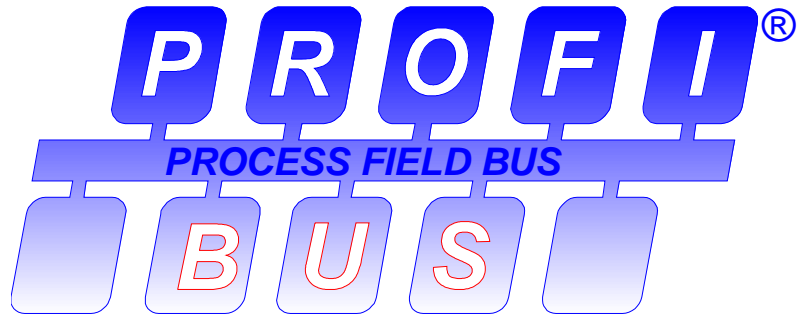


PROFIBUS



Technical Guideline

PROFIBUS PA

User and Installation Guideline

Version 2.2

February 2003

PROFIBUS Guideline, Order No. 2.092

Technical Guideline PROFIBUS PA User and Installation Guideline

**Version 2.2
February 2003**

Developed by the PROFIBUS Working Group „ Intrinsic Safety “ (WG7)
in the Technical Committee for „ Communication Profiles “ (TC2).

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Chapter 1 Introduction

Provides a **general introduction** and describes the basic **concept** for an intrinsically safe fieldbus

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1 Introduction

1.1 Goals and Target Groups

PROFIBUS PA is a communication system for decentralized automation systems and field devices using the special physical layer according to the standard IEC 61158-2, clause 21. This physical layer is characterised by the term “Manchester Coded and Bus Powered” (MBP, see Figure 1-1) and is customized to the special requirements of process engineering (e.g., remote powering and intrinsic safety). In a PROFIBUS PA device it is combined with the PROFIBUS DP-V1 protocol in accordance with IEC 61158, Parts 2- 6 , Type 3 /S2/, and especially with the “Profile for Process Control Devices”, Version 3.0 specification (known as “PROFIBUS PA Profile”) it offers the fieldbus solution for the process industry.

These guidelines supplement the information provided by the standards. They describe, how to develop and to use devices with a PROFIBUS PA interface. Emphasis has been placed on the special intrinsically safe characteristics of PROFIBUS PA. In addition, information is provided on the differences when PROFIBUS PA is used in non-potentially explosive areas.

The guidelines provide the following groups of personnel with useful information:

- Developers of fieldbus components: Essential detailed information from model preparation to testing
- Planners: Necessary information on the configuration of a fieldbus network
- Installation technicians: Helpful information on the laying of cables and commissioning
- Maintenance personnel: Useful information on working on a running network

PROFIBUS devices with an RS 485 interface, which are also permitted by the standard, are not discussed in these guidelines, as well as the basics of explosion protection (e.g., types of protection and classifications). Detailed information on the latter subject can be found in the applicable standards (e.g., /S3/, /S4/) and related specialized literature. The characteristics of an intrinsically safe RS 485 interface are specified in the Guideline “PROFIBUS RS485-IS” /S6/

This documentation is divided into four chapters.

- Chapter 1** Provides a **general introduction** and describes the basic **concept** for an intrinsically safe fieldbus
- Chapter 2** Contains the basic requirements and additional notes on the **implementation** of line interfaces of remote-powered fieldbus components (e.g., transmitters or bus power supplies)
- Chapter 3** Describes possible **network topologies, cabling, grounding concepts, component selection** and **component connection**. This chapter is directly primarily to system planners.
- Chapter 4** Summarizes the most important **terms** and **documents** and contains a list of addresses of important **approval and certification offices**

In order to facilitate the understanding of these guidelines a part of the glossary in chapter 4 may be copied to this introduction:

PROFIBUS PA Physical Layer

Physical Layer according to the standard IEC 61158-2, clause 21 (listed as “Communication Profile Family CPF 3/2 -Manchester coded, Bus Powered (MBP)” in IEC 61784, see Figure 1-1)

PROFIBUS PA Profile

Process Automation branch profile according to PROFIBUS specification “Profile for Process Control devices”, Version 3.0

PROFIBUS PA Device

Device combining a PROFIBUS PA Physical Layer with the PROFIBUS DP-V1 protocol in accordance with IEC 61158, Parts 2- 6, Type 3 /S2/, and with the PROFIBUS PA profile 3.0 specification and designed in accordance with these guidelines.

PROFIBUS PA System

Communication system using PROFIBUS PA devices and satisfying the requirements of these guidelines.

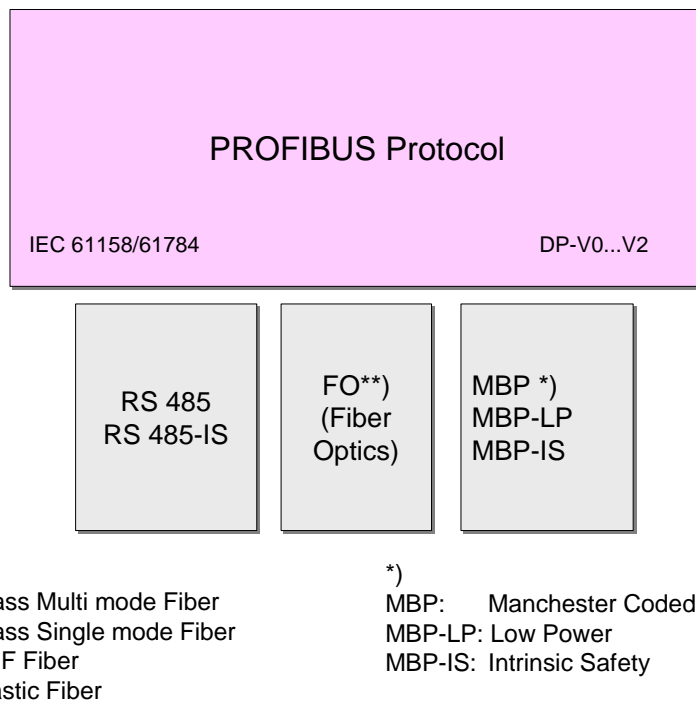


Figure 1-1 PROFIBUS Physical Layer family

1.2 Special Requirements of Chemical/Petrochemical Engineering and Other Process Engineering Applications

PROFIBUS PA is the communications system for process automation. It links decentralized automation systems and field devices, covering the entire world of general automation for process automation. At the same time, its transmission technology also meets the special requirements of process engineering (e.g., chemical and petrochemical engineering):

- Uniform application profiles for process automation and full interoperability of different PROFIBUS PA devices
- Power and data provided via the same conductor pair
- Use of PROFIBUS in potentially explosive areas in explosion protection class "intrinsic safety" by using transmission technology in accordance with IEC 61158-2
- Simple coupling of bus segments with different physical layers using segment couplers

Just as PROFIBUS PA can be used outside hazardous areas, it can also be used in potentially explosive areas with the "intrinsic safety" type of protection (MBP-IS). Planning of the non-intrinsically safe and intrinsically safe systems follows the same open concept. Field devices can be connected together to create different topologies and be completely powered by the bus. The devices can be manipulated and connected or disconnected during running operation within potentially explosive areas. Devices with higher power requirements can also be powered by separate local power sources (i.e., local powering).

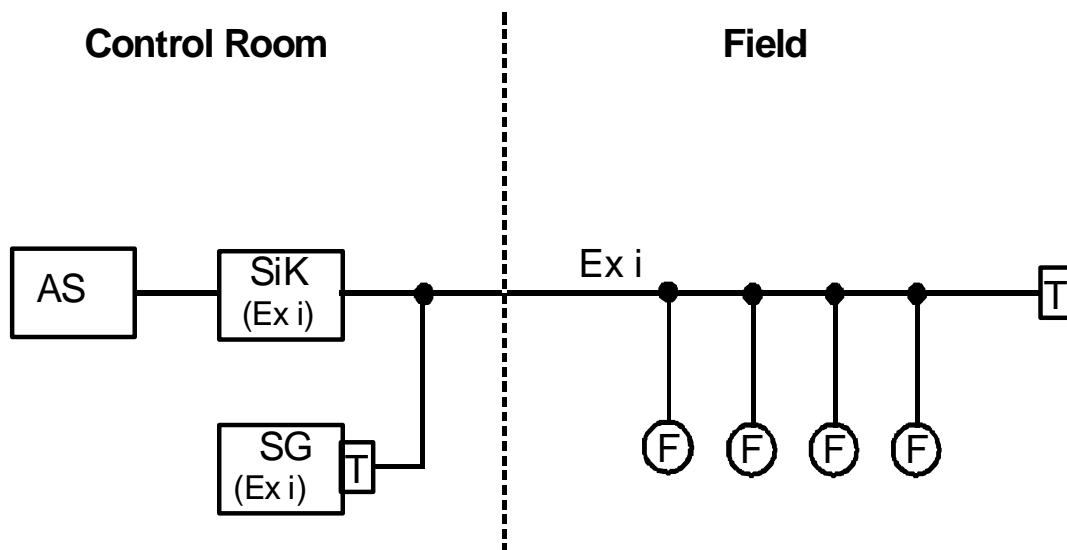
1.3 Basis of the Intrinsically Safe PROFIBUS PA / Fieldbus Model

The "i" intrinsically safe type of protection is advantageous for electrical apparatus and electric circuits which require low current due to their design.

This offers a number of advantages:

- Measurements or calibrations are possible in potentially explosive areas while a device is energized.
- Development and manufacturing of intrinsically safe devices is economical (i.e., added expense over the standard model of a device is low in comparison to the cost of other types of protection).
- Intrinsic safety is the only type of protection, which also includes the cables outside the devices in the explosion protection.

The limited electrical power, which intrinsically safe electric circuits can transmit, and the relatively complex rules and general conditions which apply to the connection of active and passive devices, creates certain restrictions. The characteristics of connection lines must also be considered here. Given today's technology, it is easy to evaluate intrinsically safe systems that usually consist of only one active and one passive device. However, an intrinsically safe fieldbus is harder to evaluate since a large number of devices are connected together.



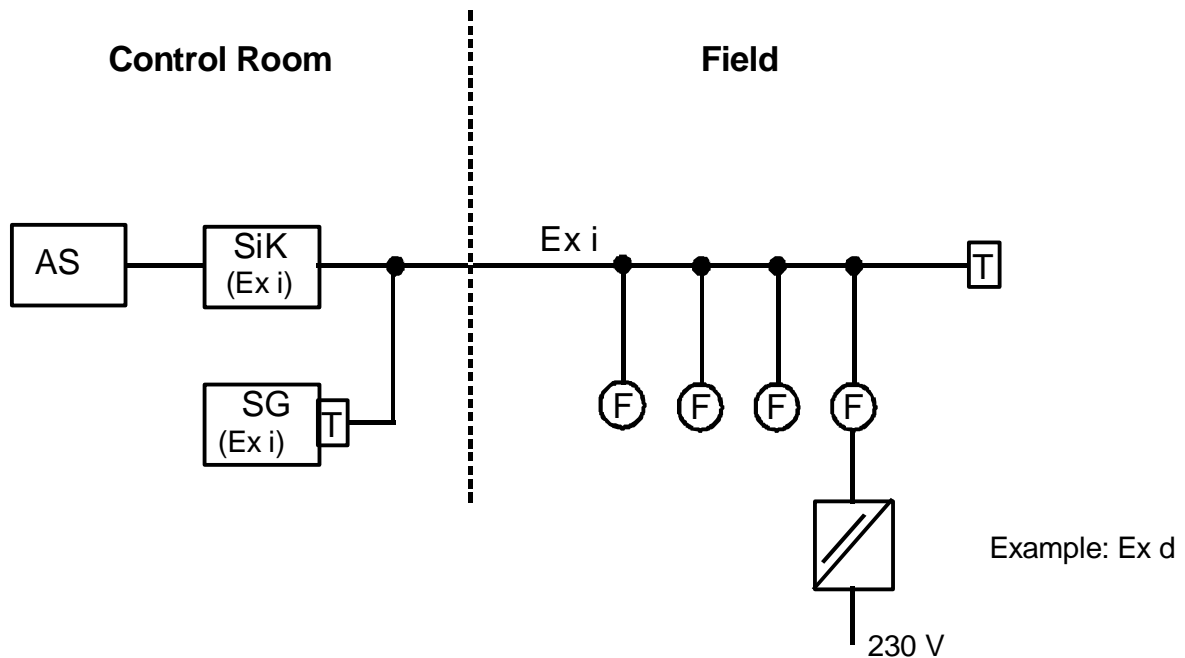
AS: Automation System
SiK: Signal coupler
SG: Power supply

Ex i: Intrinsically safe
F: Field device
T: Line terminator

Figure 1-2 Typical fieldbus architecture

Figure 1-2 shows a typical fieldbus architecture. The field devices with low power consumption (e.g., pressure or temperature transmitters) are powered by a two-wire bus. Signal transmission is also performed over the bus. The sensors/actuators are located in the field area while the plant-floor monitoring unit or components and the signal coupler connecting them to the bus are located in the control room or are to be explosion protected. Intrinsic safety must be ensured by suitable construction of all devices connected to the bus even when they are not installed in the field.

IEC 61158-2 states that a maximum of 32 field devices can be connected to the bus. However, under certain conditions, this number may have to be reduced. Some applications use field devices (e.g., transmitters) that cannot be operated on the power available from the fieldbus. Another source of power can be used here. The intrinsically safe fieldbus then transfers the data while separate electric circuits supply the auxiliary power to the transmitters (see Figure 1-3).



AS: Automation System
SiK: Signal coupler
SG: Power supply device

Ex i: Intrinsically safe
F: Field device
T: Terminating resistors

Figure 1-3 Fieldbus with stations supplied by auxiliary power sources

The **FISCO (Fieldbus Intrinsically Safe COnccept)** model /1/ /2/ is described in the Technical Standard IEC 60079-27 /S5/ and was originally prepared by the German Physikalisch technische Bundesanstalt (PTB) in cooperation with well-known manufacturers. It provides the capability of implementing an "i" fieldbus for use in potentially explosive areas. The main characteristic of this model is that only one active device (typically the bus power supply device) is connected to the fieldbus. The other devices are passive (i.e., they do not supply power on the line). In case of malfunctions, which must always be kept in mind (fault conditions), there is only one device that can supply power on the bus line. This maximizes the number of devices, which can be connected. Since only the bus power supply device can provide power on the line, only this one device needs to be equipped with a current and voltage limiter safety circuit. Table 1-1 and Table 1-2 show the limits of the parameter areas for use of the FISCO model for EEx ib IIC/IIB or EEx ia IIC. These areas are based on the results of previous studies and reasonable extrapolations.

It is interesting to note that the limit values usually given for maximum permissible external inductance L_a and capacitance C_a are not listed for the supply current circuit of the bus power supply device. If these values had been included, it would create the impression that L_a and C_a are presenting the intrinsically safe circuit as *unprotected inductance and capacitance*, which is not the case for the FISCO model.

In addition, the following requirements apply:

- Intrinsic safety (category 'ib' or 'ia' in accordance with EN 50020 /S3/)
- Only one active source in the sense of intrinsic safety. No power is supplied when a station is sending
- Each station consumes a basic current (direct current), which remains constant after the transient recovery time
- The stations (i.e., transmitter, hand-held terminal, bus master and repeater) act as a passive current sink
- The effective inner inductivities and capacities of the stations can be disregarded in relation to intrinsic safety
- Different types of lines can be used.
- The main bus line must be terminated at both ends.
- The power supply is connected to one end of the bus line.

EEx ib IIC / IIB

Power supply device: Output characteristic curve approaching square form

$U_z = 14$ to 24 V (Maximum output voltage)

I_k = Short-circuit current in accordance with PTB report W-39

Examples:

Up to 128 mA at $U_s = 15$ V (group IIC)

Up to 280 mA at $U_s = 15$ V (group IIB)

Cable characteristics (values per km):

$R' = 15$ to 150 Ω (loop resistance)

$L' = 0.4$ to 1 mH

$C' = 80$ to 200 nF (incl. an existing shield)

$C' = C_{\text{core/core}} + 0.5 C_{\text{core/shield}}$ if bus circuit is floating or

$C' = C_{\text{core/core}} + C_{\text{core/shield}}$ if the shield is connected to a port of the power supply device)

Cable length :

Total length ≤ 5000 m

Drop cables (each) : ≤ 30 m

Line terminations:

RC elements with:

$R = 90$ to 100 Ω

$C = 0$ to 2.2 μF

A line termination is permitted at each end of the main bus line.

The resistor must be infallible in the sense of EN 50 020.

Table 1-1 Valid parameter range of the FISCO model for use as EEx ib IIC / IIB

EEx ia IIC
<p>Power supply device: Trapezoidal output characteristic curve</p> <p>$U_s = 14 \text{ to } 20 \text{ V}$ (highest safe value)</p> <p>$U_o \geq 2 * U_s$ (See chapter 2.)</p> <p>I_k Short-circuit current in accordance with PTB report W-39 Example: Up to 215 mA at $U_s = 15 \text{ V}$ (group IIC)</p>
<p>Lines (values per km):</p> <p>$R' = 15 \text{ to } 150 \ \Omega$ (loop resistance) $L' = 0.4 \text{ to } 1 \text{ mH}$ $C' = 80 \text{ to } 200 \text{ nF}$ (incl. an existing shield) $C' = C'_{\text{core/core}} + 0.5 C'_{\text{core/shield}}$ if bus electric circuit is floating or $C' = C'_{\text{core/core}} + C'_{\text{core/shield}}$ if the shield is connected to one pin of the power supply device)</p> <p>Cable length :</p> <p>Total length $\leq 1000 \text{ m}$ Drop cables (each) : $\leq 30 \text{ m}$</p>
<p>Line terminations:</p> <p>RC elements with:</p> <p>$R = 90 \text{ to } 100 \ \Omega$ $C = 0 \text{ to } 2.2 \ \mu\text{F}$</p> <p style="text-align: center;">A line termination is permitted at each end of the main bus line. The resistor must be infallible in the sense of EN 50020.</p>

Table 1-2 Valid parameter range of the FISCO model for use as EEx ia IIC

The specifications described up to now constitute a basic set-up of the fieldbus model as shown in Figure 1-4.

The power supply for powering the bus and the bus master for the coupling to components close to the process are usually located in the control room (i.e., a non potentially explosive area). The power supply device contains circuits for reliable limitation of current and voltage on the bus.

In contrast to the RS485 physical layer PROFIBUS PA with IEC 61158-2 physical layer /S2/ uses a bit-synchronous transmission protocol and a direct-current-free signal. This standard meets the special requirements of the chemical and petrochemical industries described in sections 1.2 and 1.3. It is also compatible with the FISCO model described above.

It is assumed for the modulation that each bus station consumes a basic current, which shall be at least 10 mA and is usually used to power the device. The sending devices generate the communication signals by modulating +/-9 mA to the basic current (see Figure 1-5)

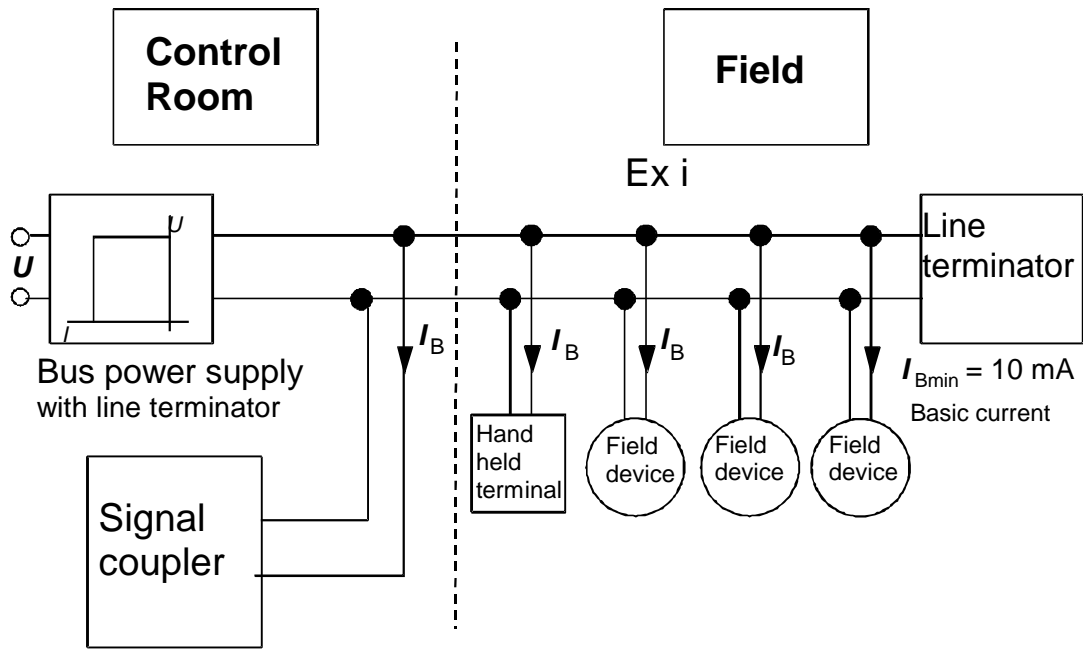


Figure 1-4 Fieldbus model

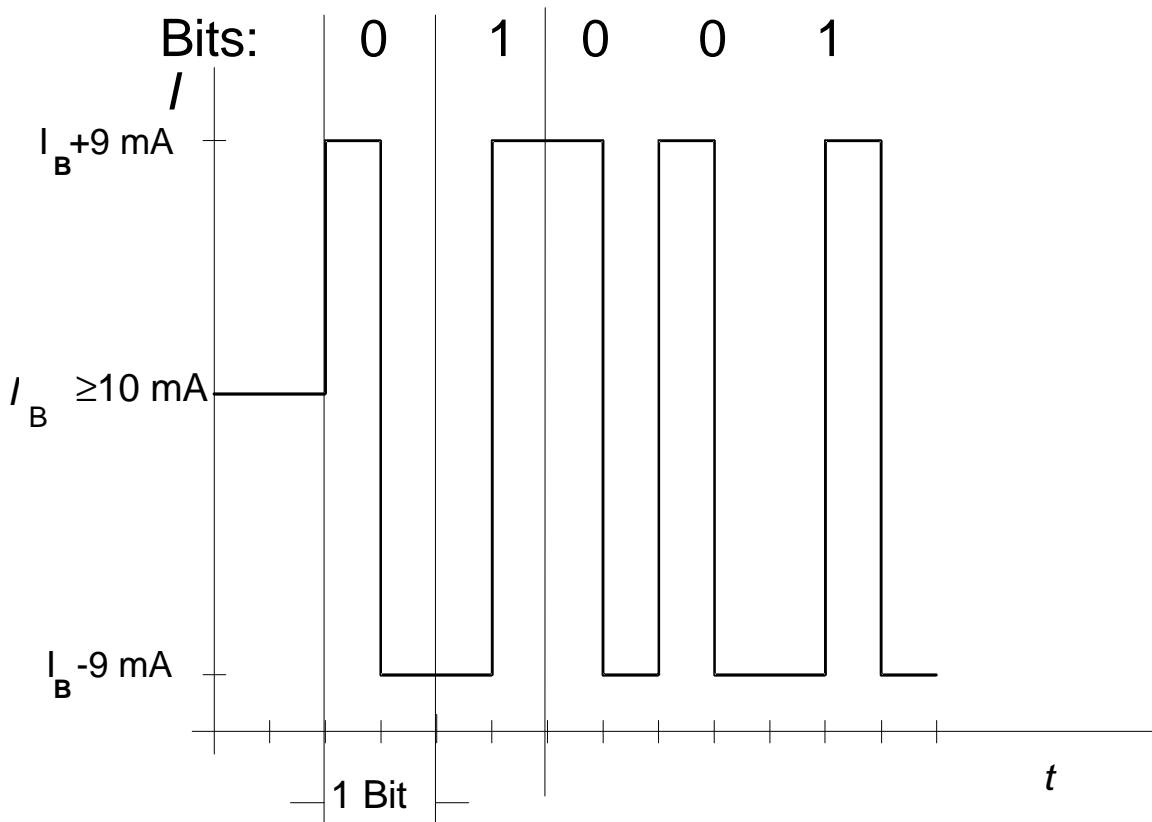


Figure 1-5 Current modulation (Manchester II code)

The primary characteristics of the transmission layer in accordance with IEC 1158-2 /S3/ are listed below:

- Digital, bit-synchronous data transmission
- Data transmission speed of 31.25 kbit/sec
- Manchester encoding
- Preamble with adapted coding
- Fault-proof start and end delimiter
- Sending level of $0.75 V_{SS}$ to $1 V_{SS}$
- Signal transmission over twisted-pair cables (shielded/unshielded)
- Remote powering via signal cable possible
- Intrinsically safe operation possible
- Linear bus and tree topology
- Up to 32 stations per line segment
- Can be expanded with up to 4 repeaters

Chapter 2 Implementation Hints

Contains basic requirements and additional information on the **implementation** of line interfaces of remote-powered fieldbus components (e.g., transmitters or bus power supplies)

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2 Implementation hints

This chapter contains information on the transmission layer (i.e., physical layer) for developers of fieldbus components. Remember that this information is only an interpretation of the applicable standards and does not have the status of a standard itself. The same applies to the statements on the problems of intrinsic safety.

2.1 Power supply

A power supply must be connected to the bus to supply the field devices with power. The supply voltage depends on the requirements of the particular application.

The power for an intrinsically safe bus can either be provided by a power supply with intrinsically safe output or by a non-intrinsically safe power supply supplemented by a barrier.

To prevent any impact on the data transmission, the electrical characteristics specified in the IEC 61158-2 standard and listed in Table 2-1 are mandatory for all power supplies.

The output terminals of a power supply must be clearly marked with "+" and "-".

Although a power supply isolated against earth is not specifically required by the standard, asymmetrical grounding of the bus cable conductors is not permitted. It is essential that any connection between the conductors and earth is balanced. For more details, see chapter 3.5.

NAMUR recommendation "Interference Immunity Requirements" /5/ must be met to ensure electromagnetic compatibility.

	Not Intrinsically Safe	Intrinsically Safe, IIC FISCO ¹⁾	Intrinsically Safe, IIB FISCO ¹⁾	Intrinsically Safe, IIC linear barrier ²⁾
According to FISCO model	no	yes	yes	
Max. DC supply voltage U_0	$\leq 32 \text{ V}$	$\leq 17.5 \text{ V}$	$\leq 17,5 \text{ V}$	$\leq 24 \text{ V}$
Max DC short circuit current I_0		$\leq 360 \text{ mA}$	$\leq 380 \text{ mA}^{7)}$	$\leq 250 \text{ mA}$
Max. output power P_0		$\leq 2,52 \text{ W}$	$\leq 5,32 \text{ W}$	$\leq 1,2 \text{ W}$
Ripple, noise	$\leq 16 \text{ mV}^{3)}$	$\leq 16 \text{ mV}^{3)}$	$\leq 16 \text{ mV}^{3)}$	$\leq 16 \text{ mV}^{3)}$
Output impedance ⁷⁾	$\geq 3 \text{ k } \Omega^{3) 4)}$	$\geq 400 \Omega^{3) 4)}$	$\geq 400 \Omega^{3) 4)}$	$\geq 400 \Omega^{3) 4)}$ ⁵⁾
Ripple, noise	$\leq 16 \text{ mV}^{3)}$			
Asymmetry attenuation	$\geq 50 \text{ dB}^{6)}$			$\geq 50 \text{ dB}^{5) 6)}$
1) Power supply with rectangular or trapezoidal characteristic in accordance with the FISCO model 2) Power supply or barrier with linear characteristic 3) In frequency range from 7.8 to 39 kHz. Otherwise see Figure 2-1 4) With integrated line terminator: $100 \Omega \pm 2\%$. It is recommend to provide each power supply with a terminating resistor. 5) Including barrier if required 6) No mandatory specification in the standard, but required functionally 7) The current limit results from a rectangular characteristic.				

Table 2-1 Electrical characteristics of power supplies

Power supplies which are used to supply field devices located in potentially explosive areas must be certified as intrinsically safe associated apparatus for use in hazardous locations.

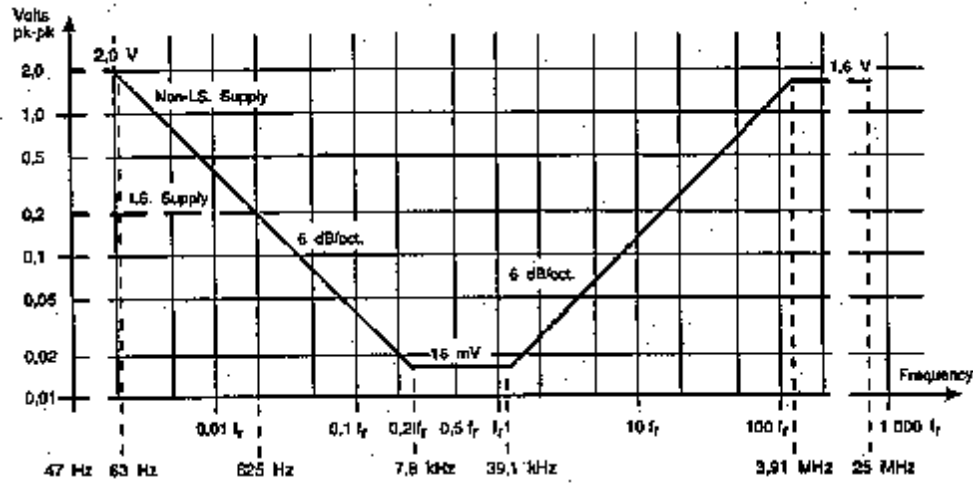


Figure 2-1 Max. ripple and noise according to IEC 61158-2

Table 2-2 provides an overview of the specifications recommended for the data sheets of power supplies.

	Not Intrinsicly Safe Power Supply	Intrinsicly Safe Power Supply
Associated apparatus in acc. w. IEC 60079-11		x
Power supply in acc. w. IEC 61158-2	x	x
Power supply in acc. w. FISCO model		x
Supply voltage (output voltage with tolerance)	x	x
Internal voltage drop (characteristic curve)	x	x
Maximum (available) supply current	x	x
Maximum output voltage (U_0)		x
Maximum output current I_0	x	x
Maximum output power P_0		x
Isolation class	x	x
Supply voltage	x	x
Power consumption	x	x
EMC classification	x	x
Permissible ambient temperature	x	x
Protection rating of the housing	x	x

Table 2-2 Recommended data sheet specifications for PROFIBUS PA power supplies

2.1.1 Non Intrinsically Safe Power Supply

Non-intrinsically safe power supplies must have the technical characteristics listed in Table 2-1. The block circuit diagram of a sample implementation is shown in Figure 2-2.

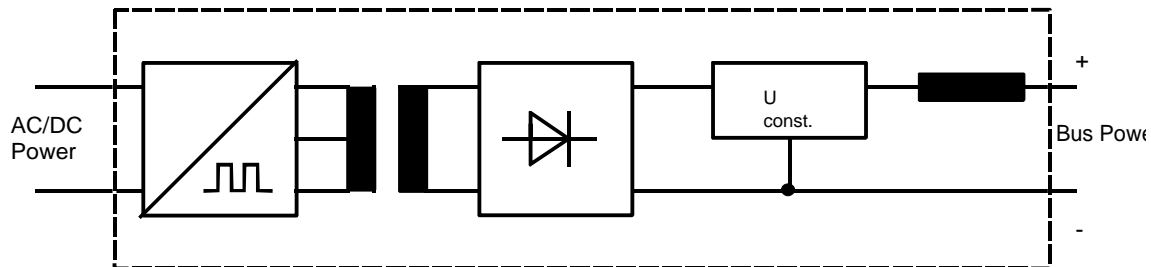


Figure 2-2 Block circuit diagram of a fieldbus power supply

Non-intrinsically safe power supplies can be used together with an approved barrier to supply an intrinsically safe bus.

2.1.2 Intrinsically Safe Power Supply

To supply field devices in potentially explosive areas, a power supply with intrinsically safe output can be connected to the bus instead of the combination of non-intrinsically safe power supply and barrier. This device is usually located outside the hazardous area in the control room. In the sense of EN 50 020, this is a so-called associated apparatus since, although it is not protected against explosion itself, it does generate an intrinsically safe electric circuit which leads to the potentially explosive area.

In addition to the requirements of IEC 61158-2 (see Table 2-1), intrinsically safe power supplies must meet the safety requirements stated in the IEC 60079-14/S4/ and IEC 60079-11 /S3/ standards.

If the power supply is to be located within the hazardous area, an additional standardized type of protection must be provided (e.g., installation in a housing of protection type " flameproof enclosure d").

Intrinsically safe power supplies can be part of other fieldbus components (e.g., segment couplers).

The investigations of the German Physikalisch Technische Bundesanstalt (PTB) concerning the FISCO model are based on a rated DC voltage of 13,5 V. The ignition curves for power supplies with rectangular characteristic presented in /7/ indicate that the maximum permissible power considerably decreases if the voltage increases. On the other hand, a low voltage power supply may not be advantageous because of the voltage drop caused by the transmission line. Therefore the voltage of 13,5 V seems to be an acceptable compromise.

Due to tolerances and in order to offer a margin for the signal amplitude the maximum output voltage U_0 of a power device must be greater than the rated output voltage. In the case of PROFIBUS, the signal amplitude is $\leq 1 V_{PP}$, therefore a margin of 0,5V is needed. If the tolerances are assumed to be $\leq 1 V$ the calculation results in a guaranteed maximum output voltage $U_0=15 V$. The admissible maximum output current (short circuit current), depending on the gas group, can be taken from available ignition curves or can be derived from ignition tests. In our case the PTB report W-39 states that for group IIC the allowed output current is $I_0=128 mA$. Other voltage/current combination in accordance with W-39 may be chosen.

Design and implementation of the safety-related voltage, and current limiters depends on the chosen category of the intrinsically safe circuit („ia“ or „ib“) The maximum values of the output parameters have to meet the requirements of the PTB report W-39 /7/.

An inspection certificate must be obtained for the bus power supply as " associated apparatus " in the sense of EN 50 020. This certificate must state that the power supply conforms to the FISCO model. In addition to the usual data (i.e maximum output parameters), the certificate may also contain primary specifications applicable to permissible fieldbus configuration.

Usually limit values for the maximum permissible external inductance L_a and capacity C_a are not required. If these values had been included, it would create the impression that L_a and C_a are present in the intrinsically safe circuit as unprotected inductivity and capacity, which is not the case for the

FISCO model. The cable here is not considered as concentrated inductivity and capacity as long as the parameters of the system remain within the range of limits defined in the FISCO model.

In addition to designation as a power supply in accordance with IEC 61158-2 and as an associated apparatus in accordance with IEC 60079-11/S3/, the data listed in Table 2-2 must also be included in the technical data sheet for the device.

2.1.3 Power Supply of the Category "ib"

Since the output current circuit of the power supply should have a low inner resistance for direct current, use of a power supply with a voltage regulator and an active current control (i.e., electronic current limitation) comes to mind. An inner resistance $\geq 400 \Omega$ in the signal frequency range (cf. Table 2-1) can be achieved by using a frequency-dependent negative feedback, for example.

The ideal output characteristic curve of such a power supply (i.e., current/voltage characteristic) is rectangular (see Figure2-3 and Figure 2-4). When the output current increases, the output voltage remains constant until the current reaches a certain limit. IEC 60079-11 permits such a solution under the assumption that redundant current and voltage limitation has been set up and reliable galvanic isolation (optional) from the non-intrinsically safe electric circuits has been provided.

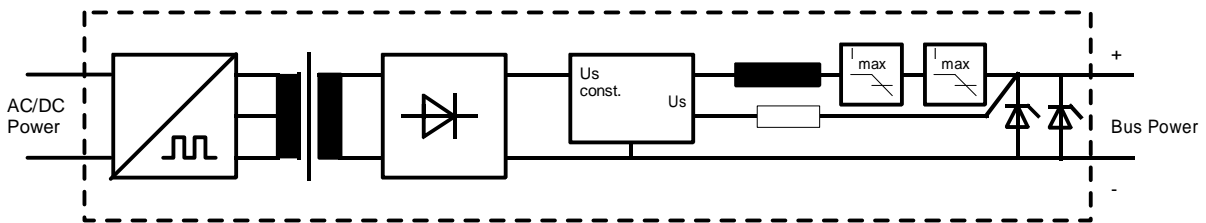


Figure2-3

Block circuit diagram of an intrinsically safe fieldbus power supply of the category "ib"

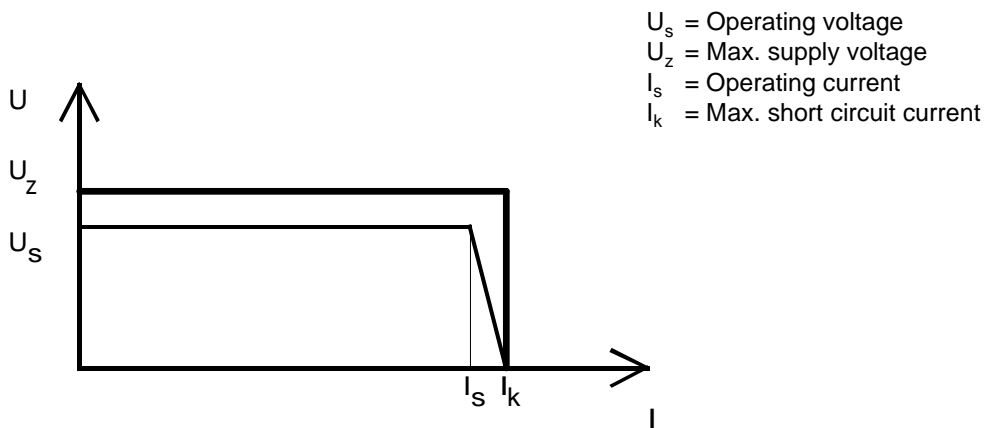


Figure 2-4 Output characteristic curve of a power supply of the category EEx ib

During the studies of the PTB, a voltage of 13.5 V direct current was first assumed for the output voltage. This value seems realistic since higher voltages would restrict the available power. The explosion limit curves for sources with square output characteristic curve /7/ show that the permissible power decreases significantly when the voltage increases.

2.1.4 Power Supply in Category "ia"

Power supplies with electronic current limitation must only be certified in accordance with IEC 60079-11 for category "ib". Since European countries except Germany (e.g., Italy and England) tend to use the "ia" category as the standard for intrinsically safe electric circuits, the FISCO model also describes an alternate power supply. This alternate device meets the requirements of intrinsic safety category "ia" and at the same time satisfies the need for the smallest possible inner resistance by replacing the electronic current limitation with a circuit with fixed resistance and Zener diodes (see Figure 2-5).

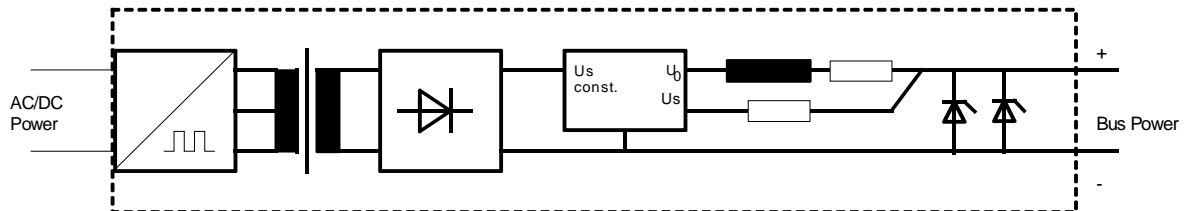


Figure 2-5

Block circuit diagram of an intrinsically safe, fieldbus power supply of the category "ia"

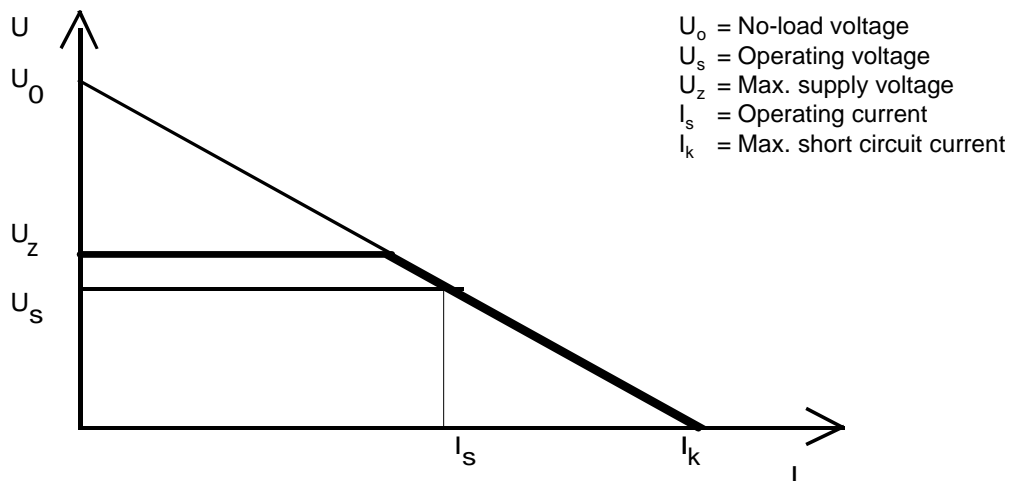


Figure 2-6

Output characteristic curve of a power supply of the category EEx ia

The design of the ia-power supply has to follow the rules described above, according to the PTB report W-39 /7/. The maximum output current I_k of Figure 2-4 corresponds to the current I_{zul} (at $U=U_z$) of Figure 2-6.

An example of a power supply suitable for category "ia" contains the following safety-related elements: Voltage source with $U_0 = 34$ V, fixed resistance with $R = 158 \Omega$, and Zener diodes with $U_{ZD} = 15$ V (maximum value). Such a circuit has a trapezoidal output characteristic curve as shown in Figure 2-6. The approximate operational values that can be achieved for the power supply are listed below.

$$U = 13.5 \text{ V}$$

$$I = 120 \text{ mA}$$

$$P = 1.7 \text{ W}$$

Thus, the operational values are comparable to those of the "ib" concept with electronic current limitation. Cf. 2.1.3. A disadvantage, which should be mentioned, is the requirement of a relatively

high thermal stress of the series resistor and the power loss in the series resistor, which is always present under operational conditions.

$$P_{v \max} = \frac{U_0^2}{R_v} = 7,32 \text{ W} \quad (\text{For short circuit on the output})$$

Applying a safety factor of 1.5, the allowed power dissipation of the resistor should be 11 W. Use of two resistors in series may be helpful.

The maximum power dissipation of the Zener diodes is shown below.

$$P_{v \max} = \frac{U_o - U_z}{R_v} \cdot 15 \text{ V} = \frac{34 \text{ V} - 15 \text{ V}}{158 \Omega} \cdot 15 \text{ V} = 1,8 \text{ W}$$

Taking into account the safety factor, the Zener diodes must be suitable for a maximum power dissipation of 2.7 W. The use of two diodes in series is also possible here.

All other points regarding intrinsic safety that must be taken into account when developing power supplies are based on the IEC 60079-14 and IEC 60079-11 standards.

2.2 Communication Devices

Communication devices include all devices, which are active in the transmission of information over the bus. A common characteristic of these devices is the MAU (i.e., Medium Attachment Unit) in accordance with IEC 61158-2 as an interface to PROFIBUS. Some examples of PROFIBUS PA communication devices are listed below.

- Field devices
- Components close to the process
- Hand-held terminals
- Repeaters
- PA-DP signal couplers

Communication devices can obtain their auxiliary power either wholly or partially from the bus. When intrinsically safe devices are involved, at least the medium attachment unit is powered by the bus. When another source of power is used to supply the device with auxiliary power, this is called local powering (in contrast to remote powering).

2.2.1 General Characteristics of the Fieldbus Interfaces

To ensure compatibility with the IEC 61158-2 standard, the electrical characteristics shown in Table 2-3 are mandatory for all fieldbus interfaces.

The table only gives an overview of the primary requirements. Details can be found in the standard.

If the device is sensitive to reverse wiring (i.e. the device will become inoperable if the terminals are reversed), then, the input terminals of a communication device must be clearly marked with "+" and "-". This is not mandatory for devices equipped with automatic polarity identification.

It is essential to avoid unbalanced capacitance between the two bus terminals and earth, i.e. the CMRR requirements have to be met. This is particularly important when the connection from the connection room to the electronics is made via feed-thru capacitors with high tolerances. For more details on CMRR, see also chapter 2.4.2.

NAMUR recommendation "Electromagnetic compatibility (EMC) of industrial process and laboratory control equipment" /5/ must be adhered to in order to ensure electromagnetic compatibility.

		Chapter of IEC 61158-2
Signal coding	Manchester II	9.2
Start delimiter	1, N+, N-, 1, 0, N-, N+, 0 ¹⁾	9.4
End delimiter	1, N+, N-, N+, N-, 1, 0, 1 ¹⁾	9.5
Preamble	1, 0, 1, 0, 1, 0, 1, 0	9.6
Data transmission rate	31.25 kbit/sec \pm 0.2 %	11.1
Output level (peak - peak)	0.75 V to 1 V	11.3
Max. difference between pos. and neg. transmit amplitude	\pm 50 mV	11.3
Max. transmit signal distortion (oversvoltage, ringing and drop)	\pm 10%	11.3
Transmitter noise	1 mV (RMS) ²⁾	11.3
Output impedance	\geq 3 k Ω ³⁾	11.3
Operating voltage	9 V to 32 V ⁴⁾	11.3
Common Mode Rejection Ratio CMRR	\geq 50 dB ⁵⁾	11.3
Leakage current ⁶⁾	50 μ A	
<p>1) N+ and N- are non-data symbols in accordance with IEC 1158-2.</p> <p>2) In frequency range of 1 to 100 kHz</p> <p>3) In frequency range of 7.8 to 39 kHz</p> <p>4) Operational voltage range. Can be limited to 9 V to 17.5 V or to 9 V to 24 V for intrinsically safe devices. Cf. supply voltages in Table 2-1.</p> <p>5) Corresponds to a unbalanced capacitance of 250 pF at 39 kHz</p> <p>6) Only for intrinsic safety</p>		

Table 2-3 Electrical characteristics of fieldbus interfaces

A further important requirement aims to the system fault tolerance. It must be avoided that a defective device impairs the operation of the other devices in the system. Appropriate means or methods (e.g. FDE / **F**ault **D**isconnection **E**lectronics) shall prevent unwanted excessive current consumption in case of fault. The increase of DC current compared with the rated current is called "fault current". Additionally appropriate means (e.g. Jabber Inhibit) must prevent the device from unwanted excessive signal transmission.

The requirements can be summarised as follows :

- 1) In case of a single fault the current consumption of a device may exceed the rated current by not more than 9 mA (fault current \leq 9 mA). Faults of components close to the bus interface shall not be regarded.
- 2) In case of a single fault the input impedance of a device must not fall short of 1 k Ω within the signal frequency range. Faults of components close to the bus interface shall not be regarded.
- 3) The device shall contain a self-interrupt capability (Jabber Inhibit) according to IEC 61158-2, clause 11.5.

The fault current (\leq 9 mA) shall be described in the data sheet as well as the normal operation current. Communication devices, which are used in potentially explosive areas, must be certified as intrinsically safe apparatus. The certificates must contain a statement specifying that the devices conform to the FISCO model. Other specifications which should also be given include permissible operating voltage,

maximum operating current, maximum leakage current, maximum current consumed during a malfunction (i.e., limiting current of a fault current limiter which may be installed or fault disconnect equipment), and maximum permissible power of the corresponding power supply. Since the permissible operating voltage can be specified based on the maximum permissible power of the related power supply, one and the same communication device can either be operated with a FISCO power supply (output voltage up to 17.5 V and permissible output power up to 1.8 W) or with a linear barrier (output voltage up to 24 V and permissible output power up to 1.2 W). Cf. also table 2.1 and chapter 2.2.6.

If the devices are powered locally, the certificate must contain a note on galvanic isolation from the bus interface. Table 2-4 provides an overview of recommended specifications for the data sheets of the primary devices.

	Non intrinsically safe devices	Non intrinsically safe devices
Fieldbus interface in acc. w. IEC 1158-2	x	x
Type of explosion protection in acc. w. IEC 60079-11 ¹⁾		x
Communication device in acc. w. the FISCO model ²⁾		x
Permissible operating voltage	x	
Permissible output voltage of the power supply		x
Permissible output current of the power supply		x
Max. permissible output power of power supply		x
Maximum operating current	x	x
Maximum fault current	x	x
Permissible ambient temperature	x	x
Isolation class	x	x
Housing protection rating	x	x
1) Other supplementary explosion protection types if necessary. Fieldbus electric circuit is always intrinsically safe.		

Table 2-4 Recommended data sheet specifications for PROFIBUS PA communication devices

2.2.2 Field Devices, Hand-Held Terminals and Components Close to the Process

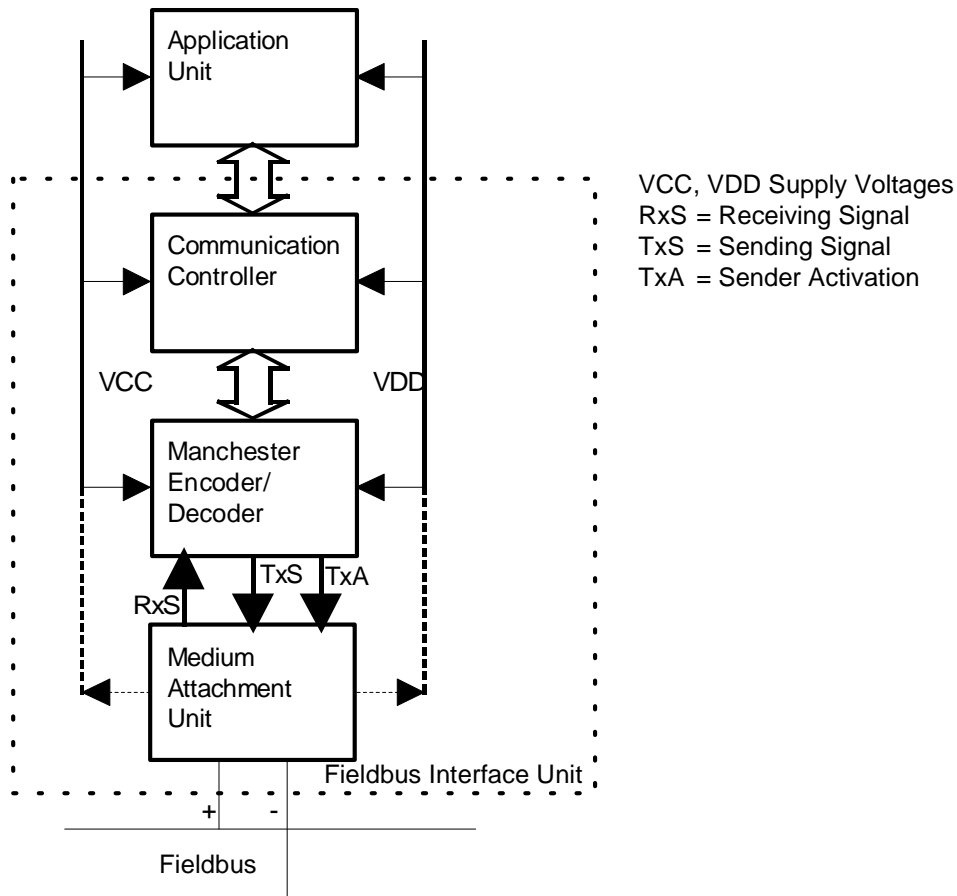


Figure 2-7 Principal setup of a field device with fieldbus interface

Field devices, hand-held terminals and components close to the process with PROFIBUS PA connection usually include the units shown in Figure 2-7.

Integrated circuits permitting simple implementation of a fieldbus connection are available for both digital units (i.e., communication controller and Manchester encoder/decoder) and analogue units (i.e., medium attachment unit). For more details, see the data sheets of the individual IC's.

2.2.3 Coupling Elements

Coupling elements are used to connect a PROFIBUS PA segment to another PROFIBUS PA segment or to a PROFIBUS RS485 segment.

With the exception of signal levels, the IEC 61158-2 standard does not describe the required characteristics of a coupling element. This means that it is the task of the system planner to ensure that "Network Configuration Rules" standard is complied with when coupling elements are used. The following specifications are important.

- Maximum signal delay
- Maximum deviation from nominal signal zero crossing (signal jitter)

Two types of coupling elements can be used.

- PA repeaters
- PA-RS485 signal couplers

2.2.3.1 PROFIBUS PA Repeater

A PROFIBUS PA repeater connects two PROFIBUS PA segments. It contains the components shown in Figure 2-8. To ensure compatibility with the IEC 61158-2 standard, the electrical characteristics shown in Table 2-3 are mandatory for both fieldbus interfaces. The notes on medium attachment unit design contained in chapter 2.2.1 also apply to repeaters.

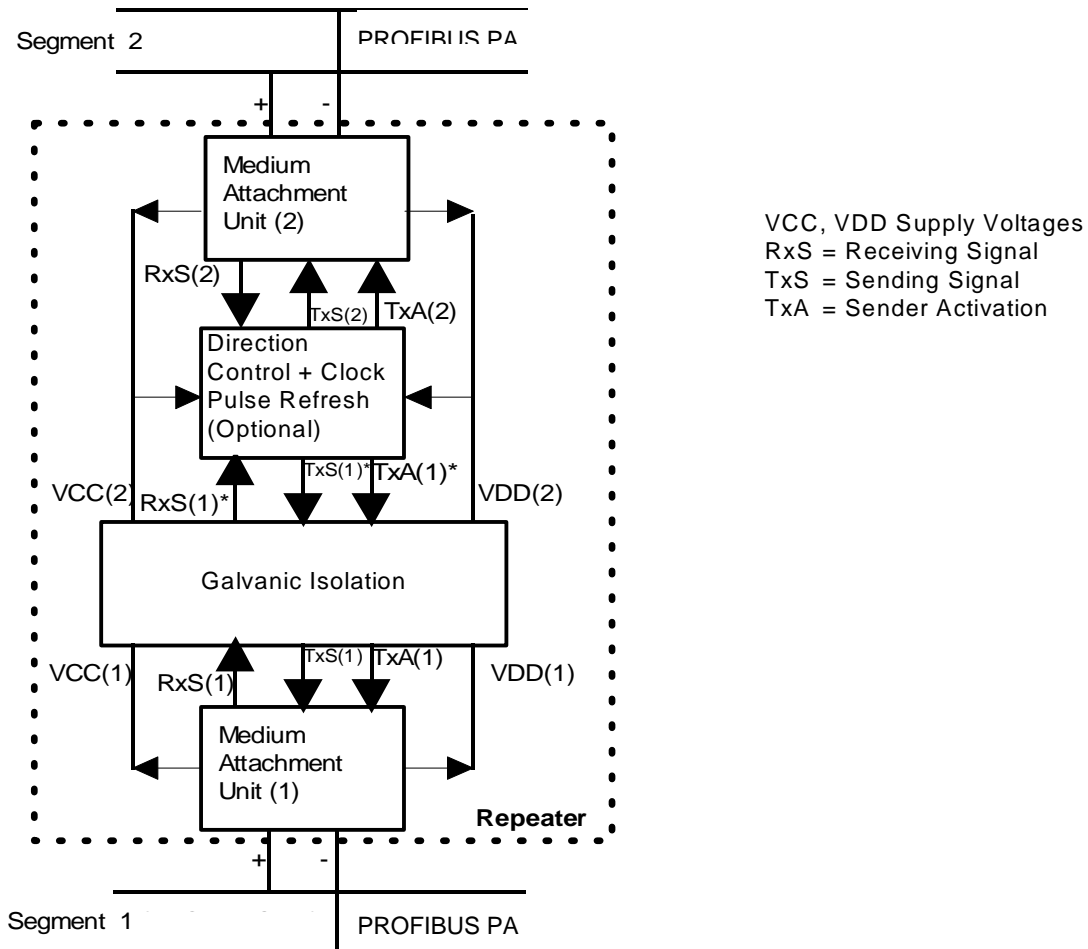


Figure 2-8 Circuit diagram of the principle of a repeater

Repeaters, which are connected to intrinsically safe bus segments, must be certified as intrinsically safe apparatus. The certificate must contain a statement that the devices conform to the FISCO model. The specifications of IEC 60079-11/S3/ must be adhered to for galvanic isolation. Cf. chapter 2.2.4.

To be able to determine whether the "Network Configuration Rules" contained in the IEC 61158-2 standard have been met, the system planner requires information on the signal delay caused by repeaters and the maximum deviation from the nominal signal zero crossing (i.e., signal jitter). This information must be documented in the data sheet.

A repeater can be combined with a power supply and with line terminators.

2.2.3.2 PROFIBUS PA-RS485 Signal Coupler

A PROFIBUS PA-RS485 signal coupler connects a PROFIBUS PA segment with a PROFIBUS RS485 segment. It contains the components shown in Figure 2-9.

To ensure compatibility with the IEC 61158-2 standard, the electrical characteristics shown in Table 2-3 are mandatory for the PROFIBUS PA interface. The notes on medium attachment unit design contained in chapter 2.2.1 also apply to PA-RS485 signal couplers. The specifications contained in volume 2 of EN 50 170 apply to the design of the PROFIBUS RS485 bus interface.

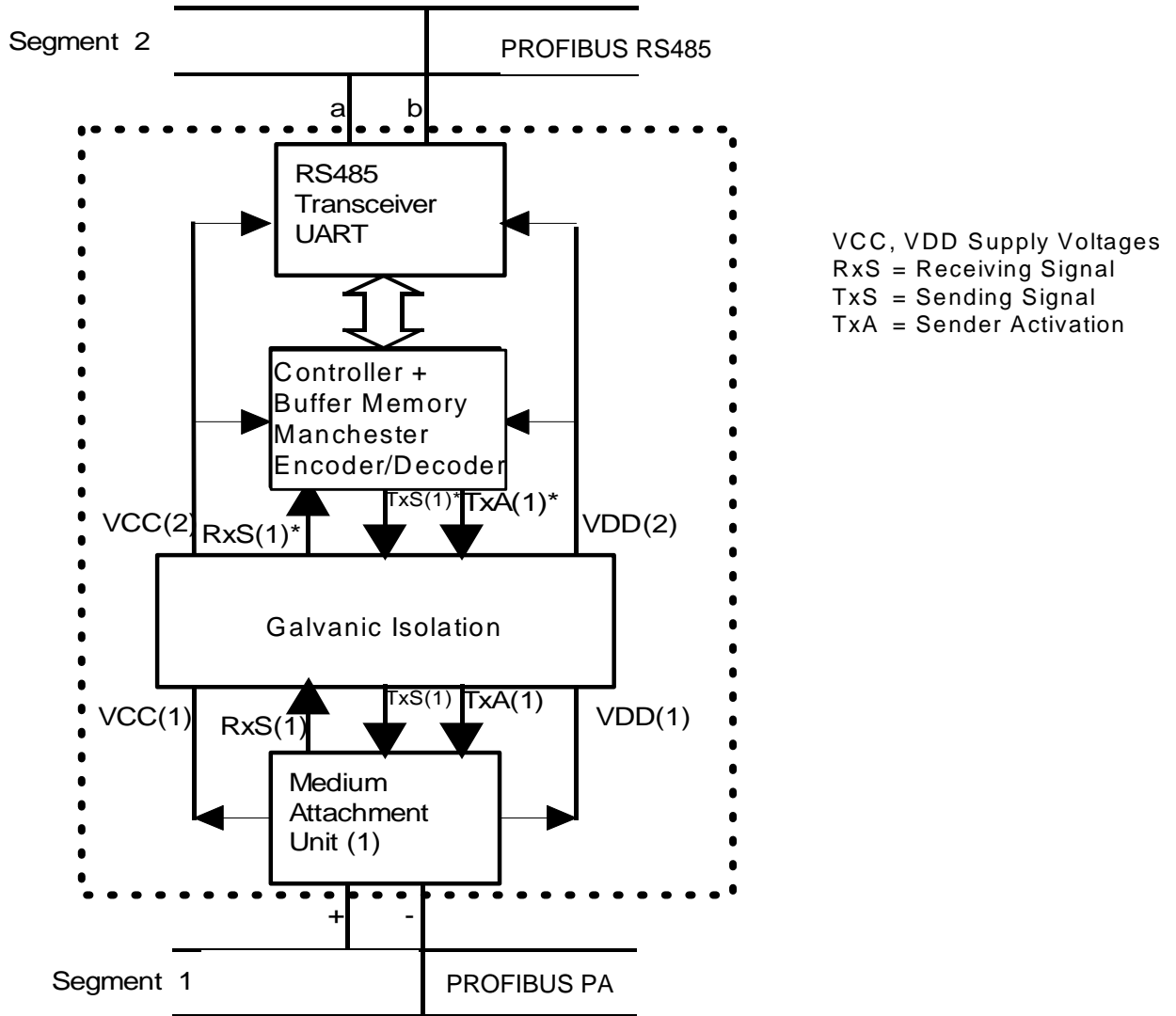


Figure 2-9 Diagram of the principle of a PA-RS485 signal coupler

PROFIBUS PA-RS485 signal couplers, which are connected to intrinsically safe bus segments, must be certified as intrinsically safe apparatus. The certificate must contain a statement that the devices conform to the FISCO model. The specifications of IEC 60079-11/S3/ must be adhered to for galvanic isolation. Cf. chapter 2.2.4.

To be able to determine whether the "Network Configuration Rules" contained in the IEC 61158-2 standard have been met, the system planner requires information on the signal delay caused by a - RS485 signal coupler and the maximum deviation from the nominal signal zero crossing (i.e., signal jitter). This information must be documented in the data sheet.

A PROFIBUS PA-RS485 signal coupler can be combined with a power supply and with a bus terminator. Such a device is usually called segment coupler.

2.2.4 Galvanic Isolation

The IEC 61158-2 standard states that all devices with fieldbus connections must be operated without direct connection to earth. For intrinsically safe devices, chapter 5.7 of IEC 60079-11 states that the isolation voltage (i.e., effective value) between the intrinsically safe electric circuit and grounded / earthed parts must be twice as high as the voltage of the intrinsically safe electric circuit, but at least 500 V.

VCC, VDD Supply Voltages
 RxS = Receiving Signal
 TxS = Sending Signal
 TxA = Sender Activation

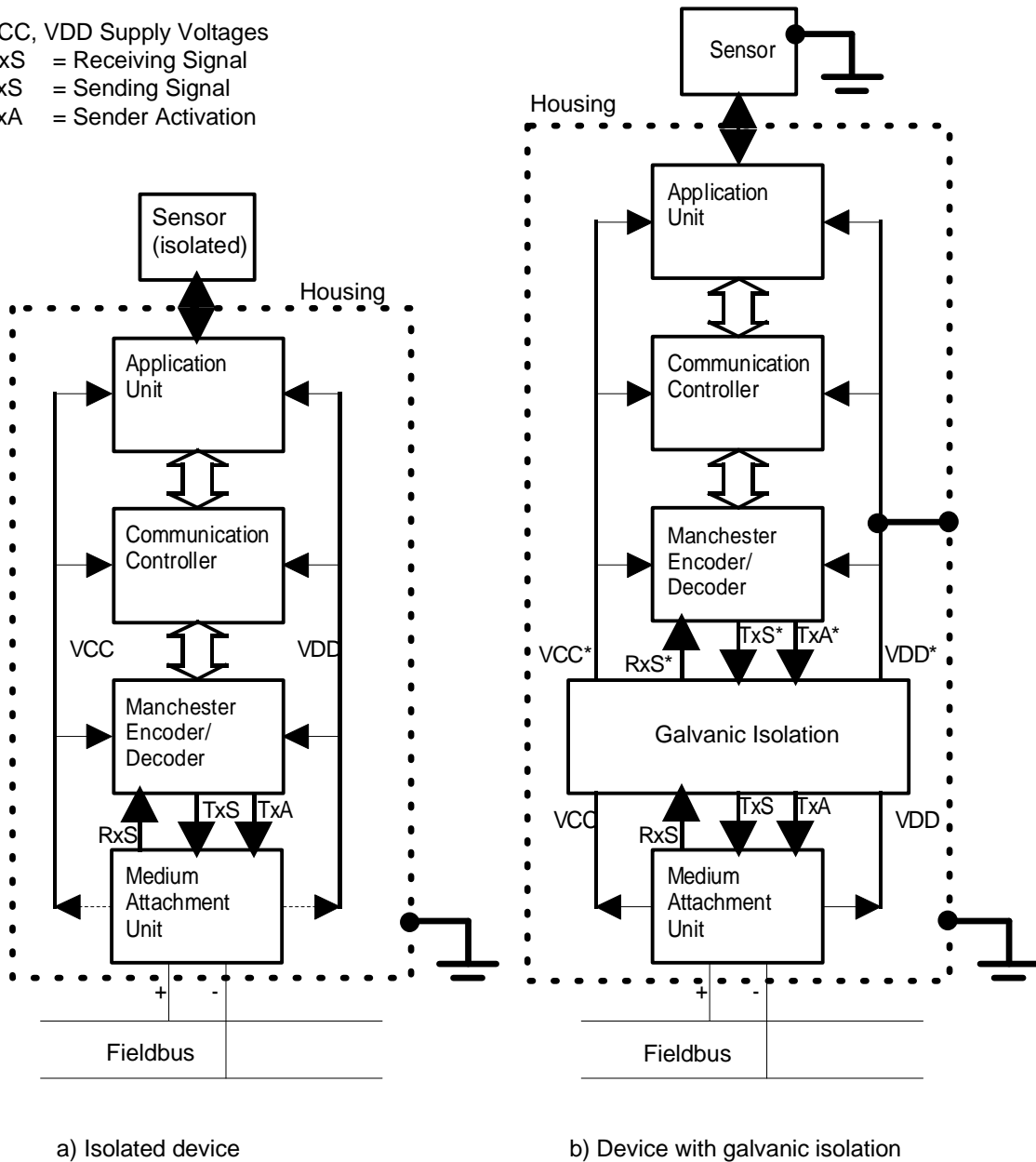


Figure 2-10 Isolation of field devices

For some special devices, it is possible to meet these requirements by setting up the entire field device isolated from the environment. An example of such a device is a temperature transmitter with its sensor contained in non-conducting material as shown in Figure 2-10a. Remember, however, that IEC 61158-2 requires that the unbalanced capacitance measured between the two bus terminals and earth must not exceed 250 pF.

If a part of the field device cannot be operated ungrounded, galvanic isolation must be provided between this part and the fieldbus. The device developer decides where this isolation will be provided. The isolation between the medium attachment unit and Manchester encoder/decoder shown in Figure

2-10b is particularly useful since the unbalanced capacitance can be kept very low when isolation is performed near the bus cable.

When a bus-powered field device is involved, the galvanic isolation must cover both the signals (i.e., capacitive, inductive or optical transmission) and the power supply of the field device (i.e., DC/DC converters).

Locally powered devices do not require DC/DC converters. In case of locally powered devices only the medium attachment unit is powered by the bus while the other parts of the field device are powered by a second power circuit. If this electric circuit is intrinsically safe, the above requirements (i.e., isolation voltage of 500 V) apply to signal isolation. If the supply circuit is not intrinsically safe, isolation voltage must be at least 1500 V. In addition, the requirements of table 2 of IEC 60079-11 (i.e., clearances, creepage, distances and separations between conducting parts) must be met.

If the intrinsically safe electric circuit is connected capacitively to earth (e.g., by a capacitive EMC suppresser filter), the guidelines of the individual certification authority applicable to safety isolation by capacitors must be adhered to.

2.2.5 Reverse Powering

With the exception of one power supply per segment, the FISCO model (cf. chapter 1) does not permit devices which are connected to the intrinsically safe fieldbus to feed power back to the bus, even when a short circuit occurs on the bus line. This is usually ensured by connection in series of two (for EEx ib) or three (for EEx ia) silicon or Schottky diodes in the input electric circuit. The field device conforms to the FISCO model when the leakage current of these diodes (up to the maximum reverse voltage in the permissible temperature range) does not exceed 50 μ A. Diode manufacturer specifications (i.e., typical values as per data sheet) usually apply here in addition to a safety factor.

Remember, however, that final judgment of these measures is the responsibility of the certifying authority performing the safety tests and certification of the particular field device.

2.2.6 Thermal Ignition

Thermal ignition due to excessive surface temperatures must be prevented by restricting the maximum permissible power of the related power supply depending on circuit design and device construction. When intrinsically safe apparatus which are used in potentially explosive areas are involved (i.e., field devices), the maximum permissible values for input voltage, input current and input power must be specified together with the temperature class of the device.

These maximum values must not be exceeded by the bus power supply. IEC 60079-11 states that intrinsically safe resources can be viewed in a very simplified way when the power is limited to 1.3 W and the devices assigned to temperature class T4. When a higher permissible power can be applied, special construction measures are sometimes required. A few examples are listed below.

- Limitation of the input current or the input voltage for certain parts of the circuit
- Encapsulation of the circuit by casting compound
- Installation of the circuit in a flame-proof housing

Remember, however, that final judgment of these measures is the responsibility of the certifying authority performing the safety tests and certification of the particular field device.

To simplify physical constructive measures, the permissible value for the input voltage can be specified based on the maximum output power of the related power supply (e.g., 17.5 V for power supply with a maximum output power of ≤ 1.8 W and 24 V for power supplies with a maximum output power of ≤ 1.2 W).

2.3 Line Terminators

Line termination consists of a series circuit of one capacitor and one resistor on both ends of the main bus line.

Permissible values:

$$R = 100 \Omega \pm 2 \%$$

$$C = 1 \mu\text{F} \pm 20 \%$$

When considering safety of the line terminations, remember that although a single resistor can be designed as infallible in the sense of EN 50 020, a capacitor cannot. If a capacitor short circuits, the resistor is located directly parallel with the bus. This must be considered when providing for prevention of thermal ignition.

2.4 Test Circuits

It is absolutely essential that the specifications of the IEC 61158-2 standard be complied with to ensure correct interplay of the fieldbus components. Problems can occur particularly when measuring some of the physical variables described in chapter 11 of the standard. Notes on possible measuring circuits and characteristics of the required measuring devices are given below.

For information on measuring circuits for the required EMC tests, see the applicable standards.

2.4.1 Impedances

For both the bus interfaces (i.e., medium attachment unit MAU) of the field devices and coupling elements and the power supplies, chapter 11.4 of the standard requires that the input impedance (can be measured from the bus line) in the signal frequency range (7.8 to 39 kHz) does not pass below a minimum value during normal operation. With the exception of the first 10 msec following connection of a field device to a power supply, this requirement applies to all aspects of operation.

	Impedance	Voltage Range	Current Range
Bus interface (e.g., field device)	$\geq 3 \text{ k}\Omega$	9 to 32 V	For operating current
Intrinsically safe bus power supply	$\geq 400 \Omega$	For operating voltage	0 to I_{Max}
Non intrinsically safe bus power supply	$\geq 3 \text{ k}\Omega$	For operating voltage	0 to I_{Max}

Table 2-5 Input Impedances of bus interfaces and power supplies

The standard states that the input impedance of the bus interface is to be measured with a sinus signal whose amplitude should be greater than the receiver sensitivity but always less than $2 V_{\text{SS}}$. No measuring signal is defined for the power supply.

Impedance of the field device and the power supply can be determined using the measuring circuit shown in Figure 2-11.

Impedance X of the tested device is calculated from the ratio of the two voltages U_D and U_R .

$$X = R_M \cdot \frac{U_D}{U_R}$$

Remember that the two measured voltages represent complex values whose phase difference is included in the result. If U_R is used as the reference, then:

$$X = R_M \cdot \frac{|U_D|}{|U_R|} \cdot e^{j\varphi} \quad \text{whereby } \varphi \text{ is the phase angle } \varphi(U_D) - \varphi(U_R)$$

This reduces impedance measurement to a ratio measurement of two voltages and one phase difference measurement.

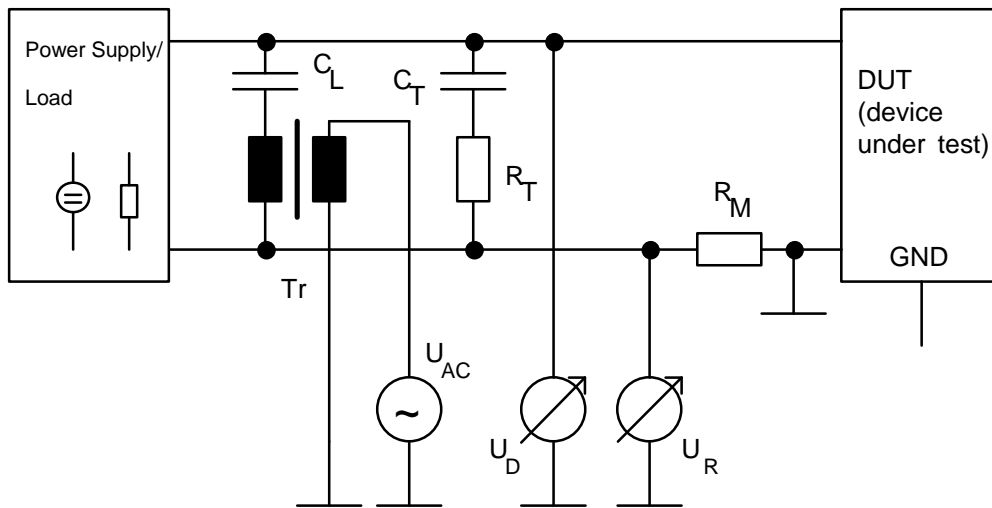


Figure 2-11 Circuit diagram of the principle of measuring impedance (example: $C_L=C_T=2\ \mu\text{F}$, $R_T=R_M=100\ \Omega$)

Remember that the phase angle can also be negative. If so, the object to be measured represents a negative load that amplifies rather than attenuates. This can be disregarded (it even has positive effects) for the signal frequency range from 7.9 kHz to 39 kHz as long as $|X|$ remains within the specified range. Problems can occur outside this range, however. There is no specification for the impedance. Its amount can be any low value. In combination with unfavourable outside circuiting conditions (e.g., long stub lines), negative impedance can create an unattenuated oscillating circuit which turns the bus system into an oscillator although the object to be measured remains stable in the measuring circuit.

The following sources of errors can affect the result of the impedance measurement.

- I. Non-linear distortions. Correction: Use frequency-selective measurement (i.e., only evaluate the fundamental wave) and oscillographic monitoring of the measuring signal.
- II. Asymmetries in the measuring setup. Correction: Use symmetrical transformer Tr and avoid ground capacitances. Leave open any ground connection on the test object (e.g., caused by EMC filter) when measuring the impedance.
- III. Noise signals generated by the test object. Correction: Measure the background noise. Table 2-3 states that this must be $\leq 1\ \text{mV}_{\text{eff}}$ (measured at $50\ \Omega$). If this condition is met, the effect on the impedance measurement can be disregarded.

2.4.2 Symmetry

The standard states that all bus interfaces must be isolated from earth. The unbalanced capacitance between the two bus terminals and earth must not exceed 250 pF. Although not specifically mentioned in the standard, barriers and power supplies must also meet these conditions.

Under the condition that the impedance between each of the two bus terminals and earth only contains one capacitive component, measuring the two effective earth capacitances and then calculating the difference can determine asymmetry. However, this is usually not the case. Particularly when non-intrinsically safe bus interfaces, which can be coupled to the bus via a transformer, are used, significant inductive components are present. Even when coupling elements are used, which do not contain inductivities as components, inductive behaviour caused by parasitic effects can be detected particularly for higher frequencies. At best, a purely capacitive asymmetry only can be assumed within a limited frequency range. For this reason, it is recommended to determine the Common Mode Rejection Ratio CMRR as defined in Figure 2-12 to evaluate the characteristics of symmetry.

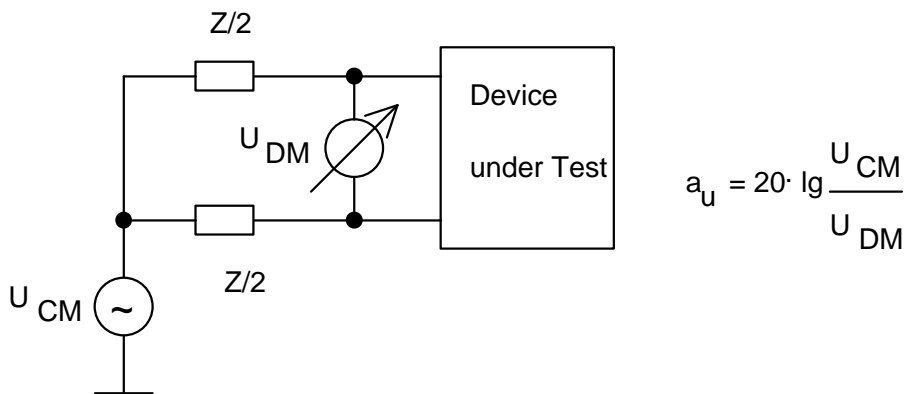


Figure 2-12 Definition of CMRR

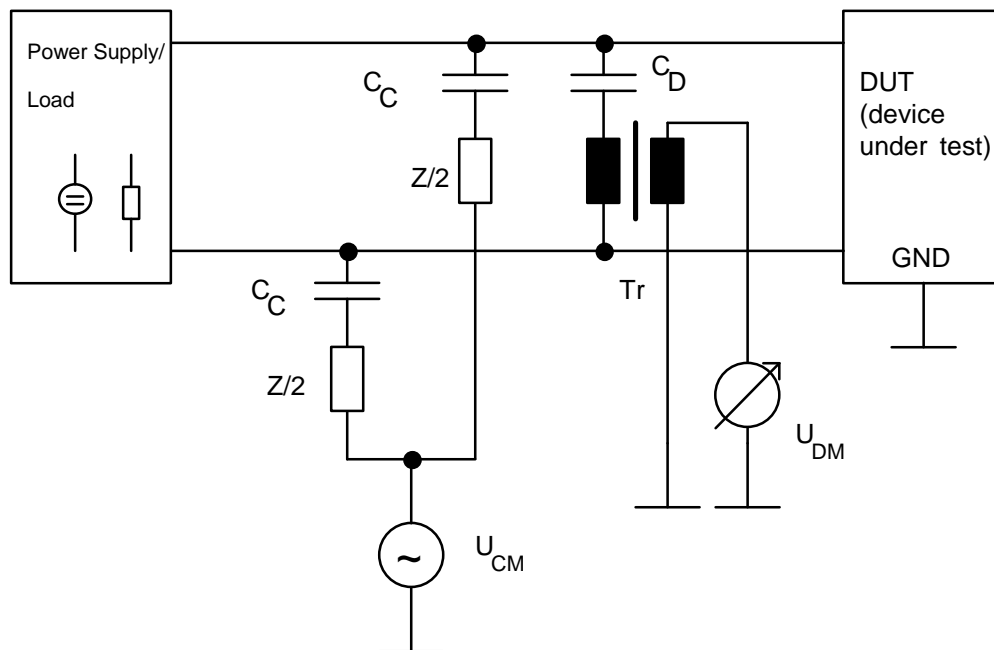


Figure 2-13 Block circuit diagram of the principle of measuring CMRR ($C_C=C_D=2\mu\text{F}$, $Z/2=25\Omega \pm 0.1\%$)

If a field device, barrier or power supply is to meet the specifications of IEC 61158-2 (chapter 11) with regard to the unbalanced capacitance the CMRR must be higher than the values listed in Table 2-6.

CMRR of the measuring instrument (e.g. as shown in Figure 2-13) without the device under test (i.e., DUT) must be at least 10 dB above the listed values.

Frequency	kHz	≤ 40	120	400	1200
CMRR	dB	≥ 50	≥ 40	≥ 30	≥ 20

Table 2-6 Required CMRR

Chapter 3 Configuration Hints

Describes possible **network topologies, cables, grounding concepts, component selection and component circuiting.**

3	Configuration Hints	3-2
3.1	System Topology	3-2
3.2	PROFIBUS PA Topology	3-3
3.3	Bus Cable	3-6
3.3.1	Cable Parameters	3-6
3.3.2	Maximum Cable Lengths, Spur Cables	3-7
3.3.3	Shielding and Grounding.....	3-9
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3.6	Certification and Identification	3-14
3.6.1	Certificates for Individual Devices	3-14
3.6.2	System Considerations	3-15
3.7	Configuration of the Bus Parameters	3-15

3 Configuration Hints

This chapter contains information for planners of systems with PROFIBUS PA devices. Remember that this information is only an interpretation of the applicable standards and does not have the status of a standard itself. The same applies to the statements on the problems of intrinsic safety.

3.1 System Topology

One of the primary characteristics of PROFIBUS PA is that it is easy to integrate into systems using PROFIBUS devices with different physical layers, as RS485 or fiber optic. This means that the entire PROFIBUS infrastructure (e.g., gateways to other networks, engineering consoles, and display and operator control components) can be utilized.

PROFIBUS PA is linked to the components close to the process by either an integrated PROFIBUS PA interface with a physical layer according to IEC 61158-2, chapter 11 or via a PA/RS485 signal coupler. This adapts the interface of the components close to the process to the transmission technology used by the PROFIBUS field devices. The combination of signal coupler, power supply and bus terminator (may possibly be switched off) is called a segment coupler.

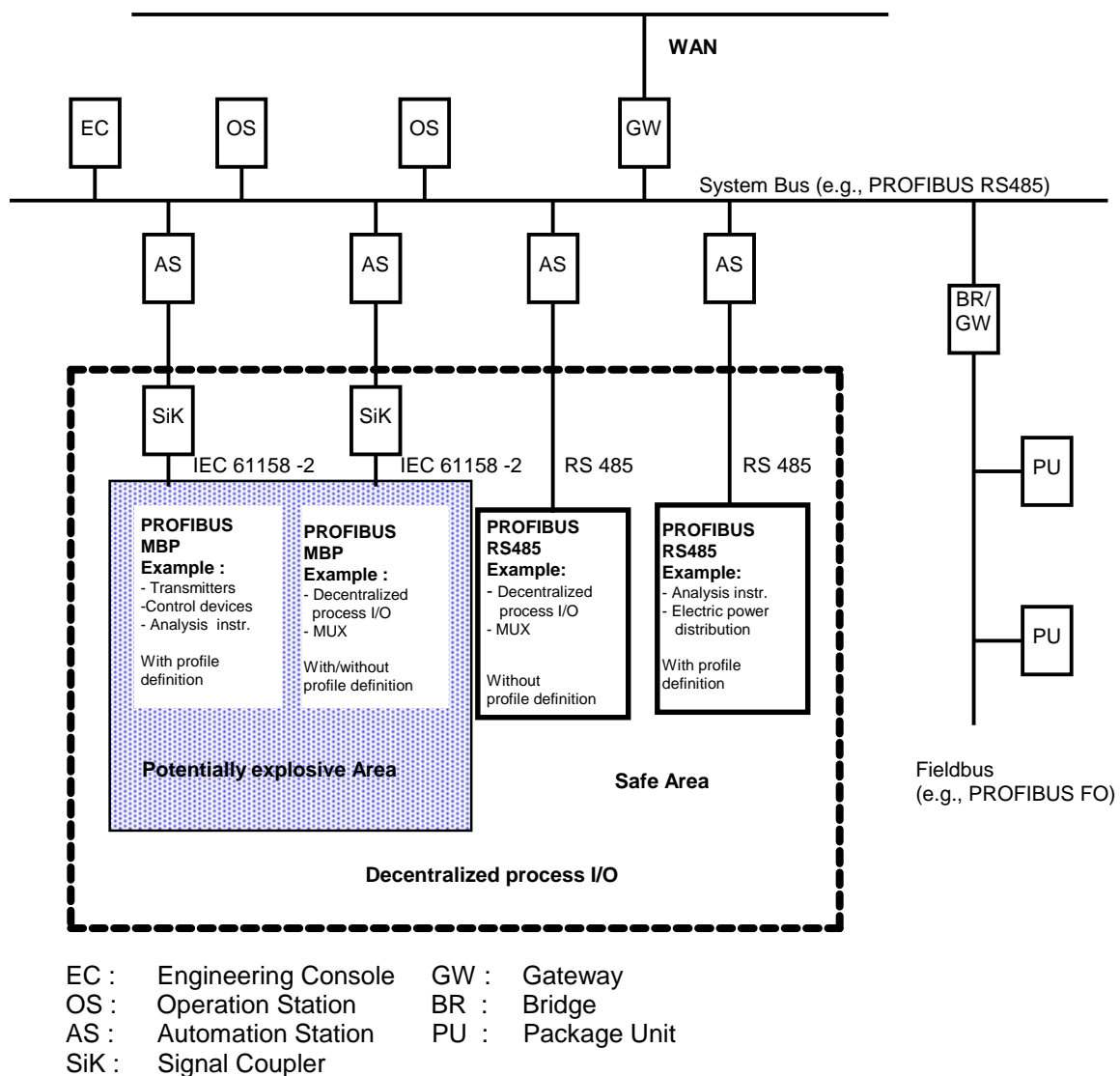
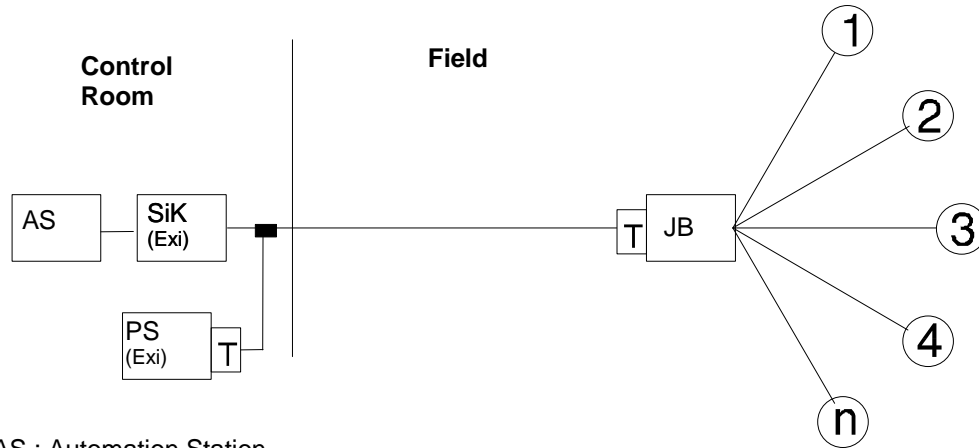


Figure 3-1 Connection of PROFIBUS PA and PROFIBUS RS485

3.2 PROFIBUS PA Topology

Tree topology, linear topology or a combination of both can be used as the bus structure for the PROFIBUS PA shown in

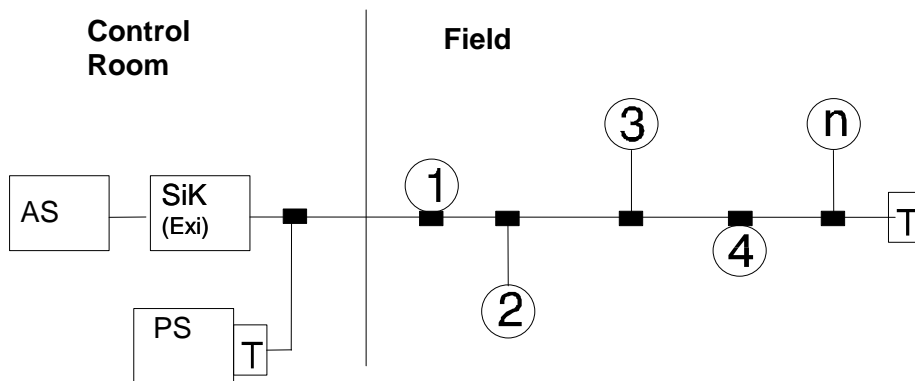
Figure 3-1.



AS : Automation Station
SiK : Signal Coupler
PS : Power Supply
T : Line Terminator
JB : Junction Box
(1)...(n) : Field Devices

Figure 3-2 Tree topology

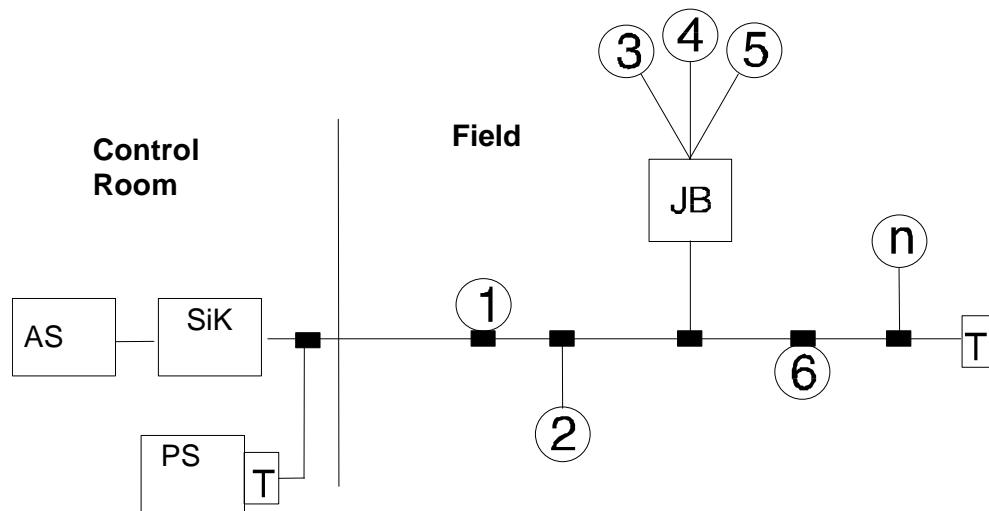
The tree topology (Figure 3-2) can be compared to classic field installation topology. The multi-wire trunk cable is replaced by the two-wire bus trunk cable. The junction box retains its role as a central connection unit where all field devices are connected in parallel.



AS : Automation Station
SiK : Signal Coupler
PS : Power Supply
T : Line Terminator
JB : Junction Box
(1)...(n) : Field Devices

Figure 3-3 Linear bus topology

The linear bus topology (Figure 3-3) offers connection points (taps or passive couplers) along the Field Bus cable. The cable can be looped through the individual field devices. Field devices may also be connected to the trunk cable via spurs. The combination of tree topology and linear bus topology (Figure 3-4) permits the optimization of the Field Bus length and the adaptation to existing system structures. The restricting factor for Field Bus design is the attenuation of the communication signal between the Field Bus stations and the signal distortions caused by the concentration of Field Bus stations along the Field Bus cable. For more details, see IEC 61158-2.



AS : Automation Station
SiK : Signal Coupler
PS : Power Supply
T : Line Terminator
JB : Junction Box
(1)...(n) : Field Devices

Figure 3-4 Combination of the tree topology and the linear bus topology

It must be taken into account that the limitation of the spur length for intrinsically safe installations according to FISCO (≤ 30 m, see Table 3-2 and Table 3-5) bases on a pure tree- or linear bus topology. If a combination as shown in Figure 3-4 is used in a hazardous area then the limit has to be applied to each connection between a field device and the trunk cable (via the junction box). As an example, if the cable length between the trunk and the junction box is 20 m, then the cable length between the junction box and any device connected to it must not exceed 10 m. This rule is also to be applied to the topology shown in Figure 3-5.

The number of field devices that can be used on the fieldbus depends on the supply voltage, the current consumption of the field devices and the extension of the fieldbus (see chapter 3.4). To improve availability and dependability, redundant Field Bus segments may be installed. However, this makes connection of simple fieldbus stations (e.g., transmitters, actuators, initiators, valves, and so on) more complicated (e.g., double lines, double powering, intrinsic safety, and so on).

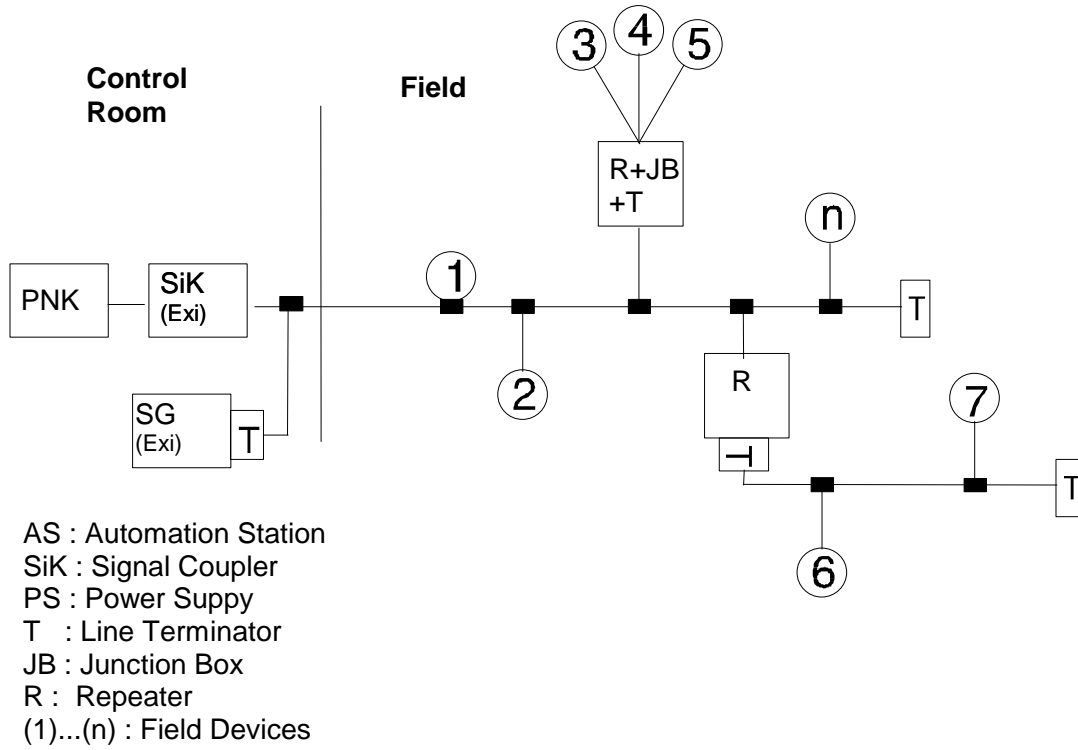


Figure 3-5 Bus extension

3.3 Bus Cable

3.3.1 Cable Parameters

IEC 61158-2 states that a two-wire cable must be used as the transmission medium for the Field Bus. Although the electrical data are not specified, these data influence the performance that can be achieved by the Field Bus (i.e., distances which can be covered, number of stations, electromagnetic compatibility). The standard (chapter 11.7.2, mandatory for Field Bus tests, and annex C, not mandatory, for information purposes only) distinguishes between four types of cables whose data are listed in Table 3-1 for a temperature of 25° C.

	Type A (Reference)	Type B	Type C	Type D
Cable description	Twisted pair, shielded	One or more twisted pairs, total shielding	Several twisted pairs, not shielded	Several non-twisted pairs, not shielded
Nominal conductor cross sectional area	0.8 mm ² (AWG 18)	0.32 mm ² (AWG 22)	0.13 mm ² (AWG 26)	1.25 mm ² (AWG 16)
Maximum DC resistance (loop)	44 Ω/km	112 Ω/km	264 Ω/km	40 Ω/km
Characteristic impedance at 31.25 kHz	100 Ω ± 20%	100 Ω ± 30%	**	**
Maximum attenuation at 39 kHz	3 dB/km	5 dB/km	8 dB/km	8 dB/km
Maximum Capacitive Unbalance	2 nF/km	2nF/km	**	**
Group delay distortion (7.9 to 39 kHz)	1.7 µsec/km	**	**	**
Surface covered by shield	90%	**	-	-
Recommended extent of network (including spur cables)	1900 m	1200 m	400 m	200 m

(** Not specified)

Table 3-1 Types of cable in accordance with IEC 61158-2, chapter 11.7.2 and annex C

The reference cable (i.e., type A) must be used for the conformance tests.

When new systems are installed, cables that meet the minimum requirements of types A and B should be used. When multi-pair cables (i.e., type B) are used, several Field Buses (31.25 kbit/sec) may be operated in one cable. Installation of other electric circuits in the same cable should be avoided.

Type C and D cables should only be used for so-called retrofit applications (i.e., use of already installed cables) for substantially reduced networks. In such cases, remember that the interference susceptibility of the transmission frequently does not meet the requirements described in the standard.

Cables installed in hazardous area have to meet the requirements of the relating standards (e.g. IEC 60079-14, chapter 12.2.2.7 and 12.2.2.8 /S4/). Installations based on FISCO are not subject to safety restrictions when the limit values listed in Table 3-2 are complied with. See also chapter 1. Although operation outside these limit values is not prohibited in general, each case must be judged on an individual basis.

	EEx ia	EEx ib IIC / IIB
Loop resistance (direct current)	15 to 150 Ω /km	15 to 150 Ω /km
Inductivity per unit length	0.4 to 1 mH/km	0.4 to 1 mH/km
Capacitance per unit length	80 to 200 nF/km ¹⁾	80 to 200 nF/km ¹⁾
Stub line length	≤ 30 m ²⁾	≤ 30 m ²⁾
Line length	≤ 1 km	≤ 5 km ³⁾

¹⁾ Cf. chapter 1, tables 1-1 and 1-2 for definition.

²⁾ Preliminary values in accordance with the FISCO model, for tree- and linear bus topologies

³⁾ For operational reasons the line length has to be limited to 1,9 km

Table 3-2 Safety limit values for the bus cable

The wires of all Field Bus cables must be clearly marked (e.g., by colour or with rings). Cables with intrinsically safe electric circuits must be identified in accordance with related standards (e.g., with light blue jackets).

When multi-pair cables are used in potentially explosive areas, the special installation requirements stated in IEC 60079-14 /S4/ must be complied with.

3.3.2 Maximum Cable Lengths, Spur Cables

Every Field Bus installation must comply with certain rules (i.e., the "network configuration rules"). Cf. IEC 61158-2, chap. 11.2.2. Among other information, these rules specify the following limit values for attenuation, reflection and distortions (i.e., rule 8), and the maximum signal delay (i.e., rule 4) permitted in the network.

Attenuation between any two bus interfaces (at 31.25 kHz)	10.5 dB
Attenuation distortion $a(f=39 \text{ kHz})-a(f=7.8 \text{ kHz})$, ascending monotonically with f	6 dB
Mismatching distortion at any point (7.8 to 39 kHz)	0.2
Maximum propagation delay between any two devices	640 μ sec

Table 3-3 Limit values for distortion, reflection and signal delay

In a not hazardous area all topologies and all cables are permitted within the framework of these limit values. For intrinsic safe installations according to FISCO the limits and restrictions listed in Table 3-2 have to be taken into account.

Since individual calculation of the above four parameters for all possible connections between two bus interfaces to obtain the optimal layout is very time-consuming, rules have been specified for a basic topology which, although below the optimum, will ensure that the above limit values will not be exceeded.

A tree topology was selected as the basic model of a network. This network consists of a main cable (i.e., trunk), a number of stub cables (i.e., spurs), connection elements (i.e., splices), and two line terminators. The total cable length is the sum of the lengths of the main cable and all spurs.

Type of Cable	Total Cable Length
A	1900 m
B	1200 m
C	400 m
D	200 m

Table 3-4 Recommended maximum cable lengths including spurs

Number of Stub Cables	Length of One Stub Cable (Intrinsically Safe)	Length of One Stub Cable (Not Intrinsically Safe)
25 to 32	-	-
19 to 24	30 m	30 m
15 to 18	30 m *)	60 m
13 to 14	30 m *)	90 m
1 to 12	30 m *)	120 m

Table 3-5 Recommended length of the spurs

*) Preliminary values in accordance with FISCO. (Spurs ≤ 1 m can be considered as splices.)

Total Cable Length	Total Length of the Splices
> 400 m	8 m
< 400 m	2 %

Table 3-6 Maximum length of the splices

Chapter 11 and annex C of IEC 61158-2 recommend not exceeding the values listed in Table 3-4, Table 3-5 and Table 3-6. Although different cable types can be mixed in one network segment, this should be avoided. Determining the maximum cable lengths for such mixed structures is more time-consuming and less accurate than using structures consisting of only one type of cable.

The network can be enlarged with repeaters. The above limit values then apply to each individual network segment, and only the maximum signal delay has to be calculated for the total network.

Compliance with these recommendations will ensure accurate signal transmission. When systems with remote-powered bus interfaces are involved, preparation of a power balance as described in chapter 3.4 is required.

3.3.3 Shielding and Grounding

Defining the shielding and grounding rules of a Field Bus system there are three aspects to be considered:

- Electromagnetic compatibility (EMC)
- Protection against explosion
- Protection of persons

According to IEC 61158-2 grounding means “permanently connected to earth through a sufficiently low impedance and with sufficient carrying capability to prevent voltage built up which might result in undue hazard to connected equipment or persons”. Zero Volts (common) lines may be connected to ground where they are galvanically isolated from the Field Bus trunk.

To comply with the requirements of the standard, Field Bus devices shall be able to function with the mid-point of one terminator or one inductive coupler directly to ground.

Neither of the two conductors of the twisted pair may be grounded at any point in the network. Signals shall be applied and preserved differentially throughout the network. The maximum unbalanced capacity to ground and the resulting Common Mode Rejection Ratio (CMRR) of Field Bus devices are described in chapter 2.4.2. During planning and installation of a network it has to be avoided that any auxiliary equipment, which is not described in the standard (e.g. connectors, overvoltage protection), impact the CMRR of the complete network.

In addition to the handling of the signal conductors particular attention should be paid to the cable shield and its connection to earth.

Traditional field devices (e.g. with 4-20 mA interface), connected via multi-pair cables to control instruments located in the control room, are transmitting analogue DC signals or low frequency signals. Using receive filters matched to the narrow and low transmission frequency band the impact of interfering electromagnetic noise of higher frequencies can easily be reduced. Additionally it is useful (and standard practice) for the shield of the transmission cable to be grounded at one point along the length of the cable in order to provide an effective shielding against (static) **electric** fields.

However, transmission systems using signal frequencies > 10 kHz should also be protected against (dynamic) **electromagnetic** fields. Therefore the cable shield and the (metallic) housings of the field devices and of any auxiliary equipment (e.g. connectors) shall make up a common shielding system, avoiding unnecessary gaps. The importance of this requirement increases with the signal frequencies processed in the system. With regard to the Field Bus, this means that ideally the cable shields are connected to the field devices' housings (or other protective coverings), which are frequently made of metal. The connections between the cable shield and the metallic housings as well as the connections between the shields of different cable segments have to be low-impedance (for high frequencies). Extended wires usually do not meet this requirement.

As far as unshielded devices are connected to a shielded cable further methods may be applied to reduce the impact of noise (e.g. galvanic isolation or filtering). Housings of field devices or power supplies may be connected to earth due to operational or safety reasons. This results in a shielding system, which is connected to earth at several points (Figure 3-6). Taking into account EMC aspects as well as safety against electrical shocks this is the preferable method and can be used without any restriction in systems with an optimum potential equalization.

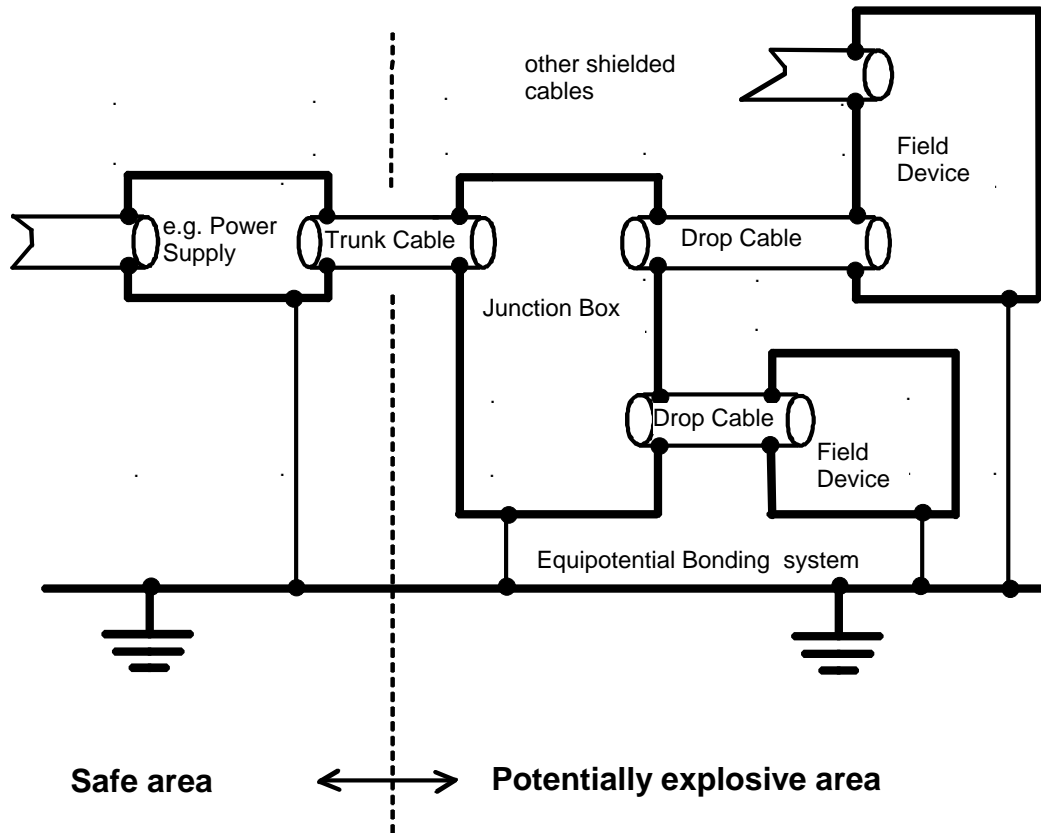


Figure 3-6 Ideal combination of shielding and grounding

In this context it has to be noted that, according to IEC 60079-14, chapter 6.3, a potential equalization is principally required for installations in hazardous areas. The rules concerning the equipotential bonding system described in this document (inclusion of protective conductors, metal conduits, metal cable sheaths, steel wire armoring and metallic parts of structures) may be supplemented by

- placing the cables on metal racks
- integration of the metal cable racks into the potential equalization system
- interconnecting the metal cable racks by permanent, current carrying and low-impedance bonds

Following these instructions it is possible to create at least "equipotential islands". Low-frequency ground current (50/60 Hz, including harmonics), flowing between the islands, will not impact the signal quality because of the high Common Mode Rejection Ratio and the filter characteristics of the receiver circuit. However, damage of the cable shield by exceeding its current carrying capability must be avoided.

If a sufficient potential equalization between the hazardous area ("equipotential island" with one or more field devices) and the safe area (e.g. the control room) cannot be guaranteed, the cable shield shall be directly connected to the equipotential bonding system (earth) only in the hazardous area. In the safe area the shield shall be connected to earth through a capacitor. The impedance of the connection should be minimized for high frequencies. Extended wires usually do not meet this requirement.

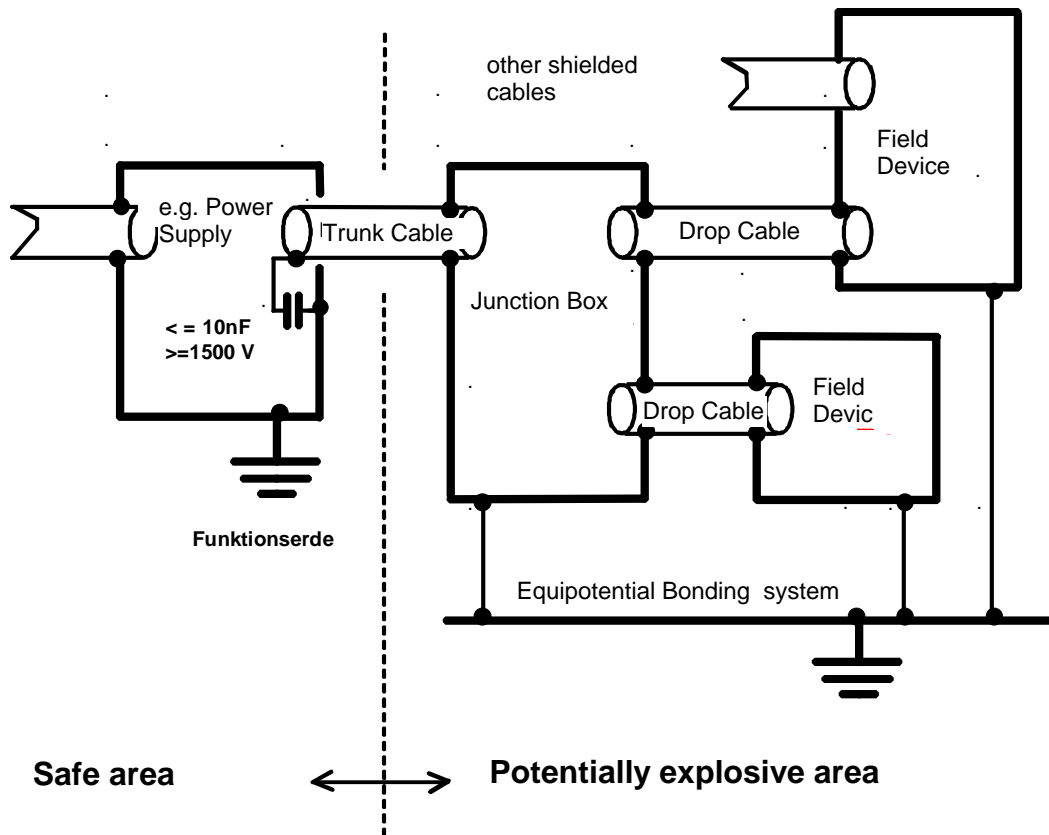


Figure 3-7 Capacitive grounding

Figure 3-7 shows a possible solution. However, the need for an electric envelope as complete as possible cannot be entirely fulfilled. The shown connection between both grounding systems through a capacitor may also be placed at an other position between power supply and the hazardous area (or between different hazardous areas), but it has always to be in a safe area.

The capacitor has to meet the following requirements:

- solid dielectric (e.g. ceramic)
- $C \leq 10\text{ nF}$
- isolation voltage $\geq 1.5\text{ kV}$

If the described system of equipotential islands cannot be realized then the "classic" concept may be used and the screen shall be electrically connected to earth at one point only, normally at the non-hazardous area, far away from the field device. In this case it should be noted that all EMC tests according to IEC 801 standards assume a direct connection between the cable shield and earth close to the device under test (e.g. a field device). Therefore in case of single earthing the EMC may be reduced compared with the test environment.

If a network does not cover or cross a hazardous area single earthing is not recommended. If there is danger of exceeding current carrying capability of the shield multiple earthing through small capacitors (for example 10 nF) is acceptable, but the impedance of the connection should be minimized for high frequencies, as already mentioned.

3.4 Power Budget

Due to the load in the signal frequency range and due to the reflections and distortions related to this, the number of stations, which can be connected to one Field Bus segment, is limited to 32. Another restriction that is usually quite important concerns powering via the signal conductors.

For intrinsically safe networks, both the maximum supply voltage and the maximum supply current are specified within narrow limits. Even for non-intrinsically safe networks, the power of the power device is limited. In addition, a large portion of the available power is lost because of voltage drops on the transmission line. An optimally designed Field Bus network requires the precise calculation of the partial voltage drops between the power supply and the individual field devices. The supply voltage on the remote-powered field devices must be at least 9 V. In most cases, it is sufficient to calculate the required current, select a power supply e from Table 3-7, and take the minimum line length from Table 3-8 for the core cross section chosen.

To the extent related to the power balance, the characteristics of a power supply are completely described by specification of the supply voltage and the maximum current, regardless of whether an intrinsically safe or non-intrinsically safe power supply is involved. It can be built up as an ideal voltage source followed by a current limitation. Table 3-7 lists the characteristics of standard power supplies. Other combinations are possible.

Type	Area of Use	Supply Voltage	Supply Current	Max. Power
I	EEx ia/ib IIC	13.5 V	110 mA	2,52 W
II	EEx ib IIC	13.5 V	110 mA	2.52 W
III	EEx ib IIB	13.5 V	250 mA	5,32 W
IV	Not intrinsically safe	24 V	500 mA	12 W

Table 3-7 Standard power supply (operational values)

Power Supply Device		Type I	Type II	Type III	Type IV	Type IV	Type IV
Supply voltage	V	13.5 V	13.5 V	13.5 V	24 V	24 V	24 V
Σ current demand	mA	≤ 110	≤ 110	≤ 250	≤ 110	≤ 250	≤ 500
Max. loop resistance	Ω	≤ 40	≤ 40	≤ 18	≤ 130	≤ 60	≤ 30
Σ Line length for core cross section $q=0.5 \text{ mm}^2$	m	≤ 500	≤ 500	≤ 250	≤ 1700	≤ 850	≤ 400
Σ Line length for core cross section $q=0.8 \text{ mm}^2$	m	≤ 900	≤ 900	≤ 400	≤ 1900	≤ 1300	≤ 650
Σ Line length for core cross section $q=1.5 \text{ mm}^2$	m	≤ 1000	≤ 1500	≤ 500	≤ 1900	≤ 1900	≤ 1900
Σ Line length for core cross section $q=2.5 \text{ mm}^2$	m	≤ 1000	≤ 1900	≤ 1200	≤ 1900	≤ 1900	≤ 1900

Table 3-8 Minimum line lengths which can be achieved

The required current ($=\Sigma$ current demanded) is calculated from the sum of the basic device currents of the field devices, the hand-held terminal, the coupler for the bus master, any repeaters used, and the threshold current of the fault disconnection equipment. The latter can be calculated for every device connected to the bus as the difference between the maximum current when a fault occurs and the operating current. The device with the highest threshold current is the determining factor.

The number of field devices that can be connected to a segment is determined by the device with the largest fault current (see chapter 2.2.1) and by the sum of the rated operating currents of all devices. It is up to the user to take into account the fault current (max. 9 mA) or not. Leaving out of consideration

may be accepted if a short circuit will not lead to a dangerous situation or to economically unwanted consequences (with an expected probability).

3.5 Selecting and Connecting Components

When selecting the individual components, make sure that all components meet the requirements of the FISCO model regarding safe implementation (see chapters 2.1 to 2.7). Only components that are identified as an intrinsically safe electrical apparatus or as an associated electrical apparatus in accordance with IEC 60079-11 may be installed in intrinsically safe bus segments. To comply with IEC 60079-14, sub clause 12.2.5.1, (or EN 60079-14) /S4/ the permitted values of the input parameters U_i , I_i and P_i of an intrinsically safe apparatus (e.g. a field device) must not be less than the certified maximum values of the output parameters U_o , I_o and P_o of the associated power device. Additional restrictions applicable to the individual components (e.g., limitation of the supply power to ≤ 1.2 W, cf. chap. 2.2.6) have to be taken into account as well.

Table 3-9 lists possible combinations of devices from different system categories.

Explosion protection of the Bus-Segment	Explosion protection of the power device	Explosion protection of the field device					
		EEx ia			EEx ib		
		IIC	IIB	IIC/IIB	IIC	IIB	IIC/IIB
EEx ia IIC (Group IIC)	[EEx ia] IIC	x		x			
EEx ia IIB (Group IIB)	[EEx ia] IIB	x	x	x			
	[EEx ia] IIC	x	x	x			
EEx ib IIC (Group IIC)	[EEx ib] IIC	x		x	x		x
	[EEx ia] IIC	x		x	x		x
EEx ib IIB (Group IIC)	[EEx ib] IIB	(x) ¹⁾	x	x	(x) ¹⁾	x	x
	[EEx ib] IIC	x	x	x	x	x	x
	[EEx ia] IIB	(x) ¹⁾	x	x	(x) ¹⁾	x	x
	[EEx ia] IIC	x	x	x	x	x	x

¹⁾ These combinations are possible in theory but in practice they are irrelevant, because the field devices may be certified for group IIC and for group IIB as well (cf. column IIC/IIB).

By any combination it must be assured that the absolute maximum ratings for the input of the field device fit to the output characteristics of the power device:

$$U_i \geq U_o$$

$$I_i \geq I_o$$

$$P_i \geq P_o$$

Table 3-9 Mixing devices from different categories

In general, several devices from different manufacturers may be connected via one bus.

Connection of bus-powered devices and local-powered devices on an intrinsically safe bus is permitted if the local-powered devices are provided with suitable isolation in accordance with IEC 60079-11.

Although connection of a bus station (i.e., field device, hand-held terminal, and coupler for the bus master) with its poles reversed does not affect the functionality of the other devices connected to the bus, an incorrectly installed bus station which is not equipped with automatic polarity detection will not be supplied with power or be able to send and receive. Stations with automatic polarity detection operate correctly with any allocation of the input terminals to the wires.

3.6 Certification and Identification

Three parties share responsibility for a Field Bus installation. The testing and certification authority, which tested and certified the individual components of the system, is responsible for ensuring that the design of the devices meets the applicable standards.

The manufacturer of the individual devices is responsible for ensuring that each individual unit manufactured corresponds to the documentation, which was available to the certifying authority, and final inspection and quality assurance are performed correctly.

The user also bears a significant share of the total responsibility; he installs the Field Bus system or give the order to install it, and then puts it into operation. The user is responsible for ensuring that installation regulations (e.g., IEC 60079-14) are complied with and the special requirements and notes, concerning installation, operation and maintenance, are met, which may be included in the test certifications or in the instruction manuals. In addition, maintenance work and system modifications must be carried out in accordance with the applicable standards and regulations.

Generally, when several devices of different manufacturers are connected to a common intrinsically safe circuit, a system certification is required for this special situation. In general, high certification costs and time required make this solution uneconomical. When the FISCO model is applied to a Field Bus installation the system is characterised by a small set of well-known parameters. This permits the user to connect devices of different manufacturers to one intrinsically safe Field Bus system without having to obtain special system certification.

3.6.1 Certificates for Individual Devices

It is assumed that the bus stations (i.e., **field devices**, **hand-held terminal** and **coupler for the bus master**) are certified as intrinsically safe devices. The certificates of the field devices must contain a statement that the devices conform to FISCO. The values for maximum no-load voltage, maximum short-circuit current and maximum permissible power should be specified as well as the inductivity and capacitance effective on the bus interface. When the field device is powered locally, a statement concerning the galvanic isolation from the bus interface must be included in the certificate.

A test certificate indicating that the **bus power supply** is an associated apparatus in the sense of IEC 60079-11 is mandatory. This certificate must contain a statement indicating that the power supply conforms to FISCO. It must be noted that the limit values usually given for maximum permissible external inductance L_a and capacitance C_a are not listed for the power supply.

If these values had been included, it would create the impression that *concentrated inductivity L_a* and *capacity C_a* are effective and unprotected in the intrinsically safe circuit as. According to FISCO the distributed capacity and inductivity of the bus cable (within the allowed range shown in Table 3-2) do not impact the explosion protection.

On the subject of **Bus Terminators**, remember that, although the resistor can be designed as infallible in the sense of IEC 60079-11, the capacitor cannot. If the capacitor short circuits, the resistor is then directly parallel to the bus.

In this case, communication is no longer possible but additionally a safety danger exists. In the worst-case scenario, the resistor may consume all power available from the power supply and may presumably create excessive surface temperatures (depending on the particular temperature class).

Thus, the line termination is a component which must be evaluated by a certification authority and which must be certified for certain maximum electrical values.

3.6.2 System Considerations

In addition to functional considerations (cf. also chapter 3.6.2) concerning the combination of different Field Bus devices and components, safety and reliable protection against explosion are also considerations. Since both of these points are often linked together, a systematic analysis is required.

Extensive studies have shown that, under the parameter ranges examined, the probability of ignition is not increased by connection of cables with distributed inductivities and capacitances and line terminations on a power supply.

The length of the main bus cable (trunk cable) can thus be selected almost without regard to safety restrictions. This does not mean that environmental conditions resulting from the functional structures can be disregarded. They must indeed be considered.

The maximum number of bus stations that can be connected (including the PA-RS485-coupler for and, if present, hand-held terminal) depends on two factors: the bus power supply characteristics (i.e. U/I characteristics) and the basic current requested by every station. If one field device consumes more than a basic current of 10 mA (e.g., 20 mA), this reduces the number of devices, which can be connected.

It is easy to determine the minimum current to be delivered by the power supply by adding the basic currents for the field devices (plus those of the hand-held terminal and the coupler, if present) and the threshold current for the fault disconnection equipment (i.e., FDE) and for the modulation.

Optimization of the system (i.e., longest possible line lengths and increased number of devices which can be connected) depends on selecting the correct power supply and the appropriate type of cable.

In individual situations, the installer or user for a specific bus configuration must calculate valid parameters and limit values. To make this analysis easier, chapter 3.5 contains a suggested procedure.

The last step is concerned exclusively with safety.

Field devices, coupler for the bus master and line terminations must be checked for conformance to safety regulations.

Permissible maximum input values for field devices, couplers and line terminations must be checked to determine whether they are equal to or greater than the maximum output safety values of the bus power supply.

3.7 Configuration of the Bus Parameters

A PROFIBUS PA network can be customized to a wide variety of requirements and applications by configuring the PROFIBUS stations. Since treatment of the communication reference list and the object directory for PROFIBUS PA does not differ from PROFIBUS RS485/ FO, configuration can be performed as generally described for PROFIBUS devices. The only exception is that when coupler elements (i.e., repeaters and PROFIBUS PA-RS485 segment couplers) are used, the transmission delay is increased. This additional delay (see device data sheets) must be considered when configuring the bus.

Chapter 4 Annex

Summarizes the most important **terms** and **documents** and provides a list of important **test and certification bodies**.

4	Annex.....	4-2
4.1	Terms.....	4-2
4.2	Standards, specifications and guidelines	4-4
4.3	Literature.....	4-5
4.4	Addresses of test and certification bodies for Intrinsic Safety (selection)	4-6

4 Annex

4.1 Terms

Bus powering

Type of power supply whereby field devices obtain their required auxiliary power via the fieldbus communication lines.

Common Mode Rejection Ratio (CMRR)

Measure for the deviation from an ideal electrical symmetry of a device symmetrically built to its environment.

Fault Disconnect Electronic (FDE)

Equipment used to limit the current consumed by a field device during a malfunction. This unit can be a part of the field device, or it can be connected in front of it.

FISCO model

Fieldbus Intrinsically Safe COncept model. Prepared by the Physikalisch-Technische Bundesanstalt (PTB) in cooperation with renowned manufacturers, this model describes a possible implementation of an I.S. fieldbus for use in potentially explosive areas. The primary characteristic of this model is that only one active device (i.e., the bus power supply device) is connected to the fieldbus. The other devices are passive with regard to their ability to supply power to the line. Within certain limits, the characteristics of the bus cables do not affect intrinsic safety /1/.

Grounding

Grounding is a permanent connection earth through a sufficiently low impedance with sufficient current carrying capability to prevent voltage built up which might result in undue hazard to connected equipment or persons. (IEC 61158-2)

Human Machine Interface (HMI)

Component of a Process Control System in use for data acquisition from an automated process and its appropriate representation as well as for manipulation of this process.

Intrinsically safe circuit

An electric circuit in which sparks or thermal effects cannot occur under specified test conditions (e.g., EN 50020 standard) either during normal operation (i.e., opening and closing of the circuit) or during a malfunction (i.e., short circuit or grounding error) which could cause ignition in a potentially explosive area. Opening or short circuiting of intrinsically safe electric circuits only cause low-energy, non-ignitable sparks. Intrinsic safety must also be maintained under certain fault conditions defined in the standards.

Local Powering

In case of Local Powering field devices do not obtain the main portion of their auxiliary power via the fieldbus. The medium attachment unit may be supplied by the bus.

Manchester Encoding

A binary encoding method enabling receivers of serial communications to unambiguously determine the start, end, or middle of each bit without reference to an external clock (synchronous). Used within IEC 61158-2. /S3/.

Medium Attachment Unit (MAU)

Part of a bus node providing the connection to the bus cable. Within IEC 61158-2, this unit primarily consists of a sending amplifier (i.e., current modulator), receiving filter, receiving comparator and impedance converter for bus power extraction.

Physical Layer

The Physical Layer receives messages from the Communications Stack and converts the messages into physical signals on the fieldbus transmission medium, and vice-versa (transmission system). In case of PROFIBUS this layer consists of a two-wire line as the transmission medium, terminators, connection elements (e.g., plug and socket connectors), bus interfaces, and an optional bus powering (possibly with safety barrier).

Process Controller (PC)

Central component of a Process Control System that is used for direct processing of information in accordance with configured algorithms in connection with process management.

PROFIBUS PA Device

Device combining a PROFIBUS PA Physical Layer with the PROFIBUS DPV1 protocol in accordance with IEC 61158 , Parts 2- 6 , Type 3 /S2/, and with the PROFIBUS PA profile 3.0 specification and designed in accordance with these guidelines.

PROFIBUS PA Physical Layer

Physical Layer according to the standard IEC 61158-2, clause 21 (listed as "Communication Profile Family CPF 3/2 -Manchester coded, Bus Powered MBP" in IEC 61784)

PROFIBUS PA Profile

Process Automation branch profile according to PROFIBUS specification "Profile for Process Control devices", Version 3.0

PROFIBUS PA System

Communication system using PROFIBUS PA devices and satisfying the requirements of these guidelines

4.2 Standards, specifications and guidelines

/S1/ /S2/	EN 50 170 Volume 2 CDV IEC 61158-2	PROFIBUS Specification Fieldbus standard for use in industrial control systems – Part 2: Physical Layer specification and service definition –Type 3
/S3/	IEC 60079-11:1999 or EN 50020:2002	Electrical apparatus for explosive gas atmospheres - Part 11: Intrinsic safety "i"
/S4/	IEC 60079-14: 1996	Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)
/S5/	IEC TS 60079-27: 11/2002	Electrical apparatus for explosive gas atmospheres – Part 27: Fieldbus Intrinsically Safe Concept (FISCO)
/S6/	PROFIBUS Guideline RS485-IS	PROFIBUS RS485-IS User and Installation Guideline

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Oldenbourg Industrieverlag, Muenchen 2001

4.4 Addresses of test and certification bodies for Intrinsic Safety (selection)

Germany

Fachstelle für Sicherheit elektrischer Betriebsmittel (BVS)
DMT Gas & Fire Division
Carl-Beyling-Haus
Dinnendahlstrasse 9
44809 Bochum
FAX 0201 172 3924

Physikalisch Technische Bundesanstalt (PTB)
Bundesallee 100
38116 Braunschweig
FAX 0531-592-3405

Frankreich

INSTITUT NATIONAL DE
L'ENVIRONNEMENT INDUSTRIEL ET
DES RISQUES
Parc Technique ALATA BP 2
60550 VERNEUIL-EN-HALATTE
France
FAX 0033-44 55 67 04

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