

PROFINET
Planning guideline redundancy

Guideline
for PROFINET

Version 1.00 - *Date 07. 05. 2023*
Order No.: 8.132

Prepared by the PROFIBUS Working Group Installation Guides "PG3" in the Technical Committee CB.

The attention of adopters is directed to the possibility that compliance with or adoption of PI (PROFIBUS&PROFINET International) specifications may require use of an invention covered by patent rights. PI shall not be responsible for identifying patents for which a license may be required by any PI specification, or for conducting legal inquiries into the legal validity or scope of those patents that are brought to its attention. PI specifications are prospective and advisory only. Prospective users are responsible for protecting themselves against liability for infringement of patents.

NOTICE:

The information contained in this document is subject to change without notice. The material in this document details a PI specification in accordance with the license and notices set forth on this page. This document does not represent a commitment to implement any portion of this specification in any company's products.

WHILE THE INFORMATION IN THIS PUBLICATION IS BELIEVED TO BE ACCURATE, PI MAKES NO WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, WITH REGARD TO THIS MATERIAL INCLUDING, BUT NOT LIMITED TO ANY WARRANTY OF TITLE OR OWNERSHIP, IMPLIED WARRANTY OF MERCHANTABILITY OR WARRANTY OF FITNESS FOR PARTICULAR PURPOSE OR USE.

In no event shall PI be liable for errors contained herein or for indirect, incidental, special, consequential, reliance or cover damages, including loss of profits, revenue, data or use, incurred by any user or any third party. Compliance with this specification does not absolve manufacturers of PROFIBUS or PROFINET equipment, from the requirements of safety and regulatory agencies (TÜV, BIA, UL, CSA, etc.).

PROFIBUS® and PROFINET® logos are registered trade marks. The use is restricted for members of PROFIBUS&PROFINET International. More detailed terms for the use can be found on the web page www.profibus.com/Downloads. Please select button "Presentations & logos".

In this specification the following key words (in **bold** text) will be used:

- may:** indicates flexibility of choice with no implied preference.
- should:** indicates flexibility of choice with a strongly preferred implementation.
- shall:** indicates a mandatory requirement. Designers **shall** implement such mandatory requirements to ensure interoperability and to claim conformance with this specification.

Publisher:
PROFIBUS Nutzerorganisation e.V.
Haid-und-Neu-Str. 7
76131 Karlsruhe
Germany
Phone : +49 721 986 197 0
Fax : +49 721 96 61 97 11
E-mail: info@profibus.com
Web site: www.profibus.com

© No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

This document was created by the "Installation Guide" (CB/PG3) working group of the PROFIBUS user organization.

Revision log

Version	Date	Editor	Changes/History
1.00	07.05.2023	Niemann	Release candiate

Table of contents

1	INTRODUCTION	9
1.1	FOREWORD	10
1.2	EXCLUSION OF LIABILITY	11
1.3	REFERENCED PNO DOCUMENTS AND STANDARDS	12
1.4	SYMBOL EXPLANATIONS	14
1.4.1	<i>Symbols for text structuring</i>	14
1.4.2	<i>Symbols for components</i>	15
1.4.3	<i>Symbols for PROFINET cables and application relationships</i>	17
1.4.4	<i>Symbols for areas</i>	18
1.5	AIM OF THIS GUIDELINE	19
2	AVAILABILITY BASICS	20
2.1	MEAN TIME TO FAILURE (<i>MTTF</i>)	21
2.2	MEAN TIME TO RECOVER (<i>MTTR</i>)	21
2.3	MEAN TIME BETWEEN FAILURES (<i>MTBF</i>)	22
2.4	AVAILABILITY (<i>V</i>)	22
2.5	RECOMMENDATIONS FOR ACHIEVING HIGH AVAILABILITY	23
3	PROFINET REDUNDANCY FUNCTIONS	24
3.1	INTRODUCTION TO PROFINET REDUNDANCY	25
3.2	PROFINET MEDIA REDUNDANCY	28
3.2.1	<i>Media redundancy with MRP</i>	30
3.2.2	<i>Media redundancy with MRPD</i>	33
3.3	PROFINET SYSTEM REDUNDANCY	37
3.3.1	<i>PROFINET configuration S1</i>	37
3.3.2	<i>PROFINET System Redundancy S2</i>	38
3.3.3	<i>PROFINET System Redundancy R1</i>	40

3.3.4	<i>PROFINET system redundancy R2</i>	41
3.4	COMPARISON OF PROFINET REDUNDANCIES.....	44
4	EXAMPLE APPLICATIONS FOR HIGHLY AVAILABLE NETWORKS AND SYSTEMS.....	45
4.1	TECHNICAL STRUCTURE OF THE PROFINET DEVICES USED	46
4.1.1	<i>PROFINET Devices</i>	46
4.1.2	<i>PROFINET Controller</i>	49
4.2	EXAMPLE APPLICATIONS FOR PROFINET	53
4.2.1	<i>Example application 1: Tunnel System</i>	53
4.2.2	<i>Example application 2: Manufacturing industry plant</i>	56
4.2.3	<i>Example application 3: Process Industry Plant without increased availability requirements</i>	58
4.2.4	<i>Example application 4: Process Industry Plant with increased availability requirements</i> 60	
4.2.5	<i>Example application 5: Process industry plant with Advanced Physical Layer (APL)</i> ..	62
5	SUMMARY	65
6	INDEX	67

List of Figures

Figure 2-1: Relationship between MTTF, MTTR and MTBF	22
Figure 3-1: Non-redundant PROFINET topologies.....	25
Figure 3-2: PROFINET ring topology	28
Figure 3-3: PROFINET media redundancy with distributed subscriber roles for MRP	31
Figure 3-4: Closed PROFINET ring with MRP function	32
Figure 3-5: Opened PROFINET ring with MRP function	33
Figure 3-6: Media redundancy with MRPD	35
Figure 3-7: PROFINET configuration S1	38
Figure 3-8: PROFINET system redundancy S2	39
Figure 3-9: PROFINET system redundancy R1	40
Figure 3-10: Communication connections for PROFINET system redundancy R2	42
Figure 3-11: Application relationships for PROFINET system redundancy R2	43
Figure 4-1: PROFINET device with simple interface module design	46
Figure 4-2: PROFINET device with redundant interface module design	47
Figure 4-3: Internal wiring of a PROFINET device with redundant interface module ..	48
Figure 4-4: PROFINET controller	49
Figure 4-5: Redundancy coupling of CPUs via fiber optic cable for PROFINET system redundancy	51
Figure 4-6: Redundancy coupling of the CPUs via PROFINET cable for PROFINET system redundancy S2	52
Figure 4-7: Tunnel system.....	53
Figure 4-8: Plant manufacturing industry	56
Figure 4-9: Plant Process industry without increased availability requirements	58
Figure 4-10: Plant Process industry with increased availability requirements.....	60
Figure 4-11: Process industry plant with advanced physical layer	62

List of tables

Table 1-1: Symbols for text structuring.....	14
Table 1-2: Symbols for components.....	15
Table 1-3: Symbols for PROFINET cables and application relationships	17
Table 1-4: Symbols for areas	18
Table 3-1: PROFINET redundancies	44

1 Introduction

1.1 Foreword

The availability of production plants is becoming increasingly important. While in the past production plants in the process industry required the use of highly available systems, today more and more plants in the manufacturing industry but also infrastructure projects, such as tunnels and airports, are also equipped with high availability technology in order to reduce downtimes and the associated costs.

PROFINET offers various redundancy concepts to meet the different requirements of different applications. This ranges from ring redundancy, where essentially one line is closed to form a ring, to R2 redundancy, where almost all components of the automation system are duplicated.

This guideline is aimed at system planners who would like to gain easy access to redundancy from a planning perspective. After an explanation of the basic concepts of high availability, the document describes the various PROFINET redundancy concepts. This is followed by a description of typical use cases and an explanation of the general conditions that must be observed.

This document should be considered as a supplement to the PNO's existing redundancy documents and does not replace them.

1.2 Exclusion of liability

PROFIBUS Nutzerorganisation e.V. (PROFIBUS user organization, hereinafter in this disclaimer referred to as "PNO") has taken almost care in the preparation of this document and compiled all information to the best of its knowledge. This document is nevertheless based on present knowledge, is of an informative character and is provided on the basis of liability exclusion. This document may be subject to change, enhancement or correction in the future without any expressive reference.

This document has no normative character. It may be useful in certain operating environments, in certain technical constellations or when used in certain countries to deviate from the given recommendations for action. In this case, the installer and operator of the installation should weigh up the advantages and disadvantages of the recommendations made in the specific application and, if deemed appropriate, decide on the implementation of a different solution if necessary.

The user may not distribute, rent or make available the information in any other way to any third party at any time.

Any liability for defects as to quality or title of the information, especially in relation to the correctness or absence of defects or the absence of claims or third-party rights or in relation to completeness and/or fitness for purpose are excluded, except for cases involving gross negligence, willful misconduct or fraudulent concealment of a defect. Any further liability is excluded unless required by law, e.g. in cases of personal injury or death, willful misconduct, gross negligence, or in case of breach of fundamental contractual obligations.

1.3 Referenced PNO documents and standards

[APL2022] Ethernet-APL Engineering Guideline. Order No.: 8.122, Version 1.14, September 2022

[IEC_62439-2] Industrial communication networks - High availability automation networks - Part 2: Media redundancy protocol (MRP) (IEC 62439-2:2020)

[PNA2022] PROFIBUS Nutzerorganisation e.V.: PROFINET Application layer protocol for decentralized periphery. Version 2.4MU3. June 2022. Order Nr: 2.722.

[MIL217F] US Department of Defense MIL-HDBK-217. F: Military Handbook Reliability Prediction of Electronic Equipment, Washington DC, 1991.

[PNP2022] PROFIBUS Nutzerorganisation e. V.: PROFINET Planning Guideline. Version 1.53, September 2022. Order No. 8.062.

[PNM2018] PROFIBUS Nutzerorganisation e. V.: Media Redundancy Guideline for PROFINET. Version 1.03. April 2018. Order No. 7.212.

[PNH2020] PROFIBUS Nutzerorganisation e.V.: High Availability Guideline for PROFINET. Version 1.2. April 2020. Order Nr. 7.242.

[TEL2011] Telcordia Technologies, Inc: TEL Telcordia - Reliability Prediction Procedure for Electronic Equipment - SR-332.. <http://telecom-info.telcordia.com/site-cgi/ido/docs.cgi?ID=SEARCH&DOCUMENT=SR-332&#ORD>, 01/08/2012.

[VDI_2183] VDI/VDE Society for measurement and automation technology. VDI/VDE 2183. Reliable operation of Ethernet-based bus systems in industrial automation. January 2018.





1.4 Symbol explanations

The illustrations in this guideline are intended to help you better understand the text. In addition, symbols are used to structure the text. These symbols provide references to important passages in the text or summarize sections.

1.4.1 Symbols for text structuring

The following Table 1-1 represents the symbols for text structuring.

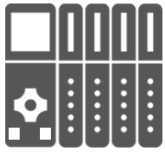
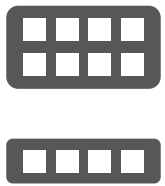
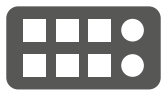
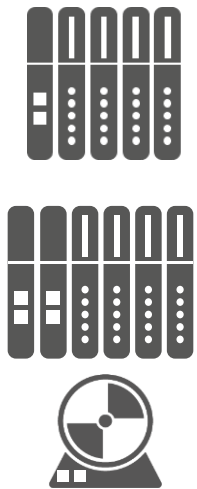
Table 1-1: Symbols for text structuring

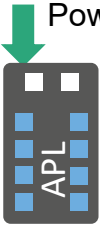

Symbol	Name	Meaning
	Tip	Used to indicate a recommendation and / or summary of the current facts.
	Important	Used for instructions which, if not followed, may cause malfunctions during operation.
	Action statement	Used for direct action instruction.
	Danger	Used in case of danger to life and safety. Observance of the instruction is extremely important!

1.4.2 Symbols for components

The following Table 1-2 represents the symbols used for the components.

Table 1-2: Symbols for components





Symbol	Name	Meaning
	Controller	Device that initiates the data traffic.
	Switch	Device for connecting several PROFINET devices with each other. Switches have 4 or 8 PROFINET copper cable connections
	Switch	Device for interconnection of several PROFINET devices. Six ports for copper cable plus two ports for fiber optic cable.
	Device	<p>Decentrally assigned field device that is assigned to a controller.</p> <p>This guideline distinguishes between two different Devices. The focus in this document is on the number of available ports, which serve as a bus connection for a PROFINET cable with suitable connector assembly. The field devices have two or four ports in the further course. Devices with two PROFINET ports meet the requirements for simple (singular) PROFINET network structures, while devices with four installed ports meet the requirements of redundant networks.</p> <p>The drive is defined as a further field device. Has 2 ports for copper cable.</p>

 <p>Power</p>	<p>Ethernet-APL Field Switch</p>	<p>Device establishes a connection between PROFINET and the connected APL field devices via the spur ports. Through a direct connection to an auxiliary power source, the APL field switch is able to supply the connected APL field devices with power.</p>
	<p>APL field device</p>	<p>APL field device with integrated Ethernet-APL interface. Typical APL field devices are e.g. temperature transmitters, pressure transmitters, flow transmitters and positioners.</p>

1.4.3 Symbols for PROFINET cables and application relationships


The following Table 1-3 shows the symbols used for cables and application relationships.

Table 1-3: Symbols for PROFINET cables and application relationships

Symbol	Name	Meaning
	PROFINET copper cable	<p>PROFINET Industrial Ethernet cable with copper wires</p> <p>Sheath color: green</p> <p>In this guideline, two different shades of green are used to better differentiate the lines in the graphics. The color light green is used to identify the primary PROFINET network used, while the color dark green represents the secondary network connection.</p>
	PROFINET fiber optic cable (FO)	<p>Fiber optic cable</p> <p>Sheath color: green, orange</p> <p>Note: to better distinguish between copper and fiber optics, the fiber optics are shown in orange in this guideline, even if the sheath of the cable is usually green. An exception is the redundancy link as an FO, which generally has an orange sheath.</p>
	PROFINET application relationships (Application Relations)	<p>The dashed lines with the colors black and yellow represent the assignment of the application relationships between a controller and a device.</p>
	Ethernet-APL copper cable	<p>Ethernet-APL cable with copper wires.</p> <p>Sheath color: not defined</p>

1.4.4 Symbols for areas

Table 1-4: Symbols for areas

Symbol	Name	Meaning
	Ex area	Potentially explosive area

1.5 Aim of this guideline

This guideline is intended for planners of automation systems who need to pay particular attention to the aspect of high availability. This document adds the aspect of high availability to the PROFINET planning guideline [PNP2022] in order to describe the relevant planning aspects.

Further, detailed information on this topic can be found in the documents [PNH2020], [PNM2018], and [PNS2015].

2 Availability basics

The following chapter first provides an overview of the basics of availability calculation. The explanations are essentially based on [VDI_2183].

2.1 Mean Time to Failure (*MTTF*)

The *MTTF* which stands for "Mean Time to Failure", is a statistical number that describes the failure-free operation of a device until the first failure (also defined as "mean time to failure"). Assuming that the failure rate λ is constant, the *MTTF* can thus be determined by equation (2-1):

$$MTTF = \frac{1}{\lambda} \quad (2-1)$$

Through standardized calculation methods, such as Telcordia SR332 [TEL2011] or MIL-HDBK-217F [MIL217F], characteristic reliability values can be determined. Stress factors, such as shock, vibration or a corrosive atmosphere, can be considered when calculating the *MTTF*. The values determined only give an estimate of the service life. Therefore, it must be considered that the functional capability of a device does not necessarily correspond to the previously determined *MTTF*. The amount of the *MTTF* essentially depends on the following influencing factors:

- Number and type of components
- Operating/ambient temperature
- Other environmental conditions

Manufacturer-specific specifications for the *MTTF* are typically in the range of several years.

2.2 Mean Time to Recover (*MTTR*)

Another parameter used to determine availability is the *MTTR*. The abbreviation *MTTR* stands for "Mean Time to Recover" and describes the average time required to repair or replace a defective device (also defined as "mean repair time"). System recovery should be as fast as possible in order to achieve a short *MTTR* in the best case. This mainly depends on the service organization of the system operator and the provision of spare parts by the device manufacturer. Furthermore, the following factors influencing the *MTTR* must be considered:

- Time needed time to identify the faulty device
- Time required to repair the fault/device
- Under certain circumstances: Time to procure spare parts

The level of *MTTR* can vary due to the influencing factors described above. It can typically range from several hours to a few days.

2.3 Mean Time Between Failures (*MTBF*)

The third important parameter for calculating availability is the *MTBF* which stands for "Mean Time Between Failures". This term refers to the average operating time between two failures, which is made up of the uninterrupted operating time (*MTTF*) plus the repair time (*MTTR*). With the help of equation (2-2) the *MTBF* can be described by the previously defined parameters as follows:

$$MTBF = MTTF + MTTR \quad (2-2)$$

The terms *MTBF* and *MTTF* are often used synonymously in the literature. This can be explained by the fact that many manufacturers declare the service life of their devices with the parameter *MTBF*. This would in turn mean that the manufacturer would have complete influence on the *MTTR*. As a rule, therefore, the *MTBF* specification is to be interpreted as *MTTF*. Figure 2-1 shows the relationship between *MTTF*, *MTTR* and *MTBF*.

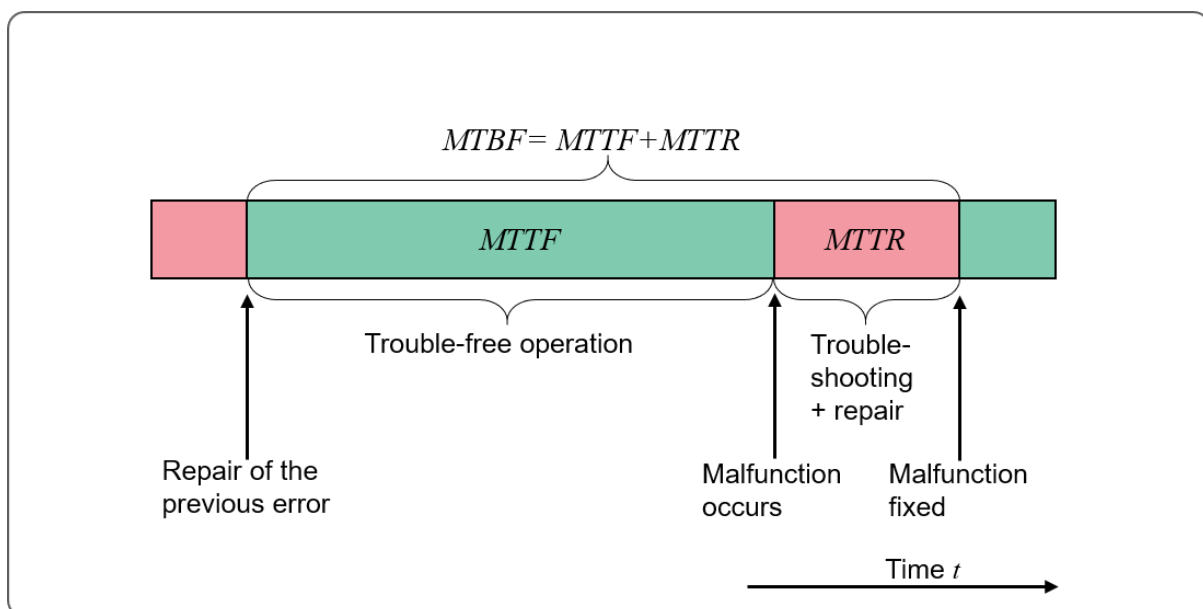


Figure 2-1: Relationship between MTTF, MTTR and MTBF

2.4 Availability (*V*)

The availability *V* indicates the probability that a device or system is operational and can assume numerical values between 0 and 1. Accordingly, availability can be derived from the already known parameters *MTTF*, *MTTR* and *MTBF* according to equation (2-3).

$$V = \frac{MTTF}{MTBF} = \frac{MTTF}{MTTF + MTTR} = \frac{Time_undisturbed_operation}{Total_operating_time} \quad (2-3)$$

On the basis of equation (2-3) it can be seen that high availability can only be achieved if the value of the *MTTF* is significantly greater than the *MTTR*. Low failure rates and short repair times are factors that lead to high availability.

2.5 Recommendations for achieving high availability

From the preceding chapters, it can be seen that high availability can be achieved by a high *MTTF* and a low *MTTR*. The following general recommendations can be derived from this.

- Use components with a high *MTTF*. This can be achieved, for example, by dispensing with components with moving parts (fans).
- Build up inventory for spare parts so that frequently used parts can be replaced quickly.
- Deploy network monitoring systems to enable rapid troubleshooting and achieve a short *MTTR*.
- Redundant components at risk of failure with low *MTTF* (e.g. power supply units).
- Use redundant system structures as described in this document.

In [VDI_2183] you will find further information on how to achieve high availability.

3 PROFINET redundancy functions

3.1 Introduction to PROFINET redundancy

High-availability automation systems are becoming increasingly important in the process and manufacturing industries. The failure of network components or a cable break usually leads to the shutdown of an industrial plant in simple line, star and tree topologies. An example of this is provided by Figure 3-1. It can be seen that if a single component fails, the overall function is no longer given.

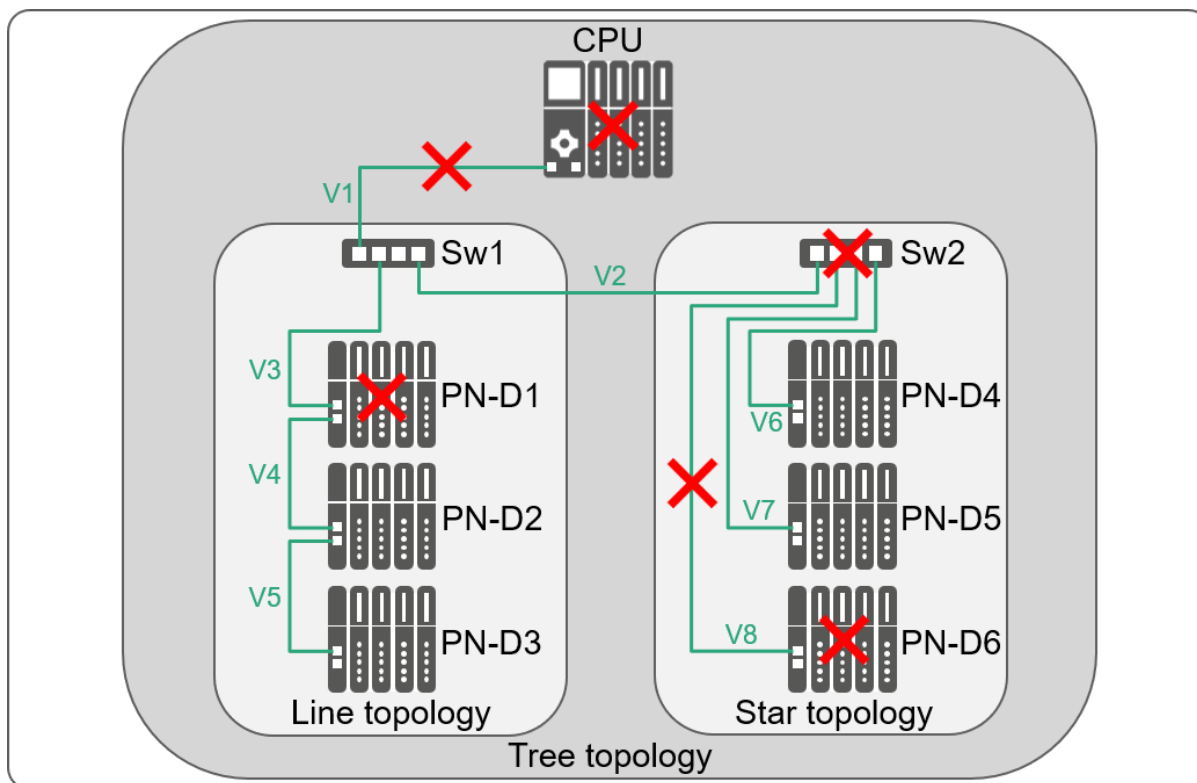


Figure 3-1: Non-redundant PROFINET topologies

PROFINET line topology:

Figure 3-1 shows a line topology in the left part. This is implemented by using the switches available in the devices. A significant advantage of this connection method is the simple and cost-effective networking of PROFINET devices. However, impairments result from the failure of a network component within the line structure. Figure 3-1 shows that a defect in the "PN-D1" device leads to an interruption in communication between the network nodes behind it.



PROFINET line topologies are not suitable for ensuring high availability. The failure of components or connections therefore leads to a disruption in communication.

PROFINET Star Topology:

Connecting several PROFINET end devices to a centrally located switch implements a star topology. Star topologies have a lower probability of failure compared to a line topology. Figure 3-1 describes, for example, that a damaged PROFINET connection "V8" or a defective end device does not have any negative effects on the communication of the remaining nodes and thus contributes to increasing availability. Nevertheless, simple star structures have a disadvantage in terms of availability. As soon as the central switch "Sw2" as the single point of failure can no longer maintain communication, this scenario leads to a complete disruption of the data exchange.



A technical defect of the central switch leads to a communication interruption of the connected PROFINET end devices within the star topology.

Star structures require more cabling than ring and line topologies. Laying long cable runs can have a negative effect on the *MTTR* because localization of the fault source may take longer, see chapter 2.2.

PROFINET Tree Topology:

Tree topologies can be implemented by cascading switches several times. The statements for star topologies apply analogously.

The methods presented so far are not aimed at increasing fail-safety. By using PROFINET redundancies, the availability of a plant can be increased through the redundant use of critical components. The following requirements must be considered in advance during planning:

- The devices/components must support the redundancy function used in each case.
- The maximum allowed number of devices depending on the redundancy type is not exceeded.
- The reconfiguration times/switching times are acceptable for the respective production process.

Switching times:

Redundant systems require a switchover time to detect an interruption and to switch over to the redundant structures. When switching over to redundant structures or network nodes, a basic distinction is made between two types:

- **"Bumpless switching"**: No data loss occurs during an interruption or device replacement.
- **"Not bumpless switching"**: Data loss may occur during an interruption or device replacement.

Redundancy protocols:

So-called PROFINET redundancy protocols are used to switch over to a replacement component in the event of a component failure. These are described in more detail from chapter 3.2.

3.2 PROFINET Media Redundancy

This section deals with the topic of PROFINET media redundancy. This form of redundancy is specially designed for PROFINET ring topologies and is based on ring-shaped cabling, as shown in Figure 3-2 illustrated.

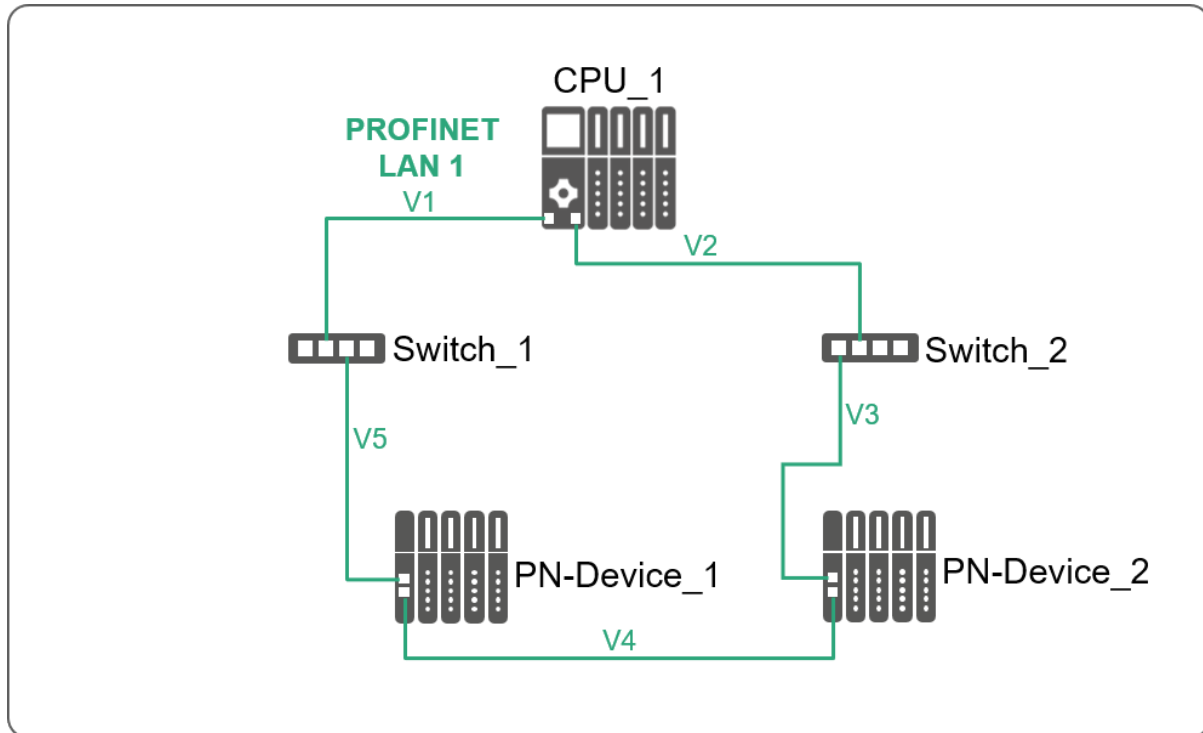


Figure 3-2: PROFINET ring topology

Combining multiple line paths into a ring is not allowed in standard Ethernet communication because it leads to the circulation of data packets in loop architectures. To prevent data packets from circling, PROFINET uses so-called ring redundancy protocols. From a technical point of view, these cause a separation of the ring structure in error-free operation, which means that data packets are sent specifically via linear communication paths between the sender and receiver. The advantages of PROFINET media redundancy are particularly evident in terms of reliability. If interference no longer ensures the functional reality of a PROFINET ring structure, the use of ring redundancy protocols guarantees the maintenance of data traffic. Two-way communication ensures that data frames continue to be forwarded via redundant paths.

PROFINET offers two different media redundancy solutions for managing ring structures. Meant are the protocols:

- "Media Redundancy Protocol" (MRP), a standardized ring redundancy protocol based on the standard [IEC_62439-2].
- "Media Redundancy for Planned Duplication" Protocol (MRPD)

However, the functional properties of MRPD and MRP are based on two different approaches to managing ring structures. It should be noted in advance, however, that MRPD alone is not capable of preventing the circulation of data packets. Another component of MRPD is the MRP protocol, which is required for checking the ring function and is thus additionally integrated in the MRPD mechanism. Further information and details about MRP and MRPD can be found in the following chapters.



Basically, MRPD is a mechanism that can be understood as a functional extension of the MRP function. MRP thus serves as a basis for the use of MRPD.

Switches are of fundamental importance for setting up ring topologies. They are capable of recognizing communication paths and forwarding the received data to the correct path. In Figure 3-2 the ring structure has two different types of switches. While "Switch_1" and "Switch_2" are shown as external switches, the field devices "PN-Device_1" and "PN-Device_2" as well as the controller "CPU_1" have an integrated switch. To be able to use PROFINET devices in ring topologies, the number of required Ethernet ports must be considered. For media redundancy it is assumed that two ports with an integrated switch are available for each PROFINET device.



A ring structure minimizes downtime in the event of simple network interruptions, e.g. when replacing a PROFINET node within the ring structure.



Laying the return path to close the ring should be done on a separate route to avoid simultaneous damage to both lines. Adjust the documentation of the cabling accordingly in your documents.

3.2.1 Media redundancy with MRP

The "Media Redundancy Protocol" (MRP) is a redundancy protocol that was developed to ensure network and plant availability. An advantage is the low configuration requirements for MRP. A disadvantage of the MRP function, on the other hand, is that interruption times must be accepted in the event of a switchover. For a PROFINET ring topology to function without problems, the following prerequisites must be observed:

- For the use of MRP, the topology structure must be a ring.
- All devices located in the ring network must support MRP according to [IEC_62439-2].
- During project engineering, MRP must be activated for all PROFINET nodes in the ring.
- The ring subscribers are to be connected to each other via the configured ring ports.
- The maximum number of PROFINET devices in a ring must be considered. This can vary depending on the manufacturer.
- For the connection settings, make sure that the ring ports support full-duplex transmission and a transmission speed of at least 100 Mbps.

As already indicated, all PROFINET nodes within the ring structure must support the Media Redundancy Protocol (MRP). The use of this protocol requires the assignment of subscriber roles for the PROFINET devices for monitoring and controlling the ring topology. These are differentiated into Media Redundancy Manager (MRM) and Media Redundancy Client (MRC), as shown in Figure 3-3 shown. It should be noted that only **one** PROFINET node is to be defined as media redundancy manager in a ring. The remaining nodes are to be defined as media redundancy clients. A method for configuring the roles in the ring enables the "Media Redundancy Auto manager" (MRA) function. This method is characterized by an automatic determination of the media redundancy manager, which eliminates manual settings for the role distribution of the PROFINET ring participants. According to the packet runtime, the assignment of the MRM is determined dynamically. Another advantage is the automatic passing on of the MRM function if a failure of the active media redundancy manager is detected.

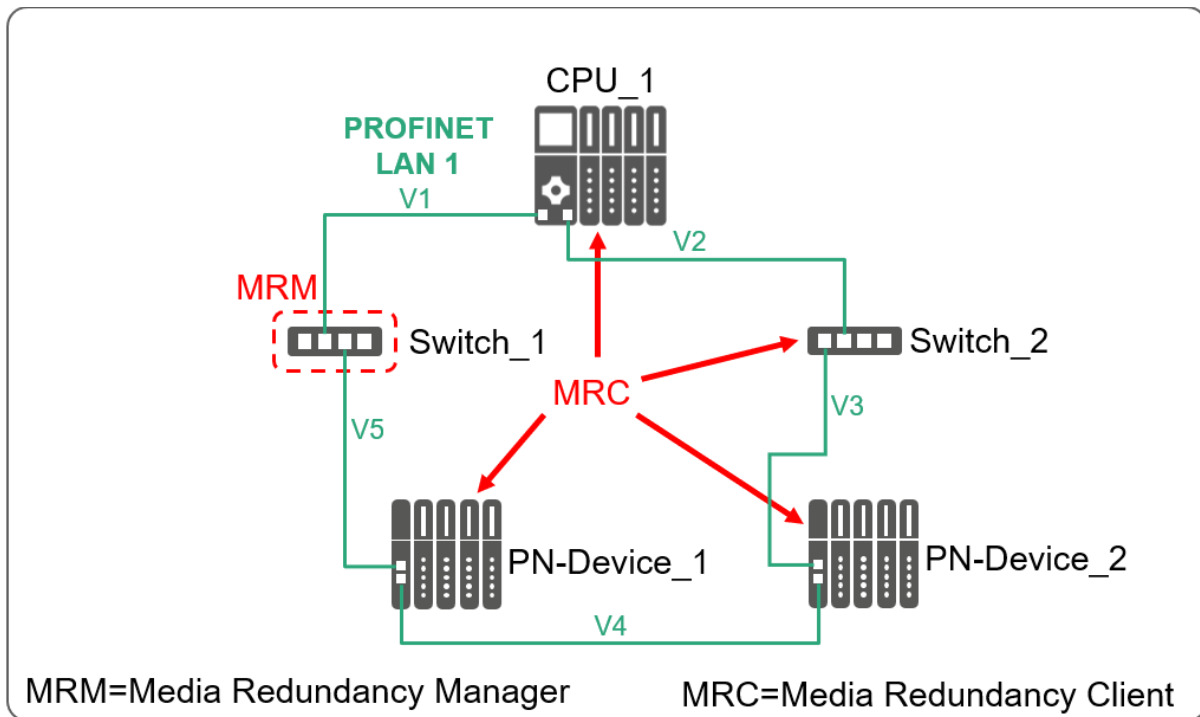


Figure 3-3: PROFINET media redundancy with distributed subscriber roles for MRP

Monitoring and controlling the ring topology is the task of the media redundancy manager. To check the functionality, the MRM sends cyclical test frames that are sent simultaneously from both ring ports. As soon as the test frames are received again internally at the opposite ring port, an intact ring structure is ensured. The media redundancy manager then blocks one of the two ring ports and thus opens the ring structure. In the error-free case, this function ensures that data is only forwarded via a linear path to prevent undesired circulation of data packets. In Figure 3-4 this functional principle is shown. The blocked ring port of Switch_1, shown as a red marked square, does not allow a forwarding and receiving of the data frames towards the controller "CPU_1". The MRM thus converts the ring structure into a line topology, which prevents the data packets from circulating.

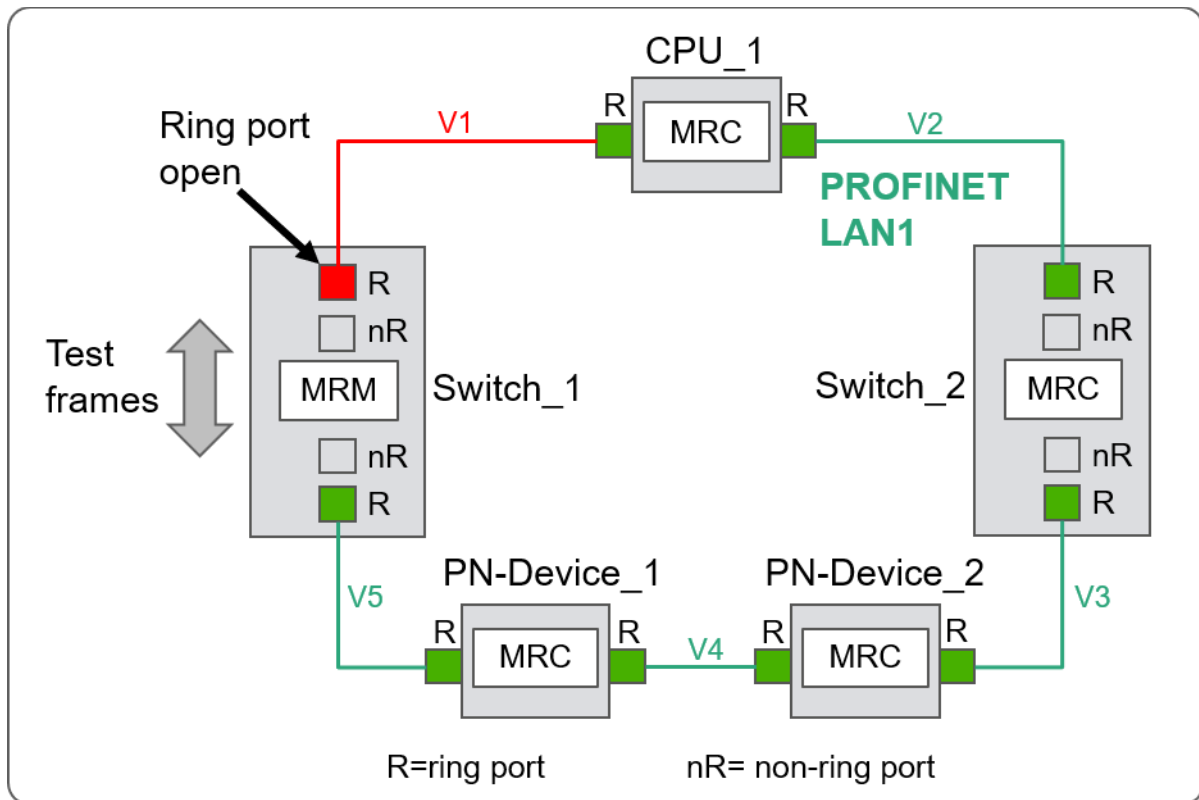


Figure 3-4: Closed PROFINET ring with MRP function

A failure in the ring (failure switch or connection) leads to the unblocking of the redundant ring port. Figure 3-5 shows an example of how an alternative path is provided by using the MRP protocol. By closing the redundant ring port shows Figure 3-5 that despite an interruption in the ring, the nodes "CPU_1" and "Switch_2" can still be reached via a linear topology.

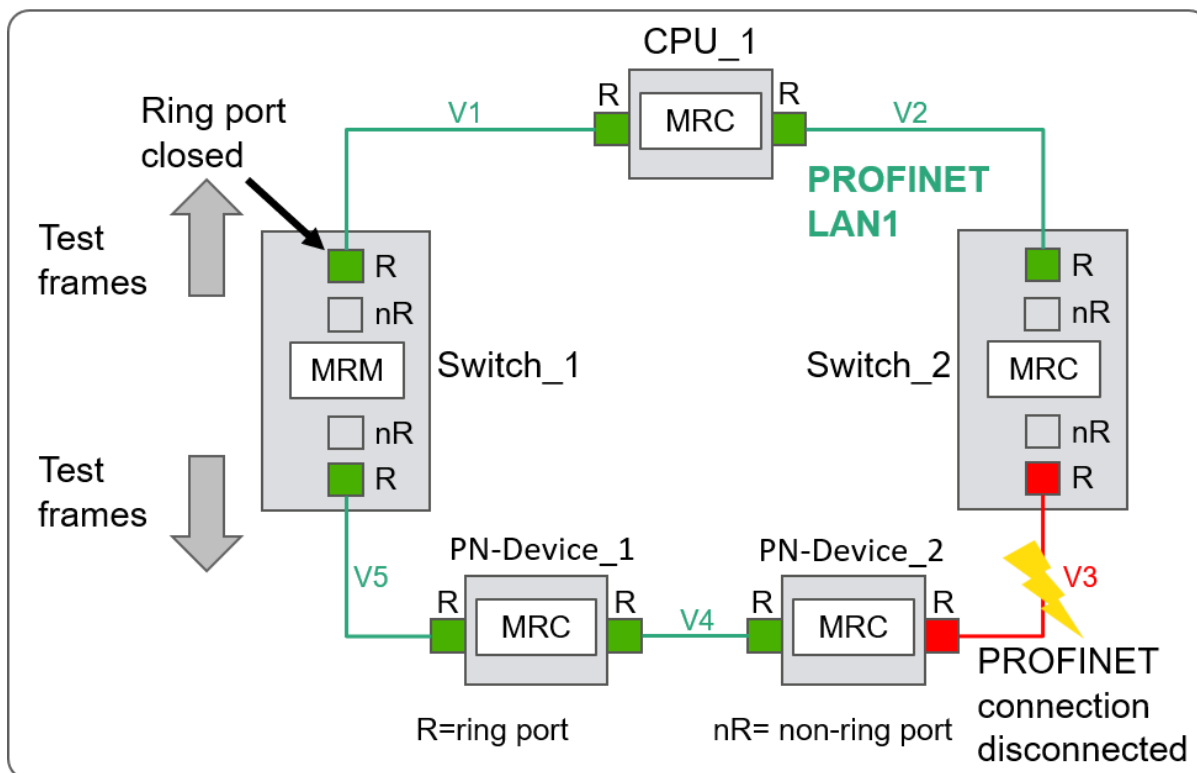


Figure 3-5: Opened PROFINET ring with MRP function

Once the interruption has been repaired and the original communication path has been restored to a functional state, this scenario again leads to an internal separation of the ring structure. The interruption time for MRP, also called reconfiguration time, must not exceed 200 ms.



For further information on "Media Redundancy Protocol" (MRP) refer to the PROFINET Media Redundancy Guideline (Order No.:7.212)

3.2.2 Media redundancy with MRPD

For PROFINET ring topologies with higher availability requirements, the use of the "Media Redundancy for Planned Duplication Protocol" (MRPD) is suitable. With MRPD, which is based on MRP and the PROFINET IRT (PROFINET Conformance Class C) real-time protocol, faults can be compensated even faster. The use of this redundancy protocol enables bump less switching for PROFINET systems, thus avoiding reconfiguration times in the event of a fault. Based on IRT communication between PROFINET ring nodes, the network infrastructure must be adapted accordingly. IRT data can only be exchanged with suitable PROFINET devices and an appropriate network according to the specifications of "Conformance Class C"

in order to meet the requirements for hard real-time. For a PROFINET ring topology with MRPD to function properly, the following requirements must be met:

- The MRPD function can only be used in PROFINET ring structures.
- The network infrastructure must be set up in accordance with the requirements of Conformance Class C to enable cyclic and clock-synchronous data transmission.
- All PROFINET devices in the ring must support the MRPD function according to [PNA2022] for the cyclic exchange of IRT data.
- Activation of the MRPD function must be considered during project planning.
- Note the limited number of PROFINET devices in a ring. This may vary depending on the manufacturer.
- The ring subscribers are to be connected to each other via the configured ring ports.
- For the connection settings, make sure that the ring ports support full duplex transmission and a transmission speed of 100 Mbit/s.

In addition to the prerequisites listed, a configuration of the media redundancy roles for the PROFINET devices used is provided, which is required for controlling and monitoring a PROFINET ring topology. For the PROFINET ring participants, it must be considered that only **one** device may perform the role of media redundancy manager (MRM). All other PROFINET nodes in the ring must be assigned the role of media redundancy client (MRC).

MRPD uses the following mechanism to send data: The transmitter sends the data telegrams with the same information via both ring ports into the ring. Thus, the receiver receives two identical IRT data telegrams in undisturbed operation, which may arrive slightly delayed. The IRT data telegram that arrives first at the addressed device is used for the further process and then evaluated. The second IRT data telegram is discarded unused. To ensure a redundant transmission mechanism, shows Figure 3-6 that the media redundancy manager (MRM) must close both ring ports. Consequently, a closed ring results for the communication, with the property to enable redundant data transmission. Circling of IRT data packets does not occur due to the use of the MRPD protocol.

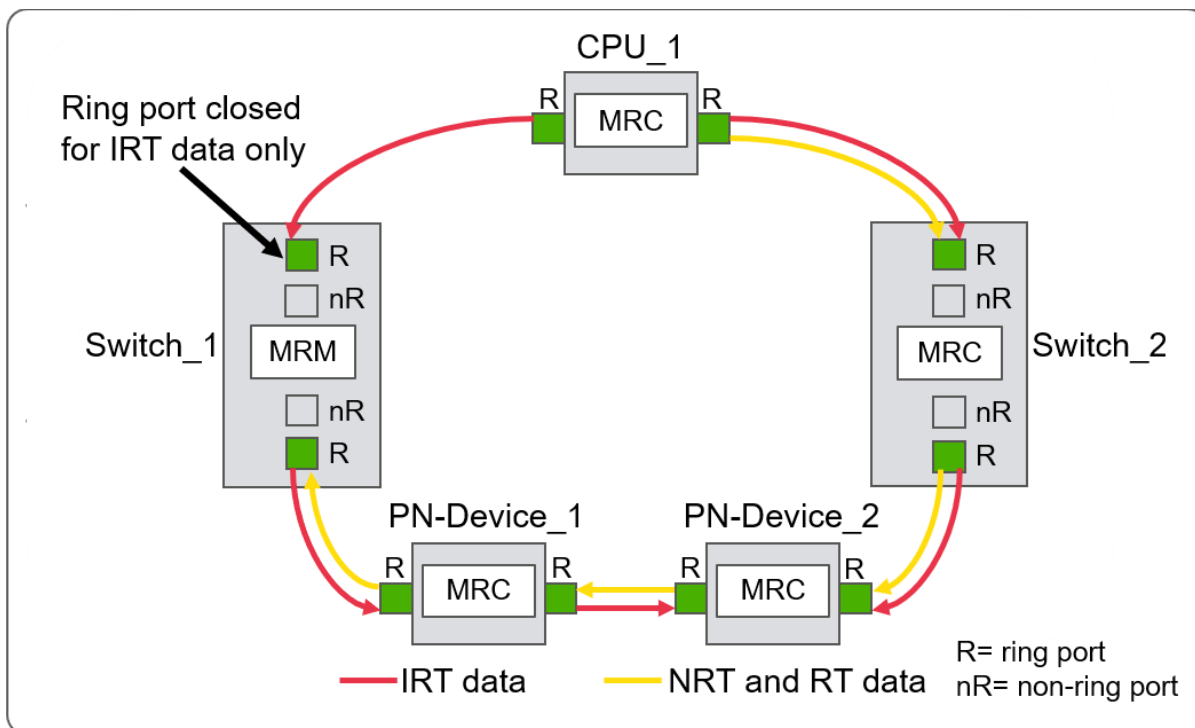


Figure 3-6: Media redundancy with MRPD

In addition to MRPD, the PROFINET devices must also support the MRP protocol, since additional data packets may be in circulation that are not compatible for MRPD. This concerns NRT (Non-Real-Time) and RT (Real-Time) data packets .

Another task of the media redundancy manager (MRM) is the monitoring of the PROFINET ring topology. By sending test frames on both sides via the configured ring ports, it can be determined whether the ring structure is in a faultless state. The functionality of the ring topology can be determined by receiving the test frames on the opposite ring ports of the MRM.



Check whether all PROFINET devices in a ring support the MRPD functionality. PROFINET devices that only fulfill the MRP function are not allowed in an MRPD ring.

When planning PROFINET ring networks, redundant ring couplings of MRPD rings must be avoided and are therefore not possible.



For more information on "Media Redundancy for Planned Duplication" (MRPD), refer to the PROFINET Media Redundancy Guideline (Order No.:7.212).

3.3 PROFINET System Redundancy

PROFINET system redundancy is standard for redundant communication between controllers and devices via the PROFINET bus system. The following configuration options exist for this:

- Configuration S1
- System redundancy S2
- System redundancy R1
- System redundancy R2

The abbreviations S or R in the preceding list define the number of PROFINET interfaces required. Accordingly, an S communication requires a single network, while an R communication requires two separate networks.

In addition, this information can be used to determine how many interface modules are required for a device. An interface module is the connection that connects the PROFINET with the internal bus of the device (see chapter 4.1.1). A system redundancy S2, for example, uses only one interface module, while a system redundancy R1 or R2 provides two interface modules.

The numbers 1 and 2 additionally describe the maximum number of application relationships (ARs) between the PROFINET nodes.



Note that system redundancy is independent of the selected topology form (ring, star, line or tree) of a PROFINET network. The selection of PROFINET devices that must be compatible with system redundancy is of much more crucial importance.

Another prerequisite for PROFINET system redundancy is the network infrastructure of PROFINET systems. These must comply with the specifications of "Conformance Class B" in order to enable the transmission of process data via PROFINET Real-Time (RT) in accordance with Conformance Class B.

3.3.1 PROFINET configuration S1

The PROFINET system connection S1 describes a simple connection of the interface module contained in the device with a controller. In order to understand the properties of an S1 communication in more detail, shows Figure 3-7 that the device with port P1a can only establish an application relationship (AR) to the controller via its PROFINET interface "IOC".

Furthermore, the data exchange of the PROFINET nodes can only take place via a communication link.

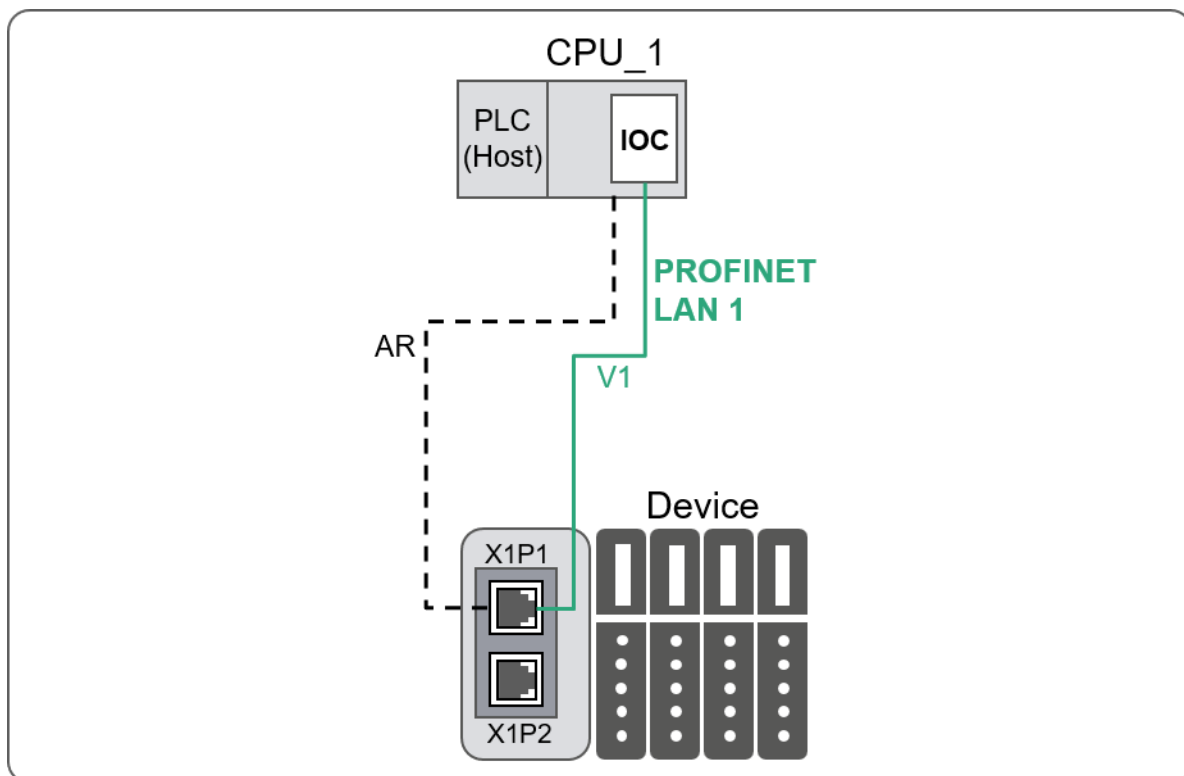


Figure 3-7: PROFINET configuration S1

An interruption of the PROFINET connection V1 would mean the loss of the application relationship "AR" for the S1 communication. The failure of the automation system could therefore no longer be avoided. Switching to another communication connection is not possible due to the non-redundant design of the device. This means that the S1 system connection does not contribute to increasing the availability of PROFINET systems and must therefore be regarded as a simple system connection.

3.3.2 PROFINET System Redundancy S2

PROFINET system redundancy S2 is the connection of a device via an interface module that establishes an application relationship (AR) to one of the two controllers of a redundant controller pair. Figure 3-8 shows that via the PROFINET connection V1 the active application relationship AR1a exists between the device via port P1a and the controller "CPU_1a", which is used for active data exchange. The backup application relationship AR1b is in a standby mode, which is only left when a failure of the application relationship AR1a is detected.

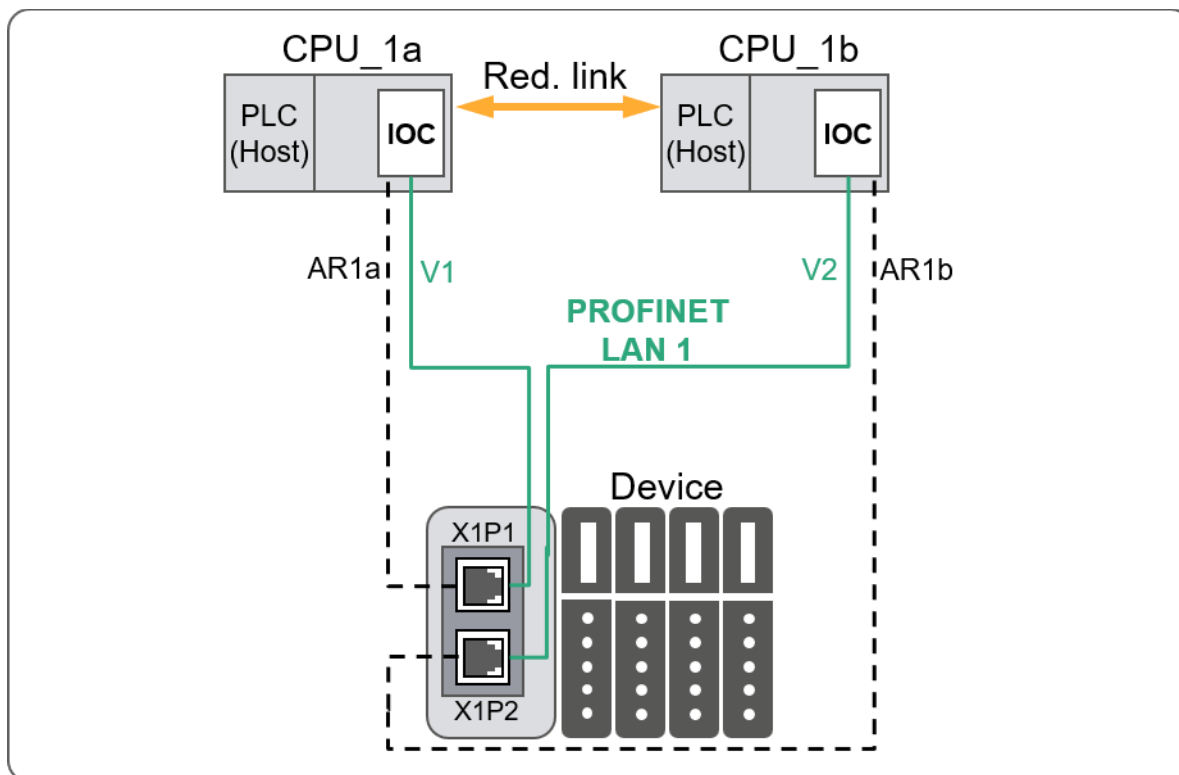


Figure 3-8: PROFINET system redundancy S2

This scenario would result if there is a failure of the "CPU_1a" or a defect of the PROFINET connection V1. This is followed by a bumpless switchover, which results in the activation of the backup controller "CPU_1b". With the help of the PROFINET connection V2 in combination with the system redundancy S2 a maintenance of the data traffic has been created, as the backup controller can now communicate with the device via the interface "IOC" using the port X1P2. The secondary communication path via the PROFINET connection V2 is used for this purpose.



Communication between controller and device does not necessarily have to take place via a specific or defined port for the PROFINET system redundancy function, as shown in Figure 3-8. The use of system redundancy S2 in a PROFINET ring structure serves as an example, see Figure 4-6 in Chapter 4.1.2. This loop architecture enables communication between controller and device via two different paths for system redundancy S2. This means that in the example of the primary controller "CPU_1a", a communication connection is supported via port X1P1 as well as via port X1P2.

Due to the parallel connection of the device, all data and diagnostic functions in the system are retained in the event of a failure of the communication links. The redundant controller design has the effect of improving the availability of a PROFINET system. A disadvantage of the system redundancy S2 is that the failure of the network cannot be compensated. In addition, a defect of the interface module in the device must be considered, which also leads to a total failure of the device.

3.3.3 PROFINET System Redundancy R1

PROFINET system redundancy R1 describes the connection of a device via **two** interface modules, each of which establishes **an** application relationship to a controller. In Figure 3-9 it can be seen that the application relationship AR1a is used for active data exchange, which describes a communication between the primary controller "CPU_1a" and the device via the PROFINET connection V1. The AR2a application relationship is used as a reserve communication connection, which can only be used as soon as the primary AR1a application relationship fails. The difference to system redundancy S2 is that the backup AR requires a second, separate PROFINET network.

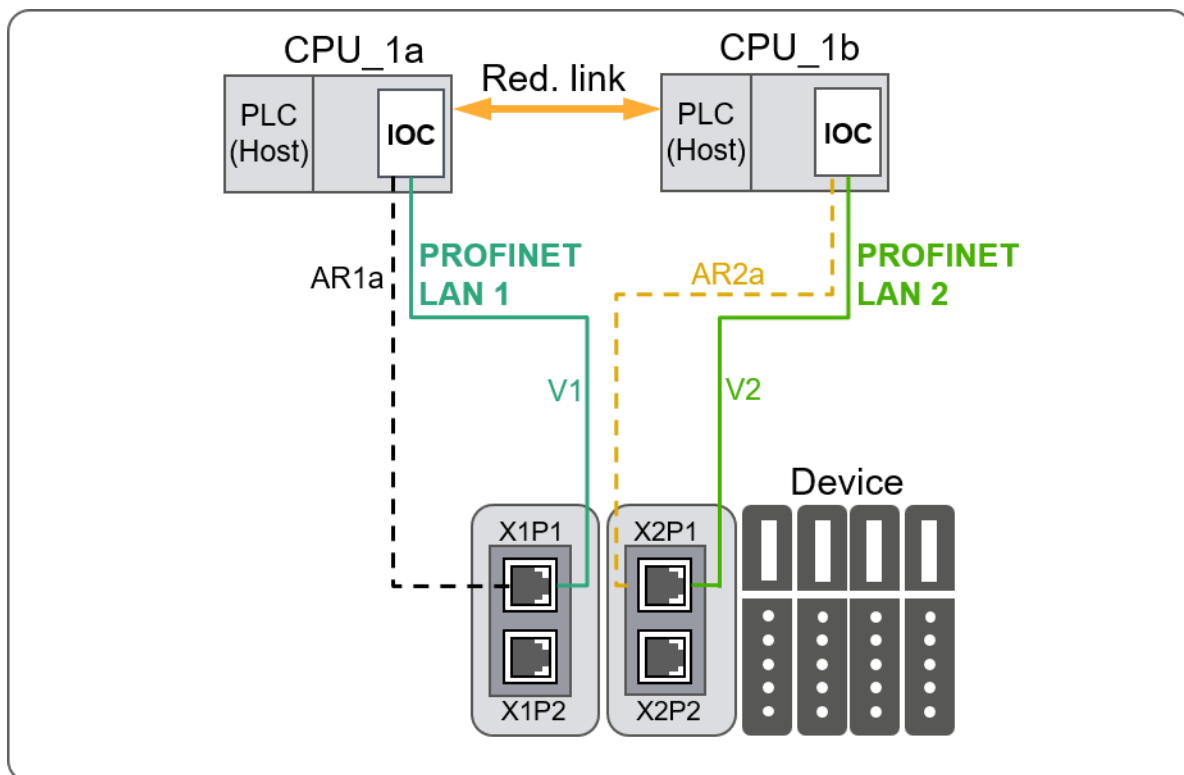


Figure 3-9: PROFINET system redundancy R1

A communication failure between "CPU_1a" and the Device leads to an uninterrupted switch-over to the controller "CPU_1b". The activation of "CPU_1b" ensures that there is still a communication connection to the Device. The data exchange of both devices takes place via

the "IOC" interface of the backup controller and the port X2P1 of the device by the PROFINET connection V2.

The failure of an interface module, one of the two networks or a communication link would not have any negative consequences on the functionality of the system. Thus, all data and diagnostic functions are still available. A significant advantage of the R1 configuration is that communication with the controllers takes place via two separate networks, which entails increased cabling effort. This leads to the doubling of the PROFINET interfaces and can continue to guarantee the functionality of the PROFINET system in the event of a failure of the primary network.

3.3.4 PROFINET system redundancy R2

PROFINET system redundancy R2 refers to the connection of the devices via **two** interface modules, each of which establishes **two** application relationships (AR) to both controllers. Figure 3-10 shows the structure of the PROFINET connections between the redundant controller unit and the device. It is striking that, compared to the system redundancies we have seen so far, the controllers each have two controller interfaces (IOC). Communication between the controller unit and the device takes place via two separate PROFINET networks. Furthermore, the device has two interface modules and thus two separate PROFINET interfaces. The communication runs in error-free operation between the primary controller CPU_1a and the Device via the PROFINET connections V1 and V3.

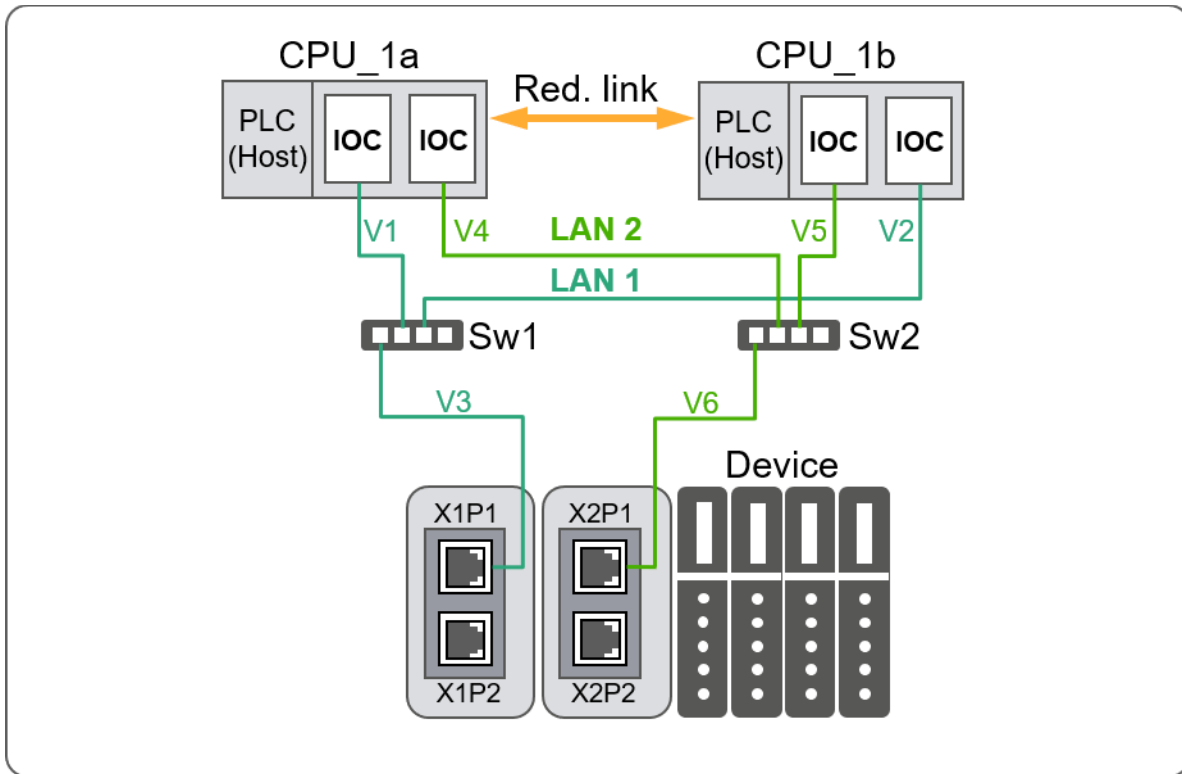


Figure 3-10: Communication connections for PROFINET system redundancy R2

In Figure 3-11 the composition of the application relationships is shown. In fault-free operation, communication takes place via the AR1a application relationship. A failure of the communication relation AR1a would result in a switchover to one of the three functional application relations (AR1b, AR2a or AR2b). Which reserve AR is used depends in the end on the failure case and on the fastest communication recovery. The total failure can be caused exclusively by the complete failure of the controller unit or by a simultaneous defect of the interface modules on the device.

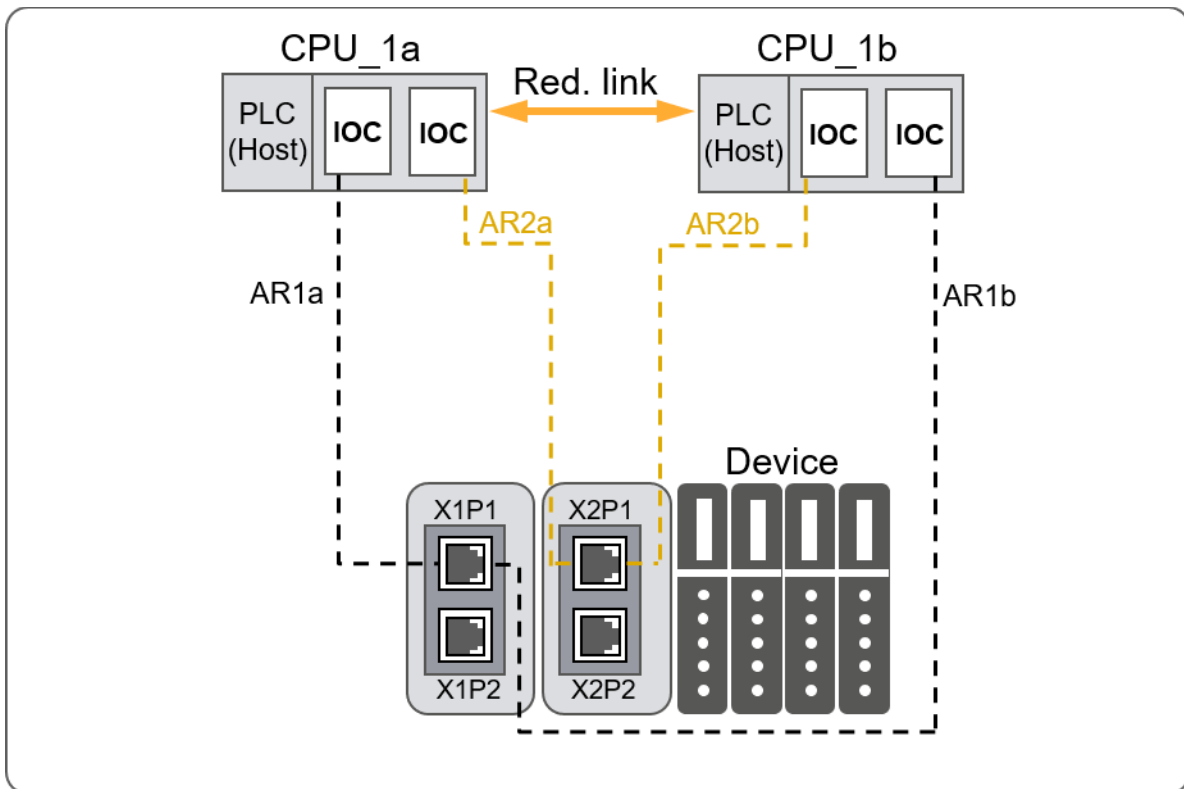


Figure 3-11: Application relationships for PROFINET system redundancy R2



For more information on PROFINET system redundancy, refer to the PROFINET High Availability Guideline (Order No.:7.122).

3.4 Comparison of PROFINET Redundancies

An overview for comparison of the described PROFINET redundancy functions shows Table 3-1.

Table 3-1: PROFINET redundancies

PROFINET redundancy		Maximum switching time	Maximum allowable system size
Media redundancy	MRP	approx. 200 ms	There are no exact numerical values for this. The max. number of PROFINET devices in a ring can vary on the part of the manufacturers. Note that exceeding the number of participants of 50 devices causes time-dependent delays.
	MRPD	Almost uninterrupted	
System redundancy	S2	Almost uninterrupted	No precise data could be extracted.
	R1		
	R2		

4 Example applications for highly available networks and systems

4.1 Technical structure of the PROFINET devices used

This chapter describes the structure of the PROFINET components considered in the following.

4.1.1 PROFINET Devices

Figure 4-1 shows the basic structure of a device that has an integrated interface module. The interface module, also called a **Network Access Point (NAP)**, is equipped with two network connections "X1P1" and "X1P2" .

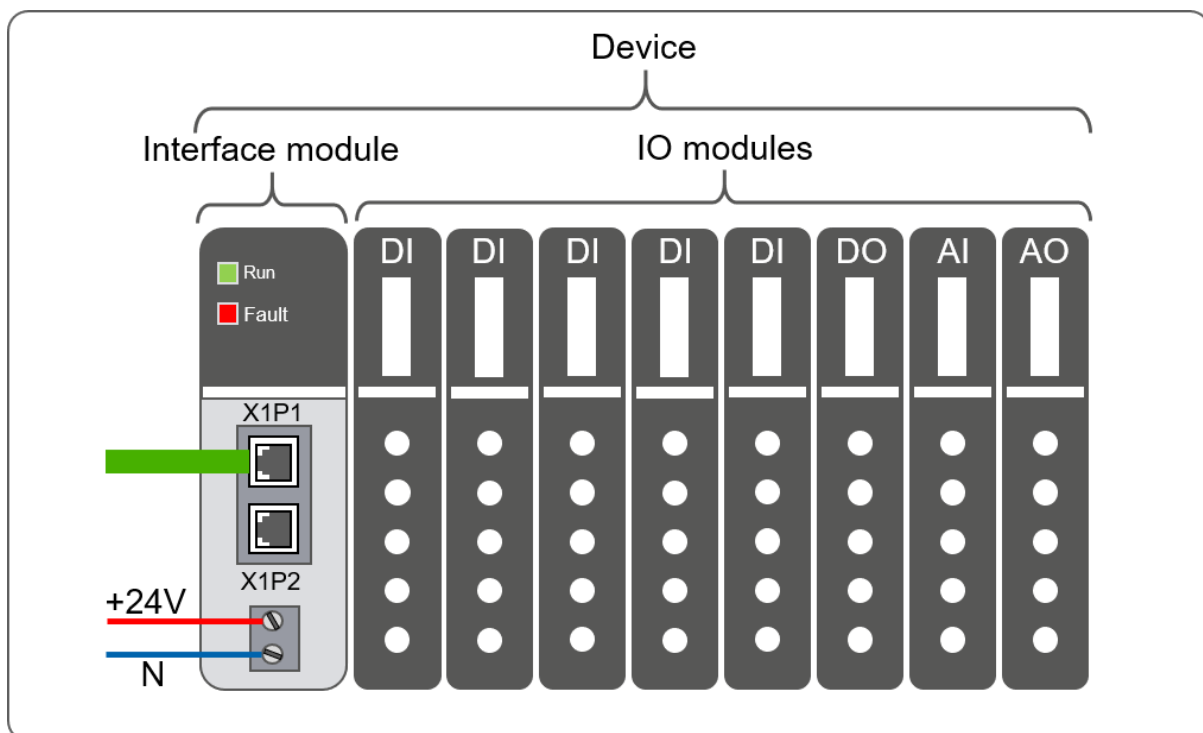


Figure 4-1: PROFINET device with simple interface module design

The use of the device from Figure 4-1 is to be integrated exclusively in singularly equipped PROFINET networks. For further consideration in this document, the device supports the configuration S1 as well as the redundancy mechanisms of the system redundancy S2 and the PROFINET media redundancy with MRP. A combination of system redundancy S2 and MRP already exists for certain devices that are used in high-availability PROFINET systems based on the example in section 4.2.1.



Note that the redundancy functions of the media and system redundancy only support certain devices. For PROFINET ring topologies with Conformance Class C requirements, the implementation of the MRPD function in the device must be taken into account.

Figure 4-2 shows the structure of a device with two integrated interface modules.

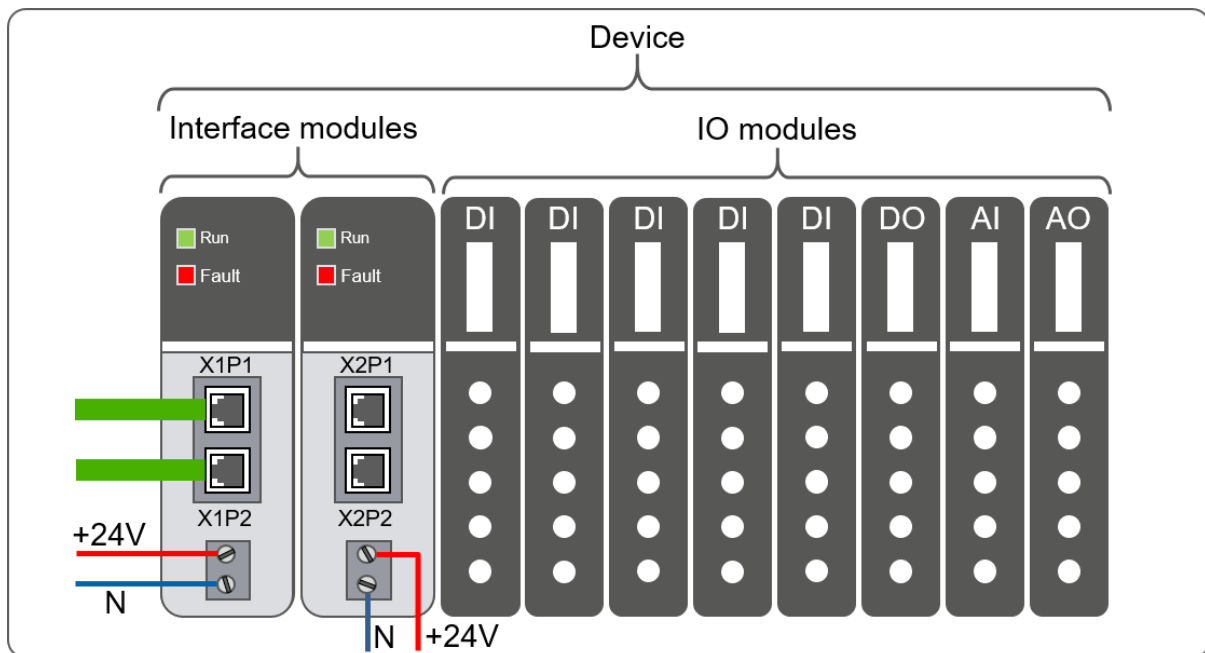


Figure 4-2: PROFINET device with redundant interface module design

This device supports the connection to two PROFINET networks. Ports X1P1 and X1P2 connect the device to the primary network, ports X2P1 and X2P2 to the secondary network. This means that NAP1 and NAP2 are to be regarded as two separate PROFINET interfaces. This device thus supports R1 and R2 redundancy.

Figure 4-3 shows the internal structure of the device. Both interface modules have an internal switch.

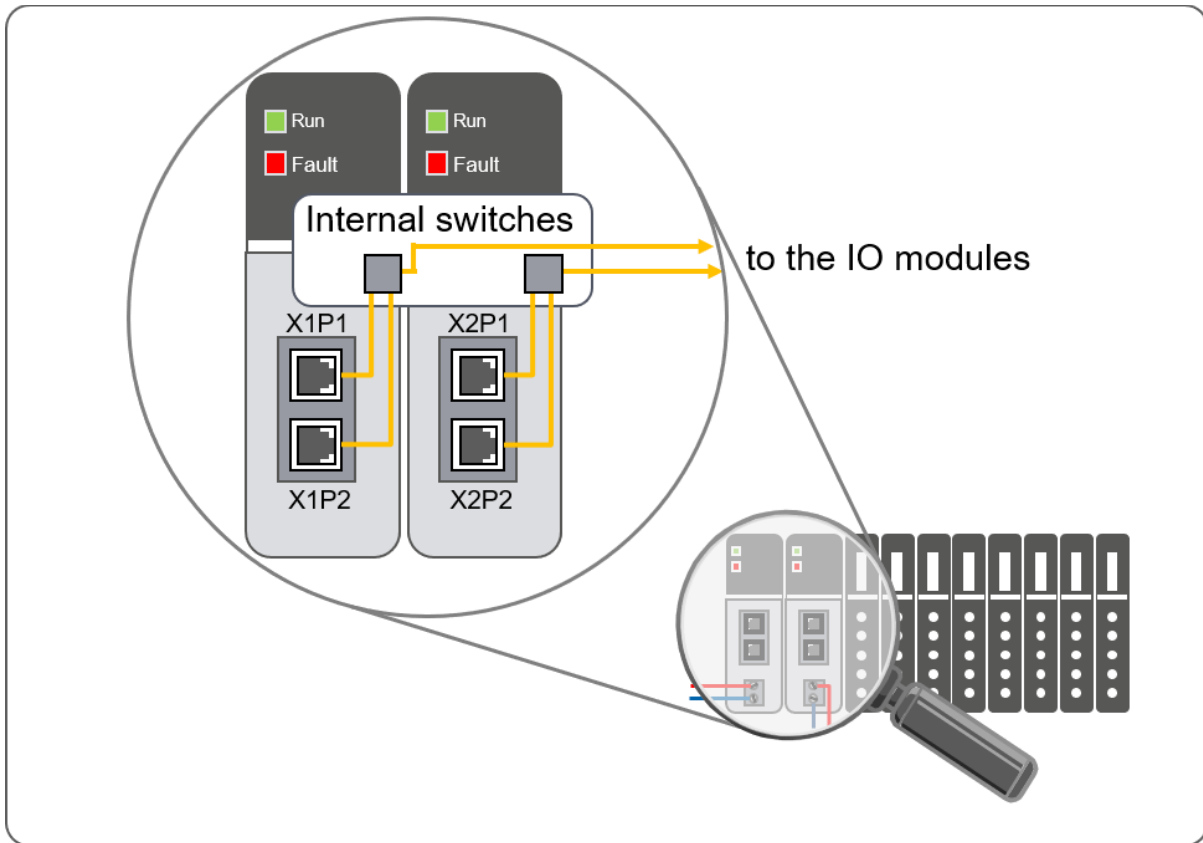


Figure 4-3: Internal wiring of a PROFINET device with redundant interface module

4.1.2 PROFINET Controller

In principle, simple controllers are not suitable for communication in high-availability PROFINET networks. Due to a lack of functions, simple PROFINET controllers do not meet the requirements of highly available systems. Some manufacturers of the PROFIBUS user organization therefore offer special controller models that enable these devices to be used in high-availability PROFINET networks. Considering the technical composition Figure 4-4 as an example shows a highly available PROFINET controller consisting of two power supplies and one CPU.

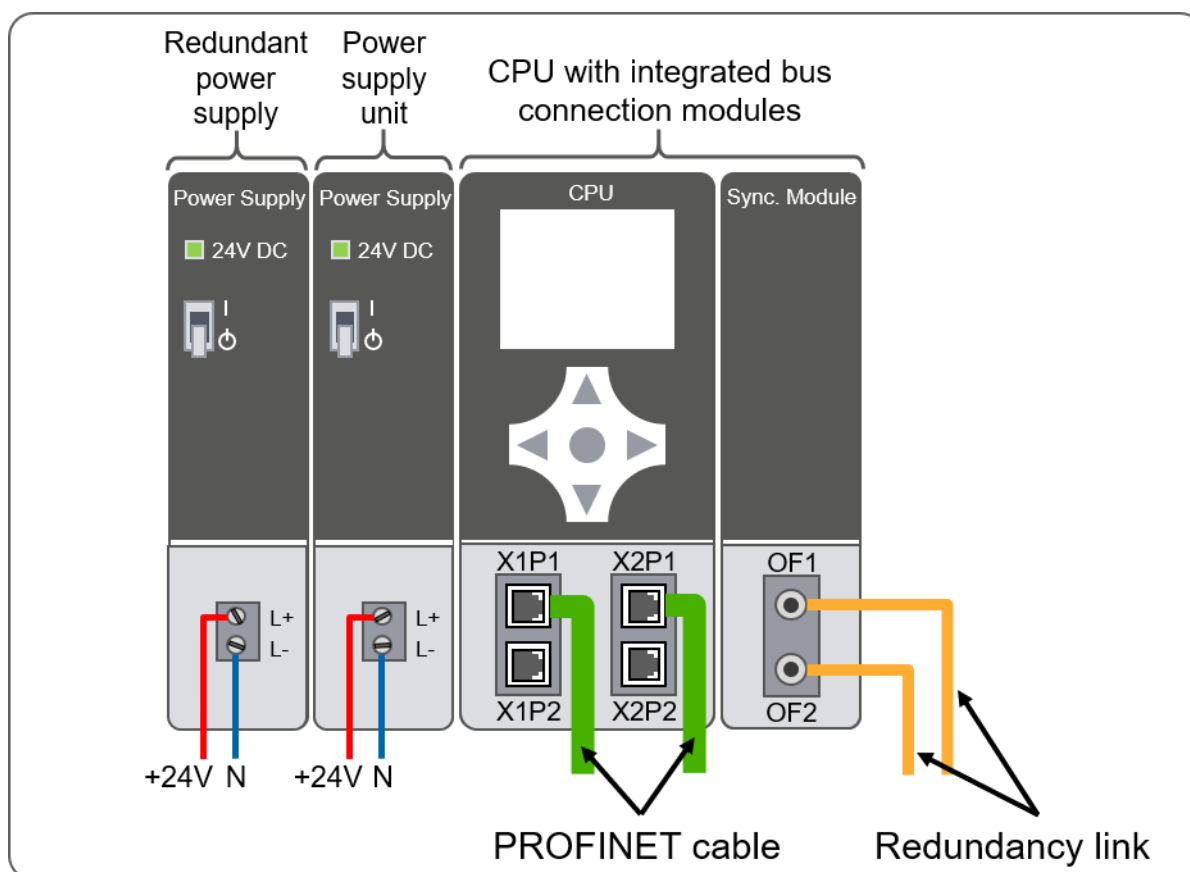


Figure 4-4: PROFINET controller

Power supply redundancy:

To optimize the reliability of PROFINET controllers, shows Figure 4-4 a redundant power supply design. Based on this form of redundancy, a defective power supply unit has no effect on a PROFINET system. The redundantly operated power supply unit ensures that the power supply is maintained and remains in standby mode during fault-free operation. As soon as the primary configured power supply unit signals a failure, an automatic switchover to the redundant power supply unit takes place. There are also concepts in which the control system is supplied 50% from each of the two power supply units. In the event of a fault, one of the two

power supplies then takes over the overall supply. This procedure leads to a higher *MTTF* of the power supply units, since they are only 50% loaded during normal operation.

High availability CPU

Controller models with the equipped functionality of high availability are characterized by a functionally extended CPU. Fast switching behavior and early error detection are important features for maintaining PROFINET data traffic. Compared to simple CPU modules, high availability CPUs have the following features:

- Redundant number of port connections for communication via PROFINET
- Integrated redundancy function/s
- To use PROFINET system redundancy: Two installed synchronization modules (model-dependent).

A closer look at the PROFINET connections shows the dual design of the Network Access Point (NAP). Divided into NAP1 for X1P1 and X1P2, the additional NAP2 (X2P1 and X2P2) results in a total of four access points for PROFINET communication.

The bus connection module of the CPU is characterized by redundant synchronization modules. Marked by the connection designations OF1a and OF1b the synchronization modules serve for the coupling with a second CPU system for the PROFINET system redundancy. In this example, this type of connection is based on an optical fiber connection, which is referred to as a redundancy link in the context of PROFINET system redundancy. The use of the fiber optic connections is reserved exclusively for synchronization between the active (primary) CPU and the reserve (backup) CPU and is therefore **not** used as a communication medium for data exchange via PROFINET. An overview to this installation instruction shows Figure 4-5.

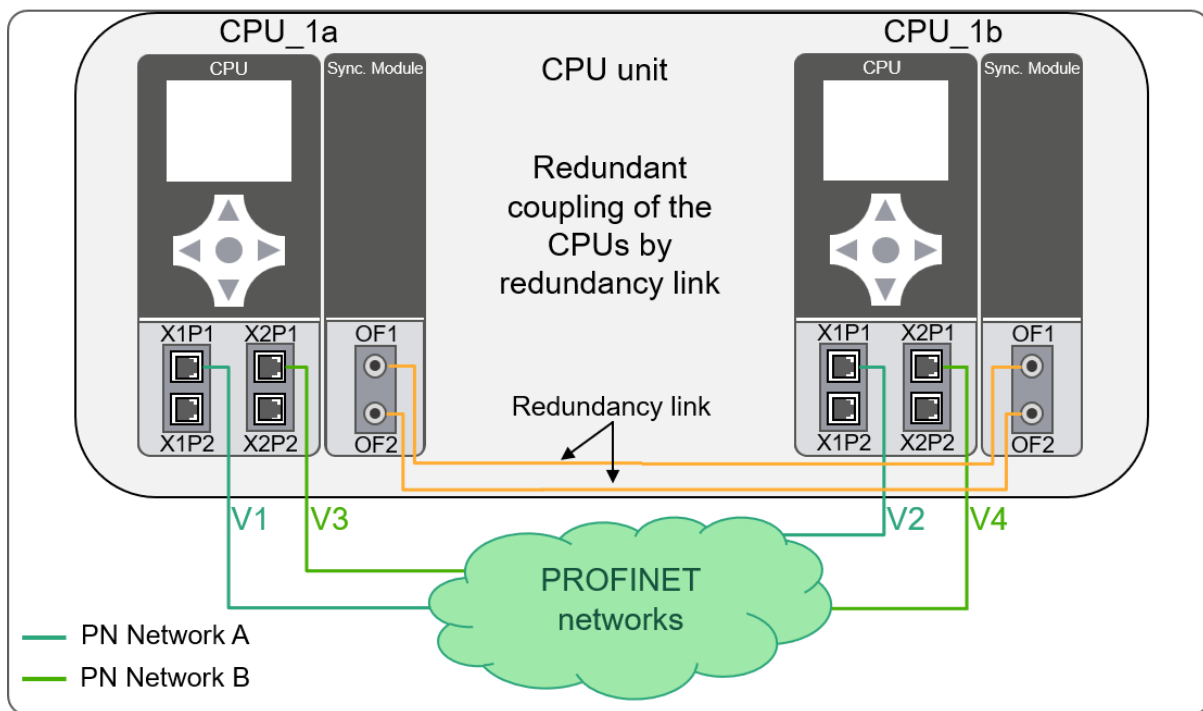


Figure 4-5: Redundancy coupling of CPUs via fiber optic cable for PROFINET system redundancy



Note that both PROFINET controllers perform an automatic synchronization on their own in case of an error.

For the installation of the redundancy link, ready-made cable lengths with a size range between 1 m and 10 km are possible. The selection of cable lengths offered varies between manufacturers.

Another variant of redundant PROFINET controllers shows Figure 4-6. With regard to controller synchronization for PROFINET system redundancy, no fiber optic connections are provided for redundancy coupling. Instead, the synchronization for the controller system is done via the PROFINET connection V3, which additionally supports data exchange via PROFINET. Note that not all companies offer this type of controller connection for synchronization. CPU systems with the extended functionality of the system redundancy S2 support this synchronization variant so far.

The installation of redundant controllers in PROFINET ring structures requires the media redundancy function. Both controllers must be compatible with the MRP ring redundancy protocol. In addition, a minimum number of two ports must be considered. An overview is provided by Figure 4-6.

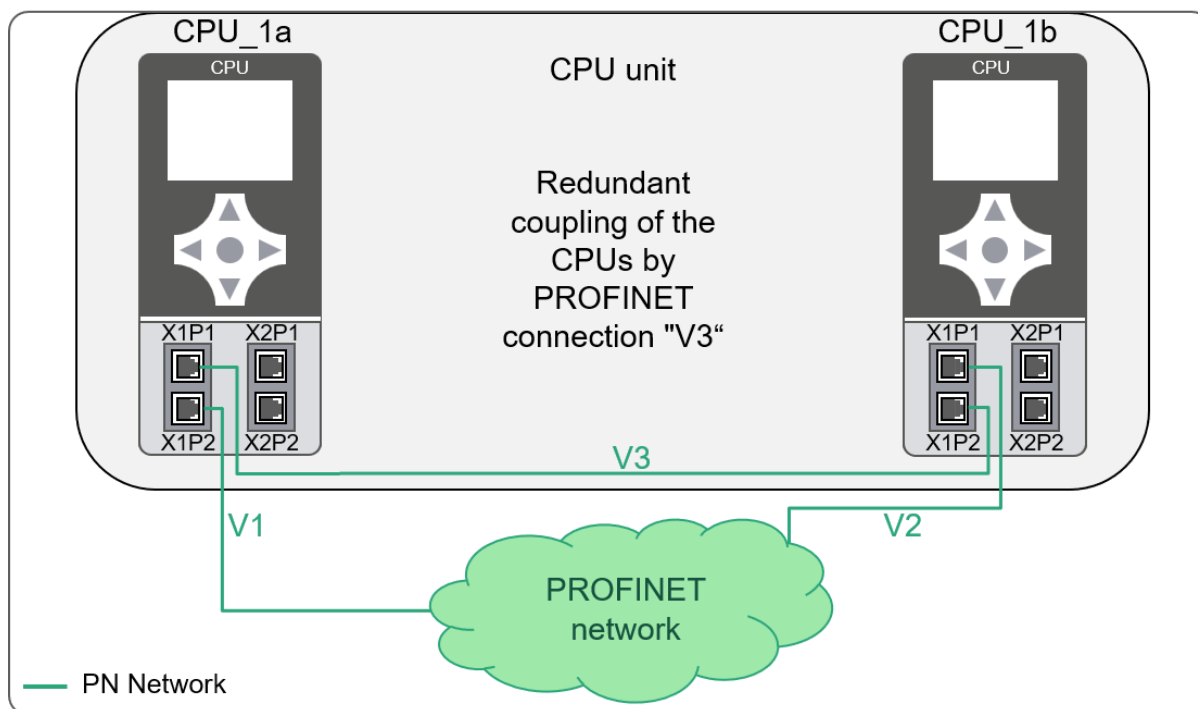


Figure 4-6: Redundancy coupling of the CPUs via PROFINET cable for PROFINET system redundancy S2

Certain manufacturers also provide a combined variant of the redundancy protocols. This means that the media redundancy and system redundancy S2 are included together in both controllers and thus ensure higher fault security with this variant.



The length of the PROFINET connection "V3" is limited to max. 100m to meet the requirements for redundancy coupling. This specification corresponds to the max. permitted transmission length for the use of PROFINET copper cables.

System redundancy S2 uses bumpless switching, while media redundancy with MRP has a switching time (reconfiguration time) of 200 ms.

4.2 Example applications for PROFINET

For PROFINET, five different topologies are presented in the following section, which uses the application examples to help in the planning process for PROFINET systems with increased availability requirements.

4.2.1 Example application 1: Tunnel System

Figure 4-7 describes the use case of a tunnel system for car traffic. Due to the high safety and availability requirements for tunnel systems, the use of the PROFINET ring topology has proven itself. The setup in this diagram has one controller (CPU) and three devices. The peripheral devices are distributed in three separate sections, each equipped with its own control cabinet.

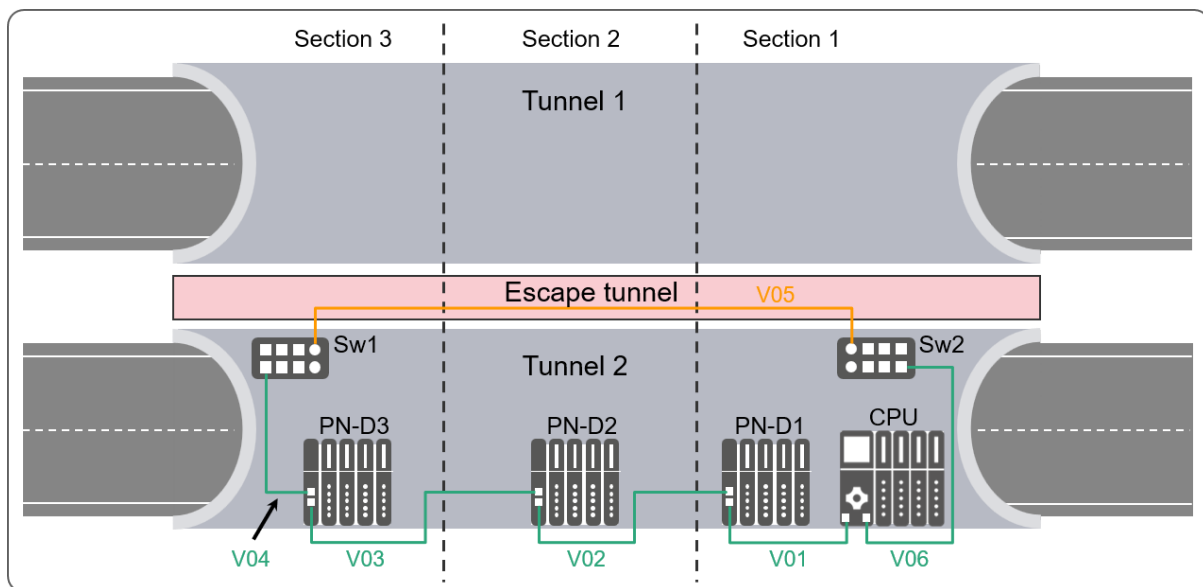


Figure 4-7: Tunnel system

Advantages:

- The redundant ring structure of the PROFINET system ensures the function of media redundancy with the correspondingly required components.
- Using a ring topology is a cost-effective option for increasing the availability of a PROFINET system.
- The additional cabling effort is kept within limits compared to simple line topologies.
- By using the Media Redundancy Protocol (MRP), an automatic switchover to an alternative communication path takes place in the event of an error. All PROFINET nodes can then still be reached.
- The failure of a device does not result in a total failure of the PROFINET system.

Requirements and limitations:

- Based on the simple design of the controller, this PROFINET system meets the criteria of configuration S1.
- The use of the ring topology results in a higher configuration and administration effort. By using the redundancy protocol MRP, PROFINET provides further functions to prevent interruption of the ring connection, such as error detection and ring recovery.
- For PROFINET ring networks the selection of the Media Redundancy Manager (MRM) is required. Two external switches (Sw1 and Sw2) are available in this PROFINET system, which are relevant for assigning the MRM function. Alternatively, it is possible to set the choice of the ring manager to the controller. Some member companies of the PNO offer MRM capable controllers for this case.
- All devices must support the Media Redundancy Client (MRC) function. As soon as a field device does not include this feature, PROFINET does not guarantee media redundancy functionality.
- The PROFINET connection "V04" is routed via a separate route (separate fire section). Note that the routing of the return path must take place outside the tunnel, e.g. in the escape tunnel or in the opposite tube.
- The interconnection of several network nodes to form a ring topology is limited to 50 devices in order to be able to comply with a reconfiguration time of 200 ms. The number of devices can be lower if necessary. Please refer to the manufacturer's specifications in this regard.

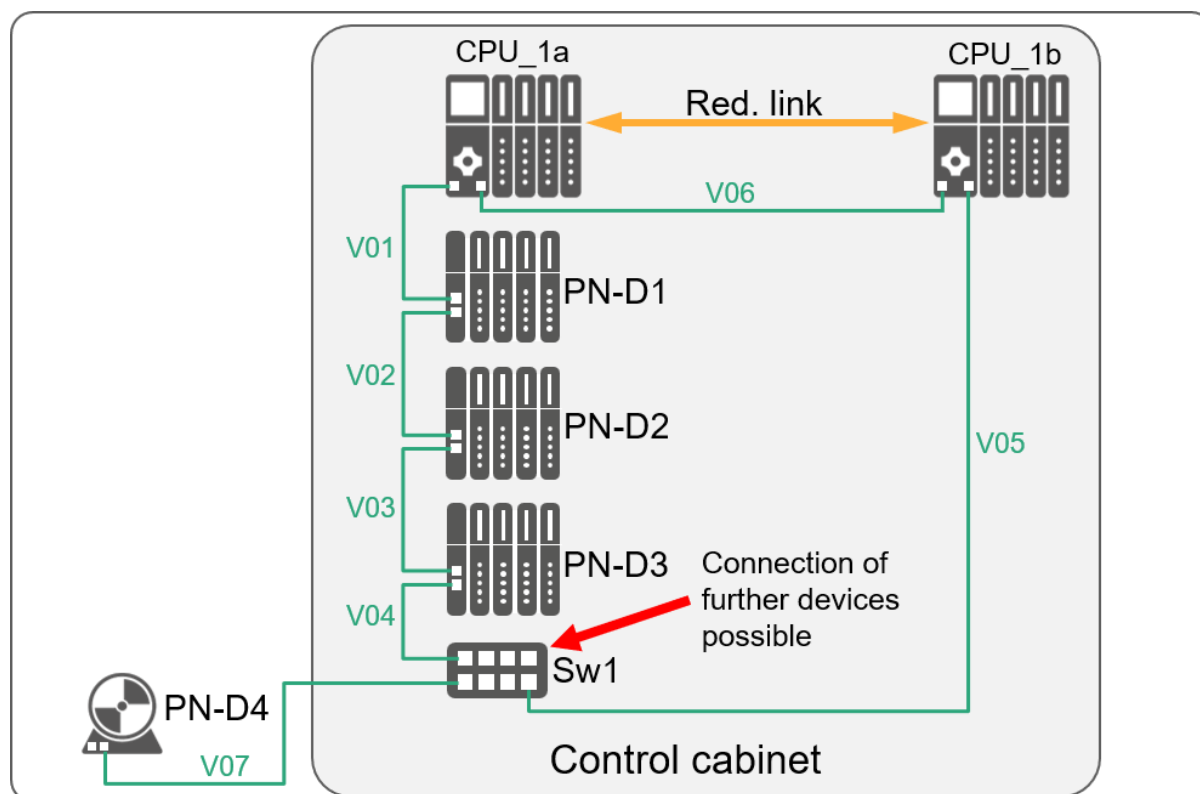
Disadvantages:

- The PROFINET system can only be expanded if at least two Ethernet ports are available for a PROFINET device. For the connection of additional components, such as an HMI panel, an external switch must also be considered.
- A critical point of this plant is the use of a single PROFINET controller. A failure of the controller would result in a system shutdown. A network failure must be considered equally.

This page is intentionally left empty

4.2.2 Example application 2: Manufacturing industry plant

In Figure 4-8 the structure of a PROFINET ring topology in combination with system redundancy S2 is shown. Depending on the selected synchronization method, two solution approaches result for seamless controller-to-controller communication, which can be operated under PROFINET both via the "V06" link and via the redundancy link (see chapter 4.1.2). Furthermore, this system offers additional expansion options for connecting further field devices by using switch "Sw1", which are limited on the basis of a simple line topology.



© 2023

Figure 4-8: Plant manufacturing industry

Advantages:

- The redundant ring structure of the PROFINET system ensures the function of media redundancy with the correspondingly required components.
- Media redundancy management can be performed by the Sw1 switch. For optimized purposes, the switch should be able to support the MRM tasks.
- The failure of a PROFINET node or network path can be compensated by using the Media Redundancy Protocol (MRP). The switchover to an alternative network path is performed automatically. The switchover is implemented by the configured MRM. All PROFINET devices can still be reached afterwards.

- The controller redundancy fulfills the requirements for the function of the system redundancy S2. A failure of the controller "CPU_1a" leads to an almost uninterrupted switch-over to "CPU_1b".
- The integration of further network components can be realized under consideration of the prerequisites.

Requirements and limitations:

- The role distribution of the PROFINET nodes require a higher configuration and management effort when integrating the PROFINET media redundancy. Provided that the managed Ethernet switch "SW1" does not fulfill the task of the MRM for technical reasons, the choice of the ring manager must be set to one of the redundant PROFINET controllers. Make sure that the controller supports the function of the MRP manager. Further participants of the PROFINET ring are to be defined as MRC.
- When setting the ring port, ensure the correct port assignment during project planning. An incorrect port selection leads to a non-functional PROFINET network.
- The laying of the return path to close the ring structure by the cable connection "V05" is carried out on a separate route.
- The failure of a device would not have any negative consequences with regard to the accessibility of other network nodes. All functioning devices are not prevented from exchanging data.

Disadvantages:

- A replacement or failure of the switch Sw1 leads in the worst case to a communication interruption of PN-D4.
- This PROFINET system has a singular network. Therefore, in the event of a network failure, a communication interruption of the PROFINET nodes must be considered.

4.2.3 Example application 3: Process Industry Plant without increased availability requirements

The topology structure from Figure 4-9 describes the composition of a non-redundant PROFINET network consisting of one controller, two switches and six devices. A combination of star and line topology defines the tree architecture frequently named in the literature. The switches and devices are arranged in the control cabinets, which are interconnected via a star connection. The "V01" and "V02" connections enable the "Sw1" and "Sw2" switches to be connected to the controller in the form of a line topology.

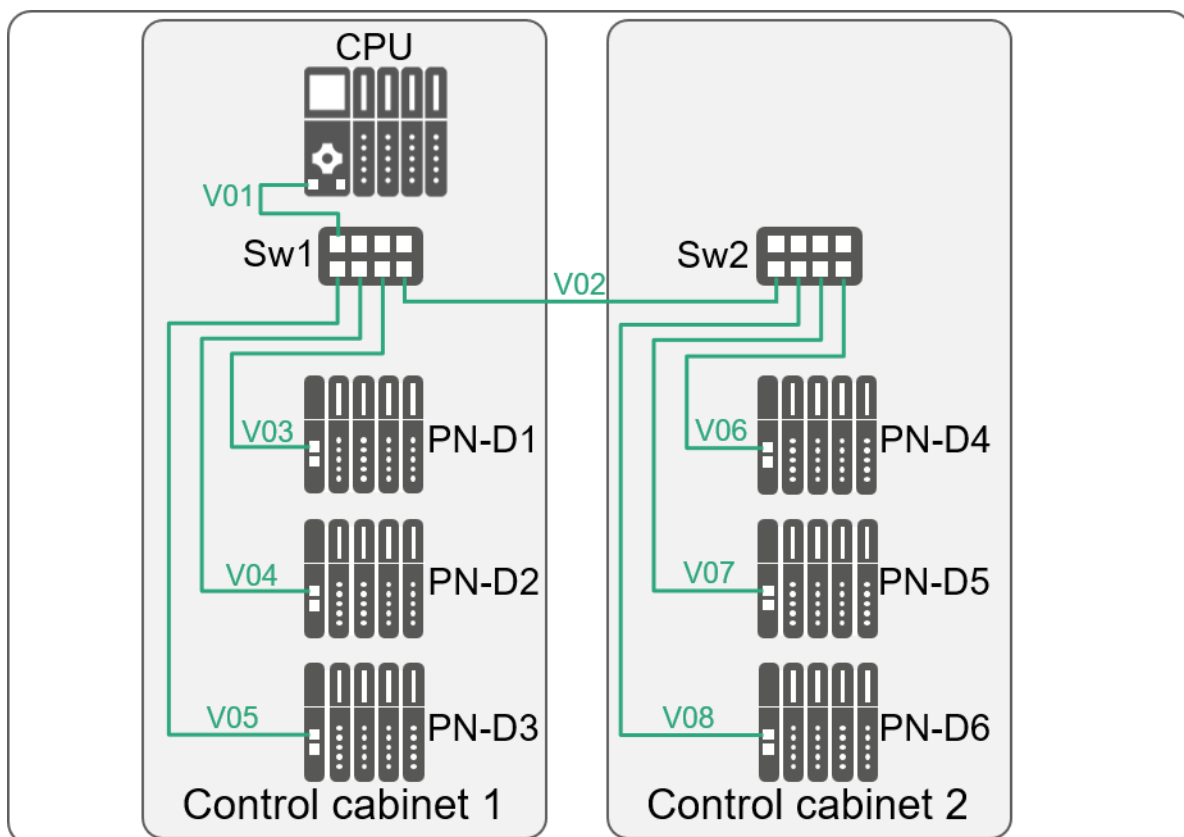


Figure 4-9: Plant Process industry without increased availability requirements

Advantages:

- The combination of star and line topologies does not have a redundant network structure. Therefore, the use of a redundancy protocol is not to be considered.
- Tree topologies, especially in the area of the star structure, enable the uncomplicated exchange of field devices without affecting the active operation of the other devices.
- The non-redundant network structure results in minimal configuration and administration effort.
- To avoid delay times during data transmission, this setup is suitable for connecting several field devices.

Requirements and limitations:

- This PROFINET system meets the criteria of system connection S1 on the basis of the simple controller design.
- In the event of a switch error, the data traffic between the controller and the device is likely to be affected.

Disadvantages:

- Due to a non-redundant network structure, fail-over functionality is not provided for this PROFINET plant. The use of individual PROFINET lines and a non-redundant configuration of PROFINET components can lead to a partial or total failure of a production plant in the event of a fault. The complete failure of this topology is due to the following mechanisms:
 - Defect of CPU and/or "Sw1
 - Network failure
 - Cut PROFINET line of the "V01" connection
- A cable break of the connection "V02" or a defect of the switch "Sw2" lead to a partial failure of the communication between the controller and the connected field devices in the control cabinet 2.

4.2.4 Example application 4: Process Industry Plant with increased availability requirements

Figure 4-10 shows the structure of a PROFINET system with the specification for system redundancy R1. A key feature of this topology is the ring-free network architecture, which eliminates the use of media redundancy. All PROFINET nodes are interconnected by line topology via a redundant network.

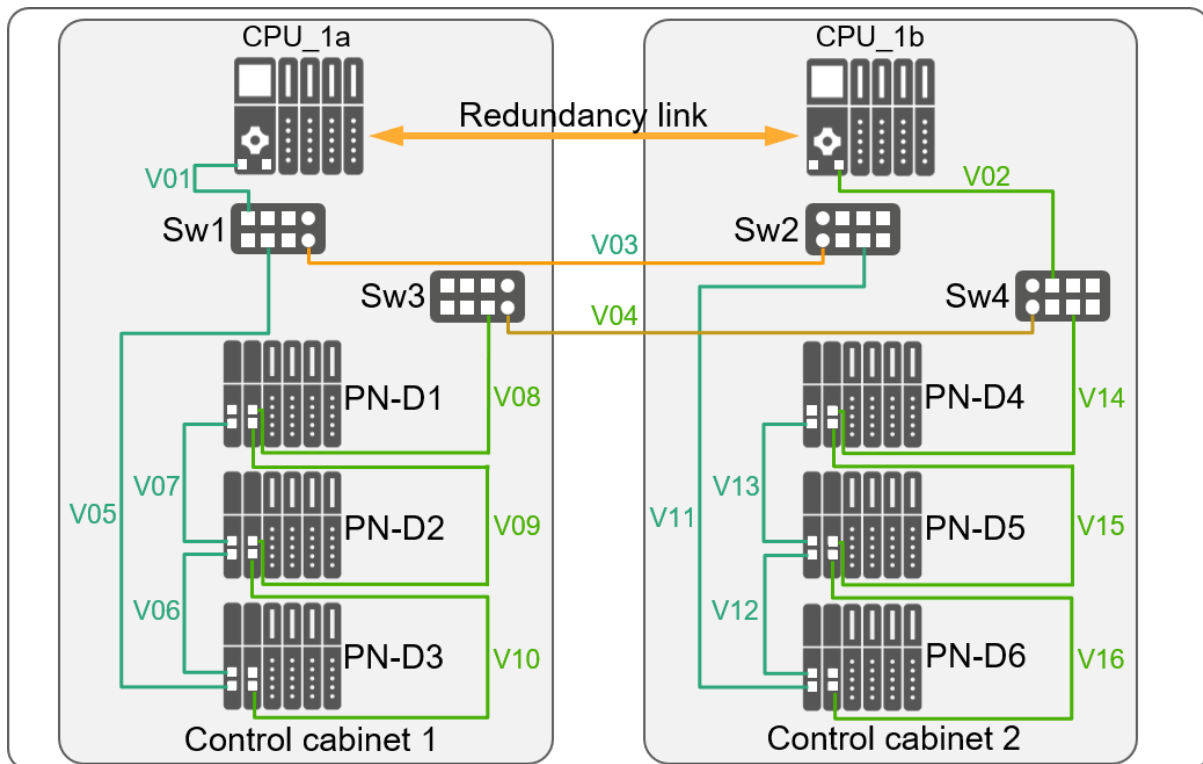


Figure 4-10: Plant Process industry with increased availability requirements

Advantages:

- The controller redundancy fulfills the requirements for the function of the system redundancy R1. A failure of the controller "CPU_1a" and /or switch "Sw1" leads to a switch-over to "CPU_1b".
- The use of a ring redundancy protocol, such as MRP, is not necessary, due to the ring-free network structure.

Requirements and limitations:

- All devices require 4 Ethernet ports with two separate PROFINET interfaces.
- The maximum line depth is between the PROFINET nodes. to be considered. Each switch leads to a delay of the data transmission.
- All network nodes are connected via a line topology. The transmission of the data frames between the PROFINET devices may cause delays due to the setup in case of high network loads.
- No ring topologies considered, therefore the use of media redundancy is not possible.

Disadvantages:

- A cable break of the connection V03 and/or V04 between control cabinet 1 and control cabinet 2 leads to a decreased availability of the plant.

4.2.5 Example application 5: Process industry plant with Advanced Physical Layer (APL)

The following system example in Figure 4-11 shows the network structure of a PROFINET ring topology in combination with system redundancy S2. Another feature of this plant is the use of Ethernet-APL, which enables a direct connection of Ethernet-APL sensors with PROFINET.

Ethernet-APL uses a two-wire cable to connect sensors and actuators to PROFINET, which are marked by blue spurs (connections V5 to V16) in the example in Figure 4-11. The connection provides a data rate of 10 Mbit/s and delivers data and power to the field devices. For more information, refer to the Ethernet-APL Engineering Guideline [APL2022].

In this example, the APL field switches, which are placed in the area with potentially explosive atmosphere (zone 2), serve as the central interface between the Industrial Ethernet network (100 Mbit/s) and Ethernet-APL (10 Mbit/s). The spurs (V5 to V16) connect the APL field switches to the APL field devices installed in zone 1 via a star topology.

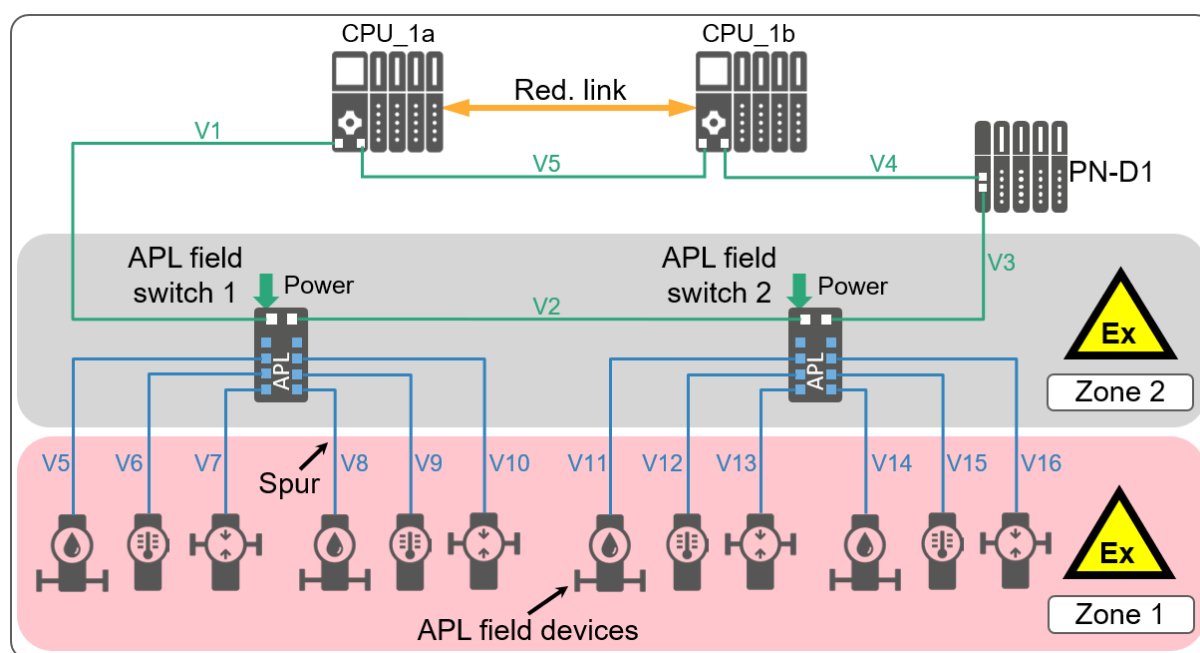


Figure 4-11: Process industry plant with advanced physical layer

Advantages:

- The PROFINET ring structure ensures the function of media redundancy with the correspondingly required components.
- Using a ring topology is a cost-effective option for increasing the availability of a PROFINET system.

- The failure of a PROFINET node or network path can be compensated by using the Media Redundancy Protocol (MRP). The switchover to an alternative network path is performed automatically. The switchover is implemented by the configured MRM. All PROFINET devices can still be reached afterwards.
- The controller redundancy fulfills the requirements for the function of the system redundancy S2. A failure of the controller "CPU_1a" leads to an almost uninterrupted switch-over to "CPU_1b".

Requirements and limitations:

- The role distribution of the PROFINET nodes require a higher configuration and management effort when integrating the PROFINET media redundancy.
- If the APL field switches do not fulfill the function of the MRM for technical reasons, the choice of the ring manager must be specified to one of the redundant PROFINET controllers. Make sure that the controller supports the task of the MRP manager. Further nodes in the PROFINET ring are to be defined as MRC.
- When setting the ring port, ensure the correct port assignment during project planning. An incorrect port selection leads to a non-functional PROFINET network.
- In the event of technically induced faults and interruptions, S2 system redundancy enables faster switchover compared to media redundancy with MRP. Therefore, the reconfiguration time for S2 redundancy in the event of a fault is much shorter, which cannot be achieved from the point of view of media redundancy (MRP) with 200ms.
- APL field switches allow only a point-to-point connection between the APL field switches and the APL field devices.
- Depending on the selected cable category, the maximum cable length of the spur connections is $\leq 200\text{m}$.
- The connection between the APL field switch and the APL field devices may only be made via the designated spur ports. The data rate for Ethernet-APL in this area is 10 Mbit/s.
- Note that the installation location of APL field devices and APL field switches depends on the classification of the Ex zone and other environmental conditions. Further notes may be found in the Ethernet-APL Engineering Guideline [APL2022].

Disadvantages:

- A defect of the APL field switches leads to a total communication failure of the connected APL field devices.
- A total network failure causes a complete interruption of the PROFINET communication.



An Ethernet-APL topology with a powered APL trunk [APL2022] is not considered here, as APL trunk redundancy is not specified yet.

5 Summary

Summary

This guideline describes the various options for planning high-availability networks for manufacturing and process automation. To simplify understanding, however, not all possible combinations were considered in full. The aim was rather to provide a simple introduction to the topic and to familiarize the reader with the most important redundancy concepts.

Readers seeking a deeper dive into the topic can refer to the [PNH2020] and [PNM2018] documents for more in-depth coverage.

6 Index

Advanced Physical Layer.....	62	<i>MTTR</i>	21
APL.....	62	Power supply redundancy.....	49
APL field device.....	16	Process Industry Plant.....	58, 60
Availability <i>V</i>	22	PROFINET configuration S1.....	37
Comparison of PROFINET Redundancies.....	44	PROFINET Controller.....	49
Configuration S1.....	37	PROFINET Devices.....	46
Controller.....	15	PROFINET Media Redundancy.....	28
Device.....	15	PROFINET Star Topology.....	26
Ethernet-APL.....	12	PROFINET System Redundancy.....	37
Ethernet-APL field switch.....	16	PROFINET System Redundancy R1.....	40
High availability CPU.....	50	PROFINET system redundancy R2.....	41
High Availability Guideline for PROFINET.....	12	PROFINET System Redundancy S2.....	38
Introduction to PROFINET-redundancy.....	25	PROFINET Tree Topology.....	26
Manufacturing industry plant.....	56	Referenced PNO documents.....	12
Mean repair time.....	21	Standards.....	12
Mean Time Between Failures (<i>MTBF</i>).....	22	Switch.....	15
Mean Time to Failure (<i>MTTF</i>).....	21	Symbol explanations.....	14
Mean Time to Recover (<i>MTTR</i>).....	21	system redundancy R1.....	37
Media Redundancy Guideline.....	12	system redundancy R2.....	37
Media Redundancy Protocol (MRP).....	30	system redundancy S2.....	37
Media redundancy with MRPD.....	33	Telcordia SR-332.....	12
MIL-HDBK-217.....	12	Tunnel System.....	53
<i>MTBF</i>	22	VDI/VDE 2183.....	12
<i>MTTF</i>	21		

© Copyright by:

PROFIBUS User Organization e. V. (PNO)
PROFIBUS & PROFINET International (PI)
Haid-und-Neu-Str. 7 • 76131 Karlsruhe • Germany
Phone +49 721 986197 0 • Fax +49 721 986197 11
E-mail info@profibus.com
www.profibus.com • www.profinet.com