



PROFIBUS

Installation Guideline

for Planning

Version 1.0

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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).

This Design Guideline does not replace any previous documents. It is an application-oriented document which complements existing documents. The previous PNO documents therefore continue to be valid.

1.2 Liability exclusion

The PROFIBUS User Organization has taken utmost care in the preparation of this document and compiled all information to the best of their knowledge. This document is nevertheless based on present knowledge, is of an informative character and is provided on the basis of a liability exclusion. Therefore, this document may be subject to change, enhancement or correction in the future without any expressive reference. PROFIBUS Nutzerorganisation e.V. expressly refuses all types of contractual or legal liability for this document, including the warranty for defects and the assurance of certain usage properties. Under no circumstances shall PROFIBUS Nutzerorganisation e.V. accept liability for any loss or damage caused by or resulting from any defect, error or omission in this document.

1.3 PNO documents

PROFIBUS PA (2003-02)

2.092, Version 2.2 - User and Installation Guideline

Installation Guideline for PROFIBUS DP/FMS (1998-09)

2.111, Version 1.0 - Installation Guideline

PROFIBUS Interconnection Technology (2007-01)

2.42, Version 1.4 - PROFIBUS Guideline

PROFIsafe - Requirements for Installation, Immunity and electrical Safety (2007-05)

2.232, Version 2.5 - PROFIBUS Guideline

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

2.262, Version 1.1 - PROFIBUS Guideline

PROFIBUS Installation Guideline (2006-05)

8.021, Version 1.0.6 - Installation Guideline

PROFIBUS Commissioning Guideline (2005-11)

8.031, Version 1.0.2 - Commissioning Guideline

Diagnosis, Alarms and Time Stamping (2004-07)

3.522, Version 1.0 - PROFIBUS Profile Guidelines

PROFIBUS System Description (2002-10)

4.001, PROFIBUS Technology and Application

PROFIBUS Glossary (2007-01)

4.300, Version 0.92, PROFIBUS Glossary

1.4 Referenced standards

IEC 24702 (2006-10)

Information technology – Generic cabling – Industrial premises

IEC 60079

Electrical apparatus for explosive gas atmospheres – General requirements

IEC 60079-7

Electrical apparatus for explosive gas atmospheres – Increased safety “e”

IEC 60079-11; VDE 0170/0171-6

Electrical apparatus for explosive gas atmospheres – Intrinsic safety “i”

IEC 60079-14

Electrical apparatus for explosive gas atmospheres, Part 14:
Electrical installations in hazardous areas (other than mines)

IEC 60079-25; VDE 0170-10-1

Electrical apparatus for explosive gas atmospheres – Intrinsically safe systems “i”

IEC 60079-27

Explosive atmospheres – Part 27: Fieldbus intrinsically safe concept (FISCO)

DIN EN 60204-1; VDE 0113-1

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

IEC 60364-4-41

Erection of high-voltage installations with rated voltages up to 1000 V - Protection for safety; Protection against electrical shock

IEC 60364-5-34 (VDE 0100-540)

Erection of high-voltage installations with rated voltages up to 1000 V – Selection and erection of electrical equipment – Earthing arrangements, protective conductors and protective bonding conductors

IEC 60529

Degrees of protection provided by enclosures (IP code)

IEC 60874-10

Connectors for optical fibers and cables; Part 10: Detail specification for fiber-optic connector type BFOC/2.5 (ST)

IEC 61140

Protection against electrical shock – Common aspects for installations and equipment

IEC 61158-2

Digital data communications for measurement and control – Fieldbus for use in industrial control systems - Part 2: Physical layer specification and service definition

IEC 61241-1-2

Electrical apparatus for use in the presence of combustible dust – Part 1-2: Electrical apparatus protected by enclosures

IEC 61784-5-3

Industrial Communications Networks - Profiles

Part 5-3: Installation of Fieldbusses – Installation profiles for CPF 3

IEC 61918

Digital data communications for measurement and control - Profiles covering installation practice for fieldbus communications media within and between the Automation Islands

EN 50174-2

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

EN 50174-3

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

EN 50310

Application of equipotential bonding and earthing in buildings with information technology equipment

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

Symbols for structuring the text





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

Table 1-1 Symbols for structuring the text

Symbols for components

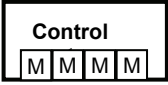







Symbol	Name	Meaning
	Master	PROFIBUS controller, contains one or more master(s) class 1
	DP / PA converter	A converter between PROFIBUS DP and MBP (PA) or DP-IS
	Fieldbus barrier	PROFIBUS-MBP (PA) link between the EEx e main bus and EEx i stubs
	Junction box	Passive junction for PROFIBUS-MBP (PA)
	OLM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

Table 1-2 Symbols for components

Symbols for areas



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

Table 1-3 Symbols for areas and zones

Symbols for PROFIBUS cables









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

Table 1-4 Symbols for PROFIBUS cables

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 & 5:** In the chapters 4 (Determining power supply) and 5 (Planning plant acceptance) the planning process is completed.

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, optimise the planning results.

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

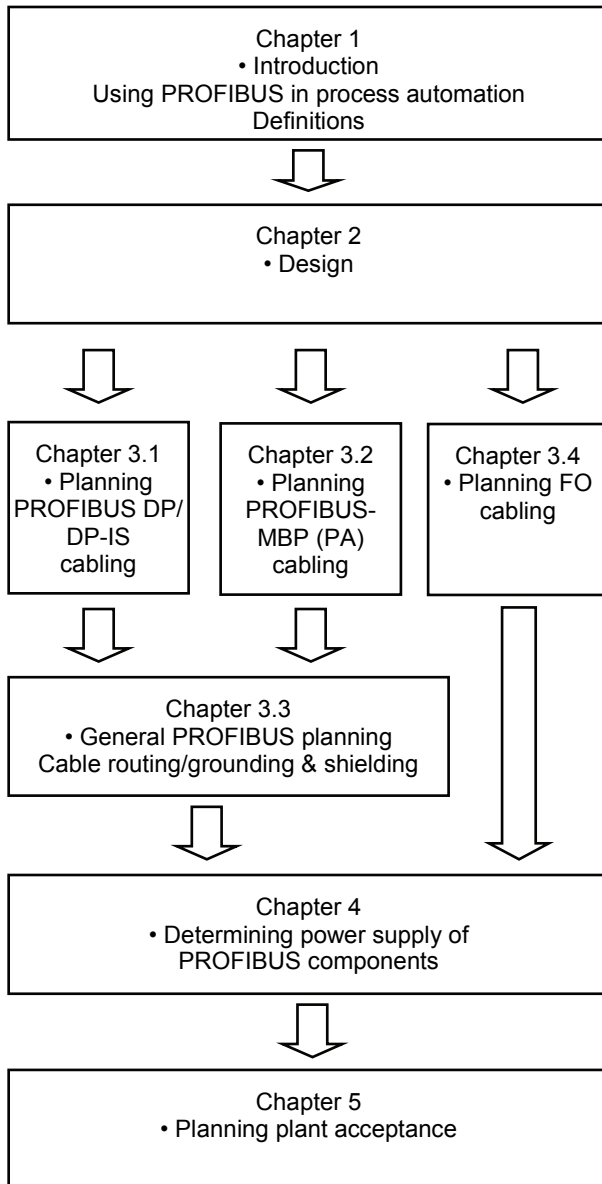


Figure 1-1 Structure of this guideline

1.7 Collection of lists

This guideline contains dedicated lists to allow a structured approach to planning your project.

When you work through the individual chapters of this guideline, you will be requested at several points to fill out these lists. In this way you can easily document your planning process and obtain a better overview. The guideline itself is separated from the list collection which is provided in a separate document for a better understanding and structuring. The lists are provided in PDF-Format as well as Word documents.



You can download the list collection under:

www.profibus.com

1.8 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.

1.9 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.

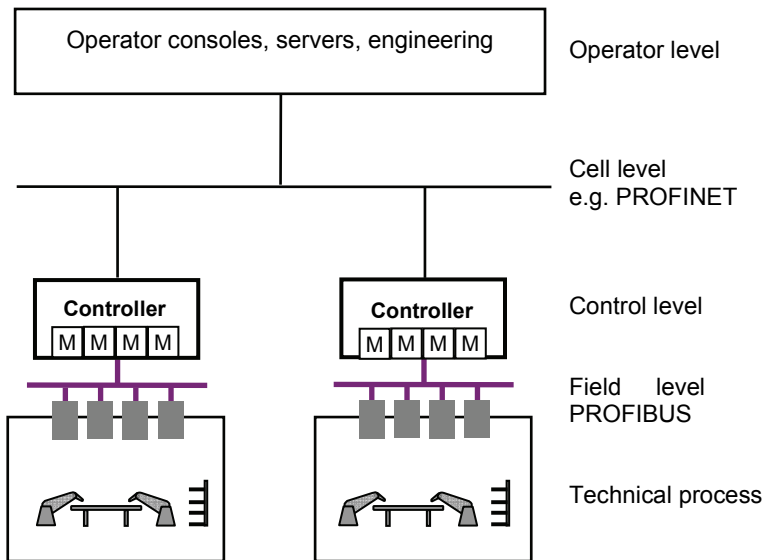


Figure 1-2 Using PROFIBUS in process automation

1.10 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 are 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 realising 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.

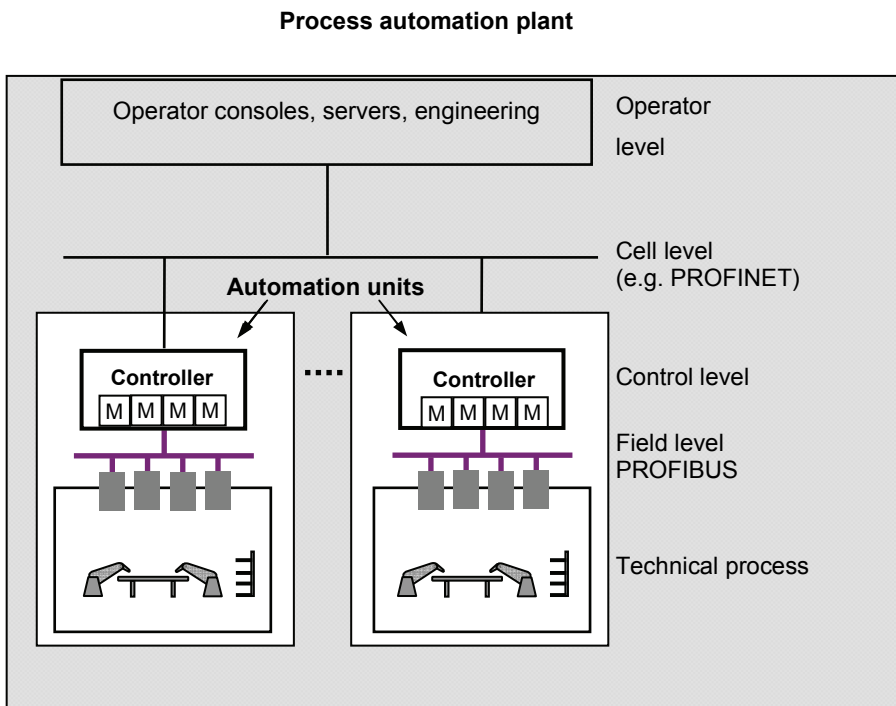


Figure 2-1 Dividing a process automation plant

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.

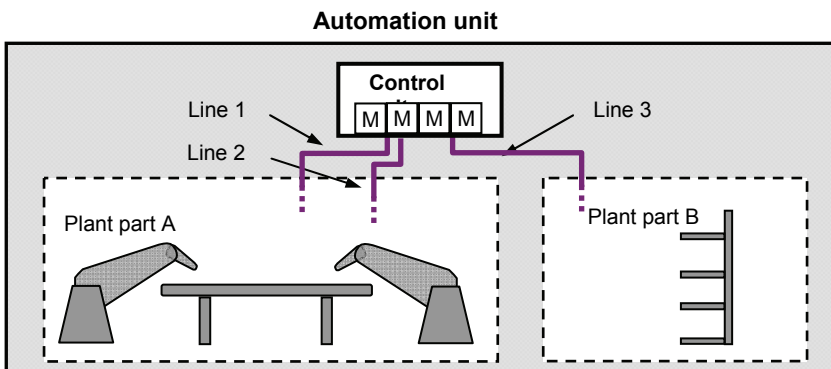


Figure 2-2 Dividing a process automation unit



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 area(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

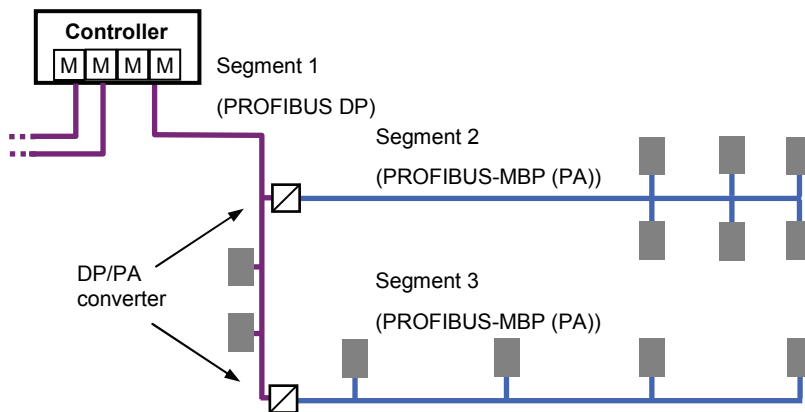


Figure 2-3 Possible line setup

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 summarises the essential features and applications of PROFIBUS DP and PROFIBUS-MBP (PA).

	PROFIBUS DP	PROFIBUS-MBP (PA)
Automation branch	Production automation and process automation	Process automation
Description	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.
Typical devices connected	Remote I/Os, actuators, balances, dosing units, display panels	Analog sensors (e.g. for pressure or temperature), analog actuators (e.g. positioners).
No. of bus nodes per segment	Up to 32	Non-hazardous areas: Up to 32 Hazardous areas: When used with fieldbus barriers typically 16, when used with Ex-type DP/PA couplers <10.
Transmission rates	9.6 kbits/s to 12,000 kbits/s in defined steps	31.25 kbits/s
Transmission technology	<ul style="list-style-type: none">• RS 485• RS 485(IS)• Fiber-optic	<ul style="list-style-type: none">• MBP (Manchester Bus Powered)
Transmission medium	<ul style="list-style-type: none">• Copper cables FO cables: Glass/plastic/HCS	<ul style="list-style-type: none">• Copper cables

Design

	PROFIBUS DP	PROFIBUS-MBP (PA)
Max. transmission path	1200 m per segment for copper cables. Less with higher transmission rates. Many km when using FO cables.	Non-Ex: 1900 m Ex: up to 1000 m; depending on type of protection

Table 2-1 Properties and applications of the PROFIBUS types

Arrange the segments to be formed into node groups which can be assigned to either PROFIBUS DP or PROFIBUS-MBP (PA). These node 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.

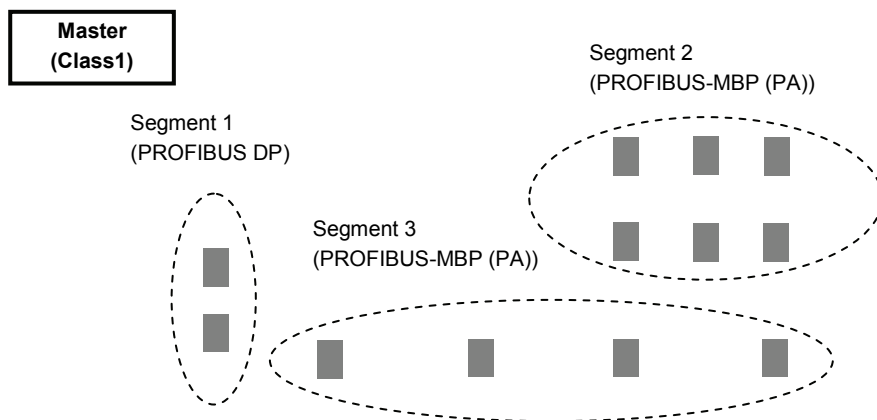


Figure 2-4 Segment forming using node groups



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.

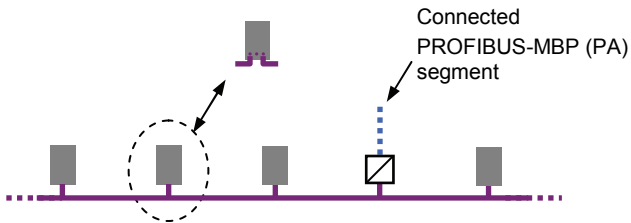


Figure 2-5 Line topology of a PROFIBUS DP with copper cables

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.



According to the standard, stubs are permissible at low transmission rates. For the sake of standardised and simplified planning, however, we recommend not to use stubs for PROFIBUS DP as stubs produce reflections and, therefore, must be considered as a potential source of interference to the signal.

Depending on the data transmission rate, transmission paths of up to 1200 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.

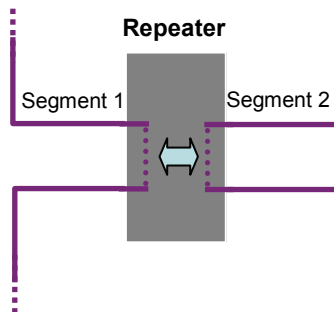


Figure 2-6 Connecting two segments to a repeater



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 manufacturers 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.

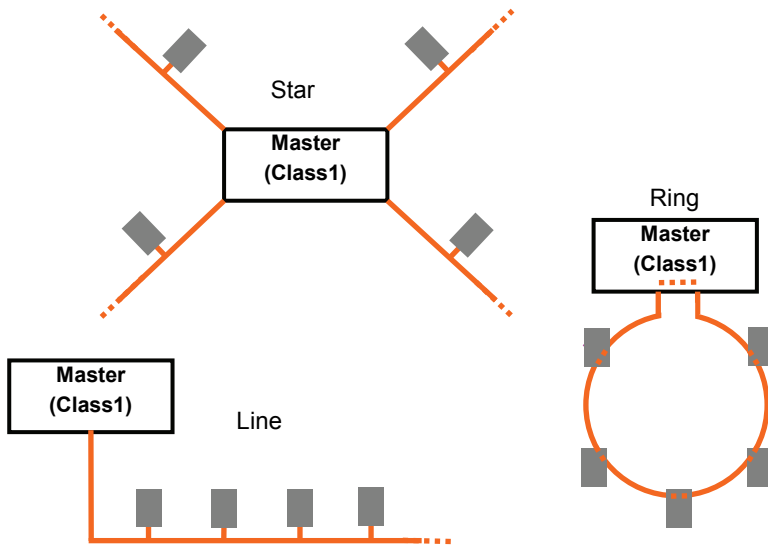


Figure 2-8 PROFIBUS DP topologies using FO cables

Besides their suitability for long transmission distances of several kilometers, FO cables feature have 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 using the template provided in the supplement (see List 2.2 of the supplement). Fill in the following items:

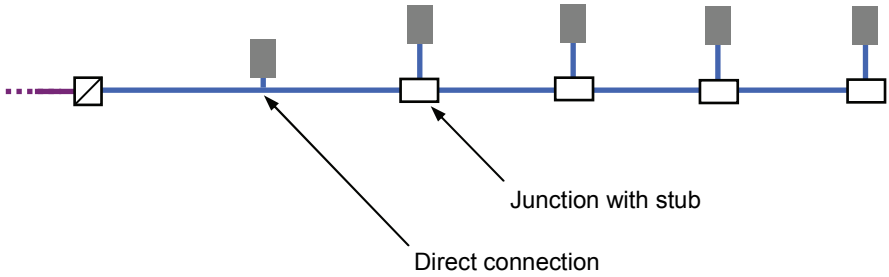
- Automation unit; plant area; line and segment numbers
- The connected bus nodes (node number; device type/name)
- Approximate cable lengths; selected transmission medium; path numbers

2.1.3.3 Topologies of PROFIBUS-MBP (PA)

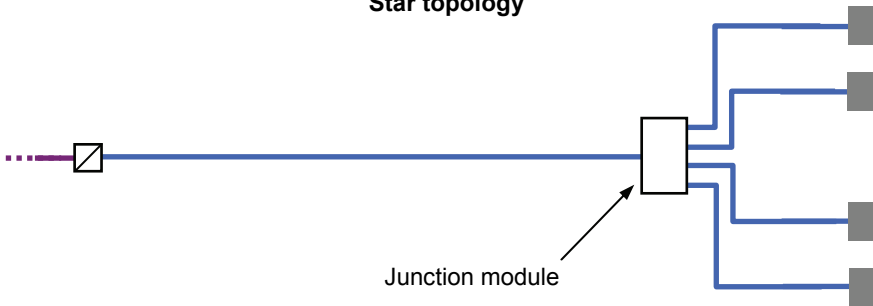
With PROFIBUS-MBP (PA) the slaves are powered via the bus. As a result, copper cables have to be used as the transmission medium.

For PROFIBUS-MBP (PA) line and tree topologies as well as a combination of these are permissible. The nodes are either connected in the same way as with PROFIBUS DP or directly to the bus or to stubs of the main bus. In the last case dedicated junction boxes are used.

Line topology



Star topology



Combined line and star topology

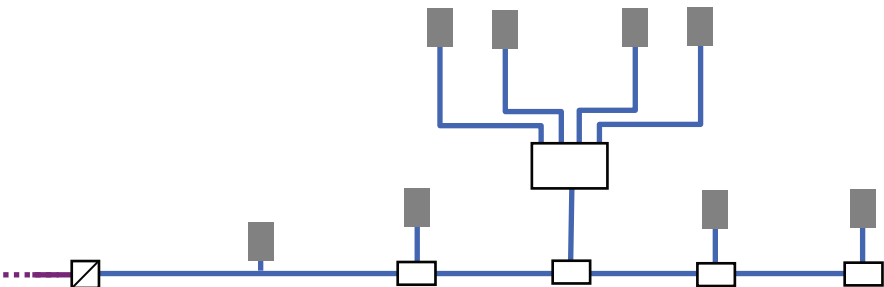


Figure 2-9 PROFIBUS-MBP (PA) topologies

With PROFIBUS-MBP (PA) a transmission distance of up to 1900 m can be covered. This length is the total of the main bus line length plus all the stubs. A stub must not be longer than 120 m dependant on how many nodes are connected.



For hazardous areas shorter stub lengths must be used.



Design the segment structure plans of the PROFIBUS-MBP (PA) segments (List 2.3 of the supplement). 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 main bus and the stubs (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.

Transmission rate [kbits/s]	maximum Transmission distance [m]
9.6	1200
19.2	1200
45.45	1200
93.75	1200
187.5	1000
500	400
1500	200
3000	100
6000	100
12000	100

Table 2-2 MaximumTransmission distance as a function of transmission rate (PROFIBUS DP)

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 (List 2.1 of the supplement):

- 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 bus or their power consumption, respectively
- Cable type used
- Power supplied to the bus
- 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.

Transmission rate	Transmission distance
31.25 kbits/s	Use in non-hazardous areas: 1900 m; max. length of individual stub limited to 120 m dependent on the number of nodes
	Use in hazardous areas: 1000 m; max. length of individual stub limited to 60 m

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

Number of stubs	Maximum length of a stub in non-hazardous areas [m]	Maximum length of a stub in hazardous areas [m]
25-32	-	-
19-24	30	30
15-18	60	60
13-14	90	60
1-12	120	60

Table 2-4 Maximum stub lengths with PROFIBUS-MBP (PA)



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 stub lengths for future calculations (List 2.3. of the supplement) using Table 2-4. Subsequently, add the following items to the plant overview (List 2.1 of the supplement).

- 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.

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

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



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 (List 2.1 of the supplement):

- 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 MBit/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.

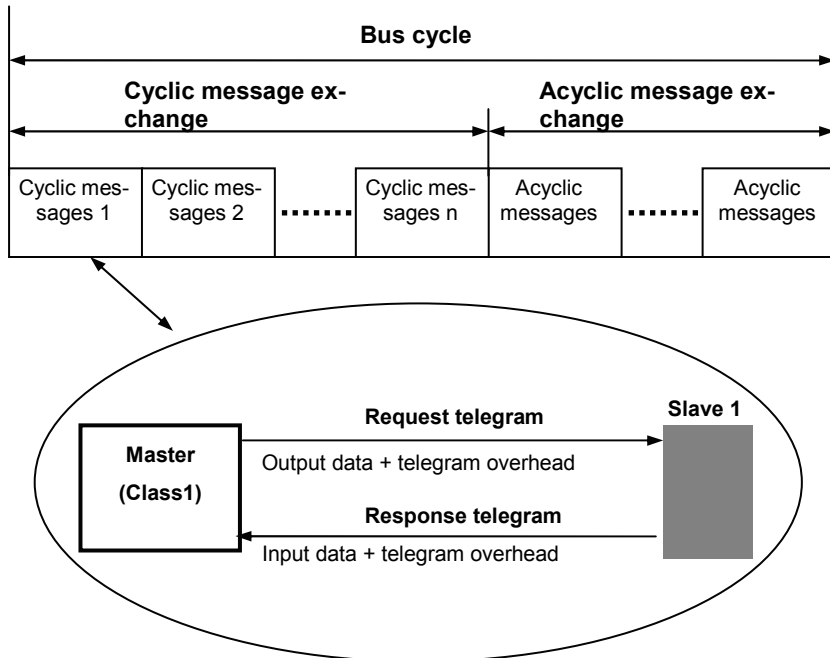


Figure 2-10 Basic structure of a bus cycle

Cyclic data exchange utilises 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.

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

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

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.

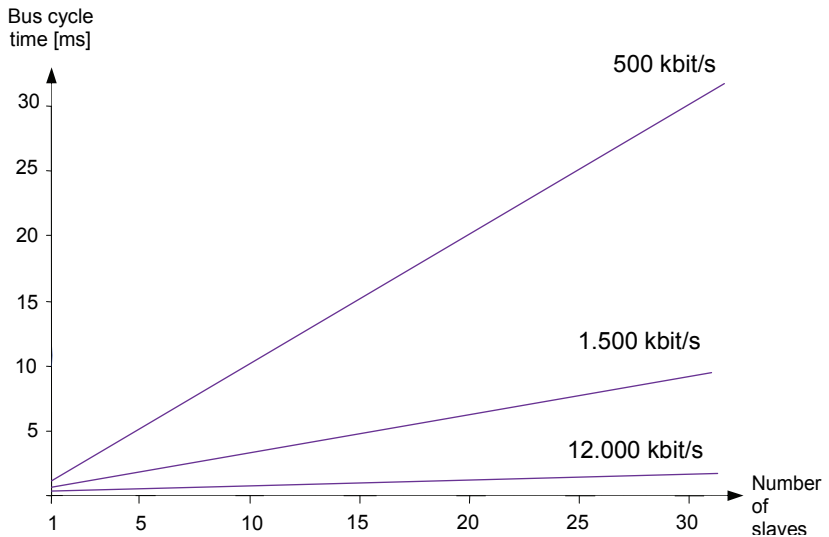


Figure 2-11 PROFIBUS DP bus cycle times

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**.

Formula for estimating the bus cycle time

$$t_{\text{Partialcycle_PA}} = \frac{\sum_{i=1}^n \left(\text{Tel_OV} + \text{Bit_PA} \cdot (L_o + L_i)_i \right)}{\text{Transmissionrate}}$$

Tel_ OV = Telegram overhead (317 bits)

Bit_ PA = PROFIBUS-MBP (PA) data format ($8 \frac{\text{Bit}}{\text{Byte}}$)

i = slaves' run variable

$(L_o + L_i)_i$ = Total of the output and input data of the slave i

n = Number of all slaves

Transmission rate: Value in kbit/s

$t_{\text{Partialcycle_DP}}$: Cycle time in ms

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

Figure 2-12 provides a graphical representation of the formula shown in Table 2-7 for the fixed transmission rate of 31.25 kbits/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.

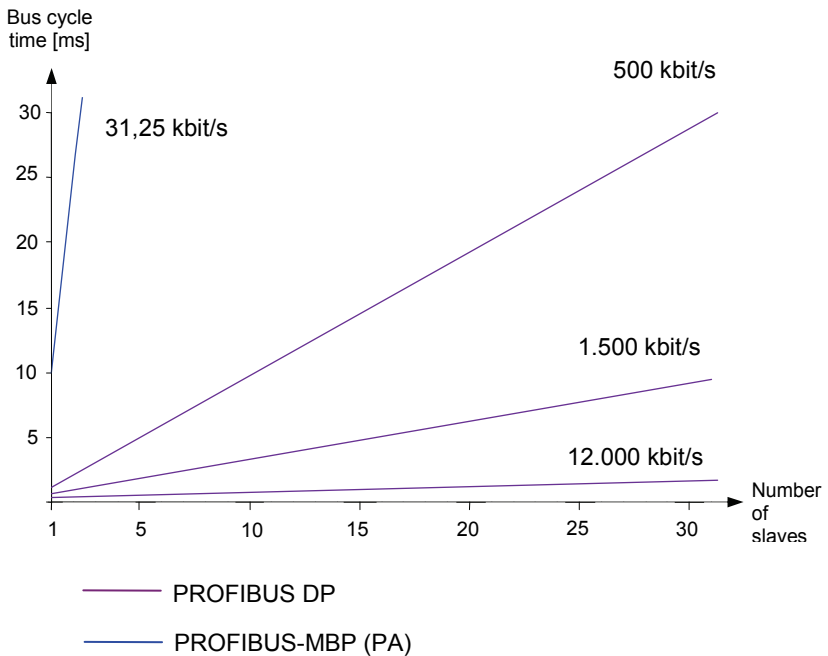


Figure 2-12 PROFIBUS bus cycle times

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 3.2.1.4.



Note that the bus cycle time only represents the time required for data transmission via the bus. 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 bus.



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" (EEx i)
 - PROFIBUS types for hazardous areas
- Safety
- Redundancy
- Spare cables

2.3.1 Intrinsic safety

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.

Zone classification for gases and vapors	
Zone	Frequency of occurrence
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 2-8 Zone classification for gases and vapors

Zone classification for combustible dusts	
Zone	Frequency of occurrence
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.

Table 2-9 Zone classification for combustible dusts



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" (EEx i)

PROFIBUS segments located in hazardous areas are usually realized in the protection class "intrinsically safe" (EEx i) or in a combination of "intrinsically safe" (EEx i) and the protection class "increased safety" (EEx e). The principle of intrinsic safety is based on the limitation of the energy supplied to the hazardous area. 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 bus 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" (EEx 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 Table2-10.

Zone	Required type of protection
Zone 0	EEx ia
Zone 1	EEx ib
Zone 2	EEx i without special safety factor (also called EEx ic)

Table2-10 Categories of type of protection EEx i

For hazardous areas where combustible dusts are present there is no such categorization of the type of protection EEx 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 characterise 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" (EEx e)

As an alternative to the type of protection "intrinsic safety" (EEx i) the type of protection "increased safety" (EEx 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 bus than the type of protection "intrinsic safety" (EEx 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" (EEx i) and "increased safety" (EEx e) are used in combination. The trunk cable is routed through the plant using the protection class "increased safety" (EEx e). At certain locations so called Fieldbus Barriers split of spurs in the protection class "intrinsic safety" (EEx 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.

PROFIBUS-MBP (PA)

PROFIBUS-MBP (PA) has already been detailed in the previous chapters. For this reason, it is only briefly described here.

If you intend to use PROFIBUS-MBP (PA) in hazardous areas, you must take into account that the maximum number slaves that can be connected to the bus is restricted due to the limitations regarding power supply.

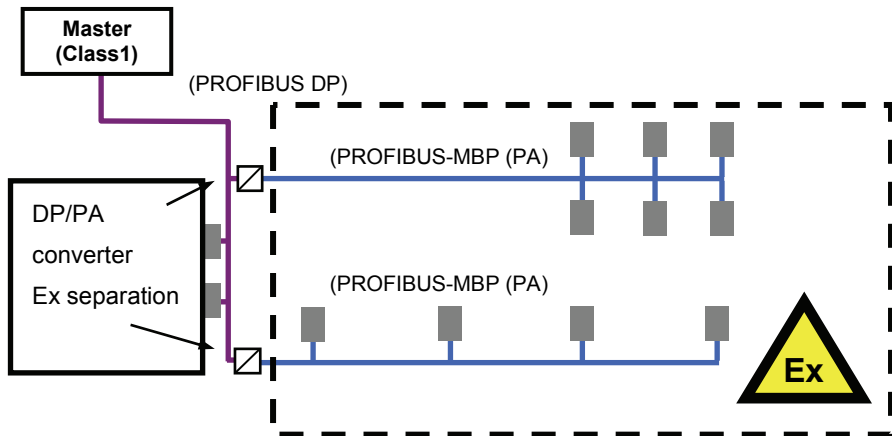


Figure 2-13 PROFIBUS-MBP (PA) in hazardous areas



For an exact calculation of the number of nodes that can be connected to the PROFIBUS-MBP (PA) segment you must take into account the power supply unit used (often integrated in the DP/PA converter). This aspect will be detailed in chapter 3.2.1. For the time being consider six to eight nodes per intrinsically safe segment as a recommended value.

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 thus specified for the type of protection EEx 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 EEx ib)
- Transmission technology: RS 485-IS
- Transmission rate limited to a maximum of 1500 kbits/s (see Table 2-2 for the reachable transmission distance)
- Transmission medium: copper cable, only



Like PROFIBUS DP, this PROFIBUS type is suitable for linear topologies, only. Branch segments from the PROFIBUS DP (see Figure 2-13) can be made by using DP/DP-IS converters.



Verify the segment structure plans (List 2.2 and List 2.3 in the supplement) and select one of these two PROFIBUS types for segments in hazardous areas. Additionally fill in the type of protection (EEx e; EEx ia; EEx 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 realised 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 are 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 realising 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.

2.3.3 Redundancy

For automation plants requiring a high availability of either 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.

2.3.4 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 bus cable.
- 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 connections
- 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 also 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.

Parameter	Specified limits
Impedance	135..165 Ω with $f = 3...20$ MHz
Operational capacity	≤ 30 pF / m
Loop resistance	≤ 110 Ω / km
Wire diameter	> 0.64 mm
Wire CSA	> 0.34 mm ²
L/R proportion for PROFIBUS DP-IS	≤ 30 μ H / Ω

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

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

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.

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

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



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 manufacturers 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.

- **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.

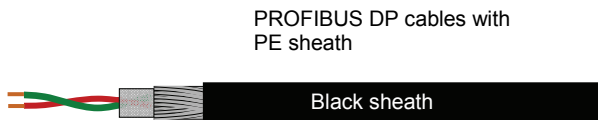


Figure 3-3 PROFIBUS DP cable with PE sheath



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 unsheathed cable fit common connectors. This cable type usually has a black cable sheath. Its cable diameter is approx. 10 mm.

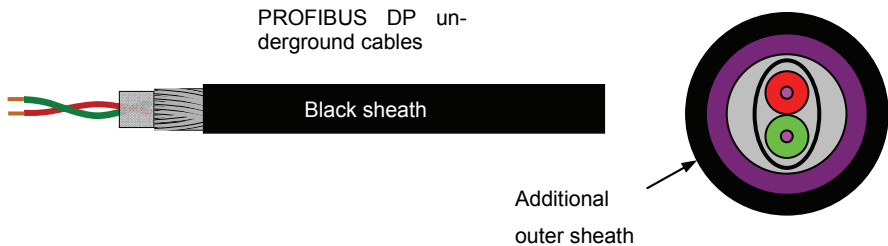


Figure 3-4 PROFIBUS DP cable for laying in the ground



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.

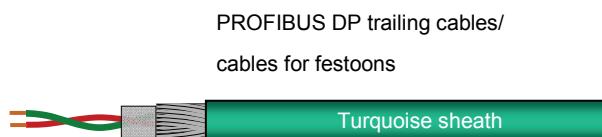


Figure 3-5 PROFIBUS DP cable as trailing cable / festoon cable

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 bus, 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 Table 3-2.

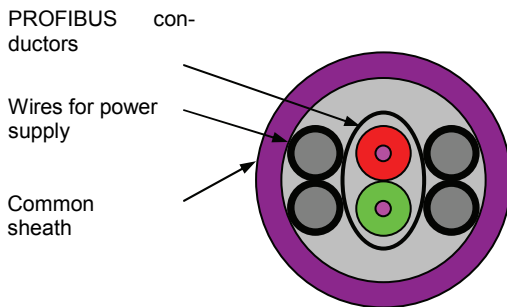


Figure 3-6 Structure of a hybrid cable



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 (List 3.1 of the supplement).

For each required cable type you additionally create a dedicated material list (List 3.2 of the supplement). 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 connections

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.

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

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



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.

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). 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 PROFIBS DP bus terminations”).

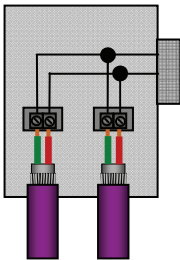


Figure 3-7 Sub-D connection principle

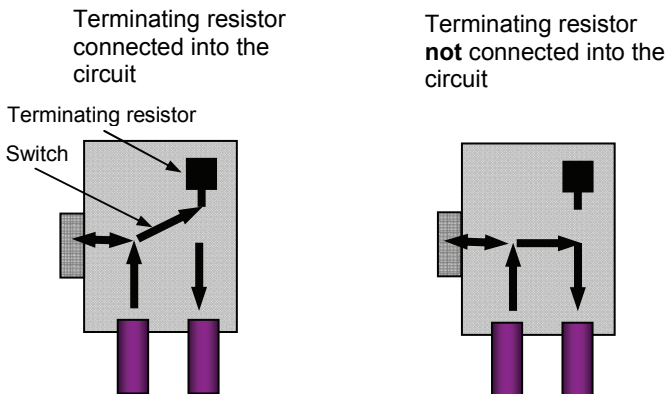


Figure 3-8 Sub-D connector with switchable terminating resistor

Planning the cabling

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 parameterisation device (master Class 2).

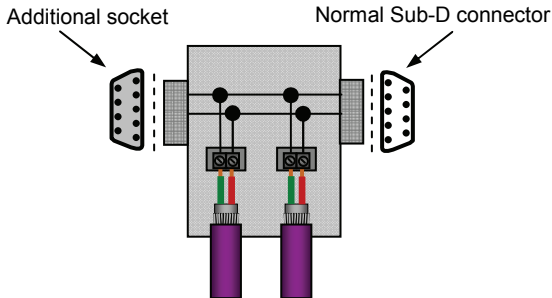


Figure 3-9 Sub-D connector with additional socket



Bear in mind that the connection cable of a diagnostic device is an additional stub which, in certain circumstances, may cause disruption to the data transmission on the bus. 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.

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.

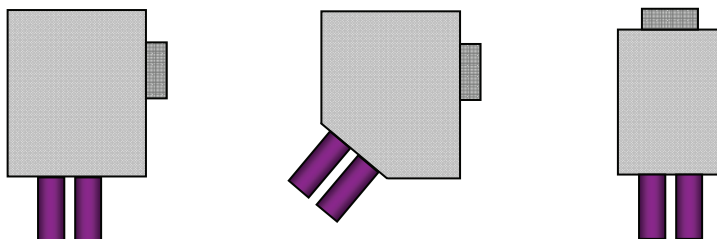


Figure 3-10 Design variants of Sub-D connectors

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.8.021).



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.

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

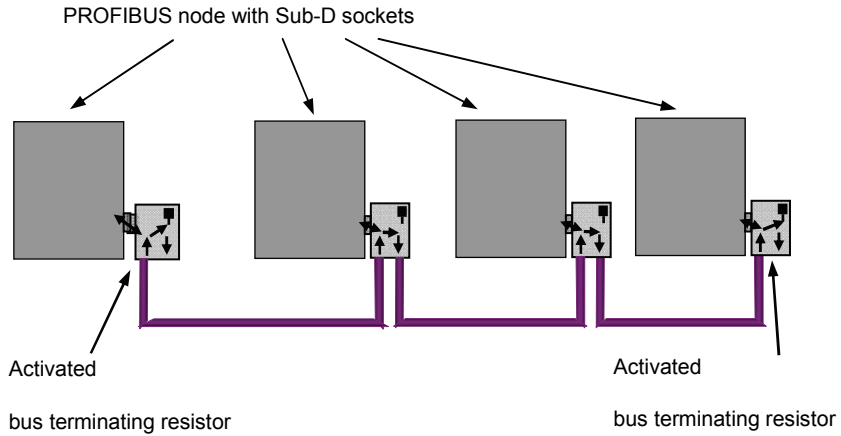


Figure 3-11 Schematic view of a transmission path with Sub-D connectors

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).

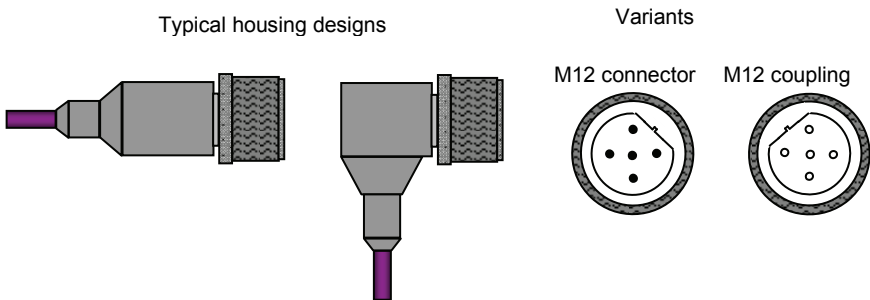


Figure 3-12 M12 connector housings and design variants

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.

Figure3-13 provides a schematic view of a transmission path set up using M12 connectors

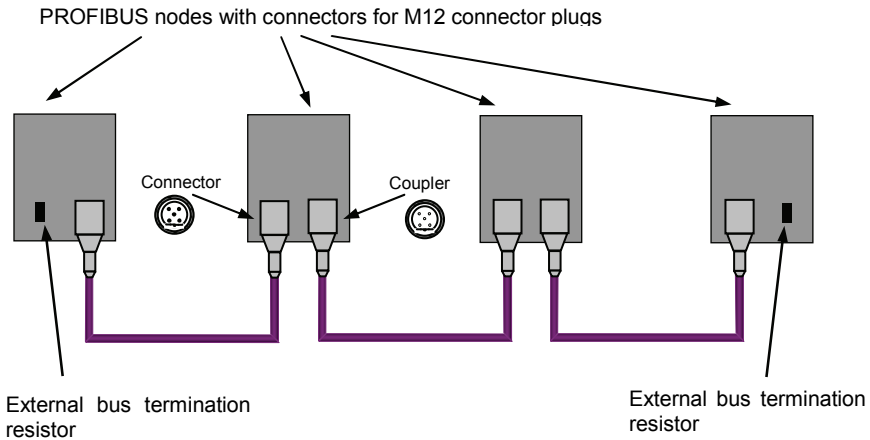


Figure3-13 Schematic view of a transmission path with M12 connectors

Please note that a transmission path according Figure3-13 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 (List 3.1 of the supplement).

For each required connector type you additionally create a dedicated material list (List 3.3 of the supplement).

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 minimise 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 active and must be 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, no proper bus termination will be available and the network may become unstable.



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.

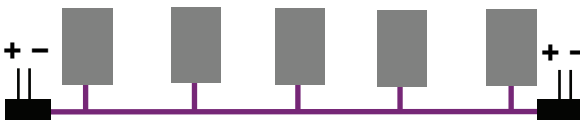


Figure 3-14 Active power supply of the bus termination

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 (List 2.2 of the list collection) 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.

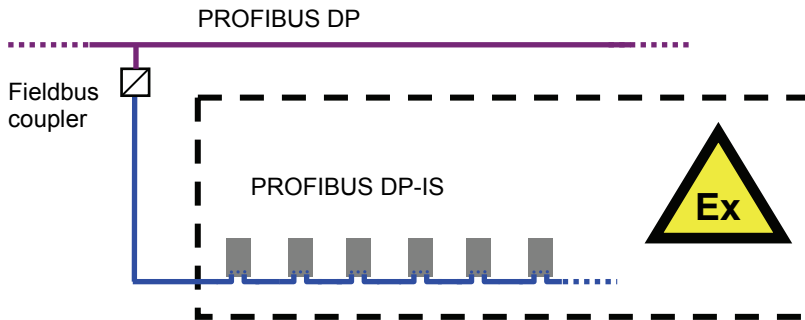


Figure 3-15 Coupling PROFIBUS DP-IS

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.



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 (List 2.2 of the list collection).

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 (List 2.2 of the list collection). Document the verification process in a list (List 4.1 of the list collection).

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 < 4800 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 (List 2.2 of the list collection) 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.

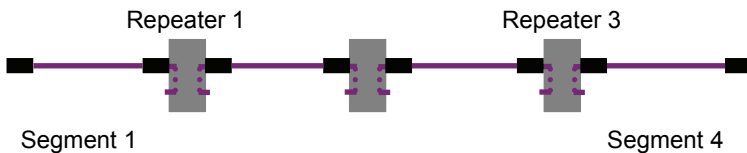


Figure 3-16 Repeaters for extending the path

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 realising the lines of your automation unit (List 3.4 of the list collection).

It may be necessary to re-visit the segment structure plans (List 2.2 of the list collection) 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. (See chapter 4.)

3.2 Planning PROFIBUS-MBP (PA) cabling

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

This chapter is arranged as follows:

- Planning DP/PA transitions
- Selecting cables
- Determining connections
- Selecting the junction technology
- Planning bus terminations
- PROFIBUS-MBP (PA) segments according to the FISCO model

3.2.1 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 hints
- Selecting the power supply unit
- Use in hazardous areas
- DP/PA converter

3.2.1.1 General notes

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

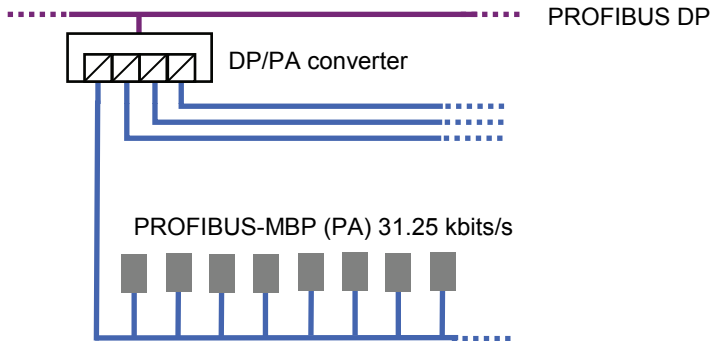


Figure 3-17 Coupling the PROFIBUS-MBP (PA)

The following DP/PA converter types are available, depending on the PROFIBUS DP data transmission rate:

- DP/PA converters that limit the transmission rate on the PROFIBUS-DP segment
- DP/PA converters that do not limit the transmission rate on the PROFIBUS-DP segment

Some DP/PA converters fix the transmission rate on the PROFIBUS DP-side, normally to 93.75 or 45.45 kbits/s.

In practice, mainly DP/PA converters without transmission rate limitation are used allowing for flexible planning of the PROFIBUS-MPB (PA).

Therefore, DP/PA converters with transmission rate limitation are not detailed in this guideline.

For DP/PA converters without transmission rate limitation a distinction is made between transparent and non-transparent DP/PA converters. Transparent DP/PA converters pass the addresses of the PROFIBUS-MBP (PA) slaves to the PROFIBUS DP. The maximum number of slaves is limited by the PROFIBUS DP address range.

Non-transparent DP/PA converters are a slave on the PROFIBUS DP side and a master on the PROFIBUS-MBP (PA) side.

3.2.1.2 Selecting the power supply unit

As the slaves are powered via the bus, the power supply unit, which is often integrated in the DP/PA converter has to provide all the applications power.

For applications in hazardous areas, approved power supply units in accordance with the FISCO model that limit the voltage and current must be used only.

- DP/PA converter powers the segment
- Current consumption of the slaves ≥ 10 mA (reference values for slaves to be connected).
- Current modulation ± 9 mA for signal transmission.

When choosing a suitable power supply unit you first have to determine the total power requirements of the connected nodes.

Example calculation of the power requirements of a PROFI-BUS-MBP (PA) segment

The total power of a segment results from the power consumption of the slaves and from the power loss of the cable. In order to simplify the planning, a worst case scenario is assumed where all slaves are placed at the end of the cable. In this case a supply voltage of at least 9 V must be provided for remote-powering of the slaves.



Now determine – on a segment to segment basis – the total power of the slaves to be connected to a line using the calculation example; then document the results (List 4.2).

In the next step, you have to select the appropriate type of power supply (Table 3-4).

Type	Applications	Supply voltage	Supply current	Max. power
I	EEx ia/ib IIC	13.5 V	110 mA	1.8 W
II	EEx ib IIC	13.5 V	110 mA	1.8 W
III	EEx ib IIB	13.5 V	250 mA	4.2 W
IV	not intrins. safe	24 V	500 mA	12 W
V	not intrins. safe	31 V	1000 mA	31 W

Table 3-4 Standard power supply unit

This calculation example is intended for applications in hazardous areas. The selection of the power supply unit and the cable has been assumed but is only intended as an example.



When designing a PROFIBUS-MBP (PA) segment for use in non-hazardous areas, more slaves can be powered due to the higher supply voltage and current available.

It is assumed, that eight slaves are to be connected to a PROFIBUS-MBP (PA) segment:

Slaves to be powered:	8 slaves of 12 mA each = 96 mA
	Error current in case of slave failure: 9 mA
	Total of all currents: 105 mA
Supply voltage of power unit (type 1)	13.5 V
Min. supply voltage of slaves:	9 V
Max. voltage drop along bus line	$13.5 \text{ V} - 9 \text{ V} = 4.5 \text{ V}$

Max. line resistance: $R = 4.5 \text{ V} / 105 \text{ mA} = 42.9 \Omega$

The following max. cable length results for a cable of type A (loop resistance $44 \Omega / \text{km}$):

$$L_{\text{Max}} = \frac{42.9 \Omega}{44 \Omega / \text{km}} = 0.974 \text{ km}$$

3.2.1.3 Use in hazardous areas

For use in hazardous area also make sure to observe the requirements resulting from the types of protection.

Type of protection "increased safety" (EEx e)

EEx e protection allows significantly greater energy into a hazardous area. However equipment cannot be worked on while live.

Type of protection "intrinsically safe" (EEx i)

EEx i protection limits the energy into a hazardous area to safe levels allowing live work on equipment.

Connection concept using 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 EEx i. It is therefore necessary to sub-divide the PROFIBUS-MBP (PA) in order to ensure full safety.

Nodes must be connected via fieldbus barriers that separate them from the main bus using protection type "increased safety" (EEx e), as shown in Figure 3-18.

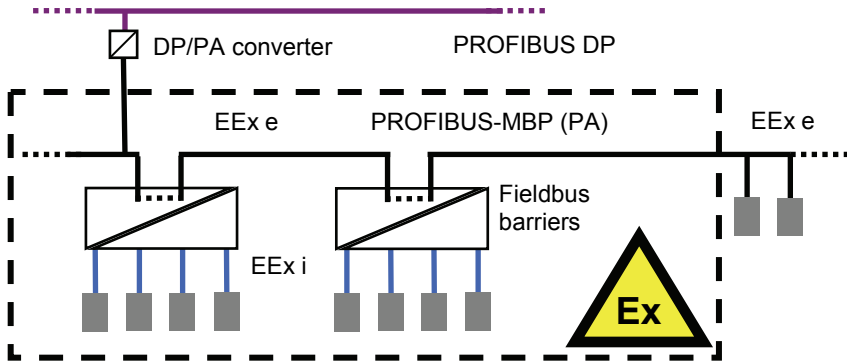


Figure 3-18 Fieldbus barriers for PROFIBUS-MBP (PA)

PROFIBUS-MBP (PA) is fed into the hazardous area via the main EEx e bus which supplies both the fieldbus barriers as well as the slaves located outside the hazardous area.

Due to the combination of EEx e and EEx 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 EEx i.

The slaves of the individual segments in hazardous areas are connected to fieldbus barriers using providing protection type “intrinsically safe” (EEx i).

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

- Easy planning of a plant in terms of bus extension and number of slaves in hazardous areas.
- Short-circuit protection of intrinsically safe stubs.
- Electrical isolation from main bus (EEx e).
- Increase of bus extension to 1900 m (for EEx i only 1000 m).
- **Clearly smaller number of lines.**
- Extension of intrinsically safe stubs to up to 120 m.



Since the slaves are connected to fieldbus barriers via slaves, there are changes of the cable lengths in the segment structure plans (List 2.3 of the list collection).

Connecting slaves and fieldbus barriers

When using fieldbus barriers, the slaves are connected in a star topology using stubs (EEx i). In order to increase the stability, only one field device should be connected per fieldbus barrier to each outgoing cable.

The number of slaves depends on the power of the fieldbus barrier. For connection details please see the manufacturer specifications.

Connect the fieldbus barriers in series to form a main bus of protection EEx e. The main bus carries the power of all connected slaves. Due to the electrical isolation in the fieldbus barrier, the supply to the connected slaves is intrinsically safe.

Short circuit protection is normally afforded at the barrier preventing interference onto the main bus.



Please see the manufacturer specifications for the number of fieldbus barriers connected in series.

3.2.1.4 DP/PA converters

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

- 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).
- Guaranteed Ex separation.

The following DP/PA converters without transmission rate limitation are used to create tree structures in hazardous areas and to convert from PROFIBUS DP to PROFIBUS-MBP (PA):

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

DP/MBP (PA)-LINK

A LINK comprises of a LINK Master section and 1 to 5 transparent couplers. The LINK can run over the full range of PROFIBUS DP speeds and more than one LINK can be on a network.

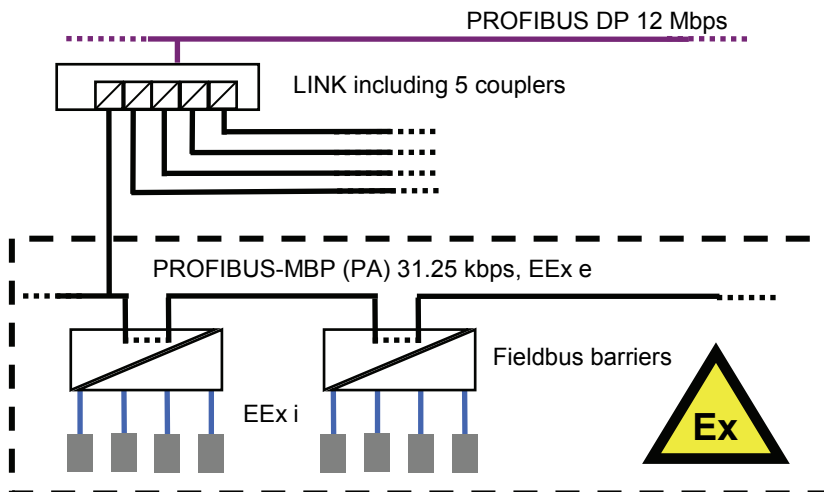


Figure 3-19 Use of LINKs

The main features of a LINK are:

- Baud rates up to 12 Mbps on the PROFIBUS DP side.
- 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.
- The output current of a channel is approx. 400 to 1000 mA (depending on the manufacturer).

Operation in hazardous areas is possible if the appropriate fieldbus barrier is selected. Only one field device should be connected to each spur of the fieldbus barrier.



The concept of fieldbus barriers and LINK or DP/MBP (PA) segment couplers requires an update of the segment structure plans (list 2.3 of the list collection) and of the corresponding material lists. This results in new cable lengths of the segments, due to the connection via stubs.

DP/MBP (PA) segment couplers

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. DP/MBP (PA) segment couplers are suitable for applications with a lower number of slaves.

The protocol remains unchanged during transmission and DP/MBP (PA) segment couplers do not have to be planned separately.

Additional features of DP/MBP (PA) segment couplers:

- Parallel operation of several DP/MBP (PA) segment couplers possible on PROFIBUS DP, limited by the maximum address range of PROFIBUS DP.
- Baud rates up to 12 Mbps on the PROFIBUS DP side.

Installation site for DP/PA converters

A DP/PA converter can only be installed in a hazardous area if it is certified.

If the converter is installed in a hazardous area, the connection between PROFIBUS DP and converter can use the protection class "intrinsically safe" (EEx i) or in the protection class "increased safety" (EEx e).



This problem can be avoided by always installing the DP/PA converter outside the hazardous area (see Figure 3-20 Installation site for DP/PA converters) and by providing an intrinsically safe connection (EEx i) or a connection in "increased safety" (EEx e) between the converter and the PROFIBUS-MBP (PA) network. When using the protection class "increased safety" (EEx e) additional elements (Fieldbus Barriers) will be required.

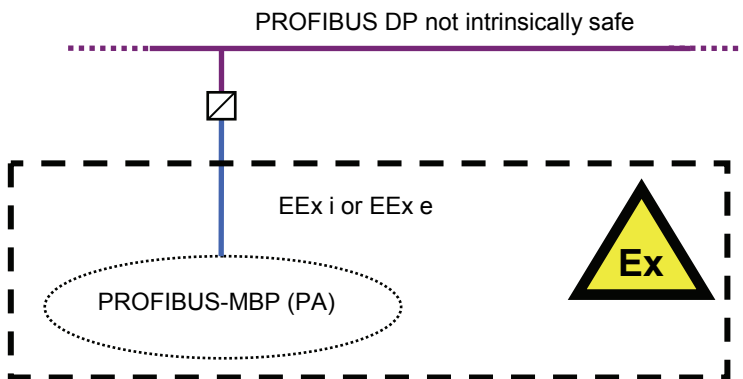


Figure 3-20 Installation site for DP/PA converters

3.2.2 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
 - Overview of all cable types

3.2.2.1 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 3-5 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.

Parameter	Specified limits
Impedance	100 Ω at $f = 31.25$ kHz
Operational capacity	≤ 2 nF/km
Loop resistance	≤ 44 Ω / km
Wire diameter	> 1.00 mm
Wire CSA	> 0.80 mm ²

Table 3-5 Parameters of line type A (PROFIBUS-MBP (PA))

3.2.2.2 Types of PROFIBUS-MBP (PA) cables

Table 3-6 shows the most commonly used cable types for PROFIBUS-MBP (PA) and their applications.

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

Table 3-6 Types of PROFIBUS-MBP (PA) cables



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.

Standard cables

Standard cables for PROFIBUS-MBP(PA) have a light blue or black sheath color, depending on the application. Light blue indicates the use in hazardous areas, black indicated the use in non-hazardous areas.

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



Figure3-21 PROFIBUS-MBP (PA) standard cable for hazardous areas

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



Figure3-22 PROFIBUS-MBP (PA) standard cable for non-hazardous areas



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 3.2.1.2). 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. Here, they support the higher power supply into the hazardous area (see Figure 3-19).



Determine the cables required for the PROFIBUS-MBP (PA) segments. Create a cable and connection overview for each link (List 3.5 of the supplement).

For each required cable type you additionally create a dedicated material list (List 3.6 of the supplement). Assign a material number which is valid for the entire automation unit.

3.2.3 Determining connections

PROFIBUS-MBP (PA) bus nodes can be connected to the bus either directly using the bus cable or using a stub branching from the bus cable.

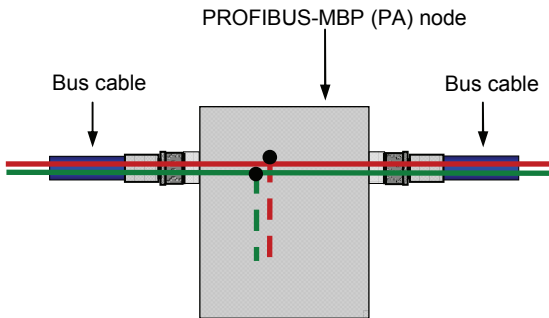


Figure3-23 Node connection on the main bus cable

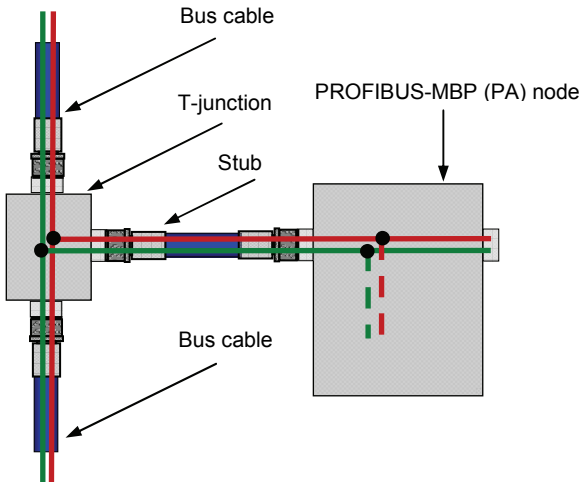


Figure 3-24 Node connection using a stub

The selection of T pieces or junctions (see Figure 3-24) is described in chapter 3.2.4. 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.

3.2.3.1 Connection via connectors

Table 3-7 shows the connectors used for PROFIBUS-MBP (PA) including the relevant protection class.

Connector	Protection class
M12 connector (4-pin)	IP 65/IP 67
7/8 inch connectors	IP 67

Table 3-7 Connectors for PROFIBUS-MBP (PA)



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 3-7, 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).



Special connectors with type of protection "intrinsically safe" (EEx i) and "increased safety" (EEx e) are available for PROFIBUS-MBP (PA). The connector's type of protection must be identical to the type of protection of the relevant segment.

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.

3.2.3.2 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 (List 3.5 of the supplement).

For each required connector type you additionally create a dedicated material list (List 3.7 of the supplement).

3.2.4 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 range of application (hazardous areas and non-hazardous areas) and their connection options.

This chapter is arranged as follows:

- Junction technology for non-hazardous areas
 - Junction modules to connect connectors
 - Junction modules for direct cable connection
- Junction technology for hazardous areas
 - Junction technology for the type of protection "intrinsically safe" (EEx i)
 - Junction technology for the type of protection "increased safety" (EEx e)

3.2.4.1 Junction technology in non-hazardous areas

So-called junction modules or boxes are used to connect PROFIBUS-MBP (PA) segments. the type of connection.

Junction modules to connect connectors

Junction boxes that use connectors are usually designed for protection class IP67. They are thus suited for direct use in the field. Such junction boxes are available with various numbers of branches. Typical ones are one (T-junction) to eight (multi-junction) branches per module. They are connected in series to the main bus (Figure 3-24) which means that each branch represents a stub. The normal rules for stub lines still apply.

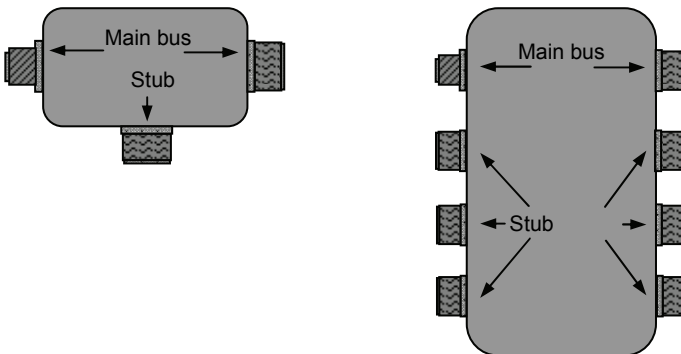


Figure 3-25 Typical variants of PROFIBUS-MBP (PA) junction modules

Junction boxes are usually equipped with M12 connectors for connection to the main bus. Stubs can be connected using M12 or 7/8 inch connectors depending on the type of module.



You can use such modules whenever ease of installation and removal of PROFIBUS nodes is required. In each segment, you should also provide at least one branch which remains available for the connection of diagnosis equipment.

Junction modules for direct cable connection

Junction boxes for direct cable connection are designed to protection class IP20, usually for installation on a DIN rail. They have between four and eight branches. Due to their open design these modules should only be used in cabinets or special junction boxes.



When used in cabinets, these junction modules provide a clearly arranged cabling. As these use screwed terminals they are not recommended for frequent connection and removal.



When using these junction modules, observe the minimum segregation distances to power cables (see chapter 3.3.1).

3.2.4.2 Junction technology for hazardous areas

Junction technology for hazardous areas needs to be differentiated into the types of protection "intrinsically safe" (EEx i) and "increased safety" (EEx e).

Junction technology for the type of protection "intrinsically safe" (EEx i)

The same junction technologies are available for this type of protection as for non-hazardous areas (see chapter 3.2.4.1). However, they must be explicitly certified for use in hazardous areas, and especially for "intrinsically safe" protection (EEx i).

In addition to these junction modules, fieldbus barriers as described above are available. These have a number of advantages over junction modules (see chapter 0).



Employ appropriately qualified personnel for planning intrinsically safe circuits.

Junction technology for the type of protection "increased safety" (EEx e)

The same junction technology is available for the type of protection "increased safety" (EEx e) as it is for non-hazardous areas (see chapter 3.2.4.1)

This type of protection is frequently used when using fieldbus barriers.



As the main bus, uses EEx e protection ("increased safety") working at the bus is not allowed without special work approval.



Use the created segment structure plans (List 2.3 of the supplement) 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 (List 3.8 of the supplement).

3.2.5 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.

This chapter is arranged as follows:

- Bus terminations for segments in non-hazardous areas
- Bus terminations for segments of the type of protection "intrinsically safe" (EEx i)
- Bus terminations for segments of the type of protection "increased safety" (EEx e)

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 main cable as possible,

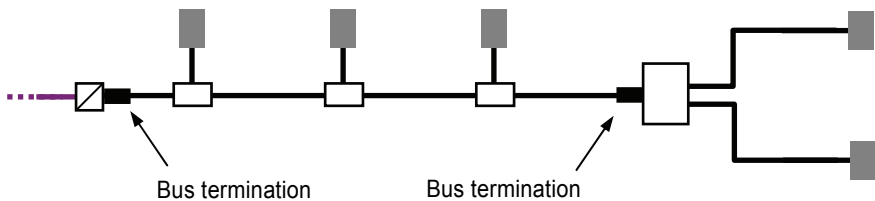


Figure 3-26 Installation of bus terminations for PROFIBUS-MBP (PA)

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 bus. However, bear in mind that in case of PROFIBUS-MBP (PA) such a segment topology should only be used in exceptional cases.

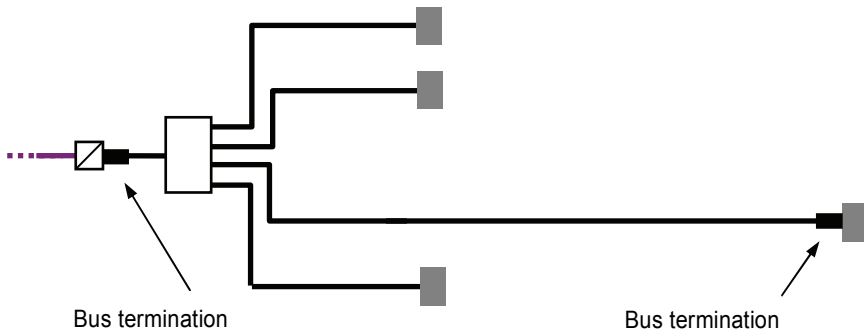


Figure 3-27 Alternative installation of bus terminations for PROFIBUS-MBP (PA)



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

Bus terminations for segments of the type of protection "intrinsically safe" (EEx i)

Segments designed for "intrinsically safe" protection (EEx i) may only be used with external bus terminations. Junction box modules with internal bus terminations are not permitted. Bus terminations may only be installed at the two ends of the main cable (see Figure 3-26).



You may only use bus terminations that are certified for use in hazardous areas (type of protection "intrinsically safe" (EEx i).

Bus terminations for segments of type of protection "increased safety" (EEx e)

Fieldbus barriers are frequently used in segments that are designed for the type of protection "increased safety" (EEx e). The fieldbus barriers are equipped with an integrated bus termination that can be connected if required, the use of which is also permitted in hazardous areas. The second bus termination is usually integrated into the DP/PA converter.

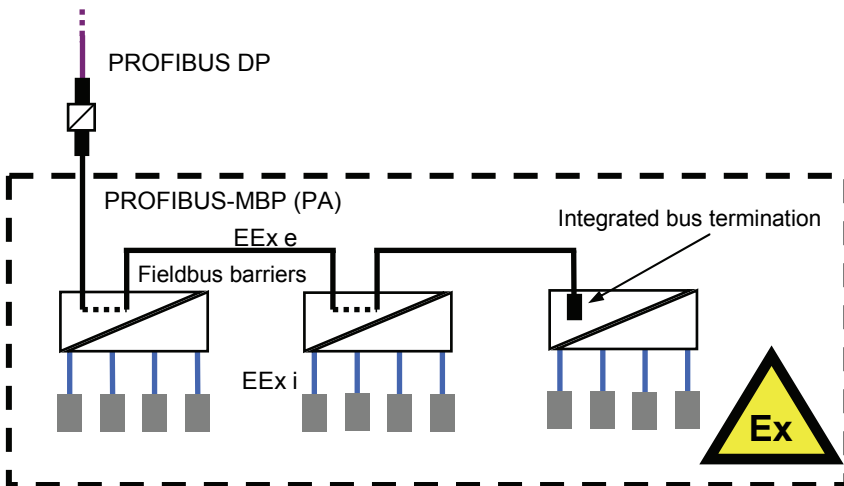


Figure 3-28 Integrated bus termination of fieldbus barriers



Remember that the stubs branching from the fieldbus barriers must not have any additional bus terminations.



Use the segment structure plans (List 2.3 of the supplement) to plan the bus terminations required for the PROFIBUS-MBP (PA) segments. Create a dedicated material list (List 3.9 of the supplement) for the external bus terminations.

3.2.6 PROFIBUS-MBP (PA) segments according to the FISCO model

If PROFIBUS-MBP (PA) is used in hazardous areas, it must meet a number of special requirements in terms of design and approval.

PROFIBUS segments located in hazardous areas must be designed to EEx i protection "Intrinsically safe" or EEx e "Increased safety". EEx e can be implemented by means of construction, EEx i protects by limiting the amount of power supplied to the bus. The type of protection "Intrinsically safe" (EEx i) relates to the entire circuit. Therefore, in an intrinsically safe PROFIBUS-MBP (PA) segment all devices and components must be certified to EEx i.

Proof of intrinsic safety must be provided for these segments including the devices on the segment. The so-called FISCO model has been developed to keep such evidence as simple as possible. FISCO stands for Fieldbus Intrinsically Safe Concept and is a general concept for intrinsically safe fieldbus systems. If a PROFIBUS-MBP (PA) segment meets all specifications detailed in this concept, intrinsic safety is considered as substantiated.

PROFIBUS-MBP (PA) segments designed according to the FISCO model are based on the following principles:

- Power and data are transmitted according to IEC 61158-2.
- No power is fed into the bus from the nodes.
- There is only one source of power source in each segment
- The minimum basic power consumption of each slave is 10 mA.
- The slaves act as current sinks.
- PROFIBUS approved cables with specified maximum cable lengths are used.
- The bus terminations are passive and located on each end of the main cable.

The FISCO model is an international standard for the operation of fieldbuses in hazardous area, which is detailed in the IEC 60079-27.

Refer to the following sources for further details concerning the use of PROFIBUS-MBP (PA) in hazardous areas or concerning the FISCO model:

- IEC 60079-27 Explosive atmospheres – Part 27: Fieldbus intrinsically safe concept (FISCO)
- “PROFIBUS PA User and Installation Guideline” (Order No: 2.092)



Please bear in mind that proof of intrinsic safety is mandatory for PROFIBUS-MBP (PA). Evidence of intrinsic safety may be provided by authorised personnel only.

For PROFIBUS-MBP (PA) segments to be designed or accepted according to the FISCO model, they must meet the following specifications. Please note that the information provided in this chapter is a summary. They do not replace the IEC 60079-27 and the “PROFIBUS PA User and Installation Guideline” (Order No: 2.092)

General system requirements

Each transmission of the relevant segment must meet the following cable parameters:

- Resistance load per unit length: $15 \Omega / \text{km} < R' < 150 \Omega / \text{km}$
- Inductance load per unit length: $0.4 \text{ mH} / \text{km} < L' < 1 \text{ mH} / \text{km}$
- Capacitance load per unit length: $45 \text{ nF} / \text{km} < L' < 200 \text{ nF} / \text{km}$ (including shield)



So-called "FISCO cables" which meet the above cable parameters are available on the market. With such cables it is not necessary to additionally check the cable parameters. However, please make sure that the cables are specified as "PROFIBUS-MBP (PA) cables" and that they are of line type A (see chapter 3.2.2).

With the maximum permissible cable length according to FISCO, a distinction is made between categories "ia" and "ib" of the type of protection "Intrinsically safe" (EEx i).

	EEx ia (IIC)	EEx ib (IIC/IIB)
Cable length	$\leq 1000 \text{ m}$	Limited to 1900 m for PROFIBUS-MBP (PA)

Table 3-8 Maximum cable lengths according to FISCO

Planning the cabling

The cable lengths detailed in Table 3-8 are comprised of the total cable lengths of main lines and stubs. The individual stubs are subject to a line limitation which depends on the number of stubs in the relevant segment.

Number of stubs per segment	Length of a stub
25-32	---
19-24	30 m
15-18	60 m
13-14	60 m
1-12	60 m

Table 3-9 Maximum length of a stub against number per segment

If a stub is shorter than one meter, it can be treated as a so-called splice. Table 3-10 shows the total of splices or their length against the total cable length of the segment.

Total cable length	Total length of splices
> 400 m	8 m
< 400 m	2 % (of cable length)

Table 3-10 Total length of splices against cable length

Power supply unit

According to FISCO, each segment is allowed to have only one feeding energy source, which for PROFIBUS-MBP (PA) segments is the power supply unit. The output power P_0 of such power supplies must not exceed 5.32 W. Table 3-11 shows the maximum permissible output current for the resource groups IIC and IIB against the output voltage.

U_0 [V]	Permissible current for IIC (including safety factor 1.5) [mA]	Permissible current for IIB (including safety factor 1.5) [mA]
14	183	380
15	133	354
16	103	288
17	81	240
17,5	75	213

Table 3-11 Maximum permissible output currents for FISCO power supplies (according to IEC 60079-27)



Only power supplies with special FISCO certificate may be used.

Slaves

All slaves in a FISCO system must meet the following specifications:

- Slaves must not feed power into the bus, exclusively acting as current sinks.
- The minimum basic power consumption of a slave is 10 mA.
- The internal capacity C_i of a slave must not exceed 5 nF.
- The internal inductance L_i of a slave must not exceed 10 μ H.
- Each slave must be suitable for group IIC.



The manufacturer specifications of the slave must clearly state the suitability for use in a FISCO system. Only FISCO-certified slaves are allowed for use in FISCO systems. Such slaves automatically meet the above specifications.

Bus terminations

Each bus segment must be equipped with a bus termination at both ends. According to FISCO, this bus termination must meet the following limit specifications:

- $90\ \Omega < R < 102\ \Omega$
- $0\ \mu\text{F} < C < 2.2\ \mu\text{F}$

The setting and the design versions of bus terminations are described in chapter 3.2.5.



Only bus terminations with FISCO certification may be used.
Suitability for hazardous areas is not sufficient.



Please use the list shown in the supplement (List 4.3) in order to check whether the configuration rules according to FISCO have been met for your segment.

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 Assembly Guideline“ (Order No: 8.021).

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. See table 3-12 for the minimum distances between cables.

Distance of PROFIBUS cables to other cables	Distance		
	without/ non-metallic separating web	aluminum separating web	steel separating web
Signal transmission cables			
Shielded bus cables such as other PROFIBUS cables Data signals for PCs, programming devices, printers etc. Shielded analog inputs	0 mm	0 mm	0 mm
Power supply cables			
Unshielded	50 mm	20 mm	5 mm
Shielded	0 mm	0 mm	0 mm

Table 3-12 Minimum distances for cables according to EN 50174-2(2000)



If possible, use only conducting cable ducts and plan for regular connections to a functional ground. 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 grounding and corrosion protection.



Use List 4.4 of the list collection to document the cable route planning.

Cable routing in cabinets

When planning a cabinet, you should always provide for a grounding bar for connecting the cable shields. If you plan to jointly install power and data cables in the same cabinet, you should provide for separate cable routes.

Please observe the following items when planning the cable routing in a cabinet:

- Please see Table 3-12 for the required minimum distance between two cables.
- 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 3-12). 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.
- In addition to the grounding bar, sufficient space for the shield terminals should be provided at the cabinet entry.

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 3-12).



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

This chapter describes the grounding and shielding with PROFIBUS. The explanations of this guideline are restricted to those issues most relevant for PROFIBUS.

This chapter is arranged as follows:

- General notes on grounding and shielding
- EMC-compatible design of a plant
- Provisions in case of large potential differences
- EMC-compatible cable routing

For more detailed background information on grounding and shielding, please refer to appropriate technical literature. For information on the technical realisation and definition of the described grounding types see the “PROFIBUS Installation Guideline” (Order No: 8.021).



For planning purposes, you should use a floor plan of the plant which shows the position of the nodes, the routing of PROFIBUS cables as well as existing equipotential bonding conductors.

3.3.2.1 General notes on grounding and shielding

Shielded twisted-pair cables are used as the transmission medium in PROFIBUS plants. If the system has been correctly designed, electromagnetic interference will be discharged via the connected cable shield so that it does not interfere with the data.

In order to discharge interference, PROFIBUS nodes, PROFIBUS cable shields and other components must be connected to an equipotential bonding system.

The concept of the equipotential bonding system varies depending on the PROFIBUS configuration.

3.3.2.2 EMC-compatible design of a plant

The standard concept (Figure 3-29) for grounding of PROFIBUS DP and PROFIBUS-MBP (PA) is based on the use of a common equipotential bonding system for:

- Nodes (grounding according to manufacturer specifications)
- Cable shields (put on both sides)
- Additional grounding of the cable shield at cabinet entry



Figure 3-29 Standard grounding concept for PROFIBUS

In order to provide for complete and comprehensive equipotential bonding throughout the entire plant, you have to establish a conducting connection between the shields of all linking components (cable) and functional ground.

For the purposes of this book, it is presumed that the plant has a sufficient earthing system.

Particularities of PROFIBUS DP-IS

The grounding concept of PROFIBUS DP-IS differs from the standard grounding concept as follows:

- PROFIBUS DP and PROFIBUS DP-IS must not be grounded via the same equipotential bonding system.
- The fieldbus couplers required to connect to PROFIBUS DP are grounded according to the following circuit diagram.

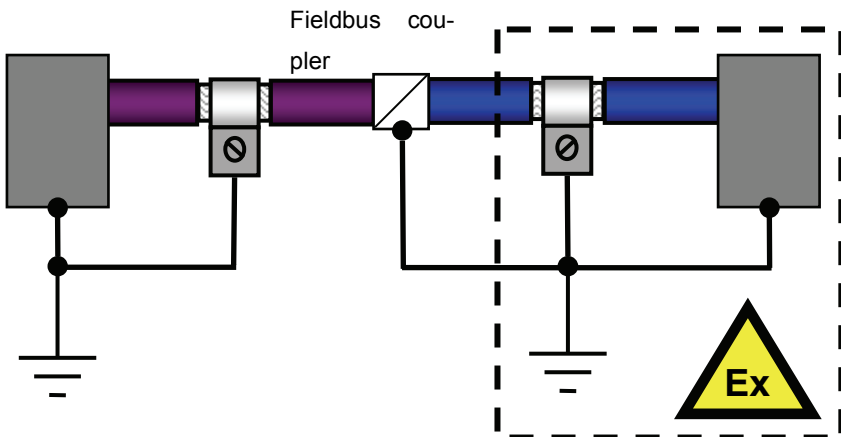


Figure 3-30 PROFIBUS DP-IS grounding concept

Particularities of PROFIBUS-MBP (PA)

If PROFIBUS-MBP (PA) is operated in hazardous areas, you should pay special attention to sufficient equipotential bonding between the hazardous area and the non-hazardous area.

For plants without good equipotential bonding between these areas it is possible, in contrast to the normal situation (cable shields applied on both sides), that cable shields in non-hazardous areas can be coupled capacitively.

We do not recommend putting on cable shields on one side, only.

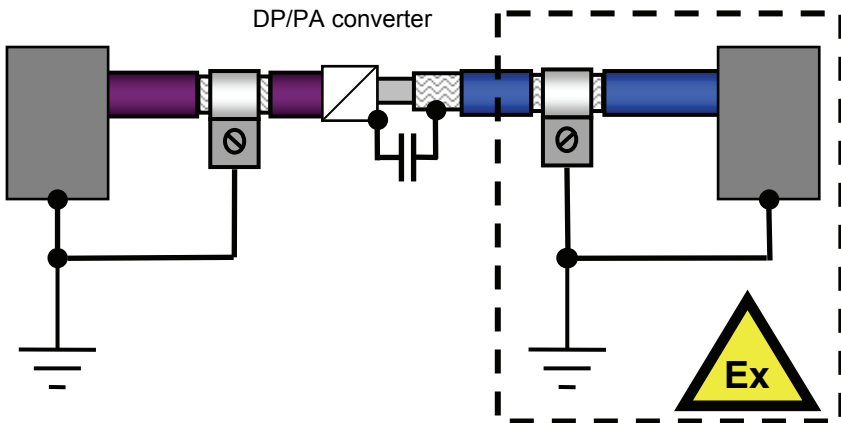


Figure 3-31 Capacitive coupling for PROFIBUS-MBP (PA)

Applying shields to a grounding bar

In general, PROFIBUS cables shall be grounded via the cable shield at the cabinet entry and exit. You should therefore provide a well earthed grounding bar at the cabinet entry to apply the cable shields.

Allow for sufficient space at the cabinet entry point to connect as much of the cable screen as possible. Plan the cable entry in a way that the cables do not deform.

It is recommended that additional strain relief of the cables is provided (Figure 3-32).

For detailed installation information and notes concerning the technical implementation, please see the “PROFIBUS Installation Guideline” (Order No: 8.021). Figure 3-32 shows how to apply PROFIBUS cables in general.

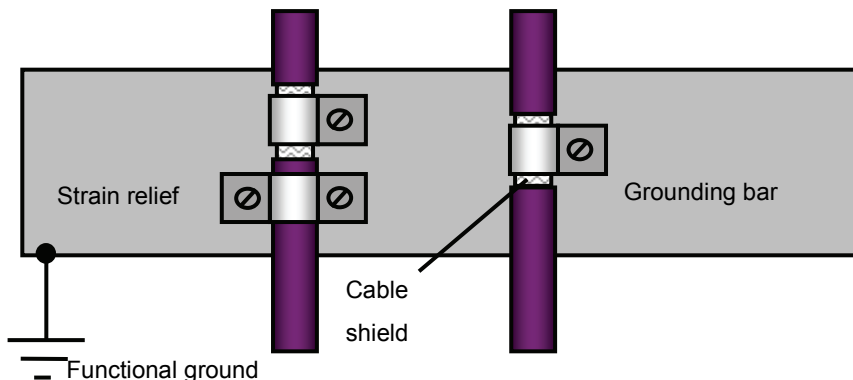


Figure 3-32 Shield connection on conducting surfaces

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).

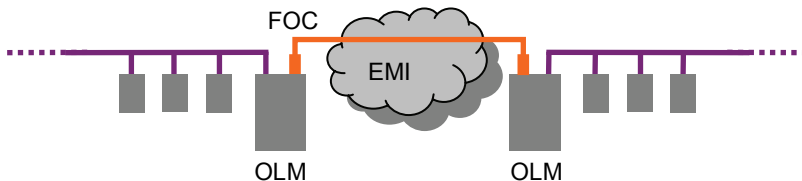


Figure 3-33 Application of FO technology with EMI

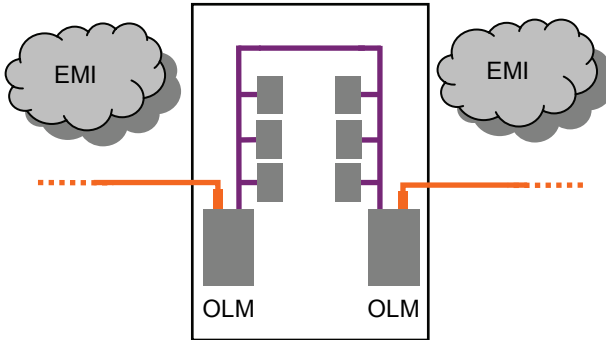


Figure 3-34 Application of FO technology for connection of cabinet with EMI

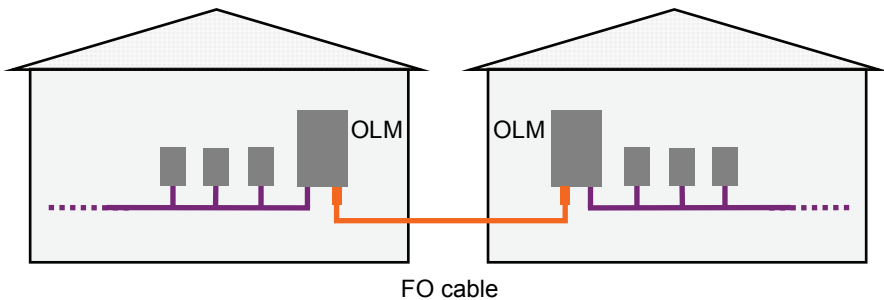


Figure 3-35 Application of FO technology for the connection of buildings

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.

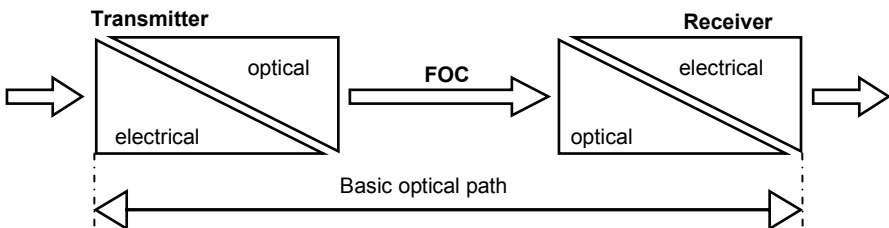


Figure 3-36 Basic optical path

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.

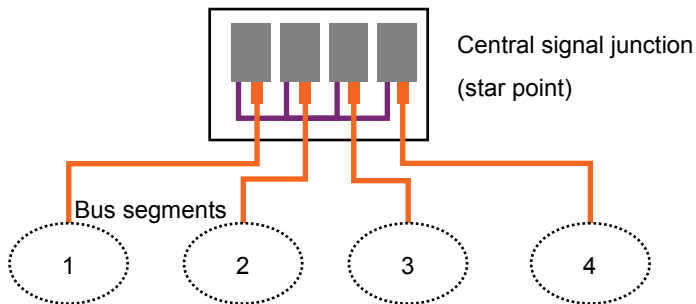


Figure 3-37 Star topology using OLMs

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.

Fiber type	Transmission distance
Single-mode glass fiber (9/125 μm)	up to 15 km
Multi-mode glass fiber (50-62,5/125 μm)	up to 3 km
PCF or HCS fiber* (200/230 μm)	up to 500 m
Plastic fiber (980/1000 μm)	up to 100 m
* PCF and HCS are trademarks	

Table 3-13 Maximum transmission distances of fiber types



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.

Fiber type	Wavelength [nm]	Attenuation [dB/km]
Single-mode glass fiber (9/125 μm)	1300	≤ 1.0
Multi-mode glass fiber (50-62,5/125 μm)	860	$\leq 2.7\text{-}3.5$
PCF or HCS fiber* (200/230 μm)	650	≤ 10
Plastic fiber (980/1000 μm)	650	≤ 230
* PCF and HCS are trademarks		

Table 3-14 Attenuation and wavelength of fiber types



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

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_{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 have 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 (List 2.2 of the supplement).

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 stem from IEC 61784-5-3.

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

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

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 3.2.2.1) 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.

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

Table 3-16 Versions of FO cables



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

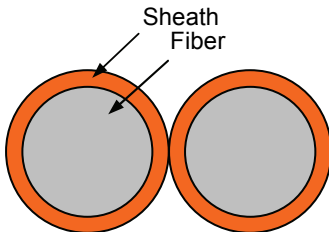


Figure 3-39 Duplex cable



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)

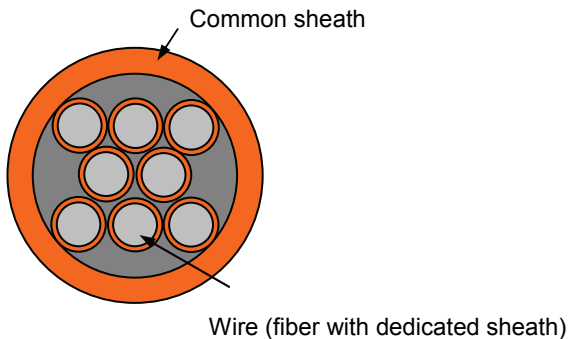
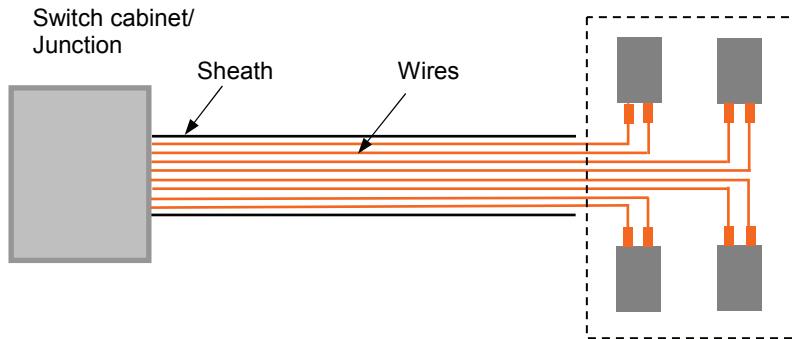


Figure 3-40 Break-out cable

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

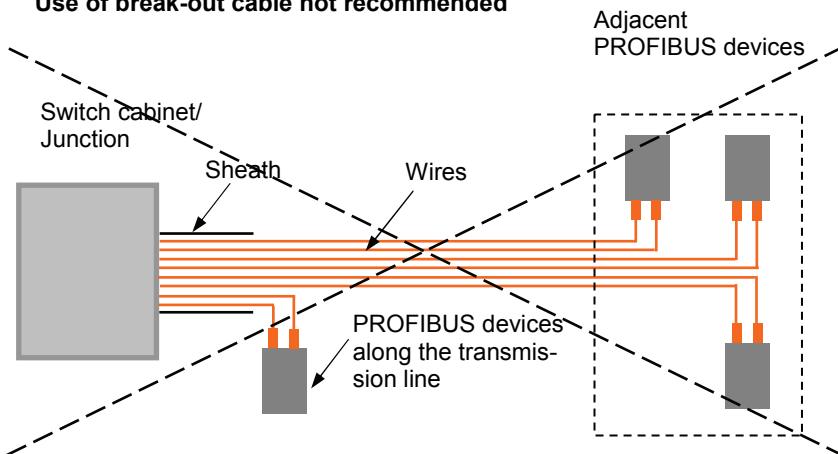


Figure 3-41 Problem when stripping break-out cables



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.

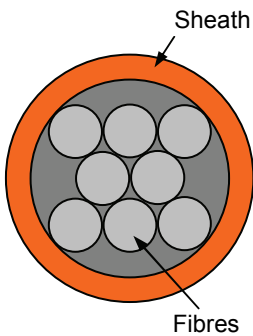


Figure 3-42 Universal cable with buffered fiber design



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 (List 3.1 of the supplement) and the segment structure plans (List 2.2 of the supplement). 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 connectors

For FO cables, the PROFIBUS standard requires type BFOC/2.5 connectors for the connection of devices. This connector is standardised 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 customised 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 (List 3.1 of the supplement).

Create a dedicated material list (List 3.3 of the supplement) 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 (List 3.1 of the supplement).

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 α 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
- 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 μm (step index profile)
- MM Multi-mode glass fiber 62.5/125 μm (gradient index profile)
- HCS HCS fiber 200/ 230 μm (step index profile)
- POF Plastic fiber 980/1000 μm (step index profile)

Planning the cabling

	SM	MM	HCS	POF	Unit
+ Output power	-20	-15	-16	-6	[dBm]
- Receiver sensitivity	-27	-24	-22	-20	[dBm]
Level budget (difference)	7	9	6	14	[dB]
= Total attenuation	7	9	6	14	[dB]
(Max.) cable length	8000	1700	300	44	[m]
Spec. fiber attenuation	0,5	3,5	10	250	[dB/km]
Fiber attenuation	4	6	3	11	[dB]
System reserve	3	3	3	3	[dB]

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

4 Determining power supply

This chapter discusses issues to observe when planning the power supply. Various types of mains as well as low voltage are described.

This chapter is arranged as follows:

- Various types of mains
 - TN-C
 - TN-S
 - Protection against electric shock

4.1 Various types of mains

As the implementation of the power supply is part of the general planning of electrical plants, it will not be discussed in detail in this guideline. What is relevant for the purposes of this document is the basic difference between the concepts related to the use of PE and N conductors.

- with combined PE (protective earth) and N (neutral) conductor TN-C
- with separate PE and N conductor TN-S

4.1.1 TN-C

TN-C systems do not have separate PE and N conductors (4-wire system), but combined PEN conductors. Although this version is permissible according to applicable standards, it should only be used for communication systems after considering the following.

Where PROFIBUS segments extend over a large geographical area and have different power supplies (from different sources) potential separation using an FO link or galvanic isolation must be used.

4.1.2 TN-S

This concept uses separate PE and N conductors (5-wire system). This type of mains is strongly recommended for the implementation of PROFIBUS plants.

4.1.3 Protection against electric shock



IEC 60364 defines general requirements for the protection against electric shock: Electrical Installations for Buildings - Part 4-41: Precautions; Protection against electric shock.

All PROFIBUS and PROFIsafe devices have to meet these requirements. You should also observe the requirements as described in IEC 60204 „Safety of machinery - Electrical equipment of machines“.

This standard also defines the low voltage supply using SELV and PELV. When planning your PROFIBUS plant you should only use power supplies based on SELV or PELV output voltage.

Please see applicable installation guidelines for details on the technical implementation of specified grounding of resources. In addition, please see the “PROFIsafe Guideline” (Order No: 2.232) and the “PROFIBUS Installation Guideline” (Order No: 8.021).

5 Planning plant acceptance

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: 8.031) 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.

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.

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6 Annex

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