Process **Fi**eld **Bus**

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Timeline

1986

- Master development plan "fieldbus" created in Germany
- 21 companies, including Siemens, involved

1989

- First promoted by *Bundesministerium für Bildung und Forschung (BMBF)*
- Goal to implement a bit-serial field bus for factory and process automation

1999

- Published openly as part of standard **IEC 61158** *Digital data communication for measurement and control - Fieldbus for use in industrial control systems*

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System Structure: Introduction

- *Profibus* is a multi-master system
- Operation of multiple systems over a single bus
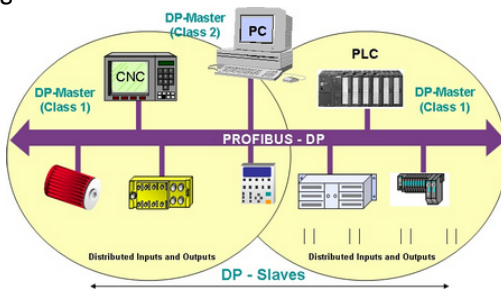- Devices are categorized in different types
  - Masters
  - Slaves

Figure: Structure of a DP system [1]

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System Structure: Master Station

Master Station

- Active station
- Can control multiple slaves
- Requests data from slaves
- When having the *bus access token*:
  send telegrams on the bus

System Structure: Slave Station

Slave Station

- Passive station
- No self-initiated bus access
- Immediate response to data requested by a master
- Can only be controlled by a single master

System Structure: Layer

Profibus in the OSI reference model [1]

Layer	Name	Content
Layer 7	Application Layer	FMS / DP / PA protocol
Layer 2	Data Link Layer	Field Data Link (FDL) protocol
Layer 1	Physical Layer	Transmission Technology

Protocols

- FMS *(Fieldbus Message Specification)*
- DP *(Decentralized Peripheral)*
- PA *(Process Automation)*

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Physical Layer: Transmission Technology

Profibus FMS and **Profibus DP**

- Mostly using RS 485 transmission
- Optical transmission via FOC *(fibre optical cable)* possible

Profibus PA

- Uses MBP *(Manchester bus powered)*, providing power supply

Type	Transmission technology
0	copper cable with RS 485
1	synchronous MBP
2	synthetic FOC
3	glass FOC
4	HCS FOC

Transmission technology after standard **IEC 61784** [1]

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Physical Layer: RS 485

RS 485

- Bus-topology
- Twisted-pair cables with 150Ω
- Data rates from 9.6$kbit/s$ to 12$Mbit/s$
- Distance between repeaters 100m to 1200m
- UART coding
  - Start = 0, Parity = EVEN, Stop = 1
Start	Databit 1	2	3	4	5	6	7	8	Parity	Stop

Mainly used with *Profibus FMS* and *Profibus DP*

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Physical Layer: FOC

Fibre Optical Cable (FOC)

- Star-, bus- or ring-topology
- Resistant against electromagnetic noise
- Distance between repeaters up to 15*km*

Physical Layer: MBP

Manchester Bus Powered (MBP)

- Bus-topology
- Stations are powered through the bus
- Safe in explosion-hazardous environments, power can be reduced to a bare minimum
- Data rate is fixed to $31.25 kbit/s$
- Bus length up to $1900 m$
- Allows branches up to $60 m$ to field devices

Physical Layer: MBP

Manchester Bus Powered (MBP)

- Can be connected to an existing *Profibus DP* network
    - Using a DP/PA coupler
    - The faster *DP* network is used as a backbone
- Uses Manchester coding

Physical Layer: MBP

Manchester coding

- Every bit is coded as a change
  - Positive change: "0"
  - Negative change: "1"
  - Every bit has the same average value
  - Average used to power the peripherals
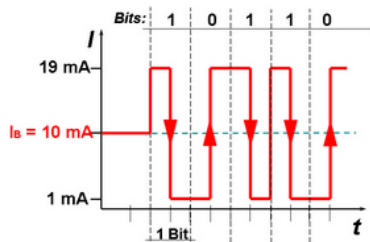 - Time synchronization possible with every bit

Figure: Manchester coding

Mainly used with *Profibus PA*

Data Link Layer

The **Fieldbus Data Link (FDL)** layer handles data transmission in *Profibus*

FDL consists of three functions:

- Medium Access Control *(MAC)*
- Fieldbus Link Control *(FLC)*
- Fieldbus Management *(FMA)*

Data Link Layer: MAC

Medium Access Control (MAC)

- Make sure only one station transmits data on the bus
- When multiple masters are present
  - Masters need the access token to send data
  - Token is cyclically passed via token telegram
  - To ensure that all master stations can access the bus, token must be passed on after a certain timeout
- Slaves only respond to requests by a master

Profibus FDL combines master-slave and token passing in a hybrid access principle

Data Link Layer: FMA

Fieldbus Management (FMA) provides functions to manage the layers 1 and 2

- Reset the layers
- Get/set parameters
- Inform the user about events or errors
- Activate/Deactivate *service access point (SAP)*

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Data Link Layer: Error handling

Errors can be caused by

- Faulty transmitters
- Badly shielded cables
- Signal reflections
- Large divergences in time synchronization between stations

The error rate in a typical *Profibus* network is smaller than 10^{-4} and can be reduced further by error detection and correction

Data Link Layer: Error detection

Error Detection

- *Hamming Distance* of 4 by adding a checksum to each packet
- At least 4 bits must change to result in an undetected error
- This results in *integrity class 2* after standard **IEC 870-5-1**

Data Link Layer: Error correction

Send Data with No acknowledge (SDN) service

- Mainly used for synchronization and status messages
- The erroneous telegram is discarded
- Telegram from the next cycle is used instead

Send Data with Acknowledge (SDA) service

- Mainly used between masters, slaves may not access the bus without request
- When the sender does not get a response, the telegram is retransmitted

Data Link Layer: Error correction

Send and Request Data (SRD) service

- Service used between masters and slaves
- Acknowledgement is piggybacked on top of the data telegram
- When the sender does not get a response, the telegram is retransmitted

Application Layer: Addressing

Every station has a unique address, coded in 1 byte

Address	Use
0	reserved for tools, e.g. programming devices
$1 - n$	n master stations
$n - 125$	slave stations
126	reserved as *delivery address*
	used for changing the address of a slave during runtime
127	reserved as broadcast address

Components used for the infrastructure, e.g. repeaters, couplers
transmit the data transparently and do not require an address

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Application Layer: Telegram Formats

- Without data field
- Variable length from $4 - 249$ byte, payload $1 - 246$ byte

SD2	LE	LEr	SD2	DA	SA	FC	PDU	FCS	ED

SD2: Delimiter, LE: Length, LEr: Length repeated, DA: Destination Address, SA: Source Address, FC: Function Code, PDU: Protocol Data Unit, FCS: Frame Check Sequence, ED: End Delimiter

- Fixed payload length of 8 bytes
- Token telegram
- Short telegram
- Telegram Delimiter, featuring a *Hamming Distance* of 4

SD1	SD2	SD3	SD4	ED	SC
0x10	0x68	0xA2	0xDC	0x16	0xE5

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Application Layer: FMS Protocol

Fieldbus Message Specification (FMS)

- FMS master controls the relationship with FMS slaves
- Replaced by *Profibus DP*

Application Layer: DP/PA Protocol

Profibus DP masters are separated into classes

- Class 1: control a DP system and the slaves assigned, mostly *Programmable Logic Controller (PLC)* based
- Class 2: tool for commissioning, engineering and maintenance, mostly PC based
- Class 3: clock master, used for time synchronization

Profibus PA uses the same protocol as *Profibus DP*

Application Layer: DP - Cyclic process data

The exchange of data between masters and slaves is separated into three phases: [1]

Phase	Action
Diagnosis	Master requests diagnostic data from slaves
Initialization	Master sets parameters and checks configuration of slaves
Data Exchange	Master cyclically sends and requests data from the slaves

Application Layer: DP - Data Exchange

Class 1 master station

- Relationship with a slave is called *MS0*
- Data exchange is cyclic
- Master sends output data to a slave
- Slave immediately responds with input data
- Master continues with the next slave or restarts the cycle

The minimum cycle time T_{BCycle} can be calculated:

$$T_{BCycle} = \frac{380 + (N_{Slaves} \cdot 300) + (N_{Bytes} \cdot 11)}{Bitrate} + 75 \mu s$$

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Application Layer: DP - Data Exchange

Class 2 master station

- Can exist in addition class 1 masters
- Can simultaneously be a class 1 master
- Relationship with a slave is called *MS1*
- Acyclic communication with a slave in an existing MS0 relationship

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