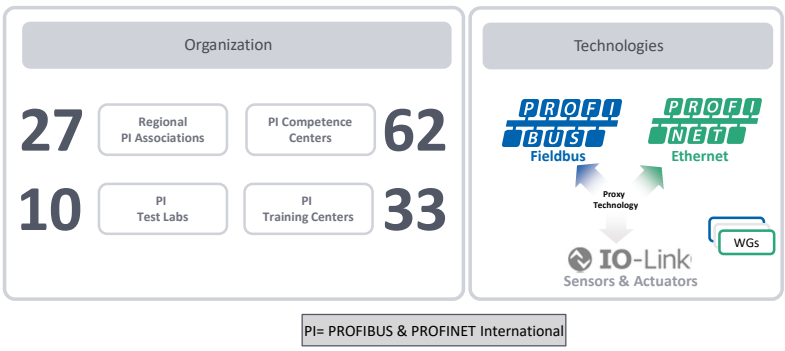
PROFIBUS Introduction

PROFIBUS & PROFINET International (PI)

- International creator, maintainer, and promoter of open, industrial communication standards PROFINET and PROFIBUS
- Founded 1989



PI= PROFIBUS & PROFINET International

PI North America

- North American Regional PI Association
- Founded in 1994 as PROFIBUS Trade Organization
- Non-profit and member-supported

Support in North America:

	PICC	PITC	PITL
PROFI Interface Center	✓	✓	✓
JCOM Automation	✓	✓	
Phoenix Contact Software	✓		
HMS	✓		

PICC = PI Competence Center
PITC = PI Training Center
PITL = PI Test Lab

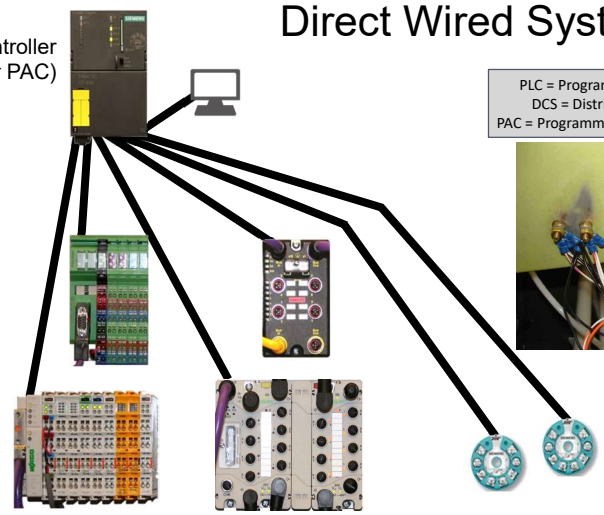
What's a fieldbus?

- A Fieldbus is a digital, serial, two-way, multi-drop communication link among controllers and its remote I/O, sensors, actuators and inter-networking components.
- In comparison to standard Local Area Networks (LAN), fieldbuses are specialized for the rugged industrial environment, determinism, bus powering, etc.

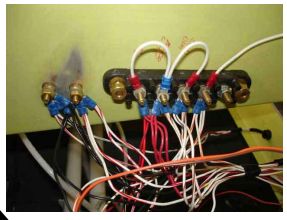
Before Fieldbuses

Direct Wired System

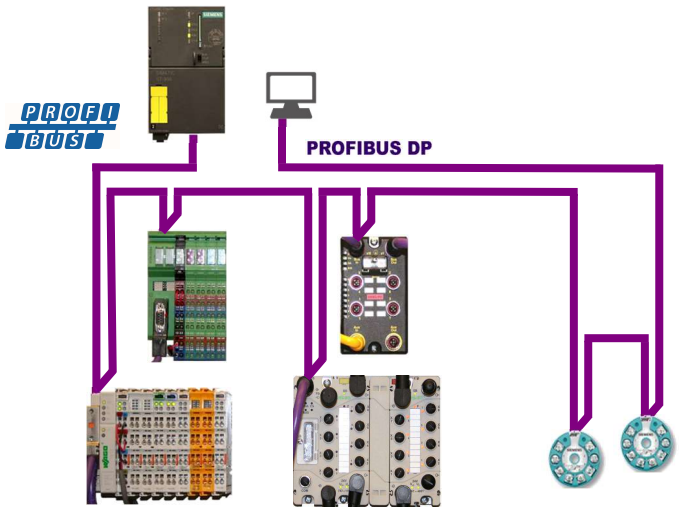
Process Controller
(PLC, DCS, or PAC)



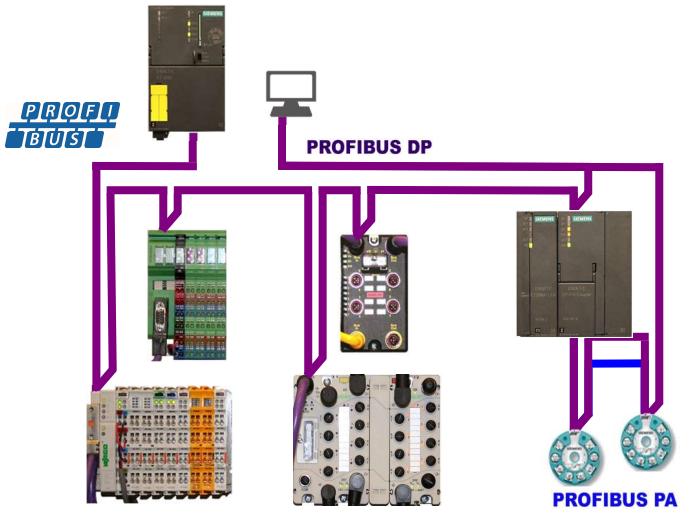
PLC = Programmable Logic Controller
DCS = Distributed Control System
PAC = Programmable Automation Controller



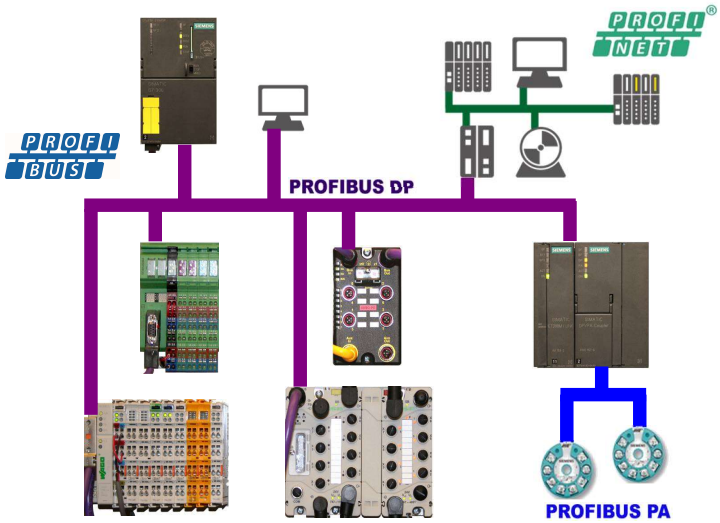
Fieldbuses



Fieldbuses



Architecture



Why use a fieldbus?

- Engineering and documentation
  - Easier configuration
  - Easier to use and up-to-date documentation
- Hardware
  - Less hardware: I/O, terminal blocks, enclosures, barriers, wire
- Installation
  - Easier, quicker, and less time-consuming
- Commissioning
  - Faster
- Maintenance/Operations
  - Improved availability & reduced down time
  - Improved asset management
- Manufacturing Flexibility
  - Changes are implemented rapidly

PROFIBUS and PROFINET Timeline

- In 1987 the German Federal Ministry for Research and Technology requested a collaboration project called “Field Bus”
- 13 Companies and 5 Universities developed an open field bus under the name PROFIBUS for PROcess FIeld BUS based on the ISO/OSI reference model

ISO = International Standards Organization
OSI = Open Systems Interconnection

PROFIBUS and PROFINET Timeline

- PROFIBUS DP for discrete IO (1993)
  - DP = Decentralized Peripheral
  - DP-V0
- PROFIBUS PA for process instruments (1996)
  - PA = Process Automation
  - DP-V1 and PA
- PROFIBUS for PROFIsafe & PROFIdrive (2001)
  - DP-V2
- PROFINET for CBA and IO (2001)
  - CBA = Component Based Automation
- PROFINET for PROFIsafe & PROFIdrive (2005)
- PROFIBUS PA Profile 3.02 (2009)
- PROFIenergy (2010)
- PROFINET for Process Automation (2011)

PROFIBUS Key Application

- Factory automation
  - Vehicle manufacturing
  - Bottling plants
  - Warehousing systems
- Process automation
  - Chemical industry
  - Petrochemical industry
  - Paper and textiles
  - Power stations
- Drive technology
  - Machine tools
  - Packaging machines
  - Paper production
- Hybrid applications

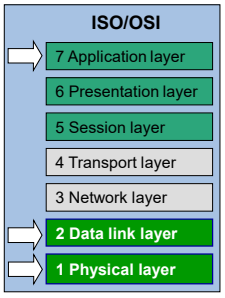
PROFIBUS DP and PA

- PROFIBUS is mainly used for high speed input/output devices and to link intelligent devices such as drives.
  - It can use different physical layers such as RS-485 (most common), wireless or fiber optics.
- PROFIBUS PA refers to the following additional features:
  - Bus powered by using the Manchester encoded Bus Powered (MBP) physical layer according to IEC 61158-2
  - Intrinsically safe design
  - Configuration over the bus
  - Device profile

DP = Decentralized Periphery
PA= Process Automation

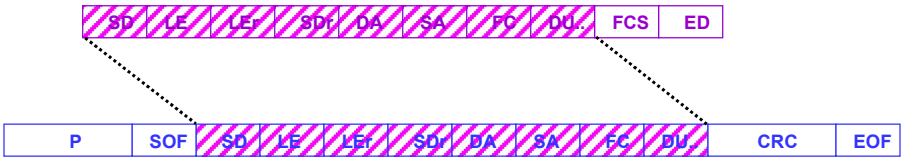
PROFIBUS DP

- Open, international standard (IEC 61158)
- Serial Fieldbus
- RS-485 transporting 244 bytes at up to 12Mbit/s
- Uses layers 1, 2, and 7 of the ISO Model



PROFIBUS PA

- Open, international standard (IEC 61158)
- Serial fieldbus
- Same protocol as DP, different physical layer: MBP at 31.25kbit/s
- Suitable for hazardous environments



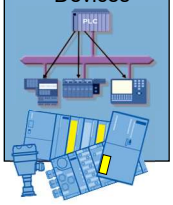
PA= Process Automation
MBP = Manchester-encoded, Bus-Powered

PROFIBUS DP- Decentralized Periphery

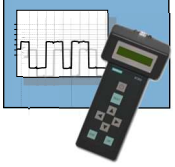
Network Design

PROFIBUS DP Project Steps

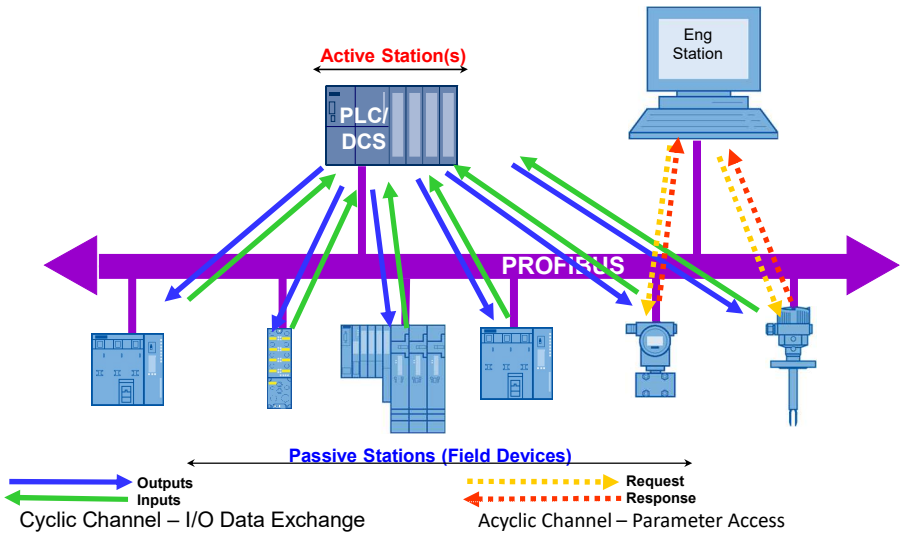
Plan/Design	Configuration	Installation	Commissioning	Maintenance
• How PROFIBUS works • Plan and Design your Network • Choose the Devices	• Configure your Network • Fail to known state • Demo of Configuration	• RS485 Signaling • Segmentation Review • Grounding • Cables and Connectors • Terminations • Set Address • Best Practice	• Using a Physical Layer Bus Tester • Using other Diagnostic tools	• Diagnostic Information • Using HMI's








Controller - Device Concept

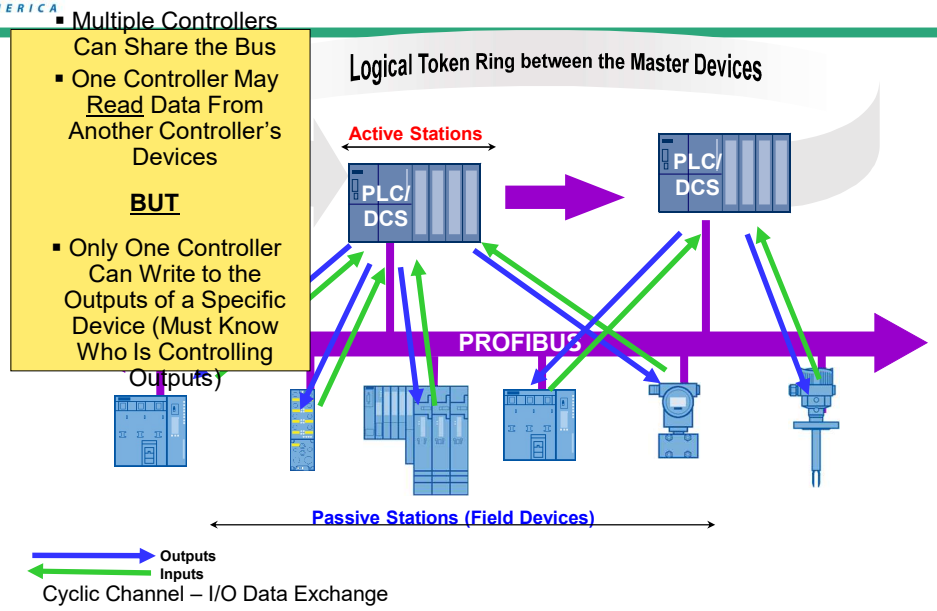


Controller - Device Concept

- Multiple Controllers Can Share the Bus
- One Controller May Read Data From Another Controller's Devices

BUT

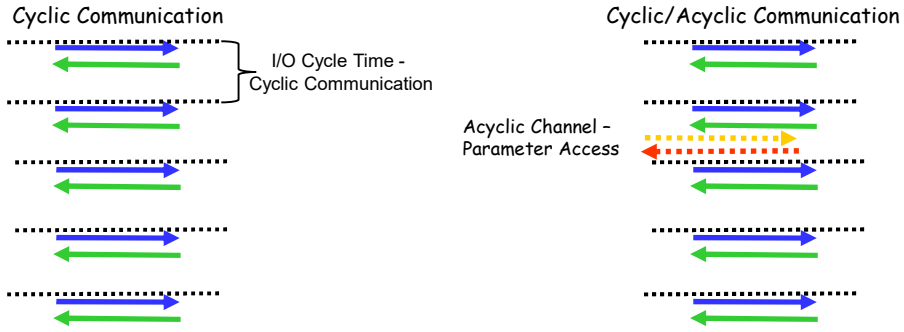
- Only One Controller Can Write to the Outputs of a Specific Device (Must Know Who Is Controlling Outputs)



Cyclic Channel – I/O Data Exchange

PROFIBUS Features

- Cyclic and acyclic channel accesses
  - Cyclic channel is used for high-speed I/O Data Exchange and Is automatic when PROFIBUS communication is activated
  - Acyclic channel communication is not automatic but is used for on-demand access to parameter data
    - Via PLC Instruction
    - Engineering tool request



PROFIBUS Features

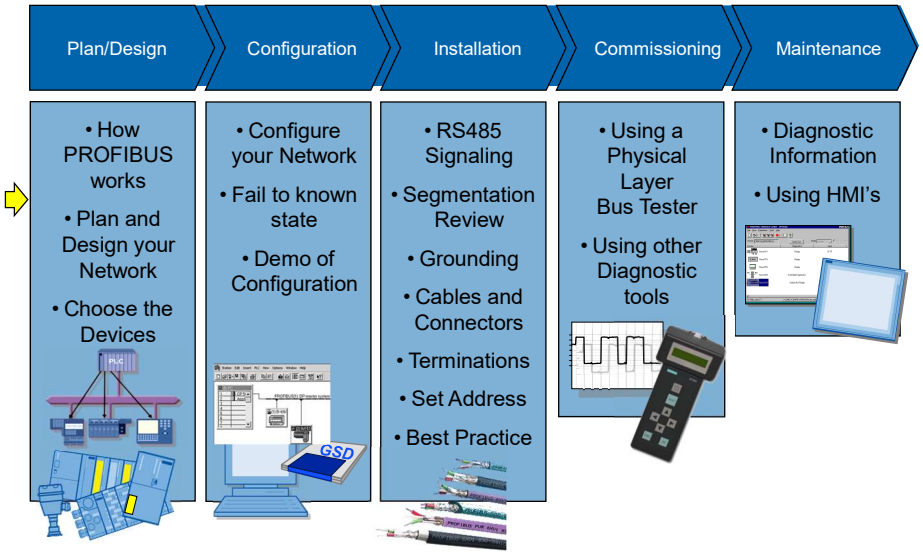
- High-speed decentralized periphery (DP) I/O data exchange features
  - All field devices have the same priority
    - Every device is scanned every cycle
  - Configuration is permanent and cyclic
    - Devices to be controlled are specified
    - Amount of I/O data to be exchanged is specified during configuration
    - Controllers with Configuration-in-Run (CiR) support on-line configuration changes
  - Communication rate up to 12Mbits/s
    - 1.5Mbits/s most frequently used

PROFIBUS Features

- PROFIBUS DP and PA utilize the same protocol
  - DPV0 Is the base protocol for cyclic I/O and diagnostics
    - Exchanging inputs/outputs
    - Reporting diagnostics such as wire break, short circuit, etc.
  - DPV1 extensions to DPV0 support acyclic channel and alarms
    - On-demand access of device parameters
      - Reading measuring units, i.e., atm, mm Hg, mm H_2O
      - Setting alarm limits, i.e., HI, LO, HI-HI
    - Reporting limit alarm, etc.

DP – Decentralized Periphery
PA – Process Automation

PROFIBUS Project Steps



Plan and Design DP Network

- Design considerations
  - Do I have any very long distances to cover?
  - How many devices will I have?
  - What communication medium/media will I use?
  - Are there any high-EMI areas?
  - Does my architecture require the use of "stub" lines?
  - What is the required I/O update cycle time?
  - How many networks do I need?
- Many of these constraints/requirements are inter-related

Segment and Network Lengths

- We need to start with learning some definitions
  - What constitutes a network?
    - In the simplest case, a network is a single RS485 length (segment) of copper cable
  - What constitutes a copper segment?
    - The longest run of copper cable possible at the baud rate used without too much signal degradation from attenuation
      - Higher baud rate signals are attenuated and distorted more rapidly than lower baud rates
    - A run of copper cable with no more than 32 devices to prevent loss of signal integrity due to loading
      - Every device adds capacitance and loads down and distorts the signal
    - The maximum length of a segment supports a fully loaded segment, i.e., 32 devices

Segment and Network Lengths

- What are the constraints on segment length?
  - The following table gives the maximum RS485 copper segment lengths for the PROFIBUS baud rates
    - What if our network needs to be longer than a segment?

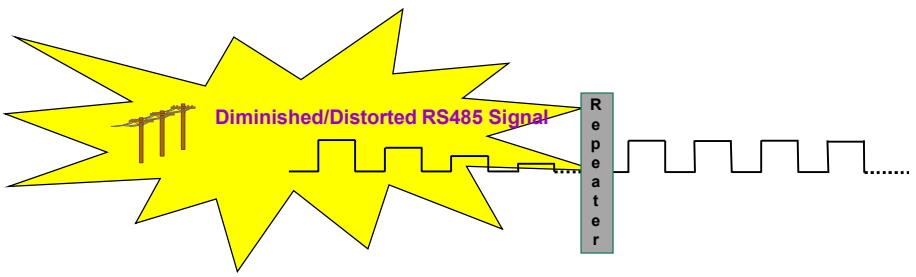
Baud Rate (kbits/s)	Max. Segment Length
9.6	1,200m/3,934ft
19.2	1,200m/3,934ft
45.45	1,200m/3,934ft
93.75	1,200m/3,934ft
187.5	1,000m/3,278ft
500	400m/1,311ft
1,500	200m/656ft
3,000	100m/328ft
6,000	100m/328ft
12,000	100m/328ft

Number of Devices on a Segment

- What are the constraints on the number of devices?
  - The EIA/TIA 485 specification says that 1 RS485 transmitter can drive 31 RS485 receivers
  - Therefore, a maximum of 32 RS485 devices are permissible on a single copper segment
    - What if we have more than 32 devices?
- What constitutes a device?
  - Any component attached to a segment that has RS485 circuitry counts as one of the 32 devices.
    - PLCs
    - I/O devices
    - HMIs
    - Repeaters
    - PROFIBUS DP/PA gateways
    - Fiber optic repeaters (OLMs)
    - Bus diagnostic tools
    - Basically anything with a copper connection
      - The one exception is an active termination box

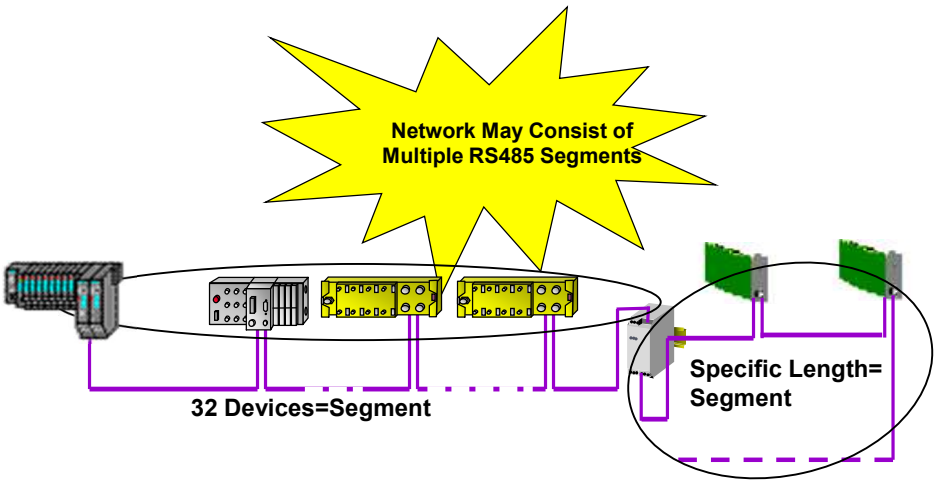
Segment and Network Lengths

- What if the total network must be longer than the segment length allowed at the baud rate used?
- What if the total number of devices is greater than 32?
  - The network is “segmented” by connecting the previous segment having the diminished or distorted signal to a Repeater to refresh the signal.
    - Refreshes the voltage level
    - Reshapes the waveform



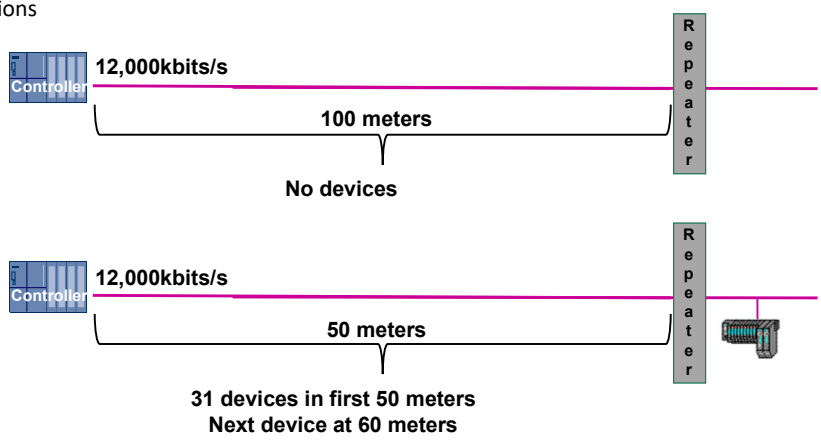
Segment and Network Lengths

- The network is “segmented” when the maximum segment length for the baud rate is reached or when 32 devices are attached…either situation requires segmentation no matter which is reached first.



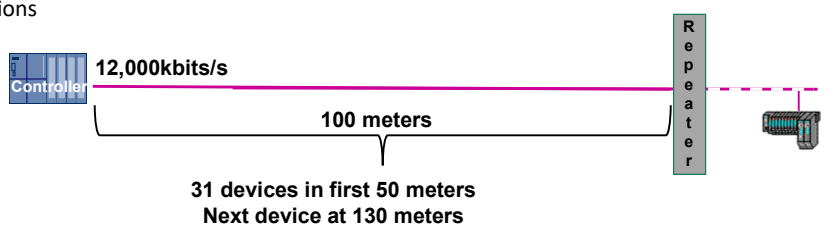
Segment and Network Lengths

- Example segmentations



Segment and Network Lengths

- Example segmentations

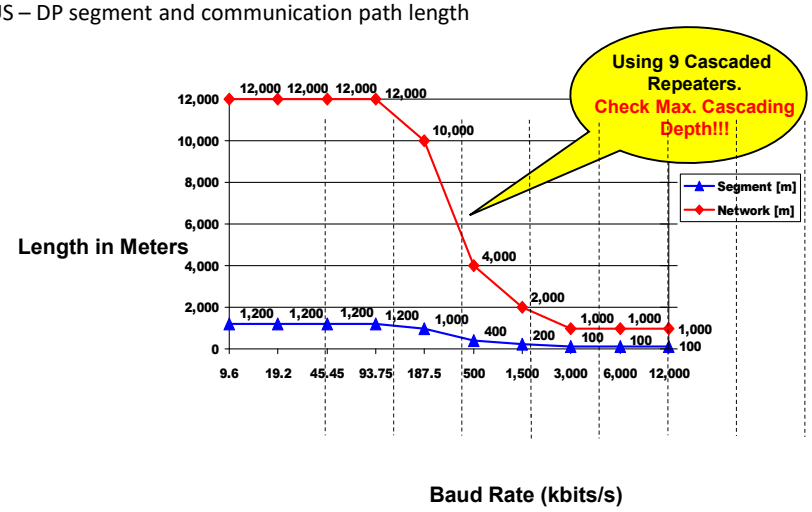


Communication Path Lengths

- There is a limit to the number of repeaters that can be used in a communication path between a PLC and a device.
  - The reason is to avoid the possibility of timing problems.
    - There is a slight time lag through each repeater on outgoing messages from a PLC and incoming messages from the device.
      - A PLC will wait only a specific amount of time for a response from the device.
    - A vendor's repeater manual will typically list a "maximum cascading depth" that can be tolerated without the possibility of timing problems.
      - For example, Siemens repeaters have a limit of 9 and Procentec repeaters have virtually no limit
      - Some other repeaters have a limit of 3
        - Slower electronics
        - Don't amplify the voltage…just reshape signal

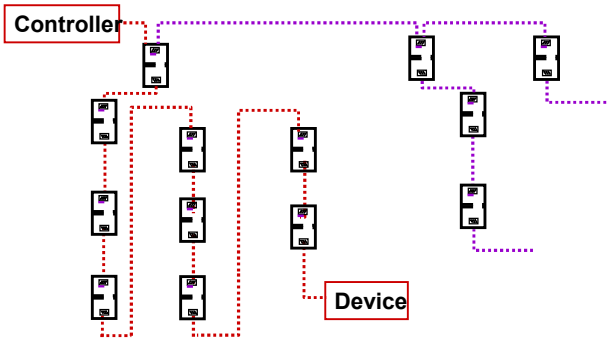
Cascading Repeaters

- PROFIBUS – DP segment and communication path length



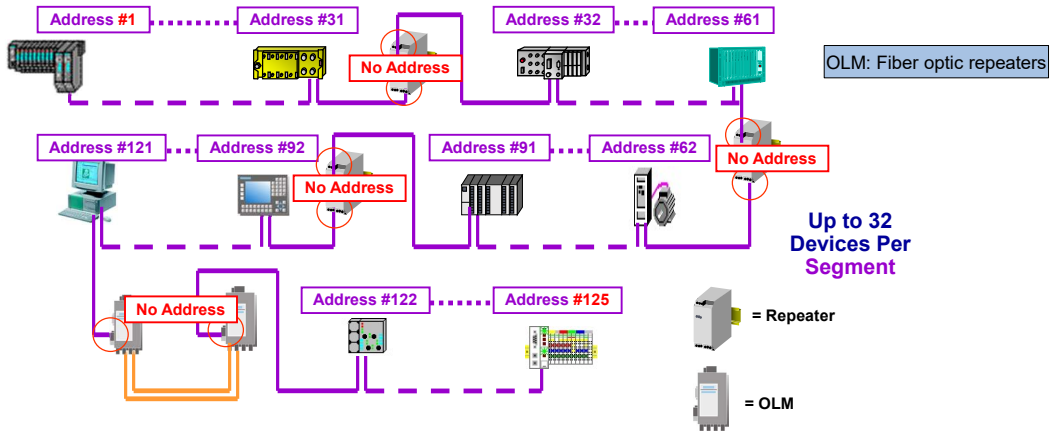
Total Repeaters In A Network

- Although a single communication path has a cascading depth limit, there can be more repeaters used in the entire network.



Network Segmentation

- DP network segmentation example



PROFIBUS DP Communication Media

What communication medium/media will I use? Wide range of available media and technologies.

- Copper is the most commonly-used with a wide variety of connector technologies
  - Almost all devices have a copper connection
  - RS485 signaling technology used
  - Wide variety of connectors available
- Fiber optics
  - Long distances with high-quality fiber
  - Variety of topologies and redundancy
  - Immune to ground plane differences
  - Suitable for use in high EMI areas
  - Few devices have a direct FO connection
- Infrared communicators
  - Good for lateral motion
  - Limited to about 15m/50ft distances
  - Maximum baud rate = 1,500kbits/s

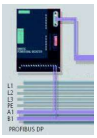
PROFIBUS Communication Media

- What communication medium/media will I use? Wide range of available media and technologies.
  - Laser communicators.
    - Good for linear, in-line motion
    - Can communicate to about 400m/1,311ft
    - Typically used to eliminate trailing cable
  - Radio transceivers.
    - Some models communicate up to several miles
    - Radio-radio communication generally at baud rates of 9.6 or 19.2kbits/s
    - Two general types available:
      - Transparent – each device is front-ended by a transceiver
      - Non-transparent – transceiver acts as a master to devices behind it and must be configured

PROFIBUS Communication Media

What communication medium/media will I use? Wide range of available media and technologies.

- Other communication technologies:
  - Slip rings.
    - For rotating machinery even at up to 12Mbits/s
  - Hanging conveyor power rails.
    - Limited to 1.5Mbits/s
    - For moving assemblies from workstation to workstation

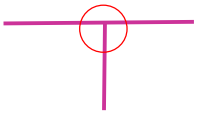


PROFIBUS Physical Layers

- Most commonly used physical layers will be covered in this class
  - RS485 on copper
    - Already covered basics needed for planning and design
  - Fiber optics
  - MBP on copper – used by PROFIBUS PA and Foundation Fieldbus (FF)

Use of Stub Lines

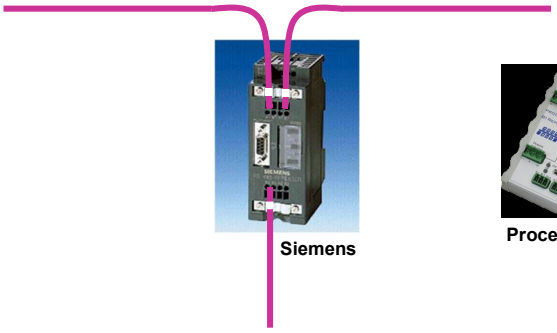
- What is a stub/spur/tee line?
  - Direct connection into main trunk/segment, basically a splice or the electrical equivalent of a splice



- Why are stub lines “bad”?
  - Stub lines generate reflections on the bus and can cause communication problems at higher baud rates
  - All energy from a waveform is not absorbed at the end of a segment and “bounces back” or reflects, possibly corrupting the signal being sent from the transmitter

Use of Stub Lines

- For baud rates above 500kbits/s, it's safer to use a repeater to facilitate a branch away from the main trunk line.
  - There will never be a problem to extend the segment or increase the baud rate because it is not a spur/stub line
- Repeater product availability from Siemens, Procentec, Phoenix Contact, Kunbus, Helmholz, Indusol, Hirschmann, etc.



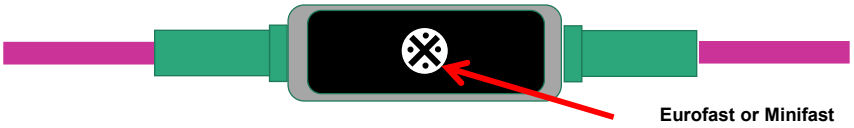
Siemens

Procentec

Phoenix Contact

Use of Stub Lines

- Some architectures are facilitated by using stub lines.
  - Drops from a conduit adapter to a valve, for example, to maintain waterproof integrity of the conduit



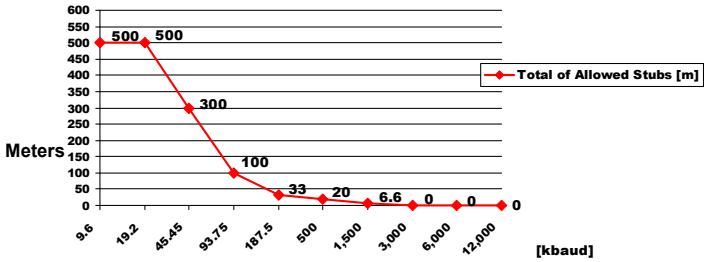
Eurofast or Minifast
Connector – Cable to valve

  - Stub lines from a trunk line to removable buckets in an MCC, for example
  - Both architectural examples seem to have some justification, although most MCC wiring uses daisy-chaining
- Architectures are possible using stub lines; however, the baud rate restrictions from the PROFIBUS standard must be observed.
  - The standard states the restrictions in terms of the total amount of capacitance allowed due to the total of stub lines on a segment for a given baud rate
  - Using the Type A cable capacitance of 30pF/m, it's easy to convert these allowed capacitances to distances,

as shown in the next table

Use of Stub Lines

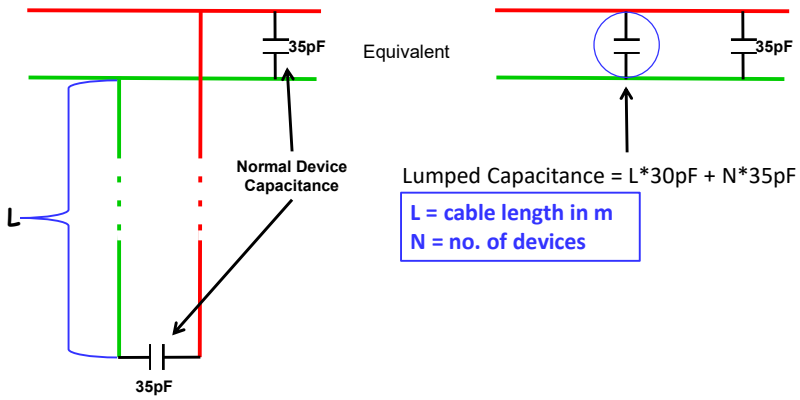
- Table of total length of allowed stub lines at the different baud rates.
  - Remember that this is the total for ALL stub lines…not the limit for each individual stub!!



Extensive Use of Stub Lines May Prevent Later Expansions to the Network and/or Preclude Higher Baud Rate Operation.

Use of Stub Lines

- Stub lines result in "lumped" capacitance at the point of the stub line

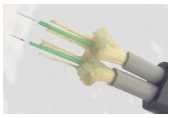


Fiber Optic Media

- Plastic
  - Low performance, large diameter plastic core
- Plastic Clad Silica/Poly Clad Fiber (PCS/PCF)
  - Medium performance, intermediate diameter glass core
  - Cladding is plastic or lower grade glass
- Single Mode Glass Fiber
  - High performance, small diameter glass core
  - Cladding is less pure glass than glass core

Least expensive, lowest performance, easiest to use.

Most expensive, best performance, hardest to use.



Use of Fiber Optic

- Fiber optics - advantages
  - Noise immune – resistant to EMI
  - Potential difference independent
    - No worry about ground current loops

- Longer Distances
- Line, ring, redundant ring and star configurations are possible

Use of Fiber Optic

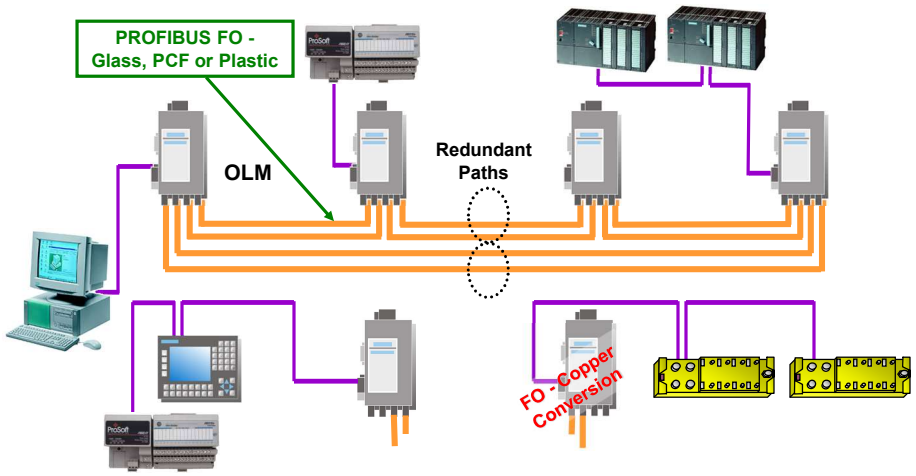
- Cable lengths with fiber

Cable Spacing, Core/Cladding (µm)	Distance Between FO Repeaters (m)	Operating Wavelength (nm)
Plastic, 980/1000	50 - 80	650
PCF/PCS, 200/230	300 - 400	650
Multi-Mode Glass, 62.5/125	3,000	860
Multi-Mode Glass, 50/125 Becoming more popular with use of VCSELs *	3,000	860
Single-Mode glass, 10/125	15,000	1300

* VCSEL is Vertical Cavity Surface Emitting Lasers

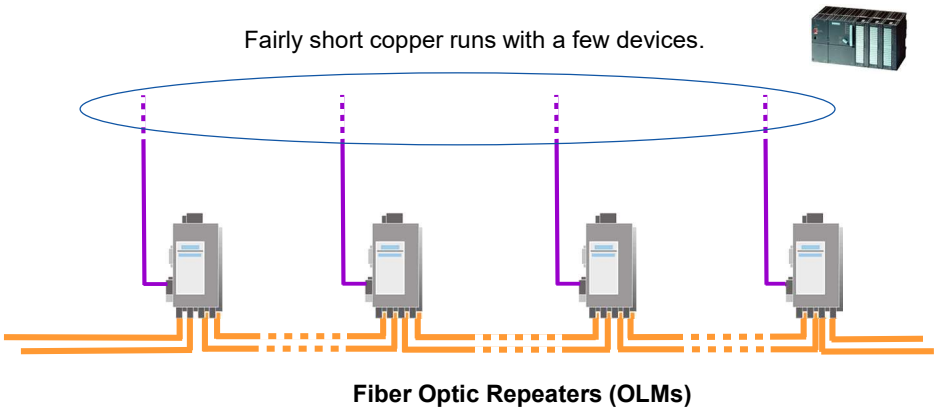
Use of Fiber Optic

- Fiber optic – redundant ring
  - Used on US Navy carriers



Use of Fiber Optic

- Fiber optic backbone
- Used in high EMI areas
- Induction furnaces, high-HP motors, etc.
- Areas having tendency for grounding problems



Fiber Optic Repeaters (OLMs)

Instruments In Explosive Areas

- Do I have explosive areas into which instruments must be installed?
  - Must decide whether to use traditional protection technologies, e.g., purged cabinets, pressurized cabinets, oil/sand submersion, etc., or intrinsically safe technology
  - Can choose to do "business as usual" by using the older technologies

    OR
  - PROFIBUS PA (or FF) can be used, both of which use MBP bus physics
    - Install devices directly into explosive areas without housing the devices and be able to perform "hot" maintenance

Address Assignment

- PROFIBUS DP address assignment
  - Assignment of addresses to the devices has no effect on bus performance
  - However, as an aid in commissioning and later maintenance, planned address assignment can be an aid
    - Consider assignment of address ranges based on the segmentation, for example:
      - First segment: addresses 1 – 19
      - Second segment: address 20 – 39

I/O Cycle Time

- What do I need to consider to determine the I/O cycle (update) times required?
  - The PLC/DCS control cycle time
    - Should have several I/O updates for each control cycle
  - Required I/O response times
    - Input to output
- What do I need to consider that affects the DP I/O cycle time?
  - The communication baud rate
    - Higher baud rates = faster I/O cycle times
  - The total number of devices to scan each cycle
    - More devices = longer I/O cycle times
  - The total number of bytes of data (outputs + inputs) transferred each cycle
    - More data = longer I/O cycle times
  - The total number of networks
    - More networks for same number of devices or the same amount of data = faster cycle times
  - Communication with PA sub-networks
    - Certain DP/PA couplers can drastically slow down the DP cycle time (covered in PA section)

I/O Cycle Time

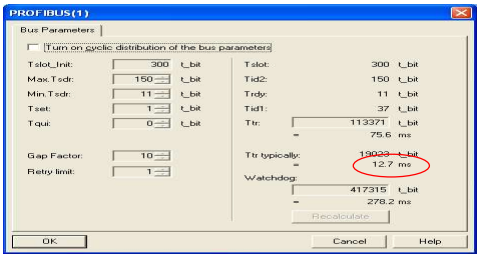
- What do I need to consider to meet the I/O cycle (update) times required by my control cycle time?
  - The effect of communication baud rate on cycle time is pretty much self-explanatory
  - The effect of more/less devices to scan each cycle is also pretty much self-explanatory
  - The effect of more/less data to be transferred each cycle is also pretty much self-explanatory
  - The effect of the total number of networks may not be self-explanatory
  - Some DP/PA couplers are “dumb” and require slowing the baud rate on the DP network to 45.45kbits/s or 93.75kbits/s – more details later

I/O Cycle Time

- Up to 126 devices are possible on a single PROFIBUS DP network
  - PROFIBUS Utilizes Addresses 0 – 127
  - Address 127 Is Used for Broadcast Messages
    - No Device Can Have Address 127
  - Address 126 Reserved for Devices Without Address Switches…Cannot Exchange I/O Data
  - Address 0 Frequently Used By Engineering, Programming or Configuration Tools
    - Some cannot have their address changed
  - Only addresses 1 – 125 can be used for active devices exchanging I/O data…typically one controller and the rest devices
    - More than one controller is possible – HMI devices typically sit on the bus as a controller device
- Device address assignment has no effect on bus performance
  - Address assignment has no effect on bus performance since the controller only attempts communication with addresses that are assigned in the configuration

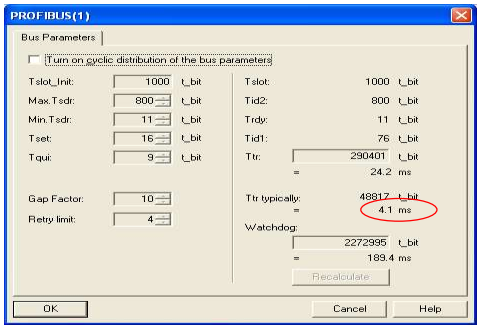
I/O Cycle Time

- Assume that our required I/O cycle time is 10ms
- Assume a single network with one controller PLC and 50 devices having one byte of output and one byte of input data each
  - Some PROFIBUS configuration tools calculate an estimated I/O cycle time for the configuration and display it in the “bus parameters”
    - One such configuration tool gave an estimated cycle time for the above configuration of 12.7ms at 1.5Mbits/s



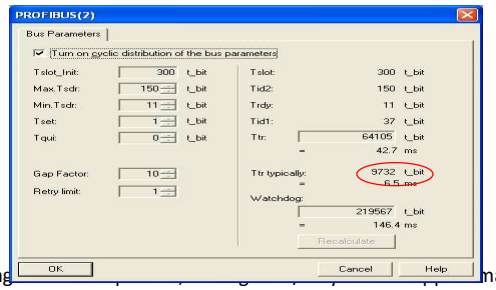
I/O Cycle Time

- What are the primary things we can do to meet the requirement of 10ms?
  - Increase the baud rate
  - Split the devices out onto more than one network
- Increasing the baud rate to 12Mbits/s in our configuration tool gave an estimated I/O cycle time of 4.1ms



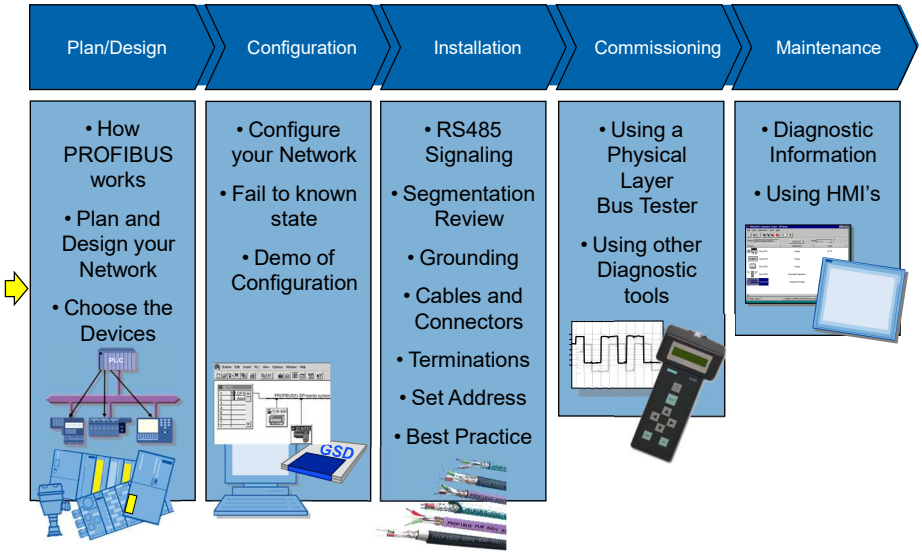
I/O Cycle Time

- Splitting the 50 devices across two networks of 25 devices at 1.5Mbits/s with our configuration tool gave an estimated I/O cycle time of 6.5ms



- The two separate networks are being [illegible] mately in half

PROFIBUS Project Steps



Device Selection: Devices

- Choose your PROFIBUS devices
  - Choose devices that best fulfill your specific application requirements
  - Look for features that make your job easier
    - Soft starter
    - Intelligent breaker
    - Good diagnostic capabilities
  - Devices should be certified by an accredited PI test lab – such as the one in Johnson City, TN
    - Certified to meet the IEC 61158 standard
    - PROFIBUS communication won't fail under some "weird" circumstance

Device Selection: Controller

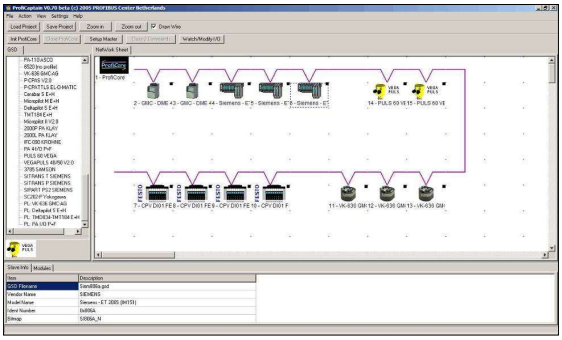
- Choose your PROFIBUS controller
  - Must be able to handle all requirements of the devices, i.e., bytes or words of input and output data, amount of parameter data, etc.
    - Some low-end controllers only support the minimum stated in the PROFIBUS standard
      - 32 bytes inputs and outputs
      - 32 bytes of parameter data
  - Controller should be certified by an accredited PI test lab

Selecting a certain vendor's Controller PLC or DCS requires the use of that vendor's PROFIBUS Configuration Software as well!

Check out both their Hardware and Software before you decide.

Configuration Software Selection

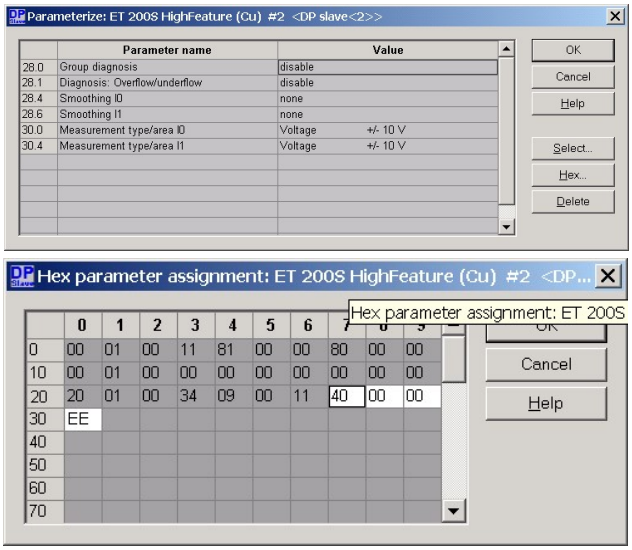
- PROFIBUS configuration software requirements
  - Should be user-friendly and able to handle all device requirements, e.g., large number of user-selectable parameters
  - Should utilize the textual entries from the device GSD file for listing the parameters by name and listing the possible values for parameter settings
  - Some configuration tools require the user to dig through a manual to determine what parameters the device has, the appropriate flag/field settings for parameter selection and then require the user to input raw hexadecimal values



Configuration Software Selection

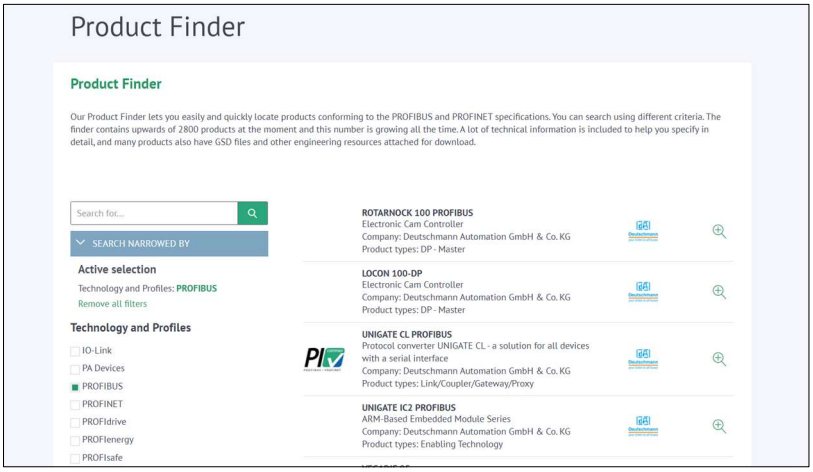
- Parameter selection

This
Or
This?



Device Selection

- How do I find available devices?
  - Product Finder at profibus.com



Configuration Software Selection

- How can you find out if a device is certified?
  - If there is a write-up in the product guide, there will be an indication if the product is certified
    - It is the vendor's responsibility to put a write-up in the product guide
  - If there is no write-up, you can ask the vendor to provide a copy of one of the following:
    - The certificate issued by PI showing the product is certified
    - The test report from the lab that tested the product, which will have a pass/fail recommendation

PROFIBUS • PROFINET NORTH AMERICA

PROFIBUS DP- Decentralized Periphery

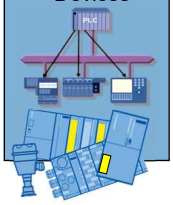
Network Configuration

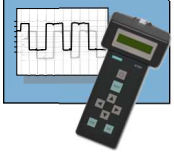
PROFINET PROFIBUS PROFIsafe PROFIenergy PROFIdrive IO-Link FDI

PROFIBUS • PROFINET NORTH AMERICA

PROFIBUS Project Steps

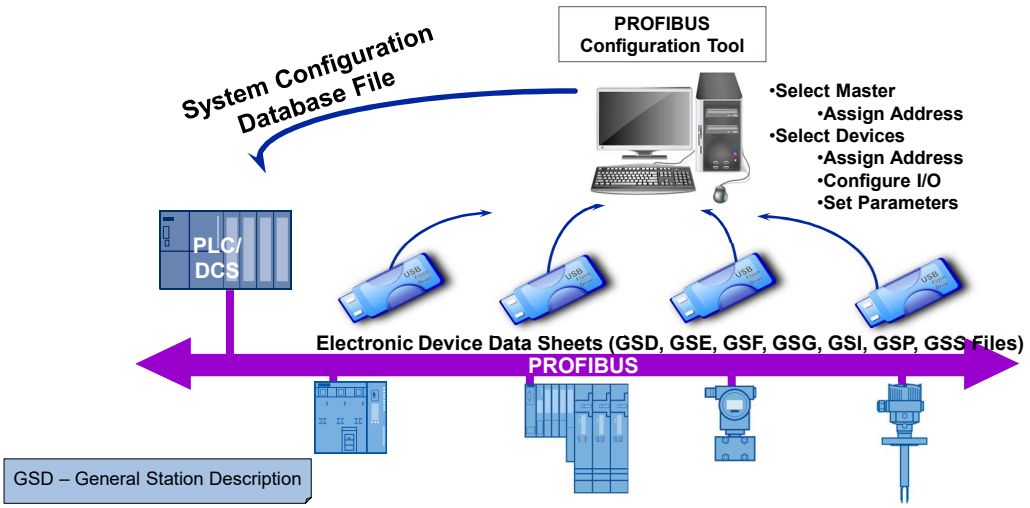
Plan/Design	Configuration	Installation	Commissioning	Maintenance
• How PROFIBUS works • Plan and Design your Network • Choose the Devices	• Configure your Network • Fail to known state • Demo of Configuration	• RS485 Signaling • Segmentation Review • Grounding • Cables and Connectors • Terminations • Set Address • Best Practice	• Using a Physical Layer Bus Tester • Using other Diagnostic tools	• Diagnostic Information • Using HMI's





System Configuration

- Plug and Play With Electronic Device Data Sheets



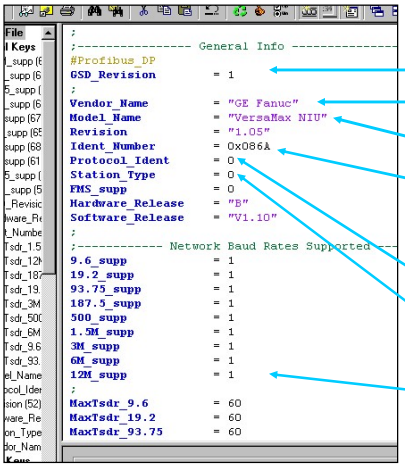
GSD Files

- Plug and play with electronic device data sheets – gsds
  - Provided by the device vendor – check web site
  - Describes device's PROFIBUS features
    - PROFIBUS Ident number
  - What baud rates are supported
  - What I/O configurations are supported
    - What plug-in modules are available
  - Any special PROFIBUS features supported
    - Fail-to-Known-State
    - SYNC/FREEZE
  - Any PROFIBUS protocol extensions supported
    - DPV1
    - DPV2
  - Any PROFIBUS profiles supported
    - PROFIdrive
    - PROFIsafe

GSD Files

- Example of a GSD file

GSD



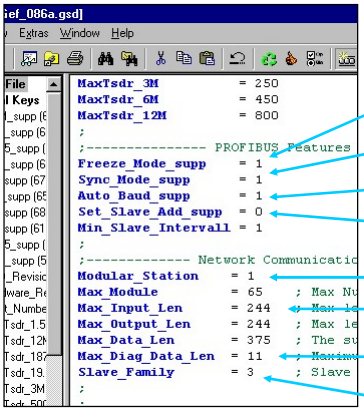
```
;
;---------------- General Info ----------------
#Profibus_DP
GSD_Revision          = 1
;
Vendor_Name           = "GE Fanuc"
Model_Name            = "VersaMax NIU"
Revision              = "1.05"
Ident_Number          = 0x086A
Protocol_Ident        = 0
Station_Type          = 0
FMS_supp              = 0
Hardware_Release      = "B"
Software_Release      = "V1.10"
;
;------------ Network Baud Rates Supported ---
9.6_supp              = 1
19.2_supp             = 1
93.75_supp            = 1
187.5_supp            = 1
500_supp              = 1
1.5M_supp             = 1
3M_supp               = 1
6M_supp               = 1
12M_supp              = 1
;
MaxTsdr_9.6           = 60
MaxTsdr_19.2          = 60
MaxTsdr_93.75         = 60
```

- GSD Revision According to Standard
- Vendor/Manufacturer Name
- Device Name (Displayed in Config Tool)
- Unique ID Number of Product
  - ❑ Mandatory for Class 1 and devices
  - ❑ Issued by PI
- Services Supported (0=DP; 1=DPandFMS)
- Type (0=Device; 1=Master)
- Supported Transmission Rates and Related Timing Parameters

GSD Files

- Example of a GSD file

GSD

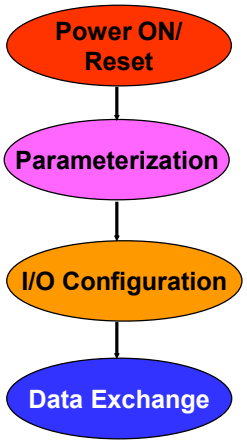


```
ef_086a.gsd]
Extras  Window  Help
MaxTsdr_3M            = 250
MaxTsdr_6M            = 450
MaxTsdr_12M           = 800
;
;---------------- PROFIBUS_Features
Freeze_Mode_supp      = 1
Sync_Mode_supp        = 1
Auto_Baud_supp        = 1
Set_Slave_Add_supp    = 0
Min_Slave_Intervall   = 1
;
;------------- Network Communicatic
Modular_Station       = 1
Max_Module            = 65    ; Max Nu
Max_Input_Len         = 244   ; Max le
Max_Output_Len        = 244   ; Max le
Max_Data_Len          = 375   ; The su
Max_Diag_Data_Len     = 11    ; Maximu
Slave_Family          = 3     ; Slave
;
```

- 1=Freeze of Input Data Supported
- 1=Synchronization of Output Data Supported
- 1=Transmission Rate Detected by Device
- 0=Address Can NOT Be Set Via PROFIBUS
- 1=Station Accepts Plug-In Modules
- Length Definitions for Modular Stations
- Maximum Amount of Diagnostic Data Reported by the Device
- Used by Configuration Tool to Categorize Devices in the Hardware Catalog

Startup Sequence

- Startup sequence - high-speed data exchange
  - I/O configuration and parameter data must be downloaded to the devices



Power ON/Reset of Master or Device — System Parameter and Configuration Database File Loaded into Controller

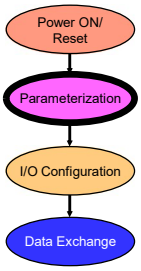
Parameters selected during configuration by the user are downloaded into the device for processing and validation

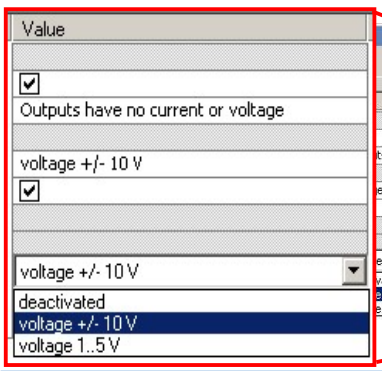
I/O Configuration data selected during configuration by the user are downloaded into the device for processing and validation

Cyclic Data Exchange (I/O Data)
And Field Device Reports Diagnostics

Startup Sequence: Parameterization

- Device parameterization
  - Select parameters with configuration tool

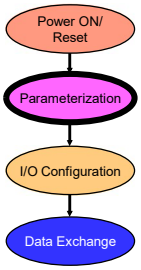




Fewer DIP Switches - NO Handheld - NO Extensive Additional Documentation
User Defines Every Function in ONE Tool.

Startup Sequence: Parameterization

- Device parameterization
  - Download parameters to device



Parameter Download (Up to 244 Bytes)

Controller ✓ Device

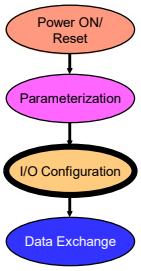
- ❑ Features Implemented in Device
- ❑ Described in GSD File
- ❑ Processed by Configuration Tool
- ❑ Selected at Configuration
- ❑ Examples:
  - ✓ Enable Channel Diagnostic
  - ✓ Operation Range for Analog Channels (e.g. ±10V or 0..10V)
  - ✓ Fail-to-Known State Behavior (e.g. Hold Last Value)

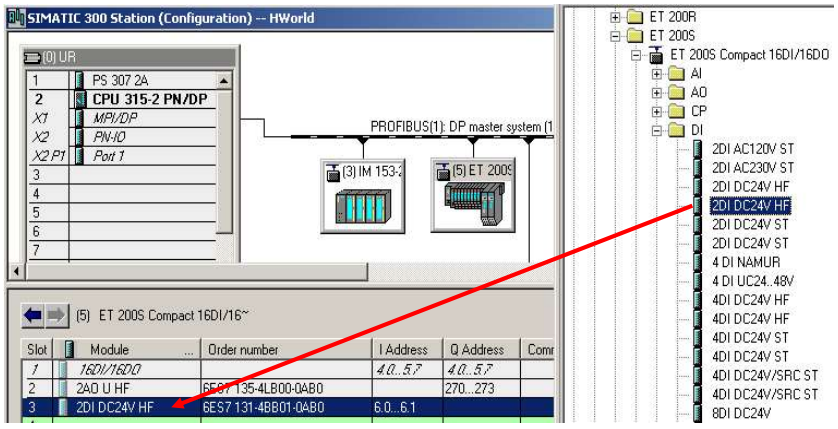
 = Parameterization Data

✓ = Confirmation (Data Received)

Startup Sequence: I/O Configuration

- Device I/O configuration
  - Describe I/O data to exchange





Startup Sequence: I/O Configuration

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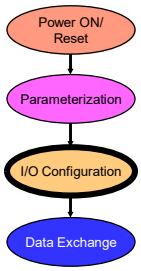
- Device I/O configuration
  - Download description of I/O data to exchange

Configuration Download (Up to 244 Bytes)



- ❑ Possible I/O Selections Described in GSD File
- ❑ Processed by Configuration Tool
- ❑ Selected at Configuration
- ❑ Examples
  - ✓ 8DI (1 Byte), 8DO (1 Byte)
  - ✓ 2AI (2 Words), 2AO (2 Words)
  - ✓ RS232 Interface, Counter Module

= Configuration Data

= Confirmation (Data Received)

High-Speed I/O Data Exchange

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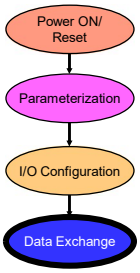
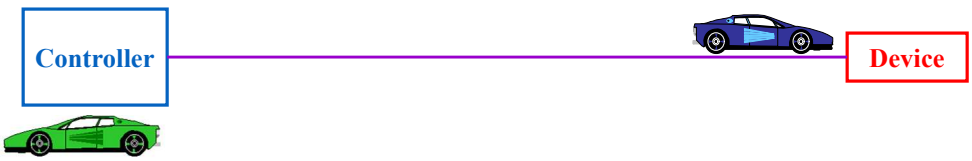
- High-speed I/O - data exchange
  - Up to 244 bytes of input data and 244 bytes of output data
    - Only transfer what is configured





= Output Data

= Input Data

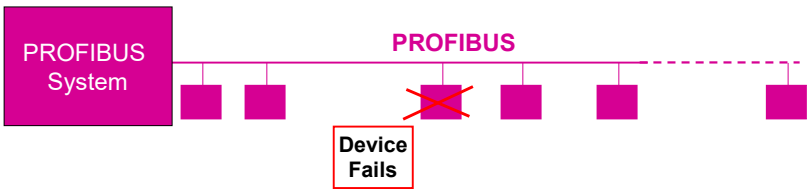
Use of Startup Sequence

- Importance of startup sequence
  - Controller has all information stored in retentive memory to start up a failed device replacement
    - Parameters
    - I/O configuration

Plug ‘n Play Replacement!!!

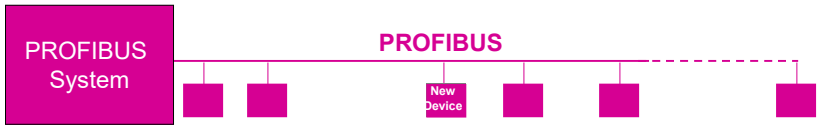
Use of Startup Sequence

- Plug ‘n Play replacement of a failed device



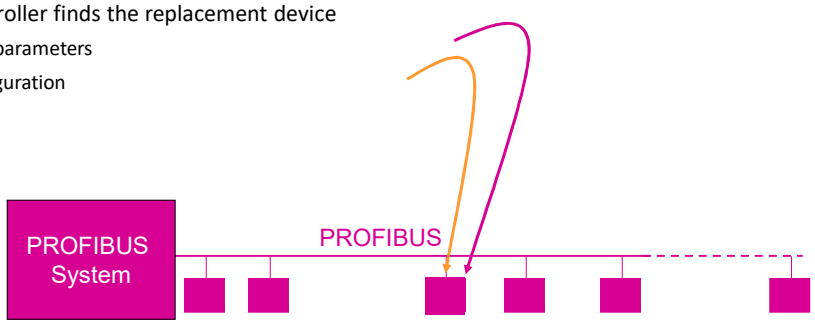
Use of Startup Sequence

- Plug ‘n Play replacement of a failed device
  - Take same device from spare parts
  - Set address to that of the failed device
    - Rotary/DIP switches
    - Software
  - Connect to bus



Use of Startup Sequence

- When the controller finds the replacement device
  - Sends startup parameters
  - Send I/O configuration



Plug ‘n Play Replacement!!!

PROFIBUS Project Steps

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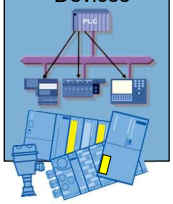
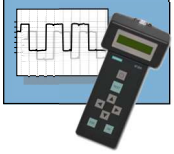
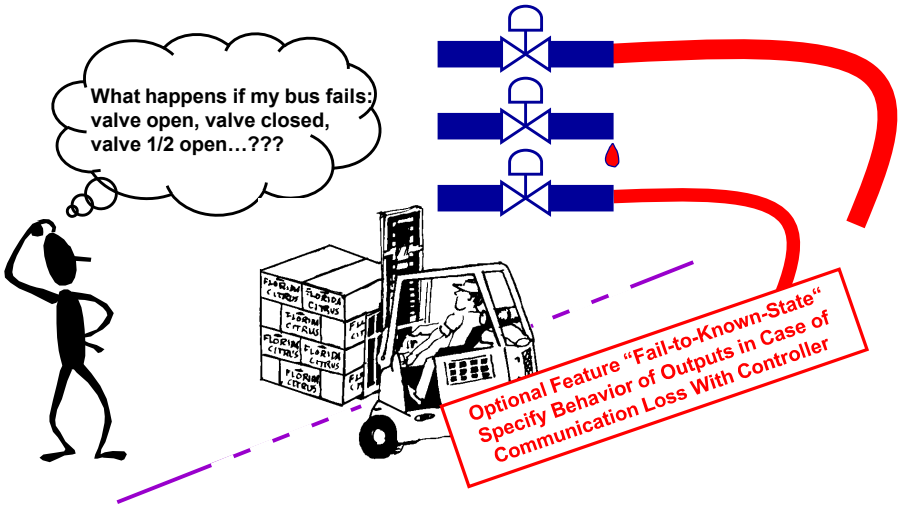







Fail-to-Known-State

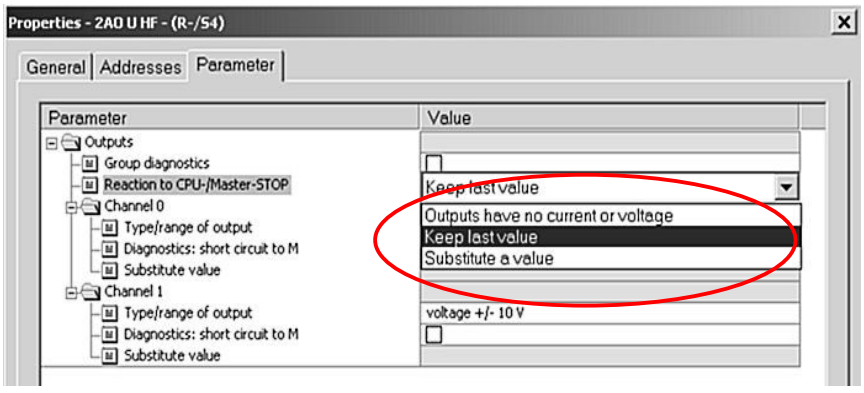
- State of outputs on failure– fail-to-known-state



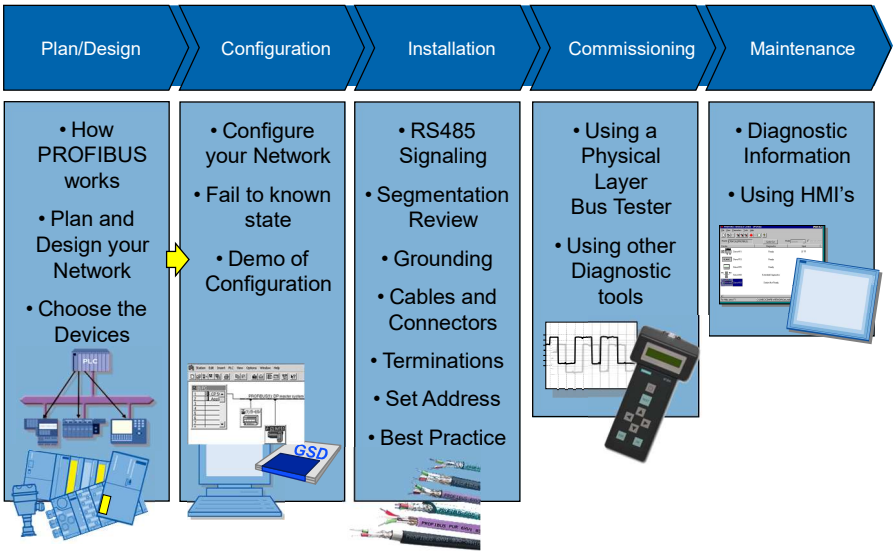
Fail-to-Known-State

- Optional feature for field devices
- Specified in GSD File
- Manufacturer has the capability to allow the end user to specify the action of device outputs on loss of communication between controller and device
  - Clear the outputs
  - Hold outputs at the last value received (e.g., Valve 1/2 Open)
  - Set outputs to a specified value (e.g., Open or Close Valve Completely)
- User defines action with configuration tool while setting up parameters

Fail-to-Known-State

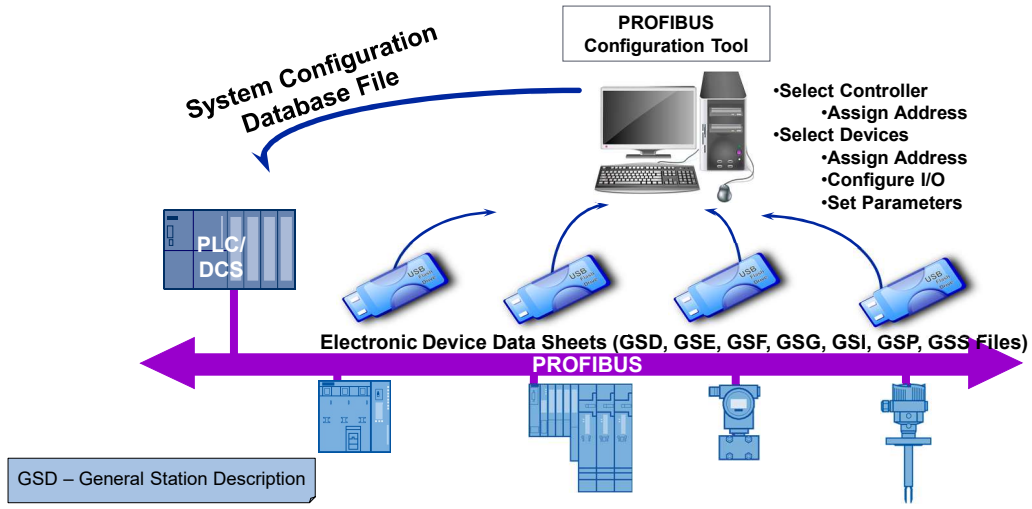


PROFIBUS Project Steps

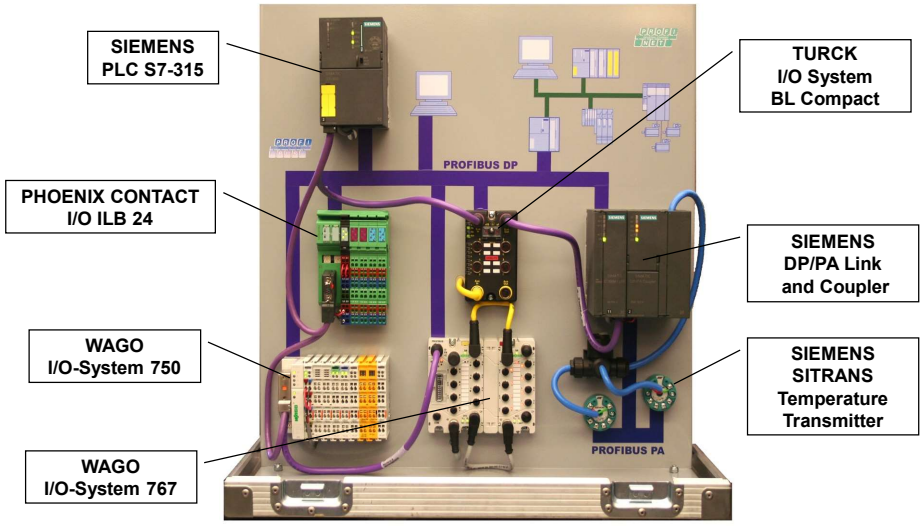


System Configuration

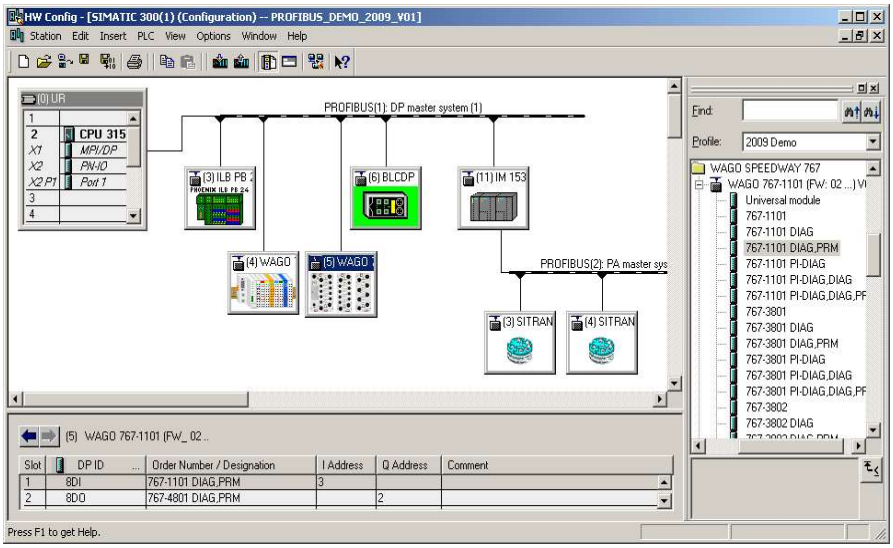
- Plug and Play With Electronic Device Data Sheets



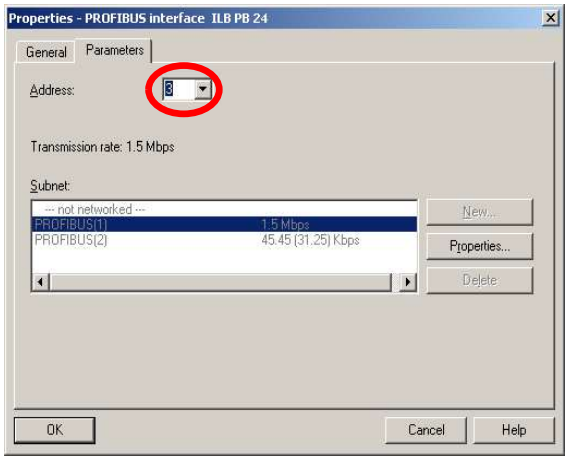
Demo Rack



Configuration Overview

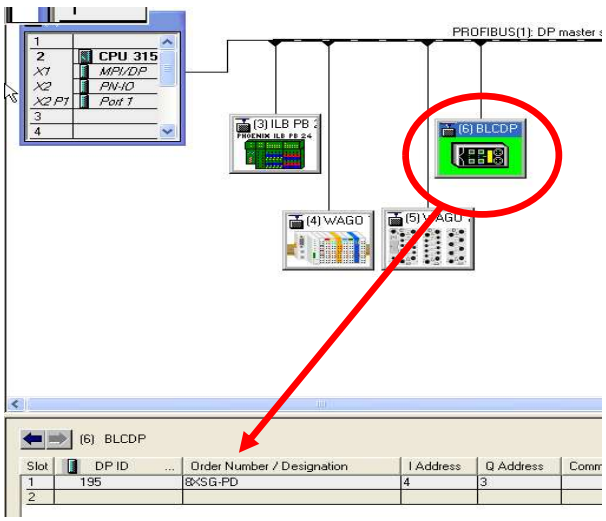


Address Assignment



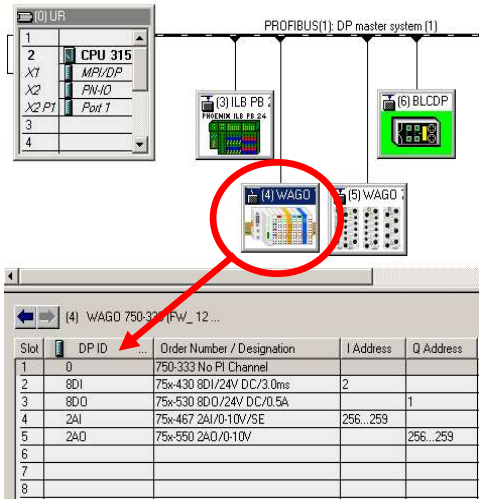
Example I/O Configuration

- Compact Device

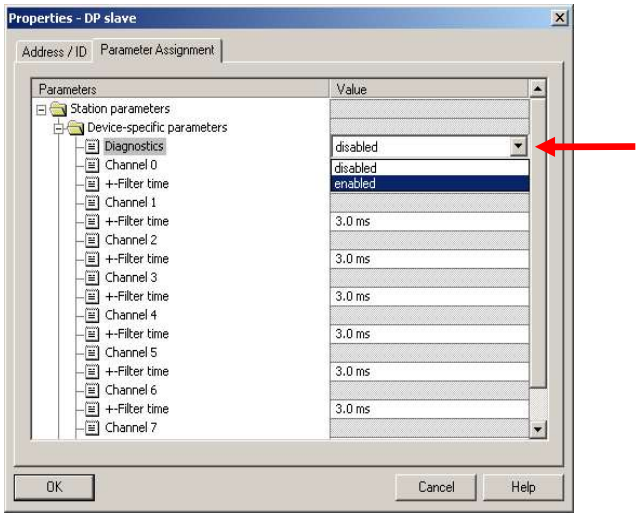


Example I/O Configuration

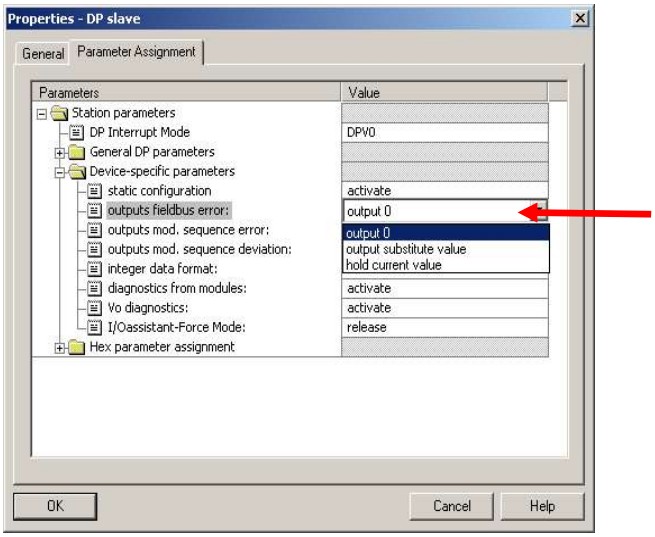
- Modular Device



Parameter Assignment

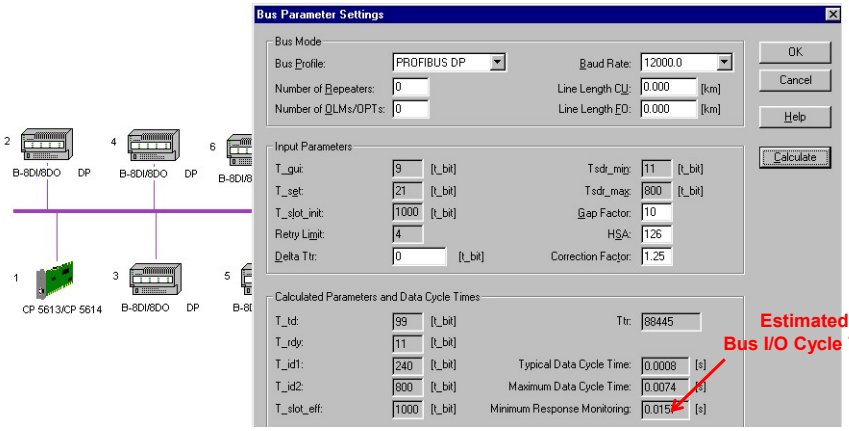


Fail-to-Known-State



Bus Timing

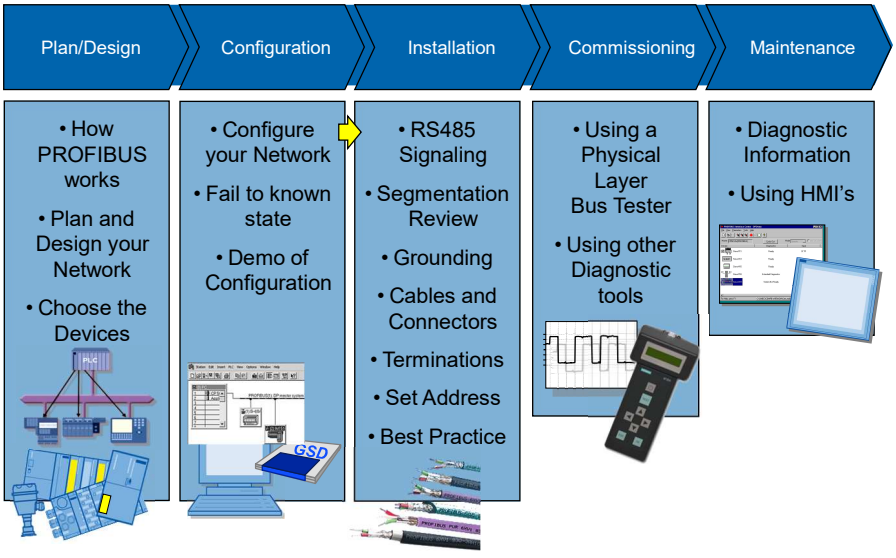
- High-Speed Data Exchange (DP) Timing
  - 10 Stations With 2 Byte I/O (160 In/Output Signals)
    - Bus Cycle Time = 0.8ms



PROFIBUS DP- Decentralized Periphery

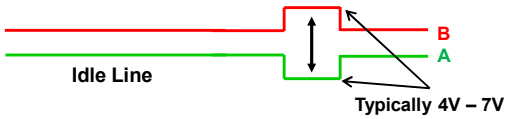
Installation

PROFIBUS Project Steps



RS485 Signal

- PROFIBUS copper uses RS485 signaling
  - Cable is a Shielded, Twisted Pair (STP)
    - Differential signal difference between the two signal lines (B-A)
      - Idle line is at a mark (One) state
      - B-Line drives positive from idle
      - A-Line drives negative from idle
      - Receiver measures difference

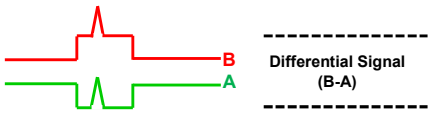


RS –Recommended Standard
STP – Shielded Twisted-Pair

RS485 Signal

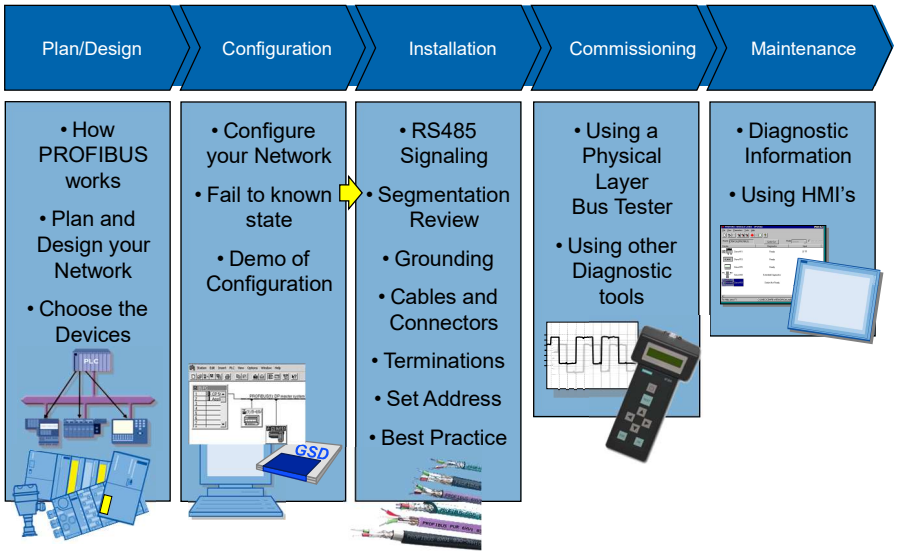
- More noise immune than single-wire technologies which transmit and receive on one wire
  - RS485 uses two wires
    - Transmits and receives on both wires
    - Any noise typically couples onto both wires of the STP in the same way

    - Up to a limit, the noise differences out at the receiver



RS –Recommended Standard
STP – Shielded Twisted-Pair

PROFIBUS Project Steps



Segment and Network Lengths

- The following table gives the maximum RS485 copper segment lengths at the PROFIBUS baud rates.

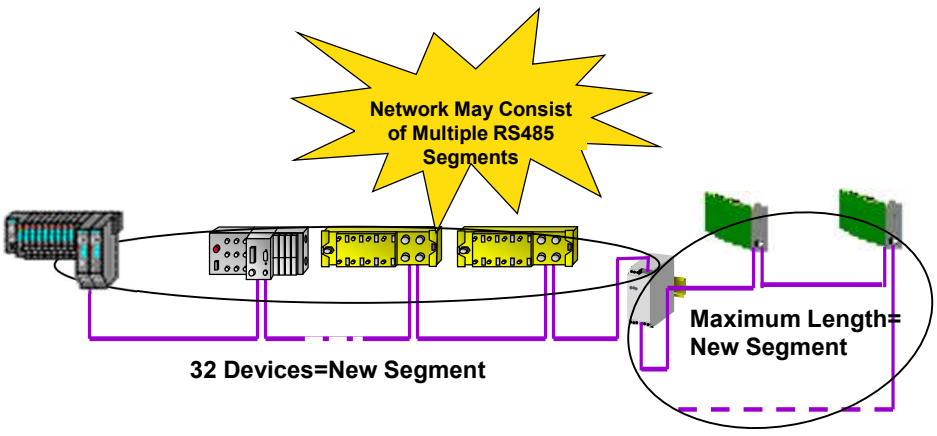
Baud Rate (kbits/s)	Max. Segment Length
9.6	1,200m/3,934ft
19.2	1,200m/3,934ft
45.45	1,200m/3,934ft
93.75	1,200m/3,934ft
187.5	1,000m/3,278ft
500	400m/1,311ft
1,500	200m/656ft
3,000	100m/328ft
6,000	100m/328ft
12,000	100m/328ft

Number of Devices on a Segment

- The EIA/TIA 485 specification says that one RS485 transmitter can drive 31 RS485 receivers
- Therefore, a maximum of 32 RS485 devices are permissible on a single copper segment
- What constitutes a device?
  - Any component attached to the segment that has RS485 circuitry counts as one of the 32 devices.
    - PLCs
    - I/O devices
    - HMIs
    - Repeaters
    - PROFIBUS DP/PA gateways
    - Fiber optic repeaters (OLMs)
    - Bus diagnostic tools
    - Basically anything with a copper connection
      - Exception is active termination box

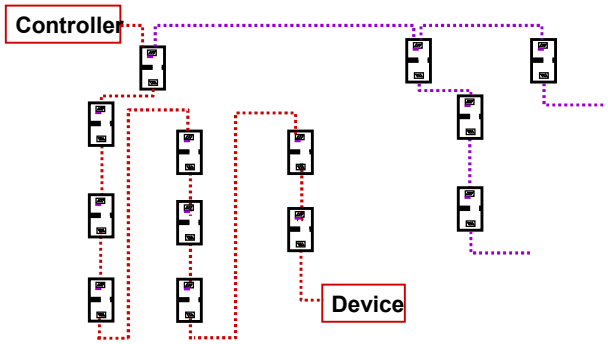
Segment and Network Lengths

- The network is segmented when the maximum segment length for the baud rate is reached or when 32 devices are attached…either situation requires segmentation no matter which is reached first.



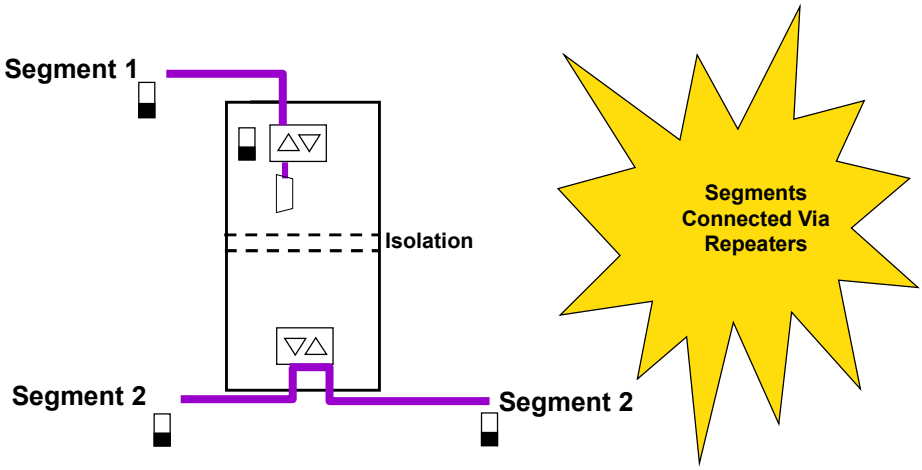
Total Repeaters In A Network

- Although a single communication path has a cascading depth limit, there can be more repeaters used in the entire network.



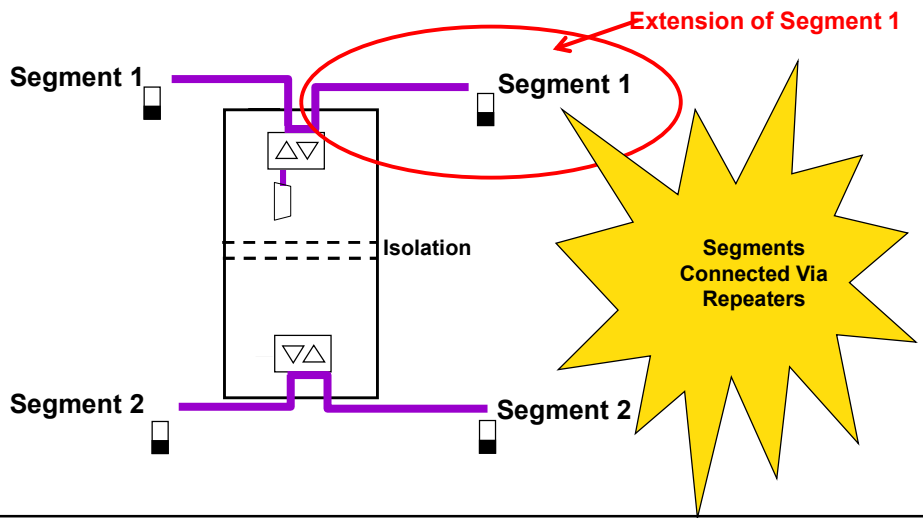
Use of Repeaters

- PROFIBUS DP segments are joined with repeaters

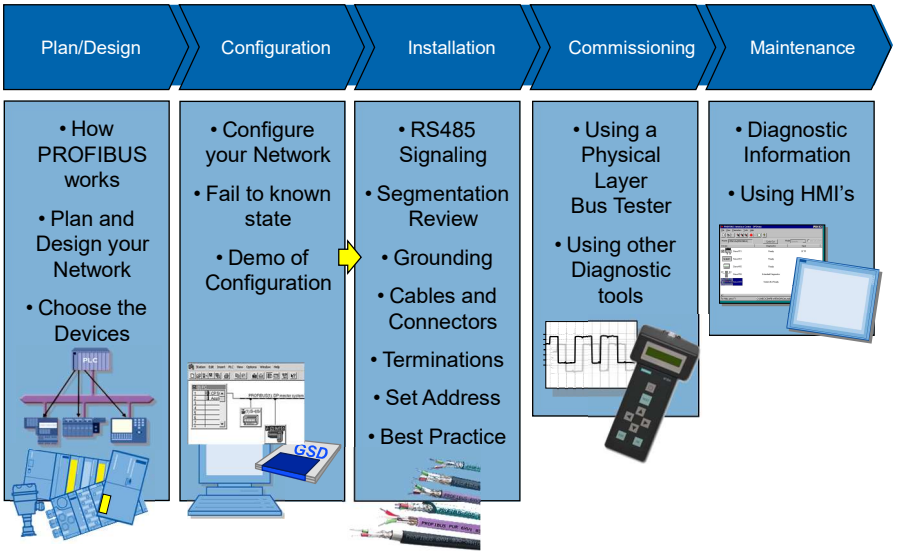


Use of Repeaters

- Branching structures built with repeaters instead of splices into the trunk line

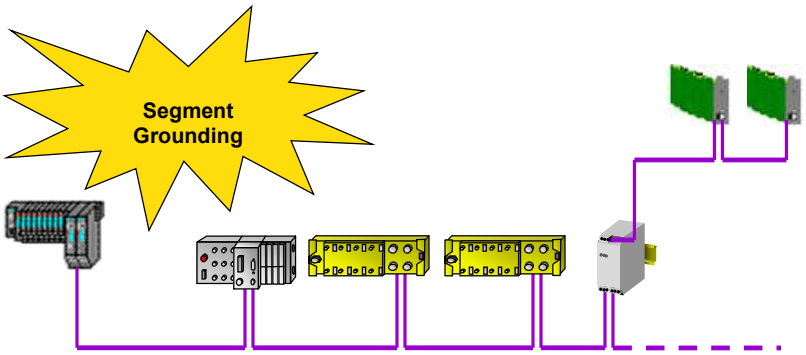


PROFIBUS Project Steps



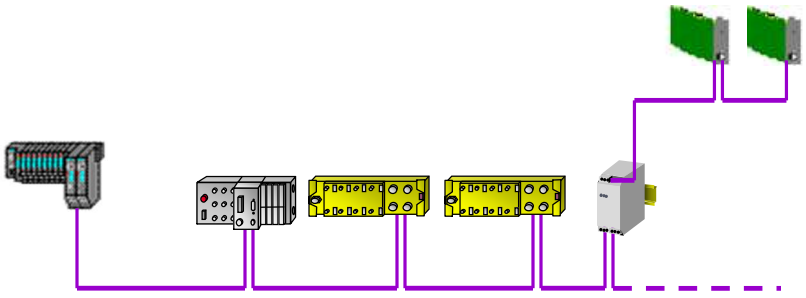
Segment Grounding

- PROFIBUS DP – RS485 copper.....what else do we need to consider?



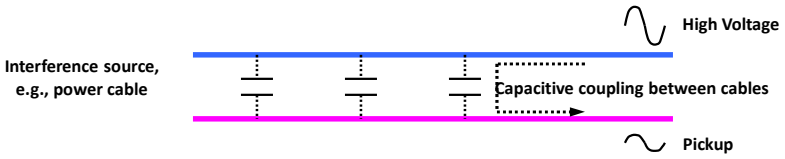
Segment Grounding

- RS485 copper - segment grounding
- Grounding protects against high-frequency interference pickup and emissions

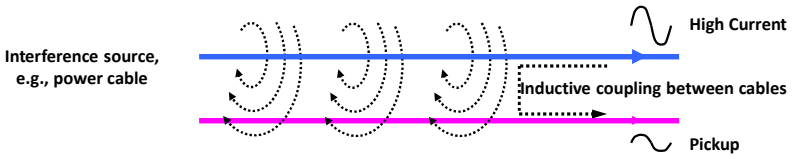


Interference From External Sources

- Electrostatic injection
  - Capacitive coupling caused by nearby high voltage power lines

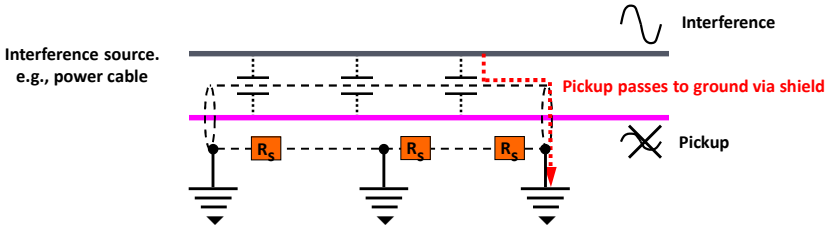


- Electromagnetic injection
  - Inductive coupling caused by varying currents in nearby power lines



Reduction of Coupling

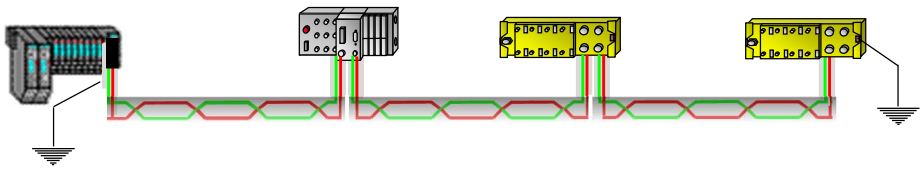
- Shielding reduces coupling effects
- Provides low impedance path to ground for any pickup
- Ground wire should be as large practical
- Ungrounded shield provides no protection



R_S = Shield resistance
For PROFIBUS cable, R_S = 9.5Ω/km

Segment Grounding

- RS485 copper... Segment grounding
  - Each segment must have the shield grounded
    - PROFIBUS Recommendation – ground the shield at both ends or at multiple points of the segment, especially for Baud Rates > 500kbaud
      - Provides lower impedance paths for higher frequencies
    - Typically see all devices on a segment grounded regardless of the baud rate

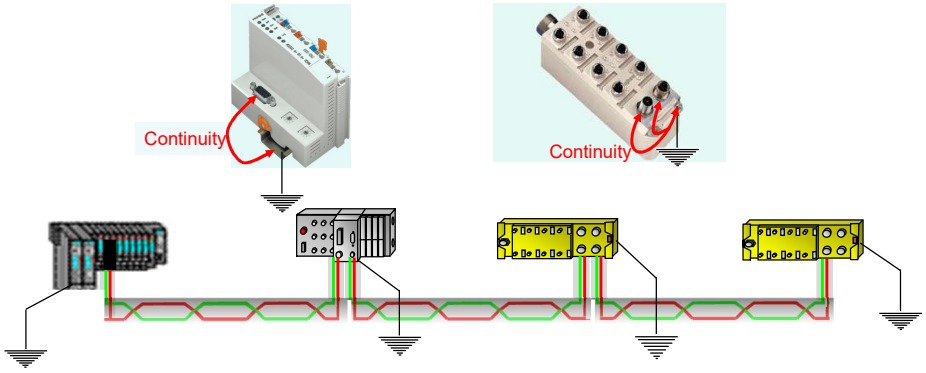


Segment Grounding

- RS485 Copper...Segment grounding – what about ground current loops?
  - Employ Multi-Point Grounding – Easy for PROFIBUS
    - Most PROFIBUS devices provide continuity between the metal shroud on a 9-Pin Sub-D Connector or M12 metal threads and
      - A device ground lug
      - A device metallic DIN rail connector
        - This continuity is not a requirement...check the device manual or ohm it out!!
  - Employ hybrid grounding
  - Utilize a separate potential equalization line (10-12 AWG) between grounding points with large potential differences

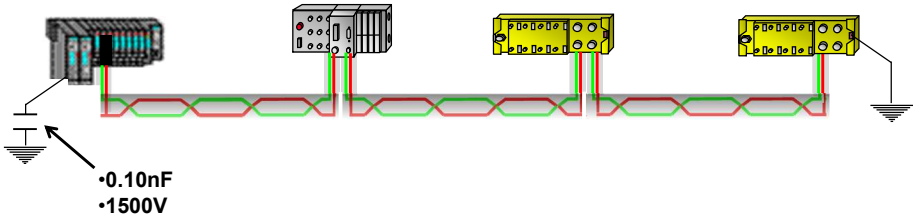
Segment Grounding

- RS485 copper...Segment grounding – what about ground current loops?
  - Employing Multi-Point Grounding
    - If continuity is provided, grounding the lug or din rail connector provides a grounding point for the shield, making multi-point grounding straightforward



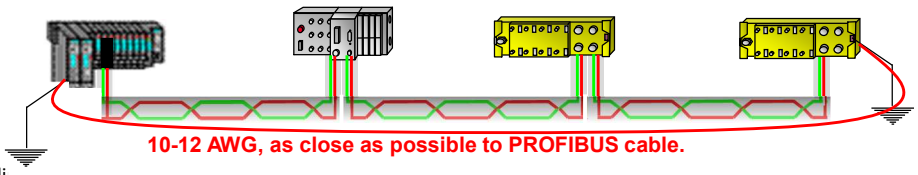
Segment Grounding

- RS485 copper...Segment grounding – what about ground current loops?
  - Employ Hybrid Grounding
    - Capacitive ground to block DC potential but provide ground path for higher-frequency noise

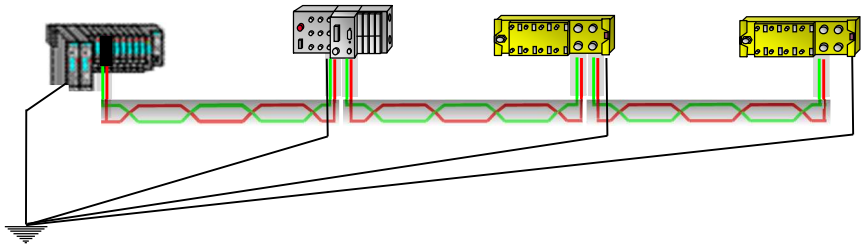


Segment Grounding

- RS485 copper...Segment grounding – what about ground current loops?
  - Employ potential equalization line

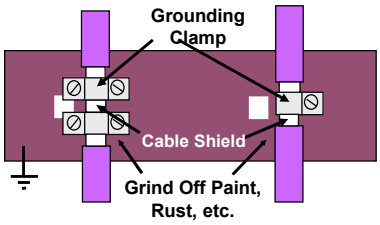


  - Star grounding



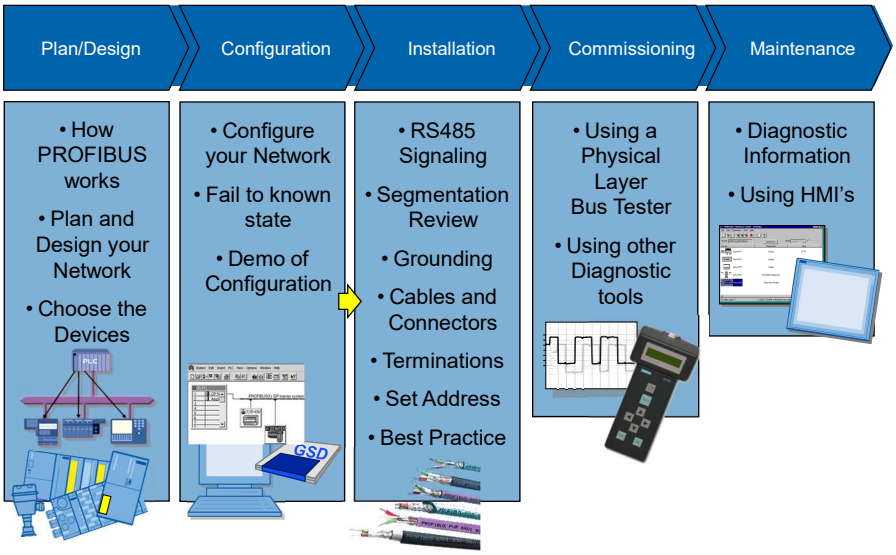
Segment Grounding

- RS485 copper... Segment grounding
  - Ground the shield entering/exiting a cabinet
    - Provides a ground path for devices mounted on din rails
      - Provides *possible* shield grounding point



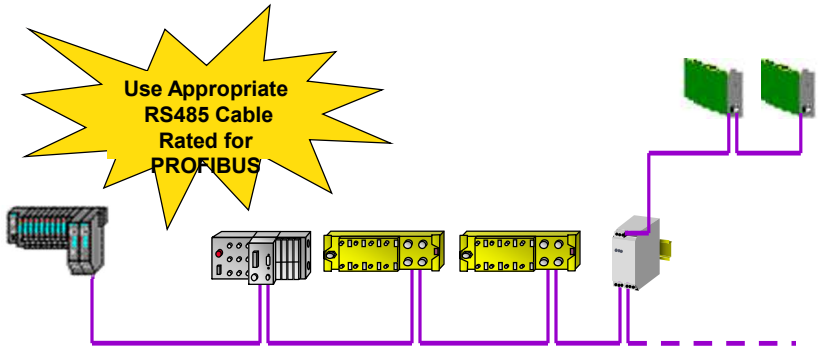
- RS485 Copper...Segment Grounding – what about ground current loops?
  - Ultimate Solution – use fiber optics

PROFIBUS Project Steps



PROFIBUS Cables and Connectors

- RS485 Copper...what else is there to address?



PROFIBUS Cable

RS485 copper installation - use correct cable

- Use approved PROFIBUS Cable
  - Capacitance: < 30 pF/m
  - Loop resistance: < 110 Ω/km
  - Impedance: 135 Ω - 165 Ω (Nominal 150 Ω)
  - Conductor area: ≥ 0.34 mm² (22 AWG)
  - Frequency : 3 - 20 MHz
- Capacitance and impedance are most critical
  - Both vary with frequency (impedance until characteristic impedance is reached)
  - Capacitance is cumulative with distance

PROFIBUS Cable

- RS485 copper installation - use correct cable
- For a Greenfield Installation, Just do it!
- If you have existing wiring, and it's not cost-prohibitive to replace, Just do it!
- If you have existing wiring, and it is cost-prohibitive to replace, Do some research.
- How close are my cable parameters to PROFIBUS cable?
- Do I really need higher baud rates? (>187.5 kbaud)?
  - Higher Cable Capacitance => Lower Baud Rates
- Higher Cable Resistance => Shorter Distances
  - Use more repeaters for longer runs

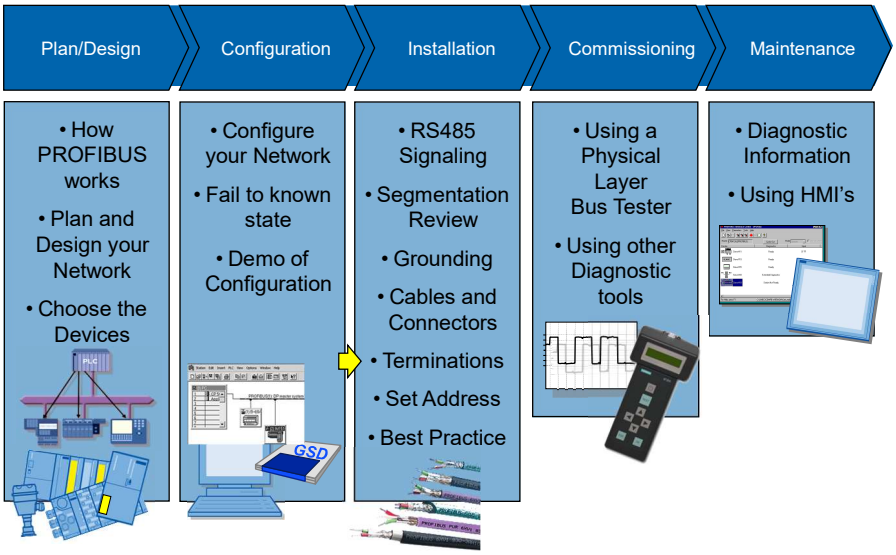
Connectors for PROFIBUS DP

- Connectors- two main types utilized
  - Directional 9-Pin Sub-D
    - Pins defined in the PROFIBUS Standard
    - Connectors with integrated termination are available
    - Inductors built in for higher baud rates
      - Decrease reflections above 1.5Mbits/s
    - Daisy-Chaining allows unplugging of devices without interrupting the bus
    - Shield is connected with the Sub-D shell
  - EuroFast (M12)
    - Pins defined in the PROFIBUS Standard
    - Frequently used in extreme environments
    - Connect sensors, actuators and PROFIBUS stations

Connectors for PROFIBUS DP

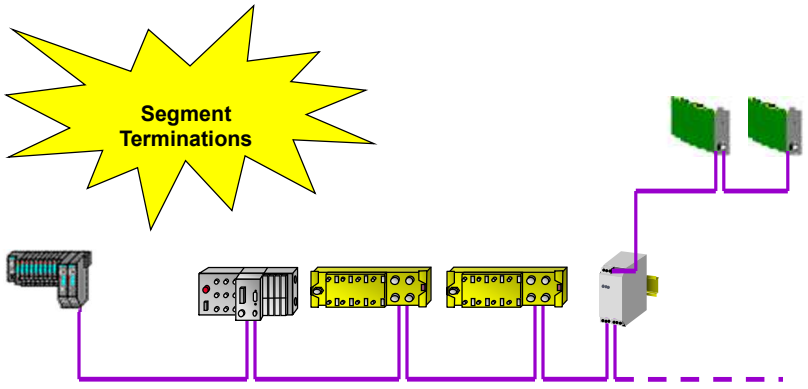
- Other common types
  - MiniFast (7/8")
    - Also used in extreme environments
  - Phoenix-Style Terminal Blocks
    - IP20
  - Screw terminals are seen with some drives and instruments

PROFIBUS Project Steps



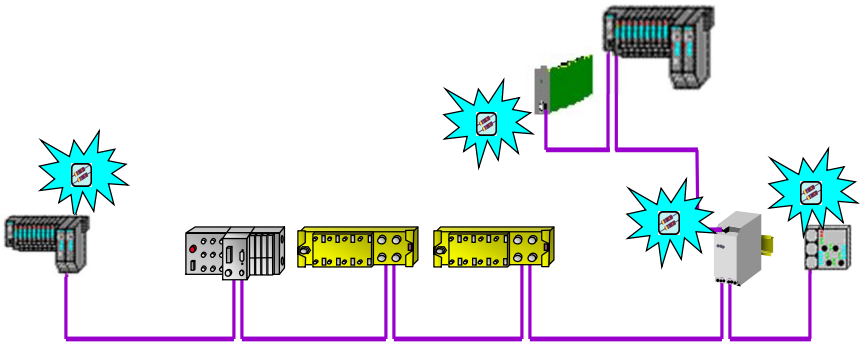
Segment Termination

- RS485 copper... Anything else to consider?



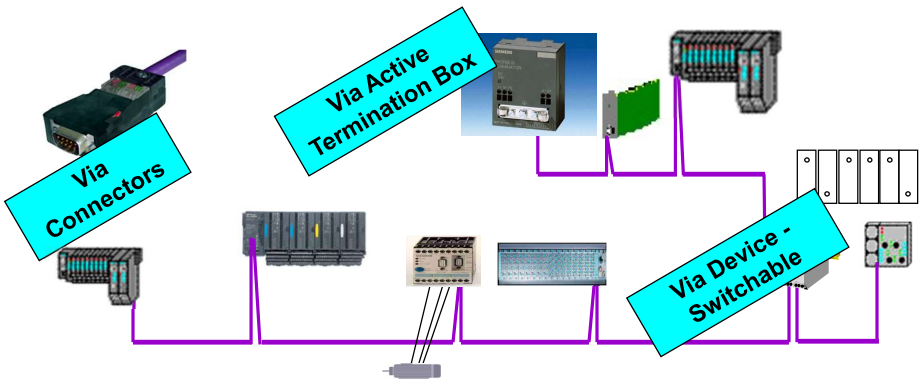
Segment Termination

- RS485 copper segment termination
  - Terminate both ends of a segment
    - Impedance Matching
    - Eliminates/diminishes reflections



Segment Termination

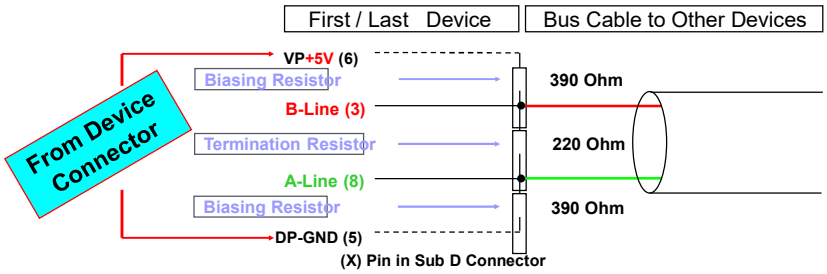
- DP copper segment termination
  - Where do we get it?



Segment Termination

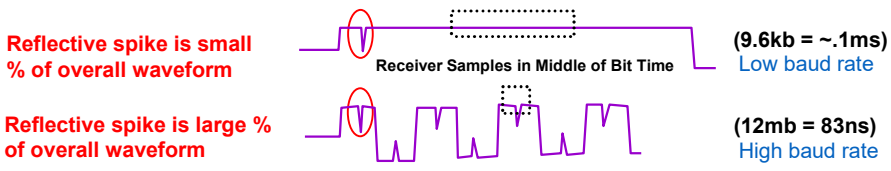
- Termination
  - If device is not powered, the terminating and biasing resistor network is not fully active
    - Reflections may be generated due to impedance mismatch

Device Must Be Powered



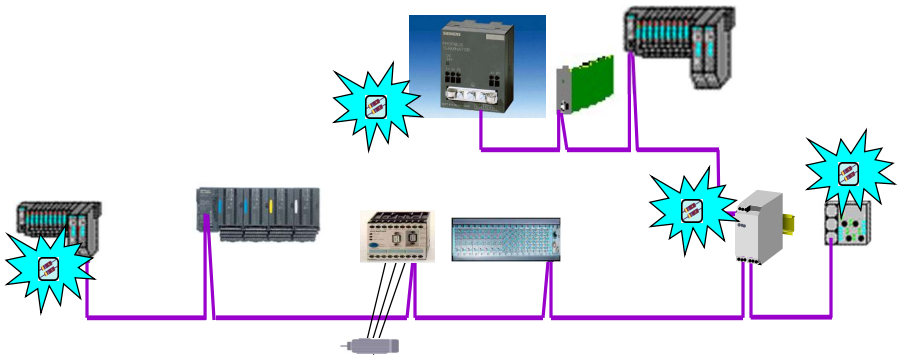
Reflections in General

- RS485 copper installation - avoiding reflections
  - What Are They?
    - Unwanted signals, waves (fuzzy tv picture, echoes on phone)
    - Reflected in all directions from a particular point on the bus
    - Caused by an impedance mismatch
    - Can destroy telegrams
  - The level or existence is independent of baud rate but the risk of causing a problem increases at higher baud rates due to decreasing bit times



Segment Termination

- RS485 copper segment termination
  - Use active termination box If PC Card would be last node
    - Some lose +5V to connector over a restart

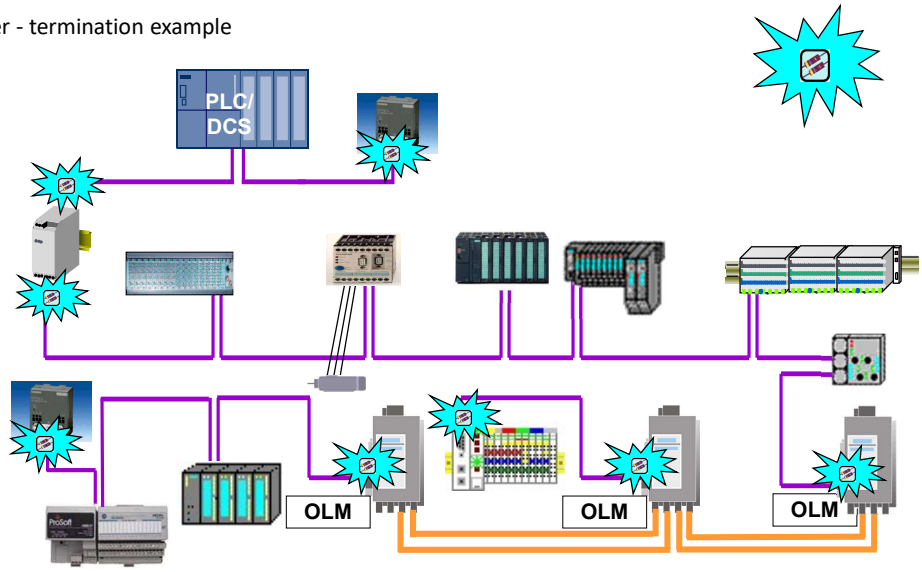


Segment Termination

- RS485 copper segment termination
  - Use active termination box at spare drive at segment end in MCC Cabinet
    - Many times spares are powered off

Segment Termination

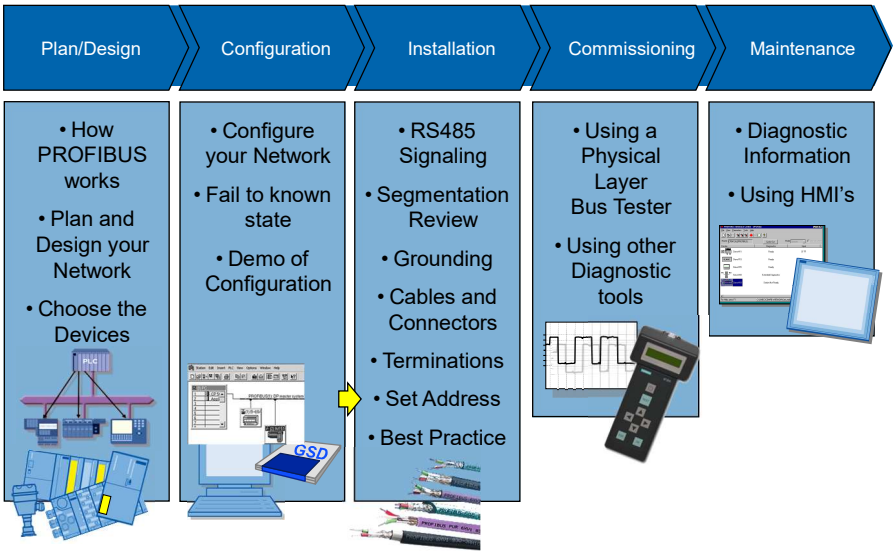
- RS485 copper - termination example



Segment Termination

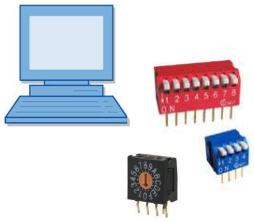
- RS485 copper segment termination
  - Unterminated or improperly terminated segments is still one of the leading problems seen in the field

PROFIBUS Project Steps

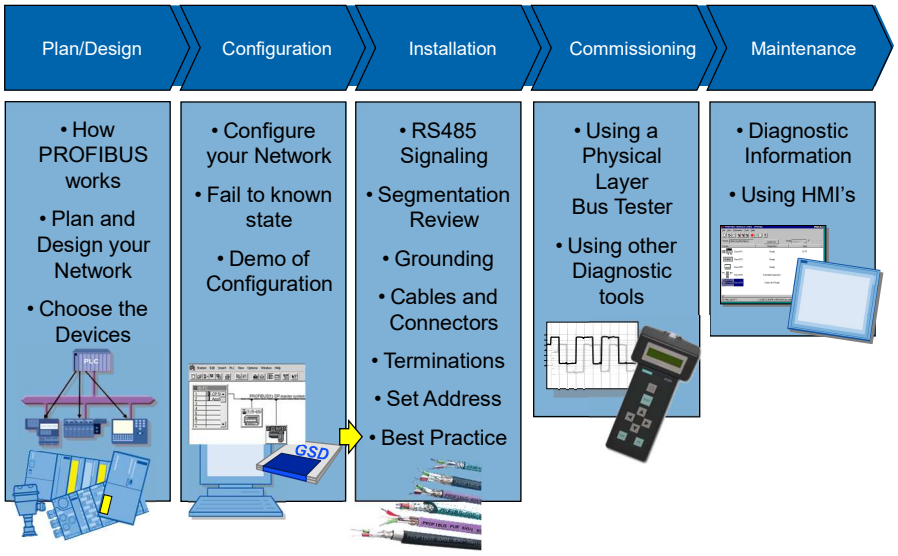


Set Device Addresses

- Set Controller address
  - The Controller address is defined when doing the configuration in the engineering software. There are no physical address switches on Controllers.
- Set device address
  - Most devices have DIP or rotary switches for their address setting
    - BEWARE - Some rotary switches use HEX coding although the DP address is decimal
  - Some devices support changing their addresses over the bus (an optional service)
    - Such devices (should) come with the address pre-set to 126

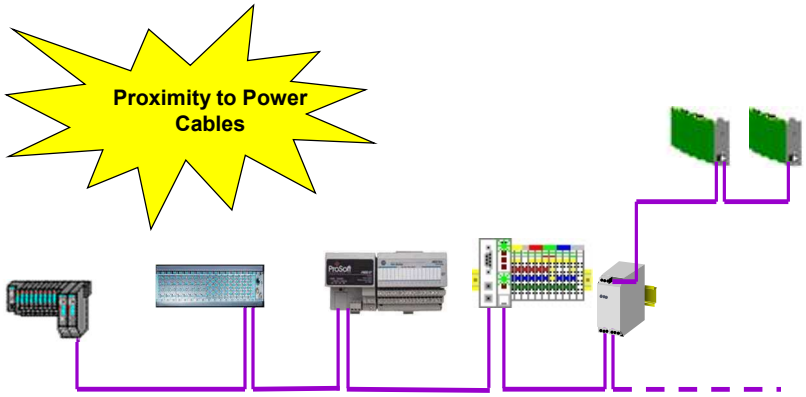


PROFIBUS Project Steps



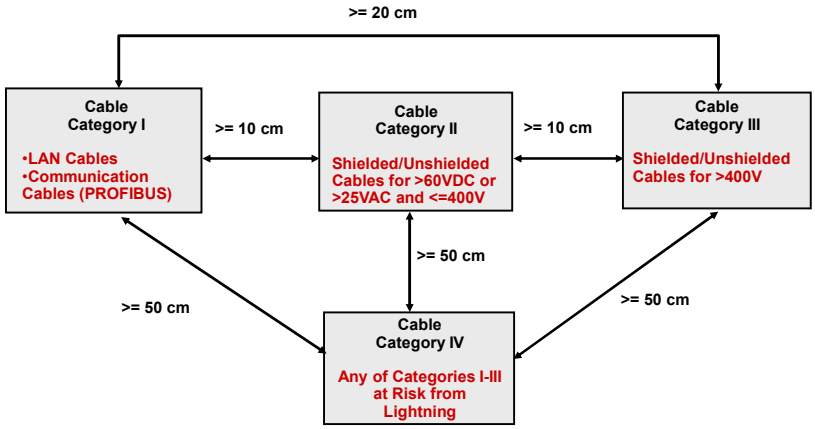
Installation: Best Practice

- RS485 copper...Other rules to follow!



Installation: Best Practice

- RS485 copper cable...Recommended air-separation distances from power cables
  - A frequent violation



Installation: Best Practice

- RS485 copper cable installation – cable tray usage.
  - If channeled cable trays are used, same cable categories can be bundled in a tray
  - Channels in metal trays are suitable for separation
  - Ground the cable trays – provides a big potential equalization line
  - Bond any joints together for continuity
    - Butt weld
    - Join with large gauge wire

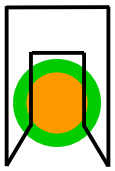
Installation: Best Practice

- Connectors/wiring
  - Interconnection Standard specifies: A to Green / B to Red
  - Leave 1 Meter between uncertified or uncertain devices or at baud rates > 187.5kbits/s
    - Avoids "lumped" capacitance

Device capacitances look like a single "lumped" capacitance.

Installation: Best Practice

- Connectors/wiring
  - No Sharp Bends – minimum bend radius typically 10 x cable diameter
    - Can crimp copper
  - Do not mix different cable types
  - Ensure that each segment has a piggy-back Sub-D connector at least at one end for connection of diagnostic tools
    - Better to have one at each end
  - When using insulation displacement (ID) connectors, make sure the scissor blades of the connector make good contact with the copper wire
    - If possible, use connectors and cables from the same vendor
  - If possible, start with a new cable end when re-using an ID connector
    - Don't use same cable end more than twice
  - Check continuity when re-using an ID connector



Installation: Best Practice

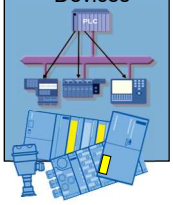
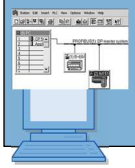
- Terminations
  - Ensure terminations are at segment ends and that the terminations will have constant power
  - Make sure that there are exactly two terminations per segment…no more and no less!
- Bus segmentation
  - Make sure that all segments meet the length restrictions for the baud rate
  - Make sure that no segment has more than 32 devices
- Check stub line usage
  - Ensure that the baud rate restrictions due to stub line usage are followed
- Check that device addresses are correctly set on the device as shown in your drawings
- Device power
  - If at all possible, fuse each device so it can be powered up/down separately
  - Ensure that the device has adequate power in all conditions, e.g., high current outputs all turned ON simultaneously
  - Power a device down prior to connecting or disconnecting the connector, especially at high baud rates

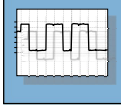
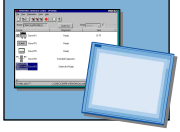
PROFIBUS DP- Decentralized Periphery

Commissioning and Maintenance

PROFIBUS Project Steps

Plan/Design	Configuration	Installation	Commissioning	Maintenance
• How PROFIBUS works • Plan and Design your Network • Choose the Devices	• Configure your Network • Fail to known state • Demo of Configuration	• RS485 Signaling • Segmentation Review • Grounding • Cables and Connectors • Terminations • Set Address • Best Practice	• Using a Physical Layer Bus Tester • Using other Diagnostic tools	• Diagnostic Information • Using HMI's

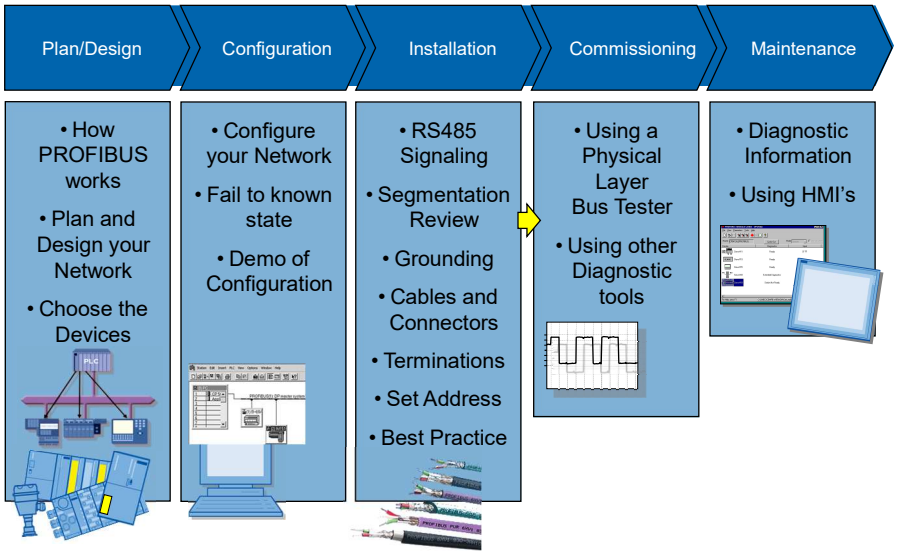



Static Physical Layer Test

- Check the physical layer with a physical layer test tool
- Such tools can detect many types of wiring errors
  - Swapped wires
  - Broken wire
  - Short circuit lines A-B
  - Short circuit A/B-shield
  - Open in shield
  - Missing or excessive termination
  - Segment length
  - Reflections
- Integrity of the physical layer is important
  - Physical layer problems complicate commissioning
    - Is device communicating?
    - Did it get set up incorrectly?


PROFIBUS Project Steps



Run-Time Analysis

- Run-time analysis tools connect to operational bus and perform
  - Determination of a "Live List" (All Active Stations On the Bus)
  - Analysis of protocol for PROFIBUS DP and PA Networks and Devices
    - Assists in finding startup problems
  - Collection of statistics for repeats, drop-outs, corrupted messages, etc.
  - Trigger Functions / Decoding / Logging
- Vendors with PROFIBUS DP (RS485) tools
  - ProCentec
  - Softing
  - Indusol

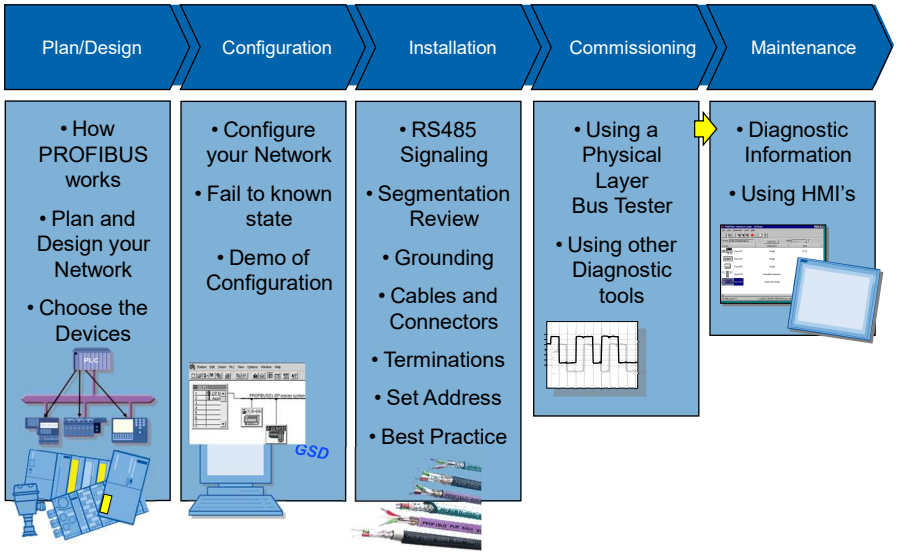
Run-Time Analysis

- Run-time analysis tools perform
  - Oscilloscope functions
    - Wave forms
    - Signal levels
    - Reflections
  - Network topology determinations
  - Assist in locating cabling errors, faulty devices, etc.

ProCentec/
Grid Connect

Softing North
America

PROFIBUS Project Steps



Diagnostic Information

- PROFIBUS provides a wide variety of diagnostics
- Vendors have the capability to build any type of error detection into the device and report it to the PLC/DCS

Diagnostic Information

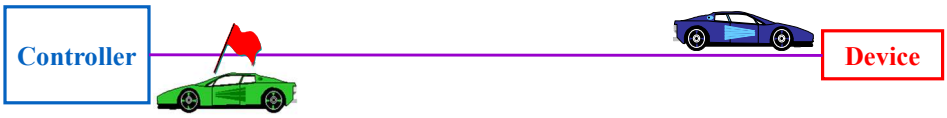
- High-speed I/O - data exchange

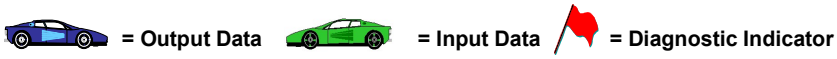
 = Output Data  = Input Data

Diagnostic Information

- High-speed I/O - data exchange and diagnostics

Device Indicates Diagnostics to Report

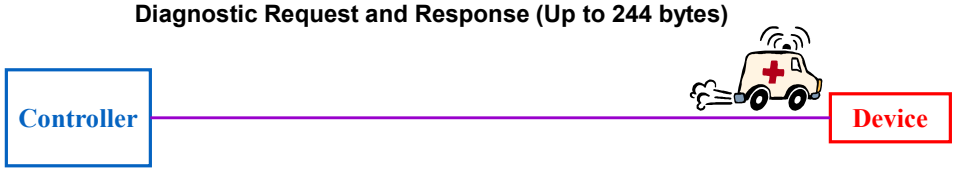




Diagnostic Information

- High-speed I/O - data exchange and diagnostics

Diagnostic Request and Response (Up to 244 bytes)



Diagnostic Information

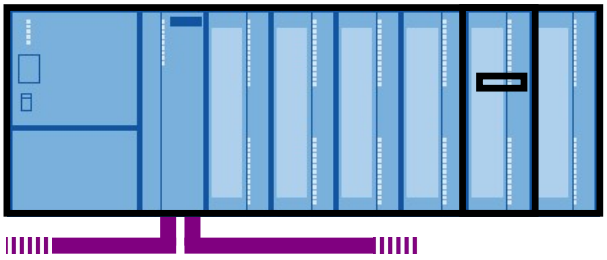
- High-speed I/O - data exchange and diagnostics

Back to Data Exchange (Up to 244 bytes)

 **= Output Data**  **= Input Data**

Diagnostic Information

- Mandatory diagnostics – standard across vendors/devices
  - I/O Configuration Mismatch
  - Wrong Device at Address



Device-Related (Vendor Specific)
- ❑ Missing Load Power
- ❑ Actuator Stuck
- ❑ …

Identifier-Related (Standard)
- ❑ Module in this Slot has a Diagnostic

Channel-Related (Standard)
- ❑ This Device has a Diagnostic
- ❑ This Module has a Diagnostic
- ❑ This Input/Output Channel has a Diagnostic
  - ▪ The Diagnostic is
    - ▪ Wire Break
    - ▪ Short Circuit
    - ▪ Undervoltage
    - ▪ Overvoltage
    - ▪ …

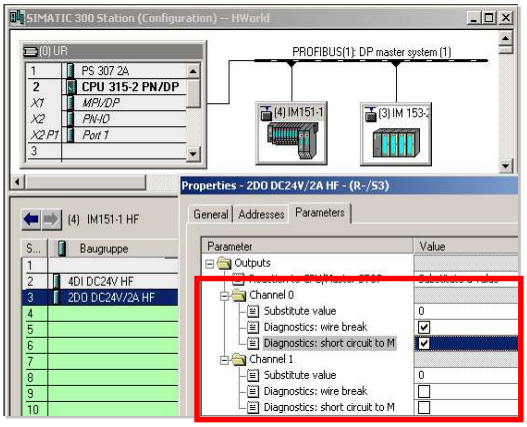
Diagnostic Information

- Examples of diagnostic information
  - The Device Monitors the Output Channels
    In Order to Discover a **Wire Break** (No Current Is Flowing Although the Output Is Set to '1')
  - An Analog Input Has a Range of 0..10V
    An Input Voltage of 12V Is Detected and Reported As **Overvoltage**

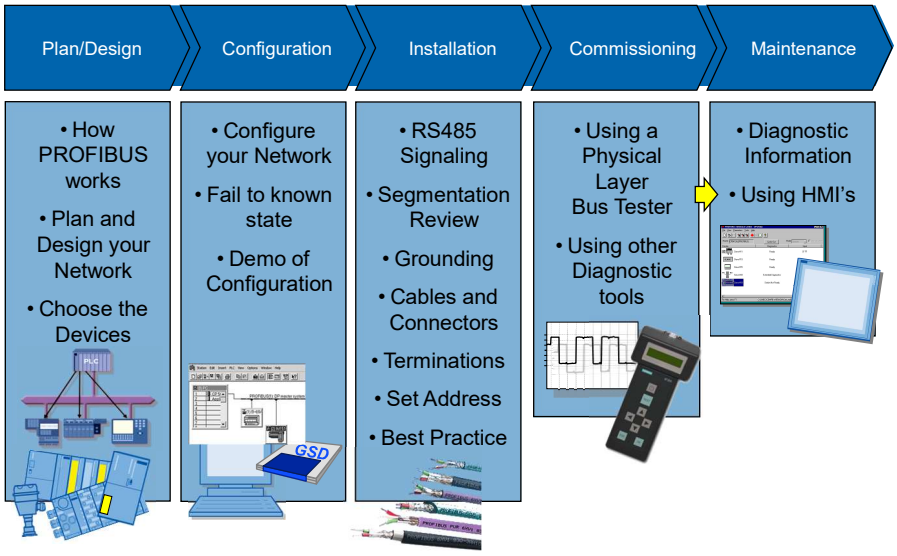
Diagnostic information is not only "PROFIBUS related" but may also be used to report application/process problems

Diagnostic Information

- Typically can choose what to detect and report during parameterization
  - Enable/disable wire break, etc.



PROFIBUS Project Steps



Diagnostic Information

- Available diagnostic information can be
  - Used by the Application (PLC or PC)
  - Passed on for further processing
  - Can be stored and archived for analysis and history
  - Displayed by HMIs