

***PROFIBUS***  
***Design Guideline***

***Guideline***  
***for PROFIBUS***

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Publisher:  
PROFIBUS Nutzerorganisation e.V.  
Haid-und-Neu-Str. 7  
76131 Karlsruhe  
Germany  
Phone : +49 721 / 96 58 590  
Fax: +49 721 / 96 58 589  
E-mail: [info@profibus.com](mailto:info@profibus.com)  
Web site: [www.profibus.com](http://www.profibus.com)

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## Revision log

Version	Date	Changes/history
1.0	Aug. 17, 2009	Initial release of final version
1.0.1		Discarded version
1.0.2	Feb. 25, 2013	PROFIBUS PA adaptations by Marketing workgroup, 1m rule, distances between cables, PROFIBUS DP spurs
1.0.3 to 1.0.7	Aug. 12, 2014	Internal versions, not published
1.0.8	Aug. 21, 2014	Review version for PROFIBUS PA Marketing workgroup
1.0.9	Oct. 31, 2014	Internal version, not published
1.0.10	Nov. 3, 2014	Review version
1.11	Nov. 21, 2014	Reviewed by head of workgroup. Changed revision index to double-digit number.
1.12	Feb. 02, 2015	Integration of changes from the German Version and translation of the new parts
1.13	May, 13, 2015	Release Version
1.14 to 1.26	March 26, 2019	Internal Version, not published, Layout changes made, chapter "PROFIBUS design guideline" added, in chapter 3.3.1 the tables for minimum cabling distances have been added, new template inserted (cover page), symbols changed, chapter PI-documents (1.3) and referenced standards (1.4) updated, information on the supplement has been removed
1.27	Sept 17, 2019	Final Review prior to release. Chapter Grounding and Energy supply removed. Hint to separate Guideline. References to standards updated. Error corrections. Disclaimer about cable distances added.
1.28	June 20, 2020	Cable distances in chapter 3.3.1 updated. Earthing of cable shield PROFIBUS PA removed. Earthing rail removed at cabinet entry.
1.29		Document cleaned up. Review comments removed. Figure 3-32 added. Liability exclusion updated.

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# 1 Introduction

### 1.1 Preface

The aim of this PROFIBUS Design Guideline is to support engineers who have to design PROFIBUS plants in a professional manner. Moreover, it is intended to simplify the design process of a plant in a step-by-step manner and to serve as an orientation guide.

The information is presented as short and as easy to understand as possible. It is nevertheless assumed that the reader has basic knowledge of PROFIBUS technology and electrical engineering.

This guideline is not intended to be a PROFIBUS compendium. If you should need more detailed information about PROFIBUS, please use the appropriate documents published by PROFIBUS Nutzerorganisation e.V. or comparable technical literature. This PROFIBUS Design Guideline does not deal with PROFIBUS installation or implementation. Please refer to the PROFIBUS Installation Guideline for details of this subject (Order No.: 8.021).

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### 1.3 PI documents

#### **PROFIBUS Interconnection Technology (2007-01)**

Order No.: 2.142, Version 1.4 - PROFIBUS Guideline

#### **PROFIsafe – Environmental Requirements (2015-12)**

Order No.: 2.232, Version 2.6 - PROFIBUS Guideline

#### **PROFIBUS RS 485-IS User and Installation Guideline (2003-06)**

Order No.: 2.262, Version 1.1 - PROFIBUS Guideline

#### **PROFIBUS Assembling Guideline (2020-09)**

Order No.: 8.022, Version 1.47 – Guideline for PROFIBUS

#### **PROFIBUS Commissioning Guideline (2019-09)**

Order No.: 8.032, Version 1.21 – Guideline for PROFIBUS

#### **Diagnosis, Alarms and Time Stamping (2004-07)**

Order No.: 3.522, Version 1.0 - PROFIBUS Profile Guidelines

#### **PROFIBUS System Description (2016-10)**

Order No.: 4.331, PROFIBUS Technology and Application

#### **Functional Equipotential Bonding and Shielding of PROFIBUS and PROFINET**

Order No.: 8.102, Version 2.3, September 2020 – Guideline for PROFIBUS and PROFINET

### 1.4 Referenced standards

#### **IEC 24702-07 (20016)**

Information technology – Generic cabling – Industrial premises

#### **IEC 60079-0 (2017)**

Explosive atmospheres - Part 0: Equipment - General requirements

#### **IEC 60079-7 (2015 + A1 2017)**

Explosive atmospheres - Part 7: Equipment protection by increased safety "e"

#### **IEC 60079-11 (2011 + Corr. 2012)**

Explosive atmospheres - Part 11: Equipment protection by intrinsic safety "i"

#### **IEC 60079-14 (2013 + Cor 1 2016)**

Explosive atmospheres - Part 14: Electrical installations design, selection and erection

#### **IEC 60079-25 (2015))**

Explosive atmospheres - Part 25: Intrinsically safe electrical systems

#### **IEC 60204-1 (2016)**

Safety of machinery – Electrical equipment of machines – Part 1: General requirements (IEC 60204-1:2005, modified); German version EN 60204-1:2006

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### **IEC 60364-4-41 (2017)**

Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock

### **IEC 60364-5-54 (2011)**

Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors

### **IEC 60529 (1989 + A1 1999 + A2 2013)**

Degrees of protection provided by enclosures (IP code)

### **IEC 60874-14-10 (1999)**

Connectors for optical fibres and cables - Part 14-10

### **IEC 61140 (2016)**

Protection against electrical shock – Common aspects for installations and equipment

### **IEC 61158-2 (2014)**

Industrial communication networks - Fieldbus specifications - Part 2: Physical layer specification and service definition

### **IEC 61241-1-2 (2004)**

Electrical apparatus for use in the presence of combustible dust. Electrical apparatus protected by enclosures and surface temperature limitation. Section 2. Selection, installation and maintenance

### **IEC 61784-5-3 (2018); VDE 0800-500-3 (2015)**

Industrial communication networks - Profiles - Part 5-3: Installation of fieldbuses - Installation profiles for CPF 3

### **IEC 61918 (2018); VDE 0800-500 (2014)**

Industrial communication networks - Installation of communication networks in industrial premises

### **EN 50174-2 (2018)**

Information technology – Cabling installation – Part 2: Installation planning and practices inside buildings

### **EN 50174-3 (2017)**

Information technology – Cabling installation – Part 3: Installation planning and practices outside buildings

### **EN 50310 (2016)**

Telecommunications bonding networks for buildings and other structures

### 1.5 Symbols and their meaning





This document contains various images intended to help the reader understand the text. Additionally, symbols are used for structuring the text. These symbols mark especially important passages in the text or combine text to form text sections.

The following symbols are used consistently throughout the text and in images.

- Table 1-1: Symbols for structuring the text
- Table 1-2: Symbols for components
- Table 1-3: Symbols for areas and zones
- Table 1-4: Symbols for PROFIBUS cables

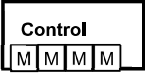







### 1.5.1 Symbols for structuring the text

Table 1-1: Symbols for structuring the text

Symbol	Name	Meaning
	<b>Tip</b>	Used to mark a recommendation and / or summary of the current topic.
	<b>Important</b>	Used for information which, if not observed, may result in malfunctions during operation.
	<b>Instruction</b>	Used for direct instructions.
	<b>Danger!</b>	Used to mark a danger to life and health. The observance of an instruction marked in this way is extremely important!



## 1.5.2 Symbols for components

Table 1-2: Symbols for components

Symbol	Name	Meaning
	<b>Master</b>	PROFIBUS controller, contains one or more master(s) class 1
	<b>DP / PA converter</b>	A converter between PROFIBUS DP and MBP (PA) or DP-IS
	<b>Fieldbus barrier</b>	PROFIBUS-MBP (PA) link between the Ex e main bus and Ex i stubs
	<b>Junction box</b>	Passive or active junction for PROFIBUS-MBP (PA)
	<b>OLM (Optical Link Module)</b>	Converter from electrical to optical signals and vice versa
	<b>Slave</b>	Bus node (slave) PROFIBUS DP, DP-IS, MBP (PA)
	<b>Terminating resistor</b>	The terminating resistor of a bus segment
	<b>BFOC connector</b>	Fiber-optic connector type









### 1.5.3 Symbols for areas

Table 1-3: Symbols for areas and zones

Symbol	Name	Meaning
	<b>EMI</b>	Area where the occurrence of electromagnetic interference (EMI) must be expected.
	<b>Hazardous area</b>	Area in which an explosive gas atmosphere is likely to occur

## 1.5.4 Symbols for PROFIBUS cables

Table 1-4: Symbols for PROFIBUS cables

Symbol	Name	Meaning
	<b>PROFIBUS DP standard cable</b>	PROFIBUS DP cable, sheath color: violet
	<b>PROFIBUS DP-IS hazardous area</b>	PROFIBUS DP-IS cable, sheath color: blue
	<b>PROFIBUS DP PE sheath / underground cable</b>	PROFIBUS DP cable, sheath color: black
	<b>PROFIBUS-MBP (PA) hazardous area</b>	PROFIBUS-MBP (PA) cable, sheath color: light blue
	<b>PROFIBUS-MBP (PA) non-hazardous area</b>	PROFIBUS-MBP (PA) cable, sheath color: black
	<b>FOC</b>	Fiber-optic internal cable
	<b>Splice</b>	Splice connection of optical fiber cables
	<b>Electrical link</b>	Conductive electrical link

### 1.6 About the structure of this guideline

This guideline will guide you step-by-step through the planning process. The introduction chapter outlines the basic planning process for the overall structure of this guideline.

In the following sections, you will find the below-listed concept:

- **Chapter 2:** This chapter focuses on topology planning (plant design). The arrangement of the nodes in segments and lines is planned.
- **Chapter 3:** This chapter enhances the topology worked-out in chapter 2 with more details, adding selected components. The chapter specifies, for example, which cables and connectors are used and which facts must be taken into account when planning the cable routes.
- **Chapters 4:** The planning process is completed by the planning of the acceptance test.

To allow for a better orientation and navigation in the individual chapter, the topic and the detail are briefly described at the beginning of each chapter.

It is recommended to work through the chapters and the corresponding lists in parallel in order to be able to document and, thus, optimize the planning results.

Figure 1-1 shows the basic planning procedure mapped by the structure of this guideline.

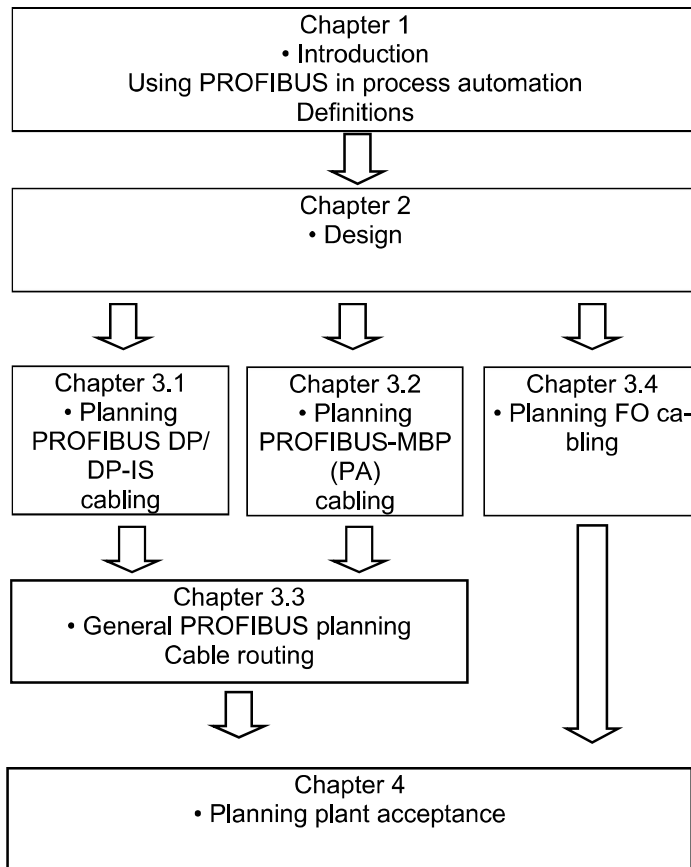


Figure 1-1: Structure of this guideline

### **1.7 Before you can start your planning ...**

...you first have to obtain an overview of your project. You can, for example, use a floor plan of the plant to get a first idea of your planning project.

You should note hazardous areas, the positions of the individual machines and the probable position of your PROFIBUS nodes. You can also clarify if specific plant parts must be designed to meet special safety requirements (SIL).

In this way, you can already get a first impression of the size and complexity of the PROFIBUS network to be planned.

### 1.8 Using PROFIBUS in process automation

Low level field buses (sensor-actuator) can seamlessly integrate with higher level systems such as PROFIBUS and PROFINET.

At the field level field devices (e.g. transmitters, actuators and valves) can communicate with a PROFIBUS master (e.g. PLC) via a real-time communication system like PROFIBUS. Process data is transmitted using a cyclic master-slave method. If required, acyclic transmission of alarms, parameters or diagnostic data is also possible.

In this guideline, the design of the master-slave topology for PROFIBUS is limited to mono-master systems, i.e. only one master exists for cyclic data exchange with the slaves assigned to it.

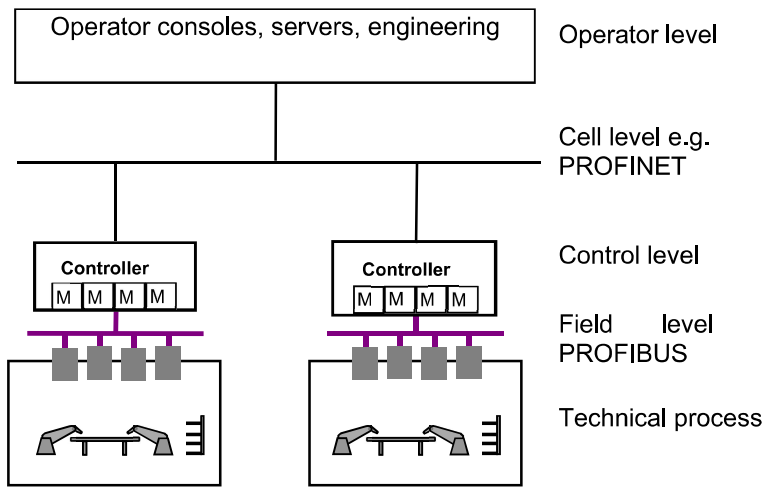


Figure 1-2: Using PROFIBUS in process automation

### 1.9 Definitions

#### **PROFIBUS node**

In this guideline, the addressable devices (masters and slaves) connected to the PROFIBUS network are called nodes.

#### **Controller**

A controller contains one or more master(s) class 1 which control the communication of all slaves in this unit.

#### **Master**

In the PROFIBUS world, there are two types of masters. A master class 1 is a central controller which exchanges data with the local PROFIBUS nodes (slaves) in a defined messaging cycle. An example for a typical master class 1 device is a PLC.

Although PROFIBUS allows for using several masters class 1, there is usually only one per system (mono-master system).

The master class 2 is used for configuring and diagnosing PROFIBUS nodes. Masters class 2 is often included in a master class 1 or additional hardware (e.g. a PC) must be used.

#### **Slave**

A slave is an addressable peripheral device which reads process information and/or delivers output information. Seen from the communication point of view, slaves are passive and only respond to a request from a master.

#### **Components**

In this guideline, components are all devices and component parts that are required for realizing the desired topologies (for example: junctions, fieldbus barriers, DP/PA converters or connectors).

## 2 Design



Designing a PROFIBUS network is an iterative process which may require modification or restructuring of your original concept while it is being developed.

### 2.1 Determining the PROFIBUS structure

It is very helpful for the design process to create a basic PROFIBUS structure to start with.

For this purpose, it is necessary to divide the automation plant into individual automation units.

This chapter is arranged as follows:

- Dividing the process automation plant
- Setup of an automation unit
- Setup of a PROFIBUS line
  - PROFIBUS types
  - PROFIBUS DP topologies
  - PROFIBUS-MBP (PA) topologies

### 2.1.1 Dividing the process automation plant

Depending on the plant size, your process automation solution may involve several thousand bus nodes. In order to be able to integrate them in a network in the best way you first have to divide the plant into individual plant units.

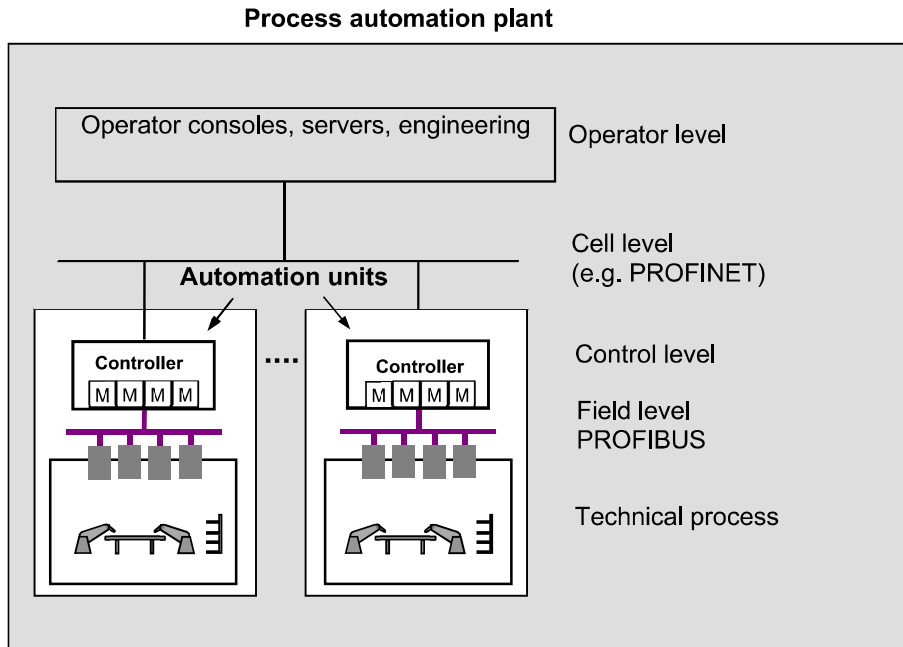


Figure 2-1: Dividing a process automation plant

Each automation unit contains only one controller with one or several master(s) class 1 that control(s) the communication with all slaves of this automation unit. The controllers can communicate with each other via a high level bus system (e.g. PROFINET). This subject, however, is not covered by this guideline.



Controllers (PLCs) often have different capabilities. Their capabilities must be in accordance with the requirements of the process to be automated.

### 2.1.2 Setup of an automation unit

An automation unit serves for executing individual tasks for the realization of which a specific number of PROFIBUS slaves (e.g. remote I/Os, actuators, etc.) is required. The slaves are connected to the controllers via so called lines. In theory, a maximum of 126 bus nodes (all masters and slaves together) may be run on a line. This limitation is due to the address range (0 to 125) provided by the master. In practice, however, the number of nodes actually connected is often by far smaller than this.

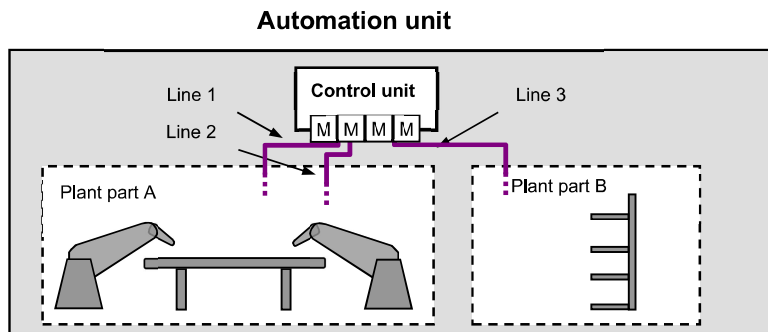
The number of slaves to be connected to a line depends on various factors that will be further detailed later in this document. Among these factors are, for example:

- Transmission rate of the line
- Data quantities of the individual slaves
- Power consumption of the slaves (PROFIBUS-MBP (PA), only)
- Max. permissible cycle time



At this stage of the design process, do not assign the maximum number of slaves to a line. It is possible to merge several lines at any time later in the process.

A controller can only control a limited number of lines, depending on its type. Typically, one to four PROFIBUS lines per controller are possible. Each of these lines is controlled by one master. The tasks of an automation unit should be assigned to a plant area. The slaves of a plant area can then be assigned to one or more lines.



**Figure 2-2: Dividing a process automation unit**



Divide your process automation plant into individual automation units, taking into consideration the controllers used. Next, create a plant overview (see List 2.1 in the supplement) and record the following:

- Automation unit; controller; number of lines; line number(s); plant areas(s)

### 2.1.3 Setup of a PROFIBUS line

A line consists of one or several coupled bus segments.

Up to 32 nodes may be connected to each segment however you cannot mix PROFIBUS DP and PROFIBUS-MBP (PA) on the same segment as they use different technologies. The network is built up using repeaters and PROFIBUS DP/PA couplers which are considered to be bus nodes as well.

Figure 2-3 shows a possible setup of a network to provide an overview

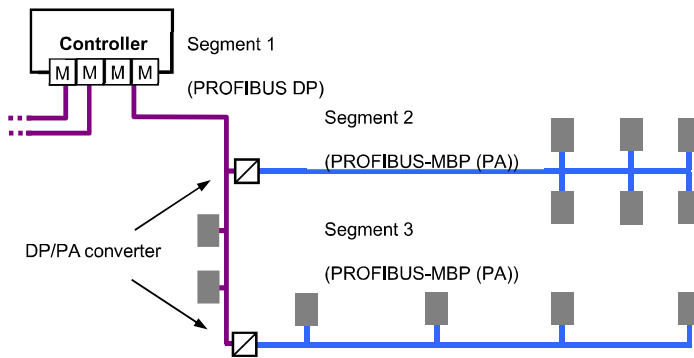


Figure 2-3: Possible line setup

### 2.1.3.1 PROFIBUS types

There are different PROFIBUS types. The two most common types are described in the following section.

- **PROFIBUS DP**

PROFIBUS DP is a high speed bus (up to 12,000 kbits/s) intended for connecting remote I/Os, actuators and other intelligent units.

- **PROFIBUS-MBP (PA)**

PROFIBUS-MBP (PA) is a low speed bus (31.25 kbits/s) designed for direct connection of transmitters (e.g. pressure or temperature transmitters) which can be powered over the bus cable. Due to its special features that will be further detailed in the following sections this bus is especially suitable for use in hazardous areas.

Each segment can be assigned to one PROFIBUS type, only. Table 2-1 summarizes the essential features and applications of PROFIBUS DP and PROFIBUS-MBP (PA).

## Design

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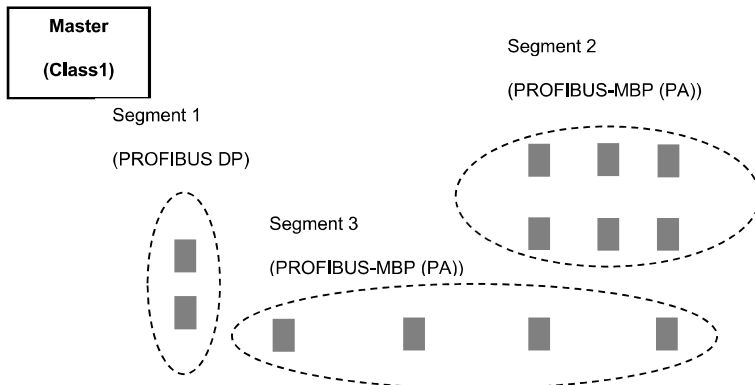
**Table 2-1: Properties and applications of the PROFIBUS types**

	<b>PROFIBUS DP</b>	<b>PROFIBUS-MBP (PA)</b>
<b>Automation branch</b>	Production automation and process automation	Process automation
<b>Description</b>	Used for discrete and continuous tasks. Use in hazardous areas possible with special equipment (RS485-IS), but not common.	Used for continuous tasks. When used with Ex couplers or barriers also suitable for hazardous areas. The slaves are powered via the bus.
<b>Typical devices connected</b>	Remote I/Os, actuators, balances, dosing units, display panels	Analog sensors (e.g. for pressure or temperature), analog actuators (e.g. positioners).
<b>No. of bus nodes per segment</b>	Up to 32	Max. 32, typically 6 to 16
<b>Transmission rates</b>	9.6 kbits/s to 12,000 kbits/s in defined steps	31.25 kbits/s
<b>Transmission technology</b>	RS 485 RS 485(IS) Fiber-optic	MBP (Manchester Bus Powered)
<b>Transmission medium</b>	Copper cables FO cables: Glass/plastic/HCS	Copper cables

## Design

	PROFIBUS DP	PROFIBUS-MBP (PA)
<b>Max. transmission path</b>	1 200 m per segment for copper cables. Less with higher transmission rates. Max. 9 segments per line. Many km when using FO cables.	Up to 1 900 m

Arrange the segments to be formed into node groups which can be assigned to either PROFIBUS DP or PROFIBUS-MBP (PA). These nodes groups should be placed close to each other or on the same line. Figure 2-4 illustrates this segment forming method using the line shown in Figure 2-3 as an example.



**Figure 2-4: Segment forming using node groups**



Divide the bus nodes to be connected to a line into individual segments and assign one of the two PROFIBUS types to them. In order to obtain a better overview, you should use a sketch in the first step (see Figure 2-4).

### 2.1.3.2 PROFIBUS DP topologies

When cabling a PROFIBUS DP, you can select either copper cables or fiber-optic cables (FO) for transmission. Different topologies are permissible, depending on the transmission medium used.

Note that PROFIBUS DP is higher level network to PROFIBUS-MBP (PA). As a result, all PROFIBUS-MBP (PA) segments have to be linked to the line using couplers. The DP/PA couplers used for this purpose must always be considered when planning the bus topology.

#### PROFIBUS DP topology using copper cables

When using copper cables without additional active components, the PROFIBUS DP within a segment has a pure linear topology.

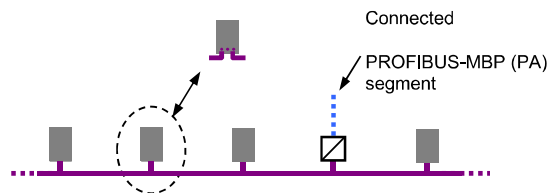


Figure 2-5: Line topology of a PROFIBUS DP with copper cables

Note that the connections of the individual nodes shown in the illustrations do not use spurs. The bus cable just links in a linear fashion from one node to another. The bus signal is looped through either the connector or directly within the node.

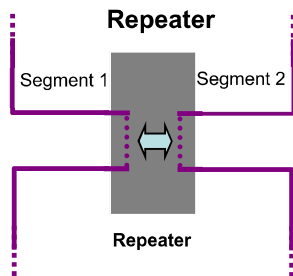


However, we strongly recommend not using stubs for PROFIBUS DP as stubs produce reflections and, therefore, must be considered as a potential source of interference to the signal.

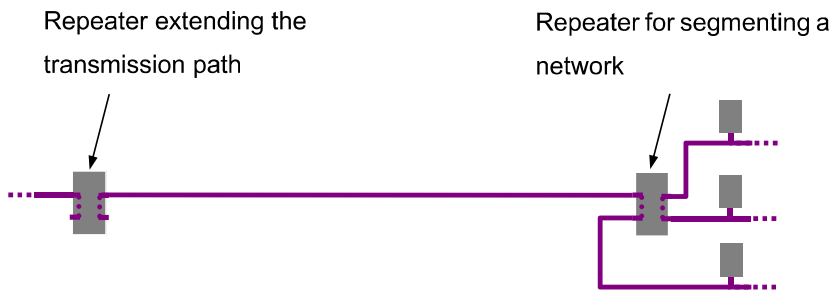
## Design

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Depending on the data transmission rate, transmission paths of up to 1 200 m per segment can be made using copper cables. Where longer transmission paths are required, two PROFIBUS DP segments can be coupled by a repeater. This type of connection can be used at any point on the transmission path. Repeaters can be used not only for achieving longer transmission paths, but also for segmenting the network.



**Figure 2-6: Connecting two segments to a repeater**



**Figure 2-7: Possible application of repeaters**

Different repeater types are available. The PROFIBUS standard does not specify the signal conditioning method. Consequently this may vary between manufacturers.

Always observe the manufacturer's specifications regarding the repeater usage, especially the specified maximum number of repeaters that can be series-connected. It is not recommended to mix repeaters from different manufacturers on the same PROFIBUS line. You should also note that using repeaters always implies a certain signal delay. As this is an important factor it must be considered when planning time-critical automation tasks.



Prior to planning to use repeaters you should always refer to the manufacturer specifications.

Repeaters have to be considered as bus nodes and counted accordingly. If there is a repeater at the start and end of a segment, you can connect a maximum of 30 other nodes to this segment.

### PROFIBUS DP topology using FO cables

When using FO cables, you can use different topologies (line, star, ring), including the mixed topologies resulting from them.

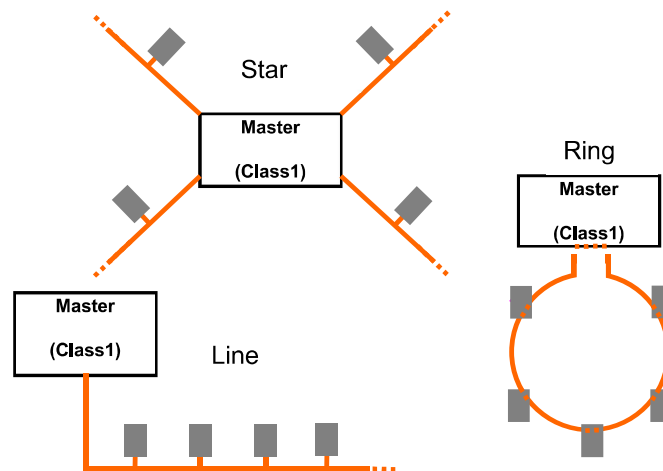


Figure 2-8: PROFIBUS DP topologies using FO cables

Besides their suitability for long transmission distances of several kilometers, FO cables feature an excellent resistance to electromagnetic interference. Additionally, they allow for bridging potential differences between different parts of the site.

### PROFIBUS DP topology using copper cables and FO cables

It is possible to set up a PROFIBUS DP segment or line using a combination of copper and FO cables.



It is recommended to use FO cables for the following applications:

- long transmission paths
- links crossing areas with high electromagnetic interference
- links between buildings
- links requiring lightning protection
- Links between plant areas with different power supplies



Based on the previous explanations, design a topology for the PROFIBUS DP Network. For this purpose, create a segment structure plan. Fill in the following items:

- Automation unit; plant area; line and segment numbers
- The connected bus nodes (node number; device type/name)
- Approximate cable lengths; selected transmission medium; path numbers

### 2.1.3.3 Topologies of PROFIBUS-MBP (PA)

With PROFIBUS-MBP (PA) the slaves are powered via the bus. As a result, copper cables have to be used as the transmission medium.

For PROFIBUS-MBP (PA) line and tree topologies as well as a combination of these are permissible. The nodes are either connected directly to the bus (hereinafter called “trunk”), in the same way as with PROFIBUS DP, or to stubs (hereinafter called “spur”) of the main bus. In the last case, which is basically permitted, dedicated junction boxes are used. In the following sections, only the terms “trunk” and “spur” will be used.

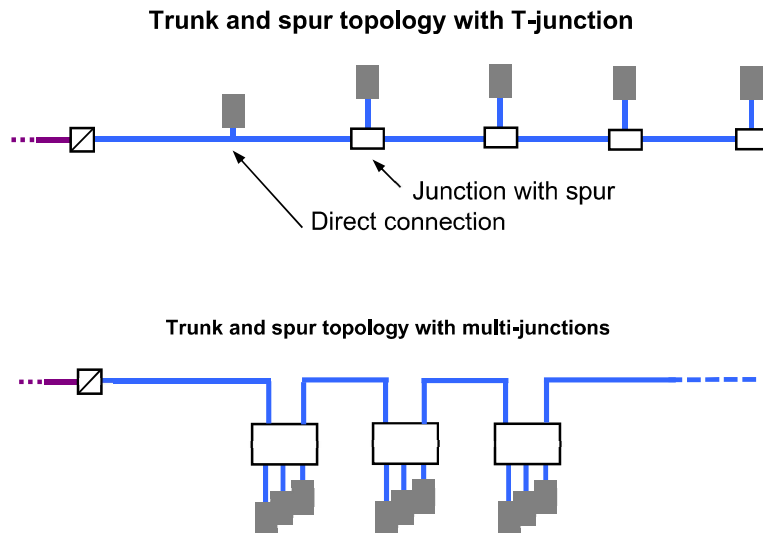


Figure 2-9: PROFIBUS-MBP (PA) topologies

Figure 2-9 shows how different topologies can be realized with T-junctions and junction modules. In addition to using junctions it is also often possible to set up a line with the devices themselves, as the devices pass through the PROFIBUS MBP (PA) signal.

With PROFIBUS-MBP (PA) a cable length of up to 1 900 m per segment can be reached. This length is the total of the trunk length plus the spur length. A spur must not be longer than 120 m dependent on how many nodes are connected.

Although connecting several devices to a spur is possible, usually only one device is connected.



Design the segment structure plans of the PROFIBUS-MBP (PA) segments.  
Fill in the following items:

- Automation unit; plant area; line and segment numbers
- The connected bus nodes (node number; device type / name)
- The approximate cable lengths of the trunk and the spur (including path numbers) as well as the required junctions

### 2.2 Determining data relevant for the line

The basic properties of the lines that are connected to an automation unit need to be confirmed prior to specifying the lines.

We recommend to work through this chapter separately for each line.

This chapter is arranged as follows:

- Data transmission rate and transmission distance
  - Data transmission rate and transmission distance for PROFIBUS DP
  - Data transmission rate and transmission distance for PROFIBUS-MBP (PA)
- Communication protocol
- Bus cycle time

### 2.2.1 Data transmission rate and transmission distance

The maximum transmission distance that can be achieved using copper cables is directly related to the transmission speed chosen for the PROFIBUS network. As a result, these two variables must always be considered together.

The maximum transmission distance of FO cables is independent of the transmission rate.

#### 2.2.1.1 Data transmission rate and transmission distance of PROFIBUS DP

The data transmission rate of PROFIBUS DP is adjustable in defined steps between 9.6 kbits/s and 12,000 kbits/s. The data transmission rate must be identical for all segments of a PROFIBUS line. Table 2-2 shows the maximum possible transmission distances that can be reached when using copper cables.

**Table 2-2: Maximum transmission distance as a function of transmission rate (PROFIBUS DP)**

<b>Transmission rate [kbits/s]</b>	<b>maximum transmission distance [in m]</b>
9.6	1 200
19.2	1 200
45.45	1 200
93.75	1 200
187.5	1 000
500	400
1 500	200
3 000	100
6 000	100
12 000	100

The maximum distances listed above are valid for an individual segment, provided that type A PROFIBUS cable is used (see also chapter 3.1.1.1). Using repeaters allows you to couple multiple segments. As a result, longer transmission distances can be reached. The data transmission rate is set in the master and is then the same for all PROFIBUS DP segments of the line. This means that, theoretically, the maximum adjustable transmission rate depends on the longest PROFIBUS DP segment of the line. If the line is further subdivided using repeaters,

the segment length can be reduced and the transmission rate increased. See chapter 2.1.3.2 for details.



Verify the transmission distances of the PROFIBUS DP segments and determine the maximum possible data transmission rate. Subsequently, add the following items to the plant overview:

- Data transmission rate
- Number of PROFIBUS DP segments (of line)

### **2.2.1.2 Data transmission rate and transmission distance of PROFIBUS-MBP (PA)**

The data transmission rate of PROFIBUS-MBP (PA) is fixed to 31.25 kbits/s. The maximum transmission distance of a PROFIBUS-MBP (PA) segment depends on various additional factors. The most important ones are listed below:

- Number of slaves connected to the trunk or their power consumption, respectively
- Cable type used
- For applications in hazardous areas: Type of protection of the segment

All these factors will be detailed later in this document. For this reason, only the theoretical maximum transmission distance of the individual applications can be shown here.

## Design

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**Table 2-3: Transmission rate and transmission distance (PROFIBUS-MBP (PA))**

Transmission rate	Transmission distance
31.25 kbits/s	Use in non-hazardous areas and in hazardous areas with high-power trunk concept:  1 900 m; max. length of individual spur limited to 120 m dependent on the number of nodes
	Use in hazardous areas using FISCO Power Supply to IEC 60079-11:  1 000 m; max. length of individual spur limited to 60 m

**Table 2-4: Maximum spur lengths with PROFIBUS-MBP (PA)**

Number of devices incl. DP/PA converters on a spur	Maximum length of a spur in m	Maximum length in m of a spur intrinsically safe to FISCO <sup>1</sup>
1-12	120	60
13-14	90	60
15-18	60	60
19-24	30	30
25-32	1	1

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<sup>1</sup> Fieldbus Intrinsically Safe Concept, detailed in section 3.2.4.1



As the transmission rate of PROFIBUS-MBP (PA) segments is fixed, there is no need to document it explicitly. It is however necessary to verify and note the spur lengths for future calculations using Table 2-4. Subsequently, add the following items to the plant overview.

- Number of PROFIBUS-MBP (PA) segments

### 2.2.2 Communication protocol

PROFIBUS is available in three scalable versions. These versions are called DP-V0; DP-V1; DP-V2 and they offer different functionality.

Depending on the required communication scope, a function stage must be assigned to the line in order to be able to find the appropriate master for it.

Operation with slaves with a lower function stage is permissible (e.g. a DP-V0 slave can be used with a DP-V2 master).

Table 2-5 shows the individual versions.

**Table 2-5: Function stages of the PROFIBUS DP communication protocol**

<b>PROFIBUS version</b>	<b>Description</b>
DP-V0	<p>Provides the basic functionality of the communication protocol. This includes:</p> <ul style="list-style-type: none"><li>• <b>Cyclic data exchange</b> between master and slaves for exchanging process data</li><li>• Diagnostic functions</li></ul>
DP-V1	<p>Extends function stage DP-V0, mainly with the following features:</p> <p><b>Acyclic data exchange</b> between master and slaves for diagnosis, control, monitoring and alarm handling of the slaves in parallel with cyclic data traffic.</p>
DP-V2	<p>Adds the following features to the functionality of function stages DP-V0 and DP-V1:</p> <ul style="list-style-type: none"><li>• <b>Slave to slave(s) communication</b> for direct data exchange between slaves (must be supported by the master)</li><li>• <b>Isochronous mode</b> for synchronous control in the master and the slaves, independently of the trunk load (primarily required for servo drives)</li><li>• Other functions like clock control</li></ul>



Class 2 Masters should be at least DP-V1. Function stage DP-V2 is used for drives run in isochronous mode.



PROFIBUS-MBP (PA) always uses function stage DP-V1. As a result all PROFIBUS-MBP (PA) devices support this protocol functionality. For this reason, no additional specifications regarding the communication protocol are made for PROFIBUS-MBP (PA).



Many device manufacturers do not explicitly specify the function stage of their devices. In these cases, pay special attention to the specifications regarding cyclic and acyclic data exchange.



Estimate the function stage of the communication protocol required for the line. Subsequently, add the following item to the plant overview:

- Communication protocol

### 2.2.3 Bus cycle time

During a bus cycle all data is exchanged either between the master and the slaves (normal cyclic data exchange) or slave to slave (DP-V2 only). This bus cycle time should be kept as short as possible up to transmission rates up to 1.5 Mbits/s. Transmission rates greater than 1.5 Mbits/s should only be selected if the system response time of the process requires a shorter bus cycle time. The following chapter provides a general description of the bus cycle. Later, conclusions are drawn from this general description for the design of the PROFIBUS network.

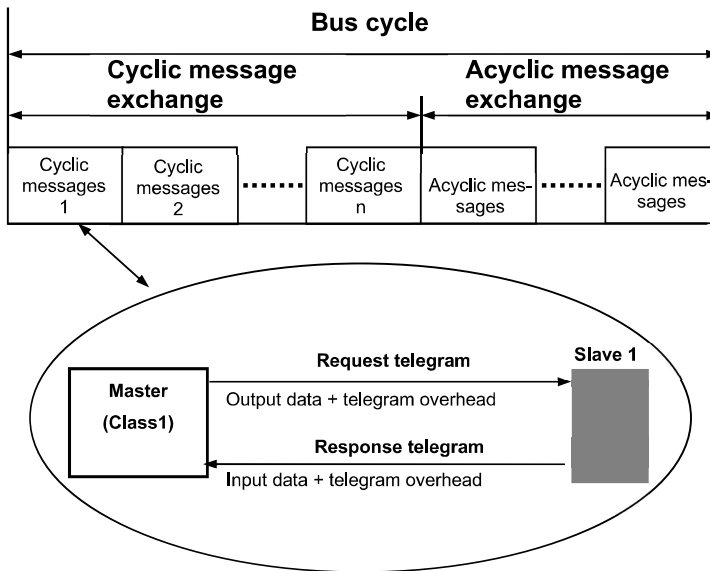


Figure 2-10: Basic structure of a bus cycle

Cyclic data exchange utilizes PROFIBUS DP-V0 and acyclic data DP-V1 messages. Data traffic between slaves using PROFIBUS DP-V2 is only required for very few automation tasks and is not covered here.

The communication between the master and a slave always includes the transmission of two telegrams into which the process data (input and output data) is packaged. The amount of process data to be transmitted depends on the input and output data of the slaves. Intelligent devices usually have between 2 to 20 bytes of input and output data. The process data volume of remote I/Os depends on the equipment and may amount up to a maximum of 244 bytes.

The bus cycle time required for this communication essentially depends on the following factors:

- Number of slaves
- Transmission rate
- Bus physics (PROFIBUS DP/ PROFIBUS-MBP (PA))
- Data volume (input and output data)

The exact calculation of the bus cycle time is usually made using manufacturer-specific calculation programs. In order to provide a better overview, the PROFIBUS DP and PROFIBUS-MBP (PA) bus cycle times are examined in the following using a simplified approach.

Only cyclic message exchange is considered here. If required, some additional time must be provided for acyclic messages.

## PROFIBUS DP

An estimation of the bus cycle time for PROFIBUS DP can be made using the formula provided in Table 2-6.

**Table 2-6: Formula for estimating the PROFIBUS DP bus cycle time**

Formula for estimating PROFIBUS DP bus cycle time
$t_{\text{Partial cycle\_DP}} = \frac{\sum_{i=1}^n (\text{Tel\_OV} + \text{Bit\_DP} \cdot (L_o + L_i))}{\text{Transmission rate}}$
Tel_OV = Telegram overhead (317 bits)
Bit_DP = PROFIBUS DP data format ( $11 \frac{\text{Bit}}{\text{Byte}}$ )
i = slaves' run variable
$(L_o + L_i)$ = Total of slave output and input data in bytes
n = Number of all slaves
Transmission rate: Value in kbit/s
$t_{\text{Partial cycle\_DP}}$ : Cycle time in ms

## Design

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Figure 2-11 provides a graphical overview of the formula shown in Table 2-6 for various transmission rates. It is assumed that each slave uses 5 bytes of input and output data. This calculation rather represents a particularly favorable case, as no reserves for the repetition of corrupted messages and acyclic communication for masters Class 2 is taken into account.

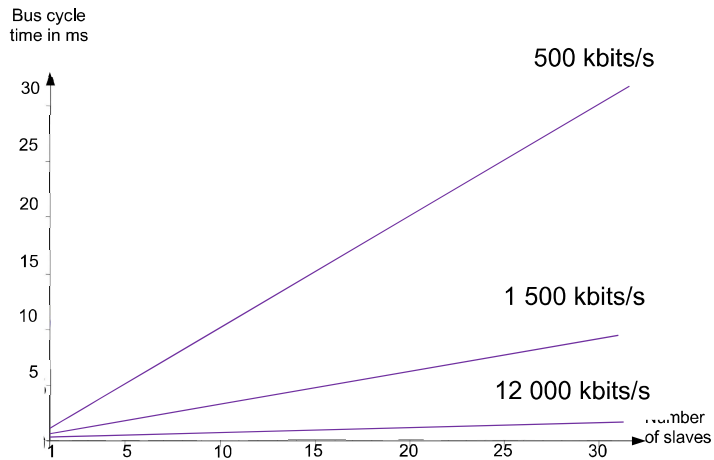


Figure 2-11: PROFIBUS DP bus cycle times

**PROFIBUS-MBP (PA)**

An estimation of the bus cycle time for PROFIBUS-MBP (PA) can be made using the formula provided in Table 2-7.

**Table 2-7: Formula for estimating the PROFIBUS-MBP (PA) bus cycle time**

Formula for estimating the bus cycle time
$t_{\text{Partial cycle\_PA}} = \frac{\sum_{i=1}^n (\text{Tel\_OV} + \text{Bit\_PA} \cdot (L_o + L_i))}{\text{Transmissionrate}}$
<p>Tel_OV = Telegram overhead (317 bits)</p>
<p>Bit_PA = PROFIBUS-MBP (PA) data format ( <math>8 \frac{\text{Bit}}{\text{Byte}}</math> )</p>
<p>i = slaves' run variable</p>
<p><math>(L_o + L_i)</math> = Total of the output and input data of the slave i</p>
<p>n = Number of all slaves</p>
<p>Transmission rate: Value in kbits/s</p>
<p><math>t_{\text{Partial cycle\_DP}}</math> : Cycle time in ms</p>

Figure 2-12 provides a graphical representation of the formula shown in Table 2-7 for the fixed transmission rate of 31.25 kbit/s for PROFIBUS-MBP (PA). The bus cycle times for PROFIBUS DP are shown in the same graphic as a reference. Again, it is assumed that each slave uses 5 bytes of input and output data.

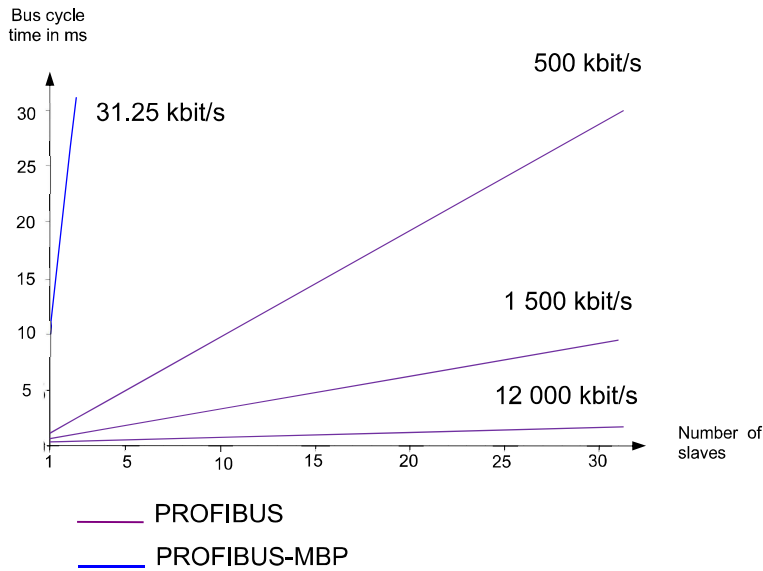


Figure 2-12: PROFIBUS bus cycle times

Compared to the bus cycle time of PROFIBUS DP, the bus cycle time of PROFIBUS-MBP (PA) is quite long. However, this does not necessarily mean that the total cycle time of a line consisting of both PROFIBUS DP and PROFIBUS-MBP (PA) segments is that long as well. Nevertheless, the DP/PA transfer must be known in order to be able to determine the bus cycle time of such a line. For details see chapter 3.2.5.3.



Note that the bus cycle time only represents the time required for data transmission via the trunk. In order to be able to make an overall time estimate for a PROFIBUS system (to determine the total cycle time or the possible response time) you also have to take into account the application processes and the master versions (PLC, controller, PC) used. As these are manufacturer-specific and application-specific, it is not possible to provide a universal specification here. It is, however, generally valid that the achievable response time of a PROFIBUS system is always directly proportional to the bus cycle time. When designing a PROFIBUS network, you should therefore always take into account the following facts:

- Remote I/Os usually have to transmit a large amount of process data. In order not to unnecessarily slow down the data exchange of

individual intelligent units, remote I/Os are often run on separate lines.

- The data exchange of PROFIBUS-MBP (PA) nodes is very slow (typically 15 -17.5 ms per bus node). For this PROFIBUS type you therefore have to pay special attention to the number of nodes connected to the trunk.



Contact the master manufacturer for information regarding the verification and determination of the cycle times. Many manufacturers provide special calculation methods or tools for this purpose.

### 2.3 Special requirements

PROFIBUS offers various features for meeting the requirements in terms of safety-relevant processes.

This chapter is arranged as follows:

- Intrinsic safety
  - Definition and classification of hazardous areas
  - Type of protection "intrinsically safe" (Ex i)
  - PROFIBUS types for hazardous areas
- Safety
- Redundancy
- Spare cables

### 2.3.1 Explosion protection



The explanations in this document regarding explosion protection are for information purpose, only. Usually, additional national guidelines must be observed which are not explicitly mentioned in this document. The company operating a plant is solely responsible for validating the explosion protection.

If you intend to use PROFIBUS for automation tasks in hazardous areas, you have to take various measures to avoid the ignition of the hazardous gas atmosphere.

The European Directives 94/9/EC (called explosion protection directive or ATEX directive) and the norm IEC 60079 have to be observed. All specifications made in the following subchapters refer to these directives, although they must not be considered as their substitute.



When planning PROFIBUS applications for hazardous areas you must employ sufficiently qualified personnel.

### 2.3.1.1 Definition and classification of hazardous areas

In Europe, the zone concept described in the following is the basis for planning PROFIBUS applications in hazardous areas. In the U.S.A. and in some other countries other zones and zone designations are valid which are different from the zones described here.

**Table 2-8: Zone classification for gases and vapours**

<b>Zone classification for gases and vapors</b>	
<b>Zone</b>	<b>Frequency of occurrence</b>
Zone 0	Areas in which an explosive atmosphere is present either continuously or frequently.
Zone 1	Areas in which an explosive atmosphere is occasionally present.
Zone 2	Areas where an explosive atmosphere is present only infrequently and for a short time.

**Table 2-9: Zone classification for combustible dusts**

<b>Zone classification for combustible dusts</b>	
<b>Zone</b>	<b>Frequency of occurrence</b>
Zone 20	Areas in which an explosive atmosphere is present either continuously or over a long time.
Zone 21	Areas in which an explosive atmosphere may occasionally be present as a cloud of combustible dust in the air.
Zone 22	Areas where an explosive atmosphere is not likely to be present as a cloud of combustible dust in the air under normal operation.



In the majority of cases there is a combination of these zones. A zone 0 area for example, is usually surrounded by a zone 1 area, which is surrounded by a zone 2 area.



Check your automation plant for the existence of hazardous areas and which zones (0, 1 or 2) are present. Next highlight all PROFIBUS segments that are in hazardous areas. Include all nodes in hazardous areas even if there is only one device on a network in a zone.

**2.3.1.2 Type of protection "intrinsically safe" (Ex i)**

PROFIBUS segments located in hazardous areas are usually realized in the protection class "intrinsically safe" (Ex i) or in a combination of "intrinsically safe" (Ex i) and the protection class "increased safety" (Ex e). The principle of intrinsic safety is based on the limitation of the energy supplied to the trunk. This avoids the possibility of sparks or hot surfaces igniting a gas. Disconnecting a bus connector or damaging a bus cable during operation hence no longer implies a risk.

In order to design a PROFIBUS segment with this type of protection you must select the appropriate PROFIBUS type and make sure that every component connected to the trunk is specified with the required type of protection.

For hazardous areas resulting from the presence of explosive gases or vapors the type of protection "Intrinsically safe" (Ex i) is further classified into the categories "ia" and "ib" indicating the probability of failure of the corresponding component. They therefore, indicate a safety factor. For details of the suitability of these categories for the individual zones please refer to Table 2-10.

**Table 2-10: Categories of type of protection Ex i**

<b>Zone</b>	<b>Required type of protection</b>
Zone 0	Ex ia
Zone 1	Ex ib
Zone 2	Ex i without special safety factor (also called Ex ic)

For hazardous areas where combustible dusts are present there is no such categorization of the type of protection Ex i.



When selecting the components to be used in such a hazardous area you must always observe the manufacturer specifications and the corresponding test certificates. Besides their suitability for use in a specific zone and the corresponding type of protection, other specifications like the temperature class and their assignment to specific device groups characterize the components. A detailed consideration of these aspects is beyond the scope of this document. However, you should always bear in mind that a special proof for intrinsic safety must be provided for all segments used in this zone.

### **2.3.1.3 Type of protection "increased safety" (Ex e)**

As an alternative to the type of protection "intrinsic safety" (Ex i) the type of protection "increased safety" (Ex e) may be used for PROFIBUS applications in hazardous areas. The principle of this type of protection is based on the special construction of the components used and allows for a higher energy power supply to the trunk than the type of protection "intrinsic safety" (Ex i). As a result, more nodes can be connected to a segment. However, on PROFIBUS segments with this type of protection no work may be executed during operation. This means that it is no longer possible to easily replace nodes or disconnect connectors while the bus system is running.

In the field frequently the protection class "intrinsic safety" (Ex i) and "increased safety" (Ex e) are used in combination. The trunk cable is routed through the plant using the protection class "increased safety" (Ex e). At certain locations so called Fieldbus Barriers split of spurs in the protection class "intrinsic safety" (Ex i).

### **2.3.1.4 PROFIBUS types for hazardous areas**

There are two special PROFIBUS types that are explicitly specified for use in hazardous areas. These types allow for integrating intrinsically safe segments into a line.

### 2.3.1.5 PROFIBUS DP-IS

A special variant called PROFIBUS DP-IS was developed for use in hazardous areas. It is based on PROFIBUS DP. This variant uses the RS 485-IS transmission technology and, similar to PROFIBUS-MBP (PA), must be connected to the PROFIBUS DP via a special PROFIBUS DP/DP-IS converter. PROFIBUS DP-IS can be used in zone 1 and is specified for the type of protection Ex ib. A maximum of 32 nodes can be connected to a PROFIBUS DP-IS segment. PROFIBUS DP-IS differs from PROFIBUS DP in the following features:

- Suitable for use in zone 1 (type of protection Ex ib)
- Transmission technology: RS 485-IS
- Transmission rate limited to a maximum of 1 500 kbit/s (see Table 2-2 for the reachable transmission distance)
- Transmission medium: copper cable, only



There are alternative solutions using FO cables or mechanically protected copper cables.



Like PROFIBUS DP, this PROFIBUS type is suitable for linear topologies, only. Branch segments from the PROFIBUS DP can be made by using DP/DP-IS converters.



Verify the segment structure plans and select one of these two PROFIBUS types for segments in hazardous areas. Additionally fill in the type of protection (Ex e; Ex ia; Ex ib) required for the respective segment.

### 2.3.2 Safety

Besides the requirements of hazardous areas, automation plants often confront the planners with safety-relevant tasks that imply a potential risk in the case of a human error or component failure. In order to protect both people's lives and health and the environment, special precautions must be taken. They are often referred to as "functional safety".

For PROFIBUS these precautions can be realized by using the PROFIsafe application profile. This profile allows the use of the same bus line for both safety-related communication and standard communication and is suitable for all previously described PROFIBUS types (PROFIBUS DP/ PROFIBUS-MBP (PA)). PROFIsafe is designed as a pure software layer that is implemented in the device or system. As a result neither the topology of the PROFIBUS network (including cables, connectors, etc.) nor the maximum number of bus nodes is affected. In a safety-related PROFIBUS system using PROFIsafe it is permissible to use both safety-related and not safety-related devices. In these cases safety-related communication is made between safety-related devices, only. For detailed information please refer to the "PROFIsafe guideline" (Order No.: 2.232).



Please note that, when realizing a safety-related task, you must clearly define it in advance and assign it to a SIL (Safety Integrity Level). In certain circumstances people's lives may depend on this. Exclusively employ sufficiently qualified personnel for these tasks.

### Redundancy

For automation plants requiring a high availability of the entire plant or parts of it, a bus system redundancy must be included in the planning. Various redundancy concepts are available, but they are quite manufacturer-specific. For this reason only the essential concepts will be described in this document.

- **Master redundancy**

In the case of master redundancy two masters (Class 1) are connected to a line. However, only one at a time is communicating with the field devices. The redundant bus master takes over communication only when the primary master fails. Master redundancy is often used in conjunction with line redundancy.

- **Line or cable redundancy**

In the case of line redundancy each PROFIBUS cable is provided twice. If one cable should be damaged, the bus communication is continued using the second cable. The redundant bus cable should not be laid in parallel with the primary bus cable. If, for example, the damage is produced by mechanical impact, there would be a high risk that both bus cables fail at the same time. The bus nodes connected must be specifically designed for this purpose. (The bus node must have connectors for the redundant cable).

- **Slave redundancy**

The slave redundancy refers to the slave interface modules which connect a slave to the PROFIBUS. If the active module of a slave should fail, the slave automatically changes over to the redundant module.



Redundant PROFIBUS are normally used for automating and monitoring tasks that require a high availability.

### 2.3.3 Reserve cables

Reserve cables are spare cables run in the installation phase and provide certain advantages that should be taken into account in the planning phase. These advantages are:

- Extensions of the plant are simplified.
- Cable problems (e.g. wire breaks) can be remedied quickly by using a reserve cable instead.

In order to find out for which sections using reserve cables would make sense, you should clarify the following questions in advance:

- Is a plant extension planned or expected?
- Which sections are subject to high mechanical load / are endangered.
- How demanding and complex is the laying of the bus cable? (If the bus cable is to be laid in the ground or in a plant part that is difficult to access, it is recommended to lay a reserve cable).

If you intend to consider reserve cables, special attention must be paid to the site installation and the intended use of the cable when laying the cable.

- If, for example, the reserve cable is intended to improve the failure safety, it must be laid separately from the normal trunk.
- If the reserve cable is to be used to extend the plant at a later time, laying this cable in parallel with the actual bus cables is permissible.



Reserve cables provide many advantages, but may also increase the overall costs.

## 3 Planning the cabling

### 3.1 Planning PROFIBUS DP/ DP-IS cabling

In order to be able to make the final planning of the PROFIBUS DP/DP-IS copper sections you should work through all subchapters in this chapter one after the other.

- Selecting cables
- Determining the connection technology
- Planning the bus terminations
- PROFIBUS DP-IS coupling
- Planning repeaters

#### 3.1.1 Selecting cables

The bus cable used must meet the requirements of the project and also comply with the PROFIBUS standard. Cable manufacturers offer a wide range of PROFIBUS DP/DP-IS cables which differ in their possible applications and their special features.

This chapter is arranged as follows:

- Properties of PROFIBUS DP/DP-IS cables
  - Electrical properties (line parameters)
  - Mechanical properties
  - Chemical properties
- Versions of PROFIBUS DP/DP-IS cables
  - Standard cables
  - Cables with PE sheath
  - Underground cables
  - Trailing cables / festoon cables
  - Hybrid cables

### 3.1.1.1 Properties of PROFIBUS DP/DP-IS cables

PROFIBUS cables are shielded twisted-pair copper cables which differ from each other in the type of wire (fixed/flexible) and/or sheath. The two inner cores of a DP-IS cable have green and red insulation.

The specifications in this chapter are primarily intended to provide a general introduction and describe the cable properties to be considered (see IEC 61784-5-3). The actual cable selection is described in chapter 3.1.1.2.

#### Electrical properties (line parameters)

The cables for PROFIBUS DP/ DP-IS are assigned to categories, the so-called line types, which define specific physical parameters.

The individual line types are identified by the capital letters A, B, C and D. When planning a network you should exclusively use line type A.

Table 3-1 shows the parameters of line type A that must be complied with.

**Table 3-1: Parameters of line type A (PROFIBUS DP/DP-IS)**

Parameter	Specified limits
Impedance	$135..165\Omega$ with $f = 3..20$ MHz
Operational capacity	$\leq 30\text{pF} / \text{m}$
Loop resistance	$\leq 110\Omega / \text{km}$
Wire diameter	$> 0.64\text{mm}$
Wire CSA	$> 0.34\text{mm}^2$
L/R proportion for PROFIBUS DP-IS	$\leq 15\mu\text{H} / \Omega$

### **Mechanical properties**

Besides the physical properties like the wire diameter or material, the cable manufacturers also specify the mechanical properties, indicating the possible applications and laying options of the cables. Typical manufacturer specifications are:

- Bending radius
- Bending frequency
- Tensile strength

While bending radius and bending frequency are mainly dependent on the wire type of the cable (solid wires, flexible wires) an increased tensile strength is achieved by additional elements, e. g. aramid fibers in the cable. For special requirements special cables are available on the market that are reinforced with glass fibers, woven steel, or steel braids. The usage of such cables is due to the special areas of application an exception

### **Chemical properties**

The sheaths of PROFIBUS DP/DP-IS cables can be made of different materials providing them with the appropriate properties to protect them against environmental influences.

Cable manufacturers often specify the properties resulting from the chemical composition or the presence of a specific material (e.g. halogen, silicone) in the data sheets of the cable. Typical manufacturer specifications are:

- UV resistance
- Freedom from silicone
- Resistance against mineral oils and greases
- Permitted temperatures

## Planning the cabling

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Special attention must be paid to the flammability of the cables. The flammability is usually separately specified by the cable manufacturer, plus the following features:

- Freedom from halogen
- Flame retardance
- Smoke density



The smoke density is closely related to the freedom from halogen and is not specified by all manufacturers. Therefore, also pay special attention to additional specifications like FRNC (Flame-Retardant-Non-Corrosive). The acronym FRNC indicates that a cable is halogen-free and flame-retardant.



No other than halogen-free and flame-retardant cables may be used in areas where human life is threatened by toxic gas and smoke in case of fire.

### 3.1.1.2 Versions of PROFIBUS DP/DP-IS cables

Various special cable versions for PROFIBUS DP/DP-IS are available on the market. The most commonly used ones and their applications are listed in Table 3-2.

**Table 3-2: Versions of PROFIBUS DP/DP-IS cables**

Cable version	Applications
Standard cables	Installed inside or outside buildings
Cables with PE sheath	Uses in the food and beverages industry
Underground cables	Laid directly in the ground
Trailing cable	Used for lines on moving machine parts
Cables for festoons	Festoon cables for indoor and/or outdoor applications



Always ensure that the correct cable for the PROFIBUS type is used.

Most of the cable versions listed in Table 3-2 are also offered as a special variant allowing you to easily strip off the cable sheath. This feature considerably reduces the time required for preparing the cables to make them ready for installation. However, manufacturer specific installation kits are required for this installation.



Consideration should be given to using one manufacturer's cabling system throughout a PROFIBUS project for ease of installation.

### Standard cables

Usually, standard cables meet most of the requirements of an automation project. For this reason, this cable version is most frequently used for PROFIBUS DP/DP-IS. Both conductors consist of flexible or solid copper wires. You can select either type that best fits with your installation. Standard cables are only available of line type A. Usually they can be identified by their typical violet sheath color and a cable diameter of approx. 8 mm.



Figure 3-1: PROFIBUS DP standard cable



The standard cable is designed for fixed laying e.g. on cable trays.

There are two more standard cable groups which differ only by the sheath material or sheath color used.

- **Halogen-free standard cables**

These are standard cables with a sheath made of a halogen-free material. The sheath color is usually violet; the cable diameter is approx. 8 mm.



Use halogen-free standard cables for the cabling in areas with special requirements regarding the flammability of cables in case of a fire (refer to chapter 3.1.1.1). Possible applications are e.g. installations in residential building or hospitals.

## Planning the cabling

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### ▪ Standard cables for PROFIBUS DP-IS

A cable with a blue cable sheath is available for PROFIBUS DP-IS. Its cable diameter is approx. 8 mm.

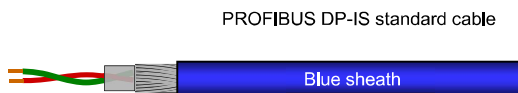


Figure 3-2: PROFIBUS DP-IS cable



Use the blue PROFIBUS DP-IS standard cable for PROFIBUS DP-IS

### Cables with PE sheath

Due to their cable sheath made of polyethylene (PE) these cables have special properties like an improved abrasion resistance and freedom from halogen. These cables typically have a black cable sheath. Its cable diameter is approx. 8 mm.

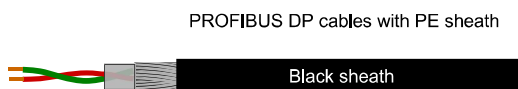


Figure 3-3: PROFIBUS DP cable with PE sheath



Use this cable type for cabling applications in the food and beverages industry. It is designed for fixed cabling inside buildings.

### Underground cables

Underground cables are covered with an additional sheath layer, often made of polyethylene (PE), which allows you to lay these cables directly in the ground. When using these cables you should bear in mind that they have a greater cable diameter and, thus, cannot use standard cabling systems. Some manufacturers allow to remove the sheath in order make the un-sheathed cable fit common connectors. This cable type usually has a black cable sheath. Its cable diameter is approx. 10 mm.

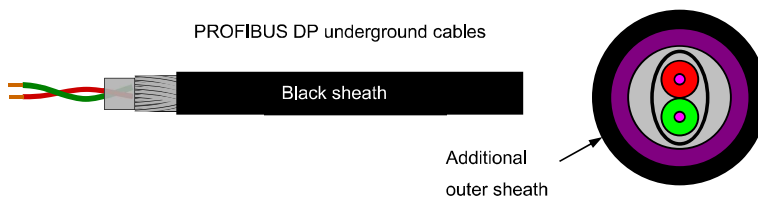


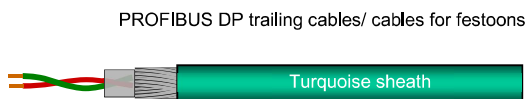
Figure 3-4: PROFIBUS DP cable for laying in the ground



Use this cable type for direct laying in the ground.

### Trailing cables/Festoon cables

The wires of these two flexible cable types are braided copper wires and often have a higher loop resistance that exceeds the limits specified for type A cable (see Table 3-1). In this case you may not be able to achieve the theoretical maximum length of the segment. Materials meeting high environmental requirements like polyurethane (PUR) are used as the sheath material. This cable type is typically identified by its turquoise sheath color. The cable diameter is approximately 8 to 10 mm.



**Figure 3-5: PROFIBUS DP cable as trailing cable / festoon cable**

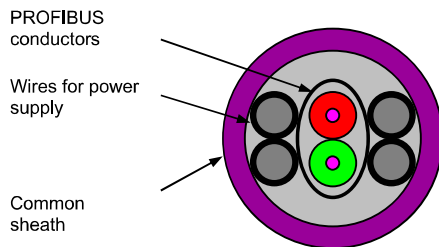
PROFIBUS festoon cables usually have a strain relief made of aramid fibers integrated in the cable sheath and may increase the cable diameter. As a result, it may be impossible to easily prepare ready-made cables with commonly used connectors.



Use these specifically designed cables for applications implying frequent movement of the cables, e.g. applications with moving machine parts. Special cables for cable carriers, festoon cables and torsion movements are available on the market.

### Hybrid cables

Besides the twisted-pair cable of the trunk, hybrid cables also contain a variable number of copper wires for power supply. Strictly speaking these cables are only special variants of all cable versions listed in Table 3-2.



**Figure 3-6: Structure of a hybrid cable**



In order to prepare ready-made hybrid cables you will need special hybrid connectors. As a result, this cable type should be used only if the bus nodes explicitly require the connection of such a cable.



Determine the cables required for the PROFIBUS DP/DP-IS segment. We recommend you do this separately for each segment using the cables and connections overview.

For each required cable type you additionally create a dedicated material list. Assign a material number (already mentioned above) to this material list which can then be used for all lines of an automation unit.

### 3.1.2 Determining connection technology

There are various methods of connecting the components of a PROFIBUS network together.

This chapter is arranged as follows:

- Connection by means of connectors
  - Sub-D connectors
  - M12 connectors
  - Hybrid connectors
- Direct cable connection



Which connections are possible depends on the component to be connected.

### 3.1.2.1 Connection via connectors

The connection via connectors is the most frequently used connection type for PROFIBUS components. Table 3-3 lists the connectors used for PROFIBUS DP/DP-IS and the corresponding types of protection.

**Table 3-3: Types of PROFIBUS DP/DP-IS connectors**

Connectors	Protection class
Sub-D connectors (9-pin)	IP20 (partially also available with higher type of protection)
M12 connectors (5-pin, B-encoded)	IP65/IP67
Hybrid connectors	IP65/IP67



You should only use connectors expressly specified by the manufacturer for use with PROFIBUS DP (/DP-IS). Only such connectors will ensure smooth commissioning and permanent, trouble-free operation of the plant.

All connectors listed in Table 3-3 are available as connectors for on-site assembly. Alternatively, most of the manufacturers also offer ready-made cables with the connectors already attached to the cable.

## Planning the cabling

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### Advantages of ready-made cables:

- Reduce the installation time as cable-assembly on site is no longer required
- Assembly errors at the on-site assembly are avoided

### Disadvantages of ready-made cables:

- When laying cables, already assembled connectors may be quite hindering.
- The cable lengths must already be defined when ordering the cables.

### Sub-D connectors

In case of the 9-pin Sub-D connectors the incoming PROFIBUS cable is connected to the outgoing cable as seen in Figure 3-7. This does away with the need to use T-junctions. Moreover, most of the connector types already include a switchable terminating resistor (Figure 3-8: Sub-D connector with switchable terminating resistor). In advanced connectors, the outgoing PROFIBUS cable is electrically separated when the terminating resistor is activated. (See also chapter 3.1.3, subchapter “Supply voltage of PROFIBUS DP bus terminations”).

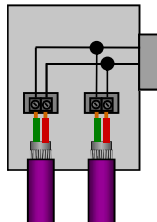
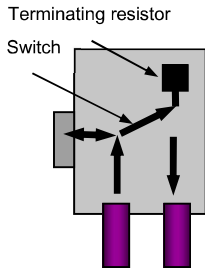


Figure 3-7: Sub-D connection principle

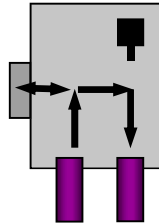
## Planning the cabling

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Terminating resistor  
connected into the circuit

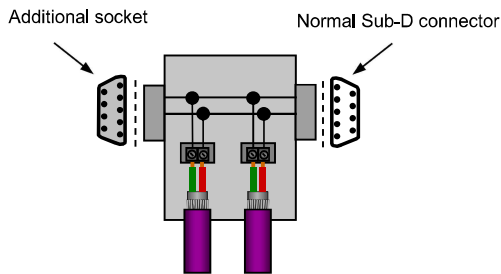


Terminating resistor  
**not** connected into the circuit



**Figure 3-8: Sub-D connector with switchable terminating resistor**

Besides these variants, SUB-D connectors with an additional socket connector are available (Figure 3-9). This socket is used e.g. for connecting a diagnostic or parameterization device (master Class 2).



**Figure 3-9: Sub-D connector with additional socket**



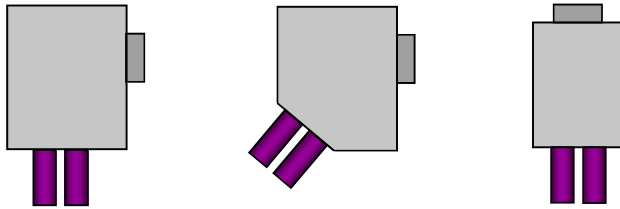
Bear in mind that the connection cable of a diagnostic device is an additional spur which, in certain circumstances, may cause disruption to the data transmission on the trunk. So-called “active bus connection cables” containing an additional repeater are available for this purpose. It is recommended that these bus connection cables are used for connecting diagnostic devices.

Plan to use at least one connector with an additional free socket connector somewhere on the transmission path. It makes sense to have it in a place that is easily accessible to the service personnel.

## Planning the cabling

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There is a choice of various connector designs, depending on the installation site and the space requirements of the PROFIBUS node. The designs differ in the direction of their outgoing cables and location of the connector. Figure 3-10 shows some of the commonly used variants available on the market.



**Figure 3-10: Design variants of Sub-D connectors**

The following techniques can be used for assembling cables with Sub-D connectors.

- Screwing technology
- Cutting clamp technology
- Spring-loaded clamp technology

All of these technologies are suitable for assembling the cables in the field. For detailed information refer to the “PROFIBUS Installation Guideline“(Order No.: 8.022).



If possible all connectors should be assembled using the same connection technology. This facilitates work for the service technician who assembles the cables and may also save some assembly time. The manufacturer specifications for the connectors must be observed. Usually, these specifications also define the cable versions permitted for assembly.

## Planning the cabling

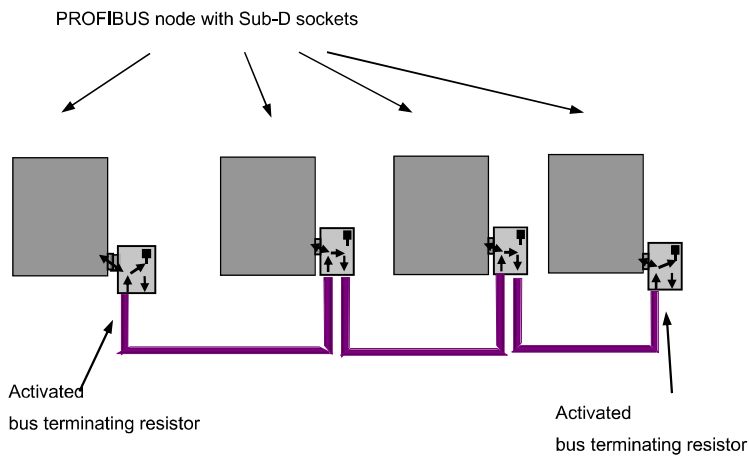
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Additionally, the installation site must be considered for these connectors. If you intend to use Sub-D connectors in intrinsically safe areas, make sure to use only specified versions.



For PROFIBUS DP-IS only those connectors explicitly specified for this PROFIBUS type may be used. Sub-D connectors for PROFIBUS DP differ from Sub-D connectors for PROFIBUS DP-IS and must not be interchanged.

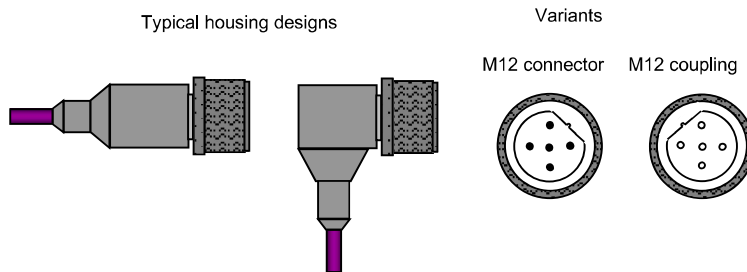
Figure 3-11 provides a schematic view of a transmission path set up using Sub-D connectors



**Figure 3-11: Schematic view of a transmission path with Sub-D connectors**

### M12 connectors

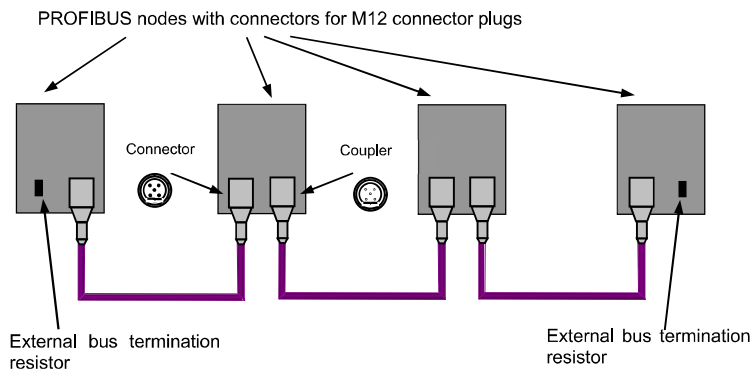
M12-connectors for PROFIBUS DP are designed for protection IP 65/IP 67. M12 connectors have no integrated switchable terminating resistors, have a different housing design and use a different connection method (via connector or coupling). A terminating connector which comprises the required terminating resistor must be connected to the last device.



**Figure 3-12: M12 connector housings and design variants**

PROFIBUS nodes connected via this connector type have two connectors. One of these is provided for an M12 connector and one for an M12 coupling. In contrast to Sub-D connectors, the bus signals are looped through in the node in this case and not in the connector. As a result, every cable must be assembled with a connector and a coupling.

Figure 3-13 provides a schematic view of a transmission path set up using M12 connectors.



**Figure 3-13: Schematic view of a transmission path with M12 connectors**

Please note that a transmission path according Figure 3-13 will cause an interruption of the transmission line when replacing a defective instrument.

### Hybrid connectors

Hybrid connectors are used exclusively for connecting hybrid cables. The properties of these connectors are manufacturer-specific and therefore cannot be detailed in this document. For more information please refer to the guideline "Interconnection Technology" (Order Nr.: 2.142).



When using hybrid connectors, make sure to use the manufacturer-specific assembly tools. Additionally, using ready-made cables for this type of connectors should be taken into consideration.

#### 3.1.2.2 Direct cable connection

Directly connecting PROFIBUS components have terminals for direct connection of PROFIBUS cable wires.



The options for connecting cables by direct clamping are manufacturer-specific. Always observe the manufacturer specification for the individual components. These specifications also define the permissible cable versions for connection.



Determine the connections of the components contained in the DP/DP-IS segments. For this purpose, use the cables and connections overview created before.

For each required connector type you additionally create a dedicated material list.

### 3.1.3 Planning bus terminations

Bus terminations are required for ensuring proper functioning of the PROFIBUS DP/DP-IS and should be considered accordingly in the planning phase.

This chapter is arranged as follows:

- General notes
- Supply voltage for PROFIBUS DP bus terminations

#### General notes

In order to ensure an offset voltage in the bus quiescent state (i.e. no telegrams) and to minimize line reflections you have to provide a bus termination at each end of the segment and nowhere else.

With PROFIBUS DP and PROFIBUS DP/IS the bus terminations have a combination of resistors that are often integrated in the connectors.

Bus terminations are sometimes provided on repeaters when used as the start of a segment.



Verify your planned topology to see at which points bus terminations must be provided. Then check the material lists to see if connectors with integrated bus terminations are listed. If required add the appropriate connectors for the terminals.

### Supply voltage for PROFIBUS DP bus terminations

With PROFIBUS DP/DP-IS the bus terminations are integrated in the connectors and can be activated and deactivated by a switch. The bus terminations are active and must be electrically powered.

This supply voltage for the active bus termination can be taken from the connected bus node. This applies to the first and last node of a segment. However if one of these bus nodes is switched off during operation, e.g. for troubleshooting, the bus termination is no longer powered. As a result, no proper bus termination will be available and the network may become unstable. To solve this problem, active bus termination elements are available, which are independent of the PROFIBUS nodes and can be powered separately.



You should provide a fixed bus termination with separate power supply if PROFIBUS DP bus nodes may have to be replaced during operation. See Figure 3-14.

A separately powered bus terminator allows one or more nodes to be disconnected in the event of failure or repair.

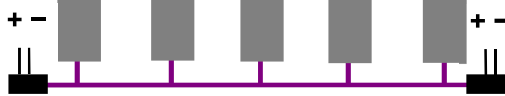


Figure 3-14: Active power supply of the bus termination

### 3.1.4 PROFIBUS DP-IS coupling

This chapter describes how to plan the use of fieldbus couplers (DP/DP-IS converters) for coupling the PROFIBUS DP-IS to the PROFIBUS DP. Additionally, the segment structure plans for PROFIBUS DP-IS segments created in chapter 2 are to be verified.

This chapter is arranged as follows:

- Using fieldbus couplers
- Verifying the segment structure plans

#### Using fieldbus couplers

Special fieldbus couplers (Figure 3-15) are needed for coupling the PROFIBUS DP-IS to the PROFIBUS DP. They provide for electrical isolation of the PROFIBUS DP from the PROFIBUS DP-IS and limit the current and voltage to safe values at which no ignition of an explosive atmosphere may occur. The appropriate voltage and current values depend on the selected type of protection.

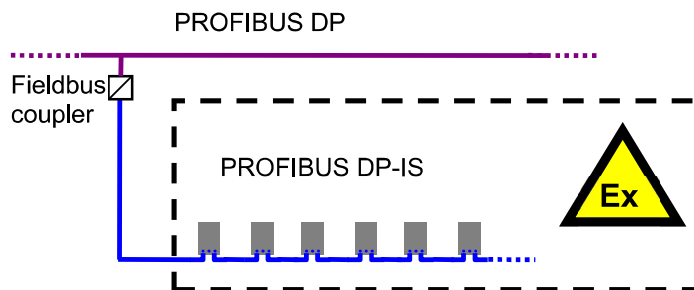


Figure 3-15: Coupling PROFIBUS DP-IS

The fieldbus coupler must be placed outside the hazardous area.

Refer to the manufacturer specifications for information on grounding the fieldbus coupler. In general, the ground connection is established through the functional ground of the PROFIBUS DP-IS if fieldbus couplers are used for coupling several intrinsically safe segments in the hazardous area.

## Planning the cabling

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As a rule, the electrical isolation of the PROFIBUS DP-IS segments from other current circuits must be ensured.

Fieldbus couplers must be installed outside the hazardous area.

When selecting a fieldbus coupler, observe the maximum output current of 149 mA.



Incorporate the fieldbus couplers for coupling the PROFIBUS DP-IS segments into your segment structure plan.

### Verifying the segment structure plans

The verification of the PROFIBUS DP-IS segments is intended to provide safety for use in hazardous areas. Proof of the segments' intrinsic safety must be submitted to the inspection authority in charge.



Proceed as detailed below to verify the segments of the segment structure plans. Document the verification process in a list.

## Planning the cabling

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### Step 1: Basic suitability

In the first step of this verification of PROFIBUS DP-IS segments is to check the manufacturers information to ensure the nodes connected to the bus are suitable for use in hazardous areas.

### Step 2: Providing evidence of intrinsic safety



Please note that the FISCO model for providing evidence of a segment's intrinsic safety is used for PROFIBUS-MBP (PA), but not for PROFIBUS DP-IS!

To provide evidence of intrinsic safety, any special requirements of the inspection authority in charge must be met. In general, intrinsic safety of the segments can be assumed if the following conditions are fulfilled:

- All nodes must be certified for use in hazardous areas and for operation with PROFIBUS DP-IS; this can be determined from the product manufacturers datasheet.
- The number of nodes is equal to or less than 32, plus 2 bus terminations.
- Output currents of the nodes < 149 mA
- The two bus terminations consume 16 mA each
- Max. total current < 4 800 mA
- Use of type A cable only

### 3.1.5 Planning repeaters

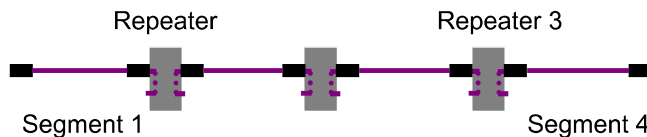
The planning of repeaters has been detailed in chapter 2. This chapter is intended to verify if using repeaters is required at all.

This chapter is arranged as follows:

- Use for extending the path
- Use as junctions
- Use for potential separation

#### Use for extending the path

Check the segment structure plans to see the total length of the individual lines of your topology planned so far. If the total length of the lines or of individual segments exceeds the maximum permissible segment length (Table 2-2), you have to provide repeaters.



**Figure 3-16: Repeaters for extending the path**

When using standard cables (type A) the maximum cable length of a segment for the corresponding data transmission rate is specified in Table 2-2, chapter 2.



The number of repeaters that can be connected to a line one after the other is manufacturer-dependent and becomes the maximum reachable transmission distance.

### Use as junctions

Repeaters can be provided as junction points if your network topology requires it.

The maximum possible cable length resulting from the junction topology must be observed, and is dependent on the data transmission rate.



Record all repeaters necessary for realizing the lines of your automation unit.

It may be necessary to re-visit the segment structure plans for segments that must begin with a repeater.

### Use for potential separation

If the individual plant parts are powered from different mains supplies, differences may occur in the ground potential which may corrupt the data transmission. In this case repeaters could be used to provide a potential separation.

#### 3.1.6 Minimum cable length between two PROFIBUS DP nodes

The IEC 61158-2 standard recommends the use of connectors with integrated inductors for connecting a PROFIBUS DP node to a PROFIBUS DP network. However, connectors without integrated inductors are also available on the market. If connectors of this kind or screw terminals should be used instead of the connectors recommended in the standard, a minimum cable length of one meter between two PROFIBUS nodes should be observed. The impedance of this cable segment will attenuate possible reflections that may result from the increased starting current of the connected nodes and thus provide for reliable network operation.

### 3.2 Planning PROFIBUS-MBP (PA) cabling

This chapter defines all the components needed for realizing a PROFIBUS-MBP (PA) network. For the final planning of the copper wiring please work through the subchapters of this chapter sequentially.

First the conditions for the realization of such a network in plants without explosion protection requirements are explained and all necessary fundamental information is provided. Based on this, the additional limitations for use in hazardous areas are detailed in a second step.

This chapter is arranged as follows:

- General notes
- PROFIBUS MBP (PA) planning
- PROFIBUS MBP (PA) specification and design
- PROFIBUS MBP (PA) for hazardous areas
- Planning DP/PA transitions
- Selecting cables
- Connecting cables
- Selecting the junction technology
- Planning the bus terminations

### 3.2.1 General notes

Thorough planning of the fieldbus segments ensures that they are correctly dimensioned. This is an important step which provides for accelerated commissioning as compared to the conventional interface method.

Both PROFIBUS DP and PROFIBUS MBP (PA) must be considered for the fieldbus planning. The PROFIBUS DP combines the subordinate MBP (PA) networks and connects them to the process control system.

Usually, the necessary calculations for PROFIBUS MBP (PA) can be made using free planning support tools such as Segment Checker ([www.segmentchecker.com](http://www.segmentchecker.com)) or similar.

#### 3.2.1.1 Sources of information for planning

The technical requirements for the fieldbus topology planning can be derived from the design details relevant for measurement and control such as:

- Device data sheets
- Installation site in the field
- Cable route planning
- Local conditions in the control room

### 3.2.2 PROFIBUS MBP (PA): planning steps

The basic steps for planning the PROFIBUS MBP (PA) fieldbus segments include:

- Specifying the environmental conditions
- Designing typical control and monitoring loops
- Calculating or specifying the required bus cycle time
- Verifying the maximum required cable lengths
- Selecting the appropriate topology
- Selecting the appropriate fieldbus cable
- Selecting the power supply and field wiring components
- Determining the number of devices that can be connected to a segment
- Taking into account sufficient power reserves (typically 25 to 30 %)
- Verifying the reachable cable lengths on the basis of the determined number of devices
- Planning PROFIBUS MBP (PA) terminators
- Validating the selected type of explosion protection

Monitoring loops are segments for acquiring measuring data such as temperature or pressure values. In this case “longer cycle times”, for example 0.5 to 5 seconds, are permissible.

The field devices of a control loop are typically planned on one segment. In order to be able to keep the cycle time low, for example at 250 to 500 ms, a smaller number of field devices are allowed.

The cycle time ranges specified above are deliberately wide reference ranges. The actual cycle time depends on the process requirements.

### 3.2.3 PROFIBUS MBP (PA) specification and design

The design rules for a PROFIBUS MBP (PA) segment are defined in IEC 61158-2. For planning, they can be simplified and summarized as follows:

- Number of nodes  $\leq 32$
- Total segment length  $\leq 1\,900$  m
- Length of a spur = a function of the number of nodes
- Maximum current of the segment  $<$  maximum current of power supply - 20% reserve
- Voltage on field device  $> 9\text{ V} \pm 10\%$

In the list above the master must be considered as a node regarding the power supply. Redundant masters are taken into account as two nodes. Note the following:

$$\text{Number of nodes} = \text{number of field devices} + \text{number of bus masters}$$

The maximum spur length is defined as a function of the number of nodes on the segment. It can be derived from Table 3-4:

**Table 3-4: Spur length as a function of the number of fieldbus nodes**

Number of	Maximum spur length (only 1 device per spur)
1 – 12	120 m
13 – 14	90 m
15 – 18	60 m
19 – 24	30 m
25 – 32	1 m

### 3.2.3.1 Instructions for PROFIBUS MBP (PA) planning

- Check the spur lengths according to Table 3-4 and observe the maximum permissible length.
- The current consumption of the connected nodes and device couplers must not exceed the maximum permissible supply current of the bus. A 20% reserve is recommended. Provide terminators at the beginning and end of each PROFIBUS segment.
- Be sure to have read and observe the valid PROFIBUS installation guidelines. They are available under <https://www.profibus.com/download>.

Designing a segment is an iterative process which may require modification to achieve the optimal topology for your plant: First design the segment with the highest current consumption and cable lengths. If its correct functionality can be proved even for a worst case scenario assumed, correct functioning of all other segments is automatically ensured.



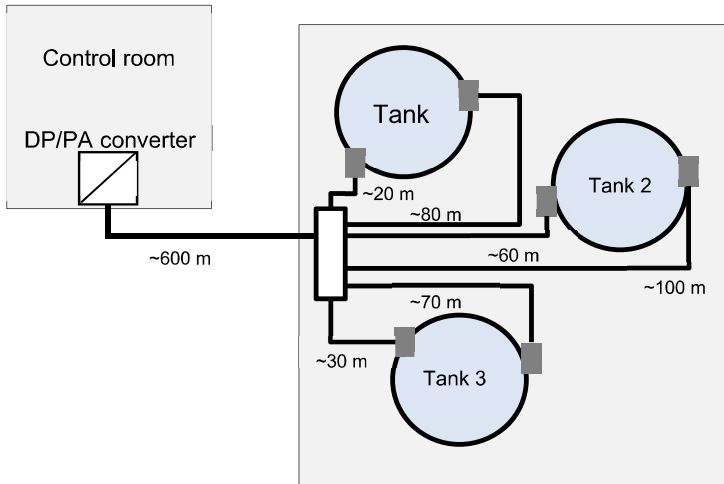
In order to save repetitive planning efforts, it is often possible to define a typical segment, validate its dimensioning and use these results to verify the design of the majority of segments.

Only “special” segments, for example with many devices or long cable paths, must be verified individually using the above-described specifications.

If one or more boundary conditions are violated, a “typical” segment with shorter cable paths and / or less nodes is calculated. The calculation results are valid for most of the segments. Only some “exceptional segments” with very long cable paths or a high number of nodes are left. It is recommended to calculate these separately.

**3.2.3.2 Example calculation – PROFIBUS PA (MBP) segment**

In the following example, a tank storage facility is considered and the segment design is calculated.



**Figure 3-17: Layout plan example of a tank storage facility**

The following information has been derived from the above-shown layout plan:

**Table 3-5: Information derive from layout plan**

Parameter	Value
Ambient temperature	20 °C
Trunk length	Larger than or equal to 600 m
Topology	Tree
Cable type	A
Cable loop resistance	44 Ω/km
Current consumption per field device	20 mA
Redundant PROFIBUS DP/PA converter	No
Max. spur length	100 m
No. of field devices per segment	10
Non-redundant power supply unit	24 V / 360 mA

It must be proved that the field devices are powered correctly and in accordance with the fieldbus standard.

### 3.2.3.3 Result of the calculation example

It must be checked if the physical variables fulfill the requirements of the fieldbus standard IEC 61158-2. This will ensure in advance that the segment will work correctly.

Number of nodes = number of field devices + number of masters

$$N_{nodes} = 6 + 1$$

$$N_{nodes} = 7 \leq 32$$

Segment length = bus length + total of all spur lengths

$$L_{segment} = 600 \text{ m} + 20 \text{ m} + 80 \text{ m} + 60 \text{ m} + 100 \text{ m} + 70 \text{ m} + 30 \text{ m}$$

$$L_{segment} = 960 \text{ m} \leq 1\,900 \text{ m}$$

Spur length = max. 120 m for 7 nodes according to table

$$L_{spur} = 100 \text{ m} \leq 120 \text{ m}$$

Current consumption of segment = total current of field devices

$$I_{segment} = 6 \cdot 20 \text{ mA}$$

$$I_{segment} = 120 \text{ mA} < I_{supply\ current} (240 \text{ mA})$$

Voltage on fieldbus coupler = voltage on source - voltage drop along trunk

$$U_{fieldbus\ coupler} = 24 \text{ V} - (120 \text{ mA} \cdot 44 \text{ ohms / km} \cdot 0.6 \text{ km})$$

$$U_{fieldbus\ coupler} = 20.83 \text{ V} > 9 \text{ V} \pm 10 \%$$

Voltage on field device = voltage on fieldbus coupler – voltage drop on spur

$$U_{field\ device} = 20.83 \text{ V} - (20 \text{ mA} \cdot 44 \text{ ohms / km} \cdot 0.1 \text{ km})$$

$$U_{field\ device} = 20.3 \text{ V} > 9 \text{ V} \pm 10 \%$$

### 3.2.3.4 Result

The segment has a sufficient reserve regarding the total cable length and the electrical load.



The example above is intended to show that these calculations are easy and just use Ohm's law and Kirchhoff's laws. Various free design tools are available for practical application.

### 3.2.4 PROFIBUS-MBP (PA) for use in hazardous areas

For use in hazardous areas observe the boundary conditions defined in the Fieldbus standard and also make sure to observe the requirements resulting from the types of protection defined in IEC 60079.

#### **Type of protection "increased safety" (Ex e)**

Ex e protection allows the same cable lengths as used in plants without hazardous areas and, thus, significantly greater energy compared to the type of protection "intrinsically safe" (Ex i). However equipment cannot be worked on while live. Explosion protection is solely provided by mechanical equipment. The design rules described above apply.

#### **Type of protection "intrinsically safe" (Ex i)**

Ex i protection limits the energy into a hazardous area to safe levels, preventing the ignition of potentially explosive atmosphere through sparks. This allows safe live work on equipment without requiring a permit for high-temperature processes.

### 3.2.4.1 Intrinsically safe segment

Figure 3-18 shows a segment with the type of protection “intrinsically safe” (Ex i). All rules described above apply. The power supply is limited by the power unit in order to prevent the occurrence of incentive sparks (intrinsic safety).

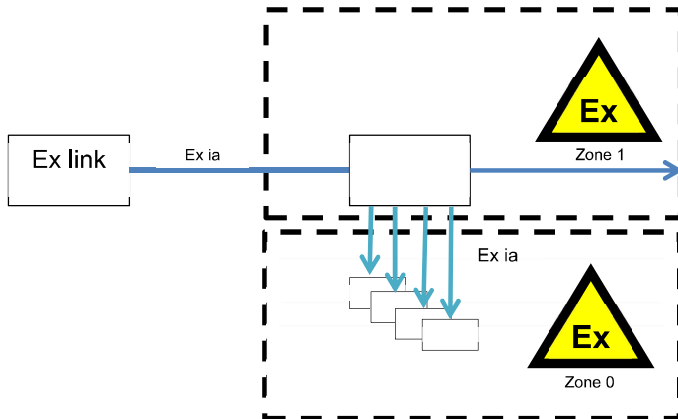


Figure 3-18: Fieldbus with intrinsically safe power supply for zone 1 and zone 0

The FISCO standard (Fieldbus Intrinsically Safety Concept) has become established throughout the world for intrinsically safe fieldbuses. Virtually all field devices have a FISCO certificate, which is widely accepted as a standard in practice. Table 3-6 shows the maximum spur length as a function of the number of devices used.

Table 3-6: Maximum spur length for intrinsically safe PROFIBUS-MBP (PA) to FISCO

No. of devices per segment, including DP/PA converter	Max. spur length in m with intrinsically safe PROFIBUS MPP(PA) to FISCO
25-32	1
19-24	30
15-18	60
13-14	60
1-12	60

## Planning the cabling

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Table 3-7 compares the limit values to FISCO with those specified in the IEC standard 61158-2. Limit values to FISCO must be complied with by all FISCO certified devices and are listed here for information, only.

**Table 3-7: Boundary conditions according to Fieldbus standard and FISCO Standard**

IEC 61158-2	IEC 60079-11 (FISCO)
$N_{nodes} \leq 32$	$N_{nodes} \leq 32$
$L_{segment} \leq 1\,900\text{ m}$	$L_{segment} \leq 1\,000\text{ m}$
$L_{spur} = \text{function}(N_{node})$	$L_{spur} = f(N_{nodes}) = \text{max. } 60\text{ m}$
$I_{segment} < I_{power\ supply}$	$I_{segment} < I_{power\ supply}$
	$I_{output} \leq I_{input}$
$U_{field\ device} > 9\text{ V} \pm 10\%$	$U_{field\ device} > 9\text{ V} \pm 10\%$
	$U_o (\text{max. } 17.5\text{ V}) \leq U_i (\text{min. } 17.5\text{ V}) *$
	$P_o (\text{max. } 5.32\text{ W}) \leq P_i (\text{min. } 5.32\text{ W}) *$
	*) Maximum values for zone 2, intrinsically safe Ex ic. Lower values apply to zone 1 and zone 0

By limiting the power fed to the bus segment, an intrinsically safe power supply unit ensures the explosion protection of the trunk and the spurs. The resulting limitation of the available active power allows using this topology with shorter distances between the power unit and the field devices and with a typically smaller number of nodes per segment.

### Validating intrinsic safety with the FISCO model

The FISCO model gives a simple procedure for providing evidence of intrinsic safety of a fieldbus to allow its usage in the hazardous area. The FISCO model requires that

- only one power supply per segment is allowed,
- the cables and devices must fulfill the FISCO requirements, and
- the requirements regarding the cable length specified in Table 3-7 are met.

The FISCO model considerably simplifies the validation of intrinsic safety. Only the certificates of all devices used have to be documented. A manufacturer declaration for the cable is sufficient.

#### 3.2.4.2 High-power trunk (fieldbus barriers)

To supply a larger number of slaves it is necessary to feed into the hazardous area larger amounts of energy than allowed according to Ex i. It is therefore necessary to adapt the connection concept of the PROFIBUS-MBP (PA) in order to ensure full safety.

Nodes must be connected via fieldbus barriers that separate them from the main bus (trunk) using protection type “increased safety” (Ex e).

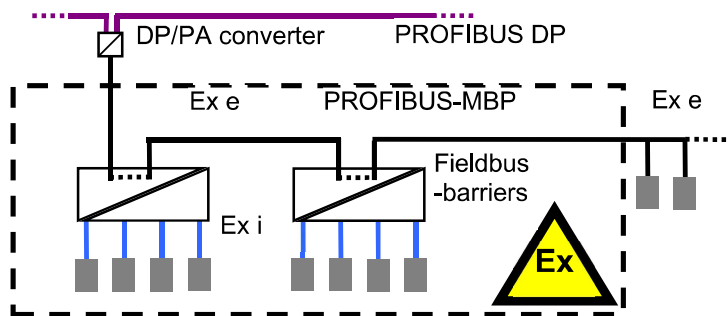


Figure 3-19: Fieldbus barriers for PROFIBUS-MBP (PA)

## Planning the cabling

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PROFIBUS-MBP (PA) is fed into the hazardous area via the Ex e trunk. A larger amount of energy can be fed into the hazardous area than is permitted for Ex i. However, the trunk cannot be worked on while live. The trunk supplies both the fieldbus barriers as well as the slaves located outside the hazardous area. The fieldbus barriers ensure the current and voltage limitations required by the type of protection Ex i. The cables to the slaves meet the requirements of the type of protection “intrinsically safe” (Ex i). The slaves connected to the fieldbus barriers may be replaced during ongoing operation.

Due to the combination of Ex e and Ex i, the safety of PROFIBUS-MBP (PA) can be ensured although a larger amount of energy is fed into the hazardous area than is permitted according to Ex i.

The intrinsically safe outputs of the fieldbus barriers are approved according to FISCO. Providing evidence of the intrinsic safety of the spurs is done in the same simple way as already described above.

For intrinsically safe applications, fieldbus barriers fulfill the following functions and considerably simplify planning:

- Consistent topology for all areas
- Easy planning of a plant in terms of bus extension and number of slaves in hazardous areas
- Intrinsically safe device connection, short-circuit proof
- Safe live work on equipment without requiring a permit for high-temperature processes
- Spurs (Ex i) electrically isolated from trunk (Ex e)
- Simplified provision of evidence of the spurs' intrinsic safety using the FISCO model
- Increase of the maximum possible number of field devices and cable lengths: bus extension 1 900 m instead of 1 000 m, spur length up to 120 m instead of 60 m
- Clearly smaller number of lines



Since the slaves are connected to fieldbus barriers via slaves, there are changes of the cable lengths in the segment structure plans.

### 3.2.5 Planning DP/PA transitions

This chapter plans the connection of PROFIBUS DP networks with PROFIBUS-MBP (PA) networks using converters.

This chapter is arranged as follows:

- General notes
- Selecting the power supply unit
- Use in hazardous areas
- DP/PA converter

#### 3.2.5.1 General notes

With PROFIBUS-MBP (PA) the slaves are powered via the trunk and the DP/PA converters are used for powering the connected segments.

The DP/PA converters must be supplied with 24 V DC. An appropriate power supply must be considered in the planning phase.

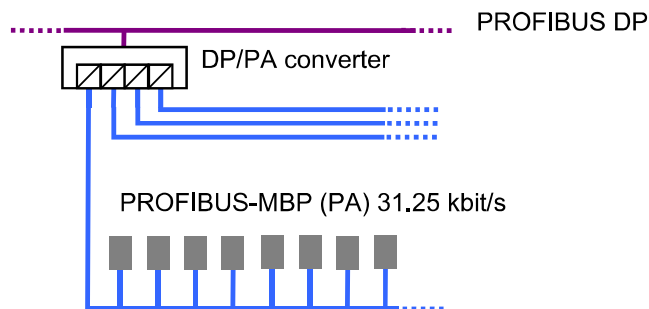


Figure 3-20: Coupling the PROFIBUS-MBP (PA)

### 3.2.5.2 Selecting the power supply unit

The power supply unit, which is often integrated in the DP/PA converter, powers the slaves via the trunk.

When choosing a suitable power supply unit you first have to determine the total power requirements of the connected nodes. The total power supply of the line is an essential criterion for selecting the appropriate DP/PA converter.

### 3.2.5.3 DP/PA converters

DP/PA converters provide connectivity between PROFIBUS DP and PROFIBUS-MBP (PA). DP/PA converters basically have three functions (see Figure 3-19):

- Conversion of the PROFIBUS DP protocol, with transmission based on the RS 485 standard, to the PROFIBUS-MBP (PA) protocol, with transmission according to IEC 61158-2.
- Provision of supply voltage required for the MBP (PA) segment and limitation of supply current (maximum supply current of the MBP (PA) segment).
- If required, guaranteed Ex separation.

There is a choice of two converters:

- DP/MBP (PA)-LINK (non-transparent coupler)
- DP/MBP (PA) segment coupler (transparent coupler)

A distinction is made between transparent and non-transparent DP/PA converters. Transparent DP/PA converters pass the addresses and telegrams of the PROFIBUS-MBP (PA) slaves to the super-ordinate PROFIBUS DP. Converters of this type do not need to be configured. The maximum number of slaves is given by the PROFIBUS DP address range.

Non-transparent DP/PA converters concentrate the signals of all PROFIBUS-MBP (PA) nodes in one PROFIBUS DP address. They are a single slave on the PROFIBUS DP side.

## Planning the cabling

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It is possible to operate several links or segment couplers on the same PROFIBUS DP line. They are automatically adapted to the transmission rate of PROFIBUS DP. Redundant links and segment couplers can be provided for highly available applications.

### DP/MBP (PA)-Link

A link comprises a link master section with couplers and supplies, typically for 1 to 5 segments.

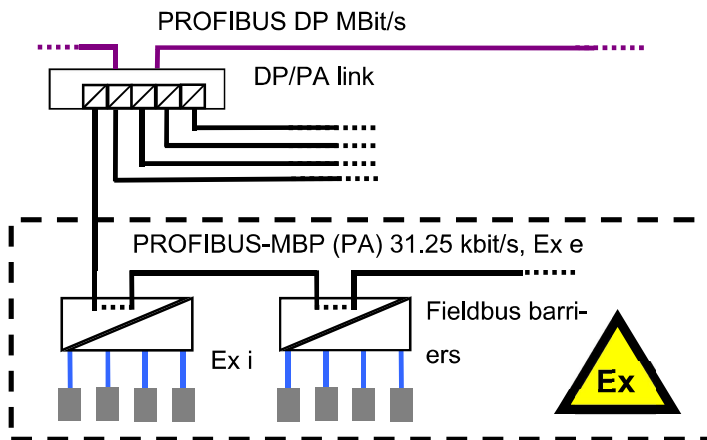


Figure 3-21: Connection example of PROFIBUS DP and PROFIBUS-MBP (PA) with DP/PA link, shown for a hazardous area with fieldbus barriers

- On the PROFIBUS DP side, the link appears as a slave, while on the PROFIBUS-MBP (PA) side it appears as a master. In the planning of the link as PROFIBUS DP slave, the link uses one of the available PROFIBUS DP addresses. The connected PROFIBUS-MBP (PA) slaves of the subordinate MBP (PA) segments are mapped to this address.

### **DP/MBP (PA) segment couplers**

A segment coupler consists of a gateway module and power supply modules for up to four segments.

The DP/MBP (PA) segment couplers are transparent in terms of communication; the bus addresses of the PROFIBUS-MBP (PA) slaves are visible on the PROFIBUS DP side. The gateway module contains a separate PA master for each PA segment.

The protocol remains unchanged during transmission and DP/MBP (PA) segment couplers do not have to be planned or configured separately. The electrical connection is made as shown in Figure 3-21.

### 3.2.6 Selecting cables

Cable selection for PROFIBUS-MBP (PA) is based on the cable selection for PROFIBUS DP/DP-IS (see chapter 3.1.1)

This chapter is arranged as follows:

- Properties of PROFIBUS-MBP (PA) cables
- Types of PROFIBUS-MBP (PA) cables
  - Standard cables
  - Long distance cables

### 3.2.6.1 Properties of PROFIBUS-MBP (PA) cables

The physical properties of PROFIBUS-MBP (PA) cables are the same as PROFIBUS DP/DP-IS cables (shielded twisted pair cables). The difference between them is in properties of the cable. Please see Table 3-8 for line type A parameters to be observed for PROFIBUS-MBP (PA) cables.



You should only use cables expressly specified by the manufacturer as "PROFIBUS-MBP (PA) cables". Only such cables will ensure smooth commissioning and, trouble-free operation of the plant.

Table 3-8: Parameters of line type A (PROFIBUS-MBP (PA))

Parameter	Specified limits
Impedance	100 $\Omega$ at $f = 31,25$ kHz
Operational capacity	$\leq 2$ nF/km
Loop resistance	$\leq 44$ $\Omega$ /km
Wire CSA	$> 0,80$ mm <sup>2</sup>

#### Notes on the cable shield

In order to ensure efficient shielding against low-frequency and radio frequency interference, a conductor with an aluminium foil combined with a braided copper shield should be used.

It is recommended to use PROFIBUS MBP (PA) cable type 'A', a shielded twisted-pair cable that meets the shielding requirements.

### 3.2.6.2 Types of PROFIBUS-MBP (PA) cables

Table 3-9 shows the most commonly used cable types for PROFIBUS-MBP (PA) and their applications.

**Table 3-9: Types of PROFIBUS-MBP (PA) cables**

Cable version	Applications
Standard cable	Installation inside or outside buildings
Long distance cable	For long transmission distances



A large number of cable types are available on the PROFIBUS-MBP (PA) market for special applications (e.g. festoon mounting, reinforced cables), which are not discussed here in detail.

## Planning the cabling

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### Standard cables

Standard cables for PROFIBUS-MBP (PA) have the same parameters for use in the hazardous and non-hazardous areas, but have different sheath colors, depending on the application:

- Cables for intrinsically safe segments: light blue
- Cables for non-intrinsically safe segments: black or orange

The wires of the PROFIBUS-MBP (PA) cables have the following colors

+	red, orange or brown
-	green or blue

PROFIBUS-MBP (PA) standard cable for use in hazardous areas



Figure 3-22: PROFIBUS-MBP (PA) standard cable for intrinsically safe segments

PROFIBUS-MBP (PA) standard cable for use in non-hazardous areas



Figure 3-23: PROFIBUS-MBP (PA) cable for non-intrinsically safe segments



Use standard cables for cabling in indoor and outdoor areas of the automation plant. This type of cable has been designed for permanent installation, e.g. using trays.

### Long distance cables

Long distance cables differ from standard cables in their larger wire CSA. These cables therefore have a lower loop resistance (lower voltage loss) and are able to cover longer transmission distances (see the example calculation in chapter 3.2.5.2). For this cable type, observe the larger cable diameter which results in the necessity for special connectors to be used for cable assembly. The sheath color of long distance cables is identical to the standard cables.



Use long distance cables to cover large transmission distances. These cables are often used to connect fieldbus barriers.



Determine the cables required for the PROFIBUS-MBP (PA) segments. Create a cable and connection overview for each link.

For each required cable type, you additionally create a dedicated material list. Assign a material number which is valid for the entire automation unit.

### 3.2.7 Determining connections

The selection of T pieces or junctions is described in chapter 3.2.8. This chapter only describes the connection options of nodes, or junctions, to the bus cable.

This chapter is arranged as follows:

- Connection by means of connectors
  - M12 connectors
  - 7/8 inch connectors
- Direct cable connection



Which connections are possible depends on the component to be connected.

### 3.2.7.1 Connection via connectors

Table 3-10 shows the connectors used for PROFIBUS-MBP (PA) including the relevant protection class.

**Table 3-10: Connectors for PROFIBUS-MBP (PA)**

Connectors	Protection class
M12 connector (4-pin), A-coded	IP 65/IP 67
7/8 inch connector	IP 67



You should only use connectors expressly specified by the manufacturer for "PROFIBUS-MBP (PA) cable". Only such connectors will ensure smooth commissioning and permanent, trouble-free operation of the plant.

All connectors listed in Table 3-10 , just as the PROFIBUS DP/DP-IS connectors, are available in field-assembly or in a ready-made (fitted to cable) version (see chapter 3.1.2.1).

### M12 connectors

Many PROFIBUS-MBP (PA) components can be connected via this type of connector. Bear in mind that PROFIBUS-MBP (PA) M12 connectors differ from PROFIBUS DP M12 connectors in terms of number of pins and connector coding. Apart from that the available housing types and assembly options are identical (see chapter 3.1.2.1).

### 7/8 inch connectors

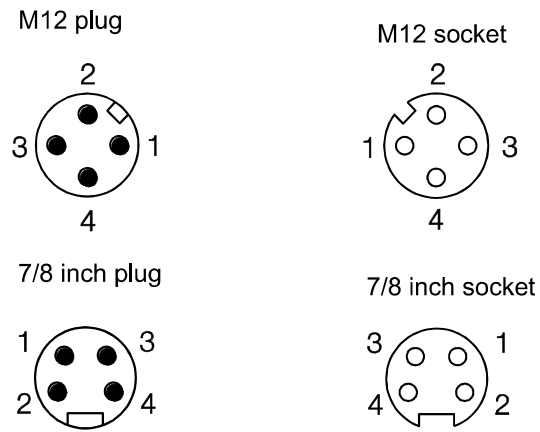
The only difference between these connectors and M12 connectors is their 7/8 inch thread. Apart from that, the general housing types and properties are identical to those of M12 connectors.



7/8 inch connectors have a larger housing than M12 connectors. It is therefore easier to assemble cables with these connectors.

### Pin assignment of M12 and 7/8 inch male and female connectors

Figure 3-24 shows the pin assignment of the M12 and 7/8 inch male and female connectors.



Signal assignment:

1 = Signal +

2 = not used

3 = Signal -

4 = Shield

Figure 3-24: Pin assignment of M12 and 7/8 inch plug and socket connectors

### 3.2.7.2 Direct cable connection

The direct connection of PROFIBUS-MBP (PA) components does not differ from the direct connection of PROFIBUS DP/DP-IS components. Please refer to chapter 3.1.2.2.



Determine the connections of the components contained in the PROFIBUS-MBP (PA) segments. Complete the cables and connections overviews already created.

For each required connector type you additionally create a dedicated material list.

### 3.2.8 Selecting the junction technology

Several types of junction technology are available to build up a PROFIBUS-MBP (PA) segment. These differ from each other in terms of their mechanical design and therefore meet different requirements regarding the availability of the plant to be automated. Another distinction has to be made in terms of the operation area (hazardous and non-hazardous areas). For details refer to the description of the explosion protection methods in chapter 3.2.4. The information in this chapter exclusively refers to the installation technology itself.

The chapter 2.1.3.3 details the individual topologies for PROFIBUS-MBP (PA). In this chapter the junction technologies required for realizing these topologies are considered.

Typically, the junction box is placed in an easily accessible place in the field. One field device per output is connected to the junction.

This chapter is arranged as follows:

- Passive junction modules
- Active junction modules

#### 3.2.8.1 Passive junction technologies

Using passive junction modules without electronic units is the most cost-effective way of setting up PROFIBUS-MBP (PA) segments. On the junction, the field devices are connected to the main bus (trunk) via a spur. The individual spurs are not electrically isolated from the trunk, and no current limitation is provided on the spur side. As a result, a short-circuit caused for example by work on a spurs or other electrical faults such as ground faults directly affect the entire segment and may cause a segment failure.

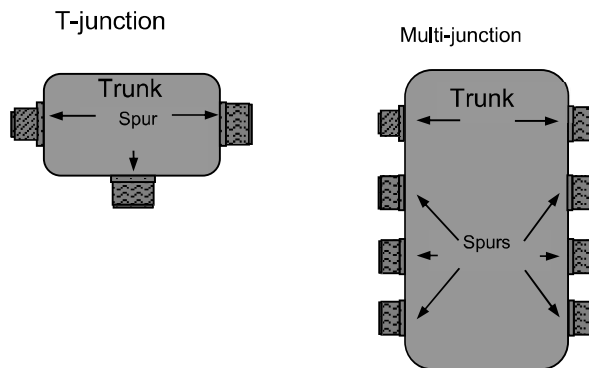


Figure 3-25: Typical variants of passive PROFIBUS-MBP (PA) junctions (T-junctions and multi-junctions)



You should only use these junctions if the availability of your plant is of minor importance, for example if the process automation system may be shut down temporarily for servicing a field device. In each segment, you should also provide reserve branches which remain available for the connection of additional nodes diagnosis equipment.

For wiring intrinsically safe segments, basically, the same junction technologies are available as for segments to be used in non-hazardous areas. They are approved by manufacturer declarations for use in hazardous areas according to the type of protection “intrinsically safe” (Ex i) or for use in a FISCO segment.

### 3.2.8.2 Active junction modules

An active junction module as shown in Figure 3-26 is provided with a current limitation for every spur. This allows working on the connected transmitters during operation and provides short-circuit and error protection and diagnosis of the spurs. Plant enhancements and other works on the field devices without the need to shut down the system are thus possible.

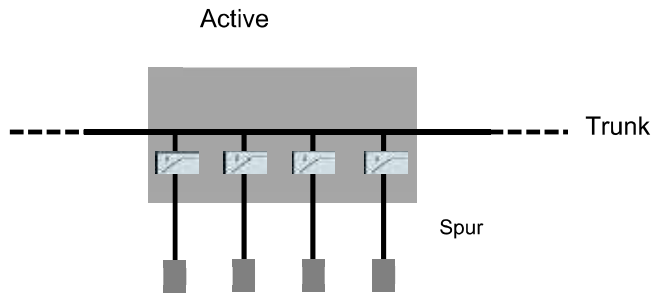


Figure 3-26: Example of an active junction module, non-Ex

Contrary to passive junctions the active junctions provide for a significantly higher availability of the process automation system and are therefore used in a majority of applications.

### 3.2.8.3 High-power trunk with fieldbus barriers

When using fieldbus barriers, the slaves are connected in a star topology via spurs (Ex i). In order to improve the system reliability, it is recommended to connect only one field device per spur.

The maximum number of slaves depends on the fieldbus barrier power. For details of how to connect please refer to the manufacturers specifications.

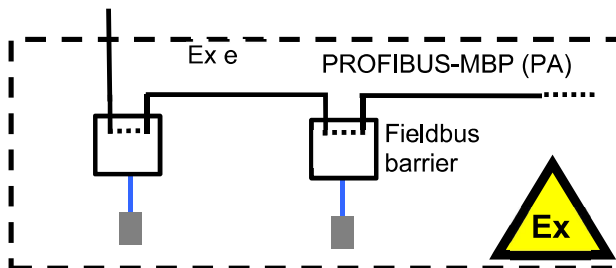


Figure 3-27: Spur coupler in hazardous area

## Planning the cabling

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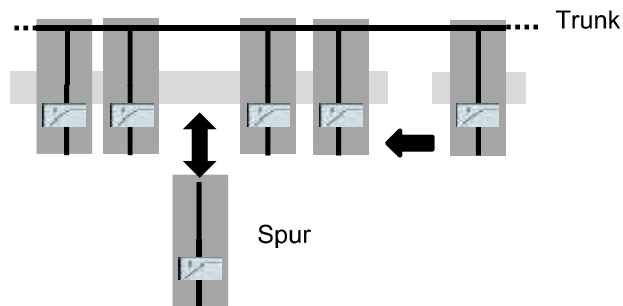
Use the created segment structure plans to determine the junction box modules required for the PROFIBUS-MBP (PA) segments.

For each required junction module type you additionally create a dedicated material list.

Scalable junction modules as shown in the example in Figure 3-28 are modular devices that can be stringed by means of a bus coupler in the DIN rail. They allow for a modular junction.

The modular concept permits:

1. Replacement of individual spur couplers during operation
2. Enhancement of spur couplers during operation



**Figure 3-28: Active junction module, replacement and enhancement**

Regarding explosion protection the described scalable junction modules are compatible with all commonly used methods such as the high-power trunk concept.

### 3.2.8.4 Intrinsically safe high-power trunk

DART (Dynamic Arc Recognition and Termination) allows for a higher transmittable active power with explosion protection type “intrinsically safe”. An intrinsically safe main bus (trunk) is realized by using compatible fieldbus power supplies and junction modules. The spurs connected to the junction are conventionally intrinsically safe and suitable for the connection of state-of-the-art intrinsically safe PROFIBUS-MBP (PA) nodes.

The following special boundary conditions must be considered for the design:

- The maximum trunk cable length is 1 000 m.
- A trunk with connected spurs must be used to realize the topology.
- Line type 'A' must be used.

With DART the main bus (trunk) is also intrinsically safe and can be accessed during operation without the glow of a fire. Sufficient power for realizing long cable paths and large amounts of devices is available. Figure 3-29: Intrinsically safe topology with trunk and spur and high power shows a system of this type.

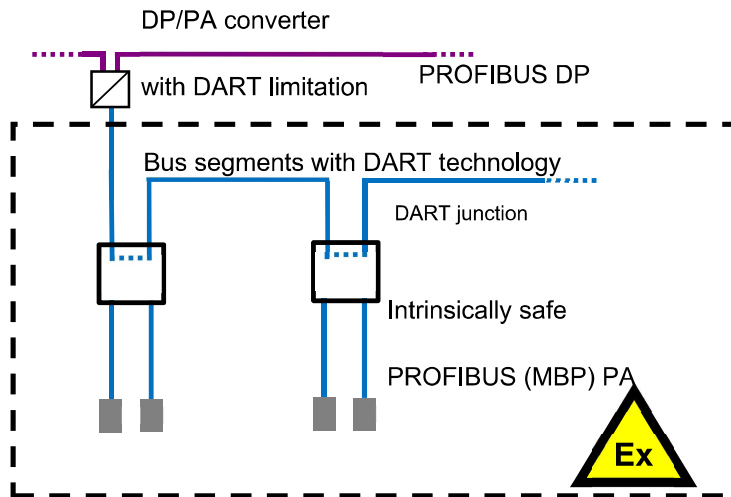


Figure 3-29: Intrinsically safe topology with trunk and spur and high power

### 3.2.9 Planning bus terminations

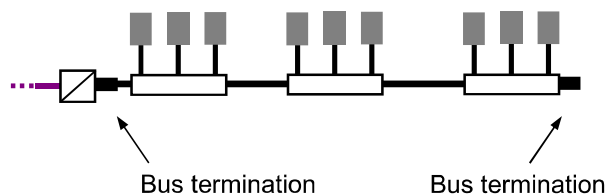
To avoid line reflections, each PROFIBUS segment must be equipped with bus terminations at both ends of the segment. For PROFIBUS-MBP (PA), you also have to observe the respective type of protection of the segment:

- Bus terminations for segments in non-hazardous areas
- Bus terminations for segments in hazardous areas

#### Bus terminations for segments in non-hazardous areas

For PROFIBUS-MBP (PA), a bus termination consists of a capacitor and a resistor connected in series. The bus termination is purely passive, not requiring any power supply.

The bus terminations are available both externally and internally. In the internal version, these bus terminations are directly integrated into the junction box module or the slave and can be switched in as necessary. The DP/PA converter (e.g. segment coupler or link) at the start of a segment usually has an integrated bus termination. The second bus termination should be installed as close to the end of the trunk as possible, see Figure 3-30.



**Figure 3-30: Installation of bus terminations for PROFIBUS-MBP (PA)**

In case of very complex bus segments, the bus node located at the furthest distance from the DP/PA converter represents the end of the trunk. However, bear in mind that in case of PROFIBUS-MBP (PA) such a segment topology should only be used in exceptional cases.

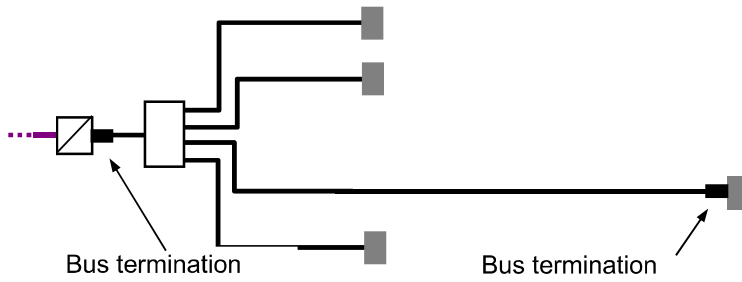


Figure 3-31: Alternative installation of bus terminations for PROFIBUS-MBP (PA)



Only terminate at the ends of the segment and nowhere else.

### Bus terminations in hazardous areas



You may only use bus terminations that are certified for use in hazardous areas.



Use the segment structure plans to plan the bus terminations required for the PROFIBUS-MBP (PA) segments. Create a dedicated material list for the external bus terminations.

### 3.3 General PROFIBUS planning

This chapter discusses common aspects which should be considered when planning individual PROFIBUS configurations.

This chapter is arranged as follows:

- Planning of cable routing for copper cables
- Planning of grounding and shielding

#### 3.3.1 Planning of cable routing for copper cables

This chapter clarifies which aspects must be considered when planning the cable routing of copper cables.

The specifications for cable routing apply to both PROFIBUS DP/DP-IS and PROFIBUS-MBP (PA).

At this point it should be known which lines, segments and routes are planned to be used. This way you can consecutively check for any special requirements for each route. For planning purposes it may be helpful to transfer the planned topology to a floor plan of the plant. You will have a better overview and will be able to easier identify problem areas after entering the real routes, segments and lines.

This chapter is arranged as follows:

- General notes on cable routing inside buildings
- Cable routing in cabinets and outside buildings



For details on the technical implementation (bending radii, mechanical protection, etc.), please see the “PROFIBUS Installation Guideline for Cabling and Assembly“(Order No.: 8.022).

### General notes on cable routing inside buildings



In general, power supply cables and communication cables shall be laid separately.

You should first check where the power supply cables are laid or planned to be laid in the plant. In practice, it may be impossible to completely separate the cables from each other. It is permissible to use the same cable duct provided that the required minimum distances are observed. Alternatively use special ducting with steel segregation sections or webs.

The Guidelines for the minimum cable distances are based on the following assumptions:

- Power cables with 1000 V maximum at 50/60 Hz are used.
- A meshed bonding network is in place.
- The shield of the PROFIBUS cable is connected at both ends.

If your plant deviates from these assumptions, it is recommended to increase the cable distances.

The specification for PROFIBUS cables does not specify a shield attenuation. Typically, the shield attenuation is  $\geq 80$  dB for cables with a combined braid and foil shield. In this case you can use separation class d in Table 3-11. If you are unaware about the shield attenuation of the cable, please use separation class b according Table 3-11.

## Planning the cabling

**Table 3-11: Minimum required separation distances S between PROFIBUS cables and power cables to EN 50174-2(2009)**

		Conduits used for information technology cables and mains power cables		
Separation class	Separation without electromagnetic barriers	Open metallic conduits a	Perforated metallic conduits b, c	Solid metallic conduits d
<b>b</b>	100 mm	75 mm	50 mm	0 mm
<b>d</b>	10 mm	8 mm	5 mm	0 mm
	<p><sup>a</sup> Shielding effect (0 MHz to 100 MHz) equivalent to welded meshed steel basket with mesh size 50 mm × 100 mm. The same shielding effect can be achieved using steel cable trays (cable bundles, without cover) with a wall thickness of less than 1.0 mm and/or an evenly perforated surface of more than 20%.</p> <p><sup>b</sup> Shielding effect (0 MHz to 100 MHz) equivalent to a steel cable tray (cable bundles, without cover) with a minimum wall thickness of 1.0 mm and an evenly perforated surface of not more than 20%. This shielding effect can also be achieved with shielded power cables which do not provide the features specified in footnote d.</p> <p><sup>c</sup> The top surface of the installed cables must be at least 10 mm below the top surface of the barrier.</p> <p><sup>d</sup> Shielding effect (0 MHz to 100 MHz) equivalent to a steel installation pipe with a wall thickness of 1.5 mm. The specified separation distance must be taken into account in addition to the separation distance required by dividers/barriers.</p>			

## Planning the cabling

Table 3-12: Factor P for power cabling

Type of electrical circuit a, b, c	Number of circuits	Factor for $P$ the power supply cabling $P$
20 A, 230 V, single-phase	1 to 3	0,2
	4 to 6	0,4
	7 to 9	0,6
	10 to 12	0,8
	13 to 15	1,0
	16 to 30	2
	31 to 45	3
	46 to 60	4
	61 to 75	6
	>75	6
	<p><sup>a</sup> Three phase cable must be treated as 3 single-phase cables.</p> <p><sup>b</sup> More than 20 A must be treated as a multiple of 20 A.</p> <p><sup>c</sup> Power cables for lower AC or DC power must be treated based on their rating, i.e. H. a 100 A / 50 V-DC cable is equivalent 5 of the 20-A-cables (<math>P = 0,4</math>).</p>	

As a next step we will look at a calculation example for the recommend distances.

Assumptions:

- PROFIBUS cable used with shield attenuation  $\geq 80$  dB: Use separation class d according Table 3-11.
- Open metallic conduit: according Table 3-11 Minimum distance  $S = 8$  mm
- 20 Power circuits with 20 A each according Table 3-12: Factor  $P = 2$
- Recommended distance is twice the minimum distance according sections 11.5.2 of the standard.

## Planning the cabling

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This results in:

$$\text{Recommended\_distance} = 2 \cdot \text{Minimum\_Distance}$$

$$\text{Minimum\_Distance} = S \cdot P$$

$$\text{Recommended\_distance} = 2 \cdot S \cdot P$$

$$\text{Recommended\_distance} = 2 \cdot 8 \text{ mm} \cdot 2 = 32 \text{ mm}$$

### Disclaimer:

The information regarding the minimum cable distances refers to installations in which PROFINET / PROFIBUS cables run parallel to unshielded power lines over longer distances. The values given here provide an orientation framework. For shorter parallel cable runs, e.g. inside machines, with shielded power cables or when using hybrid cables, it is permissible to stay below the minimum distances.

The application-specific reduced distances must be specified by the manufacturer of the system cables. This procedure is provided for in EN 50174-2.



For more details about minimum separation distances please refer to the IEC 61784-5-3 or EN 50174-2 standard, respectively.



If possible, use only conducting cable ducts and plan for regular connections to a functional equipotential bonding system. In case of extreme interference you should use steel conduit or a closed metal duct for the bus cable. For both versions, you should provide for regular connection to the functional equipotential bonding system and corrosion protection.

### Cable routing in cabinets

- Please observe the following items when planning the cable routing in a cabinet. For the minimum required separation distance between two cables refer to Table 3-11.
- In case there is not possible to have sufficient distance between the signal and the energy cables, the installation in separate, metallically conducting ducts allows achieving a smaller distance (see Table 3-11 ). Each duct should only accept cables of one category. These ducts can be arranged directly next to each other. Make sure during planning that appropriate space is provided.
- Cable crossings should always be perpendicular in order to minimize mutual interference between the cables.
- If a PROFIBUS device does not contact the cable shield with sufficiently low impedance, an additional shield clamp can be installed near the device, as shown in Figure 3 32, for an additional support of the cable shield.

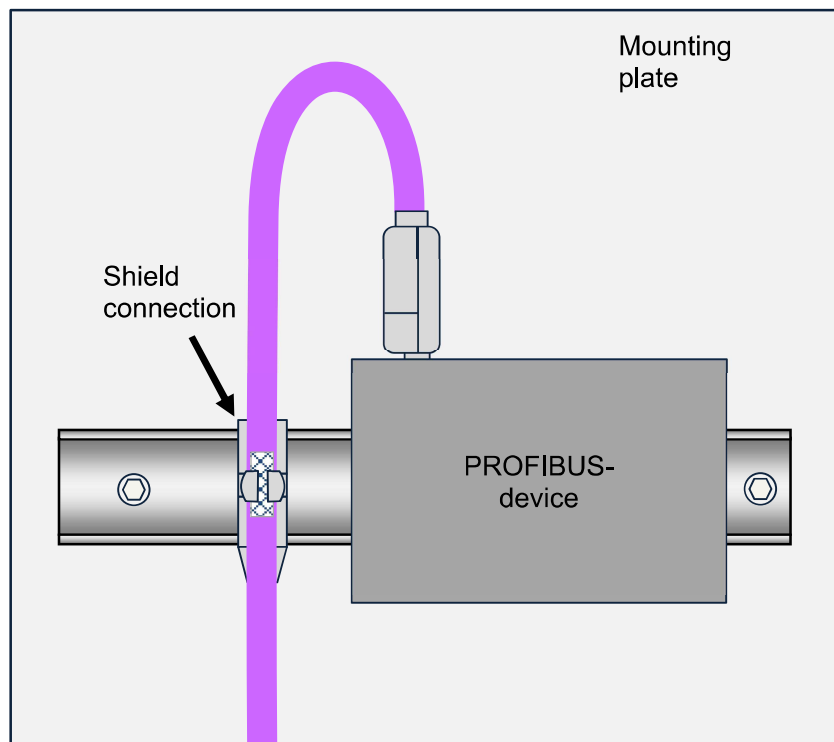


Figure 3-32: Additional connection of cable shield near the device

### Cable routing outside buildings

For cable routing outside buildings you should consider the use of fiber optic cables. In case you decide to lay the cables directly in the ground, the cable manufacturer must have specified this cable for this purpose. You should also bear in mind for outdoor installation the environmental effects like temperature, moist and UV radiation. The cable manufacturer should specify the cable for outdoor use accordingly.

- In all cases it is recommended that direct buried cables are protected against mechanical damage.
- When laying cables outside buildings, observe the same minimum segregation distances (Table 3-11).



Provide for the use of an intermediate terminal box when implementing the transfer from outdoor facilities to indoor facilities.

The intermediate terminal box ensures the transfer from earth laid cables to standard cables and usually contains an appropriate protection circuit with overvoltage protection (lightning protection). Provide for lightning protection circuits (at least basic protection) directly at the point of building entry.

### 3.3.2 Planning of grounding and shielding

Information on functional equipotential bonding and shielding can be found in the Directive on functional equipotential bonding and shielding of PROFIBUS and PROFINET, Order No.: 8.102.

### 3.4 Planning FO cabling

This chapter describes the planning of fiber optic (FO) cables. For this purpose, we will explain the components to be used and discuss special issues to be observed when planning FO technology systems.

This chapter is arranged as follows:

- Particularities of FO
- Optical connection technology
- Selecting fibers
- Selecting cables
- Determining connections
- Determining fiber-fiber couplings
- Checking FO paths

### 3.4.1 Particularities of FO systems

This chapter describes the particularities and terms related to fiber optic technology. As FO technology largely differs from conventional copper cable technology, this chapter will not only deal with planning aspects, but will also discuss some issues to facilitate the general understanding of this technology.

This chapter is arranged as follows:

- FO applications
- Potential separation and lightning protection
- Optical transmission path
- Principle of operation of fiber optic cables
- Electro-optical transducers or OLMs (Optical Link Modules)

#### FO applications

In plant areas where heavy electromagnetic interference fields or large potential differences can be expected, you should use FO technology for connecting plant parts when planning PROFIBUS cabling.

The benefits of using fiber optic technology for data transmission are:

- Large distances can be covered.
- Complete galvanic isolation between segments coupled by means of FO cables.
- Insensitivity of cables to electromagnetic interference (EMI).

The diagrams below illustrate applications for the use of FO technology. OLMs are used for conversion from electrical to optical data transmission (for OLMs see chapter 3.4.1.1).

## Planning the cabling

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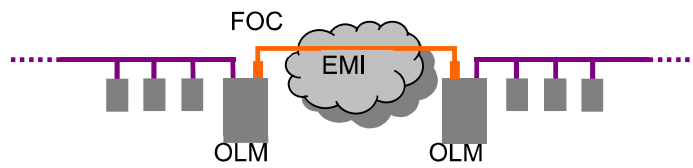


Figure 3-33: Application of FO technology with EMI

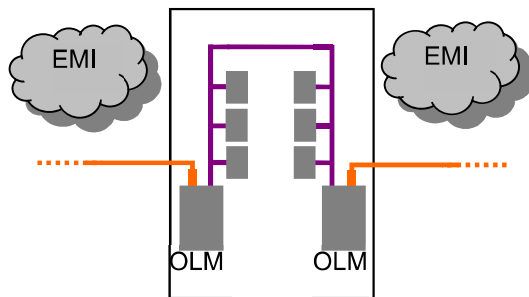


Figure 3-34: Application of FO technology for connection of cabinet with EMI

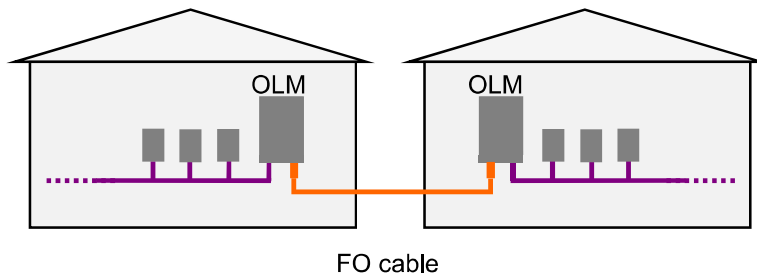


Figure 3-35: Application of FO technology for the connection of buildings

### Potential separation and lightning protection



When using FO cables, the transmit and receive site are connected by means of isolating fibers and can therefore be at electrically different potentials without causing interference.

If possible, use FO cables to connect buildings and premises.

If possible, use FO cables for connections between two floors.

### Optical transmission path

An optical transmission path includes:

- An electro-optical transducer acting as a transmitter which converts electrical signals to optical signals.
- A passive optical path formed by a fiber optic cable with appropriate connectors which attenuate the amplitude of the optical signal.
- An opto-electrical transducer acting as a receiver which converts the received optical signals into electrical signals.

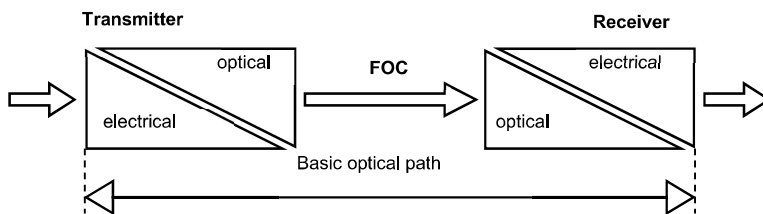


Figure 3-36: Basic optical path

## Planning the cabling

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The feasibility of optical transmission paths depends on the attenuation characteristic of the used components, on the transmission power of the transmitter and on the input sensitivity of the receiver. After selecting the components you should therefore check the attenuation budget of these components. This way you can determine whether the signal, attenuated by the transmission path, can be correctly interpreted by the receiver (chapter 3.4.7).

Please note that two fibers are always required to connect two components. These two fibers are usually combined in a so-called duplex cable.

### Principle of operation of fiber optic cables

FO cables consist of an optically transparent core and a sheath. Data transmission using FO cables is based on the principle of total internal reflection of irradiated light between core and sheath. Total internal reflection is only possible if the core and sheath have slightly different refraction indices. The fibers are protected by means of additional layers made of various materials.

FO cables are basically divided into glass fiber (single- and multi-mode) and plastic optical fiber (POF). HCS is a hybrid fiber with a glass core and a plastic sheathing. The following fiber types are normally used for FO cables (see chapter 3.4.3):

- Glass fiber (single-mode)
- Glass fiber (multi-mode)
- HCS (Hard Cladded Silica)
- POF (Plastic Optical Fiber)

### 3.4.1.1 Electro-optical transducers

Electro-optical transducers (OLM) are the links between the electrical part and the optical part of the network. OLMs convert electrical signals to optical signals and feed them into the connected FO cables. At the other end, appropriate OLMs convert the received optical signals into electrical signals. As described below, different topologies can be implemented using OLMs.



OLMs are active components requiring a power supply. You should provide an appropriate power supply in your planning.

#### Line topology

A line topology is implemented by connecting individual OLMs in pairs by means of duplex cables (duplex cable, see chapter 3.4.4). For this purpose, you simply need OLMs with one optical channel at the end of each segment, and OLMs with two optical channels in between. Both individual nodes and complete segments can be connected in RS-485 technology to each OLM (Figure 3-33).

#### Ring topology

A ring topology is implemented by connecting individual OLMs in pairs using duplex cables. In contrast to line topologies, ring topologies use OLMs with two optical channels.

Both individual nodes and complete segments can again be connected in RS 485 technology to each OLM.

#### Star topology

By connecting a number of OLMs to the PROFIBUS DP a star topology can be formed.

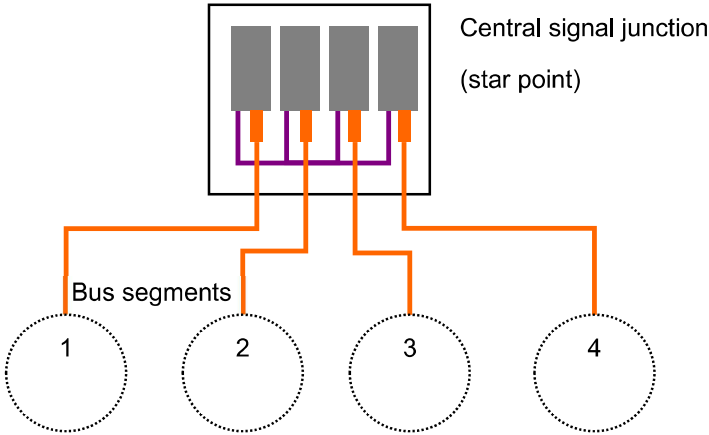


Figure 3-37: Star topology using OLMs

### 3.4.2 Optical connection technology

Various connector types are available for FO cables. They are described in this chapter. Possible connector assemblies are discussed in chapter 3.4.5.

Patch panels and splice boxes are also described as components for structured FO cabling.

This chapter is arranged as follows:

- Recommendation for connectors
- BFOC connectors



Typical attenuation values are provided for connectors in the manufacturer specifications. However, the actual attenuation not only depends on the quality of the connector, but to a large degree also on the optical transition between the fiber ends to be connected, i.e. on the quality of connector assembly.

### 3.4.2.1 Recommendation for connectors

#### Glass fiber cable

For glass fiber cable (single mode E 9/125 or E 10/125, multi-mode G 50/125 or G 62.5/125), use type BFOC/2.5 connectors according to IEC 60874-10.

#### Plastic fiber/hybrid fiber POF and HCS

For POF and HCS we also recommend the use of BFOC/2.5 connectors. In addition, there are various manufacturer-specific connectors for PROFIBUS devices with POF/PCF interfaces.



Connectors are selected according to the devices to be connected (usually OLMs). Please see the manual of the manufacturer to find out which connectors are recommended. BFOC/2.5 connection systems are the standard.

### 3.4.2.2 BFOC connectors

These connectors are recommended as default connectors in the PROFIBUS standard. Different versions are widely used for all FO types (single-mode, multi-mode, PCF, POF).

A bayonet-type system is used to lock the connector, with a metal pin preventing the connector from twisting.



Figure 3-38: BFOC (ST) connector

### 3.4.3 Selecting fibers

Various types of fibers are available for use with FO cables, selection of which should consider the requirements of the planned automation project.

This chapter is arranged as follows:

- Properties of fibers
  - Maximum transmission distance
  - Attenuation and wavelength
- Support for the selection of fibers
  - General notes
  - Fiber selection for existing devices
  - Fiber selection without existing devices

### 3.4.3.1 Properties of fibers

#### Max. transmission distance

Only a limited transmission distance can be achieved with each type of fiber due to the relevant attenuation and the used operational wavelength.

**Table 3-13: Maximum transmission distances of fiber types**

Fiber type	Transmission distance
Single-mode glass fiber (9 / 125 $\mu\text{m}$ )	up to 15 km
Multi-mode glass fiber (50-62,5 / 125 $\mu\text{m}$ )	up to 3 km
PCF or HCS fiber* (200 / 230 $\mu\text{m}$ )	up to 500 m
Plastic fiber (980 / 1 000 $\mu\text{m}$ )	up to 100 m
* PCF and HCS are trademarks	



Table 3-13 only indicates typical limits of the transmission distance attainable with various types of fiber. These values can be optimized by using so-called long distance OLM versions.

#### Attenuation and wavelength

The attenuation of a fiber is directly related to the operational wavelength.

**Table 3-14: Attenuation and wavelength of fiber types**

Fiber type	Wavelength [in nm]	Attenuation [in dB/km]
Single-mode glass fiber (9 / 125 $\mu\text{m}$ )	1 320	$\leq 1.0$
Multi-mode glass fiber (50-62,5 / 125 $\mu\text{m}$ )	850	$\leq 2.7-3.5$
PCF or HCS fiber* (200 / 230 $\mu\text{m}$ )	660	$\leq 10$
Plastic fiber (980 / 1 000 $\mu\text{m}$ )	860	$\leq 230$
* PCF and HCS are trademarks		



The attenuation values listed in Table 3-14 are only typical limit values. Many cable manufacturers produce cables with lower attenuation values, which results in longer attainable transmission distances than those listed in Table 3-13. In any case please observe the specifications of the fiber or cable manufacturer.

### 3.4.3.2 Support for the selection of fibers

#### General notes

Although it is possible to use different types of fiber in the same plant, it is not recommended as the mixing of different fibers requires additional tools and equipment resulting in higher costs.

- If the majority of the links or segments in a plant area can use plastic and perhaps only one run needs glass then it makes sense to use different fibers
- If most of the links or segments use glass fiber and only a few need to be plastic fiber then the additional tools, materials and devices would cause higher costs

#### Fiber selection for existing devices

If you already have devices which are designed for connection to a certain type of fiber, you should first determine the maximum transmission distances that can be achieved with these devices or these fibers.

Check the devices for the following features:

- Power output of transmitter
- Required receive power of the receiver (receiver limit value)
- Supported type of fiber

## Planning the cabling

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Using these device specifications (features) it is possible to determine the maximum distances possible by means of a certain type of fiber. You should first calculate the attenuation losses possible using these devices.

### Permissible attenuation losses:

$$A_{\text{perm.}} = P_T - P_R$$

$A_{\text{perm.}}$  : Permissible attenuation losses in dB

$P_T$  : Power output of transmitter in dBm

$P_R$  : Required receive power of receiver in dBm

You should deduct approx. 20% from this result to make sure there is sufficient reserve for any coupling sites that may occur along the path.

After that you should calculate the transmission distance attainable with this fiber. Please see Table 3-14 for the attenuation of the respective fiber.

### Maximum attainable transmission distance:

$$L = \frac{A_{\text{perm.}}}{a_{\text{fiber}}}$$

$L$  : Attainable distance in km

$A_{\text{perm.}}$  : Determined permissible attenuation losses in dB

$a_{\text{fiber}}$  : Attenuation of fiber in dB/km



You should use a device only in conjunction with the fibers specified for this device.



The attenuation values listed in Table 3-14 only are typical limit values. Check the manufacturers' specifications concerning fiber attenuation as soon as a specific cable type has been decided.

You have the following options in case the maximum transmission distance attainable with these devices is not sufficient:

- Segmentation of a line and use of an additional OLM as optical repeater.
- Change to a different type of fiber that allows a longer distance (e. g. PCS instead of POF, glass multi mode fiber instead of PCF, single mode fiber instead of multi mode fiber). When changing to a different kind of fiber, check if a different optical interface at the OLM or a different type of OLM is needed.

### Fiber selection without existing devices

If no devices exist, the fiber type should be selected according to the transmission distance to be covered. For this purpose you can use the values listed in Table 3-13. When purchasing devices, make sure that the devices are suited for connection to the relevant fiber type.



Use the data provided in this chapter to determine the fiber types required for your transmission distances. Enter this data in the prepared segment structure plans.

### 3.4.4 Selecting cables

No special FO cables are prescribed for PROFIBUS although a large range of types are available. However, only certain FO cables are normally used for PROFIBUS. This chapter offers guidance on those types of cables. For special requirements of FO cables, you may have to contact the cable manufacturers directly.

This chapter is arranged as follows:

- Properties of FO cables
  - Optical properties
  - Mechanical properties
  - Chemical properties
- Types of FO cables
  - Cable types based on glass fibers
  - Cable types based on plastic fibers

### 3.4.4.1 Properties of FO cables

The information in this chapter serves as a general introduction to the different properties of FO cables to be considered. The selection of the cables required for your transmission path will be described in detail in chapter 3.4.4.2.

#### Optical properties

The optical properties of FO cables largely depend on the type of fiber used (see chapter 3.4.3.1).

#### Mechanical properties

The mechanical properties of the cable give guidance on the area of application and the range of use. In order to give an overview, Table 3-15 gives an overview on specific mechanical properties. These values come from IEC 61784-5-3.

**Table 3-15: Mechanical properties of FO cables (according to IEC 61784-5-3)**

	<b>Glass fiber cable</b>	<b>PCF or HCS fiber cable</b>	<b>Plastic fiber cable</b>
<b>Minimum bending radius</b>	50-200 mm	75-200 mm	30-100 mm
<b>Tensile strength</b>	500-800 N	100-800 N	50-100 N
<b>Permanent tensile force</b>	500-800 N	<=100 N	not allowed
<b>Cross pressure strength</b>	300-500 N/cm	<=75-300 N/cm	50-100 N/cm

## Planning the cabling

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The cable properties in the above table cover the requirements of most current industrial applications. Special applications such as trailing cables, festoon cables or torsion movement may require special cables outside the normal range.

### Chemical properties

FO cables, just as the copper cables described above (see chapter 3.1.1.1 and 3.2.6.1) use various sheath materials which allow them to be used in various applications.

Typical types are:

- UV resistance
- Freedom from silicone
- Resistance against mineral oils and greases
- Permitted temperatures

For FO cables as well, special attention must be paid to the flammability of the cable. Manufacturer specifications include:

- Freedom from halogen
- Flame retardance
- Smoke density



Only halogen-free and flame-retardant cables may be used in areas where human life may be threatened by toxic gas and smoke in case of fire.

### 3.4.4.2 Types of FO cables

The following section describes the available FO cable types.

#### Cable types based on glass fibers

Table 3-16 lists the most common types of cable for PROFIBUS and their applications.

**Table 3-16: Versions of FO cables**

Cable version	Applications
Duplex cable	For simple point-to-point links between two devices
Break-out cable	For parallel FO paths with optional cable assembly
Universal cable with buffered fiber design	For parallel FO paths, interconnect the patch fields or splice boxes



When using parallel FO cables it is recommended that a single cable be used to reduce costs. Plan for spare fibers in this cable.

### Duplex cable

Duplex cables consist of two parallel fibers. Some manufacturers use a thin plastic link to connect the two fibers/wires. In this case the wires can easily be separated and assembled. Duplex cables are also available with a sheath enclosing both fibers.

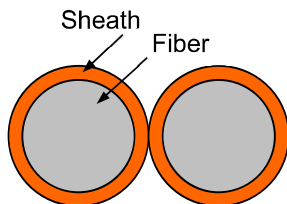


Figure 3-39: Duplex cable



These cables should only be used under minor mechanical stress.

### Break-out cable

Break-out cables consist of several fibers with a common sheath. These cables can be directly fitted with connectors since each fiber is enclosed as a separate wire. PROFIBUS FO cables typically consist of two fibers. Break-out cables are usually available with a higher number of fibers (e.g. 2 to 48 fibers)

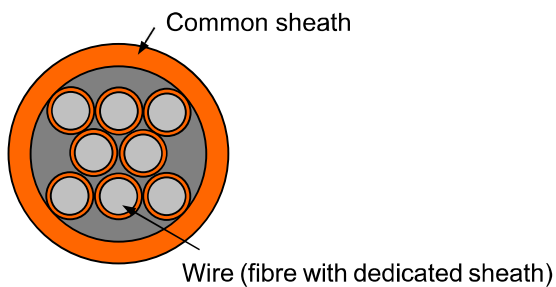
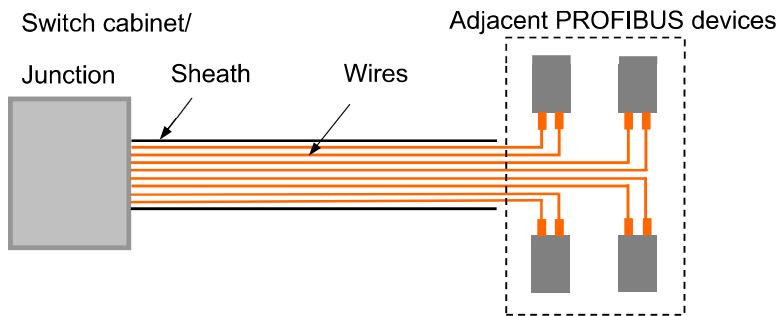


Figure 3-40: Break-out cable

Since no individual wires can be lead through the cable, the connection points of the connector at the respective end point of the cable should not be too far apart. Strip the insulation of the cable sheath starting from the first branching wire. Figure 3-41 illustrates this situation.

**Useful application for multi core break-out cable**



**Use of break-out cable not recommended**

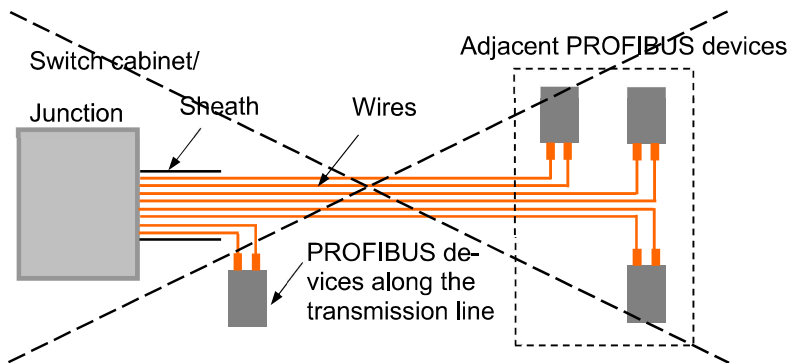


Figure 3-41: Problem when stripping break-out cables



Only use these cables if the fibers at both end points of the cable are to be connected by means of connectors and if the connection points of the connectors are close to each other.

### Universal cable with buffered fiber design

Unlike a break-out-cable the single wires in universal cables based on buffered fiber design do not have a protective sheath. Therefore they cannot be directly fitted with connectors. The fibers lie as bundle in one or several plastic tubes. This type of cable is usually available with 2 to 48 fibers.

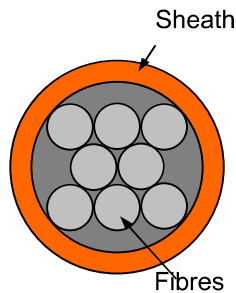


Figure 3-42: Universal cable with buffered fiber design



Use this cable only for direct connection to splice boxes or patch panels.

### Cable types based on plastic fibers

Due to the relatively short transmission distances, plastic fibers are usually used only with the following types of cable:

- Duplex cables (see Figure 3-39)
- Break-out cables with two fibers



Determine the cables required for the FO links. This should be done separately for each line using the cables and connections overview and the segment structure plans. From this create a material list with.

### 3.4.5 Determining connections

Several types of connections are available for the connection of bus nodes or components with FO cables. The following section describes the advantages and disadvantages of each.

This chapter is arranged as follows:

- Connection via connector for glass fiber cables
  - Field assembly of cables
  - Splicing of pigtails
  - Use of ready-made cables
- Connection via connector for plastic fiber cables
  - Field assembly of cables
  - Use of ready-made cables
- Connection by means of direct clamping



The type of connection is determined by the connection on the device.

### 3.4.5.1 Connecting FO cables using connector

For FO cables, the PROFIBUS standard requires type BFOC/2.5 connectors for the connection of devices. This connector is standardized and is offered by many manufacturers using the product name "ST connectors". The assembly options for cables described below exclusively refer to this type of connector.

#### Field assembly of cables

An adhesive technology is usually used to fit the connectors to glass fiber cables. This method is suitable for field assembly under normal environmental conditions, but can be very time consuming. Additional cutting tools, exactly customized to the fiber and connector, are required. Such cutting tools are offered by various connector manufacturers in so-called "assembly cases".



Please note that the BFOC/2,5 type connector is available for different types of fiber. Check the manufacturer's specifications to ensure the connector and fiber match.



Field assembly of glass fiber cables requires special tools and trained personnel.

### Splicing of pigtails

Pigtails are short cables with a pre-assembled connector at one end, which are connected to installed FO cables by using suitable splicing devices; this type of assembly is well suited for field assembly. Assembly using pigtails has the following advantages and disadvantages.

#### Advantages:

- Precise alignment of fiber core in the connector
- Minor expenditure of time and costs for assembly
- Well suited for field assembly (even under adverse environmental conditions, depending on splicing device)

#### Disadvantages:

- A splicing device and trained personnel is required for assembly.
- Each optical connection, in this case the splice, results in additional attenuation losses.
- Additional protection of splice required.



If specialist splicing is not available then it may be necessary to employ a specialist company.

### Use of ready-made cables

Most cable manufacturers offer ready-made cables with various designs and lengths. Some manufacturers even offer the assembly of cables tailored to the individual requirements of the buyer. Ready-made cables have the following advantages and disadvantages:

#### Advantages:

- Lower overall costs compared to splicing solutions or field assembly of connectors.
- Short installation time due to easy and safe handling.
- Quality check of connector assembly already at the manufacturing plant.

#### Disadvantages:

- Connectors are mechanically put at risk when installing them in cable ducts.
- Cable length must be known at the time of ordering.



The use of ready-made cables makes sense in the following cases:

- There are only few cables to be assembled.
- Your company has no equipment for fitting connectors.
- Your company does not have specialist knowledge of FO cable assembly

### 3.4.5.2 Connection of plastic fiber cables using connectors

For plastic fiber cables, the use of type BFOC/2,5 connectors is recommended. However, many devices are available with other connector types, such as the FSMA connector or company-specific solutions. Since the assembly of plastic fiber cables with such different connector types is almost alike, this chapter only describes the general requirements for cable assembly.

#### Field assembly of cables

Fitting connectors to plastic fibers is a simple and well suited method for field assembly. Most connector manufacturers offer assembly sets specially configured for the assembly of plastic fibers.



The assembly of plastic FO cables is, compared to the assembly of glass fiber cables, easier to learn and requires less effort for assembly tools.

#### Use of ready-made cables

Many cable manufacturers also offer ready-made plastic fiber cables. The pre-assembled connectors of these cables usually are of higher quality.



Ready-made plastic fiber cables should be used in the following cases:

- There are only few cables to be assembled.
- No suitable assembly tools are available.
- The required cable lengths are known in advance.

### 3.4.5.3 Connection by means of direct clamping

Some devices have an exclusive connection option where the plastic fiber is fed directly into the housing to the transmitter or to the receiver. The fibers are fixed using a clamping device.



Please observe the manufacturer specifications in case of connection by means of direct clamping. Only fiber types approved by the manufacturer may be connected. In some cases special tools for front face treatment may also be required.



Determine or check the connections of the FO components contained in the segments. For this purpose, use the cables and connections overview created before.

Create a dedicated material list for each required connector or pigtail version.

### 3.4.6 Determining fiber-fiber couplings

For a transmission path using fiber optic cables it may be necessary under certain circumstances to interconnect two cables or fibers. The direct connection of two fibers is called a fiber-fiber coupling and must be considered separately for the different fiber types.

This chapter covers the following items:

- Fiber-fiber coupling of glass fibers
- Fiber-fiber coupling of plastic fibers



When using fiber-fiber couplings, ensure both fibers are of the same type with the same core diameter otherwise coupling losses would be too high.

#### 3.4.6.1 Fiber-fiber coupling of glass fibers

Fiber-fiber coupling of two glass fibers must be provided in the following cases:

- To connect a pigtail with an installed FO cable
- To implement a long transmission path which requires several FO cables
- In case of very complex installations, if a cable has to be pulled through several cable ducts, it is easier to pull several cable lengths. These cable lengths can be connected later by means of a fiber-fiber coupling.
- For potential repair purposes

### Fiber-fiber coupling by means of splicing

We talk here about thermal splicing where the fiber ends are fused directly with each other by using an electric arc. Consider that special tools will be required.



Thermal splicing of glass fiber yields very low attenuation losses ( $<0.2$  dB), giving a permanent and high-quality coupling. Note that the splice point has to be protected and special splice sets are available for this purpose.

### Fiber-fiber coupling by means of plugging

A fiber-fiber coupling of glass fibers can also be implemented by plugging together two connectors fitted to the fibers.



Fiber-fiber coupling of glass fibers implemented by plugging together two connectors is a good alternative to splicing. Due to the higher attenuation losses, however, this method should only be used if no splicing device is available.

### Fiber-fiber coupling by means of clamping

Clamping mechanically (mechanical splicing) couples the faces of the fibers mechanically together. Various products for aligning and clamping the fibers are available. Compared to thermal splicing, mechanical splicing has a higher attenuation loss.

For a permanent solution, thermal splicing is the preferred method.



If possible, you should use this type of coupling for repair and test purposes, only. For single-mode glass fibers clamping connections should not be used at all. Various versions of these products are available on the market under the name "mechanical splices".

### 3.4.6.2 Fiber-fiber coupling of plastic fibers

Due to the mechanical properties of plastic fibers, fiber-fiber couplings can only be achieved by clamping or by the use of two connectors attached to the fibers. However this is not recommended due to the high attenuation losses and should only be used in exceptional circumstances. If clamping of plastic fibers is used the attenuation budget (chapter 3.4.7) should be re-calculated. Various clamping solutions are available.



Check the FO links for potential fiber-fiber coupling points and document them in the segment structure plans.

### 3.4.7 Checking FO paths

This section checks the FO paths as previously described and considers the attenuation of the signal and is arranged as follows:

- Terms used for the calculation of attenuation budgets
- Attenuation budget



The calculation and the graphical display of the attenuation budget shows, whether the planned FO link meets the transmission requirements.



You should therefore check your planned FO links according to the given example.

### Terms used for budget calculation

- The output power is the transmitter power that can be fed into the fiber.
- The receiver thresholds describe the operable range of the receiver (dynamic range). In this context, “overmodulation” describes the highest and “sensitivity“ the lowest level.
- The level budget is the resulting dynamic range of the transmitter/receiver combination (difference between output power and sensitivity).
- The total attenuation includes:
  - the fiber attenuation of the FO cable
  - coupling losses of connectors and splices, if applicable
  - a system reserve
- The system reserve accounts for the transmitter power loss caused by aging.
- The fiber attenuation describes the attenuation of the FO cable.
- The specific fiber attenuation is the attenuation of an FO cable related to the length.
- The cable length results from the ratio of the fiber attenuation contained in the total attenuation and of the specific fiber attenuation.

### Attenuation budget

You need the following (manufacturer) specifications to calculate the attenuation budget:

- **Transmitter:** Output power coupled to the fiber in dBm
- **Receiver:** Sensitivity in dBm
- **FO cable:** Specific fiber attenuation in dB/km
- **Length** of FO cable.
- Number of splices
- Number of connectors

The following calculation verifies the requirements for the FO link.

### Transmit power - total attenuation $\geq$ receiver sensitivity

The total attenuation (fiber attenuation, coupling losses and system reserve) is largely determined by the cable length.

Based on the configuration of the components of the basic optical link you can calculate the attenuation budget as follows (specified values depend on the installation quality and should therefore be considered as practice-related examples):

- From the minimum transmitter power (in dBm, related to 1 mW) you deduct:
- The fiber attenuation of the total link (specific fiber attenuation  $\alpha$  in dB/km multiplied by the FO cable length in km)
- The splice points, multiplied by the typical splicing attenuation of approx. 0.2 dB
- The number of BFOC connections, multiplied by the maximum coupling attenuation of:
  - POF/HCS 1.5 dB
  - Multi-mode 0.75 dB
  - Single-mode 0.75 dB

## Planning the cabling

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- a planned system reserve of approx. 3 dB.

If the result is higher than the receiver sensitivity in dBm (also related to 1 mW), the optical link is acceptable. If not then an additional repeater, transmitter or a verification of the required cable length should be considered.

Table 3-17 shows example calculations for the following fiber types:

- SM Single-mode glass fiber 9 / 125  $\mu\text{m}$  (step index profile)
- MM Multi-mode glass fiber 62.5 / 125  $\mu\text{m}$  (gradient index profile)
- HCS HCS fiber 200 / 230  $\mu\text{m}$  (step index profile)
- POF Plastic fiber 980 / 1000  $\mu\text{m}$  (step index profile)

**Table 3-17: Examples for level budget calculations for various optical fibers**

	SM	MM	HCS	POF	Unit
<b>+ Output power</b>	-20	-15	-16	-6	dBm
<b>- Receiver sensitivity</b>	-27	-24	-22	-20	dBm
<b>Level budget (difference)</b>	7	9	6	14	dB
<b>= Total attenuation</b>	7	9	6	14	dB
<b>(Max.) cable length</b>	8 000	1 700	300	44	m
<b>Spec. fiber attenuation</b>	0,5	3,5	10	250	dB/km
<b>Fiber attenuation</b>	4	6	3	11	dB
<b>System reserve</b>	3	3	3	3	dB

## 4 Planning plant acceptance

## **Planning plant acceptance**

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Acceptance and commissioning of a PROFIBUS plant is a multi-stage process. The individual steps of acceptance and commissioning are correlated. This series of documentation includes a separate document, the “PROFIBUS Commissioning Guideline“ (Order No.: 8.032) which describes the process of acceptance and commissioning.

In addition to a detailed description of the implementation of the individual steps, the “PROFIBUS Commissioning Guideline“ also includes log templates for the measurements to be carried out.

The information provided in this chapter will allow the planning supervisor to estimate the time required for commissioning and to add this time to the project plan.

## Planning plant acceptance

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The acceptance of the PROFIBUS plant includes the following steps:

- Step 1: Visual check:

The installed PROFIBUS cables are visually checked for ensuring observance of bending radii and correct installation, i.e. segregation distances.

- Step 2: Acceptance measurements:

The electrical properties of PROFIBUS copper cables are checked for observance of line parameters using a line tester. Check for cable break, shorts, observance of maximum permissible length etc. After installation of connectors, the attenuation of the FO cables is measured.

Step 3: Project planning:

For the commissioning of the connected PROFIBUS devices, the planning of the master station includes preparing the inputs and outputs of the connected PROFIBUS devices for reading and writing.

- Step 4: Checking the address setting of PROFIBUS nodes:

If not pre-configured, PROFIBUS devices need to have their addresses set accordingly.

- Step 5: Commissioning master and slaves

Using the master class 1, check whether all PROFIBUS devices can be read and whether there are any errors

- Step 6: Checking signal inputs:

Check whether all signal inputs of the connected PROFIBUS devices can be read correctly.

- Step 7: Checking signal outputs:

Check whether all signal outputs of the connected PROFIBUS devices can be written correctly.

- Step 8: Creating acceptance protocol:

Documentation of the results.

## 5 Annex

## 5.1 PROFIBUS Documentation

This chapter makes a proposal for the documentation of PROFIBUS networks. The notes are to be regarded as recommendations. Depending on the conditions in the system or in the company, it is possible to deviate from the specifications.

### 5.1.1 PROFIBUS information relevant for documentation

Prior to starting the documentation, the following aspects should be clarified:

- Responsibilities
  - For the creation of the network documentation
  - For the management of the network documentation
  - Are there any persons responsible for the plant? Are there any responsibilities for individual plant sections?
- How and where will the documentation be distributed?

The cover page should contain all relevant information needed for identifying the document:

- ID of the documentation
  - Document type (here: Network documentation)
  - ID number / name
  - Date of issue
  - Revision index or version
  - Revision date
  - Document status (is it a draft or final version?)
  - Specific data (customer name, plant name)
- Information on the creator
  - Company name
  - Company address
  - Responsible author

The network documentation should range from a network overview for the entire plant over detailed views of the networks of plant section up to device-specific information. A topology overview is a visual representation and, hence, provides a good introduction.

- For example an R&I diagram or the architecture.
- Draw the bus nodes.
  - Automation devices
  - Bus infrastructure
    - Cabling
    - The cabling order must be represented correctly.
  - The persons responsible of the plant must be noted.
- The identifiers/names of the devices must be included.

- Device type (e.g. PLC, repeater, etc.)
- Make a clear allocation to the locality.
  - Specify the building (part).
  - Specify the room.
  - Make a note of the spot height to allow for easy device localization (e.g. in a high-bay storage).
  - Note the cabinet.
- The connection terminals (ports) of the devices must be designated.
- Segmentation plan
- Information on the cable
  - Cable length between two nodes
  - Used cable type (included in cable list?)
  - The medium must be noted.

For reasons of simplicity, further information should be documented in a separate Annex about topology.

- Information on the products
  - Manufacturer
  - Serial numbers of the devices
  - Model name / type designation
  - Spare parts
    - Serial number
    - Order number
    - Version number
    - Supplier (or alternative supplier)
    - Reference picture
  - Store data sheets.
  - Describe the device functionality.
  - Certificates
  - Used software or firmware revision levels
- Document the reference measurements of the network.
  - Measure and document the network load in normal operation.
  - Mark any points where EMC disturbances have to be expected.
  - Validation report of the physical layer (what are the physical variables during commissioning?)
  - Validation report of the communication layer (what does data modulation look like?)
  - Validation report of the hazardous area (which devices are used in the hazardous area?) Are these devices certified?
  - Are there any delays? How long is the delay?
- Information for cases of faults
  - List for fault localization

- Description of integrated diagnostic systems
- Drawings and diagrams
- Contact information for further help (hotline/support)
- Who is responsible of the plant (parts)?

The following information is required for PROFIBUS networks

- Where are terminating resistors?
- Where are diagnostic connectors?
- The device addresses must be noted at the nodes in the plan.
- Note the data transmission rate (Mbit/s) of the segments.
- Which protocol is used?
- Are the GSD files saved? Which GSD files are used?

### **5.1.2 Proposal for a PROFIBUS forwards documentation**

This section is intended to further explain the information in section 5.1.1. The individual steps of forwards documentation are discussed and the difficulties are described.

A network documentation often addresses more than one target group (persons in charge of the installation, revision, operation, troubleshooting or audit). In a simplified approach, however, it is possible to identify two fields of interest (see Figure 5-1).

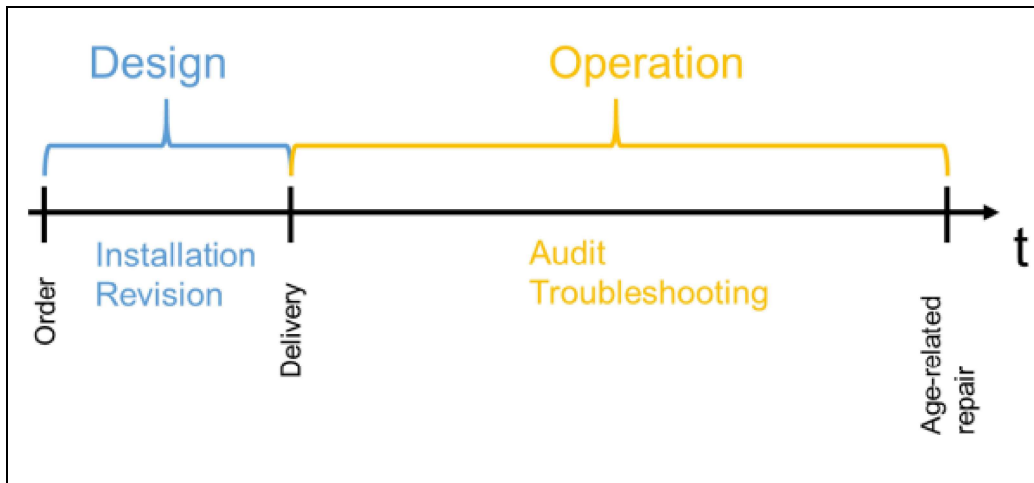


Figure 5-1: Fields of interest in a plant lifecycle

As the installation and revision departments normally use electrical wiring diagrams, the plant operators are the main target group of the network documentation.

The next step defines the format in which the network documentation is to be created. It must be clarified whether printed plans are to be published or digital documentation is to be used instead. Mind the fact that sensitive data must be access-protected. Digital plans must be saved in a file format which ensures (read and write) access and data readability and integrity. Also pay attention to the retention obligation. The documentation must be available for the retention period.

The persons responsible for the document creation and management during the operation phase must be defined. For large companies or plants the persons responsible for the corresponding plant or plant sections must be contacted.

Every forwards documentation begins with a cover page. The cover page should provide the information relevant for identification (plant, creator, responsibility). The document revision information (index, date) provides the revision level and allows you to clearly determine whether the document is up to date. It is also useful to indicate the status on the cover page. Moreover, it must be possible to clearly identify the creator for possible questions.

A table of contents must be included after the cover page. The more details the table of contents contains, the better, as you can directly access the information needed.

Begin with the topology plan. A template of the architecture of an R&I diagram is helpful. All necessary network nodes must be integrated and numbered consecutively. Assign a unique device name. The name contains the type or function of a node and should also be enhanced with its location (building or building part, room). Indicating the spot height is useful in high

halls (e.g. a high-bay storage). For each device, write down the device name, the device address and the status of the terminating resistor (on or off). Document the transmission rate (kbit/s or Mbit/s) for every segment.

Then add the connections of all network nodes. Be sure to draw the connections in the correct order. The port of each node must be noted in the plan to allow for unique identification of the device connectors. Is it useful to assign a unique name to each connection (does a cable list exist?) and to note down the length of the laid cables (actual length).

Any further information and details should be moved to the Annex in order to keep the actual overview short and clear. It is recommended to list all further information in the Annex in a table and group the individual items by categories (products, cables).

Every network node should be specified in details by the information listed in Table 5-1. Additionally, the used GSD files must be saved. All data sheets and certificates must also be stored. Saving a functional description of the device is helpful. Defective devices can be replaced quickly by means of an exact list of information. It is recommended to record in the documentation not only the information shown in Table 5-1, but also the serial number, (alternative) suppliers and a picture of the node.

Add a network load calculation and measurement results of the network load in the individual segments to the network documentation. Also record the data communication delays in the commissioning phase. Areas where EMC disturbances are likely to occur must also be marked. It is helpful to add a validation report for the physical layer and the communication layer. The reports should indicate whether and to which extent the physical (current, voltage) and communication-related (edge rise and fall times) PROFIBUS requirements were initially met by the plant. If required, provide a validation report about the hazardous area or the corresponding certificates.

Document the integrated diagnostic systems (diagnostic connectors) and note the data of contact persons who may provide support (e.g. line manager, consultant engineer, hotline and support).

**Table 5-1: Further information on the devices in the topology**

No.	Device name	Manufacturer	Model/type	HW revision level	Firmware revision level	Serial number
1	HMI+HA1_1	Manufacturer 1	HMI 17	1.3	1.3.1	ABC-12345
2	PLC+HA1_1	Manufacturer 2	PLC 5	2.0	2.2	1920-1812-8212-0

### 5.1.3 Example of a PROFIBUS forwards documentation

Table 5-2 shows the preliminary considerations.

**Table 5-2: Example of PROFIBUS forwards documentation, preliminary considerations**

Target group	Operator, special knowledge yes, special language yes	
Target country/language	Germany/German	
Type of publication	Printed documents, centrally managed plans, access only by counter-signature	
Number of copies	3 (1 design dpt, 1 operator, 1 external backup copy)	
Retention period	12 years, ensured by storage of printed plans in different locations	
Responsibilities	Creation	Company A, Mr. Sample
	Management	Company B, Ms. Example
	Plant	Ms. Meyer (administration) Mr. Smith (hall 1) Ms. Schulz (hall 2)

Figure 5-2 shows a cover page example.

<h1 style="margin: 0;">Network Documentation</h1> <h2 style="margin: 0;">PROFIBUS</h2>			
Plant: ID No.: Issue date: Status:	Plant sections in hall 1 2508 25.08.2016 Released	Revision:	
		Index	Date
		Created by	Approved by
		1	
		2	
		3	
		4	
Customer:		Customer Ltd. Customer Road 2 56723 Customer City	
Created by:	Company Inc. Example Road 12 123456 Example Town	Responsible author: Mr. S. Sample	

**Figure 5-2: Cover page example for PROFIBUS forwards documentation**

The information provided on the cover page should be repeated on all other pages. A title block on each page is a suitable means of achieving this. The title block must be placed in the bottom right corner of each page and contains all relevant information on the document. Table 5-3 lists the 15 most important items. Table 5-4 shows the structure of the title box in accordance with [ISO 7200] and Table 5-5; it also contains an example of the title box which will be represented on the following pages by a grey box for the purpose of simplification.

Table 5-3: Information in the title box in accordance with [ISO 7200]

Number	Data field
1	Legal owner of the document
2	Title
3	Supplementary title
4	Reference number
5	Change index
6	Date of issue of the initial version of the document
7	Language
8	Number of pages/sheets
9	Document type
10	Document status
11	Responsible department
12	Technical reference (contact person with required knowledge)
13	Name of the person who created the document
14	Name of the person who approved the document
15	Classification/key words

Annex

Table 5-4: Table 4: Proposal for title box in accordance with [ISO 7200]

<b>Responsible dept.</b> (11)	<b>Technical reference</b> (12)	<b>Created by</b> (13)	<b>Approved by</b> (14)		(15)
		<b>Document type</b> (9)			
(1)		<b>Title, Supplementary title</b> (3)	(4)		<b>Rev.</b> (5)

Table 5-5: Example of title box in accordance with [ISO 7200]

<b>Responsible dept.</b> Design 2	<b>Technical reference</b> Ms. N. Meyer	<b>Created by</b> Mr. S. Sample	<b>Approved by</b> Mr. K. Smith					
				<b>Document type</b> Network Documentation	<b>Document status</b> Released			
Company Inc.		<b>Title, Supplementary title</b> PROFIBUS Plant sections in hall 1	2508					
								<b>Rev.</b> A

Figure 5-3 shows the plant to be automated. It consists of three plant sections in hall 1 (responsible: Mr. Smith) of a company. A cabinet is already planned to be installed in the hall; therefore, it is represented by a dotted line.

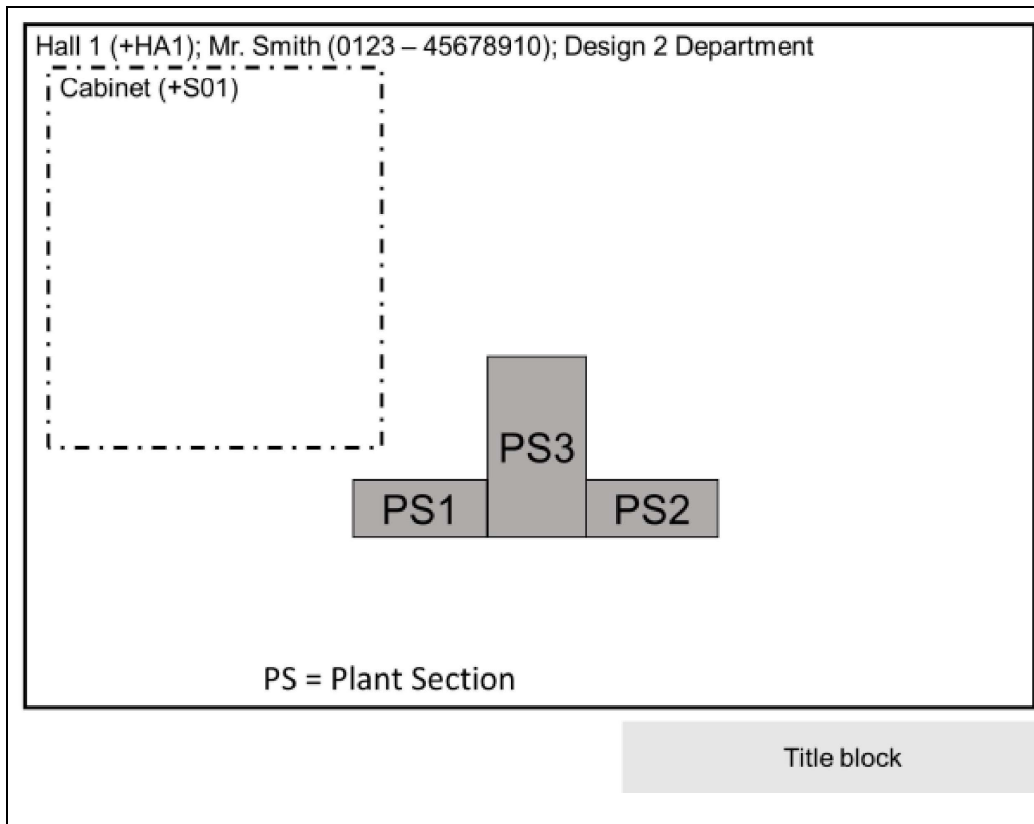


Figure 5-3: Example of forwards documentation for the automation of three plant sections

Figure 5-4 shows the configured automation devices and the required network infrastructure. In addition to a PLC and three remote IOs, there is a switch for connecting the network nodes and an HMI (Human Machine Interface) for visualizing the process.

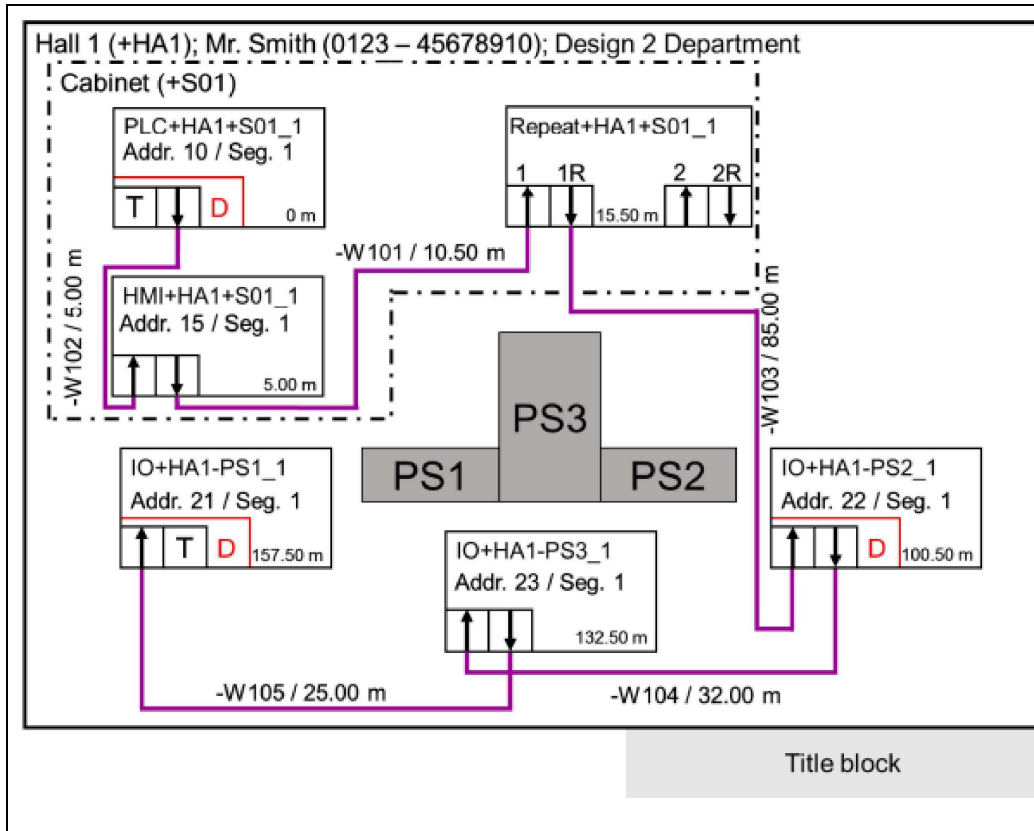


Figure 5-4: Example of PROFIBUS forwards documentation, physical topology plan

Table 5-6 contains further information on the automation devices and additional network nodes. Table 5-7 provides additional information for the replenishment. Table 5-8 summarizes the most important information about the cables. An enhancement of the cable list is shown in Table 5-9.

## Annex

Table 5-6: Example for PROFIBUS forwards documentation, additional device information

No.	Device name	Address	Segment	Firmware re- vision level	GSD saved?	Port	Cable	Device
1	PLC+HA1+S01_1	10	1	2.2	10.5 Server on 31.08.2016	IN	T	-
						OUT	-W102	HMI+HA1+S01_1
2	HMI+HA1+S01_1	15	1	2.1	8.4 Server on 02.09.2016	IN	-W102	PLC+HA1+S01_1
						OUT	-W101	Repeat+HA1+S01_1
						1 IN	-W101	HMI+HA1+S01_1
3	Repeat+HA1+S01_1		1	1.3.1	1.1 Server on 02.09.2016	1R OUT	-W103	IO+HA1-PS2_1
						2 IN	-	-
						2R OUT	-	-
						IN	-W105	IO+HA1-PS3_1
4	IO+HA1-PS1_1	21	1	2.5	1.3 Server on 02.09.2016	OUT	T	-
						IN	-W103	Repeat+HA1+S01_1
5	IO+HA1-PS2_1	22	1	2.5	1.3 Server on 02.09.2016	OUT	-W104	IO+HA1-PS3_1

Annex

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6	IO+HA1-PS3_1	23	1	2.5	1.3 02.09.2016	Server	on	IN	-W104	IO+HA1-PS2_1
								OUT	-W105	IO+HA1-PS1_1

Annex

Table 5-7: Example of PROFIBUS forwards documentation, enhanced device information

No.	Device name	Manufacturer	Model	HW/ FW revision level	Serial number	(Alternative) supplier Order number
1	PLC+HA1+S01_1	Manufacturer 1	PLC 5	2.0 / 2.1	1920-1812-8212-0	Vendor X 1855215
2	HMI+HA1+S01_1	Manufacturer 1	HMI 17	2.5 / 2.5.1	1231-3017-0111-5	Vendor X 6532978
3	Repeat+HA1+S01_1	Manufacturer 2	Repeater 2	1.3 / 1.3	ABC-12345	Vendor X 1582649
4	IO+HA1-PS1_1	Manufacturer 3	IO S2	2.0 / 2.2	14-93-15	Vendor X 4561286

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5	IO+HA1-PS2_1	Manufacturer 3	IO S2	2.0 / 2.2	14-93-15	Vendor X 4561286
6	IO+HA1-PS3_1	Manufacturer 3	IO S2	2.0 / 2.2	14-93-15	Vendor X 4561286

## Annex

Table 5-8: Example of PROFIBUS forwards documentation, cable list

Name	Connection	Connector 1		Connector 2		Actual length/m	Medium	Type / Nature
		Device	Port	Device	Port			
-W101	Sub-D	HMI+HA1+S01_1	OUT	Repeat+HA1+S01_1	1 IN	10.50	Cu	A
-W102	Sub-D	PLC+HA1+S01_1	OUT	HMI+HA1+S01_1	IN	5.00	Cu	A
-W103	Sub-D	Repeat+HA1+S01_1	1R OUT	IO HA1-PS2	IN	85.00	Cu	A
-W104	M12	IO+HA1-PS2_1	OUT	IO HA1-PS3	IN	32.00	Cu	A
-W105	M12	IO+HA1-PS3_1	OUT	IO HA1-PS1	IN	25.00	Cu	A

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Table 5-9: Example of PROFIBUS forwards documentation, enhancement of cable list

Name	Line		Connector	
	Manufacturer	Order number	Manufacturer	Order number
-W101	Manufacturer A	PBK1050A	Manufacturer A	PBS3
-W102	Manufacturer A	PBK1050A	Manufacturer A	PBS3
-W103	Manufacturer A	PBK1050A	Manufacturer A	PBS3
-W104	Manufacturer A	PBK1050A	Manufacturer B	M12PB5
-W105	Manufacturer A	PBK1050A	Manufacturer B	M12PB5

Describe normal plant operation in a clear manner (see Figure 5-5). For detailed checklists for visual inspection, installation dimensions and commissioning refer to the Annex of the PRO-FIBUS Commissioning Guideline [PBI2015].

Figure 5-6 shows how the diagnostic port could be marked.

Segment: ___		
Protocol: DP-V___		
Adjusted transmission rate: _____ kbit/s		
EMC disturbances expected?	<input type="checkbox"/> No	<input type="checkbox"/> Yes, where: _____
Delay in communication?	<input type="checkbox"/> No	<input type="checkbox"/> Yes:
Visual inspection?	<input type="checkbox"/> OK	<input type="checkbox"/> not OK
Acceptance measurement?	<input type="checkbox"/> OK	<input type="checkbox"/> not OK
Planning?	<input type="checkbox"/> OK	<input type="checkbox"/> not OK
Address setting?	<input type="checkbox"/> OK	<input type="checkbox"/> not OK
Signal inputs check	<input type="checkbox"/> OK	<input type="checkbox"/> not OK
Signal outputs check	<input type="checkbox"/> OK	<input type="checkbox"/> not OK
		Title block

Figure 5-5: Example of PROFIBUS forwards documentation, information in cases of faults

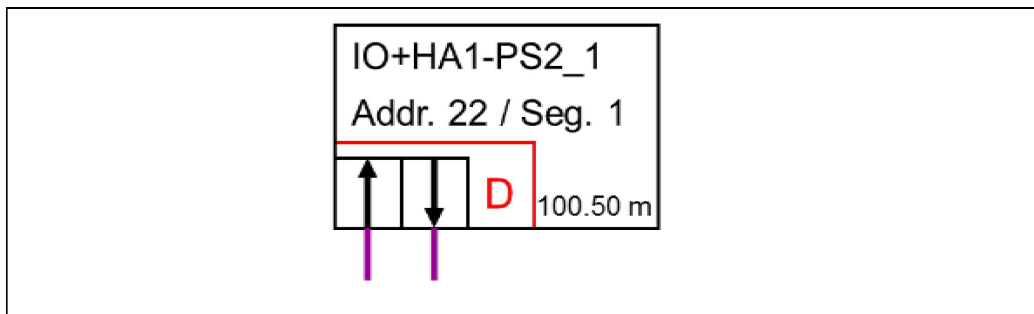


Figure 5-6: Example of PROFIBUS forwards documentation, diagnostic port example

Keep all data sheets and the manuals of the used devices. Also provide a functional description of the plant to allow for easy familiarization.

### **5.1.4 Problems of forwards documentation in the product lifecycle**

Deviations frequently occur in the installation or commissioning phase already. They should be eliminated in a revision. However, the large number of manual user interactions by different employees results in a high risk of faults. Once the system has been delivered to the plant operator, the designers are no longer responsible, and the knowledge recorded in a good network documentation is no longer available. In cases of faults, the employees of the plant operator normally attempt to eliminate the faults themselves. Minor changes of the plant are often not recorded as they have to be made under some time pressure.

A forwards documentation often contains many items throughout the entire lifecycle of the plant. These reduce the quality of the network documentation. The network documentation becomes unclear, difficult to understand or faulty. Often the network documentation is not up-to-date, the access is denied or the documents are missing.

Due to these detriments it is not recommended to use the forwards documentation in the operational phase of the lifecycle. Writing an up-to-date network documentation on site is more suitable for troubleshooting. A standardized backwards documentation helps reduce the time required for documentation.

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PROFIBUS Nutzerorganisation e. V. (PNO)  
PROFIBUS & PROFINET International (PI)  
Haid-und-Neu-Str. 7 • 76131 Karlsruhe • Germany  
Phone +49 721 96 58 590 • Fax +49 721 96 58 589  
E-mail [info@profibus.com](mailto:info@profibus.com)  
[www.profibus.com](http://www.profibus.com) • [www.profinet.com](http://www.profinet.com)

KHN