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Fundamentals of

Profibus PA Networks

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PROFIBUS PA

Page

Contents:

Notes:

- SIMATIC PDM and HW-Config are trademarks of Siemens
- Data provided by other manufacturers are also quoted. All information given in this brochure is understood to be non-binding and designed purely as an aid to engineers planning a potential PROFIBUS-PA system.
  However, technical progress will undoubtedly cause these specifications to change in the course of time.
- In case of doubt, the relevant directives and standards are always applicable.
- No liability whatsoever shall be accepted in respect of any and all details given in this brochure.

1 Introduction

The 0/4...20mA interface is nowadays still the standard equipment used to link up sensor and actuator systems with, for example, a digital control system. The advantage of this interface lies in the fact that it is in widespread use and allows relatively easy interchangeability of devices supplied by different manufacturers.

In this age of communications technology, one-way communication, i.e. transmission of measured values from the field device to the control system, for example, is no longer sufficient to meet the requirements for profitability and high flexibility demanded in many industrial sectors.

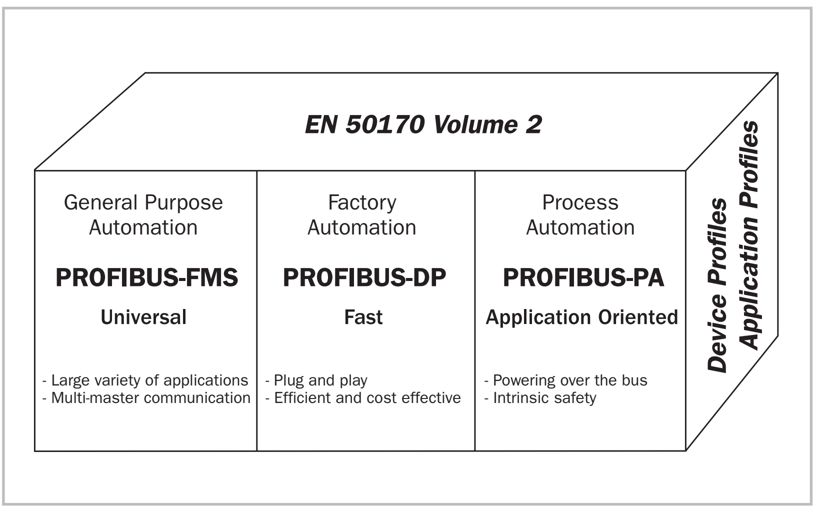
The so-called smart technology was introduced as far back as 1983 to enable the measuring ranges of differential-pressure transmitters to be changed from the control room. Today, the HART® technology has developed into a quasi-standard for many sectors and is indeed gaining more and more significance.

The true benefits of serial digital communications technology, however, can only be exploited in conjunction with a standardized open system fieldbus. Here, the PROFIBUS presents itself with its PA variant (**P**rocess **A**utomation), which has been optimized to suit process engineering requirements.

In addition to more cost-effective instrumentation, the PROFIBUS-PA is characterized by substantially greater functionality. The PA profile, referred to the basic functionality of the field devices, is designed to meet the demand for interchangeability of devices from different vendors, as naturally also the possibility of service in hazardous areas and the feeding of so-called two-wire devices.

For further information on communications, please ask for the KROHNE brochure "Communications Engineering".

Figure 1



2 PROFIBUS – General

The **PRO**cess **Fi**eld **BUS** (PROFIBUS) is the outcome of a joint project founded in 1987 by the companies of Bosch, Klöckner-Möller and Siemens. In all, 13 companies and 5 universities were involved in the project. PROFIBUS allows exchange of data between devices made by different manufacturers without the need for special adaptation of the interface.

The specifications of the PROFIBUS are described in detail by Layers 1, 2 and 7 of the ISO/OSI reference model. Information on the reference model and the various communication techniques are also given in the brochure "KROHNE Communications Engineering". PROFIBUS has to date already acquired a considerable share of the market and is Europe's fieldbus No. 1. Worldwide, more than 1000 companies with over 1200 products are represented in the umbrella organization of PROFIBUS International. PROFIBUS is a multi-master system. Controlled bus access is regulated by a hybrid bus access method, i.e. the token passing method is used for the distributed system and the master/slave principle for the centralized system.

2.1 PROFIBUS variants

Since the PROFIBUS is used in both production and process automation and also for building services management systems, variously optimized variants of the PROFIBUS are available, as shown in Figure 1. FMS stands for Fieldbus Messaging Specification, DP for Distributed Peripheral, and PA for Process Automation.

2.2 Typical PROFIBUS-DP/PA network

The automation structure shown in Figure 2 illustrates one of a number of possible interconnections. Some useful explanations now follow on the basis of this diagram:

The **Class 1 master** is the automation system and performs the open-loop and closed-loop functions. It transmits measured values and status **cyclically** from all e.g. connected measuring devices using the so-called cyclic services. With extended DP functionality, one or several **Class 2 masters** (the engineering station or the operator's station) are basically capable of accessing all parameters and functions of the connected PA devices by means of the so-called **acyclic** services.

Access can also be made to existing **HART-capable devices**. Accordingly, these devices can be connected e.g. via a distributed interface module (e.g. ET200M from Siemens) to the PROFIBUS-DP and be incorporated with complete functionality in the engineering or operator's station.

A further point to be borne in mind is that the **baud rate in the DP network** depends upon the segment coupler/link used (see "Segment coupler").

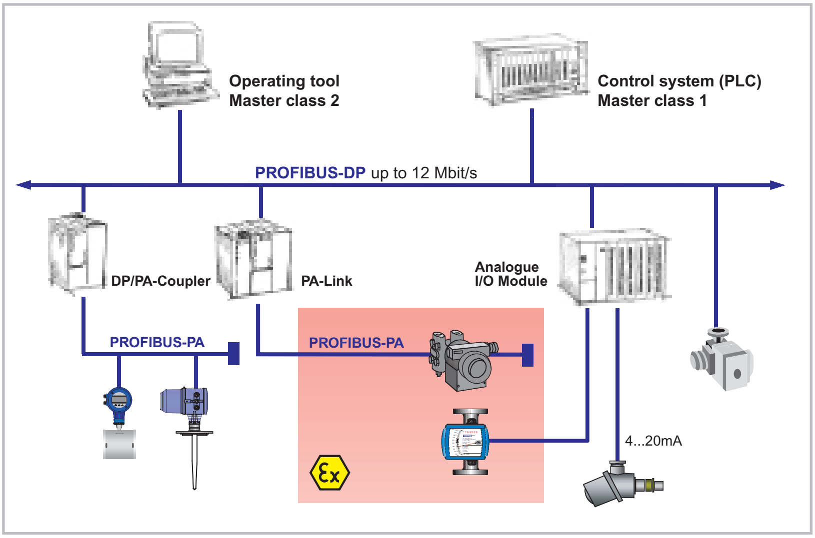


Figure 2

3 PROFIBUS-PA – the standardized solution

One part of the european Fieldbus standard EN50170 and of the International fieldbus standard IEC 61158 is PROFIBUS. PROFIBUS-PA therefore is integrated as well.

The physical layer of the PROFIBUS-PA variant, in addition, conforms to the IEC 61158-2 Standard which is also used for the Fieldbus Foundation fieldbus (see Table 1)

Table 1

	Physical layer acc. to IEC 61158-2, Variant H1
Baud rate	31.25 kbit/s
Topology	line or tree
Power via the bus	DC supply possible
Intrinsic safety	possible
No. of devices	max. 32 (non-“Ex“) approx. 9 (Explosion Group IIC) approx. 23 (Explosion Group IIB)
Cable length max.	1900 m
Spur length max.	120 m per spur Non-Ex, 30 m per spur Ex (see Section on “Fieldbus cable types“)
Redundancy	possible

4 PROFIBUS-PA – the economical solution

There are basically two important reasons for adopting the fieldbus technology as the standard interface in the near future: substantially improved functionality combined with reduced installation and operating costs.

Functional advantages

- High resolution of the measured value
- Transmission reliability
- Multifunctional field devices
- Corrective functions in the field device
- Distributed intelligence
- Support on the maintenance side
- Self-test functions and diagnostic capabilities
- Standard, vendor-independent operator control
- Reduced requirement for stockable devices (due to wide measuring ranges)

Economic benefits

Two areas are considered in which users can achieve substantial cost savings by using the field bus technology. This has been shown by a survey carried out by several NAMUR member firms. The cost blocks are:

Installation costs

Cost calculations were based on a system with 400 input and output signals, of which approx. 50% had a direct bus connection and the other 50% were connected via a field multiplexer. The cost categories considered were hardware (racks, subracks, etc,), assembly (assembly material and wage costs), and planning for wiring, power supply and rack equipment. Compared to a conventional system of the same size, costs for the fieldbus system worked out at approx. **43%** less! Not included were the field devices and the control system. A different user survey arrived at a cost reduction of approx. 25% for the complete automation package. Of course, potential savings will depend essentially on local conditions. The first systems in operation, however, basically confirm that figure.

Maintenance costs

This cost group proved much more difficult to estimate. The outcome undoubtedly involves a wider range of variation. Nevertheless, cost reductions were also achieved here. Due to the numerous support possibilities in maintenance (e.g. central error reporting station, error identification and diagnostic functions, maintenance requests, automatic documentation, fewer replacement devices and fewer operator errors), potential savings proved out at approx. **24%**.

5 PROFIBUS-PA – planning

5.1 Mode of operation

In the PROFIBUS-PA, information and, if necessary, power supply are routed via a two-wire line. Use in both hazardous and non-hazardous areas is envisaged with the PA variant. For hazardous duty the PA bus including all connected devices must be designed in **Intrinsic Safety "i" type of protection**. For field devices requiring a separate supply, so-called "**fourwire devices**", the fieldbus connection at least must be designed in Intrinsic Safety. Accordingly, both device types, two- and four-wire devices, can readily be coupled together. Together with the Physikalisch Technische Bundesanstalt (PTB), who on behalf of KROHNE

But first to illustrate the mode of operation according to the FISCO model, see also Figure. 3.(and other companies) developed the so-called Fieldbus Intrinsically Safe COncept (FISCO in short), it was demonstrated that taking into account a number of boundary conditions the customary calculations for intrinsically safe circuits can be replaced by a more simplified approach.

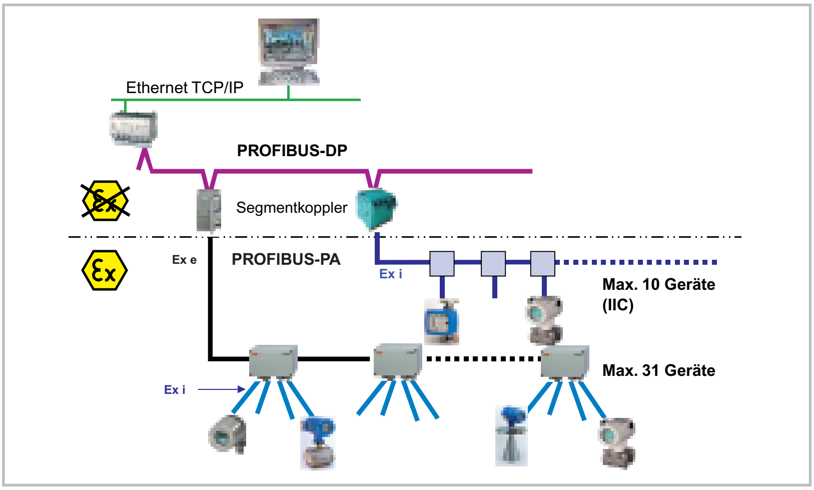
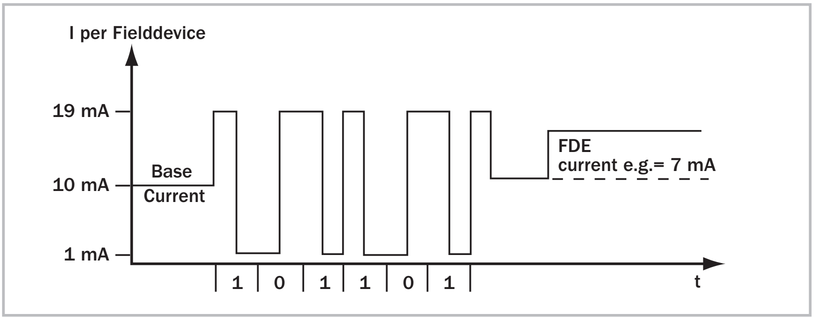


Figure 3

Only the so-called **segment coupler** is capable of supplying power to the line. All other users (field devices and bus termination) only take up power. Each field device should on average have an input of at least 10mA. This is the so-called **base current**. Ideally, it should not take up more than 10mA as otherwise it may prove necessary to reduce the number of connectable devices.

The bus must be terminated at both ends. At one end the termination is included in the segment coupler. At the other end a termination module is connected which requires suitable hazardous duty approval for harzadous area. The physical interface of the PROFIBUS-PA and the applied FISCO model are in conformity with IEC Standard IEC 61158-2.

Figure 4



The communication signal, a Manchester-coded BI-L phase signal (see Figure 4), is obtained by suitable modulation of the current within the limits of +/- 9mA, referred to the base current.

The so-called **Fault Disconnection Electronics (FDE)** has been defined to prevent one field device, also in the case of a fault, from immobilizing the entire bus. This limits the maximum input of continuous current. The fault current, which is the continuous current over and above the base current (see Figure 4) that the device can take up in the case of a fault, has however not been defined to date. There are indications that the fault current is to be limited to max. 9 mA. Hence, the planning engineer is required to consider all potential devices in a PA segment in terms of fault currents and include the maximum possible fault current in his calculations. See also "Number of devices per fieldbus segment".
The classic practice when planning an intrinsically safe circuit is to infer from the details of the feeder unit the maximum concentrated capacitances and inductances that are allowed for connection of a field device and the connecting cable. As already mentioned, a considerably simplified approach was found by the PTB studies in conjunction with the FISCO model. A special feature noticeable with the segment coupler (incl. bus feed unit) is that the normally given limit values for the maximum allowable external inductance Lo and capacitance Co are not listed for the supply circuit. The investigations have shown that when the line parameters given in Table 2 are conformed to, the lines themselves have no negative consequences on explosion probability and so the customary calculation methods can be dispensed with. A **system certificate** for a complete PA segment is also not required, provided all components of a segment have FISCO certification. The following Table lists the limits of the parameter ranges for application of the FISCO model for EEx ib IIC/IIIB and EEx ia/IIC, which result from the PTB studies and acceptable extrapolations in terms of safety requirements.

Table 2

EEx ib IIC/IIB		EEx ia/IIC	
Feed unit:	Approx. square-wave output characteristic Uo = 14...24V (safety peak value)	Feed unit:	Trapezoidal output characteristic Uo = 14...24V (safety peak value)
Line:	R' = 15...150 Ohm L' = 0,4...1 mH/km C' = 80...200 nF/km (incl. shield)	Line:	R' = 15...150 Ohm L' = 0,4...1 mH/km C' = 80...200 nF/km (incl. shield)
No restrictive safety requirements up to 5000m cable length. Limited to 1900m by IEC 61158-2.		No restrictive safety requirements up to 1000m cable length.	

5.2 Interconnection rules for hazardous-duty devices

Before detailed planning of a PROFIBUS segment can proceed, a few definitions need to be made for systems in hazardous areas. The definition of the Explosion Group is especially important in terms of the maximum number of connectable devices per segment. Explosion Group IIB or IIC is to be defined here. The required category "ia" or "ib" also needs to be defined, which likewise has crucial effects on the planning of the fieldbus segment.

The rules given in the following apply to PTB's FISCO model. Differing rules may apply in other countries.

Interconnection of "FISCO devices" only.

If the degree of freedom opened up by the PTB with the FISCO model is to be utilized when planning the PROFIBUS-PA in hazardous areas, then all components connected to an "Ex" PA segment must have been certified in conformity with the FISCO model.

Interconnection of "ia" and "ib" devices.

When defining which devices are allowed to be interconnected, a check should first be made on whether devices are available whose sensor can come into contact with **Zone 0** and features **restricted galvanic isolation** (as a rule 500V, one additional lightning protection system required). Such devices may e.g. be conductive or capacitive probes. These devices are designed in category "ia" and need a segment coupler that must also have type of protection "ia" approval. Moreover, these devices compel all other users to be "ia"-certified as well. The use of such devices should be given careful consideration, since they unnecessarily increase the demands on the other bus users and rule out the use of "ib"-certified devices.
In all other cases, devices (incl. segment couplers) with "ia" and "ib" certification may be interconnected as required.
Tip: Where a device has both "ia" and "ib" approval, it can be used in both the given cases.

Gas Group IIB or IIC

IIB and IIC bus components can only be interconnected if consideration is given to the safety data of the devices and the actually existing explosive atmosphere.
As a rule, this means that when only a IIB gas can occur and the segment coupler is IIB-certified, all connected bus devices also need to be IIB-certified, since a IIC-device typically has not been certified with the higher safety engineering data (U, I, P).
Tip: If a device has both "IIB" and "IIC" certification, there is no problem in using it for these applications.

5.3 The segment coupler

The name **segment coupler** derives from its function to link or couple the two different segments PA and DP. Further functions of the segment coupler are, typically supplying the PA segment and, if necessary, the "Ex' separation. In addition, the bus termination is also located in the segment coupler. As already mentioned, a further bus termination is needed for the other end of the PA segment in order to minimize reflections of the communication signal.
The **bus termination** consists of the series connection of a resistance (R = 100 Ohm) and a capacitance (C = 1 uF). See also "Components from other manufacturers".
Basically, two different variants of the segment coupler are available: the **transparent coupler** with a fixed baud rate on the DP side, and the **"intelligent" coupler** with a variable baud rate.

The transparent coupler

Currently available are e.g. a transparent coupler from Pepperl+Fuchs with 93.75 kbitsls on the DP side, and one from Siemens with 45.45 kbit/s on the DP side. Neither coupler is identifiable from the DP master, and therefore requires no adjustment. Put simply, they convert the asynchronous 11-bit/byte DP protocol into the 8-bit/byte synchronous PA protocol. A point worth mentioning is that the two above baud rates are supported by all devices connected to the DP segment. Because the baud rate is relatively low, the cycle time of the segment in particular needs to be taken into account (see "The cycle time"). Since the coupler is transparent, every device in the DP segment (and the PA segments) must be given an unambiguous address. An address is not assigned to the coupler.

The "intelligent" coupler

The "intelligent” coupler from Siemens or Pepperl+Fuchs is capable of supporting different DP baud rates on the DP side. To the PA-Link from Siemens up to 5 couplers can be connected. The number of field devices that can be connected per PA-Link is, however, limited to 31 which can be divided among several couplers. This PA-Link is given only one address on the DP line and is treated as a slave. In the PA line, however, it is the master. All PA devices of a PA-Link, also on several PA lines, are to be considered as a logical bus. Accordingly, the devices must be given a different address.

The intelligent version of the Pepperl+Fuchs segment coupler is a transparent device. Up to 125 devices can be connected to this device on as much as 20 PA segments. All DP baudrates are being supported.

The described segment couplers, which are suitable for "Ex” applications, are all made and certified according to the FISCO model, although present-day couplers may still only be installed outside the hazardous location. Pepperl+Fuchs actually offers segment couplers for Zone 2 as option. For use of the PA segment entirely in the non-"Ex" area, variants are available which support the max. number of 31 devices in one PA segment. Details of the operating current and operating voltage are important for the planning of a segment. By selecting a segment coupler with a specific operating current and a specific operating voltage, the planning engineer can maximize or at least influence the number of devices to be connected, and also the cable length.

Technical data of available segment couplers:

Table 3

Manufacturer	Siemens	Siemens	Siemens	Pepperl+Fuchs	Pepperl+Fuchs	Pepperl+Fuchs
Type No.	6ES7157-0AD00-0XA0	6ES7157-0AC00-0XA0	6ES7157-0AA00-0XA0 (PA-Link)	KFD2-BR-Ex1.PA.	KFD2-BR-1.PA	KLD2-GT-DP(R).xPA KLD2-PL2-Ex1.PAPA
"Ex"	EEx ia IIC	-	EEx ia IIC	EEx ia IIC	-	-
Operating voltage	12,5V	19V	(3)	12.6V	24V	12.6-26V
Max. operating current	90 mA	400mA	(3)	100 mA	400mA	110mA-400mA
Max.power	1.8W		(3)	1.93W		
Max. line resistance	35 Ω	25 Ω	(3)	32.7 Ω	34,2 Ω	
Max. cable length	1000 m (1)	1900 m (2)	(3)	1000 m (1)	1900 m (2)	1000m/1900m
DP baud rate	45.45 kbits/s	45.45 kbits/s	up to 12 Mbits/s	93.75 kbits/s	93.75 kbits/ls	up to 12 Mbits/s

(1) In the FISCO model, the max. cable length has been limited for EEx ia IIC to 1000m.
(2) Max. value specified in IEC1158-2 =1900m; in practice, this can only be achieved with a very low-resistance cable.
(3) Both coupler from Siemens can be connected and provide relevant data.

5.4 Fieldbus cable types

As shown in the section on "Mode of operation", the technical data of the fieldbus cable from the "Ex" viewpoint are permitted to vary within a wide range. **IEC61158-2** recommends four cable types, of which types A+B are shielded.

Protection of the automation network against electromagnetic interference can only be ensured when shielded cables are used throughout. Types C+D should therefore not be used and so are not included in the list. The data are as follows:

Table 4

	Type A	Type B
Cable structure	shielded, twisted-pair	one or several twisted cables with common shielding
Cross-sectional area	0.8 mm^2, AWG 18	0.32^2 mm, AWG 22
Loop resistance (DC)	44 Ohm/km	112 Ohm/km
Impedance at 31.25 kHz	100 Ohm +/- 20%	100 Ohm +/- 30%
Damping at 39 kHz	3 dBlkm	5 dBlkm
Capacitive unbalance	2 nF/km	2 nF/km
Percentage coverage of the shield	90%	-
Max. cable length	1900 m	1200 m

Available fieldbus cables

We recommend using two-core twisted and shielded cables, e.g. the following types:

Table 5

Manufacturer/ Marketed by	Cable type	Surge impedance	No. of cores	Core cross-section	Loop resistance	Effective capacitance	Damping	Shielding	Remarks
Siemens AG	SINEC 6XV1 830-5AH10	100Ω ± 20Ω	1 x 2	0.75 mm^2 Cu stranded wire	44 Ω/km	<90 nF/km	<3 dB/km 39 KHz	copper braiding	Bus cable polyvinyl chloride sheath **blue**
Siemens AG	SINEC L2 6XV1 830-3BH10	100Ω ± 20Ω	1 x 2	0.75 mm2 Cu stranded wire	44 Ω/km	<90 nF/km	<3 dB/km 39 KHz	copper braiding	Bus cable polyvinyl chloride sheath **black**
Belden	3079A	150 Ω	1 x 2	AWG 22 (032 mm^2)	105 Ω/km	29,5 nF/km	<3 dB/km 39 KHz	foil	Bus cable polyvinyl chloride sheath

Max. cable lengths in practice

The max. cable length (incl. all spurs) is obtained from the operating voltage and the operating current of the segment coupler, which is maintained even in unfavourable conditions, plus the resistance per unit length of the cable. In this connection, it needs to be borne in mind that min. 9V must be input at the field device. The following Table gives the max. possible cable lengths:

Table 6

Manufacturer	Siemens	Siemens	Pepperl+Fuchs	Pepperl+Fuchs
Type No.	6ES7157-0AD00-0XA0 ("Ex")	6ES7157-0AC00-0XA0 (Non-"Ex")	KFD2-BR-Ex1.PA. ("Ex")	KFD2-BR-1.PA (Non-"Ex")
Max. cable length with Siemens cable	795 m	568m	743 m	777 m
Max. cable length with Belden cable	333 m	238 m	311 m	326 m

The total cable length is made up of the length of the main cable and the lengths of all spurs; the maximum allowed length of one spur cable is given in the following Table. Figure 7 shows, for example, the wiring system using a star box. The max. possible spur length is made up of the length of the main spur (from the T connector to the star box) plus the line length from the star box to a field device.

Table 7

Number of spur cables	Length of a spur cable - intrinsically safe	Length of a spur cable - not intrinsically safe
25-32	-	-
19-24	30 m	30 m
15-18	30 m *)	60 m
13-14	30 m *)	90 m
1-12	30 m *)	120 m

*) provisional values according to the FISCO model

The cores of all fieldbus cables must be clearly selectable (e.g. colour coded or with ring marking). Cables with intrinsically safe circuits need to be identified in conformity with DIN VDE 0165/2.91, Section 6.1.3.2.3 (e.g. by light blue sheathing).
When multi-paired cables and lines are used in hazardous locations, the special installation conditions to DIN VDE 0165/2.91, (Section 6.1.3.2) should be observed.

5.5 Number of devices per fieldbus segment

The maximum number of connectable devices for non-"Ex" applications is defined by the standard as being 32 (including the master).
The choice of segment coupler defines the operating current, the operating voltage and the max. possible power. From the operating current it can then be established whether all devices envisaged for this fieldbus segment can actually be connected.

Calculation of the number of devices per fieldbus segment

- All base currents of the potential devices must be added up
- If one device should be allowed to fail without disturbing operation of the segment, the additional max. fault current of all connected devices needs to be taken into account (see Sect. "Mode of operation"). This is the continuous current plus the base current that is the maximum amount that can be taken up. The max. fault current of all devices should be checked and the highest fault current taken into account. This current must also be added.
- If necessary, a reserve amount should be included to allow for devices connected either temporarily or subsequently.

The sum total of currents must be smaller than the operating current of the segment coupler
Example: The operating current is 100 mA. The maximum fault current is e.g. 7mA. For the sake of simplicity, it is assumed that all devices have a base current input of 10mA. Therefore, max. **9 devices** can be connected up ((100-7)/10).

Accordingly, a maximum of **24 devices** can be connected to a Gas Group IIB certified segment coupler with an operating current of e.g. 250mA.

Note: If too many devices are inadvertently connected in the hazardous location (current input higher than operating current), the **safety engineering** aspects will not be affected, but **operation** of the segment is no longer guaranteed.

5.6 The cycle time

Dynamic information is exchanged between field device and the Class 1 master during one cycle, i.e. 5 bytes useful data per cycle for e.g. a simple measuring device (approx. 15 ms). This may be e.g, the pressure and the status of a pressure gauge. In more complex devices, such as a mass flow meter which is capable of supplying several values, the cycle time per additional cyclic value increases approx. 1.3 ms.
The cycle time of the PA segment is directly dependent on the number of connected devices and the number of values being transmitted. Since the majority of devices transmit only one dynamic value, 5 bytes useful data per device can be presumed for an approximate calculation of the cycle time. If it is further assumed that the baud rate on the DP side is selected such that it does not constitute any appreciable bottleneck for the PA segment data, the delay on the DP side can be neglected (at 12 Mbauds, this is max. 1 ms). Fig. 5 illustrates the interrelation ship.

For the acyclic services, a time window per cycle is provided for transmission of e.g. parameterization data. This is specified during configuration of the network. A realistic value of 20 ms has been assumed in the following calculation.

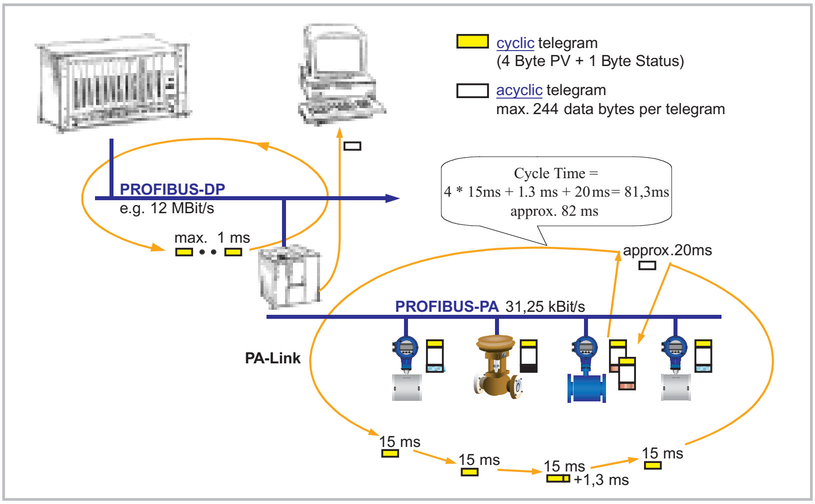
Cycle time = number of devices x 15ms + 20ms for acyclic services of the Class 2 master + 1.3ms for every additional cyclic value.

Example: Given 9 connected devices, the cycle time is approx. 155 ms.

5.7 Remote I/O and redundancy

When speaking of redundancy, it must be clearly defined what level of redundancy is actually meant. This may be anything up to full redundancy, where everything is of redundant design, starting with the PLC and ending with the field devices. As far as the field devices are concerned, there is no telling whether these will ever feature a redundant bus connection. The reliability of a conventional system with an I/O board of a PNK, to which the e.g. 8 devices are connected, and of a PA segment (segment coupler in the control room) also with approx. 8 devices, is comparable. If redundant design was not needed earlier it will not be needed now either.

Figure 5



The situation is different when, for example in conjunction with a remote I/O, the segment couplers are also moved into the fleld, meaning that only one DP bus is to be used for a considerably larger plant part. In addition, the earlier system bus, which interconnected the remote I/Os in the control room, is now practically routed into the field. In this case it would probably make sense to consider a redundant design for the DP bus. To be able to use this variant in practice, it will be necessary to utilize the following possibilities, some of which are not yet even available today:

- Remote I/O for field applications (also in Zone 1)
- Segment coupler in the remote I/O, suitable for Zone 1
- Redundant DP module in the remote I/O
- Full support of the intelligent field devices by the remote
- I/O (parameter setting, diagnostics, ...)
- PLC with redundancy functionality!

Should the requirements be realized, the combination of a remote I/O with the PROFIBUS PA and, if necessary, HART modules would seem to be a useful variant. Using this variant, the conventional signals, HART-capable devices and PROFIBUS-PA devices can simply be interconnected with at the same time minimized expenditure in the control room and hence also the necessary cable in the field. Figure 6 shows an impression of this as yet non-existing variant.

5.8 Connection technique, bus termination, repeater

Field devices can be connected to the PROFIBUS-PA in a number of different ways, so allowing also simple expansion of existing system parts. Connection to the bus line is made with conventional T connectors or junction boxes.

T connectors are also available which can be inserted direct into the screwed conduit entry (PG) of a field device. In that case, the field device is equipped with a ready-wired mating connector integrated in the PG. The fieldbus can then be joined to the field device using a simple slip-on connector. For PROFIBUS-PA segments in hazardous locations, the bus termination is not allowed to be made inside the T connector but must be made outside, e.g. by mounting a bus termination on to a connector in the T connector. T connectors (or junction boxes) with integrated bus termination are certified only for Non- "Ex" applications. T connectors, including those for hazardous-duty applications, are e.g. marketed by Weidmüller Turck, Hirschmann or Siemens (see "Components from other manufacturers").

Bus termination
In PROFIBUS-PA networks, the bus line must from the communications viewpoint be *terminated* at both ends in order largely to avoid reflections on the cable and thus to optimize transmission quality. The bus termination is normally already integrated in the segment coupler, and thus only needs to be fitted to the other end, as shown in Figure 7. Available are "Ex"-certified bus terminations for separate installation or, as described, those which can be fitted to a T connector, for example. In the case of topologies that are typical for the chemical industry, the bus cable is routed from the control room in the plant to a terminal distributor. From there, the individual field devices are connected in radial arrangement to this distributor. In this case, the bus termination should be made at the terminal distributor.

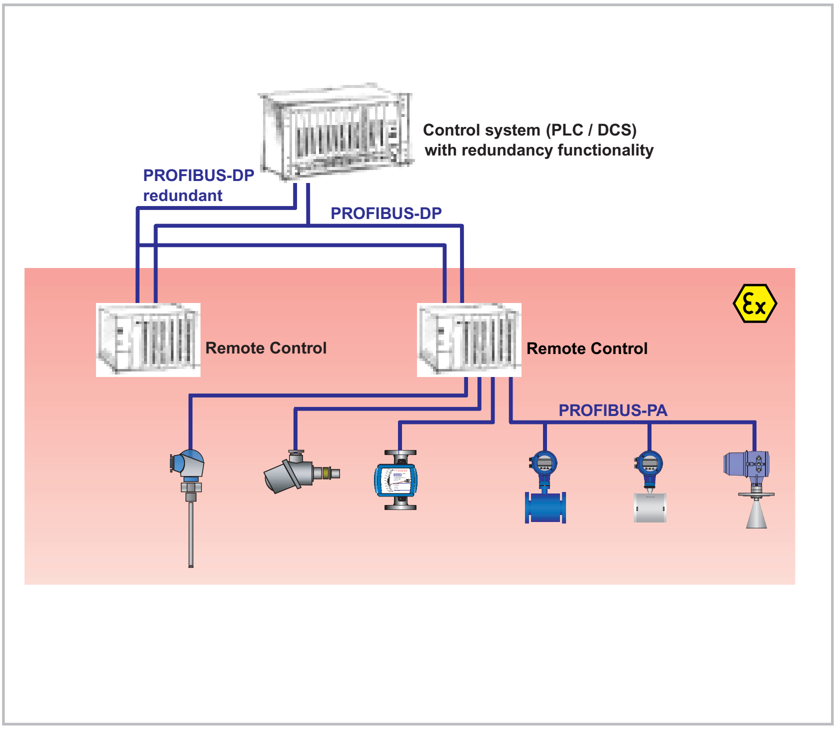
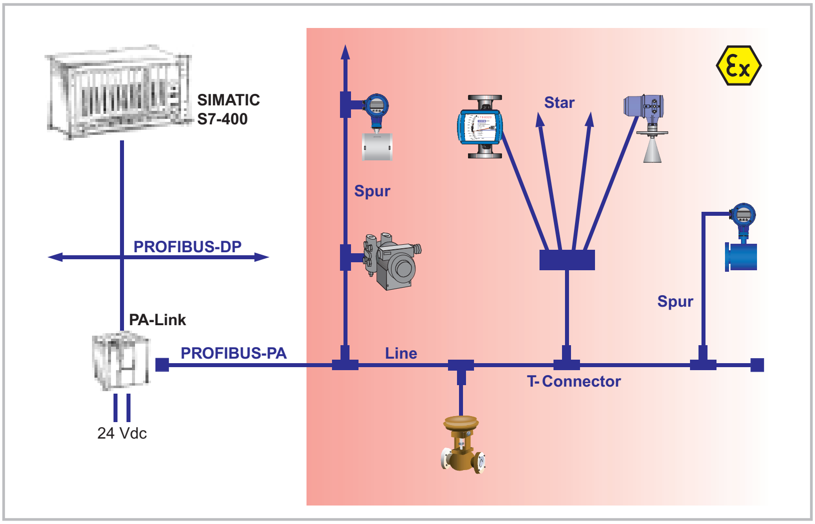


Figure 6

Repeater

A so-called repeater can in principle be used to increase the number of devices or the max. cable length of a segment. At the present time, no repeaters are known that are suitable for hazardous duty and certified to the FISCO model.

Figure 7 shows the different connection topologies.



5.9 Shielding and grounding

Shielded lines are recommended for the bus cables. For EMC reasons, shielding should be continuous ("Faraday cage") and grounded as often as possible. This is inconsistent, however, with the conventional practice of using for the most part only one grounding point for hazardous-duty systems.

Variant I (Figure 8) shows a grounding concept considered ideal from the EMC viewpoint. However, this calls for adequate equipotential bonding covering the entire expanse of the fieldbus in both the hazardous and non-hazardous location.

Equalizing currents can arise when there is no adequate equipotential bonding between the hazardous and non-hazardous location (adequate equipotential bonding must always be provided in the hazardous location).

6 PROFIBUS-PA– project planning

Projecting of a PROFIBUS network naturally depends quite substantially on the masters used. Generally speaking, the masters need to be informed of the structure of the subordinate network in its entirety. This includes the configuration of the subnetworks with their field devices and components. Several tools are available for e.g. the Siemens master systems, such as

COM PROFIBUS
as testing, diagnostics and parametering software for the PROFIBUS-DP, for configuration of ET200 systems or for projection of SIMATIC S5 systems.

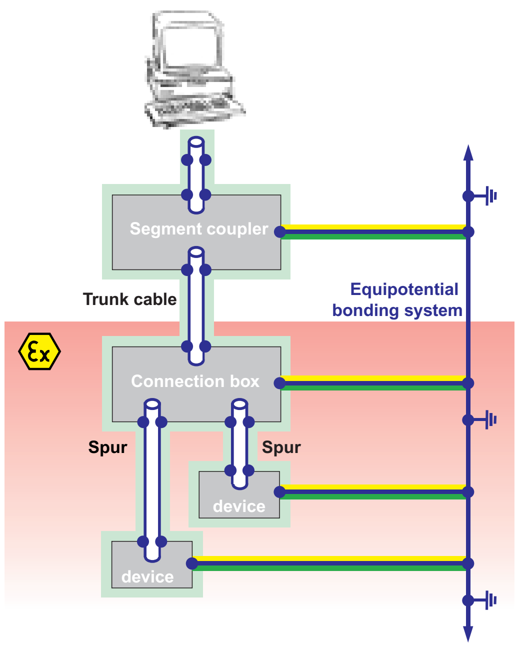
Field device modules
to transmit process data between the input/output level and the master level.

HW configuration
to generate the hardware structures of the PROFIBUS network (in STEP 7), see Figure 9

SIMATIC PDM
for vendor-independent control of field devices on the basis of the DD.

What is a GSD?
To project a PROFIBUS-DP and thus also a PA network, the GSD (device master data) is required for every device to be connected. Apart from general details such as software and hardware revisions, the GSD file contains data on bus timing of the device and and status information in plain text. The GSD is included with the field devices and can also be obtained from the Internet page of the PROFIBUS (http://www.profibus.com).

Figure 8



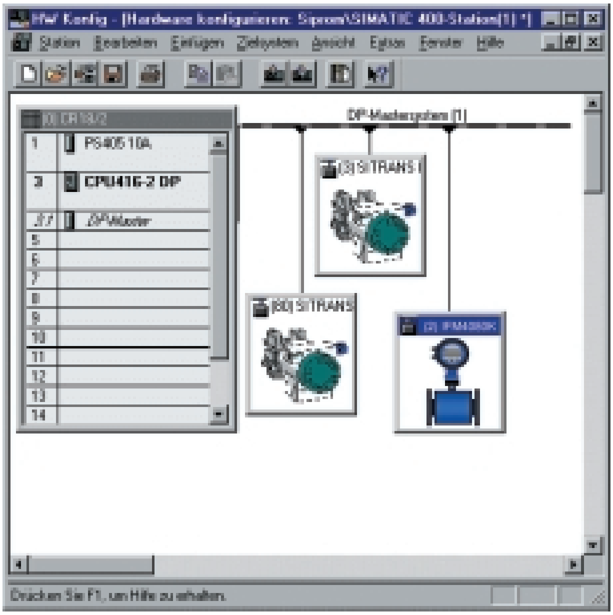


Figure 9

Add-on devices for the PROFIBUS
Once the complete network has been projected and installed, the PROFIBUS addresses still need to be assigned to the individual field devices. The addresses have to be set before the devices are connected to the PROFIBUS. Known extensions should be included directly in the project stage so that further devices can be easily added later. Automatic address allocation is basically also possible, when only one new device with the Default Address 126 is connected and a master is used that can allocate a free address and communicate this fact to the field device.

Plug and Play
When an unequipped slot is already configured with a specific address in the project planning phase, and the associated field device is connected later, it is recognized automatically and incorporated in the network. If this has not been done, and a new device is connected at a later date to an operating bus, it may happen that the programmable controller (PLC) will need to be reconfigured!

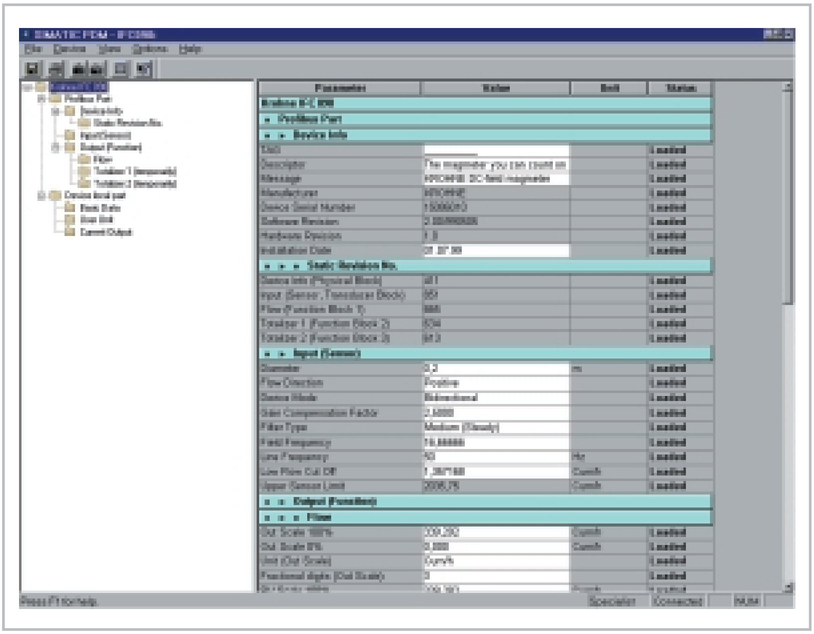


Figure 10

7 PROFIBUS-PA–Operator control of field devices

Depending on the variant, most field devices can be equipped with a display and operator interface at the device. However, an appropriate operator program is needed if operator control is to be implemented via the PROFIBUS. Ideally from the user viewpoint would be a vendor-independent program which could be operated both direct at the PROFIBUS-DP and also from a central location (e.g. the engineering station). From the present vantage point the SIMATIC PDM program from Siemens is the only one that meets these requirements. SIMATIC PDM is based on the Electronic Device Description (EDD) and can thus be considered to be vendor-independent. Figure. 10 shows the screen layout of SIMATIC PDM. Every manufacturer whose devices are to be operated completely by the PDM is required to provide a DD for his devices. KROHNE devices will be completely operable by means of SIMATIC PDM.

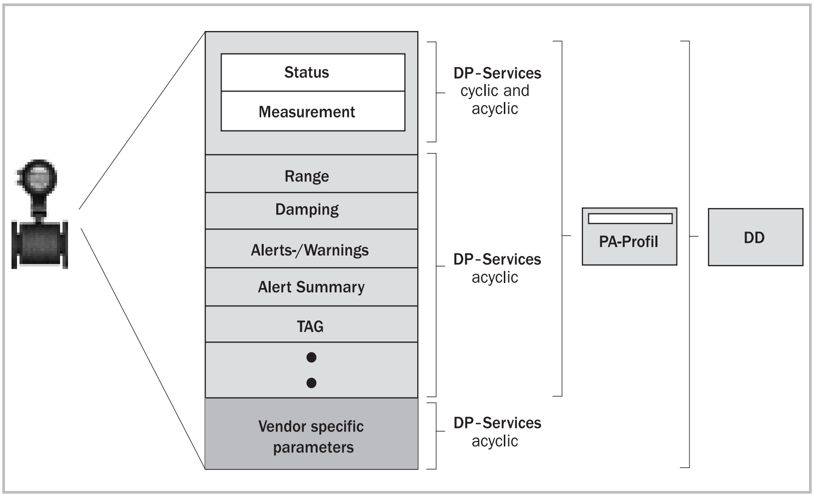
What does DD stand for?

DD stands for Device Description and is a description of the menu structure and operability of a device. This DD has been used for many years by HART. It is generated with a type of C programming language (the DDL).

8 PROFIBUS-PA–device profile B

To enable device performance to be as consistent as possible, the decision was made to define the device profiles used for PROFIBUS. For "PA" the so-called Profile B V3.0 is the most actual version.

Figure 11



The profile shown in Figure 11 has the following logical structure:

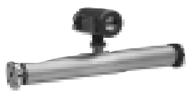
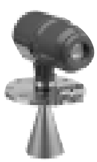
1. Dynamic process values: In respect of measuring devices, these are the measured value and the status. Both are cyclically or acyclically read by the automation device. This group belongs to PROFILE B.
2. Standard parameters: Depending on the device type (e.g. level, pressure, etc. in sensor systems), different parameters and functions have been standardized which are to be found here. These data can only be read and written acyclically. This group comprises mandatory data that have to be implemented, and others that are optional. If used, however, they must be implemented in keeping with Profile B. The standard parameters also belong to Profile B.
3. Manufacturer-specific parameters: All parameters not defined in the Profile are to be found here. As the Figure shows, these parameters can only be fully operator-controlled using the Device Description (DD). The operating tool here, as mentioned earlier, is the SIMATIC PDM.

Interchangeability means that same-type devices from different manufacturers can be interchanged and the cyclic values (e.g. the measured value supplied by a pressure gauge) are identical. For this purpose the profile data set must be loaded into the new device and if necessary device-specific calibrations (e.g. zero adjustment) or settings carried out (e.g. antenna extension fitted to a radar device). Profile B is, therefore, used for cyclic transmission of the automation functions measured values, control outputs and the status of the devices, and for defining a basic set of parameters for the operating functions. However, the Device Description with an appropriate operating program is needed to be able to operate all device functions.

9 PROFIBUS-PA – technical data of KROHNE devices

The following KROHNE devices with PROFIBUS-PA interface are available or in preparation:

Table 9

	Electromagnetic flowmeters ALTOFLUX, PROFIFLUX, ECOFLUX, AQUAFLUX, VARIFLUX
	Ultrasonic flowmeters ALTOSONIC UFM 500
	Mass flowmeters CORIMASS P, E and G+
	Variable-area flowmeters H250 ESK
	Level Radar BM70 A
	Level and interface detection Radar BM100

Nearly all the KROHNE devices with PROFIBUS-PA interface feature a standardized modular interface. Accordingly, the following technical data are identical for most of the devices.

Hardware:

Physical	To IEC61158-2 and the FISCO model
Bus characteristics	"Ex" = 9...30 V: 0.3 A max.; 4.2 W max.
	Non-"Ex" = 9...32 V: 0.3 A max.: 4.2 W max.
Base current	10.5 mA
Fault current	6 mA; (in the event of a fault, at most the fault current plus base current can be drawn from the device; the signal current is not limited)
Starting current	Lower than base current
"Ex" certification	EEx ia IIC T6 or EEx ib IIC/IIB T6 in conformity with the FISCO model;
Power supply	Either with separate voltage supply or completely bus-fed, depending on device
Connection	Polarity independent

Software:

GSD	Device master file supplied on diskette together with device
DD	Device Description for SIMATIC PDM from Siemens
Device profile	Profile B
Address range	1-126, default 126
Operator control	Local display and operator interface at device; and/or via SIMATIC PDM from Siemens

10 Components from other manufacturers

The following Table shows a list of some components available on the market:

Table 10

Component	Manufacturer
Segment coupler	Siemens,6ES7157-0AD00-0XA0 (EEx ia IIC)
	Siemens, 6ES7157-0AC00-0XA0 (Non-Ex)
	Siemens, 6ES7157-0AA00-0XA0 (PA-Link)
	Pepperl+Fuchs, KFD2-BR-Ex1.PA (EEx ia IIC)
	Pepperl+Fuchs, KFD2-BR-1.PA (Non-Ex)
	Pepperl+Fuchs, KLD2-GT-DP(R).xPA+KLD2-PL2-Ex1.PA
T connector	Weidmüller, Ex, Order No.842606
	Weidmüller, Non-Ex, Order No.842600
	Bosch T-Box, Order No.064 142
	Sprecher + Schuh T-Box, Order No. PTS-0
	Turck, Siemens ...
Bus termination	Weidmüller, Ex, Order No.842607
	Pepperl+Fuchs, KCD0-FT -Ex1
	Ship Star Associates, 1158-2-24T
Cable	Siemens, Sinec 6XV1830-5AH10 (blue, Ex i)
	Siemens, Sinec L2 6XV1830-3BH10 (black)
	Belden, 3076F
	Kerpen Cel-PE/OSCR/PVC/FRLA FB-Ø2YS(ST)YFL

Source documentation

- PROFIBUS Standard EN50170 Part 1+2, DIN 19245 Part 1-4, Beuth Verlag GmbH, Berlin
- Vergleichende Studie von verfügbaren und in Entwicklung befindlichen Feldbussen für Sensor- und Aktorsysteme; VDI/VDE Technologiezentrum Informationstechnik GmbH
- Feldbus-Systeme, Volume 374, Kontakt&Studium, Expert Verlag
- Offene Kommunikation im Feldbereich mit PROFIBUS, VDI-Berichte 728, VDI-Verlag
- PROFIBUS brochure published by PNO, October 1995 issue
- Braucht die Chemie den Feldbus? (Does the chemical industry need the fieldbus?) Paper presented at the NAMUR general meeting on 04./05.11.1993 in Lahnstein by Dr. Jens Rathje, Bayer AG, Brunsbüttel
- P+F brochure on segment couplers, terminal resistance
- Siemens, brochures on segment couplers, cables
  Weidmüller, Data Sheet: Bus- T-Connector