If you use any of the affected calls (OBs and SFCs) in your user program, you will need to adapt your program accordingly.

Additional functions of fault-tolerant systems

Function	Additional programming
Redundancy error OBs	• I/O redundancy error OB (OB 70) • CPU redundancy error OB (OB 72) For detailed information, refer to the *System and Standard Functions* Reference Manual.
CPU hardware fault	Depending on the configuration, OB 82 or OB 84 is also called if the performance of the redundant link between the two CPUs is reduced.
Additional information in OB start information and in diagnostic buffer entries	The rack number and the CPU (primary/standby) are specified. You can evaluate this additional information in the program.
SFC for fault-tolerant systems	You can control processes in fault-tolerant systems using SFC 90 "H_CTRL".
Fault-tolerant communication connections	Fault-tolerant connections are configured and do not require further programming. You can use the SFBs for configured connections when using fault-tolerant connections.
Self-test	The self-test is performed automatically, no further programming is required,
High-quality RAM test	The CPU performs a high-quality RAM test after an unbuffered POWER ON.
Switched I/O	No additional programming required, see section Using single-channel switched I/O (Page 153).
Reading type and serial number of a synchronization module	How to read the serial number of a memory card.

Function	Additional programming
Information in the system status list	• You can also obtain data records for the fault tolerance-specific LEDs from the partial list with SSL ID W#16#0019. • You can also obtain data records for the redundancy error OBs from the partial list with SSL ID W#16#0222. • You can obtain information on the current status of the fault-tolerant system from the partial list with SSL ID W#16#xy71. • You can also obtain data records for the fault tolerance-specific LEDs from the partial list with SSL ID W#16#0174. • You can obtain information about the status of the communication between the H-system and switched DP secondaries from the partial list with SSL ID W#16#xy75.
Update monitoring	The operating system monitors the following four configurable timers: • Maximum cycle time extension • Maximum communication delay • Maximum disabling time for priority classes > 15 • Minimum I/O retention time No additional programming is required for this. For more details, see section Link-up and update (Page 125).
SSL ID W#16#0232 index W#16#0004 byte 0 of the "index" word in the data record	Fault-tolerant CPU in stand-alone mode: W#16#F8 Fault-tolerant CPU in single mode: W#16#F8 or W#16#F9 Fault-tolerant CPU in redundant mode: W#16#F8 and W#16#F1 or W#16#F9 and W#16#F0

Restrictions of the fault-tolerant CPU compared to a standard CPU

Function	Restriction of the fault-tolerant CPU
Hot restart	A hot restart is not possible. OB 101 is not possible
Multicomputing	Multicomputing is not possible. OB 60 and SFC 35 are not supported
Startup without configuration loaded	Startup without loaded configuration is not possible.
Background OB	OB 90 is not supported.
Multi-DP primary mode	The H-CPUs do not support multi-DP primary mode in REDUNDANT system state.
Direct communication for DP secondaries	Cannot be configured in STEP 7
Constant bus cycle time for DP secondaries	No constant bus cycle time for DP secondaries in the H-system
Synchronization of DP secondaries	Synchronization of DP secondary groups is not possible. SFC 11 "DPSYC_FR" is not supported.
Disabling and enabling of DP secondaries	Disabling and enabling of DP secondaries is not possible. SFC 12 "D_ACT_DP" is not supported.

Function	Restriction of the fault-tolerant CPU
Runtime response	The command execution time for a CPU 41x–5H is slightly higher compared to the corresponding standard CPU (see *S7–400 Instruction List* and *S7-400H Instruction List*). This must be taken into account for all time-critical applications. If necessary, you must increase the cycle monitoring time.
DP cycle time	A CPU 41x-5H has a slightly longer DP cycle time compared to the corresponding standard CPU.
Delays and inhibits	During update: • The asynchronous SFCs for data records are acknowledged negatively • Messages are delayed • All priority classes up to 15 are initially delayed • Communication jobs are rejected or delayed • Finally, all priority classes are disabled For more detailed information, refer to chapter 7.
Use of symbol-oriented messages (SCAN)	The use of symbol-oriented messages is not possible.
Global data communication	GD communication is not possible (neither cyclically, nor by calling system functions SFC 60 "GD_SND" and SFC 61 "GD_RCV")
S7 basic communication	Communication functions (SFCs) for basic communication are not supported.
S5 connection	The connection of S5 modules by means of an adapter casing is not possible. The connection of S5 modules via IM 463-2 is only supported in stand-alone mode.
CPU as DP secondary	Not possible
CPU as I-Device	Not possible
Use of SFC 49 "LGC_GADR"	You are operating an S7-400H automation system in redundant mode. If you specify the logical address of a module of a switched DP secondary when calling SFC49 in parameter LADDR, the DP primary system ID of the active channel is returned in the high byte of parameter RACK. If no active channel exists, the DP primary system ID of the associated DP primary system of the primary CPU is output.
Call of SFC 51 "RDSYSST" with SSL_ID=W#16#xy91	The data records of the SSL partial lists shown below cannot be read with SFC 51 "RDSYSST": • SSL_ID=W#16#0091 • SSL_ID=W#16#0191 • SSL_ID=W#16#0291 • SSL_ID=W#16#0391 • SSL_ID=W#16#0991 • SSL_ID=W#16#0E91
Web server	Not integrated
PROFINET CBA	Not possible
IRT	Not possible
Isochronous mode on PN	Not possible
Tool changer	Not possible

Function	Restriction of the fault-tolerant CPU
Fast Startup	Not possible
Use of an external PN controller	Not possible

See also

System and operating states of the S7–400H (Page 107)

Function modules and communication processors supported by the S7-400H

D

You can use the following function modules (FMs) and communication processors (CPs) on an S7-400H automation system.

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
Counter module FM 450	6ES7 450–1AP00–0AE0	As of product version 2	Yes	No
Function module FM 458-1 DP	6DD 1607-0AA1	As of firmware 1.1.0	Yes	No
	6DD 1607-0AA2	As of firmware 2.0.0	Yes	No
Communication processor CP 441-1 (point-to-point link)	6ES7 441–1AA02–0AE0	As of product version 2	Yes	No
	6ES7 441–1AA03–0AE0	As of product version 1 As of firmware V1.0.0		
	6ES7 441–1AA04–0AE0	As of product version 1 As of firmware V1.0.0		
Communication processor CP 441-2 (point-to-point link)	6ES7 441–2AA02–0AE0	As of product version 2		
	6ES7 441–2AA03–0AE0	As of product version 1 As of firmware V1.0.0		
	6ES7 441–2AA04–0AE0	As of product version 1 As of firmware V1.0.0		
	6ES7 441–2AA03–0AE0	As of product version 1 As of firmware V1.0.0	Yes	No
Communication processor CP 443-1 Multi (Industrial Ethernet, TCP / ISO transport)	6GK7 443–1EX10–0XE0	As of product version 1 As of firmware V2.7.3	Yes	Yes
	6GK7 443–1EX11–0XE0	As of product version 1 As of firmware V2.7.3	Yes	Yes
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 443–1GX20–0XE0 S7 connections via gigabit port are not permitted	As of product version 3 as of firmware V2.0	Yes	Yes
Communications module CP443-1 Advanced[3)] (Industrial Ethernet ISO and TCP/IP, 4-port switch, Gigabit port)	6GK7 443–1GX30–0XE0 6GK7 443–1EX30–0XE0	As of product version 1 as of firmware V3.0	Yes	Yes

Module	Order No.	Release	One-sided	Redundant
Communication processor CP 443-5 Basic (PROFIBUS; S7 communication)	6GK7 443–5FX01–0XE0	As of product version 1 as of firmware V3.1	Yes	Yes
	6GK7 443–5FX02–0XE0	As of product version 1 as of firmware V3.2	Yes	Yes
Communication processor CP 443-5 Extended (PROFIBUS; master on PROFIBUS DP) [1]	6GK7 443–5DX02–0XE0	As of product version 2 As of firmware V3.2.3	Yes	Yes
Communication processor CP 443-5 Extended (PROFIBUS DPV1) [1] [2]	6GK7 443–5DX03–0XE0	As of product version 1 As of firmware V5.1.4	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).

[3] Do not use this CP directly on the Internet. If you want to connect the system to the Internet, you need to install appropriate protection devices in front of the CP, for example, a SCALANCE SC with firewall. Observe also the information in Service and Support (https://support.industry.siemens.com/cs/ww/en/view/109799025).

FMs and CPs usable for distributed one-sided use

Note

You can use all the FMs and CPs released for the ET 200M with the S7-400H in distributed and one-sided mode.

FMs and CPs usable for distributed switched use

Module	Order No.	Release
Communication processor CP 341–1 (point-to-point link)	6ES7 341–1AH00–0AE0 6ES7 341–1BH00–0AE0 6ES7 341–1CH00–0AE0	As of product version 3
	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

Module	Order No.	Release
Counter module FM 350–1	6ES7 350–1AH01–0AE0 6ES7 350–1AH02–0AE0	As of product version 1
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
High Speed Boolean Processor FM 352–5	6ES7352–5AH00–0AE0	As of product version 1 As of firmware V1.0.0
Control module FM 355–2 C	6ES7 355–0CH00–0AE0	As of product version 1 As of firmware V1.0.0
Control module FM 355–2 S	6ES7 355–0SH00–0AE0	As of product version 1 As of firmware V1.0.0

Note

One-sided or switched function and communication modules are

not synchronized if they exist in pairs. For example, two identical FM 450 modules operating in one-sided mode do **not** synchronize their counter states.

Connection examples for redundant I/Os

E

E.1 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.

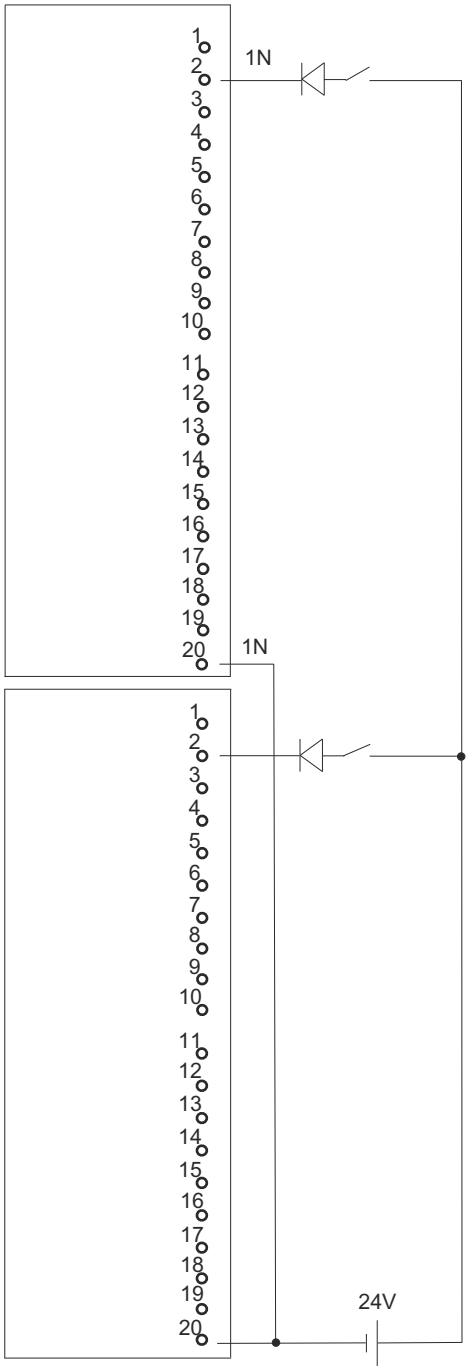


Figure E-1 Example of an interconnection with SM 321; DI 16 x DC 24 V

E.2 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.

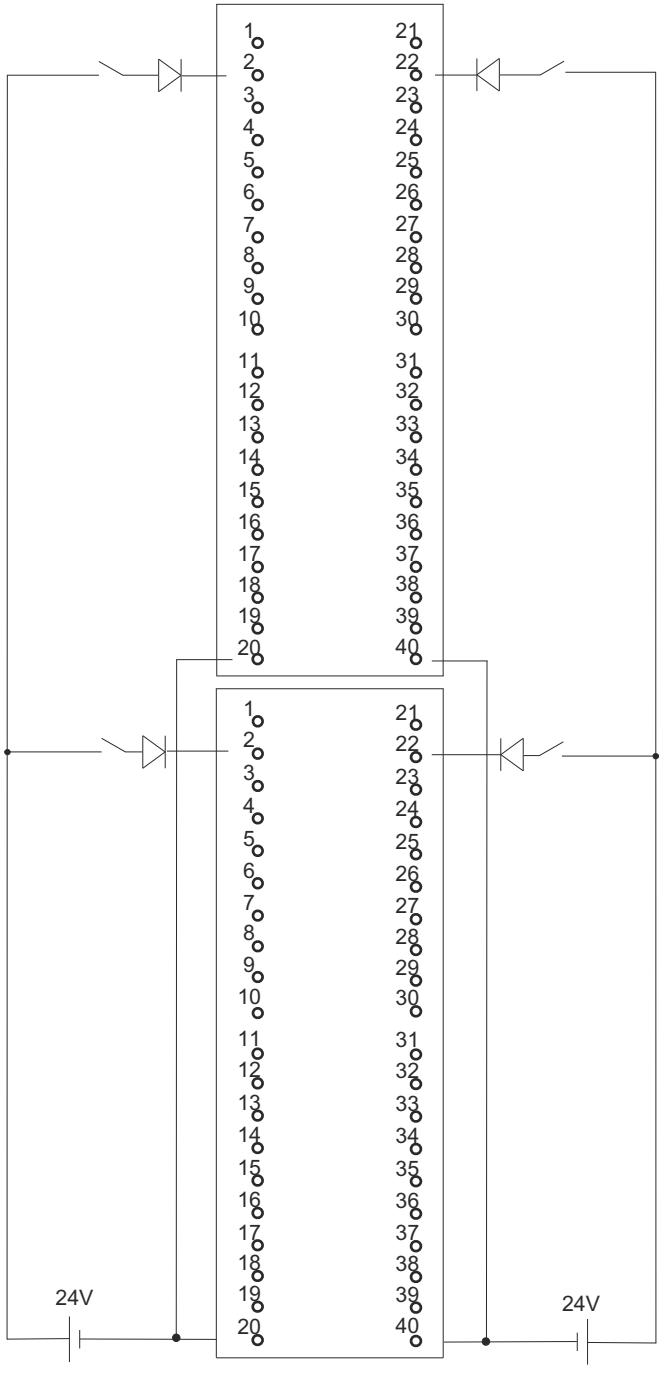


Figure E-2 Example of an interconnection with SM 321; DI 32 x DC 24 V

E.3 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.

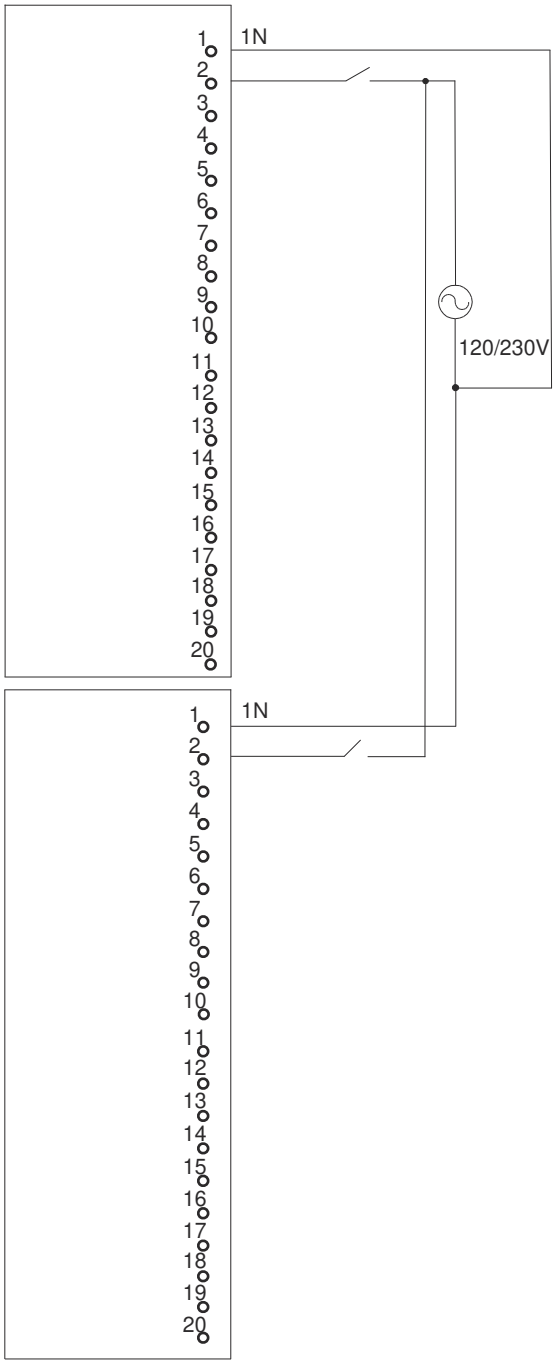


Figure E-3 Example of an interconnection with SM 321; DI 16 x AC 120/230 V

E.4 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.

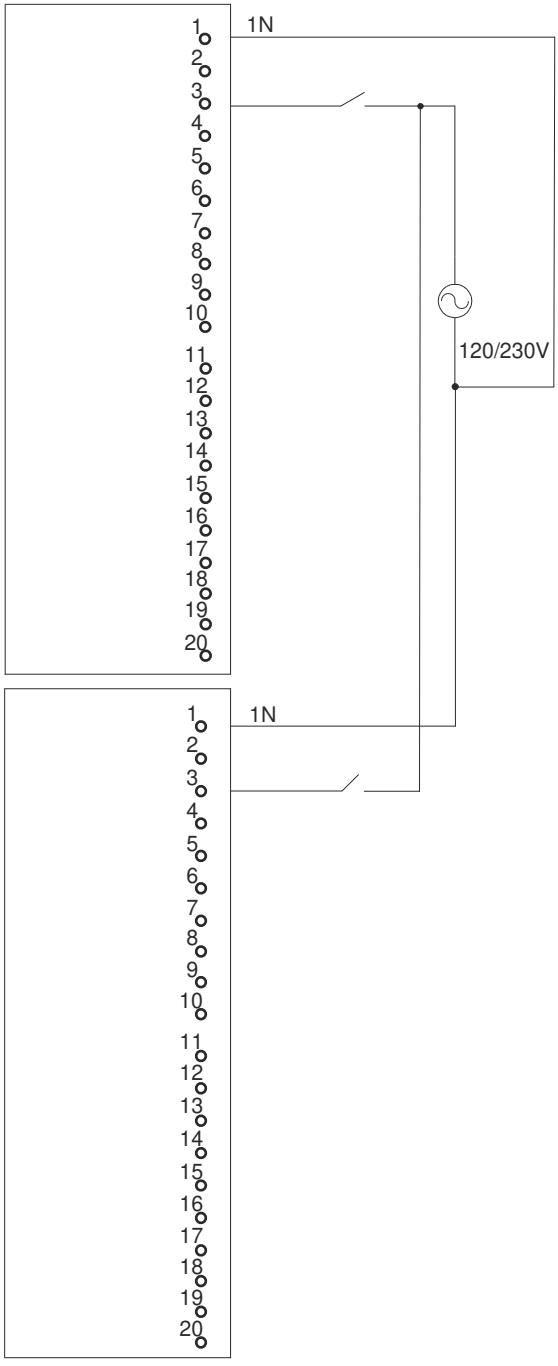


Figure E-4 Example of an interconnection with SM 321; DI 8 x AC 120/230 V

E.5 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.

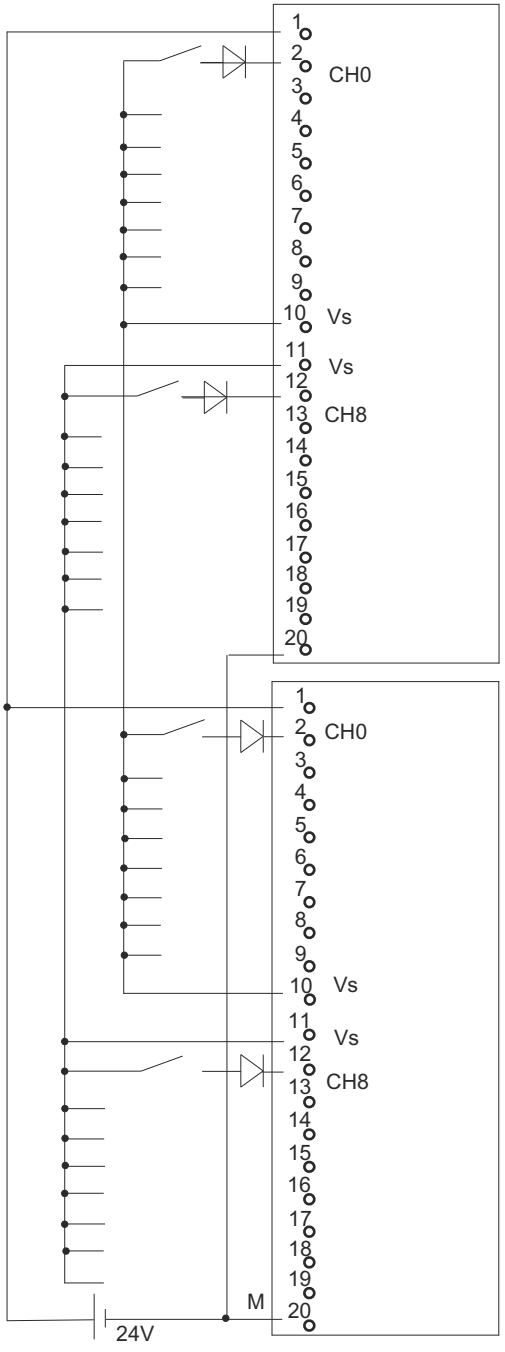


Figure E-5 Example of an interconnection with SM 321; DI 16 x DC 24V

E.6 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.

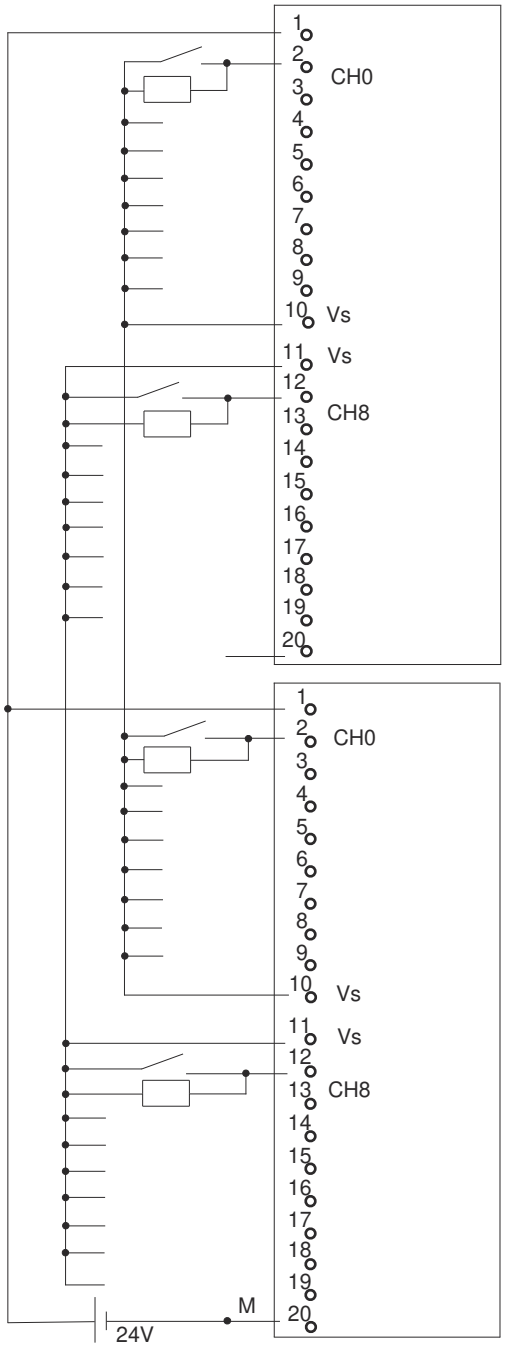


Figure E-6 Example of an interconnection with SM 321; DI 16 x DC 24V

E.7 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.

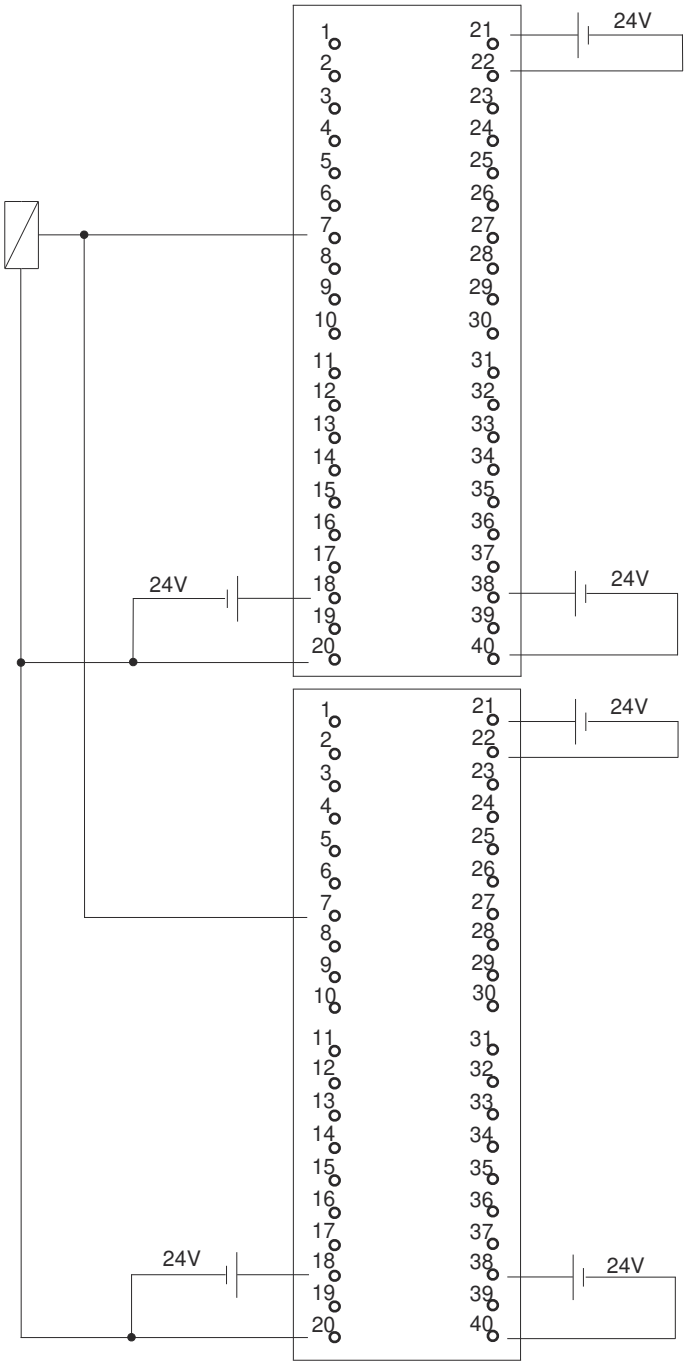


Figure E-7 Example of an interconnection with SM 326; DO 10 x DC 24V/2A

E.8 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.

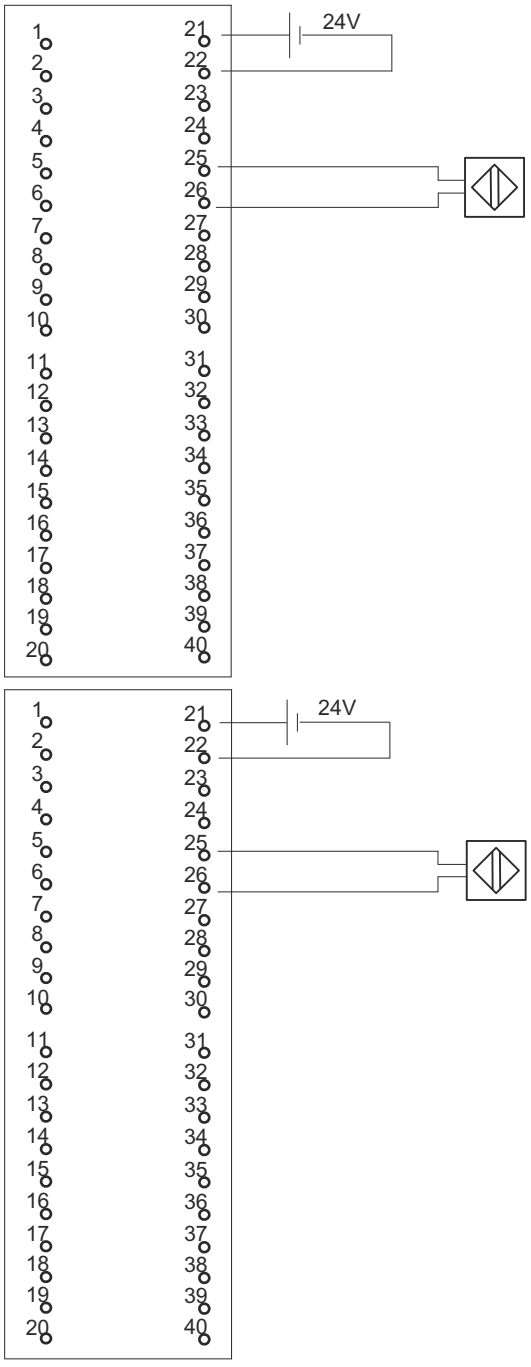


Figure E-8 Example of an interconnection with SM 326; DI 8 x NAMUR

E.9 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.

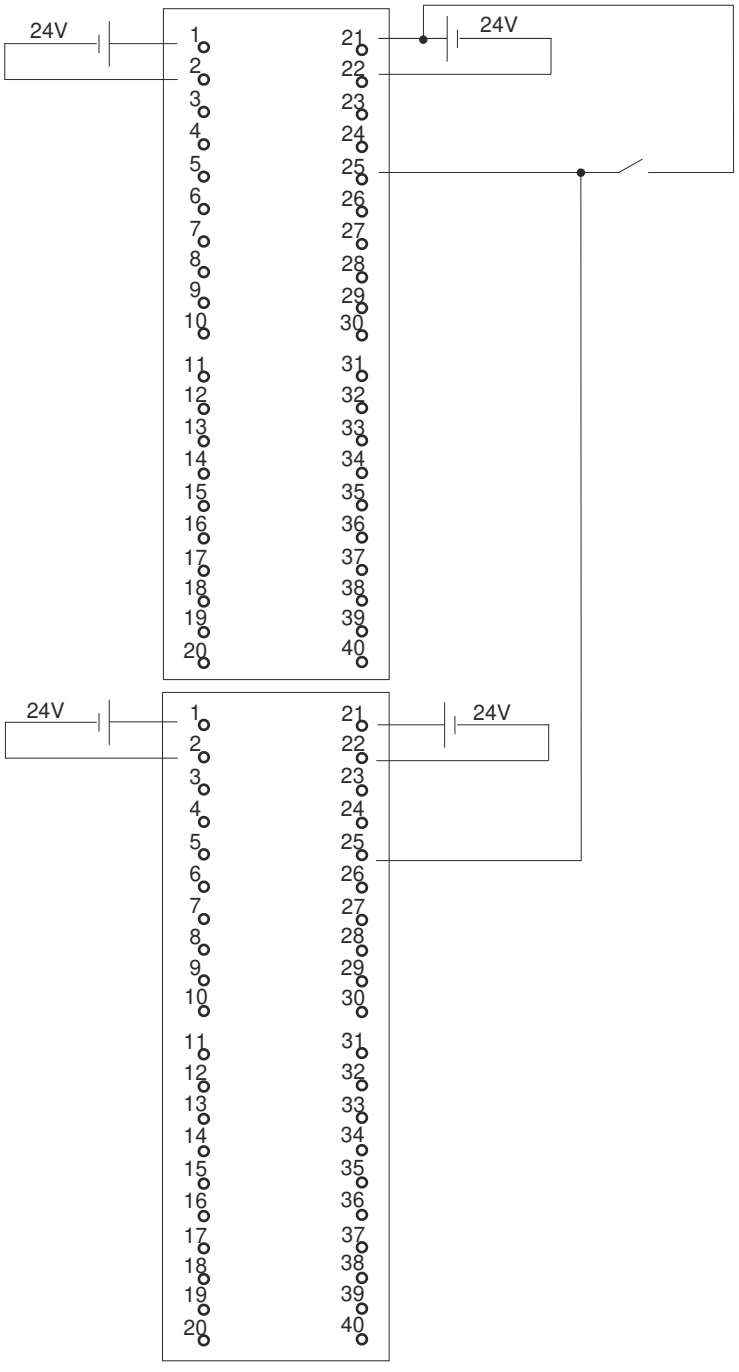


Figure E-9 Example of an interconnection with SM 326; DI 24 x DC 24 V

E.10 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.

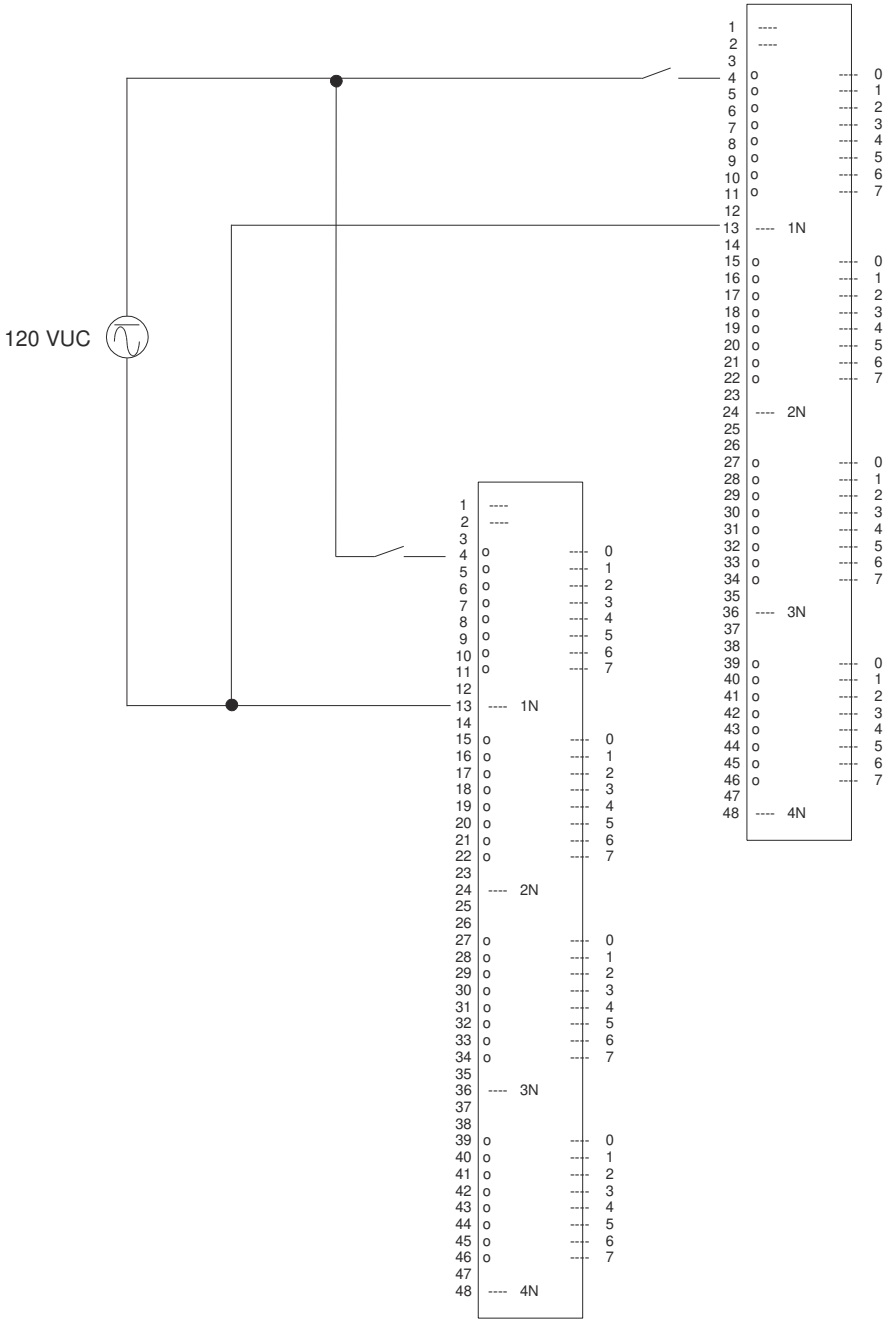


Figure E-10 Example of an interconnection with SM 421; DI 32 x UC 120 V

E.11 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.

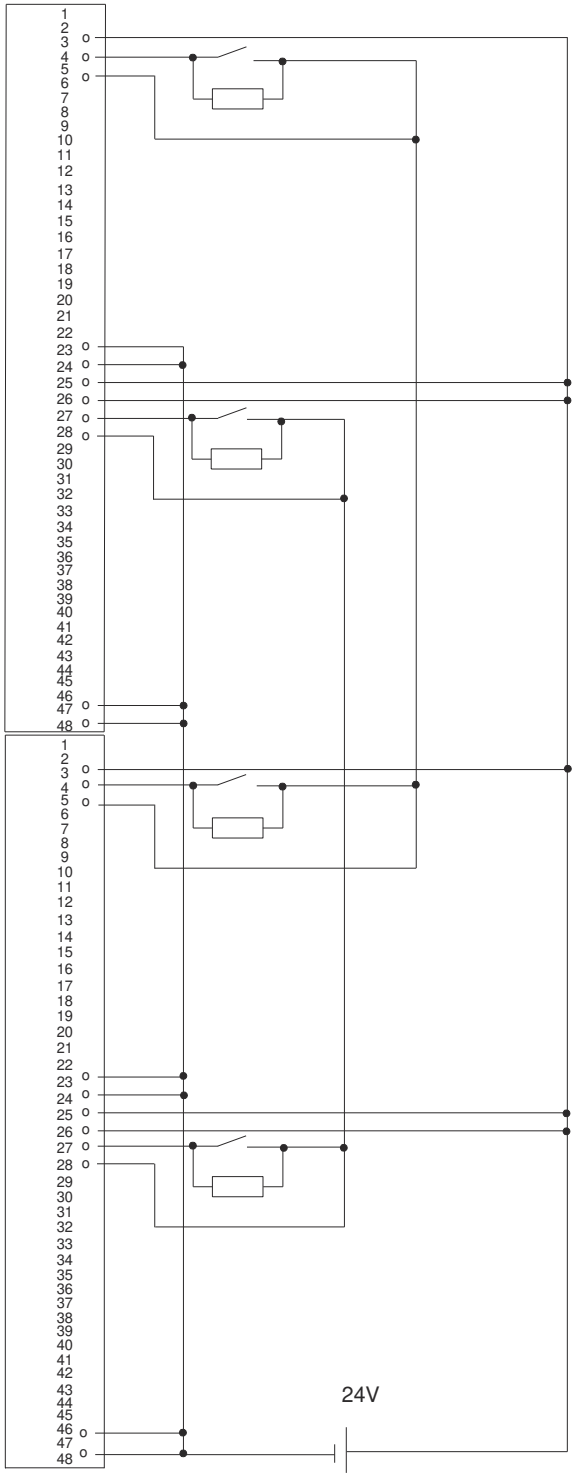


Figure E-11 Example of an interconnection with SM 421; DI 16 x 24 V

E.12 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.

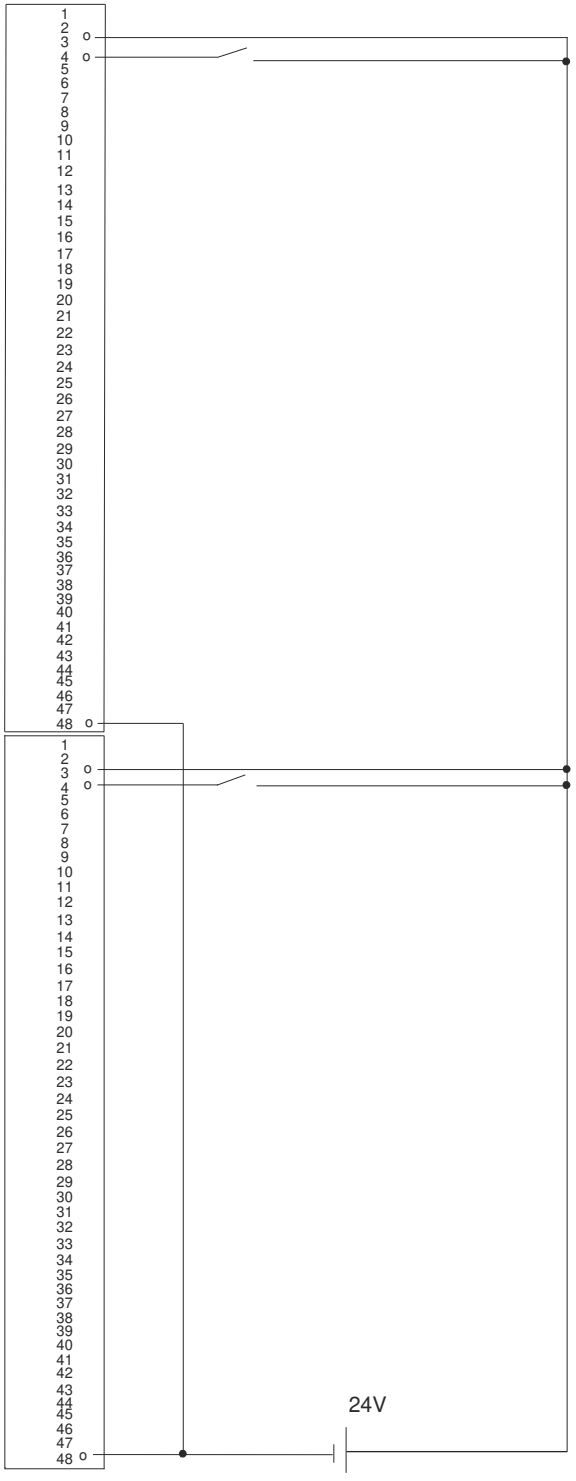


Figure E-12 Example of an interconnection with SM 421; DI 32 x 24 V

E.13 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.

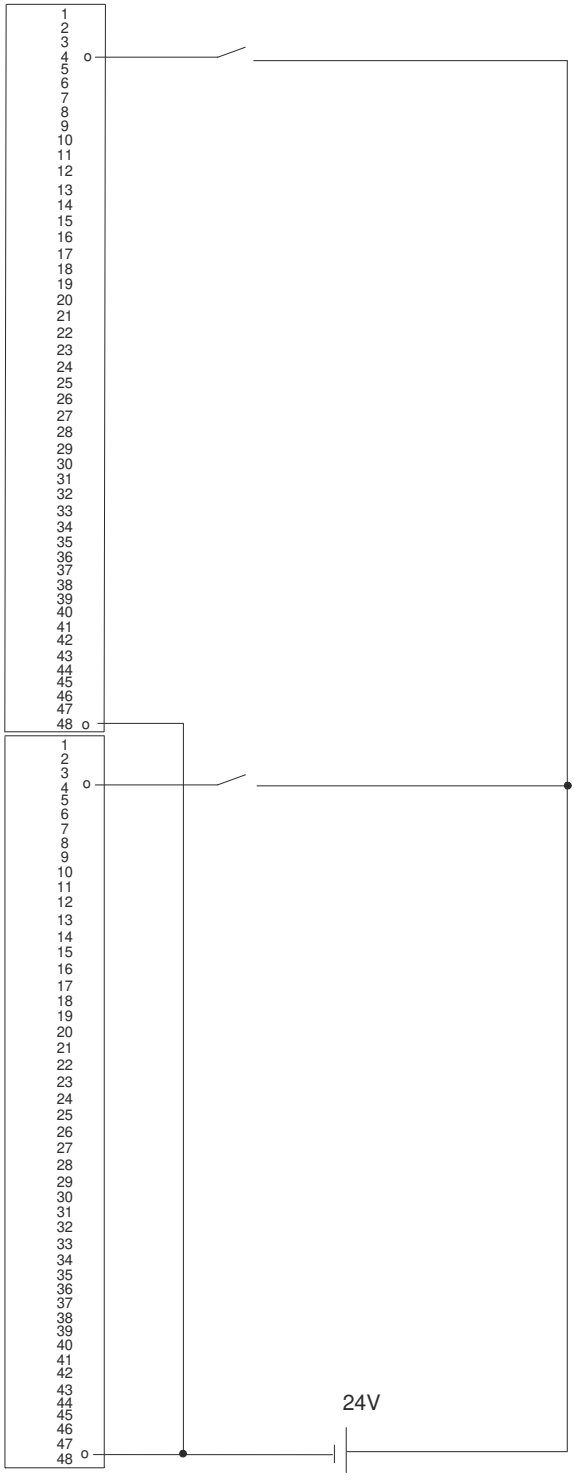


Figure E-13 Example of an interconnection with SM 421; DI 32 x 24 V

E.14 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

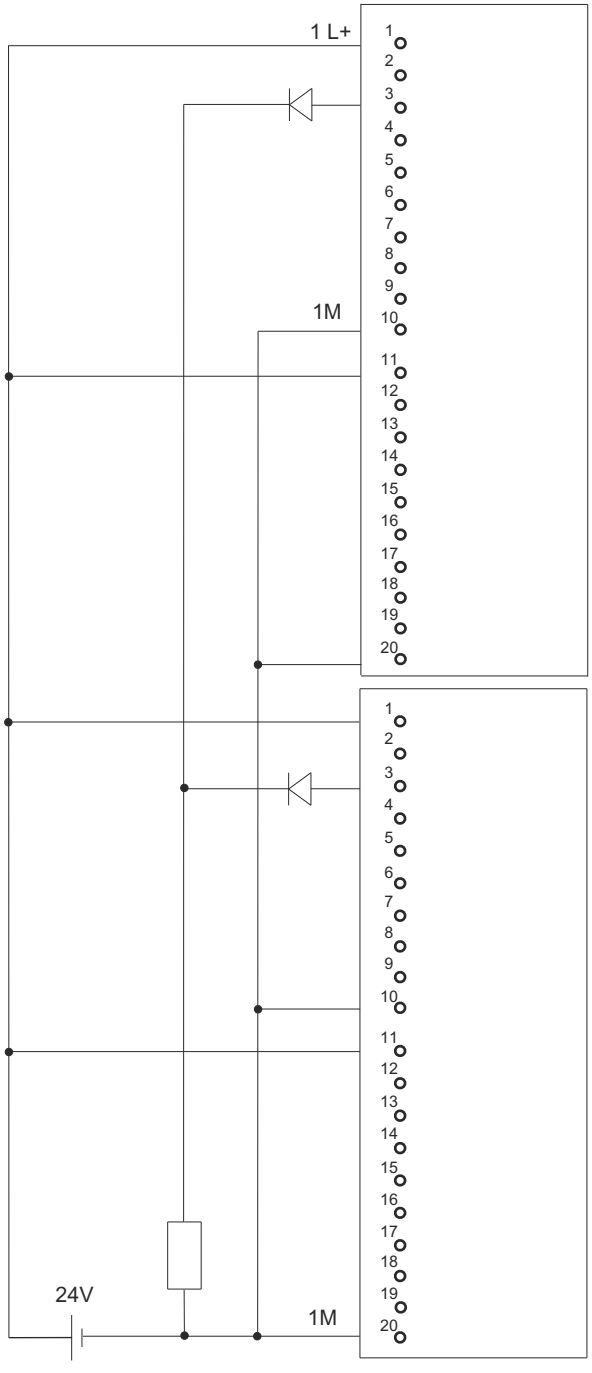


Figure E-14 Example of an interconnection with SM 322; DO 8 x DC 24 V/2 A

E.15 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

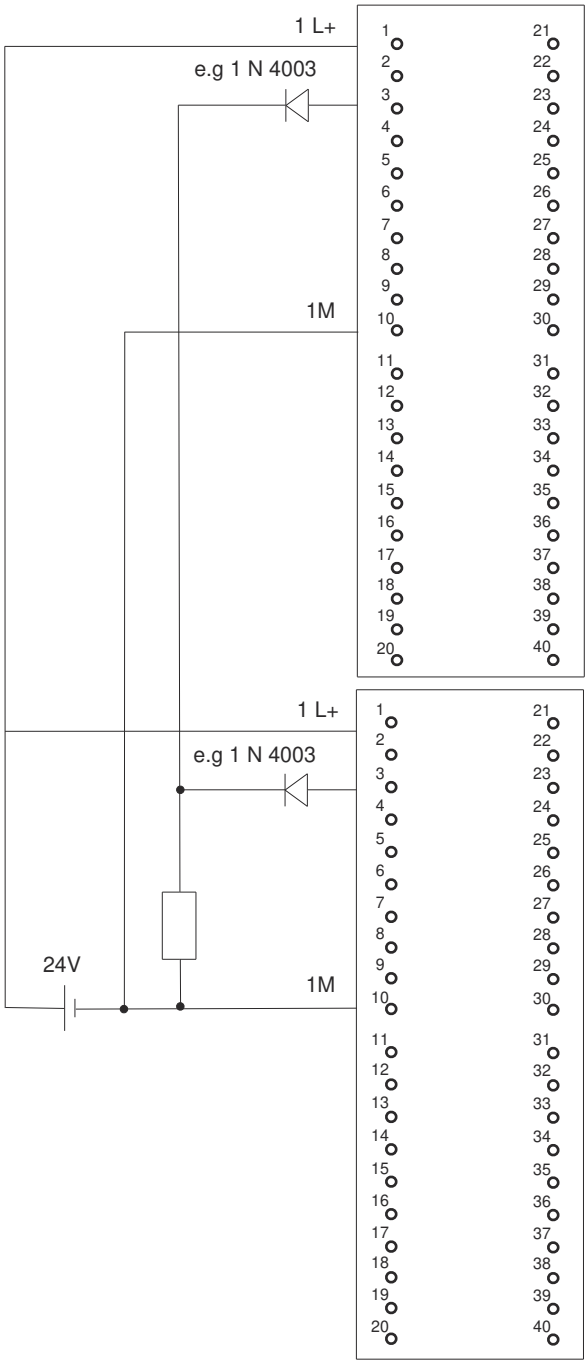


Figure E-15 Example of an interconnection with SM 322; DO 32 x DC 24 V/0.5 A

E.16 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.

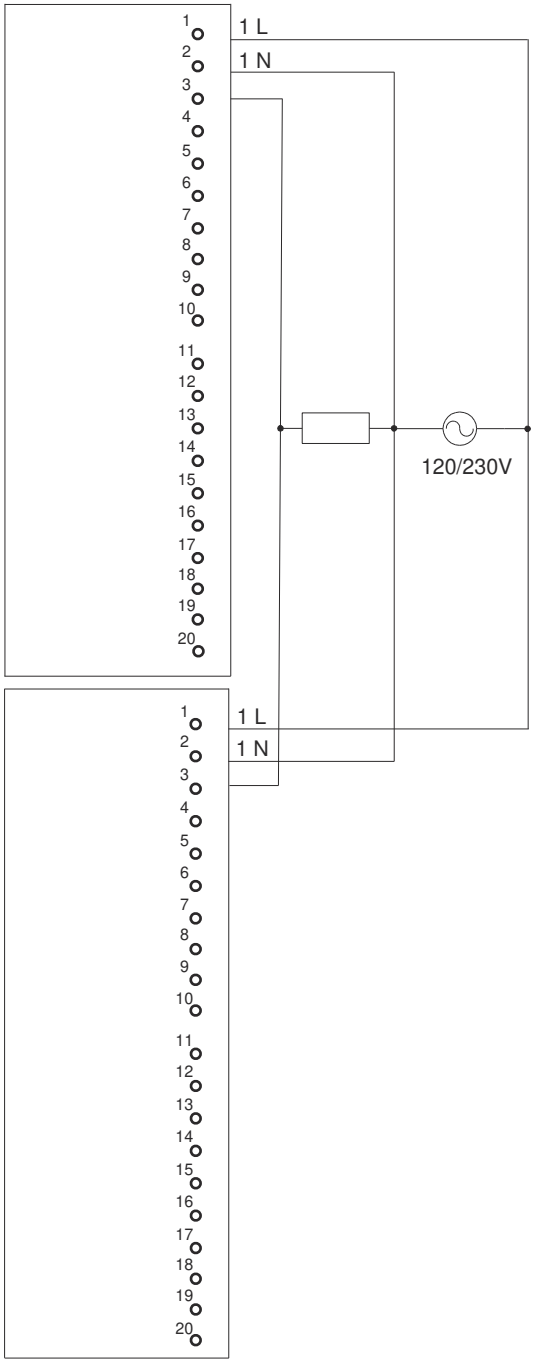


Figure E-16 Example of an interconnection with SM 322; DO 8 x AC 230 V/2 A

E.17 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

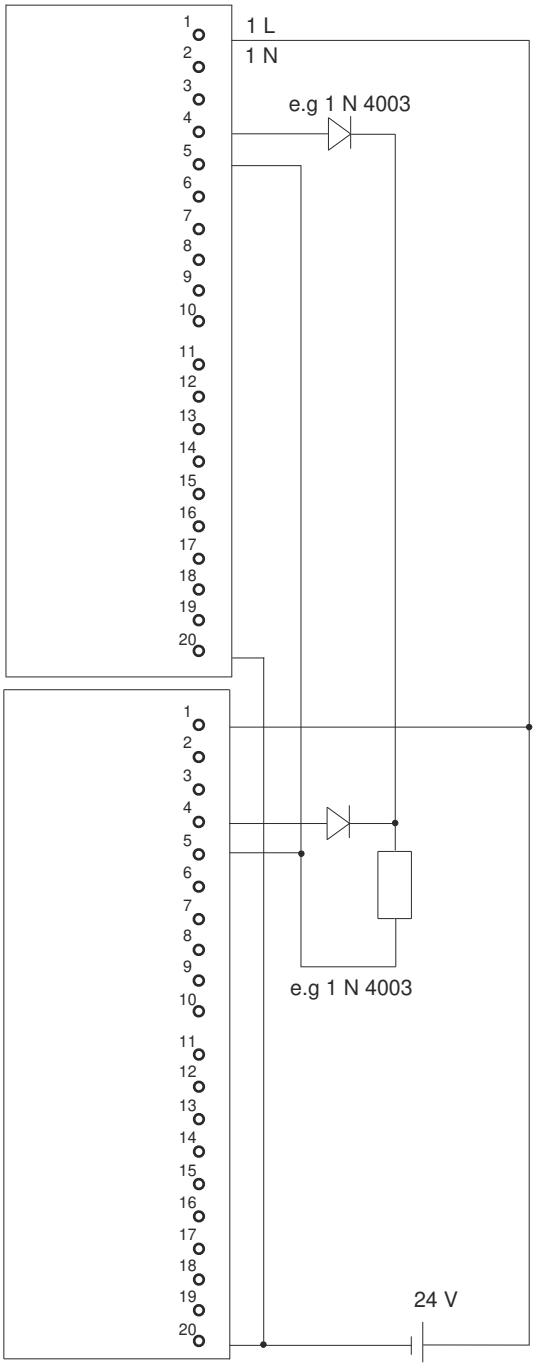


Figure E-17 Example of an interconnection with SM 322; DO 16 x DC 24 V/10 mA [EEx ib]

E.18 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

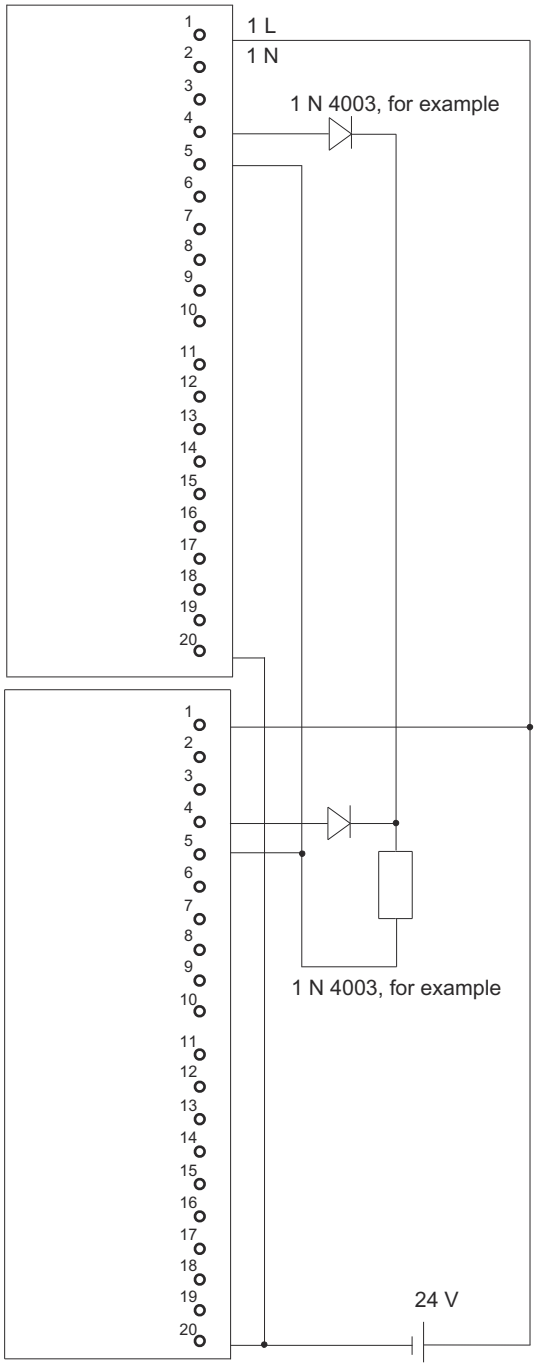


Figure E-18 Example of an interconnection with SM 322; DO 16 x DC 15 V/20 mA [EEx ib]

E.19 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.

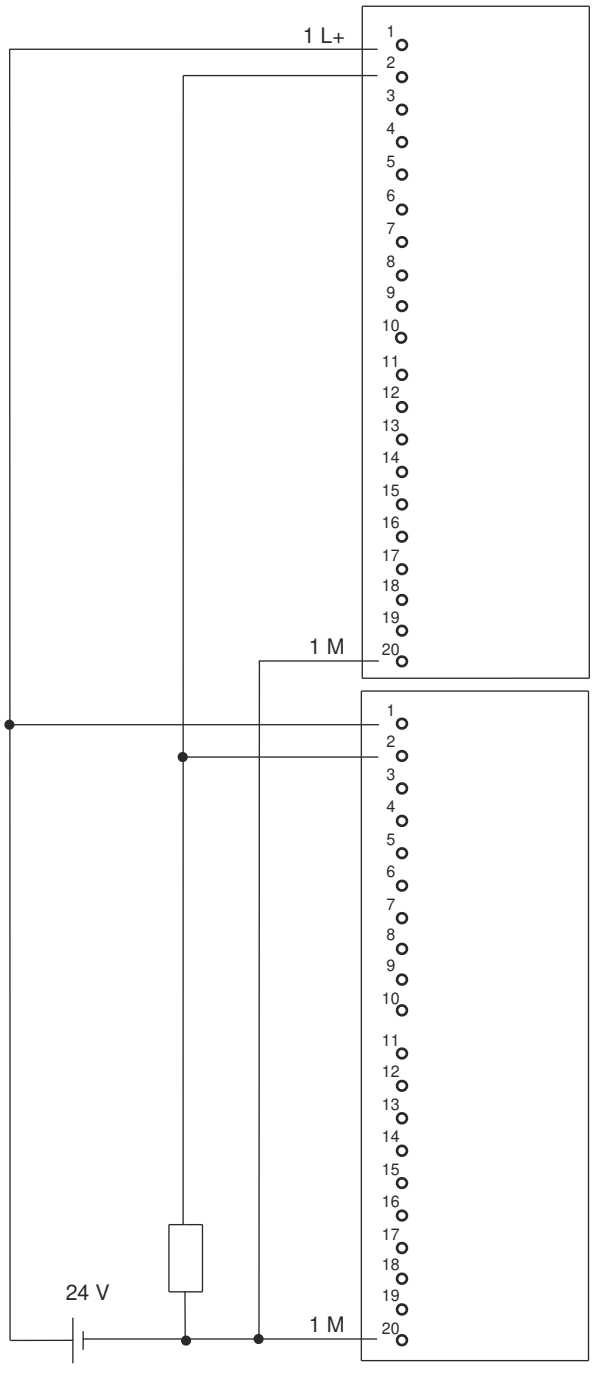


Figure E-19 Example of an interconnection with SM 322; DO 8 x DC 24 V/0.5 A

E.20 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.

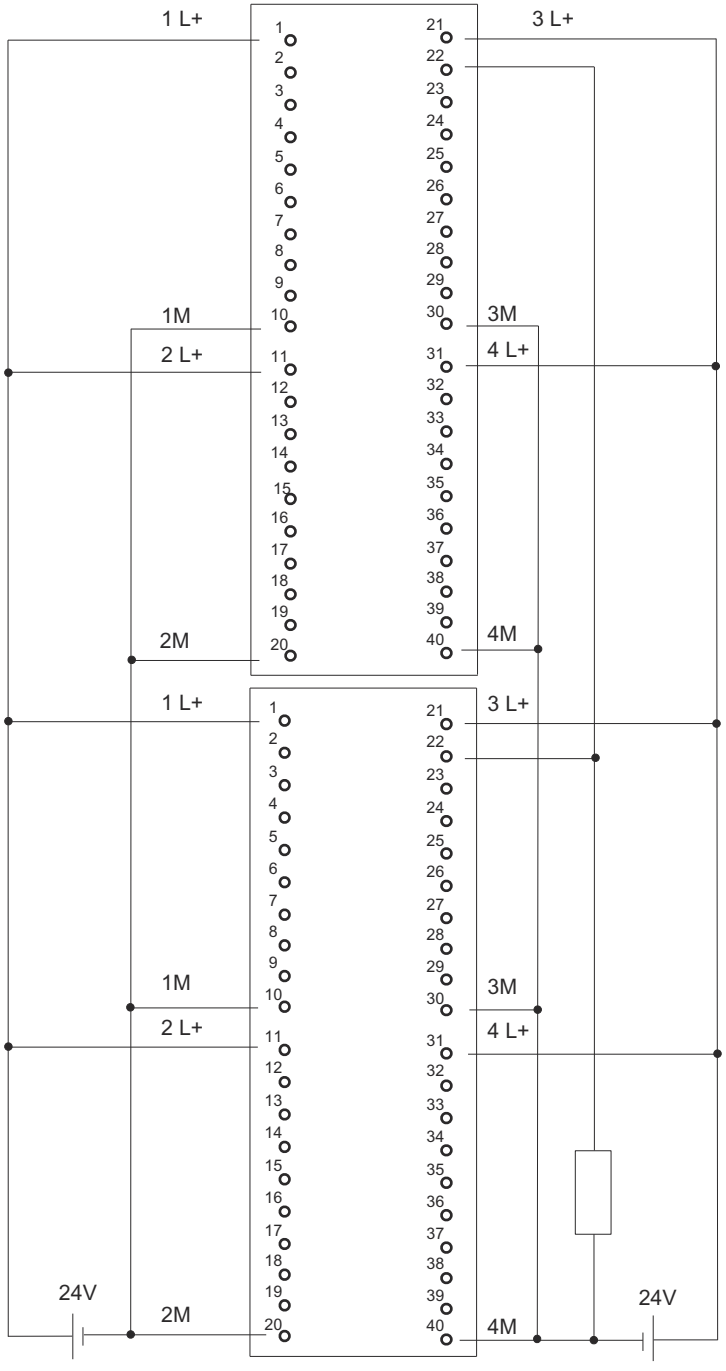


Figure E-20 Example of an interconnection with SM 322; DO 16 x DC 24 V/0.5 A

E.21 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

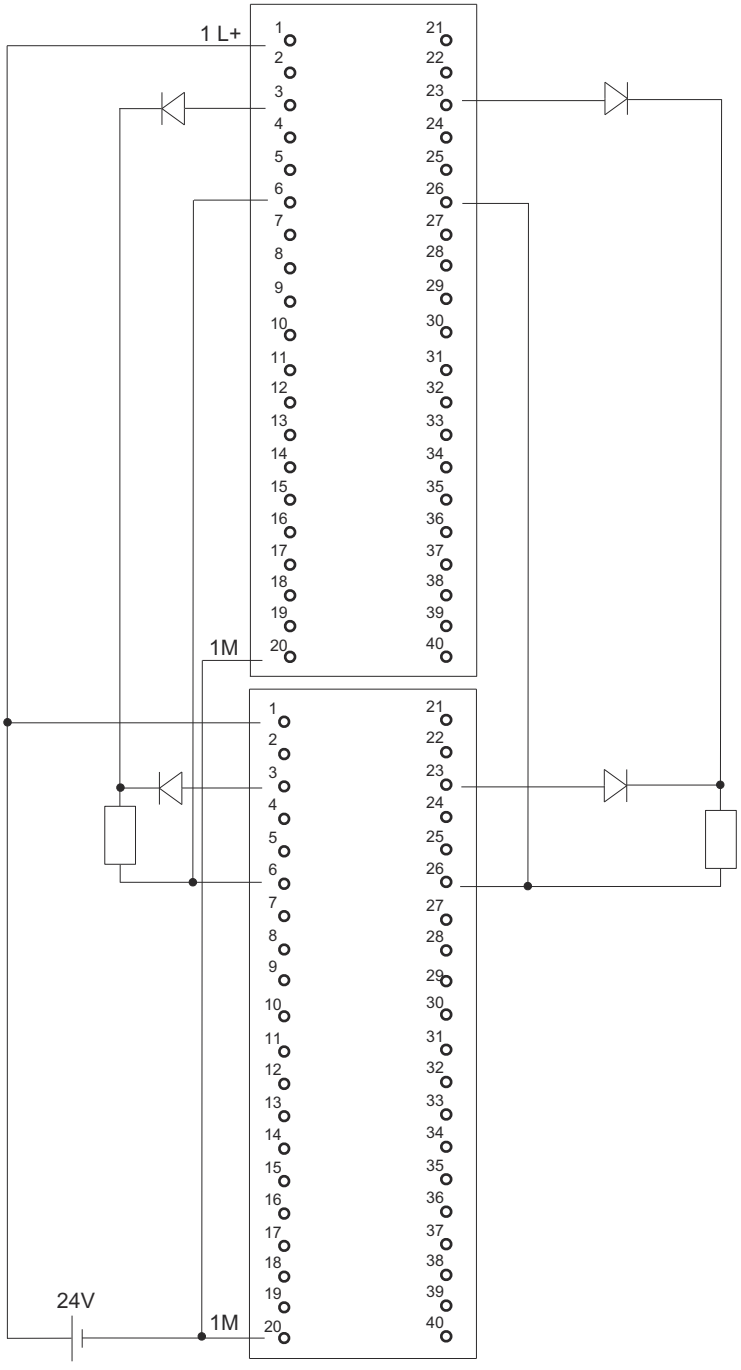


Figure E-21 Example of an interconnection with SM 332, AO 8 x 12 Bit

E.22 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

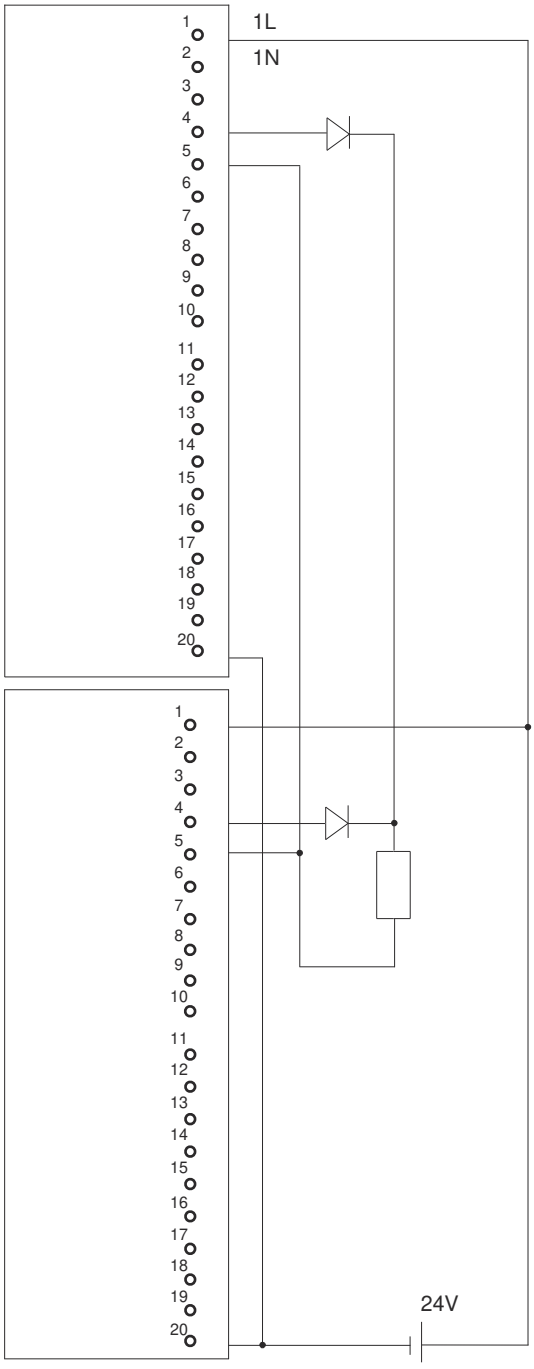


Figure E-22 Example of an interconnection with SM 332; AO 4 x 0/4...20 mA [EEx ib]

E.23 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.

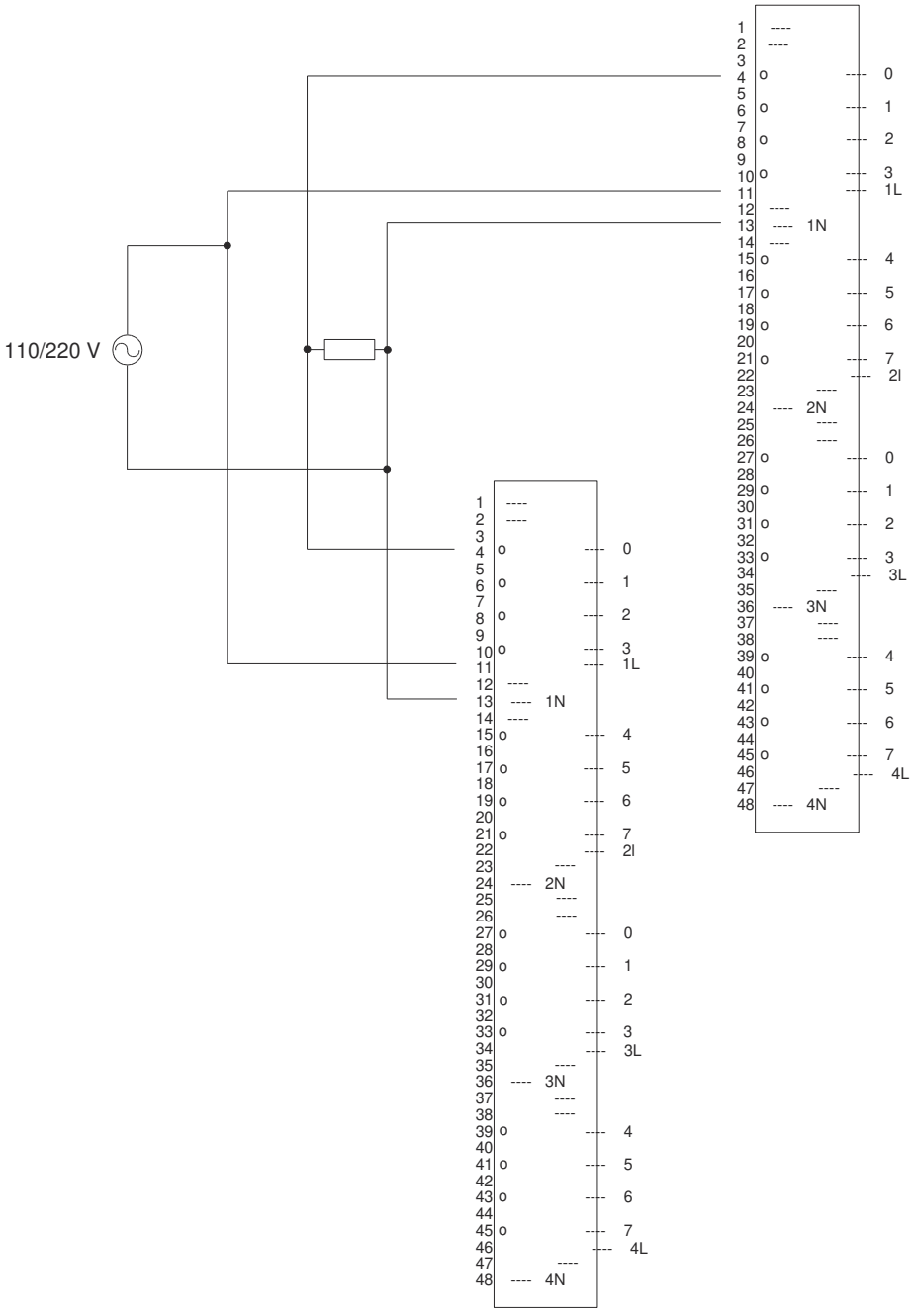


Figure E-23 Example of an interconnection with SM 422; DO 16 x 120/230 V/2 A

E.24 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

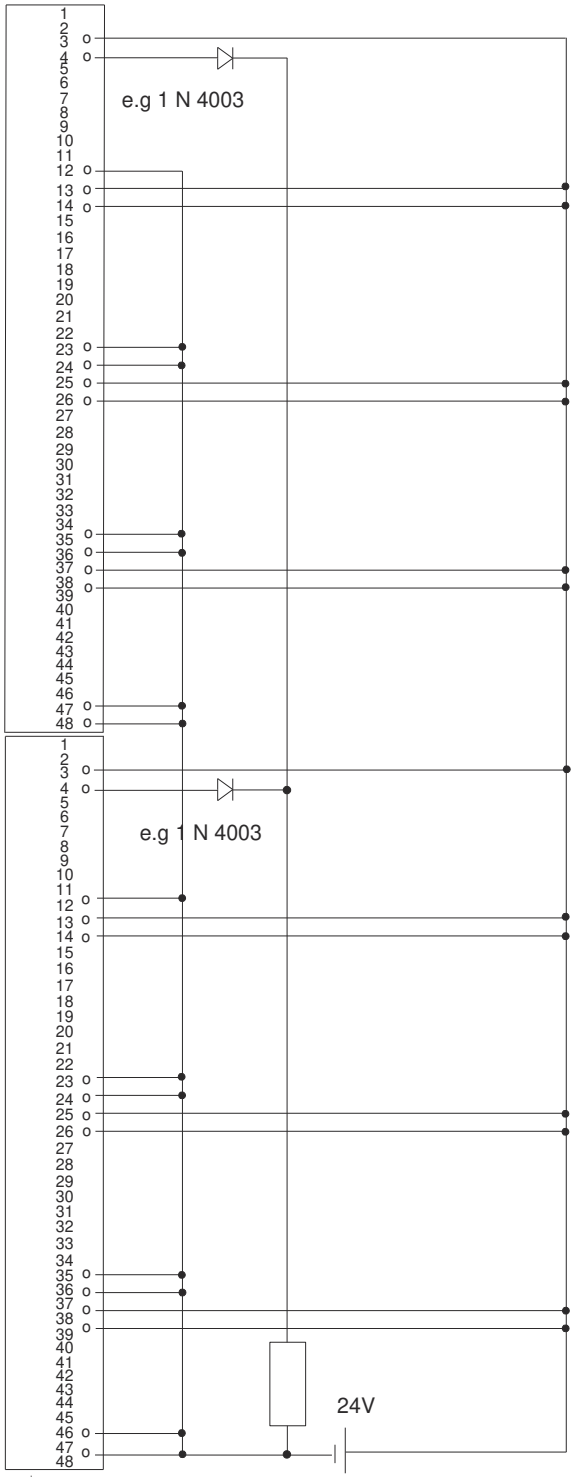


Figure E-24 Example of an interconnection with SM 422; DO 32 x DC 24 V/0.5 A

E.25 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.

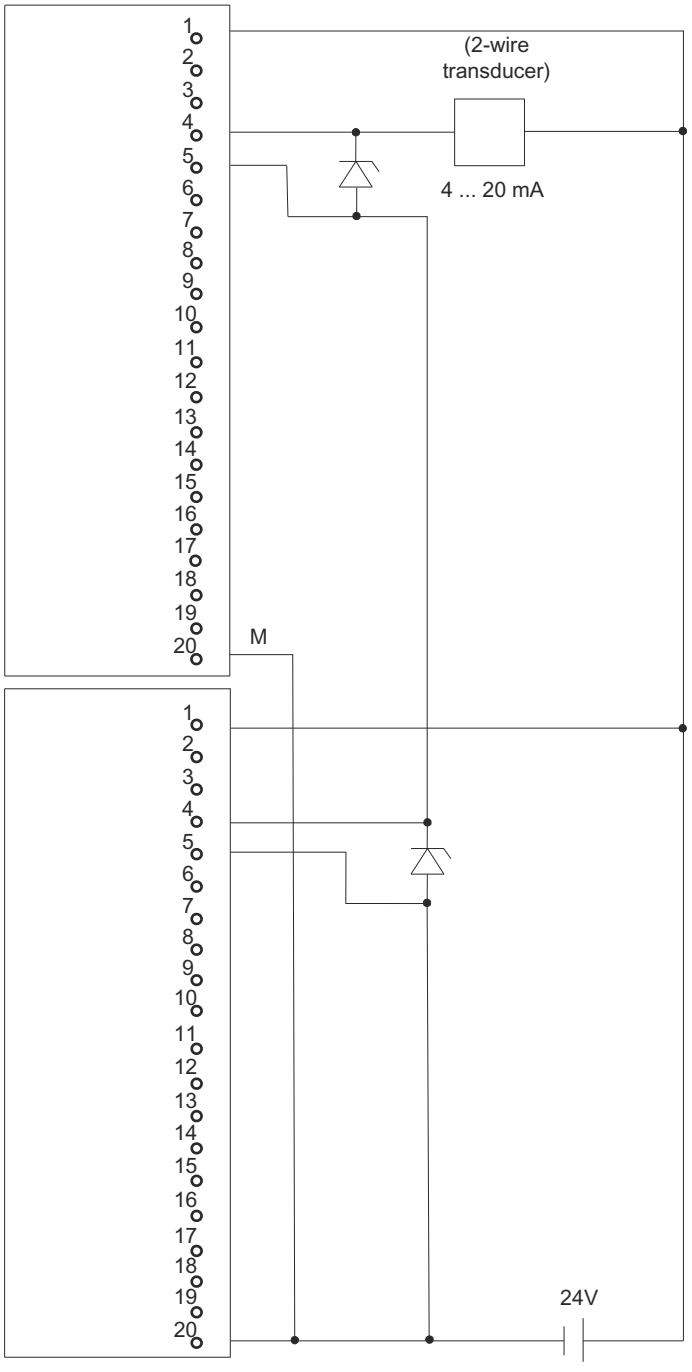


Figure E-25 Example of an interconnection with SM 331, AI 4 x 15 Bit [EEx ib]

E.26 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.

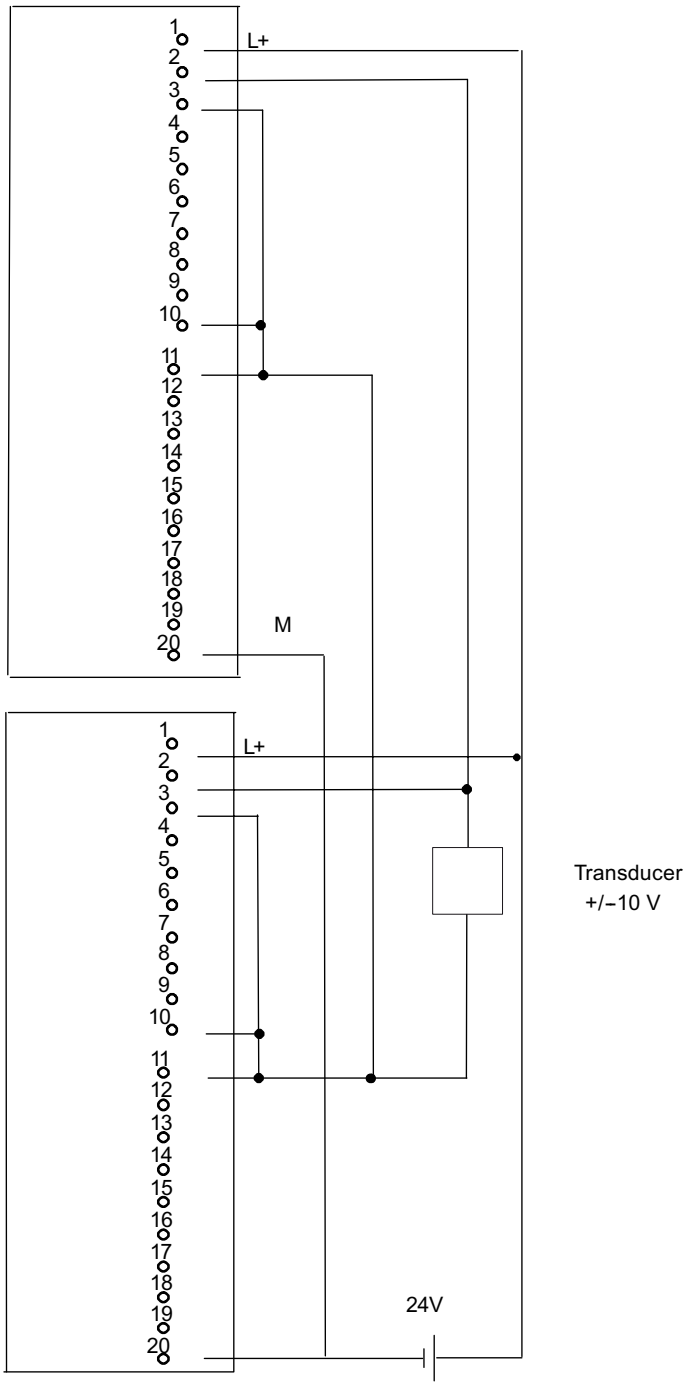


Figure E-26 Example of an interconnection with SM 331; AI 8 x 12 Bit

E.27 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.

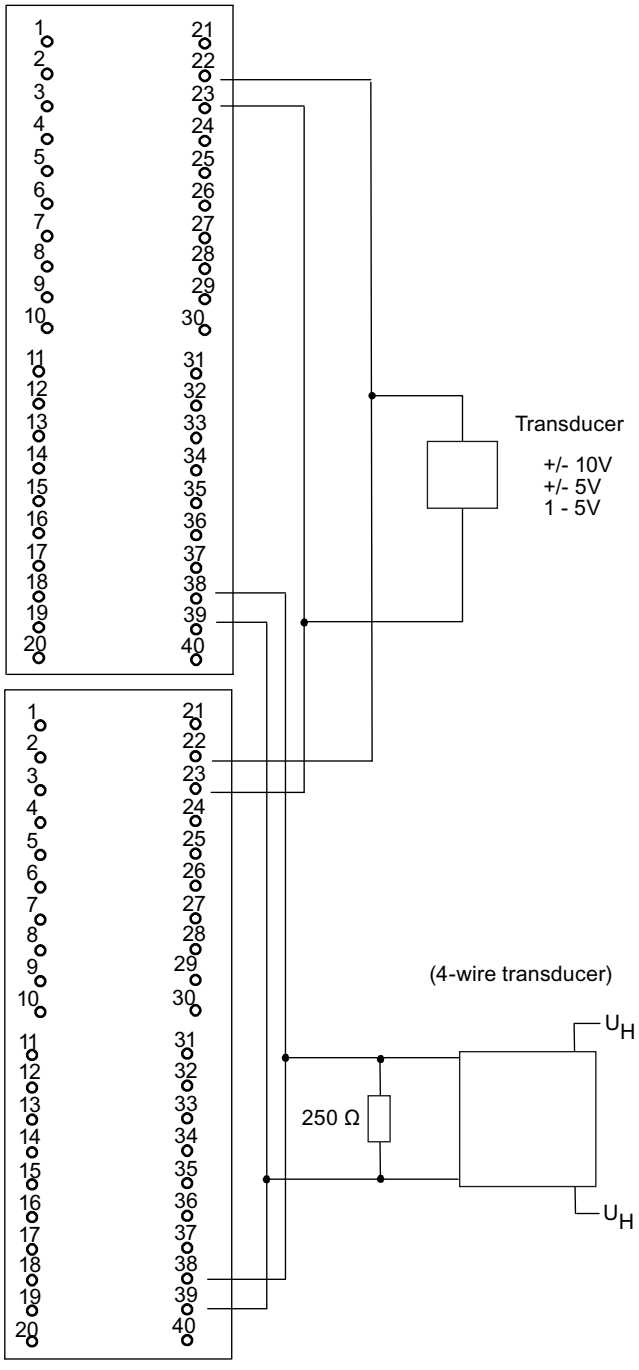


Figure E-27 Example of an interconnection with SM 331; AI 8 x 16 Bit

E.28 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.

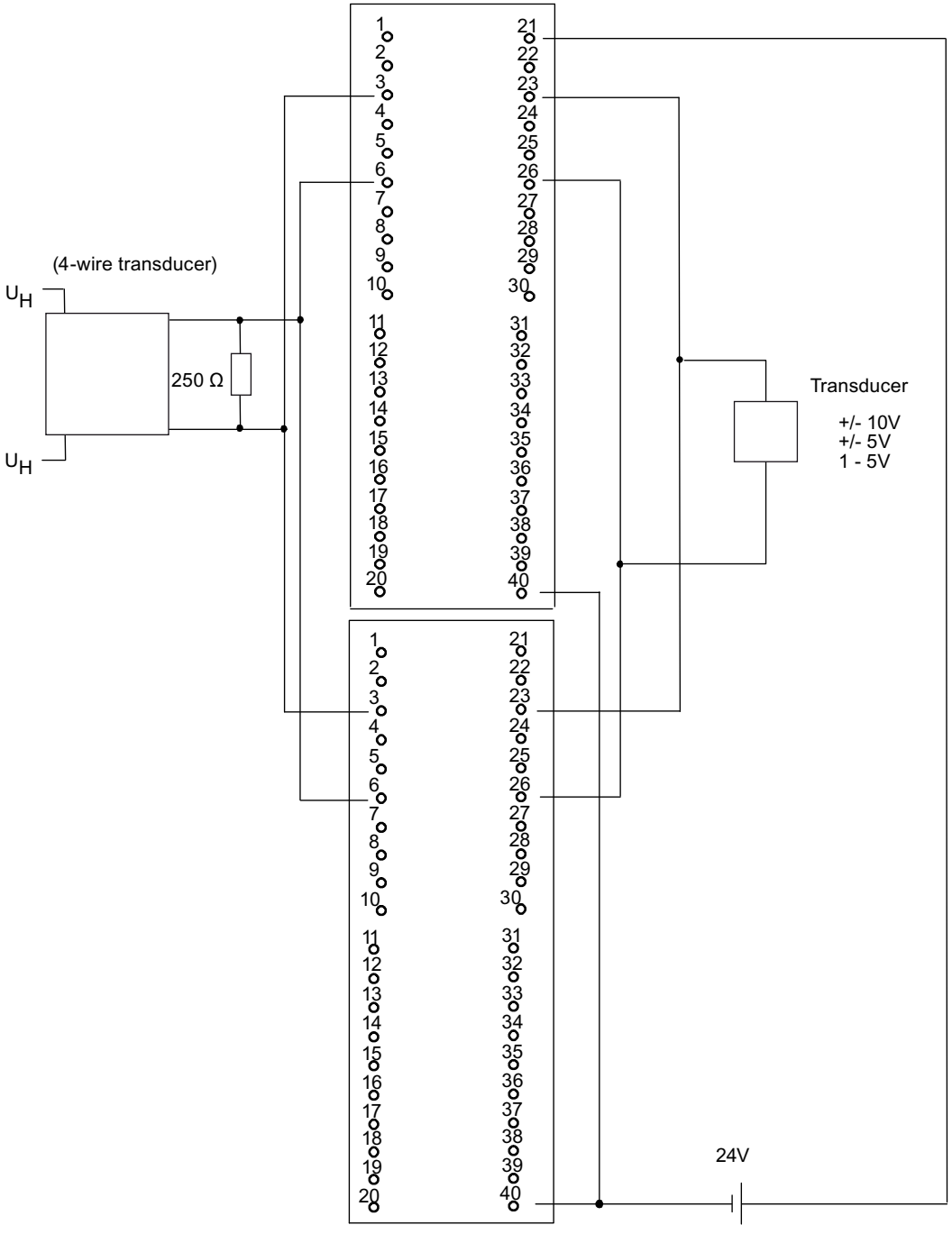


Figure E-28 Example of an interconnection with SM 331; AI 8 x 16 Bit

E.29 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.

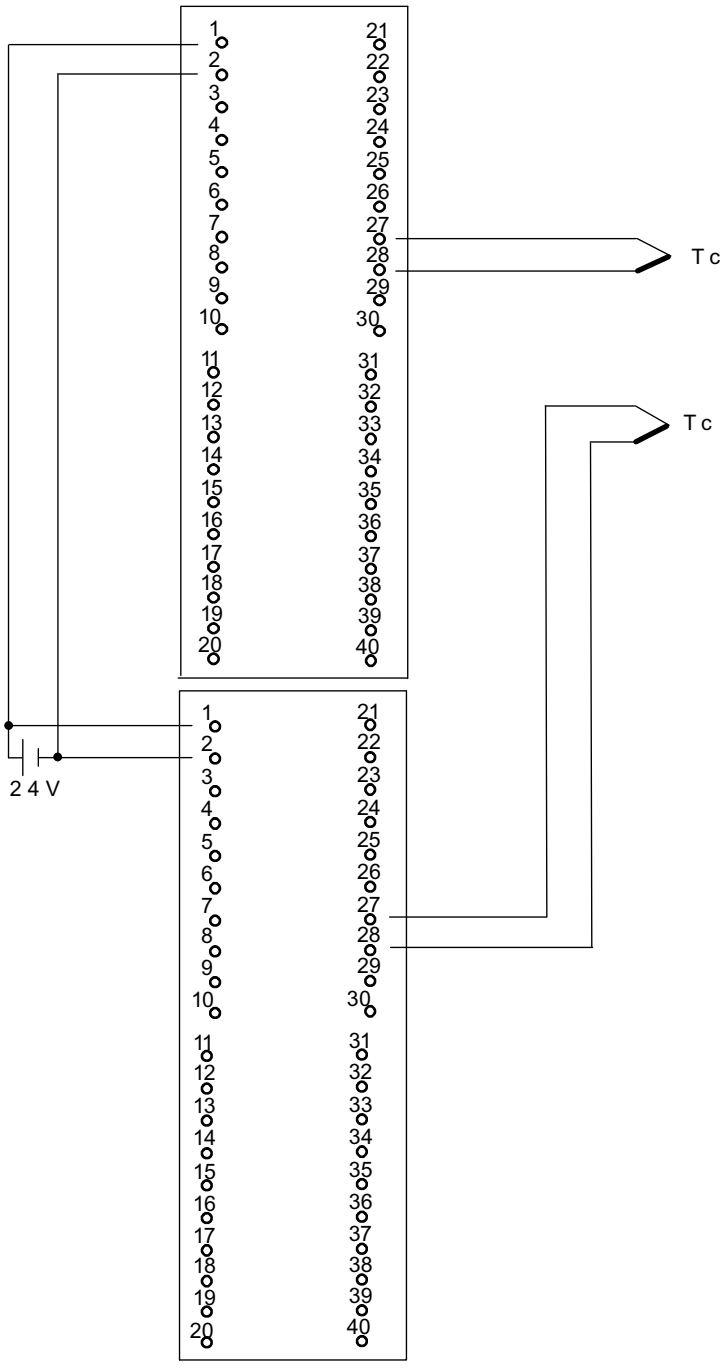


Figure E-29 Example of an interconnection AI 6xTC 16Bit iso

E.30 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.

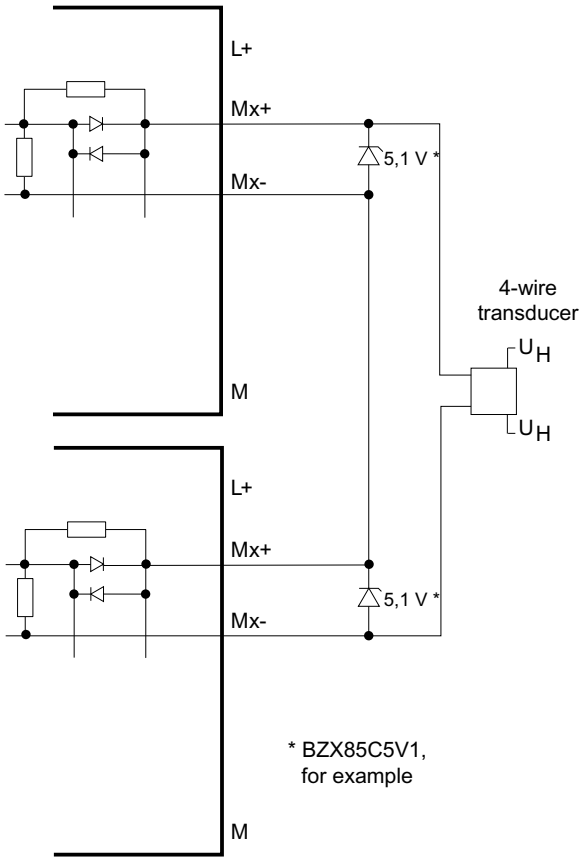


Figure E-30 Interconnection example 1 SM 331; AI 8 x 0/4...20mA HART

The diagram below shows the connection of a 2-wire transmitter to two redundant SM 331; AI 8 x 0/4...20mA HART.

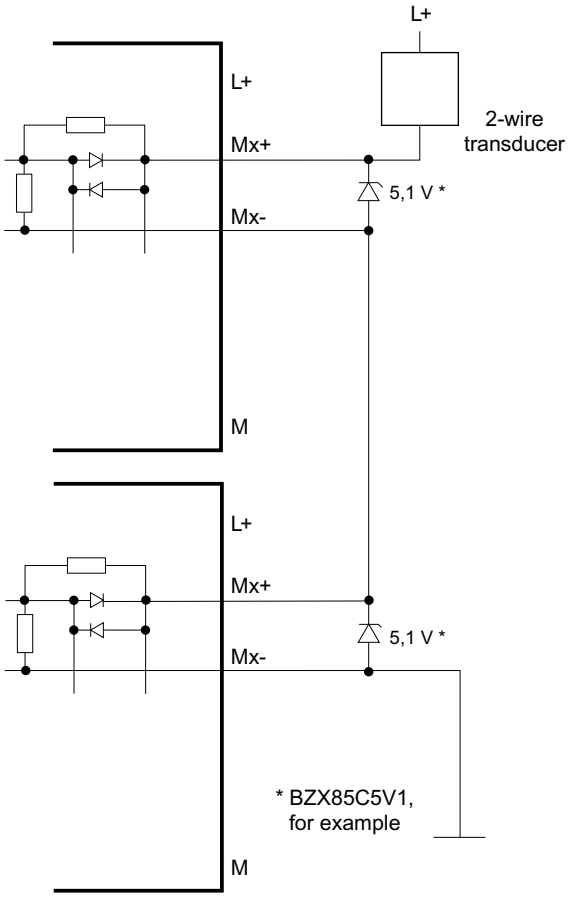


Figure E-31 Interconnection example 2 SM 331; AI 8 x 0/4...20mA HART

E.31 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

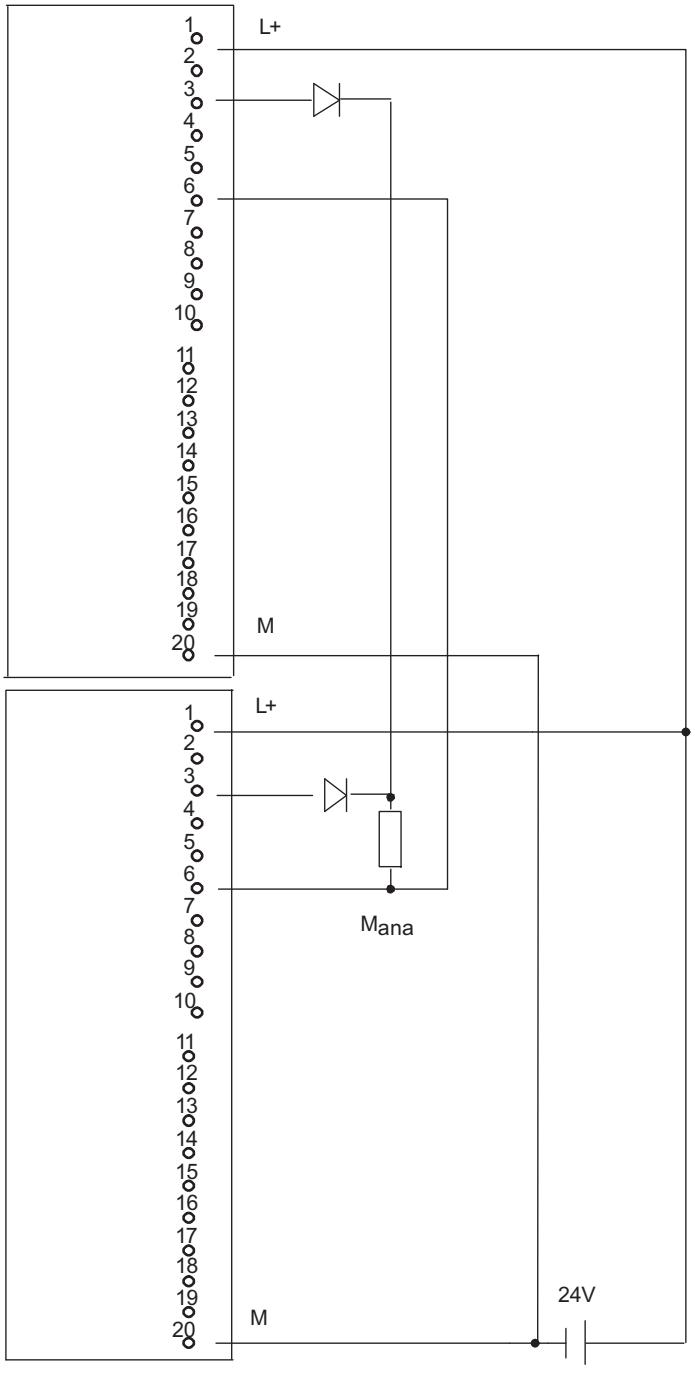


Figure E-32 Example of an interconnection with SM 332, AO 4 x 12 Bit

E.32 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.

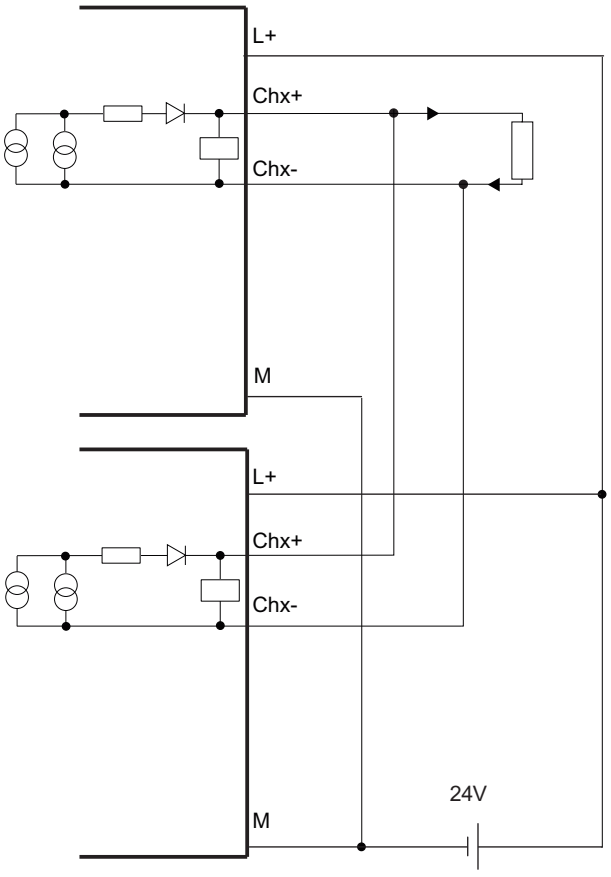


Figure E-33 Interconnection example 3 SM 332; AO 8 x 0/4...20mA HART

E.33 SM 431; AI 16 x 16 Bit, 6ES7 431–7QH00–0AB0

The diagram below shows the connection of a sensor to two SM 431; AI 16 x 16 Bit. Suitable Zener diode: BZX85C6v2.

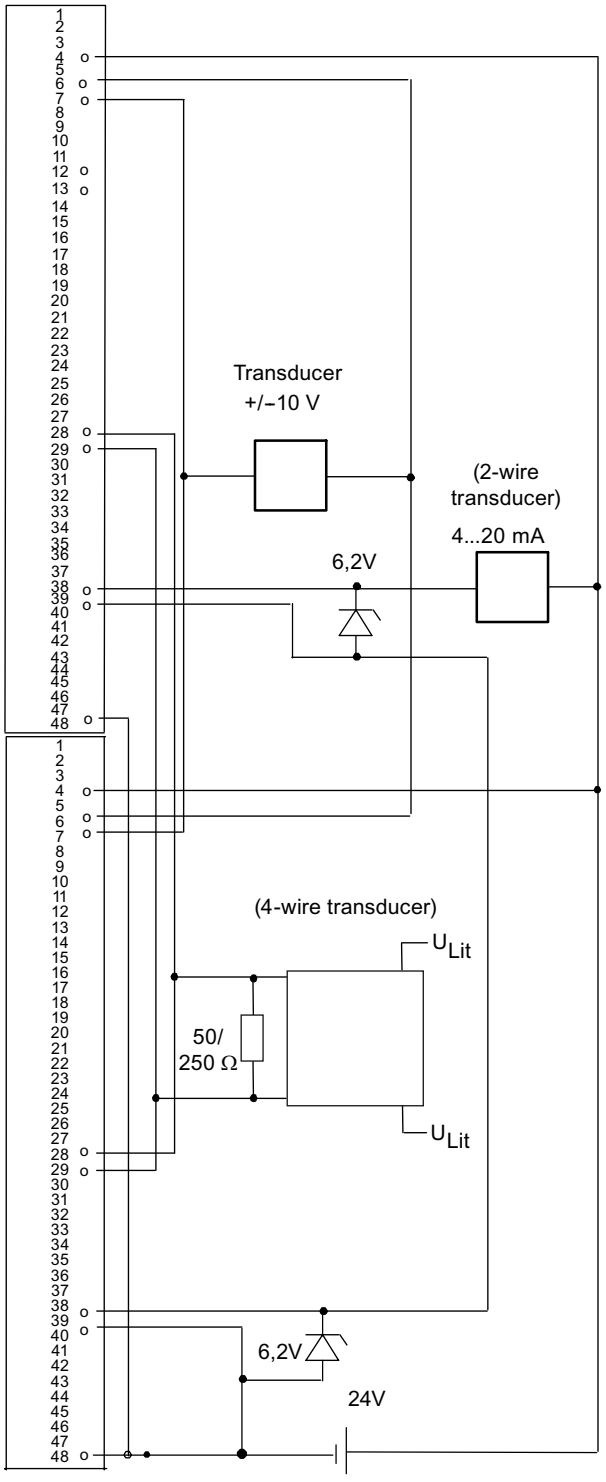


Figure E-34 Example of an interconnection with SM 431; AI 16 x 16 Bit

Glossary

1-out-of-2 system

See dual-channel fault-tolerant system

Comparison error

An error that may occur while memories are being compared on a fault-tolerant system.

Dual-channel fault-tolerant system

Fault-tolerant system with two central processing units

ERROR-SEARCH

An operating mode of the reserve CPU of a fault-tolerant system in which the CPU performs a complete self-test.

Fail-safe systems

Fail-safe systems are characterized by the fact that, when certain failures occur, they remain in a safe state or go directly to another safe state.

Fault-tolerant station

A fault-tolerant station containing two central processing units (master and reserve).

Fault-tolerant system

A fault-tolerant system consists of at least two central processing units (master and reserve). The user program is processed identically in both the master and reserve CPUs.

Fault-tolerant systems

Fault-tolerant systems are designed to reduce production downtime. Availability can be enhanced, for example, by means of component redundancy .

I/O, one-sided

We speak of a one-sided I/O when an input/output module can be accessed by only one of the redundant central processing units. It may be single-channel or multi-channel (redundant) module.

I/O, redundant

We speak of a redundant I/O when there is more than one input/output module available for a process signal. It may be connected as one-sided or switched module. Terminology: "Redundant one-sided I/O" or "Redundant switched I/O"

I/O, single-channel

When there is only one input/output module for a process signal, in contrast to a redundant I/O, this is known as a single-channel I/O. It may be connected as one-sided or switched module.

I/O, switched

We speak of a switched I/O when an input/output module can be accessed by all of the redundant central processing units of a fault-tolerant system. It may be single-channel or multi-channel (redundant) module.

Link-up

In the link-up system mode of a fault-tolerant system, the master CPU and the reserve CPU compare the memory configuration and the contents of the load memory. If they establish differences in the user program, the master CPU updates the user program of the reserve CPU.

Master CPU

The central processing unit that is the first redundant central processing unit to start up . It continues to operate as the master when the redundancy connection is lost . The user program is processed identically in both the master and reserve CPUs.

Mean Down Time (MDT)

The mean down time MDT essentially consists of the time until error detection and the time required to repair or replace defective modules.

Mean Time Between Failures (MTBF)

The average time between two failures and, consequently, a criterion for the reliability of a module or a system.

Mean Time to Repair (MTTR)

The mean time to repair MTTR denotes the average repair time of a module or a system, in other words, the time between the occurrence of an error and the time when the error has been rectified .

Redundancy, functional

Redundancy with which the additional technical means are not only constantly in operation but also involved in the scheduled function. Synonym: active redundancy.

Redundant

In redundant system mode of a fault-tolerant system the central processing units are in RUN mode and are synchronized over the redundant link.

Redundant link

A link between the central processing units of a fault-tolerant system for synchronization and the exchange of data .

Redundant systems

Redundant systems are characterized by the fact that important automation system components are available more than once (redundant). When a redundant component fails, processing of the program is not interrupted.

Reserve CPU

The redundant central processing unit of a fault-tolerant system that is linked to the master CPU. It goes to STOP mode when the redundancy connection is lost. The user program is processed identically in both the master and reserve CPUs.

Self-test

In the case of fault-tolerant CPUs defined self-tests are executed during startup, cyclical processing and when comparison errors occur. They check the contents and the state of the CPUs and the I/Os.

Single mode

An H system changes to single mode, when it was configured to be redundant and only one CPU is in RUN. This CPU is then automatically the master CPU.

Stand-alone operation

Stand-alone mode is the use of a fault-tolerant CPU in a standard SIMATIC-400 station.

Stop

With fault-tolerant systems: In the stop system mode of a fault-tolerant system, the central processing units of the fault-tolerant system are in STOP mode.

Synchronization module

An interface module for the redundant link in a fault-tolerant system.

Update

In the update system mode of a fault-tolerant system, the master CPU updates the dynamic data of the reserve CPU.

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