PROFIBUS PA- Process Automation

PROFI NET PROFI BUS PROFIsafe PROFIenergy PROFIdrive IO-Link FDI

Design	Configuration	Installation	Commissioning	Maintenance
• 'PA' – Why and What ? • Design your Network • Hazardous Areas • Redundancy	• Configure your Network • Profiles and Interchange-ability • Demo of Configuration	• Connection Technology • Terminations	• Diagnostic tools	• Diagnostic Information and Asset Management

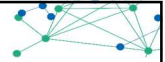PROFI Interface Center
PROFINET & PROFIBUS

PROFIBUS PA

- PA physical layer (MBP) is different so it can be used in hazardous areas
- Consistent data across discrete, process and hybrid applications
- Many vendors offer the same device with DP or PA interface
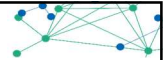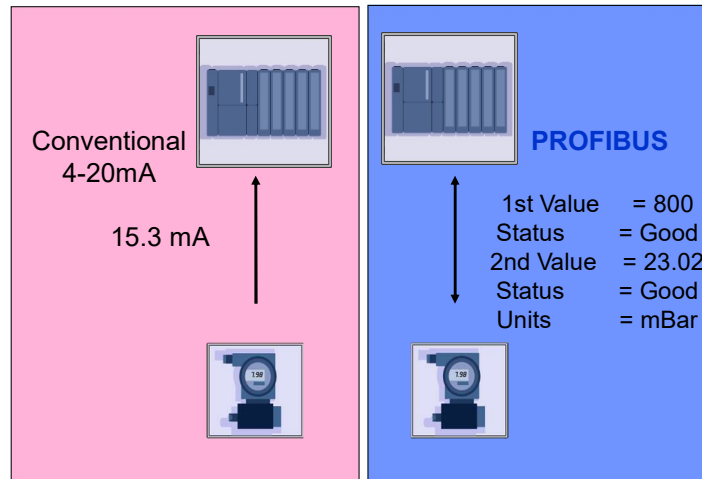

PROFIBUS PA
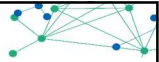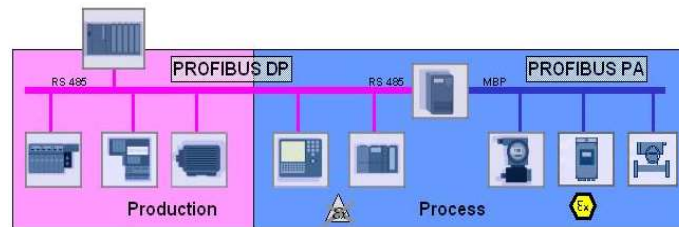
- Installations that have primarily process applications ordinarily also have a need for some high-speed discrete applications
  - Front-end handling of incoming raw materials
  - Back-end handling of finished product, e.g., packaging, palletizing, etc.

PROFIBUS PA vs. 4-20mA

More device and process information provided

Conventional
4-20mA

15.3 mA

PROFIBUS

1st Value = 800
Status = Good
2nd Value = 23.02
Status = Good
Units = mBar

PROFIBUS PA vs. 4-20mA

Less cabling

Conventional

process control system
I/O modules

marshalling rack

EX [i] → U/I supply

marshalling rack

terminal block

field device | field device | field device

field device | field device

PROFIBUS

process control system
supply and link to Ex [i] network

control room

field device | field device | field device

field device | field device | field

PROFIBUS PA Project

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PROFIBUS Physical Layer - MBP

▰ PROFIBUS PA = PROFIBUS with physical layer for process automation

  ▰ Protocol is based on standard PROFIBUS DPV0 and DPV1 protocol extensions

  ▰ Standard Controller performs I/O Data Exchange for all Field Devices: RS485, Fiber Optic, MBP, etc.

  ▰ MBP Devices start up just like RS485 Devices:

    ▰ Parameterization, configuration, cyclic data exchange, diagnostics

▰ MBP physical setup

  ▰ Physical layer based on MBP from IEC 61158

    ▰ Manchester-encoded, Bus-Powered (may be intrinsically safe)

  ▰ Synchronous data transfer

  ▰ Power AND data via the same cable

  ▰ Different components than RS485 (cable, connectors, termination…)

  ▰ Rules regarding topology and length According to MBP and MBP-IS

  ▰ Transmission rate is 31.25Kbaud

  ▰ Same setup as FF – both came from SP50

- FF uses two protocols: HSE and H1
- PROFIBUS uses a single protocol, regardless of the medium
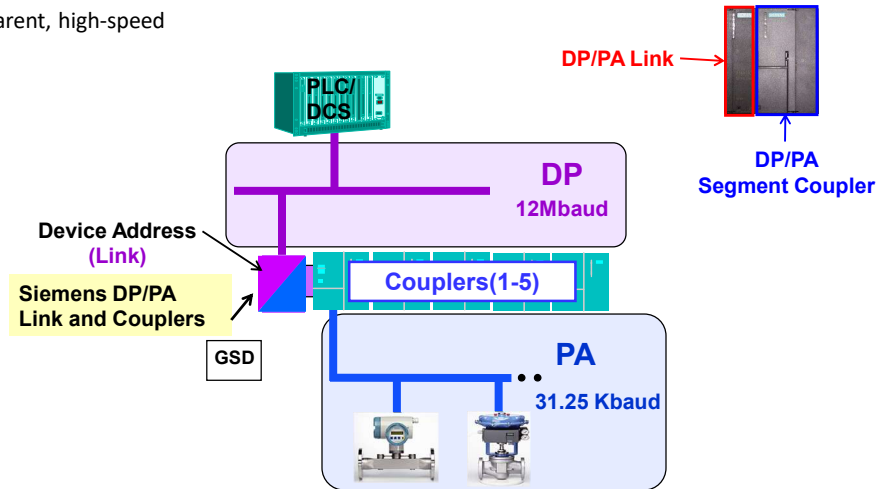
DP – Wide variety of media

SD	LE	LEr	SDr	DA	SA	FC	DU.	FCS	ED

PA – Copper only

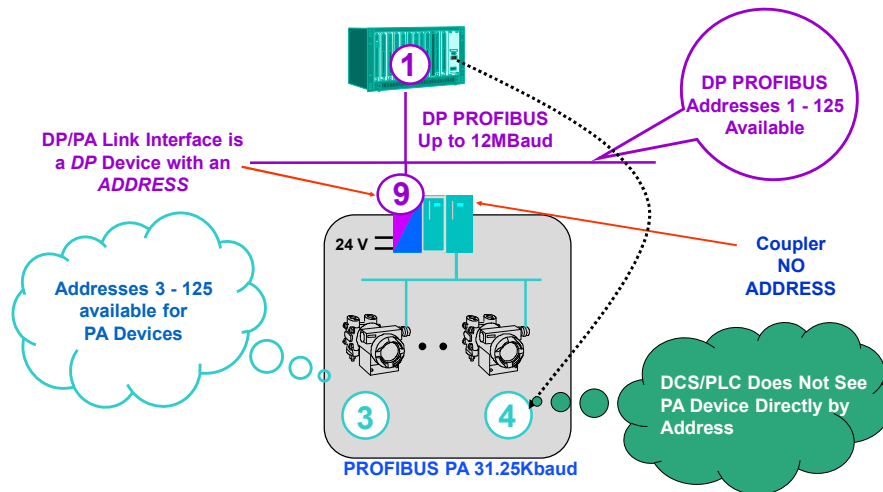| P	SOF	SD	LE	LEr	SDr	DA	SA	FC	DU.	CRC	EOF

- Connection between PROFIBUS DP and a PROFIBUS PA segment is accomplished using segment couplers or DP/PA links. These components perform the following tasks:
  - Convert the asynchronous RS485 bus physics into the synchronous MBP bus physics
  - Decouple the transmission speeds of RS485 and MBP bus physics (9.6…12,000kbits/s to 31.25kbits/s)
  - Supply voltage for the PA segment and limit the segment current supply
  - Optional: Provide isolation and power limitation for hazardous areas (IS)
- Two types of PROFIBUS DP - PA interfaces
  - Non-transparent link
    - PLC or DCS is not able to see the PA devices directly by their addresses
    - Sees only the DP/PA interface component by address
  - Transparent coupler
    - PLC or DCS sees all devices, Both DP and PA, directly by their addresses
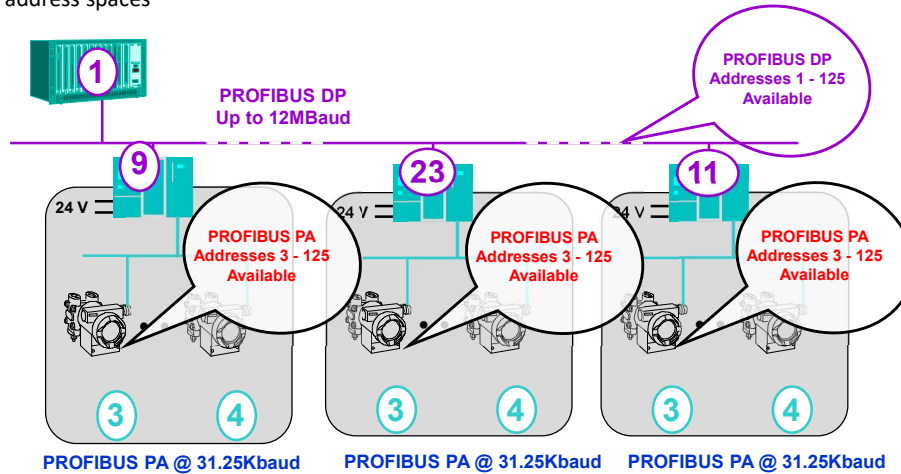   - DP/PA interface component is not seen

PROFIBUS DP - PA Interfaces

- PROFIBUS DP - PA interface
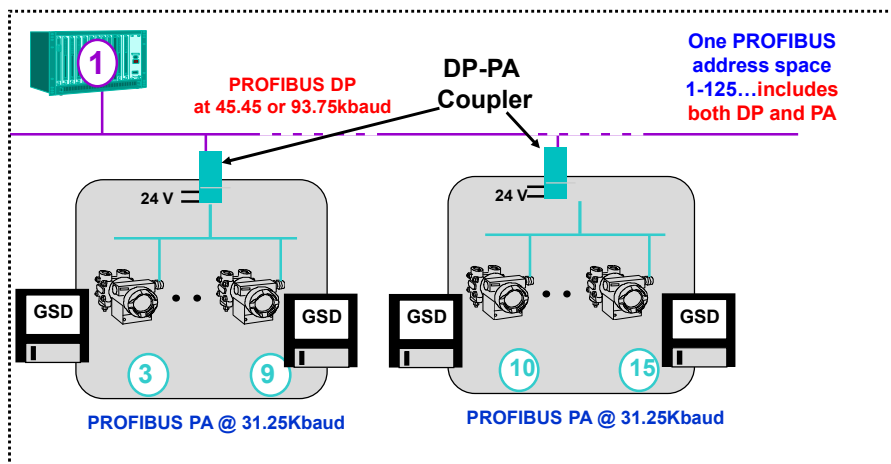 - Non-transparent, high-speed

DP/PA Link

DP/PA Segment Coupler

PLC/DCS

DP
12Mbaud

Device Address (Link)

Siemens DP/PA Link and Couplers

GSD

Couplers(1-5)

PA
31.25 Kbaud

PROFIBUS DP - PA Interfaces

- Non-transparent, high-speed interface – device addressing

1

DP PROFIBUS Up to 12MBaud

DP PROFIBUS Addresses 1 - 125 Available

DP/PA Link Interface is a *DP* Device with an *ADDRESS*

9

24 V

Coupler NO ADDRESS

Addresses 3 - 125 available for PA Devices

3 ⋅ ⋅ **4**

DCS/PLC Does Not See PA Device Directly by Address

PROFIBUS PA 31.25Kbaud

PROFIBUS DP - PA Interfaces

13

Non-transparent, high-speed interface – device addressing – flexible architecture
- Interface to process areas wherever needed
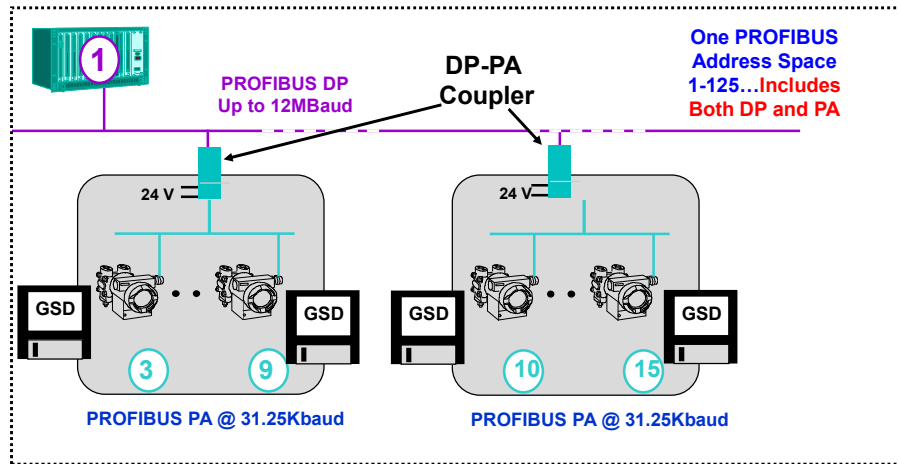 - Separate address spaces

PROFIBUS DP
Up to 12MBaud

PROFIBUS DP
Addresses 1 - 125
Available

24 V

PROFIBUS PA
Addresses 3 - 125
Available

PROFIBUS PA @ 31.25Kbaud   PROFIBUS PA @ 31.25Kbaud   PROFIBUS PA @ 31.25Kbaud

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PROFIBUS DP - PA Interfaces

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PROFIBUS DP - PA interface
- Transparent, low-speed – Siemens, P+F

PROFIBUS DP
at 45.45 or 93.75kbaud

DP-PA
Coupler

One PROFIBUS
address space
1-125…includes
both DP and PA

24 V   24 V

GSD   GSD   GSD   GSD

PROFIBUS PA @ 31.25Kbaud   PROFIBUS PA @ 31.25Kbaud

PROFIBUS DP - PA Interfaces

PROFIBUS DP - PA interface

Transparent, high-speed – P+F, PROCENTEC, Phoenix Contact

DP-PA Coupler

PROFIBUS DP Up to 12MBaud

One PROFIBUS Address Space 1-125…Includes Both DP and PA

24 V — 24 V —

GSD GSD GSD GSD

1 3 9 10 15

PROFIBUS PA @ 31.25Kbaud   **PROFIBUS PA @ 31.25Kbaud**

PROFIBUS PA Network Topologies

Basically - anything goes

PROFIBUS DP

24 V

PROFIBUS PA

Spur Lines

Star

(Main) Line

T Branch

PROFIBUS PA Network Topologies
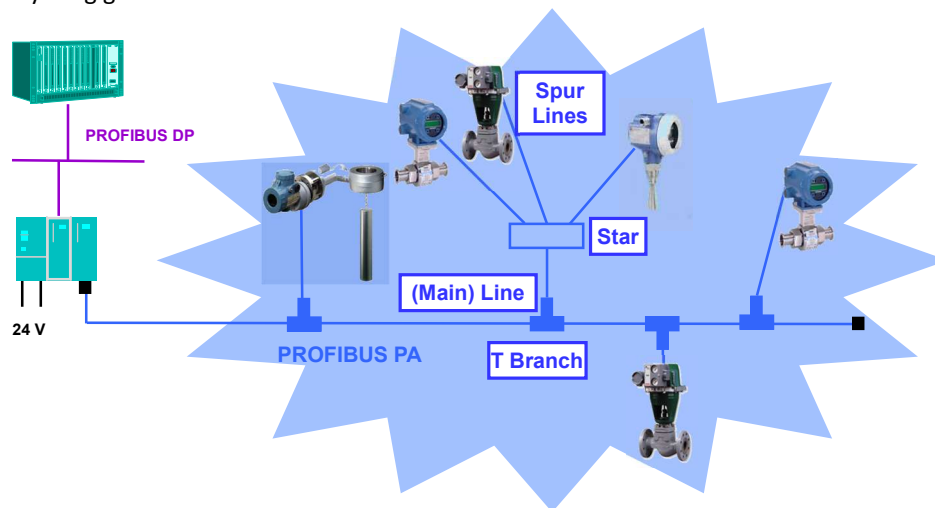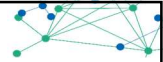
All topologies are supported
- 'Trunk and Spur' is a very popular topology
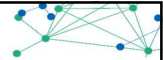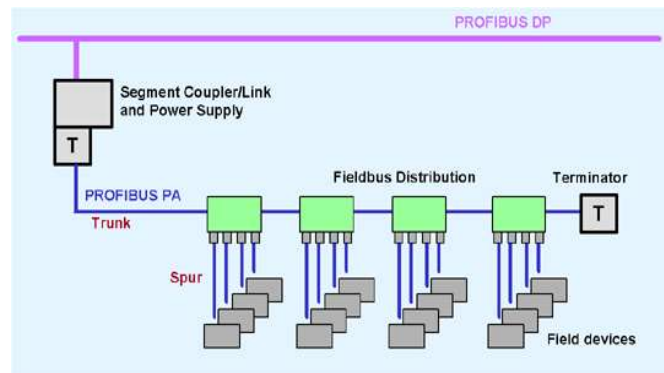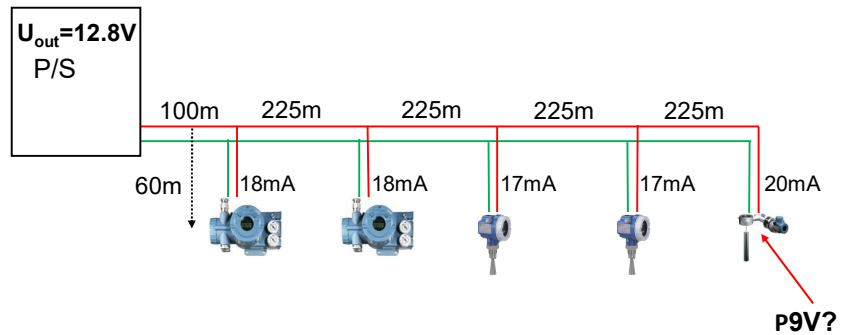

PA Power Budgets

PA segment setup rules - general
- Verify the power budget
  - Maximum current consumption
    - Each device draws a minimum of 10mA from the bus
    - Steady state current specified by vendor
  - Cable length/voltage drop
    - Devices require a minimum 9V to power up

For non-intrinsically safe segments, these are the only constraints

PA Network Setup Rules

Calculating bus load – how long?

- Devices require 9V to operate
  - Type A cable resistance is 44Ω/km (.044 Ω /m)

$U_{out}=12.8V$ P/S

100m   225m   225m   225m   225m

60m   18mA   18mA   17mA   17mA   20mA
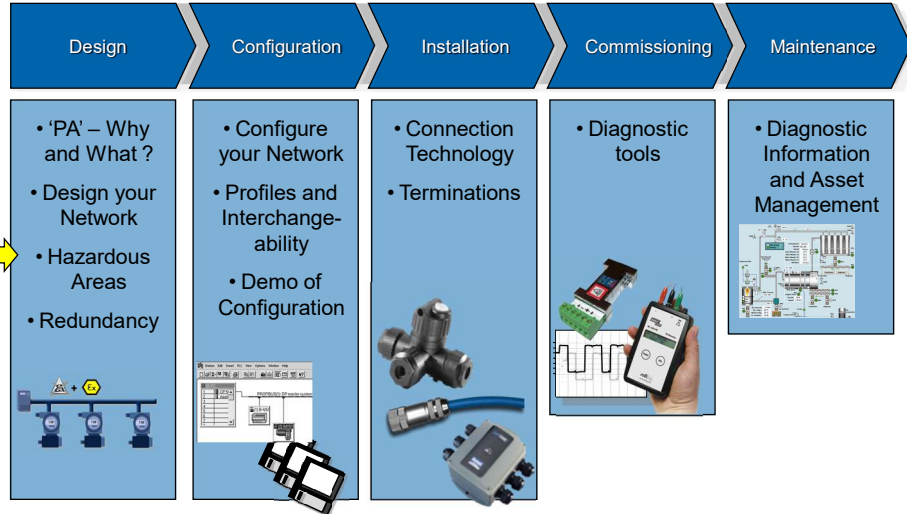
P9V?

PA Network Setup Rules

PA network setup rules – maximum segment lengths

- Theoretical maximums based on cable type

Cable Type	Structure	Wire Cross Section	Max. Cable Length
TYPE A	Single STP	18 AWG	1900m
TYPE B	Single/Multiple UTPs Overall Shield	22 AWG	1200m
TYPE C	Multiple UTPs	26 AWG	400m
TYPE D	Multiple Non-Twisted Pairs, Overall Shield	16 AWG	200m

STP = Shielded, Twisted Pair   UTP = Unshielded, Twisted Pair

PROFIBUS PA Project Steps

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Hazardous Areas

- Areas where an explosive atmosphere is present: gas, dust, metal filings, etc.
  - Different classifications depending on the amount of time such an atmosphere is present
    - Always or frequently present (>1000 hours/year), e.g., vapor space above liquid inside a tank
    - Expected to be present for long periods of time (10 – 1000 hours/year) in normal operation, e.g., certain production areas
    - Only present under abnormal conditions (<10 hours/year)

CAUTION
HAZARDOUS AREA
AUTHORIZED
PERSONNEL ONLY
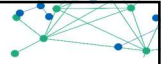
- Three basic methods of explosion protection:
  - Containment
    - Explosion-proof enclosures
  - Segregation
    - Pressurization, encapsulation, etc.
    - Purged enclosures
    - Pressurized enclosures
    - Oil immersion
    - Powder filled
  - Prevention
    - Intrinsic safety – limits electric and thermal energy under both normal operation and fault conditions
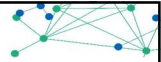
- Three categories of intrinsically safe operation
  - Ex ia: maintains IS operation across 2 faults => Zone 0, 1, 2 operation
  - Ex ib: maintains IS operation across 1 fault => Zone 1, 2 operation
  - Ex ic: maintains IS operation only under normal operating conditions => Zone 2 operation
- Intrinsically safe segments must be proven to be IS
  - Models for Proving Segment Intrinsically Safe
    - Entity Model
      - Extension of 4-20mA concepts to fieldbus
        - Individual devices and associated apparatus certified to be IS
        - Comparison of device and power source U/I/P ratings required
    - FISCO Model – (Fieldbus Intrinsically Safe COncept)
      - Easier to prove segment IS and More Devices Per Segment
        - Devices and associated apparatus certified to FISCO specification

For all intrinsically safe models, the device parameters (U_i, I_i, P_i), must satisfy the following relationship to the power source parameters (U_o, I_o, P_o):

- $U_i \geq U_o$ for the Power Source
- $I_i \geq I_o$ for the Power Source
- $P_i \geq P_o$ for the Power Source

U:	voltage
I:	current
P:	power

FISCO-Certified devices and associated apparatus, e.g., power sources, are guaranteed to satisfy these conditions
- All devices and associated apparatus are certified to the FISCO specification, i.e., a *system* certification
- Individual devices need not be examined against the power source for conformance

Entity-Certified devices and associated apparatus provide no such guarantee
- Individual devices and associated apparatus are *individually* certified to be intrinsically safe
- Individual devices must be examined against the power source for conformance

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Maximum segment and spur lengths
- Hazardous area cable length maximums for different models using type a cable

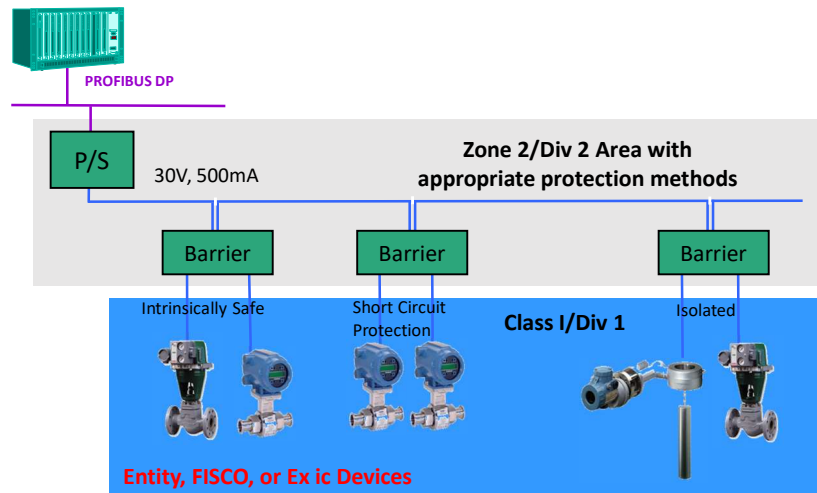| Characteristic	Entity	FISCO
Maximum cable length (trunk + spurs)	1900m	1000m
Maximum spur length	120m	60m
Consideration of cable and device capacitance and inductance	Yes	No

- Entity model
  - Requires calculations to determine current usage and voltage drop
  - Requires complex calculations for total capacitance and inductance
    - Requires recalculation if segment is modified
- FISCO model
  - Requires calculations to determine current usage and voltage drop - ONLY
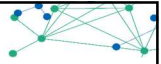
- High-power trunk concept
  - High current on trunk (30V, 500ma)
    - Assumes no "hot" maintenance on trunk line
    - Trunk can lie in Div 2 area with Div 2 protection methods
    - Gives longer trunk line and more power
  - Energy is limited on the spur connections
    - Spurs typically short-circuit protected
    - Each spur considered to be an IS "segment"
      - Proof of IS involves only the field barrier spur and the device
    - Spurs can be 120m in length – typically only one device

Additional Concepts

High-power trunk concept

PROFIBUS DP

P/S — 30V, 500mA

Zone 2/Div 2 Area with appropriate protection methods

Barrier — Barrier — Barrier

Intrinsically Safe — Short Circuit Protection — **Class I/Div 1** — Isolated

Entity, FISCO, or Ex ic Devices

Additional Concepts

Dynamic Arc Recognition and Termination (DART)

- Concept based on detection of beginning of a sparking condition, e.g., making/breaking a contact, and immediately switching off power supply, thus reducing the energy to a safe level within a few microseconds to prevent the spark from occurring
  - The DART concept allows much higher power levels and device counts in hazardous areas compared to FISCO

Dynamic Arc Recognition and Termination (DART)

Electrical characteristics of a spark
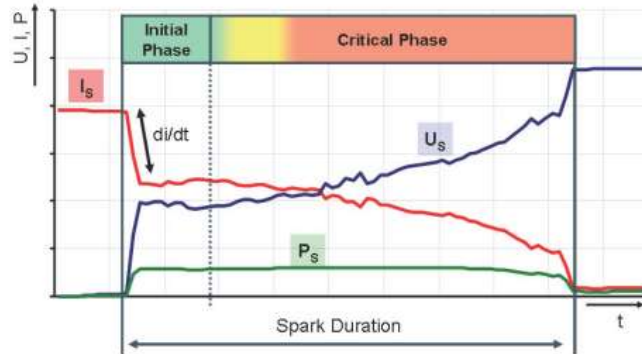
Potential spark slowly "heats up" but remains non-incendive during the initial phase but becomes incendive during the critical phase

Figure taken from an ARC whitepaper about Pepperl+Fuchs' DART technology

Dynamic Arc Recognition and Termination (DART)

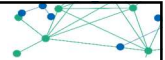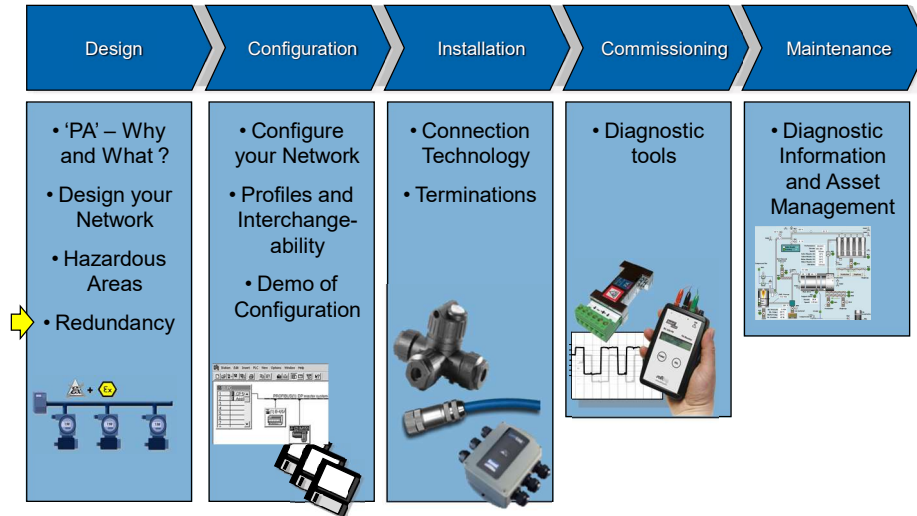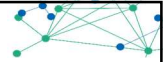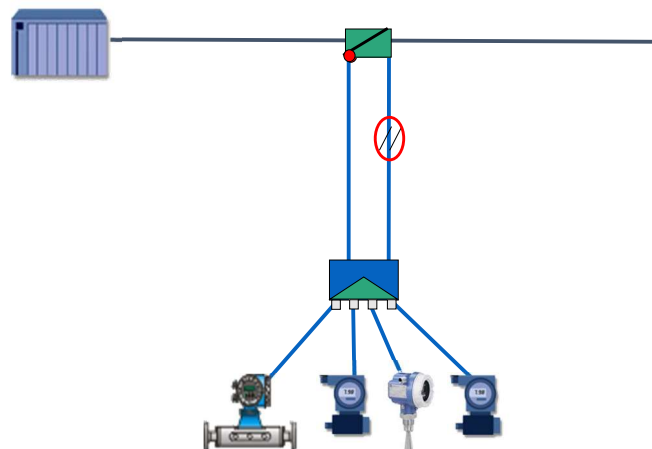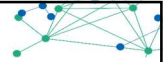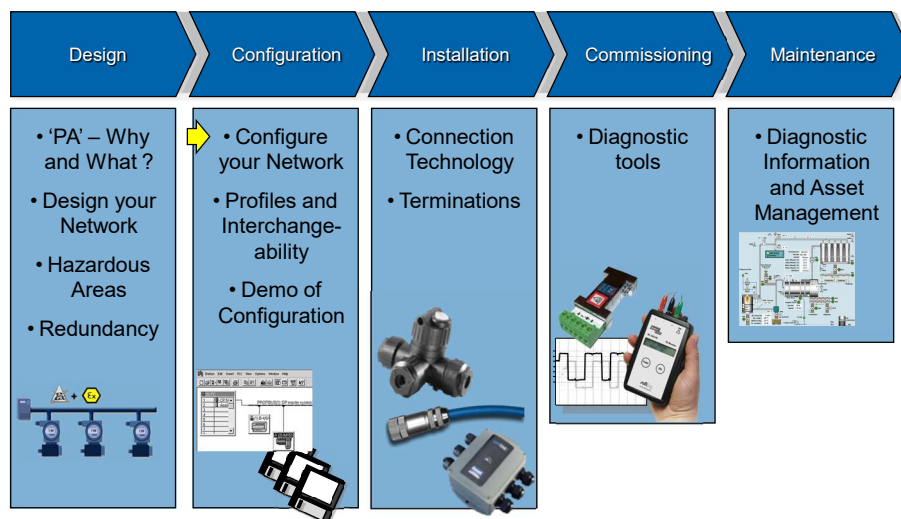DART monitors the characteristic current drop (di/dt) and switches off power before the critical phase is reached
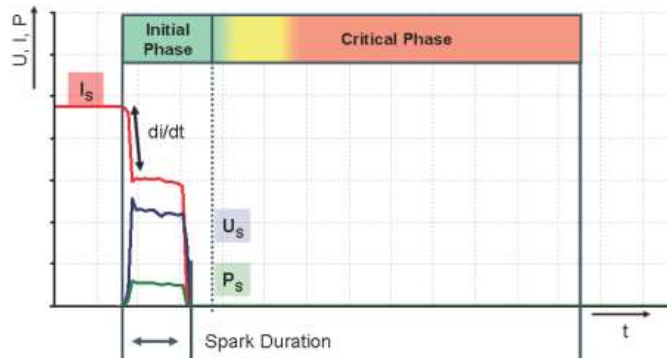
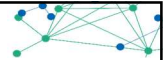**Figure taken from an ARC whitepaper about Pepperl+Fuchs' DART technology**

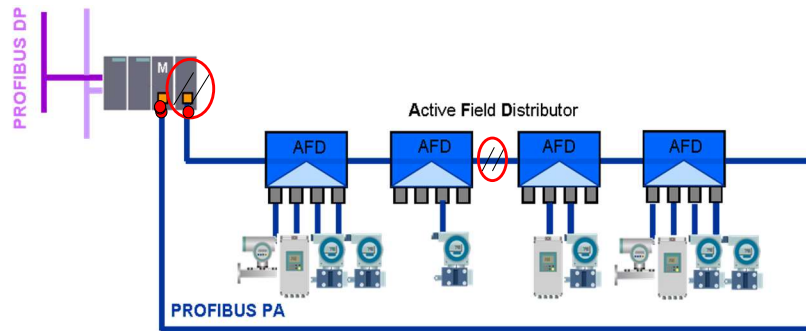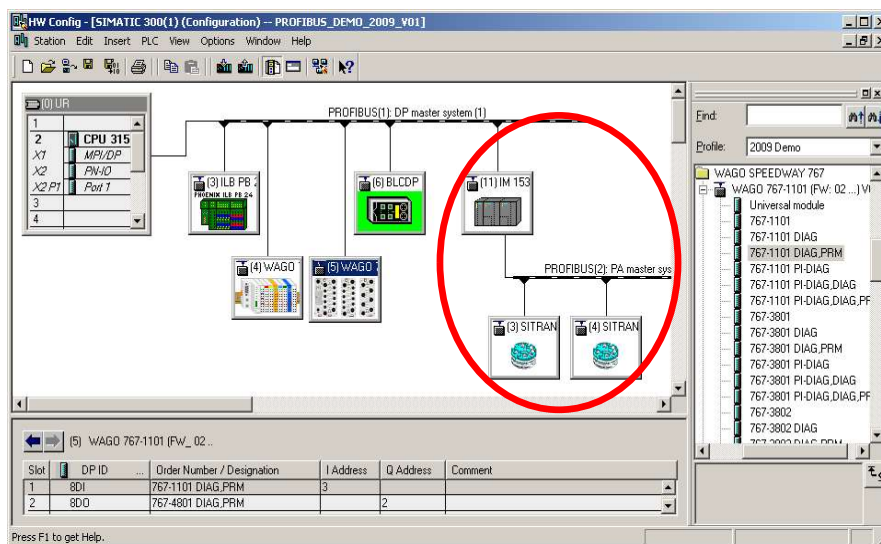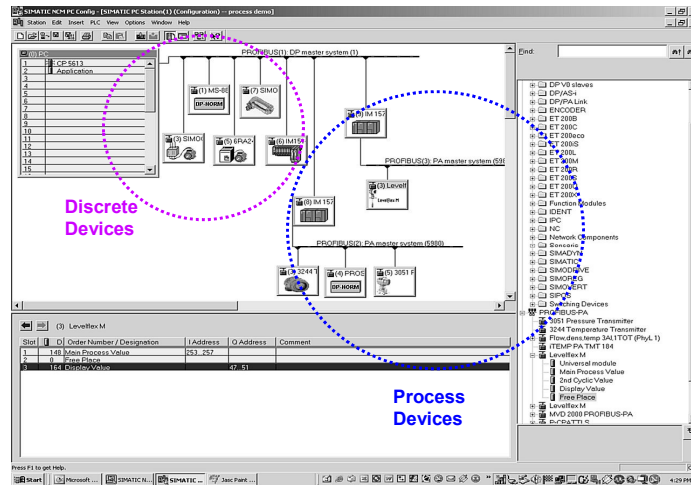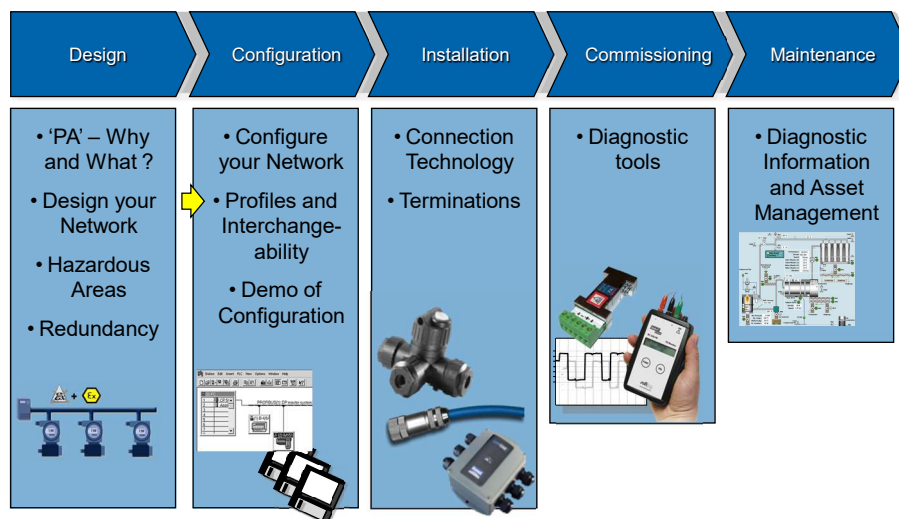| Design	Configuration	Installation	Commissioning	Maintenance
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MBP redundancy – Moore industries international solution

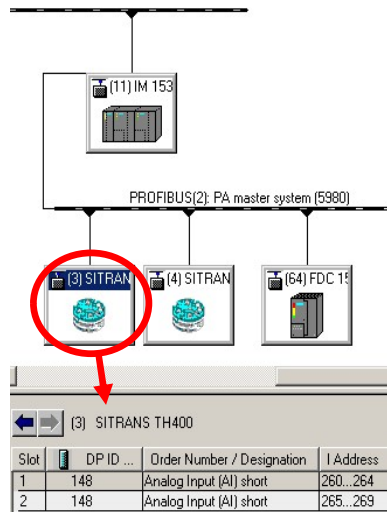**PROFIBUS PA Redundancy**

MBP redundancy – Siemens solution

PROFIBUS PA Project Steps

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PROFIBUS PA Configuration

▪Process automation device configuration
  ▪ Single configuration tool

Demo Rack Configuration Overview

Typical process variables

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PA Profile 4

- Definition at the Application Layer

- For a Given Instrument Type, the Profile Defines Variables, Function Blocks, Operational Parameters, Meaning of the Data, Mapping to Communication Services...

- Devices implementing the same profile can be exchanged, e.g., Vendor A pressure transmitter with Vendor B pressure transmitter, etc.

  - When operating in Profile Ident Mode

- Available as official PROFIBUS International Doc. #4.01

- Pre-Defined Profile Ident GSD Files for various PA field devices are available on www.profibus.com

- Ident_Number adaptation - automatic Ident_Number adaptation of a device offers the possibility to replace incompatible device variants without host modifications. Thus, a crossover from (Older) installed device technology to a (Newer) further developed technology is possible without disturbing the process.

Device Interchangeability in Profile Mode!

Similarly executed functions and parameters in all devices of same type

PA Device Parameter Setup

- Set up with engineering tool
  - EDDL-based tool
  - FDT/DTM-based tool

PA Device Data Sheets
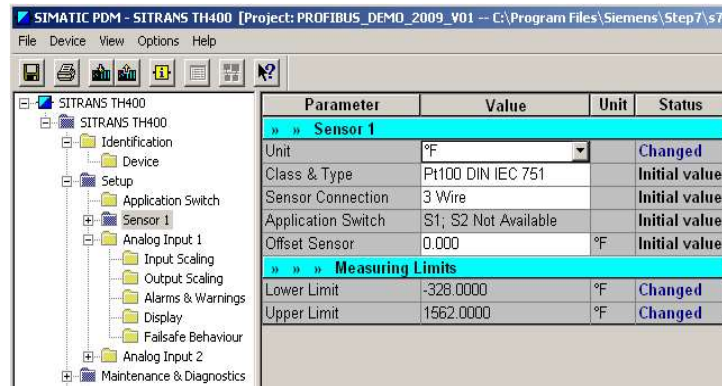
- Electronic device data sheets

GSD File For Description of **Cyclic** Communication Parameters

PROFIBUS MBP

GSD → PROFIBUS Configuration Tool

DD → EDDL-Based PROFIBUS Engineering Tool

Device Description File For Specification of **Acyclic** Communication Functionality

PA Field Device

DTM → FDT-Based PROFIBUS Engineering Tool

Device Type Manager File For Specification of **Acyclic** Communication Functionality
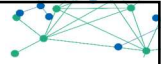
DD = Device Description
EDDL = Electronic Device Description Language
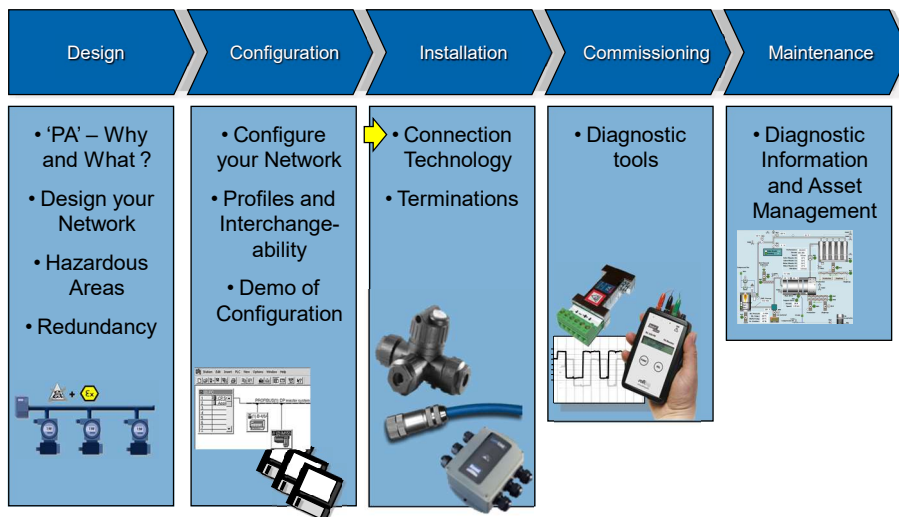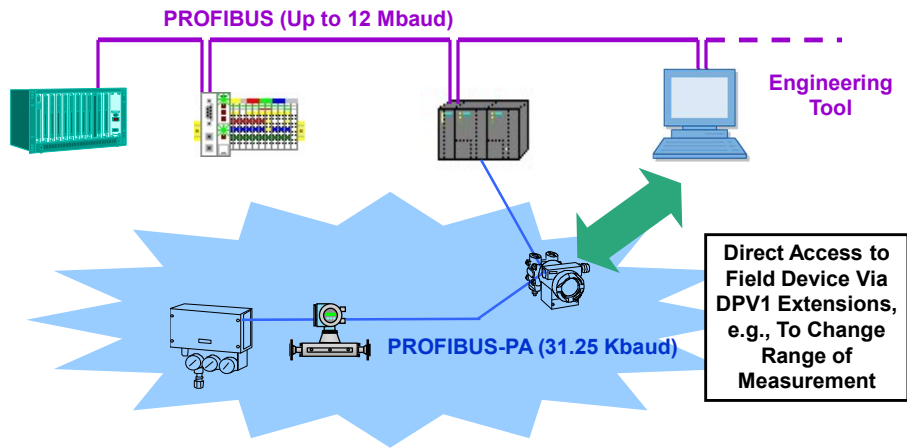DTM = Device Type Manager
FDT = Field Device Tool

Next tool technology: FDI – Field Device Integration

- Company "FDI Cooperation" formed in September, 2011, by several groups:
  - FDT Group, Fieldbus Foundation (FF), Hart Communication Foundation, PROFIBUS and PROFINET International, and OPC Foundation
  - Company headed by a Board of Managers:
    - Representatives of the founding organizations
    - Management of global automation suppliers including ABB, Emerson, Endress + Hauser, Honeywell, Invensys, Siemens and Yokogawa
- Purpose
  - To complete the standardization of FDI under the IEC
  - Manage the FDI Specification
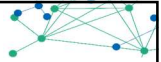 - Finalize the FDI tool kits for system and device manufacturers
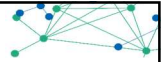
Both PROFIBUS PA and Foundation Fieldbus users may wind up using both EDDL- and FDT-based engineering tools

- Some device vendors provide both EDDs and DTMs
- Some vendors provide only one of EDD or DTM

FDI will alleviate the problem

- FDI will support the re-use of existing EDD and DTM files

Accessing Device Parameters

Access via PROFIBUS engineering tool

PROFIBUS (Up to 12 Mbaud)

Engineering Tool

Direct Access to Field Device Via DPV1 Extensions, e.g., To Change Range of Measurement

PROFIBUS-PA (31.25 Kbaud)

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Connection technology - PA

Connection technology - PA

PROFIBUS PA Project Steps

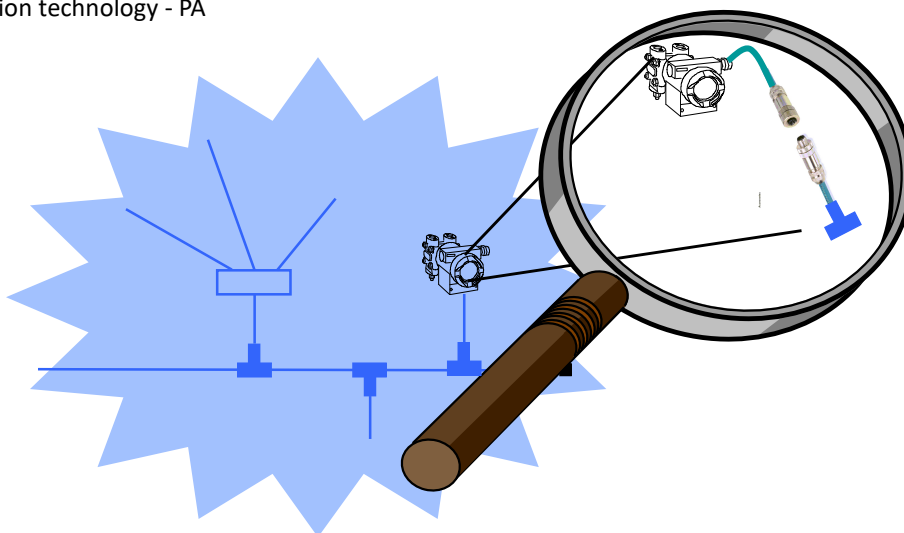| Design	Configuration	Installation	Commissioning	Maintenance
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PROFIBUS Physical Layers - PA

◢ PA segment terminations

1uF   Fieldbus Terminator

100 Ω

Termination:
•**Acts as a shunt**
•**Prevents reflections (secondarily)**

PROFIBUS Physical Layers - PA

▰ PA segment terminations

- PROFIBUS
- 24 V
- **Termination** — **At the power source**
- **(Main) Line**
- PROFIBUS PA
- **Spur Line**
- **Star**
- **T Branch**
- **Termination** — **At end of longest cable run (Typically at last junction box)**

▰ At power source
▰ At end of longest cable run

PROFIBUS PA Project Steps

Design	Configuration	Installation	Commissioning	Maintenance
• 'PA' – Why and What ? • Design your Network • Hazardous Areas • Redundancy	• Configure your Network • Profiles and Interchange-ability • Demo of Configuration	• Connection Technology • Terminations	• Diagnostic tools	• Diagnostic Information and Asset Management

Bus and Protocol Analyzers
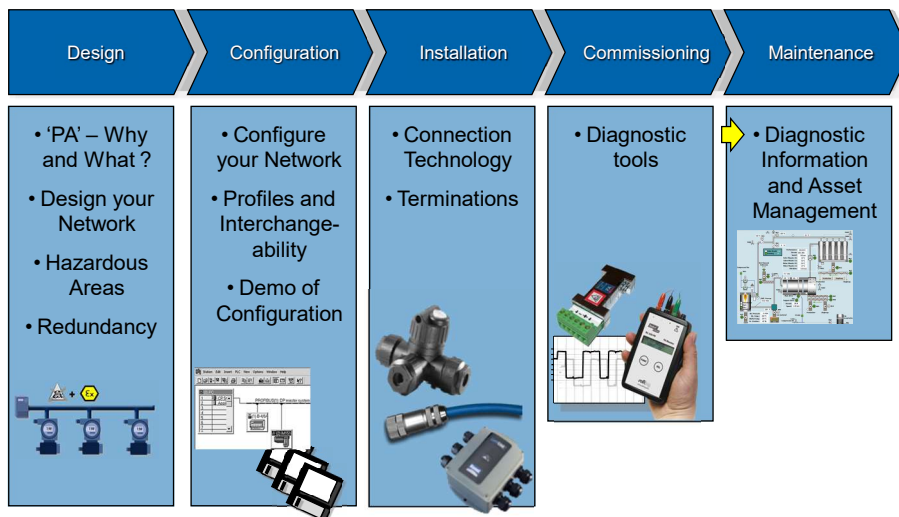
■ Tools available for physical test of the PA Network
- ■ Some stand-alone PA tools available
  - ■ Pepperl+Fuchs (Handheld and DIN Rail Mount)
  - ■ Softing (Handheld)
  - ■ MTL Relcom (Handheld)
- ■ Some with PA adapters for PROFIBUS DP Tools
- ■ Some are powered from the bus – don't overload
- ■ Analysis of the protocol possible if connected directly to the PA Segment or when a transparent gateway is used

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PROFIBUS PA Project Steps

| Design	Configuration	Installation	Commissioning	Maintenance
• 'PA' – Why and What ? • Design your Network • Hazardous Areas • Redundancy	• Configure your Network • Profiles and Interchange-ability • Demo of Configuration	• Connection Technology • Terminations	• Diagnostic tools	• Diagnostic Information and Asset Management

What is an asset?
- Plant, Factory, Equipment, Machinery, Component, or Sub-Component used in the Manufacturing Process of a Product

How are assets managed/maintained?
- Mostly - Reactive Maintenance
  - It's broken and we have to fix it
- Sometimes - Preventive Maintenance
  - If we do the following things on schedule, the equipment won't break—or at least will run longer before breaking
- Rarely - Predictive Maintenance
 - Data collected and analyzed lets us estimate when we actually need to work on the device to prevent a failure

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Cyclic I/O with PA devices
- Process variable and status byte in every I/O cycle

IEEE 754 32-BIT FLOATING POINT VALUE   **STATUS BYTE**

| BYTE 1 | BYTE 2 | BYTE 3 | BYTE 4 | STATUS |
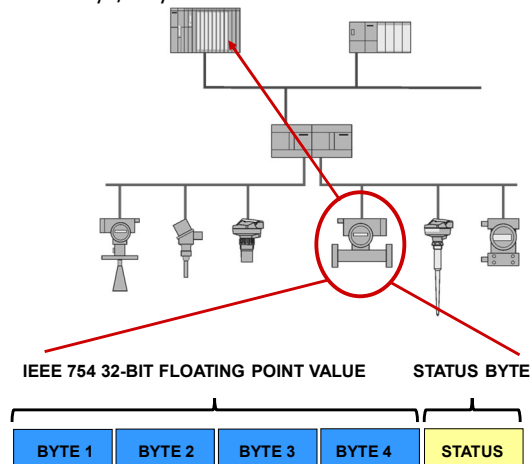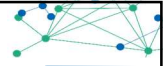
Status byte provides information regarding the "usability" of the process value

Status byte is considered an integral part of any input process variable (PV) and specifying the "quality/health" of the variable:

Good – value is a real PV

Conditionally usable – may be of lower accuracy or may be a substitute value

Failure – value does not represent the PV due to an error

Function check/local override – device is under local control, maintenance or performing a function check

Passivated (diagnostic alerts inhibited) – device forced into an idle mode by operator

Status byte also indicates the presence of a high/low limit warning or alarm with respect to the PV value
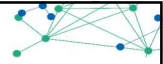
Status byte provides information regarding the condition of the device

Status byte is considered an integral part of any input process variable (PV) and specifying the condition of the device:

Good – device OK, no maintenance needed

Maintenance required – based on the previous conditions, the "wear spare" will be exhausted in the medium term or faster than expected

Maintenance demanded – based on the previous conditions, the "wear spare" will be exhausted in the short term; maintenance needed in short term to guarantee availability

Maintenance alarm – the "wear spare" is exhausted or a sudden defect occurred; maintenance required immediately

Function check/local override – device is under local control, maintenance or performing a function check

Profile 3.01, amendment 2, provided definitions for end user to specify alarm routing:
- Operator station
- Maintenance station
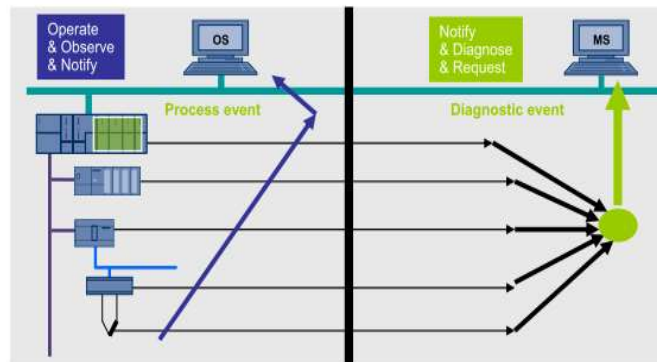
NAMUR is an international user association of automation technology in process industries
NE 91 *Requirements for Online Plant Asset Management Systems*
NE 107 *Self-Monitoring and Diagnosis of Field Devices*

Vendors can build many capabilities into devices
- Failure prediction to improve asset availability
  - Detailed messages for maintenance technician
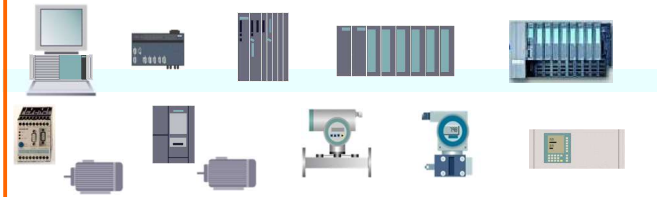- Users can adjust boundaries to match their process

Prediction: In 3 days this device will fail!
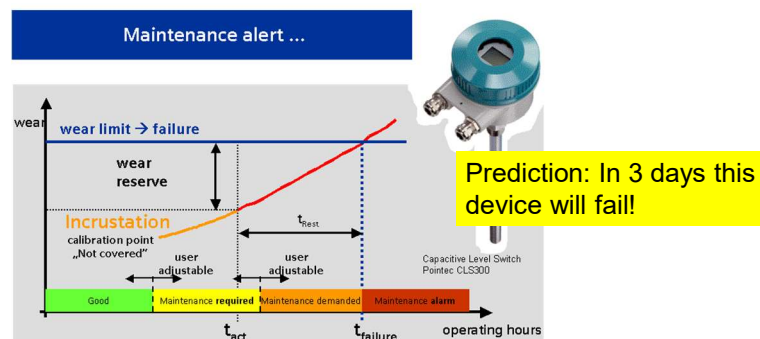
As the probe gets coated in service, the device issues an alert for maintenance.

Simple Graphical Diagnostics

Vendors can implement very detailed diagnostic capabilities in their devices

All Plant Assets Capable of Providing Diagnostic Information

Standards for representing status in Asset Management

|					
Good		Announcement of request for maintenance (low)		Request for maintenance unknown/not activated	
Simulation		Request for maintenance (medium)		Request for maintenance activated	
Function control/ local		Maintenance alert (high)		Request for maintenance in process	

Process and Device Diagnostics

Detailed diagnostic information – access with an engineering tool

- **Wear of valve seat or plug**
- **Static friction of stuffing box**
- **General fault in fitting**

- **Pneumatic Leak**
- **Deposits in pipeline**
- **Valve cone torn off**
- **Reached valve stroke limit**

Life-Cycle Asset Management
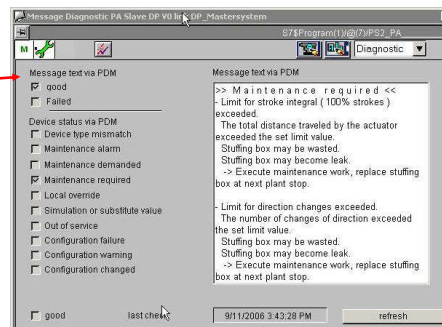
- A problem with life-cycle management of devices was replacing an older device with a newer version
- Profile 3.02 added life-cycle asset management enhancements
  - Ident Number Adaptation

Device replacement after 10 years

Defaults to Ident No. 1547
Supports Profile Ident No. 9700
Device S/W V4.0

Defaults to Ident No. 1591
Adapts to Ident No. 1547
Adapts to Profile Ident No. 9700
Device S/W V4.0…V6.0

Preferred PA Devices
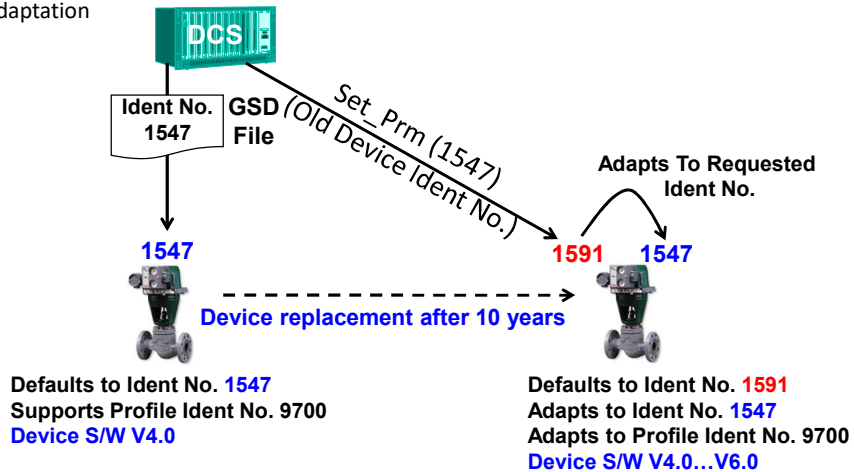
- Try to find PA devices which include implementations to
  - At least Profile 3.01, Amendment 2
  - Preferably also Profile 4.01
- Check the device documentation for Profile versions