

# PROFIBUS

## Technology and Application

### *System Description*



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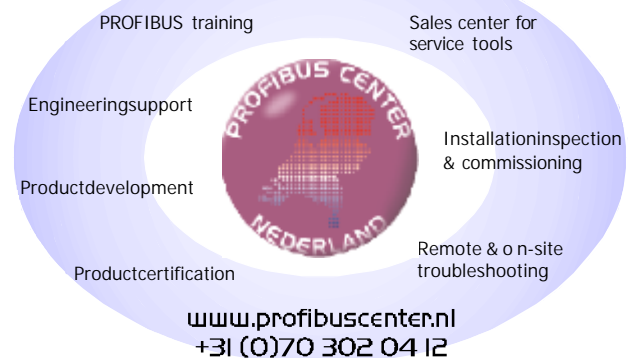
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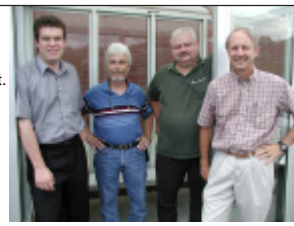
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## Commitment

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## Introduction

From the outset, the field of automation has been subject to continuous change. Not so long ago, this change was limited to the production area of a company. In production, the implementation of fieldbus technology has meant considerable innovation, enabling the migration from centralized to decentralized automation systems. This has been the PROFIBUS objective for more than 10 years.

In those 10 years PROFIBUS has become the world market leader in fieldbus technology. In spite of the outstanding success of recent years, PROFIBUS development continues with undiminished enthusiasm and energy. Initially the focus was on communication technology. Current activities center

around system integration, engineering and, in particular, the application profiles. These profiles have made PROFIBUS the only fieldbus that provides comprehensive both factory and process automation.

Additionally, Information Technology (IT) increasingly determines development in today's world of automation. Modern fieldbus systems have adopted IT principles and are achieving greater consistency with the corporate management level. In this respect, industrial automation is following the development trends of the office world, where IT has long since left its mark, radically transforming infrastructure, systems and processes. The integration of informa-

tion technology in the world of automation opens up many new prospects for global data communication between automation systems. In pursuit of this objective, PROFIBUS is enhanced by the Ethernet-based communication standard PROFINet.

The use of open standards rather than proprietary solutions ensures long-term compatibility and expandability - in other words - protection of existing investment. This is a matter of key importance to the PROFIBUS User Organization. The continuous development of PROFIBUS technology provides members with a long-term perspective.

## Contents

<b>1. Communication in Automation .....</b>	<b>1</b>	<b>6. System Profiles.....</b>	<b>23</b>
1.1 Industrial Communication.....	1	<b>7. Device Management .....</b>	<b>25</b>
1.2 Fieldbus Technology Terms .....	2	7.1 GSD .....	25
1.3 International Standardization.....	3	7.2 EDD .....	26
<b>2. PROFIBUS at a Glance.....</b>	<b>4</b>	7.3 FDT/DTM Concept .....	27
2.1 History .....	4	<b>8. Quality Assurance .....</b>	<b>28</b>
2.2 Market Position .....	4	8.1 Test procedure .....	28
2.3 Organization.....	4	8.2 Conformance Certificate.....	28
2.4 The PROFIBUS "Tool Box" .....	5	<b>9. Implementation .....</b>	<b>29</b>
2.5 PROFIBUS - The keys to success .....	6	9.1 Standard Components.....	29
<b>3. PROFIBUS Transmission and Communication .....</b>	<b>7</b>	9.2 Implementation of Interfaces .....	30
3.1 Transmission Technology .....	7	<b>10. PROFINet .....</b>	<b>31</b>
3.2 Communication Protocol DP .....	10	10.1 The PROFINet Engineering Model .....	31
<b>4. General Application Profiles .....</b>	<b>17</b>	10.2 The PROFINet Communications Model.....	32
4.1 PROFIsafe .....	17	10.3 The PROFINet Migration Model.....	32
4.2 HART on PROFIBUS DP .....	17	10.4 XML .....	32
4.3 Time Stamp.....	18	10.5 OPC and OPC DX.....	32
4.4 Slave Redundancy .....	18	<b>11. PROFIBUS International.....</b>	<b>33</b>
<b>5. Specific Application Profiles .....</b>	<b>19</b>		
5.1 PROFIdrive .....	19		
5.2 PA Devices.....	20		
5.3 Fluid Power .....	21		
5.4 SEMI Devices.....	22		
5.5 Ident Systems .....	22		
5.6 Remote I/O for PA.....	22		

## Contents

This document describes the essential aspects of PROFIBUS and takes into account the level of technology available at the end of 2002. Its objective is to provide a comprehensive description of the world's leading fieldbus system, PROFIBUS, without becoming too engulfed in specific details.

This brochure not only offers sufficient information to those with a basic knowledge and readers interested in an overview, but it also introduces experts to more extensive specialized literature. In this context, we would like to point out

that, in spite of the care that has been taken in the preparation of this overview, only the PROFIBUS documents available on the Internet are definitive and binding. Please refer to them for more detailed information.

**Chapters 1 and 2** offer an introduction to the principles of fieldbus technology and their implementation with PROFIBUS.

**Chapters 3 to 6** deal with the core aspects of PROFIBUS and any repetition of subject matter dealt with in Chapter 2 is intentional for reasons of completeness.

These chapters emulate the modular layout of PROFIBUS, from communication technology through application profiles to system profiles.

**Chapters 7 to 9** are more practically oriented. They deal with subjects such as device management, implementation and certification.

**Chapter 10** presents the theory of operation of PROFINet.

**Chapter 11** completes the brochure with details of PROFIBUS International and the PROFIBUS User Organization.



## 1. Communication in Automation

The communication capability of devices and subsystems and consistent information methodology are indispensable components of future-oriented automation concepts. Communications are increasingly occurring horizontally at the field level as well as vertically through several hierarchical levels simultaneously. Layered and coordinated industrial communication systems, such as PROFIBUS with lower-level interfacing to AS-Interface and upper level interfacing to Ethernet (over PROFINet) (see Figure 1), offer ideal preconditions for transparent networking in all areas of the production process.

### 1.1 Industrial Communication

**At the sensor-actuator level** signals of binary sensors and actuators are transmitted over a sensor actuator bus. This provides a simple and cost-effective technology where data and power are transmitted over a shared medium. AS-Interface offers a suitable bus system for this field of application.

**At field level** distributed devices such as I/O modules, transducers, drive units, analysis devices, valves or operator terminals, communicate with automation systems over a powerful, real-time communication system. Transmission of the process data is cyclic, while additional interrupts, configuration data and diagnosis data are transmitted acyclically as required.

PROFIBUS fulfills these criteria and offers an universal solution for both factory and process automation.

**At the cell level** programmable controllers such as PLCs and IPCs, communicate with each other and with IT systems of the office world using standards such as Ethernet, TCP/IP, Intranet and Internet. This information flow requires large data packets and a range of powerful communication functions.

As well as PROFIBUS, Ethernet-based PROFINet offers a trendsetting solution for this purpose.

In the following PROFIBUS will be described in detail as the central connecting link for the information flow in the automation industry. For information on AS-Interface please refer to the relevant literature. Furthermore PROFINet will be briefly presented in chapter 10.

**Fieldbuses** are industrial communication systems that use a range of media such as copper cable, fiber optics or wireless, with bit-serial transmission for coupling distributed field devices (sensors, actuators, drives, transducers, etc.) to a central control or management system. Fieldbus technology was developed in the 80s with the aim of replacing the commonly used central parallel wiring and prevailing analog signal transmission (4-20 mA- or +/- 10V interface) with digital technology. Due, in parts, to the different industry-specific demands and preferred proprietary solutions of large manufacturers, several bus systems with varying properties were established in the market. The key technologies are now included in recently

adopted standards IEC 61158 and IEC 61784. PROFIBUS is an integral part of these standards.

Recently, Ethernet-based communication systems have emerged in industrial automation. They offer wide-ranging options for communications between the different levels of industrial automation and the office world. PROFINet is an example of one such Ethernet-based communication system.

A need for the coordinated development and distribution of these fieldbus systems in the market has seen the emergence of a number of *User Organizations* comprising manufacturers, users and institutes, such as the PROFIBUS User Organization (PNO) and its parent organization PROFIBUS International (PI) for PROFIBUS and PROFINet technologies.

**User benefits** are the motivation for the emergence and continual development of fieldbus technology. This ultimately manifests itself as a reduction of the total cost of ownership, as well as an increase in performance and quality improvement during the setup and operation of automation plants. The benefits are achieved during configuration, cabling, engineering, documentation, assembly and commissioning, as well as during production. An additional benefit is achieved by the reduction of the total life-cycle costs in the form of easy modification and continuous availability due to regular diagnosis information, preventive maintenance, simple parameter assignment, consistent data flow and asset management.

Fieldbuses increase the productivity and flexibility of automated processes compared to conventional technology and they create the basic prerequisite for the configuration of distributed automation systems.

Today PROFIBUS is used in virtually all areas of automation, in factory automation and process automation, but also in traffic engineering, power generation and power distribution.

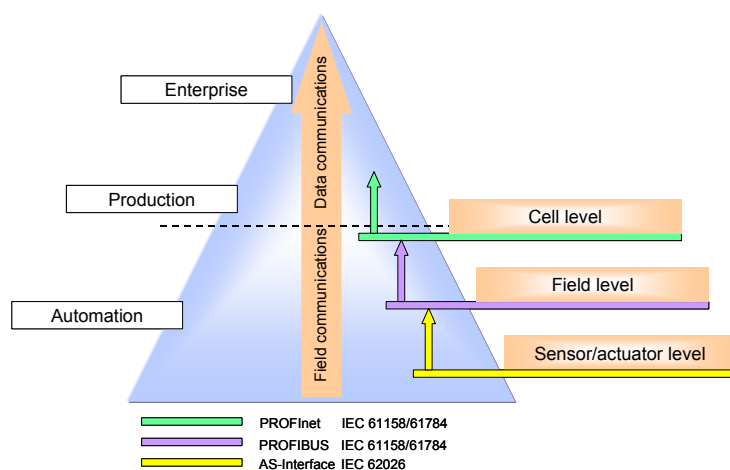


Fig. 1: Communication in automation technology

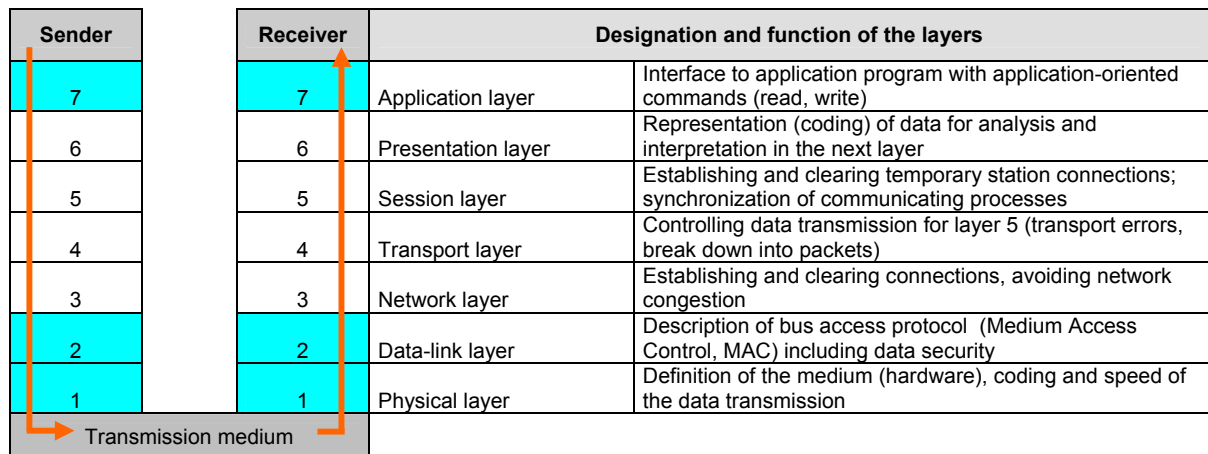


Fig. 2: The OSI reference model

## 1.2 Fieldbus Technology Terms

**The ISO/OSI reference model** describes communications between the stations of a communication system. In order for it to run effectively, defined rules and transfer interfaces need to be used for the communications protocol. In 1983, the International Organization for Standardization (ISO) developed the OSI reference model ("Open Systems Interconnection Reference Model") for just this purpose. This protocol defines the elements, structures and tasks required for communication and arranges them into seven *layers* with each layer building upon the layer beneath (Fig. 2). Each layer has to fulfill specified functions within the communication process. If a communication system does not require some of those specific functions, the corresponding layers have no purpose and are bypassed. PROFIBUS uses layers 1, 2 and 7.

**Communications Protocols** define how two or more stations exchange data using message frames. A data frame contains different fields for messages and control information. The actual data field is *preceded* by the header information (source and destination address and details of the subsequent message) and *followed* by the data security part containing check information with regard to the correctness of the transmission (fault recognition).

A feature of fieldbuses is that they enable optimum transmission of small, time-critical data volumes

and simplify the transmission process.

**Bus access control (MAC, Medium Access Control)** is a specific procedure that determines at which point in time a station can send data. While *active* stations can start the exchange of information, *passive* stations may only begin communication when prompted by an active station.

A distinction is made between a controlled, *deterministic* access procedure with real-time capability (master-slave with PROFIBUS) and a random, *non-deterministic* access procedure (CSMA/CD with Ethernet).

**Addressing** is necessary to selectively identify a station. For this purpose, station addresses are assigned either by an address switch (hard addresses) or during parameter assignment during commissioning (soft addresses).

**Communication Services** fulfill communication tasks of the station either cyclic or acyclic user data communication. The number and type of these services are criteria for the application area of a communications protocol. A distinction is made between *connection-*

*oriented* services (that means with handshake procedure and monitoring) and *connectionless* services. The second group includes multicast and broadcast messages that are sent either to a specific group or to all stations.

**Profiles** are used in automation technology to define specific properties and behavior for devices, device families or entire systems. Only devices and systems using a vendor-independent profile provide interoperability on a fieldbus, thereby fully exploiting the advantages of a fieldbus.

*Application profiles* refer primarily to devices (field devices, controls and integration tools) and comprise both an agreed selection of bus communications and the specific device application. This type of profile serves manufacturers as a specification for the development of profile-conforming and interoperable devices. *System profiles* describe classes of systems that include functionality, program interfaces and integration tools.

IEC 61158 document	Contents	OSI layer
IEC 61158-1	Introduction	
IEC 61158-2	Physical layer specification and service definition	1
IEC 61158-3	Data-link service definition	2
IEC 61158-4	Data-link protocol specification	2
IEC 61158-5	Application layer service definition	7
IEC 61158-6	Application layer protocol specification	7

Table 1: Breakdown of IEC 61158

Profile set	Data link	Physical layer	Implementation
Profile 3/1	IEC 61158 subsets; <u>asynchronous</u> transmission	RS485 Plastic fiber Glass fiber PCF fiber	PROFIBUS
Profile 3/2	IEC 61158 subsets; <u>synchronous</u> transmission	MBP	PROFIBUS
Profile 3/3	ISO/IEC8802-3 TCP/UDP/IP/Ethernet	ISO/IEC 8802-3	PROFINet

Table 2: Properties of the Communication Profile Family CPF 3 (PROFIBUS)

### 1.3 International Standardization

**International standardization** of a fieldbus system is necessary for its acceptance, establishment and its benefits. PROFIBUS achieved national standardization in 1991/1993 in DIN 19245, Part 1-3 and Europe-wide standardization in 1996 in EN 50170.

Together with other fieldbus systems, PROFIBUS has been standardized in IEC 61158 since 1999. 2002 saw the completion of activities to update IEC 61158. In the course of these activities, the latest PROFIBUS and PROFINet developments were incorporated in this standard.

**IEC 61158** bears the title "Digital Data Communication for Measurement and Control – Fieldbus for Use in Industrial Control Systems"

and is broken down into 6 parts that are designated 61158-1, 61158-2 etc. The contents of Part 1 deal with introductory subjects, while the subsequent parts are oriented towards the OSI reference model (layers 1, 2 and 7); see Table 1.

The various parts of IEC 61158 define, among other things, the numerous services and protocols for communication between stations which are regarded as the total available set, from which a specific selection (subset) is made for specific fieldbus systems.

The fact that a wide range of different fieldbus systems is available on the market is acknowledged in IEC 61158 by the definition of 10 "fieldbus protocol types" with the designation Type 1 to Type 10.

PROFIBUS is Type 3 and PROFINet Type 10.

IEC 61158 notes that bus communication (by definition) is only possible between devices that belong to the same protocol type.

**IEC 61784** bears the title "Profile Sets for Continuous and Discrete Manufacturing Relative to Fieldbus Use in Industrial Control Systems". Assignment to IEC 61158 is established through the following introductory comment: "This international standard (i.e. IEC 61784) specifies a set of protocol specific communication profiles based on IEC 61158, to be used in the design of devices involved in communications in factory manufacturing and process control".

IEC 61784 depicts which subsets of the total available set of "services" and "protocols" specified in IEC 61158 (and other standards) are used by a specific fieldbus system for communication. The fieldbus-specific "communication profiles" determined in this manner are summarized in the "Communication Profile Families (CPF)" according to their implementation in the individual fieldbus systems.

The profile sets implemented with **PROFIBUS** are summarized under the designation "Family 3" with subdivisions 3/1, 3/2 und 3/3. Table 2 shows their assignment to PROFIBUS and PROFINet.

## 2. PROFIBUS at a Glance

**PROFIBUS** is an open, digital communication system with a wide range of applications, particularly in the fields of factory and process automation. PROFIBUS is suitable for both fast, time-critical applications and complex communication tasks.

PROFIBUS *communication* is anchored in the international standards IEC 61158 and IEC 61784. The *application and engineering aspects* are specified in the generally available guidelines of the PROFIBUS User Organization. This fulfills user demand for manufacturer independence and openness and ensures communication between devices of various manufacturers.

### 2.1 History

The history of PROFIBUS goes back to a association venture project supported by the public authorities, which began in 1987 in Germany. Within the framework of this venture, 21 companies and institutes joined forces and created a strategic fieldbus project. The goal was the realization and establishment of a bit-serial fieldbus, the basic requirement of which was the standardization of the field device interface. For this purpose, the relevant member companies of the

ZVEI (Central Association for the Electrical Industry) agreed to support a mutual technical concept for factory and process automation.

A first step saw the specification of the complex communications protocol PROFIBUS FMS (Fieldbus Message Specification), which was tailored to demanding communication tasks. A further step in 1993 saw completion of the specification for the more simply configured and faster PROFIBUS DP protocol (Decentralized Periphery). This protocol is now available in three functionally scaleable versions DP-V0, DP-V1 and DP-V2.

### 2.2 Market Position

Building on these two communications protocols, coupled with the development of numerous application-oriented profiles and a fast growing number of devices, PROFIBUS began its advance, initially in factory automation and, since 1995, in process automation. Today, PROFIBUS is the fieldbus world market leader with more than a 20% share of the market, approx. 500,000 equipped applications and more than 5 million nodes. Today, there are more than 2000 PROFIBUS products available from a wide range of manufacturers.

### 2.3 Organization

The success of PROFIBUS stems in equal measures from its pro-

gressive technology and the success of its non-commercial PROFIBUS User Organisation e.V. (**PNO**), the trade body of manufacturers and users founded in 1989. Together with the 22 other regional PROFIBUS associations in countries around the world, and the international umbrella organization PROFIBUS International (**PI**) founded in 1995, this organization now boasts more than 1,100 members worldwide. Objectives are the continuous further development of PROFIBUS technology and increased acceptance worldwide.

As well as sponsoring the wide range development of technology and its acceptance, PI also undertakes additional tasks for the worldwide support of members (users and manufacturer) with advice, information and procedures for quality assurance as well as the standardization of technology in international standards.

PI forms the largest fieldbus user association in the world. This represents future opportunities and responsibility in equal measure, *opportunity* to continue creating and establishing leading technologies that are useful to users and *responsibility* for those at the head of these user associations to be unwavering in their endeavors to target openness and investment protection for PROFIBUS in the future. This commitment (see introduction) serves as the guiding principle for all concerned.

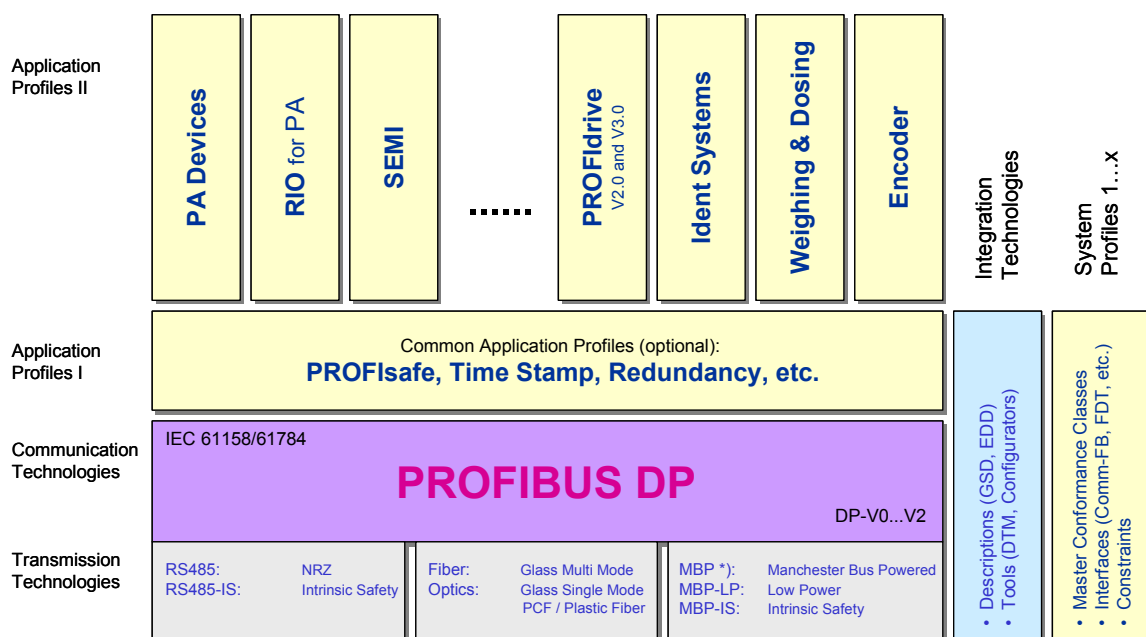


Fig. 3: Technical system structure PROFIBUS



## 2.4 The PROFIBUS "Tool Box"

**PROFIBUS** has a modular design and offers a range of communication technologies, numerous application and system profiles, as well as device management tools. Thus PROFIBUS covers the diverse and application-specific demands from the field of factory and process automation. The number of installed PROFIBUS plants are proof of the high acceptance of this fieldbus technology.

From the **technological standpoint** the lower level (communications) of the system structure of PROFIBUS (see Fig. 3) is based on the aforementioned ISO/OSI reference model. This intentionally gave an abstract description of the communication steps without providing details of content/practical implementation. Fig. 3 contains the implementation of the OSI model (layers 1, 2 and 7) in PROFIBUS with details on how the layers are individually implemented/specified.

Specifications agreed between manufacturers and users on specific device applications are arranged above layer 7 in application profiles I and II.

Across several layers, the modular system as shown in Fig. 3 has the following:

- Functions and tools for device description and integration (umbrella term: Integration Technologies, see Chapter 7) and
- A range of standards (interfaces, master profiles; umbrella term: system profiles) that primarily serve the realization of uniform, standardized systems, see Chapter 6.

From the **user standpoint** PROFIBUS presents itself in the form of different typical-application main emphases that are not specifically defined but have proven useful as a result of frequent applications. Each main emphasis results from a typical (but not specifically defined) combination of modular elements from the groups "transmission technology", "communications protocol" and "application profiles". The following examples explain this principle using the

best known PROFIBUS versions (Fig. 4).

**PROFIBUS DP** is the main emphasis for factory automation; it uses RS485 transmission technology, one of the DP communications protocol versions and one or more application profile(s) typical of factory automation, such as *Ident Systems* or *Robots/NC*.

**PROFIBUS PA** is the main emphasis for process automation, typically with MBP-IS transmission technology, the communications protocol version DP-V1 and the application profile *PA Devices*.

**Motion Control with PROFIBUS** is the main emphasis for drive technology using RS485 transmission technology, the communications protocol version DP-V2 and the application profile *PROFIdrive*.

**PROFIsafe** is the main emphasis for safety-relevant applications (universal use for almost all industries), using RS485 or MBP-IS transmission technology, one of the available DP versions for communication and the application profile *PROFIsafe*.

protection type EEx-i for use in potentially explosive areas. The specified levels of voltage and current refer to the safety-relevant maximum values that must not be exceeded in either individual devices or during interconnection in the system. In contrast to the FISCO model (see Chapter 3.1.2), which only has one intrinsically safe source, in this case all stations represent active sources.

The **MBP** transmission technology (*Manchester Coded, Bus Powered*, previous designation "IEC 1158-2 - Physics", see Chapter 3.1) is available for applications in process automation with a demand for bus powering and intrinsic safety of devices. Compared to the previously used procedure, the "Fieldbus Intrinsically Safe Concept" (FISCO, see Chapter 3.1.2), which was specially developed for interconnection of intrinsically safe fieldbus devices, considerably simplifies planning and installation.

**Fiber-optic** transmission is suitable for use in areas with high electromagnetic interference or where greater network distances are required (see chapter 3.1.3).

### 2.4.1 Transmission Technologies

There is a whole range of transmission technologies available for PROFIBUS.

**RS485** is the most commonly used transmission technology. It uses a shielded twisted pair cable and enables transmission rates up to 12 Mbit/sec.

The newly specified version **RS485-IS** has been recently specified as a 4-wire medium in

### 2.4.2 Communication Protocols

At the protocol level, PROFIBUS with DP and its versions DP-V0 to DP-V2 offers a broad spectrum of options, which enable optimum communication between different applications. Historically speaking, FMS was the first PROFIBUS communications protocol.

**FMS (Fieldbus Message Specification)** is designed for communication at the cell level, where programmable controllers, such as

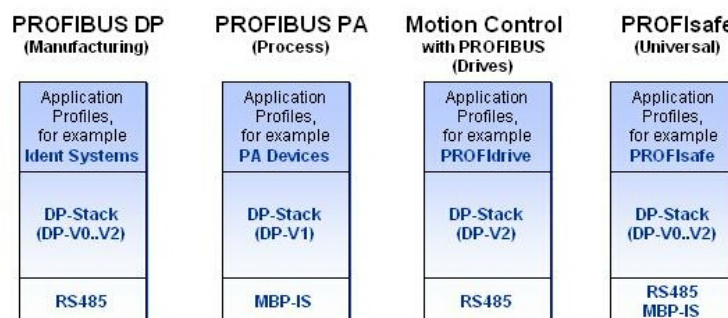


Fig. 4: Typical, application-oriented features of PROFIBUS

PLCs and PCs primarily communicate with each other. It was the forerunner of PROFIBUS DP.

## DP

**(Decentralized Periphery)** is the simple, fast, cyclic and deterministic process data exchange between a bus master and the assigned slave devices. The original version, designated DP-V0, has been expanded to include version DP-V1, offering acyclic data exchange between master and slave. A further version DP-V2 is also available, which provides for direct slave-to-slave communication with an isochronous bus cycle.

The **Bus Access Protocol**, layer 2 or the data-link layer, defines the master-slave procedure and the token passing procedure for coordination of several masters on the bus (Fig. 5). The tasks of layer 2 also include functions, such as data security and the handling of data frames.

The **Application Layer**, Layer 7, defines the *application layer* and forms the interface to the application program. It offers various services for cyclic and acyclic data exchange.

## 2.4.3 Profiles

*Profiles* are the specifications defined by manufacturers and users regarding specific properties, performance features and behavior of devices and systems. Profile specifications define the parameters and behavior of devices and systems that belong to a profile family built around to profile-conformance development, which facilitate device interoperability and, in some instances, device interchangeability on a bus. Profiles take into account application and type-specific spe-

cial features of field devices, controls and methods of integration (engineering). The term profile ranges from just a few specifications for a specific device class through comprehensive specifications for applications in a specific industry. The generic term used for all profiles is *application profiles*.

A distinction is then drawn between **general application profiles** with implementation options for different applications (this includes, for example, the profiles PROFIsafe, Redundancy and Time Stamp), **specific application profiles**, which are developed for a specific application, such as PROFIdrive, SEMI or PA Devices, and **system and master profiles**, which describe specific system performance that is available to field devices.

PROFIBUS offers a wide range of such application profiles, which allow application-oriented implementation.

## 2.5 PROFIBUS - The keys to success

The **success of PROFIBUS**, its world market leadership is determined by many factors:

- **PROFIBUS** offers plant manufacturers and operators an industry-wide, universal, open technology.
- **PROFIBUS** is a key factor in noticeably reducing costs in the field of machine and plant engineering.
- **PROFIBUS** has consistently and logically expanded its application area while taking into account the demands of the respective application fields. This ensures optimum support of industry-specific applications.
- **PROFIBUS** means optimum integration in many automation and engineering systems for users due to its overall acceptance and widespread use.
- **PROFIBUS** has pursued the stabilization and broad acceptance of communication platforms, the further development of application profiles and the connection of industrial automation to the IT world of corporate management.

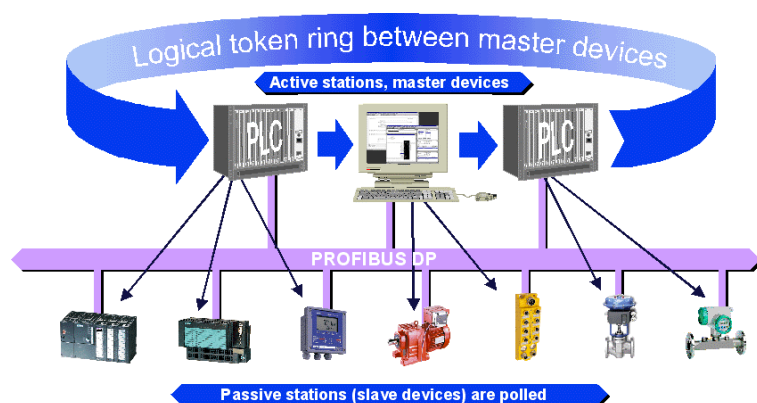


Fig. 5: PROFIBUS configuration with active masters and slaves

### 3. PROFIBUS Transmission and Communication

#### 3.1 Transmission Technology

In the **ISO/OSI** reference model, layer 1 defines the method of "physical" data transmission, i.e. electrical and mechanical. This includes the type of encoding and the transmission standard used (RS485). Layer 1 is called the physical layer.

**PROFIBUS** provides different versions of layer 1 as a transmission technology (see Table 4). All versions are based on international standards and are assigned to PROFIBUS in both IEC 61158 and IEC 61784.

Transmission Rate [KBit/s]	Range per Segment [m]
9.6; 19.2; 45.45; 93.75	1200
187.5	1000
500	400
1500	200
3000; 6000; 12000	100

The values refer to cable type A with the following properties:

Impedance	135 to 165 $\Omega$
Capacity	$\leq 30$ pF/m
Loop resistance	$\leq 110$ $\Omega$ /km
Wire diameter	$> 0.64$ mm
Core cross-section	$> 0.34$ mm <sup>2</sup>

Table 3: Transmission rate and range for cable type A

##### 3.1.1 RS485 Transmission Technology

**RS485** transmission technology is simple and cost-effective and primarily used for tasks that require high transmission rates. Shielded, twisted pair copper cable with one conductor pair is used.

RS485 transmission technology is easy to use. No expert knowledge is required for installation of the cable. The bus structure allows addition or removal of stations or the step-by-step commissioning of the system without influencing other stations. Subsequent expansions (within defined limits) have no ef-

fect on stations already in operation.

One new option is the ability of RS485 to also operate in intrinsically safe areas (RS485-IS, see explanation at the end of this section).

#### Characteristics of RS485

Various **transmission rates** can be *selected* between 9.6 Kbit/s and 12 Mbit/s. One uniform speed is selected for all devices on the bus when commissioning the system. Up to 32 *stations* can be connected. The maximum permissible *line length* depends on the transmission rate. These and other properties are summarized in Table 4.

#### Installation instructions for RS485

##### Topology

All devices are connected in a bus structure (line). Up to 32 stations (masters or slaves) can be connected in a single segment. The beginning and end of each segment is fitted with an active *bus terminator* (Fig. 6). Both bus terminators have a permanent power supply to ensure error-free operation. The bus terminator is usually switched in the devices or in the connectors. If more than 32 stations are implemented or there is a need to expand the network area, *repeaters* must be used to link the individual bus segments.

##### Cables and Connectors

Different cable types (type designation A - D) for different applications are available on the market for connecting devices either to each other or to network elements (segment couplers, links and repeaters). When using RS485 transmission technology, PI recommends the use of *cable type A* (see data in Table 3).

"PROFIBUS" cables are offered by a wide range of manufacturers; PI particularly recommends the fast-connect system which, when used with a suitable cable and special stripping tool, allows fast, reliable and extremely simple wiring.

When connecting the stations, always ensure that the data lines are not reversed. Always use a shielded data line (type A is shielded) to ensure high interference immunity of the system against electromagnetic emissions. The shield should be grounded on both sides where possible and large-area shield clamps should be used for grounding to ensure good conductivity. Furthermore, always ensure that the data line is laid separately and, where possible, away from all power cables. Never use spur lines for transmission rates  $\geq 1.5$  Mbit/s.

Commercially available connectors support direct connection of the incoming and outgoing data cable in the connector. This eliminates the need for spur lines and the bus connector can be connected and disconnected to the bus at any time without interrupting data communications. The type of connector suitable for RS485 transmission technology depends on the degree of protection. A 9-pin D-Sub connector is primarily used for protection rating IP 20. For IP 65/67 there are three common alternatives:

- M12 circular connector in accordance with IEC 947-5-2
- Han-Brid connector in accordance with DESINA recommendation
- Siemens hybrid connector

The hybrid connector system also provides a version for the transmission of data using fiber optics and 24 V working voltage for peripherals over copper cable in a shared hybrid cable.

Problems with data transmission in PROFIBUS networks can usually be attributed to incorrect wiring or installation. These problems can often be solved using *bus test devices*, which are able to detect many typical wiring errors even before commissioning.

For a list of *suppliers* of the many different connectors, cables, repeaters, bus test devices mentioned here, please refer to the PROFIBUS online Product Catalog ([www.profibus.com](http://www.profibus.com)).

#### RS485-IS

There has been great demand among users to support the use of

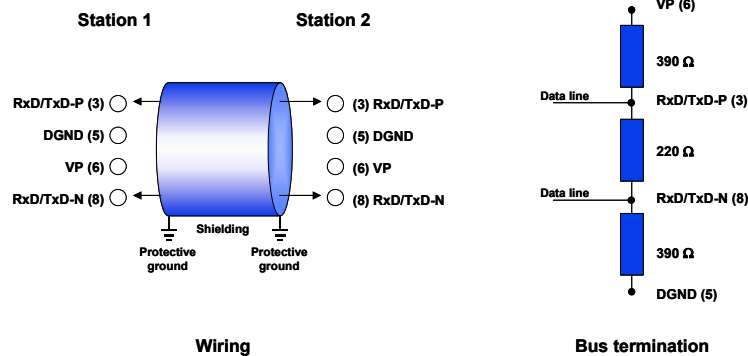


Fig. 6: Wiring and bus termination for RS485 transmission technology

RS485 with its fast transmission rates in intrinsically safe areas.

The PNO has addressed this task and worked out a guideline for the configuration of intrinsically safe RS485 solutions with simple device interchangeability.

The specification of the interface details the levels for current and voltage that must be adhered to by all stations in order to ensure safe functioning during operation. An electric circuit permits maximum currents at a specified voltage level. When connecting active sources, the sum of the currents of all stations must not exceed the

maximum permissible current.

An innovation of the RS485-IS concept is that, in contrast to the FISCO model that only has *one* intrinsically safe source, *all* stations now represent active sources. The continuing investigations of the testing agency lead us to expect that it will be possible to connect up to 32 stations to the intrinsically safe bus circuit.

### 3.1.2 Transmission in Accordance with MBP

The term MBP stands for transmission technology with the follow-

ing attributes

- "Manchester Coding (M)", and
- "Bus Powered", (BP).

This term replaces the previously common terms for intrinsically safe transmission "Physics in accordance with IEC 61158-2", "1158-2", etc. The reason for this change is that, in its definitive version, the IEC 61158-2 (physical layer) describes *several different* connection technologies, including MBP technology, not being therefore unambiguous.

MBP is *synchronous transmission with a defined transmission rate of 31.25 Kbit/s and Manchester coding*. This transmission technology is frequently used in process automation as it satisfies the key demands of the chemical and petrochemical industries for *intrinsic safety* and *bus power using two-wire technology*. The characteristics of this transmission technology are summarized in Table 4. This means that PROFIBUS can also be used in potentially explosive areas and be intrinsically safe.

	MBP	RS485	RS485-IS	Fiber Optic
Data transmission	Digital, bit-synchronous, Manchester encoding	Digital, differential signals according to RS485, NRZ	Digital, differential signals according to RS485, NRZ	Optical, digital, NRZ
Transmission rate	31.25 KBit/s	9.6 to 12,000 KBit/s	9.6 to 1,500 KBit/s	9.6 to 12,000 KBit/s
Data security	Preamble, error-protected, start/end delimiter	HD=4, Parity bit, start/end delimiter	HD=4, Parity bit, start/end delimiter	HD=4, Parity bit, start/end delimiter
Cable	Shielded, twisted pair copper	Shielded, twisted pair copper, cable type A	Shielded, twisted 4-wire, cable type A	Multimode glass fiber, singlemode glass fiber, PCF, plastic
Remote feeding	Optional available over signal wire	Available over additional wire	Available over additional wire	Available over hybrid line
Protection type	Intrinsic safety (EEx ia/ib)	None	Intrinsic safety (EEx ib)	None
Topology	Line and tree topology with termination; also in combination	Line topology with termination	Line topology with termination	Star and ring topology typical; line topology possible
Number of stations	Up to 32 stations per segment; total sum of max. 126 per network	Up to 32 stations per segment without repeater; up to 126 stations with repeater	Up to 32 stations per segment; up to 126 stations with repeater	Up to 126 stations per network
Number of repeaters	Max. 4 repeater	Max. 9 repeater with signal refreshing	Max. 9 repeater with signal refreshing	Unlimited with signal refreshing (time delay of signal)

Table 4: Transmission technologies (Physical Layer) at PROFIBUS



## Installation Instructions for MBP

### Connection technology

The intrinsically safe transmission technology MBP is usually limited to a specific segment (field devices in hazardous areas) of a plant, which are then linked to the RS485 segment (control system and engineering devices in the control room) via a *segment coupler* or *links* (Fig. 7).

**Segment couplers** are signal converters that modulate the RS485 signals to the MBP signal level and vice versa. They are transparent from the bus protocol standpoint.

In contrast, **links** have their own intrinsic intelligence. They map all the field devices connected to the MBP segment as a single slave in the RS485 segment. There is no limit to the transmission rate in the RS485 segment when using links, so that fast networks can also be implemented using field devices with MBP connection.

### Network Topologies with MBP

Tree or line structures (and any combination of the two) are network topologies supported by PROFIBUS with MBP transmission.

In a *line structure*, stations are connected to the trunk cable using tee adapters. The *tree topology* is comparable to the classic field installation method. The multi-core master cable is replaced by the two-wire bus master cable, the field distributor retains its function of connecting the field devices and detecting the bus terminator im-

pedance. When using a tree topology, all field devices connected to the fieldbus segment are wired in parallel in the field distributor. In all cases, the maximum permissible spur line lengths must be taken into account when calculating the overall line length. In intrinsically safe applications, a spur line has a max. permissible length of 30 m.

### Transmission Medium

A shielded two-wire cable is used as the transmission medium, see Fig. 6. The bus trunk cable has a passive line terminator at each end, which comprises an RC element connected in series with  $R = 100\ \Omega$  and  $C = 2\ \mu\text{F}$ . The bus terminator is already integrated in the segment coupler or link. When using MBP technology, incorrect connection of a field device (i.e. polarity reversal) has no effect on the functionality of the bus as these devices are usually fitted with an automatic polarity detection function.

### No. of Stations, Line Length

The number of stations that can be connected to a segment is limited to 32. However, this number may be further determined by the protection type selected and bus power (if any).

In intrinsically safe networks, both the maximum feed voltage and the maximum feed current are defined within strict limits. But the output of the supply unit is limited even for nonintrinsically safe networks.

As a rule of thumb for determining the max. line length, it suffices to calculate the power requirements of the connected field devices, and

to specify a supply unit and the line length for the selected cable type. The required current ( $=\Sigma$  power requirements) is derived from the sum of the basic currents of the field devices connected in the respective segment plus, where applicable, a reserve of 9 mA per segment for the operating current of the FDE (Fault Disconnection Electronics). The FDE prevents faulty devices permanently blocking the bus.

Joint operation of bus-powered and externally fed devices is permissible. Please note that externally fed devices also consume a basic current over the bus terminator, which must be taken into account accordingly when calculating the max. available feed current.

The FISCO model considerably simplifies the planning, installation and expansion of PROFIBUS networks in potentially explosive areas (see chapter 3.1.4).

### 3.1.3 Fiber Optic Transmission Technology

Some fieldbus application conditions place restrictions on wire-bound transmission technology, such as those in environments with very high electromagnetic interference or when particularly large distances need to be covered.

Fiber optic transmission over fiber optic conductors is suitable in such cases. The PROFIBUS guideline (2.022) for fiber optic transmission specifies the technology available for this purpose. When determining these specifications, great care was naturally taken to allow problem-free integration of existing PROFIBUS devices in a fiber optic network without the need to change the protocol behavior of PROFIBUS (layer 1). This ensures *backward compatibility with existing PROFIBUS installations*.

The supported *fiber optic types* are shown in Table 5. The transmission characteristics support not only *star* and *ring topology structures*, but also *line structures*.

In the simplest case, a fiber optic network is implemented using electrical/optical transformers that are connected to the device and the fiber optics over a RS485 interface. This allows you to switch between RS485 and fiber optic transmission

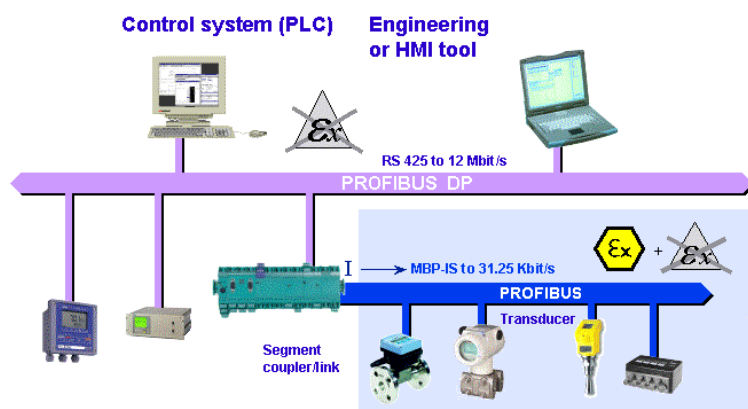


Fig. 7: Plant topology and bus powering of field devices using MBP transmission technology

within a plant, depending on the circumstances.

### 3.1.4 The FISCO model

The FISCO model (Fieldbus Intrinsically Safe Concept) considerably simplifies the planning, installation and expansion of PROFIBUS networks in potentially explosive areas.

This model was developed in Germany by the **PTB** (Physikalisch Technische Bundesanstalt - German Federal Technical Institute) and is now internationally recognized as the basic model for the operation of fieldbuses in potentially explosive areas.

The model is based on the specification that a network is intrinsically safe and requires no individual intrinsic safety calculations when the relevant four bus components (field devices, cables, segment couplers and bus terminators) fall within predefined limits with regard to voltage, current, output, inductance and capacity. The corresponding proof can be provided by certification of the components through authorized accreditation agencies, such as PTB (Germany) or UL (USA) and others.

If FISCO-approved devices are used, not only is it possible to operate more devices on a single line, but the devices can be replaced during runtime by devices of other manufacturers or the line can be expanded - all without the need for time-consuming calculations or system certification. So you can simply plug & play - even in hazardous areas! You merely need to ensure adherence to the aforementioned rules (see "Installation instructions for MBP) when selecting supply unit, line length and bus terminator.

Transmission according to MBP and the FISCO model is based on the following principles:

Fiber type	Core diameter [μm]	Range
Multimode glass fiber	62.5/125	2-3 km
Singlemode glass fiber	9/125	> 15 km
Plastic fiber	980/1000	< 80 m
HCS® fiber	200/230	approx. 500 m

Table 5: Characteristics of optical fibers

### Boundary conditions for the application of FISCO

- Only one power source permitted per segment
- All stations must be approved in accordance with FISCO
- The cable length must not exceed 1000 m (ignition protection class i, category a)/ 1900 m (ignition protection class i, category b)
- The cable must satisfy the following values:  
 $R' = 15 \dots 150 \Omega/\text{km}$   
 $L' = 0.4 \dots 1 \text{ mH}/\text{km}$   
 $C' = 80 \dots 200 \text{ nF}/\text{km}$
- All combinations of power supply unit and field devices must ensure that the permissible input variables of any of the field devices ( $U_i$ ,  $I_i$  and  $P_i$ ) must be above the, in case of a fault, maximum possible and approved output variables ( $U_0$ ,  $I_0$  and  $P_0$ ; in the US:  $V_{\text{max}}$ ,  $I_{\text{max}}$  and  $P_{\text{max}}$ ) of the relevant supply unit.

### User benefits of FISCO

- Plug & Play supported, even in hazardous areas
- No system certification
- Interchangeability of devices or expansion of plant without time-consuming calculations
- Maximization of the number of connected devices

- No power is fed to the bus when a station is sending.
- Each segment has only *one* source of power, the supply unit.
- Each field device consumes a constant basic current of at least 10 mA in steady state.
- The field devices act as a passive current sink.
- Passive line termination is implemented at both ends of the bus trunk line.
- Networks in line, tree and star topology are supported.

With bus power, the basic current of at least 10 mA per device serves to supply power to the field device. Communication signals are generated by the sending device, which modulates  $\pm 9$  mA to the basic current.

### 3.2 Communication Protocol DP

The communications protocol DP (Decentralized Peripherals) has been designed for *fast data exchange at field level*. This is where central programmable controllers, such as PLCs, PCs or process control systems, communicate with distributed field devices, such as I/O, drives, valves, transducers or analysis devices, over a fast serial connection. Data exchange with the distributed devices is primarily cyclic. The communication functions required for this are specified through the DP basic functions (version DP-V0). Geared towards the special demands of the various areas of application, these basic DP functions have been expanded step-by-step with special functions, so that DP is now available in three versions; DP-V0, DP-V1 and DP-V2, whereby each version has its own special key features (see Fig. 8). This breakdown into versions largely reflects the chronological sequence of specification work as a result of the ever-increasing demands of applications. Versions V0 and V1 contain both "characteristics" (*binding* for implementation) and options, while version V2 only specifies options.

The key contents of the three versions are as follows:

**DP-V0** provides the basic functionality of DP, including cyclic data exchange as well as station diagnosis, module diagnosis and channel-specific diagnosis.

**DP-V1** contains enhancements geared towards process automation, in particular acyclic data communication for parameter assignment, operation, visualization and alarm handling of intelligent field devices, parallel to cyclic user data communication. This permits online access to stations using engineering tools. In addition, DP-V1 defines alarms. Examples for different types of alarms are status alarm, update alarm and a manufacturer-specific alarm.

**DP-V2** contains further enhancements and is geared primarily towards the demands of drive technology. Due to additional functionalities, such as isochronous slave mode and slave-to-slave communication (DXB, Data eXchange Broadcast) etc., the DP-V2 can also be implemented as a drive bus for controlling fast movement sequences in drive axes.

The various versions of DP are specified in detail in the IEC 61158. The following explains the key characteristics.

### 3.2.1 Basic Functions DP-V0

The central controller (master)

- reads input information from the slaves cyclically and
- writes output information to the slaves cyclically.

The bus cycle time should be shorter than the program cycle time of the central automation system, which is approx. 10 ms for many applications. However, a faster data throughput alone is not enough for successful implementation of a bus system. Simple handling, good diagnosis capabilities and interference-proof transmission technology are also key factors. DP provides an optimum combination

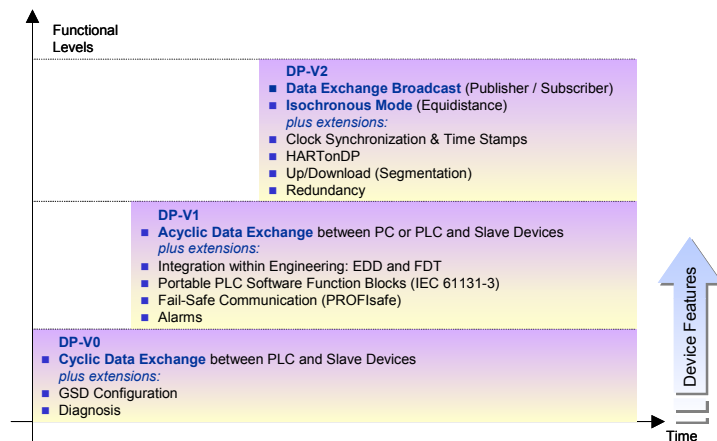


Fig. 8: Functionality of the PROFIBUS DP version with key features

of these characteristics (see summary in table 6).

### Transmission Speed

DP only requires approx. 1 ms at 12 Mbit/s for the transmission of 512 bits of input and 512 bits of output data distributed over 32 stations.

Fig. 9 shows typical DP transmission times, depending on the number of stations and the transmission rate. When using DP, input and output data are transmitted in a *single* message cycle. With DP, user data is transmitted using the **SRD Services** (Send and Receive Data Service) of layer 2.

### Diagnosis Functions

The comprehensive diagnosis functions of DP enable fast location of faults. The diagnosis messages are transmitted over the bus and collected at the master. These messages are divided into three levels:

#### Device-Specific Diagnosis

Messages on the general readiness for service of a station, such as "Overheating", "Undervoltage" or "Interface unclear".

#### Module-Related Diagnosis

These messages indicate whether a diagnosis is pending within a specific I/O subdomain of a station (for example 8-bit output module).

#### Channel-Related Diagnosis

These messages indicate the cause of a fault related to an individual input/output bit (channel), such as "Short-circuit at output".

## System Configuration and Device Types

DP supports implementation of both mono-master and multi-master systems. This affords a high degree of flexibility during system configuration. A maximum of 126 devices (masters or slaves) can be connected to a bus. The specifications for system configuration define the following:

- number of stations
- assignment of station addresses to the I/O addresses,
- data consistencies of I/O data,
- the format of diagnosis messages and
- the bus parameters used.

### Device Types

Each DP system is made up of 3 different device types.

#### DP Master Class 1 (DPM1)

This is a central controller that cyclically exchanges information with the distributed stations (slaves) at a specified message cycle. Typical DPM1 devices are programmable logic controllers (PLCs) or PCs. A DPM1 has active bus access with which it can read measurement data (inputs) of the field devices and write the setpoint values (outputs) of the actuators at fixed times. This continuously repeating cycle is the basis of the automation function.

### DP Master Class 2 (DPM2)

Devices of this type are engineering, configuration or operating devices. They are implemented during commissioning and for maintenance and diagnosis in order to configure connected devices, evaluate measured values and parameters and request the device status. A DPM2 does not have to be permanently connected to the bus system. The DPM2 also has active bus access.

### Slaves

A slave is a peripheral (I/O devices, drives, HMIs, valves, transducers, analysis devices), which reads in process information and/or uses output information to intervene in the process. There are also devices that solely process input information or output information. As far as communication is concerned, slaves are passive devices, they only respond to direct queries. This behavior is simple and cost-effective to implement (in the case of DP-V0 it is already completely included in the hardware).

In the case of **mono-master systems**, only *one* master is active on the bus during operation of the bus system. Figure 10 shows the system configuration of a mono-master system. The PLC is the central control component. The slaves are decentrally coupled to the PLC over the transmission medium. This system configuration enables the shortest bus cycle times.

In **multi-master operation** several masters are connected to one bus. They represent either independent subsystems, comprising one DPM1 and its assigned slaves, or additional configuration and diagnosis devices. The input and output images of the slaves can be read by all DP masters, while only one DP master (the DPM1 assigned during configuration) can write-access the outputs.

### System Behavior

In order to ensure a high degree of device interchangeability among devices of the same type, the *system behavior* of DP has also been standardized. This behavior is determined primarily by the operating state of the DPM1.

This can be controlled either locally or over the bus from the configura-

Bus access	<ul style="list-style-type: none"><li>• Token passing procedure between masters and data passing between masters and slaves</li><li>• Mono-master or multi-master system option</li><li>• Master and slave devices, max. 126 stations on one bus</li></ul>
Communication	<ul style="list-style-type: none"><li>• Peer-to-peer (user data communication) or multicast (control commands)</li><li>• Cyclic master-slave user data communication</li></ul>
Operating states	<ul style="list-style-type: none"><li>• Operate Cyclic transmission of input and output data</li><li>• Clear Inputs are read, outputs remain in fail-safe state</li><li>• Stop Diagnosis and parameter assignment, no user data transmission</li></ul>
Synchronization	<ul style="list-style-type: none"><li>• Control commands enable the synchronization of inputs and outputs</li><li>• Sync mode Outputs are synchronized</li><li>• Freeze mode Inputs are synchronized</li></ul>
Functionality	<ul style="list-style-type: none"><li>• Cyclic user data transfer between DP master and slave(s)</li><li>• Dynamic activation/deactivation of individual slaves; checking of slave configuration</li><li>• Powerful diagnosis functions, 3 levels of diagnosis messages</li><li>• Synchronization of inputs and/or outputs</li><li>• Optional address assignment for slaves over the bus</li><li>• Maximum 244 bytes of input/output data per slave</li></ul>
Protective functions	<ul style="list-style-type: none"><li>• Message transmission at Hamming Distance HD=4</li><li>• Watchdog control of DP slaves detects failure of assigned master</li><li>• Access protection for outputs of slaves</li><li>• Monitoring of user data communication with adjustable monitoring timer in master</li></ul>
Device types	<ul style="list-style-type: none"><li>• DP master class 1 (DPM1) for example central programmable controllers, such as PLCs, PCs.</li><li>• DP master class 2 (DPM2) for example engineering or diagnosis tools</li><li>• DP slave for example devices with binary or analog inputs/outputs, drives, valves</li></ul>

Table 6: Overview of DP-V0

tion device. There are three main states:

#### Stop

No data communication between the DPM1 and the slaves.

#### Clear

The DPM1 reads the input information of the slaves and keeps the outputs of the slaves in a fail-safe state ("0" output).

#### Operate

The DPM1 is in the data transfer phase. In cyclic data communica-

tion, inputs are read from the slaves and output information written to the slaves.

The DPM1 cyclically sends its status to all its assigned slaves at configurable intervals using a multicast command.

The reaction of the system to a fault during the data transfer phase of the DPM1, for example the failure of a slave, is determined by the "auto clear" configuration parameter.



If this parameter is set to *True*, the DPM1 switches the outputs of all assigned slaves to a fail-safe state the moment a slave is no longer ready for user data transmission. The DPM1 subsequently switches to the clear state.

If this parameter is set to *False*, the DPM1 remains in the operate state even in the event of a fault and the user can control the reaction of the system.

## Cyclic Data Communication between the DPM1 and the Slaves

Data communication between the DPM1 and its assigned slaves is automatically handled by the DPM1 in a defined, recurring sequence (see Fig. 11). The user defines the assignment of the slave(s) to the DPM1 when configuring the bus system. The user also defines which slaves are to be included/excluded in the cyclic user data communication.

Data communication between the DPM1 and the slaves is divided into three phases: parameterization, configuration and data transfer. Before the master includes a DP slave in the data transfer phase, a check is run during the parameterization and configuration phase to ensure that the configured setpoint configuration matches the actual device configuration. During this check, the device type, format and length information and the number of inputs and outputs must also correspond. This provides the user with reliable protection against parameterization errors. In addition to user data transfer, which is automatically executed by the DPM1, the user can also request that new parameterization data are sent to the slaves.

## Sync and freeze mode

In addition to the station-related user data communication, which is automatically handled by the DPM1, the master can also send control commands to all slaves or a group of slaves simultaneously. These control commands are transmitted as multicast commands and enable sync and freeze modes for *event-controlled synchronization* of the slaves.

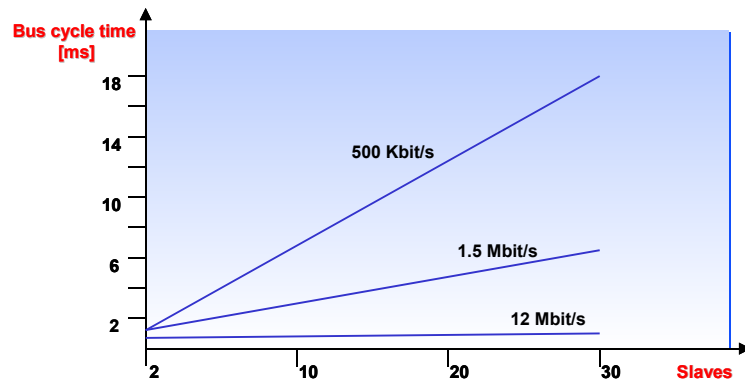


Fig. 9: Bus cycle times of a DP mono-master system. Boundary conditions: each slave has 2 bytes of input and output data

The slaves begin **sync mode** when they receive a sync command from the assigned master. The outputs of all addressed slaves are then frozen in their current state. During subsequent user data transmission, the output data are stored at the slave while the output states remain unchanged. The stored output data are not sent to the outputs until the next sync command is received. Sync mode is terminated with the "unsync" command.

In the same way, a freeze command causes the addressed slaves to enter **freeze mode**. In this mode, the states of the inputs are frozen at their current value. The input data are not updated again until the master sends the next freeze command. Freeze mode is terminated with the "unfreeze" command.

## Protective Mechanisms

For safety reasons, it is necessary to ensure that DP has effective protective functions against incorrect parameterization or failure of transmission equipment. For this purpose the DP master and the

slaves are fitted with monitoring mechanisms in the form of time monitors. The monitoring interval is defined during configuration.

### At the DP Master

The DPM1 uses a Data\_Control\_Timer to monitor the data communication of the slaves. A separate timer is used for each slave. The time monitor is tripped if no correct user data transfer is executed within the monitoring interval. In this case, the user is notified. If the automatic error handling (Auto\_Clear = True) is enabled, the DPM1 exits the operate state, switches the outputs of the assigned slaves to the fail-safe state and shifts to the clear mode.

### At the Slave

The slave uses the watchdog control to detect errors of the master or transmission. If no data communication with the master occurs within the watchdog control interval, the slave automatically switches its outputs to the fail-safe state.

In addition, access protection is required for the outputs of the slaves operating in multi-master systems. This ensures that only the author-

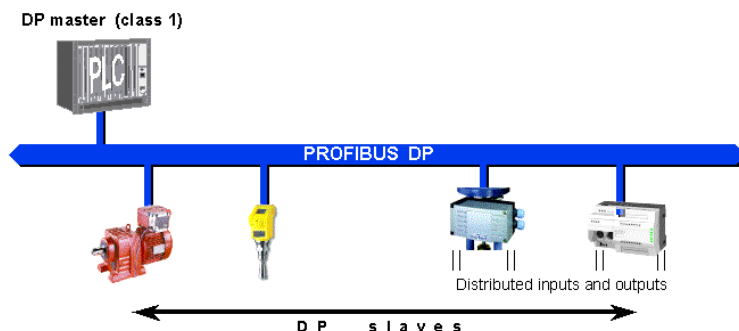


Fig. 10: PROFIBUS DP mono-master system

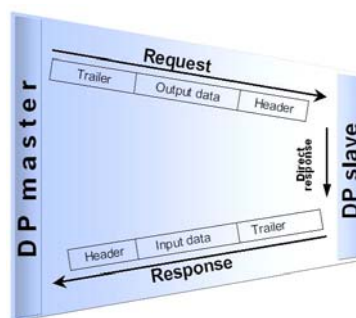


Fig. 11: Cyclic user data transmission in DP

ized master has direct access. For all other masters, the slaves provide an image of their inputs and that can be read without access rights.

### 3.2.2 Version DP-V1

#### Acyclic data communications

The key feature of version DP-V1 is the extended function for acyclic data communication. This forms the requirement for parameterization and calibration of the field devices over the bus during runtime and for the introduction of confirmed alarm messages. Transmission of acyclic data is executed parallel to cyclic data communication, but with lower priority. Figure 13 shows some sample communication sequences. The master class 1 has the token and is able to send messages to or retrieve them from slave 1, then slave 2, etc. in a fixed sequence until it reaches the last slave of the current list (MS0 channel); it then passes on the token to the master class 2. This master can then use the remaining available time ("gap") of the programmed cycle to set up an acyclic connection to *any* slave (in Figure 13 slave 3) to exchange records (MS2 channel); at the end of the current cycle time it returns the token to the master class 1. The acyclic exchange of records can last for several scan cycles or their "gaps"; at the end, the master class 2 uses the gap to clear the connection. Similarly, as well as the master class 2, the master class 1 can also execute acyclic data exchange with slaves (MS1 channel).

Additional available services are shown in Table 7.

#### Extended diagnosis

As a further function, the device-specific diagnosis of the DP-V1 have been enhanced and divided

into the categories alarms and status messages (see Fig. 12).

### 3.2.3 Version DP-V2

#### Slave-to-Slave Communications (DXB)

This function enables direct and time-saving communication between slaves using broadcast communication without the detour over a master. In this case the slaves act as "publisher", i.e., the slave response does not go through the coordinating master, but directly to other slaves embedded in the sequence, the so-called "subscribers" (see Fig. 15). This enables slaves to directly read data from other slaves and use them as their own input. This opens up the possibility of completely new applications; it also reduces response times on the bus by up to 90 %.

#### Isochronous Mode

This function enables clock synchronous control in masters and slaves, irrespective of the bus load. The function enables highly precise positioning processes with clock deviations of less than one microsecond. All participating device cycles are synchronized to the bus master cycle through a "global control" broadcast message. A special sign of life (consecutive number) allows monitoring of the synchronization. Fig. 14 shows the available times for data exchange (DX, green), access of a master class 2 (yellow) and reserve (white). The red arrow identifies the route from

the actual data acquisition ( $T_1$ ) over control ( $R_x$ ) through to the setpoint data output ( $T_0$ ), which usually extends over two bus cycles.

#### Clock Control

This function (a real-time master sends time stamps to all slaves over the new connectionless MS3 services, designed for this purpose) synchronizes all stations to a system time with a deviation of less than one millisecond. This allows the precise tracking of events. This is particularly useful for the acquisition of timing functions in networks with numerous masters. This facilitates the diagnosis of faults as well as the chronological planning of events.

#### Upload and Download (Load Region)

This function allows the loading of any size of data area in a field device with few commands. This enables, for example, programs to be updated or devices replaced without the need for manual loading processes.

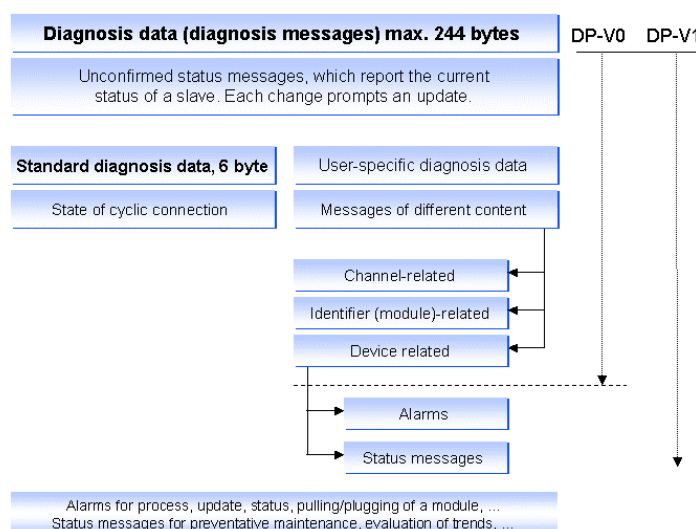


Fig. 12: Configuration of diagnosis messages in DP-V0 and DP-V1

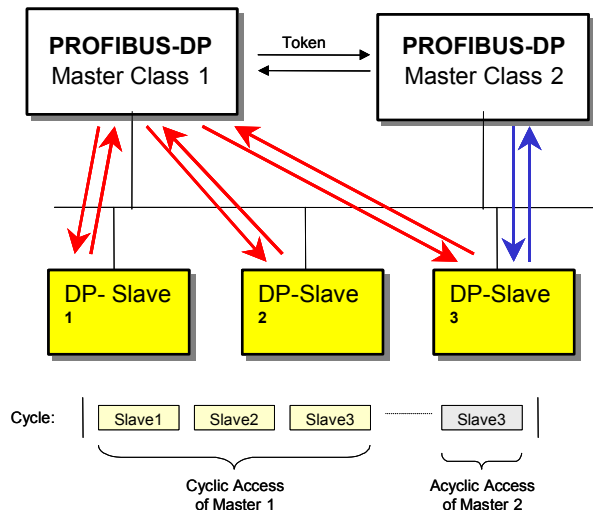


Fig. 13: Cyclic and acyclic communication in DP-V1

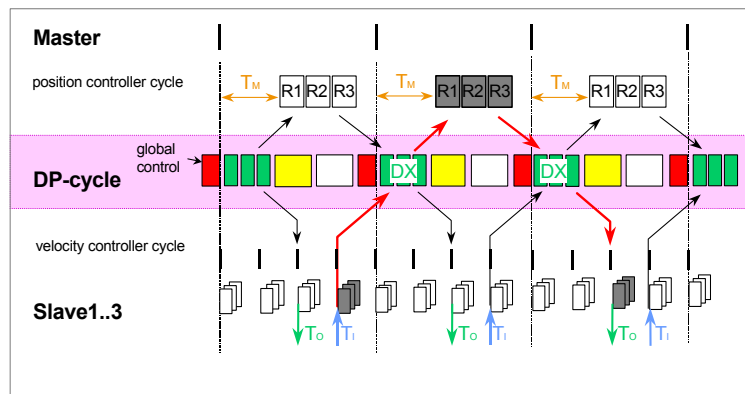


Fig. 14: Isochronous mode

### Function Invocation

Function Invocation services allow to control (start, stop, return, re-start) of programs or call of functions (for example acquisition of measured values) in a DP slave.

### 3.2.4 Addressing with Slot and Index

When addressing data, PROFIBUS assumes that the physical structure of the slaves is *modular* or can be structured internally in logical functional units, so-called *modules*. This model is also used in the basic DP functions for cyclic data communication, where each module has a constant number of input/output bytes that are transmitted in a fixed position in the user data telegram. The addressing procedure is based on identifiers, which characterize a module type as input, output or a combination of both. All identifiers combined produce the configuration of a slave,

which is also checked by the DPM1 when the system starts up.

The acyclic data communication is also based on this model. All data

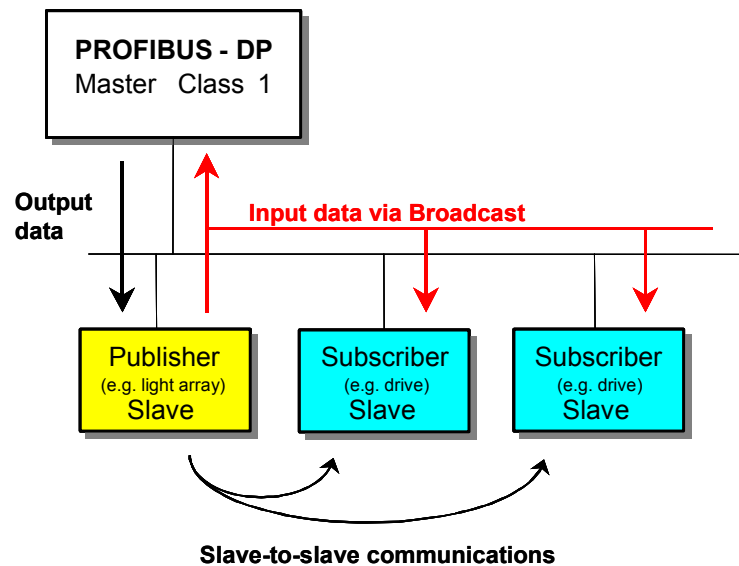


Fig. 15: Slave-slave data exchange

blocks enabled for read/write access are also regarded as assigned to the modules and can be addressed using slot number and index. The **slot number** addresses the module and the **index** addresses the data blocks assigned to a module. Each data block can be up to 244 bytes (see Fig. 16). In the case of modular devices, the slot number is assigned to the modules. The modules begin at 1 and are numbered in ascending contiguous sequence. The slot number 0 is for the device itself.

Compact devices are regarded as a unit of virtual modules. These can also be addressed with slot number and index.

Through the length specification in the read/write request it is also possible to read/write parts of a data block. When access to the data block was successful, the slave sends a positive read/write response or may otherwise be able to classify the problem by means of its negative response.

### Services for Acyclic Data Communication between the DPM1 and Slaves

Read	The master reads a data block from the slave
Write	The master writes a data block to the slave
Alarm	An alarm is transmitted from the slave to the master, which explicitly acknowledges receipt. The slave can only send a new alarm message after it has received this acknowledgment; this prevents any alarms being overwritten.
Alarm_Acknowledge	The master acknowledges receipt of an alarm to the slave
Status	A status message is transmitted from the slave to the master. There is no acknowledgment.

Data transmission is connection-oriented over a MS1 connection. This is set up by the DPM1 and is closely linked to the connection for cyclic data communication. It can be used by the master that has parameterized and configured the respective slave.

### Services for Acyclic Data Communication between the DPM2 and Slaves

Initiate	Setup and termination of a connection for acyclic data communication between the DPM2 and the slave
Abort	
Read	The master reads a data block from the slave
Write	The master writes a data block to the slave
Data_Transport	The master can write application-specific data (specified in profiles) acyclically to the slave and, if required, read data from the slave in the same cycle.

Data transmission is connection-oriented over a MS2 connection. This is set up before the start of the acyclic data communication by the DPM2 using the Initiate service. The connection is then available for Read, Write and Data\_Transport services. The connection is terminated correspondingly. A slave can maintain several active MS2 connections simultaneously. However, the number of connections is limited by the resources available in the respective slave.

Table 7: Services for acyclic data communication

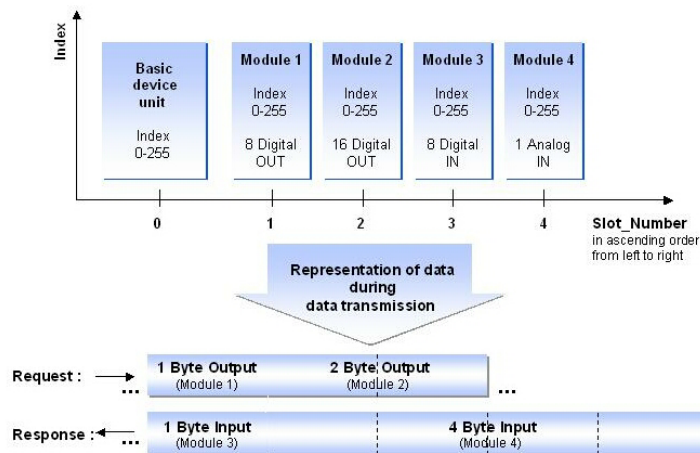


Fig. 16: Addressing with slot and index



## 4. General Application Profiles

**General application profiles** describe functions and characteristics that relate to more than just one application. They can also be used in conjunction with *specific* application profiles.

### 4.1 PROFIsafe

For considerable time, the distributed fieldbus technology for factory and process automation was subject to the restriction that safety tasks could only be solved using conventional technology in a second layer or distributed over special buses. With PROFIsafe, PROFIBUS has created a comprehensive, open solution for safety-relevant applications that satisfies most known safety criteria.

PROFIsafe defines how fail-safe devices (emergency stop pushbuttons, light arrays, overfill cutouts, etc.) can communicate over PROFIBUS with fail-safe controllers so safely that they can be used for safety-related automation tasks up to KAT4 compliant with EN954, AK6 or **SIL3** (Safety Integrity Level). It implements safe communications over a profile, i.e. over a special format of user data and a special protocol.

The specification has been jointly drawn up by manufacturers, users, standardization committees and inspectorates (TÜV, BIA). It is based on the relevant standards, primarily the IEC 61508, which address the concerns of software development in particular.

PROFIsafe takes into account a number of error possibilities that can occur in serial bus communications, such as the delay, loss or repetition of data, incorrect sequences, addressing or corrupt data.

There are a range of remedial measures, the following of which have been selected for PROFIsafe:

- Consecutive numbering of safety telegrams.

- Timeout for incoming message frames and their acknowledgment.
- Identifier between sender and receiver ("password").
- Additional data security (Cyclic Redundancy Check, **CRC**).

By skillfully combining these remedial measures in connection with a patented "SIL monitor" (monitoring of the frequency of failed messages) PROFIsafe achieves safety classes up to SIL 3 and beyond.

PROFIsafe is a single-channel *software solution*, which is implemented in the devices as an additional layer "above" layer 7 (see Fig. 17); the standard PROFIBUS components, such as lines, ASICs or protocols, remain unchanged. This ensures redundancy mode and retrofit capability.

Devices with the PROFIsafe profile can be operated in coexistence with standard devices without restriction on the same cable.

PROFIsafe uses acyclic communication and can be used with RS485, fiber optic or MBP transmission technology. This ensures both fast response times (important for the manufacturing industry) and intrinsically safe operation (important for process automation).

In process technology, it is only necessary to provide and prepare *one* standard device type for fail-safe or normal operation, as the fail-safe functionality can be configured during application (SIL2 for operational reliability).

As a generic software driver, PROFIsafe is available for a wide range of development and runtime environments. The specification

can be found in the document "PROFIsafe, Profile for Safety Technology", Order No. 3.092.

### 4.2 HART on PROFIBUS DP

In view of the large number of HART devices installed in the field, the integration of these devices in existing or new PROFIBUS systems is of key importance to most users.

The PROFIBUS "HART" specification offers an open solution for this problem. It includes the benefits of the PROFIBUS communication mechanisms without any changes required to the PROFIBUS protocol and services, the PROFIBUS **PDU**s (Protocol Data Units) or the state machines and functional characteristics.

This specification defines a profile of PROFIBUS that is implemented in the master and slave above layer 7, thus enabling mapping of the HART client-master-server model on PROFIBUS. The cooperation of the HART Foundation on the specification work ensures complete conformity with the HART specifications.

The HART-client application is integrated in a PROFIBUS master and the HART master in a PROFIBUS slave (see Fig. 19), whereby the latter serves as a multiplexer and handles communication to the HART devices.

For the transmission of HART messages, a communication channel has been defined that operates independently of the MS1 and MS2 connections. An **HMD** (HART Master Device) can support several clients. The number of clients depends on the implementation.

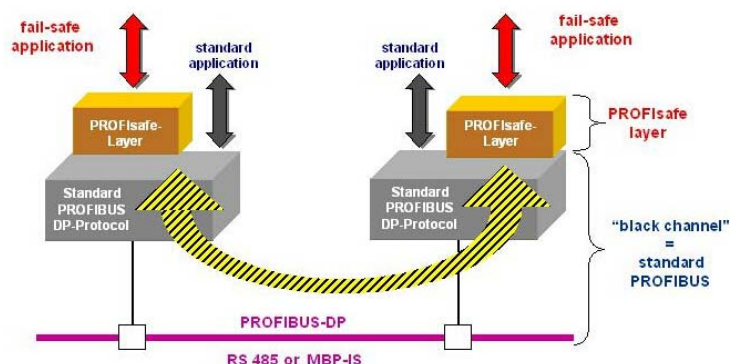


Fig. 17: Fail-safe mode with PROFIsafe

HART devices can be connected with the HMD to PROFIBUS over different components (PROFIBUS Guideline "PROFIBUS Profile for HART" Order No. 3.102).

### 4.3 Time Stamp

When recording timing functions in networks, particularly those such as diagnosis or fault location, it is useful to be able to provide certain events and actions with a time stamp, which enables precise time assignment.

For this purpose, PROFIBUS offers the *time stamp* profile. Precondition is clock control in the slaves through a clock master over MS3 services. An event can be given a precise system time stamp and read out accordingly. A concept of graded messages is used. The message types are summarized

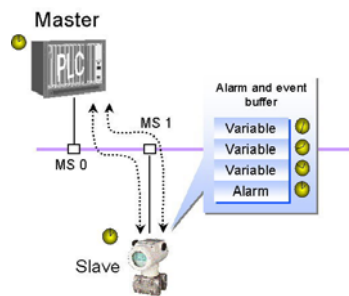


Fig. 18: Time stamp and alarm messages

under the term "*Alerts*" and are divided into high-priority "alarms" (these transmit a diagnosis message) and low-priority "events". In both cases, the master acyclically reads (using the MS1 services) the time-stamped process values and alarm messages from the alarm and event buffer of the field device (see Fig. 18). Please refer to the corresponding document, the PROFIBUS Guideline "Time Stamp", Order No. 2.192.

### 4.4 Slave Redundancy

The installation of field devices with redundant communication behavior is desired in many applications. For this reason, PROFIBUS has drawn up the specification for a *slave-redundancy mechanism* that describes the following device characteristics (see Fig. 20):

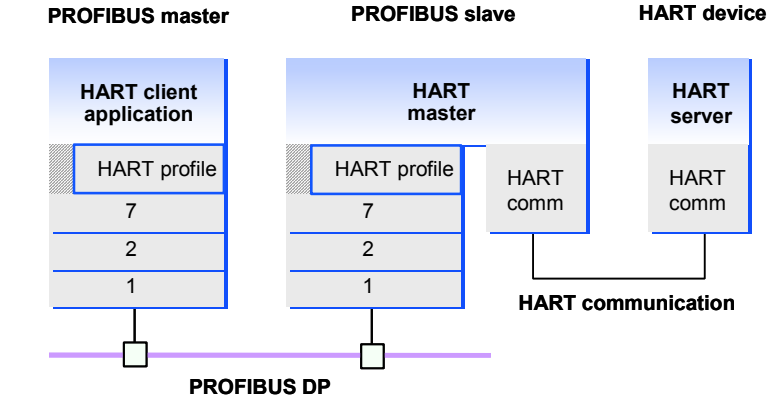


Fig. 19: Integration of HART devices into PROFIBUS DP

- Slave devices contain two different PROFIBUS interfaces that are called *primary* and *backup* (slave interface). These may be either in a *single* device or distributed over *two* devices.
- The devices are equipped with two independent protocol stacks with a special *redundancy expansion*.
- A **redundancy communication (RedCom)** runs between the protocol stacks, i.e. within a device or between two devices, that is independent of PROFIBUS and whose performance capability is largely determined by the redundancy reversing times.
- No additional configuration of the backup slave required, thus no need for complex tools.
- Complete monitoring of both slave parts possible.
- The slave device has no influence on the bus load and therefore on the dynamic response of PROFIBUS.

The redundancy of PROFIBUS slave devices provides high availability, short reversing times, no data loss and ensures fault tolerance. Please refer to the corresponding document, the PROFIBUS Guideline "Specification Slave Redundancy", Order No. 2.212.

In normal mode, communications are sent exclusively over the primary slave; only this slave is configured, it also sends the diagnosis data of the backup slave. In the event that the primary slave fails the backup slave takes over its functions, either because it has detected the failure itself or because it was requested to do so by the master. In addition, the master monitors all slaves and sends a diagnosis message as soon as the backup slave fails and there is no further redundancy.

A redundant slave device can be operated on one PROFIBUS line or, in the event of an additional line redundancy, on two PROFIBUS lines. The advantages of this redundancy solution for the user are as follows:

- Only one device version required to implement different redundancy structures.
- Master, line and slave redundancy are available independently of one another.

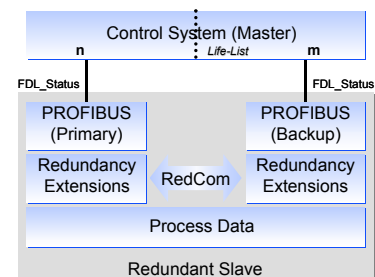


Fig. 20: Slave redundancy in PROFIBUS

## 5. Specific Application Profiles

PROFIBUS stands out from other fieldbus systems primarily due to the extraordinary breadth of application options. The PROFIBUS concept has set new standards. Not only has it developed specific profiles that take into account key industry-specific user demands - it has also successfully united all key aspects across all applications in a standardized and open fieldbus system, thus ensuring full protection of existing investment.

Table 8 shows all current specific PROFIBUS application profiles as well as those pending.

### 5.1 PROFIdrive

The PROFIdrive profile defines device behavior and the access procedure to drive data for electric drives on PROFIBUS, from simple frequency converters through to highly dynamic servo-controls.

The integration of drives in automa-

tion solutions is highly dependent on the task of the drive. For this reason, PROFIdrive defines six application classes, which cover the majority of applications.

With **standard drives (class 1)**, the drive is controlled by means of a main setpoint value (for example rotational speed), whereby the speed control is carried out in the drive controller.

In the case of **standard drives with technological function (class 2)**, the automation process is broken down into several subprocesses and some of the automation functions are shifted from the central programmable controller to the drive controllers. PROFIBUS serves as the technology interface in this case.

Slave-to-slave communication between the individual drive controllers is a requirement for this solution.

**The positioning drive (class 3)** integrates an additional position controller in the drive, thus covering an extremely broad spectrum of applications (for example the twist-

ing on and off of bottle tops). The positioning tasks are passed to the drive controller over PROFIBUS and started.

The **central motion control (classes 4 and 5)** enables the coordinated motion sequence of multiple drives. The motion is primarily controlled over a central numeric control (CNC). PROFIBUS serves to close the position control loop as well as synchronize the clock (Fig. 21). The position control concept (Dynamic Servo Control) of this solution also supports extremely sophisticated applications with linear motors.

**Distributed automation** by means of clocked processes and electronic shafts (**class 6**) can be implemented using slave-to-slave communication and isochronous slaves. Sample applications include "electrical gears", "curve discs" and "angular synchronous processes".

PROFIdrive defines a device model as functional modules that operate together internally and which reflect the intelligence of the drive system. These modules are assigned ob-

Designation	Profile contents	Current status of PNO guideline
<b>PROFIdrive</b>	The profile specifies the behavior of devices and the access procedure to data for variable-speed electrical drives on PROFIBUS.	V2 3.072  V3 3.172
<b>PA devices</b>	The profile specifies the characteristics of devices of process engineering in process automation on PROFIBUS.	V3.0 3.042
<b>Robots/NC</b>	The profile describes how handling and assembly robots are controlled over PROFIBUS.	V1.0 3.052
<b>Panel devices</b>	The profile describes the interfacing of simple human machine interface devices (HMI) to higher-level automation components.	V1.0D 3.082
<b>Encoders</b>	The profile describes the interfacing of rotary, angle and linear encoders with single-turn or multi-turn resolution.	V1.1 3.062
<b>Fluid power</b>	The profile describes the control of hydraulic drives over PROFIBUS. In cooperation with VDMA.	V1.5 3.112
<b>SEMI</b>	The profile describes characteristics of devices for semiconductor manufacture on PROFIBUS (SEMI standard).	3.152
<b>Low-voltage switchgear</b>	The profile defines data exchange for low-voltage switchgear (switch-disconnectors, motor starters, etc.) on PROFIBUS DP.	3.122
<b>Dosing/weighing</b>	The profile describes the implementation of weighing and dosage systems on PROFIBUS DP.	3.162
<b>Ident systems</b>	The profile describes the communications between devices for identification purposes (bar codes, transponders).	3.142
<b>Liquid pumps</b>	The profile defines the implementation of liquid pumps on PROFIBUS DP. In cooperation with VDMA.	3.172
<b>Remote I/O for PA devices</b>	Due to their special place in bus operations, a different device model and data types are applied to the remote I/Os compared to the PROFIBUS PA devices.	3.132

Table 8: The PROFIBUS specific application profiles

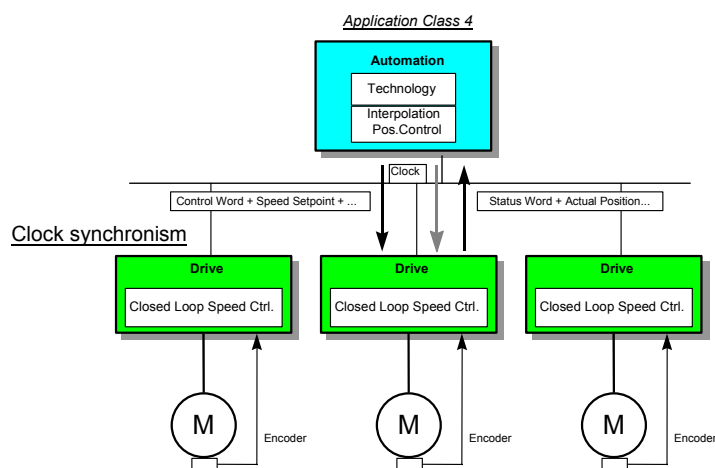


Fig. 21: PROFIdrive, positioning with central interpolation and position control

jects that are described in the profile and defined with regard to their functions. The overall functionality of a drive is described by the sum of its parameters.

In contrast to other drive profiles, PROFIdrive only defines the access mechanisms to the parameters and a subset of approx. 30 *profile parameters*, which include fault buffers, drive controllers, device identification, etc.

All other parameters (which may number more than 1,000 in complex devices) are *manufacturer-specific*, which provide drive manufacturers great flexibility when implementing control functions. The elements of a parameter are accessed acyclic over the DP-V1 parameter channel.

PROFIdrive V3 uses the version DP-V2 as its communications protocol with its innovative slave-to-slave communication and isochronous mode, see Chapter 3.2.

Both application profiles are available on the Internet: "Profiles for variable speed drives", V2, Order-No.: 3.072; "PROFIdrive Profile Drive Technology", V3, Order-No.: 3.172.

## 5.2 PA Devices

Modern process devices are intrinsically intelligent and can execute part of the information processing or even the overall functionality in automation systems. The PA Devices profile defines all functions and parameters for different classes of process devices that are

typical for signal flow - from process sensor signals through to the preprocessed process value which is read out at the control system together with a measured value status. The various steps of information processing (signal chain) and the status forming process are shown in Fig. 25.

The PA devices profile is documented in a *general requirement part* containing the currently valid specifications for all device types and in *device data sheets* containing the agreed specifications for specific device classes. The PA device profile is available in version 3.0 and contains device data sheets for the following:

- Pressure and differential pressure
- Level, temperature and flow rate
- Analog and digital inputs and outputs
- Valves and actuators
- Analyzers

### The Block Model

In process engineering it is common to use *blocks* to describe the characteristics and functions of a measuring point or manipulating point at a certain control point and to represent an automation application through a combination of these types of blocks. The specification of PA devices uses this function block model to represent functional sequences as shown in Fig. 22.

The following *three block types* are used:

### Physical Block (PB)

A PB contains the characteristic data of a device, such as device name, manufacturer, version and serial number, etc. There can only be one physical block in each device.

### Transducer Block (TB)

A TB contains all the data required for processing an unconditioned signal delivered from a sensor for passing on to a function block. If no processing is required, the TB can be omitted.

Multifunctional devices with two or more sensors have a corresponding number of TBs.

### Function Block (FB)

An FB contains all data for final processing of a measured value prior to transmission to the control system, or on the other hand, for processing of a setting before the setting process.

The following function blocks are available:

### Analog Input Block (AI)

An AI delivers the measured value from the sensor/TB to the control system.

### Analog Output Block (AO)

An AO provides the device with the value specified by the control system.

### Digital Input (DI)

A DI provides the control system with a digital value from the device.

### Digital Output (DO)

A DO provides the device with the value specified by the control system.

The blocks are implemented by the manufacturers as software in the field devices and, taken as a whole, represent the functionality of the device. As a rule, several blocks work together in an application, see Fig. 22, which shows a simplified block structure of a multifunctional field device.

The configuration corresponds to the division of a signal chain in two subprocesses:

The functionality of the first subprocess "measuring/actuating principle" (Fig. 25- calibration, linearization, scaling) is in the **transducer blocks**, the functionality of the second subprocess "preprocessing measured val-



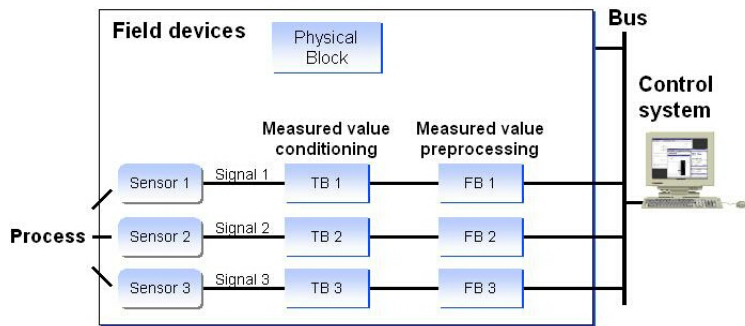


Fig. 22: Block structure of a field device (with multifunctionality)

ues/postprocessing settings" (Fig. 21- filter, limit value control, fail-safe behavior, operating mode selection) is in the **function blocks**.

### Specifications in the PA Device Profile

It is only possible to show a selection of the specifications in brief. For further details, please refer to the specification or the relevant literature, for example "PROFIBUS PA" (Ch. Diedrich/ Th. Bange-mann, Oldenbourg-Industrie-verlag).

### Illustration of the Signal Chain

The profile PA Devices specifies the functions and parameters that are related to each step of the signal chain, as shown in Fig. 25. As an example, Fig. 23 and Table 9 provide details of the step "calibration" and Fig. 24 shows the step "limit-value check".

### Addressing Parameters

Blocks are determined by means of their start address and parameters through a relative index within the block; as a rule, these can be freely selected by the device manufacturer. For access to the parameters (for example using an operator tool) the device-specific block structures are stored in the directory of the device.

### Batch Parameter Sets

For implementation of field devices in batch processes, the profile allows storage of several parameter sets even during the commissioning phase. The current batch process is then switched to the assigned parameter set during run-time.

### Modular Devices

With PROFIBUS a distinction is made between compact and modular devices, whereby a function

block is a "module" in this context. The PA Device profile offers a selection of function blocks for this purpose. Devices with a configured modularity are described as multi-variable devices.

### Devices with Several Process Variables

Process devices increasingly offer several process variables, for example using several sensors or in the form of derived variables. This is taken into account in the transducer blocks of the profile by differentiating between **Primary Value (PV)** and **Secondary Value (SV)**.

### Limit-Value Check

Part of the information processing transferred to the device is the limit-value check. For this purpose, PA Devices offers corresponding mechanisms for signalling when

warning/alarm limits are exceeded or fallen below (see Fig. 24).

### Value Status

A value status information item is added to the measured value, which delivers a statement of the quality of the measured value. There are three quality levels *bad*, *uncertain* and *good* and additional information is provided on a sub-status that is assigned to each quality level.

### Fail-Safe Behavior

The PA Device profile also provides fail-safe characteristics. If a fault has occurred in the measuring chain, the device output is set to a user-definable value. Users can select between three different fail-safe behavior types.

Please refer to the relevant document, the PROFIBUS Guideline "Profile for Process Control Devices", Order No. 3.042.

### 5.3 Fluid Power

This profile describes data exchange formats and parameters for proportional valves, hydrostatic pumps and drives and is based closely on the PROFIdrive definitions. Either a parameter channel on DP-V0 or acyclic communication over DP-V1 are used for supplying device parameters.

Parameter	Parameter description
LEVEL_HI	Range of measured filling level
LEVEL_LO	
CAL_POINT_HI	Section from the sensor measuring range with which the level range is mapped.
CAL_POINT_LO	

Table 9: Parameters for the calibration function

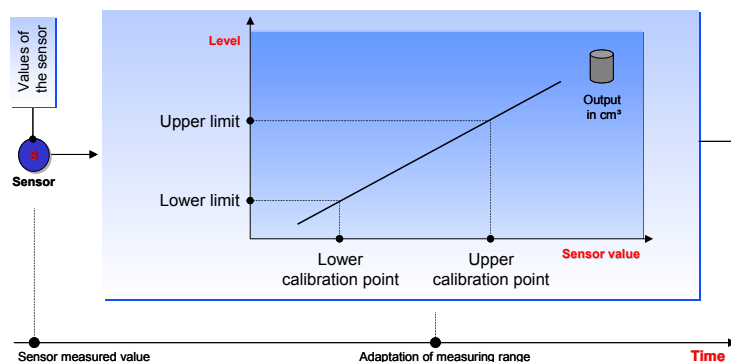


Fig. 23: Specification of the calibration function

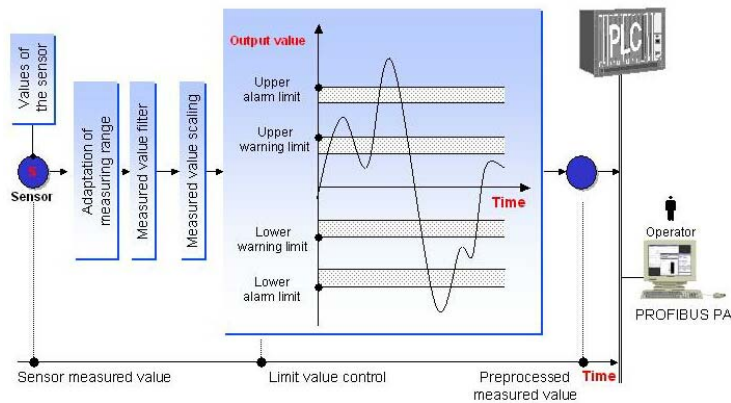


Fig. 24: Specification of the limit-value check function

Please refer to the corresponding document, the PROFIBUS Guideline "Profile Fluid Power Technology", Order No. 3.112.

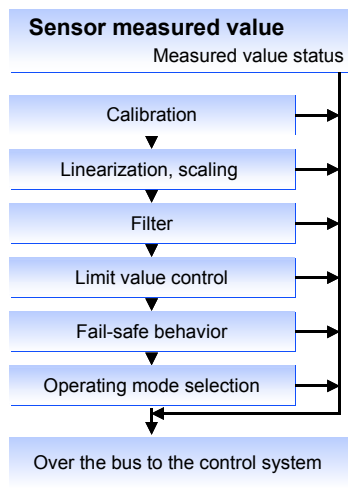


Fig. 25: Signal chain in the PA device profil

## 5.4 SEMI Devices

Some kind of devices used in process automation are, together with others, also applied in semiconductor manufacturing, such as vacuum pumps or flow meters.

The organization "Semiconductor Equipment and Materials International" did already specify a branch-specific device standard (SECS, Semiconductor Equipment Communication Standard) to which the PROFIBUS Application Profile SEMI is compatible.

SEMI is structured in 4 parts (General Definitions, Massflow Controllers, Vacuum Pressure Gauges and Vacuum Pumps).

## 5.5 Ident Systems

Ident systems is a profile for barcode readers and transponder systems. These are primarily intended for extensive use with the DP-V1 functionality. While the cyclic data transmission channel is used for small data volumes to transfer status/control information, the acyclic channel serves the transmission of large data volumes that result from the information in the barcode reader or transponder. The definition of standard function blocks has facilitated the use of these systems and paves the way for the application of open solutions on completion of international standards, such as ISO/IEC 15962 and ISO/IEC18000.

## 5.6 Remote I/O for PA

Due to their largely (fine) modular design, remote I/O devices are difficult to bring in line with the "ideal" PA Device model. For this reason, they have a special place in the field of distributed process automation. Furthermore, economic sensitivity also strongly influences the selected device configurations (modules, blocks, ...), resources (memory, records, ...) and functions (for example acyclic access). For this reason a simplified device model has been defined and the quantity framework restricted. The aim is to offer maximum support on the basis of cyclically exchanged data formats.

## 6. System Profiles

**Profiles** in automation technology define specific characteristics and behavior for devices and systems so that these are uniquely characterized (in classes or families) and are vendor-independent, thus supporting device interoperability and interchangeability on a bus.

**Master Profiles for PROFIBUS** describe classes of controller, each of which support a specific "subset" of all the possible master functionalities, such as

- Cyclic communications
- Acyclic communications
- Diagnosis, alarm handling
- Clock control
- Slave-to-slave communication, isochronous mode
- Safety

**System Profiles for PROFIBUS** go a step further and describe classes of systems including the master functionality, the possible functionality of *Standard Program Interfaces* (FB in accordance with IEC 61131-3, safety layer and FDT) and *integration options* (GSD, EDD and DTM). Fig. 26 shows the standard platforms available today.

In the PROFIBUS system, the master and system profiles provide the much needed counterpart to the application profiles (Fig. 27):

- Master and system profiles describe specific system pa-

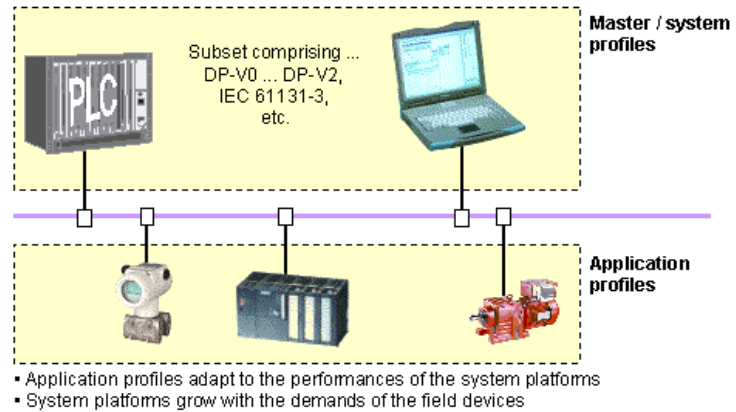


Fig. 27: System and application profiles (in correlation)

rameters that are made available to the field devices,

- application profiles require specific system parameters in order to simplify their defined characteristics.

By using these profiles the *device manufacturers* focus on existing or specified system profiles and the *system manufacturers* can provide the platforms required by the existing or specified device application profiles.

PROFIBUS has realized a number of system profiles based on tried and tested applications in the field, (see Fig. 26). These are expected to be stipulated in specifications in the near future and extended by further profiles in keeping with future demands.

### Standardized Function Blocks (Communication Function Blocks)

To realize manufacturer independent system profiles, it is necessary to specify, additionally to the already existing *communications* platform, an *Application Programmer's Interface* (API, Fig. 27), using standardized function blocks.

While application programmers can usually access cyclic communication data (MS0 channel) over the process image of a control system, in the past there was no system-neutral program interface for acyclic data. In view of the wide range of manufacturers and devices, standards are needed to be established in this area to enable integration of different field devices without specific communication knowledge in the application programs of different control systems. For this purpose, the PNO has now specified its guideline "Communication and Proxy Function Blocks according to IEC 61138-3". This guideline specifies function blocks in a "combinations of standards" that are based on the widely used standard IEC 61131-3 (programming languages) and also use the PROFIBUS-defined communication services of the IEC 61158.

The guideline defines communications blocks for Master Classes 1 and 2 as well as slaves and several auxiliary functions. The technological functionality of a field device can be addressed under a compact identification, which is used consistently by all blocks. All blocks also have a common concept for displaying errors with coding in accordance with IEC 61158-6.

The PLC manufacturers of the corresponding system classes/profiles

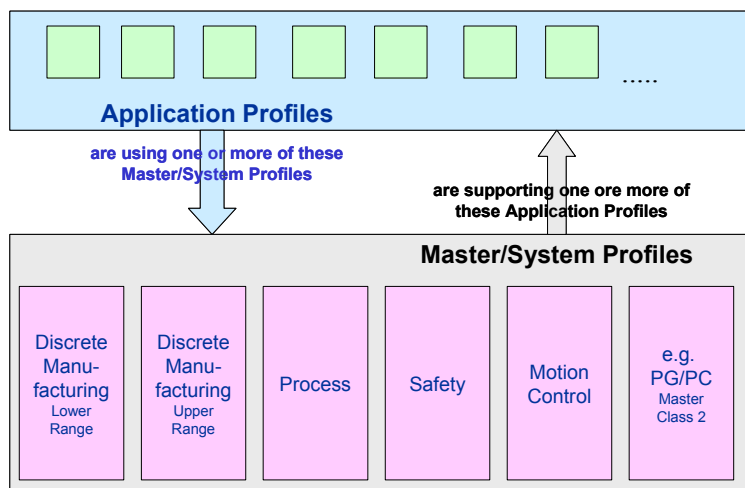


Fig. 26: Master/system profiles for PROFIBUS

offer these standard communication blocks ("Comm-FBs") in PLC-specific "IEC libraries". The *field device manufacturers* can respond by creating uniform proxy function blocks, which can be used with all control systems.

### Application Programmer's Interface (API)

In order to make it as easy as possible for application programmers to use the communication services, blocks or function calls are made available in the standard programming language libraries. Together with the FDT interface, the PROFIBUS "Comm-FBs" expand the Application Programmer's Interface as shown in Fig. 28.

### Proxy Function Blocks

Proxy function blocks represent a technological device function by providing all the necessary input and output parameters at the block interface. These proxy function blocks are usually created once by the field device manufacturers and can be implemented in the control systems of the relevant system classes/profiles without any special adjustment (see Fig. 29).

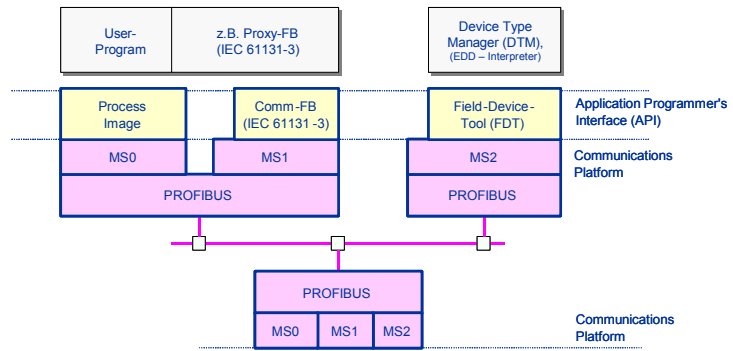


Fig. 28: Application Programmer's Interface, API

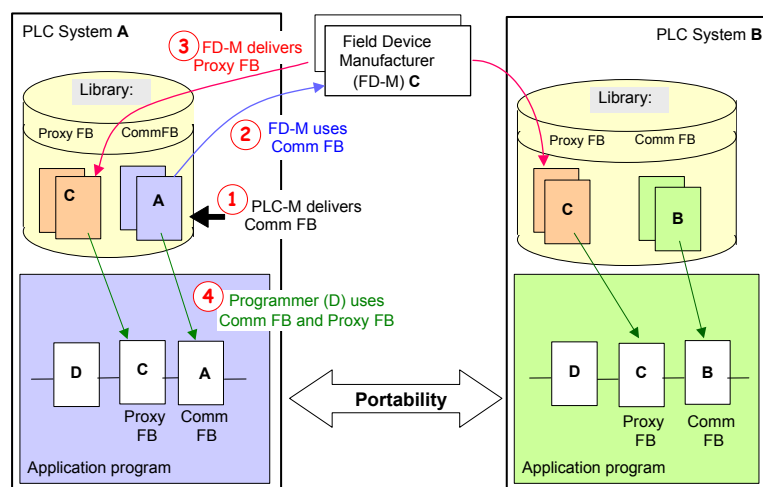


Fig. 29: Portable function blocks



## 7. Device Management

Modern field devices provide a wide range of information and also execute functions that were previously executed in PLCs and control systems. To execute these tasks, the tools for commissioning, maintenance, engineering and parameterization of these devices require an exact and complete *description of device data and functions*, such as the type of application function, configuration parameters, range of values, units of measurement, default values, limit values, identification, etc. The same applies to the controller/control system, whose device-specific parameters and data formats must also be made known (integrated) to ensure error-free data exchange with the field devices.

PROFIBUS has developed a number of methods and tools ("integration technologies") for this type of device description which enable standardization of device management. The performance range of these tools is optimized to specific tasks, which has given rise to the term *scaleable device integration*. Therefore the tools are put together in one specification with three volumes.

In factory automation, for historical reasons, the GSD is used preferably, but the use of FDT increases as well. In process automation, depending on the requirements, EDD and FDT are used (see Fig. 30).

Methods of device description:

The **communication features** of a

PROFIBUS device are described in a communication feature list (**GSD**) in a defined data format; the GSD is very much suited for simple applications. It is created by the device manufacturer and is included in the delivery of the device.

The **application features** of a PROFIBUS device (device characteristics) are described by means of a universal Electronic Device Description Language (EDDL). The file (**EDD**) created in this manner is also provided by the device manufacturer. The interpreter based EDD is very much proven for applications with medium complexity.

For **complex applications** there is also the solution of mapping all device-specific functions, including the user interface for parameterization, diagnosis, etc., as *software component* in a **Device Type Manager (DTM)**. The DTM acts as the "driver" of the device opposite the standardized FDT interface, which is implemented in the engineering tool or in the control system.

### 7.1 GSD

A GSD is a readable ASCII text file and contains both general and device-specific specifications for communication. Each of the entries describes a feature that is supported by a device. By means of keywords, a configuration tool reads the device identification, the adjustable parameters, the corresponding data type and the permitted limit values for the configuration of the device from the GSD. Some of the keywords are *mandatory*, for example `Vendor_Name`. Others

are *optional*, for example `Sync_Mode_supported`. A GSD replaces the previously conventional manuals and supports automatic checks for input errors and data consistency, even during the configuration phase.

### Structure of a GSD

A GSD is divided into three sections:

#### General Specifications

This section contains information on vendor and device names, hardware and software release versions, as well as the supported transmission rates, possible time intervals for monitoring times and signal assignment on the bus connector.

#### Master Specifications

This section contains all the master-related parameters, such as the maximum number of connectable slaves or upload and download options. This section is not available in slave devices.

#### Slave Specifications

This section contains all slave-specific information, such as the number and type of I/O channels, specification of diagnosis text and information on the available modules in the case of modular devices.

It is also possible to integrate bit-map files with the symbols of the devices. The format of the GSD is designed for maximum flexibility. It contains lists, such as the transmission rates supported by the device, as well as the option to describe the modules available in a modular device. Plain text can also be assigned to the diagnosis messages.

There are two ways to use the GSD:

- GSD for compact devices whose block configuration is already known on delivery. This GSD can be created completely by the device manufacturer.
- GSD for modular devices whose block configuration is not yet conclusively specified on delivery. In this case, the user must use the configuration tool to configure the GSD in accordance with the actual module configuration.

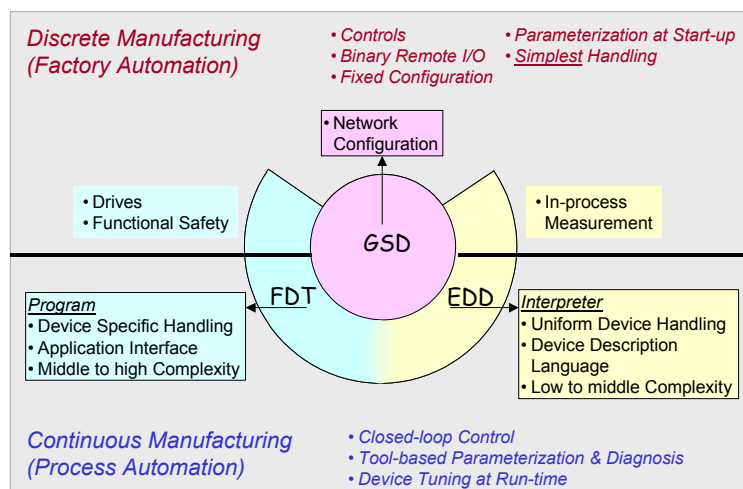


Fig. 30: Integration technologies at PROFIBUS

By reading the GSD into the configuration tool (into a PROFIBUS configurator), the user is able to make optimum use of the special communication features of the device.

### Certification with GSD

The device manufacturers are responsible for the scope and quality of the GSD of their devices. Submission of a GSD profile (contains the information from the profile of a device family) or an individual device GSD (device-specific) is essential for certification of a device.

### PNO Support

To support device manufacturers, the PROFIBUS Web site has a special GSD editor/checker available to download, which facilitates the creation and checking of GSD files.

The specification of the GSD file formats is described in the following PROFIBUS guideline GSD, order No. 2.122.

### New Development Stages

of the communication functions of PROFIBUS are continually integrated in the GSD by the PNO. Thus, the keywords for DP-V1 can be found in the GSD Revision 3 and those for DP-V2 in the GSD Revision 4.

### Manufacturer ID

Every PROFIBUS slave and every master class 1 must have an *ID number*. This is required so that a master can identify the types of connected devices without the need for extensive protocol overheads. The master compares the ID number of the connected devices with the ID numbers specified in the configuration data by the configuration tool. Transfer of the user data is not started until the correct device types with the correct station addresses are connected to the bus. This ensures optimum protection against configuration errors.

For an ID number for each device type, device manufacturers must apply to the PROFIBUS User Organization who also handle administration of the ID numbers. Application forms can be obtained from any regional agency or from the PROFIBUS Web site on the Internet.

### Profile ID

A special range of ID numbers (generic ID numbers) have been reserved for field devices for process automation and drives respectively: 9700h - 977Fh or 3A00h - 3AFFh. All field devices corresponding exactly to the specifications of the PROFIBUS PA Devices profile version 3.0 or higher, or PROFIdrive version 3, may use ID numbers from this special range. The specification of these profile ID numbers has further increased the interchangeability of these devices. The ID number to be selected for the respective device depends on various factors for example in the case of PA Devices on the type and number of existing function blocks. The ID number 9760H is reserved for PA field devices that provide several different function blocks (multivariable devices). Special conventions also apply to the designation of the GSD files of these PA field devices. These are described in detail in the PA Devices profile.

The first profile ID number reserved for PROFIdrive (3A00h) is used during the DP-V1 connection buildup to check that the master and slave are using the same profile. Slaves that positively acknowledge this identifier support the DP-V1 parameter channel described in the PROFIdrive profile. All further profile ID numbers serve to identify vendor-independent GSD files. This enables the interchangeability of devices of different manufacturer without the need for new bus configurations. For example, the VIK-NAMUR mode with vendor-independent PROFIdrive GSD is defined as a component of the PROFIdrive profile for the chemical industry.

## 7.2 EDD

The GSD is inadequate for describing *application-related* parameters and functions of a field device (for example configuration parameters, ranges of values, units of measurement, default values, etc.). This requires a more powerful description language, which has been developed in the form of the universally applicable **Electronic Device Description Language (EDDL)**. Above all, the EDDL provides the language means for the description of the functionality of field devices.

This also contains support mechanisms to

- integrate existing profile descriptions in the device description,
- allow references to existing objects so that only supplements require description,
- allow access to standard dictionaries and
- allow assignment of the device description to a device.

Using the EDDL device manufacturers can create the relevant **EDD file** for their devices which, like the GSD file, supplies the device information to the engineering tool and then subsequently to the control system.

### EDD application

An EDD is a very versatile source of information, for example

- Engineering
- Commissioning
- Runtime
- Asset Management
- Documentation and eCommerce

### EDD advantages

An EDD provides significant advantages to both device users and device manufacturers.

The uniform user and operation interface supports *the user* by

- Reducing training expenses
- Reliable operation
- Only one tool for all applications
- Validation of the input data

The *device manufacturer* is supported by the fact, that developing an EDD is very easy and cost effective

- Without specific knowledge, by the device developer
- By using existing EDDs and text libraries
- By universal suitability for simple to complex devices

An EDD also provides investment protection to *both users and manufacturers* because an EDD is independent of operating systems and easy to extend.

### New Development Stages

As with the GSD, the EDDL will also be subject to upgrade that

keep it in step with the continuous development of advancing device technology. Work is currently underway on a unique specification for dynamic semantics and for the description of hardware modular slaves.

The specification of the EDDL is an integral component of the international standard IEC 61804. It is included in the PROFIBUS guideline 2.152.

### 7.3 FDT/DTM Concept

The existing description languages for configuration and parameterization have their limits. This becomes clear when, for example

- complex, non-standardized characteristics of intelligent field devices including the diagnosis capabilities are to be made useable for the plant operator or
- in the "Optimization of assets" field, functions for preventative maintenance or for maintenance procedures are to be supported.
- the operation of devices needs to be "encapsulated" in software (safety technology, calibration, etc).

These complex task areas, require an "auxiliary tool" that allows device manufacturers to provide users with expanded and also very specific characteristics of their field devices in standardized form and which at the same time allows the manufacturers of automation systems to integrate these field device characteristics in the control system over standardized interfaces.

The solution to this is the fieldbus-independent interface concept **FDT/DTM** (see Fig. 31), which was developed in a working group of the PNO and the ZVEI (Central Association for the Electrical Industry) and made generally available.

#### The FDT Interface

The definition of a universal interface provides the ability to implement suitable created software components on all engineering or other integration platforms of automation systems fitted with this interface. Such an interface has been specified and designated **FDT** (Field Device Tool).

The FDT specification is currently available as version 1.2. The specification of FDT is contained in the PROFIBUS guideline 2.162.

#### Device Description as Software Component

The specific functions and dialog of a field device for parameterization, configuration, diagnosis and maintenance, complete with user interface, are mapped in a *software component*. This component is called the **DTM** (Device Type Manager) and is integrated in the engineering tool or control system over the FDT interface.

A DTM uses the routing function of an engineering system for communicating across the hierarchical levels. Furthermore it uses its project data management with versioning. It works as a "driver", similar to a printer driver, which the printer supplier includes in delivery and must be installed on the PC by the user. The DTM is generated by the device manufacturer and is included in delivery of the device.

#### DTM generation

There are various options for generating the DTM:

- Specific programming in a higher programming language.
- Reuse of existing component or tools through their encapsulation as DTM.
- Generation from an existing device description using a compiler or interpreter.
- Use of the DTM toolkit of

MS VisualBasic.

With DTMs it is possible to obtain direct access to all field devices for planning, diagnosis and maintenance purposes from a central workstation. A DTM is not a stand-alone tool, but an ActiveX component with defined interfaces.

#### User Benefits of FDT/DTM

The FDT/DTM concept is protocol-independent and, with its mapping of device functions in software components, opens up interesting new user options.

The concept incorporates integration options where they are most useful, in the areas of engineering, diagnosis, service and asset management - liberated from the specific communication technologies of the various fieldbuses and the specific engineering environment of automation systems.

The FDT standard provides a basis for integrated solutions from the field to the tools and methods of corporate management.

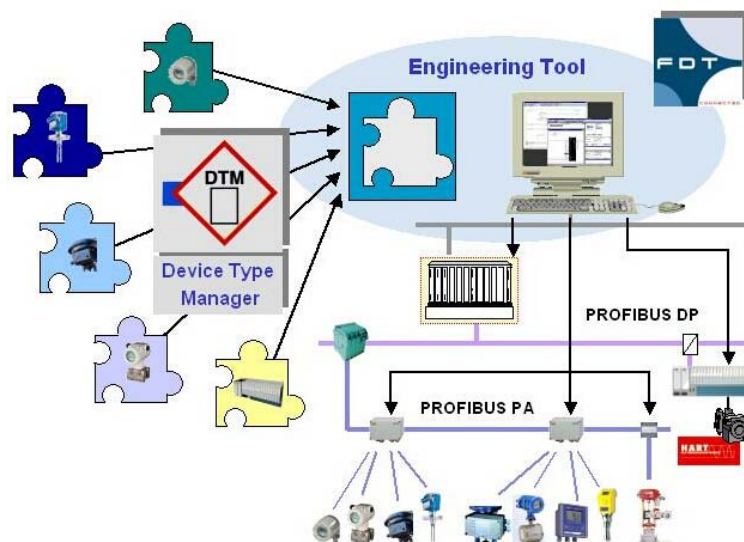


Fig. 31: FDT/DTM concept



## 8. Quality Assurance

In order for PROFIBUS devices of different types and manufacturers to correctly fulfill tasks in the automation process, it is essential to ensure the error-free exchange of information over the bus. The requirement for this is a standard-compliant implementation of the communications protocol and application profiles by device manufacturers.

To ensure that this requirement is fulfilled, the PNO has established a *quality assurance procedure* whereby, on the basis of test reports, certificates are issued to devices that successfully complete the test.

The *aim of the certification* is to provide users the necessary security for error-free functionality during the common operation of devices of different manufacturers. To achieve this, the device undergoes rigorous practical testing in independent test laboratories. This enables early detection of any misinterpretations of the standards by developers, thus allowing remedial action by manufacturers before devices are implemented in the field. Interoperability of the device with other certified devices is also part of the test. Upon successful completion of the test, the manufacturer can apply for a device certificate.

*Basis for the certification procedure* (see Fig. 35) is the standard EN 45000. The PROFIBUS User Organization has approved manufacturer-independent *test laboratories* in accordance with the specifications of this standard. Only these test laboratories are authorized to carry out device tests, which form the basis for certification.

The test procedure and sequence for certification are described in the guidelines No. 2.032 (DP slaves), No. 2.062 (PA field devices) and No. 2.072 (DP master).

### 8.1 Test procedure

A precondition for the test is the assigned ID number and a GSD file, as well as an EDD for the device where applicable.

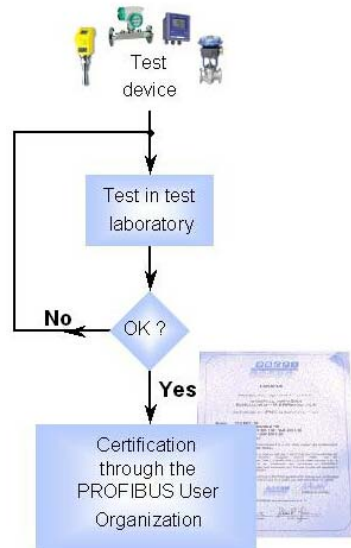


Fig. 32: Device certification procedure

The test procedure, which is the same for all test laboratories, is made up of several parts:

**The GSD/EDD Check** ensures that the device description files comply with the specification.

**The Hardware Test** tests the electric characteristics of the PROFIBUS interface of the device for compliance with the specifications. This includes terminating resistors, suitability of the implemented drivers and other modules and the quality of line level.

**The Function Test** examines the bus access and transmission protocol and the functionality of the test device. The GSD is used to parameterize and customize the test system. The black-box procedure is used during testing, which means that no knowledge is required of the internal structure of the implementation. The reactions generated in the test specimen and their time ratios are recorded on the bus monitor. If necessary, the outputs of the test device are monitored and logged.

**The Conformity Test** forms the main part of the test. The object is to test conformity of the protocol implementation with the standard. Essentially, the test deals with the:

**State machine:** the PROFIBUS protocol is defined in the form of a state machine. All externally visible state transitions are tested. The target behavior is summarized in programmable sequences. The actual behavior is analyzed, com-

pared with the target behavior and the result is written to the protocol file.

**Behavior in the Case of Fault,** which simulates bus faults, such as interruptions, short-circuits of the bus line and power failure.

**Addressability:** the test device is addressed under three arbitrary addresses within the address range and tested for error-free functionality.

**Diagnosis Data:** the diagnosis data must correspond to the entry in the GSD and the standard. This requires external activation of the diagnosis.

**Mixed Operation:** combination slaves are checked for correct functioning with an FMS and DP master.

**Interoperability test:** the test device is checked for interoperability with the PROFIBUS devices of other manufacturers in a multivendor plant. This checks that the functionality of the plant is maintained when the test device is added. Operation is also tested with different masters.

Each step of the test is carefully documented. The test records are made available to the manufacturer and the PROFIBUS User Organization. The test report serves as the basis for issuing a certificate.

### 8.2 Conformance Certificate

Once a device has successfully passed all the tests, the manufacturer can apply for a certificate from the PROFIBUS User Organization. Each certified device contains a certification number as a reference. The certificate is valid for 3 years but can be extended after undergoing a further test.

The addresses of the test laboratories can be obtained from the PROFIBUS Web site.



## 9. Implementation

This chapter contains instructions on how to implement the communications protocol and the interfaces in automation/field devices.

For the device development or implementation of the PROFIBUS protocol, a broad spectrum of standard components and development tools (PROFIBUS ASICs, PROFIBUS stacks, monitor and commissioning tools) as well as services are available that enable device manufacturers to realize cost-effective development. A corresponding overview is available in the product catalog of the PROFIBUS User Organization ([www.profibus.com/productguide.htm](http://www.profibus.com/productguide.htm)). For further details please use technical literature and, for expert advice, contact one of the PROFIBUS Competence Centers.

During implementation of a PROFIBUS interface, please note that the certification refers to the overall device. Standard components are not subject to the certification process as this does not provide a guarantee for the end product device. However the quality of the standard components also plays an important role in the successful certification of devices.

### 9.1 Standard Components

#### Interface Modules

The use of a complete PROFIBUS interface module is ideal for a low/medium number of devices. These credit card size modules implement the entire bus protocol. They are fitted on the master board of the device as an additional module.

#### Protocol Chips

In the case of high numbers of devices, an individual implementation on the basis of commercially available PROFIBUS basic technology components is recommendable, whereby a distinction is made between

- **Single chips**, in which all protocol functions are integrated on the chip and which do not require an additional controller,
- **Communications chips**, which implement smaller or larger parts of the protocol on

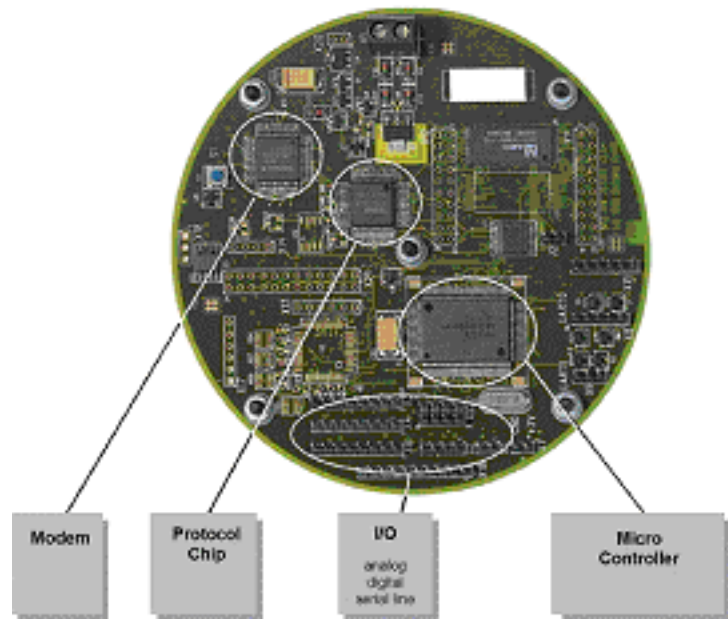


Fig. 33: Example for the implementation of a PROFIBUS slave

the chip and also require an additional controller and

- **Protocol chips** with integrated microcontroller.

The type of implementation version largely depends on the complexity of the field device, and the performance and functionality required. The following offers some examples.

#### Implementation of Simple Slaves

The implementation of single-chip ASICs is ideal for simple I/O devices. All protocol functions are already integrated on the ASIC. No microprocessors or software are required. Only the bus interface driver, the quartz and the power electronics are required as external components.

#### Implementation of Intelligent Slaves

In this form of implementation, the essential layer-2 parts of the PROFIBUS protocol are implemented on a protocol chip and the remaining protocol parts implemented as software on a microcontroller. In most of the ASICs available on the market all cyclic protocol parts have been implemented, which are responsible for transmission of time-critical data.

Alternatively, protocol chips with interpreted controllers may be used, where part of the protocol for less time-critical data transmission can be realized.

These ASICs offer a universal interface and operate together with common microcontrollers. A further option is offered by microprocessors with an integrated PROFIBUS core.

#### Implementation of Complex Masters

In this form of implementation, the time-critical parts of the PROFIBUS protocol are also implemented on a protocol chip and the remaining protocol parts implemented as software on a microcontroller. Various ASICs of different suppliers are currently available for the implementation of complex master devices. They can be operated in combination with many common microprocessors.

A corresponding protocol chip overview is available on the PROFIBUS website. For further information please contact the suppliers directly.

#### PROFIBUS Stacks

Frequently, chips and the respective protocol software (PROFIBUS stacks) may originate from different suppliers, positively increasing the variety of solutions available in the market.

Based on that, technically optimized and cost effective products can be developed, which meet application specific market requirements, in accordance with the respective commitment of the PROFIBUS User Organization. This

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This also proves the openness and multi-vendor capability of PROFIBUS which are not limited to specifications but also comprise product implementations.

Pure software solutions are rare because of their unfavorable cost/performance relation compared with chip-oriented implementations. Therefore, they are used only for specific applications.

A corresponding overview of PROFIBUS stacks that are available on the market is presented on the PROFIBUS website. For further information please contact the respective suppliers.

## **9.2 Implementation of Interfaces**

### **MBP transmission technology**

When implementing a bus-powered field device with MBP transmission technology, particular attention

must be paid to low power consumption.

As a rule, only a feed current of 10-15 mA over the bus cable is available for these devices, which must supply the overall device, including the bus interface and the measuring electronics.

Special modem chips are available to meet these requirements. These modems take the required operating energy for the overall device from the MBP bus connection and make it available as feed voltage for the other electronic components of the device. At the same time, the digital signals of the connected protocol chip are converted into the bus signal of the MBP connection modulated to the energy supply. A typical configuration with a commercially available roundboard is shown in Fig. 36.

For further details on how to implement the bus connection for field devices with MBP transmis-

sion technology, please refer to the technical PNO guideline No. 2.092.

### **RS485 Transmission Technology**

For field devices that cannot be powered over the bus, it is possible to use the standard RS485 interface. This increases flexibility when implementing the device as this can then be connected to a PROFIBUS DP segment without a coupler or link.

Key features of RS485 Technology are its low interface costs and ruggedness. Data rates of 9.6 Kbit/s to 12 Mbit/s are supported without the need to implement any changes.

As a further enhancement, the RS485 IS has been developed, which offers an intrinsically safe version of the RS485.

The RS485 modules are available from various manufacturers and proven in millions of applications.

## 10. PROFINet

PROFINet is a comprehensive automation concept that has emerged as a result of the trend in automation technology towards modular, reusable machines and plants with distributed intelligence. With its comprehensive design (uniform model for engineering, runtime and migration architecture to other communication systems, such as PROFIBUS and OPC) PROFINet fulfills all the key demands of automation technology for

- consistent communications from field level to corporate management level using Ethernet,
- a vendor-independent plant-wide engineering model for the entire automation landscape,
- openness to other systems,
- implementation of IT standards and
- integration capability of PROFIBUS segments without the need to change them.

PROFINet is available as a *specification* and as an operating system-independent *source software*. The specification describes all aspects of PROFINet: the object and component model, the runtime communication, the proxy concept and the engineering. PROFINet software covers all runtime communications. This combination of specification and software as source code enables simple and efficient integration of PROFINet in the broadest range of device operating system environments. The chosen path of preparing a source software upon which all product implementations are built presents an outstanding opportunity to ensure the consistent quality of the PROFINet interface in products. The procedure ensures that any interoperability problems are reduced to a minimum.

### 10.1 The PROFINet Engineering Model

A vendor-independent engineering concept has been defined to enable user-friendly configuration of a PROFINet system. It is based on an engineering object model which enables the development of configuration tools as well as the

#### PROFINet components

The basic approach of PROFINet is the application of the object model, already tried and tested in the software world, on automation technology. For this purpose, machines, plants and their parts are divided into technological modules, each of which comprises mechanical, electrical/electronic and application software. The functionality of the technological module is encapsulated in PROFINet components, which can be accessed over universally defined "interfaces". The components can be combined over their interfaces according to the modular principle and interconnected to applications.

In this context "components" means an encapsulated, reusable software unit. For the implementation of this component model, PROFINet uses the model most common in the PC world, the Microsoft Component Object Model (COM), in its expansion for distributed systems (DCOM). In this case, all the objects of a system are equal and, to all outward appearances, identical.

This type of distributed automation system enables the modular design of plants and machines and supports reusability of plant and machine parts.

specification of manufacturer/customized functional expansions.

The PROFINet engineering model distinguishes between the *programming* of the control logics of the individual technological modules and the *configuration* of the overall plant for an application.

As previously, programming of the individual devices and their configuration and parameterization is carried out by the manufacturer with manufacturer-specific tools. The software created during programming is then encapsulated in the form of a PROFINet component using the component editor interface that is also to be integrated in the tool. The component editor interface generates the component description in the form of an XML file whose configuration and contents are defined in the PROFINet specification.

The plant is configured by interconnecting the PROFINet compo-

nents to an application using the PROFINet engineering tool (connection editor). To do this, the generated PROFINet components are transferred to the connection editor by importing their XML files and the relationship is established over graphical lines. This allows plant-wide combination of distributed applications (of different manufacturers) to an overall application (see Fig. 34). The decisive advantage of this is the fact that the communication no longer needs to be programmed. Instead, the communication relationships between the components are established over lines, called interconnections.

The interconnection information is then downloaded to the device with a simple mouse click. This means that each device knows its communication partners and relationships and the information to be exchanged.

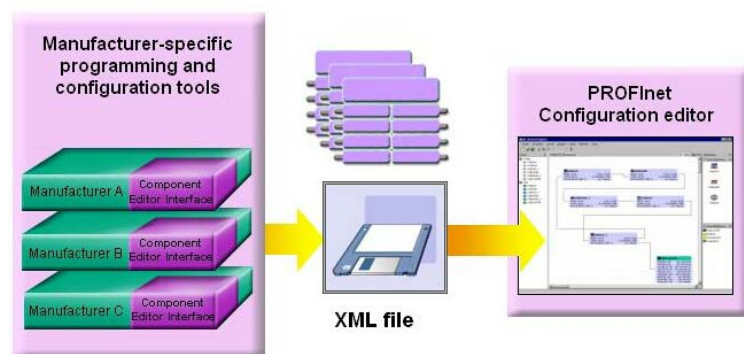


Fig. 34: Creation and interconnection of components

## 10.2 The PROFINet Communications Model

The PROFINet communications model defines a vendor-independent standard for communication on Ethernet with conventional IT mechanisms (runtime communications). It uses TCP/IP and COM/DCOM, the most common standards of the PC world. It provides direct access from the office world to the automation level and vice versa (vertical integration).

With PROFINet, the DCOM wire protocol, together with the aforementioned standards, defines the data exchange between the components of different manufacturers over Ethernet. Alternatively, there is also an optimized communication mechanism available for application areas with hard real time requirements.

Devices that are operated on Ethernet require the implementation of communication mechanisms in accordance with the PROFINet-standard (see Fig. 35). The connection technology required for the link to Ethernet is available in protection classes IP 20 and IP65/67.

## 10.3 The PROFINet Migration Model

The integration of PROFIBUS segments in PROFINet is implemented using proxies (see Fig. 36). These assume a proxy function for all the devices connected to PROFIBUS. This means that when rebuilding or expanding plants, the entire spectrum of PROFIBUS devices, including products of PRO-Flidrive and PROFIsafe can be

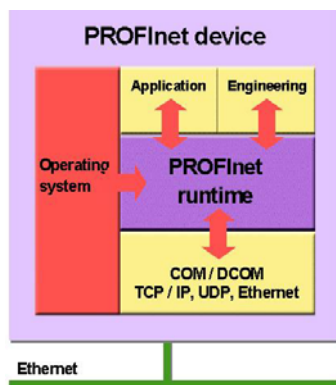


Fig. 35: Device structure of PROFINet

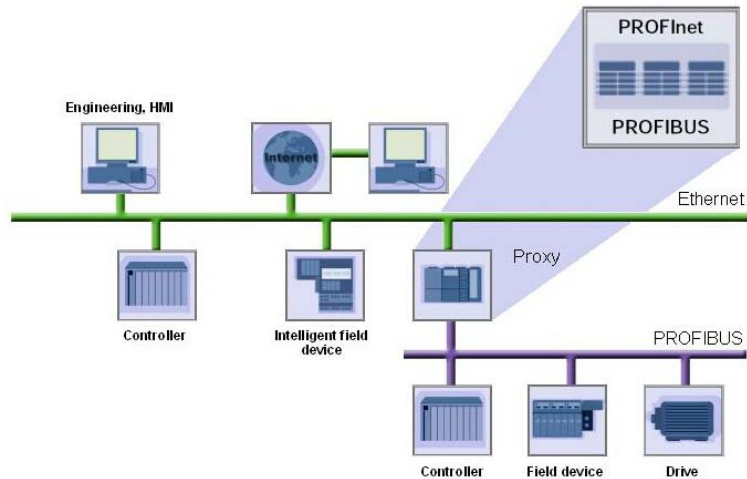


Fig. 36: PROFINet migration model

implemented unchanged, thus providing users with maximum investment protection. Proxy technology also allows integration of other fieldbus systems.

## 10.4 XML

**XML** (EXtensible Markup Language) is a flexible data description language based on a simple ASCII code. XML documents can be exchanged with applications in a number of ways, for example on diskette, by e-mail, using TCP/IP or with HTTP over the Internet.

XML is important in automation technology for, among other things, parameter descriptions in FDT, as import and export format for field device parameters in engineering tools or as a means of vertical integration (data exchange independent of the operating system used).

## 10.5 OPC and OPC DX

OPC is a standard interface introduced in 1996 for access to Windows-based applications in automation. The implementation of OPC enables the flexible, manufacturer-independent selection of components and their interconnection without the need for programming. OPC is currently based on the Microsoft DCOM model.

Since 2000, OPC data and OPC services are mapped in XML, which means that OPC data can even be exchanged between non-Windows platforms by means of readable XML documents.

**OPC DX** (Data EXchange) is being developed within the framework of

the OPC Foundation with the goal of developing a protocol for the exchange of non-time-critical user data between automation systems of different manufacturers and types (PLC, DCS, PC).

OPC DX is based on the existing specification OPC **DA** (Data Access). At the same time an engineering interface has been defined, which enables configuration of the connected systems. In contrast to PROFINet, OPC DX is not object-orientated, but tag-orientated, i.e. the automation objects do not exist as COM objects but as (tag) names.

OPC DX will enable the connection of different automation systems in a plant at the Ethernet level. However, it is not possible to access field level, so that existing fieldbus systems and PROFINet are not influenced in any way.



## 11. PROFIBUS International

In order to ensure its maintenance, development and market dominance, open technology requires a company-independent institute as a working platform. In 1989, the **PROFIBUS User Organization e.V. (PNO)** was founded to promote PROFIBUS technology in this very manner. It is a nonprofit trade body of manufacturers, users and institutes. The PNO is a member of **PROFIBUS International (PI)** founded in 1995, which now boasts 23 regional user organizations (**Regional PROFIBUS Associations, RPA**) and more than 1,100 members including those in the US, China and Japan who represent the largest trade body in the field of industrial communications worldwide (Fig. 38).

The RPAs organize exhibitions and information seminars but take care that new market demands are considered during future development work.

### Tasks

The key tasks of PI are as follows:

- Maintenance and development of PROFIBUS technology.
- Extending worldwide acceptance and use of PROFIBUS technology.
- Investment protection for users and manufacturer through influencing control of standardization.
- Representation of members' interests with regards to stan-



dardization committees and associations.

- Worldwide technical support of companies through the Competence Centers.
- Quality assurance through device certification.

### Organization

PI has handed over the development of PROFIBUS technology to PNO Germany. The advisory committee of PNO Germany now controls the development activities. The development teams are organized in 5 **Technical Committees (TCs)** with more than 35 permanent **Working Groups (WGs)**. In addition to this, there are also a changing number of ad hoc WGs that handle specific subjects limited to certain time periods. The WGs with more than 300 experts draw up new specifications and profiles, deal with quality assurance and standardization, work in standardization committees and undertake effective marketing measures (trade fairs, presentations) for expanding PROFIBUS technology. The PI support center coordinates all ongoing events.

### Membership

Membership in the PNO is open to all companies, associations, institutes and persons who would like to play a constructive role in the development and acceptance of PROFIBUS technology. The mutual efforts of members who are of-

ten very different and come from a broad spectrum of industries (particularly in the WGs) produce a considerable synergy effect and generate a rigorous exchange of information. This leads to innovative solutions, effective use of resources and last but not least, a significant market advantage.

### Working Groups

The WGs with their 300 honorary members make a key contribution to the success of PROFIBUS. Fig. 37 shows how the 5 TCs are broken down to deal with different areas. The further division into more than 35 WGs allows very focussed development work on specific technologies and industries.

All members are entitled to participate in the working groups and are thus able to take a proactive stance on further development. All new work results are submitted to members for further comment before they are released by the advisory committee.

### Competence Centers

PI has approved 22 Competence Centers worldwide as well as 7 test laboratories for certification work. These facilities offer all manner of advice and support to users and manufacturers as well as carrying out tests for the certification of devices. As part of PROFIBUS International, they offer their services company-neutral according to the agreed documents of rules.

Competence Centers as well as Test Laboratories are regularly checked with respect to their qualification by performing an approval procedure specifically oriented to their tasks. Current addresses can be found on the PI Web site.

### Documentation

By way of further support, the PNO offers all users and manufacturers a wide and very comprehensive range of documentation. This is provided in English and divided into the following categories:

**PROFIBUS Standard** contains the basic PROFIBUS specification and a selection of other documents.

**PROFIBUS Guidelines** contains specifications on implementations, test procedures, installations, description languages, as well as application-oriented specifications, such as Time Stamp or PROFInet.

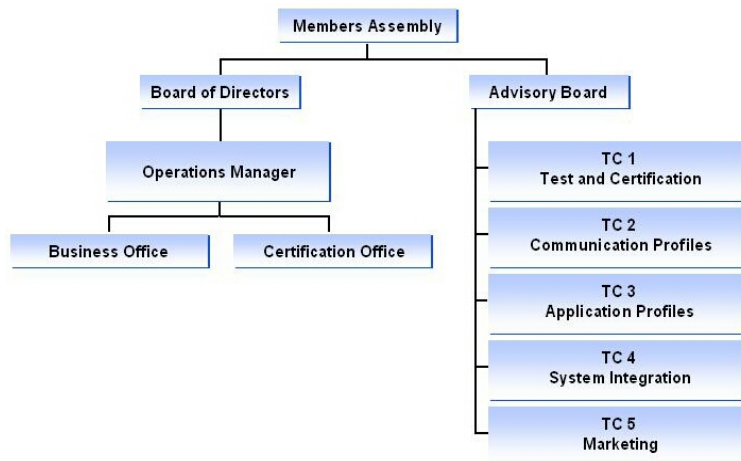


Fig. 37: Structure of the PROFIBUS User Organization

**PROFIBUS profiles** contains all approved profile specifications.

**Technical overviews and catalogs**

The key themes of PROFIBUS are presented in numerous technical overviews from a marketing standpoint. The product catalog, containing more than 2000 PROFIBUS products and services, offers an excellent overview of the performance capability of the member companies of PROFIBUS.

The documents are available in PDF format on the PROFIBUS Web site. If required you can also obtain the documentation on CD-ROM.

A list of all available documentation can also be obtained from the PNO or on the PROFIBUS Web site.

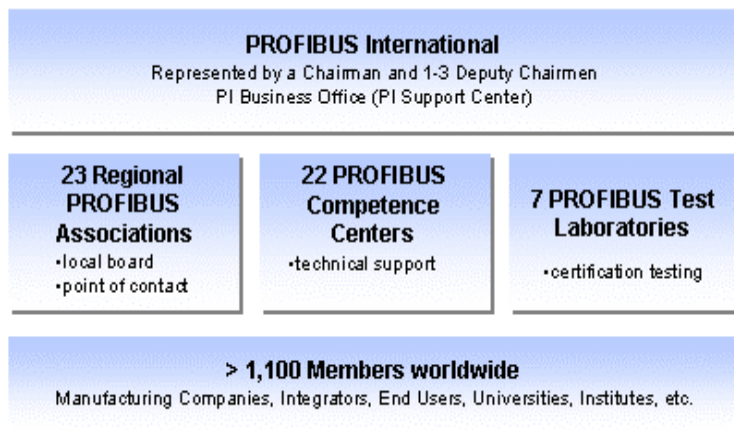


Fig. 38: PI Organization

## Index

### **A**

Actuator/sensor level .....	1
Acyclic data communication .....	11
Addressing .....	2
Addressing with slot and index .....	15
AS-Interface .....	1

### **B**

Block model .....	20
Broadcast .....	2
Bus access control .....	2

### **C**

Cell level .....	1
Certification .....	28
Clock synchronization .....	11
Comm-FB .....	24
Communication	
Communication in automation .....	1
Communications protocols .....	10
Competence Centers .....	33
conformity test .....	28
CPF .....	3
Cyclic data communication .....	13

### **D**

Data	
Data frame .....	2
Lateral data communication .....	11
Device management .....	25
Device types .....	11
Diagnostic functions .....	12
Documentation .....	33
DP .....	6
DP-V0 .....	11
DP-V1 .....	11
DP-V2 .....	11
DPM	
DPM1 .....	11, 12
DPM2 .....	12
DTM .....	25

### **E**

EDD .....	25, 26
-----------	--------

### **F**

FDT/DTM concept .....	27
Fiber optics .....	9
Field level .....	1
FISCO model .....	10
Fluid power .....	21
FMS .....	5

### **G**

General application profiles .....	17
GSD .....	25

### **H**

HART .....	17
------------	----

### **I**

Ident systems .....	22
IEC	
IEC 61158 .....	3
IEC 61784 .....	3
Implementation .....	29
Installation instructions	
Installation instructions for MBP .....	9
Interface module .....	29
ISO/OSI reference model .....	2
Issue of a certificate .....	28

### **K**

Keys to success .....	6
-----------------------	---

### **L**

Links .....	9
-------------	---

### **M**

Manufacturer ID .....	26
MBP .....	8
Modular devices .....	21

### **O**

OPC .....	32
-----------	----

### **P**

PA devices .....	20
Physical Block (PB) .....	20
PROFIBUS .....	4
PROFIBUS DP .....	10
PROFIBUS International .....	4
PROFIBUS User Organization .....	33
PROFIdrive .....	19
Profiles .....	2, 6
Profile ID .....	26
PROFINet .....	3, 31
The PROFINet engineering model .....	31
PROFIsafe .....	17
Protocol chips .....	29

### **R**

Remote I/Os .....	22
Repeaters .....	7
RPA .....	33
RS485	
RS485 .....	5
RS485-IS .....	5, 7

### **S**

Segment couplers .....	9
SEMI .....	22
SIL monitor .....	17

---

Slaves		Transmission technology .....	7
Slave redundancy .....	18	<i>U</i>	
Slaves.....	12	Upload and download .....	14
Slave-to-slave communications .....	14	User benefits.....	1
Software components.....	27	<i>V</i>	
Specific application profiles .....	19	Version	
Sync and freeze mode.....	13	Version DP-V1.....	14
System		Version DP-V2.....	14
System behavior .....	12	<i>X</i>	
System profiles.....	23	XML.....	32
<i>T</i>			
Time stamps .....	18		
Transducer Block (TB).....	20		



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