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S7-1500

S7-1500R/H redundant system

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S7-1500
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System Manual

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Legal information

Warning notice system

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

> **⚠ DANGER**
>
> indicates that death or severe personal injury **will** result if proper precautions are not taken.

> **⚠ WARNING**
>
> indicates that death or severe personal injury **may** result if proper precautions are not taken.

> **⚠ CAUTION**
>
> indicates that minor personal injury can result if proper precautions are not taken.

> **NOTICE**
>
> indicates that property damage can result if proper precautions are not taken.

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

Qualified Personnel

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

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Note the following:

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

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Disclaimer of Liability

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

Preface

Purpose of the documentation

This documentation provides important information on the following aspects of the S7-1500R/H redundant system:

- An overview of the redundant system
- Configuration and failure scenarios
- How to install, wire and commission the redundant system
- Information on maintenance and fault correction

Basic knowledge required

General knowledge in the field of automation engineering is required to understand this documentation.

Validity of the documentation

This documentation applies to all products of the SIMATIC S7-1500R/H redundant system.

Conventions

STEP 7: In this documentation, "STEP 7" is used as a synonym for all versions of the configuration and programming software "STEP 7 (TIA Portal)".
Please also see the notes indicated as follows:

Note

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

Recycling and disposal

For environmentally friendly recycling and disposal of your old equipment, contact a certified electronic waste disposal company and dispose of the equipment according to the applicable regulations in your country.

Security information

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

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

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

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

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

Siemens Industry Online Support

You can find current information on the following topics quickly and easily here:

- **Product support**

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

- **Application examples**

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

- **Services**

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

- **Forums**

  For answers and solutions concerning automation technology.

- **mySupport**

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

This information is provided by the Siemens Industry Online Support in the Internet (https://support.industry.siemens.com).

Industry Mall

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

You can find catalogs for all automation and drive products on the Internet (https://mall.industry.siemens.com).

Table of contents

Documentation guide

<div style="text-align: right; font-size: 48px;">1</div>

The documentation for the redundant S7-1500R/H system is divided into three areas. This division enables you to access the specific content you require.

General information — Function manuals on general topics
- Diagnostics
- Communication
- Structure and use of the CPU memory
- Cycle and response times
- PROFINET

Device information — Manuals with detailed information about modules
- CPUs
- Power supply modules

Basic information — Information about the system
- S7-1500R/H Getting Started
- S7-1500R/H System Manual
- TIA Portal online help

Figure 1-1   S7-1500R/H guide

Basic information

The System Manual and Getting Started describe in detail the configuration, installation, wiring and commissioning of the redundant S7-1500R/H system. The STEP 7 online help supports you in the configuration and programming.

Device information

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

General information

The function manuals contain detailed descriptions on general topics regarding the redundant S7-1500R/H system, e.g. diagnostics, communication.

You can download the documentation free of charge from the Internet (https://support.industry.siemens.com/cs/ww/en/view/109742691).

Changes and supplements to the manuals are documented in a Product Information.

You can download the product information free of charge from the Internet (https://support.industry.siemens.com/cs/ww/en/view/109742691).

S7-1500/ET 200MP Manual Collection

The S7-1500/ET 200MP Manual Collection contains the complete documentation on the redundant S7-1500R/H system gathered together in one file.

You can find the Manual Collection on the Internet (https://support.industry.siemens.com/cs/ww/en/view/86140384).

SIMATIC S7-1500 comparison list for programming languages

The comparison list contains an overview of which instructions and functions you can use for which controller families.

You can find the comparison list on the Internet (https://support.industry.siemens.com/cs/ww/en/view/86630375).

"mySupport"

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

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

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

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

"mySupport" - Documentation

In the Documentation area in "mySupport" you can combine entire manuals or only parts of these to your own manual.
You can export the manual as PDF file or in a format that can be edited later.

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

"mySupport" - CAx data

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

You configure your own download package with a few clicks.

In doing so you can select:

● Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files

● Manuals, characteristics, operating manuals, certificates

● Product master data

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

Application examples

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

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

PRONETA

With SIEMENS PRONETA (PROFINET network analysis), you analyze the PROFINET network during commissioning. PRONETA features two core functions:

- The topology overview independently scans PROFINET network and all connected components.

- The IO check is a fast test of the wiring and the module configuration of a system.

You can find SIEMENS PRONETA on the Internet (https://support.industry.siemens.com/cs/ww/en/view/67460624).

SINETPLAN

SINETPLAN, the Siemens Network Planner, supports you in planning automation systems and networks based on PROFINET. The tool facilitates professional and predictive dimensioning of your PROFINET installation as early as in the planning stage. In addition, SINETPLAN supports you during network optimization and helps you to exploit network resources optimally and to plan reserves. This helps to prevent problems in commissioning or failures during productive operation even in advance of a planned operation. This increases the availability of the production plant and helps improve operational safety.

The advantages at a glance

- Network optimization thanks to port-specific calculation of the network load

- Increased production availability thanks to online scan and verification of existing systems

- Transparency before commissioning through importing and simulation of existing STEP 7 projects

- Efficiency through securing existing investments in the long term and optimal exploitation of resources

You can find SINETPLAN on the Internet (https://www.siemens.com/sinetplan).

System overview

<div style="text-align: right; font-size: 3em; font-weight: bold;">2</div>

2.1 What is the S7-1500R/H redundant system?

S7-1500R/H redundant system

For the S7-1500R/H redundant system, the CPUs are duplicated, in other words redundant. The two CPUs process the same project data and the same user program in parallel. The two CPUs are synchronized over two redundancy connections. If one CPU fails, the other CPU maintains control of the process.

Aims of using redundant automation systems

Redundant automation systems are used in practice to achieve greater availability or fail-safety.

- Purpose of fault-tolerant systems: to reduce the probability of production downtime by operating two systems in parallel.

- Purpose of fail-safe systems: to protect life, the environment and capital with safe shutdown to a secure state.

> ⚠️ **WARNING**
>
> **Please note the difference between fault-tolerant and fail-safe systems.**
>
> S7-1500R/H is a fault-tolerant automation system, but not a fail-safe system. The S7-1500R/H system must not be used to control safety-critical processes.

2.1.1 Areas of application

Objective

The S7-1500R/H redundant system offers a high degree of reliability and system availability. A redundant configuration of the most important automation components reduces the probability of production downtimes and the consequences of component errors.

The higher the risks and costs of a production downtime, the more worthwhile the use of a redundant system. You can compensate for the generally higher investment costs by avoiding production downtimes.

Use

In redundantly operated systems, failure or malfunction of individual automation components must not impede the operation of the plant. S7-1500R/H redundant systems are used in the following areas, for example:

- Tunnels
- Airports (for example baggage conveyors)
- Subways
- Shipbuilding
- Wastewater treatment plants
- High-bay warehouse

Example 1: Avoiding downtimes

Automation task

An automation solution is required for a road tunnel to:

- Control the lighting in the tunnel
- Control the ventilation in the tunnel in line with the concentration of pollutants in the tunnel

Feature

Uninterrupted operation of the ventilation system is required to keep the concentration of pollutants below a set level. Constant availability must be ensured for the event that individual automation components fail, for example because of a fire in the tunnel.

Solution

Three fans (M) ventilate the tunnel. The automation solution controls the fan speeds in line with the measured pollutant concentration. Three sensors in the tunnel measure the pollutant levels in the air. The S7-1500H redundant system with two redundant CPUs is used to ensure fan availability.

As well as controlling the fans, the S7-1500H redundant system also controls the illumination and the traffic lights.
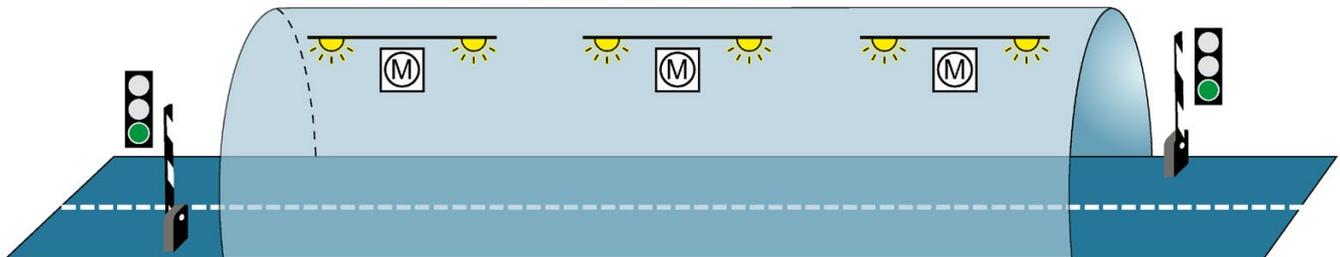
Figure 2-1   Example: Tunnel automation

Benefits

The user program for controlling the fans runs on both CPUs in the S7-1500H redundant system. You can position the two CPUs up to 10 kilometers apart. If one CPU or one redundancy connection fails due to a local incident, the incident does not affect the controlled process. The fans continue to operate.

You can find a detailed description of tunnel automation with S7-1500H in Getting started (https://support.industry.siemens.com/cs/ww/en/view/109757712) Redundant system S7-1500R/H.

Example 2: Avoiding high system restart costs as a result of data loss

Automation task

A logistics company needs a matching automation solution for controlling the storage and retrieval unit in a high-bay warehouse.

Feature

The failure of a controller would have serious consequences. After the system restart, you would have to reposition the storage and retrieval units and record the content of the containers again. The automation solution must ensure that no data is lost if a CPU fails and that the warehouse can continue to operate.

Solution

To store goods in and retrieve them from the bays, the storage and retrieval unit moves along an X, Y and Z axis. If the process is interrupted, data can be lost and the location of the goods is not known. To guard against the loss of data, the storage and retrieval unit is controlled by the S7-1500R redundant system.
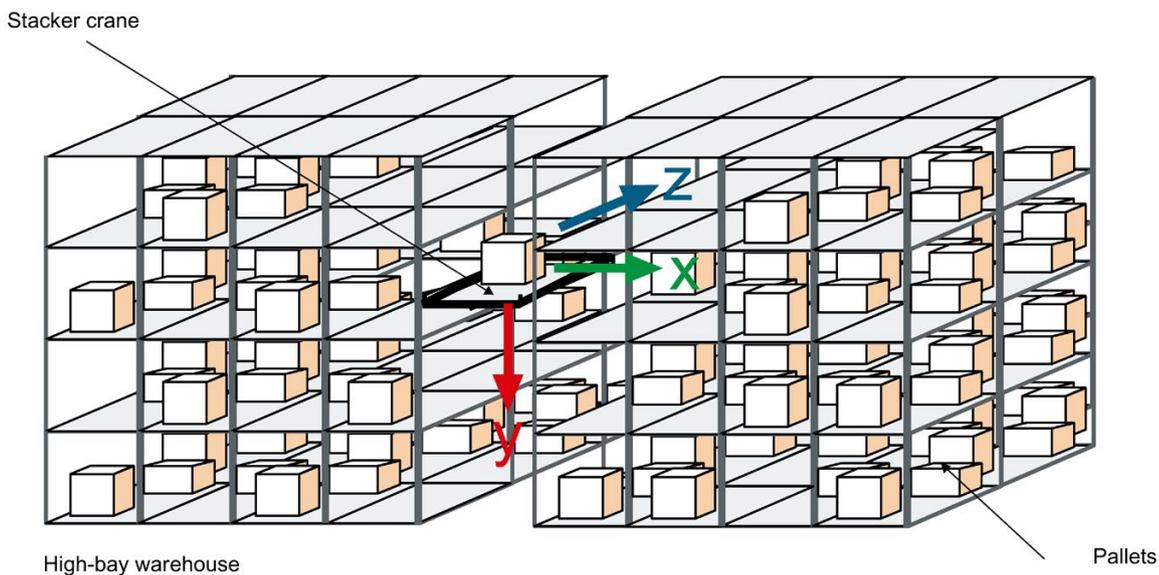
Figure 2-2   Example: High-bay warehouse

Benefits

If one CPU fails, the second CPU maintains control of the process. The project data and the user program are saved redundantly and are not lost if a CPU fails. Once you have replaced the defective CPU and switched it to RUN, the redundant system automatically synchronizes the project data with the user program in the new CPU. The solution saves you service time and downtime costs for the warehouse.

Example 3: Avoiding equipment and material damage

Automation task

A steel works needs a matching automation solution to control a blast furnace for the steel production.

Feature

Failures, especially in the process industry, can result in damages to the system, workpieces or material. In a steelworks, there is a danger of the pig iron cooling if the process is interrupted. The pig iron then cannot be used for the production of steel. The automation solution must ensure that the plant continues to run if a CPU fails and that the material is not damaged.

Solution

The S7-1500R redundant system controls the blast furnace. The distributed automation components of the redundant system control the temperature, volume and pressure parameters.
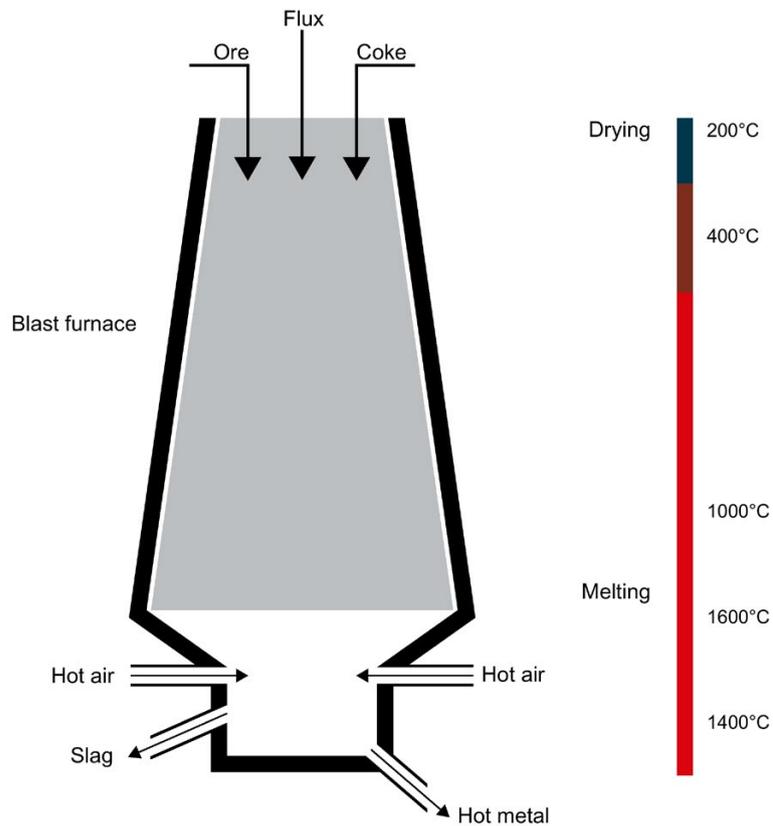
Figure 2-3   Example: Blast furnace

Benefits

The S7-1500R redundant system compensates for the possible failure of a CPU or redundant connection. You do not have to interrupt the smelting process when replacing a CPU while the plant is running. Uninterrupted plant operation avoids high restart and material costs.

2.1.2 Operating principle of the S7-1500R/H redundant system

Introduction

S7-1500R/H redundant systems tolerate the failure of one of the two CPUs or an interruption in the PROFINET ring. The S7-1500R and S7-1500H systems differ in structure, configuration limits and performance.

S7-1500 design and operating principle

The figure below shows the typical structure of the S7-1500R redundant system.

①   S7-1500R CPU
②   PROFINET cable (redundancy connections, PROFINET ring)
③   IO device
④   Switch
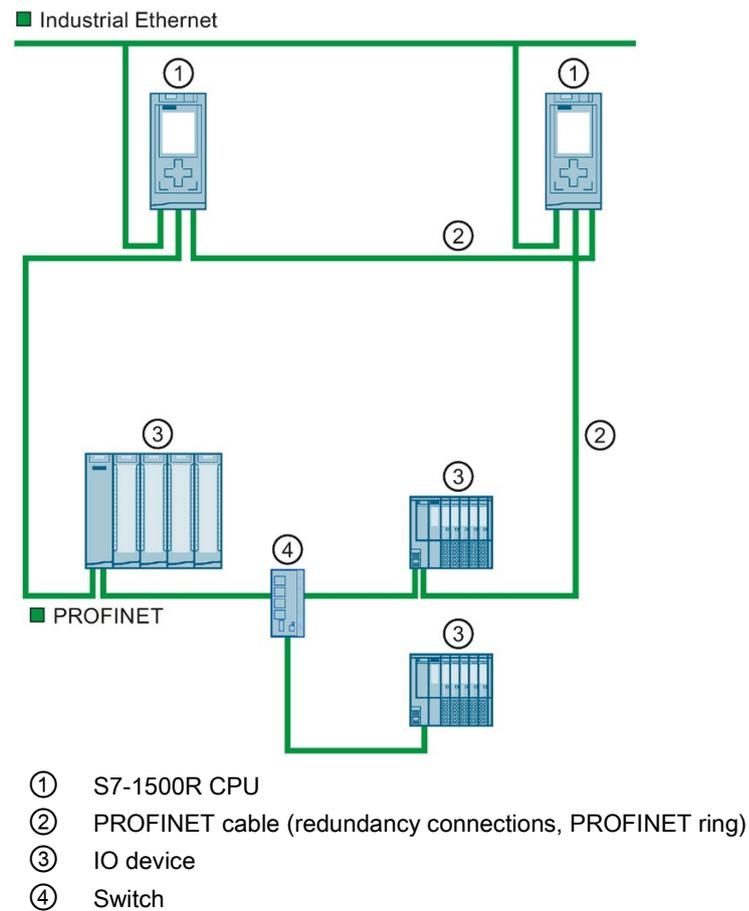
Figure 2-4   Structure of an S7-1500R redundant system

The S7-1500R redundant system consists of:

- Two S7-1500R CPUs ①

- A PROFINET ring with the Media Redundancy Protocol ②

- IO devices ③

- if needed, Switches ④

All PROFINET IO devices assigned to the S7-1500R system must support system redundancy S2. These PROFINET IO devices can be located in the PROFINET ring or they can be separated with a switch.

All PROFINET devices in the PROFINET ring must support media redundancy (MRP). The H-Sync forwarding function is also recommended. System redundancy S2 is not a prerequisite. For example, you can use switches and HMI devices without system redundancy S2.

The redundancy connections in an S7-1500R system are the PROFINET ring with MRP ②. The two CPUs must be directly connected to each other with a PROFINET cable. All nodes can still communicate with each other in the event of an interruption in the ring. PROFINET devices that do not support MRP must be separated from the ring with a switch ④.

One of the two CPUs in the redundant system takes on the role of primary CPU. The other CPU takes on the role of the following CPU (backup CPU). The role of the CPUs can change during operation. Synchronization of primary and backup CPU ensures rapid switchover between CPUs in the event of a failure of the primary CPU. If the primary CPU fails, the backup CPU takes over control of the process as the new primary CPU.

The redundancy connections use part of the bandwidth on the PROFINET cable for the synchronization of the R-CPUs. This bandwidth is therefore not available for PROFINET IO communication.

S7-1500H structure and operating principle

The figure below shows the typical structure of the S7-1500H redundant system.

①   S7-1500H CPU
②   PROFINET cable (PROFINET ring)
③   Redundancy connections (fiber-optic cables)
④   IO device
⑤   Switch
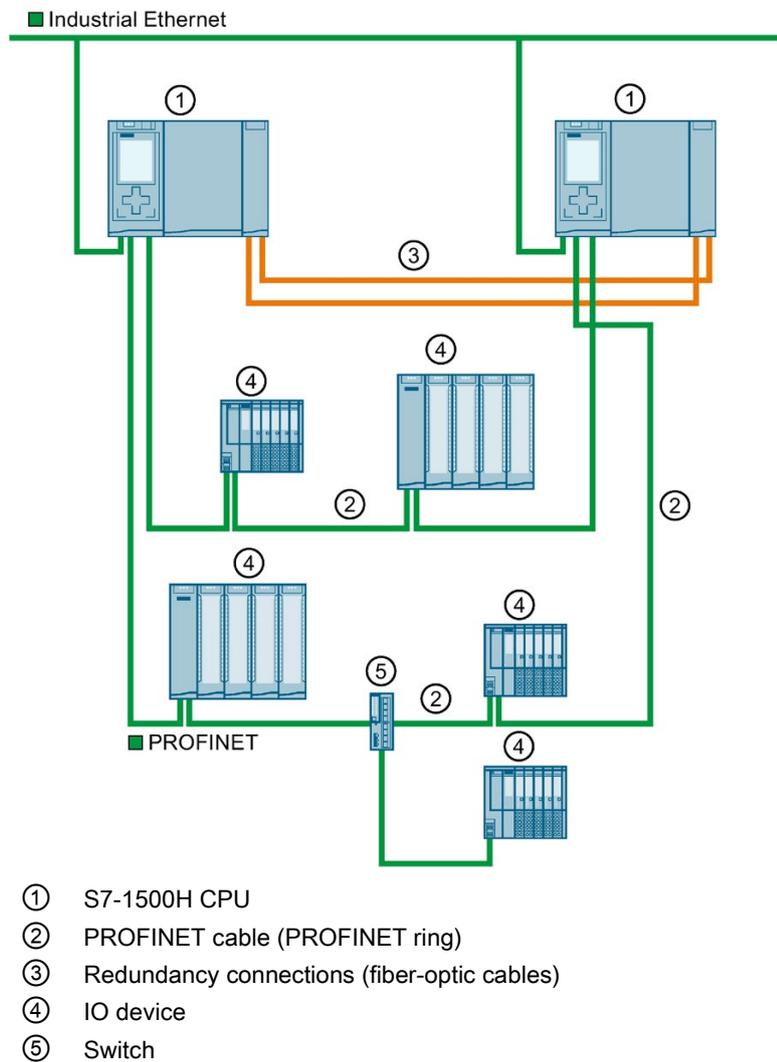
Figure 2-5   Structure of an S7-1500H redundant system

The S7-1500H redundant system consists of:

- Two S7-1500H CPUs ①

- A PROFINET ring with the Media Redundancy Protocol ②

- Two redundancy connections ③

- IO devices ④

- if needed, Switches ⑤

All nodes in the redundant system must support system redundancy S2 and media redundancy (MRP).

All PROFINET IO devices assigned to the S7-1500H system must support system redundancy S2. These PROFINET IO devices can be located in the PROFINET ring or they can be separated with a switch.

All PROFINET devices in the PROFINET ring must support media redundancy (MRP). System redundancy S2 is not a prerequisite. For example, you can use switches and HMI devices without system redundancy S2.

As with S7-1500R, the S7-1500H redundant system requires a PROFINET ring ② closed by the CPUs. All nodes can still communicate with each other in the event of an interruption in the ring. Devices that do not support MRP must be separated from the ring with a switch ⑤. Unlike in S7-1500R, the PROFINET ring and redundancy connections in S7-1500H are separate. The two redundancy connections are fiber-optic cables that connect the CPUs directly over synchronization modules ③.

One of the two CPUs in the redundant system takes on the role of primary CPU. The other CPU takes on the role of the following CPU (backup CPU). The role of the CPUs can change during operation.

Synchronization of primary and backup CPU ensures rapid switchover between CPUs in the event of a failure of the primary CPU. If the primary CPU fails, the backup CPU takes over control of the process as the new primary CPU.

The synchronization of the H-CPUs does not affect the bandwidth on the PROFINET.

Differences between S7-1500R and S7-1500H

Table 2- 1   S7-1500R and S7-1500H system differences

	S7-1500R	S7-1500H
	CPU 1513R-1 PN **CPU 1515R-2 PN**	**CPU 1517H-3 PN**

Performance	• Transfer rate of 100 Mbps (for synchronization and communication)
	• Data work-memory:
	  – CPU 1513R-1 PN: max. 1.5 MB
	  – CPU 1515R-2 PN: max. 3 MB
	• Code work-memory:
	  – CPU 1513R-1 PN: max. 300 KB
	  – CPU 1515R-2 PN: max. 500 KB
		• Significantly greater performance than S7-1500R due to
		  – separate redundancy connections over fiber-optic cable
		  – high computing power
		• transfer rate of 1 Gbps (for synchronization)
		• Data work-memory: max. 8 MB
		• Code work-memory: max. 2 MB

Hardware	• The CPUs are identical in design with the respective S7-1500 standard versions. • Synchronization of the CPUs takes place over the PROFINET ring. • The H-Sync forwarding function is recommended for all nodes in the PROFINET ring. • Part of the bandwidth on the PROFINET cable is required for synchronization of the CPUs. Less bandwidth is therefore available for PROFINET IO communication.	• Each CPU has two optical interfaces. • Synchronization of the CPUs runs separately from the PROFINET ring over fiber-optic cables. • The full bandwidth of the PROFINET cable is available for PROFINET IO communication.

Range	• Distance between the two R-CPUs:
	  – Max. 100 m without media converter
	  – Several kilometers with media converter (depends on the media converter used)
		• Distance between the two H CPUs:
		  – Maximum of 10 km (depends on the synchronization modules used)

Configuration limits	• In the PROFINET ring: Max. 50 PROFINET devices, including R-CPUs (max. 16 PROFINET devices recommended) • In the PROFINET ring and separated with switches (line): Max. 66 PROFINET devices (including R-CPUs)	• In the PROFINET ring: Max. 50 PROFINET devices (including H-CPUs) • In the PROFINET ring and separated with switches (line): Max. 258 PROFINET devices (including H-CPUs)

Comparison of S7-1500 standard system and S7-1500R/H

The table below sets out the key features of comparable CPUs of the S7-1500 automation system and of the S7-1500R/H redundant system.

Table 2- 2   S7-1500 and S7-1500R/H comparison

	S7-1500		S7-1500R/H
	CPU 1513-1 PN CPU 1515-2 PN CPU 1517-3 PN/DP	CPU 1513F-1 PN CPU 1515F-1 PN CPU 1517F-3 PN/DP	CPU 1513R-1 PN CPU 1515R-2 PN CPU 1517H-3 PN
Support for distributed I/O	✓	✓	---
Configuration control	✓	✓	---
Web server	✓	✓	---
CPU redundancy	---	---	✓
System redundancy S2	---	---	✓
Isochronous mode	✓	✓	---
Shared Device	✓	✓	---
IRT	✓	✓	---
MRP	✓	✓	✓
MRPD	✓	✓	---
OPC UA	✓	✓	---
Motion Control	✓	✓	---
PID control	✓	✓	✓[1]
Security Integrated	✓	✓	✓
Protection function: Copy protection	✓	✓	---
Safety mode [2]	---	✓	---
Integrated system diagnostics	✓	✓	✓

[1]   Only support the PID basic functions (do not support PID_Compact, PID _3Step or PID_Temp).

[2]   For personal, environmental or investment protection, you will need fail-safe automation systems (F-systems).

2.1.3 Plant components and automation levels

Plant components and automation levels

The schematic diagram below shows the key components of the redundant system from the management level to the control level and the field level.
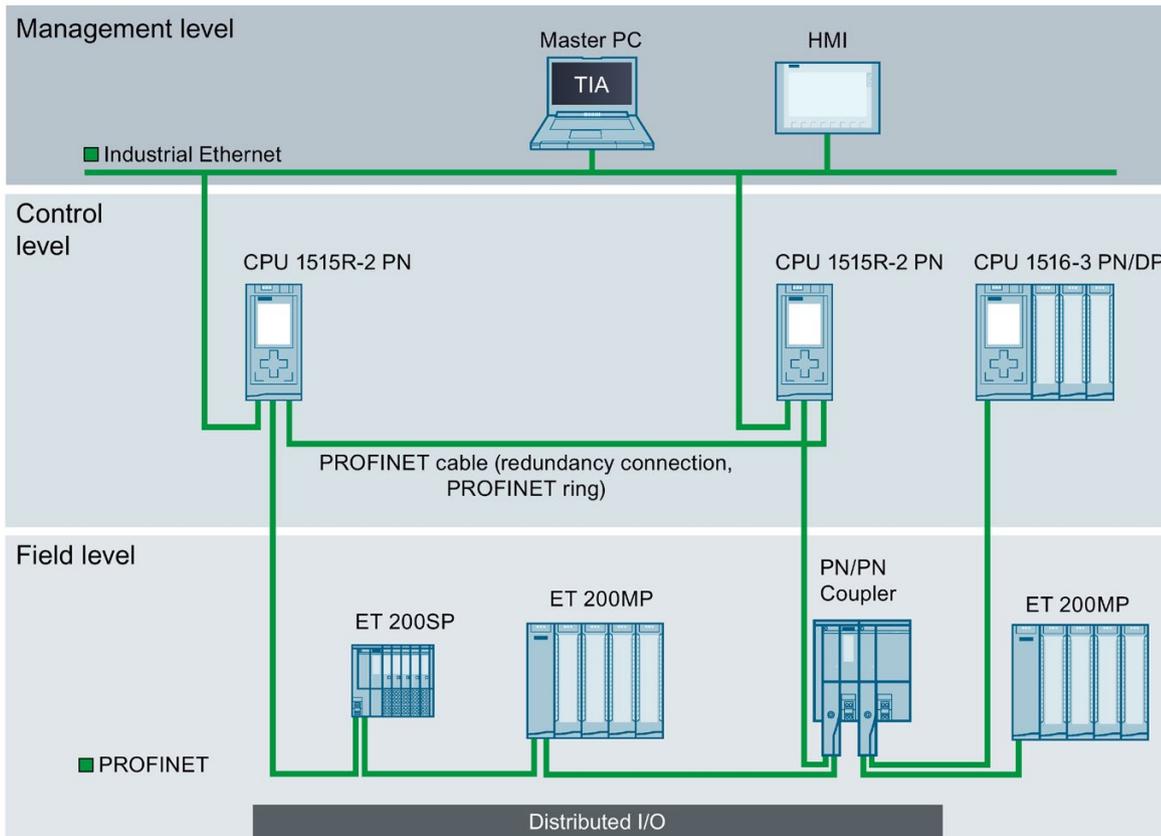
Figure 2-6   Possible configuration at the management, control and field level using the example of S7-1500R

From the management level, the master PC accesses the various devices at the control and field level. The master PC is connected to the CPUs over Industrial Ethernet.

The R-CPUs at the control level are redundant in design. The IO devices at the field level are connected to the R-CPUs within a PROFINET ring.

The redundant S7-1500R system cyclically exchanges IO data with another PROFINET IO system via a PN/PN coupler. The left-hand side of the PN/PN coupler is assigned to the S7-1500R redundant system. The right-hand side of the PN/PN coupler is assigned to the CPU 1516-3 PN/DP (IO controller).

The configuration tolerates the failure of one CPU or an interruption in the PROFINET ring. The primary CPU and the backup CPU execute the user program in parallel. If one CPU fails, the second CPU maintains control of the process.

If the PROFINET ring is interrupted, for example as a result of a cable break or an IO device failure, redundancy in the ring is lost. However, the IO devices that have not failed continue to operate and can be accessed.

2.1.4 Scalability

Introduction

Redundant systems are more cost-intensive to use than non-redundant systems:

- There are two CPUs.
- The physical connections (PROFINET ring and redundancy connections) can be required over large distances.

The S7-1500R/H redundant system is scalable. In other words, the S7-1500R and S7-1500H systems have the same functional scope, but differ in terms of:

- Performance
- Hardware
- Range
- Configuration limits
- Costs

S7-1500R

You connect the CPUs to the Industrial Ethernet over X2 PROFINET interfaces of CPUs S7-1515R-2 PN or using an additional switch.

S7-1500R supports the following number of PROFINET devices (switches, S7-1500R/H CPUs, S7-1500 CPUs (V2.5 or later), HMI devices, and IO devices such as ET 200MP and ET 200SP):

- In the PROFINET ring: max. 50 (recommended: max. 16)
- In the PROFINET ring and separated with switches (line): max. 66

Note

Recommendation for S7-1500R: Operate a maximum of 16 PROFINET devices (including R-CPUs) in the PROFINET ring.

The number of devices in the PROFINET ring affects the availability of the S7-1500R system. You should therefore operate no more than 16 PROFINET devices (including R-CPUs) in the PROFINET ring. Operating significantly more devices in the PROFINET ring will reduce the availability of the IO devices and the R-CPUs.

The technical specifications in the documentation are based on the recommended maximum of 16 PROFINET devices in the ring in S7-1500R.

The redundancy connections in S7-1500R are the PROFINET ring with MRP. The CPUs are synchronized over the PROFINET ring.
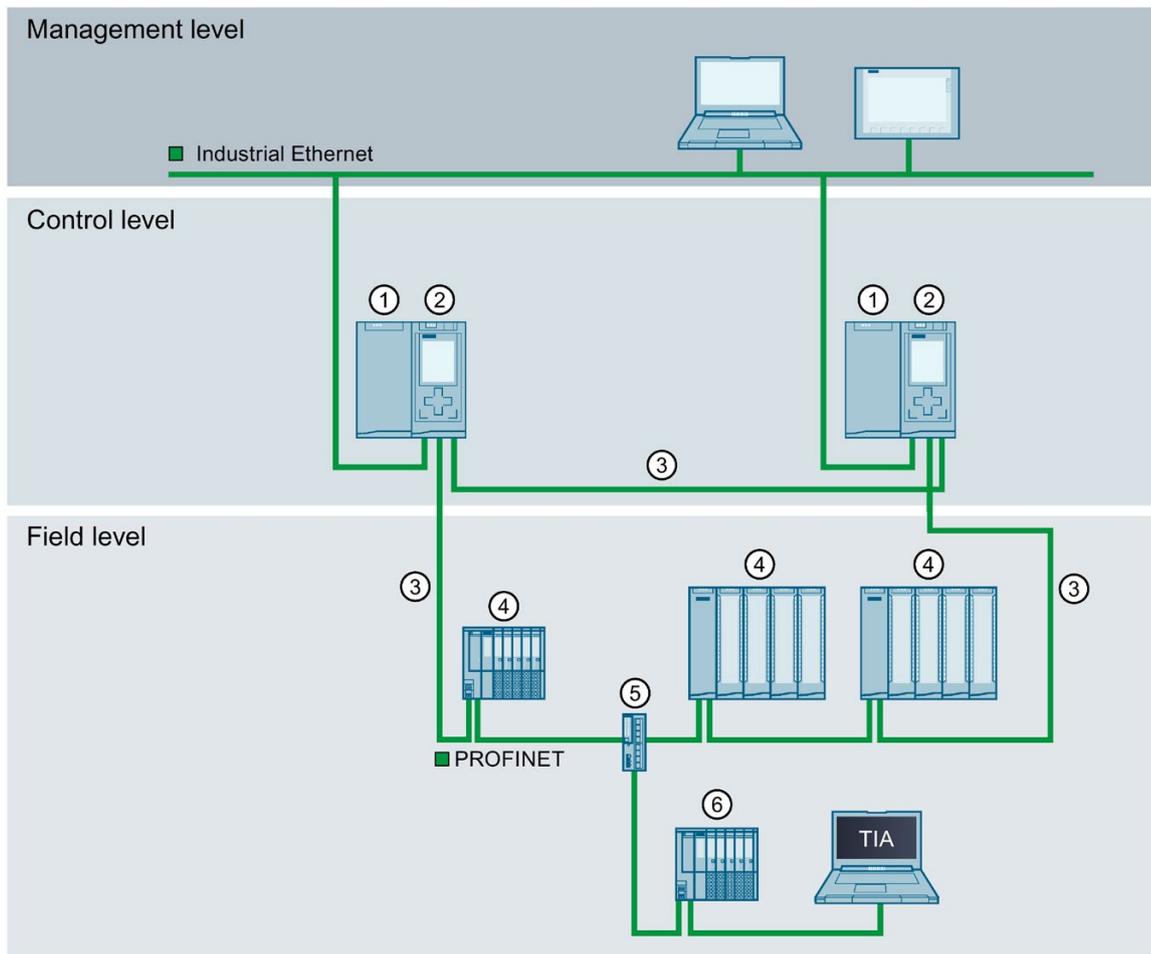
① Load power supply (optional)
② CPU S7-1515R-2 PN
③ PROFINET cable (redundancy connections, PROFINET ring)
④ IO device in the PROFINET ring
⑤ Switch
⑥ IO device outside the PROFINET ring (separated with a switch)

Figure 2-7   S7-1500R configuration version

S7-1500H

You connect the CPUs to the Industrial Ethernet over a PROFINET interface or using an additional switch.

S7-1500H supports the following number of PROFINET devices (switches, S7-1500R/H CPUs, S7-1500 CPUs (V2.5 or later) and HMI devices):

● In the PROFINET ring: max. 50

● In the PROFINET ring and separated with switches (line): max. 258

The redundancy connections in S7-1500H are two duplex fiber-optic cables that connect the CPUs directly with plug-in synchronization modules.
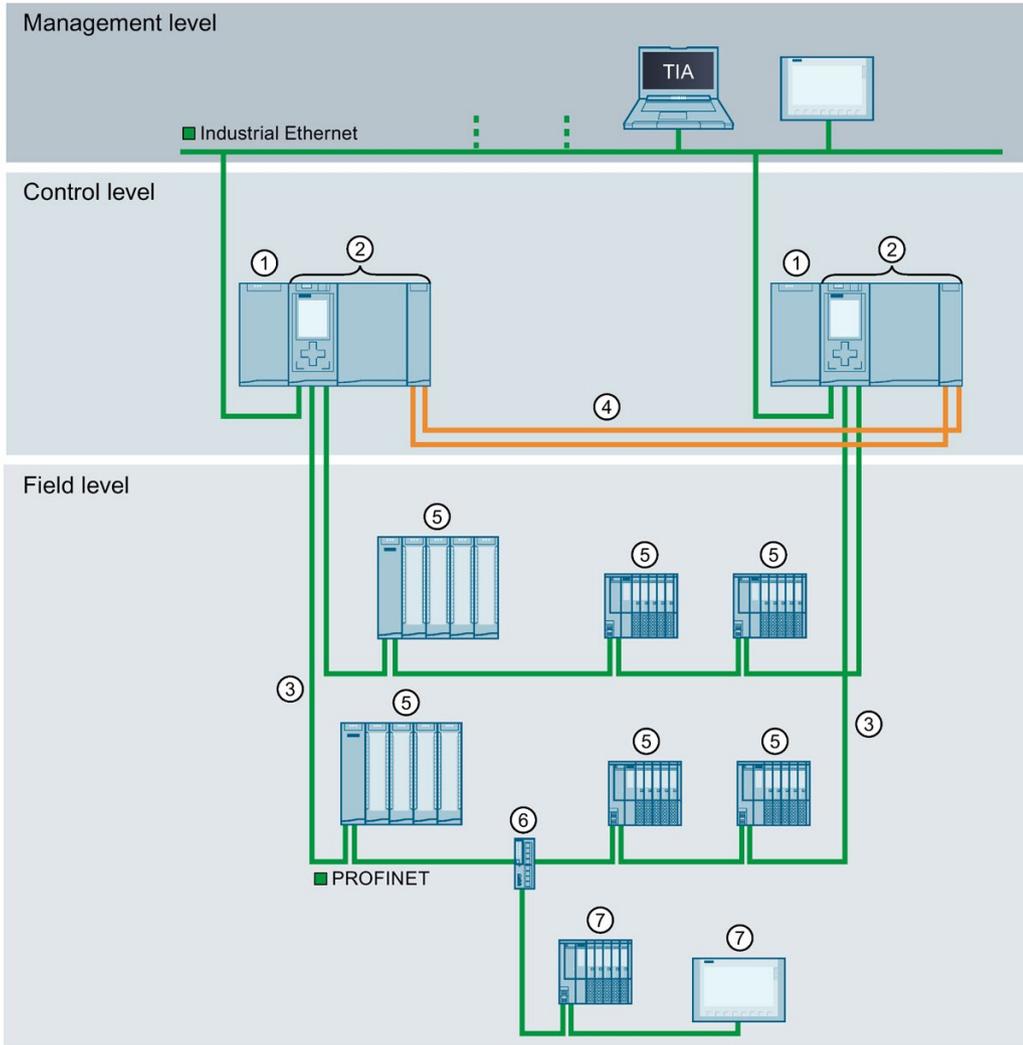
①	Load power supply (optional)
②	CPU 1517H-3 PN
③	PROFINET cable (redundancy connections, PROFINET ring)
④	Redundancy connections (two duplex fiber-optic cables)
⑤	IO device in the PROFINET ring
⑥	Switch
⑦	IO device outside the PROFINET ring (separated with switch)

Figure 2-8   S7-1500H configuration version

2.1.5 Overview of features

The S7-1500R/H redundant system meets all the requirements for a fault-tolerant system. The figure below sets out the main features.

System redundancy

- Uninterrupted operation
- User can scale availability of system redundancy S2
- Component replacement in runtime

Communication standards

- PROFINET IO

Security Integrated

- Protection level concept for greater access protection

Innovative design

- Onboard display for diagnostics and commissioning
- Innovative labeling system for clear and simple organization in small spaces

Efficient engineering

- All features of a fault-tolerant system can be configured in the TIA Portal as usual
- Supports a range of programming languages (STL, LAD, FBD, SCL)
- Consistency check with STEP 7 instead of in the CPU

Easy to use

- Easy installation and configuration as for S7-1500 standard systems
- Easy connection to distributed I/O with interface modules
- Redundant operation with automatic CPU synchronization
- Display functions optimized for redundant system operation

Wide range of diagnostics

- Integrated system diagnostics for uniform display concept without additional programming
- Evaluate system errors using system blocks

Figure 2-9   S7-1500R/H features

2.2 Configuration

2.2.1 Structure of the S7-1500R redundant system

Configuration

The S7-1500R redundant system comprises the following components:

- Two R-CPUs
- Two SIMATIC memory cards
- PROFINET cable (redundancy connections, PROFINET ring)
- IO devices
- Load power supply (optional)
- System power supply (optional)

The S7-1500R redundant system should be installed either on one shared mounting rail or on two separate mounting rails. Connecting the PROFINET cable to the PROFINET interfaces X1 P2 R of the CPUs directly connects the two CPUs. You set up the PROFINET ring from the first CPU to the IO devices and the second CPU with the PROFINET interfaces X1 P1 R of the CPUs.

Configuration example
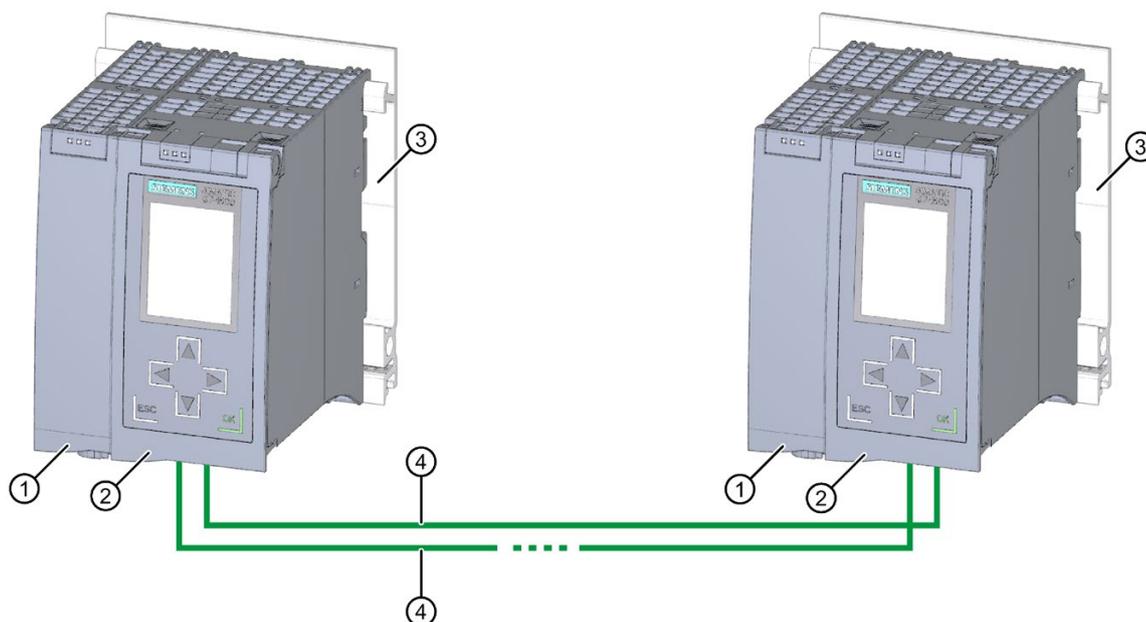
①	Optional load or system power supply
②	CPU
③	Mounting rail with integrated DIN rail profile
④	PROFINET cable (redundancy connections, PROFINET ring)

Figure 2-10   S7-1500R configuration example

2.2.2   Structure of the S7-1500H redundant system

Configuration

The S7-1500H redundant system comprises the following components:

- Two H-CPUs

- Two SIMATIC memory cards

- Four synchronization modules (two synchronization modules in each H-CPU)

- Two redundancy connections (two duplex fiber-optic cables)

- IO devices

- Load power supply (optional)

- System power supply (optional)

The S7-1500H redundant system should be installed either on one shared mounting rail or on two separate mounting rails. You connect the two CPUs with fiber-optic cables to two synchronization modules in each CPU. You set up the PROFINET ring with the PROFINET interfaces X1 P1 R and X1 P2 R of the CPUs.

Configuration example
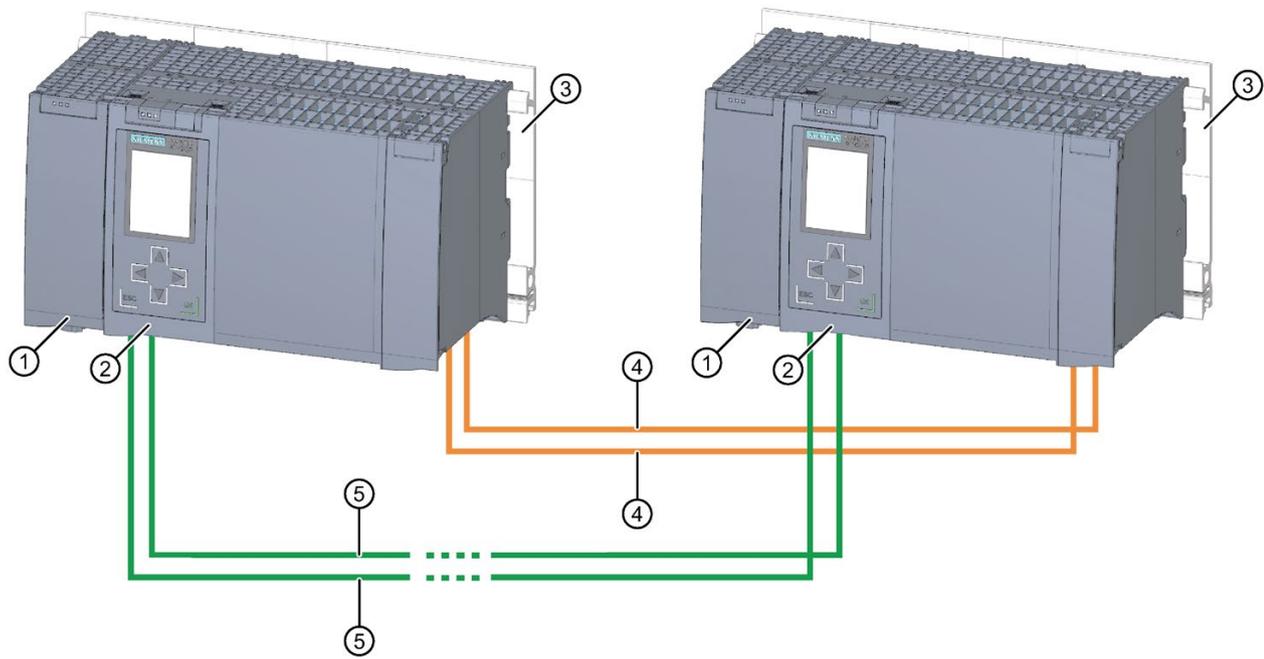
①   Optional load or system power supply

②   CPU (with two synchronization modules, connected underneath, not visible in the diagram)

③   Mounting rail with integrated DIN rail profile

④   Redundancy connections (fiber-optic cables)

⑤   PROFINET cable (PROFINET ring)

Figure 2-11   S7-1500H configuration example

2.2.3 Components

Components of the S7-1500R/H redundant system

Table 2- 3   S7-1500R/H components

Component	Function	Diagram
Mounting rail	The mounting rail is the rack of the S7-1500R/H automation system. You can use the entire length of the mounting rail. You can order the mounting rail as Accessories/spare parts (Page 305).	
PE connection element for mounting rail	The screw set is inserted in the mounting rail's T-profile groove, and is required for grounding the mounting rail. The set of screws is included in the scope of delivery of the mounting rails in the standard lengths (160 mm to 830 mm) and can be ordered as Accessories/spare parts (Page 305).	
R/H-CPUs	The CPU runs the user program. Additional features and functions of the CPU: • Communication via Industrial Ethernet • Communication via PROFINET IO • Redundant mode • HMI communication • Integrated system diagnostics • Integrated protection functions (access and know-how protection)	
PROFINET cable	You connect the CPUs and the IO devices in a PROFINET ring using PROFINET cables.	
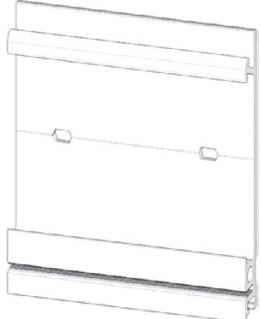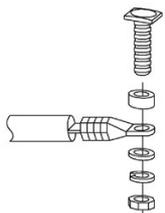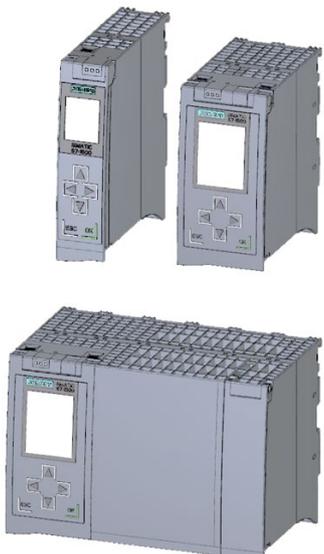
Component	Function	Diagram
Synchronization modules (for S7-1500H)	You create two redundancy connections between the H-CPUs with fiber-optic cables using a total of four synchronization modules (two in each H-CPU). The following synchronization module versions can be ordered: • Sync module 1 GB FO 10 m: for fiber-optic cables up to 10 m in length • Sync module 1 GB FO 10 km: for fiber-optic cables up to 10 km in length	
Fiber-optic cable (for S7-1500H)	You connect the two synchronization modules for each CPU in a pair with a fiber-optic cable. The following lengths of fiber-optic cables can be ordered: • 1 m • 2 m • 10 m • Up to 10 km (on request)	
4-pin connection plug for CPU supply voltage	The 4-pin connection plug provides the supply voltage.	
System power supply (PS)	The system power supply can be connected to the backplane bus using a U connector. In the S7-1500R/H redundant system, the system power supply does not support diagnostics. Various models of system power supplies are available: • PS 25 W 24 V DC • PS 60 W 24/48/60 V DC • PS 60 W 24/48/60 V DC HF Extended retentivity of the PS is not supported in S7-1500R/H. • PS 60 W 120/230 V AC/DC A power cable connector with coding element and U connector is included in the scope of delivery for the system power supply and can be ordered as spare part.	
Load power supply (PM)	The load power supply (PM) supplies the system power supply (PS) and central modules (CPU) with 24 V DC. If you are using load power supplies, we recommend the devices from our SIMATIC series. These devices can be mounted on the mounting rail. Various models of load power supply are available: • PM 70 W 120/230 V AC • PM 190 W 120/230 V AC	
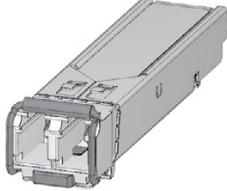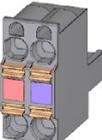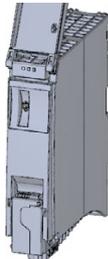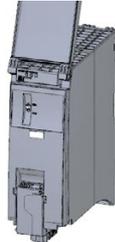
2.3 S7-1500 R/H-CPUs

The S7-1500R/H redundant system tolerates the failure of one of the two R- or H-CPUs in the PROFINET ring. If the primary CPU fails, the backup CPU takes over control of the process as the new primary CPU at the point of the interruption.

All relevant data is permanently synchronized between the CPUs over the redundancy connections between primary CPU and backup CPU.

The primary CPU and the backup CPU execute the user program in parallel.

The display of the CPU shows you the control and status information in various menus. Quick access to diagnostic alarms minimizes plant downtimes in the event of a service call.

For effective commissioning and fast optimization of drives and controls, the CPUs support trace functions for all CPU tags.

2.3.1 Overview of the CPU technical specifications

The table below sets out the main technical specifications for the S7-1500 R/H CPUs.

Table 2- 4   Overview of the R/H-CPU technical specifications

	CPU 1513R-1 PN	CPU 1515R-2 PN	CPU 1517H-3 PN
Data work-memory, max.	1.5 MB	3 MB	8 MB
Code work-memory, max.	300 KB	500 KB	2 MB
Plug-in load memory (SIMATIC memory card), max.	32 GB	32 GB	32 GB
I/O address area, max.	32 KB/32 KB	32 KB/32 KB	32 KB/32 KB
PROFINET IO interfaces	1	1	1
PROFINET interfaces	-	1	1
Processing time for bit operations	0.04 µs	0.03 µs	0.002 µs
Display screen size	3.45 cm	6.1 cm	6.1 cm
Suitable PROFINET devices (switches, S7-1500R/H CPUs, S7-1500 CPUs (V2.5 or later) and HMI devices) in the PROFINET ring, max.	50 (recommended: max. 16)	50 (recommended: max. 16)	50
Suitable PROFINET devices (see above) in the PROFINET ring and separated with switches (line), max.	66	66	258
Modules per rack, max.	2 (PM/PS and CPU)	2 (PM/PS and CPU)	2 (PM/PS and CPU)
Distance between CPUs, max.	Depends on media converter used (with PROFINET cable, max. 100 m)	Depends on media converter used (with PROFINET cable, max. 100 m)	Depends on the synchronization module used: max. 10 km
Redundancy connections (synchronization link)	PROFINET ring	PROFINET ring	Fiber-optic cable
System redundancy	Yes	Yes	Yes
Switchover time [1]	300 ms	300 ms	50 ms

[1] The switchover time is the time between failure of the primary CPU until the backup CPU takes over control of the process as the primary CPU at the point of interruption. The switchover time can lengthen the cycle time.

Reference

The full technical specifications can be found in the manuals for the CPUs and on the Internet (https://mall.industry.siemens.com).

2.3.2　　Redundancy

Introduction

The S7-1500R/H redundant system is based on media redundancy (MRP) in the PROFINET ring.

All PROFINET IO devices assigned to the S7-1500R system must support system redundancy S2. These PROFINET IO devices can be located in the PROFINET ring or they can be separated with a switch.

All PROFINET devices in the PROFINET ring must support media redundancy (MRP). The H-Sync forwarding function is also recommended for S7-1500R. System redundancy S2 is not a requirement. For example, you can use switches and HMI devices without system redundancy S2.

Media redundancy

Media redundancy is a function for ensuring network and plant availability.

The two CPUs in the redundant system must be located in a PROFINET ring that uses the MRP media redundancy protocol.

S7-1500R uses the PROFINET ring to synchronize the two CPUs. S7-1500H uses the redundancy connections over fiber-optic cables to synchronize the two CPUs. The PROFINET ring (over PROFINET interfaces X1) of the H CPUs is also mandatory for S7-1500H.

To set up a ring topology with media redundancy, you need to bring together the free ends of a linear network topology in one device using two ports (ring ports, port label "R"). You specify the ring ports in the device configuration.

In the S7-1500R/H redundant system, you need to set the media redundancy role for each of the two CPUs to Manager (Auto). For all other PROFINET devices in the PROFINET ring, the media redundancy role Client must be configured. There is a communication connection based on MRP between the redundancy manager and the redundancy clients. The Media Redundancy Protocol (MRP) automatically reconfigures the data paths between the individual devices if the ring is interrupted at any point.

You configure the media redundancy role for PROFINET devices with system redundancy S2 in STEP 7. For switches without system redundancy S2, you set the media redundancy role to "Client" over the Web interface.

System redundancy S2

An IO device with system redundancy S2 supports system redundancy ARs.

In a redundant system, an IO device with system redundancy S2 has a system redundancy AR with each of the two CPUs (IO controllers). An IO device thus supports ARs of two IO controllers simultaneously (for the same modules).

A system redundancy AR can be the primary AR or the backup AR. There must only ever be one primary AR for one IO device at any given time. The other AR, if there is one, must be the backup AR. An IO device activates the data of the primary AR at the outputs. The data of the backup AR is merely saved.

- Behavior in the RUN-Redundant system state:

  Both CPUs are IO controllers. PROFINET communication runs on both system redundancy ARs simultaneously, in each case between one of the CPUs (IO controller) and the IO device. If the primary CPU then fails, the backup CPU becomes the primary CPU and also switches the backup AR to primary AR. The data of this AR then becomes active at the outputs.

- Behavior in the RUN-Solo system state:

  Only the primary CPU is the IO controller. PROFINET communication runs on the primary AR between the primary CPU (IO controller) and the IO device. There is no AR between the backup CPU and the IO device.

In STEP 7, you configure system redundancy S2 for an IO device by assigning the IO device to both CPUs of the S7-1500R/H redundant system.

Reference

Additional information on media redundancy and system redundancy S2 can be found in the PROFINET function manual (http://support.automation.siemens.com/WW/view/en/49948856).

2.3.3 Security

Security means the protection of technical systems against sabotage, espionage and human error.

Protection functions

For the setup of secure networks, the S7-1500R/H redundant system has an integrated security concept from authorization levels up to block protection:

Table 2- 5   Overview of protection functions

Protection function	Description
Access protection	Protection against unauthorized configuration changes through four authorization levels and an integrated firewall
Know-how protection	Protection against unauthorized access and modifications to algorithms with password protection
CPU lock	Protection against unauthorized access by locking the front cover with a seal or a lock

Access protection example

You can choose from four different access levels in the TIA Portal to restrict user access to functions and memory areas.

Figure 2-12   Access protection

If you only want to allow users access over HMI, for example, select the access level "HMI access" in the TIA Portal. Only HMI access and access to diagnostics data is then possible without entering a password.

Users can read and write tags over an HMI device with this access level.

Users **cannot**:

*   Download blocks or the hardware configuration to the CPU

*   Upload blocks or the hardware configuration from the CPU to the PG/PC

*   Run writing test functions

*   Change the operating state from the PG/PC

*   Run firmware updates

Advantages and customer benefits of protection functions

The protection functions listed above protect your investments from unauthorized access and manipulation, helping to secure plant availability.

Reference

You can find additional information on the protection functions described in the section Protection (Page 168) and in the STEP 7 online help.

Siemens products and solutions are only one element of a comprehensive industrial security concept. Please note the additional information on Industrial Security (http://www.siemens.com/industrialsecurity).

2.3.4   Diagnostics

All levels of automation in the S7-1500R/H redundant system have integrated diagnostics. All SIMATIC products have integrated diagnostic functions that you can use to analyze, localize and log faults and errors efficiently.

System diagnostics is integrated into the firmware of the CPUs and works independently of the cyclic user program. Faults in the plant are immediately detected and reported on the display devices.

A uniform display concept visualizes error messages as plain text information over:

- TIA Portal
- HMI devices
- CPU displays

Displaying faults in an IO device

The various components of the S7-1500R/H redundant system are connected over PROFINET/Industrial Ethernet (IE). The devices detect faults in their modules (for example IO device ET 200SP) and send diagnostics data to the assigned CPU. The CPU analyzes this diagnostic information and notifies the connected display media. The information analyzed is shown in graphic form in the configuration and programming software (TIA Portal), on the HMI devices and on the CPU displays.
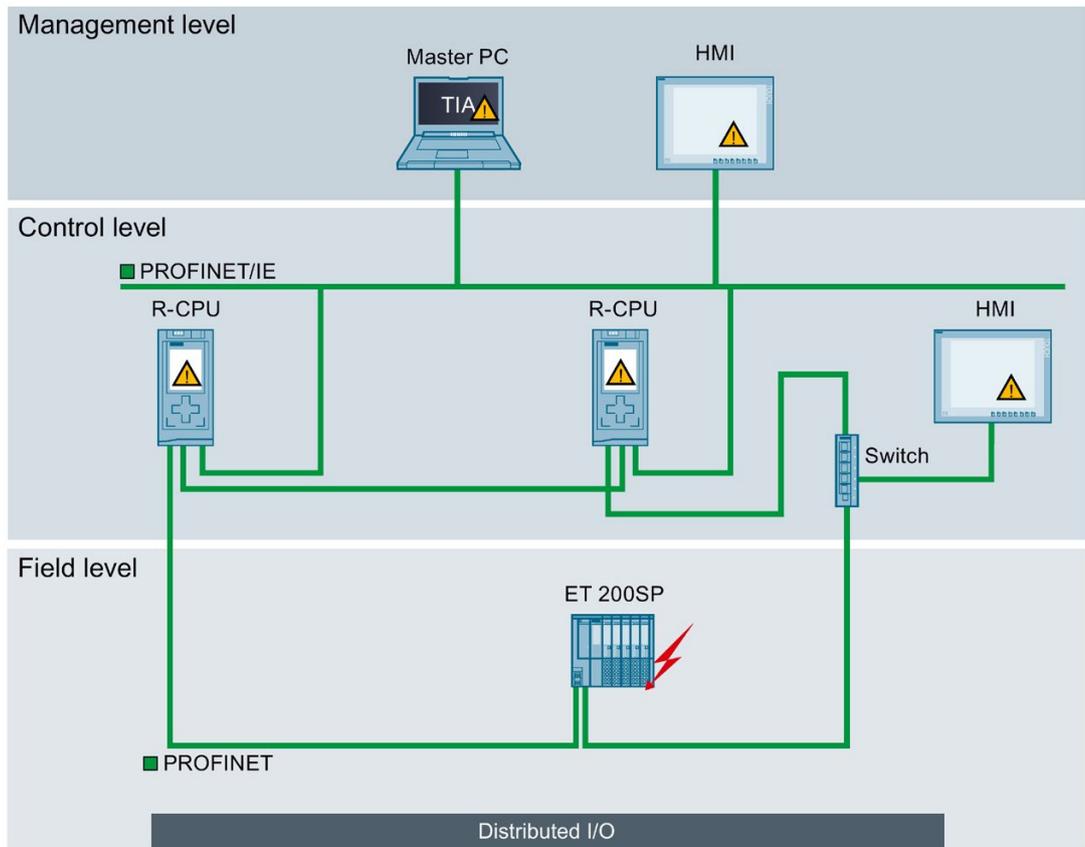
Figure 2-13   Overview of system diagnostics in a plant

Advantages and customer benefits

Integrated system diagnostics offers the following advantages:

- Diagnostics is always consistent with the actual state of the plant. In S7-1500R/H redundant mode, the diagnostic information is synchronized between the CPUs.

- The uniform display concept enables efficient error analysis.

- The immediate identification of the error source in the event of an error speeds up commissioning and minimizes production downtimes.

- By configuring diagnostics events, you tailor the diagnostics to the requirements of your automation task.

Reference

You will find more information on diagnostics in the Diagnostics (https://support.industry.siemens.com/cs/ww/en/view/59192926) function manual.

2.3.5 Trace

The trace functionality facilitates troubleshooting and optimization for the user program. Trace records device tags and evaluates the recordings. This allows you to analyze defective signal responses. Tags are, for example, drive parameters or the system and user tags of a CPU. Because the CPU records tags directly, the trace and logic analyzer function is suitable for monitoring highly dynamic processes.

Note

Trace restrictions

The S7-1500R/H redundant system does not support the storage of measurements on the SIMATIC memory card.

Example of signal response analysis

To analyze a specific signal response, you define the recording and trigger conditions for the signals to be recorded.

① The trace function can be called in the project tree from the "Traces" folder under the top CPU of the redundant system.

The trend diagram ② displays the selected signals of a recording. Bits are shown in the lower diagram as a bit track.

The signal table ③ lists the signals of the selected measurement and provides setting options for specific properties.
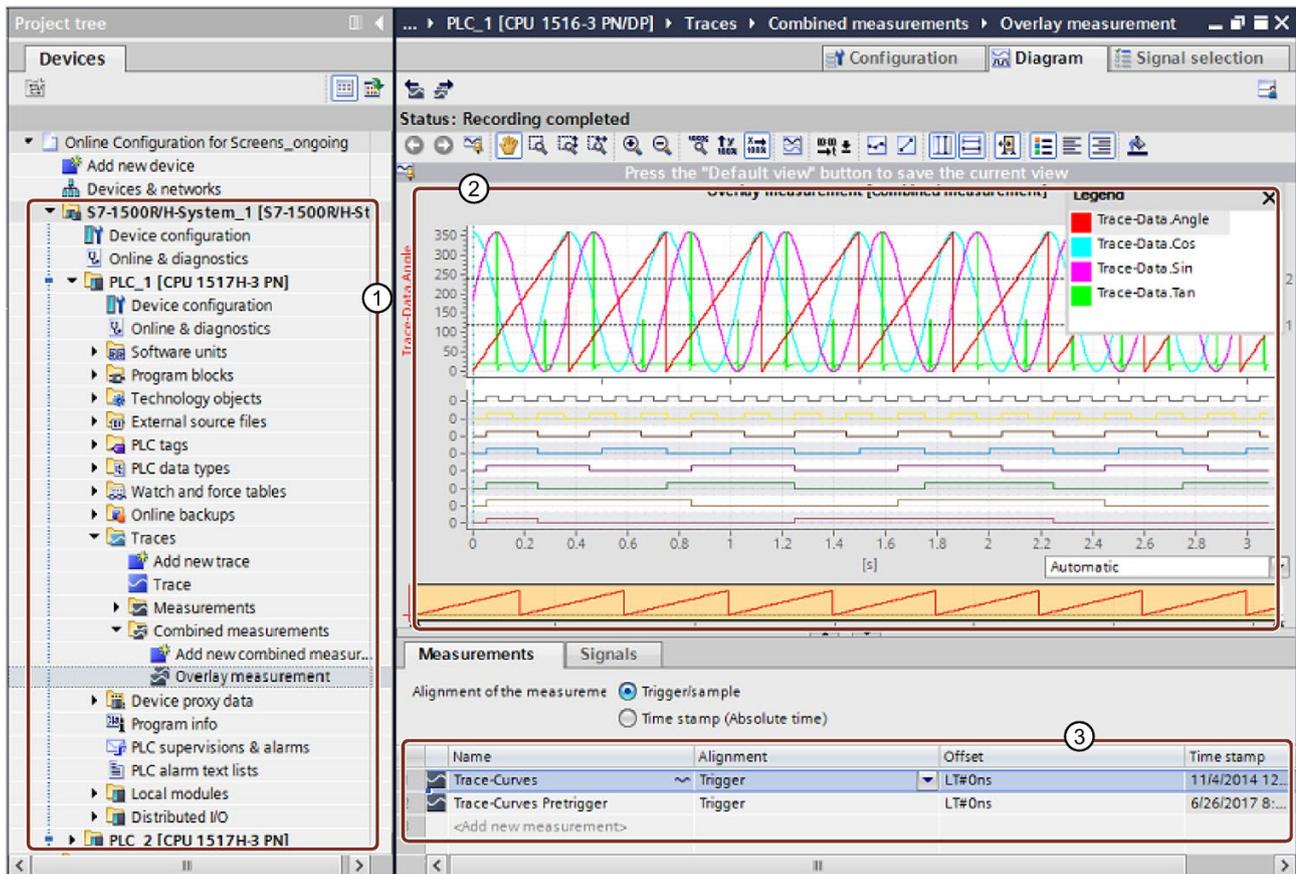
①   Trace recordings for S7-1500R/H in the project tree
②   Trend diagram
③   Signal table

Figure 2-14   Trace measurement for S7-1500R/H

Advantages and customer benefits

The trace function offers the following advantages:

- Simultaneous recording of up to 16 different signals and up to four separate trace jobs

- A uniform standard for tag analysis that allows even sporadic errors to be located rapidly

Reference

You can find additional information on the trace function in the section Test functions (Page 282) and in the Using the trace and logic analyzer function manual (http://support.automation.siemens.com/WW/view/en/64897128).

2.4 Communication

2.4.1 System and device IP addresses

Device IP addresses

For the interfaces of the CPUs and the IO devices to be accessible, the interfaces require IP addresses that are unique within the network (device IP addresses).

MAC addresses

The CPUs have a unique MAC address for each interface and its ports. The MAC addresses of the PROFINET ports are needed for the LLDP protocol, for example for the neighborhood discovery function.

The number range of the MAC addresses is sequential. The first and last MAC addresses are printed on the rating plate on the right-hand side of each CPU.

System IP addresses

In addition to the device IP addresses of the CPUs, the redundant system S7-1500R/H supports system IP addresses:

- System IP address for the X1 PROFINET interfaces of the two CPUs (system IP address X1)

- System IP address for the X2 PROFINET interfaces of the two CPUs (system IP address X2)

You use the system IP addresses for communication with other devices (for example, HMI devices, CPUs, PG/PC). The devices always communicate over the system IP address with the primary CPU of the redundant system. This ensures that the communication partner can communicate with the new primary CPU (previously backup CPU) in the RUN-Solo system state after failure of the original primary CPU in redundant operation.

There is a virtual MAC address for each system IP address. The virtual MAC addresses of the two PROFINET interfaces must be different from each other.

You enable the system IP addresses in STEP 7.

You can find information on configuring the system IP addresses and the virtual MAC addresses in the section Configuration procedure (Page 136).

Advantages of system IP addresses over device IP addresses

- Targeted communication of the communication partner with the primary CPU.

- The S7-1500R/H redundant system can continue to communicate over a system IP address even if the primary CPU fails.

Configuration example

The figure below shows a configuration in which the S7-1500R/H redundant system communicates with other devices over the system IP address X2. The other devices are connected to the S7-1500 redundant system over the X2 PROFINET interfaces.
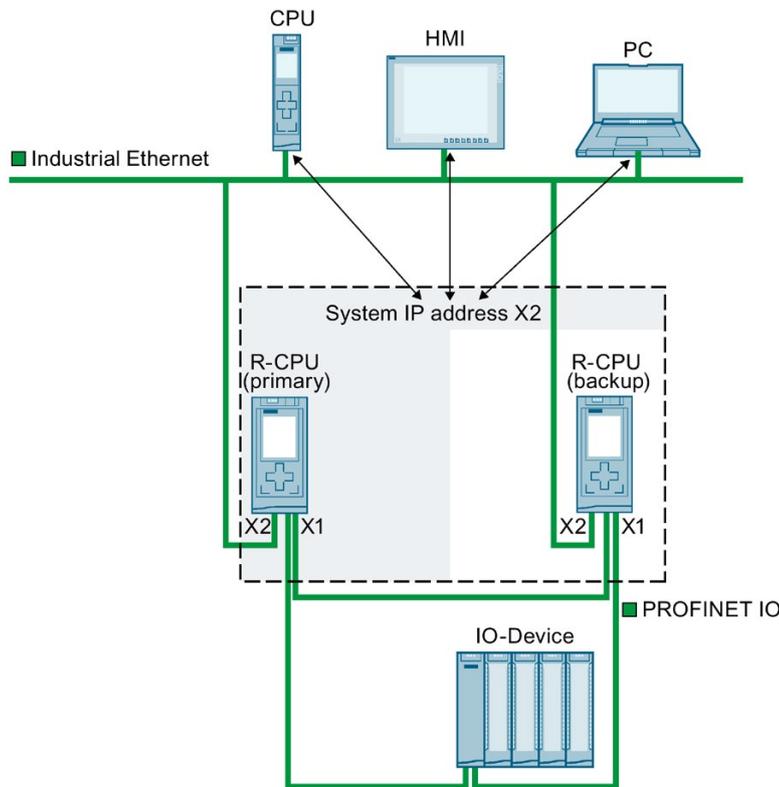
Figure 2-15   Example: Communication of the S7 1500R/H redundant system over the system IP address X2

Reference

You can find more information on the system IP address in the S7-1500R/H redundant system in the PROFINET (http://support.automation.siemens.com/WW/view/en/49948856) function manual.

2.4.2 Integrated interfaces for communication

The table below provides an overview of CPU communication options in the S7-1500R/H redundant system.

Table 2- 6   S7-1500R/H communication options

Communication option	Service available over:		
	PROFINET interface X1 (device IP address)	PROFINET interface X2 (device IP address)[1]	System IP address (at interfaces X1 and X2)
PROFINET IO	✓	---	---
MRP (Media Redundancy Protocol)	✓	---	---
LLDP (network topology detection)	✓	✓	---
PG communication for commissioning, testing and diagnostics	✓	✓	---
HMI communication for operator control and monitoring	✓[2]	✓[2]	✓
Open User Communication	✓[3]	✓[3]	✓
Data exchange via HTTP(S), for example for diagnostics	---	---	---
Time synchronization	✓	✓	---

[1] Not with CPU 1513R-1 PN

[2] Communication mainly over system IP address: If the CPU with the device IP address fails, communication with the HMI device also fails.

[3] Communication mainly over system IP address: If the CPU with the device IP address fails, Open User Communication with S7-1500R/H also fails.

Reference

For more information on communication options, please refer to the Communication function manual (https://support.industry.siemens.com/cs/ww/en/view/59192925).

2.4.3 HMI devices

HMI devices are used for machine-level process visualization and control. You use the same HMI devices for the S7-1500R/H redundant system as for the standard S7-1500 system.

Using HMI communication, one or more HMI devices exchange data with the CPUs (for example HMI Basic/Comfort/Mobile Panel).

The connection of the HMI device to the redundant system depends on the specific application. In STEP 7, you can configure the following communication options:

● The HMI device communicates with the redundant system over the system IP address.

● The HMI device communicates with the R/H-CPUs (for example for diagnostics purposes) over the device IP addresses.

Reference

You can find additional information on using HMI devices in the section Using HMI devices (Page 92) and in the Communication function manual (https://support.industry.siemens.com/cs/ww/en/view/59192925).

You can find an overview of all available HMI devices in the Industry Mall (https://mall.industry.siemens.com/mall/en/WW/Catalog/Products/9109999?tree=CatalogTree).

2.5 Power supply

The CPUs of the redundant system have an integrated system power supply. It provides the necessary power to the backplane bus. You can add one load power supply or one system power supply each to the integrated system power supply.

The table below sets out the key differences between load power supplies (PM) and system power supplies (PS).

Table 2- 7   Differences between load and system power supplies

Power supply	Description
Load power supply (PM)	The load power supply (PM) supplies the system components, such as the CPU and system power supply (PS). You can install the load power supply directly to the left of the CPU (without connection to the backplane bus). Supply of the R/H CPUs with 24 V DC is optional if you supply the voltage for the backplane bus via a system power supply.
System power supply (PS)	The system power supply (PS) only supplies system voltage required internally. The system power supply (PS) supplies parts of the module electronics and the LEDs.

2.6 Software

2.6.1 TIA Portal

The SIMATIC controllers are integrated into the Totally Integrated Automation Portal. Engineering with TIA Portal offers:

- Configuration and programming
- Shared data management
- A uniform operating concept for control, visualization and drives

The TIA Portal simplifies integrated engineering in all configuration phases of a plant.
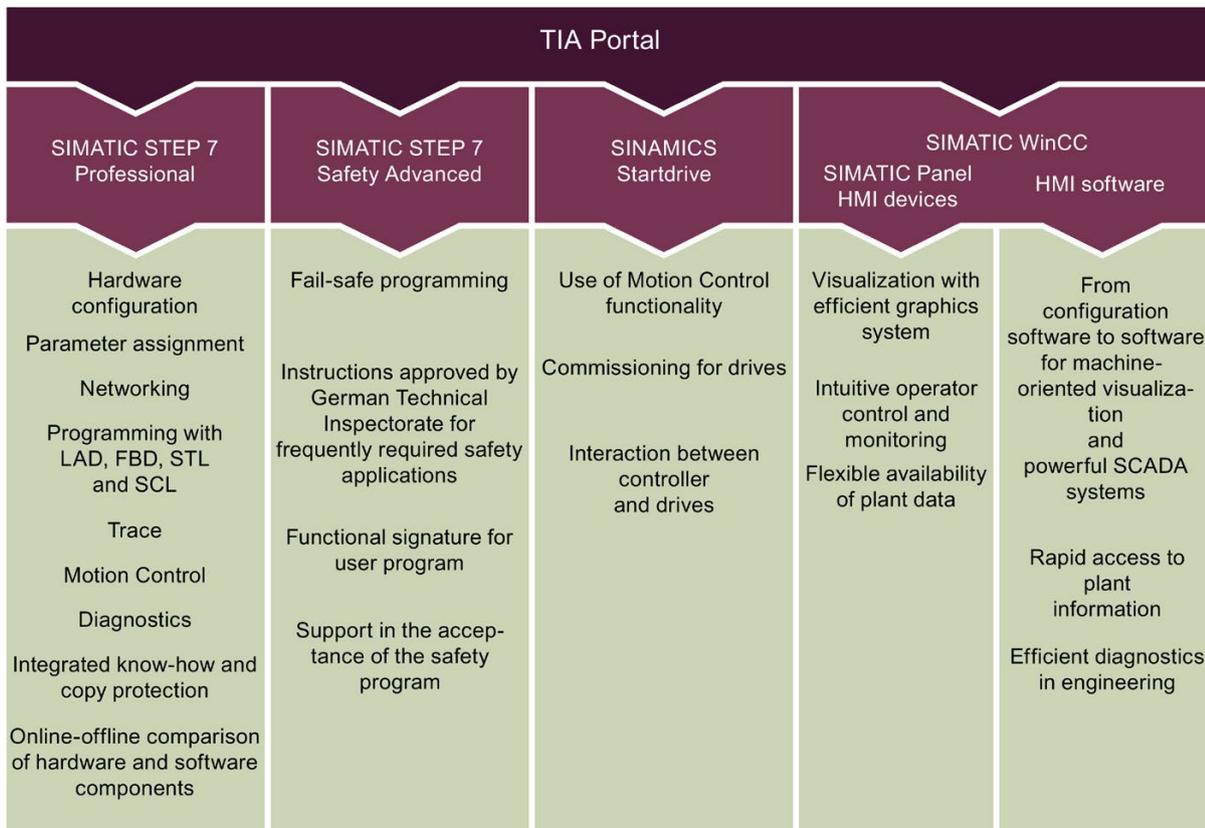
Figure 2-16   TIA Portal overview

2.6.2 SINETPLAN

SINETPLAN (https://www.siemens.com/sinetplan), the Siemens Network Planner, helps you plan automation systems and networks based on PROFINET. The tool facilitates the professional and predictive dimensioning of your PROFINET system right from the planning stage. SINETPLAN also assists with network optimization and helps you to make the best possible use of network resources and to plan for reserves. This allows you to avoid problems in commissioning and failures during productive operation even before planned use. This increases the availability of the production plant and helps improve operational safety.

The advantages at a glance

- Network optimization thanks to port-specific calculation of the network load

- Increased production availability thanks to online scan and verification of existing systems

- Transparency before commissioning with the import and simulation of existing STEP 7 projects

- Efficiency through securing existing investments in the long term and the optimal use of resources

2.6.3 PRONETA

SIEMENS PRONETA (PROFINET network analysis) allows you to analyze the plant network during commissioning. PRONETA features two core functions:

- The topology overview independently scans PROFINET and all connected components.

- The IO check is a rapid test of the wiring and the module configuration of a plant.

SIEMENS PRONETA (https://support.industry.siemens.com/cs/ww/en/view/67460624) is also available for free on the Internet.

Application planning

<div style="text-align: right; font-size: 3em;">3</div>

3.1 Requirements

Introduction

Please note the following requirements for use of the S7-1500R/H redundant system.

Hardware requirements

Table 3- 1   Hardware requirements

Property	Requirement
S7-1500R/H CPUs	• Two identical R or H CPUs in the redundant system • Identical article numbers, function versions and firmware versions for the two CPUs
PROFINET ring	A PROFINET ring is required for all configuration versions (Page 54) of the S7-1500R/H redundant system.

Property	Requirement

PROFINET devices	• All PROFINET IO devices assigned to the S7-1500R/H system must support system redundancy S2. These PROFINET IO devices can be located in the PROFINET ring or they can be separated with a switch.
	
	• With S7-1500R/H, all PROFINET devices in the PROFINET ring must support the media redundancy function.
	
	• For S7-1500R, the H-Sync forwarding function[1] is also recommended for the PROFINET devices in the PROFINET ring.
	
	• The following PROFINET IO devices support system redundancy S2, media redundancy and H-Sync forwarding:
	  – ET 200SP IM 155-6 PN HF (6ES7155-6AU00-0CN0), FW version V4.2 or later
	  – ET 200SP IM 155-6 PN/2 HF (6ES7155-6AU01-0CN0), FW version V4.2 or later
	  – ET 200SP IM 155-6 PN/3 HF (6ES7155-6AU30-0CN0), FW version V4.2 or later
	  – ET 200MP IM 155-5 PN HF (6ES7155-5AA01-0AB0), FW version V4.2 or later
	  – PN/PN coupler (6ES7158-3AD10-0XA0), FW version V4.2 or later
	
	• Switches of the product families XC-200, XP-200 and XF-200BA support system redundancy S2, media redundancy and H-Sync-Forwarding, for example SCALANCE XC208 (6GK5208-0BA00-2AC2), FW version V4.0 or later.
	
	• In STEP 7, "Manager (auto)" is set as the media redundancy role for each of the two R/H CPUs. For all other devices in the PROFINET ring, set "Client" as the media redundancy role.
	
	• PROFINET devices that do not support system redundancy S2 can be located in the PROFINET ring or be separated with a switch.
	  – Switches without system redundancy S2:
	    Set the media redundancy role to "Client" over the Web interface.
	    Configure the ring ports in line with the wiring.
	  – HMI devices without system redundancy S2:
	    Set the media redundancy role to "Client" in the HMI configuration.
	
	• S7-1500 CPUs: Firmware version V2.5 or later
	The redundant system does not recognize the S7-1500 CPUs when calculating the maximum number of IO devices within and outside the PROFINET ring. If you use S7-1500 CPUs, you will have to check the maximum number yourself.

System power supply PS or load power supply PM	System power supply PS or load power supply PM for the R/H CPUs The use of the PS or PM is optional. Suitable system power supplies: • PS 25 W 24 V DC (not suitable for CPU 1517H-3 PN) • PS 60 W 24/48/60 V DC • PS 60 W 24/48/60 V DC HF • PS 60 W 120/230 V AC/DC Suitable load power supplies: • PM 70 W 120/230 V AC • PM 190 W 120/230 V AC

[1] If you use PROFINET devices that do not support H-Sync Forwarding in S7-1500R, additional cycle time increases may occur in system state RUN-Redundant. If the cyclic program exceeds the cycle monitoring time, the timeout OB (OB 80) may be started. You can find additional information in the section Start events (Page 153).

Special case: Operating R/H CPU individually

You can operate an R/H CPU as a single CPU. If you do, please note the following:

- You always need to configure two R- or H-CPUs for S7-1500R/H even if you only set up one.
- The MAINT LED on the CPU is always yellow (maintenance demanded):
  - The R/H system is not in redundant mode.
  - No partner CPU found.

Software requirements

Table 3- 2   Software requirements

Function	Requirement
STEP 7	SIMATIC STEP 7 Professional, V15.1 or later

3.2 Restrictions compared to the S7-1500 automation system

Introduction

Please note the following restrictions with the S7-1500R/H redundant system compared to the S7-1500 automation system.

Hardware restrictions

Table 3- 3   Hardware restrictions

Property	Restriction
Fail-safe modules	Fail-safe modules are not supported in the S7-1500R/H redundant system.
Power segment overview with system power supply	Not supported
Series machine projects, configuration control (option handling)	Not supported
Central I/O	Central I/O is not supported in the hardware configuration of the S7-1500R/H redundant system. Exceptions: • Load power supply (PM) • System power supply (PS); the PS cannot be configured.
Cycle and response times	Longer cycle and response times: You can find additional information in the Cycle and response times (https://support.industry.siemens.com/cs/ww/en/view/59193558) function manual.

Software restrictions

Table 3- 4   Software restrictions

Function	Restriction
Instructions	Not supported, restrictions for specific instructions: You can find additional information in the section Restrictions (Page 150).
Display: "Modules" menu command	Not supported
Firmware update	Firmware update via accessible devices is not supported.
Hardware detection in STEP 7 (read out configuration)	Not supported
HMI tags	The direct entry of tags on the HMI device is only possible in the RUN-Solo system state.
I-device	Cannot be used as I-device[1]
IRT	Not supported
Configured connections	Connection type not support for communication connection. Only programmed connections are supported.
Motion Control	Motion Control functions are not supported in the CPUs
MRPD	Not supported
Multiuser Engineering	Not supported
Online functions	• Download not possible in the RUN-Redundant system state • SIMATIC Automation Tool (SAT tool) not supported
OPC UA	OPC UA (server and client) not supported
PID controller	Compact PID controllers not supported: • PID_Compact • PID_3Step • PID_Temp Only the PID basic functions are supported. The PID basic functions can only be commissioned online in the RUN-Solo system state.
Protection functions	Not supported: Copy protection
Secure OUC	Not supported as certificate management is not possible for the R/H CPUs: If you have enabled Secure OUC, you can compile and load the user program but cannot add certificates to the R/H CPUs.
PROFINET send clock	1 ms only
Shared Device	Not supported
SIMATIC ProDiag	Not supported
S7 routing	No S7 routing between PROFINET interface X1 and PROFINET interface X2 of the R/H CPUs

Function	Restriction
S7-1500H: Failure of the IO devices in the PROFINET ring when PROFINET cables to primary CPU are disconnected	If you remove both PROFINET cables from the primary CPU (CPU 1517H-3 PN) in the RUN-Redundant system state, please note the following: • The primary CPU can no longer access the IO devices in the PROFINET ring. The IO devices will return to the substitute values. • The redundant system will not execute a primary-backup switchover. • The redundant system will remain in the RUN-Redundant system state.
Isochronous mode	Isochronous mode is not supported
Test function: Testing with breakpoints	Not supported: In STEP 7, the message "The device does not support breakpoints" appears.
Trace	The storage of measurements on the SIMATIC memory card (measurements in the device) is not supported.
Web server	Not supported
Certificate management	Not supported

[1] Distributed I/O systems can be connected over PN/PN couplers.

3.3 Configuration versions

Introduction

You can configure different versions of the S7-1500R/H redundant system. A PROFINET ring is essential in all configuration versions.

For the configuration versions of the S7-1500R/H system, there is redundancy for the following components:

- R/H-CPUs

- Interfaces of synchronization

- Network in the PROFINET ring

This section describes the admissible configuration versions and their advantages/benefits.

The following convention applies:

The system is redundant.
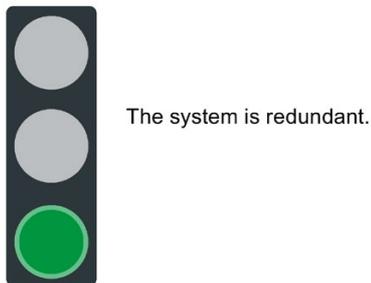
Figure 3-1   Green traffic light

3.3.1 S7-1500R/H configuration with IO devices in the PROFINET ring

Introduction

The following sections set out configurations of the S7-1500R/H redundant system with IO devices in the PROFINET ring.

Advantages/benefits

- The IO devices are connected in the PROFINET ring with system redundancy.

- The redundant system continues to operate following a cable interruption anywhere in the PROFINET ring. One of the two communication connections of the IO devices remains. A SYNCUP is prevented.

S7-1500R configuration
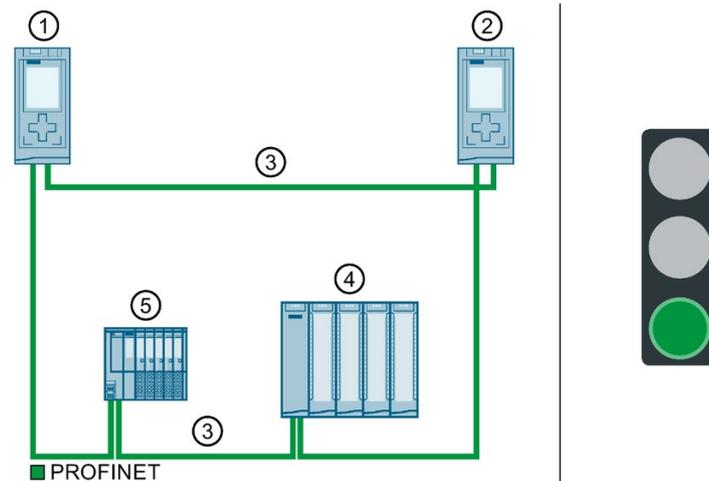
①	CPU 1
②	CPU 2
③	PROFINET cable (redundancy connections, PROFINET ring)
④	IO device ET 200MP (with system redundancy S2)
⑤	IO device ET 200SP (with system redundancy S2)

Figure 3-2   S7-1500R configuration with IO devices in the PROFINET ring

S7-1500H configuration

① CPU 1

② CPU 2

③ Two fiber-optic cables (redundancy connections)

④ IO device ET 200SP (with system redundancy S2)

⑤ IO device ET 200MP (with system redundancy S2)

⑥ PROFINET cable (PROFINET ring)
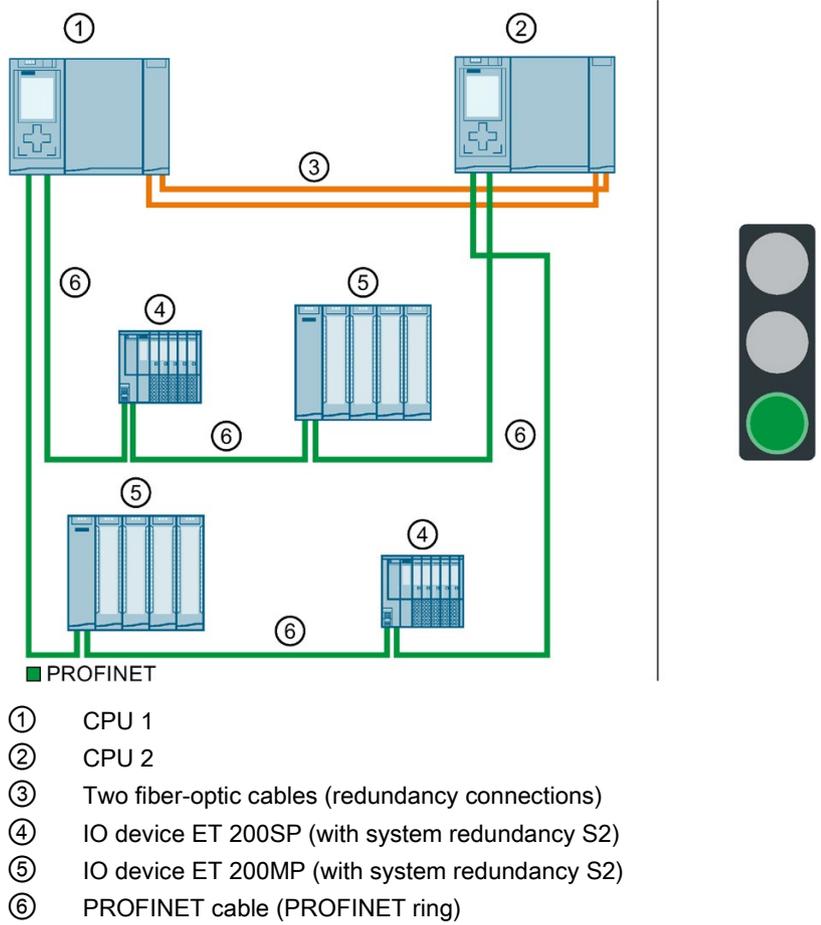
Figure 3-3   S7-1500H configuration with IO devices in the PROFINET ring

3.3.2 S7-1500R/H configuration with switches and linear topology

Introduction

The following sections set out configurations of the S7-1500R/H redundant system with switches and line topology.

Benefits/advantages

- You can use a switch to add an additional line topology to the PROFINET ring. Unlike the PROFINET ring, the line topology is not redundant.

- PROFINET IO devices assigned to the S7-1500R/H system must always support system redundancy S2. These PROFINET IO devices can be located in the PROFINET ring or they can be separated with a switch.

S7-1500R configuration
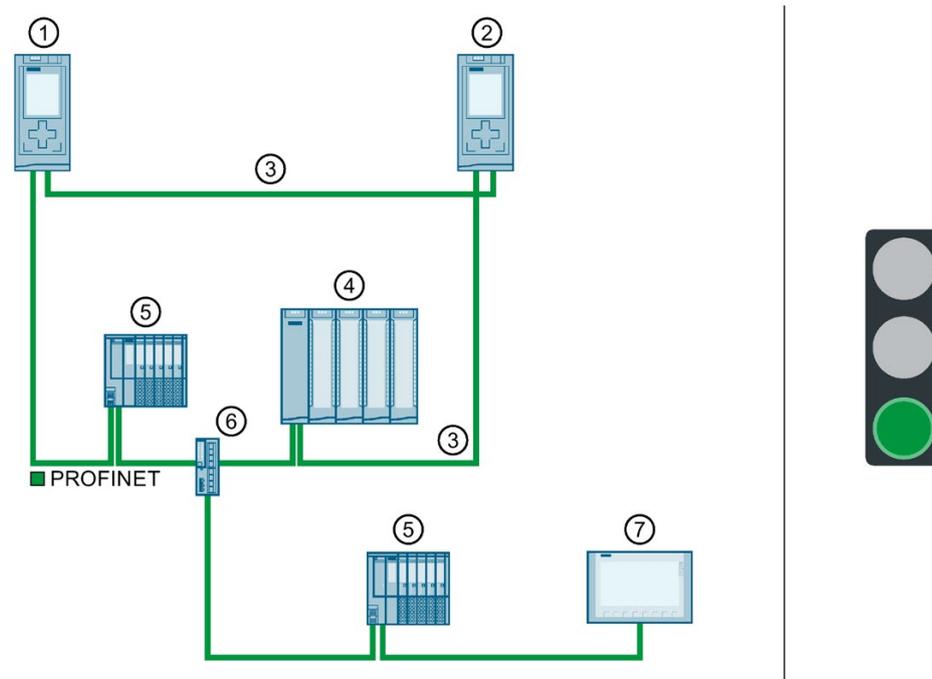
①   CPU 1
②   CPU 2
③   PROFINET cable (redundancy connections, PROFINET ring)
④   IO device ET 200MP (with system redundancy S2)
⑤   IO device ET 200SP (with system redundancy S2)
⑥   Switch
⑦   HMI device

Figure 3-4   S7-1500R configuration with switches and line topology

S7-1500H configuration
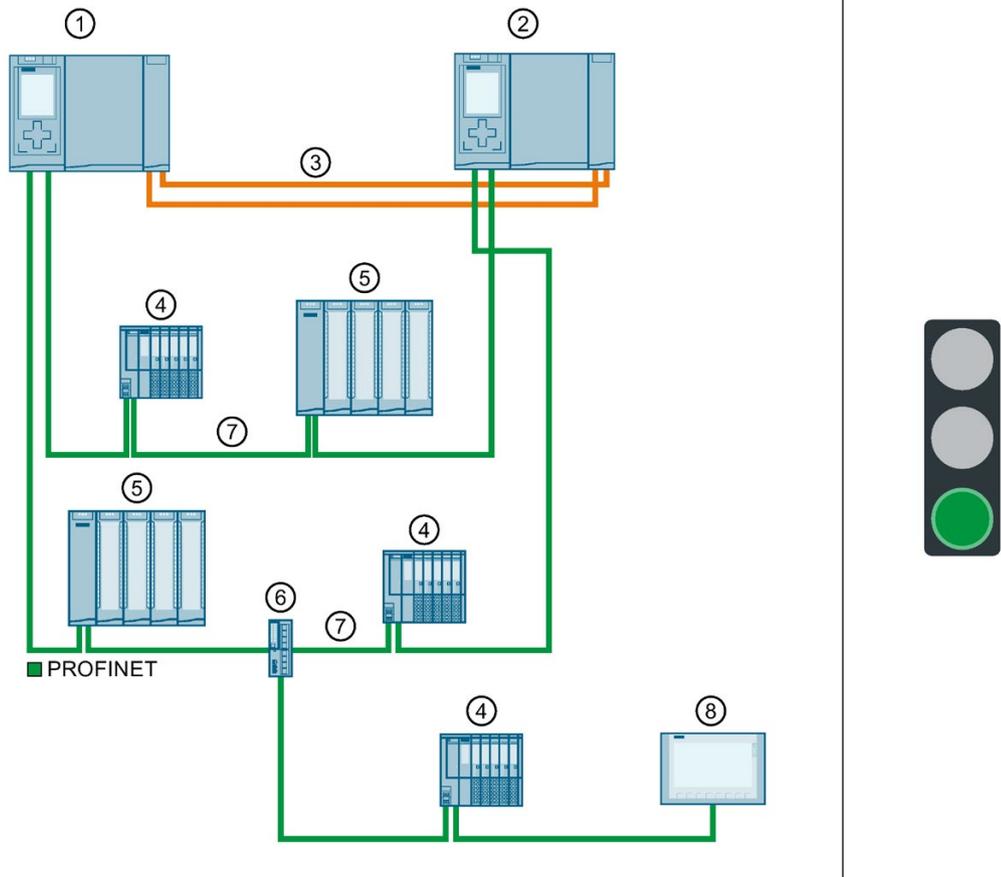
①	CPU 1
②	CPU 2
③	Two fiber-optic cables (redundancy connections)
④	IO device ET 200SP (with system redundancy S2)
⑤	IO device ET 200MP (with system redundancy S2)
⑥	Switch
⑦	PROFINET cable (PROFINET ring)
⑧	HMI device

Figure 3-5   S7-1500H configuration with switches and line topology

3.4 Redundancy scenarios

3.4.1 Introduction

Introduction

This section describes possible redundancy scenarios on the basis of various different configuration versions. The redundancy scenarios do not result in process restrictions. In the examples shown, the failures are tolerated by the redundant system.

The following convention applies:
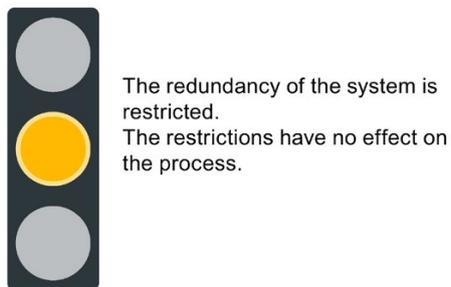
Figure 3-6   Yellow traffic light

3.4.2 Failure of the primary CPU

Introduction

The following redundancy scenario describes the effects of a defective primary CPU.

Redundancy scenario
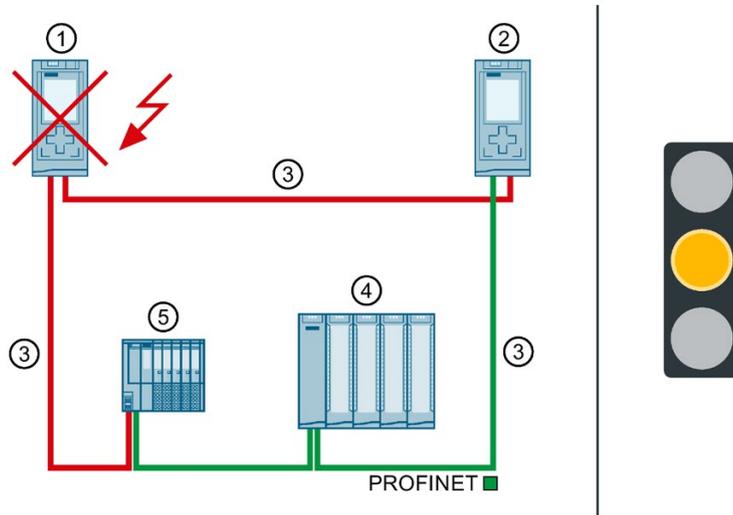
①   Primary CPU → failed
②   Backup CPU → becomes new primary CPU
③   PROFINET cable (redundancy connections, PROFINET ring)
④   IO device ET 200MP
⑤   IO device ET 200SP

Figure 3-7   Failure of the primary CPU (using S7-1500R as an example)

Sequence of events

1. The primary CPU of the redundant system fails in the RUN-Redundant system state.

2. The redundant system switches to the backup CPU. The backup CPU becomes the new primary CPU. The redundant system switches to the RUN-Solo system state. You can find additional information on the RUN-Solo system state in the section Operating and system states (Page 197).

3. The new primary CPU exchanges process data with the IO devices.

4. The redundancy of the system is restricted. The restriction has no impact on the process. If another system component or another network segment fails, this can result in the failure of the S7-1500R/H redundant system. You can find additional information in the section Failure scenarios (Page 72).

Diagnostics

System state, operating states and error displays after primary-backup switchover:

- Redundant system → RUN-Solo system state

- Primary CPU (previously backup CPU) → RUN operating state

  - MAINT LED → yellow light: The R/H system is not in the RUN-Redundant system state; no partner CPU found in the redundant system.

- Backup CPU (previously primary CPU) → failed

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective CPU. You can find additional information on the procedure in the section Replacing defective R/H CPUs (Page 260).

3.4.3 Failure of the backup CPU

Introduction

The following redundancy scenario describes the effects of a defective backup CPU.

Redundancy scenario

① Primary CPU
② Backup CPU → failed
③ PROFINET cable (redundancy connections, PROFINET ring)
④ IO device ET 200MP
⑤ IO device ET 200SP
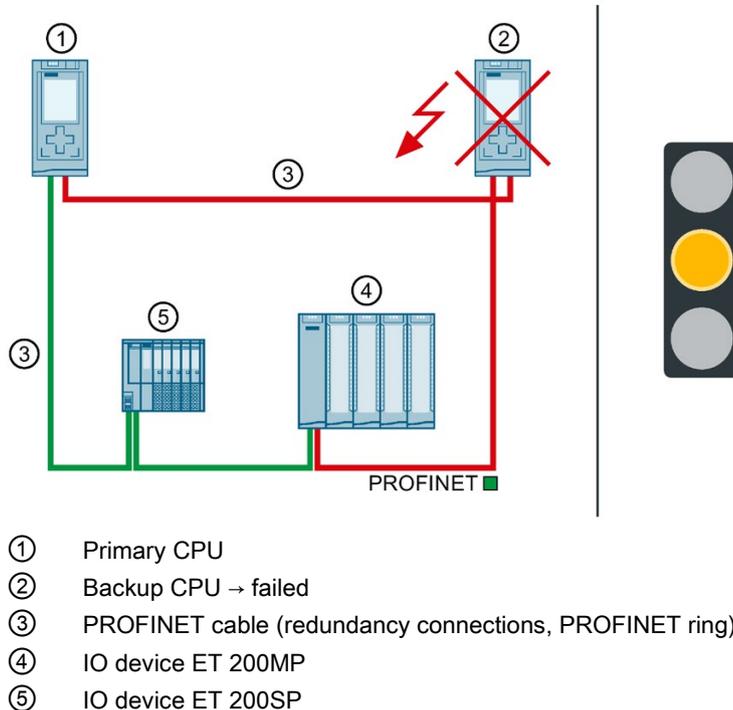
Figure 3-8   Failure of the backup CPU (using S7-1500R as an example)

Sequence of events

1. The backup CPU of the redundant system fails in the RUN-Redundant system state.

2. The redundant system switches to the RUN-Solo system state. You can find additional information on the RUN-Solo system state in the section Operating and system states (Page 197).

3. The primary CPU continues to exchange process data with the IO devices.

4. The redundancy of the system is restricted. The restriction has no impact on the process. If another system component or another network segment fails, this can result in the failure of the S7-1500R/H redundant system. You can find additional information in the section Failure scenarios (Page 72).

Diagnostics

System state, operating states and error displays after primary-backup switchover:

- Redundant system → RUN-Solo system state
- Primary CPU → RUN operating state
  - MAINT LED → yellow light: The R/H system is not in the RUN-Redundant system state. No partner CPU has been found in the redundant system.
- Backup CPU → failed

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective CPU. You can find additional information on the procedure in the section Replacing defective R/H CPUs (Page 260).

3.4.4 Failure of the PROFINET cable in the PROFINET ring

Introduction

The following redundancy scenario describes the effects of a defective PROFINET cable in the PROFINET ring.

Redundancy scenario
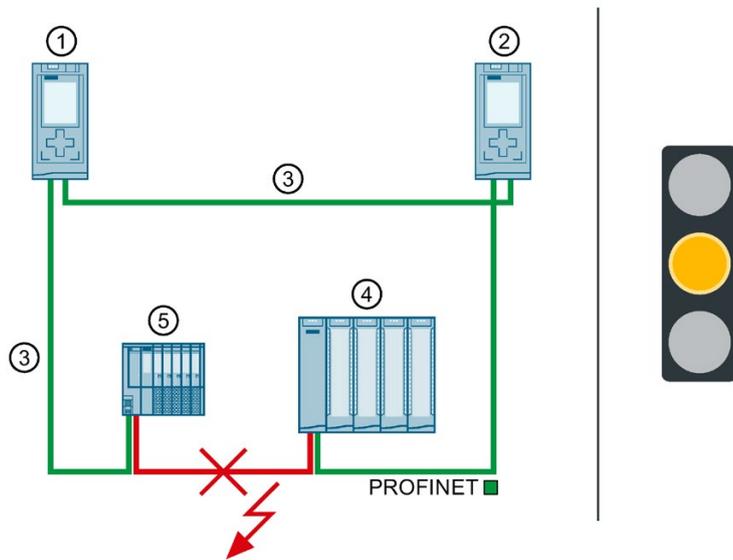
①   Primary CPU
②   Backup CPU
③   PROFINET cable (redundancy connections, PROFINET ring) → interrupted
④   IO device ET 200MP
⑤   IO device ET 200SP

Figure 3-9   Failure of a PROFINET cable in the PROFINET ring (using S7-1500R as an example)

Sequence of events

1. A defective or disconnected PROFINET cable interrupts the PROFINET ring of the redundant system.

2. The redundant system remains in the RUN-Redundant system state: The primary and backup CPUs remain in the RUN-Redundant operating state.

3. The redundant system selects an alternative connection over the backup CPU. This allows the redundant system to access all IO devices in the PROFINET ring again.

4. The redundancy of the system is restricted. The restriction has no effect on the process. In the following examples, other components also fail in the redundancy scenario described. The result is a failure scenario:

   If another system component or another network segment fails, this can result in the failure of the S7-1500R/H redundant system.

   – If the primary CPU fails in addition to a PROFINET cable, the backup CPU switches to the STOP operating state.

   – If the PROFINET cable is also interrupted at another point, IO devices in the PROFINET ring may fail depending on the location of the interruption.

   – You can find additional information in the section Failure scenarios (Page 72).

Diagnostics

System state, operating states and error displays after the failure of the PROFINET cable:

- Redundant system → RUN-Redundant system state
- Primary CPU → RUN-Redundant operating state
  - MAINT LED → yellow light: The PROFINET ring is open. There is only one redundancy connection remaining in the redundant system.
- Backup CPU → RUN-Redundant operating state
  - MAINT LED → yellow light: The PROFINET ring is open. There is only one redundancy connection remaining in the redundant system.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective PROFINET cable or reconnect the disconnected PROFINET cable. You can find additional information on the procedure in the section Replacing defective PROFINET cables.

3.4.5 Specific redundancy scenarios for S7-1500H

3.4.5.1 Failure of a redundancy connection in S7-1500H

Introduction

The following redundancy scenario describes the effects of a defective redundancy connection in S7-1500H.

Redundancy scenario
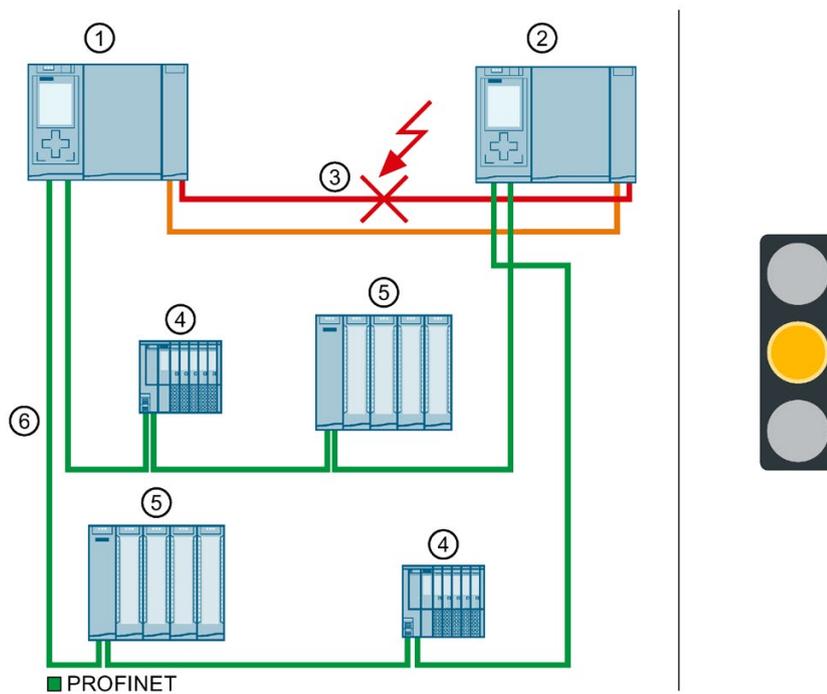
①	Primary CPU
②	Backup CPU
③	One fiber-optic cable (redundancy connection) → interrupted
④	IO device ET 200SP
⑤	IO device ET 200MP
⑥	PROFINET cable (PROFINET ring)

Figure 3-10   Failure of a redundancy connection

Sequence of events

1. One of the two redundancy connections (fiber-optic cables) is interrupted.

2. The primary CPU continues to exchange process data with the IO devices.

3. The redundancy of the system is restricted. The redundant system will remain in the RUN-Redundant system state. The restriction has no effect on the process.
   If the primary CPU fails as well as the redundancy connection, the backup CPU switches to the STOP operating state. You can find additional information in the section Failure scenarios (Page 72).

Diagnostics

System state, operating states and error displays after the failure of a redundancy connection:

- Redundant system → RUN-Redundant system state

- Primary CPU → RUN-Redundant operating state

  - MAINT LED → yellow light: There is only one redundancy connection remaining in the H system.

- Backup CPU → RUN-Redundant operating state

  - MAINT LED → yellow light: There is only one redundancy connection remaining in the H system.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective redundancy connection. You can find additional information on the procedure in the section Replacing defective redundancy connections (Page 261).

3.4.5.2 Failure of both redundancy connections in S7-1500H > 1500 ms apart

Introduction

The following redundancy scenario describes the effects of a defect in each of the two redundancy connections in S7-1500H. In this redundancy scenario, the time between the redundancy connection failures is > 1500 ms.

Redundancy scenario
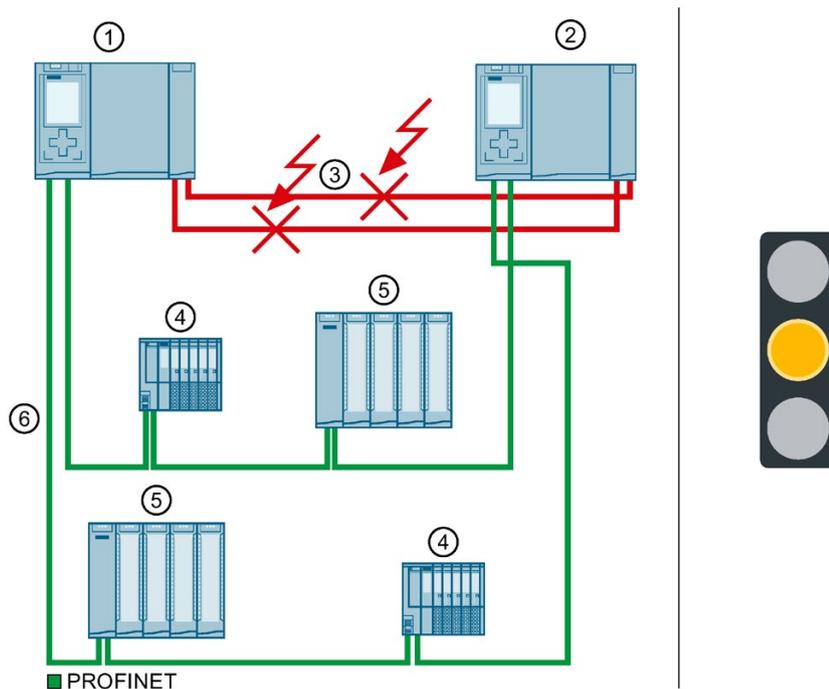
①   Primary CPU (S7-1500H)
②   Backup CPU (S7-1500H)
③   Two fiber-optic cables (redundancy connections) → interrupted
④   IO device ET 200MP
⑤   IO device ET 200SP
⑥   PROFINET cable (PROFINET ring)

Figure 3-11 Failure of both redundancy connections (> 1500 ms apart)

Sequence of events

1. The two redundancy connections (fiber-optic cables) are interrupted, one > 1500 ms after the other.

2. The redundant system switches to the RUN-Solo system state. The primary CPU remains in the RUN operating state. The backup CPU switches to the STOP operating state.

3. The primary CPU continues to exchange process data with the IO devices.

4. The redundancy of the system is restricted. The restriction has no impact on the process. If another system component or another network segment fails, this can result in the failure of the S7-1500R/H redundant system. You can find additional information in the section Failure scenarios (Page 72).

Diagnostics

System state, operating states and error displays after the failure of both redundancy connections:

● Redundant system → RUN-Solo system state

● Primary CPU → RUN operating state

  – MAINT LED → yellow light: The H-system is not in the RUN-Redundant system state. No partner CPU has been found in the H-system.

● Backup CPU → STOP operating state

  – MAINT LED → yellow light: The H-system is not in the RUN-Redundant system state. No partner CPU has been found in the H-system.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective redundancy connections. You can find additional information on the procedure in the section Replacing defective redundancy connections (Page 261).

3.4.5.3 Failure of both redundancy connections and the PROFINET cable in the PROFINET ring

Introduction

The following redundancy scenario describes the effects of a defect in each of the two redundancy connections and in the PROFINET cable in the PROFINET ring.
In this redundancy scenario, the time between the redundancy connection failures is > 1500 ms.

Redundancy scenario

■ PROFINET

①   Primary CPU

②   Backup CPU

③   Two fiber-optic cables (redundancy connections) → interrupted

④   IO device ET 200SP

⑤   IO device ET 200MP

⑥   PROFINET cable (PROFINET ring) → interrupted
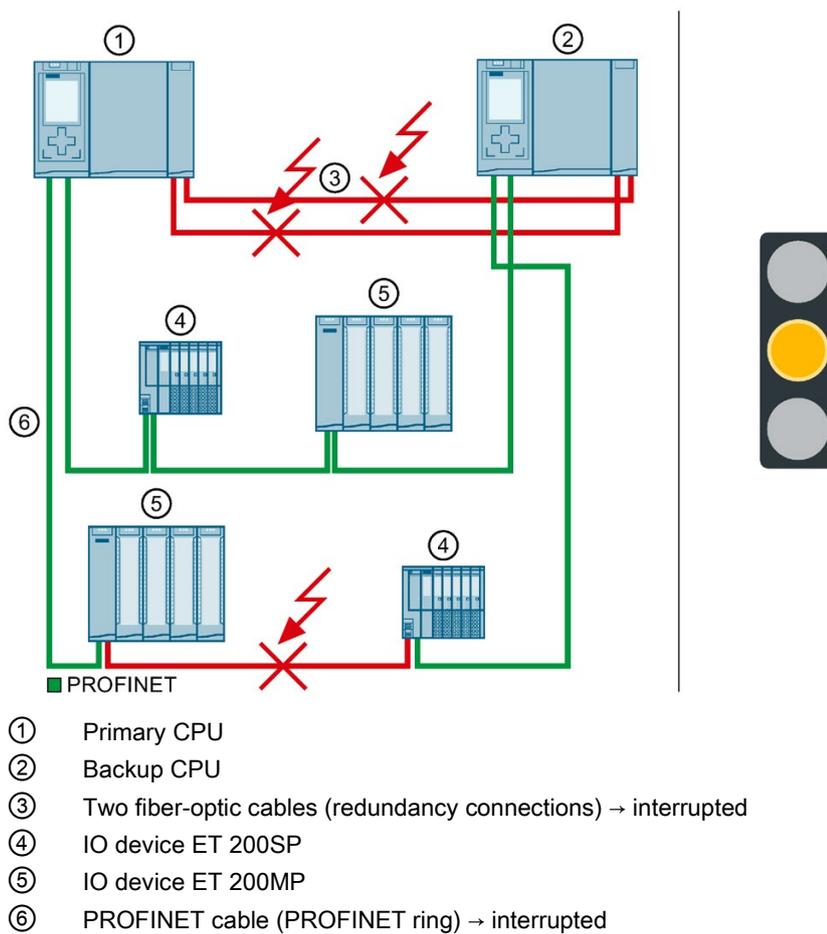
Figure 3-12   Failure of both redundancy connections and a PROFINET cable in the PROFINET ring

Sequence of events

1. Both redundancy connections (fiber-optic cables) fail in the redundant system. The time between the failures is > 1500 ms.

2. The redundant system switches to the RUN-Solo system state. The primary CPU remains in the RUN operating state. The backup CPU switches to the STOP operating state.

3. A defective PROFINET cable also interrupts the PROFINET ring.

4. The redundant system accesses all IO devices in the PROFINET ring again over the remaining PROFINET cables.

5. The redundancy of the system is restricted. The restrictions have no effect on the process.

Diagnostics

System state, operating states and error displays after the failure of the redundancy connections and PROFINET cable:

● Redundant system → RUN-Solo system state

● Primary CPU → RUN operating state

   – MAINT LED → yellow light: The H-system is not in the RUN-Redundant system state. No partner CPU has been found in the H-system. The PROFINET ring is open.

● Backup CPU → STOP operating state

   – MAINT LED → yellow light: The H-system is not in the RUN-Redundant system state. No partner CPU has been found in the H-system. The PROFINET ring is open.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective redundancy connections and the defective PROFINET cable. You can find more information on the procedure in the following sections:

● Replacing defective redundancy connections (Page 261)

● Replacing defective PROFINET cables

3.5 Failure scenarios

Introduction

This section describes possible failure scenarios with the various configuration versions. The failure scenarios lead to process restrictions. In the examples shown, the redundant system cannot tolerate the failures any longer.

The following convention applies:

System redundancy has failed.
The failures have an impact on the process.

Figure 3-13   Red traffic light

3.5.1 Failure of an IO device in the PROFINET ring

Introduction

The following failure scenario describes the effects of a defective IO device in the PROFINET ring.

Failure scenario
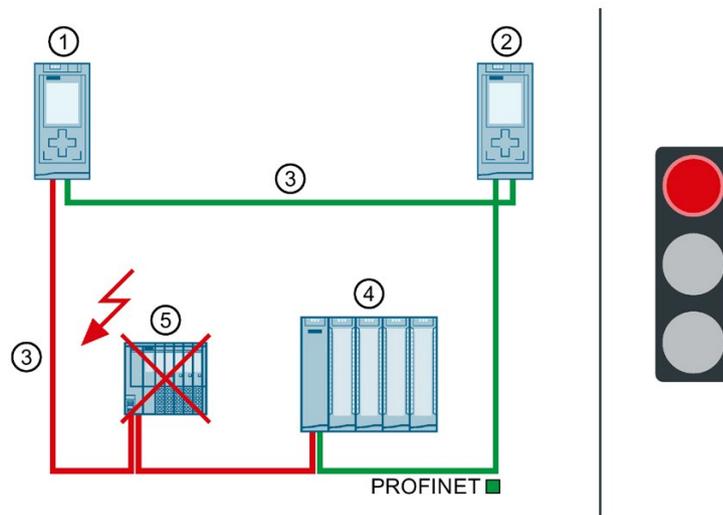
①	Primary CPU
②	Backup CPU
③	PROFINET cable (redundancy connections, PROFINET ring)
④	IO device ET 200MP
⑤	IO device ET 200SP → failed

Figure 3-14   Failure of an IO device in the PROFINET ring (using S7-1500R as an example)

Sequence of events

1. An IO device in the PROFINET ring fails.

2. The PROFINET ring is interrupted.

3. The redundant system selects an alternative connection over the backup CPU. This allows the redundant system to access all remaining IO devices in the PROFINET ring again.

4. The failure of the IO device has an impact on the process. If the failed inputs and outputs have an important function in the system, their failure can have a critical impact on the process.

Diagnostics

System state, operating states and error displays after the failure of an IO device:

- Redundant system → RUN-Redundant system state
- Primary CPU → RUN-Redundant operating state
    - MAINT LED: → yellow light: The PROFINET ring is open.
    - ERROR LED → flashes red: An IO device has failed.
- Backup CPU → RUN-Redundant operating state
    - MAINT LED → yellow light: The PROFINET ring is open.
    - ERROR LED → flashes red: An IO device has failed.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective IO device. You can find additional information on the procedure in the section Replacing defective I/O devices/switches (Page 268).

3.5.2 Failure of a switch (with line topology) in the PROFINET ring

Introduction

The following failure scenario describes the effects of a defective switch (with line topology) in the PROFINET ring.
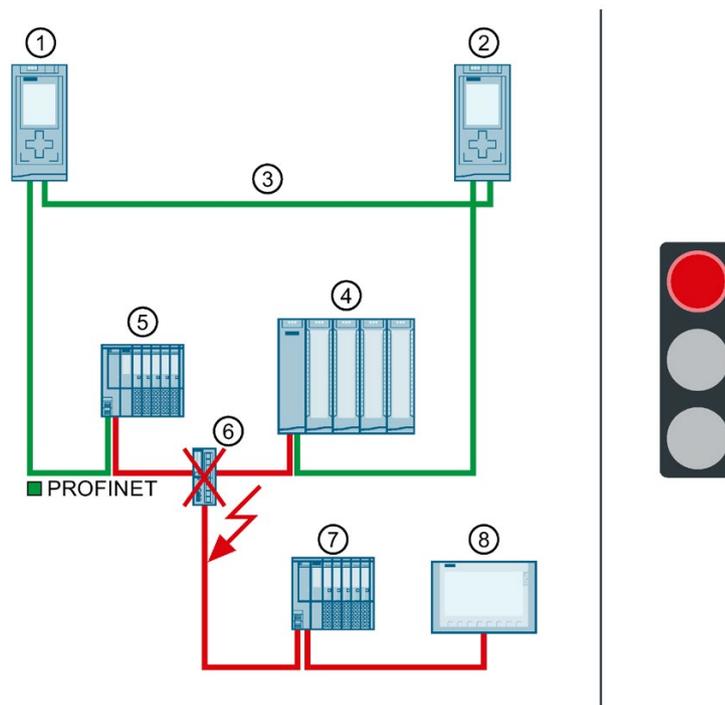
Failure scenario

①	Primary CPU
②	Backup CPU
③	PROFINET cable (redundancy connections, PROFINET ring)
④	IO device ET 200MP
⑤	IO device ET 200SP
⑥	Switch → failed
⑦	IO device ET 200SP
⑧	HMI device

Figure 3-15   Failure of a switch in the PROFINET ring (using S7-1500R as an example)

Sequence of events

1. A switch (with connected line topology) in the PROFINET ring fails.

2. The PROFINET ring is interrupted.

3. If applicable, the redundant system selects an alternative connection to the IO devices ④ and ⑤ over the backup CPU. This allows the redundant system to access all IO devices in the PROFINET ring again.

4. The failure of the switch has an impact on the process as the IO devices in the line topology can no longer be accessed.
   If the failed inputs and outputs have an important function in the system, their failure can have a critical impact on the process.

Diagnostics

System state, operating states and error displays after the failure of a switch:

● Redundant system → RUN-Redundant system state

● Primary CPU → RUN-Redundant operating state

   – MAINT LED → yellow light: The PROFINET ring is open.

   – ERROR LED → flashes red: One or more IO devices have failed.

● Backup CPU → RUN-Redundant operating state

   – MAINT LED → yellow light: The PROFINET ring is open.

   – ERROR LED → flashes red: One or more IO devices have failed.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective switch. You can find additional information on the procedure in the section Replacing defective I/O devices/switches (Page 268).

3.5.3 Specific failure scenarios with S7-1500R

3.5.3.1 Two cable interruptions in the PROFINET ring in S7-1500R > 1500 ms apart

Introduction

The following failure scenario describes the effects of two cable interruptions in the PROFINET ring. In this failure scenario, the time between the two cable interruptions is > 1500 ms.

Failure scenario
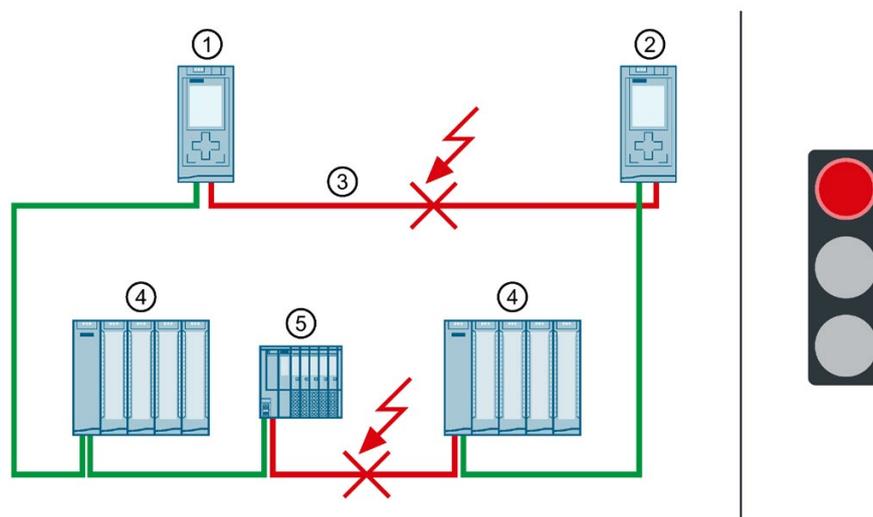
①   Primary CPU
②   Backup CPU
③   PROFINET ring → interrupted at two points
④   IO device ET 200MP
⑤   IO device ET 200SP

Figure 3-16   Two cable interruptions in the PROFINET ring (> 1500 ms apart)

Sequence of events

1. The PROFINET ring is interrupted at one point.

2. The redundant system remains in the RUN-Redundant system state: The primary and backup CPUs remain in the RUN-Redundant operating state.

3. The PROFINET ring is interrupted at a second point > 1500 ms later.

4. The redundant system switches to the RUN-Solo system state. The primary CPU remains in the RUN operating state. The backup CPU switches to the STOP operating state.

5. CPU redundancy has failed. The failure has an impact on the process. The RUN-Solo system state and the cable interruptions mean that not all IO devices in the PROFINET ring can be accessed.
   If the failed inputs and outputs have an important function in the system, their failure can have a critical impact on the process.

Diagnostics

System state, operating states and error displays after the cable interruptions:

● Redundant system → RUN-Solo system state

● Primary CPU → RUN operating state

  – MAINT LED → yellow light: The R system is not in the RUN-Redundant system state. No partner CPU has been found in the R system. The PROFINET ring is open.

  – ERROR LED → flashes red: One or more IO devices cannot be accessed.

● Backup CPU → STOP operating state

  – MAINT LED → yellow light: The R system is not in the RUN-Redundant system state. No partner CPU has been found in the R system. The PROFINET ring is open.

  – ERROR LED → flashes red: One or more IO devices cannot be accessed.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective PROFINET cables. You can find additional information on the procedure in the section Replacing defective redundancy connections (Page 261).

3.5.3.2 Two cable interruptions in the PROFINET ring in S7-1500R within ≤ 1500 ms

Introduction

The following failure scenario describes the effects of two cable interruptions in the PROFINET ring. In this failure scenario, the time between the two cable interruptions is ≤ 1500 ms.

Failure scenario
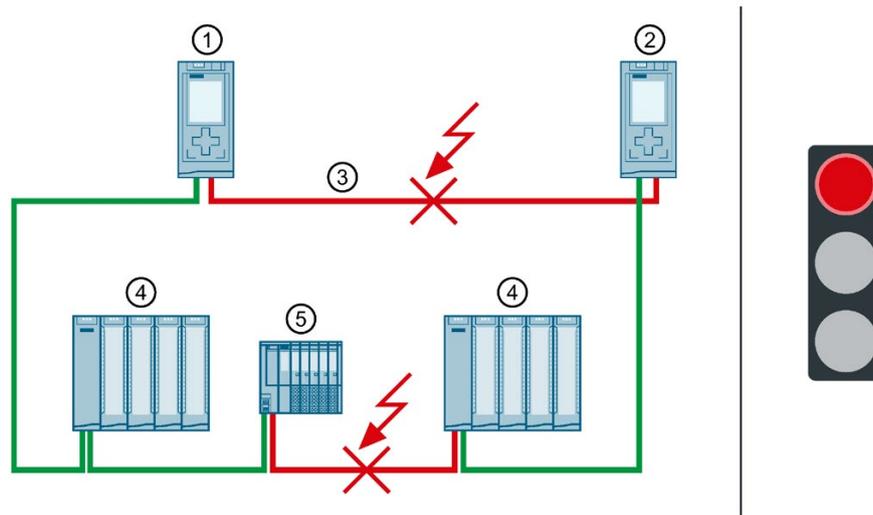
① Primary CPU
② Backup CPU
③ PROFINET ring → interrupted at two points
④ IO device ET 200MP
⑤ IO device ET 200SP

Figure 3-17   Two cable interruptions in the PROFINET ring (within ≤ 1500 ms)

Sequence of events

1. The PROFINET ring is interrupted at two points within ≤ 1500 ms.

2. The redundant system switches to an undefined system state: The primary CPU remains in the RUN operating state. The backup CPU becomes the primary CPU and remains in RUN operating state.

3. The two primary CPUs continue to exchange process data with the accessible IO devices.

4. The redundancy of the system is defective. The redundant system is in an undefined system state. The undefined system state can lead to dangerous states in the process.

⚠ **WARNING**

Undefined system state of the S7-1500R redundant system at the same time as a cable interruption in the PROFINET ring at two points within ≤ 1500 ms.

Lay the PROFINET cables so that they are securely protected from damage. PROFINET cables should also always be laid separately from each other. This makes simultaneous damage to the PROFINET cables (within ≤ 1500 ms) unlikely.

Diagnostics

System state and operating states after cable interruptions:

- Redundant system → System state defective (undefined: Each R-CPU is in the RUN-Solo system state).

- Primary CPU → RUN operating state

  – MAINT LED → yellow light: The R system is not in the RUN-Redundant system state. The PROFINET ring is open.

  – ERROR LED → flashes red: An IO device has failed.

- Primary CPU (previously backup CPU) → RUN operating state

  – MAINT LED → yellow light: The R system is not in the RUN-Redundant system state. The PROFINET ring is open.

  – ERROR LED → flashes red: An IO device has failed.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Please note the following solution:

Note

Before you replace the defective PROFINET cables, you must switch both R-CPUs to the STOP operating state. Only then repair the PROFINET cables in the PROFINET ring. Afterwards, switch the R-CPUs back to the RUN operating state.

You can find additional information on the procedure in the section Replacing defective redundancy connections (Page 261).

3.5.3.3 Failure of the primary CPU when IO devices have failed in the PROFINET ring

Introduction

The following failure scenario describes the effects of a defective IO device in the PROFINET ring and a defective primary CPU.

Failure scenario
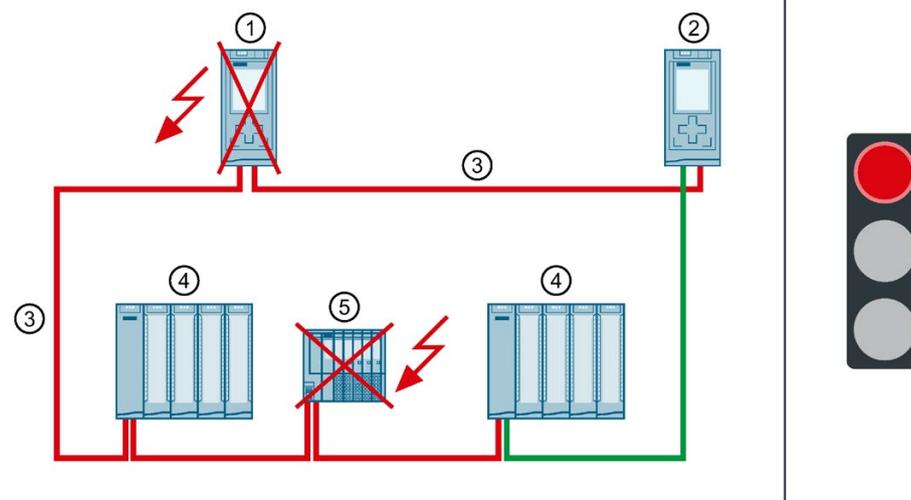
① Primary CPU → failed (2nd failure in runtime sequence)
② Backup CPU → switches to STOP operating state
③ PROFINET cable (redundancy connections, PROFINET ring)
④ IO device ET 200MP
⑤ IO device ET 200SP → failed (1st failure in sequence)

Figure 3-18   Failure of an IO device in the PROFINET ring and the primary CPU (using S7-1500R as an example)

Sequence of events

1. An IO device in the PROFINET ring fails.

2. As a result, the PROFINET ring is interrupted.

3. The redundant system selects an alternative connection over the backup CPU. This allows the redundant system to access all remaining IO devices in the PROFINET ring again.

4. The primary CPU also fails.

5. The redundant system does not switch to the backup CPU and switches to the STOP system state. The role of the backup CPU remains unchanged.

Note

The backup CPU does not differentiate between the following scenarios:

- It can no longer access the primary CPU because the latter has failed.
- The PROFINET ring has been interrupted at a second point and the primary CPU may still be running.

That is why the backup CPU does not become the primary CPU. This prevents an undefined system state.

---

6. The redundant system has failed. The process is no longer controlled by the redundant system.

Diagnostics

System state, operating states and error displays after the failure of the IO device in the PROFINET-Ring and the STOP of Backup CPU:

- Redundant system → STOP system state

- Primary CPU → failed

- Backup CPU → STOP operating state

  – MAINT LED → yellow light: The R system is not in the RUN-Redundant system state. No partner CPU has been found in the R system. The PROFINET ring is open.

  – ERROR LED → flashes red: One or more IO devices have failed.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective IO device and the defective primary CPU. You can find additional information on the procedure in the sections Replacing defective R/H CPUs (Page 260) and Replacing defective I/O devices/switches (Page 268).

Note

Proceed as follows if you have ensured that the CPU is still working in the STOP operating state and can access all important IO devices:

1. Replace the defective IO device.
2. Switch the CPU from STOP operating state to the RUN operating state.
3. Replace the defective CPU. Switch the new CPU to the RUN operating state.

3.5.4 Specific failure scenarios with S7-1500H

3.5.4.1 Failure of both redundancy connections in S7-1500H ≤ 1500 ms apart

Introduction

The following failure scenario describes the effects of a defect in each of the two redundancy connections in S7-1500H. In this failure scenario, the time between the redundancy connection failures is ≤ 1500 ms.

Failure scenario

① Primary CPU
② Backup CPU
③ Two fiber-optic cables (redundancy connections) → interrupted
④ IO device ET 200SP
⑤ IO device ET 200MP
⑥ PROFINET cable (PROFINET ring)
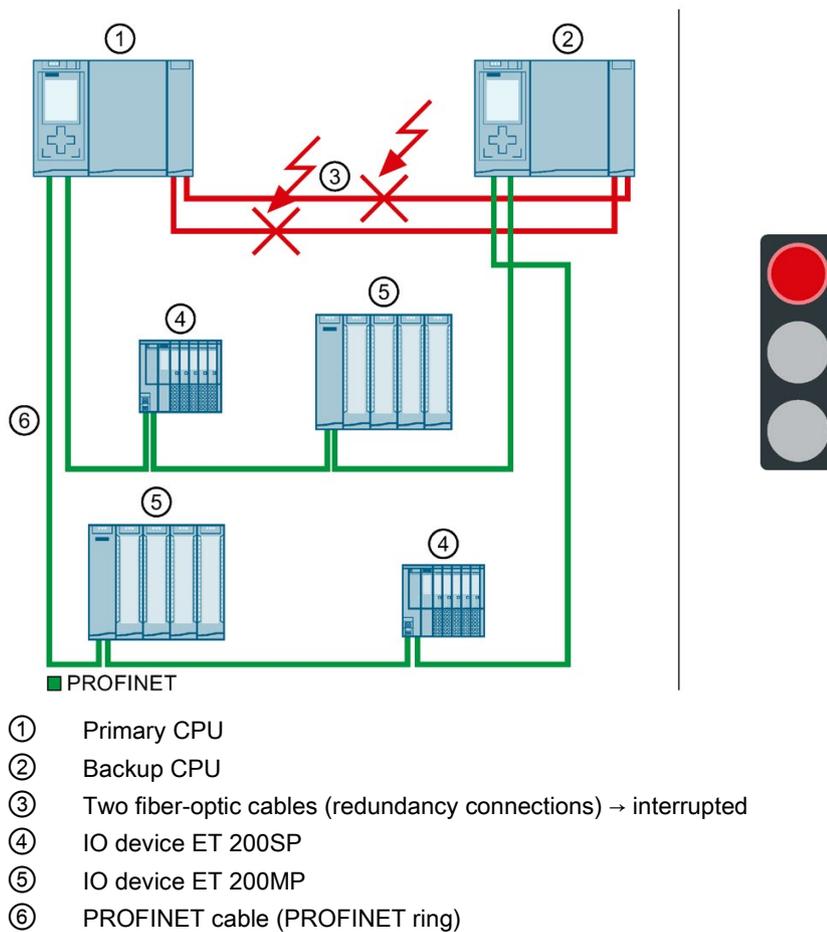
Figure 3-19   Failure of both redundancy connections

Sequence of events

1. The two redundancy connections (fiber-optic cables) are interrupted ≤ 1500 ms apart.
2. The redundant system switches to an undefined system state: The primary CPU remains in the RUN operating state. The backup CPU becomes the primary CPU and remains in RUN operating state.
3. The two primary CPUs continue to exchange process data with the PROFINET devices.
4. The redundancy of the system is defective. The redundant system is in an undefined system state. The undefined system state can lead to dangerous states in the process.

> ⚠ **WARNING**
>
> **Undefined system state of the S7-1500H redundant system when two redundancy connections are interrupted ≤ 1500 ms apart.**
>
> Lay the redundancy connections so that the fiber-optic cables are securely protected from damage. Also make sure when laying the cables that the two redundancy connections are always separate from each other. This makes simultaneous damage to the redundancy connections (< 1500 ms apart) unlikely.

Diagnostics

System state and operating states after the failure of both redundancy connections:

- Redundant system → System state defective (undefined: Each H-CPU is in the RUN-Solo system state).
- Primary CPU → RUN operating state
  - MAINT LED → yellow light: The H-system is not in the RUN-Redundant system state. No partner CPU has been found in the H-system.
- Primary CPU (previously backup CPU) → RUN operating state
  - MAINT LED → yellow light: The H-system is not in the RUN-Redundant system state. No partner CPU has been found in the H-system.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Please note the following solution:

Note

Before you replace the defective redundancy connections, you must switch both H-CPUs to the STOP operating state. Only then repair the redundancy connections. Switch the H-CPUs back to the RUN operating state.

You can find additional information on the procedure in the section Replacing defective redundancy connections (Page 261).

3.5.4.2 Failure of one redundancy connection and the primary CPU in S7-1500H

Introduction

The following failure scenario describes the effects of a defect in a redundancy connection and the primary CPU in S7-1500H. In this failure scenario, the time between the redundancy connection failure and the Primary CPU is > 1500 ms.

Failure scenario
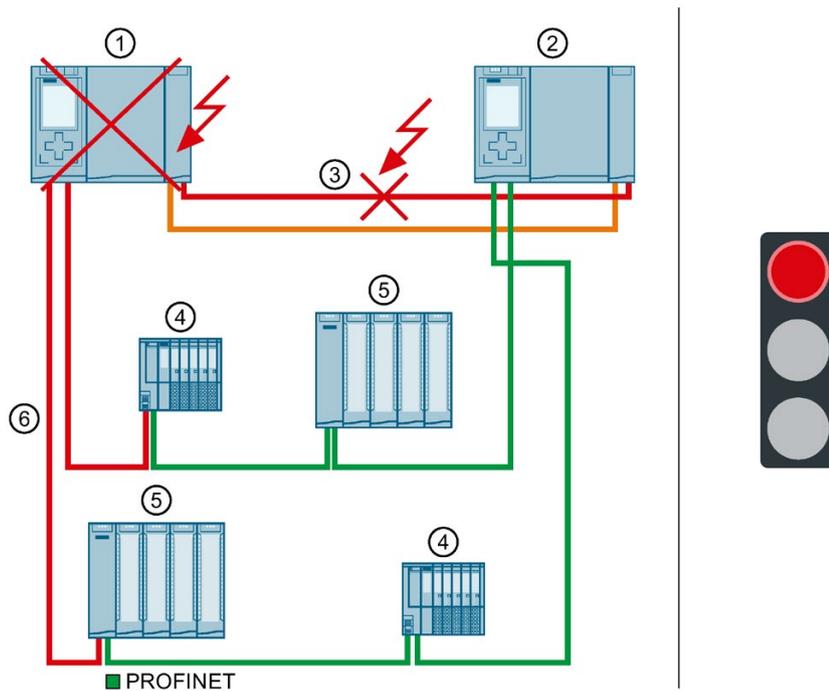
①   Primary CPU → failed (2nd failure in runtime sequence)
②   Backup CPU
③   One fiber-optic cable (redundancy connection) → interrupted (1st failure in runtime sequence)
④   IO device ET 200SP
⑤   IO device ET 200MP
⑥   PROFINET cable (PROFINET ring)

Figure 3-20   Failure of one redundancy connection and the primary CPU

Sequence of events

1. One of the two redundancy connections is interrupted.

2. Availability is restricted. The redundant system will remain in the RUN-Redundant system state.

3. The primary CPU also fails. Due to the failure, the primary CPU is no longer visible for the backup CPU.

4. The redundant system does not switch to the backup CPU, probe switches to the STOP system state. The role of the backup CPU remains unchanged.

Note

The backup CPU does not differentiate between the following scenarios:

- It can no longer access the primary CPU because the latter has failed.
- The other redundancy connection has also been interrupted and the primary CPU may still be running.

That is why the backup CPU does not become the primary CPU. This prevents an undefined system state.

---

5. System redundancy has failed. The process is no longer controlled by the redundant system.

Diagnostics

System state and operating states after the failure of the redundancy connection and primary CPU:

- Redundant system → STOP system state
- Primary CPU → failed
- Backup CPU → STOP operating state
  - MAINT LED → yellow light: The H-system is not in the RUN-Redundant system state. No partner CPU has been found in the H-system.
  - ERROR LED → flashes: IO devices cannot be accessed.

Note

To get detailed diagnostics information, evaluate the diagnostics buffer.

Solution

Replace the defective redundancy connection and the primary CPU. You can find additional information on the procedure in the sections Replacing defective redundancy connections (Page 261) and Replacing defective R/H CPUs (Page 260).

3.6 Hardware configuration

Modules suitable for R/H-CPUs

The integrated system power supply of the R/H-CPU supplies the required power for operation. Optionally, you can also use a system power supply (PS) or load power supply. The system power supply (PS) must be connected to the left of the primary and backup CPU.

The system power supply PS and load power supply PM cannot be configured with S7-1500R/H in STEP 7. The RUN LED of the PS therefore flashes permanently. You cannot evaluate pending diagnostics or errors of the PS over the R/H-CPUs.

The table below shows which modules can be used in the various R/H-CPU slots:

Table 3- 5   Assignment of slot numbers

Module type	Maximum number of modules, primary CPU (mounting rail)	Maximum number of modules, backup CPU (mounting rail)
Load power supply (PM) [1]	unlimited	unlimited
System power supply (PS) [2]	1	1
CPU	1	1

[1]   No connection to the backplane bus.

[2]   Connection to the backplane bus cannot be configured. The RUN LED on the PS flashes green.
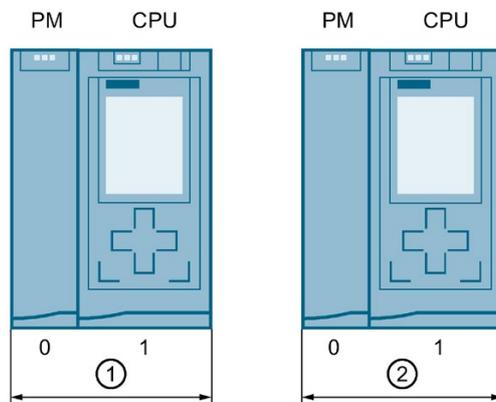
①   Optional load power supply and first R/H-CPU
②   Optional load power supply and second R/H-CPU

Figure 3-21   Maximum configuration

PROFINET devices suitable for the redundant system

The table below shows the maximum number of PROFINET devices in the redundant system. The maximum number includes switches, S7-1500R/H CPUs, S7-1500 CPUs (V2.5 or later) and HMI devices. It does not include media converters.

Table 3- 6   Number of PROFINET devices in the redundant system

PROFINET devices	Maximum number, S7-1500R	Maximum number, S7-1500H
In the PROFINET ring	50 (Recommendation 16) [1]	50
In the PROFINET ring and separated with switches (line)	66	258

[1]   Recommendation: The number of devices in the PROFINET ring affects the availability of the S7-1500R system. You should therefore operate no more than 16 PROFINET devices (including R-CPUs) in the PROFINET ring. If you operate significantly more devices in the PROFINET ring, the availability of the IO devices and R-CPUs is reduced.
The technical specifications in the documentation are based on the recommended maximum of 16 PROFINET devices in the ring in S7-1500R.

3.7 Use of a system power supply

Infeed options

There are three options for the infeed of the required system voltage in the backplane bus:

- Infeed via the CPU
- Infeed via the CPU and system power supply
- Infeed only via system power supply in slot 0

Infeed via the CPU

Supply the CPU with the permissible supply voltage 24 V DC.

Procedure

Proceed as follows to set up the supply via the CPU:

1. In STEP 7, open the "Properties" tab for the R/H-CPU. Select "System power supply" in the navigation.

2. Select the option "Connection to supply voltage L+".
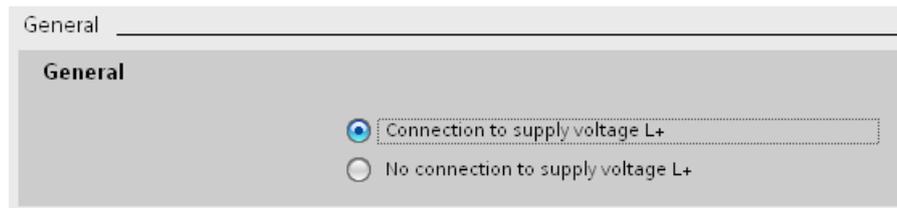
Figure 3-22   Supply voltage via CPU only

Infeed via CPU and system power supply

Supply the system power supply with the permissible supply voltage and the CPU with 24 V DC.

Both the system power supply and the CPU supply current to the backplane bus. The supplied power is summed.

Power addition: Infeed power of the system power supply + infeed power of the CPU

Procedure

Proceed as follows to set up the supply through the CPU and system power supply:

1. In STEP 7, open the "Properties" tab for the CPU. Select "System power supply" in the navigation.

2. Select the option "Connection to supply voltage L+".
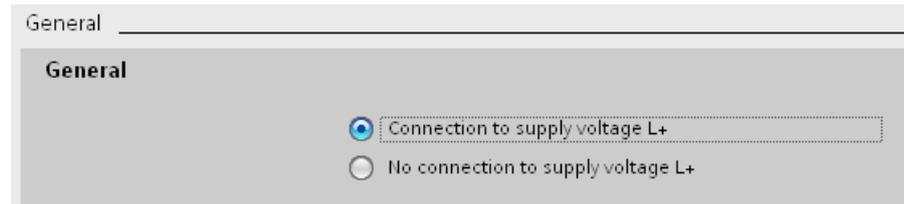
Figure 3-23   Supply voltage via the CPU and system power supply

Infeed via system power supply only

You can also feed the required power into the backplane bus using only a system power supply. In this case, the CPU is supplied from the backplane bus rather than with 24 V DC. In this case, the system power supply must be inserted to the left of the R/H-CPU in slot 0.

In general, you can use a system power supply with AC or DC infeed for the configuration.

Procedure

To set up infeed only via the system power supply, follow these steps:

1. In STEP 7, open the "Properties" tab for the CPU. Select "System power supply" in the navigation.

2. Select the option "No connection to supply voltage L+".
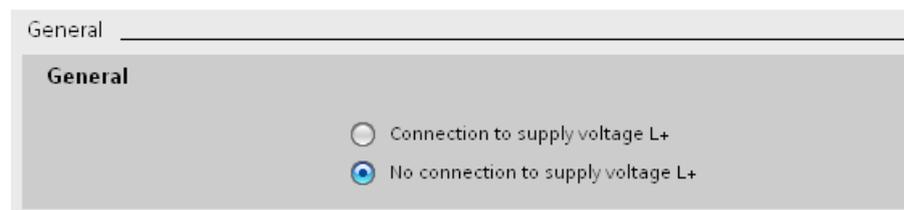
Figure 3-24   No supply to the backplane bus through the CPU

Note

If you select the option "No connection to supply voltage L+", the power required for the R/H CPU is supplied through the system power supply only. If you then compile the hardware configuration in STEP 7, the warning "Power segment undersupplied" appears. This warning has no effect on the functioning of the user program or of the redundant system.

3.8 Using HMI devices

Introduction

You can use the same HMI devices for the S7-1500R/H redundant system as for the S7-1500 automation system.

If you use HMI devices in the PROFINET ring with S7-1500R, those HMI devices must support media redundancy; we also recommend that you use the H-Sync forwarding function.

If you use HMI devices in the PROFINET ring with S7-1500H, those HMI devices must support media redundancy.

You transfer the HMI configuration to your HMI device using the configuration and programming software (Engineering Station).

You can connect the HMI device to the redundant system with the system IP address. Connection to the redundant system is possible within and outside the PROFINET ring. The HMI device always communicates with the primary CPU over the system IP address in the RUN-Redundant, RUN-Solo and STOP system states, provided you have activated the system IP address and selected it in the connection configuration for the HMI device.

If the role of primary CPU switches to the other CPU, the communication relationship of the HMI device also switches to the other (primary) CPU.

As an alternative to the system IP address, you can also use the device IP address to connect the HMI device to an R/H-CPU. The HMI device then only communicates with the connected CPU.

When exchanging data via device proxy data, make sure that the IP addresses and system IP addresses are correctly assigned to the PROFINET interfaces. You can find additional information on devices proxy data in the STEP 7 online help.

Connecting HMI devices over Industrial Ethernet, example with CPU 1517H-3 PN

The figure below is an example of how you can connect the CPU 1517H-3 PN to an HMI device over Industrial Ethernet.
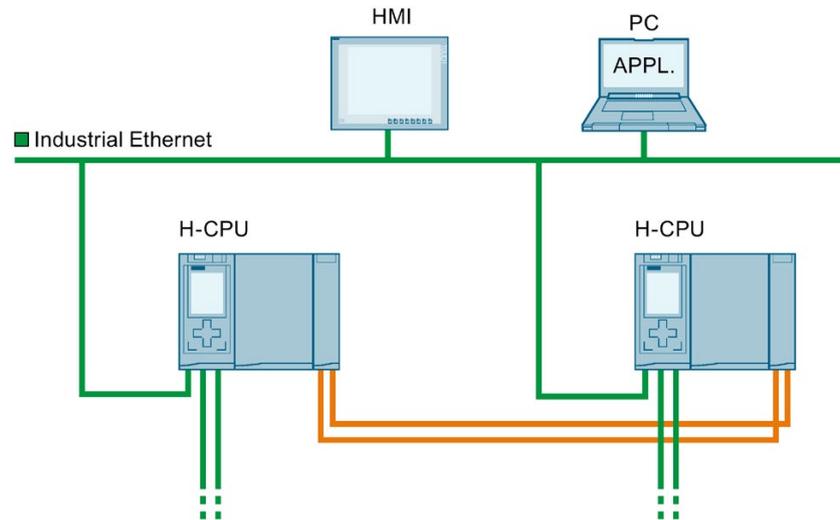
Figure 3-25   H-CPU configuration example

CPU 1517H-3 PN has a PROFINET IO interface with two ports (X1 P1 R and X1 P2 R) and one PROFINET interface (X2 P1).

To connect an HMI device to the CPUs over Industrial Ethernet, you use the X2 PROFINET interfaces of the CPU. PROFINET interface X2 supports PROFINET basic functionality. The interface is, for example, suitable for communication with an HMI device or configuration and programming software (Engineering Station).

Note

A PROFINET device (such as an HMI device) can only communicate with the redundant system over the system IP address if it has been connected to both R/H-CPUs. Always connect the PROFINET device to the same interfaces, X1 or X2, on both R/H-CPUs. Do not mix interfaces X1 and X2: If you mix interfaces X1 with X2, the HMI connection is no longer redundant.

The R/H-CPUs do not support S7 routing: If you connect the HMI device over the system IP address of the PROFINET X2 interfaces, only the backup CPU will be accessible if the cable to the primary CPU is interrupted.

You can find additional information on the interfaces of CPU 1517H-3 PN in the relevant device manual.

Connecting HMI devices over Industrial Ethernet, example with CPU 1513R-1 PN

The figure below shows how to connect an HMI device over Industrial Ethernet with the CPU 1513R-1 PN.
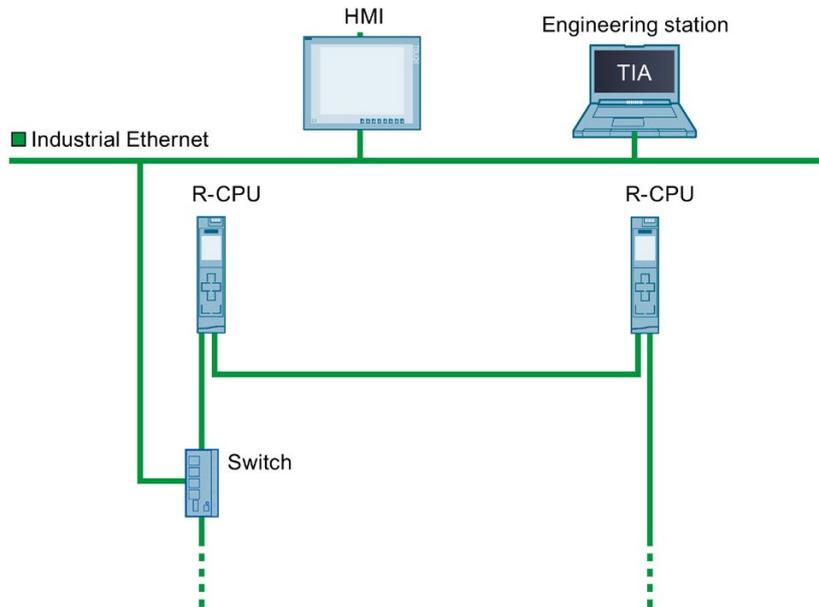
Figure 3-26   Configuration example with HMI device connected over a switch

CPU 1513R-1 PN has a PROFINET IO interface with two ports (X1 P1 R and X1 P2 R).

To connect an HMI device to the CPUs over Industrial Ethernet, you set up the PROFINET ring over PROFINET interface X1. Integrate a switch into the PROFINET ring. Use this to establish an Industrial Ethernet connection.

You can find additional information on the interfaces of CPU 1513R-1 PN in the relevant device manual.

Connecting HMI devices within the PROFINET ring, example with CPU 1515R-2 PN

The figure below shows an example of how to connect an HMI device with CPU 1515R-2 PN within the PROFINET ring.
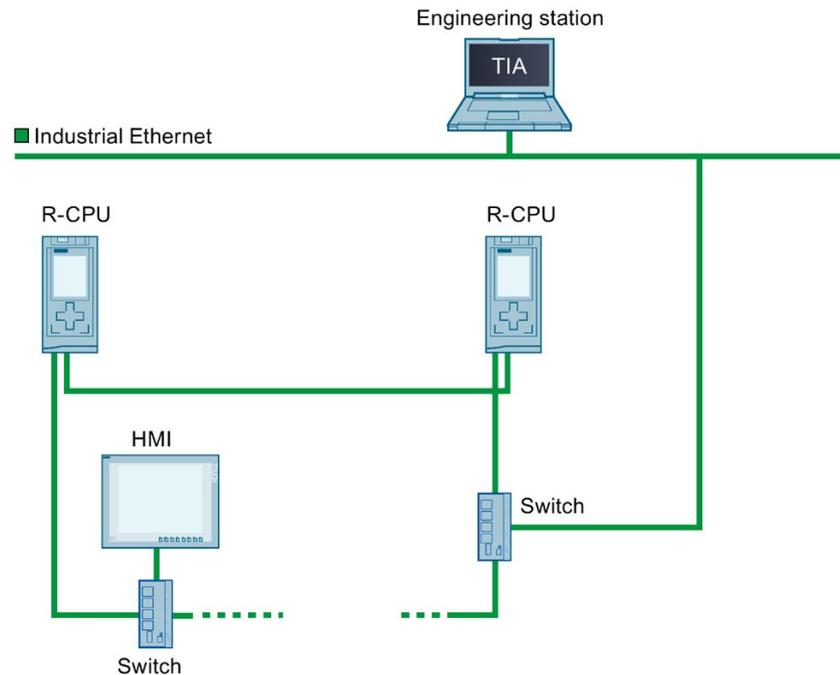
Figure 3-27   Ring configuration example

CPU 1515R-2 PN has a PROFINET IO interface with two ports (X1 P1 R and X1 P2 R) and one PROFINET interface (X2 P1).

Integrate a switch into the PROFINET ring to connect an HMI device to the PROFINET ring. Use this to establish a connection to the HMI device.

The PROFINET ring is set up using the PROFINET IO interfaces (X1) of the CPUs. If you operate HMI devices within the ring, you need to assign the MRP role "Client" to the MRP domain. You can find more information on HMI device application planning in the section Requirements (Page 49).

You can find more information on the interfaces of CPU 1515R-2 PN in the relevant device manual.

Reference

You can find more information on the system IP address in the section Configuration process (Page 136) and in the Communication (https://support.industry.siemens.com/cs/ww/de/view/59192925/en) function manual.

More information on how to set up an HMI connection to the S7-1500R/H redundant system is available in the Communication (https://support.industry.siemens.com/cs/ww/de/view/59192925/en) function manual.

Installation

4

4.1 Basics

Installation site

All modules of the S7-1500R/H redundant system are unenclosed equipment. You may only install unenclosed equipment in housings, cabinets or electrical operating rooms. The housings, cabinets and electrical operating rooms must guarantee protection against electric shock and spread of fire. The requirements for mechanical strength must also be met. The housings, cabinets, and electrical operating rooms must not be accessible without a key or tool. Personnel with access must have been trained or authorized.

Installation position

The S7-1500R/H redundant system is designed for use in the following mounting positions:

- Horizontal mounting position up to 60° C

- Vertical mounting position up to 40° C

Additional information can be found in the section Mechanical and climatic environmental conditions.

Mounting rail

You can mount the following components on the mounting rails alongside the S7-1500R/H CPUs, load and system power supplies:

- Terminals

- Circuit breakers

- Small contactors

- Similar components

These components can influence the installation dimensions for the cable duct.

Modules can be mounted right to the outer edge of the mounting rail.

The mounting rails are available in various lengths. You order the mounting rails using the online catalog or the online ordering system. The available lengths and article numbers can be found in the appendix Accessories/spare parts (Page 305).

Minimum clearances

Modules can be mounted right to the outer edge of the mounting rail. Maintain the following minimum clearances when installing or dismantling the S7-1500R/H redundant system.
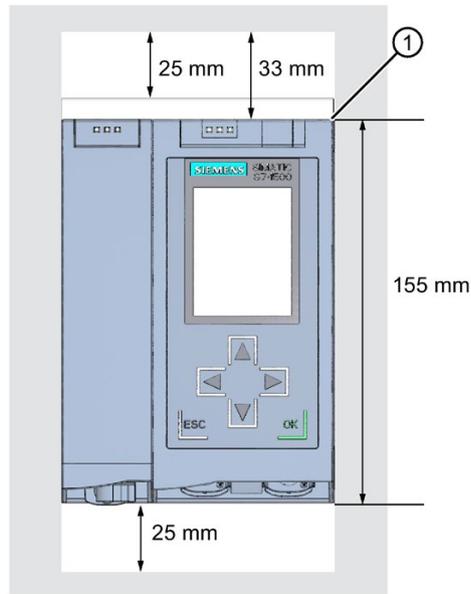
①   Upper edge of the mounting rail

Figure 4-1   Minimum clearances in the control cabinet

Installation rules

The redundant system configuration consists of:

R/H-CPU and an optional load or system power supply.

> ⚠️ **WARNING**
>
> **Protection from conductive contamination**
>
> Taking into consideration the ambient conditions, the devices must be protected from conductive contamination.
>
> Protection from conductive contamination can, for example, be achieved by installing the devices in a control cabinet with the appropriate degree of protection.

4.2   Installing the mounting rail

Introduction

The R/H-CPUs should be mounted either on one mounting rail or on two separate mounting rails.

Lengths and drill holes

The mounting rails are delivered in six lengths:

- 160 mm

- 245 mm

- 482.6 mm (19 inches)

- 530 mm

- 830 mm

- 2000 mm

You can find the article numbers in the appendix Accessories/spare parts (Page 305).

The mounting rails (from 160 to 830 mm) come with two drill holes for fixing screws. A set of screws for grounding the mounting rail is provided.

The 2000 mm mounting rail is designed for assemblies with special lengths and does not have holes for fixing screws. No set of screws for grounding is included with the mounting rail (can be ordered as accessories/spare parts (Page 305)).

The specifications of the maximum offsets between two drill holes can be found in the table, "Dimensions for the drill holes".

Tools required

- Commercially available hacksaw

- Drill ⌀ 6.5 mm

- Screwdriver

- Size 10 adjustable screw-wrench or socket wrench for grounding cable connection

- Adjustable screw-wrench, matching the selected fixing screws

- Stripping tool and crimp tool for the grounding cable

Accessories required

Use the following screw types for fastening the mounting rails:

Table 4- 1 Accessories required

For ...	use ...	Explanation
• Outer fixing screws • Additional fixing screws (for mounting rails > 482.6 mm)	M6 fillister head screws according to ISO 1207/ISO 1580 (DIN 84/DIN 85)	Choose a suitable screw length for your assembly.
	M6 hexagon head screws according to ISO 4017 (DIN 4017)	You also need washers for cylinder head screws with an internal diameter of 6.4 mm and an external diameter of 11 mm in accordance with ISO 7092 (DIN 433).

Dimensions for the drill holes

Table 4- 2 Dimensions for the drill holes

"Standard" mounting rails			"Longer" mounting rails

Length of the mounting rail	Distance a	Distance b
160 mm	10 mm	140 mm
245 mm	10 mm	225 mm
482.6 mm	8.3 mm	466 mm
530 mm	15 mm	500 mm
830 mm	15 mm	800 mm

Additional fixing screws (for mounting rails > 530 mm)

For mounting rails > 530 mm, we recommend using additional fixing screws at intervals of ≤ 500 mm on the identification groove.

Preparing the 2000 mm mounting rail for installation

Proceed as follows to prepare the 2000 mm mounting rail for installation:

1. Cut the 2000 mm mounting rail to the required length.

2. Mark the holes. The necessary dimensions can be found in the table "Dimensions for the drill holes":

   – Two drill holes at the beginning and end of the mounting rail

   – Additional drill holes at equal intervals of 500 mm maximum, along the identification groove

3. Drill the marked holes according to the selected type of fastening.

4. Ensure that there are no burrs or shavings on the mounting rail.

Note

To ensure secure installation of the modules, make sure that the drill holes are centered in the identification groove. Only use the maximum size of screws.

---
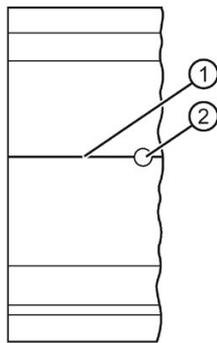
①   Identification groove for additional drill holes
②   Additional drill hole

Figure 4-2   Preparing the 2000 mm mounting rail for installation

Installing the mounting rail

Install the mounting rails for the R/H-CPUs so that there is still sufficient space for installation and heat dissipation. Please study the figure Minimum clearances in the control cabinet (Page 97).

Screw the rail onto the mounting surface.

Attaching the protective conductor

The mounting rails of the S7-1500R/H redundant system must be connected to the protective conductor system of the electrical system to ensure electrical safety.

Proceed as follows to connect the protective conductor:

1. Strip the grounding conductor with a minimum diameter of 10 mm². Attach a ring terminal for M6 bolts with the crimping pliers.

2. Slide the enclosed bolt into the T profile groove.

3. Insert the spacer, ring terminal with the grounding connector, flat washer, and lock washer onto the bolt (in that order). Thread on the hexagon nut. Fasten the components in place with the nut (torque 4 Nm).

4. Connect the opposite end of the grounding cable to the central grounding point/protective conductor busbar (PE).

5. If you mount the redundant system on separate mounting rails, repeat steps 1 to 4 for the second mounting rail.

T-profile groove
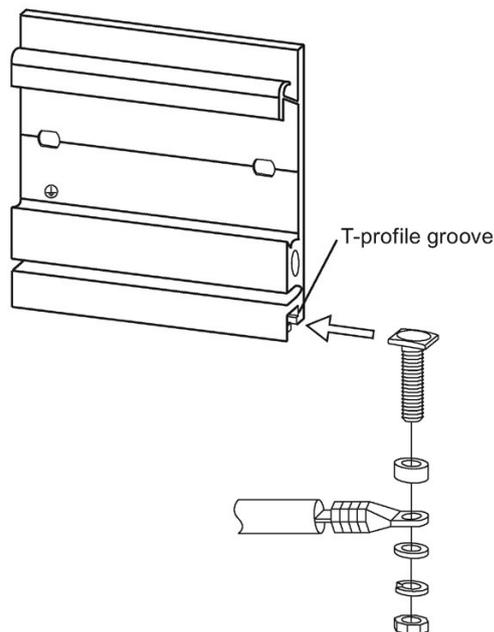
Figure 4-3   Attaching the protective conductor

Note

Alternative grounding of the mounting rails

Grounding with the grounding screw is not required if the following requirements are met:

The mounting rails must be permanently connected to the protective conductor system using an equivalent fitting that complies with the applicable standards, for example by permanent attachment to a grounded control cabinet wall.

Reference

You can find more information on the exact dimensions of the mounting rails in the appendix Dimension drawings (Page 302).

4.3 Installing a load current supply

Introduction

Load power supplies do not have a connection to the backplane bus of the S7-1500R/H redundant system and do not occupy a slot on the backplane bus. The load power supply supplies the system power supply and optionally the R/H-CPU with 24 V DC.

Requirements

The mounting rail is installed.

Tools required

Screwdriver with 4.5 mm blade

Installing a load current supply

Watch the video sequence (http://www.automation.siemens.com/salesmaterial-as/interactive-manuals/getting-started_simatic-s7-1500/videos/EN/mount/start.html)

To install a load current supply, follow these steps:

1. Hook the load current supply on the mounting rail.

2. Swivel the load current supply to the rear.
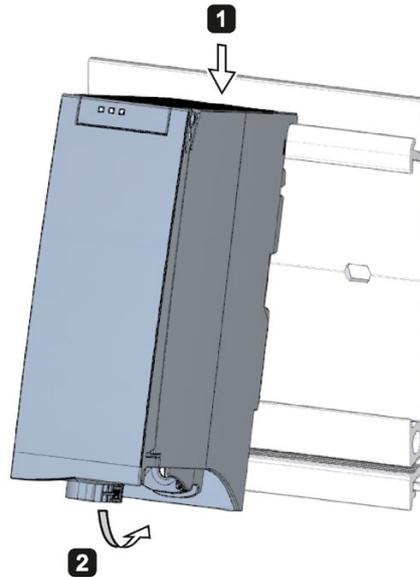
Figure 4-4   Installing a load current supply

3. Open the front cover.

4. Disconnect the power cable connector from the load current supply.

5. Screw the load power supply tight (torque 1.5 Nm).

6. Insert the already wired-up power cable connector into the load current supply.

For a description of how to wire the power cable connector, please see section Wiring the system power supply and load power supply (Page 117).

Note

Load power supplies can only be mounted on the left or right side outside the S7-1500R/H redundant system. If you mount a load current supply on the right of the configured setup, the heat development of the load current supply may make a gap to the configured setup necessary. For additional information, refer to the relevant manuals. The number of load current supplies that can be used is unlimited.

Uninstalling the load current supply

The load current supply is wired up.

To uninstall a load current supply, follow these steps:

1. Open the front cover.

2. Shut down the load current supply.

3. Turn off the supply voltage.

4. Disconnect the power cable connector, and remove the connector from the load current supply.

5. Unscrew the fixing screw.

6. Swivel the load current supply out of the mounting rail.

Reference

Additional information can be found in the manuals for the load current supplies.

4.4 Installing a system power supply

Introduction

The system power supply has a connection to the backplane bus and supplies the connected modules with the internal supply voltage.

Requirements

The mounting rail is installed.

Tools required

Screwdriver with 4.5 mm blade

Installing a system power supply

To install the system power supply, follow these steps:

1. Insert the U-connector into the back of the system power supply.

2. Hang the system power supply on the mounting rail.

3. Swivel the system power supply to the rear.
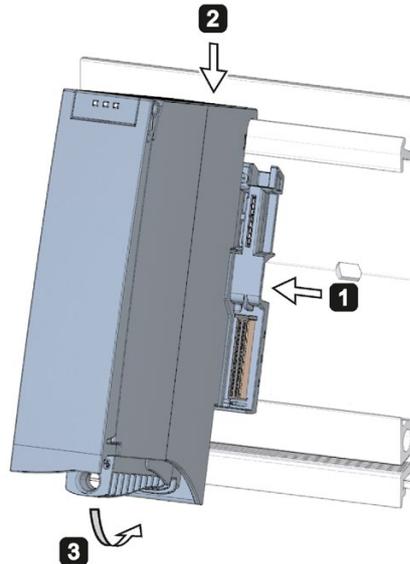
Figure 4-5   Installing a system power supply

4. Open the front cover.

5. Disconnect the power cable connector from the system power supply.

6. Screw the system power supply tight (torque 1.5 Nm).

7. Insert the already wired-up power cable connector into the system power supply.

Information on wiring the power cable connector is available in the section Wiring the system power supply and load power supply (Page 117).

Uninstalling a system power supply

The system power supply is wired up.

To uninstall the system power supply, follow these steps:

1. Open the front cover.

2. Shut down the system power supply.

3. Turn off the supply voltage.

4. Disconnect the power cable connector, and remove the connector from the system power supply.

5. Unscrew the fixing screw.

6. Swivel the system power supply out of the mounting rail.

Reference

Additional information can be found in the manuals for the system power supplies.

4.5 Installing R/H-CPUs

Introduction

CPUs in the S7-1500R/H redundant system are installed in exactly the same way as CPUs in the S7-1500 automation system.

Requirements

The mounting rail is installed.

Note

Protective film

Please note that the R/H-CPUs come with a removable protective film on the display.

Tools required

Screwdriver with 4.5 mm blade

Installing R/H-CPUs

Watch the video sequence (http://www.automation.siemens.com/salesmaterial-as/interactive-manuals/getting-started_simatic-s7-1500/videos/EN/mount/start.html)

Proceed as follows to install an R/H-CPU:

1. Install the CPU to the mounting rail.
   Only with optional load or system power supply Move the CPU to the load or system power supply on the left. Ensure that the U-connector is inserted at the system power supply.
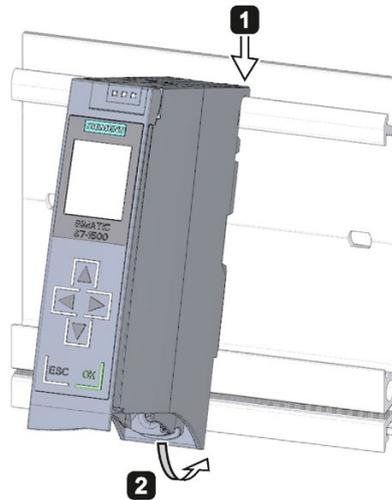
2. Swivel the CPU in to the rear.

3. Screw the CPU tight (torque 1.5 Nm).

Uninstalling R/H-CPU

The R/H-CPU is wired.

Proceed as follows to uninstall an R/H-CPU:

1. Open the front cover.

2. Switch the CPU into STOP mode.

3. Turn off the supply voltage.

4. Pull off the connector for the supply voltage.

5. Disconnect the cables at the CPU:
   - R-CPU: Disconnect the PROFINET cables.
   - H-CPU: Disconnect the PROFINET cables and fiber-optic cables.

6. Undo the CPU fixing screw(s).

7. Pivot the CPU out of the mounting rail.

Wiring $\qquad$ 5

5.1 Rules and regulations for operation

Introduction

The S7-1500R/H redundant system is a plant and system component. Special rules and regulations must be adhered to in line with the area of application.

This section gives an overview of the key rules for integration of the redundant system into a plant or system. Please follow these rules when connecting the S7-1500R/H redundant system.

Specific application

Observe the safety and accident prevention regulations that are applicable to specific applications (for example Machinery Directive).

EMERGENCY-STOP devices

EMERGENCY OFF equipment to IEC 60204 (corresponds to DIN VDE 0113) must remain effective in all operating modes of the plant or system.

Excluding hazardous plant states

Hazardous operating states must not occur in the following situations:

- The plant restarts after a voltage dip or power failure.
- Bus communication is reestablished following a fault.
- An undefined system state occurs in the S7-1500R/H. Example: Failure of both redundancy connections ≤ 1500 ms apart.

If a hazardous operating state occurs, force an EMERGENCY STOP.

An uncontrolled or undefined redundant system startup must not occur after the EMERGENCY STOP device is unlocked.

Line voltage

The points to note for line voltage are set out below:

- For fixed plants or systems without multipole circuit breaker, a mains disconnection device (multipole) must be available in the building installation.
- For the load power supply, the configured rated voltage range must correspond to the local line voltage.
- For all power circuits of the S7-1500R/H redundant system, the fluctuation/deviation of the line voltage from the rated value must be within the permitted tolerance.

You can find more information in the section Specifications for insulation tests, protection class, degree of protection, and rated voltage (Page 300).

24 V DC supply

The points to note for a 24 V DC supply are set out below:

- Power supply units for the 24 V DC supply must supply safety extra low voltage in accordance with IEC 61131-2 or IEC 61010-2-201.
- To protect the S7-1500R/H redundant system from lightning and overvoltages, use overvoltage arresters.

   Suitable components for the lightning and overvoltage protection are specified in the Defining interference-free controllers (http://support.automation.siemens.com/WW/view/en/59193566) function manual.

Protection against electrical shock

The mounting rails of the S7-1500R/H redundant system must be connected conductively to the protective conductor to protect against electric shock.

Protection against external electrical influences

The following describes what you must pay attention to in terms of protection against electrical influences and/or faults:

- The system for discharging electromagnetic interference must be connected to a protective conductor with a sufficient cross-section for all plants with an S7-1500R/H redundant system.
- You must ensure that all supply, signal and bus cables are correctly laid and installed.
- For signal and bus lines, a cable break, wire break or a cross-circuit must not lead to undefined states in the plant or system.

Protection of redundancy connections against unauthorized access

Protect the redundant connections in a redundant S7-1500H system so that the fiber-optic cables are protected against unauthorized access, e.g. by spatial access protection.

Reference

Additional information can be found in the function manual, Designing interference-free controllers (http://support.automation.siemens.com/WW/view/en/59193566).

5.2 Operation on grounded infeed

Introduction

Information is provided below on the overall configuration of an S7-1500R/H redundant system on a grounded incoming supply (TN-S network). The specific subjects discussed are:

- Shut-off devices, short circuit and overload protection in accordance with
  - IEC 60364, corresponds to DIN VDE 0100
  - IEC 60204, corresponds to DIN VDE 0113
- Load current supplies and load circuits

Grounded infeed

In the case of grounding incoming supplies (TN-S system) the neutral conductor (N) and the protective conductor (PE) are each grounded. Both wires form a part of the overvoltage concept. When a plant is in operation, the current flows across the neutral conductor. When a fault occurs, for example a single ground fault between a live conductor and ground, the current flows through the protective conductor.

Safe electrical isolation (SELV in accordance with IEC 61131-2 or IEC 61010-2-201)

Load power supplies/system power supplies with a 24 V DC output voltage require safe electrical isolation and a voltage limit (extra low voltage). Load power supplies/system power supplies with a 24 V DC output voltage are not connected to the protective conductor. In accordance with IEC 61131-2 / IEC 61010-2-201, this protection is referred to as SELV (Safety Extra Low Voltage).

Either the wiring of SELV circuits must be isolated from the wiring of other circuits that are not SELV, or the insulation of all wires must be dimensioned for the higher voltage.

Protective extra-low voltage (PELV in accordance with IEC 61131-2 or IEC 61010-2-201)

Load power supplies/system power supplies with a protective 24 V DC output voltage require a safe connection to the protective conductor and a voltage limit (extra low voltage). In accordance with IEC 61131-2 / IEC 61010-2-201, this protection is referred to as PELV (Protective Extra Low Voltage).

Either the wiring of PELV circuits must be isolated from the wiring of other circuits that are not PELV, or the insulation of all wires must be dimensioned for the higher voltage.

Reference potential of the controller

The reference potential of the S7-1500R/H redundant system is connected to the mounting rail over a high-resistance RC combination in the R/H-CPU. This connection conducts high-frequency interference currents and prevents electrostatic charges. Despite the grounded mounting rail, the reference potential of the S7-1500R/H redundant system has to be considered as ungrounded due to the high-resistance connection.

If you want to configure the S7-1500R/H redundant system with a grounded reference potential, establish an electrical connection between the M connection of the CPU and the protective conductor.

You can find a simplified representation of the potentials in the section Electrical configuration (Page 113).

Short-circuit and overload protection

Various measures as protection against short-circuits and overloads are required for setting up a full installation. The nature of the components and the degree to which the required measures are binding depends on the IEC (DIN VDE) regulation applicable to your plant configuration. The table refers to the following figure and compares the IEC (DIN VDE) regulations.

Table 5- 1   Components and required measures

	Reference to following figure	IEC 60364 (DIN VDE 0100)	IEC 60204 (DIN VDE 0113)
Shut-off device for control system, sensors, and actuators	①	Main switch	Disconnector
Short-circuit and overload protection: In groups for sensors and actuators	② ③	Single-pole protection of circuits	• With grounded secondary circuit: **Single-pole** protection • Otherwise: **All-pole** protection
Load power supply for AC load circuits with more than five items of electromagnetic equipment	④	Galvanic isolation by transformer **recommended**	Galvanic isolation by transformer **recommended**

Overall configuration of S7-1500R/H

The figure below shows the overall configuration of the S7-1500R/H redundant system (load power supply and grounding concept) with supply from a TN-S network.

①	Main switch
②	Short-circuit and overload protection on the primary side
③	Short-circuit and overload protection on the secondary side
④	The load current supply (galvanic isolation)
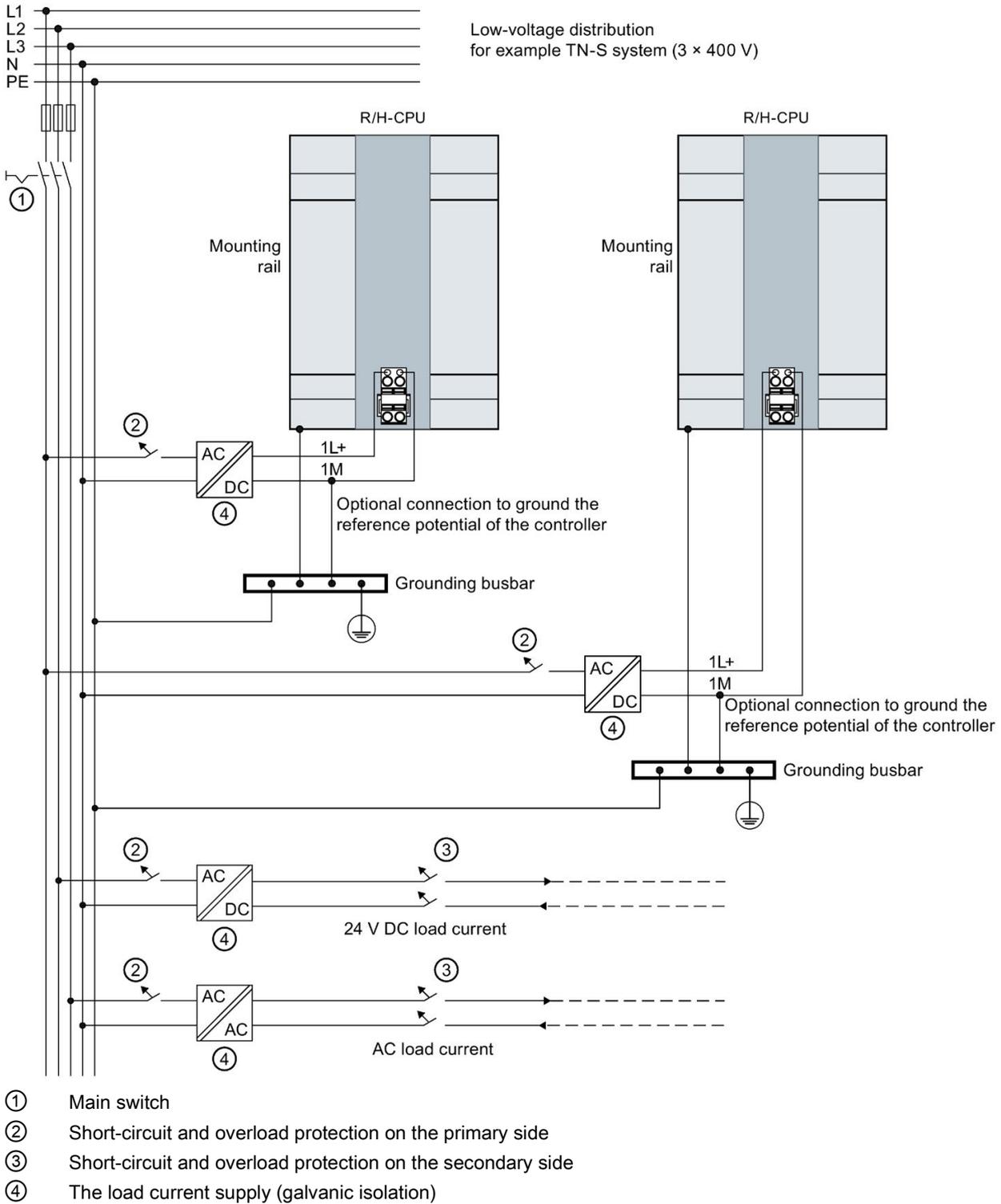
Figure 5-1   Operating the S7-1500R/H with grounded reference potential

5.3 Electrical configuration

Galvanic isolation

In the redundant System S7-1500R/H, there is electrical isolation between:

- The communication interfaces (PROFINET) of the R-CPU and all other circuit components
- The communication interfaces (PROFINET) of the H-CPU and all other circuit components

High-frequency interference currents are conducted and electrostatic charges are avoided through integrated RC combinations or integrated capacitors.

S7-1500R/H potentials

The figure below is a simplified diagram of potentials in the S7-1500R/H redundant system.
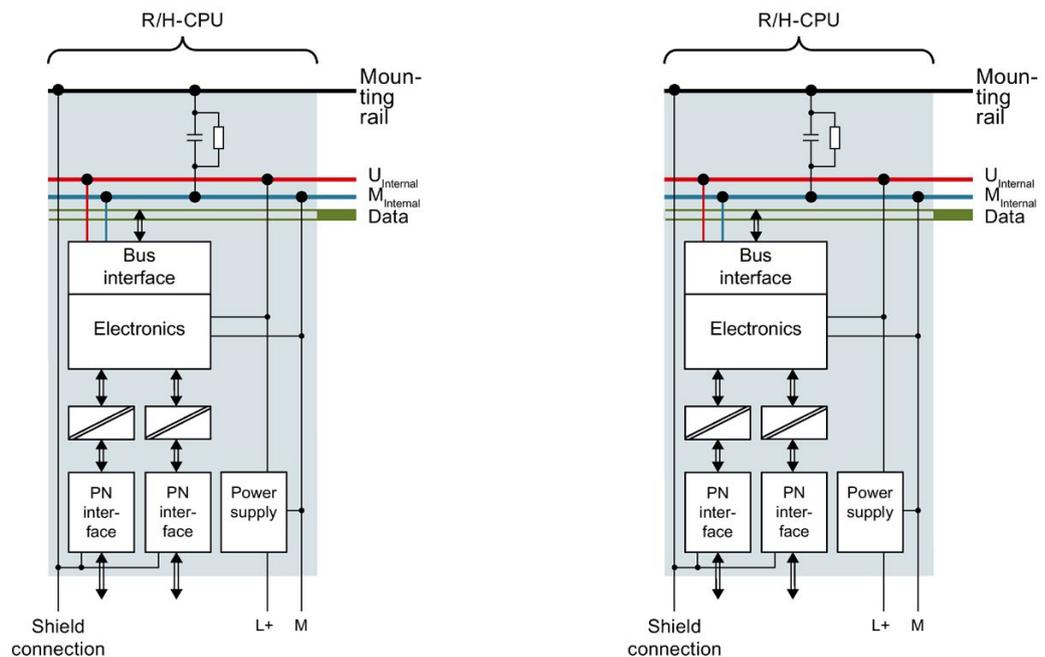
Figure 5-2   Potentials in S7-1500R/H using the example of CPU 1515R-2 PN

5.4 Wiring rules

Introduction

Use suitable cables to connect the S7-1500R/H redundant system. The tables below set out the wiring rules for the R/H-CPUs, system power supply, and load power supply.

R/H-CPUs, system power supply and load power supply

Table 5- 2   Wiring rules for R/H-CPUs, system power supply and load power supply

Wiring rules for ...		R/H-CPU	System power and load current supply
Permitted cable cross-sections of solid cables (Cu)		-	-
		-	-
Permitted cable cross-sections of flexible cables (Cu)	Without wire end sleeve	0.25 to 2.5 mm^2	0.5 to 2.5 mm^2
		AWG[1]: 24 to 14	AWG[1]: 20 to 14
	With end sleeve	0.25 to 1.5 mm^2	0.5 to 1.5 mm^2
		AWG[1]: 24 to 16	AWG[1]: 20 to 16
Number of wires per connection		1	1
Stripped length of the wires		10 to 11 mm	7 to 8 mm
End sleeves according to DIN 46228	without plastic sleeve	Design A, 10 mm long	Design A, 7 mm long
	with plastic sleeve 0.25 to 1.5 mm^2	Design E, 10 mm long	Design A, 7 mm long
Sheath diameter		-	8.5 mm
Tool		3 to 3.5 mm screwdriver, conic design	3 to 3.5 mm screwdriver, conic design
Connection system		Push-in terminal	Screw terminal
Tightening torque		-	from 0.5 Nm to 0.6 Nm

[1]   American Wire Gauge

Permissible cable temperature

> **Note**
>
> **Permissible cable temperatures**
>
> You must select sufficiently large wire cross-sections to ensure that the permissible cable temperatures are not exceeded at the maximum ambient temperature of the redundant system S7-1500R/H.
>
> Example of power supply
>
> At an ambient temperature of 40° C, a current of, for example, 4 A per wire and a cross-section of 1.5 mm² Cu, a connecting conductor must be rated for a temperature range of at least 70° C.

5.5   Connecting the supply voltage

Introduction

The supply voltage is supplied over a 4-pin connector at the front of the R/H-CPU (behind the front flap, below).

Connection for supply voltage (X80)

The connections of the 4-pole connector have the following meaning:
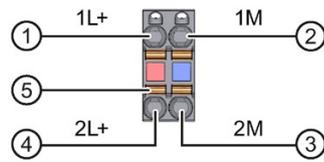
①   + 24 V DC of the supply voltage
②   Mass of the supply voltage
③   Mass of the supply voltage for looping (current limited to 10 A)
④   + 24 V DC of the supply voltage for looping (current limited to 10 A)
⑤   Spring opener (one spring opener per terminal)

Figure 5-3   Connection for supply voltage

The cable connector enables you to loop the supply voltage uninterrupted, even when it is unplugged.

Requirements

- Only wire the connection plug when the supply voltage is turned off.
- Follow the wiring rules (Page 114).

Tool-free connection of cables: multi-wire (stranded), with end sleeve or ultrasonic compressed

To connect a wire without tools, follow these steps:

1. Strip 8 to 11 mm of the wires.
2. Seal or crimp the wire with end sleeves.
3. Insert the cable into the push-in terminal as far as it will go.
4. Push the wired connector into the socket of the CPU.

Tools required

3 to 3.5 mm screwdriver

Connection of wires: multi-wire (stranded), without end sleeve, unprocessed

To connect a wire without end sleeve, follow these steps:

1. Strip 8 to 11 mm of the wires.

2. Press the screwdriver into the spring release. Insert the cable into the push-in terminal as far as it will go.

3. Pull the screwdriver out of the spring release.

4. Push the wired connector into the socket of the CPU.

Loosening a wire

To unplug a wire, follow these steps:

1. Push with the screwdriver as far as it will go into the spring release.

2. Remove the wire from the push-in terminal.

Uninstalling the connection plug

With the screwdriver, pry the connector out of the CPU.

5.6 Connecting system power supply and load current supply

Introduction

In the delivery condition of the system power supplies/load current supplies, power connectors are inserted. The modules and the associated power connectors are coded. There are two parts to the coding element. One coding element is located in the module, and the other in the power connector. The system power supplies/load current supplies use identical power connectors for the voltage connection.

The coding element prevents the insertion of a power connector into a different type of system power supply/load current supply.

Tools required

3 to 3.5 mm screwdriver

Connecting the supply voltage to a system power supply/load current supply

Watch the video sequence (https://support.industry.siemens.com/cs/media/67462859_connecting_supply_web_en/start.htm)

To connect the supply voltage, follow these steps:

1. Swing the front cover of the module up until the front cover latches.

2. Press down the unlocking button of the power cable connector (Figure 1). Remove the power cable connector from the front of the module.

3. Loosen the screw on the front of the connector. This loosens the housing latch and the cable relief. With a tightened screw the connector's cover can't be removed (Figure 2).

4. Pry off the connector cover using a suitable tool (Figure 3).
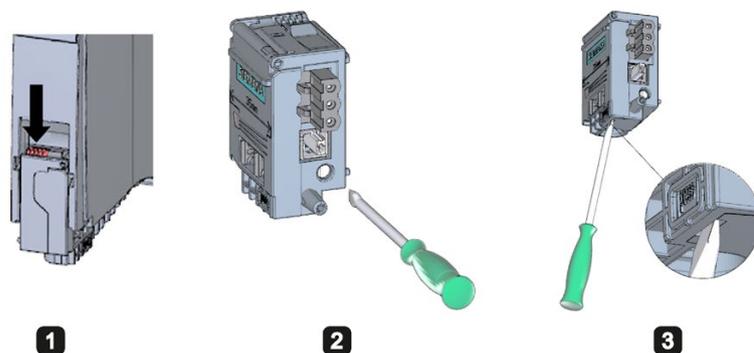
Figure 5-4   Connecting the supply voltage to a system power supply/load current supply (1)

5. Strip the cable sheathing to a length of 35 mm. Strip the wires to a length of 7 to 8 mm. Attach the end sleeves.

6. Connect the wires in the connector according to the connection diagram (Figure 4).

7. Close the cover (Figure 5).

8. Retighten the screw (Figure 6). This effects a strain relief on the lines.
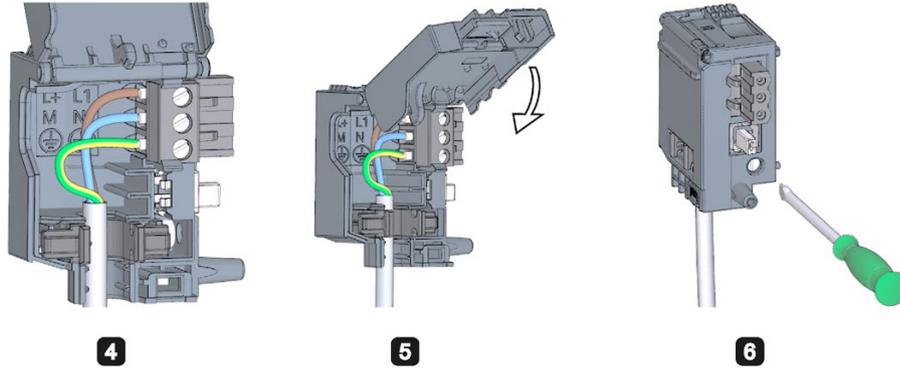
Figure 5-5   Connecting the supply voltage to a system power supply/load current supply (2)

9. Insert the power connector into the module, until the latch engages.

Reference

You can find more information on connecting the 24 V DC output voltage of the load power supply in the manuals for the relevant modules.

5.7   Connecting the CPU to the load power supply

Introduction

The load power supply is fitted with a plug-in 24 V DC output terminal (behind the front cover at the bottom). You connect the cables for the supply voltage to the CPU at this terminal.

Requirements

- Only wire the connection plug when the supply voltage is turned off.

- The connector for connecting the supply voltage to the CPU is already fitted. You can find more information in the section Connecting the supply voltage (Page 115).

Tools required

3 to 3.5 mm screwdriver

Connecting the CPU to a load power supply

Watch the video sequence
(https://support.industry.siemens.com/cs/media/78027451_S7_1500_gs_wire_web_en/start.htm)

To connect the supply voltage, follow these steps:

1. Open the front cover of the load power supply. Pull the 24 V DC output terminal down and off.

2. Wire the 24 V DC output terminal to the wires of the CPU 4-pin connector.
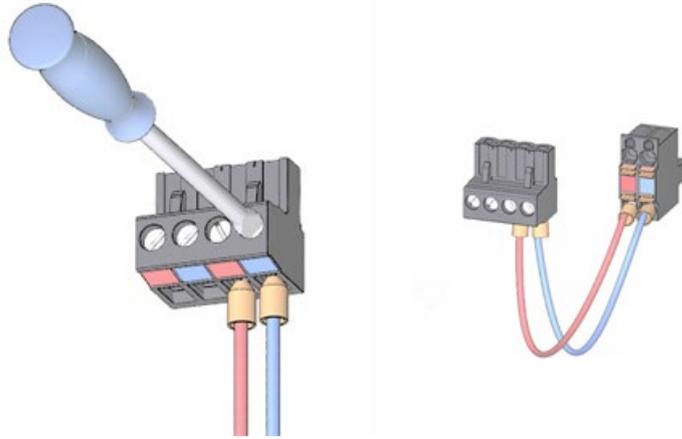
3. Connect the load power supply to the CPU.
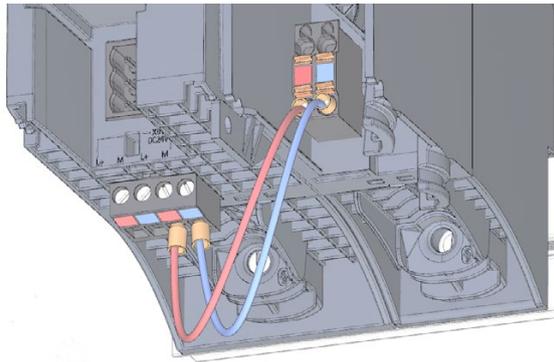
5.8 Connecting interfaces for communication with S7-1500R

Connecting interfaces for communication

Connect the communication interfaces of the CPUs using standardized plug connectors.

Use prefabricated connecting cables for the connection. If you want to prepare communication cables yourself, the interface assignment is specified in the CPU manuals. Observe the mounting instructions for the connectors.

5.8.1 Connecting the PROFINET ring to S7-1500

Introduction

You connect the PROFINET ring between the two R-CPUs at the RJ45 sockets of PROFINET interfaces X1 P1 R and X1 P2 R.

Requirements

- One of the two connections of the PROFINET ring between the two R-CPUs must not contain any other IO devices, switches or other PROFINET devices apart from transparent media converters.
  The default setting in STEP 7 is port 2 at PROFINET interface X1. Connect the PROFINET cable to the ports of the PROFINET interfaces of the two R-CPUs. The maximum length of the PROFINET cable is 100 m.
  You can increase the distance between the two R-CPUs with an (electrical/optical) media converter. In this case, the maximum length depends on the type of media converter used.
  You can find more information on the technical specifications, use and commissioning of the media converter in the relevant documentation.

- You connect the IO devices, switches and other PROFINET devices to the other PROFINET ring connection. The default setting in STEP 7 is port 1 at PROFINET interface X1.

Accessories required

- PROFINET cable for the PROFINET ring
- Optional transparent media converter (electrical ⇔ optical)

Procedure

To connect the PROFINET ring at SIMATIC S7-1500R, follow these steps:

1. Plug the PROFINET cable RJ45 connectors into the RJ45 sockets at PROFINET interfaces X1 P2 R on the two R-CPUs.

Figure 5-6   PROFINET interface X1 P2 R: Connecting R-CPUs (bottom view)

2. Plug the PROFINET cable RJ45 connectors into the RJ45 sockets at PROFINET interfaces X1 P1 R on the two R-CPUs. Connect the other PROFINET devices in the PROFINET ring.
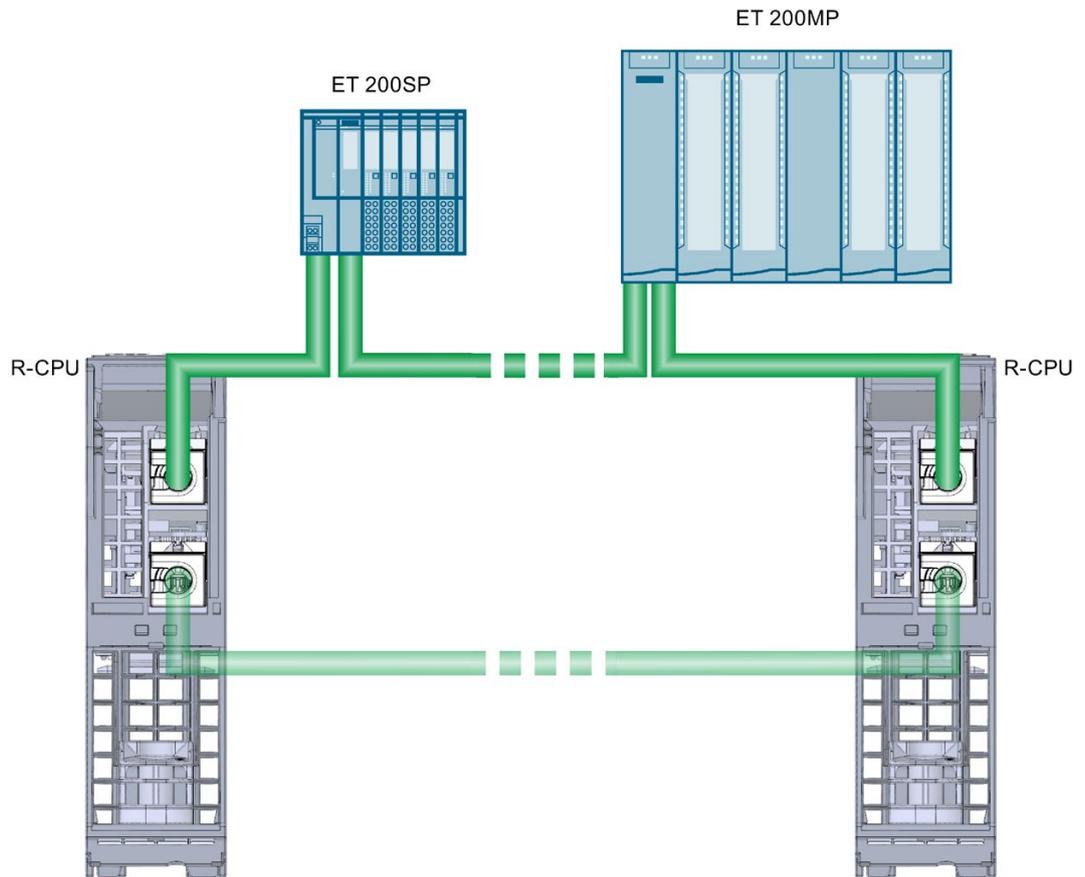
Figure 5-7   PROFINET interface X1 P1 R: Connecting PROFINET devices to S7-1500R (bottom view)

5.9 Connecting interfaces for communication with S7-1500H

Connecting interfaces for communication

Connect the communication interfaces of the CPUs using standardized plug connectors.

Use prefabricated connecting cables for the connection. If you want to prepare communication cables yourself, the interface assignment is specified in the CPU manuals. Observe the mounting instructions for the connectors.

5.9.1 Connecting redundancy connections (fiber-optic cables)

5.9.1.1 Synchronization modules for S7-1500H

Introduction

You use the synchronization modules to create two redundancy connections between the two H-CPUs. You need two identical synchronization modules per CPU which you connect with fiber-optic cables.

View
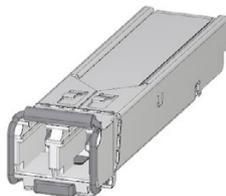
Figure 5-8   Synchronization module

Maximum distance between the two H-CPUs

In the S7-1500H redundant system, you need to use four synchronization modules of the same type. You can order the following types of synchronization modules:

Maximum distance between the two H-CPUs	Article number
10 m	6ES7960-1CB00-0AA5
10 km	6ES7960-1FB00-0AA5

Note

With long synchronization cables, the limited speed of light in the cable extends the cycle time (delay of ca. 100 µs for 10 km).

5.9.1.2 Selecting fiber-optic cables

Introduction

You need to consider the following constraints and factors when selecting fiber-optic cables:

- What length of cable do I need?
- Is the fiber-optic cable to be laid indoors or outdoors?
- Is special protection from mechanical stress required?
- Is special protection from rodents required?
- Does the outside cable need to be direct-buried?
- Does the fiber-optic cable need to be watertight?
- To what temperatures will the fiber-optic cable be exposed once laid?

Rules

Observe the following rules:

- If you use fiber-optic cables, ensure sufficient strain relief at the synchronization modules.
- Adhere to the specified ambient conditions for the fiber-optic cables used (bend radii, pressure and temperature).
- Comply with the technical specifications for the fiber-optic cables used (attenuation, bandwidth).

Cables up to 10 m

6ES7960–1CB00–0AA5 synchronization modules are operated in pairs with fiber-optic cables of up to 10 m.

Select the following specifications with cable lengths of up to 10 m:

- 50/125 µ or 62.5/125 µ multimode fiber
- Patch cable for indoor use
- 2 x duplex cables per S7-1500H, crossover
- LC-LC connector type

The following cables are available as accessories for S7-1500H:

Table 5- 3   Fiber-optic cables as accessories

Length	Article number
1 m	6ES7960–1BB00–5AA5
2 m	6ES7960–1BC00–5AA5
10 m	6ES7960–1CB00–5AA5

Cables up to 10 km

6ES7960-1FB00-0AA5 synchronization modules are operated in pairs with fiber-optic cables of up to 10 km.

For cables over 10 m, you will need to have the fiber-optic cables custom-made. Select the following specifications:

- Single-mode fiber 9/125 µ

  In exceptional cases, you can use the cables available as accessories in lengths of up to 10 m for commissioning and testing purposes. For permanent use, however, you must use the cables specified in the table below with single-mode fibers.

Please see the following tables for the other specifications applicable to your specific application.

Table 5- 4   Specifications for fiber-optic cables used indoors

Cabling	Necessary components	Specifications
Complete cabling routed within a building. • No cable junction between indoors and outdoors. • Required cable length is available as one complete length. No distribution boxes required. • Easy complete installation with pre-assembled cables.	Patch cable	2 x duplex cables for the redundant system: • LC-LC connector type • Crossover cable See also all other specifications applicable to your plant, for example: • UL approval • Halogen-free
	Installation cable	4-core multicore cables for the redundant system: • LC-LC connector type • Crossover cable See also all other specifications applicable to your plant, for example: • UL approval • Halogen-free
	Installation cable for indoor use	1 cable with 4 cores for the redundant system: • Both interfaces in one cable 1 or 2 cables with multiple shared cores for the redundant system: • Interfaces laid separately to increase availability (reduction of common cause factor) • Connector type ST or SC, for example, in line with the other components See also other specifications applicable to your plant: • UL approval • Halogen-free Avoid splicing cables in the field. Use the pre-assembled cables with pulling protection/aids in whiplash or breakout design, including measuring log.
	Patch cable for indoors	Connector type LC on ST or SC, for example, in line with the other components.

Cabling	Necessary components	Specifications
Installation through distribution boxes. Additional information can be found in the section below.	• One distribution box/junction box for each branch. • Connecting the installation and patch cables via the distribution box. Use either ST or SC plug-in connectors.	Connector type ST or SC, in line with the other components.

Table 5- 5   Specifications for fiber-optic cables used outdoors

Cabling	Necessary components	Specifications

A cable junction is required between the indoor and outdoor area.
Additional information can be found in the section below.
	Installation cable for outdoor use	Installation cable for outdoor use:
		• 1 cable with 4 cores per S7-1500H system
		   Both interfaces in one cable
		• 1 or 2 cables with multiple shared cores
		   Interfaces laid separately to increase availability (reduction of common cause factor)
		• Connector type ST or SC, for example, in line with the other components
		See also other specifications applicable to your plant:
		• UL approval
		• Halogen-free
		See also other specifications for given local conditions:
		• Protection from increased mechanical stress
		• Protection from rodents
		• Protection from water
		• Suitable for direct burial
		• Suitable for the relevant temperature ranges
		Avoid splicing cables in the field.
		Use the pre-assembled cables with pulling protection/pulling aids in whiplash design, including measuring log.

Cabling	Necessary components	Specifications
	Installation cable for indoor use also	• 1 cable with 4 cores per S7-1500H system Both interfaces in one cable • 1 or 2 cables with multiple shared cores Interfaces laid separately to increase availability (reduction of common cause factor) • Connector type ST or SC, for example, in line with the other components See also other specifications applicable to your plant: • UL approval • Halogen-free Avoid splicing cables in the field. Use the pre-assembled cables with pulling protection/aids in whiplash or breakout design, including measuring log.
	Patch cable for indoors	Connector type LC on ST or SC, for example, in line with the other components.
Installation through distribution boxes A cable junction is required between the indoor and outdoor area. Additional information can be found in the section below.	• One distribution box/junction box for each branch. • Connecting the installation and patch cables via the distribution box. Use either ST or SC plug-in connectors.	Connector type ST or SC, for example, in line with the other components.

Installation of fiber-optic cable through distribution boxes
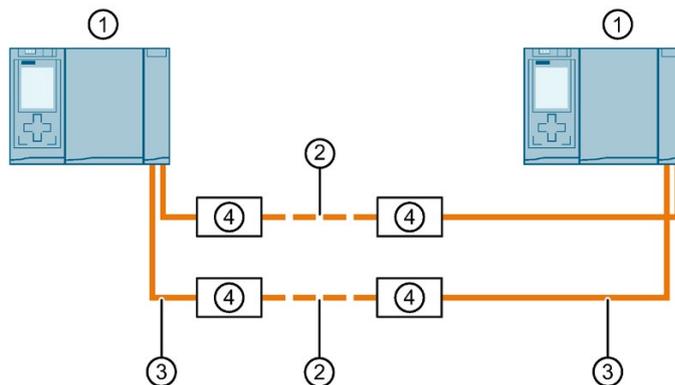
① H-CPU (CPU 1517H-3 PN)

② Additional distribution boxes, if necessary, for example with SC or ST couplers. This allows you to combine individual sections to achieve the required total length (maximum of 10 km) of fiber-optic cable.

③ Patch cable (duplex), for example LC-SC/ST

④ Distribution box, for example with SC or ST couplers

Figure 5-9   Fiber-optic cables, installation through distribution boxes

5.9.1.3 Installing fiber-optic cables

Introduction

Fiber-optic cables may only be laid by trained specialist personnel. Comply with all applicable regulations and statutory requirements.

In practice, the installation of fiber-optic cables represents the most common cause of errors and failures. These can be caused by:

- Kinks in the fiber-optic cable due to an insufficient bending radius
- Crushing as a result of excessive force caused by persons treading on the cable, by pinching, or by other heavy cables
- Overstretching due to high tensile forces
- Damage caused by sharp edges

Quality assurance on site

Check the following points before laying the fiber-optic cables:

- Has the correct fiber-optic cable been delivered?
- Is there any visible transport damage to the product?
- Have you organized suitable intermediate on-site storage for the fiber-optic cables?
- Does the category of cable match that of the connecting components?

Storage of fiber-optic cables

Store fiber-optic cables in a place where they are protected from mechanical and thermal factors.

Observe the permitted storage temperatures. These are specified in the data sheet for the fiber-optic cable. If possible, do not remove fiber-optic cables from their original packaging until you are about to install them.

Permitted bending radii for pre-assembled cables

You may not go below the following bending radii when laying the fiber-optic cables:

- Next to connector: 55 mm
- During installation: 60 mm (repeatedly)
- After installation: 40 mm (once)

Open installation, wall breakthroughs, cable ducts

Note the following points when laying fiber-optic cables:

- Fiber-optic cables can be installed in open locations provided you can safely exclude any damage in those areas (vertical risers, connecting shafts, telecommunications switchboard rooms, etc.).

- Attach fiber-optic cables to mounting rails, for example cable trays or wire mesh ducts, using cable ties. Take care not to crush the cables when fastening them. Make sure there is not too much pressure on the fiber-optic cables.

- Before laying the fiber-optic cables: Deburr the edges of the holes. Round the holes. This prevents damage to the sheathing when you pull in and fasten the cable.

- The bending radius must not be smaller than the value specified by the manufacturer.

- The branching radii of the cable ducts must correspond to the specified bending radius for the fiber-optic cable.

- Lay the redundancy connections so that the fiber-optic cables are securely protected from damage.

- Always lay the two redundancy connections separately. Laying the connections separately increases availability and protects against undefined system states. An undefined system state occurs when the two redundancy connections are interrupted simultaneously in a time period of ≤ 1500 ms.

Pressure

Do not exert any pressure on the cable, for example by the inappropriate use of clamps (cable quick-mount) or cable ties.
Do not step on the fiber-optic cable.

Heat

The cables are sensitive to direct heat. Hot air guns and gas burners as used in heat-shrink tubing must not be used on the fiber-optic cables.

5.9.1.4   Connecting redundancy connections (fiber-optic cables) to S7-1500H

Introduction

The redundancy connections (fiber-optic cables) are connected between the two H-CPUs using the sockets on the synchronization modules. You need two synchronization modules per CPU. Connect the synchronization modules in pairs to the fiber-optic cables.

Requirements

- The redundancy connections (fiber-optic cables) must not include any additional media converters, IO devices or switches. Distribution boxes (Page 124) are allowed.
- The redundancy connections can be a maximum of 10 m/10 km long.

Accessories required

- 4 synchronization modules 2 synchronization modules for each H-CPU
  - Up to 10 m: Sync module 1 GB FO 10 m
  - Up to 10 km: Sync module 1 GB FO 10 km
- 2 redundancy connections sync cable FO. The redundancy connections can be ordered in the following lengths. You can find the article numbers in the appendix Accessories/spare parts (Page 305).
  - For sync module 1 GB FO 10 m: 1 m, 2 m, 10 m
  - For sync module 1 GB FO 10 km: On request

Safety information

> ⚠️ **WARNING**
>
> **Personal injury or material damage can occur in zone 2 hazardous areas**
>
> If you remove or attach a synchronization module during operation, personal injury and damage can occur in hazardous areas of zone 2. Always disconnect the R/H-CPU from the power supply before you remove or attach a synchronization module in hazardous areas of zone 2.

> ⚠️ **CAUTION**
>
> **The synchronization module contains a laser system and is classified as a "CLASS 1 LASER PRODUCT" in accordance with IEC 60825-1.**
>
> Can cause personal injury.
>
> Avoid direct eye contact with the laser beam. Do not open the housing. Read the information in the system manual carefully.

CLASS 1 LASER PRODUCT
LASER KLASSE 1 PRODUKT
TO EN 60825

Figure 5-10   Class 1 laser products

Inserting synchronization modules and connecting fiber-optic cables

To insert the synchronization modules and connect the fiber-optic cables, follow these steps:

1. Lift up the front right-hand cover on the H-CPU.

2. Remove the blanking plugs from the synchronization modules.

3. Push the two synchronization modules up into the module slots at the H-Sync interfaces X3 (port 1) and X4 (port 1) as far as they will go. You should hear the synchronization modules click into place. Then push the clip on each synchronization module to the left. Result: The synchronization modules are locked into place.
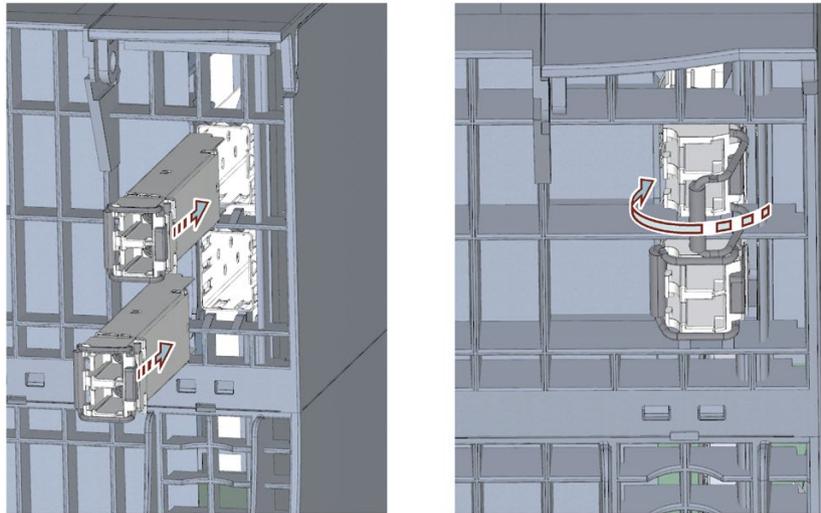
Figure 5-11   Inserting and locking synchronization modules

4. Hold the pre-assembled connectors of the redundancy connection by the housing. Push the connectors into the sockets of the synchronization modules. You should hear the connectors click into place.

5. Close the front cover of the H-CPU.

6. Repeat steps 1 to 5 for the second H-CPU.
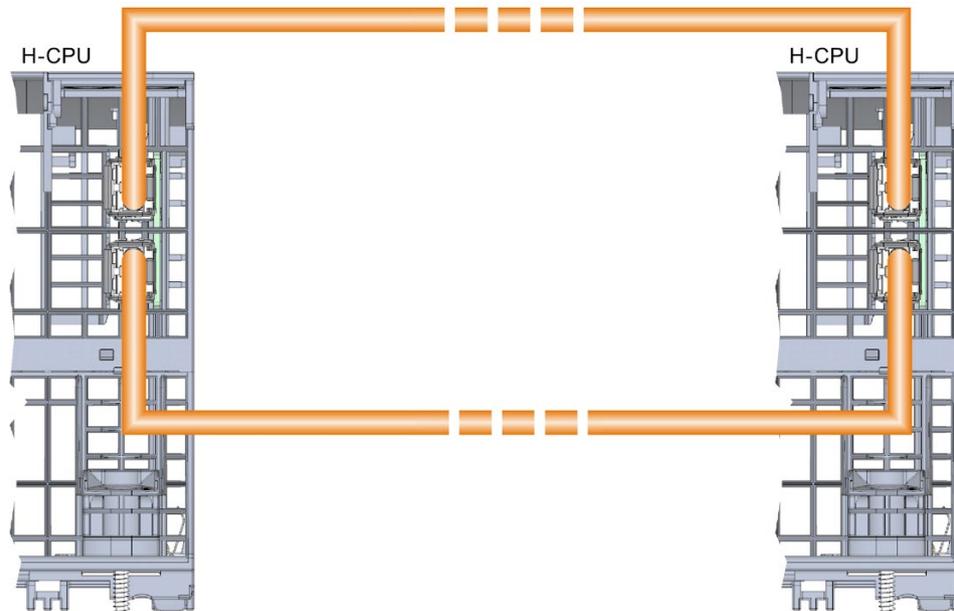
Figure 5-12   Connecting redundancy connections (fiber-optic cables) to S7-1500H

Uninstalling a synchronization submodule

To uninstall the synchronization modules, follow these steps:

1. Press down lightly on the connector release and hold while pulling the connector out of the synchronization module.

2. Flip the synchronization module clip to the right.

3. Pull the synchronization module out of the H-Sync interface on the CPU.

4. Place the blanking plug on the synchronization module.

5. Repeat the process for all H-Sync interfaces on the H-CPUs.

Protecting LC sockets on unused synchronization modules

You need to protect the LC sockets when storing unused synchronization modules.

Close off the LC sockets with the blanking plugs to protect them from dirt. The synchronization modules come with blanking plugs inserted.

NOTICE
Reduced optical performance due to dirt
Even a small amount of dirt in the LC socket can affect the quality of the signal transmission. Dirt can lead to synchronization losses in operation.
Protect the LC sockets from dirt when storing and installing the synchronization modules.

5.9.2 Connecting the PROFINET ring to S7-1500H

Introduction

You connect the PROFINET ring using the RJ45 sockets of PROFINET interfaces X1 P1 R and X1 P2 R.

Accessories required

PROFINET cable for the PROFINET ring

Procedure

Plug the RJ45 connectors on the PROFINET cable in the PROFINET ring into the RJ45 sockets at PROFINET interfaces X1 P1 R/X1 P2 R on the two H-CPUs.
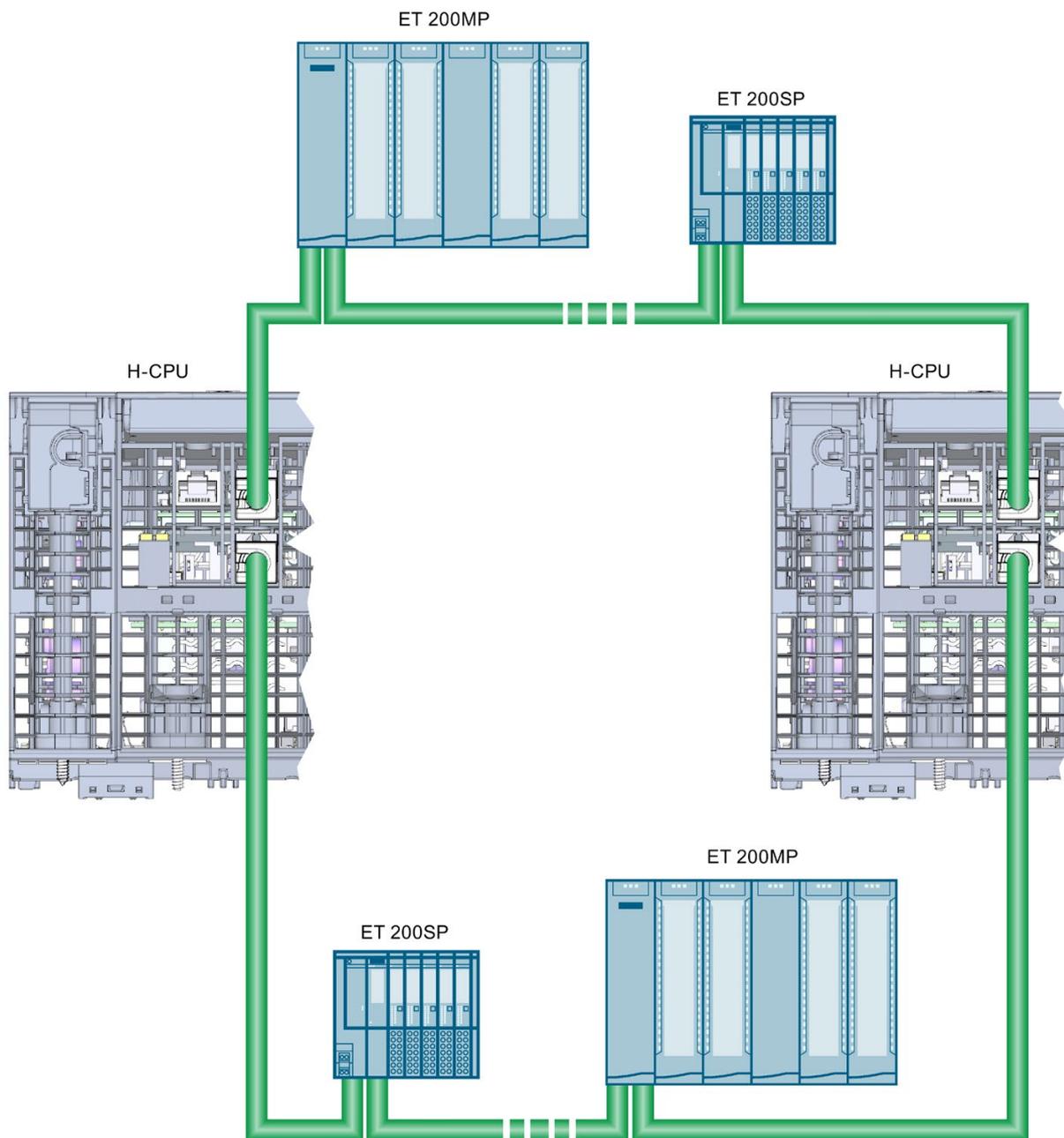
Figure 5-13   Connecting the PROFINET ring to S7-1500H

Configuration 6

6.1 Configuring the CPU

Hardware and software requirements

You will find the hardware and software requirements for operating S7-1500R/H redundant systems in the section Application planning (Page 49).

6.2 Configuration procedure

The following section takes you through the configuration process for an S7-1500R redundant system step by step. The configuration consists of two CPUs 1515R-2 PN and two IO devices (ET 200MP and ET 200SP).

Requirements

The configuration detailed assumes that:

● You have set the IP address of the PG/PC.

1. Creating a project and R-CPUs

1. Create a new project in STEP 7. Give the project a name.

2. Select CPU 1515R-2 PN from the hardware catalog in the network view of the hardware configuration.

3. Drag and drop the CPU to the task window in the network view.

Result: STEP 7 automatically creates both 1515R-2 PN CPUs for the redundant system. STEP 7 displays both CPUs in the network view graphically.

Note

Deleting CPUs from the hardware configuration

You can only delete the two CPUs as a pair.
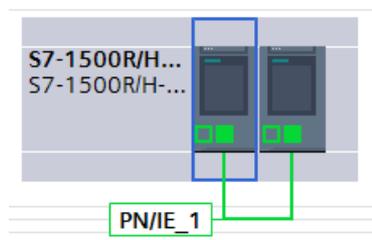
Figure 6-1   Display of CPUs in the network view

1. Open the CPUs in the device view. In the device view, the first CPU and the second CPU are each in slot 1. Slots 0 to the left of the CPUs are reserved for system power supplies (PS).

2. Give the CPUs unique names under Properties.

2. Assigning IP addresses (device IP addresses)

STEP 7 automatically assigns an IP address to each PROFINET interface of a CPU. You can also assign the IP addresses manually.

For PROFINET interface X1 of the CPUs, the IP addresses must be located in the same subnet.

The IP address is displayed in the CPU properties, in the "PROFINET interface [X1]" area of the "IP protocol" section.

IP protocol

IP address:	192 . 168 . 0 . 1
Subnet mask:	255 . 255 . 255 . 0
	☐ Use router
Router address:	0 . 0 . 0 . 0
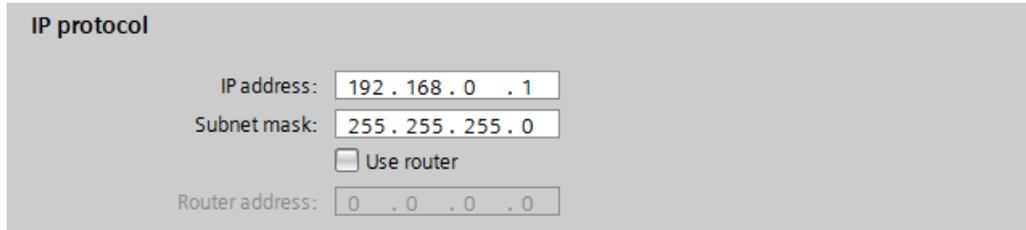
Figure 6-2   IP address

Redundancy IDs

In the STEP 7 project tree, each of the two CPUs is displayed with its own tree in the redundant system:

Project tree

Devices

- ▼ FW2.6
  - Add new device
  - Devices & networks
  - ▼ S7-1500R/H-System_1 [S7-1500R/H-Station]
    - Device configuration
    - Online & diagnostics
  - ▶ PLC_1 [CPU 1515R-2 PN]
  - ▶ PLC_2 [CPU 1515R-2 PN]
  - ▶ Ungrouped devices
  - ▶ Security settings
  - ▶ Common data
  - ▶ Documentation settings
  - ▶ Languages & resources
- ▶ Online access
- ▶ Card Reader/USB memory
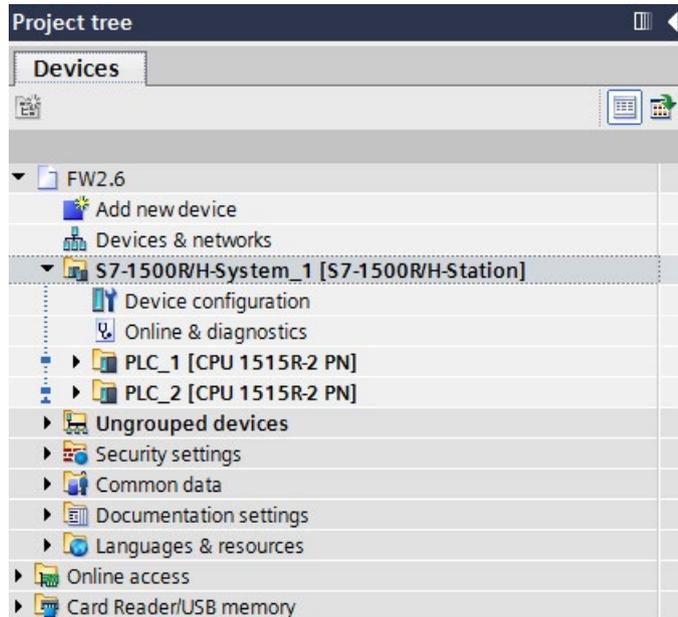
Figure 6-3   Redundant system in the project tree

Each CPU of the redundant system has a redundancy ID. The redundancy ID is used to assign a project tree to the real CPU in STEP 7. The top CPU of the two in the tree is always the CPU with the redundancy ID "1". The bottom CPU has the redundancy ID "2".

If a CPU has a valid hardware configuration and you change the redundancy ID of that CPU, you also change the CPU's name and IP addresses. You can find more information in the section Redundancy IDs (Page 187).

3. Assigning system IP addresses

In addition to the device IP addresses of the CPUs, you can also assign system IP addresses for the S7-1500R/H redundant system.

You use the system IP addresses for communication with other devices (for example, HMI devices, CPUs, PG/PC). The devices always communicate over the system IP address with the primary CPU of the redundant system. This ensures, for example, that the communication partner can communicate with the new primary CPU (previously backup CPU) in the RUN-Solo system state after failure of the original primary CPU in redundant operation.

Proceed as follows to activate the system IP address for PROFINET interfaces X1 of the two CPUs:

1. Select a CPU in the network view. Select the "Properties" tab in the Inspector window.

2. Select the area "PROFINET interface [X1]" and the section "System IP address for switched communication" in the area navigation.

3. Make sure that the checkbox "Enable the system IP address for switched communication" is selected for the interface X1. Apply or assign the system IP address in the "IP address" field.
The subnet mask cannot be modified and corresponds to the subnet mask of the IP protocol.

4. Apply or assign a virtual MAC address to the system IP address.
The virtual MAC address is six bytes long. The assignment of the bytes is hexadecimal.

Note

Virtual MAC address

Ensure that all MAC addresses stored in the Ethernet broadcast domain are unique. This applies in particular to systems with third-party devices consisting of VRRP and redundant systems that are configured through several STEP 7 projects.

---

5. The other CPU applies the settings automatically.

Figure 6-4   System IP address

You can find more information on the system IP address in the Communication function manual (https://support.industry.siemens.com/cs/ww/en/view/59192925).

4. Setting the cycle monitoring time

STEP 7 assigns default values for the minimum and maximum cycle times.

The default values are displayed in the "Cycle" area of the CPU properties.

Note

Setting as long as possible a cycle time

Select as long a maximum cycle time as your process will allow.

- The time for the ongoing synchronization of the two CPUs in redundant operation is included in the cycle time.
- A temporary increase in the cycle time can occur upon a system state transition SYNCUP → RUN-Redundant.

If only one CPU controls the process (RUN-Solo system state), the cycle time is significantly shorter than during redundant operation.

You can find more information on the cycle time in the Cycle and response times function manual (http://support.automation.siemens.com/WW/view/en/59193558).

You can find information on system states in the section Operating and system states (Page 197).

5. Creating IO devices

In the example, you add two IO devices with system redundancy S2 to the R-CPUs. To do so, proceed as follows:

1. Switch to the network view.

2. Drag the interface module IM 155-5 PN HF to the task window as an IO device from the hardware catalog.

3. Drag the required modules to the corresponding slots in the IO device.

4. Select the second IO device, IM 155-6 PN HF, in exactly the same way.

5. Assign the required modules.

6. Assigning IO devices to the redundant system

To assign IO devices to the S7-1500R/H redundant system, connect every IO device to each CPU.

To do so, proceed as follows:

1. Drag-and-drop a line between the PROFINET interface of IM 155-5 PN HF and PROFINET interface X1 of the left-hand CPU.

2. Drag-and-drop a line between the PROFINET interface of IM 155-5 PN HF and PROFINET interface X1 of the right-hand CPU.

3. Assign the second IO device, IM 155-6 PN HF, to the two CPUs in exactly the same way.

Result: The IO devices are connected to S7-1500R/H with system redundancy.
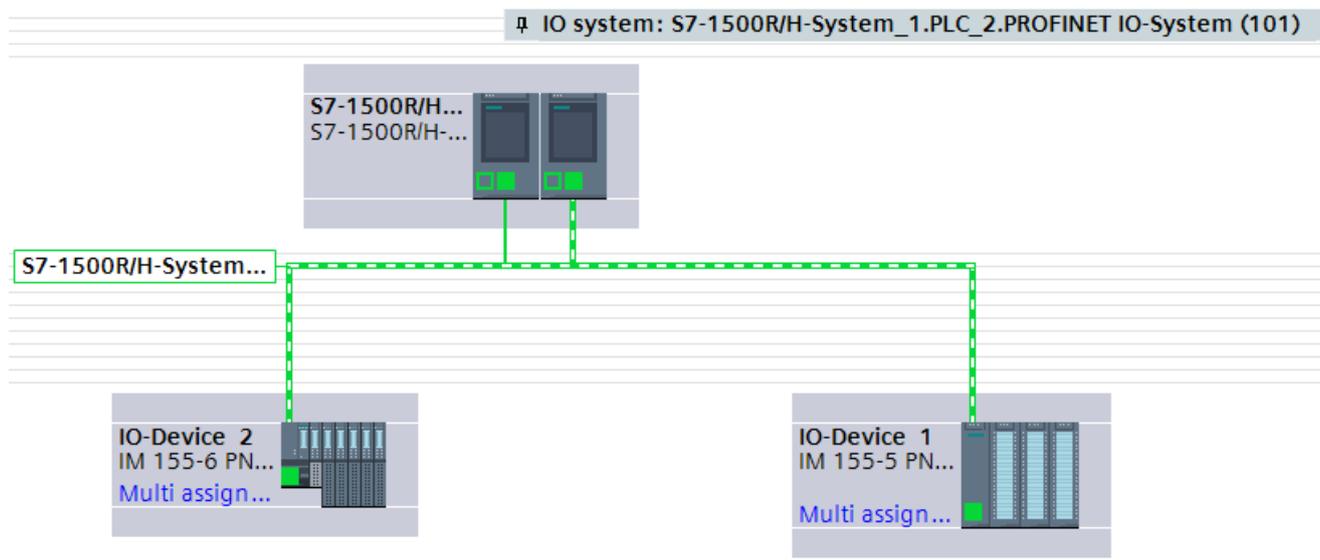
Figure 6-5   IO devices assigned in the network view with system redundancy

7. MRP role of the CPUs in the S7-1500R/H redundant system

As soon as you create an S7-1500R/H redundant system in STEP 7, STEP 7 automatically assigns the MRP role "Manager (auto)" to the PROFINET interfaces X1 of both CPUs.

8. Defining the MRP role for additional devices in the ring in STEP 7

Proceed as follows to define the media redundancy for additional devices in the ring:

1. In the network view of STEP 7, select PROFINET interface X1 of one of the two CPUs of the S7-1500R/H redundant system.

2. In the Inspector window, navigate to "Properties" > "General" > "Advanced options" > "Media redundancy".

3. Click the "Domain settings" button.
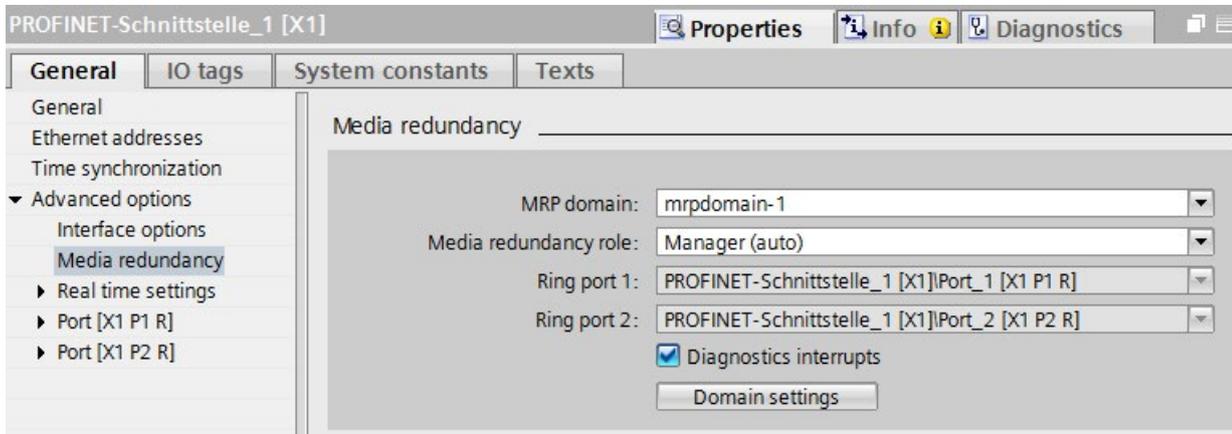
Figure 6-6   S7-1500R/H: MRP role "Manager (auto)"

In the Inspector window, STEP 7 displays the properties of the MRP domain in which PROFINET interface X1 of the CPU is located.

4. In the "MRP role" column of the "Devices" table, assign the MRP role "Client" to all other devices.

Figure 6-7   S7-1500R/H: Assigning MRP roles to ring devices

9. Configuring devices outside the STEP 7 project

Set the MRP role "Client" for devices in the ring that are not located in STEP 7.
Example: For a switch, set the MRP role "Client" via the Web interface of the switch.

Reference

You can find information on the PROFINET topologies of S7-1500R/H redundant systems in the PROFINET function manual.
(http://support.automation.siemens.com/WW/view/en/49948856)

6.3 Project tree

Structure of the project tree

In the project tree, STEP 7 creates the project tree for the CPUs. The project tree has a tree structure and contains all elements and editors of the project.

Table 6- 1   Structure of the project tree

▼ 🔲 **S7-1500R/H-System_1 [S7-1500R/H-Station]** 　　⫿Ⴅ Device configuration 　　🜲 Online & diagnostics	Below the H system, you will find the device configuration and diagnostic options that apply to the system as a whole.
▼ 🔲 **PLC_1 [CPU 1515R-2 PN]** 　　⫿Ⴅ Device configuration 　　🜲 Online & diagnostics 　▶ 🔲 Software units 　▶ 🔲 Program blocks 　▶ 🔲 Technology objects 　▶ 🔲 External source files 　▶ 🔲 PLC tags 　▶ 🔲 PLC data types 　▶ 🔲 Watch and force tables 　▶ 🔲 Online backups 　▶ 🔲 Traces 　▶ 🔲 Device proxy data 　　🔲 Program info 　　🔲 PLC supervisions & alarms 　　🔲 PLC alarm text lists 　▼ 🔲 Local modules 　　　🔲 PLC_1 [CPU 1515R-2 PN] 　▼ 🔲 Distributed I/O 　　▼ 🔲 PROFINET IO-System (100): PN/IE_1 　　　　🔲 IO-Device_1 [IM 155-5 PN HF] 　　　　🔲 IO-Device_2 [IM 155-6 PN HF]	The CPU displayed in the upper section of the project tree has the redundancy ID "1". The properties of the CPU are displayed below it. This section also contains other properties of the redundant system, the user program and other system-related project items. The IO devices assigned to the CPU are listed under "Distributed I/O".
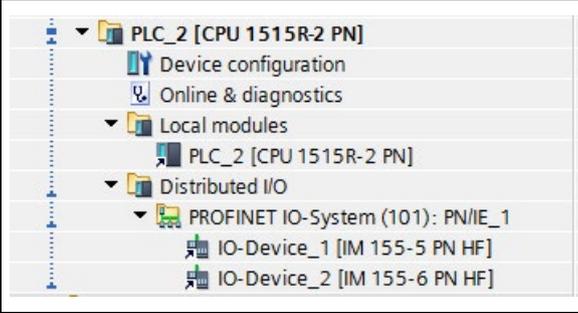
▼ 🗁 PLC_2 [CPU 1515R-2 PN] 　　🔧 Device configuration 　　🔍 Online & diagnostics 　▼ 🗁 Local modules 　　　🔲 PLC_2 [CPU 1515R-2 PN] 　▼ 🗁 Distributed I/O 　　▼ 🔲 PROFINET IO-System (101): PN/IE_1 　　　🔳 IO-Device_1 [IM 155-5 PN HF] 　　　🔳 IO-Device_2 [IM 155-6 PN HF]	The CPU in the lower section of the project tree has the redundancy ID "2". The properties of the CPU are displayed below it. The IO devices assigned to the CPU are listed under "Distributed I/O".
▼ 🖥 Ungrouped devices 　▶ 🗁 IO-Device_1 [IM 155-5 PN HF] 　▶ 🗁 IO-Device_2 [IM 155-6 PN HF]	All distributed I/O devices used are listed under "Ungrouped devices".
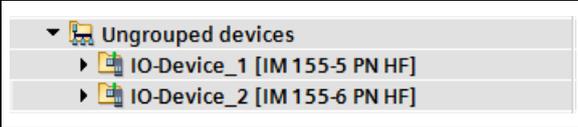
6.4　Parameters

"Parameter assignment" means setting the module properties. This includes setting addresses, enabling alarms and defining communication properties.

You assign the property parameters for the CPUs in the area navigation, in the STEP 7 Inspector window. The CPUs have general parameters and R/H-specific parameters. Some parameters must be identical for both CPUs. STEP 7 applies these parameters to the second CPU. Other parameters must be different on each CPU (for example device IP addresses). If your configuration is not consistent, STEP 7 will point out the conflict.

Reference

You can find a detailed description of all CPU parameters in the STEP 7 online help.

6.5 Process images and process image partitions

6.5.1 Process image - overview

Process image inputs and outputs

The process image of the inputs and outputs is an image of the signal states. The CPU transfers the values from the input and output modules to the process image inputs and outputs. At the start of the cyclic program, the CPU transfers the process image output as a signal state to the output modules. The CPU then transfers the signal states of the input modules to the process image inputs.

Advantages of the process image

A process image accesses a consistent image of the process signals during cyclic program execution. If a signal state at an input module changes during program execution, the signal state is retained in the process image. The CPU does not update the process image until the next cycle.

Consistency of the process image

When the process image is updated, the S7-1500R/H redundant system accesses the data of each submodule as consistent data. This behavior is identical to that of S7-1500 CPUs.

The maximum data width that is accessed as consistent data for each submodule depends on the IO system. For PROFINET IO, for example, this data width is 1024 bytes.

32 process image partitions

The CPU uses process image partitions to synchronize the updated inputs/outputs of specific modules with specific parts of the user program.

In the S7-1500R/H redundant system, the overall process image is subdivided into up to 32 process image partitions (PIP).

The CPU automatically updates PIP 0 (automatic update) in each program cycle and assigns it to OB 1.

You can assign other OBs to process image partitions PIP 1 to PIP 31 during configuration of the IO devices.

Before the start of the OB, the CPU writes the outputs of the assigned process image partition (PIPQ) straight to the peripheral outputs of the IO devices. The CPU then updates the assigned process image partition for inputs (PIPI) and reads in the process signals.

The figure below illustrates the updating of a process image partition.

Output PIPQx	Read in PIPIx	Executing the program in the OB called
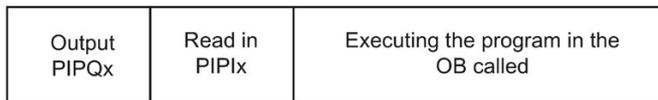
Figure 6-8   Updating a process image partition

6.5.2   Updating process image partitions in the user program

Requirements

Alternatively, you can also use the following instructions to update process images:

- "UPDAT_PI" instruction at the start of the assigned OB
- "UPDAT_PO" instruction at the end of the assigned OB

You will find the instructions in STEP 7 in the "Instructions" task card under "Extended instructions". The instructions can be called from any point in the user program.

Requirements for updating process image partitions with the "UPDAT_PI" and "UPDAT_PO" instructions:

- The process image partitions must not be assigned to any OB. This means the process image partitions are not automatically updated.

Note

Update of PIP 0

PIP 0 (automatic update) cannot be updated with the "UPDAT_PI" and "UPDAT_PO" instructions.

UPDAT_PI: Updates the process image partition of the inputs

With this instruction, you read the signal states from the input modules of the IO devices to the process image partition of the inputs (PIPI).

UPDAT_PO: Updates the process image partition of the outputs

With this instruction, you transfer the process image partition of the outputs of the IO devices to the output modules.

Direct I/O access to the inputs and outputs of the IO devices

You also have direct read and write access to the I/O as an alternative to access via the process image, should direct access be required for programming reasons. Direct (write) I/O access also writes to the process image. This prevents a subsequent output of the process image from again overwriting the value written by direct access.

Note

Avoid direct I/O access. Each instance of direct I/O access is synchronized in the RUN-Redundant system state and results in a higher cycle time. Recommendation: Access the inputs and outputs of the IO devices over the process image.

Reference

You can find more information on process image partitions in the Cycle and response times (http://support.automation.siemens.com/WW/view/en/59193558) function manual.

Basics of program execution

7

7.1 Programming the S7-1500R/H

User program for the S7-1500R/H redundant system

For the design and programming of the user program, the same rules apply for the redundant S7-1500R/H system as for the S7-1500 automation system.

The user program is stored identically in both CPUs in redundant operation. Both CPUs process the user program event-synchronously.

From the point of view of user program execution, the S7-1500R/H redundant system behaves like the S7-1500 automation system. Synchronization is integrated into the operating system and runs automatically and hidden between the primary and backup CPU.

Specific instructions and blocks for the S7-1500R/H redundant system

Specific instructions and OBs are available for the S7-1500R/H redundant system.

The "RH_CTRL" instruction is used to disable SYNCUP or to enable the running of the SYNCUP. The goal is to only permit the SYNCUP in less critical process phases (see Disabling/enabling SYNCUP with the RH_CTRL instruction (Page 157)).

You use the instruction "RH_GetPrimaryID" in the user program to read out which CPU is currently the primary CPU (see Determining the primary CPU with "RH_GetPrimaryID" (Page 160)).

In addition to the OBs of the S7-1500 CPU, you can also use OB 72 (CPU redundancy error). OB 72 is called when the S7-1500R/H redundant system has reached or left the RUN-Redundant system state.

Special features in program execution

- You create the user program for the S7-1500R/H redundant system in the top CPU (for example PLC_1) in the STEP 7 project tree.

- The S7-1500R/H redundant system does not support some of the instructions the S7-1500 CPUs. Instructions that are not supported by the S7-1500R/H redundant system are grayed out in STEP 7 in the "Instructions" task card.
  STEP 7 shows the instructions that are not supported in the program code in red. If you compile program code with instructions that are not supported, STEP 7 outputs an error message.
  The instructions that are not supported are set out in the section Restrictions (Page 150).

- In the case of instructions with the "LADDR" block parameter, you use this parameter to determine which of the two CPUs is the target of this instruction.
  Example: To read out the I&M data of the CPU with redundancy ID 1, specify the HW identifier 65149 (or the "Local1" system constant) at the "LADDR" block parameter of the Get_IM_Data instruction.
  You can find more information about the block parameters and the system constants of the S7-1500R/H redundant system in the STEP 7 online help.

- In the case of a SYNCUP, the execution time of many instructions operating asynchronously is extended.

- Temporary local data for functions (FCs): The system initialization for standard access is identical for S7-1500R/H-CPUs as for optimized block access. Information on system initialization for optimized block access can be found in the STEP 7 online help.

Programming style guide

The programming guidelines described in the programming style guide help you to create a uniform program code that is easier to maintain and reuse. This means that errors can be detected (e.g. by compiler) and avoided early on.

The programming style guide is available on the Internet (https://support.industry.siemens.com/cs/ww/en/view/109478084).

7.2 Restrictions

Instructions not supported

Table 7- 1   Unsupported instructions CPU 1513R / CPU 1515R / CPU 1517H with firmware version V2.6

Instruction	Description
Communication	
GET	Read data from a remote CPU
PUT	Write data to a remote CPU
USEND	Send data uncoordinated
URCV	Receive data uncoordinated
BSEND	Send data in segments
BRCV	Receive data in segments
T_CONFIG	Configure interface
TMAIL_C (V5.0 or later)[1]	Transfer email
OPC_UA_Connect	Create connection
OPC_UA_NamespaceGetIndexList	Read namespace indexes
OPC_UA_NodeGetHandleList	Get handles for read and write access
OPC_UA_MethodGetHandleList	Get handles for method calls
OPC_UA_TranslatePathList	Read node parameters
OPC_UA_ReadList	Read tags
OPC_UA_WriteList	Write tags
OPC_UA_MethodCall	Call method
OPC_UA_NodeReleaseHandleList	Enable handles for read and write access
OPC_UA_MethodReleaseHandleList	Enable handles for method calls
OPC_UA_Disconnect	Close connection
OPC_UA_ConnectionGetStatus	Read connection status
WWW	Synchronize user pages
FTP_CMD	Setup of FTP connections from and to an FTP server
Extended instructions	
SNC_RTCB	Synchronize slave clocks
SYNC_PI	Synchronize process image inputs
SYNC_PO	Synchronize process image outputs
GETIO	Read process image
SETIO	Transfer process image
GETIO_PART	Read process image area
SETIO_PART	Transfer process image area
D_ACT_DP	Enable/disable DP slaves
ReconfigIOSystem	Reconfigure IO system
WR_REC	Write data record to I/O
RD_REC	Read data record from I/O
RCVREC	Receive data record

Instruction	Description
PRVREC	Make data record available
DPSYC_FR	Synchronize DP slaves/Freeze inputs
DPNRM_DG	Read diagnostics data from a DP slave
DP_TOPOL	Determine topology for DP master system
PE_WOL	Start and end energy-saving mode via WakeOnLan
PE_I_DEV	Control PROFIenergy commands in I-Device
WR_DPARM	Transfer data record
ATTACH	Attach OB to interrupt event
DETACH	Detach OB from interrupt event
Program_Alarm	Generate program alarm with associated values
Get_AlarmState	Output alarm state
Gen_UsrMsg	Generate user diagnostic messages
Get_Alarm	Read pending alarm
Ack_Alarms	Acknowledge alarms
GetStationInfo	Read information of an IO device
DeviceStates[2]	Read module state information in an IO system
GEN_DIAG	Generate diagnostics information
RecipeExport	Export recipe
RecipeImport	Import recipe
DataLogCreate	Create data log
DataLogOpen	Open data log
DataLogWrite	Write data log
DataLogClose	Close data log
DataLogDelete	Delete data log
DataLogNewFile	Data log in new file
CREATE_DB	Create data block
READ_DBL	Read from data block in load memory
WRIT_DBL	Write from data block in load memory
DELETE_DB	Delete data block
FileReadC	Read file from memory card
FileWriteC	Write file on memory card
SET_CLKS	Set time of day and time-of-day status
Basic instructions	
ReadFromArrayDBL	Read from ARRAY data block in load memory
WriteToArrayDBL	Write to ARRAY data block in load memory

Instruction	Description
Technology	
All instructions for Motion Control (MC_Power, MC_Home, MC_...)	-
PID_Compact	Universal PID controller with integrated optimization
PID_3Step	PID controller with integrated optimization for valves
PID_Temp	PID controller for temperature
TIO_SYNC	Synchronize TIO modules

[1] The S7-1500R/H CPUs with firmware version V2.6 support the versions < V5.0 of the instruction "TMAIL_C".

[2] Please note: The "DeviceStates" instruction can be selected in STEP 7. The S7-1500R/H CPUs with firmware version V2.6 do not support the "DeviceStates" instruction. Do **not** use the "DeviceStates" instruction.
To read out the module state information, use the "Get_DIAG" instruction.

Unsupported OBs

The CPUs of the S7-1500R/H redundant system do not support the following OBs:

- OB 55 "Status interrupt OB"
- OB 56 "Update interrupt OB"
- OB 57 "OB for vendor or profile-specific interrupt"
- Synchronous cycle interrupt OB
- OB 67 "MC-PreServo"
- OB 91 "MC-Servo"
- OB 92 "MC-Interpolator"
- OB 95 "MC-PostServo"

7.3 Events and OBs

Start events

The table below gives an overview of the possible event sources for start events and their OBs:

Table 7- 2   Start events

Event sources	Possible priorities (default priority)	Possible OB numbers	Default system response[1]	Number of OBs
Startup	1	100, ≥ 123	Ignore	0 to 100
Cyclic program	1	1, ≥ 123	Ignore	0 to 100
Time-of-day interrupt	2 to 24 (2)	10 to 17, ≥ 123	Not applicable	0 to 20
Time-delay interrupt	2 to 24 (3)	20 to 23, ≥ 123	Not applicable	0 to 20
Cyclic interrupt	2 to 24 (8 to 17, frequency dependent)	30 to 38, ≥ 123	Not applicable	0 to 20
Hardware interrupt	2 to 26 (18)	40 to 47, ≥ 123	Ignore	0 to 50
CPU redundancy error	2 to 26 (26)	72	Ignore	0 or 1
Time error	22	80	Ignore	0 or 1
Maximum cycle time exceeded			Depends on system state[2]	
Diagnostics interrupt	2 to 26 (5)	82	Ignore	0 or 1
Removal/insertion of modules	2 to 26 (6)	83	Ignore	0 or 1
Rack error	2 to 26 (6)	86	Ignore	0 or 1
Programming error (only for global error handling)	2 to 26 (7)	121	STOP	0 or 1
I/O access error (only for global error handling)	2 to 26 (7)	122	Ignore	0 or 1

[1]   If you have not configured the OB.

[2]   See section "Response of S7-1500R/H redundant system when cycle time is exceeded"

Response to start events

The occurrence of a trigger results in the following response:

- If the event comes from an event source to which you have assigned an OB, this event triggers the execution of the assigned OB. The event enters the queue according to its priority (exception: hardware interrupts).

- If the event comes from an event source to which you have not assigned an OB, the default system response is executed.

Note

Some event sources, such as startup, pull/plug, exist even if you do not configure them.

Response of OB 72 and OB 86 to system state transitions

If an IO device has failed, the OB 86 reports a "rack failure" if programmed. OB 72 "CPU redundancy error" reports a loss of redundancy in the redundant system.

The figure below shows the behavior of the two OBs during system state transitions from RUN-Solo to RUN-Redundant and vice versa.

OB 86: Rack failure

1, 2, 3 IO devices

Failure alarm + OB 86 incoming for IO device 1, 2 or 3

Return alarm + OB 86 outgoing for IO device 1, 2 or 3

OB 72: CPU redundancy error

OB 72 incoming

Failure alarm without OB 86 call for IO device 1, 2 or 3

Return alarm without OB 86 call for IO device 1, 2 or 3

OB 86 incoming

OB 86 outgoing

Delayed execution of OB86 if alarm cannot be processed directly. The behavior is possible for both failure and return.

Figure 7-1   OB 72 and OB 86 during system state transitions

OB 86

There are three IO devices in the example. Each failure of one of the three IO devices is followed by recovery of the IO device. Each IO device failure/IO device recovery is signaled. Cyclic program execution is interrupted with an OB 86 call.

In the "Copy main memory" phase of the SYNCUP system state those OBs that interrupt the cyclic program processing are terminated. New diagnostic events are signaled but the OBs are not yet processed. In the example, the failure of IO device 2 and the recovery of IO device 3 are signaled. However, the OB 86 are not processed until the following phase, "Making up backup CPU lag".

OB 72

If the system then switches to the RUN-Redundant system state, OB 72 "CPU redundancy error" is called. If the redundant system exits redundant operation and changes to the RUN-Solo system state, OB 72 is called again.

There may also be a delay in executing OB 72 because the corresponding diagnostic event is processed asynchronously to the user program.

Example: OB 72 CPU redundancy failure

Automation task

You use the S7-1500R redundant system to control a blast furnace. The S7-1500R redundant system controls the blast furnace temperature, volume and pressure parameters.

Feature

In the event of a loss of redundancy, for example because the primary CPU fails, a signal lamp in the blast furnace control room signals this event. The control room notifies the service personnel. The service personnel replace the defective CPU.

Solution

OB 72 is called in the event of a CPU redundancy error. The user program in OB 72 controls a digital output module (relay) in an ET 200SP with a connected signal lamp.

Response of S7-1500R/H redundant system when cycle time is exceeded

The tables below show how the redundant system responds when the cycle time is exceeded.

If the user program does not reach the cycle control point within the maximum cycle time, the redundant system responds as described in the column "1st time cycle time is exceeded". The redundant system then resets the cycle time.

If the maximum cycle time is exceeded for a second time in the same cycle, the redundant system responds as described in the column "2nd time cycle time is exceeded". The redundant system then resets the cycle time.

If the maximum cycle time is exceeded for a third time in the same cycle, the redundant system responds as described in the column "3rd time cycle time is exceeded". The redundant system then resets the cycle time.

Table 7- 3   Response of S7-1500R/H redundant system when cycle time is exceeded, without OB 80

Initial situation			1st time cycle time is exceeded			2nd time cycle time is exceeded		
System	Primary CPU	Backup CPU	System	Primary CPU	Backup CPU	System	Primary CPU	Backup CPU
RUN-Solo	RUN	STOP	**STOP**	STOP	STOP	---	---	---
RUN-Syncup	RUN-Syncup	SYNCUP	**RUN-Solo**	RUN	STOP	**STOP**	STOP	STOP
RUN-Redundant	RUN-Redundant	RUN-Redundant	**RUN-Solo**	RUN	STOP	**STOP**	STOP	STOP

Table 7- 4   Response of S7-1500R/H redundant system when cycle time is exceeded with OB 80

Initial situation			1st time cycle time is exceeded			2nd time cycle time is exceeded			3rd time cycle time is exceeded		
System	Primary CPU	Backup CPU	System	Primary CPU	Backup CPU	System	Primary CPU	Backup CPU	System	Primary CPU	Backup CPU
RUN-Solo	RUN	STOP	**RUN-Solo**	RUN + OB 80	STOP	**STOP**	STOP	STOP	**---**	---	---
RUN-Syncup	RUN-Syncup	SYNCUP	**RUN-Syncup**	RUN-Syncup + OB 80	SYNCUP + OB 80 [1]	**RUN-Solo**	RUN + OB 80	STOP	**STOP**	STOP	STOP
RUN-Redun-dant	RUN-Redun-dant	RUN-Redun-dant	**RUN-Redun-dun-dant**	RUN-Redun-dant + OB 80	RUN-Redun-dant + OB 80	**RUN-Solo**	RUN + OB 80	STOP	**STOP**	STOP	STOP

[1]   OB 80 is not called until the cycle time is exceeded for the first time after the SYNCUP phase "Finish tasks".

Assignment between event source and OBs

The type of OB determines where you assign OB to event source:

- For hardware interrupts: Assignment in hardware configuration
- For all other OB types: Assignment when the OB is created, where applicable after you have configured the event source

OB priority and runtime behavior

If you have assigned an OB to the event, the OB has the priority of the event. S7-1500R/H CPUs support the priorities 1 (lowest) to 26 (highest). The following items are essential to the execution of an event:

- Call and execution of the assigned OB
- The update of the process image partition of the assigned OB

The user program processes the OBs exclusively on a priority basis. This means the program processes the OB with the highest priority first when multiple OB requests occur at the same time. If an event occurs that has a higher priority than the currently active OB, this OB is interrupted. The user program processes events of the same priority in order of occurrence.

Note
Communication

Communication (for example test functions with the PG/PC) always operates with a priority of 15. To avoid unnecessarily prolonging the program runtime in the case of time-critical applications, make sure that these OBs are not delayed or interrupted by communication. Assign a priority > 15 for these OBs.

Reference

Additional information on organization blocks is available in the STEP 7 online help.

7.4 Special instructions for S7-1500R/H redundant systems

7.4.1 Disabling/enabling SYNCUP with the RH_CTRL instruction

Introduction

You use the "RH_CTRL" instruction to disable SYNCUP or to enable the execution of the SYNCUP for the S7-1500R/H redundant system. The disable applies:

- Until you cancel it with the "RH_CTRL" instruction or
- Until the S7-1500R/H redundant system switches to the STOP system state
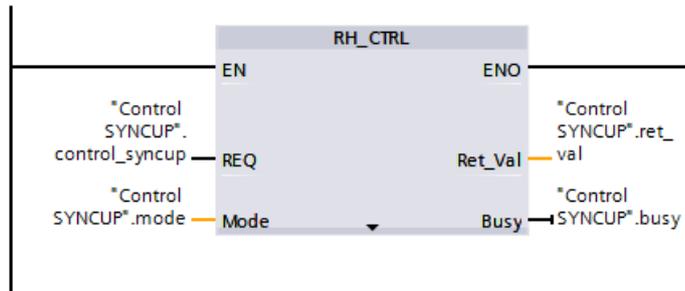
Figure 7-2   RH_CTRL instruction

Example: Disabling/enabling SYNCUP for a baggage handling system

Automation task

A baggage handling system at an airport is used to distribute pieces of baggage. When a flight lands, all baggage is loaded onto the baggage handling system. The baggage passes through a scanner at high speed. The scanner checks the destination of the baggage:

- If a piece of baggage has reached its destination airport, the baggage handling system forwards it directly to baggage claim.

- If a piece of baggage has not reached its final destination, the system immediately redirects it towards the connecting flight.
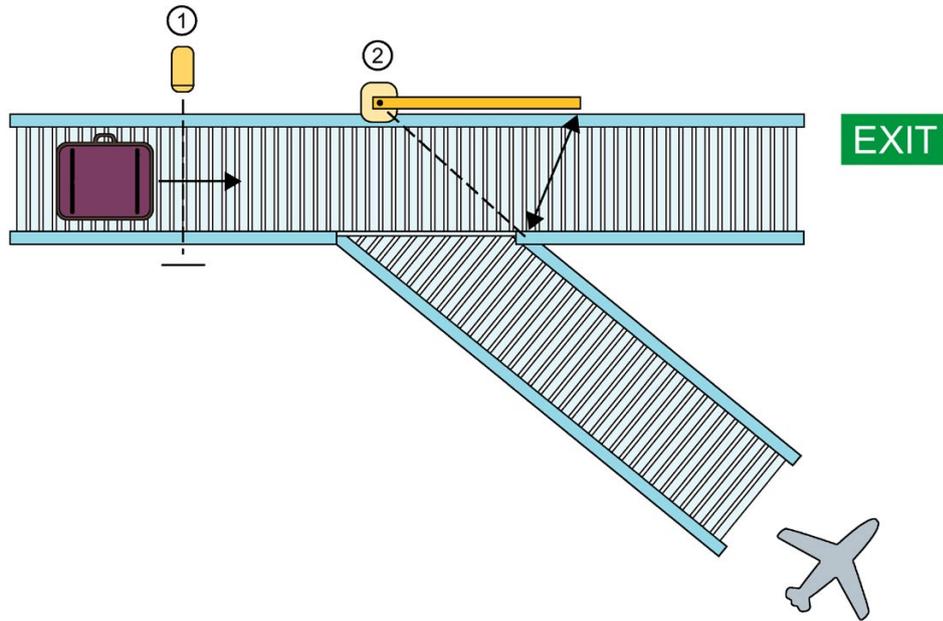
①   Scanner

②   Deflector

Figure 7-3   Airport baggage handling system

To ensure high availability for the baggage handling system, you use an S7-1500R/H redundant system as controller. If one of the CPUs fails (loss of redundancy), the S7-1500R/H redundant system switches from the RUN-Redundant system state to RUN-Solo. A CPU continues to ensure the control of the baggage handling system, but no second redundant CPU is available.

Replace the failed CPU with a replacement CPU. The procedure for replacing the CPU is described in the section Replacing defective R/H-CPUs (Page 260).

As soon as you set the exchanged CPU to RUN, the R/H-System responds as follows:

- The replaced CPU (Backup CPU) switches to SYNCUP operating state and sends a corresponding status message to the primary CPU.

- The primary CPU then switches from the RUN operating state to RUN-Syncup.

- The S7-1500R/H redundant system then does not run a SYNCUP.

During SYNCUP, the user program of the primary CPU runs through a cycle with an extended cycle time. In this cycle, there is a delay before the redundant system responds to input signal changes.

If a piece of baggage passes the scanner during the SYNCUP, the redundant system only responds to the scanner after the extended cycle described above. In the worst case scenario, the piece of baggage has already passed the deflector before the system responds. The piece of baggage is then moved to baggage claim rather than to the connecting flight.

Feature

You need the "RH_CTRL" instruction, which allows you to disable and enable the execution of the SYNCUP as required.

Solution

You use the bushing of "RH_CTRL" instruction to disable the execution of the SYNCUP system state for the S7-1500RH redundant system. If the disable is no longer required, you enable the execution of the SYNCUP again with the "RH_CTRL" instruction.

Disable the SYNCUP bushing state to avoid a long program cycle when the baggage handling system is operating at or near capacity. To do so, call the "RH_CTRL" instruction with block parameter MODE = 3 in the user program.

Replace the failed CPU with a replacement CPU.

As soon as you set the exchanged CPU with disabled SYNCUP to RUN, the R/H-System responds as follows:

- The exchanged CPU (Backup CPU) shows the SYNCUP state.

- The Primary CPU then displays the RUN-Syncup state.

- The redundant system does not **yet** perform any SYNCUP and remains in the RUN-Solo system state.

As soon as the baggage handling system is operating at low capacity, for example at night, enable the SYNCUP system state. To do so, call the "RH_CTRL" instruction with block parameter MODE = 4 in the user program.

The redundant system does not run a SYNCUP. The redundant system then switches to the RUN-Redundant system state. Now disable SYNCUP again by calling the "RH_CTRL" instruction in the user program with the block parameter MODE = 3.

Reference

You can find additional information on the "RH_CTRL" instruction in the STEP 7 online help.

You can find more information on SYNCUP in the section SYNCUP system state (Page 205).

7.4.2 Determining the primary CPU with "RH_GetPrimaryID"

You use the "RH_GetPrimaryID" instruction to read out which CPU is currently the primary CPU. The instruction outputs the redundancy ID of the primary CPU at the Ret_Val block parameter.
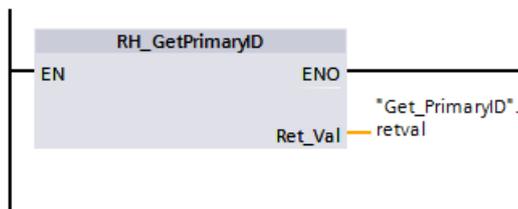
Figure 7-4   "RH_GetPrimaryID" instruction

Example: Reading maintenance information from the SIMATIC memory card of the primary CPU

Proceed as follows to read specific maintenance information from the SIMATIC memory card of the primary CPU:

1. Get the redundancy ID of the primary CPU with "RH_GetPrimaryID".

2. Read the maintenance information from the SIMATIC memory card of the primary CPU with "GetSMCInfo".

   – If the CPU with redundancy ID 1 is the primary CPU, enter "12" at the Mode block parameter ("1" for redundancy ID, "2" for maintenance information).

   – If the CPU with redundancy ID 2 is the primary CPU, enter "22" at the Mode block parameter ("2" for redundancy ID, "2" for maintenance information).

Reference

You can find more information on the "RH_GetPrimaryID" instruction in the STEP 7 online help.

7.5   Asynchronous instructions

Introduction

During program execution a distinction is made between synchronous and asynchronous instructions.

The "synchronous" and "asynchronous" properties relate to the temporal relationship between the call and execution of the instruction.

The following applies to synchronous instructions: When the call of a synchronous instruction is complete, execution of the instruction is also complete.

This is different in the case of asynchronous instructions: When the call of an asynchronous instruction is complete, execution of the asynchronous instruction is not necessarily complete yet. This means the execution of an asynchronous instruction can extend over multiple calls. The CPU processes asynchronous instructions in parallel with the cyclic user program. Asynchronous instructions generate jobs in the CPU for their processing.

Asynchronous instructions are usually instructions for transferring data (for example data records for modules, communication data, diagnostics data).

Difference between synchronous/asynchronous instructions

The figure below shows the difference between the processing of an asynchronous instruction and a synchronous instruction. In the figure below, an asynchronous instruction is called in five cycles before execution is completed, for example, a data record is transferred in full.

① First call of the asynchronous instruction, start of execution
② Intermediate call of the asynchronous instruction, execution continues
③ Last call of the asynchronous instruction, completion of execution
④ A job is fully processed by a synchronous instruction with each call.
➡ Duration of a fully executed job
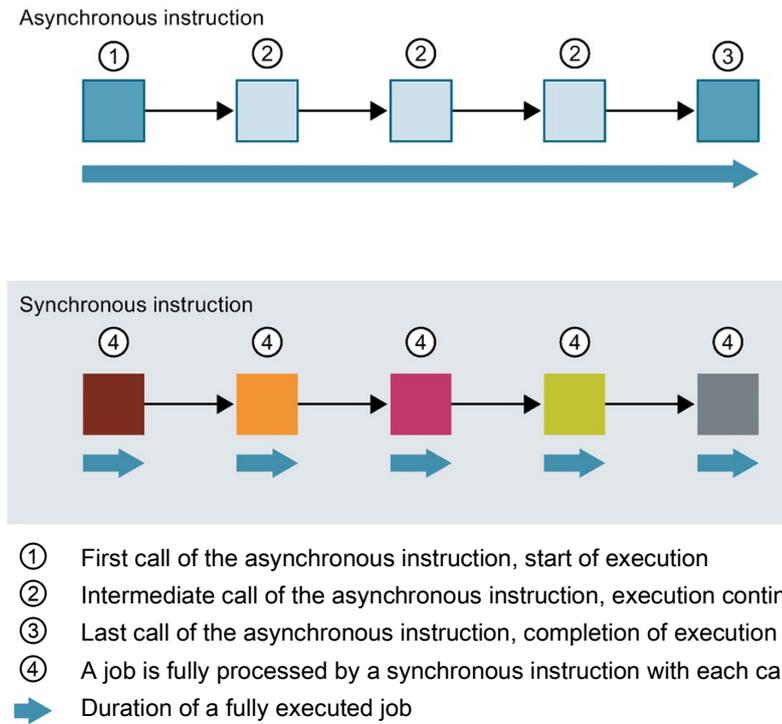
Figure 7-5   Difference between asynchronous and synchronous instructions

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Note

Processing of an asynchronous instruction during the SYNCUP system state

If the S7-1500R/H redundant system executes SYNCUP, this extends the processing time for an asynchronous instruction.

Recommendation: Always access asynchronous instructions in the cyclic user program of the S7-1500R/H redundant system, for example in OB 1.

Parallel processing of asynchronous instruction jobs

A CPU can process several asynchronous instruction jobs in parallel. The CPU processes the jobs in parallel under the following conditions:

- Jobs for an asynchronous instruction are started while other jobs for that instruction are still running.

- The maximum number of simultaneously running jobs for the instruction is not exceeded.

The figure below shows the parallel processing of two jobs of the WRREC instruction. The two instructions are executed simultaneously for a certain duration.
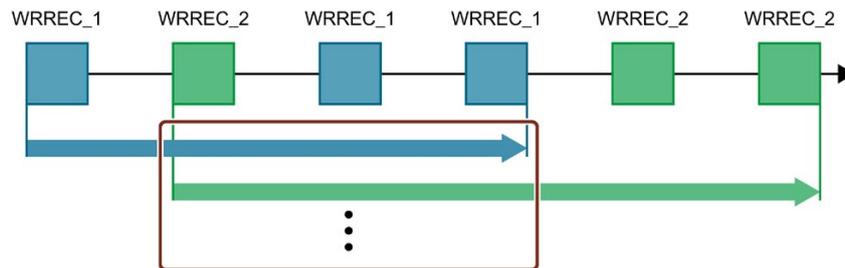
Figure 7-6   Parallel processing of the asynchronous instruction WRREC

Assigning calls of an instruction to a job

To execute an instruction over multiple calls, the CPU must be able to uniquely relate a subsequent call to a running job of the instruction.

To relate a call to a job, the CPU uses one of the following two mechanisms, depending on the type of the instruction:

- Using the instance data block of the instruction (for "SFB" type)

- Using the input parameters of the instruction that identify the job. These input parameters must match in each call during processing of the asynchronous instruction.
  Example: The instruction "RD_DPARA" is identified by LADDR and RECNUM.

Status of an asynchronous instruction

An asynchronous instruction shows its status via the block parameters STATUS/RET_VAL and BUSY. Many asynchronous instructions also use the block parameters DONE and ERROR.

The figure below shows the two asynchronous instructions WRREC and RD_DPARA.
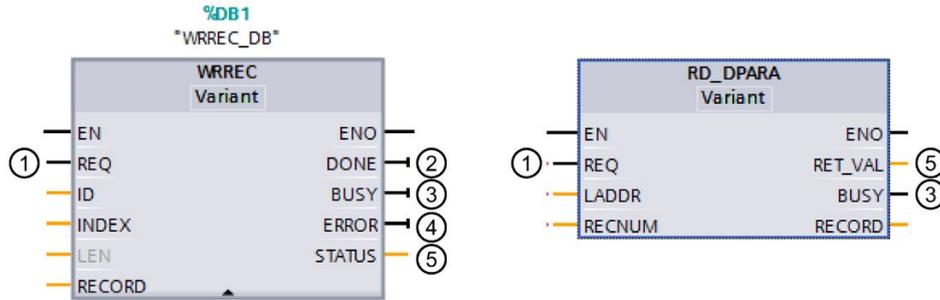
① The input parameter REQ starts the job to execute the asynchronous instruction.

② The output parameter DONE indicates that the job was completed without error.

③ The output parameter BUSY indicates whether the job is currently being executed. When BUSY=1, a resource is allocated for the asynchronous instruction. When BUSY= 0, the resource is free.

④ The output parameter ERROR indicates that an error has occurred.

⑤ The output parameter STATUS/RET_VAL provides information on the status of the job execution. The output parameter STATUS/RET_VAL receives the error information after the occurrence of an error.

Figure 7-7   Block parameters of asynchronous instructions using the instructions WRREC and RD_DPARA as examples.

Summary

The table below provides you with an overview of the relationships described above. It shows in particular the possible values of the output parameters if execution of the instruction is not complete after a call.

Note

You must evaluate the relevant output parameters in your program after each call

---

Table 7- 5   Relationship between REQ, STATUS/RET_VAL, BUSY and DONE during a "running" job.

Seq. no. of the call	Type of call	REQ	STATUS/RET_VAL	BUSY	DONE	ERROR
1	First call	1	W#16#7001	1	0	0
			Error code (e.g. W#16#80C3 for lack of resources)	0	0	1
2 to (n - 1)	Intermediate call	Not relevant	W#16#7002	1	0	0
n	Last call	Not relevant	W#16#0000, if no errors have occurred.	0	1	0
			Error code if errors occurred.	0	0	1

Use of resources

Asynchronous instructions use resources in the CPU during their execution. The resources are limited depending on the type of CPU and instruction. The CPU can only simultaneously process a set maximum number of asynchronous instruction jobs. The resources are available again after a job has been processed successfully or with errors.

Example: For the RDREC instruction, an S7-1500R/H CPU can process up to 20 jobs in parallel.

If the maximum number of simultaneous jobs for an instruction is exceeded, the following occurs if another job is started:

- The job is not executed. The ERROR output parameter returns a value of 1.

- The STATUS block parameter returns the error code W#16#80C3 (lack of resources).

Note

Lower-level asynchronous instructions

Some asynchronous instructions use one or more lower-level asynchronous instructions for their processing. This dependence is shown in the tables below.

Please note that each lower-level instruction typically occupies one resource in the instruction's resource pool.

Extended instructions: maximum number of simultaneously running jobs

Table 7- 6   Maximum number of simultaneous jobs for asynchronous extended instructions and low-er-level instructions used

Extended instructions	1513R-1 PN	1515R-2 PN	1517H-3 PN
Distributed I/O			
RDREC	20		
WRREC	20		
ASI_CTRL	uses RDREC, WRREC		
PROFIenergy			
PE_START_END	uses RDREC, WRREC		
PE_CMD	uses RDREC, WRREC		
PE_DS3_Write_ET200 S	uses RDREC, WRREC		
PE_WOL	uses RDREC, WRREC, TUSEND, TURCV, TCON, TDISCON		
Module parameter assignment			
RD_DPAR	10		
RD_DPARA	10		
RD_DPARM	10		
Diagnostics			
Get_IM_Data	10		

Communication: maximum number of simultaneously running jobs

Table 7- 7   Maximum number of simultaneous jobs for asynchronous instructions and lower-level in-
structions used for Open User Communication

Open User Communi-cation	1513R-1 PN	1515R-2 PN	1517H-3 PN
TSEND TUSEND	128	192	320
TRCV TURCV	128	192	320
TCON	128	192	320
TDISCON	128	192	320
T_RESET	128	192	320
T_DIAG	128	192	320
TSEND_C	uses TSEND, TUSEND, TRCV, TCON, TDISCON		
TRCV_C	uses TSEND, TUSEND, TRCV, TURCV, TCON, TDISCON		

Table 7- 8   Lower-level instructions used for asynchronous instructions for MODBUS TCP

MODBUS TCP	1513R-1 PN	1515R-2 PN	1517H-3 PN
MB_CLIENT	uses TSEND, TUSEND, TRCV, TURCV, TCON, TDISCON		
MB_SERVER	uses TSEND, TUSEND, TRCV, TURCV, TCON, TDISCON		

Table 7- 9   Lower-level instructions used for asynchronous instructions for communications proces-
sors

Communications pro-cessors	1513R-1 PN	1515R-2 PN	1517H-3 PN
PtP communication			
Port_Config	uses RDDEC, WRREC		
Send_Config	uses RDDEC, WRREC		
Receive_Config	uses RDDEC, WRREC		
Send_P2P	uses RDDEC, WRREC		
Receive_P2P	uses RDDEC, WRREC		
Receive_Reset	uses RDDEC, WRREC		
Signal_Get	uses RDDEC, WRREC		
Signal_Set	uses RDDEC, WRREC		
Get_Features	uses RDDEC, WRREC		
Set_Features	uses RDDEC, WRREC		
USS communication			
USS_Port_Scan	uses RDDEC, WRREC		
MODBUS (RTU)			
Modbus_Comm_Load	uses RDDEC, WRREC		

Reference

You can find additional information on block parameter assignment in the STEP 7 online
help.

Protection

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8.1 Overview of the protection functions

Introduction

This section describes the functions for protection from unauthorized access:

- Access protection
- Know-how protection
- Protection by locking the CPUs

Other CPU protective measures

The following measures provide extra protection against unauthorized access from external sources and through the network:

- Do not activate time-of-day synchronization over NTP servers.
- Do not activate PUT/GET communication.

8.2 Configuring access protection for the CPU

Introduction

The S7-1500R/H redundant system has four different access levels to limit access to specific functions.

By setting up access levels and passwords, you limit the functions and memory areas that are accessible without a password. The individual access levels and corresponding passwords are specified in the object properties of the CPUs.

Rules for passwords

Ensure that passwords are sufficiently secure. Passwords must not follow a machine-recognizable pattern.
Apply the following rules:

- Assign a password that is at least 8 characters long.
- Use different cases and characters: uppercase/lowercase, numbers and special characters.

Access levels for the CPUs

Table 8- 1   Access levels and access restrictions

Access levels	Access restrictions
Full access (no protection)	Every user can read and change the hardware configuration and the blocks.
Read access	In this access level, only read access to the hardware configuration and the blocks is possible without a password. HMI access and access to diagnostics data is also possible.
	Neither blocks nor the hardware configuration can be downloaded to the CPUs without the password.
	The following actions are **not** possible without the password either: Writing test functions and firmware updates (online).
HMI access	The same access restrictions apply to HMI access as to read access.
	The following actions are **not** possible without the password either: Change of operating state (RUN/STOP) and display of online/offline comparison status.
No access (complete protection)	When the CPUs have complete protection, no read or write access to the hardware configuration or blocks is possible (without access authorization in the form of a password). HMI access is not possible either.
	Authentication with the correct password provides full access to the CPUs again.

Reference

You can find a list of which functions are possible in the various protection levels in the STEP 7 online help under "Setting options for protection".

Properties of the access levels

Each access level allows unrestricted access to certain functions without a password, for example identification using the "Accessible devices" function.

The default setting of the CPUs is "No restriction" and "No password protection". In order to protect access to the CPUs, you need to edit the properties of the CPUs and set up a password. In the default access level "Full access (no protection)", every user can read and change the hardware configuration and the blocks. No password is configured, and no password is required for online access.

Communication between the CPUs via the communication functions in the blocks is not restricted by the access level of the CPUs.

Entering the correct password enables access to all the functions that are allowed in the given level.

Note

Configuring an access level does not replace know-how protection

Configuring access levels offers a high degree of protection against unauthorized changes to the CPU through network access. Access levels restrict the rights to download the hardware and software configuration to the CPUs. However, blocks on the SIMATIC memory card are not write-protected or read-protected. Use know-how protection to protect the code of blocks on the SIMATIC memory card.

Behavior of functions in different access levels

The STEP 7 online help includes a table listing the online functions available in the various access levels.

Configuring access levels

Proceed as follows to configure the access levels for the CPUs:

1. Open the properties of the CPUs in the Inspector window.

2. Open "Protection & Security" in the area navigation.

   A table with the possible access levels appears in the Inspector window.
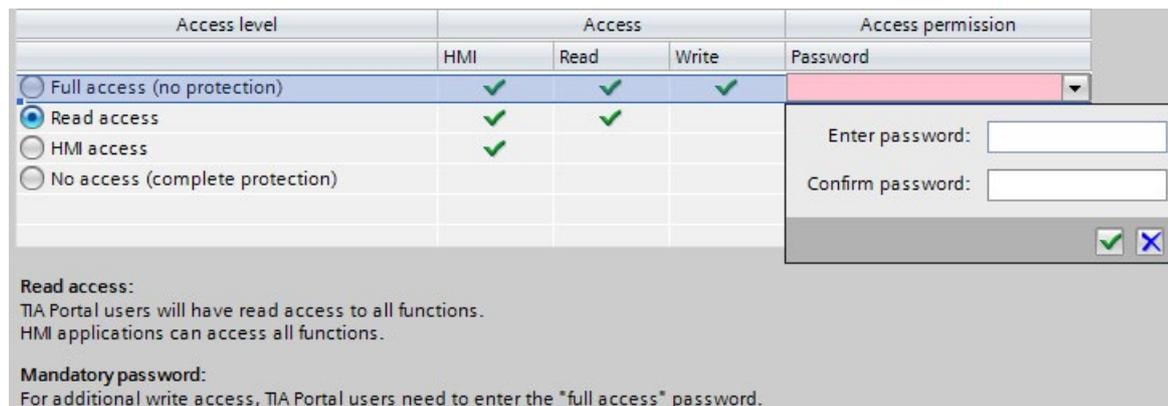
Figure 8-1   Possible access levels

3. Activate the required protection level in the first column of the table. The green check marks in the columns to the right of the access level show which operations are still possible without entering the password. In the example (Figure: Possible access levels), read access and HMI access are still possible without a password.

4. In the "Enter password" column, specify a password for the access level "Full access" in the first row. In the "Confirm password" column, enter the selected password again to avoid incorrect entries.

5. Assign additional passwords as required for other access levels.

6. Download the hardware configuration for the access level to take effect.

The CPUs log the following actions with an entry in the diagnostics buffer:

● Input of the correct or incorrect password

● Changes to access level configuration

Behavior of a password-protected CPU during operation

CPU protection takes effect for an online connection once settings have been loaded to the CPUs. If you set a higher access level and download it to the CPU, all other online connections will be interrupted. You will then need to establish a new online connection.

Before an online function is executed, the necessary permission is checked and, if necessary, the user is prompted to enter a password. The password only provides access to protected functions for the local PG/PC on which the password is entered.

Access authorization to the protected data applies for the duration of the online connection or for as long as you have STEP 7 open. The menu command "Online > Clear access rights" cancels the access authorization.

You can limit access to a password-protected CPU in RUN locally on the display. This prevents access even with a password.

8.3 Using the display to set additional password protection

Blocking access to a password-protected CPU

You can block access to password-protected CPUs (local password block) on the CPU display. The block is effective if the mode selector is set to RUN.
The access block requires a configured protection level in STEP 7 and applies regardless of password protection. Even if someone accesses the CPUs via a connected PG/PC and has entered the correct password, access to the CPUs is denied.
Set the access block separately for each access level on the display.

The backup CPU takes over the settings during SYNCUP. Changes to the access block for primary CPU or backup CPU in RUN-Redundant system state are handled by the other CPU.

Procedure

If you want to block access to the CPUs via the display, you need to configure an access level with a password in STEP 7.

If you set local access protection for the CPUs on the display, the block applies to both CPUs in the RUN-Redundant system state. Proceed as follows:

1. On the display, select the Settings > Protection menu.

2. Confirm your selection with "OK". For each access level, specify whether or not access in the RUN operating state is allowed:

   – Allow: Access to the CPUs is possible with the right password in STEP 7.

   – Disabled in RUN: If the mode selector is set to RUN, no additional logon to the CPUs is possible with the rights of this access level. Access is denied despite the fact that the user knows the password. Access with the password is enabled again in the STOP operating state.

Access protection for the display

Configure a password for the display in STEP 7 in the properties of the CPU. This protects local access protection with a local password.

8.4 Using the user program to set additional access protection

Access protection with the user program

There is another option in addition to access protection via the display. You can also restrict access to a password-protected CPU using the ENDIS_PW instruction in STEP 7.

You can find more information on this instruction in the STEP 7 online help under "ENDIS_PW: Limit and enable password legitimation".

8.5 Know-how protection

Application

You can use know-how protection to protect one or more OB, FB or FC blocks as well as global data blocks in your program from unauthorized access. Enter a password to restrict access to a block. The password offers high-level protection against unauthorized reading and manipulation of the block. Know-how protection does not involve the CPU (offline access in STEP 7).

Password provider

As an alternative to manual password input, you can assign a password provider to STEP 7. When using a password provider, you select a password from a list of available passwords. When a protected block is opened, STEP 7 connects to the password provider and retrieves the corresponding password.

You need to install and activate a password provider before you can connect it. A settings file in which you define the use of a password provider is also required.

A password provider offers the following advantages:

● The password provider defines and manages the passwords. When know-how protected blocks are opened, you work with symbolic names for passwords. For example, a password is marked with the symbolic name "Machine_1" n the password provider. The actual password behind "Machine1" is disclosed to you.
A password provider therefore offers optimum block protection as the users do not know the password themselves.

● STEP 7 automatically opens know-how protected blocks without the direct entry of a password. This saves you time.

You can find more information on connecting a password provider in the STEP 7 online help.

Readable data

If a block is know-how protected, only the following data is readable without the correct password:

● Block title, comments and block properties

● Block parameters (INPUT, OUTPUT, IN, OUT, RETURN)

● Call structure of the program

● Global tags without information on the point of use

Further actions

Further actions that can be carried out with a know-how protected block:

- Copying and deleting
- Calling in a program
- Online/offline comparison
- Loading

Global data blocks and array data blocks

You protect global data blocks (global DBs) from unauthorized access with know-how protection. If you do not have the valid password, you can read the global data block but not change it.

Know-how protection is not available for array data blocks (array DBs).

Setting up block know-how protection

Proceed as follows to set up block know-how protection:

1. Open the properties of the block in question.
2. Select the "Protection" option under "General".
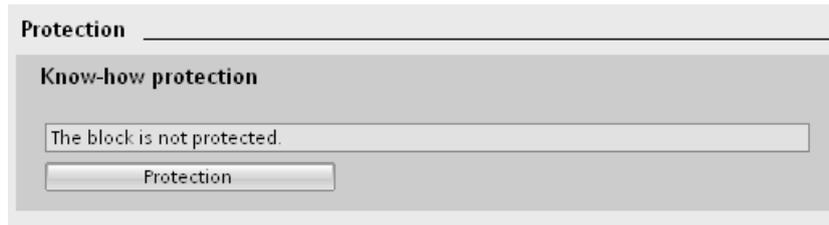
Figure 8-2   Setting up block know-how protection

3. Click the "Protection" button to display the "Define password" dialog.

Figure 8-3   Select password

4. Enter the new password in the "New password" box. Enter the same password in the "Confirm password" box.

5. Click "OK" to confirm your entry.

6. Close the "Know-how protection" dialog by clicking "OK".

Result: The blocks selected are know-how-protected. Know-how protected blocks are marked with a padlock in the project tree. The password entered applies to all blocks selected.

Note

Password provider

Alternatively, you can set up know-how protection for blocks with a password provider.

Opening know-how protected blocks

Proceed as follows to open a know-how protected block:

1. Double-click on the block to open the "Access protection" dialog.

2. Enter the password for the know-how protected block.

3. Click "OK" to confirm your entry.

Result: The know-how-protected block opens.

After opening the block you can edit the program code and the block interface of the block until you close the block or STEP 7. You need to enter the password again the next time you open the block. If you close the "Access protection" dialog with "Cancel", the block will open but the block code will not be displayed. You will not be able to edit the block.

If you copy the block or add it to a library, for example, this does not cancel the know-how protection of the block. The copies will also be know-how-protected.

Changing block know-how protection

Proceed as follows to change block know-how protection:

1. Select the block for which you want to change know-how protection. The protected block must not be open in the program editor.

2. In the "Edit" menu, select the "Know-how protection" command to open the "Change protection" dialog.

3. To change the password for know-how protection, enter the current password under "Old password".

4. Now enter a new password under "New password" and confirm the password under "Confirm password".

5. Click "OK" to confirm your entry.

Result: The password for know-how protection of the selected block has been changed.

Removing block know-how protection

Proceed as follows to remove block know-how protection:

1. Select the block from which you want to remove know-how protection. The protected block must not be open in the program editor.

2. In the "Edit" menu, select the "Know-how protection" command to open the "Change protection" dialog.

Figure 8-4   Removing know-how protection

3. To remove block protection, enter the current password under "Old password". Leave the fields for the new password blank.

4. Click "Remove" to confirm your entry.

Result: Know-how protection for the selected block has been canceled.

8.6 Protection by locking the CPU

Locking options

Provide additional protection for your CPUs from unauthorized access (for example to the SIMATIC memory card) by using a secure front cover.

You have the following options, for example:

- Attach a seal
- Secure the front cover with a lock (shackle diameter: 3 mm)
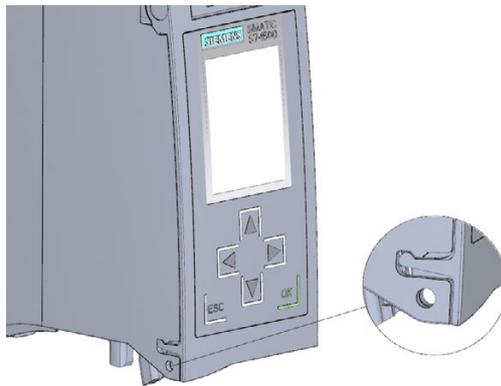
Figure 8-5   Locking latch on a CPU

Commissioning 9

9.1 Overview

Introduction

This section includes information on the following topics:

- Check before powering on for the first time
- Commissioning procedure
- Removing/inserting the SIMATIC Memory Cards
- First power-on of the CPUs
- CPU pairing
- Assigning redundancy IDs
- Downloading projects to the CPUs
- Operating and system states
- CPU memory resets
- Backing up and restoring the configuration
- Time synchronization
- Identification and maintenance data

Commissioning requirements

Note

Performing tests

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

Also allow for any possible foreseeable errors in the tests. This prevents you from putting persons or equipment at risk during operation.

Software tools for commissioning

SIEMENS PRONETA provides commissioning support. You can find more information on SIEMENS PRONETA in the section Software (Page 47).

9.2 Check before powering on for the first time

Before the first power-on, check the installation and the wiring of the S7-1500R/H redundant system.

Questions for checking

The following questions provide instructions for checking your system in the form of a checklist.

Rack

- Are the mounting rails firmly mounted to the wall, in the frame, or in the cabinet?
- Are the cable ducts correctly installed?
- Have the minimum clearances been observed?

Grounding concept

- Are the mounting rails connected to the protective conductors?
- If applicable, are all further protective conductor connection points on the S7-1500R/H redundant system connected to the protective conductor? Has the protective conductor been tested?
- Are the required equipotential bonding cables connected with low impedance to the relevant sections of the plant?

Module installation and wiring

- Are all the modules inserted / installed in accordance with the installation plan and configuration with STEP 7 and screwed firmly to the mounting rails?
- Have all synchronization modules been installed and locked in the S7-1500H redundant system? You should hear the modules click into place in the module slots.
- Are all redundancy connection connectors in the S7-1500H redundant system correctly connected to the LC sockets? You should hear the connectors click into place in the LC sockets.
- Are the redundancy connections (PROFINET cable) between the CPUs in the S7-1500R redundant system connected to the correct ports of PROFINET interface X1? The ports used must correspond to the configuration in STEP 7.
- Are the PROFINET devices in the S7-1500R/H redundant system connected as a PROFINET ring?

System power supply or load power supply

- Are all system power supplies and load power supplies switched off?
- Is the power cable connector correctly wired?
- Has the connection to line voltage been established?

9.3 Commissioning procedure

Requirements

- The CPUs are in the "Factory settings" state or have been reset to factory settings. You can find more information in the section Resetting CPUs to factory settings (Page 277).

- The CPUs have the same or compatible article numbers.

- The SIMATIC memory cards are as delivered or have been formatted and are not write-protected.

- The two CPUs of the S7-1500R/H redundant system have the same function and firmware version. You can find more information in the section Firmware update (Page 272).

Commissioning procedure

To commission the S7-1500R/H redundant system, we recommend the following procedure:

Table 9- 1   Procedure for commissioning SIMATIC S7-1500R/H

Step	Procedure	Further information
1	Configure hardware in STEP 7	Section Configuration (Page 136)
2	Create user program	Section Programming the S7-1500R/H (Page 148) and STEP 7 online help
3	Insert required modules	Section Installation (Page 96)
4	Wire configuration (supply voltage, PROFINET ring, redundancy connections)	Section Wiring (Page 108)
5	Insert SIMATIC memory cards in the CPUs	Section Removing/plugging in SIMATIC memory cards (Page 181)
6	Switch on CPUs and system power supply	Section First power-on of the CPUs (Page 184)
7	CPU pairing	Section CPU pairing (Page 184)
8	Assign CPUs redundancy IDs	Section Redundancy IDs (Page 187)
9	Check LEDs	You can find the meaning of the LEDs in the module manuals.
10	Evaluate information on the CPU displays	Section CPU display (Page 248)
11	Load hardware configuration and user program to the CPUs	Section Downloading projects to the CPUs (Page 192)
12	Test inputs and outputs	The following functions are helpful: Monitoring and modifying tags, testing with program status, forcing, and controlling outputs in STOP. You can find more information in the section Test functions (Page 282).

9.3.1   Removing/plugging in SIMATIC memory cards

Requirements

For the S7-1500R/H redundant system, you need a SIMATIC memory card for each of the two CPUs.

The CPUs only support pre-formatted SIMATIC memory cards. If required, format the SIMATIC memory cards before using them in the CPU.

You can find more information on formatting SIMATIC memory cards in the function manual Structure and use of the CPU memory (https://support.industry.siemens.com/cs/ww/en/view/59193101).

Make sure that the SIMATIC memory cards of the two CPUs are not write-protected.

Inserting SIMATIC memory cards

Proceed as follows to insert a SIMATIC memory card:

1. Open the front cover of the CPU.

2. Make sure that the CPU is either switched off or in STOP operating state.

3. Insert the SIMATIC memory card, as shown on the CPU, into the slot for the SIMATIC memory card.
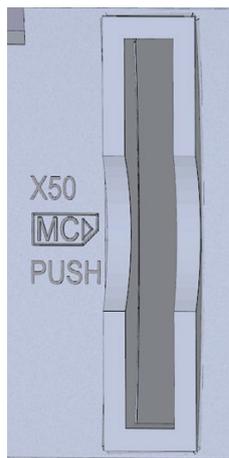
Figure 9-1   Slot for the SIMATIC memory card

4. Carefully insert the SIMATIC memory card into the CPU, pushing gently, until the card clicks into place.

Removing SIMATIC memory cards

Proceed as follows to remove a SIMATIC memory card:

1. Open the front cover.

2. Switch the CPU to STOP.

3. Gently push the SIMATIC memory card into the CPU. Once it has clicked into place, remove the SIMATIC memory card.

Only remove the SIMATIC memory card in the POWER OFF or STOP state of the CPU. Ensure that:

- No writing functions are active in STOP. Writing functions are online functions with the PG/PC, for example loading/deleting a block and test functions.

- No writing functions were active before POWER OFF

If you remove the SIMATIC memory card during a write process, the following problems can occur:

- The data contents of a file are incomplete.

- The file is no longer readable, or no longer exists.

- The entire content of the card is corrupted.

Please also note the following FAQs on the Internet (https://support.industry.siemens.com/cs/ww/en/view/59457183) for removal of the SIMATIC memory card.

Note

If you switch a CPU in redundant mode to the STOP operating state, the S7-1500R/H redundant system switches to the RUN-Solo system state. The other CPU maintains control of the process.

CPU response after a SIMATIC memory card is removed or inserted

Inserting or removing the SIMATIC memory card in STOP operating state triggers a re-evaluation of the SIMATIC memory card. The CPU compares the content of the configuration on the SIMATIC memory card with the backed-up retentive data. If the backed-up retentive data matches the data of the configuration on the SIMATIC memory card, the retentive data is retained. If the data differs, the CPU automatically performs a memory reset. A memory reset deletes the retentive data on the CPU. After memory reset, the CPU switches to STOP. You can find more information on memory resets in the section CPU memory reset (Page 231).

The CPU evaluates the SIMATIC memory card. This process is indicated by the RUN/STOP LED flashing.

Note

Using the SIMATIC memory card as a firmware update card

If you use the SIMATIC memory card as a firmware update card, removing and inserting the card will not result in the loss of retentive data.

Reference

You can find more information on the SIMATIC memory card in the function manual Structure and use of the CPU memory (https://support.industry.siemens.com/cs/ww/en/view/59193101).

9.3.2 First power-on of the CPUs

Requirements

- The SIMATIC S7-1500R/H redundant system has been installed.
- The system has been wired.
- The SIMATIC memory cards are in the CPUs.

Procedure

Proceed as follows to commission the CPUs:

1. Switch on the system power supply and load power supply.

Result:

- The CPUs run a flash test:
    - All LEDs flash at 2 Hz
    - RUN/STOP LED flashes alternately yellow/green
    - ERROR LED flashes red
    - MAINT LED flashes yellow
- The CPUs run system initialization and evaluate the SIMATIC memory cards:
    - RUN/STOP LED flashes yellow at 2 Hz
- When system initialization is complete, the CPUs switch to STOP:
    - The RUN/STOP LED lights up yellow

9.3.3 CPU pairing

Introduction

Pairing is the mutual recognition of the two CPUs within a network. During pairing, the CPUs exchange information for mutual identification. Example: Checking for matching article number and firmware version.

Successful pairing of two CPUs is a fundamental requirement for redundant operation.

Requirement

For successful pairing, the CPUs must have the same firmware version and the same or compatible article numbers.

An inadmissible version prevents the pairing of two CPUs, for example more than two R-CPUs in the PROFINET ring. Pairing errors are reported in the diagnostics buffer.

Pairing procedure

Proceed as follows to pair two CPUs

1. Create a redundancy connection between two CPUs. Connect the CPUs to the relevant ports of the interfaces (for example for R-CPUs: X1 P2 R).

2. POWER ON both CPUs.

Loss of pairing

If pairing is already established, an inadmissible configuration version will lead to the loss of pairing. Loss of pairing in RUN system state also causes the loss of synchronization between primary CPU and backup CPU. The system switches to the RUN-Solo system state.

The primary CPU switches to the RUN operating state and takes on sole control of the process. The backup CPU switches to the STOP operating state.

In the event of the loss of pairing as a result of the failure of the primary CPU, the backup CPU becomes the new primary CPU and takes on sole control of the process.

Note

An invalid configuration variant with more than two R/H CPUs can lead to a faulty system state. Both R/H CPUs become primary CPUs.

Checking pairing state

You can find out how to check the success of pairing on the display and in STEP 7 in the section Checking before replacing components (Page 257).

Checking pairing in the RUN-Solo system state

Please observe the following rules if the redundant system is in the RUN-Solo system state:

- Do not immediately start replacing components.
- Do not immediately switch the failed CPU to the RUN. operating state.

First check the pairing status in the RUN-Solo system state.

> ⚠ **CAUTION**
>
> **Do not switch the failed CPU in the RUN-Solo system state to the RUN operating state.**
>
> This could result in an undefined system state for the redundant system. Both CPUs would become primary CPUs.
>
> If the S7-1500R/H redundant system is in the RUN-Solo system state, you must not immediately switch the backup CPU to the RUN operating state.
>
> Possible cause: No pairing between the two CPUs. Check the pairing status on the display or on the basis of the diagnostics status or diagnostics buffer.
>
> If there is no pairing, the redundancy connections have been interrupted. Follow the procedure described in the section Checking before replacing components (Page 257).

Primary and backup CPU role assignment

The primary CPU and backup CPU roles are assigned by the S7-1500R/H redundant system during pairing.

The redundant system compares the following criteria of the two SIMATIC memory cards and prioritizes the assignment of roles:

● SIMATIC memory card contains a STEP 7 project
 → High priority

● SIMATIC memory card is empty and writable
 → Medium priority

● SIMATIC memory card:

 – missing or

 – inserted, is empty or is not writable

 → Low priority

Result:

If the two R/H CPUs have different priorities, the CPU with the higher priority becomes the primary CPU.

If the priorities are identical, the R/H CPU with the lower CPU serial number becomes the primary CPU (see nameplate on the CPU or on the CPU display).

Note

If an R/H CPU is in RUN mode, the assigned role does not change when pairing again.

9.3.4 Redundancy IDs

Introduction

For redundant operation, the two CPUs in the redundant system must process identical project data. In SYNCUP, the operating system copies the content of the SIMATIC memory card from the primary CPU to the backup CPU.

The load memories contain the project data of both CPUs. This duplication of the project data is necessary for ensuring redundant operation. By assigning the redundancy IDs, you define which project data a CPU uses for itself.

Redundancy IDs 1 and 2

Redundant operation is only possible if the two CPUs have different redundancy IDs. The redundancy IDs can have values of 1 and 2. The CPUs save the redundancy IDs in their retentive data areas.

Both CPUs have redundancy ID 1 in the following cases:

- Default setting upon initial commissioning
- After reset to factory settings

In the STEP 7 project tree, each of the two CPUS is displayed with its own tree. The redundancy ID is used to assign a project tree to the real CPU in STEP 7. The upper CPU of the two CPUs in the project tree always has a redundancy ID of 1. The lower CPU of the two always has a redundancy ID of 2.

Diagnostics displays are assigned to the real CPUs in the project tree in the same way.
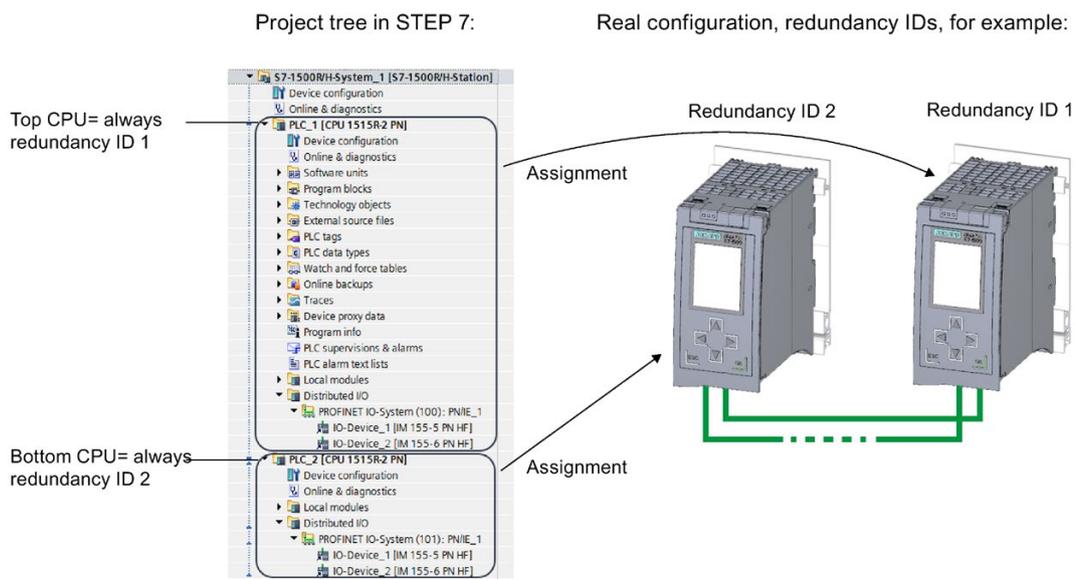
Figure 9-2   Assignment of the redundancy IDs between project tree and real configuration

Assigning redundancy IDs to CPUs in the configuration

Requirement: The CPUs have the same firmware version and the same or compatible article numbers.

You have the following options for assigning different redundancy IDs to the CPUs:

- Automatic assignment
- Assignment using the display

Automatic assignment

Requirement:

Both real CPUs of the redundant system have the same redundancy ID (e.g."1").

Options for automatic assignment:

- Both CPUs are in STOP. There is pairing between the two CPUs. The ERROR LEDs are flashing red.

  Procedure: Switch the left-hand CPU in the configuration to the RUN operating state. Result: The right-hand CPU in the configuration changes its redundancy ID.

- The left-hand CPU in the configuration is in RUN operating state. The right-hand CPU in the configuration is in STOP. There is no pairing between the two CPUs.

  Procedure: Implement pairing between the two CPUs. Result: The right-hand CPU in the configuration changes its redundancy ID.

- The left-hand CPU in the configuration is in RUN. The right-hand CPU in the configuration is in POWER OFF. There is no pairing between the two CPUs.

  Procedure: POWER ON the right-hand CPU in the configuration. Result: The right-hand CPU in the configuration changes its redundancy ID.

Assignment using the display

Requirements:

The two real CPUs in the redundant system:

- Are connected to each other
- Have a redundancy ID of 1
- Are in the STOP operating state

Procedure:

Proceed as follows to assign the redundancy IDs via the CPU display:

1. Turn on the CPU to which you want to assign redundancy ID 2.

2. On the display of that CPU, select the menu command "Overview > Redundancy". Assign the CPU redundancy ID 2.
   Once you have assigned the CPU redundancy ID 2, the CPU will automatically restart.

3. Download the project and the hardware configuration to the CPU that you want to switch to RUN first.

Figure 9-3   Assigning redundancy IDs

Reading redundancy IDs from the display

As well as assigning redundancy IDs over the display, you can read out the redundancy ID with the menu command "Overview > Redundancy". The display always shows the redundancy ID of the CPU on whose display you query the redundancy ID.

Switching redundancy IDs over the display

After each of the CPUs has its own redundancy ID, you want to the switch the redundancy IDs of the CPUs.

Switching redundancy IDs can, for example, be useful in the following situations:

- You only have access to one of the two CPUs.

- You have incorrectly assigned the redundancy IDs.

Note

Switching the redundancy IDs switches the assignment of the real CPUs to the project trees in the project navigation.

If the two CPUs contain the same project, switching the redundancy IDs switches all configured properties between the CPUs. These include, for example, the IP addresses of the PROFINET interfaces, the device names and the configured topology.

On the display, you can exchange on only one CPU the redundancy IDs already assigned for both CPUs.

Proceed as follows to switch the redundancy IDs:

1. Make sure that both CPUs are in STOP operating state:

2. Make sure that the two CPUs are connected to each other.

3. Change the redundancy ID of a CPU using the display.

Result: Once the redundancy ID has been changed on one CPU, both CPUs restart and each now has the redundancy ID of the other.

Incompatible assignment of redundancy IDs

There is pairing between the two CPUs. You can find more information in the section CPU pairing (Page 184).
In the following case, the system automatically checks the compatibility of the redundancy IDs:

- Both CPUs are in STOP operating state and they have the same redundancy ID.

If the same redundancy ID has been assigned to both CPUs, the ERROR LEDs on both CPUs flash in red. Each CPU display indicates an assignment conflict. The CPUs generate an entry in the diagnostics buffer. You can read the entry on the display, for example.

To establish redundant mode, resolve the assignment conflict in one of the following ways:

- Assign a different redundancy ID to one CPU using the display.

- Switch the CPU that is to retain its assigned redundancy ID to the RUN operating state.

Behavior of the CPUs when redundancy IDs are changed

Please note that you can only change the redundancy ID of a CPU in STOP operating state. After each successful change of a redundancy ID, the CPU in question automatically restarts.

9.3.5 Downloading projects to the CPUs

Introduction

You need to download the project data to the CPU. Download either offline using the SIMATIC memory card or over an online connection from the PG/PC/HMI device to a CPU. The complete project data (all configuration data and the complete user program) can only be downloaded when a CPU is in STOP operating state.

Note

Simultaneous online access to both CPUs

It is not possible to access both CPUs simultaneously online from STEP 7. You can access either the primary CPU or the backup CPU.

Options for downloading

You have the following options for downloading project data to the S7-1500R/H redundant system:

In the STOP system state, download:

- The complete project data to the primary CPU
- The complete project data to the backup CPU

In the RUN-Solo system state, download:

- The user program to the primary CPU
- The complete project data to the backup CPU

If you select the S7-1500R/H system in the project tree in STEP 7 and run "Download to device", the operating system downloads the project data by default to the primary CPU. In the SYNCUP system state, the project data is then transferred from the primary CPU to the backup CPU.

Downloading project data to the CPU

By default, the project data is downloaded to the primary CPU. Proceed as follows:

1. Right-click to select the S7-1500R/H system in the project tree.

2. Select the "Download to device" > "Hardware and software (changes only)" command from the shortcut menu.

The "Extended download" dialog window shows the addresses of the configured CPUs in the "Configured access nodes of..." table.

1. Select the subnet from the "Type of the PG/PC interface" drop-down lists.

2. Select the adapter at the "PG/PC interface".

3. Select the interface to which the PG/PC is connected from the "Connection to interface/subnet" drop-down list. Alternatively, select the entry "Try all interfaces".

4. Then click on the "Start search" button.

Type of the PG/PC interface:	🖳 PN/IE	▼		
PG/PC interface:	🖼 Intel(R) Ethernet Connection I217-V	▼	🌐	🔍
Connection to interface/subnet:	Try all interfaces	▼	🌐	
1st gateway:		▼	🌐	

Select target device:			Show all compatible devices	▼
Device	Device type	Interface type	Address	Target device
PLC_1	CPU 1517H-3 PN	PN/IE	192.168.0.1	PLC_1 [Primary]
PLC_2	CPU 1517H-3 PN	PN/IE	192.168.0.2	PLC_2 [Backup]
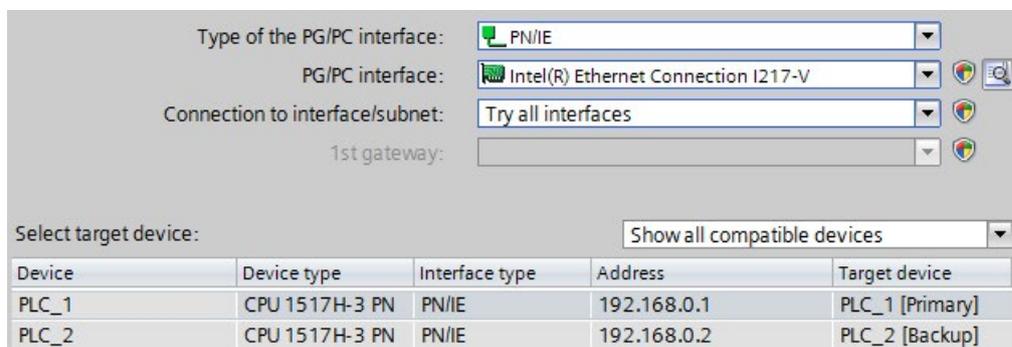
Figure 9-4   "Extended download" dialog window (primary CPU)

The "Select target device" table shows the CPUs in the S7-1500R/H system and their roles. The primary CPU is already selected. Requirement: You have already assigned the IP addresses using the displays of the CPU (for example for commissioning) or over accessible devices in STEP 7.

5. Click "Load".

Note

Remember the redundancy IDs of the CPUs in the configuration:

- The real CPU with redundancy ID 1 uses the project data of the top CPU in the STEP 7 project tree.

- The real CPU with redundancy ID 2 uses the project data of the bottom CPU in the STEP 7 project tree.

You read out the redundancy ID of a CPU over the display with the menu command "Overview > Redundancy". You can find more information on assigning redundancy IDs in the section Redundancy IDs (Page 187).

"Load preview" dialog window

If necessary, the project data is compiled before the download. You can only load project data that is consistent and has been compiled without errors.

The "Load preview" dialog window sets out the key information on the load process to be run:

1. After compilation, check the messages in the "Load preview" dialog window.

2. If the S7-1500R/H system is not in STOP, stop the system. To do so, select "Stop RH system" in the "Action" column of the drop-down menu.

3. Click the "Download" button to start the download.

Starting the CPU after loading

The "Results of loading" dialog window displays the results of the loading process.

⚠ **WARNING**

CPU startup with user program with errors

Before starting the CPU, make sure that a user program with errors:

• Cannot cause damage or injury

• Will not lead to dangerous system states

Requirement: The CPU mode selector is in the RUN position.

1. To start the primary CPU after loading is complete, select "Start module" in the "Action" column.

2. To complete loading, click "Finish".

   Result: The primary CPU switches to the RUN operating state.

3. Switch the backup CPU to the RUN operating state.

   Result: After successful SYNCUP, the S7-1500R/H system switches to redundant mode.

Note

Role change during loading

Beware of a possible role change between primary and backup CPU shortly before, during or after loading.

A role change can occur during loading if the primary CPU fails (power failure, hardware defect) or is in STOP and:

- You switch the backup CPU to RUN operating state during this time using the mode selector, the display or a communication command.

  or

- You POWER ON the backup CPU during this time and the configured startup behavior in STEP 7 is that the CPU automatically switches to RUN after POWER ON.

In the event of a role change, the new primary CPU starts up with the old project data. The new project data in the backup CPU is overwritten with the old project data during synchronization of the two CPUs for redundant operation.

Downloading project data to the backup CPU

By default, the project data is downloaded to the primary CPU. In the SYNCUP system state, the project data is then transferred from the primary CPU to the backup CPU.

You can also download the project data to the backup CPU. This makes sense if the backup CPU is to be primary CPU with its project data upon a restart.

Basic procedure:

1. Download the project data to the backup CPU. The primary CPU continues to control the process.

2. Switch the primary CPU to the STOP operating state after loading.

3. Switch the backup CPU to the RUN operating state. It becomes the new primary CPU and controls the process on its own with the newly loaded user program in the RUN-Solo system state.

4. Switch the new backup CPU to the RUN operating state.

Result: The system state is RUN-Redundant.

Note

Please note the following during download to the backup CPU:

If the project uses retentive data, the backup CPU runs with its data which may be outdated.

Detailed procedure for download to the backup CPU:

1. Right-click to select the S7-1500R/H system in the project tree.

2. Select "Hardware and software (changes only)" under "Download to backup CPU".

The backup CPU is now selected instead of the primary CPU in the "Extended download" dialog window.

Type of the PG/PC interface:	PN/IE		
PG/PC interface:	Intel(R) Ethernet Connection I217-V		
Connection to interface/subnet:	Try all interfaces		
1st gateway:			

Select target device: Show all compatible devices

Device	Device type	Interface type	Address	Target device
PLC_1	CPU 1517H-3 PN	PN/IE	192.168.0.1	PLC_1 [Primary]
PLC_2	CPU 1517H-3 PN	PN/IE	192.168.0.2	PLC_2 [Backup]
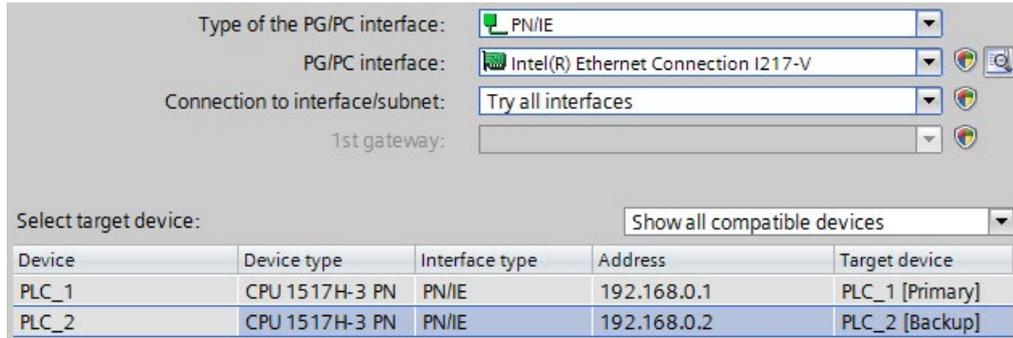
Figure 9-5   "Extended download" dialog window (backup CPU)

Load user program in RUN-Solo system state

The redundant system is in the RUN-Redundant system state. You can download a modified user program to the primary CPU. Advantage: During downloading, the primary CPU maintains control of the process. There is no plant downtime.

Proceed as follows to download the user program in RUN:

1. Switch the backup CPU to the STOP operating state. The S7-1500R/H system switches to RUN-Solo system state.

2. Download the modified user program to the primary CPU with "Download to device" > "Software (changes only)". The primary CPU continues to control the process.

3. Switch the backup CPU to the RUN operating state.

The primary CPU remains in the RUN operating state and synchronizes the modified user program with the backup CPU in SYNCUP.

Result: The S7-1500R/H system switches back to redundant mode with the modified user program.

9.4 Operating and system states

9.4.1 Overview

Operating states

Operating states describe the behavior of an individual CPU at a specific time. Knowledge of the operating states of the CPUs is useful for programming startup, testing and error diagnostics. The status LEDs on the front of the CPU and the CPU display indicate the current operating state.

Like standard S7-1500 CPUs, the S7-1500R/H CPUs have the operating states STOP, STARTUP and RUN. For operation as redundant system, one of the two CPUs can take on an additional operating state, SYNCUP, for synchronizing the two subsystems. The operating state RUN is divided into RUN, RUN-Syncup and RUN-Redundant for redundant systems.

System states

The system states enable the direct assessment of the behavior of a redundant system. They result from the combination of the operating states of the individual CPUs.

Event-controlled synchronization

Event-controlled synchronization ensures that both CPUs in a redundant system can operate redundantly (RUN-Redundant system state).

For all events that could result in different internal subsystem states, the operating system automatically synchronizes the data of the primary and backup CPU.

Primary and backup CPU are, for example, synchronized in the event of:

- Direct access to the IO devices

- Events that interrupt cycle program execution

- Updates to user times, for example S7 timer

- Updates to the process image

- Changes to data through communication functions

- Access to data that could be different on the different CPUs, for example current time, system time, or runtime messages

Synchronization for redundant mode

In the SYNCUP system state, the operating system synchronizes the user programs in the two CPUs for redundant operation.

Synchronization ensures that both CPUs can operate redundantly. In the event of failure of the primary CPU in redundant operation, the backup CPU takes over control of the process as the new primary CPU at the point of interruption.

Requirements for achieving a redundant system state

A redundant system, i.e. the system state "Redundant", is only achieved if:

- The requirements for use of the S7-1500R/H redundant system have been met (see section Application planning (Page 49));

- The two CPUs in the redundant system have recognized each other, i.e. pairing has been successful (see section CPU pairing (Page 184));

- You have commissioned the system as detailed in the section Commissioning procedure (Page 180).

Overview of system and operating states

The figure below shows the possible operating states of the CPUs and the resulting system states.

In general, the two CPUs have equal priority; each CPU can be either primary or backup. The CPU that you switch from STOP to RUN first becomes the primary CPU.
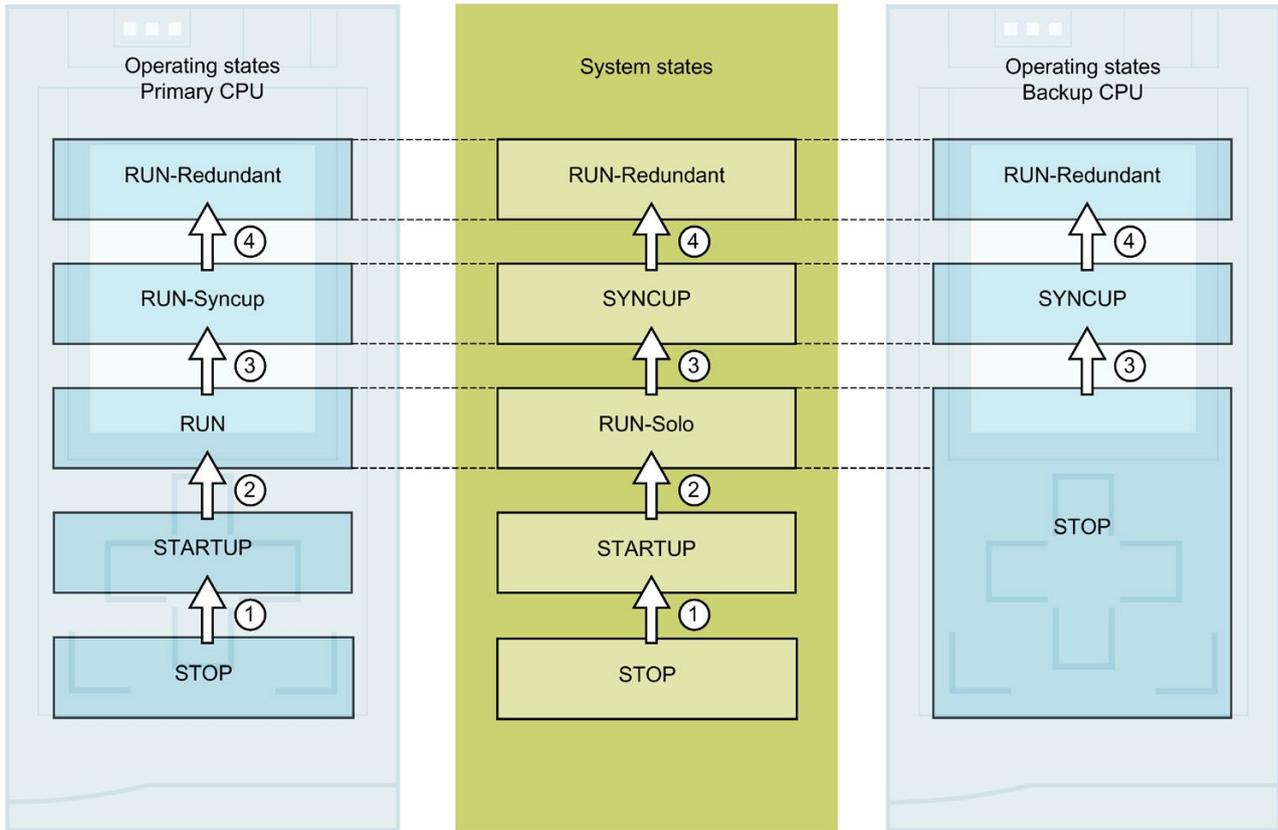
Figure 9-6   System and operating states

The table below gives an overview of how the redundant system starts up as well as the various operating and system states that it goes through in the process. The following initial situation and steps are an example.

The operating and system states are described in detail in the following sections.

Table 9- 2   Redundant system startup

No. in diagram	Primary CPU	System state	Backup CPU
Initial situation: Both CPUs are in STOP operating state. The mode selectors are also in the STOP position.			
Step 1: Switch the mode selector of the CPU that is to be **primary CPU** from STOP to RUN.			
①	The CPU switches to STARTUP and processes startup OB 100 and any other startup OBs.	STOP → STARTUP	The CPU remains in STOP.
②	Following successful STARTUP, the CPU switches to RUN. The CPU runs like a standard CPU in RUN and processes the user program.	STARTUP → RUN-Solo	The CPU remains in STOP.
Step 2: Switch the mode selector on the **backup CPU** from STOP to RUN.			
③	RUN → RUN-Syncup	RUN-Solo → SYNCUP	STOP → SYNCUP
	The two user programs are synchronized for redundant mode. The primary CPU copies the contents of the load and work memory to the backup CPU. The backup CPU catches up with user program processing on the primary CPU. After successful synchronization, the memory content is identical on the two CPUs.		
④	RUN-Syncup → RUN-Redundant	SYNCUP → RUN-Redundant	SYNCUP → RUN-Redundant
	After SYNCUP, both CPUs switch to the RUN-Redundant operating state. Both CPUs process the user program synchronously.		

9.4.2   STARTUP operating state

Startup processing (in the primary CPU only)

STARTUP is only executed by the primary CPU.

In STARTUP, the primary CPU behaves just like an S7-1500 standard CPU.

Response

Before the CPU starts to execute the cyclic user program, a startup program is executed.

In STARTUP, the CPU compares the actual I/O configuration with the hardware configuration that you created with STEP 7.

By programming startup OBs accordingly, you can specify initialization tags for your cyclic program in the startup program. You can program one or more startup OBs, or none at all.

Points to note

- All outputs are disabled or respond as configured for the given module: They provide a configured substitute value or retain the last value output and switch the controlled process to a safe operating state.

- The process image is initialized.

- The process image is not updated.
  To read the current state of inputs during STARTUP, you can access inputs with direct I/O access.
  To initialize outputs during STARTUP, you can write values via the process image or with direct I/O access. The values are output at the outputs during the transition to the RUN operating state.

- The CPU always starts up in warm restart mode.

  – If you define data as retentive, its content is retained beyond program startup after STOP or a power failure.

  – The non-retentive bit memories, timers and counters are initialized.

  – The non-retentive tags in data blocks are initialized.

- During STARTUP, cycle time monitoring is not yet running.

- The CPU processes the startup OBs in the order of the startup OB numbers. The CPU processes all programmed startup OBs regardless of the selected startup mode (see figure below, "Setting the startup behavior").

- If a relevant event occurs, the CPU can start the following OBs in startup:

  – OB 82: Diagnostics interrupt

  – OB 83: Removal/insertion of modules

  – OB 86: Rack error

  – OB 121: Programming error (only for global error handling)

  – OB 122: I/O access error (only for global error handling)
  You can find a description of how to use global and local error handling in the STEP 7 online help.

  The CPU does not start all other OBs until the transition to the RUN operating state.

Behavior when expected and actual configurations do not match

The configuration downloaded to the CPU is the expected configuration. The actual configuration is the actual, physical configuration of the automation system. If the expected configuration and actual configuration differ, the hardware compatibility setting defines the behavior of the CPU.

Aborting or not running startup

If errors occur during startup, the CPU aborts STARTUP and returns to the STOP operating state.

The CPU does not perform STARTUP under the following conditions:

- You have not inserted a SIMATIC memory card or an invalid one is inserted.

- You have not downloaded a hardware configuration to the CPU.

Configuring startup behavior

You configure the behavior of the CPU in STEP 7 in the "Startup" group of the CPU properties.

Proceed as follows to set the startup behavior:

1. Select the CPU in the device view of the STEP 7 hardware network editor.

2. In the properties, select the "Startup" area.
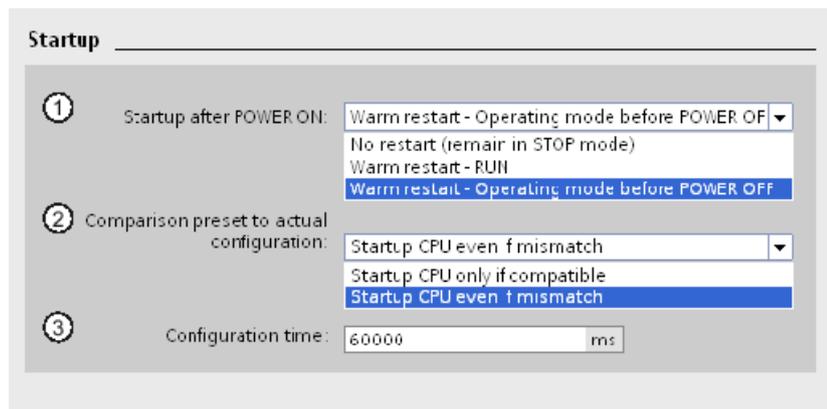
Figure 9-7   Setting the startup behavior

① Sets the startup type after POWER ON

② Defines the startup behavior for the event that a module in a slot does not correspond to the configured module. This parameter applies to the CPU and to all the modules for which no other setting has been selected.

- Startup CPU only if compatible: In this setting, a module in a configured slot must be compatible with the configured module. Compatible means that the number of inputs and outputs and the electrical and functional properties of the modules must correspond.

- Startup CPU even if mismatch: With this setting, the CPU starts up irrespective of the type of module inserted.

③ Specifies a maximum period (default: 60 000 ms) in which the distributed I/O must be ready for operation.
If the distributed I/O is ready for operation within the configuration time, the CPU switches to RUN.

If the distributed I/O is not ready for operation within the configuration time, the startup behavior of the CPU depends on the hardware compatibility setting.

9.4.3 STOP operating state

Response

The CPU does not execute the user program in the STOP operating state.

All outputs are disabled or respond as configured for the given module if both CPUs are in STOP operating state: They provide a configured substitute value or retain the last value output and thus hold the controlled process in a safe operating state.

Points to note

The backup CPU establishes no connections to the IO devices in the STOP operating state.

The primary CPU establishes connections to the IO devices in the STOP operating state. The primary CPU activates the system IP address even in the STOP operating state if the system IP address has been configured.

If both CPUs are in STOP and you download a configuration to one CPU, please note the following:

- The CPU to which you have downloaded the configuration must be started first to become/remain the primary CPU.

- Downloading to the primary CPU configures the connected IO devices in line with the downloaded hardware configuration, even in STOP operating state.

9.4.4 SYNCUP operating state

SYNCUP operating state (only in the backup CPU)

In the SYNCUP operating state, the operating system synchronizes the backup CPU with the primary CPU. The primary CPU is in the RUN-Syncup operating state and controls the process.

Unlike the primary CPU, the backup CPU does not go through the STARTUP operating state.

You can find more information in the section SYNCUP system state (Page 205).

Points to note

You have only limited access to online functions during SYNCUP. You can find more information in the section Test functions (Page 282).

9.4.5 RUN operating states

RUN operating states

The primary CPU goes through multiple operating states before reaching the RUN-Redundant system state:

- RUN
- RUN-Syncup
- RUN-Redundant

The backup CPU only has the RUN-Redundant operating state.

RUN operating state

In the RUN operating state, the primary CPU behaves just like an S7-1500 standard CPU. It performs cyclic, time-driven and interrupt-driven program execution on its own.

Addresses that are in the "Automatic update" process image are automatically updated in each program cycle. You can find more information in the section Process images and process image partitions (Page 145).

Once the CPU has written the outputs and read the inputs, it executes the cyclic program from the first instruction to the last instruction. Events with a higher priority such as hardware interrupts, diagnostic interrupts and communication can interrupt the cyclic program flow and prolong the cycle time.

If you have configured a minimum cycle time, the CPU does not terminate the cycle until after this minimum cycle time has expired, even if the user program is completed sooner.

The operating system monitors the runtime of the cyclic program on the basis of a configurable upper limit known as the maximum cycle time. You can restart this time monitoring at any point in your program by calling the RE_TRIGR instruction.

If the cyclic program exceeds the cycle monitoring time, the timeout OB (OB 80) may be started. You can find additional information in the section Start events (Page 153).

Points to note in the RUN operating state

In non-redundant operation, the CPUs are independent of each other. They can have different projects.

RUN-Syncup operating state

In the RUN-Syncup operating state, the backup CPU synchronizes with the primary CPU. The SYNCUP that temporarily affects the primary CPU (for example delay of asynchronous services, cycle time extension through compilation of the load memory contents) runs simultaneously in the backup CPU. You can find more information in the section SYNCUP system state (Page 205).

The operating system synchronizes the work memory contents of the primary CPU consistently at a cycle control point. During synchronization, the program cycle in the primary CPU is extended in line with the amount of data to be synchronized and in addition to the other cycle time of the application.

RUN-Redundant operating state

The redundant system is in the RUN-Redundant system state. Both CPUs process the user program synchronously.

9.4.6 SYNCUP system state

Requirements

- The versions and firmware versions of the two CPUs are the same.
- There is a SIMATIC memory card in each CPU.
- The PROFINET ring is closed.
- There is at least one redundancy connection (fiber-optic cable) in the S7-1500H redundant system.
- Media redundancy role: One of the R/H-CPUs is the redundancy manager in the PROFINET ring (CPU properties, Media redundancy area, default: "Manager (auto)" for both CPUs). The IO devices are redundancy clients ("Client" configured in the properties).
- Pairing for the two CPUs has been implemented.
- The primary CPU is in the RUN operating state.
- The execution of SYNCUP is not disabled (default setting).
- No load functions are running.

SYNCUP system state

Synchronization in the SYNCUP system state ensures that the two CPUs can operate redundantly. With the SYNCUP system state, the redundant system switches from RUN-Solo to the RUN-Redundant system state. Afterwards, both CPUs synchronously process the same user program.

Starting SYNCUP

The initial situation is the RUN-Solo system state. The primary CPU of a redundant system is in the RUN operating state and the backup CPU is in the STOP operating state.

The operating states are shown on the displays:

Table 9- 3   Starting SYNCUP

Primary CPU	Backup CPU
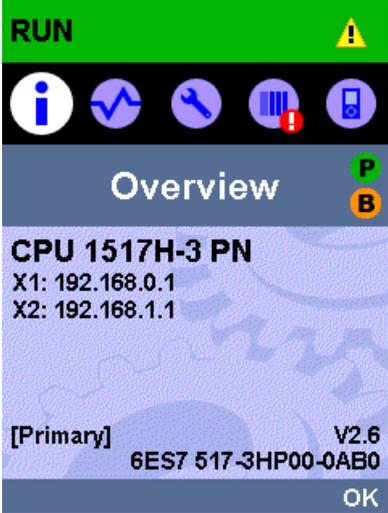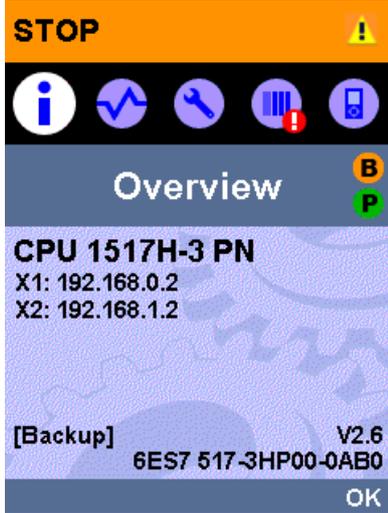
Start SYNCUP if:

- You set the backup CPU to RUN via the PG/PC/HMI device or the display, and the mode selector is set to RUN.

    or

- You switch the mode selector on the backup CPU from STOP to RUN.

    or

- You POWER ON the backup CPU (mode selector to RUN) and the system is configured accordingly.

Preparing the SYNCUP system state

After SYNCUP starts, the CPUs prepare SYNCUP:

- The backup CPU switches to SYNCUP operating state and sends a status message to the primary CPU.
- The primary CPU then switches from the RUN operating state to RUN-Syncup.

The current operating states are shown on the displays:

Table 9- 4   Preparing SYNCUP

Primary CPU	Backup CPU

Sequence of the SYNCUP system state

The operating systems of the two CPUs run through SYNCUP in five phases:

- Copying the SIMATIC memory card ①
- Restart of the backup CPU ②
- Finishing tasks ③
- Copying the work memory ④
- Making up backup CPU lag ⑤

The display of the primary CPU shows you which phase the SYNCUP system state is currently in.

The display of the backup CPU shows the RUN-Redundant during the phases ② to ⑤ until the "Connect..." system state is reached.

① Copying the SIMATIC memory card

The primary CPU copies parts of the load memory to the backup CPU:

- User program, system blocks and project data of the CPU from the \SIMATIC.S7S folder

---

Note

Overwriting load memory content

Copying overwrites the load memory contents on the SIMATIC memory card of the backup CPU with the content of the primary CPU load memory.

The display of the primary CPU indicates the operating state.

Table 9- 5   Copying the SIMATIC memory card

Primary CPU	Backup CPU

RUN-Syncup ⚠
 	
 Syncup... Ⓟ Ⓑ
 	
 ℹ Copying memory card content to Backup PLC.
 	
 [▌ progress bar]
 5%   5.82 MB / 113.73 MB
 	
 Step 1 of 5
	SYNCUP ⚠
	 ℹ ∿ 🔧 ▥ 🔲
	
	 Overview Ⓑ Ⓟ
	
	 CPU 1517H-3 PN
	 X1: 192.168.0.2
	 X2: 192.168.1.2
	
	 [Backup] V2.6
	              6ES7 517-3HP00-0AB0
	                              OK

② Restart of the backup CPU

The backup CPU restarts and automatically switches back to the SYNCUP operating state.

The display of the backup CPU shows the "Connect..." state.

Table 9- 6   Restart of the backup CPU

Primary CPU	Backup CPU
RUN-Syncup ⚠ **P** ? Syncup... ? ⓘ Waiting for restart of the Backup PLC. Step 2 of 5 ⚙	**CONNECTING...** ⓘ 〰 🔧 ▥ 🔋 Overview ? ? CPU 1517H-3 PN 6ES7 517-3HP00-0AB0 OK
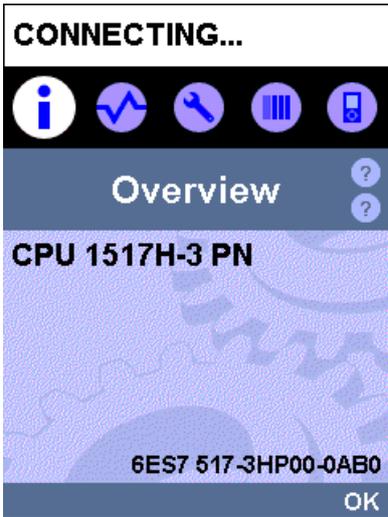
The backup CPU copies the load memory contents copied in ① to its work memory.

③ Finishing tasks

The instructions running asynchronously on the primary CPU are terminated and new ones are accepted but not started.

From this point on, restarted asynchronous instructions are delayed until the "Copying the working memory" phase. The "BUSY" output parameter of instructions is"1". However, processing does not yet start.

The communication connections in the primary CPU are temporarily ended. You can no longer delete, load, generate or compress blocks in the user program. You can no longer run any test or commissioning functions.

Table 9- 7   Preparing the copying of the work memory

Primary CPU	Backup CPU
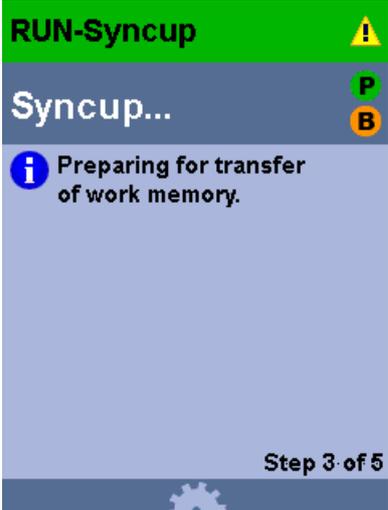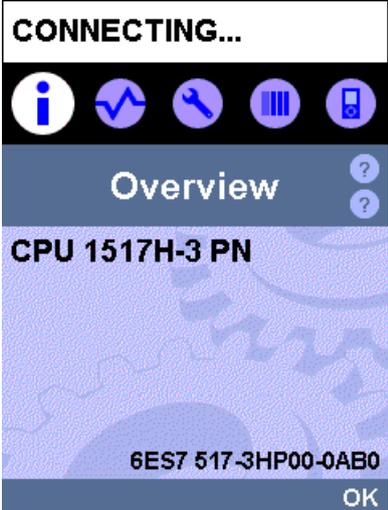
④ Copying the work memory

The backup CPU establishes connections to the IO devices in the PROFINET ring.

At the next cycle control point, the primary CPU saves a consistent snapshot of the contents of its work memory and certain system memory contents (process image, bit memory, SIMATIC timer/counter functions, temporary local files and data block content).

After the snapshot, the primary CPU immediately resumes user program execution. Communication connections are reestablished and asynchronous instructions are started.

The primary CPU copies the consistent snapshot to the backup CPU and continues operating in parallel. Data blocks, the process image, etc. are immediately overwritten with current data from the primary CPU.

The display of the primary CPU indicates the operating state.

Table 9- 8   Copying the work memory

Primary CPU	Backup CPU
RUN-Syncup ⚠ Syncup... Ⓟ Ⓑ ⓘ Copying work memory to Backup PLC. [▱▱▱] 37% Step 4 of 5	**CONNECTING...** ⓘ 〜 🔧 ▥ 🔋 Overview ❓ ❓ CPU 1517H-3 PN 6ES7 517-3HP00-0AB0 OK
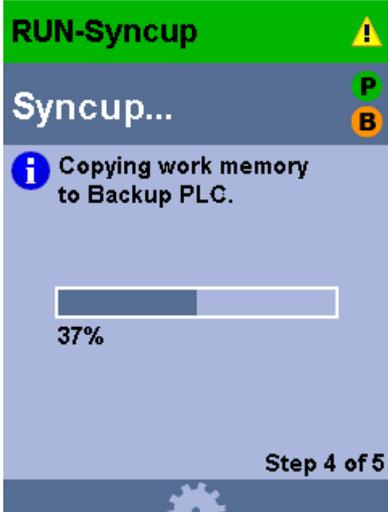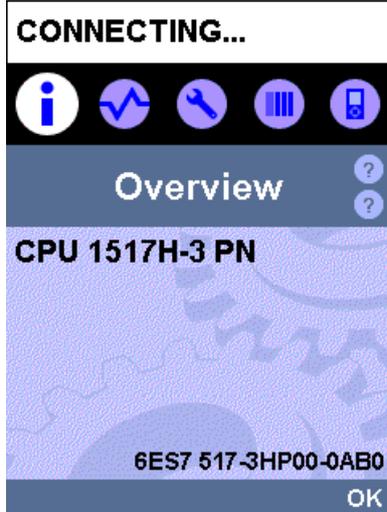
The backup CPU is busy accepting the data before it can also process the user program.

⑤ **Making up backup CPU lag**

In phase ⑤, the backup CPU catches up with the primary CPU.

The communication connections on the backup CPU become available during the catch-up process.

The backup CPU sends a status message on its program progress to the primary CPU at each cycle control point.

The display of the primary CPU indicates the overtravel of the backup CPU.

Table 9- 9   Making up backup CPU lag

Primary CPU	Backup CPU
RUN-Syncup ⚠	**CONNECTING...**
Ⓟ Ⓑ Syncup...	ℹ 〰 🔧 ▥ 📱 ? ?
ℹ Minimizing delay between this PLC and the Backup PLC.	Overview
▮▮▮▮▯▯▯	CPU 1517H-3 PN
00:00:07.359	
Step 5 of 5	6ES7 517-3HP00-0AB0
	OK
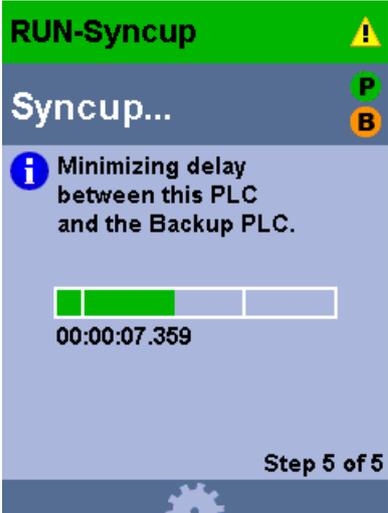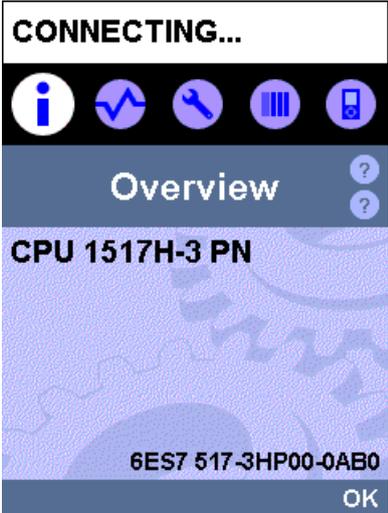
Once the backup CPU has caught up, both CPUs switch to the RUN-Redundant operating state. Both CPUs process the user program synchronously.

Note

High load during SYNCUP

The higher load during SYNCUP can prolong the program cycle.

If SYNCUP is taking too long and the displays are not showing any progress, you can abort SYNCUP and optimize your user program. You can find more information under "SYNCUP system state aborts".

Note

Setting a sufficiently long maximum cycle time

Configure a sufficiently long maximum cycle time for the CPUs. A temporary increase in the cycle time can occur upon a system state transition SYNCUP → RUN-Redundant.

Effects of the SYNCUP system state

SYNCUP has different effects on user program execution and communication functions. The effects are set out in the table below.

Table 9- 10   Properties of SYNCUP

Procedure	Effects during the SYNCUP system state
Processing of the user program on the primary CPU	All priority classes (OBs) are processed. Processing is delayed during the snapshot. After the snapshot, the primary CPU immediately resumes user program execution and asynchronous instructions are started.
Deleting, loading, generating and compressing blocks	Blocks cannot be deleted, loaded, generated or compressed.
Processing communication functions	The execution of parts of functions is limited and delayed. The system makes up the delays in all functions after SYNCUP.
PG/PC operation	Depending on the SYNCUP phase, online connections from the PG/PC to the CPU may not be possible.
Test and commissioning functions, for example "Monitor and modify tags", "Monitoring (on/off)".	Depending on the SYNCUP phase, no test and commissioning functions may be possible.
Connection handling in the primary CPU	All communication connections are initially aborted.
	After the snapshot, the primary CPU sets up communication connections again with active connection establishment. The CPU sets up connection endpoints for communication connections with passive connection establishment.
Connection handling in the backup CPU	All communication connections are initially aborted.
	The backup CPU establishes connections (ARs) to the IO devices in the PROFINET ring. The communication connections on the backup CPU become available during the backup CPU catch-up process.
Diagnostics alarms	Diagnostic alarms can be delayed during the SYNCUP system state.
	If diagnostic alarms occur during the "Making up backup CPU lag" phase, the diagnostic alarms can prolong this phase. You can find additional information in the section Basics to the Program processing (Page 153).

SYNCUP system state aborts

Abort is possible in a range of cases even if you have successfully launched the SYNCUP system state:

● If one of the two CPUs POWERS OFF.

● If you switch the backup CPU to STOP; the primary CPU continues operating in RUN operating state.
The cancellation of the SYNCUP may take a few seconds.

● If you set the primary CPU to STOP; the redundant system switches to the STOP system state as the backup CPU was not ready to take over control of the process. The backup CPU restarts.

● If the backup CPU lag is not reduced to less than the smallest value after 100 program cycles, the primary CPU aborts SYNCUP. Evaluate the diagnostics buffer of the primary and the backup CPU.

● If one of the CPUs detects an error that impedes progress, for example if the cycle time is exceeded in the primary CPU.

● If the PROFINET ring was already interrupted before changing to the SYNCUP system state or if the PROFINET ring is interrupted during SYNCUP.

You can find a detailed list of the causes of error and remedies in the table SYNCUP abort: Causes and solutions.
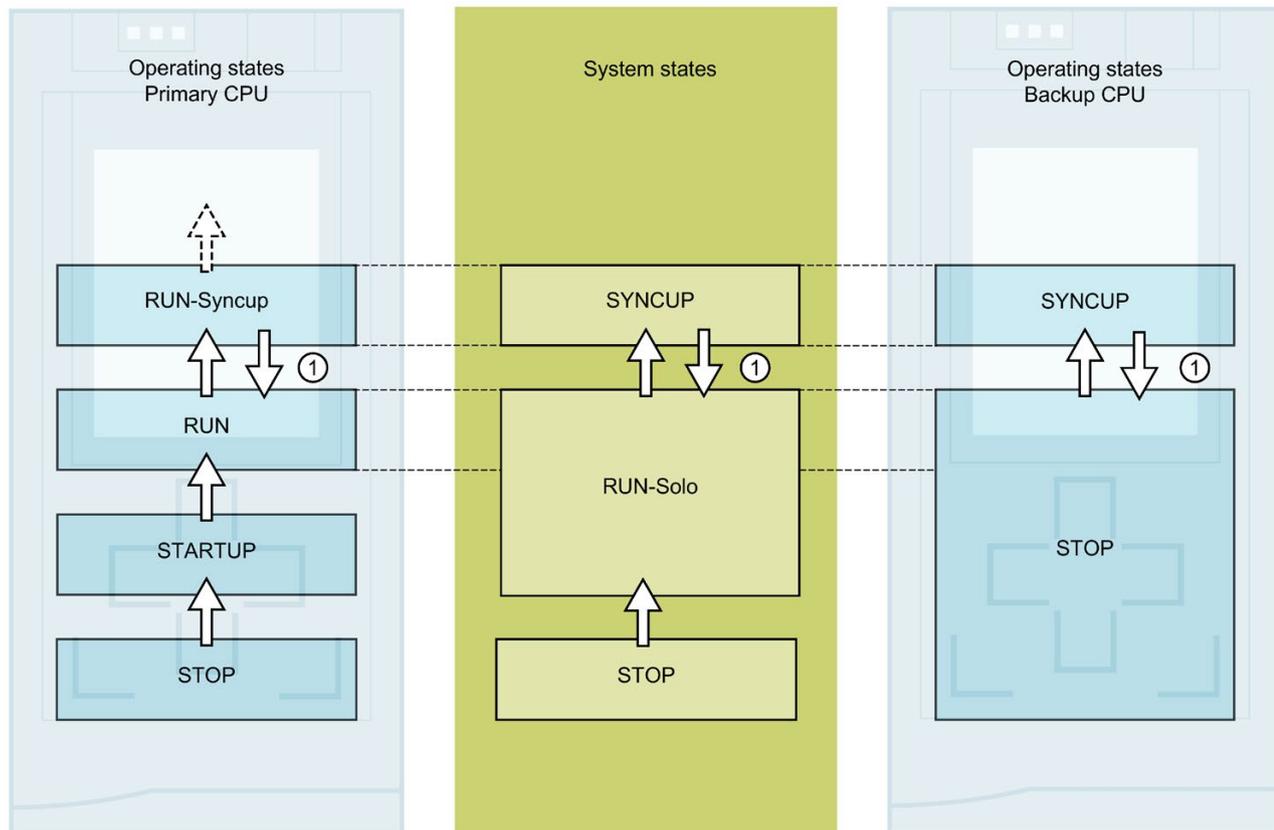
Figure 9-8   SYNCUP system state aborts

Table 9- 11   Sequence of events: SYNCUP aborts

No. in dia-gram	Primary CPU	System state	Backup CPU
Initial situation: The S7-1500R/H redundant system is in the SYNCUP system state. An error occurs in the backup CPU.			
①	The CPU does not switch from the RUN-Syncup operating state to RUN-Redundant, but instead returns to RUN and continues to execute the user program.	SYNCUP → RUN-Solo	If SYNCUP aborts, the backup CPU may restart and then switch to the STOP operating state. The backup CPU is ready for a new SYNCUP.

Procedure for error correction

1. Eliminate the error.

2. Switch the backup CPU from STOP to RUN.

The backup CPU switches from STOP to the SYNCUP operating state. Synchronization restarts.

Causes of error and troubleshooting

There are various possible causes of a SYNCUP system state abort. In the event of a SYNCUP abort, evaluate the diagnostics buffer of the primary and the backup CPU.

Table 9- 12   SYNCUP abort: Causes and solutions

Cause of SYNCUP abort	Solution
Too little memory on the SIMATIC memory card of the backup CPU.	Delete data from the SIMATIC memory card or use a SIMATIC memory card with greater memory capacity. You can find more information in the function manual Structure and use of the CPU memory (https://support.industry.siemens.com/cs/ww/en/view/59193 101).
System overload. The user program load is too high, and the backup CPU is therefore not catching up with program execution on the primary CPU.	Use the "RT_INFO" instruction to generate statistics on the runtime of OBs, communication or the user program. You can establish the system load using asynchronous instructions. You can shorten the backup CPU delay compared to the primary CPU by: • Addressing the CPU overload by reducing the post-processing of cyclic events (events from one source, for example start events for a cyclic interrupt OB). You can find more information in the Cycle and response times (http://support.automation.siemens.com/WW/view/en/59 193558) function manual. • Do not set too low a minimum cycle time for cyclic OBs or increase the minimum cycle time. This reduces the frequency at which the cyclic OBs are called.

Cause of SYNCUP abort	Solution
The load on the redundancy connections between primary and backup CPU is too high. As a result, the CPU is not catching up with program execution on the primary CPU.	Reduce the load on the redundancy connections between primary and backup CPU by: • Reducing the post-processing of cyclic events (see above) • Avoiding instructions that increase the synchronization load, for example direct access, time access (for example RD_SYS_T, WR_SYS_T, RD_LOC_T) • Reducing communication (HMI, PG/PG, Open User Communication, etc.) • Complying with the configuration rules
Maximum cycle time in the primary CPU exceeded	• Reduce the cycle time by setting a lower communication load in the hardware configuration. • Configure a sufficiently long maximum cycle time. • If there is an OB 80 (timeout OB) in the downloaded user program, it is called by the operating system to tolerate the cycle time being exceeded (see section Start events (Page 153)).
Primary CPU or backup CPU goes into STOP operating state.	Switch the primary CPU or backup CPU into RUN operating state.
PROFINET ring interrupted	Replace defective PROFINET cables or PROFINET devices in the PROFINET ring.
Supply voltage of the primary or backup CPU has failed.	Restore the supply voltage. Replace a defective PM/PS.

9.4.7 System and operating state transitions

System state transitions

The diagram below shows the system state transitions of the S7-1500R/H redundant system.
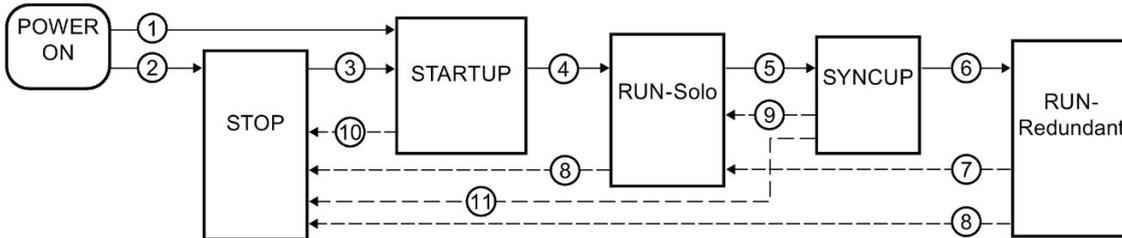
Figure 9-9   System state transitions

Operating state transitions

Redundant system operating state transitions

The diagram below shows the operating state transitions for the primary and backup CPUs.
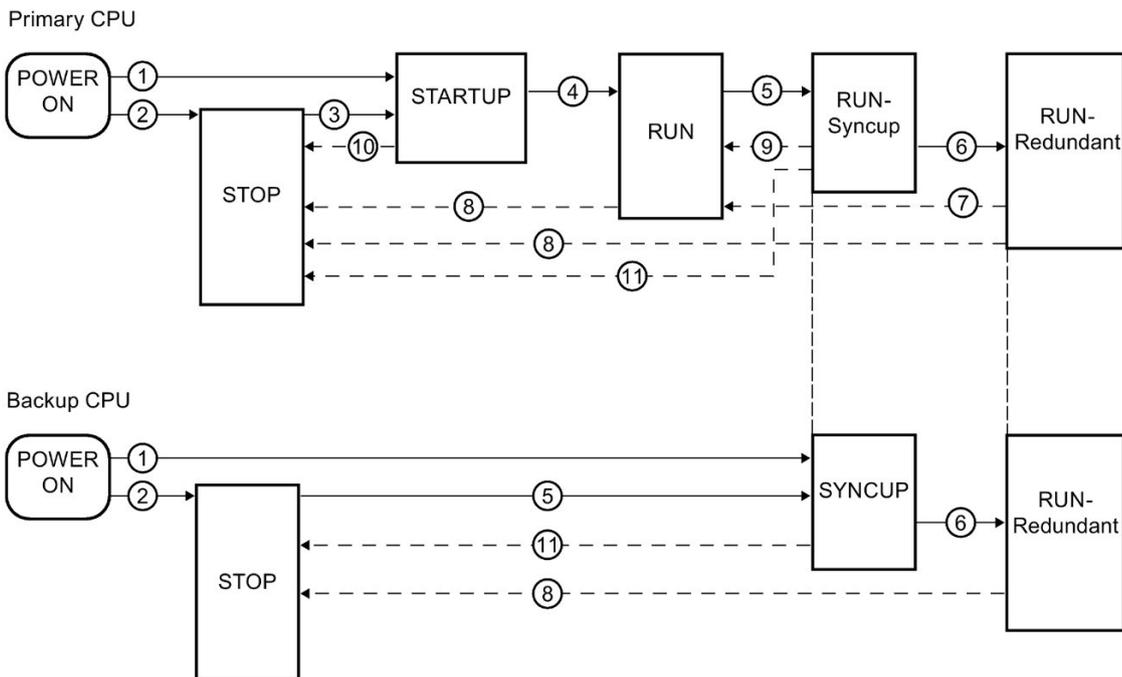
Figure 9-10   Operating state transitions

① POWER ON → STARTUP, POWER ON → SYNCUP

Transition	Description	Effect
System state transition	**POWER ON → STARTUP** The CPUs implement pairing after switch-on. The redundant system then switches to STARTUP if: • The mode selector is set to the RUN position; • The hardware configuration and program blocks are consistent, and • The startup type "Warm restart - RUN" is set or • The startup type "Warm restart - Operating mode before POWER OFF" is set and the system was in RUN-Solo, SYNCUP or RUN-Redundant before POWER OFF. The CPU that becomes the primary CPU runs the STARTUP. The primary CPU switches to the STARTUP operating state.	After POWER ON → STARTUP, the primary CPU clears the non-retentive memory and resets the contents of non-retentive data blocks to the initial values of the load memory. Retentive memory and retentive DB contents are retained.
Operating state transitions	**POWER ON → STARTUP** The CPUs implement pairing after switch-on. The primary CPU then switches to the STARTUP operating state if: • The mode selector is in the RUN position; • The hardware configuration and program blocks are consistent, and • The startup type "Warm restart - RUN" is set or • The startup type "Warm restart - Operating mode before POWER OFF" is set and the CPU was in STARTUP, RUN, RUN-Syncup or RUN-Redundant before POWER OFF.	
	POWER ON → SYNCUP The CPUs implement pairing after switch-on. The backup CPU then switches to the SYNCUP operating state if: • The mode selector is in the RUN position and • The primary CPU is in the STARTUP or RUN operating state.	

② POWER ON → STOP

Transition	Description	Effects

System state transition
 	
Operating state transitions
	POWER ON → STOP
	
	The redundant system switches to the STOP system state after switch-on if:
	
	• The mode selector is in the STOP position
	  or
	• The hardware configuration and program blocks are inconsistent
	  or
	• The startup type "No restart (remain in STOP)" is set
	  or
	• The startup type "Warm restart - Operating mode before POWER OFF" is set and the redundant system was in STOP before POWER OFF.
		The primary CPU clears the non-retentive memory and resets the contents of non-retentive data blocks to the initial values of the load memory. Retentive memory and retentive DB contents are retained.

③ STOP → STARTUP

Transition	Description	Effects
System state transition	**STOP → STARTUP** The redundant system switches to the STARTUP system state if: • You set a CPU to RUN via the PG/PC or the display and the mode selector is set to RUN or • You set the mode switch from STOP to RUN. The CPU that you switch from STOP to RUN first remains/becomes the primary CPU. It switches to the STARTUP operating state and processes startup OB 100. The backup CPU remains in STOP.	The primary CPU clears the non-retentive memory and resets the contents of non-retentive data blocks to the initial values of the load memory. Retentive memory and retentive DB contents are retained.

Operating state transition	**STOP → STARTUP**
	
	After switch-on, the primary CPU switches to the STARTUP operating state if:
	
	• The hardware configuration and program blocks are consistent
	  and
	• You set the CPU to RUN via the PG/PC or the display and the mode selector is set to RUN
	  or
	• You set the mode switch from STOP to RUN.	

④STARTUP → RUN-Solo, STARTUP → RUN

Transition	Description	Effects

System state transition	**STARTUP → RUN-Solo**
	
	The redundant system switches from STARTUP to the RUN-Solo system state if:
	
	• The primary CPU has initialized the PLC tags
	
	  and
	
	• the primary CPU has executed the startup blocks successfully
	  and
	
	• "Startup CPU only if compatible" is configured, there is feedback from all IO devices before the end of the configuration time and all IO devices match the configured hardware configuration or "Startup CPU even if mismatch" is configured and the configuration time is up.
	
	The backup CPU remains in STOP.
		The process image is updated and processing of the cyclic user program begins.
		
		The outputs of the IO devices are initialized.

Operating state transition	**STARTUP → RUN** The primary CPU switches to the RUN operating state if: • The CPU has initialized the PLC tags; • The CPU has executed the startup blocks successfully; and • "Startup CPU only if compatible" is configured, there is feedback from all IO devices before the end of the configuration time and all IO devices match the configured hardware configuration or "Startup CPU even if mismatch" is configured and the configuration time is up.	

⑤ RUN-Solo → SYNCUP, RUN → RUN-Syncup, STOP → SYNCUP

Transition	Description	Effects

System state transition	**RUN-Solo → SYNCUP**
	
	The primary CPU is in the RUN operating state. The redundant system switches from the RUN-Solo system state to the SYNCUP system state if, for example:
	
	• You set the backup CPU to RUN via the PG/PC or the display and the mode selector is set to RUN
	
	   or
	
	• You switch the mode selector on the backup CPU from STOP to RUN.
	
	   or
	
	• You POWER ON the backup CPU (mode selector to RUN)
	
	   and
	
	• the SYNCUP system state is not disabled by the RH_CTRL instruction.
		See section SYNCUP system state (Page 205)

Operating state transitions	**RUN → RUN-Syncup**
	
	The primary CPU switches from the RUN operating state to the RUN-Syncup operating state if:
	
	• You set the backup CPU to RUN via the PG/PC or the display and the mode selector is set to RUN
	
	   or
	
	• You switch the mode selector on the backup CPU from STOP to RUN.
	
	   or
	
	• You POWER ON the backup CPU (mode selector to RUN).
	
	STOP → SYNCUP
	
	The backup CPU switches from the STOP operating state to the SYNCUP operating state.
		The backup CPU gets all static and dynamic data from the primary CPU.
		
		After successful SYNCUP, the memory content is identical on the two CPUs.
		
		The updated backup CPU catches up with primary CPU program execution.
		
		You have only limited access to online functions during SYNCUP. You can find more information in the section Test functions (Page 282).

⑥SYNCUP → RUN-Redundant, RUN-Syncup → RUN-Redundant

Transition	Description	Effects
System state transition	**SYNCUP → RUN-Redundant** The redundant system switches from SYNCUP to the RUN-Redundant system state if SYNCUP has successfully run. In the RUN-Redundant system state, the two CPUs execute the user program synchronously. **Note: A temporary increase in the cycle time can occur upon a system state transition SYNCUP → RUN-Redundant. Configure a sufficiently long maximum cycle time for the CPUs.**	This system state transition does not have any effect on data.
Operating state transitions	**RUN-Syncup → RUN-Redundant** The primary CPU switches from the RUN-Syncup operating state to the RUN-Redundant operating state if SYNCUP has successfully run. **SYNCUP → RUN-Redundant** The backup CPU switches from the SYNCUP operating state to the RUN-Redundant operating state if SYNCUP has successfully run.	Communication connections (HMI, PG/PC) on the backup CPU become available. Both CPUs process the user program synchronously.

⑦RUN-Redundant → RUN-Solo, RUN-Redundant → RUN

Transition	Description	Effects

System state transition	**RUN-Redundant → RUN-Solo**
	
	The redundant system switches from the RUN-Redundant system state to the RUN-Solo system state (loss of redundancy) if:
	
	• You POWER OFF one of the CPUs.
	
	  or
	
	• A CPU detects an error that prevents continued processing, for example a hardware defect
	
	  or
	
	• You set one of the CPUs to STOP with the PG/PC, the display or the mode selector.
	
	The primary CPU switches to RUN or the backup CPU becomes the primary CPU and switches to RUN.
		This system state transition has effects on the diagnostics data.

Operating state transition	**RUN-Redundant → RUN** The primary CPU switches from the RUN-Redundant operating state to the RUN operating state and continues to execute the user program.	This operating state transition does not have any effect on data.

⑧RUN-Redundant → STOP, RUN-Solo → STOP, RUN → STOP

Transition	Description	Effects

System state transition	**RUN-Redundant → STOP, RUN-Solo → STOP**
	
	The redundant system switches from the RUN-Redundant/RUN-Solo system state to the STOP system state if:
	
	• The redundant system detects an error that prevents further processing
	
	   or
	
	• The redundant system processes a STOP command in the user program
	
	   or
	
	• You set the redundant system to STOP with the PG/PC.
		This system state transition does not have any effect on data.

Operating state transitions	**RUN-Redundant → STOP, RUN → STOP**
	
	The primary CPU switches from the RUN-Redundant/RUN operating state to the STOP operating state if:
	
	• The CPU detects an error that prevents further work on one of the two CPUs.
	
	   or
	
	• The CPU detects an error that prevents further work on both CPUs, for example if the cycle time is exceeded (if there is an OB 80, not until the 3rd time the cycle time is exceeded, see section Start events (Page 153))
	
	   or
	
	• You set the CPU to STOP with the PG/PC, the display or the mode selector.
		These operating state transitions have no effect on data.

	RUN-Redundant → STOP The backup CPU switches from the RUN-Redundant operating state to the STOP operating state.	

⑨ SYNCUP → RUN-Solo, RUN-Syncup → RUN

Transition	Description	Effects

System state transition	**SYNCUP → RUN-Solo**
	
	The redundant system switches from the SYNCUP system state to the RUN-Solo system state if:
	
	• You execute POWER OFF for the backup CPU
	
	   or
	
	• The redundant system detects an error during SYNCUP that prevents redundant operation
	
	   or
	
	• You set the backup CPU to STOP with the PG/PC, the display or the mode selector.
		This system state transition does not have any effect on data.

Primary CPU operating state transition	**RUN-Syncup → RUN** The primary CPU switches from the RUN-Syncup operating state to the RUN operating state and continues to execute the user program.	These operating state transitions have no effect on data.

⑩ STARTUP → STOP

Transition	Description	Effects
System state transition	**STARTUP → STOP** The redundant system switches from the STARTUP system state to the STOP system state if:	This system state transition does not have any effect on data.

Primary CPU operating state transition	• The primary CPU detects an error during startup that prevents further processing
	
	or
	
	• You set the primary CPU to STOP with the PG/PC, the display or the mode selector
	
	or
	
	• The primary CPU processes a STOP command in the startup OB
	
	or
	
	• In the CPU properties, you have set the following for startup behavior:
	  – Too short a configuration time for the distributed I/O and
	  – "Startup CPU only if compatible"
	The primary CPU switches to STOP.
		This operating state transition does not have any effect on data.

⑪SYNCUP → STOP, RUN-Syncup → STOP

Transition	Description	Effects
System state transition	**SYNCUP → STOP** The redundant system switches from the SYNCUP system state to the STOP system state if: • You set the primary CPU or both CPUs to STOP with the PG/PC, the display or the mode selector. • SYNCUP is aborted as a result of an error in the primary CPU or in both CPUs.	This system state transition does not have any effect on data.

Operating state transitions	**RUN-Syncup → STOP**
	
	The primary CPU switches from the RUN-Syncup operating state to the STOP operating state if:
	
	• The primary CPU detects an error that prevents further processing
	
	   or
	
	• You set the primary CPU to STOP with the PG/PC, the display or the mode selector
	
	   or
	
	• The redundant system processes a STOP command in the user program.
		These operating state transitions have no effect on data.

	SYNCUP → STOP The backup CPU restarts and switches to the STOP operating state after SYNCUP aborts if: • SYNCUP is aborted due to an error (for causes and remedies, see section SYNCUP system state (Page 205)) or • You set the CPU to STOP with the PG/PC, the display or the mode selector.	

9.4.8 Loss of redundancy

Introduction

The following section explains in more detail the system and operating state transitions ⑦, RUN-Redundant → RUN-Solo and RUN-Redundant → RUN from the System and operating state transitions (Page 217) section.

Response

Loss of redundancy means:

- The redundant system switches from the RUN-Redundant system state to the RUN-Solo system state.

- The primary CPU switches from the RUN-Redundant operating state to RUN (1)

  or

- Primary-backup switchover: The backup CPU becomes the primary CPU and switches from the RUN-Redundant operating state to RUN (2).

The primary CPU continues to execute the user program in the RUN operating state and exchanges process data with the IO devices.

Causes of redundancy loss

The redundant system switches from the RUN-Redundant system state to RUN-Solo if:

- You POWER OFF one of the CPUs.

- You set one of the two CPUs to STOP with the PG/PC, the display or the mode selector.

- A CPU detects an error that prevents continued processing, for example:

  – Failure of a CPU, for example as a result of a hardware defect.

  – Cycle time exceeded

(1) Primary CPU switches to the RUN operating state
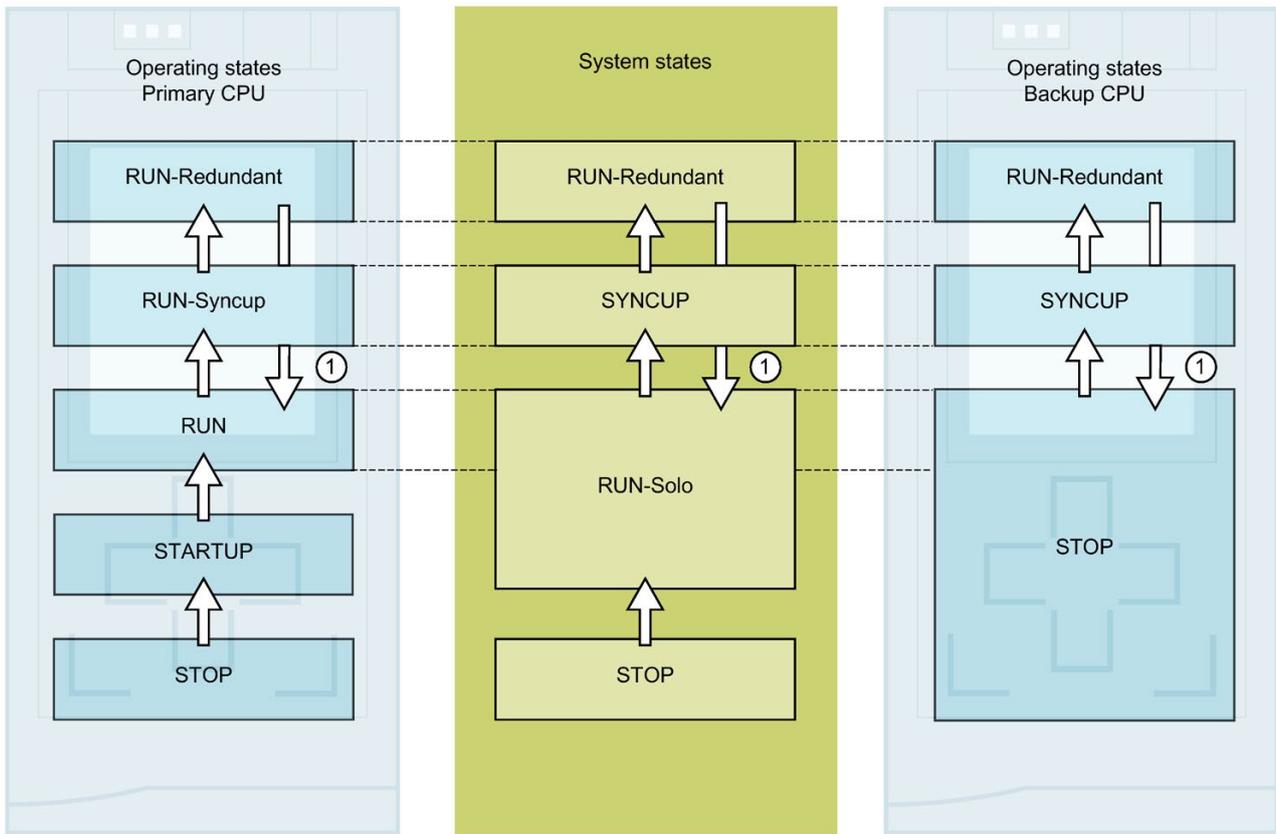
Figure 9-11   Primary CPU switches to the RUN operating state

Table 9- 13   Response to loss of redundancy: Primary CPU switches to RUN

No. in diagram	Primary CPU	System state	Backup CPU
Initial situation: The S7-1500R/H redundant system is in the RUN-Redundant system state. The backup CPU fails because of a hardware defect.			
①	The CPU switches from RUN-Redundant to RUN. The CPU behaves like a standard CPU and continues to process the user program.	RUN-Redundant → RUN-Solo	Following the error, the CPU switches from the RUN-Redundant operating state to STOP or POWER OFF.

Error elimination procedure for redundant operation

1. Eliminate the error.

2. Switch the backup CPU to the RUN operating state.

The backup CPU switches from the STOP operating state to the SYNCUP operating state.

Synchronization starts as detailed in the section SYNCUP system state (Page 205).

(2) Primary-backup switchover
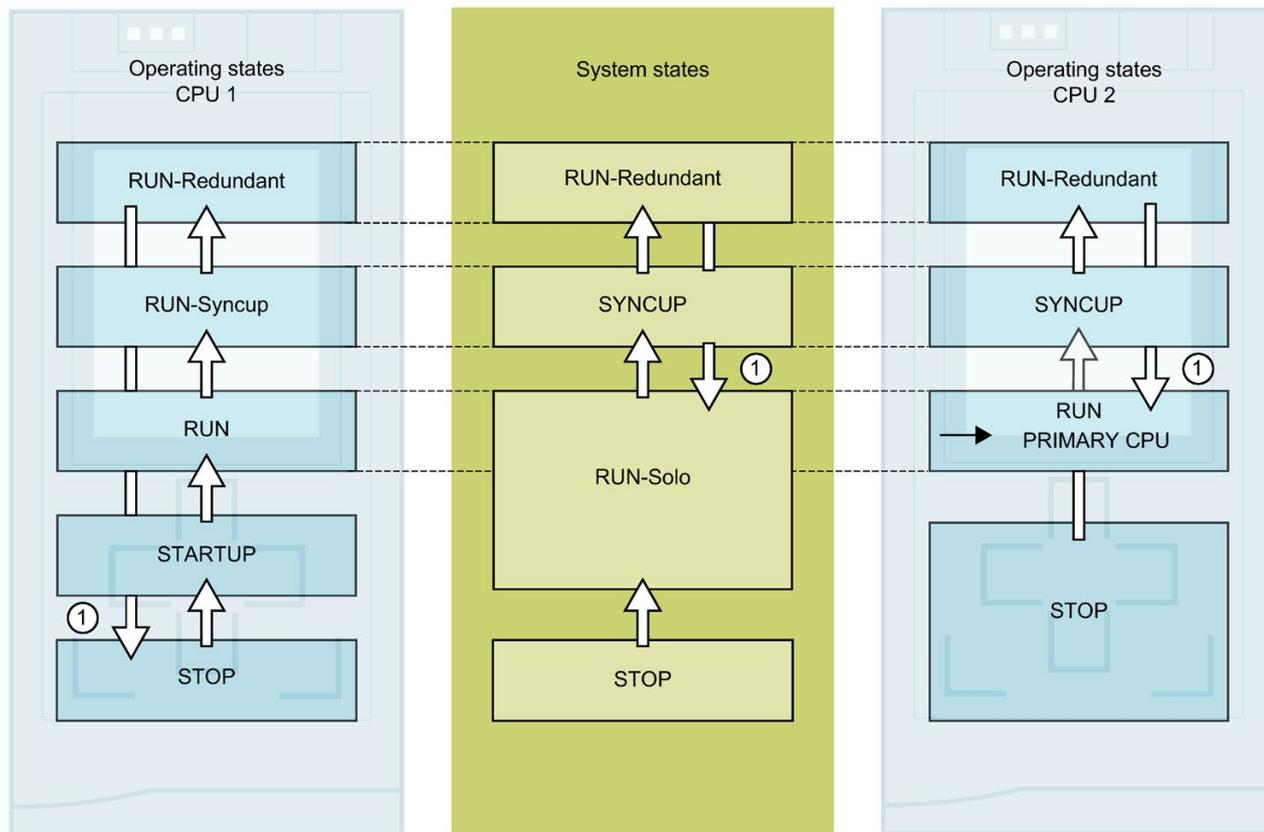
Figure 9-12   Primary-backup switchover

Table 9- 14   Response to primary CPU error: Backup CPU becomes primary CPU and switches to RUN

No. in diagram	CPU 1	System state	CPU 2
Initial situation: The S7-1500R/H redundant system is in the RUN-Redundant system state. The primary CPU (CPU 1) fails because of a hardware defect.			
①	Following the failure, CPU 1 switches from the RUN-Redundant operating state to STOP or POWER OFF.	RUN-Redundant → RUN-Solo	CPU 2 becomes primary CPU and switches to the RUN operating state. The CPU behaves like a standard CPU and continues to process the user program.

Error elimination procedure for redundant operation

1. Eliminate the error.

2. Switch CPU 1 to the RUN operating state.

CPU 1 becomes the backup CPU and switches from the STOP operating state to the SYNCUP operating state.

Synchronization starts as detailed in the section SYNCUP system state (Page 205).

9.4.9 Displaying and changing the system state

Introduction

For commissioning and service, you require information on the system state of the redundant system. Examples:

● The redundant system does not switch to the RUN-Redundant system state upon initial commissioning.

● The primary CPU has failed due to a fault.

Options

You have the following options for displaying and changing the system state of the S7-1500R/H redundant system:

● In STEP 7, for example when the R/H-CPUs are far apart

● Using the mode selectors on the CPUs, you can change the operating states of the CPUs and therefore the system state

Display of the primary and backup CPU

Displaying the operating state:

The operating state of the primary and backup CPU is shown in the status information in the top section of the displays. The two operating states define the system state.

Examples:

● Status information for the primary and backup CPUs: RUN-Redundant, RUN-Redundant. Result: The system state is RUN-Redundant.

● Status information for the primary and backup CPUs: RUN, STOP. Result: The system state is RUN-Solo.

Changing the operating state:

Switch the CPU to the required operating state in the "Settings > RUN / STOP" menu of the display.

Note

Please note that you can only implement the system states RUN-Redundant and STOP through the displays by switching both CPUs to the operating state RUN or STOP .

SIMATIC S7-1500 Display Simulator

A simulation of the display of the available menu commands is available in the SIMATIC S7-1500 Display Simulator (http://www.automation.siemens.com/salesmaterial-as/interactive-manuals/getting-started_simatic-s7-1500/disp_tool/start_en.html).

STEP 7

Displaying the system state:

The system state is displayed on the R/H system operating panel (Online & diagnostics).

Changing the system state:

On the R/H system control panel (Online & diagnostics):

- STOP system state: Press the STOP R/H-System button.
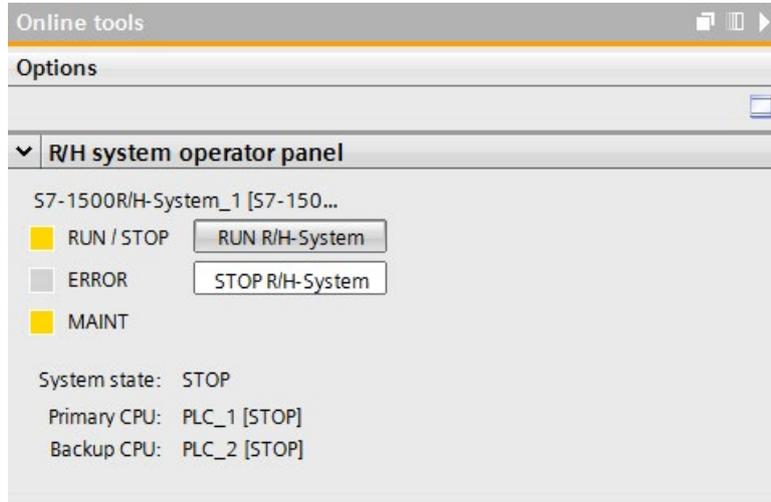
Figure 9-13   STOP system state on the R/H system control panel

On the CPU control panels (Online & diagnostics):

- RUN-Redundant system state: Press the RUN R/H-System button on both CPU operator panels.

Note

Please note that you cannot switch the S7-1500R/H system to the RUN-Redundant system state over the R/H system control panel. You implement the RUN-Redundant system state by switching each CPU on its control panel to RUN.

9.5　CPU memory reset

Basics of a memory reset

Memory resets can be performed for the primary and for the backup CPU. Memory resets are generally only useful for the primary CPU.

Reason: Following a primary CPU memory reset, you need to trigger synchronization for redundant operation. In SYNCUP, the backup CPU is synchronized with the retentive data from the primary CPU. Following SYNCUP, the backup CPU processes the same user program as the primary CPU.

The memory reset process for R/H-CPUs is identical to that for the S7-1500 standard CPUs. The CPU must be in the STOP operating state for a memory reset.

A memory reset returns the CPU to its "initial state".

Note

A memory reset only ever affects the CPU to which you have applied the function. For a memory reset of both CPUs, apply the function to each in turn.

Memory reset means:

- An existing online connection between your programming device/PC and the CPU is terminated.

- The content of the work memory and the retentive and non-retentive data are deleted (in a manual memory reset).

- The diagnostics buffer, time of day, and IP address are retained.

- Subsequently the CPU is initialized with the loaded project data (hardware configuration, code and data blocks, force jobs). The CPU copies this data from the load memory to the work memory.

- Data blocks no longer have actual values but rather their configured start values.

- Force jobs remain active.

Detecting a CPU memory reset

The RUN/STOP LED flashes yellow at 2 Hz. After completion, the CPU switches to STOP. The RUN/STOP LED is on (constant yellow light).

Result after memory reset

The following table provides an overview of the contents of the memory objects after memory reset.

Table 9- 15   Memory objects after memory reset

Memory object	Contents
Redundancy ID	Retained
Actual values of the data blocks, instance data blocks	Initialized
Bit memories, timers and counters	Initialized
Entries in the diagnostics buffer[1] (retentive area)	Retained
Entries in the diagnostics buffer (non-retentive area)	Initialized
IP addresses	Retained
Device name (module name)	Retained
Counter readings of the runtime meters	Retained
Time of day	Retained

[1]   The entries in the diagnostics buffer are the 500 most recent entries.

9.5.1   Automatic memory reset

Possible causes of automatic memory reset

The CPU executes an automatic memory reset if an error occurs that prevents normal further processing.

Examples of such errors:

- User program is too large and cannot be loaded to the work memory in full.

- The project data on the SIMATIC memory card are damaged, for example because a file was deleted.

- You remove or insert the SIMATIC memory card. The backed-up retentive data differs in structure from the data in the configuration on the SIMATIC memory card.

- SYNCUP aborts in the backup CPU. You can find more information in the section SYNCUP system state (Page 205).

9.5.2 Manual memory reset

Reason for manual memory reset

Memory reset is required to reset the primary or backup CPU to its "initial state". Memory resets can only be run in the STOP operating state of a CPU.

CPU memory reset

There are three options for performing a CPU memory reset:

- Using the mode selector
- Using the display
- Using STEP 7

Procedure using the mode selector

Note

Memory reset ↔ Reset to factory settings

The procedure described below also corresponds to the procedure for resetting to factory settings:

- Selector operation with inserted SIMATIC memory card: CPU executes a memory reset
- Selector operation without inserted SIMATIC memory card: CPU executes reset to factory settings

---

Proceed as follows for a CPU memory reset using the mode selector:

1. Set the mode selector master interface module to STOP.

   Result: The RUN/STOP LED lights up yellow.

2. Set the mode selector master interface module to MRES. Hold the selector in this position until the RUN/STOP LED lights up for the 2nd time and remains continuously lit (this takes three seconds). Then release the switch.

3. Within the next three seconds, switch the mode selector back to the MRES position and then back to STOP.

Result: The CPU executes a memory reset.

For information on resetting the CPU to factory settings, please refer to the section Resetting CPUs to factory settings (Page 277).

Procedure using the display

To navigate to the required "Memory reset" menu item, select the following sequence of menu commands and confirm each selection with "OK".

- Settings → Reset → Memory reset

Result: The CPU executes a memory reset.

Procedure using STEP 7

Requirement: There is an online connection between the CPU ad PG/PC.

Proceed as follows for a CPU memory reset with STEP 7:

1. Open the "Online Tools" task card of the CPU.

2. Click "MRES" in the "CPU operator panel" pane.

3. Click "OK" in response to the confirmation prompt.

Result: The CPU executes a memory reset.

9.6 Backing up and restoring the CPU configuration

Backup from online device

You may make changes in the operation of your plant. For example, you may add new devices, replace existing ones or adapt the user program. If these changes result in undesirable behavior, you can restore the plant to an earlier state. Before you download a changed configuration to the CPU, first use the option "Backup from online device" to create a complete backup of the current device state.

Upload from device (software)

With the option "Upload from device (software)", you load the software project data from the CPU to an existing CPU in the project.

Upload device as new station

If you are operating a new PG/PC in the plant, the STEP 7 project that was used to create the plant configuration might not be available. In this case, you can use the option "Upload device as new station" to load the device data to a project in your PG/PC.

Snapshot of the actual values

To allow you to restore the actual values at a later date, back up the actual values of the data blocks using the option "Snapshot of the actual values".

Overview of backup types

The table below shows the backup of CPU data depending on the selected type of backup and its specific characteristics:

Table 9- 16   Types of backup

	Backup from online device	Upload from device (software)	Upload device as new station	Snapshot of the actual values
Actual values of all DBs (global and instance data blocks)	✓	✓	✓	✓
Blocks of the type OB, FC, FB and DB	✓	✓	✓	--
PLC tags (tag names and constant names)	✓	✓	✓	--
Hardware configuration	✓	--	✓	--
Actual values (bit memories, timers and counters)	✓	--	--	--
Contents of the SIMATIC memory card	✓	--	--	--
Logs	✓	--	--	--
Entries in the diagnostics buffer	--	--	--	--
Current time	--	--	--	--
Properties of the type of backup				
Backup can be edited	--	✓	✓	✓
Backup possible in operating mode	STOP	RUN-Redundant, RUN, STOP	RUN-Redundant, RUN, STOP	RUN-Redundant, RUN, STOP

Example: Backup from online device

The following example shows how to carry out a complete backup of the current device state of the CPUs in STEP 7. The S7-1500R/H redundant system is in the RUN-Solo system state.

1. Right-click to select the S7-1500R/H system in the project tree.

2. Select the "Backup from online device" command from the shortcut menu.

The "Upload preview" dialog window sets out the key information on the backup process to be run:
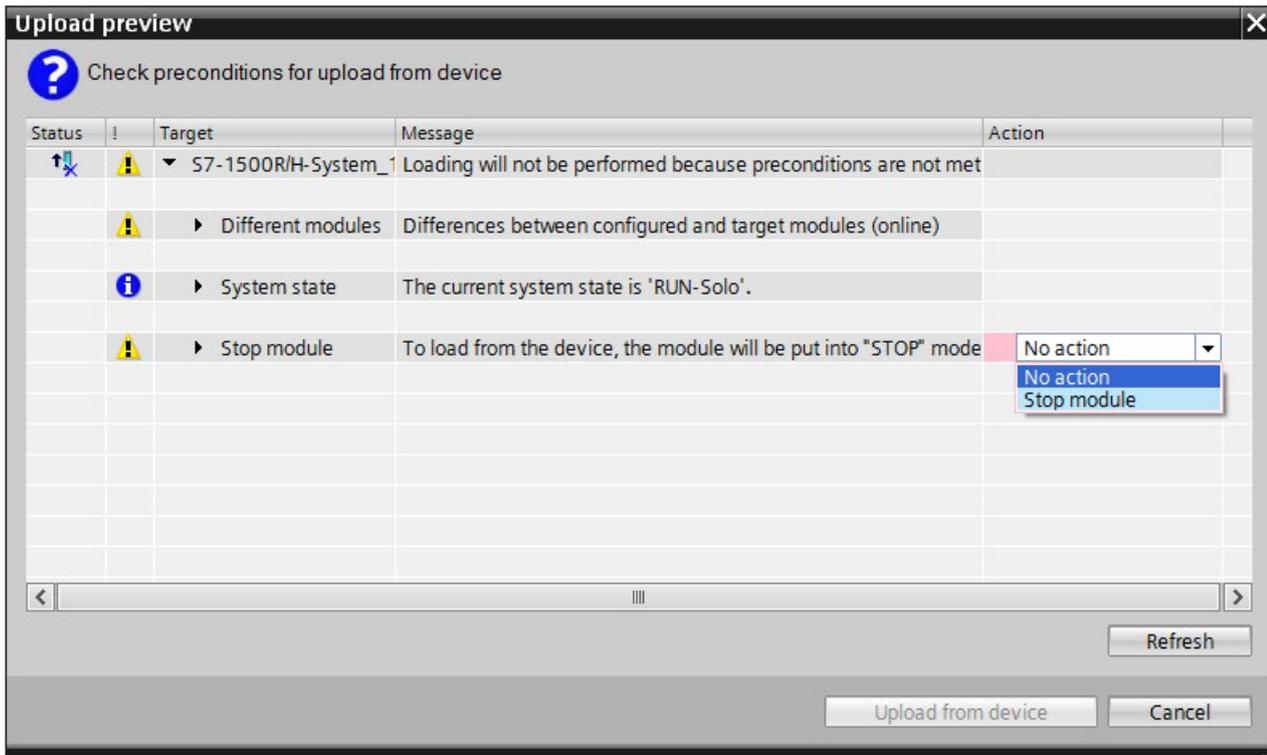
Figure 9-14   "Upload preview" dialog window

The preview shows that the backup target is H-System_1.

For a backup, the redundant system S7-1500R/H must be in the STOP system state.

In the "Action" column, select the "Stop module" command from the drop-down menu.
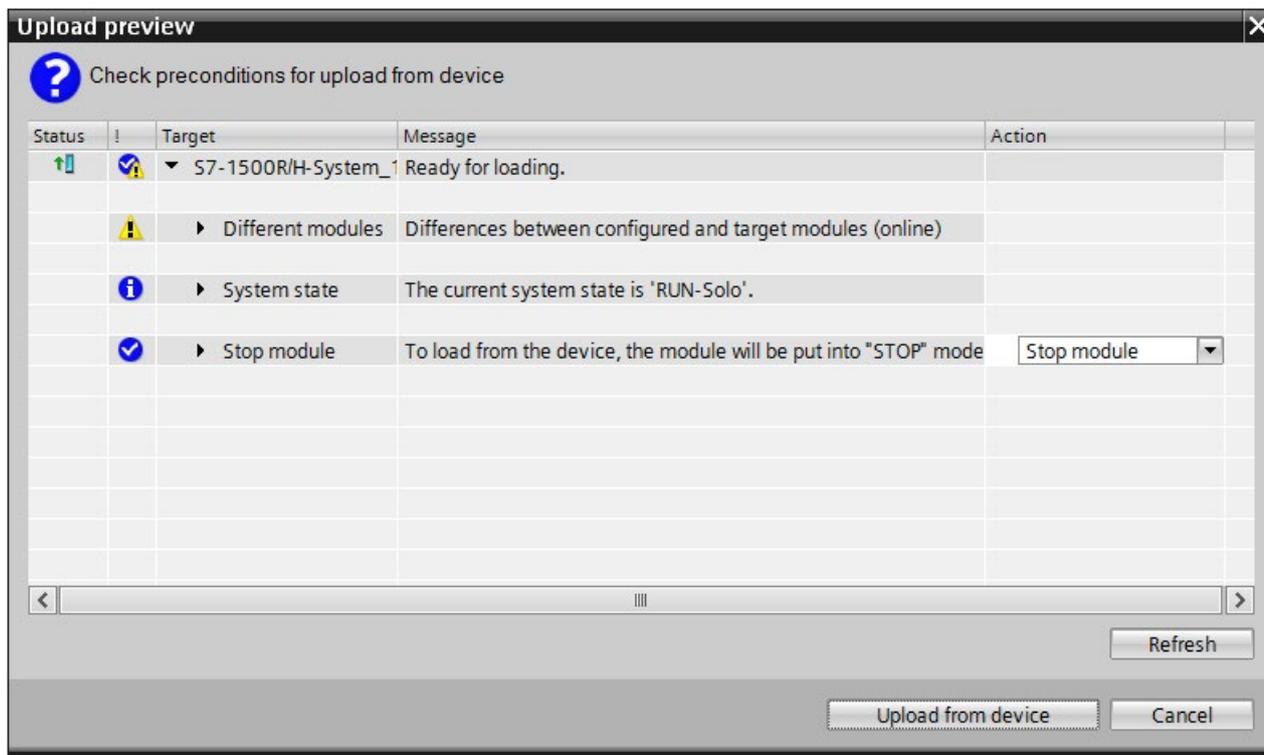
Figure 9-15   Upload from device

Click "Upload from device" to start the backup.

Reference

You can find more information on the various types of backup in the STEP 7 online help.

Emergency address (emergency IP)

If you cannot access the CPU via the IP address, you can set a temporary emergency IP address for the CPU. To the more information on emergency address options, please refer to the Communication (https://support.industry.siemens.com/cs/ww/de/view/59192925/en) function manual.

Storage of multilingual project texts

Different categories of texts are created when you configure a CPU, for example

- Object names (names of blocks, modules, tags, etc.)
- Comments (for blocks, networks, watch tables, etc.)
- Messages and diagnostic texts

Texts are provided by the system, for example texts in the diagnostics buffer, or they are created during configuration, for example, messages.

Texts exist in the project in one language or, after a translation process, in multiple languages. You can maintain project texts in all languages available to you in the project tree (Languages & resources > Project texts). The texts created during configuration can be downloaded to the CPU.

The following texts containing the project data are downloaded to the CPU in the chosen languages and are also used by the CPU display:

- Diagnostics buffer texts (not editable)
- Status texts for the module status (cannot be changed)
- Message texts with associated text lists
- Tag comments and step comments for PLC Code Viewer
- Comments in watch tables

The following texts containing the project languages are also downloaded to the CPU in the chosen languages, but are not used by the CPU display:

- Comments in tag tables (for tags and constants)
- Comments in global data blocks
- Comments of elements in block interfaces of FBs, FCs, DBs and UDTs
- Network titles in blocks written in LAD, FBD or STL
- Block comments
- Network comments
- Comments of LAD and FBD elements

The S7-1500R/H CPUs support archiving of multilingual project texts in up to three different project languages. If the project texts for a project language nevertheless exceed the memory space reserved for them on the SIMATIC memory card, the project cannot be downloaded to the CPU. The download is aborted with a notice that not enough memory space is available. In such a case, take measures to reduce the required storage space, for example by shortening comments.

Note

Size of the SIMATIC memory card

Make sure that there is enough available storage space on your SIMATIC memory card for downloading projects.

You can find information on reading out the memory usage of the CPU and the SIMATIC memory card in the Structure and Use of the CPU Memory (https://support.industry.siemens.com/cs/de/de/view/59193101/en) Function Manual.

You can find information on parameter assignment of multilingual project texts in STEP 7 in the STEP 7 online help.

9.7   Time synchronization

Introduction

All S7-1500R/H CPUs have an internal clock. The clock shows:

- The time of day with a resolution of 1 millisecond
- The date and the day of the week

The clock change for daylight saving time is also taken into account.

In redundant mode, the two CPUs of the S7-1500R/H redundant system constantly synchronize their internal clocks.

You can synchronize the time of the CPUs using the NTP procedure.

Principle of operation

In NTP mode, the device sends time queries at regular intervals (in client mode) to the NTP server in the subnet (LAN). Based on the replies from the servers, the most reliable and most accurate time is calculated and the time of day on the S7-1500R/H CPU is synchronized. The advantage of this mode is that it allows the time to be synchronized across subnets. You can synchronize the time of day of up to a maximum of four NTP servers. You address a communications processor or an HMI device, for example, as sources for time synchronization via the IP addresses.

The update interval defines the interval between the time queries (in seconds). The value range for the interval is 10 seconds to one day. In NTP mode, it is generally UTC (Universal Time Coordinated) that is transferred. UTC corresponds to GMT (Greenwich Mean Time).

Conditions

- In the S7-1500R/H redundant system, you need to configure time synchronization in NTP mode for each CPU individually. If possible, use the same settings for both CPUs.
- The settings for time synchronization with NTP mode are defined at PROFINET interface X1. PROFINET interface X2 uses the settings from PROFINET interface X1.
- Make sure that the primary CPU maintains a constant connection to the NTP server. The backup CPU then receives its synchronized time of day from the primary CPU.

Procedure

Proceed as follows to enable time synchronization for a CPU:

1. Configure the interface properties in the "Properties > General > PROFINET interface > Time synchronization" parameter group. Select the "Enable time synchronization via NTP server" option.
2. Enter the IP addresses of up to four NTP servers at parameter "Server 1-4".
3. Set the time interval for time queries at the parameter "Update interval".

9.7.1   Example: Configuring the NTP server

Configuring time synchronization with your own NTP server

Automation task

You use your own server in your network. Your own server offers the following advantages:

- Protection against unauthorized external accesses
- Every device that you synchronize with your own NTP server uses the same time.

You want to synchronize the CPUs of your S7-1500R/H redundant system with this NTP server.

Conditions and parameters

- You have your own NTP server in your network with the IP address 192.168.1.15.
- S7-1500R/H redundant system

Solution

1. Navigate to "Properties > General > PROFINET interface > Time synchronization > NTP mode" in the properties of the first CPU.
2. For "Server 1:", enter the IP address of the NTP server: 192.168.1.15.
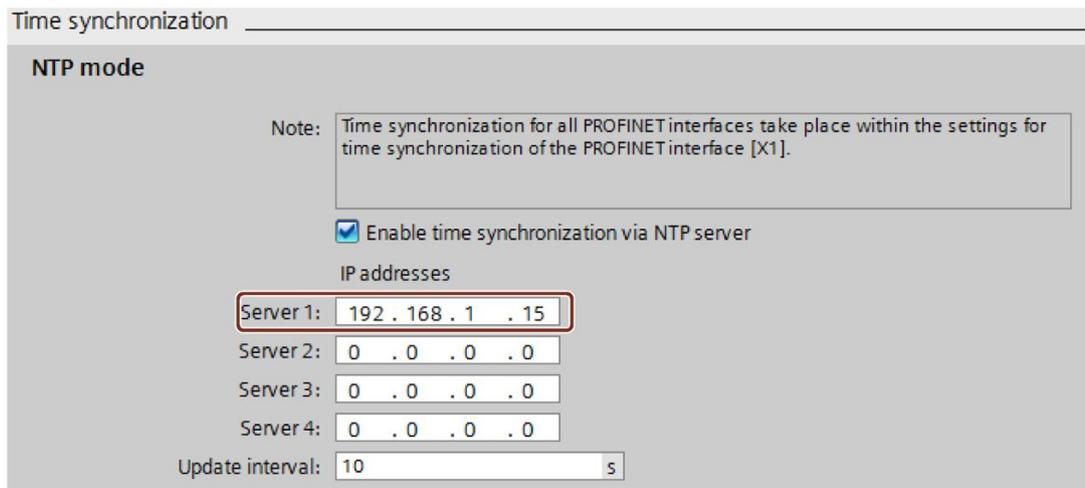
Figure 9-16   Example: Configuring the NTP server

3. Repeat steps 1 and 2 for the second CPU.
4. Download the hardware configuration to the primary CPU.

Result

The S7-1500R/H redundant system synchronizes the time with NTP server 192.168.1.15.

9.8 Identification and maintenance data

9.8.1 Reading out and entering I&M data

I&M data

Identification and maintenance data (I&M data) is information saved on the module. The data is:

- Read-only (I data) or
- Read/write (M data)

Identification data (I&M0): Manufacturer information about the module that can only be read. Some identification data is also printed on the housing of the module, for example article number and serial number.
Maintenance data (I&M1, 2, 3): Plant-specific information, for example installation location. Maintenance data for S7-1500R/H is created during configuration and downloaded to the redundant system.

S7-1500R/H supports identification data I&M0 to I&M3. Exception: The synchronization modules for S7-1500H only support identification data I&M0.

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

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

Modules can be clearly identified online using the I&M identification data.

Options for reading out I&M data

- Over the user program
- From the display of the CPUs
- Via STEP 7 or HMI devices

Reading I&M data over the user program

You have the following options for reading module I&M data in the user program:

- Using the RDREC instruction

  The data record structure for centrally inserted modules and for distributed modules accessible over PROFINET IO is described in the section Record structure for I&M data (Page 243).

- Using the Get_IM_Data instruction

Reference

The description of the instructions can be found in the STEP 7 online help.

Reading I&M data from displays

Proceed as follows to read the I&M data of a CPU:

1. Navigate to the "Overview/PLC" menu on the display of the CPU.

2. Select "Plant designation" or "Location identifier". Click "OK" to confirm.

Reading I&M data via STEP 7

Requirement: There must be an online connection to the CPU.

Proceed as follows to read I&M data using STEP 7 from the primary and backup CPU:

1. Select the CPU in the project tree.

2. Go to "Online & diagnostics".

3. In the "Diagnostics" folder, select the "General" area.

Enter maintenance data over STEP 7

STEP 7 assigns a default module name. You can enter the following information:

● Plant designation (I&M 1)

● Location identifier (I&M 1)

● Installation date (I&M 2)

● Additional information (I&M 3)

To enter maintenance data via STEP 7, follow these steps:

1. Select the CPU in the STEP 7 device view.

2. Go to properties, "General", and select the "Identification & Maintenance" area.

3. Enter the data.

During the loading of the hardware configuration, the maintenance data (I&M 1, 2, 3) are also loaded.

9.8.2 Record structure for I&M data

Reading I&M records via user program (centrally and distributed via PROFINET IO)

Use **Read data record** ("RDREC" instruction) to access specific identification data. Under the associated record index you obtain the corresponding part of the identification data.

The records are structured as follows:

Table 9- 17   Basic structure of data records with I&M identification data

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

Table 9- 18   Record structure for I&M identification data

Identification data	Access	Example	Explanation
Identification data 0: (record index AFF0$_H$)			
VendorIDHigh	Read (1 bytes)	0000$_H$	Vendor name (002A$_H$ = SIEMENS AG)
VendorIDLow	Read (1 bytes)	002A$_H$	
Order_ID	Read (20 bytes)	6ES7515-2RM00-0AB0	Article number of module (for example CPU 1515R-1 PN)
IM_SERIAL_NUMBER	Read (16 bytes)	-	Serial number (device-specific)
IM_HARDWARE_REVISION	Read (2 bytes)	1	corresponds to hardware version (e.g. 1)
IM_SOFTWARE_REVISION	Read	Firmware version	Provides information about the firmware version of the module (e.g. V1.0.0)
• SWRevisionPrefix	(1 byte)	V	
• IM_SWRevision_Functional_ Enhancement	(1 byte)	0000$_H$ - 00FF$_H$	
• IM_SWRevision_Bug_Fix	(1 byte)	0000$_H$ - 00FF$_H$	

Identification data	Access	Example	Explanation
• IM_SWRevision_Internal_ Change	(1 byte)	0000_H - $00FF_H$	
IM_REVISION_COUNTER	Read (2 bytes)	0000_H	Provides information about parameter changes on the module (not used)
IM_PROFILE_ID	Read (2 bytes)	0000_H	Generic Device
IM_PROFILE_SPECIFIC_TYPE	Read (2 bytes)	0001_H	CPU
		0003_H	I/O modules
IM_VERSION	Read	0101_H	Provides information on the ID data version
• IM_Version_Major	(1 byte)		(0101_H = Version 1.1)
• IM_Version_Minor	(1 byte)		
IM_SUPPORTED	Read (2 bytes)	$000E_H$	provides information about the available identification and maintenance data (I&M1 to I&M3)
Maintenance data 1: (Record index $AFF1_H$)			
IM_TAG_FUNCTION	Read/write (32 bytes)	-	Enter an identifier for the module here, that is unique plant-wide.
IM_TAG_LOCATION	Read/write (22 bytes)	-	Enter the installation location of the module here.
Maintenance data 2: (Record index $AFF2_H$)			
IM_DATE	Read/write (16 bytes)	YYYY-MM-DD HH:MM	Enter the installation date of the module here.
Maintenance data 3: (Record index $AFF3_H$)			
IM_DESCRIPTOR	Read/write (54 bytes)	-	Enter a comment about the module here.

9.8.3 Example: Read out firmware version of the CPU with Get_IM_Data

Automation task

You want to check whether the modules in your redundant system have the current firmware. The firmware version of the modules can be found in the I&M 0 data. The IM 0 data is the basic information for a device. I&M 0 data contains information such as:

- Manufacturer ID

- Article number and serial number

- Hardware and firmware version

To read out the I&M 0 data, use the "Get_IM_Data" instruction. You read the I&M 0 data of all modules in the user program of the CPU with "Get_IM_Data" instructions and store the I&M 0 data in a data block.

Conditions and parameters

The following block parameters of the "Get_IM_Data" instruction are important for reading out the I&M data of the CPU:

- LADDR: You enter the system constants or hardware identifier of the CPU at the LADDR parameter. You have the following options:

  - "Local1" (65149): The instruction always returns the I&M data of the CPU with redundancy ID 1.

  - "Local2" (65349): The instruction always returns the I&M data of the CPU with redundancy ID 2.

- IM_TYPE: Enter the I&M data number (for example "0" for I&M 0 data) at the IM_TYPE block parameter.

- DATA: Area for storing the I&M data read (for example in a global data block). Store the I&M 0 data in an area of the data type "IM0_Data".

This example shows you how to read out the I&M 0 data of a CPU 1513R-1 PN (redundancy ID 1, 6ES7513-1RL00-0AB0).

Solution

Proceed as follows to read out the I&M 0 data of the CPU with the redundancy ID 1:

1. Create a global data block to store the I&M 0 data.

2. Create a structure of the data type "IM0_Data" in the global data block. You can assign any name to the structure ("imData" in this case).

		Name	Data type	Start value
		SLI_gDB_Get_IM_Data		
1	▼	Static		
2	■ ▶	imData	IM0_Data	
3	■	done	Bool	false
4	■	busy	Bool	false
5	■	error	Bool	false
6	■	status	Word	16#0

Figure 9-17   Example: Data block for I&M data

3. Create the "Get_IM_Data" instruction in the user program, for example in OB 1.

4. Connect the "GET_IM_DATA" instruction as follows:
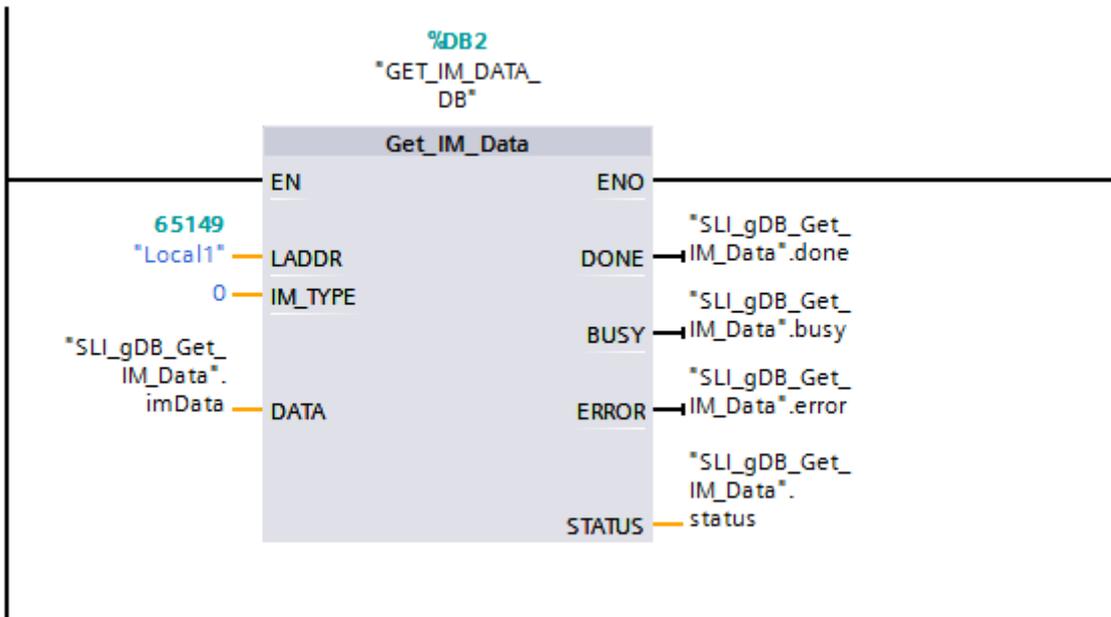
Figure 9-18   Example: Read out I&M0 data from the S7-1500R redundant system

5. Call the "Get_IM_Data" instruction in the user program.

Result

The "Get_IM_Data" instruction has stored the I&M 0 data of the CPU with redundancy ID 1 in the data block.

You can view the I&M 0 data online in STEP 7, for example with the "Monitor all" button in the data block. The CPU in the example is a CPU 1513R-1 PN (6ES7513-1RL00-0AB0) with the firmware version V2.6. The serial number of the CPU is 'S C-F9S840662018'.

		Name	Data type	Start value	Monitor value
		SLI_gDB_Get_IM_Data			
1		▼ Static			
2		▪ ▼ imData	IM0_Data		
3		▪ Manufacturer_ID	UInt	0	42
4		▪ Order_ID	String[20]	"	'6ES7513-1RL00-0...
5		▪ Serial_Number	String[16]	"	'S C-F9S840662018'
6		▪ Hardware_Revision	UInt	0	1
7		▪ ▼ Software_Revision	IM0_Version		
8		▪ Type	Char	' '	'V'
9		▪ Functional	USInt	0	2
10		▪ Bugfix	USInt	0	6
11		▪ Internal	USInt	0	0
12		▪ Revision_Counter	UInt	0	0
13		▪ Profile_ID	UInt	0	0
14		▪ Profile_Specific_Ty...	UInt	0	0
15		▪ IM_Version	Word	16#0	16#0101
16		▪ IM_Supported	Word	16#0	16#001E
17		▪ done	Bool	false	TRUE
18		▪ busy	Bool	false	FALSE
19		▪ error	Bool	false	FALSE
20		▪ status	Word	16#0	16#0000

Figure 9-19   Example: I&M 0 data of an R CPU

Benefits

You can see from the data block at a glance which module requires an update.

Display

10

10.1 CPU display

Introduction

The following section gives an overview of how the R/H-CPU display operates. Detailed information on the individual options, a training course and a simulation of the selectable menu items is available in the SIMATIC S7-1500 Display Simulator (http://www.automation.siemens.com/salesmaterial-as/interactive-manuals/getting-started_simatic-s7-1500/disp_tool/start_en.html).

Display

The R/H-CPUs have a front cover with a display and operating keys. The display of the CPUs shows you the control and status information in various menus. You use operating keys to navigate through the menus and make a variety of settings in the process.

Benefits

The display offers the following advantages:

- Reduced downtimes through diagnostic messages in plain text

- Less time required for commissioning and maintenance, shorter plant downtime.

- Shorter downtimes due to read/write access to force tables and read/write access to watch tables.
  The watch and force tables allow you to monitor and modify the actual values of individual tags of a user program on the display. You can find additional information on the watch and force tables in the section Test functions (Page 282) and in the STEP 7 online help.

- On site, an image (backup copy) of the functioning plant can be

  – Backed up on the SIMATIC memory card of the CPU

  – Restored from the SIMATIC memory card of the CPU

  You do not require an additional PG/PC.

- Visualization of the SYNCUP system state with graphic and percentage progress display

Password protection for the display

In the properties of the CPUs, you configure a password in STEP 7 for display operation. Local access protection is thus protected with a local password. Password protection can be configured differently for each display.

Operating temperature for the display

To increase the service life of the display, the display switches off when the permitted operating temperature is exceeded. When the display has cooled down again, it switches back on automatically. When the display is switched off, the LEDs continue to show the status of the CPUs.

You can find additional information on display temperatures in the technical specifications in the CPU manuals.

Display

The following figures show an example of a CPU with large display (left: for example CPU 1517H-3 PN) and small display (right: CPU 1513R-1 PN).
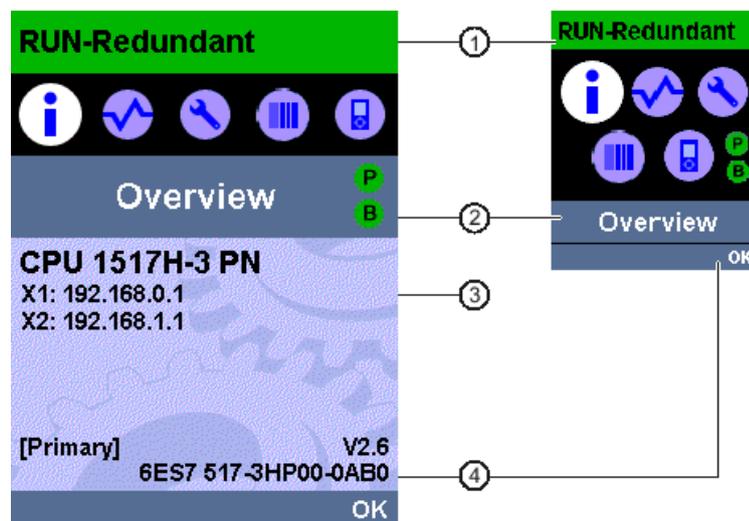
① CPU status information
② Names of the menus
③ Data display field
④ Navigation aid, e.g. OK/ESC or the page number

Figure 10-1   Example views of the displays

Regarding ①: CPU status information

The following table shows the CPU status information that can be retrieved via the display.

Table 10- 1   CPU status information

Color and icons for the status data	Meaning
Green	• RUN • RUN-Syncup • RUN-Redundant
Orange	• STARTUP • SYNCUP • STOP • STOP - firmware update
Red	FAULT
White	• Connection established between CPU and display.
🔒	Protection level configured.
⚠	• At least one interrupt is active in the CPU. • No SIMATIC memory card inserted in the CPU. • The serial number to which a know-how-protected block is bound does not match the serial number of the CPU or the SIMATIC memory card (not R/H-CPU). • No user program loaded.
F	Force job is active in the CPU.

Regarding ②: Names of the menus

The following table shows the available menus of the display.

Table 10- 2   Names of the menus

Main menu items	Meaning	Description
	Overview	The "Overview" menu contains information about: • Properties of the local CPU • Redundancy properties, for example – Display of role (primary CPU or backup CPU) – Displaying and setting the redundancy ID – Display of the pairing state • Know-how protection or serial number link • Properties of the inserted SIMATIC memory card
	Diagnostics	The "Diagnostics" menu includes: • Display of alarms • Display of the diagnostics buffer • Read and write access to force and watch tables • Display of cycle time • Display of memory used
	Settings	In the "Settings" menu you: • Assign IP address and PROFINET device name of the CPU • Set date, time of day and time zones • Set operating states (RUN/STOP) • Perform a CPU memory reset or reset to factory settings • Set protection level • Back up/restore CPU configuration to/from the SIMATIC memory card. • Disable/enable display with display password • Format SIMATIC memory card • Run firmware update and display status • Convert SIMATIC memory card or delete user program
	Modules	The "Modules" menu is not supported for R/H-CPUs.
	Display	In the "Display" menu you can configure settings related to the display, such as language setting, brightness and energy-saving mode. The energy-saving mode dims the display. Standby mode switches off the display.

Menu icons

The following table shows the icons that are displayed in the menus.

Table 10- 3   Menu icons

Icon	Meaning
🖉	Editable menu item.
🌐	Select the required language.
⚠	A message is available in the next lower level page.
⛔	There is an error in the next lower level page.
❌	The marked module is not accessible.
▶	Navigate to the next lower level page.
⬍	In edit mode you make the selection using two arrow keys: • Down/up: Jumps to the selection or is used to select the desired digits/options.
✛	In edit mode you make the selection using four arrow keys: • Down/up: Jumps to the selection or is used to select the desired digits. • Left/right: Jumps one place forward or back.
📩	The alarm is not yet acknowledged.
✉	The alarm is acknowledged.

Control keys

You operate the display using the following keys:

● Four arrow keys: "up", "down", "left", "right"
  If you press and hold an arrow key for 2 seconds, this generates an automatic scroll function.

● One ESC key

● One OK key
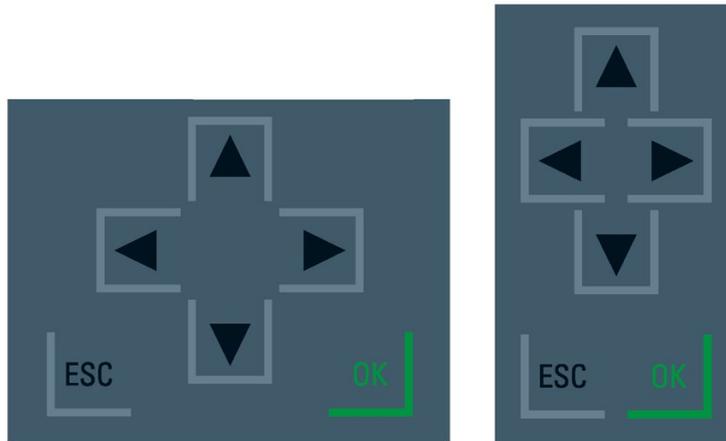
Figure 10-2   Control keys

Note

If the display is in energy-saving mode or in standby mode, you can exit this mode by pressing any key.

Functions of the "OK" and "ESC" keys

● For menu commands in which an entry can be made:

  – OK → valid access to the menu command, confirmation of input, and exit from the edit mode

  – ESC → restore original content (changes are not saved) and exit edit mode

● For menu commands in which no entry can be made:

  – OK → to next submenu command

  – ESC → back to previous menu command

Hold ESC for about three seconds on any screen of the display. Result: You automatically return to the home page.

Tooltips

Some of the values shown on the display can exceed the available display width. The values in question include:

- Device name

- Plant designation

- Location identifier

- PROFINET device name

The available display width is frequently exceeded on CPUs with small displays.

If you focus on the relevant value on the display and press the "Left" arrow key, a tooltip appears. The tooltip shows the name of the value in complete length. The tooltip is hidden again if you again press the "Left" arrow again or the ESC key.
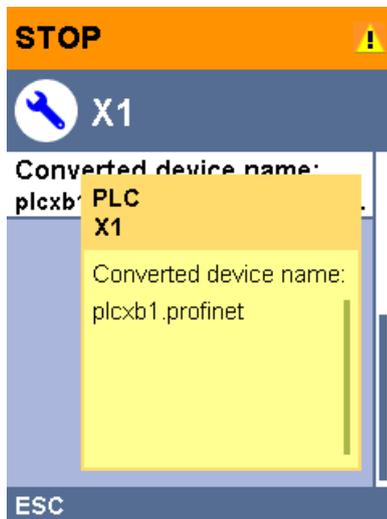
Figure 10-3 Tooltip function

Uploading image to the display via STEP 7

In the STEP 7 device view, you download an image from your file system to the CPU display with the "Display > User-defined logo" function. Different images can be downloaded to the two R/H-CPUs for clearer differentiation.
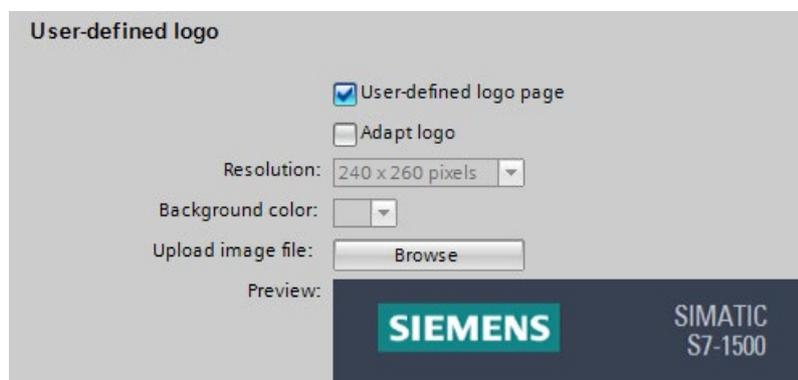
Figure 10-4   Uploading image to CPU

To display the uploaded image in the correct aspect ratio, use images with the following dimensions depending on the CPU:

Table 10- 4   Dimensions

CPU	Dimensions	Supported formats
CPU 1513R-1 PN	128 x 120 pixels	Bitmap, JPEG, GIF, PNG
CPU 1515R-2 PN	240 x 260 pixels	Bitmap, JPEG, GIF, PNG
CPU 1517H-3 PN	240 x 260 pixels	Bitmap, JPEG, GIF, PNG

If the uploaded image exceeds the specified dimensions, the display shows only part of the image. The "Adapt logo" option in STEP 7 allows you to reduce the image to the specified dimensions. However, note that the original aspect ratio of the image is not retained in such cases.

Displaying image on the display

To display the uploaded image on the display of the CPU, press the ESC key in the main screen of the display. When you upload an image and are in the main screen, the display automatically shows the image after 60 seconds. To hide the image again, press any key on the display.

Available language settings

You can set the following languages separately for menu and message texts:

- Chinese
- German
- English
- French
- Italian
- Japanese
- Korean
- Portuguese (Brazil)
- Russian
- Spanish
- Turkish

You select the required language directly at the display in the "Display" menu or in STEP 7 in the hardware configuration of the CPU under "User interface languages".

Proceed as follows to display message texts on the display:

1. Download the message texts to the CPU as a software component.
   - To do so, select the "Consistent download" option under "Text libraries" in the "Load preview" dialog.

2. Configure the project language that you want to be displayed as the interface language.
   - To do so, select a CPU and navigate to the "Multiple languages" area ("Properties > General > Multilingual support") in the Inspector window.
   - Assign the required project languages to the interface languages.

Maintenance

11

11.1 Replacing components of the S7-1500R/H redundant system

11.1.1 Checking before replacing components

Introduction

Please observe the following rules if the redundant system is in the RUN-Solo system state:

- Do not immediately start replacing components.
- Do not immediately switch the failed CPU to the RUN. operating state.

First check the pairing status in the RUN-Solo system state.

Checking pairing in the RUN-Solo system state

⚠ CAUTION
Do not switch the failed CPU in the RUN-Solo system state to the RUN operating state.
This could result in an undefined system state for the redundant system. Both CPUs would become primary CPUs.
If the S7-1500R/H redundant system is in the RUN-Solo system state, you must not immediately switch the backup CPU to the RUN operating state.
Possible cause: No pairing between the two CPUs. Check the pairing status on the display or on the basis of the diagnostics status or diagnostics buffer.
If there is no pairing, the redundancy connections have been interrupted, for example. In this case, please note the procedure below.

Checking pairing state

You have the following options for checking the pairing state:

- Directly from the display of the backup CPU.
  In the "Overview > Redundancy > Pairing state" menu:

  – Paired

  – Single paired (X*P*)

  – Not paired

  – Not paired - Too many partners

  – Not paired - Article ID mismatch

  – Not paired - Firmware mismatch

Primary CPU	Backup CPU
STOP ⚠ ℹ **Redundancy** Redundancy role: **Primary** Redundancy ID: 🖉 **1** Pairing state: **Paired** Pairing serial number: **S C-J9P136562017** **ESC**	**STOP** ⚠ ℹ **Redundancy** Redundancy role: **Backup** Redundancy ID: 🖉 **2** Pairing state: **Paired** Pairing serial number: **S C-J9P083002017** **ESC**

Example: Paired

- In STEP 7 in the diagnostic status (Online & diagnostics) of the S7-1500R/H system: Check the system state in the diagnostic status:

  – Pairing: "Paired" is shown in the "Pairing state" field.

  – No pairing: "Not paired" is shown in the "Pairing state" field.
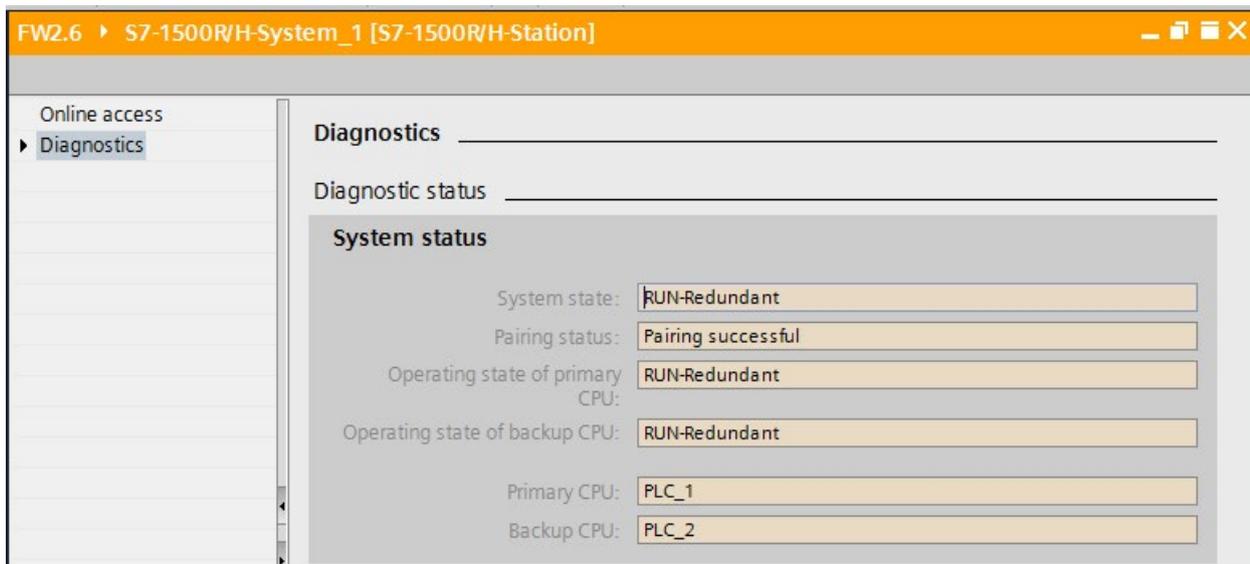
Figure 11-1   "Paired" diagnostics state

- In STEP 7 in the diagnostics buffer (Online & diagnostics): Check the entries on pairing.

Procedure

To start the pairing, for example when redundancy connections are interrupted, follow these steps:

1. Set the mode selector for the backup CPU to STOP.

2. S7-1500R: Repair the PROFINET cables in the PROFINET ring. Insert the PROFINET cables into the R-CPU interfaces.
   S7-1500H: Repair the fiber-optic cables and synchronization modules. Insert the fiber-optic cables into the synchronization modules.

3. Check for successful pairing of the redundant system. Please note the information in "Checking pairing state" above.

4. Switch the backup CPU to the RUN operating state with the mode selector.

Result

The S7-1500R/H redundant system switches to the RUN-Redundant system state.

11.1.2 Replacing defective R/H-CPUs

Initial situation

One of the two R/H-CPUs has failed or the R/H-CPU is no longer working.

The S7-1500R/H redundant system is in the RUN-Solo system state.

Requirements

- Read the information in the section Checking before replacing components (Page 257).
- The replacement CPU has the same article number and firmware version as the failed R/H-CPU.
- The replacement CPU has a SIMATIC memory card with the correct storage capacity.
- The primary CPU has not disabled SYNCUP (default).

Procedure for replacing R/H-CPUs

Proceed as follows to replace an R/H-CPU in the redundant system:

1. Switch off the supply voltage to the failed R/H-CPU.
2. Remove the connector for the supply voltage.
3. Disconnect the bus connector for the PROFINET ring. Then remove the bus connector from the R/H-CPU.
4. For H-CPUs only: Disconnect the redundancy connections (fiber-optic cables) at the H-CPU.
5. For H-CPUs only: Pull the synchronization modules out of the H-CPU.
6. Remove the failed R/H-CPU.
7. Install the replacement CPU with the SIMATIC memory card inserted and the mode selector in the STOP position.
8. For H-CPUs only: Insert the synchronization modules in the replacement CPU.
9. For H-CPUs only: Insert the redundancy connections (fiber-optic cables) in the synchronization modules.
10. Insert the PROFINET cables in the R/H-CPU.
11. Push the connector for the supply voltage into the socket on the R/H-CPU.
12. Switch the supply voltage back on.
13. Switch the replacement CPU to the RUN operating state.

Result

1. The replaced R/H-CPU executes SYNCUP.
2. The replaced R/H-CPU switches to the RUN-Redundant operating state and operates as backup CPU.

11.1.3 Replacing defective redundancy connections

Introduction

This section describes the following replacement scenarios:

S7-1500R:

- Replace defective PROFINET cable with S7-1500R.
  The PROFINET ring has been interrupted at any given point. You can find additional information in the section Replacing defective PROFINET cables (Page 265).

- Replace two defective PROFINET cables with S7-1500R.
  The PROFINET ring has been interrupted at two points.

S7-1500H:

- Replace a defective redundancy connection with S7-1500H.
  A fiber-optic cable has been interrupted.

- Replace defective synchronization module with S7-1500H.

- Replace two defective redundancy connections with S7-1500H.
  Both fiber-optic cables have been interrupted.

Evaluating the diagnostics buffer

Detailed diagnostics information is provided in the diagnostics buffer of the R/H-CPU. The entries are particularly useful in the replacement scenarios for the redundancy connections:

- S7-1500R: They contain information on whether one PROFINET cable or both PROFINET cables have been interrupted or a port of an R-CPU is defective.

- S7-1500H: You can access information on whether a fiber-optic cable has been interrupted or the synchronization module is defective (with additional module diagnostics).

11.1.3.1   Replacing two defective PROFINET cables with S7-1500R

Initial situation: Failure of two PROFINET cables, one after the other

Two PROFINET cables in the PROFINET ring have been interrupted one after the other at two points (> 1500 ms apart).

The S7-1500R redundant system is in the STOP system state.

Requirement

Read the information in the section Checking before replacing components (Page 257).

Procedure: Replacing the two PROFINET cables

Proceed as follows to replace the defective PROFINET cables:

1. Locate the defective PROFINET cables in the PROFINET ring.

2. Replace the PROFINET cables, one after the other.

3. Restart each of the two CPUs.

Result

The redundant system switches to the RUN-Redundant system state.

Initial situation: Failure of two PROFINET cables simultaneously

Two PROFINET cables in the PROFINET ring have been interrupted at two points simultaneously (≤ 1500 ms apart).

Both R-CPUs are primary CPUs. The S7-1500R redundant system is in an undefined system state.

Procedure: Replacing the two PROFINET cables

Proceed as follows to replace the defective PROFINET cables:

1. Immediately switch both R-CPUs to the STOP operating state.

2. Locate the defective PROFINET cables in the PROFINET ring.

3. Replace the PROFINET cables, one after the other.

4. Afterwards, switch the R-CPUs back to the RUN operating state.

Result

The redundant system switches to the RUN-Redundant system state.

11.1.3.2 Replacing a defective redundancy connection with S7-1500H

Initial situation

One redundancy connection (fiber-optic cable) has been interrupted. Display shows: Single pairing with information on interface and port.

The S7-1500H redundant system is in the RUN-Redundant system state.

Procedure: Replacing the redundancy connection

Proceed as follows to replace a defective redundancy connection:

1. Check the X3/X4 LEDs. You can pinpoint the defective redundancy connection on the basis of which LEDs are off.

2. Check the redundancy connection that you have located with the LEDs.

3. If the redundancy connection is defective, replace the fiber-optic cable.

Result

The defective redundancy connection has been replaced. The X3/X4 LEDs flicker yellow/green.

11.1.3.3 Replacing defective synchronization module with S7-1500H

Initial situation

A synchronization module has failed.

The redundant S7-1500H is in the RUN-Redundant system state.

Procedure: Replacing the synchronization module

Proceed as follows to replace a defective synchronization module:

1. Check the X3/X4 LEDs on the primary and backup CPU. Locate the defective synchronization module on the basis of which LEDs are off.

2. Replace the defective synchronization module. Connect the redundancy connection (fiber-optic cable).

3. If the X3/X4 LEDs remain off, replace the synchronization module on the other CPU.

Result

The defective synchronization module has been replaced. The X3/X4 LEDs flicker yellow/green.

11.1.3.4   Replacing both defective redundancy connections with S7-1500H

Initial situation: Failure of both redundancy connections, one after the other

The two redundancy connections (fiber-optic cables) have been interrupted one after the other (> 1500 ms apart).

The S7-1500H redundant system is in the RUN-Solo system state.

Requirement

Read the information in the section Checking before replacing components (Page 257).

Procedure: Replacing both redundancy connections

Proceed as follows to replace the defective redundancy connections:

1. Check the X3/X4 LEDs on the primary and backup CPU. If all LEDs are off, both redundancy connections are defective.

2. Replace the redundancy connections (fiber-optic cables) one after the other.

3. Switch the CPU, which is in STOP mode, to RUN mode.

Result

The defective redundancy connections have been replaced. The redundant system switches to the RUN-Redundant system state. The X3/X4 LEDs flicker yellow/green.

Initial situation: Failure of both redundancy connections simultaneously

The two redundancy connections (fiber-optic cables) have been interrupted simultaneously (≤ 1500 ms apart).

Both H-CPUs are primary CPUs. The S7-1500H redundant system is in an undefined system state.

Procedure: Replacing both redundancy connections

Proceed as follows to replace the defective redundancy connections:

1. Immediately switch both H-CPUs to the STOP operating state.

2. Replace the redundancy connections (fiber-optic cables) one after the other.

3. Switch the H-CPUs back to the RUN operating state.

Result

The redundant system switches to the RUN-Redundant system state. The X3/X4 LEDs flicker yellow/green.

11.1.4 Replacing defective PROFINET cables

Initial situation

The PROFINET ring has been interrupted at any given point. The MAINT LEDs on both CPUs are yellow. The following is shown on the S7-1500R display: Single pairing with information on interface and port.

The S7-1500R/H redundant system is in the RUN-Redundant system state.

Procedure: Replacing the PROFINET cable

Proceed as follows to replace the defective PROFINET cable:

1. Check the X1 P1/X1 P2 LEDs on the primary and backup CPU. LEDs that are off indicate an interruption to the PROFINET ring.

2. Locate the defective PROFINET cable in the PROFINET ring.

3. Replace the defective PROFINET cable.

Result

The defective PROFINET cable has been replaced.
The X1 P1/X1 P2 LEDs on the primary and backup CPU are yellow. The MAINT LEDs on both CPUs are off.

11.1.5 Replacing a defective SIMATIC memory card

Initial situation

The SIMATIC memory card of a CPU is defective. System diagnostics reports a system error. The CPU affected has switched to the STOP operating state.

The S7-1500R/H redundant system is in the RUN-Solo system state.

Requirement

- Read the information in the section Checking before replacing components (Page 257).
- The new SIMATIC memory card must have sufficient memory for the project.

Procedure

Proceed as follows to replace a defective SIMATIC memory card:

1. Replace the SIMATIC memory card in the CPU in STOP.
2. Switch the CPU to the RUN operating state.

Result

1. The CPU with the replaced SIMATIC memory card runs SYNCUP. SYNCUP transfers the project data from the primary to the backup CPU.
2. The CPU switches to the RUN-Redundant operating state and operates as backup CPU. The redundant system is in the RUN-Redundant system state again.

Reference

If there is not enough memory space on a SIMATIC memory card, the card can be replaced during operation. You will find the procedure, the response of the redundant system and other information on the SIMATIC memory card in the function manual Structure and use of the CPU memory (https://support.industry.siemens.com/cs/de/de/view/59193101/en).

11.1.6 Replacing a defective system power supply PS or load power supply PM

Initial situation

A system power supply PS or load power supply PM has failed.

The S7-1500R/H redundant system is in the RUN-Solo system state.

Requirement

Read the information in the section Checking before replacing components (Page 257).

Procedure

Proceed as follows to replace a defective system power supply PS or load power supply PM:

1. Switch off the mains supply (24 V DC or 230 V AC).

2. Replace the defective system power supply PS or load power supply PM.

3. Switch the mains supply back on.

4. Switch on the replaced system power supply PS or load power supply PM.

Result

1. The CPU with the replaced system power supply PS or load power supply PM runs SYNCUP. Requirement: The CPU mode selector is in RUN.

2. The CPU switches to the RUN-Redundant operating state and operates as backup CPU. The redundant system is in the RUN-Redundant system state again.

11.1.7 Replacing defective IO devices/switches

Initial situation

A PROFINET device (IO device/switch) in the PROFINET ring has failed, for example because of a defect in the IO device or failure of the power supply. The PROFINET ring has been interrupted. The MAINT LEDs on both CPUs are yellow. The ERROR LEDs on both CPUs are flashing red.

The S7-1500R/H redundant system is in the RUN-Redundant system state.

Note

If a switch/IO device fails, the S7-1500R/H redundant system has no access to the downstream devices in the connected line topology.

Procedure

Proceed as follows to replace a defective PROFINET device:

1. Locate the faulty PROFINET device.
2. Switch off the supply voltage for the PROFINET device.
3. Disconnect the supply voltage.
4. Disconnect the PROFINET cables from the ports of the PROFINET device.
5. Replace the PROFINET device.
6. Connect the PROFINET cables to the ports of the PROFINET device.
7. Connect the supply voltage to the PROFINET device.
8. Switch the supply voltage back on.

Note

Setting the media redundancy role Client for the PROFINET devices

If you replace a PROFINET device in the PROFINET ring, you need to assign the media redundancy role "Client" to the PROFINET device in STEP 7. The Client media redundancy role setting is important for devices that are not IO devices with system redundancy S2 (for example S7-1500 CPUs and switches). PROFINET devices without system redundancy S2 are not assigned parameters by the R/H-CPUs.

Replaced IO devices with system redundancy S2 are automatically configured by the R/H system and are reset to the correct settings.

Result

The PROFINET ring has been closed again. The PROFINET device can be accessed again in the S7-1500R/H redundant system. The MAINT and ERROR LEDs on both CPUs are off.

11.2 Replacing the front cover

Replacing the front cover

The front cover is pluggable. If necessary, you can take off the front cover or replace the front cover during runtime (RUN). Removing or replacing the front cover does not affect the CPU in operation.

To remove the front cover from the CPU, follow these steps:

1. Flip up the front cover until the front cover stands at a 90° angle to the front of the module.

2. In the top section of the front cover, press on the anchor(s): Two anchors with CPU 1515R-2 PN, CPU 1517H-3 PN. One anchor with CPU 1513R-1 PN.
   At the same time, pull the front cover towards you and off.

The view in the figure below is an example of CPU 1515R-2 PN.

①   Fasteners for removing and fitting the front panel

Figure 11-2   Removing and fitting the front panel

> ⚠️ **WARNING**
>
> **Personal injury or material damage can occur in zone 2 hazardous areas**
>
> If you remove or attach the front cover during operation, personal injury and damage can occur in hazardous areas of zone 2.
>
> Always disconnect the R/H-CPU from the power supply before you remove or attach the front cover in hazardous areas of zone 2.

11.3 Replacing the coding element at the power connector of the system power supply and load current supply

Introduction

The coding consists of a 2-part coding element.

Ex factory a part of the coding element is inserted into the back side of the power connector. The other part is firmly inserted in the system power supply or load power supply.

This prevents the insertion of a power connector of a system power supply or load power supply into a module of a different type.

⚠ **DANGER**

Do not manipulate the coding element, or leave it off

- Changing or replacing the coding element can result in dangerous system states.
- To avoid damage, do not change or replace the coding element.
- You must not remove the coding element.

Replacement parts scenario

Insertion of the coding element into a new power connector in the case of a replacement part.

⚠ **DANGER**

Dangerous voltage

When installing the coding element, you must take into account the supply voltage of the system power supply and load power supply: 24 V DC, 24/48/60 V DC or 120/230 V AC/DC

Only install the coding element with switched-off voltage.

You must insert the coding element in such a way that the power connector matches the power supply module in terms of voltage.

Procedure

To replace the coding element on the power connector of the system power supply and load current supply, follow these steps:

1. Orient yourself using the labeling on the power cable connection.
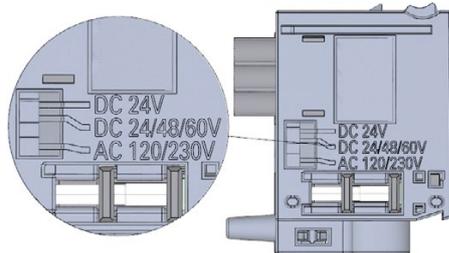
Figure 11-3   Labeling on the power connector

2. Orient yourself using the red marking on the coding element.

3. The coding element has 3 red markings. Turn the coding element in such a way that one of the 3 red markings corresponds to the voltage indicated on the connector.

4. Insert the coding element into the back side of the power cable connector, until you hear it click into place. The figure below shows you how to insert a coding element into a power cable connector for 24 V DC.
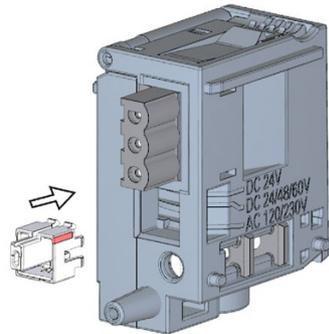
Figure 11-4   Inserting a coding element into a power connector

11.4 Firmware update

Introduction

You use firmware files to update the firmware of the CPUs, displays and the IO devices (for example for new functions). The retentive data is retained after the firmware has been updated.

Note

CPUs operating in redundant mode

CPUs operating in redundant mode must have the same article number, function version and firmware version.

For the replacement of components, the two CPUs operating in redundant mode must have the same firmware version. Downgrades are therefore possible as well as updates.

Note

CPU downgrades and upgrades

You cannot upgrade a standard CPU or F-CPU to an R-CPU or H-CPU. You cannot downgrade the firmware of an R/H-CPU to a standard or F-CPU either.

Requirement

You have downloaded the files for the firmware update from Siemens Industry Online Support (https://support.industry.siemens.com/cs/ww/en/ps).

On this Web page, select:

Automation technology > Automation systems > SIMATIC industrial automation systems > Controllers > Advanced Controller > S7-1500 > CPUs > Redundant CPUs
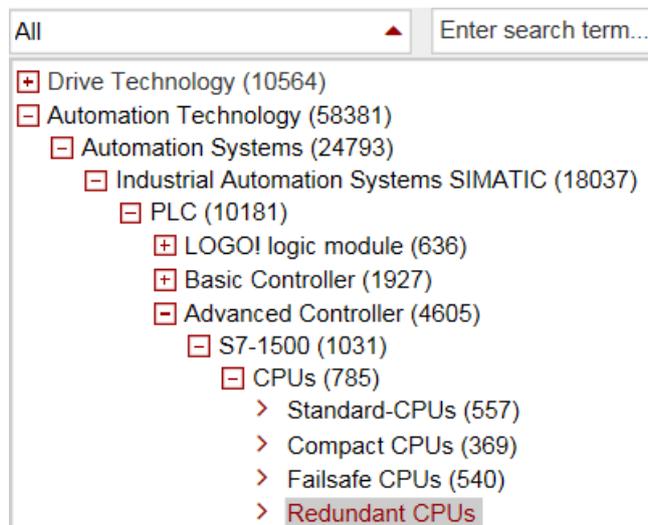
Figure 11-5   Product tree using the S7-1500 as an example

From this position, navigate to the specific type of module that you want to update. To continue, click on the "Software downloads" link under "Support". Save the required firmware update files.

Before installing the firmware update, make sure that the modules are not being used.

Options for the firmware update

The options for performing a firmware update are as follows:

● Online in STEP 7 via Online & Diagnostics

● Online in STEP 7 via accessible devices (PROFINET)

● Via the SIMATIC memory card: For CPU and display only

The table below gives an overview of the various options for a firmware update.

Firmware update	CPU	Display	PROFINET IO devices with system redundancy S2
STEP 7 via Online & diagnostics	✓		✓
SIMATIC memory card	✓		--

Procedure: online in STEP 7 via Online & diagnostics

Proceed as follows to perform a firmware update online via STEP 7:

1. Select the module in the device view.

2. Select the "Online & diagnostics" menu command from the shortcut menu.

3. In the "Functions" folder, select the "Firmware update" group.
   For a CPU, you can select whether you want to update the CPU or the display.

4. Click the "Browse" button to select the path to the firmware update files in the "Firmware update" area.

5. Select the correct firmware file. The table in the firmware update area lists all modules for which an update is possible with the selected firmware file.

6. Click the "Run update" button. If the module can interpret the selected file, the file is downloaded to the module. If you need to change the CPU operating state, STEP 7 prompts you to do so with dialogs.

Note

Updating PROFINET IO devices with system redundancy S2

The R/H system remains in the RUN-Redundant system state if you update an IO device with system redundancy S2.

Updating the firmware

The "Run firmware after update" check box is always selected.

Once the files have been successfully loaded, the CPU accepts the firmware and operates with the new firmware.

Procedure with the SIMATIC memory card

Proceed as follows to perform a firmware update using the SIMATIC memory card:

1. Insert a SIMATIC memory card into the SD card reader of your PG/PC.

2. To store the update file on the SIMATIC memory card, select the SIMATIC memory card under "Card reader/USB memory" in the project tree.

3. Select the "Card Reader/USB memory > Create firmware update memory card" command in the "Project" menu.

4. Use a file selection dialog to navigate to the firmware update file. You can then also decide whether to delete the content of the SIMATIC memory card or add the firmware update files to the SIMATIC memory card.

5. Insert the SIMATIC memory card with the firmware update files into the CPU.

   The firmware update begins shortly after the SIMATIC memory card has been inserted.

   The display indicates that the CPU is in STOP and is running a firmware update.

   The display shows a results screen after completion of the firmware update.

6. Remove the SIMATIC memory card after the firmware update is complete.
   The RUN LED on the CPU lights up in yellow and the MAINT LED flashes yellow.
   If you subsequently wish to use the SIMATIC memory card as a program card, leave the SIMATIC memory card in the CPU. To do so, after completion of the firmware update, select the "Convert memory card" menu item on the display.
   Alternatively, you can also convert the SIMATIC memory card to a program card in STEP 7.

Note

Memory size of the SIMATIC memory card

If you perform a firmware update via the SIMATIC memory card, you must use a large enough card.

Check the specified file sizes of the update files when downloading them from Siemens Industry Online Support. The total size of the update files must not exceed the available memory size of your SIMATIC memory card.

You can find more information on the capacity of SIMATIC memory cards in the section Accessories/spare parts (Page 305) and in the function manual Structure and use of the CPU memory (https://support.industry.siemens.com/cs/de/de/view/59193101/en).

Installation of the firmware update of R/H-CPUs

For a firmware update of the R/H-CPUs, you must switch both R/H-CPUs to the STOP operating state. A role change between primary and backup CPU can occur during the process. The following requirement therefore applies: CPU 1 is the primary CPU. CPU 2 is the backup CPU.

You must proceed in the following order for retentive data to be retained during a firmware update:

1. Switch CPU 2 to the STOP operating state.

2. Run the update for CPU 2.
    Please note: Ignore any pairing error (incorrect firmware) after CPU 2 startup.

3. Switch CPU 1 to the STOP operating state.

4. Now run the update for CPU 1.

5. Switch CPU 1 to the RUN operating state.

6. Switch CPU 2 to the RUN operating state.

⚠ **WARNING**

Risk of impermissible system states

The installation of the firmware update switches the CPUs to the STOP operating state and therefore the redundant system to the STOP system state. STOP can impact the operation of an online process or a machine.

Unexpected operation of a process or a machine can lead to fatal or severe injuries and/or to material damage.

Ensure before installing the firmware update that the CPU is not controlling any active process.

Installation of the firmware update for R/H-CPU displays

Firmware updates for the R/H-CPU displays should be run in the RUN-Solo system state. A role change between primary and backup CPU can occur during the process. The following requirement therefore applies: CPU 1 is the primary CPU. CPU 2 is the backup CPU.

Follow the sequence below:

1. Switch CPU 2 to the STOP operating state.

2. Run the update for the CPU 2 display.

3. Switch CPU 2 to the RUN operating state. Wait until the R/H system switches to the RUN-Redundant system state.

4. Switch CPU 1 to the STOP operating state.

5. Run the update for the CPU 1 display.

6. Switch CPU 1 to the RUN operating state. Wait until the R/H system switches to the RUN-Redundant system state.

Behavior after the firmware update

After the firmware update, check the firmware version of the updated module.

Reference

You can find more information on firmware updates in the STEP 7 online help.

11.5 Resetting CPUs to factory settings

Introduction

The CPU can be reset to its as-delivered condition using "Reset to factory settings". The function deletes all information saved internally on the CPU.

Recommendation:

Switch the CPU to its as-delivered condition if:

- You remove a CPU and use it elsewhere with a different program.
- You store the CPU.

When resetting to factory settings, remember that the IP address parameters are also deleted.

Options for resetting a CPU to factory settings

You can reset the CPU to its as-delivered condition:

- Using the mode selector
- Using the display
- Using STEP 7

Procedure using the mode selector

Make sure that the CPU is in STOP operating state: The CPU display indicates the STOP operating state: The RUN/STOP LED lights up yellow.

Note

Reset to factory settings ↔ Memory reset

The procedure described below corresponds to the procedure for a memory reset:

- Selector operation with inserted SIMATIC memory card: CPU executes a memory reset
- Selector operation without inserted SIMATIC memory card: CPU executes reset to factory settings

---

Restore the factory settings of the CPU as follows:

1. Set the mode selector to the STOP position.

   Result: The RUN/STOP LED lights up yellow.

2. Remove the SIMATIC memory card from the CPU. Wait until the RUN/STOP LED stops flashing.

3. Set the mode selector to the MRES position. Hold the mode selector in this position until the RUN/STOP LED lights up for the 2nd time and remains lit (this takes three seconds). Then release the switch.

4. Within the next three seconds, switch the mode selector back to the MRES position and then back to STOP.

Result: The CPU executes a "Reset to factory settings", during which time the RUN/STOP LED flashes yellow. When the RUN/STOP LED lights up in yellow, the CPU has been reset to factory settings and is in the STOP operating state. The "Reset to factory settings" event is entered in the diagnostics buffer.

Note

Resetting the CPU to the factory settings with the mode selector also deletes the IP address of the CPU and resets the redundancy ID to 1.

Procedure using the display

Make sure that the CPU is in STOP operating state: The CPU indicates the STOP operating state. The RUN/STOP LED lights up yellow.

1. Remove the SIMATIC memory card from the CPU. Wait until the RUN/STOP LED stops flashing.

2. To navigate to the required "Factory settings" menu command, select the following sequence of menu commands and confirm each selection with "OK".

   – Settings → Reset → Factory settings

Result: The CPU executes a "Reset to factory settings", during which time the RUN/STOP LED flashes yellow. When the RUN/STOP LED lights up in yellow, the CPU has been reset to factory settings and is in the STOP operating state. The "Reset to factory settings" event is entered in the diagnostics buffer.

Procedure using STEP 7

Proceed as follows to reset a CPU to factory settings with STEP 7:

Make sure that there is an online connection to the CPU.

1. Open the Online and Diagnostics view of the CPU.

2. In the "Functions" folder, select the "Reset to factory settings" group.

3. If you want to keep the IP address, select the "Keep IP address" option button. If you want to delete the IP address, select the "Delete IP address" option button.

Note

"Delete IP address" deletes all IP addresses, regardless of how you established the online connection.

If a SIMATIC memory card is inserted, selecting the "Delete IP address" option has the following effect:

- The IP addresses are deleted and the CPU is reset to factory settings.
- The configuration (including IP address) stored on the SIMATIC memory card is then transferred to the CPU.

If the following conditions are met, no IP address is transferred to the CPU:

- The SIMATIC memory card was formatted before the reset to factory settings.
- The SIMATIC memory card is empty.

---

4. Click the "Reset" button.

5. Click "OK" in response to the confirmation prompts.

Result: The CPU executes a "Reset to factory settings", during which time the RUN/STOP LED flashes yellow. When the RUN/STOP LED lights up in yellow, the CPU has been reset to factory settings and is in STOP. The "Reset to factory settings" event is entered in the diagnostics buffer.

Result after resetting to factory settings

The table below gives an overview of the contents of the memory objects after the reset to factory settings.

Table 11- 1   Result after resetting to factory settings

Memory object	Contents
Redundancy ID	Set to "1"
Actual values of the data blocks, instance data blocks	Initialized
Bit memories, timers and counters	Initialized
Retentive tags of technology objects	Initialized
Entries in the diagnostics buffer (retentive area)	Initialized
Entries in the diagnostics buffer (non-retentive area)	Initialized
IP address	Depends on the procedure: • Using mode selector: Is deleted • Using display: Is deleted • Using STEP 7: Depends on the setting of the "Retain IP address"/"Delete IP address" option buttons
Device name (module name)	Set to "CPU"
Counter readings of the runtime meters	Initialized
Time of day	Set to "00:00:00, Jan. 01, 2012"

Note

IP address conflict

Resetting the CPU to the factory settings also deletes the IP address of the CPU and resets the redundancy ID to 1. Please note the following:
An S7-1500R/H redundant system that is already in operation is switched to the STOP system state. If you reset the CPU with redundancy ID 2 to factory settings, that CPU is assigned the IP address of the other CPU (with redundancy ID 1). This results in an IP address conflict. You can only access the CPU with the emergency address. You can find information on the emergency address in the section Backing up and restoring the CPU configuration (Page 234).

Possible remedy: Using the display, assign the CPU the redundancy ID previously set. You can then access the CPU over the original IP address again.

Reference

You can find more information on "Reset to factory settings" in the section on memory areas and retentivity in the function manual Structure and use of the CPU memory (http://support.automation.siemens.com/WW/view/en/59193101), and in the STEP 7 online help. For information on CPU memory resets, please refer to the section CPU memory reset (Page 231).

11.6 Maintenance and repair

The R/H CPUs are maintenance-free.

Note

Repairs to the R/H CPUs may only be carried out by the manufacturer.

Test functions

<div style="text-align: right; font-size: 3em;">12</div>

12.1 Test functions

Introduction

You have the option of testing the operation of your user program on the CPU. You monitor the signal states and values of tags. You preassign values to tags to allow you to simulate specific situations for program execution.

Note

Using test functions

Using test functions affects the program execution time and thus the cycle and response times of the controller to a slight extent (a few milliseconds).

Requirements

- There is an online connection to the relevant primary or backup CPU. A simultaneous online connection to both CPUs is not possible.

- An executable user program is available in the CPU.

- The redundant system must not be in the SYNCUP system state.
  Exception: The test functions "Test with a force table" and "Trace function" are also supported in the SYNCUP system state. However, there is no online connection during the SYNCUP system state. You can find more information in this section.

Test options

- Testing with program status
- Testing with a watch table
- Testing with a force table
- Testing with a PLC tag table
- Testing with a data block editor
- Testing with the LED flash test
- Testing with a trace function

Testing with program status

The program status allows you to monitor the execution of the program. You can display the values of operands and the results of logic operations (RLO). This allows you to detect and fix logical errors in your program.

Note

Restrictions with the "Program status" function

Monitoring loops can significantly increase the cycle time. The increase in cycle time depends on the following factors:

- The number of tags to be monitored
- The actual numbers of loops run through

> ⚠️ **WARNING**
>
> **Testing with program status**
>
> Testing with the "Program status" function can cause serious damage and injury if there are functional disruptions or program errors.
>
> Make sure that you take appropriate measures to exclude the risk of dangerous states occurring before running a test with the "Program status" function.

Difference between modifying and forcing

The fundamental difference between the modifying and forcing functions is the storage behavior:

- Modifying: Modifying tags is an online function and is not stored in the CPU. You can end the modifying of tags in the watch table or force table or by terminating the online connection.

- Forcing: A force job is written to the SIMATIC memory card and is retained after a POWER OFF. The S7-1500R/H CPU displays an active force job with a symbol. You can only end the forcing of peripheral inputs and peripheral outputs in the force table. A force job is transferred to the backup CPU in SYNCUP. The force job is then effective in both CPUs in the RUN-Redundant system state.

Testing with watch tables

The following functions are available in the watch table:

- Monitoring of tags

  Using watch tables, you can monitor the actual values of the individual tags of a CPU user program.

  – On the PG/PC

  – On the display of the CPU

  Please note the following requirement for displaying the tag values on the CPU display: You must specify a symbolic name for each tag in the "Name" column of the force table.

  You monitor the following operand areas:

  – Inputs and outputs (process image) and bit memory

  – Contents of data blocks

  – Peripheral inputs and peripheral outputs

  – Timers and counters

- Modifying tags

  You use this function to assign values to the individual tags of a user program or a CPU on the PG/PC. Modifying is also possible with Test with program status.

  The following operand areas are modifiable:

  – Inputs and outputs (process image) and bit memory

  – Contents of data blocks

  – Peripheral inputs and peripheral outputs (for example, %I0.0:P, %Q0.0:P)

  – Timers and counters

Testing with a force table

The following functions are available in the force table:

- Monitoring of tags

  You use watch tables to monitor the actual values of the individual tags of a CPU user program.

  – On the PG/PC

  – On the display of the CPU

  You can monitor the table with or without trigger conditions.
  Please note the following requirement for displaying the tag values on the CPU display:
  You must specify a symbolic name for each tag in the "Name" column of the force table.

  You monitor the following tags:

  – Bit memory

  – Contents of data blocks

  – Peripheral inputs

- Forcing of peripheral inputs and peripheral outputs

  You can force individual peripheral inputs or peripheral outputs.

  – Peripheral inputs: Forcing peripheral inputs "bypasses" sensors/inputs by specifying fixed values for the program. Instead of the actual input value via a process image or direct access, the program receives the force value.

  – Peripheral outputs: Forcing peripheral outputs "bypasses" the complete program by specifying fixed values for the actuators.

The advantage of the force table is that you can simulate different test environments and overwrite tags in the CPU with a fixed value. Therefore, you can intervene in the ongoing process to regulate it.

Testing with a PLC tag table

You can monitor the current data values of tags in the CPU directly in the PLC tag table. To do so, open the PLC tag table and start the monitoring.

You may also copy PLC tags to a watch table or force table and monitor, modify or force them there.

Testing with a data block editor

The data block editor offers different options for monitoring and modifying tags. These functions directly access the actual values of the tags in the online program. Actual values are the current values of tags in the CPU work memory at any given moment during program execution. The following functions for monitoring and modifying are available in the database editor.

- Monitor tags online
- Modify individual actual values
- Create a snapshot of the actual values

Note

Setting data values during commissioning

During plant commissioning, you often need to adjust data values to adapt the program to local conditions.

The declaration table for data blocks offers some functions for this purpose.

Testing with the LED flash test

In many online dialogs, you can perform an LED flash test. This feature is useful if you are not sure which device in the hardware configuration corresponds to the device currently selected in the software.

If you click on the "Flash LED" button in STEP 7 under Online & diagnostics (online access), an LED flashes on the device currently selected. The RUN/STOP, ERROR, and MAINT LEDs flash on the CPU. The LEDs flash until you cancel the flash test.

Testing with a trace function

The trace function is used to record the CPU tags, depending on the settable trigger conditions. Examples of tags are the system and user tags of a CPU. The CPU saves the recordings. If necessary, you can display the recordings with STEP 7 and evaluate them.

- Requirement: The storage of measurements on the SIMATIC memory card (measurements in the device) is not supported for R/H-CPUs.
- Procedure
  - The trace function can be called from the folder of the top CPU in the project tree, under the name "Traces".
  - In the "Measurements" system folder, double-click to open the recording to display the measurement. The "Diagram" tab for the measurement opens in the work area.
- Feature to note
  - No trace recordings take place in the primary CPU during the "Finish tasks (Page 203)" phase in the SYNCUP system state. Trace recording resumes once the "Finish tasks" phase ends. The recording is identical on both R/H-CPUs. From this point, trace recording for the two R/H-CPUs is synchronized.

Please also see the FAQs on the Internet (https://support.industry.siemens.com/cs/ww/en/view/102781176) for testing with the trace function.

Reference

Additional information on the test functions can be found in the STEP 7 online help.

You can find more information on testing with trace functions in the function manual Using the trace and logic analyzer function (http://support.automation.siemens.com/WW/view/en/64897128).

12.2 Reading out/saving service data

Service data

In addition to the contents of the diagnostics buffer, the service data contain numerous additional data points about the internal status of the CPU. If a problem occurs with the CPU that you cannot resolve with other methods, send the service data to the Product Support team. The Product Support team will use the service data to help you with problem analysis.

Please note the following:

- Read out the service data in the following cases:
  - Immediately after a CPU has switched to the STOP operating state.
  - Immediately after a loss of synchronization in the redundant system.
- Always read out the service data of the primary and the backup CPU.

Note

You cannot execute a download to the device while reading out the service data of the CPU.

Requirement

The S7-1500R/H redundant system must not be in the SYNCUP or RUN-Redundant system state.

Methods of reading service data

You can read service data with:

- STEP 7
- SIMATIC memory card

Procedure using STEP 7

You can find more information on saving service data with the keyword "Saving service data" in the STEP 7 online help.

Procedure using the SIMATIC memory card

Use the SIMATIC memory card to read out the service data if communication with the CPU is not over the Ethernet. In all other cases, read out the service data using STEP 7.
The procedure using the SIMATIC memory card is more time-consuming than the other options for reading out the service data. You must also ensure before reading out that there is sufficient memory space on the SIMATIC memory card.

Proceed as follows for the R/H-CPU to read service data using the SIMATIC memory card:

1. Insert the SIMATIC memory card into the card reader of your PC/PG.

2. Open the job file S7_JOB.S7S in an editor.

3. Overwrite the entry PROGRAM with the STRING DUMP in the editor.
   Do not use any spaces/line breaks/quotation marks to ensure that the file size is exactly 4 bytes.

4. Save the file under the existing file name.

5. Make sure that the SIMATIC memory card is not write-protected. Insert the SIMATIC memory card into the card slot of the CPU.
   For the R/H-CPU, you require one card ≥ 32 MB in each case.

Result: The CPU writes the service data file DUMP.S7S to the SIMATIC memory card and remains in STOP.

Service data transfer is complete when the STOP LED stops flashing and is lit continuously. If service data transfer has been successful, only the STOP LED lights up.

In the event of errors in transfer, the STOP LED is lit continuously and the ERROR LED flashes. The CPU also stores a text file with a note on the error that occurred in the DUMP.S7S folder.

Technical specifications

<div style="text-align: right; font-size: 3em;">13</div>

Introduction

This chapter lists the technical specifications of the system:

- The standards and test values that the modules of the S7-1500R/H redundant system comply with and fulfill.

- The test criteria according to which the S7-1500R/H redundant system was tested.

Technical specifications for the modules

The technical specifications of the individual modules can be found in the manuals of the modules themselves. In the event of deviations between the statements in this document and the manuals, the statements in the manuals take priority.

13.1 Standards and Approvals

Currently valid markings and authorizations

> **Note**
>
> **Information on the components of the S7-1500R/H redundant system**
>
> The identifiers and approvals currently valid are printed on the components of the S7-1500R/H redundant system.

Safety information

⚠ WARNING
Personal injury and damage to property may occur
In hazardous areas, injury and damage can occur if you disconnect plug-in connections during operation of an S7-1500R/H redundant system.
Always switch off the power to the S7-1500R/H redundant system before disconnecting plug-in connections in hazardous areas.

⚠ WARNING
Explosion hazard
If you replace components, compliance with Class I, Div. 2 or zone 2 may become invalid.

⚠ WARNING
Deployment requirements
This device is only suitable for use in Class I, Div. 2, Group A, B, C, D; Class I, zone 2, Group IIC, or in non-hazardous areas.

CE mark

The S7-1500R/H redundant system complies with the harmonized European standards (EN) for programmable logic controllers published in the official gazettes of the European Community. The S7-1500R/H redundant system meets the requirements and protection targets of the following directives.

- 2014/35/EU "Electrical equipment designed for use within certain voltage limits" (Low Voltage Directive)

- 2014/30/EU "Electromagnetic Compatibility" (EMC Directive)

- 2014/34/EU "Equipment and protective systems intended for use in potentially explosive atmospheres" (Explosion Protection Directive)

- 2011/65/EU "Restriction of the use of certain hazardous substances in electrical and electronic equipment" (RoHS Directive)

EC declarations of conformity for the respective authorities are available from:

Siemens AG
Digital Factory

Factory Automation
DF FA AS SYS
Postfach 1963
D-92209 Amberg, Germany

The EC declarations of conformity are also available for download from the Siemens Industry Online Support website, under the keyword "Declaration of Conformity".

cULus approval

Underwriters Laboratories Inc. in accordance with

- UL 61010-2-201

- C22.2 No. 142 (Process Control Equipment)

OR

cULus HAZ. LOC. approval

Underwriters Laboratories Inc. in accordance with

- UL 61010-2-201

- CSA C22.2 No. 142 (Process Control Equipment)

- ANSI/ISA 12.12.01

- CSA C22.2 No. 213 (Hazardous Location)

APPROVED for use in
Class I, Division 2, Group A, B, C, D Tx;
Class I, Zone 2, Group IIC Tx

Installation Instructions for cULus haz.loc.

- WARNING - Explosion Hazard - Do not disconnect while circuit is live unless area is known to be non-hazardous.

- WARNING - Explosion Hazard - Substitution of components may impair suitability for Class I, Division 2 or Zone 2.

- This equipment is suitable for use in Class I, Division 2, Groups A, B, C, D; Class I, Zone 2, Group IIC; or non-hazardous locations.

WARNING: EXPOSURE TO SOME CHEMICALS MAY DEGRADE THE SEALING PROPERTIES OF MATERIALS USED IN THE RELAYS.

FM approval

Factory Mutual Research (FM) according to

- Approval Standard Class Number 3611, 3600, 3810

- ANSI/ISA 82.02.01 (IEC 61010-1)

- CSA C22.2 No. 213

- CSA 22.2 No. 1010.1

APPROVED for use in Class I, Division 2, Group A, B, C, D Tx;
Class I, Zone 2, Group IIC Tx

Installation Instructions for FM

- WARNING - Explosion Hazard - Do not disconnect while circuit is live unless area is known to be non-hazardous.

- WARNING - Explosion Hazard - Substitution of components may impair suitability for Class I, Division 2 or Zone 2.

- This equipment is suitable for use in Class I, Division 2, Groups A, B, C, D; Class I, Zone 2, Group IIC; or non-hazardous locations.

WARNING: EXPOSURE TO SOME CHEMICALS MAY DEGRADE THE SEALING PROPERTIES OF MATERIALS USED IN THE RELAYS.

ATEX approval

In accordance with EN 60079-15 (Electrical apparatus for potentially explosive atmospheres; Type of protection "n") and EN 60079-0 (Electrical apparatus for potentially explosive gas atmospheres - Part 0: General Requirements)

II 3 G Ex nA IIC Tx Gc
DEKRA 12ATEX0004X

IECEx approval

According to IEC 60079-15 (Explosive atmospheres - Part 15: Equipment protection by type of protection "n") and IEC 60079-0 (Explosive atmospheres - Part 0: Equipment - General requirements)

IECEx | Ex nA IIC Tx Gc
IECEx DEK 13.0010X

RCM (C-Tick) Declaration of conformity for Australia/New Zealand

The S7-1500R/H redundant system meets the requirements of EN 61000-6-4.

Korea Certification

KC registration number: KCC-REM-S49-S71500

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

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

Marking for the Eurasian Customs Union

EAC (Eurasian Conformity)

Customs Union of Russia, Belarus and Kazakhstan

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

IEC 61131-2

The S7-1500R/H redundant system meets the requirements and criteria of standard IEC 61131-2, excluding the requirements set out in sections 11 to 14 of the standard (Programmable logic controllers, part 2: Equipment requirements and tests).

IEC 61010-2-201

The S7-1500R/H redundant system fulfills the requirements and criteria of standard
IEC 61010-2-201
(Safety requirements for electrical equipment for measurement, control, and laboratory use
Part 2-201: Particular requirements for control equipment).

PROFINET standard

The S7-1500R/H redundant system is based on the standard IEC 61158 Type 10.

Marine approval

Classification societies:

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

Industrial use

The S7-1500R/H redundant system is designed for use in industrial environments. It meets the following standards for this type of use:

- Requirements on emission EN 61000-6-4: 2011
- Requirements on immunity EN 61000-6-2: 2005

Use in mixed areas

Under certain circumstances, you can use the S7-1500R/H redundant system in a mixed area. A mixed area is used for residential purposes and for commercial operations that do not significantly impact on residents.

If you use the S7-1500R/H redundant system in a mixed area, you must ensure that radio interference emission complies with the limit classes of the technical standard EN 61000-6-3. Suitable measures for observing these limits for use in a mixed area are, for example:

- Installation of the S7-1500R/H redundant system in grounded control cabinets
- Use of noise filters in the supply cables

An individual acceptance test is also required.

Use in residential areas

Note

S7-1500R/H redundant system not intended for use in residential areas

The S7-1500R/H redundant system is not intended for use in residential areas. Using the S7-1500R/H redundant system in residential areas can affect radio and television reception.

Reference

The certificates for the identifiers and approvals can be found in Siemens Industry Online Support on the Internet (http://www.siemens.com/automation/service&support).

13.2 Electromagnetic compatibility

Definition

Electromagnetic compatibility (EMC) is the ability of an electrical installation to function satisfactorily in its electromagnetic environment, without affecting that environment.

The S7-1500R/H redundant system also meets the requirements of EMC legislation for the European Single Market. This is dependent on the S7-1500R/H redundant system complying with the requirements and guidelines relating to electrical equipment.

EMC in accordance with NE21

The S7-1500R/H redundant system meets the EMC specifications of NAMUR guideline NE21.

Pulse-shaped disturbances

The table below shows the electromagnetic compatibility of the S7-1500R/H redundant system with regard to pulse-shaped disturbances.

Table 13- 1   Pulse-shaped disturbances

Pulse-shaped disturbance	Test voltage	Corresponds with degree of severity
Electrostatic discharge in accordance with IEC 61000-4-2.	Air discharge: ±8 kV	3
	Contact discharge: ±6 kV	3
Burst pulses (high-speed transient disturbances) in accordance with IEC 61000-4-4.	±2 kV (power supply cable) ±2 kV (signal cable > 30 m) ±1 kV (signal cable < 30 m)	3 3
High-energy single pulse (surge) in accordance with IEC 61000-4-5 External protective circuit required (not for 230 V modules) You can find more information in the Designing interference-free controllers function manual.		
• Asymmetric coupling	±2 kV (power supply cables) DC with protective elements	3
	±2 kV (signal/data line only > 30 m), with protective elements	
• Symmetric coupling	±1 kV (power supply cable) DC with protective elements	
	±1 kV (signal/data line only > 30 m), with protective elements	

Sinusoidal disturbances

The following table shows the electromagnetic compatibility of the S7-1500R/H redundant system with respect to sinusoidal disturbances (RF radiation).

Table 13- 2   Sinusoidal disturbances with RF radiation

RF radiation in accordance with IEC 61000-4-3/NAMUR 21 Electromagnetic RF field, amplitude-modulated		Corresponds with degree of severity
80 to 1000 MHz; 1.4 to 2 GHz	2.0 GHz to 6 GHz	
10 V/m	1 V/m	3
80 % AM (1 kHz)		

The following table shows the electromagnetic compatibility of the S7-1500R/H redundant system with respect to sinusoidal disturbances (RF coupling).

Table 13- 3   Sinusoidal disturbances with RF coupling

RF coupling in accordance with IEC 61000-4-6	Corresponds with degree of severity
from 10 kHz	
10 V_{rms}	3
80 % AM (1 kHz)	
150 Ω source impedance	

Emission of radio interference

Interference emission of electromagnetic fields in accordance with EN 55016 (measured at a distance of 10 m).

Table 13- 4   Interference emission of electromagnetic fields

Frequency	Interference emission
30 MHz to 230 MHz	< 40 dB (µV/m) QP
230 MHz to 1000 MHz	< 47 dB (µV/m) QP
From 1 GHz to 3 GHz	< 66 dB (µV/m) P
From 3 GHz to 6 GHz	< 70 dB (µV/m) P

Interference emission via the AC power supply in accordance with EN 55016.

Table 13- 5   Interference emission via the AC power supply

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

13.3 Shipping and storage conditions

Introduction

The S7-1500R/H redundant system meets the specifications regarding shippings and storage conditions pursuant to IEC 61131-2. The following information applies to modules that are shipped and/or stored in their original packaging.

Shipping and storage conditions for modules

Table 13- 6   Shipping and storage conditions

Type of condition	Permissible range
Free fall (in shipping package)	≤ 1 m
Temperature	from -40 °C to +70 °C
Barometric pressure	From 1140 to 660 hPa (corresponds to an elevation of -1000 to 3500 m)
Relative humidity	5% to 95%, without condensation
Sinusoidal vibrations in accordance with IEC 60068-2-6	5 - 8.4 Hz: 3.5 mm 8.4 - 500 Hz: 9.8 m/s^2
Shock in accordance with IEC 60068-2-27	250 m/s^2, 6 ms, 1000 shocks

13.4 Mechanical and climatic ambient conditions

Operating conditions

The S7-1500R/H redundant system is designed for stationary use in weather-proof locations. The operating conditions are based on the requirements of DIN IEC 60721-3-3:

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

Test of mechanical ambient conditions

The table below provides important information with respect to the type and scope of the test of ambient mechanical conditions.

Table 13- 7   Test of mechanical ambient conditions

Condition tested	Test Standard	Comment
Vibration	Vibration test according to IEC 60068-2-6 (Sinus)	Type of oscillation: Frequency sweeps with a rate of change of 1 octave/minute. 5 Hz ≤ f ≤ 8.4 Hz, constant amplitude 7 mm 8.4 Hz ≤ f ≤ 150 Hz, constant acceleration 2 g Duration of oscillation: 10 frequency sweeps per axis, along each of the 3 mutually perpendicular axes
Shock	Shock, tested according to IEC 60068-2-27	Type of shock: Half-sine Shock intensity: 15 g max., duration 11 ms Direction of shock: 3 shocks each in (+/-) direction, along each of the 3 mutually perpendicular axes
Continuous shock	Shock, tested according to IEC 60068-2-27	Type of shock: Half-sine Shock intensity: 250 m/s^2 peak value, 6 ms duration Direction of shock: 1000 shocks each in (+/-) direction, along each of the 3 mutually perpendicular axes

Reduction of vibrations

If the S7-1500R/H redundant system is exposed to severe shock or vibration, take appropriate measures to reduce the acceleration or the amplitude.

We recommend installing the S7-1500R/H redundant system on damping materials (for example, rubber-bonded metal mounting).

Climatic ambient conditions

The table below shows the permissible ambient climatic conditions for the S7-1500R/H redundant system:

Table 13- 8   Climatic ambient conditions

Ambient conditions	Permissible range	Comments
Temperature: horizontal mounting position: vertical mounting position:	0 °C to 60 °C 0 °C to 40 °C	To increase the service life of the display, the display switches off when the permitted operating temperature is exceeded. At certain temperatures, the display switches off an on again. You can find more information in the technical specifications in the CPU manuals.
Temperature variation	10 K/h	-
Relative humidity	from 10 % to 95 %	Without condensation
Barometric pressure	From 1140 to 795 hPa	corresponds to an altitude of -1000 m to 2000 m
Pollutant concentration	ANSI/ISA-71.04 severity level G1; G2; G3	-

13.5   Information on insulation tests, protection class, degree of protection and rated voltage

Insulation

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

Note

For modules with 24 V DC (SELV/PELV) supply voltage, electrical isolation is tested with 707 V DC (type test).

Pollution degree/overvoltage category in accordance with IEC 61131-2, IEC 61010-2-201

- Pollution degree 2
- Overvoltage category: II

Protection class according to IEC 61131-2, IEC 61010-2-201

The S7-1500R/H redundant system meets protection class I requirements and parts of protection classes II and III.

Degree of protection IP20

Degree of protection IP20 in accordance with IEC 60529 for all modules of the S7-1500R/H redundant system:

- Protection against contact with standard test fingers

- Protection against foreign objects with diameters in excess of 12.5 mm

- No protection against water

Rated voltage for operation

The S7-1500R/H redundant system works with the rated voltages and corresponding tolerances listed in the table below.

Table 13- 9   Rated voltage for operation

rated voltage	Tolerance range
24 V DC	19.2 V DC to 28.8 V DC[1)

[1)   Static value: Generation as functional extra-low voltage with safe electrical isolation in accordance with IEC 61131-2 or IEC 61010-2-201.

13.6   Use of S7-1500R/H in Zone 2 hazardous area

Reference

You can find more information in the product information Use of modules in a Zone 2 Hazardous Area (http://support.automation.siemens.com/WW/view/en/19692172).

Dimension drawings

<div style="text-align: right">

A

</div>

Mounting rail 160 mm
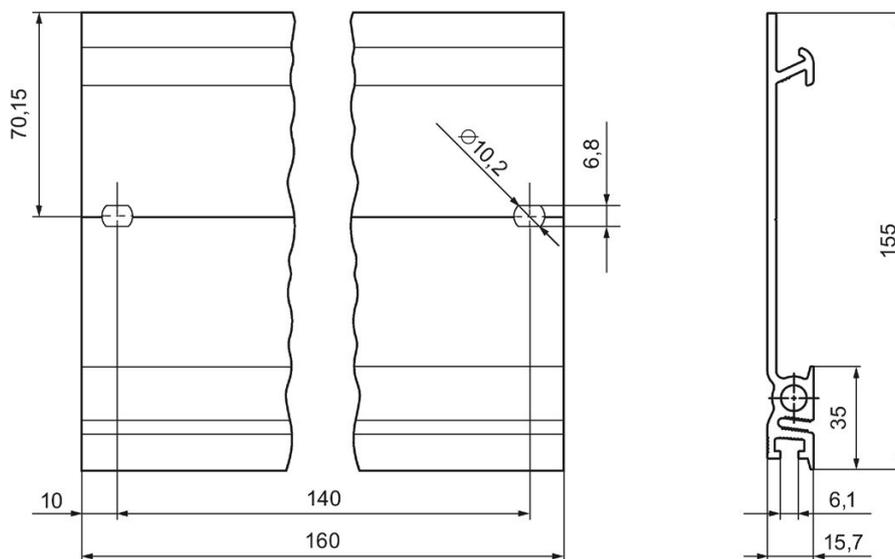
Figure A-1   Mounting rail 160 mm

Mounting rail 245 mm
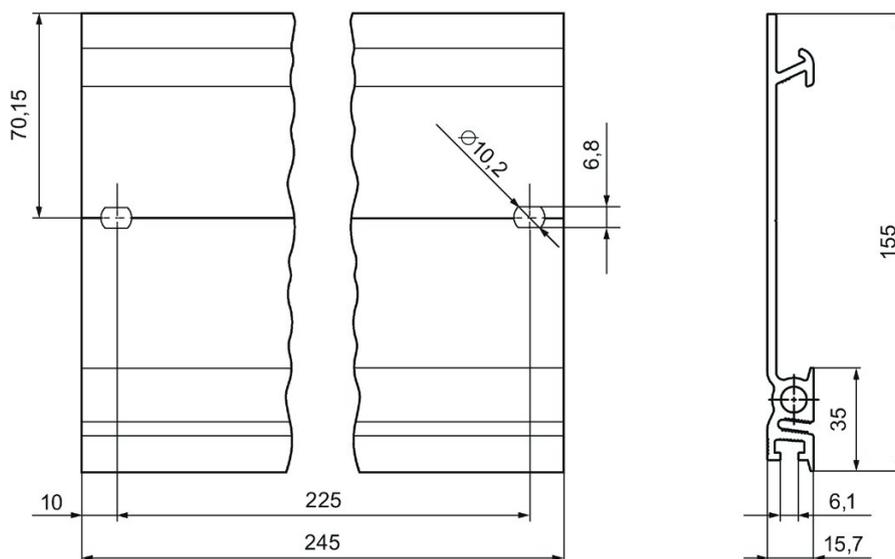
Figure A-2   Mounting rail 245 mm

Mounting rail 482.6 mm
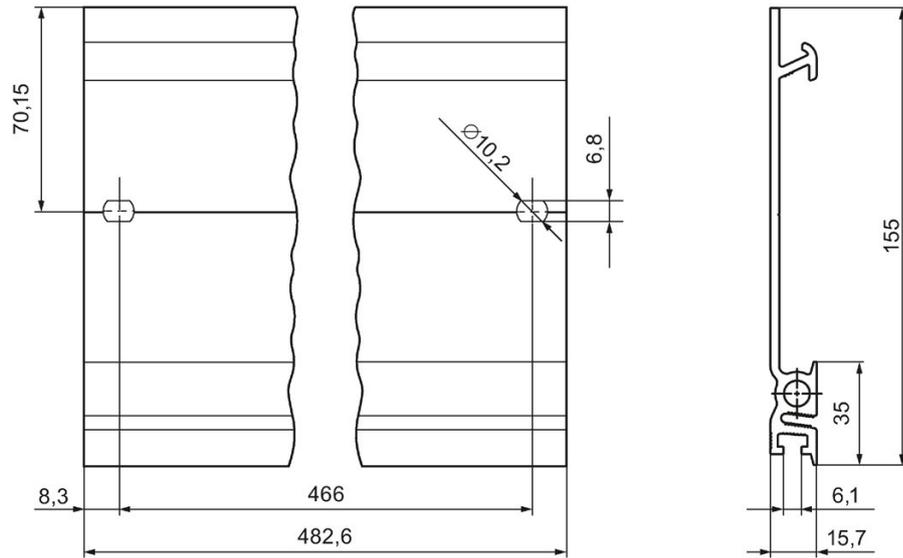
Figure A-3　　Mounting rail 482.6 mm

Mounting rail 530 mm
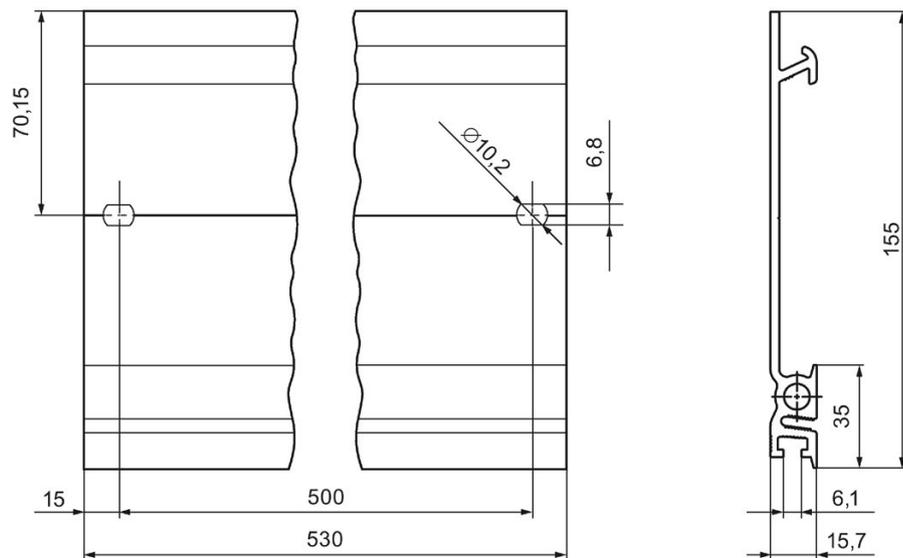
Figure A-4　　Mounting rail 530 mm

Mounting rail 830 mm
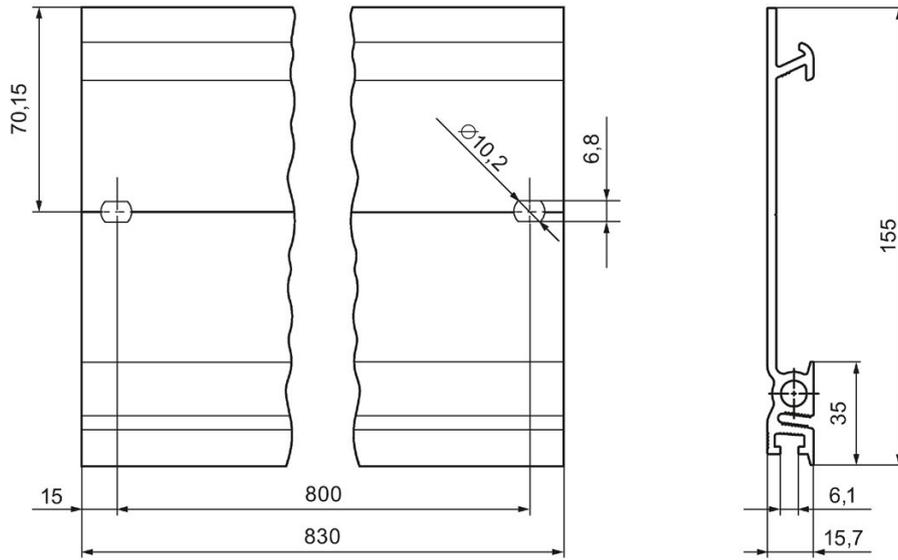
Figure A-5   Mounting rail 830 mm

Mounting rail 2000 mm
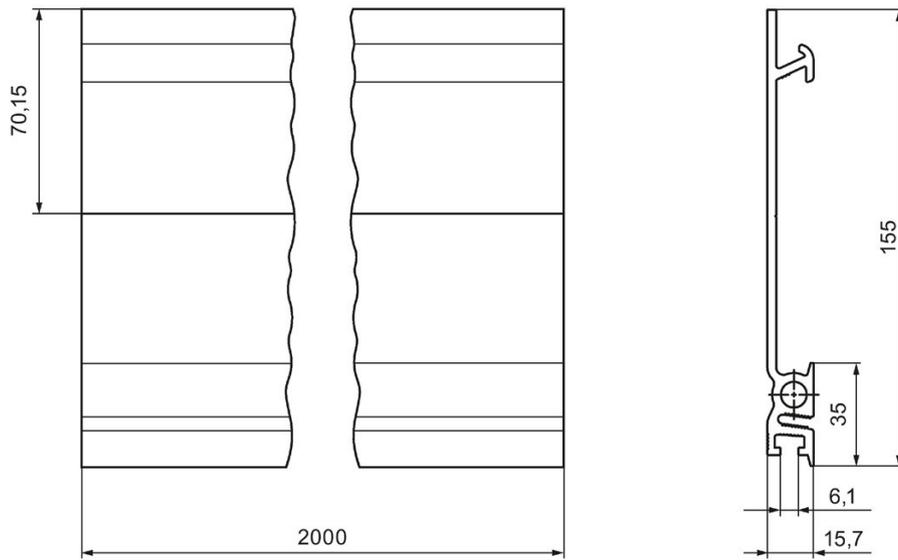
Figure A-6   Mounting rail 2000 mm

Accessories/spare parts

B

General accessories

Table B- 1   General accessories

Designation	Article number
Mounting rail	
• Mounting rail, 160 mm (with drill holes)	6ES7590-1AB60-0AA0
• Mounting rail, 245 mm (with drill holes)	6ES7590-1AC40-0AA0
• Mounting rail, 482 mm (with drill holes)	6ES7590-1AE80-0AA0
• Mounting rail, 530 mm (with drill holes)	6ES7590-1AF30-0AA0
• Mounting rail, 830 mm (with drill holes)	6ES7590-1AJ30-0AA0
• Mounting rail, 2000 mm (without drill holes) for cutting to length	6ES7590-1BC00-0AA0
PE connection element for mounting rail, 2000 mm (spare part), 20 units	6ES7590-5AA00-0AA0
4-pole connection plug for supply voltage (spare part), 10 units	6ES7193-4JB00-0AA0
U connector (spare part), 5 units	6ES7590-0AA00-0AA0
70 mm display for CPU (spare part)	6ES7591-1BA00-0AA0
35 mm display for CPU (spare part)	6ES7591-1AA00-0AA0
Power cable connector with coding element for power supplies (spare part), 10 units	6ES7590-8AA00-0AA0
Synchronization module for CPU 1517H-3 PN	
• Sync module 1 GB FO 10 m	6ES7960-1CB00-0AA5
• Sync module 1 GB FO 10 km	6ES7960-1FB00-0AA5
Redundancy connections for CPU 1517H-3 PN	
• Sync cable FO 1 m (multimode fiber)	6ES7960-1BB00-5AA5
• Sync cable FO 2 m (multimode fiber)	6ES7960-1BC00-5AA5
• Sync cable FO 10 m (multimode fiber)	6ES7960-1CB00-5AA5
• Sync cable FO up to 10 km (single-mode fiber)	On request
PROFINET cables for redundancy connections, PROFINET ring with CPU 1513R-1 PN, CPU 1515R-2 PN; PROFINET cables for PROFINET ring with CPU 1517H-3 PN	
• Industrial Ethernet FastConnect RJ45 plug 180 degrees, 1 unit	6GK1901-1BB10-2AA0
• Industrial Ethernet FastConnect RJ45 plug 180 degrees, 10 units	6GK1901-1BB10-2AB0
• Industrial Ethernet FastConnect RJ45 plug 90 degrees, 1 unit	6GK1901-1BB20-2AA0
• Industrial Ethernet FastConnect RJ45 plug 90 degrees, 10 units	6GK1901-1BB20-2AB0

SIMATIC memory cards

Table B- 2 SIMATIC memory cards

Article number	Capacity
6ES7954-8LCxx-0AA0	4 MB
6ES7954-8LExx-0AA0	12 MB
6ES7954-8LFxx-0AA0	24 MB
6ES7954-8LL02-0AA0	256 MB
6ES7954-8LPxx-0AA0	2 GB
6ES7954-8LT02-0AA0	32 GB

Media converter (electrical ⇔ optical)

Table B- 3 Media converter (electrical ⇔ optical)

Article number	Article number
SIMATIC NET Media Converter SCALANCE X101-1	6GK5101-1BB00-2AA3
RUGGEDCOM RMC-24-TXFXSM-XX	6GK6001-0AC01-0EA0
Additional media converters	On request

Online catalog

You can find more article numbers for the S7-1500R/H redundant system on the Internet (https://mall.industry.siemens.com) in the online catalog and online ordering system.

Safety symbols

C

C.1 Safety-related symbols for devices without Ex protection

The following table contains an explanation of the symbols located in your SIMATIC device, its packaging or the accompanying documentation.

Symbol	Meaning
⚠	General warning sign **Caution/Notice**
	You must read the product documentation. The product documentation contains information about the potential risks and enable you to recognize risks and implement countermeasures.
👷	Read the information provided by the product documentation.
	ISO 7010 M002
👷	Ensure the device is only installed by electrically skilled person.
	IEC 60417 No. 6182
CABLE SPEC.	Note that connected mains lines must be designed according to the expected minimum and maximum ambient temperature.
EMC	Note that the device must be constructed and connected in accordance with EMC regulations.
230V MODULES	Note that a 230 V device can be exposed to electrical voltages which can be dangerous.
	ANSI Z535.2
⟨III⟩ 24V MODULES	Note that a device of Protection Class III may only be supplied with a protective low voltage according to the standard SELV/PELV.
	IEC 60417-1-5180 "Class III equipment"
INDOOR USE ONLY INDUSTRIAL USE ONLY	Be aware that the device is only approved for the industrial field and only for indoor use.
📦	Note that an enclosure is required for installing the device. Enclosures are considered:
	• Standing control cabinet
	• Serial control cabinet
	• Terminal boxes
	• Wall enclosure

C.2 Safety-related symbols for devices with Ex protection

The following table contains an explanation of the symbols located in your SIMATIC device, its packaging or the accompanying documentation.

Symbol	Meaning
ONLY EX MODULES	The assigned safety symbols apply to devices **with Ex approval**. You must read the product documentation. The product documentation contains information about the potential risks and enable you to recognize risks and implement countermeasures.
	Read the information provided by the product documentation. ISO 7010 M002
	Ensure the device is only installed by electrically skilled person. IEC 60417 No. 6182
F<2N DISPLAY F<4N HOUSING	Observe the mechanical rating of the device.
CABLE SPEC.	Note that connected mains lines must be designed according to the expected minimum and maximum ambient temperature.
EMC	Note that the device must be constructed and connected in accordance with EMC regulations.
U = 0V	When the device is under voltage, note that it may not be installed or removed, or plugged or pulled.
230V MODULES	Note that a 230 V device can be exposed to electrical voltages which can be dangerous. ANSI Z535.2
24V MODULES	Note that a device of Protection Class III may only be supplied with a protective low voltage according to the standard SELV/PELV. IEC 60417-1-5180 "Class III equipment"
INDOOR USE ONLY INDUSTRIAL USE ONLY	Be aware that the device is only approved for the industrial field and only for indoor use.

Symbol	Meaning
ZONE 2 INSIDE CABINET IP54 EN60079-15	For Zone 2 potentially explosive atmospheres, be aware that the device may only be used when it is installed in an enclosure with a degree of protection ≥ IP54.
ZONE 22 INSIDE CABINET IP6x EN60079-31	For Zone 22 potentially explosive atmospheres, be aware that the device may only be used when it is installed in an enclosure with a degree of protection ≥ IP6x.

Glossary

AR

The AR (Application Relation) covers all communication relations between IO controller and IO device (for example IO data, data records, interrupts).

Automation system

Programmable logic controller for the open-loop and closed-loop control of process chains in the process engineering industry and in manufacturing technology. The automation system consists of different components and integrated system functions according to the automation task.

Backup CPU

Role of a CPU in the S7-1500R/H redundant system. If the R/H system is in the RUN-Redundant system state, the primary CPU controls the process. The backup CPU processes the user program synchronously and can take over process control if the primary CPU fails.

Baud rate

Data transmission rate indicates the number of bits transmitted per second (baud rate = bit rate).

Bit memory

Bit memory is a component of the system memory of the CPU for saving intermediate results. You access the bit memory through the user program bit by bit, byte by byte, word by word or double word by double word.

Bus

Joint transmission path to which all devices in a fieldbus system are connected.

Bus cable connector

The bus cable connector is the physical connection between bus node and bus cable.

Bus, self-assembling

The modules are lined up on the mounting rail. They are mechanically and electrically connected to each other with a U connector as they are swiveled into position. In this way the bus is extended with each module.

Code block

In SIMATIC S7, a code block contains part of the STEP 7 user program.

Configuration

Systematic arrangement of the individual modules (configuration).

Connection plug

The connection plug provides the physical connection between devices and the cable, for example.

Consistent data

Consistent data is data that belongs together in terms of content. Consistent data items are read and written together.

Counter

Counters are components of the system memory of the CPU. You can modify the content of the "counter cells" using STEP 7 instructions. Example: counting up or down).

CPU

The Central Processing Unit (CPU) contains the operating system and executes the user program. The user program is located on the SIMATIC memory card and is processed in the work memory of the CPU. The PROFINET interfaces on the CPU allow simultaneous communication with PROFINET devices, PROFINET controllers, HMI devices and PGs/PCs.

Crimping

Procedure whereby two components joined together, e.g. wire end sleeve and cable, are connected with one another through plastic strain.

Cycle control point

The cycle control point marks the end of a cycle and the start of the next cycle. The cycle time statistics and monitoring of the configured maximum cycle time start at the cycle control point.

Once the cycle control point has been reached, the CPU writes the process image output to the output modules, reads the state of the inputs to the input modules and then executes the first cyclic OB.

In redundant mode, the cycle control point is reached as soon as the backup CPU reports the end of the cycle to the primary CPU.

Cycle time

The cycle time is the time a CPU requires to execute the cyclic user program once.

Cyclic interrupt

You will find further information in the glossary entry "Interrupt, cyclic".

Data block

Data blocks (DBs) are data areas in the user program that contain user data. Available data blocks:

- Global data blocks that you can access from all code blocks.

- Instance data blocks that are assigned to a specific FB call.

Device

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

Device names

Each IO device must have a unique device name. This is required to allow the IO controller to communicate with an IO device. Advantage: Device names are easier to manage than complex IP addresses.

In its delivery state, an IO device has no device name. A device name must be assigned using the PG/PC before an IO device can be addressed by an IO controller. Example: For the transmission of configuration data (including the IP address) during startup or for the exchange of user data in cyclic mode.

Diagnostics

Monitoring functions include:

- Detection, localization and classification of errors, faults and alarms.

- Display and further evaluation of errors, faults and alarms.

They run automatically while the system is in operation. This increases the availability of systems by reducing commissioning times and downtimes.

Diagnostics buffer

The diagnostics buffer is a battery-backed memory area in the CPU where diagnostics events are stored in their order of occurrence.

Diagnostics interrupt

You will find further information in the glossary entry "Interrupt, diagnostics".

Distributed I/O system

System with I/O modules that are configured on a distributed basis, at a large distance from the CPU controlling them.

DP

Distributed I/O

Equipotential bonding

Electrical connection (equipotential bonding conductor) that brings the conductive parts of electrical equipment and other conductive parts to the same or approximately the same potential. This prevents disruptive or dangerous voltages arising between these parts.

Firmware of the CPU

In SIMATIC, a distinction is made between the firmware of the CPU and user programs.

The firmware is a software embedded in electronic devices. The firmware is permanently connected to the hardware in functional terms. It is usually saved in a flash memory, such as EPROM, EEPROM or ROM, and cannot be replaced by the user or only with special tools or functions.

User program: You will find further information in the glossary entry "User program".

Firmware update

You update the module firmware with a firmware update. A firmware update is, for example, run for new functions of a CPU or an interface module.

Function

A function (FC) is a code block with no static data. A function allows you to pass parameters in the user program. Functions are thus suited for programming frequently recurring complex functions, such as calculations.

Function block

A function block (FB) is a code block with static data. An FB allows you to pass parameters in the user program. Function blocks are thus suited for programming frequently recurring complex functions, such as closed-loop controls or operating mode selection.

Functional ground

Functional ground is a low-impedance current path between electric circuits and ground. It is not intended as a protective measure but rather, for example, for improvement of interference immunity.

Ground

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

All interconnected, inactive parts of a piece of equipment.

Ground

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

All interconnected, inactive parts of a piece of equipment.

Grounding

Grounding means connecting an electrically conductive part to a grounding electrode by means of a grounding system.

GSD file

As a Generic Station Description, this file contains all the properties of a PROFINET or PROFIBUS device that are necessary for its configuration.

Hardware interrupt

You will find further information in the glossary entry "Interrupt, hardware".

H-Sync forwarding

H-Sync forwarding enables a PROFINET device with MRP to forward synchronization data (synchronization frames) within the PROFINET ring only.

H-Sync forwarding also forwards synchronization data during reconfiguration of the PROFINET ring. This reduces the load for the cycle time.

H-Sync forwarding is recommended for PROFINET devices that you use in the PROFINET ring of redundant S7-1500R systems.

H-Sync forwarding is not relevant for redundant S7-1500H systems.

I/O module

Device of the distributed I/O that is used as an interface between the controller and the process.

Identification data

Information that is saved in modules, and that supports the user in reviewing the system configuration and locating hardware changes.

Instance data block

Each call of a function block in the STEP 7 user program is assigned a data block, which is automatically generated. Values of the input, output and in/out parameters are stored in the instance data block, as is the local block data.

Interface module

Module in the distributed I/O system. The interface module connects the distributed I/O system to the CPUs (IO controllers) via a fieldbus, and prepares the data of the I/O modules.

Interrupt

The operating system of the CPU distinguishes between various priority classes that control the execution of the user program. These priority classes include interrupts such as hardware interrupts. When an interrupt occurs, the operating system automatically calls an assigned organization block. You program the required reaction in the organization block (for example in an FB).

Interrupt, cyclic

The CPU generates a cyclic interrupt periodically within a parameterizable time grid and then processes the corresponding organization block.

Interrupt, diagnostics

Diagnostics-capable modules signal detected system errors to the CPU using diagnostics interrupts.

Interrupt, hardware

A hardware interrupt is triggered by interrupt-triggering modules following a certain event in the process. The hardware interrupt is signaled to the CPU. The CPU then processes the assigned organization block according to the priority of this interrupt.

Interrupt, time-delay

The time-delay interrupt is one of the program execution priority classes of SIMATIC S7. The time-delay interrupt is generated upon expiration of a timer started in the user program. The CPU then processes the corresponding organization block.

Interrupt, time-of-day

The time-of-day interrupt is one of the program execution priority classes of SIMATIC S7. The time-of-day interrupt is generated based on a specific date and time. The CPU then processes the corresponding organization block.

IP address

The IP address is made up of four decimal numbers with a range of values from 0 through 255. The decimal numbers are separated by a dot (for example 192.162.0.0).

The IP address consists of the following:

- Address of the network

- Device address (PROFINET interface of the IO controllers/IO devices)

Isolated modules

In the case of isolated input/output modules, the reference potentials of the control and load circuits are electrically isolated. Examples are optical isolators, relays or transformers. Input/output circuits can be connected to common potential.

Load current supply

The load current supply supplies the electric input and output circuits of the module.

MAC address

Each port of a PROFINET interface (PROFINET device) is assigned a unique global device identifier in the factory. This 6-byte long device identifier is the MAC address.

The MAC address is divided into:

- 3-byte manufacturer ID

- 3-byte device ID (consecutive number)

The MAC addresses are generally shown on the front of the device.
Example: 08-00-06-6B-80-C0

Non-isolated modules

In the case of non-isolated input and output modules, the reference potentials of the control and load circuits are electrically connected.

NTP

The Network Time Protocol (NTP) is a standard for synchronizing clocks in automation systems via Industrial Ethernet. NTP uses the UDP connectionless network protocol.

Operating states

Operating states describe the behavior of a single CPU at any given time.

The primary CPU of the S7-1500R/H redundant system has the operating states STOP, STARTUP, RUN, RUN-Syncup and RUN-Redundant. The backup CPU has the operating states STOP, SYNCUP and RUN-Redundant.

Organization block

Organization blocks (OBs) form the interface between the operating system of the CPU and the user program. The organization blocks determine the order in which the user program is executed.

Pairing

Pairing is the mutual recognition of the CPUs of an S7-1500R/H system within a network. During pairing, the CPUs exchange information for mutual identification. Example: Checking for matching article number and firmware version. Successful pairing of two CPUs is a fundamental requirement for redundant operation.

Parameter

- Tag of a STEP 7 code block:

- Tag for setting the behavior of a module (one or more per module). In as-delivered state, every module has an appropriate basic setting, which you can change by configuring in STEP 7. There are static and dynamic parameters

Parameters, dynamic

You can change dynamic module parameters during operation by calling an SFC in the user program, for example, limits of an analog input module.

Parameters, static

You cannot change static module parameters with the user program, but only with configuration in STEP 7, for example, the input delay of a digital input module.

PELV

Protective **E**xtra **L**ow **V**oltage = safety extra low voltage connected to protective earth

Pre-wiring

Wiring of the front connector in the "pre-wiring position" at the I/O module or before you insert the front connector into the I/O module.

Primary CPU

Role of a CPU in the S7-1500R/H redundant system. If the R/H system is in the RUN-Redundant system state, the primary CPU controls the process. The backup CPU processes the user program synchronously and can take over process control if the primary CPU fails.

Primary-backup switchover

The primary CPU has the leading role within the redundant system. If the primary CPU fails following a fault, the backup CPU takes over the primary role and operates as the primary CPU.

Process image (I/O)

The CPU transfers the values from the input and output modules to this memory area. At the start of the cyclic program, the CPU transfers the process image output as a signal state to the output modules. The CPU then reads the signal states of the input modules into the process image inputs. The CPU then executes the user program.

Product version (PV) = Function version (FV)

The product version or function version provides information on the hardware version of the module.

PROFINET

PROcess **FI**eld **NET**work, open Industrial Ethernet standard that continues PROFIBUS and Industrial Ethernet. A cross-manufacturer communication, automation, and engineering model defined by PROFIBUS International e.V. as an automation standard.

PROFINET IO

Communication concept for the realization of modular, distributed applications within the scope of PROFINET.

PROFINET IO controller

Device used to address connected IO devices (for example distributed I/O systems). The IO controller exchanges input and output signals with assigned IO devices. The IO controller is often the CPU on which the user program is running.

PROFINET IO device

Distributed field device that can be assigned to one or more IO controllers. Examples: Distributed I/O system, valve terminals, frequency converters, switches

Push-in terminal

Terminal for the tool-free connection of wires.

Redundancy connection/redundancy connections

The redundancy connection in an S7-1500R system is the PROFINET ring with MRP. The redundancy connection uses part of the bandwidth on the PROFINET cable for the synchronization of the CPUs. This bandwidth is therefore not available for PROFINET IO communication.

Unlike in S7-1500R, the PROFINET ring and redundancy connections in S7-1500H are separate. The two redundancy connections are fiber-optic cables that connect the CPUs directly over synchronization modules. The bandwidth on the PROFINET cable is available for PROFINET IO communication.

Redundancy ID

The load memory of both CPUs contains the project data of one as well as the other CPU. By assigning the redundancy IDs, you define which project data a CPU uses for itself.

Redundant systems

Redundant systems have multiple (redundant) instances of key automation components. Process control is maintained if a redundant component fails.

Reference potential

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

Restart

A warm restart deletes all non-retentive bit memory and resets non-retentive DB contents to the initial values from load memory. Retentive bit memory and retentive DB contents are retained. Program execution begins at the call of the first startup OB. A restart is triggered with CPU POWER OFF/POWER ON.

Retentivity

A memory area whose content is retained after power failure and after a STOP to RUN transition is retentive. The non-retentive area bit memory area, timers and counters are reset after a power failure and after a STOP to RUN transition. The non-retentive content of data blocks is reset to the initial values.

Row

All the modules attached to a mounting rail.

Runtime error

Error that occurs during execution of the user program in the automation system (thus not in the process).

SELV

Safety Extra Low Voltage = Safety extra-low voltage

SNMP

SNMP (Simple Network Management Protocol) is the standardized protocol for performing diagnostics on and assigning parameters to the Ethernet network infrastructure.

In the office setting and in automation engineering, devices from a wide range of vendors on the Ethernet support SNMP.

You can operate SNMP-based applications on the same network in parallel to applications with PROFINET.

The scope of supported functions varies depending on the device type. For example, a switch has more functions than a CP 1616.

Switch

PROFIBUS is a linear network. The communication nodes are linked by means of a passive cable - the bus.

By contrast, Industrial Ethernet consists of point-to-point connections: Each communication node is directly connected to exactly one communication node.

If you want to link a communication node to several communication nodes, you connect this communication node to the port of an active network component (the switch). You can connect other communication nodes (including switches) to the other ports of the switch. The connection between a communication node and the switch remains a point-to-point connection.

A switch thus has the task of regenerating and distributing received signals. The switch "learns" the MAC addresses of a connected PROFINET device or additional switches. The switch only forwards those signals that are intended for the connected PROFINET device or switch.

A switch has a specific number of connections (ports). You connect at most one PROFINET device or additional switch to each port.

Synchronization module

You use the synchronization modules to create the redundancy connections between the CPUs of the redundant S7-1500H system. You need two synchronization modules per CPU that you connect in pairs with fiber-optic cables.

System power supply

Consists of the integrated system power supply of the CPU/interface module and additional power supplies (PS), if necessary. The system power supply powers the CPU and the I/O modules via the backplane bus.

System states

The system states of the S7-1500R/H redundant system result from the operating states of the primary and backup CPU. The term system state is used as a simplified expression that refers to the operating states that occur simultaneously on both CPUs. The S7-1500R/H redundant system has the system states STOP, STARTUP, RUN-Solo, SYNCUP and RUN-Redundant.

System IP address

In addition to the device IP addresses of the CPUs, the redundant system S7-1500R/H supports system IP addresses:

- System IP address for the X1 PROFINET interfaces of the two CPUs (system IP address X1)

- System IP address for the X2 PROFINET interfaces of the two CPUs (system IP address X2)

You use the system IP addresses for communication with other devices (for example, HMI devices, CPUs, PG/PC). The devices always communicate over the system IP address with the primary CPU of the redundant system. This ensures that the communication partner can communicate with the new primary CPU (previously backup CPU) in the RUN-Solo system state after failure of the original primary CPU in redundant operation.

TIA Portal

Totally Integrated Automation Portal

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

Time-delay interrupt

You will find further information in the glossary entry "Interrupt, time-delay".

Time-of-day interrupt

You will find further information in the glossary entry "Interrupt, time-of-day".

Timer

Timers are components of the system memory of the CPU. The operating system automatically updates the content of the "timer cells" asynchronously to the user program. STEP 7 instructions define the precise function of the timer cell (for example on-delay) and trigger its execution.

Update interrupt

You will find further information in the glossary entry "Interrupt, update".

User program

In SIMATIC, a distinction is made between user programs and the firmware of the CPU.

The user program contains all instructions, declarations and data that control a system or process. The user program is assigned to the redundant system. Structuring into smaller unit is supported.

Firmware: You will find further information in the glossary entry "Firmware of the CPU".

Value status

The value status describes a specific signal state. The value status is constantly updated and cyclically transmitted by the field device as a quality statement together with the measured value.

Warm restart

You will find further information in the glossary entry "Restart".

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