PROFIBUS-PA

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SAMSON

Technical Information

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PROFIBUS-PA

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Introduction

PROFIBUS-PA is one of three PROFIBUS variants that are compatible with each other. PROFIBUS is a vendor-independent, open bus system which was standardized in the German DIN 19 245. In March 1996, this standard was embedded into the European standard EN 50170 Volume 2 without modifications.

three PROFIBUS variants

PROFIBUS-PA specifications used to be laid down in DIN E 19245 Part 4 (E = draft). Now, the CENELEC TC 65 CX standardization committee has integrated new specifications in EN 50170 as an appendix.

The following variants have been specified for different applications (Fig. 1):

▸ PROFIBUS-FMS (Fieldbus Message Specification),

▸ PROFIBUS-DP (Decentralized Periphery), and

▸ PROFIBUS-PA (Process Automation).

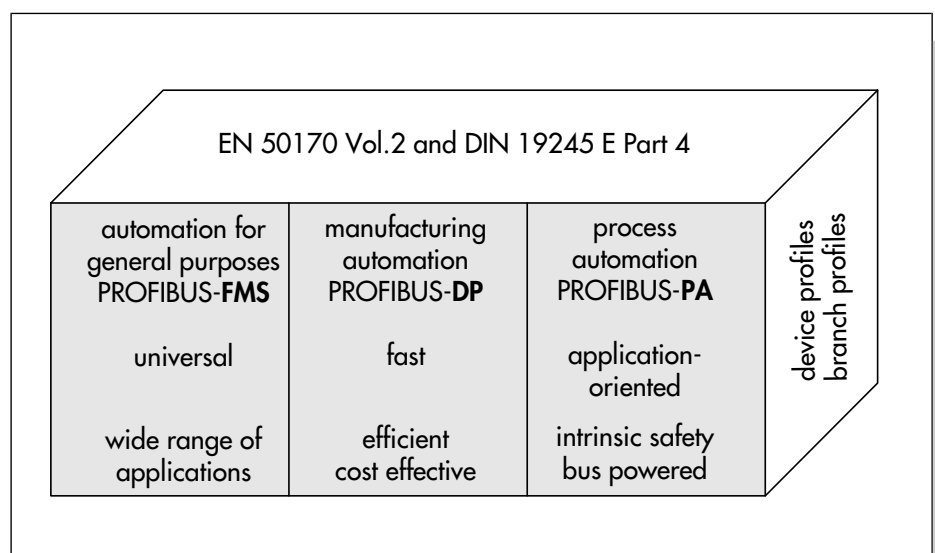| EN 50170 Vol.2 and DIN 19245 E Part 4			device profiles branch profiles
automation for general purposes PROFIBUS-**FMS**	manufacturing automation PROFIBUS-**DP**	process automation PROFIBUS-**PA**	
universal	fast	application-oriented	
wide range of applications	efficient cost effective	intrinsic safety bus powered	

Fig. 1:   PROFIBUS variants

PROFIBUS-FMS with a wide range of functions

The FMS variant provides the user with a wide selection of functions which, however, makes it more complex to implement compared to the other variants. The powerful FMS services (Fieldbus Message Specification) can be used to solve even extensive and complex communication tasks. This PROFIBUS variant supports communication between automation systems (e.g. programmable logic controllers and automation stations) as well as data exchange with field devices. FMS can therefore be used for a wide range of applications, operating at average transmission speeds.

PROFIBUS-DP for high speed

The DP variant (decentralized periphery) is the high-speed solution of PROFIBUS. It has been designed and optimized especially for communication between automation systems and decentralized field devices. Therefore, PROFIBUS-DP requires less than 2 ms for the transmission of 1 Kbyte of input and output data. In this way even extremely time-critical communication tasks can be solved.

cyclic data exchange for control systems

PROFIBUS-DP communicates via cyclic data traffic exclusively. Each field device exchanges its input and output data with the automation device, the class-1 master, within a given cycle time.

operation and monitoring with classs-2 master

In process engineering as well as in building and process automation, operation and monitoring tasks require a visualization device in addition to the automation device. This class-2 master is responsible for the various start-up, parameterization and monitoring functions of up-to-date field devices. They require that device data be read or written during operation independent of the control cycle.

acyclic services for start-up, parameterization and monitoring

Since the original DP specifications did not provide any special services for these tasks, appropriate function extensions were defined in 1997. These extensions can be implemented optionally and are compatible with the existing DP protocol and all earlier versions. The extended DP variant is referred to as PROFIBUS-DPV1. In addition to the cyclic DP communication services, it also offers acyclic services for alarm messages, diagnostics, parameterization and control of the field devices.

PROFIBUS-PA for process automation

The third PROFIBUS variant, PROFIBUS-PA, meets the special requirements of process automation. The PA communication is based on the services provided by DPV1, and is implemented as a partial system embedded in a higher-level DP communication system. Unlike the automated applications in manufacturing engineering which require short cycle times of few millisec-

onds, other factors are of importance in process automation, such as the following:

▸ intrinsically safe transmission techniques,

▸ field devices are powered over the bus cable,

▸ reliable data transmission, and

▸ interoperability (standardization of device functions).

The aspects 'intrinsic safety' and 'bus supply' were neglected at first when PROFIBUS was standardized. Only when the international standard IEC 1158-2 was published in October 1994, was a suitable transmission technique internationally specified for this area of application and implemented in the European standard EN 61158-2. The PROFIBUS-PA specifications published in March 1995 included this transmission technique for intrinsically safe installations and field devices powered over bus cables.

standardized bus access protocol

All three PROFIBUS variants operate on one standardized bus access method. They are also able to use the same transmission technique (RS 485) and operate simultaneously on the same bus line. The transmission media used include either twisted pair shielded cables – for FMS or DP, even fiber optics – or radio waves.

ISP specifications

The PROFIBUS-PA fieldbus is essentially based on the ISP 3.0 specifications which were worked out by the ISP consortium (Interoperable Systems Project). This group of companies with members from all over the world was formed with the intention to create an international and uniform fieldbus standard. This work was not completed since the participating companies re-oriented themselves for technical and environmental reasons. Due to a co-operation agreement with ISP, the PROFIBUS User Organization (PNO) was able to take over the development results of the ISP project, to finish the job they had begun and to integrate the resulting solution in the PROFIBUS product family (Fig. 2).

transition to a uniform fieldbus standard is to remain possible

In the future as well, the PNO and the Fieldbus Foundation (FF, see Lit./6/) aim at further cooperation agreements to ensure the creation of user interface solutions, i.e. function blocks, device profiles, device descriptions, that are internationally standardized as far as possible. The goal is to ensure the compatibility with an internationally standardized IEC fieldbus in the future. The transition from PROFIBUS to a possible IEC fieldbus standard is not to have any negative consequences for the user.

This way of proceeding has already shown positive results. Many important vendors (Endress + Hauser, Hartmann & Braun, Krohne, Pepperl + Fuchs, SAMSON, Siemens, etc.) sell PROFIBUS-PA products, and several installa-
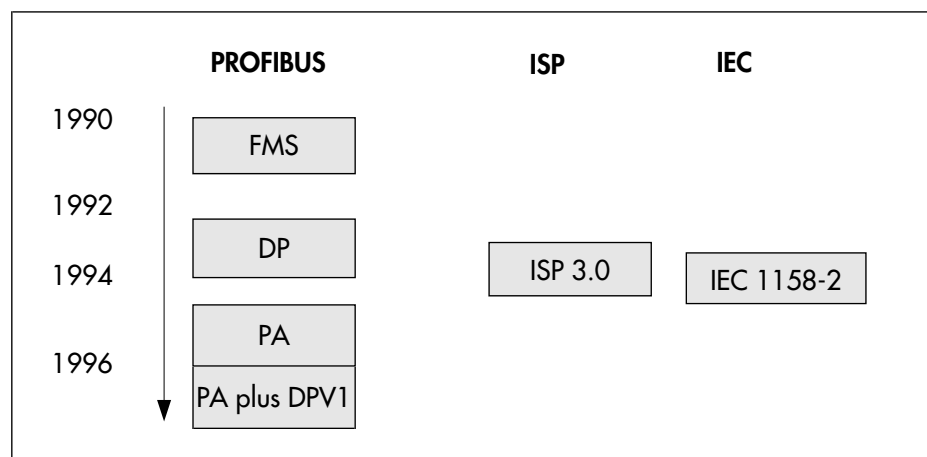

Fig. 2:   Historical development

tions (e.g. Bitburger brewery, Cerestar, DEA, Wacker Chemie) have already been started up successfully.

Device certification

A standardized, open bus standard functions only when the devices used do meet the requirements as per applicable standard. To guarantee that the devices comply with the respective standard, manufacturers can have their devices certified. Certification is performed by manufacturer-independent test labs that are officially authorized by the PROFIBUS User Organization (PNO). The test comprises hardware measurement tests, function tests and, finally, interoperability tests. Interoperability means that PROFIBUS compatible devices of different manufacturers can work together properly within a system.

test labs check for conformity and interoperability

Applications

In the area of process automation, PROFIBUS-PA connects process control stations and automated systems with field devices, thus replacing the analog 4 to 20 mA transmission technique. In addition to the simple start-up and self-diagnostic functions, the fast fieldbus communication provides users with the option of realizing real-time capable state control systems as well as monitoring status and error messages parallel to the process.

field communication replaces the analog signal

A study conducted by NAMUR (standardization committee of the instrumentation and control industry, AK 3.5) showed that compared to conventional systems, PROFIBUS-PA achieves cost savings of more than 40 % in planning, wiring, start-up and maintenance. At the same time, users gain a variety of functions as well as a considerable amount of safety. The essential difference compared to conventional wiring and the potential savings can be seen schematically in Figs. 3 and 4.

cost savings as well as more functions

PROFIBUS-PA was mainly designed for applications in explosion hazardous areas. Thanks to the possibility of supplying power over the bus, however, it can also be used for other production facilities. Bus technology combined with the two-wire technology simplifies the construction of plants in many areas without having to give up known device standards and connection techniques.

bus powered compact field devices offer a variety of applications
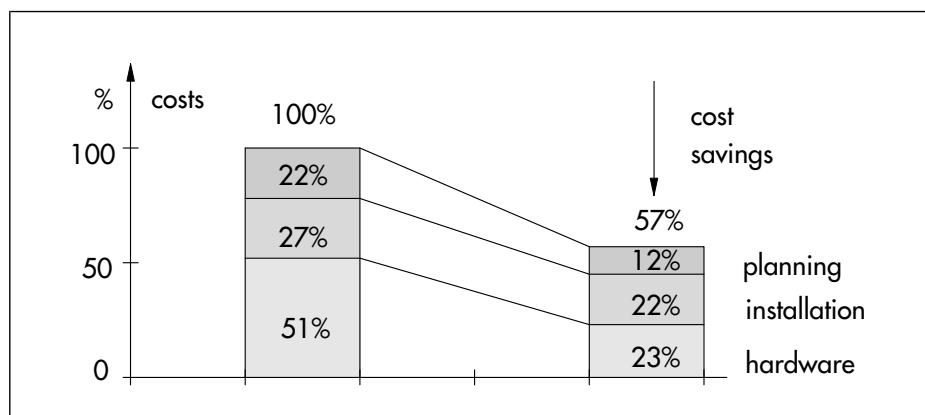

*Fig. 3:   Cost savings thanks to the use of fieldbus systems
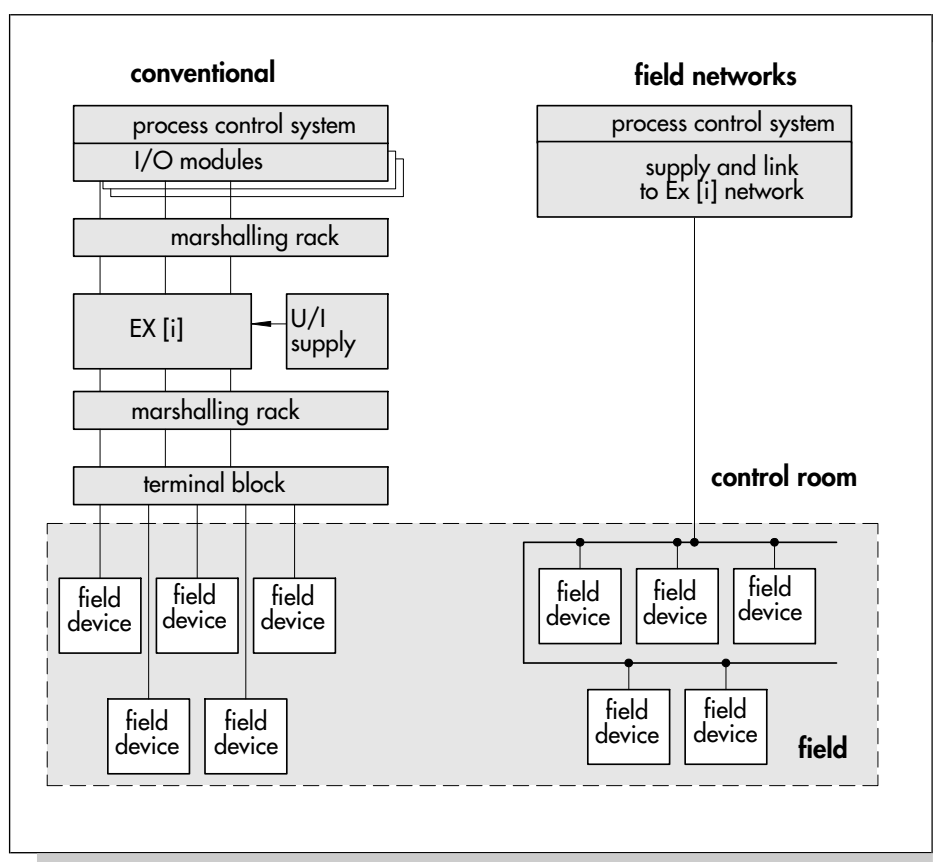   (Dr. Rathje, Bayer AG: exemplary calculation for PROFIBUS-PA)*

*Fig. 4:   Comparison of transmission techniques: conventional and
field network wiring in explosion hazardous areas*

Terminology: master and slave

The comparison in Fig. 4 shows the differences in the wiring of a bus system
schematically. Connected with this are extended device functions as well as
new terminology.

With PROFIBUS-PA – as with DP – three device types can be differentiated as
follows:

  ▸ The **class-1 master** (DPM1) is the central control unit of a system, e.g. a
PLC, which exchanges data with the field devices within a specified messa-
ge cycle. All measured values and set point values required to control the
system as well as the device status data are transmitted. When compared
with conventional techniques, the cyclic communication of the class-1
master assumes tasks of the analog 4 to 20 mA standardized signals and
additionally enables the bidirectional exchange of data.
Note: The DPV1 services also enable the class-1 master to have cyclic ac-

**class-1master, class-2
master and slaves**

**mainly cyclic data
exchange**

cess to field device data. However, masters available on the market as well as the current GSD specifications do not yet support this function (see also page 29: Device Database Files).

acyclic communication only

▶ Class-2 masters (DPM2) are used for operation and monitoring purposes as well as during start-up. The associated exchange of data takes place if required. Therefore, class-2 masters require acyclic communication services exclusively.

responds to requests issued by masters

▶ A **slave** is a peripheral or field device which communicates only when requested by a master.
  – Actuators receive input information from the master and actively influence the process.
  – Sensors collect state and process data and provide the master with this information.

OSI layer model

All PROFIBUS variants are based on the ISO/OSI reference model for communication networks (refer to ISO 7498 standard and Lit./3/). Due to the requirements in the field, only layers 1 and 2, and for the FMS version, layer 7 (Fig. 5) are implemented for reasons of efficiency.

OSI layers 1 and 2

With the three PROFIBUS variants, the two lower layers are largely identical. The differences in the upper layers are much bigger, i.e. the interface to the application program (see Page 27).
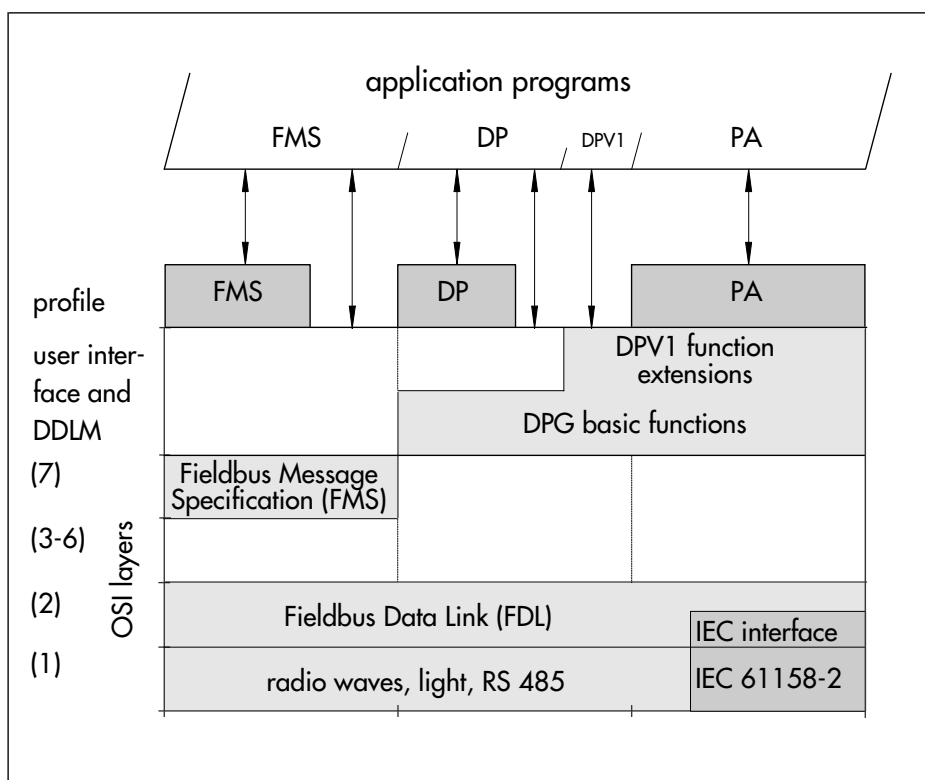
special application interfaces

Fig. 5:   Layer structure of PROFIBUS communication

PROFIBUS-PA		
transmission technique	RS 485	IEC 61158-2
transmission rate	9.6 to 1200 kbit/s	31.25 kbit/s
intrinsic safety	–	optional
bus supply	–	optional

Fig. 6:   Physical PROFIBUS-PA layer

Physical layer

There are different ways to realize the transmission technique for PROFIBUS-PA (see Fig. 6 and Lit./2/):

**RS 485 or
IEC 61158-2**

▸ either RS 485 standard, or

▸ in compliance with IEC 61158-2 which was specified especially for explosion-hazardous areas and power supply over the bus. There are four IEC 61158-2 variants, but only PROFIBUS-PA utilizes the 31.25 kbit/s voltage mode.

When using the RS 485 interface, PROFIBUS- FMS, -DP and -PA can be operated together on a common bus line. The intrinsically safe transmission in
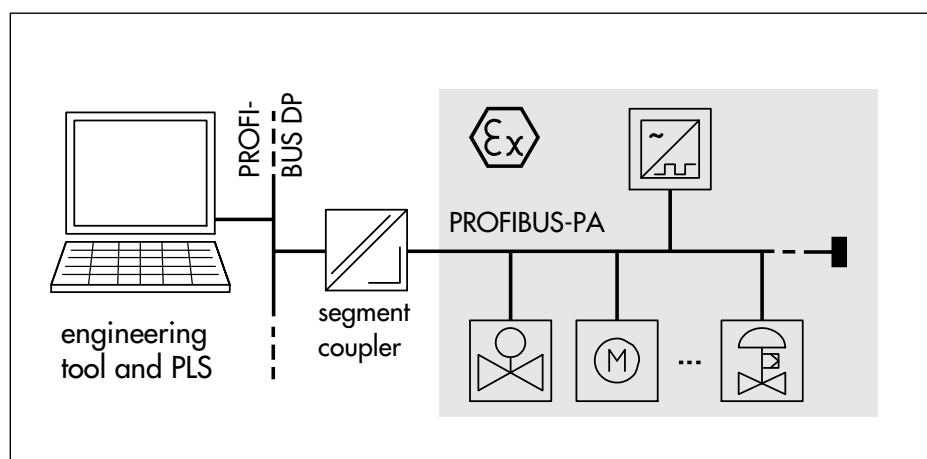

Fig. 7:   PROFIBUS-PA segment coupled to a DP bus system

explosion-hazardous areas, however, requires the installation to be in accordance with IEC 61158-2.

The masters of a PA system – the control and operating stations – always operate on a PROFIBUS-DP bus line in a safe area. For the resulting wiring of a PROFIBUS-PA network, refer to Fig. 7.

• Segment coupler

A so-called bus or segment coupler is installed between the PROFIBUS-DP and the PA segment. It adapts the different transmission techniques and powers the devices of the PA segment. It additionally powers the IS barrier.

Fig. 8 shows the block diagram of a segment coupler. It assumes the following tasks:

▸ electrical isolation between the safe and the intrinsically safe bus segment,

▸ powering of the PA bus segment,

▸ adaptation of transmission technique from RS 485 to IEC 61158-2,

▸ baud rate adaptation (e.g.: 93.75 kBaud ⇔ 31.25 kBaud) and
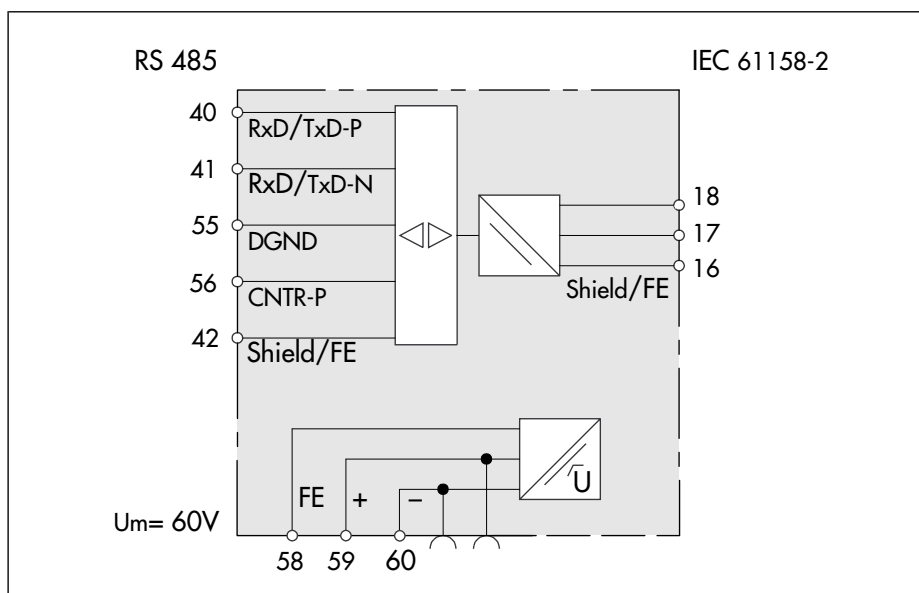
segment coupler tasks

Fig. 8:   Block diagram of a segment coupler (Pepperl+Fuchs)

▸ conversion between asynchronous UART telegrams and synchronous 8-bit/character telegrams (see telegram structure on page 24).

Regarding the assignment of addresses, segment couplers operate fully transparent, i.e. PA and DP devices must not be adjusted to identical device addresses. In addition, it should be considered that segment couplers of different manufacturers operate at different data transmission rates on the PROFIBUS-DP side (e.g. Pepperl+Fuchs: 93.75 kbit/s; Siemens: 45.45 kbit/s).

DP/PA coupling via fast network components

NOTE: Additionally, there are network components for DP/PA coupling which support DP data transmission rates of up to 1200 kbit/s, e.g. the PA-Link by Siemens.

This PA-Link is treated as a slave on the DP bus, receives its own device address and supplies up to five PA segments over its own couplers. On the PA side, the PA-Link works as a master and addresses a maximum of 30 field devices.

Note, however, that such devices must be parameterized using a suitable configuration tool before operation starts.

• Intrinsic safety and power supply over the bus

PROFIBUS-PA applies the specifications of the FISCO model for intrinsically safe operation (see Lit./4/). Each device has a current consumption of minimum 10 mA. Since the electrical power in the segments is limited in explosion hazardous areas due to intrinsic safety requirements, the number of connectable field devices is limited as well:

limited power in hazardous areas

	EEx ia IIC	EEx ia/ib IIB
max. power	1.8 W	4.2 W
max. current	110 mA	250 mA
max. device number[*]	10	22
[*] depends on the current consumption of the devices		

Fig. 9: *Maximum power and number of devices per PA segment in hazardous areas*

The total input current of all devices taken together must always be smaller than the supply current of the segment coupler. In addition, the current modulation of the Manchester coding (see page 18) as well the fault current of the "Fault Disconnection Electronic" (FDE) must be considered. The FDE in field devices ensures that the communication of the bus segment does not fail, even in case of a short circuit in a device.

Provided that maximum one FDE responds, the following condition must be fulfilled:

supply current ≥   sum of individual currents (per device ≥ 10 mA)
      + Manchester current signal (9 mA)
      + FDE fault current (0 to 9 mA)

Fig. 10: *Calculation of the total current of a PA segment*

• IEC 61158-2 transmission technique

With the IEC 61158-2 transmission technique, the PA segments are subjected to the following physical specifications:

IEC transmission specifications

▶ digital, bitsynchronous data transmission,

▶ data transmission rate: 31.25 kbit/s,

▶ Manchester coding without mean values, with a current/amplitude modulation of ± 9 mA (Fig. 11),

▶ remote DC voltage power supply: up to max. 32 volts
(with EEx ia IIC: 14 to 20 V),

▶ signal transmission and remote power supply over twisted two-wire line
(see Fig. 12 for specifications),

▶ 126 addressable devices,

▶ line or tree topology possible,

▶ up to 1900 m total line length (with EEx ia IIC: 1000 m),

▶ stub lines to the devices: up to 120 m; in hazardous areas maximum
30 m (see Fig. 13),

▶ up to 32 devices per line segment (in hazardous areas depending on
the supply current: see Fig. 9 and equation Fig. 10) and

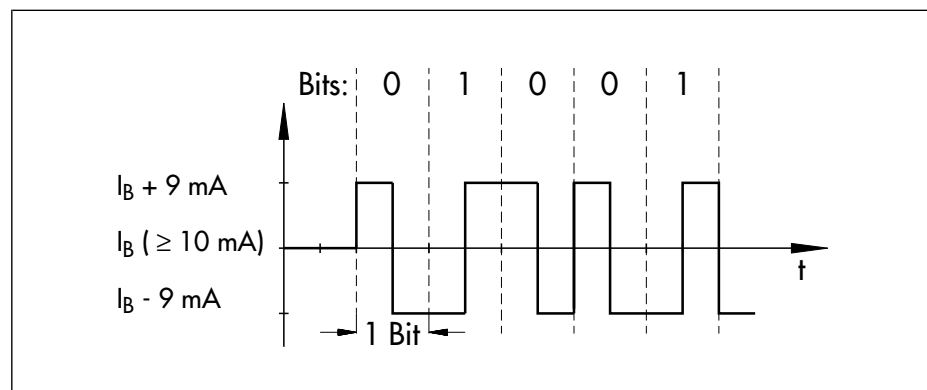▶ the network is expandable by max. 4 repeaters (line amplifiers).

Fig. 11: Manchester coding with ± 9 mA

	Type A	Type B	Type C	Type D
cable design	twisted wire pair, shielded	individual or several twisted wire pairs, totally shielded	several twisted wire pairs, not shielded	several not twisted lines, not shielded
wire diameter	0.8 mm² (AWG 18)	0.32 mm² (AWG 22)	0.13 mm² (AWG 26)	1.25 mm² (AWG 16)
cable length incl. stub lines	1900 m	1200 m	400 m	200 m

Fig. 12: Cables for IEC 61158-2 transmission

The properties of a fieldbus are also determined by the electrical specifications of the transmission cable. Although IEC 61158-2 does not specify a particular cable, the use of a reference cable is recommended (Type A as per Fig. 12). Only this type of cable enables data transmission over distances of up to 1900 meters.

For an optimum electromagnetic compatibility (EMC), the bus lines must be shielded. This shield as well as the metal cases of the field devices must be grounded. How to proceed is described in more detail in the technical guideline "PROFIBUS-PA User and Installation Guideline" (order no. 2.091).

shielded cables enhance EMC

number of stub line cables	max. length of stub line cables (hazard. areas)	max. length of stub line cables (safe area)
1-12	30 m	120 m
13-14	30 m	90 m
15-18	30 m	60 m
19-24	30 m	30 m

Fig. 13: Maximum values for the length of stub lines

• Device connection and bus termination

For intrinsically safe IEC bus lines, a uniform plug connector is not yet available, however, a work group is already in the process of solving this task.

bus termination for
IEC 61158-2...
The bus line must be equipped with a passive line termination at both ends. This termination consists of a capacitor and a resistor connected in series as shown in Fig. 14c:

$$C = 1 \ \mu F \text{ and } R = 100 \ \Omega.$$

... and RS 485
<u>NOTE</u>: With the RS-485 wiring, the bus line is equipped with a 220-Ω terminating resistor as well as a pull-up and a pull-down resistor (Fig. 14b). These determine the bus line potential and can be connected to the supply voltage by means of a 9-pin Sub-D plug (pin 5 and 6).
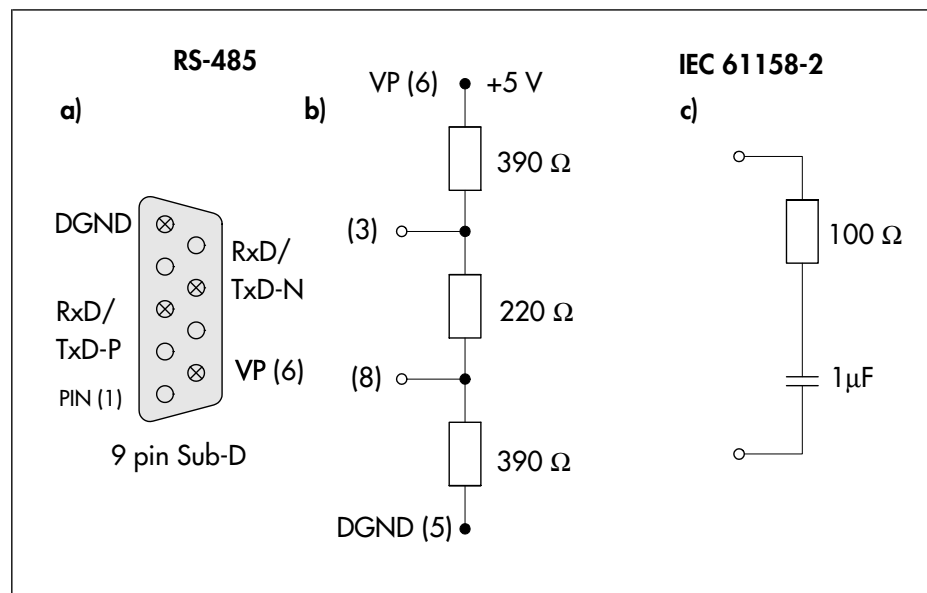

Fig. 14: Plug connector and bus termination

• Network topologies of a PROFIBUS system

The intrinsically safe PROFIBUS-PA is usually part of a hierarchically struc-
tured network topology (Fig. 15). It is connected to a DP bus system on which
also not intrinsically safe slaves and PA bus masters operate via segment
coupler.

**PROFIBUS-PA on
the DP segment**

With PROFIBUS-PA, the network topology can either be a tree structure, a
line structure, or a combination of both (Fig. 16). This combination allows the
bus length to be optimized and adapted to the given system structure.

**line and
tree structure**

The fieldbus cable can be routed through the individual field devices. The de-
vices can be connected/disconnected better if they are connected to a short
stub line via branch terminal (length of stub lines: see Fig. 12).

**branch terminals with
stub lines**

At the tree nodes, all field devices connected to the fieldbus segment are con-
nected in parallel in so-called field distributors.
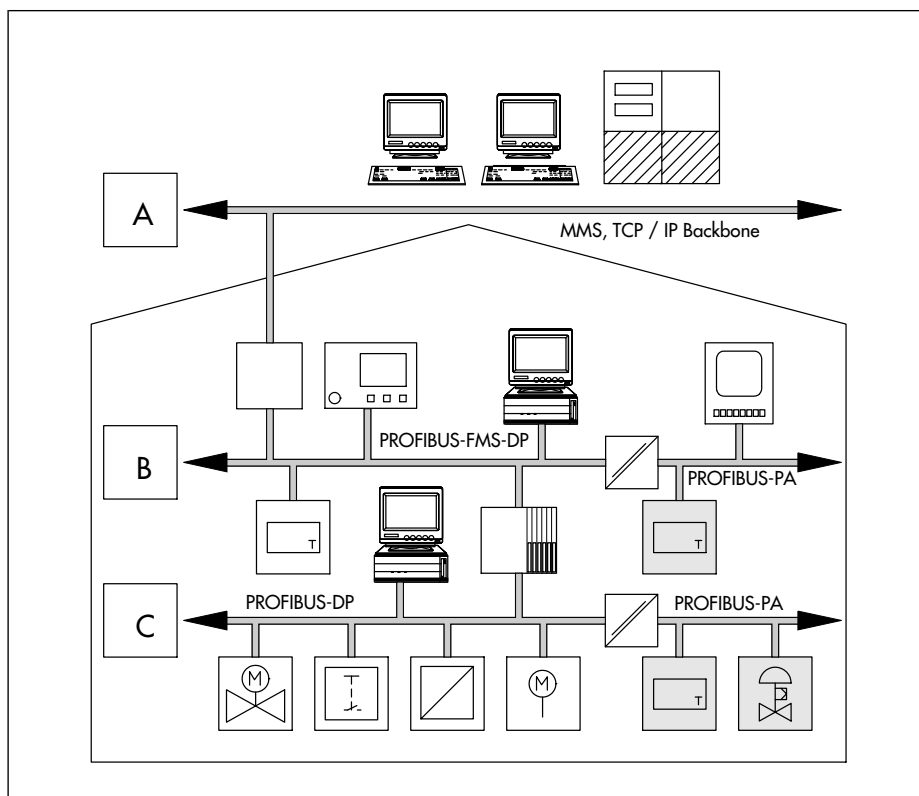
**A: Control level
B: Automation level
C: Field level**

Fig. 15: Hierarchical PROFIBUS system

PNK: **process-near component**

EXI: **barrier (intrinsically safe))**

SG: **power supply unit**

JB: **distributor**

R: **repeater**

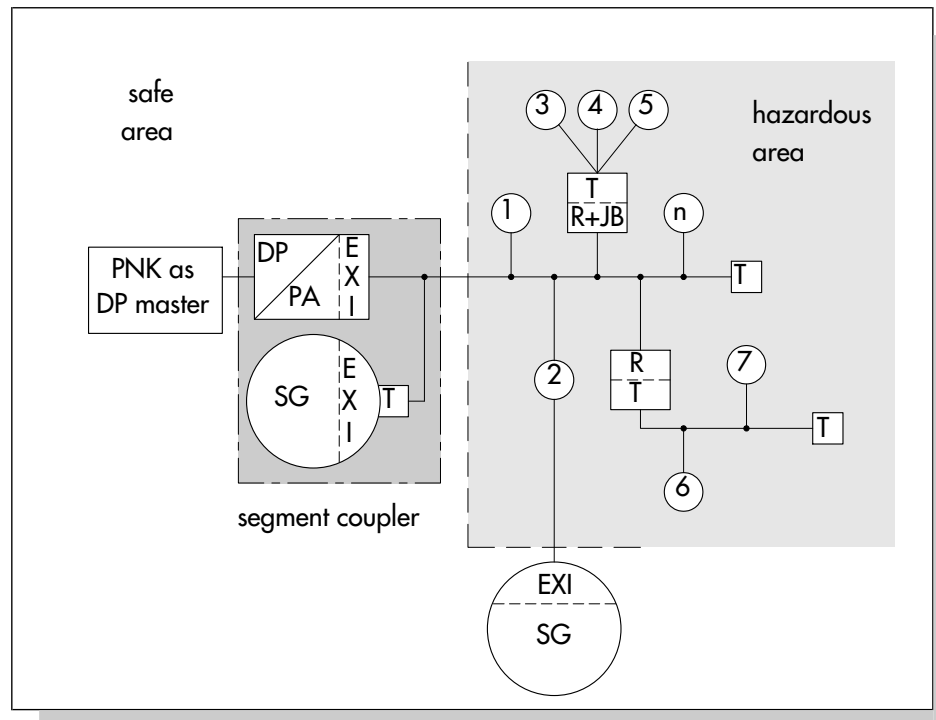T: **bus termination**

1... 7: field devices

Fig. 16: Components of a PROFIBUS-PA system

Depending on the stub line length, this distributor also contains a bus termination network.

Security layer

The efficiency of the communication system is determined considerably by the functions and services of layer 2, because they specify significant tasks, such as the bus access control, the structure of data telegrams, basic communication services, etc.

These layer-2 tasks are performed by the Fieldbus Data Link (FDL) and the Fieldbus Management (FMA):

▸ FDL manages the following tasks:
– bus access control (Medium Access Control – MAC),
– telegram structure,
– data security,
– availability of data transmission services
SDN (Send Data with No acknowledge) and
SRD (Send and Request Data with reply).

Fieldbus Data Link and Fieldbus Management

▸ FMA provides several management functions, for example:
– setting of operating parameters,
– report of events as well as the
– activation of service access points (see page 26: SAP).

• Bus access and addressing

In PROFIBUS communication, multimaster systems are possible. The hybrid bus access control system operates on the token passing method and uses the master/slave principle to communicate with the passive participants (see Lit./3/). Each master receives the token within a precisely defined time frame which allows him to have sole control over the communication network within that time frame.

hybrid bus access method

A 7-bit device address serves to identify the bus participants in the network. The addresses range from 0 to 127, and the following are reserved:

▸ Address 126:   default for automatic address assignment
via the master;

▸ Address 127:   sending broadcast telegrams.

If the address 0 is used for the class-1 master, the addresses 1 to 125 are available for addressing the field devices and the class-2 masters. The ad-

dresses are usually assigned via seven DIP switches on the device or via software.

• Telegram structure

The PROFIBUS-PA data telegrams of the IEC-61158-2 transmission are to a large extent identical with the FDL telegrams of the asynchronous RS-485 transmission.

PROFIBUS telegrams
Fieldbus Data Link (FDL) defines the following telegrams:

▸ telegrams without data field (6 control bytes),

▸ telegrams with one data field of fixed length
  (8 data and 6 control bytes),

▸ telegrams with a variable data field
  (0 to 244 data bytes and 9 to 11 control bytes),

▸ brief acknowledgement (1 byte) and

▸ token telegram for bus access control (3 bytes).

Hamming distance = 4
With all data transmissions, the parity and block checking of the telegrams is used to reach a Hamming distance of HD=4, so that up to three errors can be detected with certainty.

In Fig. 17, the top part illustrates the structure of a FDL telegram with a variable data field length. While the bytes of the FDL telegram are transmitted asynchronously in the form of UART characters over the RS 485 line, the transmission on the IEC segments is bitsynchronous. Here, the FDL telegram is additionally supplied with the preamble and the start and end delimiters (see Fig. 17 below).

• Performance data

high user data rate
The size of the telegram as shown in Fig. 17 depends on the length of the data field. Together with the length, the user data rate changes within the limits of eight and 96 per cent (one or 244 data bytes and eleven control bytes each).
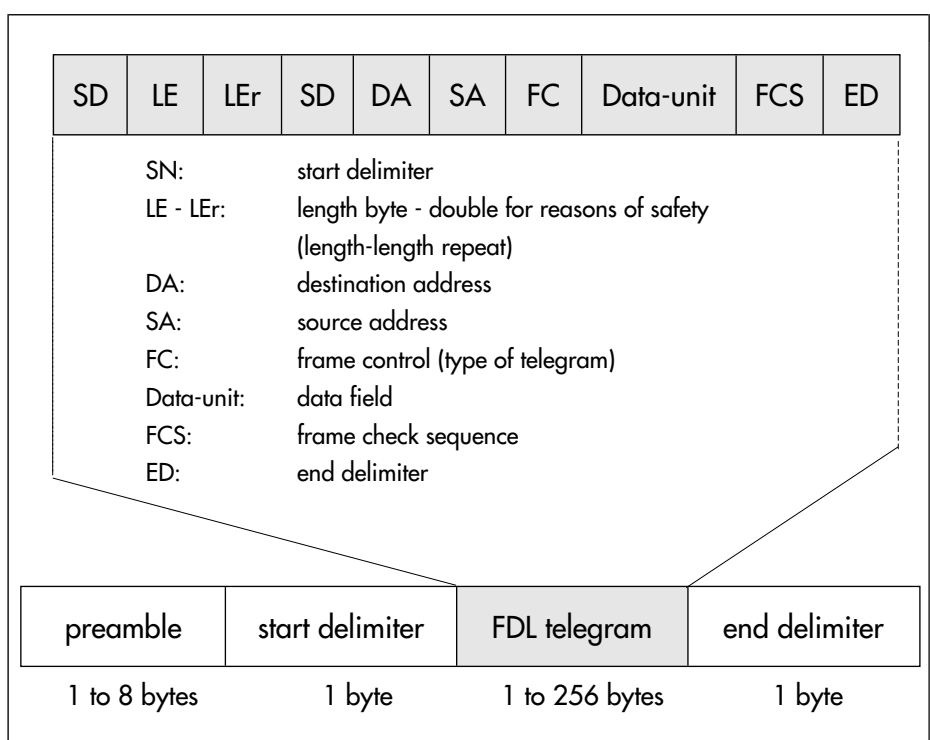
SD	LE	LEr	SD	DA	SA	FC	Data-unit	FCS	ED

SN: start delimiter
LE - LEr: length byte - double for reasons of safety
                (length-length repeat)
DA: destination address
SA: source address
FC: frame control (type of telegram)
Data-unit: data field
FCS: frame check sequence
ED: end delimiter

preamble	start delimiter	FDL telegram	end delimiter
1 to 8 bytes	1 byte	1 to 256 bytes	1 byte

*Fig. 17: Bitsynchronous transmission of IEC telegram (bottom)
and structure of the embedded FDL telegram*

A transmission rate of 31.25 kbit/s results in transmission times of 0.4 to 8.2 ms per telegram so that per user data byte an average of 0.4 ms and 34 ms is required.

This data transmission rate is sufficient, for example, to serve 10 control loops – including 10 sensors and 10 actuators respectively – within a control cycle time of approx. 210 milliseconds.

in 210 ms up to 10 control loops can be processed

During the evaluation, it was assumed that only one cyclic value (5 bytes user data) must be transmitted per device. With each additional value, the minimum cycle time increases by $(5 \times 8$ bits$)/(31.25$ kbit/s$) = 1.3$ ms .

For a first estimate, the following formula can be used:

cycle time   ≥   10 ms × number of devices
                  + 10 ms (for acyclic class-2 master services)
                  + 1.3 ms (for each additional cyclic value)

● Layer-2 communication services

Layer 2 provides the application layer with the SRD and SDN communication services:

communication with...

▶ With the SRD service (Send and Request Data with reply), the master issues a command or sends data to the slave and receives a reply from the slave within a defined time span. This reply either consists of an acknowledgement (brief acknowledgement) or of the requested data (Fig. 18).

... and without acknowledgement

▶ The SDN service (Send Data with No acknowledge) sends data to a whole group of slaves. This permits an event-controlled synchronization where all slaves set their outputs simultaneously (Sync mode) or update their input data simultaneously (Freeze mode). A master-controlled bus assignment for slave replies is not possible in this case so that SDN telegrams remain unacknowledged.

SAP: interface to communication services

The access of the application to these basic forms of communication as well as the various layer-2 services based on them is granted via so-called Service Access Points (SAP). These SAPs are used by the higher layers to perform all communication tasks of the respective application program.
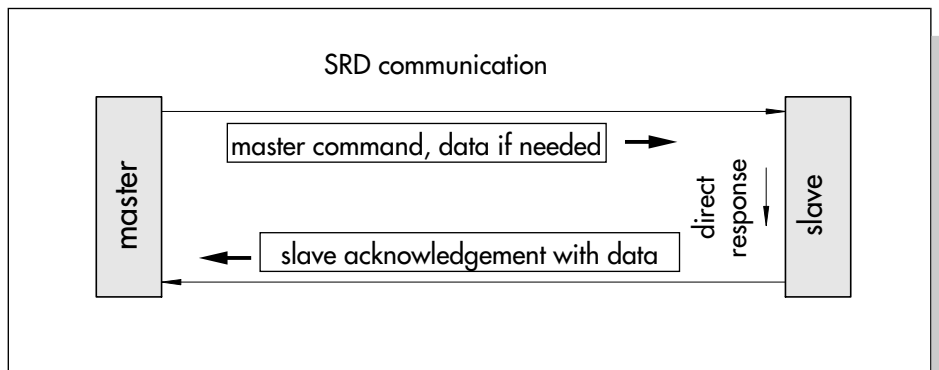

Fig. 18: SRD data exchange between master and slave

User interface

The illustrations in Figs. 5 (page 13) and 19 show that the OSI layers 3 to 7 are not used with PROFIBUS-DP and PA and that both systems utilize a uniform user interface. DP and PA can therefore also be considered standardized applications of layer 2.

DDLM and user interface

The user interface plus the Direct Data Link Mapper (DDLM) form the interface between the application program and layer 2. With the introduction of DPV1, the DDLM provides several asynchronous service functions, e.g.:

▷ DDLM_Initiate; DDLM_Read; DDLM_Write; DDLM_Abort; DDLM_Alarm_Ack;

powerful services for acyclic data exchange

These DDLM functions are used by the user interface as a basis for communication services, such as start-up, maintenance, diagnostics as well as alarm messages.
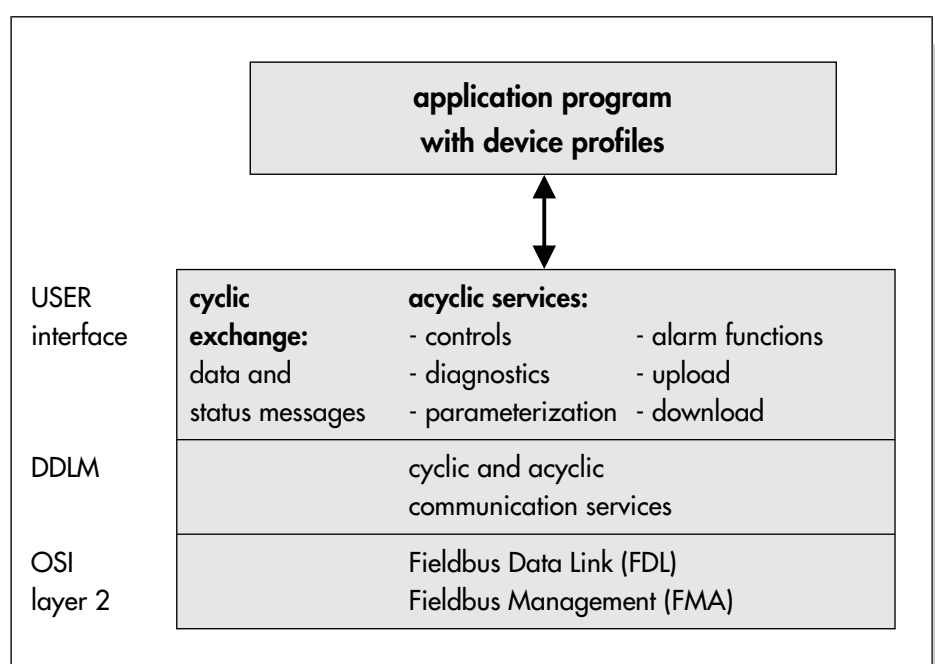
USER interface	**cyclic exchange:** data and status messages	**acyclic services:**	
		- controls	- alarm functions
		- diagnostics	- upload
		- parameterization	- download
DDLM		cyclic and acyclic communication services	
OSI layer 2		Fieldbus Data Link (FDL) Fieldbus Management (FMA)	

Fig. 19: User interface, DDLM and layer 2

control with cyclic data exchange

The system is actually controlled by the class-1 master, utilizing cyclic data exchange (see also page 11).

besides standardized communication ...

The multiple functions of the user interface form a powerful interface for a state-of-the-art communication system. Apart from that, an up-to-date, open system for process automation applications requires that components from various manufacturers can be exchanged – the key terms are 'interchangeability and interoperability'. This requires an accurate definition of all device interfaces.

... uniform device interfaces are required

For the definition of the interfaces, PROFIBUS-PA utilizes several elements or descriptions. They include the following:

▶ Device Database Files (GSD),

▶ device profiles,

▶ Electronic Device Description (EDD) or, as an
   alternative, the Field Device Tool specification (FDT).

Device Database Files

The cyclic data exchange between the class-1 master and a field device can function only, if the master knows the device-specific parameters and data formats. This information is supplied by the device manufacturer in the form of the device database file (GSD; see Fig. 20). The file contains the following details:

description of cyclic parameters and data formats

▸ device manufacturer and device identification number,

▸ transmission rate and bus parameters,

▸ number and format of the data for cyclic communication
– for instance, cyclic positioner data:
reference variable, controlled variable, final position feedback and status messages (fail-safe position, control loop fault, on-site operation, etc.).

When planning a PROFIBUS-PA or -DP system, the GSD must be loaded into the class-1 master via a configuration tool. It describes the device specific parameters in an exactly defined format. The GSD format also supports more complex types of representation, e.g.:

for the class-1 master

```
#Profibus_DP
;
GSD_Revision   =  1
Vendor_Name    = "SAMSON AG"
Model_Name     = "Positioner 3785"
Revision       = "V1.0"

Ident_Number   = 0x3785
Protocol_Ident =  0
Station_Type   =  0
FMS_supp       =  0
Slave_Family   = 12
;
Hardware_Release = "E 1.00  M 2.00"
Software_Release  = "K 1.33  R 1.23"
;
31.25_supp    =  1
45.45_supp    =  1
93.75_supp    =  1
MaxTsdr_31.25 = 100
MaxTsdr_45.45 = 200

MaxTsdr_93.75  = 1000
;
Redundancy              = 0
Repeater_Ctrl_Sig       = 0
;
Freeze_Mode_supp        = 0
Sync_Mode_supp          = 0
Auto_Baud_supp          = 0
Set_Slave_Add_supp      = 0
Min_Slave_Intervall     = 100        ;
User_Prm_Data_Len       = 0
Max_Diag_Data_Len       = 32
;
Bitmap_Device           = "SR3785_N"
;
;----- Meaning of the device related diagnostic bits:
Unit_Diag_Bit(00)  = "Hardware failure electronics"
Unit_Diag_Bit(01)  = "Hardware failure mechanics"
Unit_Diag_Bit(04)  = "Memory error"
; etc.
```

Fig. 20: Excerpt from the GSD of the Type 3785 PROFIBUS Positioner

▶ listings: for instance, to indicate several transmission rates of a device;

▶ clear texts: for diagnostic and error messages to convey more meaning;

▶ bitmap files: for symbolic device representations.

The entire information is grouped into paragraphs which are separated from each other by key words. This standardized structure of the GSD files makes it possible for the class-1 master to load and interpret the data independent of the device manufacturer.

Device profiles

A system can only be operated and monitored independent of devices and manufacturers if all device functions and parameters as well as the access to this data are standardized. PROFIBUS-PA achieves this standardization by using so-called device profiles.

These profiles determine how to implement communication objects, variables and parameters for the different types of field devices. For instance, master devices can have standardized access to the field device functions.

standardization of device and operating functions

The determination of the device profiles has the effect that the properties and functions of the field devices are predefined within wide limits. For example, the variables 'measured value, alarm limits, alarm type, scaling factor, status flags, etc.' serve to accurately describe the ability of a transmitter to be parameterized.

● Classification of parameters

The field device parameters and data which can be accessed through communication can be divided in three groups as detailed below. Fig. 21 shows the listing and classification of parameters for control valves.

▶ dynamic process values: all measuring, signal and status values which are required to control the system. The cyclic access to this data is possible for the class-1 master due to the GSD description (page 29: device database files). The class-2 master can read/write these data acyclically.

dynamic process values and status data

▶ operating and standard parameters: these parameters are exclusively read/written acyclically. The data describes different parameters and functions depending on the device type – sensor, actuator, analog or digital input/output, etc. With each device, the objects marked 'obligatory' in the device profile must be completely implemented. It is up to the device manufacturer, however, which of the 'optional' possibilities are made available.

operating and standard parameters

▶ manufacturer-specific parameters: if a manufacturer implements device functions and setting variants that go beyond the profile definition, these functionalities can be described with manufacturer-specific parameters. The extensions are only available to the user, if the class-2 master knows
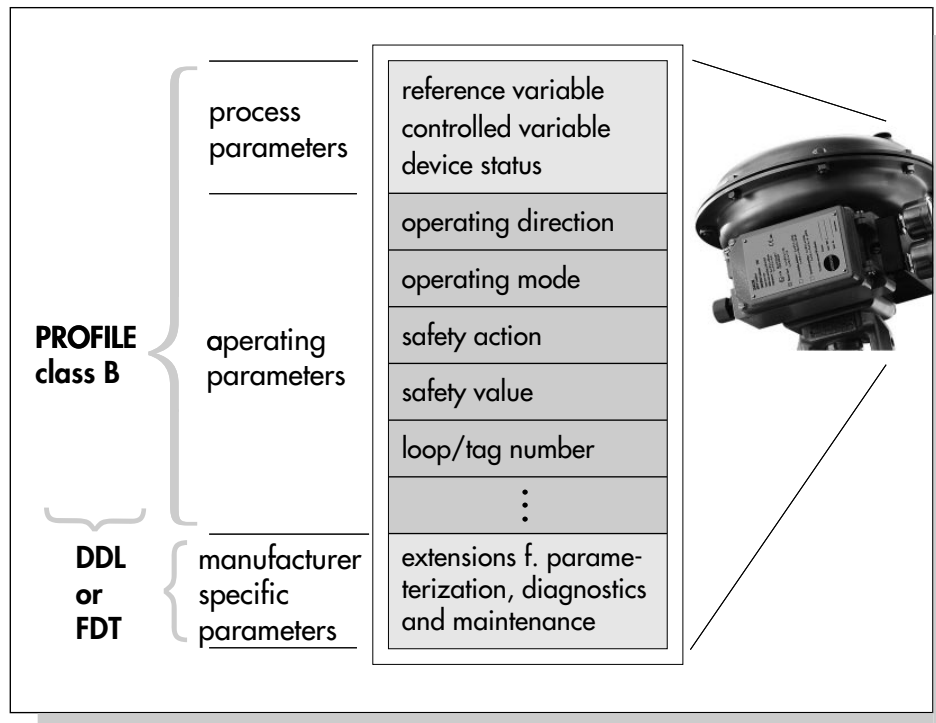
manufacturer-specific parameters

Fig. 21: Classification of device parameters – profile class B – for actuators

how to access the parameters and perform the additional functions (see section "device description and field device tool").

• Function block model

With device profiles, PROFIBUS-PA operates on the basis of a function block model. This model groups the different device parameters in several function blocks which ensure a uniform and systematic access to all parameters.

function block model provides uniform application interfaces

Due to its object-oriented assignment of device parameters and device functions, the function block model simplifies planning and operation of distributed automation systems. Additionally, this model ensures compatibility with the international fieldbus standard so that a conversion to an international fieldbus protocol would not require modifications of the application software.

various blocks and functions are required, depending on the operating mode

The function block model assigns the dynamic process values and the operating and standard parameters of a field device to different blocks (Fig. 22).

▶ the function block describes the device function during the operation (cyclic data exchange of analog input/output, alarm limit values, etc.).
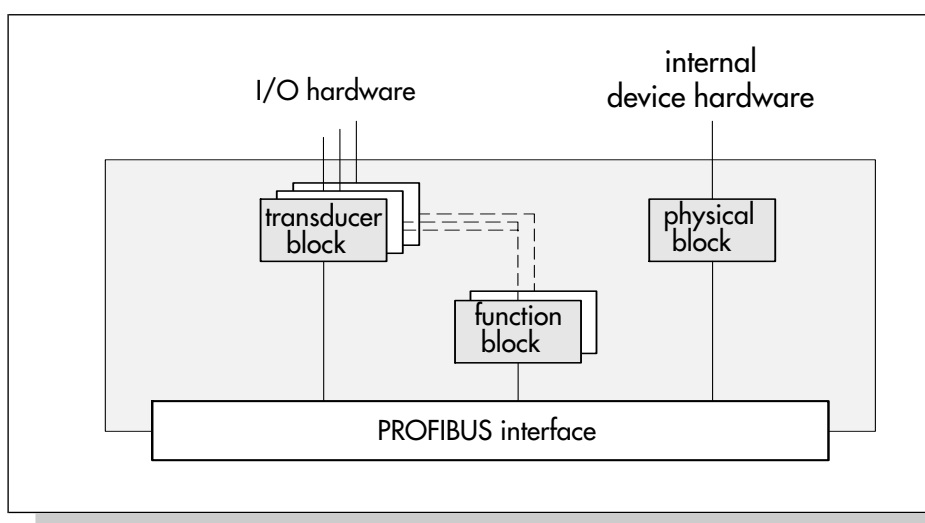
Fig. 22: Function block model of device profiles

▸ the physical block encompasses all parameters and functions required to identify the hardware and software (revision numbers, limit values, etc.).

▸ the transducer block contains the parameters which describe the coupling of the signals to the process and are required to preprocess the data in the field device (process temperature and pressure, characteristic curves, sensor type, etc.).

The operating mode – start-up, operation, maintenance or diagnosis – determines which parameters and blocks must be used. For instance, during operation, function block parameters are used almost exclusively, while during maintenance and start-up, transducer and physical block parameters are used primarily. For diagnosis, information is required from all three blocks.

function block for operation; physical block for start-up and maintenance

During operation, a transducer block can be firmly assigned to each function block. The process and system data saved in the transducer blocks can be used by the field device to preprocess its own data and, thus, to provide the master with extended process information. The more extensive the transducer blocks defined by the device profile, the more varied is the process information provided by the respective field device.

transducer blocks extend a device's range of functions

EXAMPLE: A differential pressure transmitter does not only provide the measured pressure difference (function block), but uses material and process parameters (transducer block) to calculate and pass on the resulting flow rate as well.

Some field devices have extended functions and are responsible for several tasks, eg. analog inputs and outputs. These so-called multi-channel devices are equipped with several independent function blocks and, if required, the associated transducer blocks.

- PROFILE A and B

PROFIBUS-PA differentiates the device profile classes A and B. At first, only class A profiles that were defined for the most important transmitters (temperature, pressure, level, flow rate) and control valves were used.

▸ The class A profiles contain those characteristics that describe the basic device functions. Device profile A is limited to the absolutely necessary basic parameters that are required for process operation in process engineering. This includes only parameters from the function and the physical block, e.g. the process variable, the status of the measured value, the physical unit as well as the tag number.

device profile A: only data from function and physical block

▸ Class B profiles extend the available scope of functions of the devices. The device profile B comprises all three blocks of the function block model and differentiates objects whose implementation is mandatory and those the manufacturer can provide optionally.

device profile B: data from function block, physical block and transducer block

When looking at the example of the profile definition for control valves (Fig. 23), you can see how the function blocks are assigned to the profiles A and B. It becomes clear that the device profile A is a subset of profile B. Profile A is used if there is no special device profile B for a certain field device type. Profile-B compliant field devices, for instance the SAMSON Type 3785

	profile class A	profile class B
physical block	m	m
analog output function block	m	m
transducer block:	–	m
electropneumatic transducer block	–	s
electric transducer block	–	s
electrohydraulic transducer block	–	s
additional function blocks	–	o
additional transducer blocks	–	o
mandatory (m) selected (s) optional (o)		

Fig. 23: Function block model for control valves

PROFIBUS Positioner, always meet the functions and parameters of device profile A as subset.

Profile B defines three mandatory blocks, the physical, function and transducer block. Depending on the device version, the function block can be assigned to a different transducer block (selected). For multi-channel devices with extended functions, additional function blocks are available as an option.

multi-channel devices have more than one function block

In the meantime, class B profiles have been defined for most devices – e.g. discrete input and output, analog input and output, transmitters, actuators, multivariable device – and are already used in practice. The currently (August 1999) valid version is profile B version 2.0, however, a more powerful version 3.0 is already in progress.

profile B version 3.0 supports predefined profile GSDs

A special feature of this version 3.0 is that it supports generally valid device database files defined by the profile. With these profile GSDs, there is no need for an individual manufacturer-specific GSD anymore. If the field device supports the profile B version 3.0, the profile GSD of the corresponding device type can be used during project planning.

increased functionality due to optional profile functions...

Thanks to the optional device functions, PROFIBUS-PA devices differ in their functions while the profile remains the same. Additionally, manufacturers have the possibility to equip their devices with device functions and performance characteristics that go beyond the profile's requirements.

... and manufacturer-specific extensions

The free definition of manufacturer-specific functions is important so that progress is enhanced and competition made possible. At the same time, however, difficulties are caused by the fact that these performance features can only be utilized if the operating program of the class-2 master knows the associated communication objects.

The prerequisite for using manufacturer-specific performance characteristics of devices with an open and, therefore, manufacturer-independent communication system, is a standardized extension function or interface. To fulfill this task, PROFIBUS utilizes an interface description based on the Field Device Tools or the EDD: Electronic Device Description.

Device description and Field Device Tool specification

To be able to provide the class-2 master of PROFIBUS-PA with manufacturer-specific device features and operating functions, the PNO is currently working on two different specifications:

▸ the device description (Electronic Device Description: EDD) and

▸ the Field Device Tool specification (FDT).

EDD and FDT enable more variants and functions

Both options ensure that the diversity of field device variants and functions remains as extensive as possible.

With PROFIBUS, the definition of the device description language is based on the specifications of the ISP consortium from which the PNO acquired the user rights. However, the manufacturer defines all device-specific parameters, functions and operating structures of his device with the help of a language similiar to a programming language.

The syntax of Profibus DDL clearly defines how to describe extensions. In this way, the generated device descriptions (EDDs) can be interpreted correctly by the class-2 master – independent of the manufacturer.

device description language defines how to describe device functions

Apart from the device description, there is yet another possibility to make device- and manufacturer-specific properties available via PROFIBUS-PA: the Field Device Tool specification.

Contrary to the device description, the FDT specification does not determine the object's type of description, but specifies the interface over which the operating program accesses the field device data and the associated display parameters.

FDT describes the interface field device-operating program

FDT is based on the DCOM feature of the Windows operating system. DCOM stands for 'Distributed Component Object Model' and denotes a mechanism which enables users to run an application distributed over several computers in one network.

In this case, the distributed application is the operating and monitoring program including the partial components and processes, such as communication servers, databases for historical and diagnostic data as well as additional display and engineering tools.

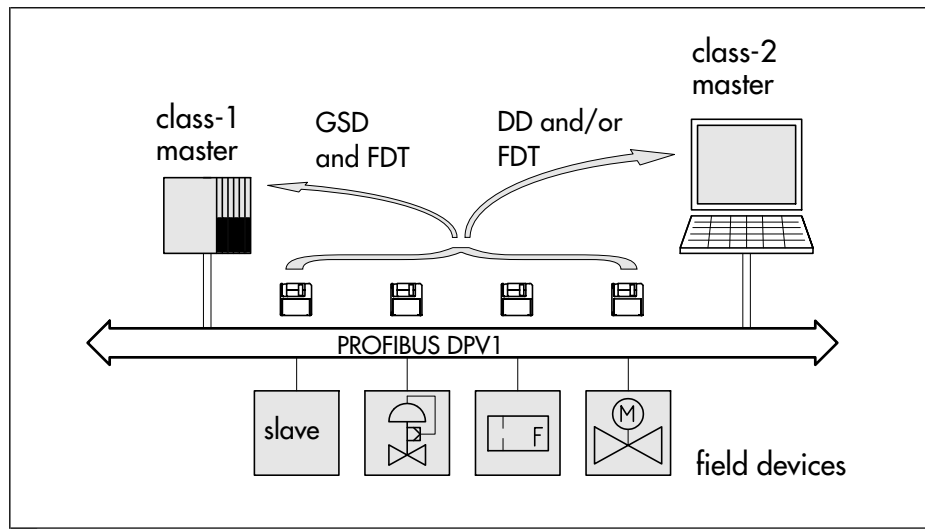**distributed application based on the DCOM service**

Fig. 24: Loading the device database files as well as manufacturer-specific device and interface descriptions

loading EDD and FDT data

The interface description based on FDT and the device description EDD both aim at - in quite different ways - enabling the class-2 master to represent and operate the full scope of functions of all field devices. The highest flexibility is reached when the user of these device or interface descriptions can load and update when still in the project planning phase (see Fig. 24).

NOTE: Many of today's available operating programs neither offer FDT functions nor the possibility of loading and evaluating device descriptions as desired. In such cases, the user must turn to manufacturer- or device-specific software and make sure himself that the used programs are capable of controlling all field devices within their full scope of functions.

Communication sequence and error protection mechanisms

PROFIBUS-PA and -DP are equipped with a variety of safety mechanisms to ensure troublefree communication. For instance, already during the initialization of the system, several possible sources of error are checked.

system check during the initialization phase

After the system is powered up, slaves are ready for data exchange only if the master has first sent a parameterization and then a configuration telegram. Only when these telegrams match its own functional properties does the slave accept the commands from the master. For instance, the number of output lines configured by the master must match those actually existing in the device.

With the help of the Get-Cfg commands, the device configuration of all slaves can be loaded. Thus, parameterization errors in the network can be avoided if the master compares the planned device arrangement to the actually existing configuration. The information required for this – device type, number of inputs and outputs, formatting and length data – is received via the device database files and descriptions. Fig. 25 shows a typical initialization cycle during the start-up of a system.

▶ Besides the controlled error check of the data telegrams during operation, the communication process is also monitored by safety mechanisms controlled by time and protocol.

error check mechanisms controlled by time and protocol

initialization sequence		
	task:	**command:**
load configuration of slaves:	master checks the network configuration	Get_Cfg
write parameters of the slaves:	communication services network parameters	Set_Prm
configure slaves:	inputs / outputs	Set_Cfg
load configuration of the slaves:	master checks the settings	Get_Cfg

Fig. 25: Initialization start of a PROFIBUS-PA system

▶ Each master controls the communication with his slaves by means of special timers which are used to check the time sequence of the useful data traffic.

▶ With the slaves, a pickup monitoring function switches the outputs in a predefined safe state if no data transfer takes place with the master within a fixed time interval.

▶ The outputs of the slaves are additionally secured by access protection. This ensures with multi-master systems that the write-access is only permitted by the authorized master while reading of inputs and outputs can also be performed without access rights.

The safety of the system is even higher because each class-1 master cyclically reports its own system status to all its assigned slaves within a configurable time interval using a multicast command. The master can be parameterized in such a manner that it can switch all slaves to a safe status and end the data transfer operation in case of a system error, i.e. when a slave fails.

Appendix A1:
Additional literature

[1] Digital Signals
     Technical Information L 150 EN; SAMSON AG

[2] Serial Data Transmission
     Technical Information L 153 EN; SAMSON AG

[3] Communication Networks
     Technical Information L 155 EN; SAMSON AG

[4] Communication in the Field
     Technical Information L 450 EN; SAMSON AG

[5] HART Communication
     Technical Information L 452 EN; SAMSON AG

[6] FOUNDATION Fieldbus
     Technical Information L 454 EN; SAMSON AG

APPENDIX

Figures

FIGURES

FIGURES