PROFIBUS

PROFIBUS Guideline

Profibus RS 485-IS User and Installation Guideline

Version 1.1
June 2003

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Version 1.1
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Prepared by the PROFIBUS Working Group WG7 „Intrinsic Safety“ in the Technical Committee TC2 „Communication Profiles“.

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1 Introduction

1.1 Goals and Target group

The classical Profibus DP is a high-speed communications system with RS 485 or optical-fibre transmission technology. It was originally intended for manufacturing automation. As it became more widespread, the Profibus DP made its way into process automation. Its deployment in process automation required an intrinsically safe "physical layer". This layer was adapted on the basis of IEC 61158-2. The FISCO model was developed for intrinsic safety.
This intrinsically safe "physical layer" was developed primarily for the connection of bus-powered field devices with a data transmission rate of 31.25 kBit/s. This system is well-proven in many applications, most notably in pressure transmitters, temperature transmitters and positioners.

For systems or subsystems in hazardous areas having a particularly high information flow or tough dynamic requirements, a field bus with a higher data transmission rate was essential.
Solutions are possible using different explosion protection measures (e.g. Ex e, Ex d, Ex i etc.).
This manual guide describes the solution for explosion protection type Ex i on the basis of the RS 485.

The name of the "physical layer" is RS 485-IS.

This guideline details the specifications for the "physical layer" of the RS 485-IS field bus on whose basis a simple combination / integration of different field devices is possible. This considerably simplifies the engineering and project planning, the installation and the verification of the intrinsic safety.

The manual is intended to

- Assist developers in developing their circuits in such a way that they function with other devices in this guideline in a sufficiently safe manner as regards function and Ex-protection,
- Support network engineers and project managers in designing the bus system in accordance with the task at hand and such that it is guaranteed to function safely following correct installation,
- Be an aid to installation technicians during on-site installations so that safe operation is assured,
- Serve as a useful reference for maintenance personnel working on the running network.

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1.2 Fundamentals of intrinsic safety

By contrast to the field bus in accordance with the FISCO model, for which there is only one active source and the remaining devices are connected passively and can only absorb power, the RS 485-IS is a field bus in which all devices are active. All devices are supplied from outside and can provide power to the field bus. The case in question involves the interconnection of intrinsically safe circuits. Usually, the safety-related verification of such systems is very laborious. This manual simplifies that verification considerably.

In an intrinsically safe circuit, only a maximum amount of energy is permissible when considering the inductances and capacitances which exist. This maximum amount of energy is described by the ignition curves.

The analysis carried out by the PTB (Physikalisch-Technische Bundesanstalt) on behalf of well-known manufacturers PTB – Mitteilungen /1/ forms the basis for the RS 485-IS.

A maximum output voltage of Uo = 4.2 V was chosen in the case of the RS 485-IS. With this voltage level and with the cable employed (L/R ratio < 15 µH/Ohm), a total maximum current of $\sum$ Io = 4.8 A is intrinsically safe.

1.3 System considerations

In addition to the function-dependent considerations, safety-related aspects must also be taken into consideration when combining heterogeneous field devices and components in one system. Both of these views are normally closely associated with one another.

Extensive measurements demonstrated that, in the range of parameters analysed, the probability of explosion does not increase on account of the connection of cables with distributed inductances and capacitances. On account of the low voltage levels on the cable, the capacitance of the cable is of minor significance. The resistance and inductance of the cable are decisive for the probability of explosion. The cable length is not limited from a safety viewpoint because the worst case was taken into account. However, the cable length is limited by functional restrictions.

When considering the system from a safety viewpoint, the parameters of the bus cable employed and the maximum total current in the bus cable must chiefly be taken into account. Furthermore, the safety-related parameters, such as the maximum permissible voltage etc., of the individual field devices must be considered.

The maximum number of devices per bus cable is limited to 32 by the specification of EIA-485 (RS 485). From a safety point of view, the number is limited via the individual currents of the stations and the permissible total current. The maximum permissible total current must be greater than or equal to the total of all individual currents in the bus segment. For 32 devices in the bus cable which comply with this manual, the

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permissible total current is not exceeded. As regards the number of devices, it must be noted that built-in repeaters or gateways must also be considered.

1.4 System topology

A significant characteristic of the RS 485-IS is that it can be integrated easily into systems with existing Profibus DP RS 485 devices. That means that the entire Profibus infrastructure (e.g. gateways to other networks, engineer consoles, display and operating devices ...) can be used. The integration of the RS 485-IS into the remaining Profibus world is realized by using fieldbus isolating repeater with integrated barriers. These fieldbus isolating repeaters can be situated both outside of and within the hazardous area. The Profibus telegrams are transmitted unaltered.

The following topologies (as well as other possibilities) can be realised with Profibus.

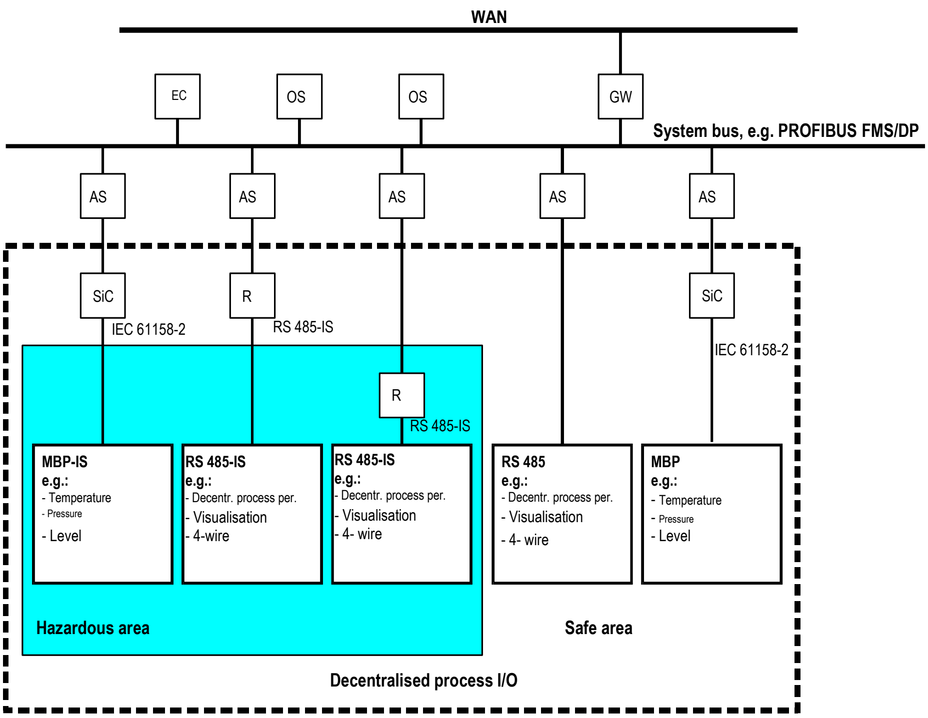

Figure 1-1

OS: **O**perating **S**tation
AS: Automation **S**ystem
EC: **E**ngineering **c**onsole
GW: **G**ate**w**ay
SiC: **Si**gnal **C**oupler
R: Fieldbus Isolating **R**epeater
WAN: **W**ide **A**rea **N**etwork
MBP: **M**anchester coded **B**us **P**owered

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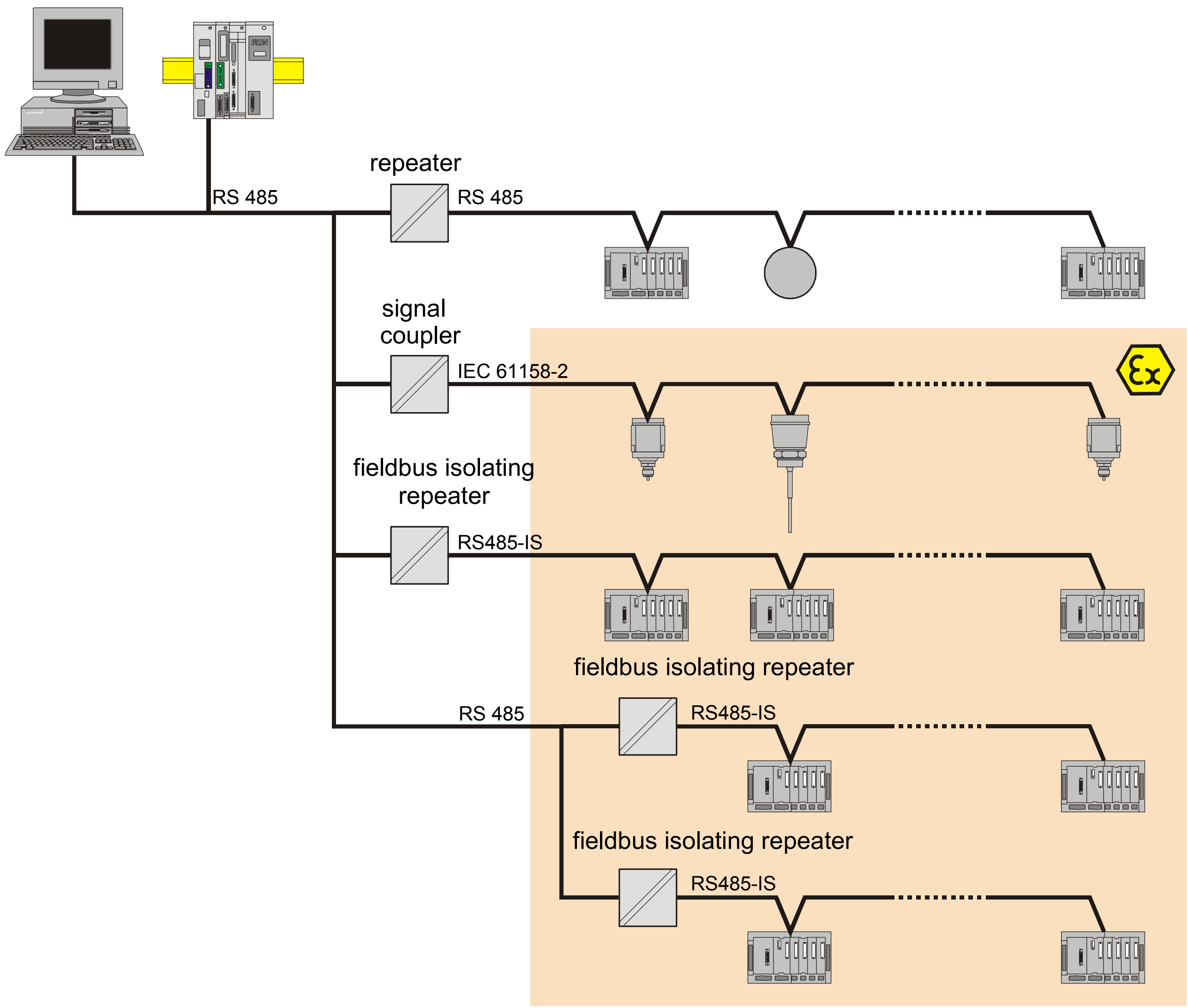

Figure 1-2 Intrinsically-safe connection of PROFIBUS RS 485-IS with PROFIBUS DP RS 485

Note: Under certain circumstances, devices which are installed in the hazardous area must be protected with additional explosion measures (Ex e, d, m, etc ....).

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2 Notes for the development of devices for the RS 485-IS

Section 2 is based on the standard IEC 61158/IEC61784 /3/ and EIA-485 /4/. This section deals with the deviations from this standard, which are necessary for the RS 485-IS.

2.1 Definitions

2.1.1 Field bus model

A basic set-up of the field bus model is shown in Figure 2-1. An fieldbus isolating repeater is (usually) located in the "non-hazardous area" for the safe separation of the intrinsically-safe bus segment from the non-intrinsically-safe bus segment. Other connected communications devices (field devices) are located in the "hazardous area". The bus cable is terminated at both ends by means of an external active bus termination or a bus termination integrated in a field device. All communications devices are supplied by external voltage sources and possess the means of safely limiting the current and voltage on the bus.

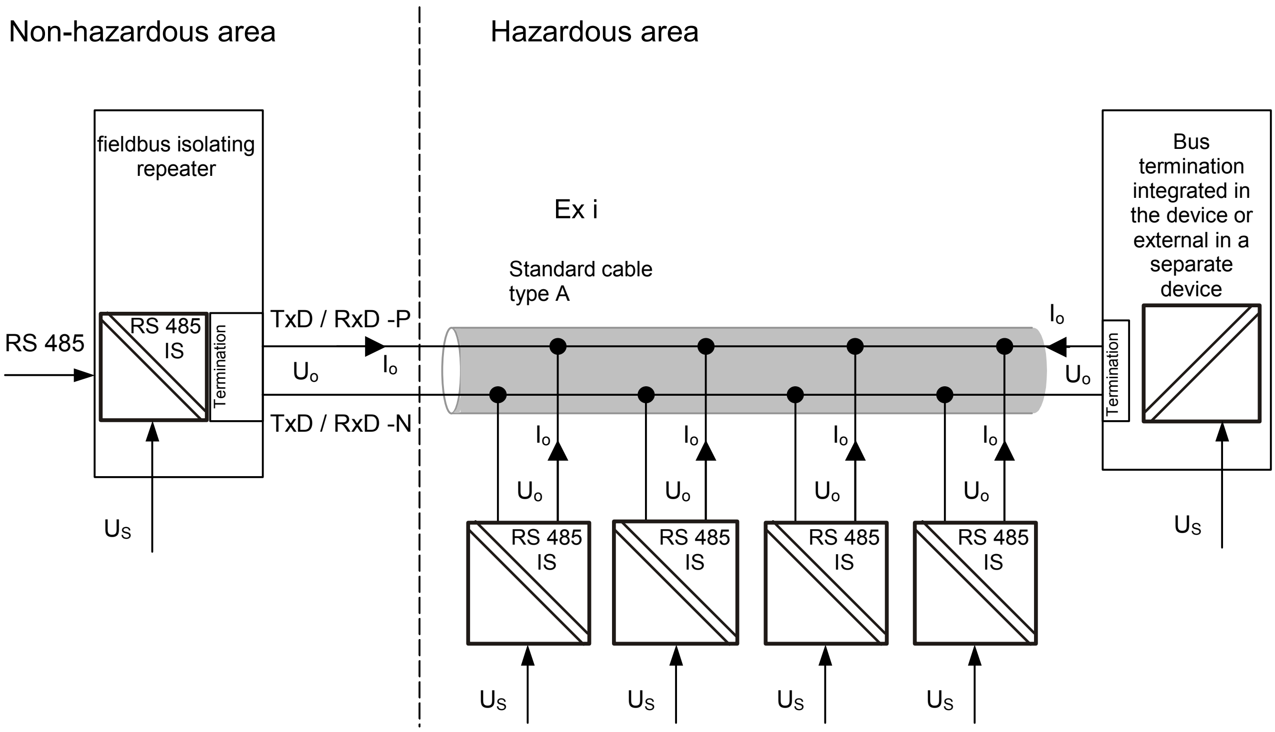

Figure 2-1: Field bus model with RS 485-IS

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2.1.2 Maximum safety values of the RS 485-IS

The stipulations pertaining to the RS 485-IS can be found in the PTB – Mitteilungen /1/ and are defined as follows:

Maximum input voltage between the signal wires $Ui = 4.2\ V$

Maximum input current in the signal wires $Ii = 4.8\ A$

The characteristic of the circuit is linear.

Maximum L/R ratio of the cable $L'/R' = 15\ \mu H/\Omega$

For a voltage below 10 V- the cable capacitance does not cause any additional danger. However, for functional reasons, the cable capacitance for the bus cable is limited to C' < 40 nF/km.
No concentrated inductances are permissible along the RS 485-IS. Capacitances along the RS 485-IS should be oriented towards a standard RS 485 installation of Profibus.
If these limiting values are observed, no ignitable sparks occur within the bus system.

The maximum safety values U_o and I_o for each device can be calculated as follows for a maximum number of stations $N_{TN} = 32$:

Maximum output voltage between the signal wires $U_o = U_i = 4.2\ V$

Maximum output current into the signal wires $I_o = \frac{I_i}{N_{TN}} = \frac{4.8\ A}{32} = 0.15\ A$

Definition: The maximum output current of a device for the RS 485-IS is determined as $I_o \leq 149$ mA. The remaining total current of 32 mA is reserved for 2 external active bus terminations.

2.1.3 Current limitation

With the known maximum safety values U_o and I_o, the safety-related effective current-limitation resistance R_s can be calculated for a linear output characteristic:

$$R_s \geq U_o / I_o = 4.2\ V / 0.149\ A = 28.3\ \Omega$$

For functional reasons, the current limitation resistance must be subdivided symmetrically. The specified value is the effective minimum resistance from a safety viewpoint. The functionally effective resistance is generally a high-impedance resistance.

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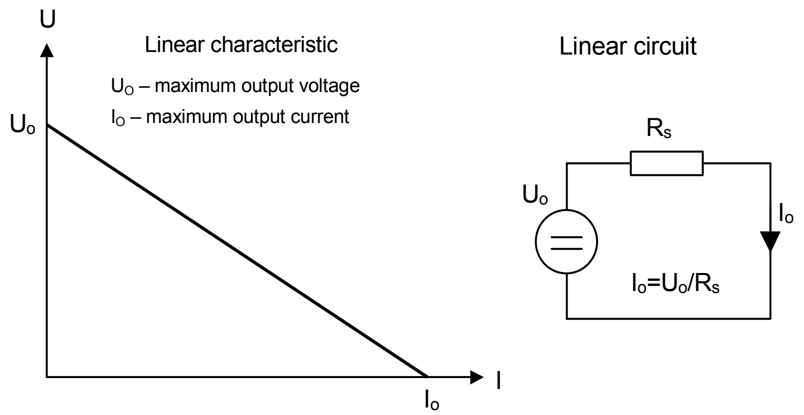

Figure 2-2: Output characteristic of an intrinsically safe communications device

After the connection of the device to the bus it is assumed that voltage addition and current addition may happen. Under worst case condition the maximum voltage across the current limiting resistor of the device is twice the maximum output voltage Uo . This causes a power dissipation at the limiting resistor that is four times higher than under normal conditions.

$$P_{\max} = \frac{4 * U_o^{\ 2}}{R_S}$$

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2.1.4 List of safety-relevant parameters

The following table shows all safety-relevant values for the entire bus system.

Parameter	**Description**	**Value**	**Remark**
<u>Bus system</u>			
Maximum input voltage	U_i [V]	±4.2	
Maximum input current	I_i [A]	4.8	
Maximum inductance to resistance ratio	L'/R' [µH/Ω]	15	For the whole operation temperature range of the bus system
Number of devices	N_{TN}	≤ 32	
<u>Communication device</u>			
Maximum output voltage	U_o [V]	±4.2	
Maximum output current	I_o [mA]	149	Total current from wires A, B and supply for bus termination
Maximum input voltage	Ui [V]	≥ ±4.2	
Maximum internal inductance	Li [H]	0	
Maximum internal capacitance	Ci [nF]	N/A	Insignificant for safety
<u>External active bus termination</u>			
Maximum output voltage	U_o [V]	±4.2	
Maximum output current	I_o [mA]	16	
Maximum input voltage	Ui [V]	≥ ±4.2	
Maximum internal inductance	Li [H]	0	
Maximum internal capacitance	Ci [nF]	N/A	Insignificant for safety

Table 2-1: Safety-relevant limiting values

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2.1.5 Requirements for galvanic isolation and insulation

In all devices connected to the RS 485-IS the bus interface circuit shall be galvanically isolated from all other electrical circuits.

Separation distances and insulation voltages between intrinsically safe circuits and/or non-intrinsically-safe circuits must meet the relevant applicable standards (e.g. EN 50020 /5/).

2.1.6 Functional parameters of the intrinsically safe interface

To ensure the interoperability of the communication devices, the parameters listed in the following table are mandatory.

Parameter	**Description**1)	**Value**2)	**Remark**
<u>Communication device:</u>			
1. Minimum idle level	U_{ODidle} [V]	0.50	Only relevant for devices with an integrated or a connectable bus termination
2. Transmission level on the bus connection (peak-to-peak)	U_{ODss} [V]	≥ 2.7	For the worst-case bus configuration and maximum load on the transmitter (see Section 2.6)
3. Positive and negative transmission level on the bus connection	U_{ODhigh} [V]	≥ 1.5	For the worst-case bus configuration and maximum load on the transmitter (see Section 2.6)
	U_{ODlow} [V]	≤ – 1.1	
4. Signal level on the receiver input	U_{IDhigh} [V]	≥ 0.8	For the worst-case bus configuration (see Section 2.6)
	U_{Idlow} [V]	≤ – 0.4	
5. Data transmission rate	KBit/s	9.6; 19.2; 45.45; 93.75; 187.5; 500; 1500	A field device can be designed with limited data transmission rate
6. Input impedance (receiver)	R_{IN} [kOhm] C_{IN} [pF] L_{IN}	≥ 12 ≤ 40 ≈ 0	For a device supplied or not supplied
7. Supply voltage RS 485 driver and bus termination	U_s [V]	3.3 ±5%	

Table 2-2: Electrical characteristics of the intrinsically safe interface

1) For the descriptions, see Section 2.1.7
2) For test circuits and test conditions, see Section 2.6

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2.1.7 Definition of the signal levels

A typical voltage waveform on the RS 485-IS bus is shown in Figure 2-3-. Three phases are defined in which characteristic signal levels are generated on the bus:

- idle state with U_{ODidle}
- low phase with U_{ODlow}
- high phase with U_{ODhigh}

The noise margin plays a crucial role in the definition of signal levels. The noise margin of a signal level is always the difference between the voltage corresponding to this level and the threshold voltage. The threshold voltage U_{TH} is an attribute of the RS485 receiver and is defined in the range of $\pm$0.2V. For reliable data transmission the noise margin must be as large as possible. In the case of the RS 485-IS, a minimum noise margin of 0.2V must be assured under "worst case" conditions.

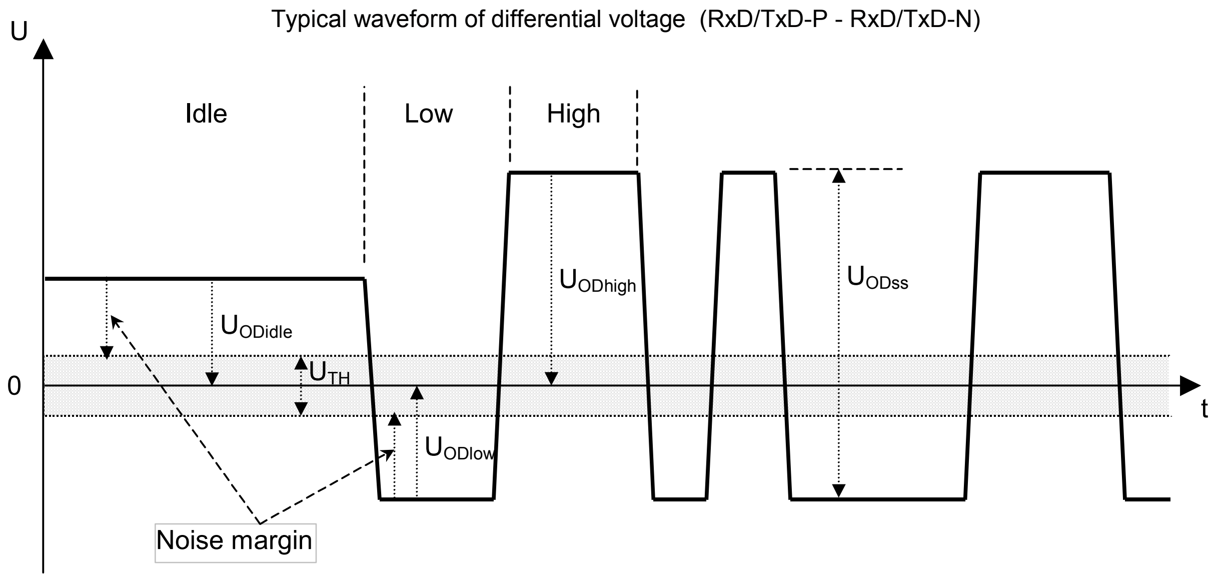

Figure 2-3: Typical behaviour of the differential voltage on the RS 485

Legend:

V_{ODidle}	– differential voltage in the idle state (no transmitter active)
U_{ODlow}	– differential voltage in the negative phase
U_{ODhigh}	– differential voltage in the positive phase
U_{ODss}	– full output level (peak-to-peak)
U_{TH}	– threshold voltage of the receiver ($\pm$0.2V in accordance with EIA 485 /4/)

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2.2 Example of a communication device

A circuit diagram for the RS 485-IS interface is described in the following. The interface is composed of the components for galvanic isolation, voltage limitation, current limitation and an RS 485 transceiver.

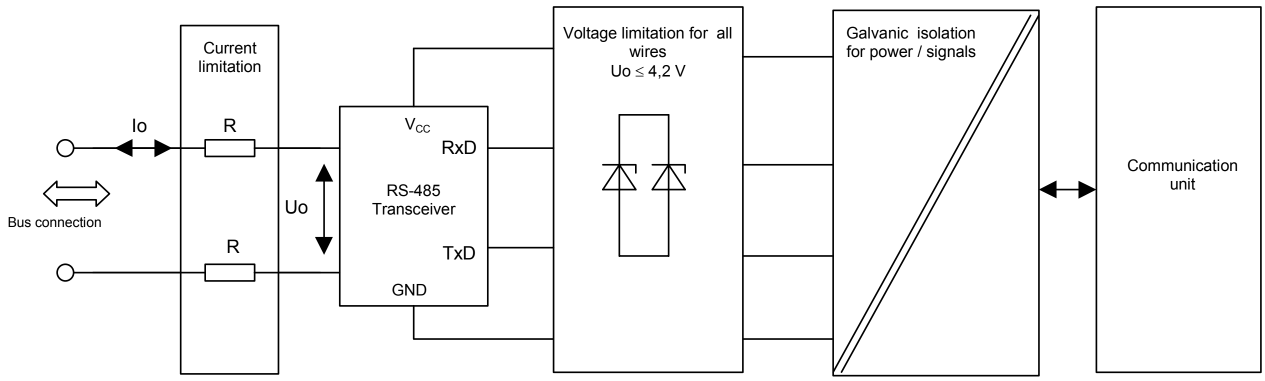

Figure 2-4 : Circuit diagram of a bus circuit

To meet the limit for U_o given in Table 2-1 all connections to the bus interface (power supply and data lines) must be limited by appropriate voltage limiting components. In this context, the tolerances and the maximum power rating of the components must be taken into account. Under certain circumstances, suitable measures for power limitation should be introduced in the communications unit / power supply.

The maximum output current I_o is calculated from the maximum output voltage U_o and the current-limiting resistor R:

$$I_o = U_o / 2xR$$

In this context, the tolerances and power ratings of the resistances must also be taken into account. Detailed requirements for the current- and voltage-limiting components are outlined in e.g. EN 50020 /5/.

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2.3 Bus termination

The termination of the RS 485-IS differs from the specification of the RS 485 on account of the modified electrical specification. In this context, the modified resistance values of the bus termination (see Figure 2-5) and the modified arrangement of the bus termination(see Figure 2-6 and Figure 2-7) must be paid attention when integrated into communication devices or plug connectors.

2.3.1 Schematic design

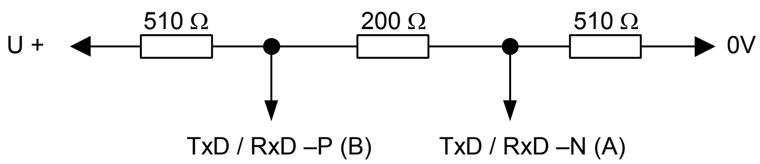

Figure 2-5: Bus termination of the RS 485-IS

Resistors tolerance ±2 %.

In the case of the bus termination's power supply, it must be considered that the supply voltage is reduced as a result of the explosion protection in the RS 485-IS (see 2.1). The bus termination illustrated in Figure 2-5 is designed for a nominal supply voltage (U+) of 3.3 V ±5 %.

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2.3.2 Example of different realisations

There are various possible realisations of the bus termination.

Bus termination in the communication device

In this version, the bus termination is already in the device by way of the resistors R3 ...R5 (Figure 2-6). Activation is done via the switch S1 for the device which is installed at the end of the bus segment.

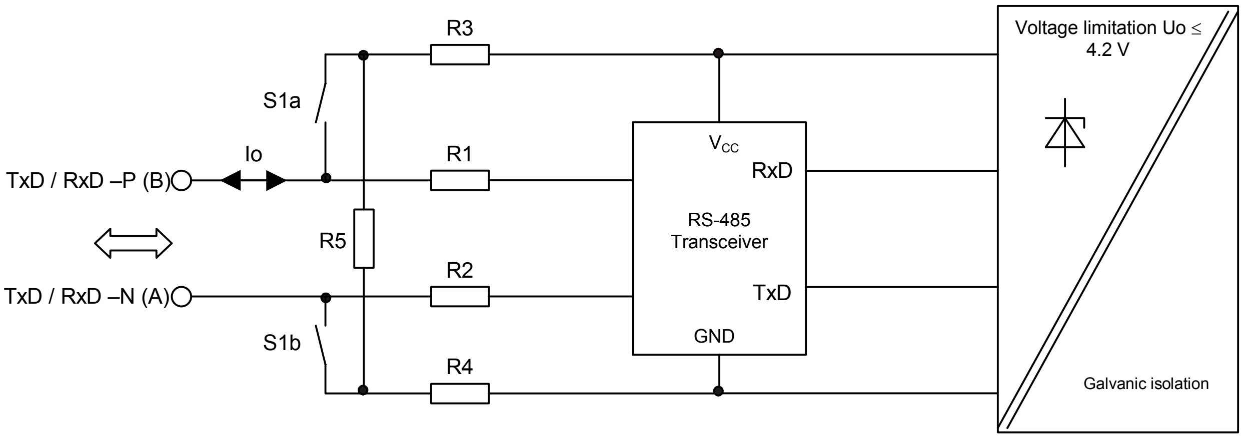

Figure 2-6 : Bus termination integrated in the communication device

R1, R2 : Current-limiting resistors for the signal path
R3, R4; R5 : Bus-termination resistors, see 2.3.1

When determining the maximum output current I_o, it shall be noted that, on account of the switch S1, the resistor R3 is connected in parallel to R1 and the resistor R4 is connected in parallel to R2. Here, the safety-related limiting values as described in 2.1 must also be adhered to. For the design of the components and the required separation distances, the relevant applicable standard shall be met (e.g. EN 50020 /5/).

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Bus termination in the connector

In this version, the bus termination is realised in the connector. For this, it is necessary that the communication devices provide the appropriate power supply. Activation is done via the switch S1 for the devices which are installed at the relevant end of the bus segment.

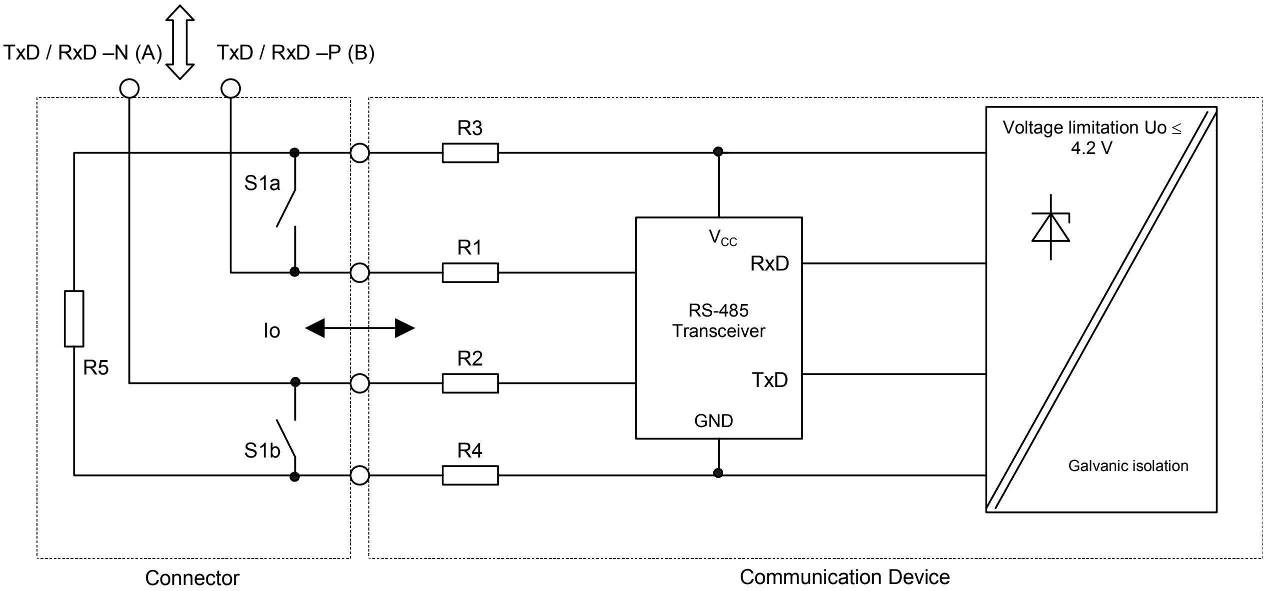

Figure 2-7 : Bus termination in the connector

R1, R2 : Current-limiting resistors for the signal path
R3, R4; R5 : Bus-termination resistors, see 2.3.1

In order to determine the maximum output current I_o, the resistor R3 must be viewed in parallel to R1 and the resistor R4 must be viewed in parallel to R2.

The maximum output current I_o is determined as follows:

$I_o = U_o / ((R1 || R3) + (R2 || R4))$

Here, the safety-related limiting values as per 2.1 must also be adhered to. Regarding to the design of the components and the required separation distances for a 10 V peak value, the relevant applicable standard (e.g. EN 50020 /5/) shall be applied.

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External bus termination

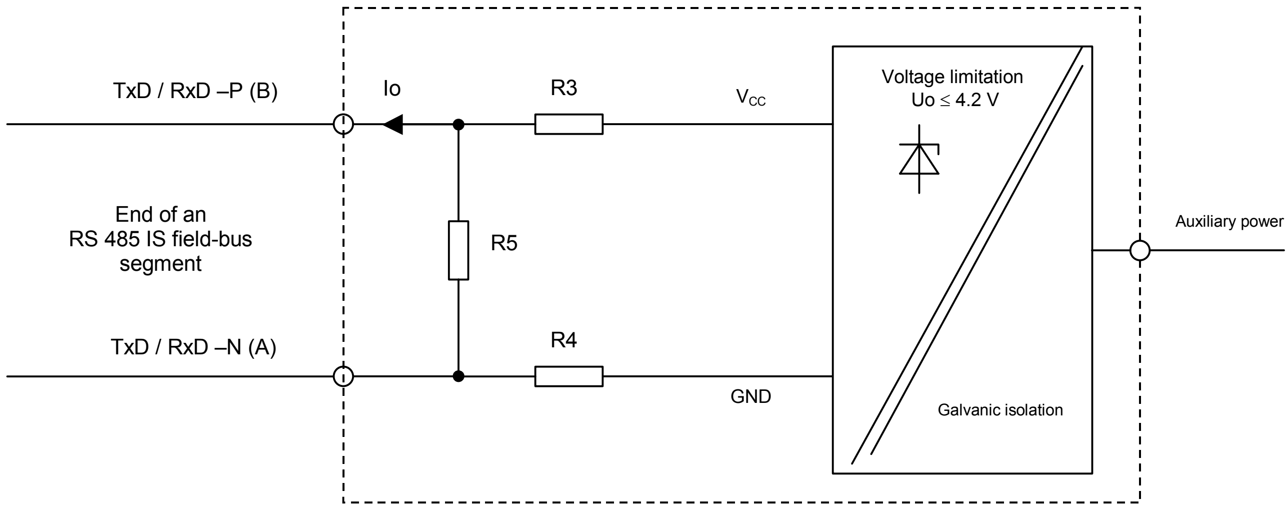

Figure 2-8 : External bus termination

R3, R4; R5 : Bus-termination resistor, see 2.3.1

The auxiliary power supply must be galvanically isolated from the field bus circuit. Details of this are provided in Section 2.1.5.
The resistors R3 and R4 are relevant for the calculation of the maximum output current I_o. In this context, the safety-related limiting values for external bus terminations as described in Section 2.1.4 must be adhered to. Regarding to the design of the components and the necessary separation distances, the relevant applicable standard (e.g. EN 50020 /5/) shall be applied.

2.4 Linking elements (fieldbus isolating repeater)

In order to create or connect RS 485-IS field bus segments, fieldbus isolating repeaters (see Figure 1-1/1-2) are required. The RS 485-IS interfaces of these devices must also be implemented in accordance with this manual. In particular, the maximum safety data (Section 2.1.4) and the galvanic isolation from all other circuits (Section 2.1.5) shall be considered from the safety point of view.

The linking elements must be designed as associated apparatus. If the linking elements are to be installed in the hazardous area, additional explosion-protection measures are necessary.

For the engineering of a Profibus network the maximum bit distortion and bit delay should be specified in the product manual.

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2.5 Connecting techniques

All connection techniques which are compliant to the standard IEC 61158/IEC 61784 /3/ and which provide the mandatory signals are permitted.

IEC 61158/IEC 61784 /3/ suggests the utilisation of a 9-pole D-Sub connector.

In accordance with the Profibus guideline "**PROFIBUS Interconnection Technology**“ (order no. 2.142 /6/), the M12 circular connector with "reverse key encryption" is permitted for IP65 applications.

Because no mechanical encryption exists between Ex and non-Ex circuits, the manufacturer is obliged to label his components appropriately in order to prevent connection mistakes.

All left open connections for the RS 485-IS (e.g. male connectors open wire ends) must be protected against unattended connections to other circuits or earth by using appropriate insulation caps or similar protection techniques.

2.5.1 IP20 connecting technique

When using the 9-pole D-Sub connector, the following assignment applies

The connector at the field device shall be a female type D-Sub connector.
The connector at the field bus cable shall be a male type D-Sub connector.

Pin no.	**Signal**	**Meaning**
1	Shield 2)	Shield
2	NC	
3	RxD/TxD-P	Received / transmitted data P; wire B
4	NC	
5	ISGND 1)	Bus termination ground
6	ISP 1)	Bus termination plus
7	NC	
8	RxD/TxD-N	Received / transmitted data N; wire A
9	NC	

1) The signal is resistor limited, see Section 2.3.2
2) The signals are optional

Table 2-3: Assignment of a 9-pole D-Sub female / male connector

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The T-functionality is realised in the connector. Series inductances, as used in the case of standard connectors, shall be omitted. The wiring from bus input to bus output in the connector shall be designed for a maximum current of 4.8 A. The trap to the communication device must be designed for the maximum input currentof 2x Io (app. 300 mA). The appropriate values for the design of the connector (track widths, separation distances etc.) must be taken from the applicable standard (e.g. EN 50020 /5/).

The separation distances between A and B wire from the connector’s trap to the current limiting resistors in the communication device shall be infallible in accordance to the applicable standard (e.g. EN 50020 /5/).

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2.5.2 IP65 connecting technique

The pin assignment is as in the case of the safe area installation. Contrary to the D-Sub plug, the connector contacts must be designed for the maximum current of 4.8 A.

Note that the pin assignment is adjusted to use for RS 485-IS.

Pin no.	Signal	Meaning
1	ISP 1)	Bus termination plus
2	RxD/TxD-N	Received / transmitted data N; wire A
3	ISGND 1)	Bus termination ground
4	RxD/TxD-P	Received / transmitted data P; wire B
5	Shield 2)	
Threaded joint	Shield	

1) The signal is resistor limited, see Section 2.3.2
2) The signals are optional

The connector at the field device must be a female type M12 connector.

IP-65 connector

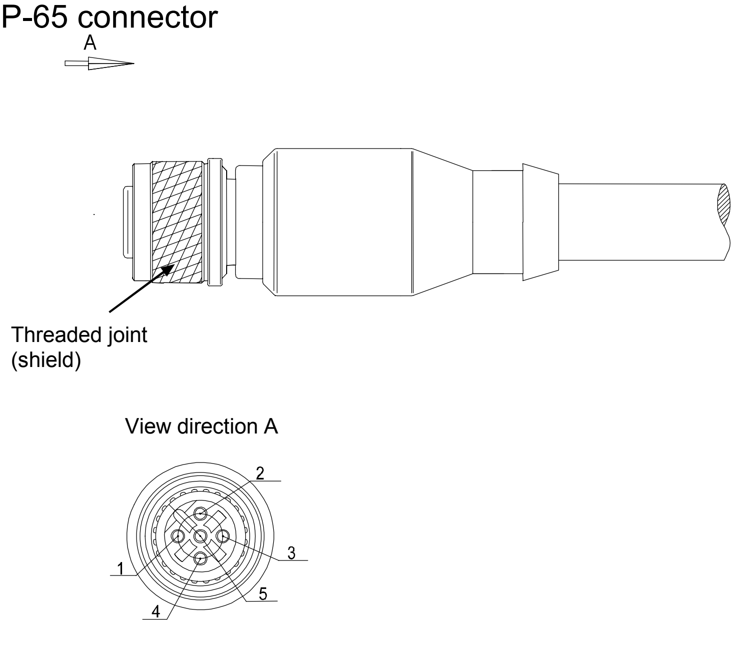

Figure 2-9: M12 connector (female)

IP-65 connector

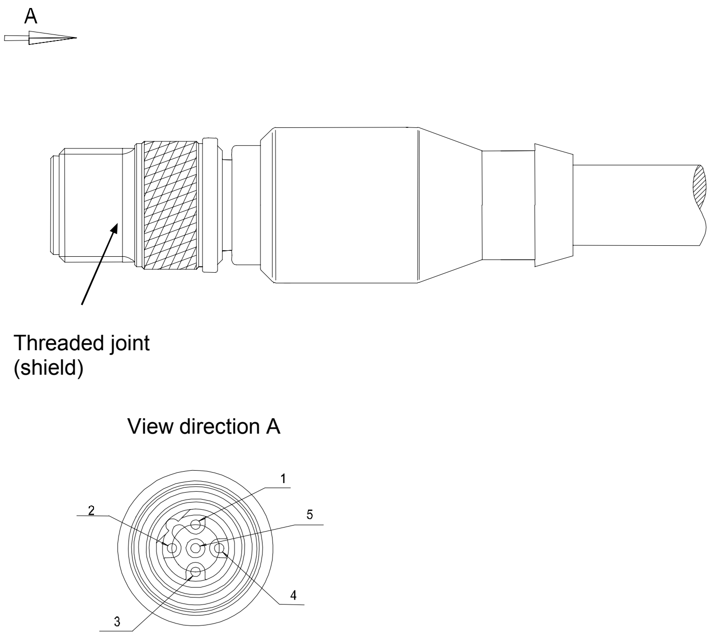

Figure 2-10: M12 plug connector (male)

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Tee

The RS 485-IS bus has a linear structure. The junctions (Tee's) connect the individual devices to the trunk cable. The spur length should be as short as possible. Spur lines ≤ 0.3 m are permitted up to a data transmission rate of 1.5 Mbit/s (see IEC 61158/61784 /3/). Series inductances, as used in standard Tee's, must be omitted.

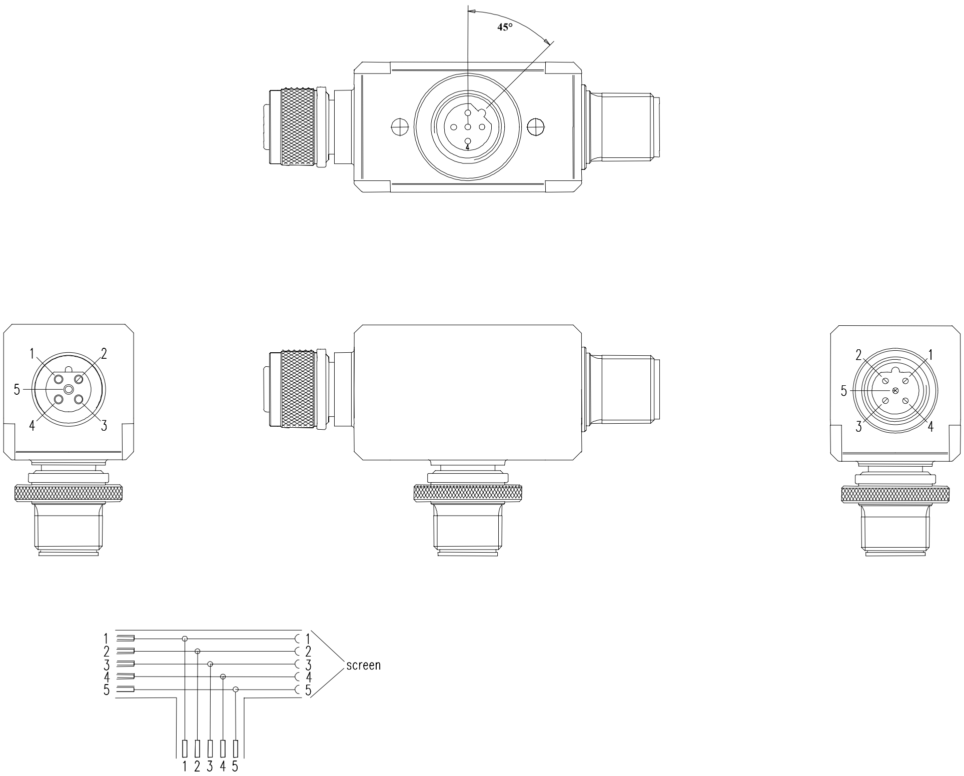

Figure 2-11: Tee

It must be ensured that the shielding in the Tee is uniform and concentric all the way to the cap nut (Threaded joint), (metal connectors and similar).

The supply voltage provided by the devices for driving the termination resistance is passed on via the Tee.

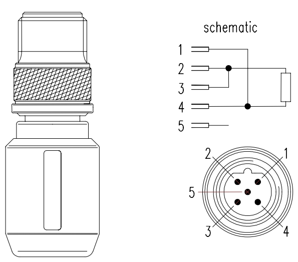

Figure 2-12: Bus termination

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2.6 Test circuits

For the error-free interconnection of the field components, the operating values described in Section 2.1.6 must be adhered to in the implementation of the RS 485-IS interface.
If a standard chip in accordance with EIA-485 /4/ is employed for an RS 485-IS interface, only the measurements detailed here must be performed. Otherwise, compliance with EIA 485 must be verified additionally.

The purpose of these measurements is the verification of the signal levels required by Table 2-2. The measurements are performed statically at a low data transmission rate so that the existing reactances, like input capacitances, do not influence the measurement results. Furthermore, the bus cable is substituted by an equivalent resistance corresponding to the loop resistance for the maximum length of the bus cable.

2.6.1 **Measurement of the idle level**

This measurement determines the characteristics of the termination resistance. For this reason, this measurement must only be performed on devices under test which are either equipped with a bus termination or provide a power supply for an external bus termination (the connections ISGND and ISP are realised).

Note: the additional components as well as switch and resistors should be connected directly to the DUT terminals (5..15cm). When a connecting cable must be used, the length of the cable must not exceed 1m.

The measurement is undertaken in two steps.

- Step 1: the open circuit voltage U_1 is measured and must be greater than specified in Table 2-2, line 1.

- Step 2: the voltage U_2 is measured under load conditions (330 Ω load). U_2 must be in a specified range ($0.65 \cdot U_1 \leq U_2 \leq 0.72 \cdot U_1$). That guarantees that the termination resistor is in the range 130..180 Ω.

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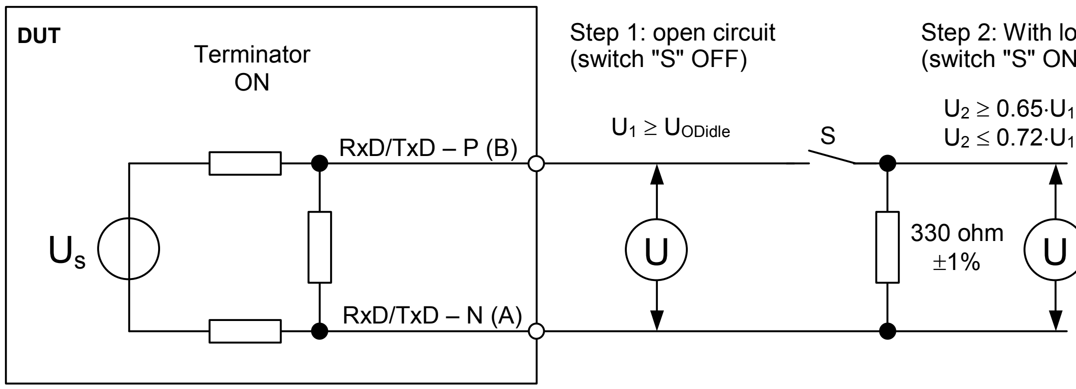

Figure 2-13: Test set-up for the measurement of the idle level for devices with an integrated termination resistor.

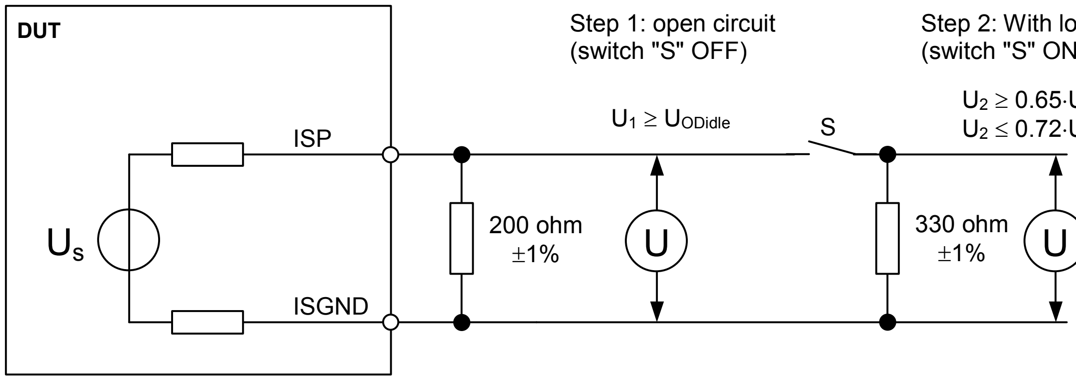

Figure 2-14: Test set-up for the measurement of the idle level for devices with a connectable termination resistor.

2.6.2 Measurement of the signal levels

For the measurement set-ups below, the following applies:

- A compliant fieldbus isolating repeater must be employed for connection on the DP master system.
- During the test, the RS 485-IS bus must be terminated at both ends in accordance with 2.3. If the bus termination is not integrated in the device under test, then an external compliant bus termination shall be used.

Notes:
1) In order to measure the signals on the RS 485-IS without external influences, it is necessary to connect an electrically isolated oscilloscope (e.g. a hand-held with a battery supply).
2) The additional components as well as resistor and resistor network should be connected as short as possible to the terminals of the DUT and the Fieldbus Isolating Repeater. When a connecting cable must be used, the entire length of the cable(s) must not exceed 2m. The oscilloscope can be attached to any suitable terminals according to set-up.

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2.6.2.1 Transmission signal levels

This measurement determines the transmission levels on the transmitter connections and for a worst-case load. This is the case for a fieldbus cable length equal to zero. In this case, the output current of the transmitter and consequently the load is at maximum.
The rated values for the transmission levels are shown in Table 2-2, lines 2 and 3.

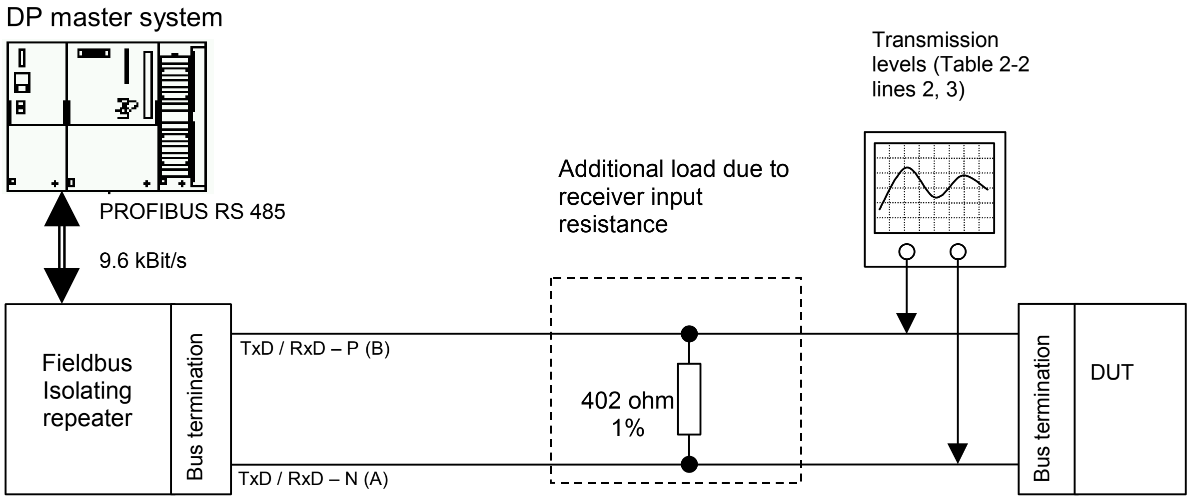

Figure 2-15: Test set-up for measurement of the transmission levels.

2.6.2.2 Receiving signal levels

This measurement attempts to verify the capability of the transmitter to generate a sufficient level for every receiver for a worst-case load. For a maximum fieldbus cable length of 1200m and additional load, this is the case roughly in the middle of the cable. The measurement values must satisfy the requirements (see Table 2-2, line 4).

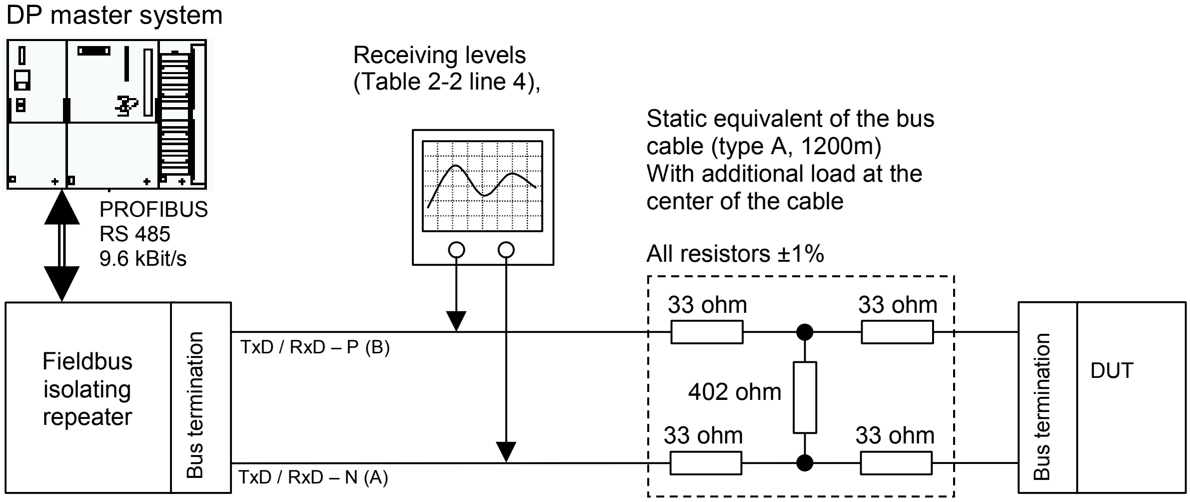

Figure 2-16: Test set-up for the measurement of the receiving levels.

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3 Configuration Hints

This section contains notes for network engineers planning a system with an RS 485-IS field bus. This configuration hints do not have the status of a normative specification, they only interpret the relevant standards. That also applies to statements regarding problems of intrinsic safety.

3.1 RS 485-IS topology

The RS 485-IS has a linear bus structure as the RS 485. Spurs shall be avoided because they give rise to poor transmission reliability.

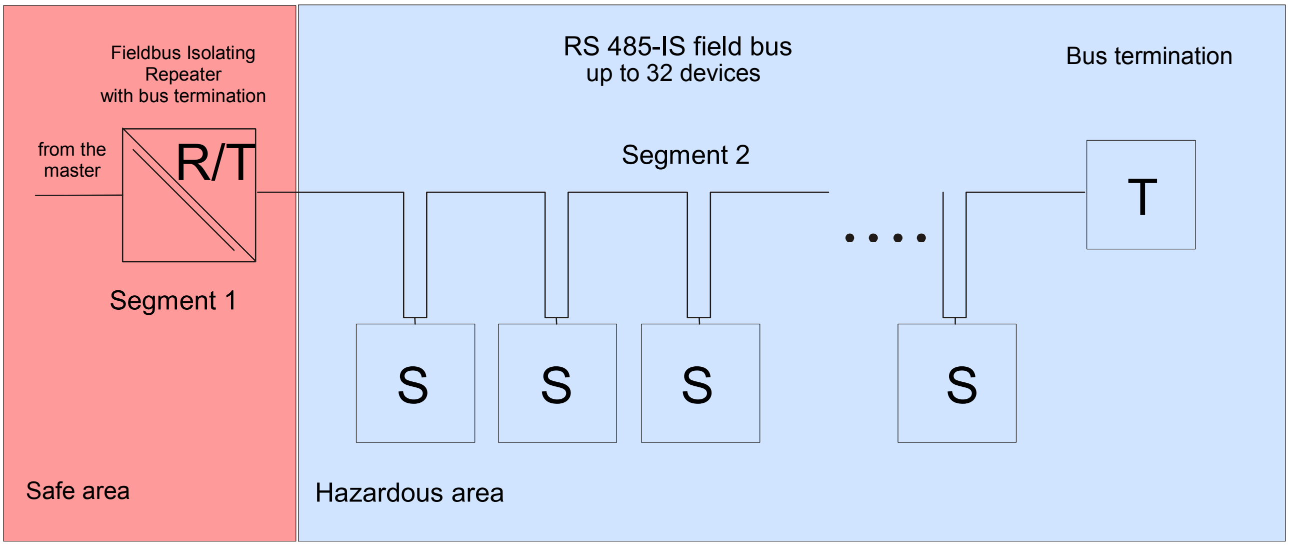

Figure 3-1: Linear structure of an RS 485-IS segment

R = Repeater; S= Profibus slave; T = Bus termination

The linear structure (Figure 3-1) permits connection points along the field bus segment similar to the installation of power supply circuits. The field bus cable should be looped through the individual field devices in order to avoid spurs. The maximum possible length of a segment depends on the transmission rate only. Additional details can be found in the following sections.
A fieldbus isolating repeater or a comparable device always forms the beginning of an RS 485-IS segment. This fieldbus isolating repeater connects a non-intrinsically-safe RS 485 segment with the intrinsically safe RS 485-IS segment and simultaneously ensures reliable galvanic isolation between the two. The RS 485-IS segment is terminated at both ends with an active bus termination. Up to 32 bus participants (field devices, fieldbus isolating repeater etc.) can be arranged along the RS 485-IS segment. The bus participants are connected to a segment of the RS 485-IS in an electrically-floating arrangement.

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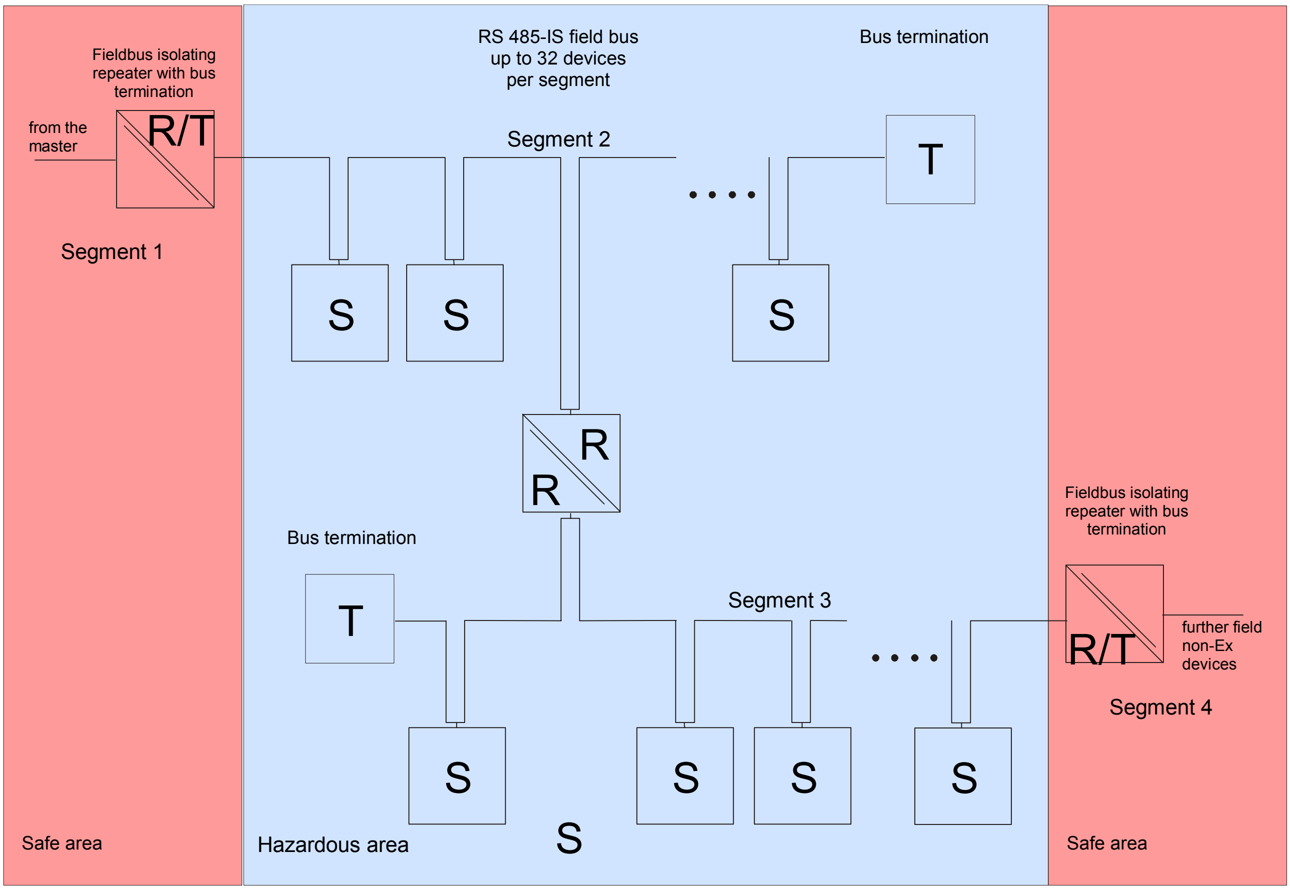

Figure 3-2: Bus extension, one possible bus structure

R = Repeater; S = Profibus slave; T = Bus termination

Figure 3-2 shows an example of the set-up and the segmentation of a Profibus system with fieldbus isolating repeaters. The RS 485-IS segments 2 and 3 are intrinsically safe. The fieldbus isolating repeater between the intrinsically safe segments 2 and 3 must maintain galvanic isolation in accordance with the relevant standard (e.g. EN 50020 /5/). The number of cascadable repeaters depends on the signal distortion and the delay of the signal (pay attention to the manufacturer's specifications).
Segment 3 in Figure 3-2 is started by means of a fieldbus isolating repeater in the middle of segment 3. Bus termination is provided at one end by means of an active bus termination and at the other end by means of another fieldbus isolating repeater which opens segment 4 into the safe area.
The bus terminations of an RS 485-IS segment can be located in a fieldbus isolating repeater, in an active bus termination (as a stand-alone device) or in a connector powered from a field device.

The repeater between segments 2 and 3 in Figure 3-2 must be installed either outside of the hazardous area, as associated apparatus. The installation in the hazardous area requires additional explosion protection measures (e.g. Ex e, Ex d, Ex i etc.)..

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3.2 Certification and labelling

The manufacturers have the obligation to manufacture their equipment (devices) in accordance with the relevant European directives and to confirm this by the issue of a declaration of conformity and the attachment of the CE mark.
The basis for the manufacturer's declaration of conformity is the testing and certification of the equipment (devices) and the issue of a EC-examination certificate by a notified body.
The manufacturer of the equipment (devices) must deliver all necessary data (documentation) for a safe installation of the equipment (devices) in a field bus installation (data sheet, EC-examination certificate and instructions) to the operator.
The operator is responsible for installing the equipment (devices) in accordance with the documentation and national regulations for installation.
According to EN 60079-14 /7/, it is permissible to connect several intrinsically safe circuits together. The intrinsic safety of the overall system must be verified by means of theoretical calculations or by a spark test. The results in the PTB – Mitteilungen /1/ consider theoretically the connection of several intrinsically safe devices, to form a field bus system.
If the limiting values specified in the PTB – Mitteilungen /1/ are adhered to, the resulting field bus system is intrinsically safe and may be installed in hazardous areas zone 1 in accordance with the directive 99/92 EC /8/.

3.2.1 Certificates of individual devices

First of all, it is assumed that the bus devices, i.e. **field units**, **hand held devices**, **gateways**, **repeaters** etc., are certified as explosion-protected devices in accordance with the directive 94/9 EC /9/. The instructions of the bus devices must contain the declaration that the intrinsically safe circuits for the field bus connection are in accordance with the PTB – Mitteilungen /1/. The maximum output voltage U_o, the maximum output current I_o, the output characteristic, the maximum input voltage U_i and the effective internal inductance and capacitance on the field bus interface must be specified.
The certificate must also include a note regarding the required galvanic isolation between the field bus circuit and other circuits.

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3.3 Field bus cable

3.3.1 Cable parameters

The field bus cable is specified in IEC 61158/IEC61784 /3/ as cable type A and shall comply with the cable parameters in table 3-1. The type-B cable also described in IEC 61158/IEC61784 /3/ is obsolete and should no longer be used.

Table 3-1 shows the cable parameters of the standard type-A cable.
Special requirements in accordance with EN 60079-14 /7/ shall be taken into account for the installation in hazardous areas.

Parameter	Cable type A	Limiting safety values
Surge impedance (Ω)	135...165 at a frequency of 3...20 MHz	not relevant
Working capacitance (nF / km)	≤ 30	not relevant
Wire diameter (mm)	> 0.64	> 0.1 single wire for a fine-stranded conductor1) > 0.352)
Core cross-sectional area (mm²)	> 0.34	> 0.09622)
Loop resistance (Ω / km)	≤ 110	not relevant
L/R ratio (µH / Ω)	≤ 15	≤ 15 for the lowest ambient temperature3)

1) In accordance with the installation rules in EN 60079-14. The wire ends of fine-stranded conductors must be protected against separation of the strands, e.g. by means of cable lugs or core end sleeves,.
2) This minimum value applies for a maximum ambient temperature of 40 °C and the temperature class T6 for a total current in the field bus cable of max. 4.8 A. According to EN 50 020 /5/
3) Cable type A fulfils this requirement for a ambient temperature above –40 °C.

Table 3-1: Cable parameters (function- and safety-related)

Installations in accordance with the PTB – Mitteilungen /1/ are not subject to any safety-related limitations if the limiting values specified in Table 3-1 are met. To differ from these limiting values is not generally forbidden, but must be examined in each individual case.

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3.3.2 Relationship between cable cross-section (diameter), temperature class, ampacity and ambient temperature

EN 50020 /5/ deals with this relationship only in the temperature range from -20 °C to 40 °C.
To get information on the ampacity at other ambient temperatures, this must be deduced from the existing requirements of EN 50020 /5/.
In the case of the RS 485-IS, a maximum current of 4.8 A occurs in the field bus cable. This necessitates a wire cross-section of ≥ 0.0962 mm^2 (diameter: ≥ 0.35 mm) for a cable used in T6 and for a maximum ambient temperature of 40 °C. Because the permissible surface temperature of the cable shall not exceed 80 °C in the case of T6, the maximum temperature rise is 40 K for 4.8 A and the above-specified wire cross-section.
For cables deployed in T4 and higher ambient temperatures than 40 °C, the sum of the ambient temperature and the cable's temperature rise must not exceed 130 °C for a current of 4.8 A.
In all cases, the insulation of the cable must be suitable for the maximum expected cable temperatures.

3.3.3 Maximum cable length

With the specified cable parameters of the standard cable (cable type A) and taking into account the permissible attenuation, reflection and distortion, the following segment lengths are allowed in relation to the data transmission rate:

data transmission rate (kBit / s)	≤ 93.75	187.5	500	1500
max. segment length (m)	1200	1000	400	200

Table 3.2: Cable lengths per segment in relation to the data transmission rate

The network can be expanded using repeaters. The above-specified limiting values apply for each separate bus segment. The maximum number of repeaters between two bus devices depends on the signal delay and can be found in the product manual of the relevant device.

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3.4 Bus termination

In order to minimise cable reflections and to ensure a defined idle level on the field bus cable, the cable must be terminated at both ends with a bus termination.
The two-ended bus termination ensures the idle level on the field bus segment (see Table 2-2). The idle level is also adhered to in the worst case (the communication devices are placed close to one end of the bus and consequently represent an additional load on account of their input resistances).

Note: Within a given RS 485-IS network, only bus terminations which are suitable and certified for that network may be deployed.

3.5 Shielding and earthing

For the operation of an installation with field bus systems, the earthing concept and thereby also the shielding of the electrical cables is a very important issue. When finalising the earthing concept, the following aspects should be taken into consideration:

- Ensuring electromagnetic compatibility (EMC)
- Explosion protection
- Human safety

Earthing means a "permanent connection to the equipotential bonding system via a sufficiently low-impedance connection with adequate current loading capacity in order to keep overvoltages out of connected devices and away from persons".

Conventional field units (e.g. with a 4-20 mA interface) which are connected via two-wire cables with isolating repeaters in the control room process DC signals or low-frequency AC signals. The influence of wire-conducted noise signals with higher frequencies can be suppressed by means of appropriate input filters having a low cut-off frequency. Thus, for such devices, a predominantly electrostatically acting cable shield (earthed on one side) is sufficient. For this reason, the earthing of the cable shield on one side developed to become the "classical" earthing concept in process technology. Nonetheless, in field bus systems, the usable frequency for the transmission of the signals is considerably higher - and the requirements placed on the earthing concept of the system accordingly tougher. Where AC signals are being processed, the components and also the interconnection of elements, such as e.g. cables, must be protected against the influence of electromagnetic fields. The protective measures should create a complete encapsulation around the sensitive components. The larger the processed signal frequencies in the systems, the greater the requirement placed on the completeness of this gapless protective encapsulation. A shielding and earthing concept which satisfies these requirements constitutes the basis for the EMC tests performed by the device manufacturers.

In order to meet the described requirements, shields of cables must be connected with the terminal locations in the devices intended for this purpose. When connecting the shields, a low-impedance connection should be ensured - considering the high noise

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frequencies. This applies not only for the connection of the cable shields, but also for the grounding connection of the device. Extended wires usually do not meet this requirements.

For the shielding and earthing measures to have their optimum effect, the devices and shields must be earthed more than once (see Figure 3-3). According to EN 60079-14:1997 /7/ Section 12.2.2.3, this method, which is optimal for electromagnetic compatibility and human safety, can be utilised without restriction in the area of the entire installation.

If the installation is made and maintained that it can be ensured with a high degree of certainty that a potential equalisation exists between each end of the circuit (i.e. between the hazardous area and safe area) then – if desired – cable screens and conducting screens at both ends of the cable and the screens at intermediate points, may be connected to earth, if necessary.

In the process, it must be remembered that in the hazardous area as per EN 60079-14 /7/, Section 6.3, an equipotential bonding system is an absolute requirement anyway. The measures detailed there (inclusion of protective conductors, protective tubes, metallic cable shields, cable reinforcements and metallic components) can be supplemented using the following measures:

- Laying of the bus cables on metallic cable trays.
- Incorporation of the cable tray into the equipotential bonding system
- Interconnections of the cable trays among each other and to metallic components - these interconnections should be safe, be of sufficient current-loading capacity and be of a high-frequency-technology and low-impedance design

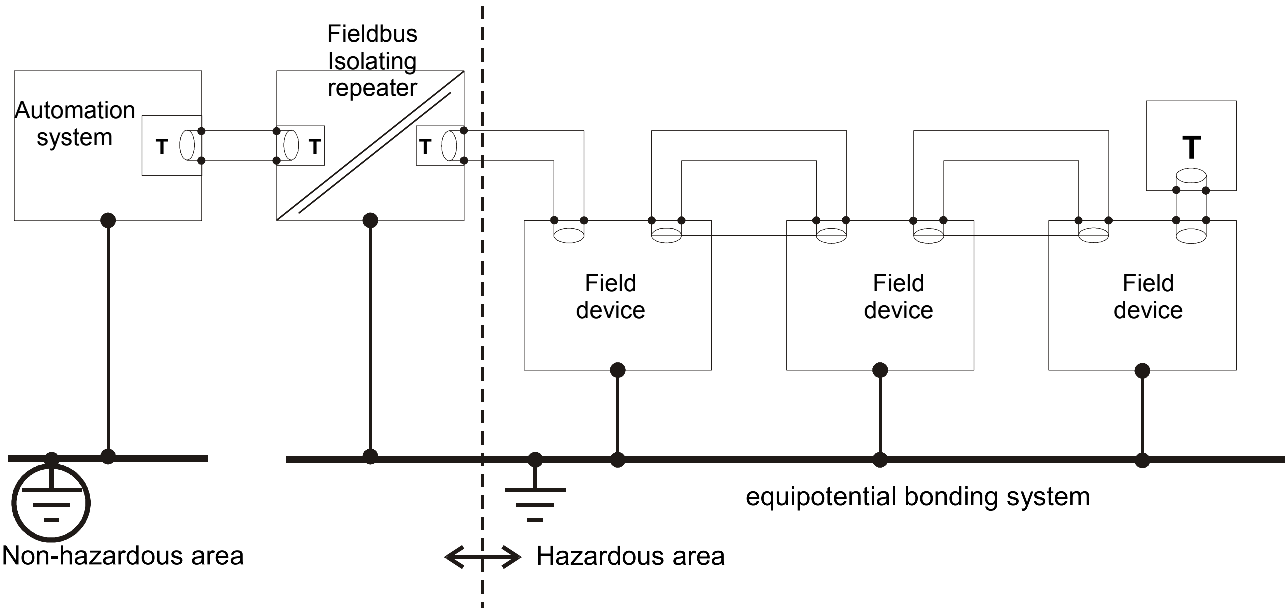

Figure 3-3: Ideal combination of shielding and earthing

By taking these measures, it is possible to at least create "equipotential islands" (areas free of potential differences). Low-frequency transient currents (50/60 Hz and harmonics) on the shielding, such as for example those which can develop due to potential differences between "equipotential islands", have practically no noise impact

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on account of the high common mode rejection ratio of the overall system and the high-pass effect of the reception filter in the case of AC-interconnected systems such as PROFIBUS-RS 485. It must nevertheless be ensured that these transient currents do not damage the cable and cannot induce ignitable sparks in the hazardous area. This can be achieved e.g. by means of a potential equalisation cable having a broad cross-section and laid parallel to the bus cable.
In order to prevent impermissible energy potentials from being carried into the hazardous area, the cable shield must be connected "safely" to the equipotential bonding system at all points of transition between the safe and hazardous areas. Here, "safely" means that the individual conductors of the cable shield be twisted, be protected from splaying by means of an end covering sleeve and be connected to an appropriate screw terminal.
The connection of the cable shields within the hazardous area is not relevant to safety. It can be realised using conventional shield terminals (clamp straps).

3.6 Selection and interconnection of components

When selecting the individual components, it must be ensured that all components are in accordance with the requirements of the PTB – Mitteilungen /1/ as far as their safety-related data are concerned.
In RS-485-IS bus segments compliant with PTB – Mitteilungen /1/, only components which are labelled as intrinsically safe electrical equipment or as associated electrical equipment in accordance with the relevant standard (e.g. EN 50020 /5/) may be installed.

The whole field bus must be installed and operated as galvanically isolated from other circuits and from earth. An earth connection of one of the two wires A or B is not permissible along the RS 485-IS segment. All left open connections for the RS 485-IS (e.g. male connectors open wire ends) must be protected against unattended connections to other circuits or earth by using appropriate insulation caps or similar protection techniques .

For EMC reasons, the cable shield along the RS 485-IS segment should be connected to the equipotential bonding system at the entry/exit point of a housing. For this purpose, the equipotential bonding system in the area of the field bus segment must be ensured to a high degree, see EN 60079-14:1997 /7/ 12.2.2.3 Section b).

The safety-related limiting values must be chosen in accordance with Section 2.1. In order to achieve an unambiguous assignment of the bus components, the product manual must, in accordance with directive 94/9 EC /9/, contain a reference to PTB – Mitteilungen /1/. Only in this way it will be possible to operate components of different manufacturers on the same field-bus segment.

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Strategy for selecting the components:

- Check the product manual whether the device is in accordance with PTB – Mitteilungen /1/.

- Check whether the device is in accordance with this PNO guideline (certificate, functional technology).

- Check whether the cable is in accordance with the specification for cable type A (IEC 61158/IEC61784 /3/) (L´, C´ and R´).

Check whether the cable fulfils the explosion-protection regulations (e.g. EN 50014 /19/, EN 50020 /5/ and EN 60079-14 /7/ for insulation, minimum conductor diameter etc.).

Procedure for connecting the components together within one physical segment:

Verification of explosion protection:

1. Verification whether all devices (field units, fieldbus isolating repeaters, bus terminations [power dissipation], connectors [current loading capacity]) are in accordance with relevant standard (e.g. directive 94/9 EC /9/) and with this guideline.

2. Verification that the maximum output current of each device is $I_o \leq 149$ mA. (exception: external active bus terminator $I_o \leq 16$ mA)

3. Verification that the maximum number of devices at the fieldbus is ≤ 32. (additionally 2 external active bus terminator are allowed)

4. Verification that the maximum output voltage of each device is $U_o \leq 4.2$ V.

5. Verification that the maximum L/R ratio of the cable employed $L/R_{cable} \leq 15$ µH/Ohm (for the minimum ambient temperature of the cable).

6. Verification if the equipotential bonding system is in accordance with the relevant standard (e.g. EN 60079-14:1997 /7/ 12.2.2.3 Section b), where necessary.

Verification of the functional technology:

1. Verification that the number of devices per bus segment is ≤ 32 (field devices and fieldbus isolating repeaters).

2. Verification that the bus segment length is in accordance with the chosen data transmission rate.

3. Verification that the number of repeaters within one Profibus segment is $\leq$ the maximum permitted number (see the product manual of applied repeater).

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4. Verification that the bus idle time for the direction changeover of the linking elements employed (fieldbus isolating repeaters) is adhered to.

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4 References

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/3/	IEC 61158-2/	Fieldbus standard for use in industrial control systems - Part 2: Physical Layer specification and service definition
	IEC 61784-1	Digital data communications for measurement and control - Part 1: Profile sets for continuous and discrete manufacturing relative to fieldbus use in industrial control systems
/4/	EIA-485	ANSI Standard
/5/	EN 50020	Electrical apparatus for potentially explosive atmospheres – Intrinsic safety „i“
/6/	order no. 2.142	PROFIBUS Interconnection Technology
/7/	EN 60079-14	Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines)
/8/	Directive 99/92 EC	OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)
/9/	directive 94/9 EC	OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 March 1994 On the approximation of the laws of the member states concerning equipment and protective systems intended for use in potentially explosive atmospheres.
/10/	EN 50 014	Electrical apparatus for potentially explosive atmospheres General requirements

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