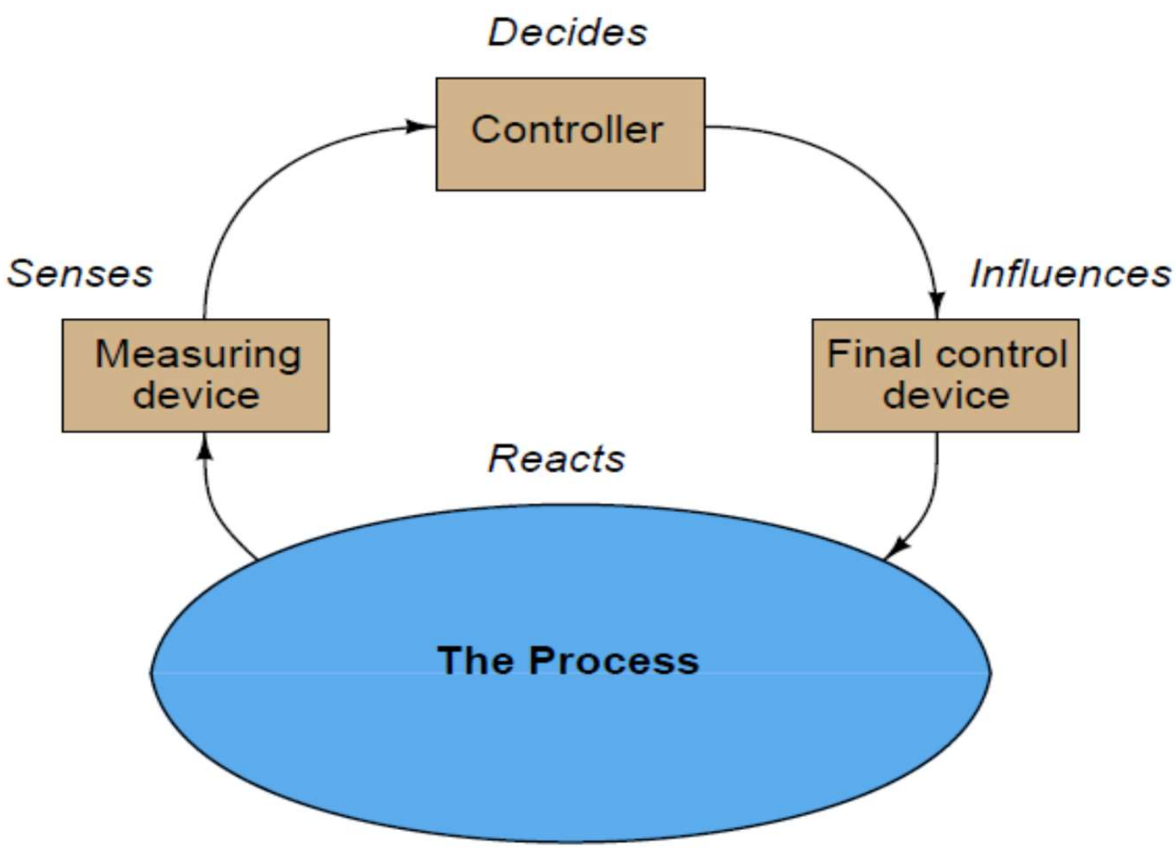
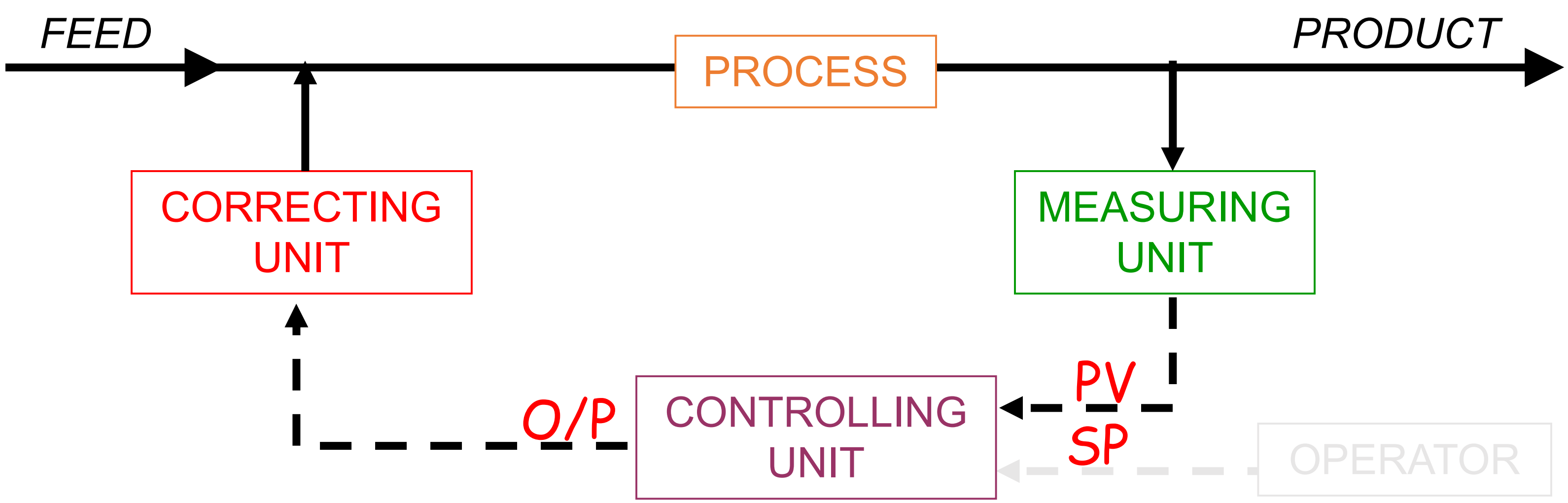
Fieldbus, Networking & Other New Concepts in Process Instrumentation

Murali Krishnan T

OVERVIEW OF A PROCESS CONTROL LOOP



Control Principle



Control theory can be encapsulated as the matching of a measured variable (PV) to the plant requirement (SP).

A controller implements a Control Algorithm so that an output signal (O/P) activates a correcting unit. The ratio of output signal (O) to input signals (I) is Gain (K).

$$\text{Proportional band} = \frac{1}{K}\,\% = \frac{100}{\text{Gain}}\% = \frac{I}{O} \times 100\%$$

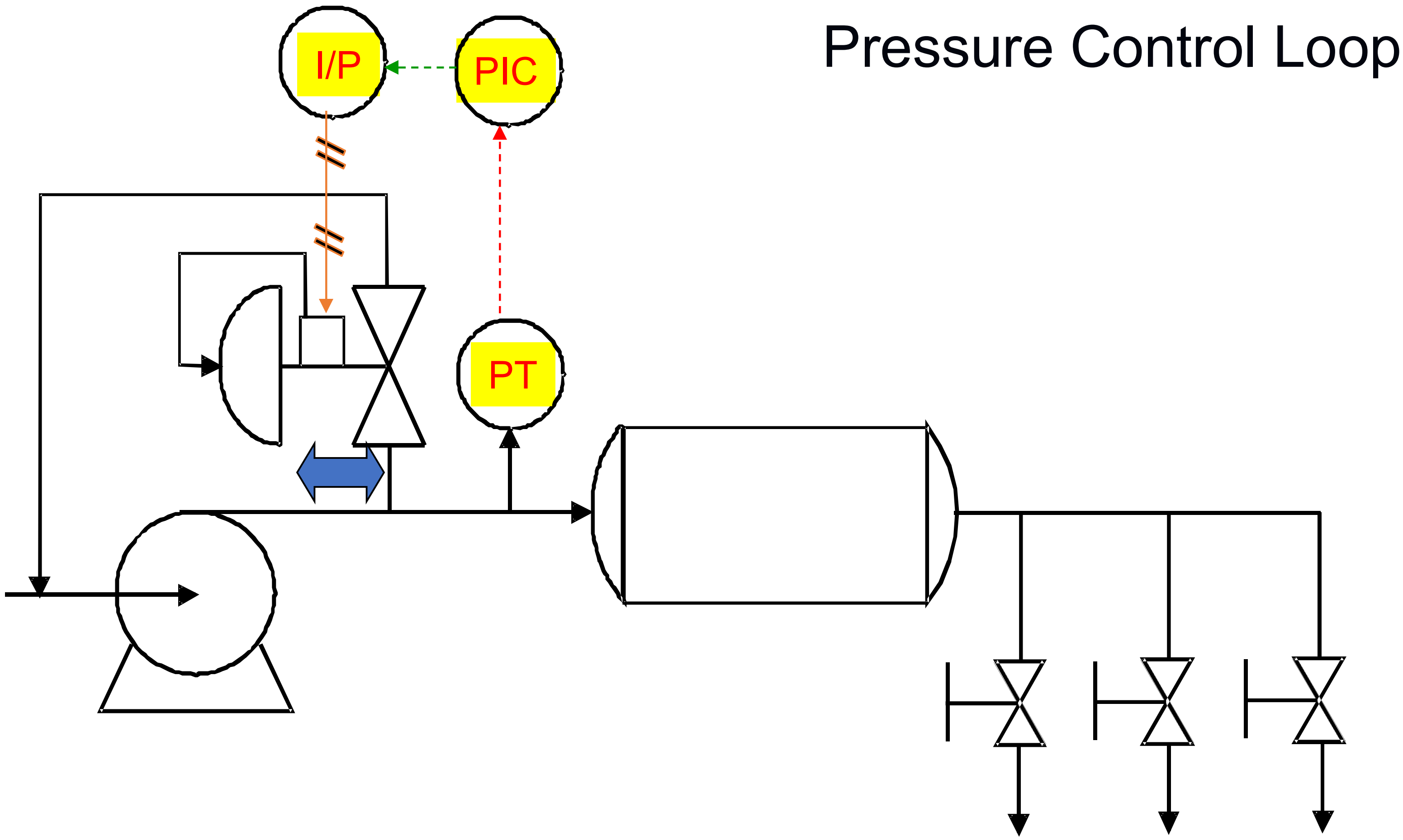
MEASURING ELEMENTS (SENSORS):

- PRESSURE
- LEVEL (DP, RADAR)
- FLOW (Orifice DP, Coriolis, Vortex, Magnetic, Annubar DP, Venturi DP)
- TEMPERATURE (Thermocouple, RTD)
- MACHINE POSITION, MOTION or ACCELERATION
- CHEMICAL CONCENTRATION SUCH AS pH, CONDUCTIVITY, O_2, CO_2, HC MEASUREMENT

FINAL CONTROL ELEMENTS:

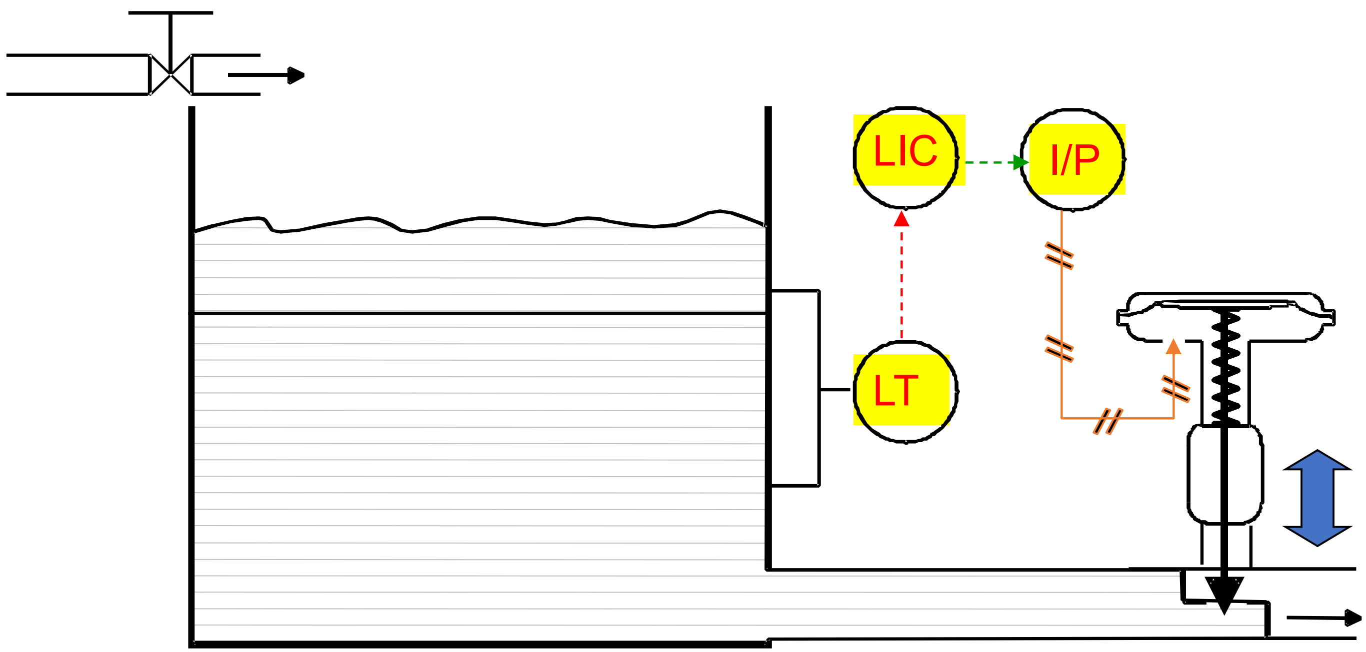
- CONTROL VALVES (Globe, Rotary, Ball)
- ON/OFF VALVES (Ball, Butterfly)
- MOVs
- ELECTRIC MOTORS
- ELECTRIC HEATERS, COOLERS ETC

Basic Control Loop



Basic Control Loop

Level Control Loop (Outflow)



Control Algorithm

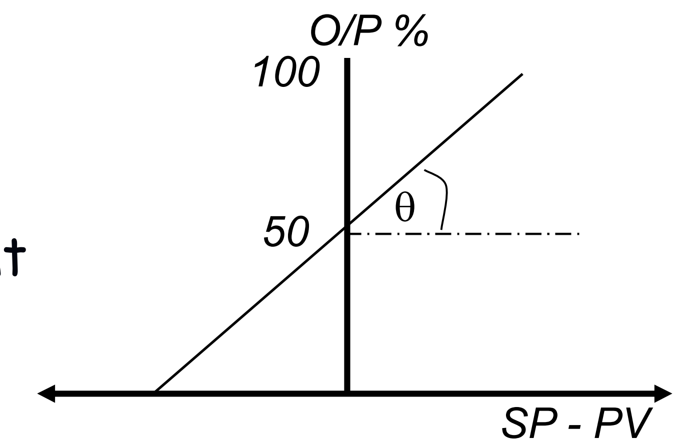
- On/Off
- Multi-step
- Proportional
- Integral
- Derivative

Proportional Action (P)

The Algorithm is :

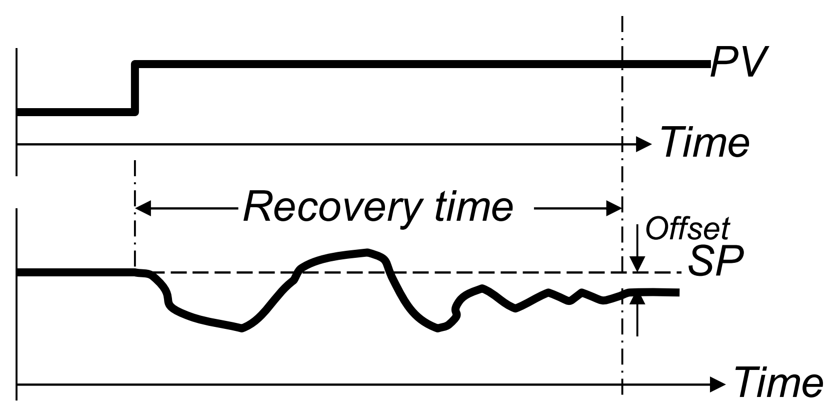
$$O/P = \frac{-\,(PV - SP)}{\text{Proportional Band}} + \text{Constant}$$

(Constant is normally 50%)



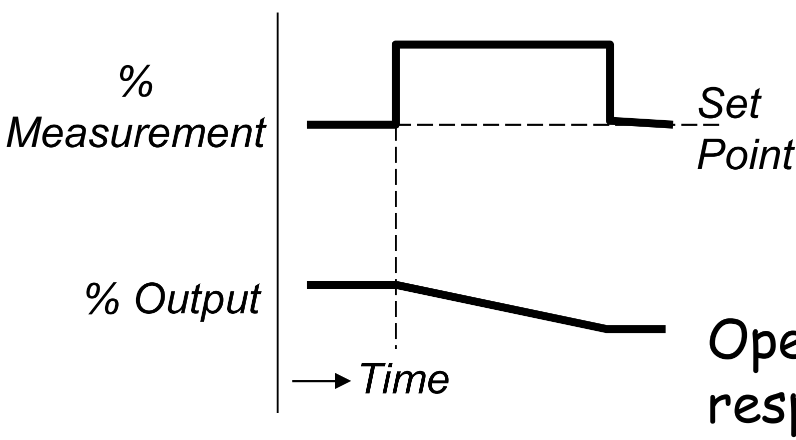
Tan θ = Gain = 100 / Proportional Band

When a disturbance alters the process away from the set-point, the controller acts to restore initial conditions. In equilibrium, **offset** (PV-SP = constant) results.



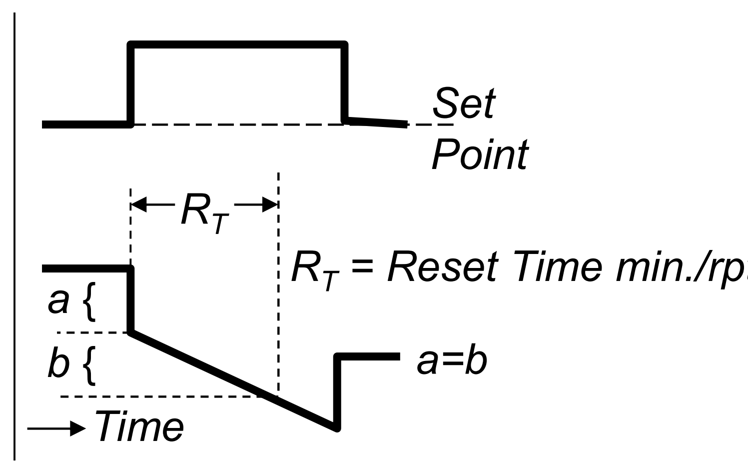
Integral Action (I)

Whilst PV $\neq$ SP, the controller operates to restore equality.
As long as the measurement remains at the set point, there is no change in the output due to the integral mode in the controller.
The output of the controller changes at a rate proportional to the offset. The <u>integral time</u> gives indication of the strength of this action. It is the time taken for integral action to counter the 'offset' induced by Proportional Action alone.



Open-loop response

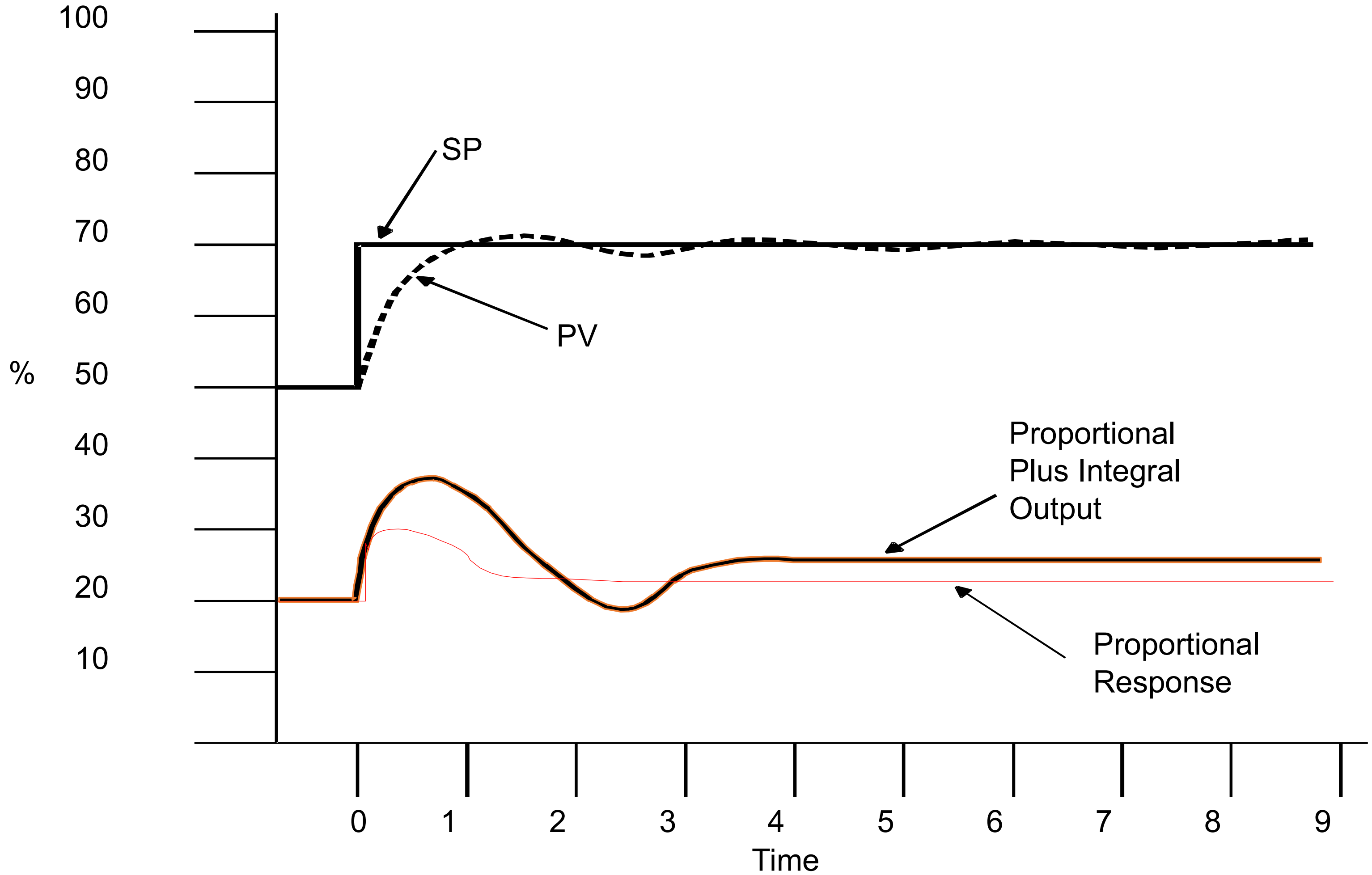
Integral mode



Proportional plus Integral mode

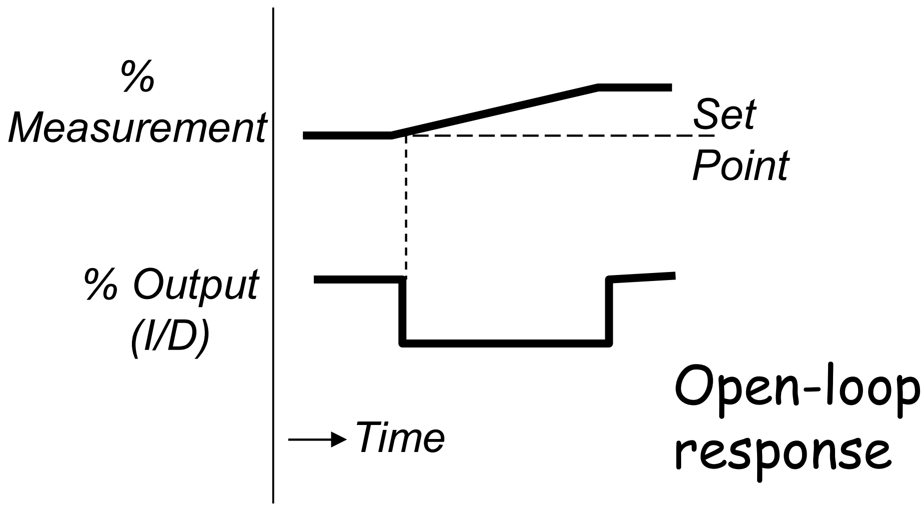
Integral Action (I)

Integral Action: (Closed Loop)

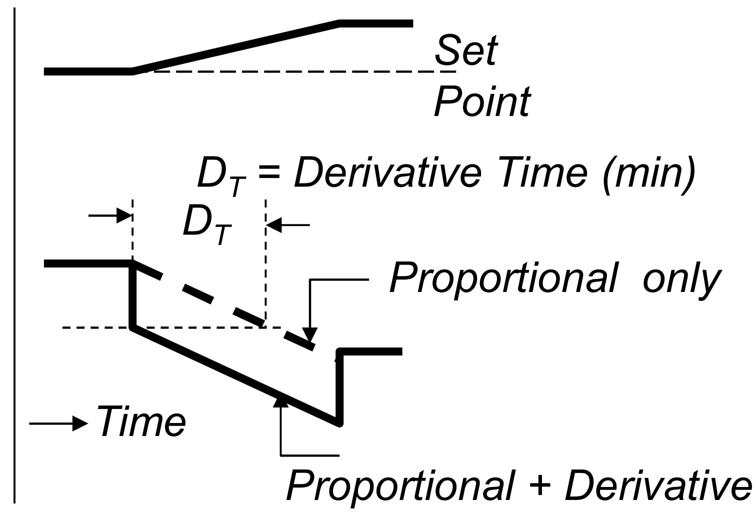


Derivative Action (D)

As the PV changes, the controller resists the change.
The controllers output is proportional to the rate at which the difference between the measured and desired value changes.
The derivative time is an indication of this action. It is the time that the open-loop **P+D** response is ahead of the response due to **P** only.

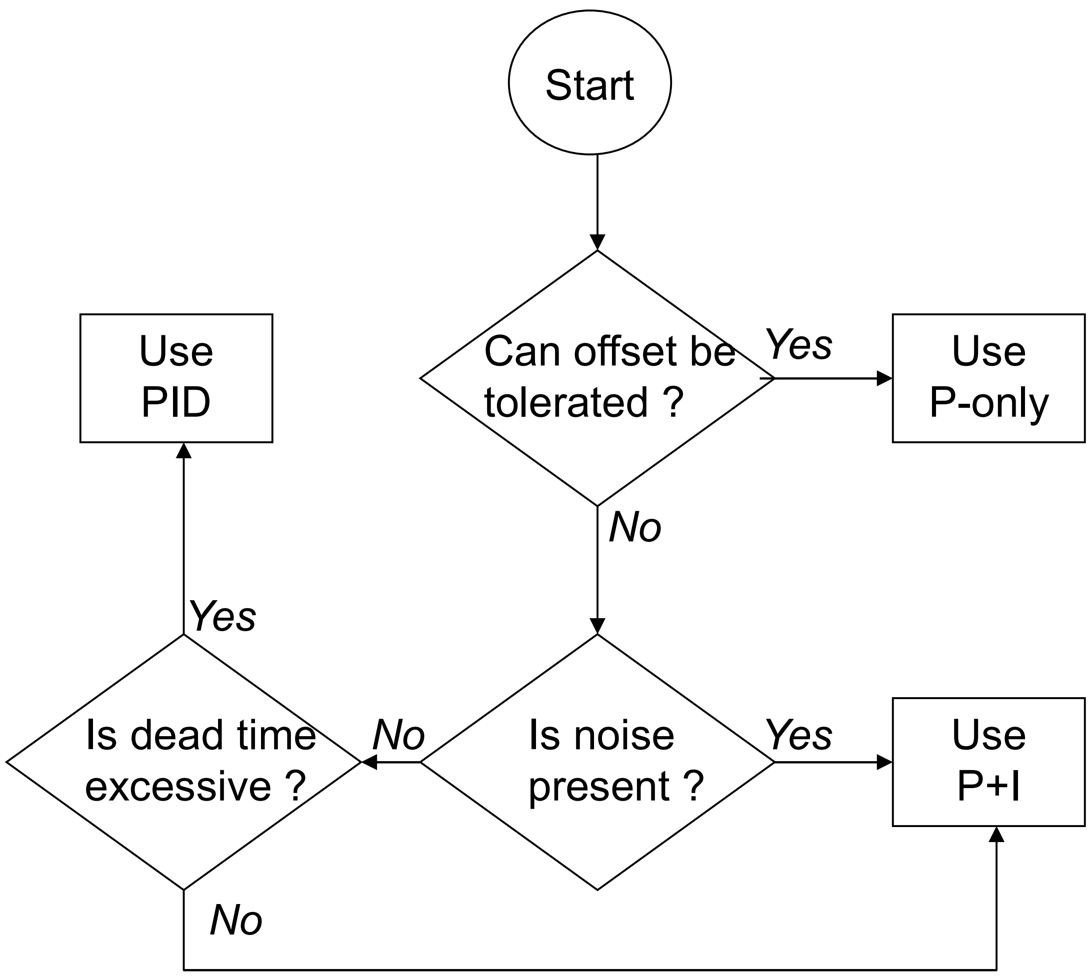


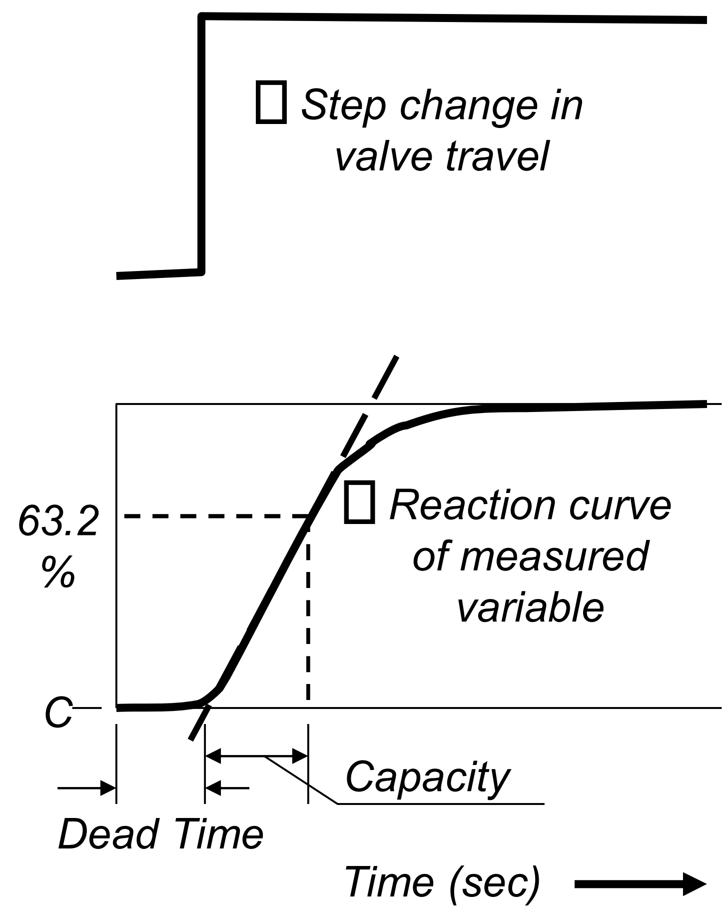
Derivative mode



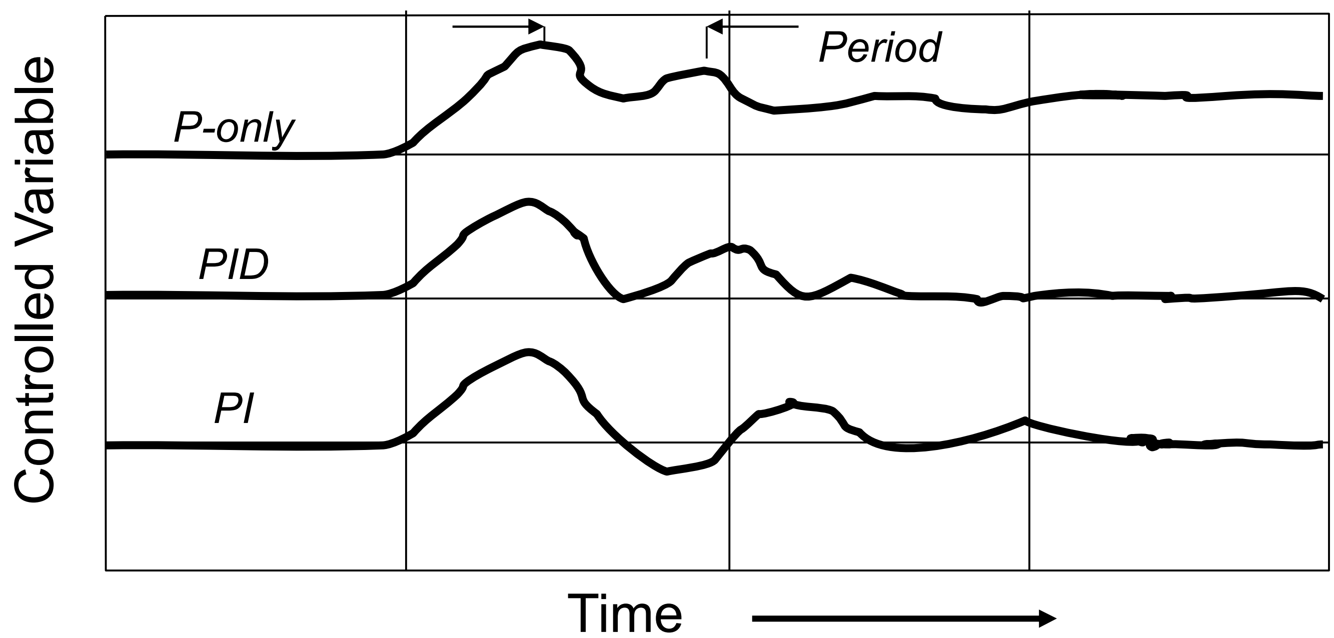
Proportional plus Derivative mode

Controller Selection



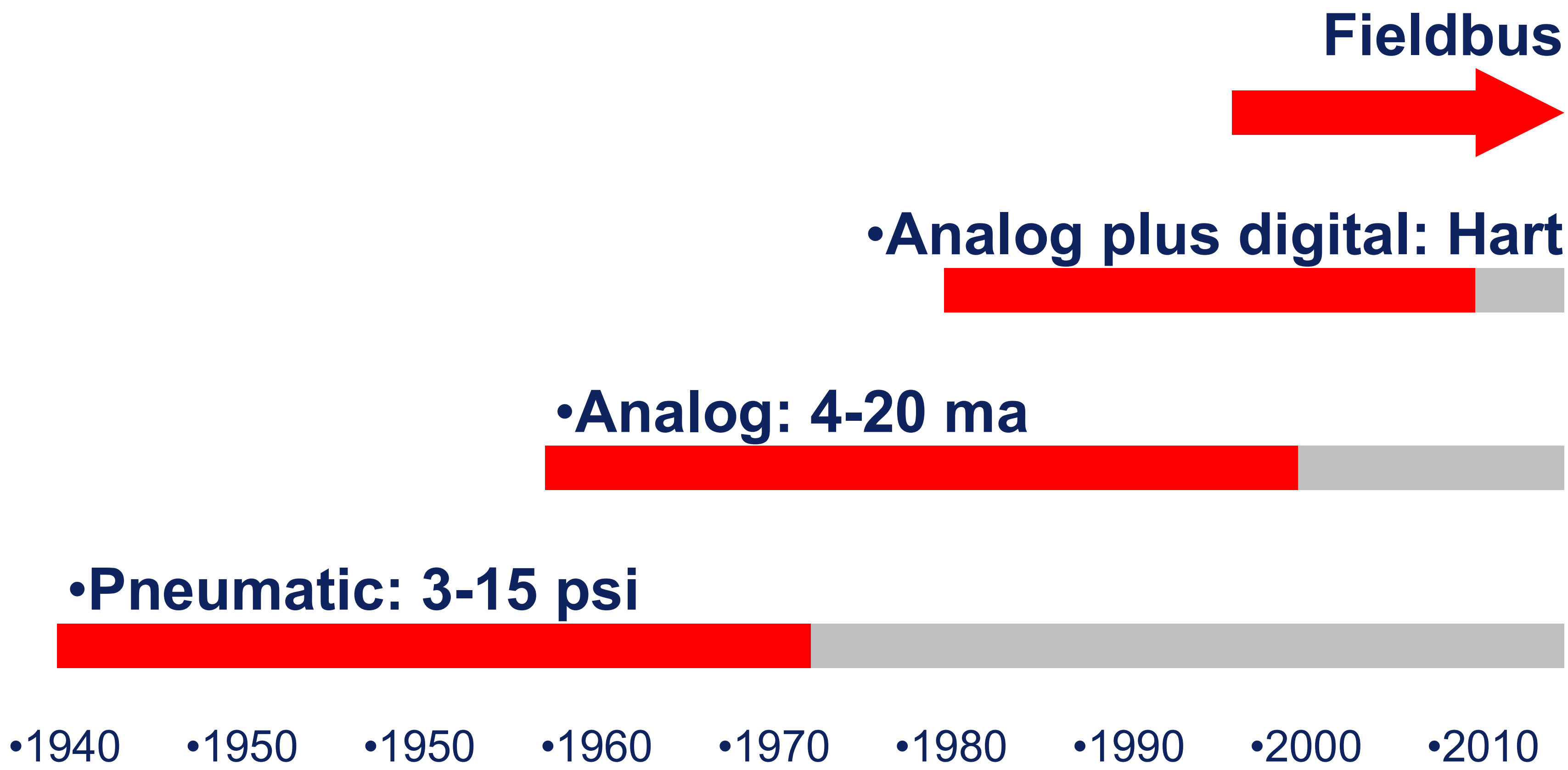


Controller Adjustment

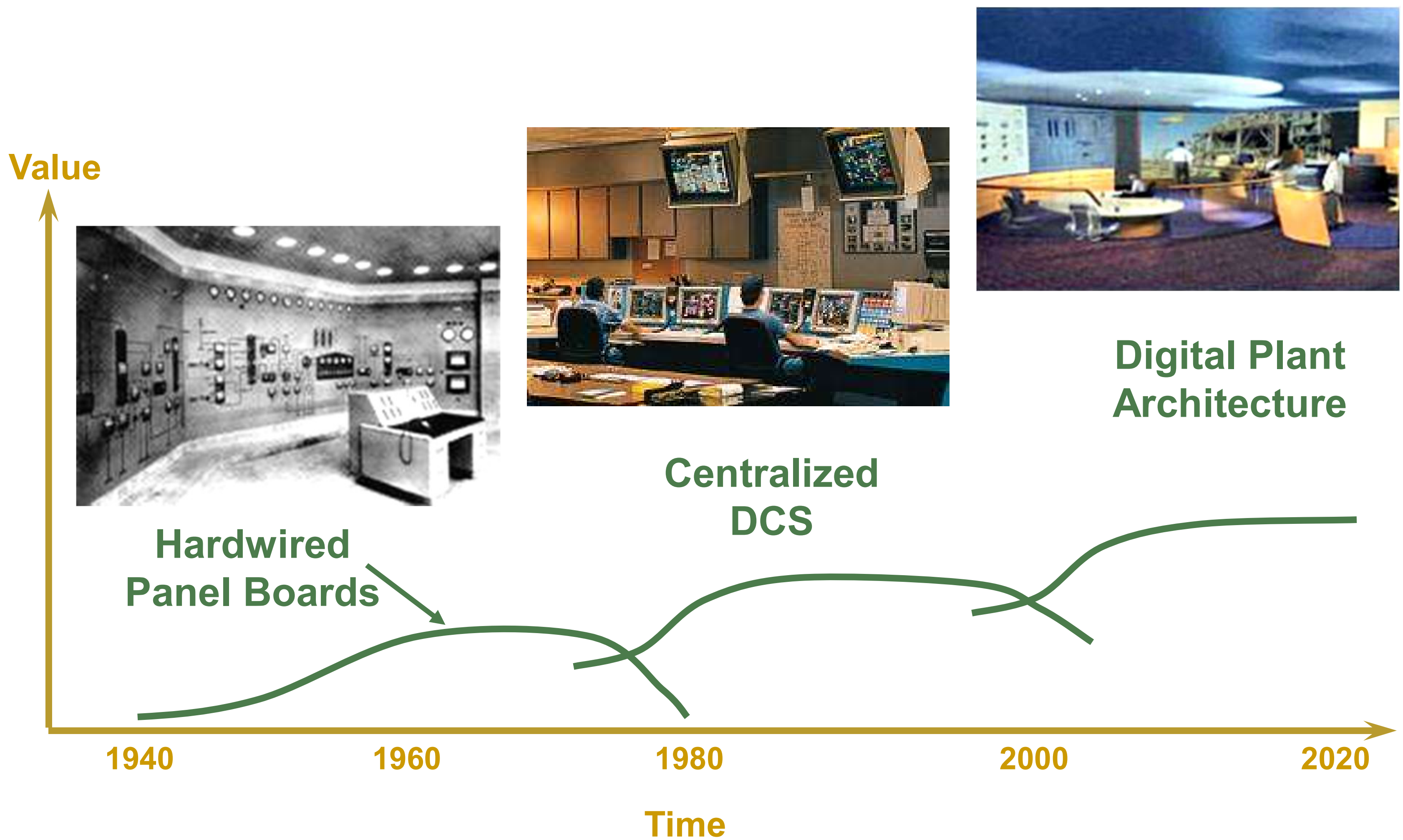


Control loop	*Proportional band*	*Time constant*	*Derivative*
Flow	High (250%)	Fast (1 to 15 sec)	Never
Level	Low	Capacity dependent	Rarely
Temperature	Low	Capacity dependent	Usually
Analytical	High	Usually slow	Sometimes
Pressure	Low	Usually fast	Sometimes

History of Process Control Signals



The Digital Plant ‘Changes the Game’ for a Step Change in Results

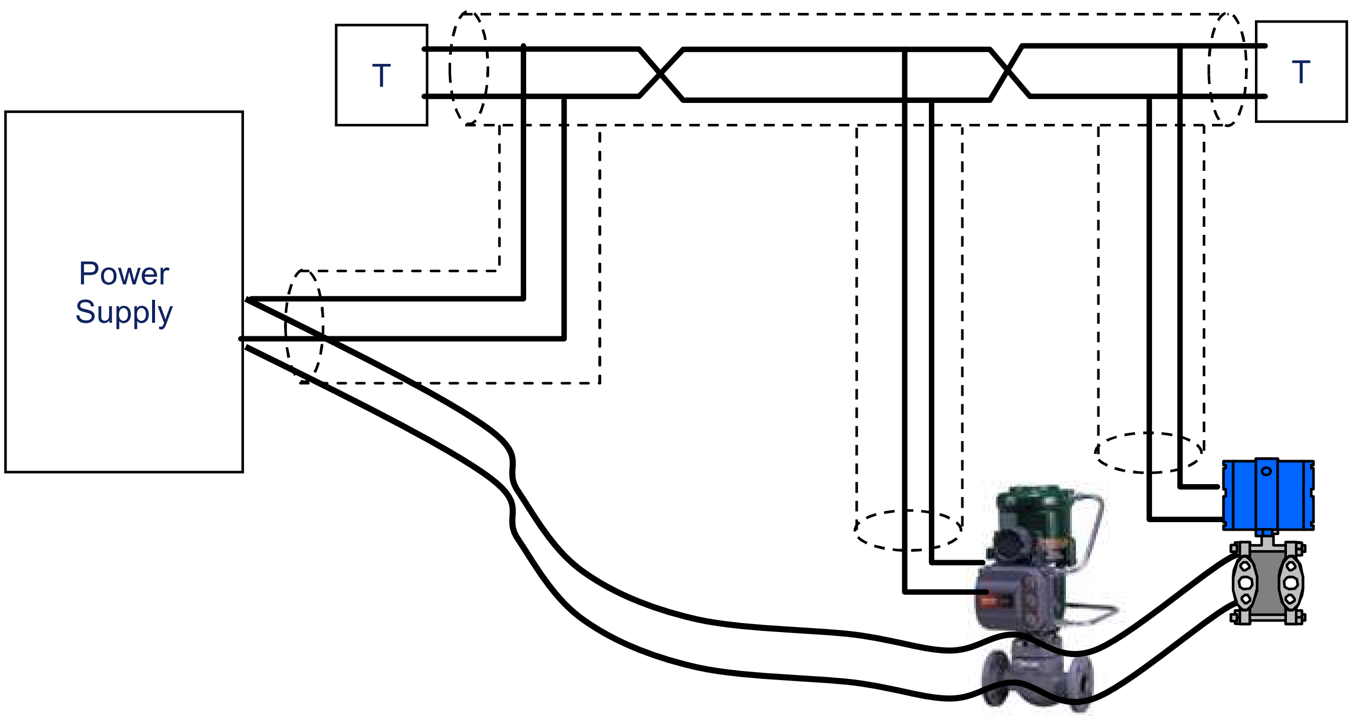


Future photo courtesy Brad Adam's Walker Architecture, P.C., Denver, Colorado:

What Is a “Digital” Bus?

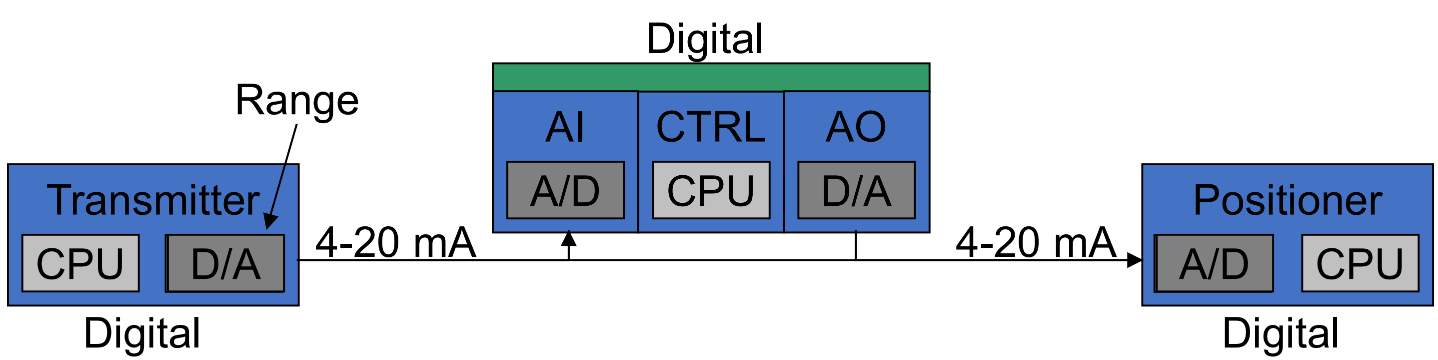
Digital communication (1s & 0s)

on parallel wiring with multiple devices attached

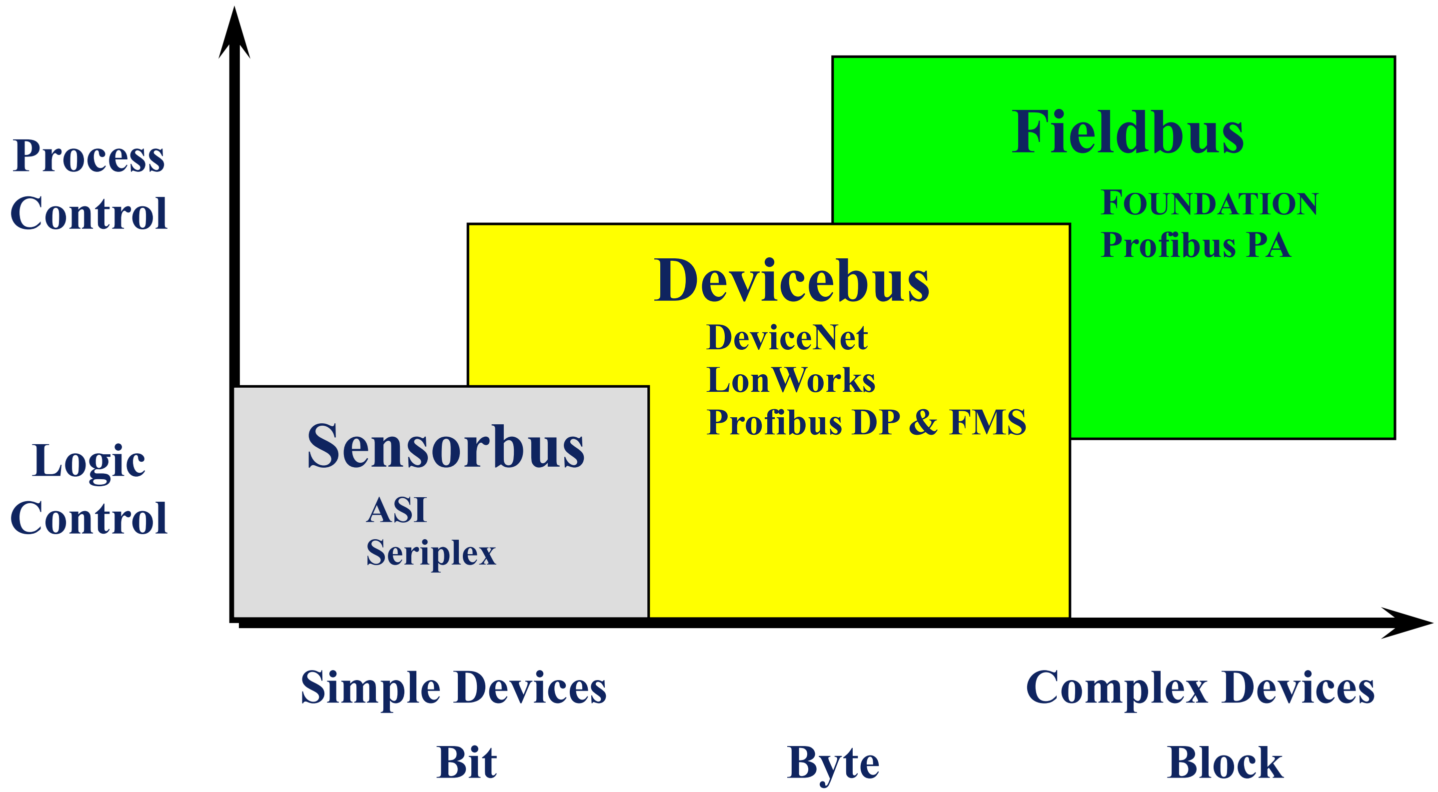


Why Digital Buses

- Less wiring
  - Multiple devices per bus
  - Multiple signals per device
    - Drives and MOV etc.
- Better accuracy
  - No precision lost in D/A & A/D
- High integrity
  - Distortions can be detected
- More powerful diagnostics
  - More current for higher processing speed
- Sends a real number
  - Measure to sensor limits
  - No mismatch
- More information...
  - Device management from control room or in the field
- Enables innovation...
  - New classes of digital devices
- Alerts
  - Predictive maintenance
- Firmware download
  - Stave off obsolescence

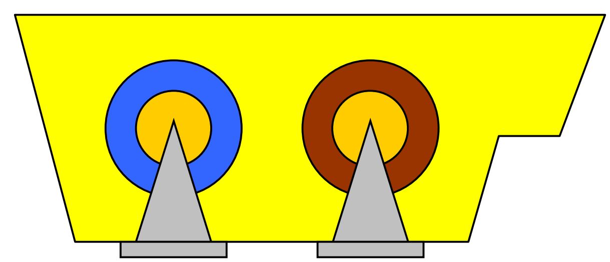


Three Types of Bus



AS-i (Actuator-Sensor-interface)

- IEC 62026-2
- Organization
  - AS-International Association
  - Frankfurt-am-Main, Germany
- Application Area
  - buttons clusters
  - inductive and optical switches
  - limit switches for level and temperature
  - motor starters, solenoids, on/off valves, pneumatic actuators
  - drive interfaces
- Others
  - Characteristic yellow cable



AS-i Characteristics

- Physical characteristics
  - 100 m, 300 m with repeaters
  - Two-wire power over the bus, 8 A
  - Not intrinsically safe
  - 187.5 kbit/s
- Data link characteristics
  - 31 slaves (62 in extension)
  - Master/slave polling without scheduled synchronization
  - Only cyclic I/O, no acyclic data (setup/diagnostics)
  - Only one master: no redundancy, no handheld
- Application characteristics
  - 248 points discrete I/O
  - Extension allows for analog – limited implementation
  - No configuration or diagnostics

Good AS-i Applications

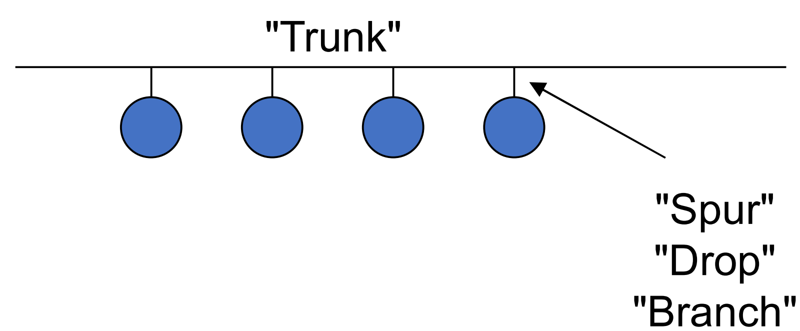
- Motor Starter
- Solenoids
- On-Off Valves
- Low cost distributed discretes
- Level Switches

DeviceNet

- IEC 62026-3 / IEC 61784 CPF 2
- Organization
  - Open DeviceNet Vendor Association (ODVA)
  - Ann Arbor, Michigan, USA
- Application Area
  - conventional I/O-blocks
  - encoders and resolves
  - barcode readers and RFID
  - electric and pneumatic actuators and valves
  - AC and DC drives
  - solenoid valve manifolds
  - motor starters

DeviceNet Characteristics

- Physical characteristics
  - 500 m at 125 kbit/s, 100 m at 500 kbit/s
  - Redundant power on separate wires in same cable, 8A
  - Not intrinsically safe
  - 500/250/125 kbit/s
  - Spurs max 6 m
- Data link characteristics
  - 64 nodes
  - Producer/consumer peer-to-peer, master/slave, change of state
  - Acyclic data and cyclic I/O (setup/diagnostics) without scheduled synchronization
- Application characteristics
  - 8 bytes of data per message
  - Common Industrial Protocol (CIP) object model
  - Device profiles



Good DeviceNet Applications

- Motor Starters (Cutler Hammer, AB)
- Variable Speed Drives
- Discrete Valve Control
- Solenoid Valve Manifolds


PROFIBUS (Process Field Bus)

Three versions of the standard:

- Profibus FMS (1991)
  - PLC-PLC, PLC-SCADA, PLC-Field device (complex, obsolete)
- Profibus DP (1994)
  - Simpler than FMS, normally 1 master (PLC), several slaves (field devices)
  - Market leader
- Profibus PA (1995)
  - Different and more robust physical layer (IEC 61158-2)

Profibus-DP
(Distributed Peripherals)

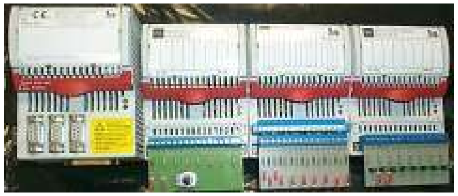
- IEC 61784-1 profile 3/1 of IEC 61158 type 3
- Organization
  - Profibus International (PI) organization
  - Karlsruhe, Germany
- Application Area
  - Conventional I/O blocks
  - Weighing scales
  - Drives, motor starters, circuit breakers
  - Valve manifolds
- Others
  - FMS
  - DPv0 pure I/O (no configuration etc.)
  - DPv1 I/O (not synchronized) and device information
  - DPv2 synchronized motion control

Profibus DP Characteristics

- Physical characteristics
  - 1.2 km for RS485 at 93.75 kbit/s or below, 100 m at 3 Mbit/s or above
  - 32 devices per RS485 segment
  - No power on the bus
  - Not intrinsically safe
  - 9.6/19.2/45.45/93.75/187.5/500 kbit/s or 1.5/3/6/12 Mbit/s
    - Most device max 1.5 Mbit/s
  - Spurs max 6.6 m for 1.5 Mbit/s and below
  - Some vendors have fiber-optic media converters for applications requiring high speed and long distance
- Data link characteristics
  - 126 slaves per network
  - Cyclic IO and acyclic device data master/slave polling
  - Free-running token rotation (no synchronization)
- Application characteristics
  - Data organized by slots and index

Good Profibus DP Applications

- Motor Starters
- Variable Speed Drives (Frequency Converters)
- Weigh Scale Interface
- Discrete Valve Control
- Solenoid Valve Manifolds



Profibus-PA

- Profibus PA is the same protocol as Profibus DP.
- The physical medium is different with reduced voltage and current levels to meet the requirements of intrinsically safe areas.
- Profibus PA is designed to operate in hazardous areas.
- Devices that operate in this environments have to follow European directive **ATEX**
- Profibus PA transmission techniques are described in IEC 61158-2.

Profibus PA Characteristics

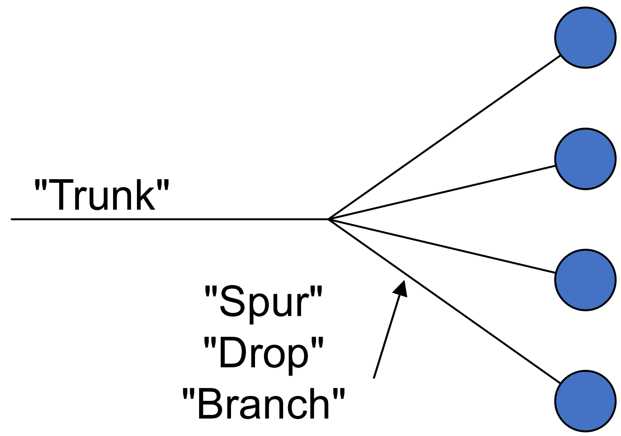
- Twisted cable
- Fixed Baud rate of 31.25 kbit/s
- Maximum distance 1900 m
- Between 10 and 32 devices per segments
- Power Supply directly from the bus
  - Each device has a current consumption of minimum 10 mA
  - The maximum device number depends on the current consumption per device. (typ. 10-20)

FOUNDATION fieldbus H1

- IEC 61784-1 profile 1/1 of IEC 61158 type 1
- Organization
  - Fieldbus Foundation
  - Austin, Texas, USA
- Application Area
  - temperature, pressure, level, flow, pH/ORP, conductivity, density, concentration, resistively, dissolved oxygen, and oxygen transmitters
  - machinery health monitors
  - control valve positioners, electric actuators, discrete switches, on/off valves, and signal converters
- Others
  - Includes the IEC 61804-2 function block diagram language for building control strategies
  - Firmware download

FOUNDATION fieldbus H1

- Physical characteristics
  - 1.9 km, 9.5 km with repeater
  - 32 devices per segment
  - Redundant power on the bus
  - Intrinsically safe
  - 31.25 kbit/s
  - Spurs max 120 m



- Data link characteristics
  - 240 slaves per network (never more than 16 in reality)
  - Publisher/subscriber peer-to-peer, master/slave, report distribution (by exception)
  - Muliple masters: redundant interfaces, handheld etc.
  - Automatic address assignment
  - Scheduled (cyclic) and unscheduled (acyclic)
  - Synchronized, minimum jitter for PID control
- Application characteristics
  - Data organized by blocks and parameters

Device Network Classification

	Sensorbus	Devicebus	Fieldbus
Message Size	< 1 byte	Up to 256 bytes	Up to 256 bytes
Distance	Short	Short	Long
Data Transfer Rate	Fast	Medium to Fast	Medium to Fast
Signal Replaced	Discrete	Discrete or Analog	Analog
Device Cost	Low	Low to Medium	Medium to High
Component Cost	Very Low	Low	Medium
Intrinsic Safety	No	No	Yes
Functionality	Low	Medium	High
Device Power	Many	No	Most
Optimization	No	No	Yes
Diagnostics	No	Minimal	Comprehensive

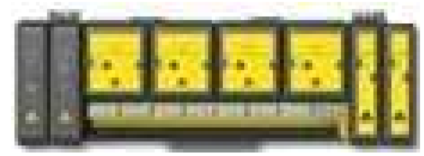
HART (Highway Addressable Remote Transducer)

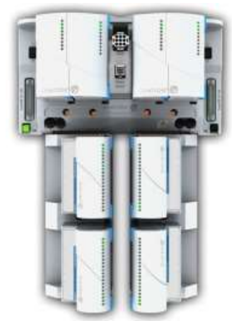
- IEC 61158 type 20 / IEC 61784-1 CPF 9
- Organization
  - HART Communication Foundation (HCF)
  - Austin, Texas, USA

- Application
  - Temperature, pressure, level, flow, pH/ORP, conductivity, density, concentration, resistively, dissolved oxygen, and oxygen transmitters
  - Control valve positioners
- Hybrid
  - 4-20 mA (real time PV)
  - Digital communication (diagnostics etc.)

HART Characteristics

- Physical characteristics
  - 1.5 km
  - Two-wire power over the wires
  - Intrinsically safe
  - 1.2 kbit/s
- Data link characteristics
  - Primary (DCS) and secondary (handheld) masters
  - 1 slave (but 15 possible)
    - E.g. ROC
  - Master/slave polling
  - Usually only acyclic data
- Application characteristics
  - Based on commands



Modbus/RTU

- IEC 61784 CPF 15
- Organization
  - Modbus Organization
  - North Grafton, Massachusetts, USA
- Application Area
  - Conventional I/O blocks
  - Flow computers
  - Remote terminal units (RTU)
  - weighing scales
  - AC and DC drives
- Supported in all DCS and most PLCs
  - Used to integrate package unit controllers to the main control system

Modbus/RTU Characteristics

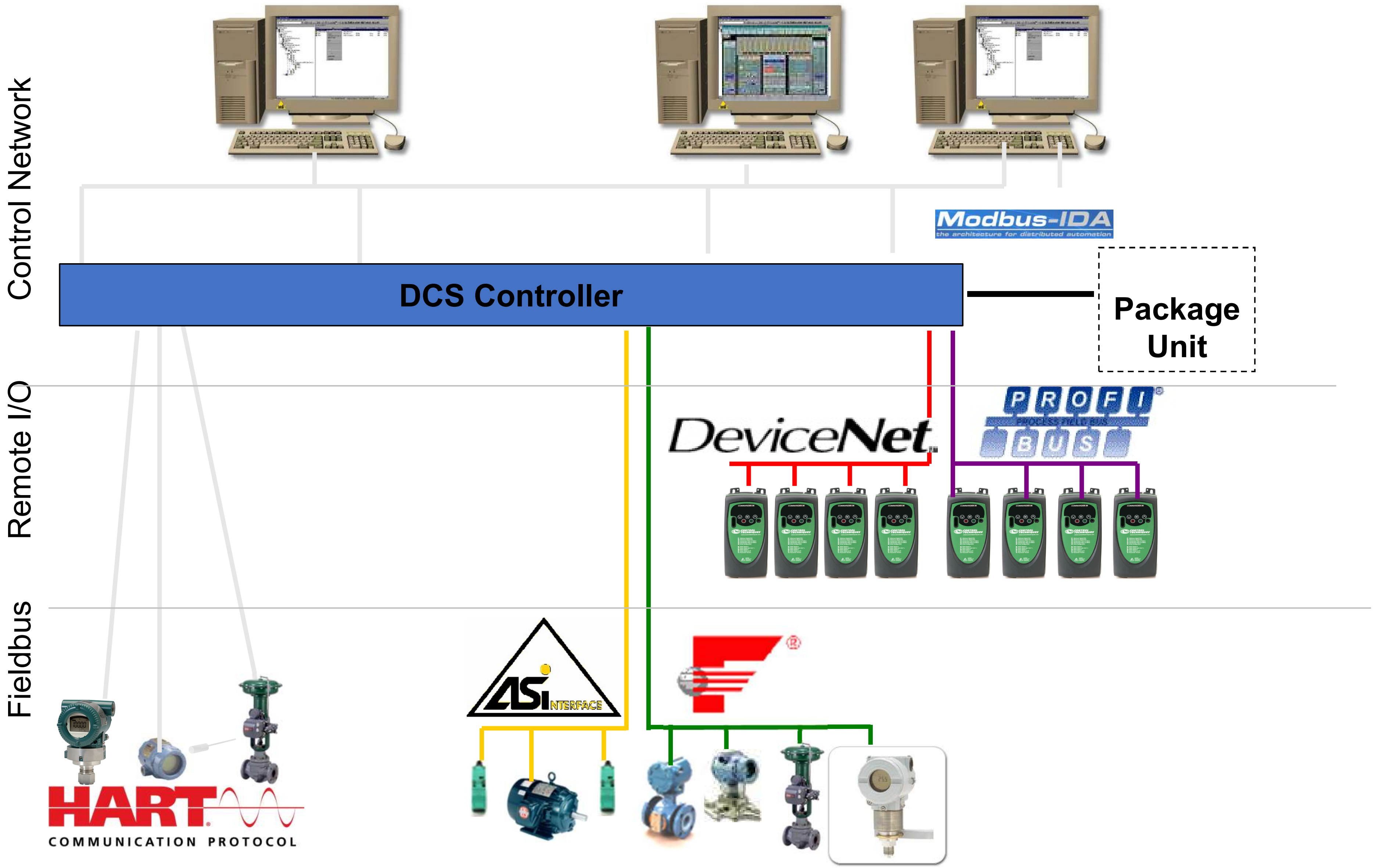
- Physical characteristics
  - 15 m for RS232, 1.2 km for RS485
  - 32 devices per RS485 segment
  - No power on the bus
  - Not intrinsically safe
  - 9.6-115.2 kbit/s or more (not defined)
  - Spurs max 6.6 m (not defined)
- Data link characteristics
  - 247 slaves per network
  - Master/slave polling without scheduled synchronization - data acquisition, not control
  - Any kind of data
  - Single master
- Application characteristics
  - Data organized in numbered registers accessed by commands

Register
0xxxx
1xxxx
3xxxx
4xxxx

Automation Areas

- Process Control ("DCS")
  - HART, Foundation Fieldbus, Profibus-PA
  - Modbus, Profibus-DPv1, DeviceNet, AS-i
- Building Automation
  - LonWorks, BACnet, EIB
- Industrial/Factory Automation ("PLC")
  - DeviceNet, Modbus, ControlNet, Profibus-DPv0, CANopen, Ethernet, Interbus, P-net, FIP, CC-Link
- Motion Control / Robotics
  - SERCOS, Profibus-DPv2

Same Plant with Different Busses Coexist



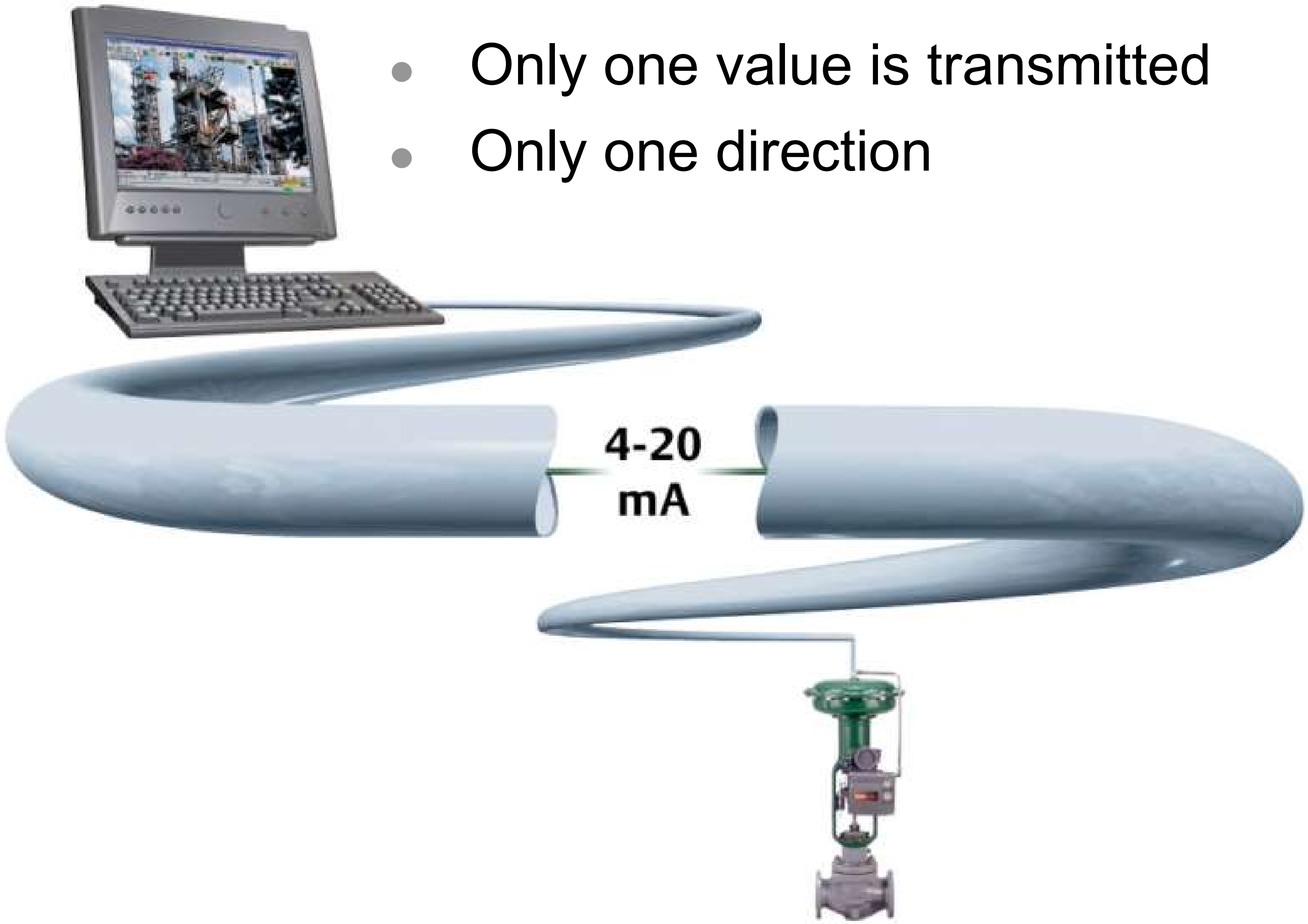
What is Fieldbus?

Definition...

A digital, two-way, multi-drop communication link among intelligent field devices and automation systems.

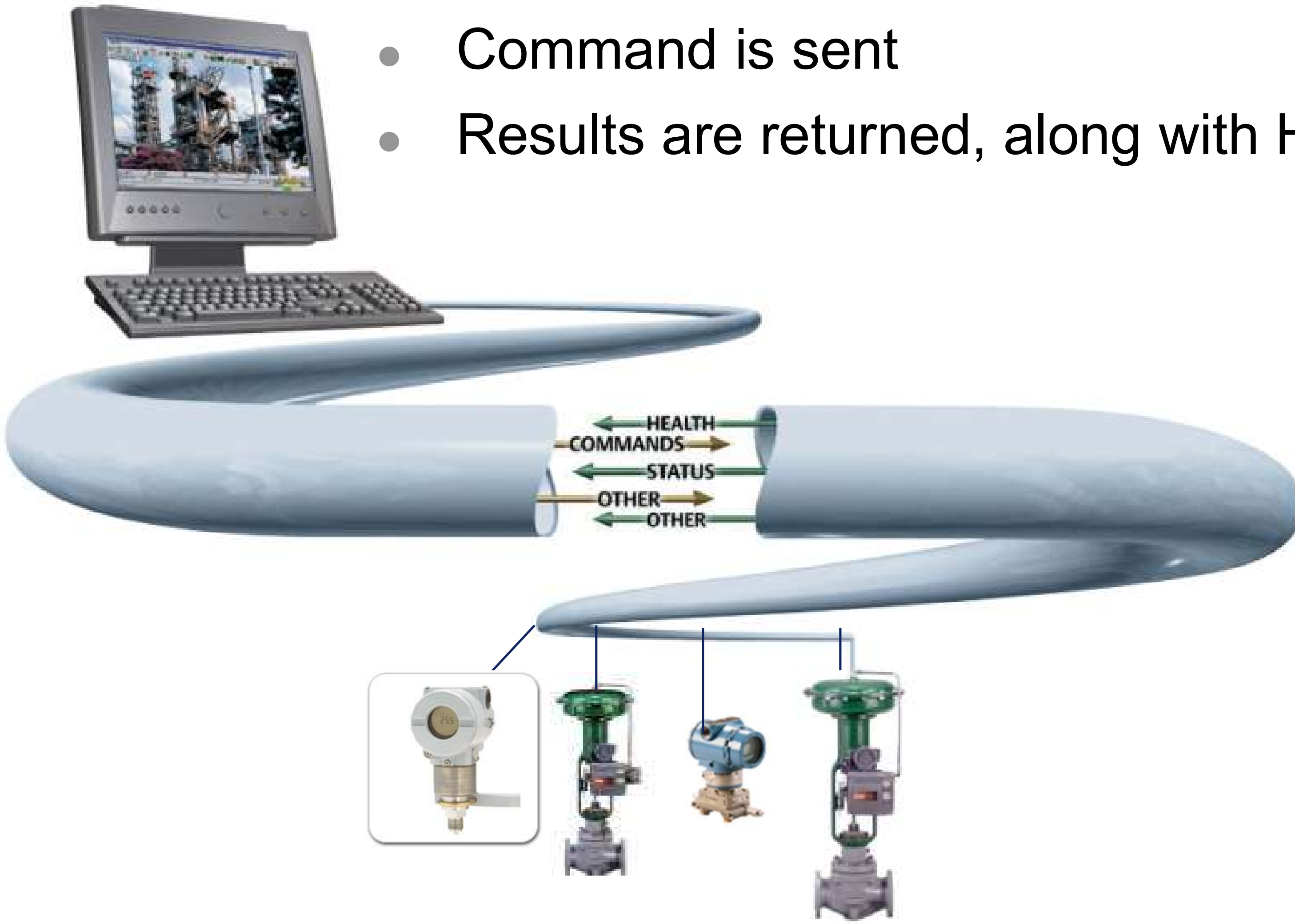
Why Buses?
The Old 4-20mA Paradigm

- Only one value is transmitted
- Only one direction



Why Buses?
The Old 4-20mA Paradigm

- Command is sent
- Results are returned, along with HEALTH



Fieldbus Benefits

Traditional 4-20

- One variable passed in one direction
- Two signal wires per device to I/O subsystem

Fieldbus

- Multiple variable communicated directly between devices and/or controller
- Fieldbus Device Alarms
- Device Alerts
- One twisted pair of wires from field devices to H1 interface (control system)

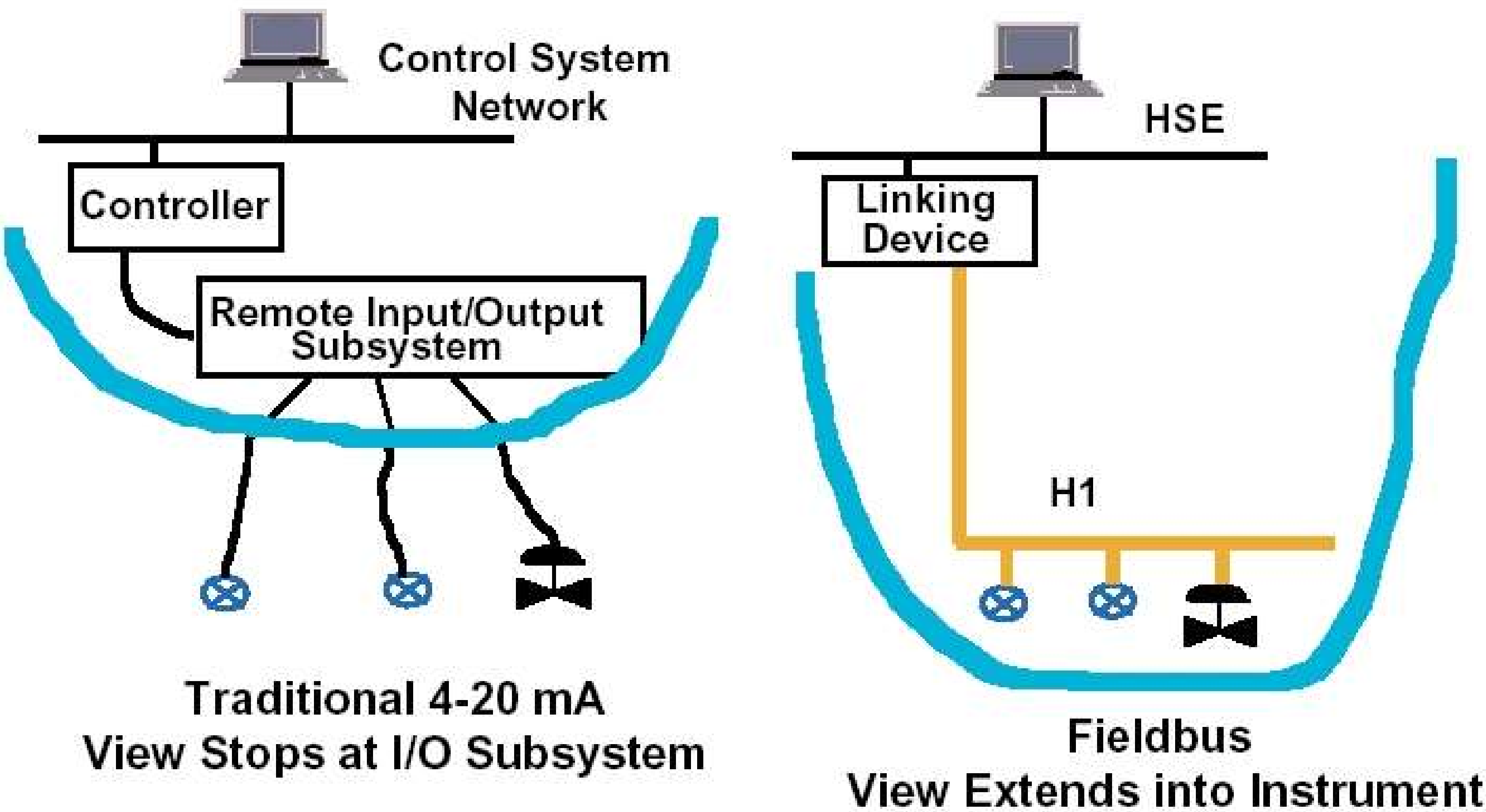
The Role of Field Devices Has Changed

- On-board computing power enables step changes in functionality
- Become “information servers” in the field based architecture
- An integral part of the process automation system
- Diagnostics and loop speed increase the value of the field device.

Head Mounted
TTH300

Field Mounted
TTF300

Foundation Fieldbus Benefits



Fieldbus Foundation

- Structure/Members
  - not-for-profit organization
  - more than 100 of the world's leading controls and instrumentation suppliers and end users.
- Beginnings
  - Established September 1994
  - Merger of WorldFIP North American and the Interoperable Systems Project (ISP)
- Goal
  - single international, interoperable Fieldbus standard

FieldComm Group™

Connecting the World of Process Automation

FieldComm Group is the Home of

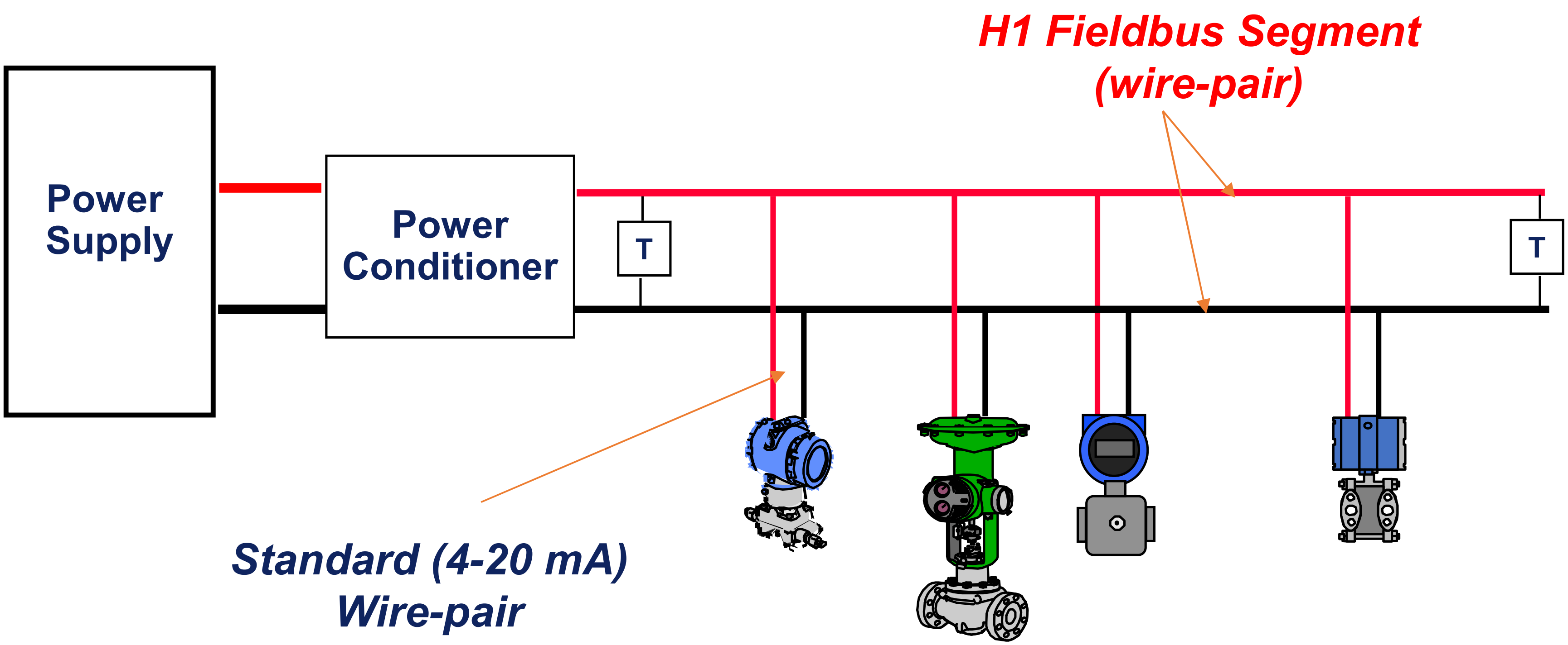
HART, FOUNDATION Fieldbus and FDI Technologies

377 MEMBERS

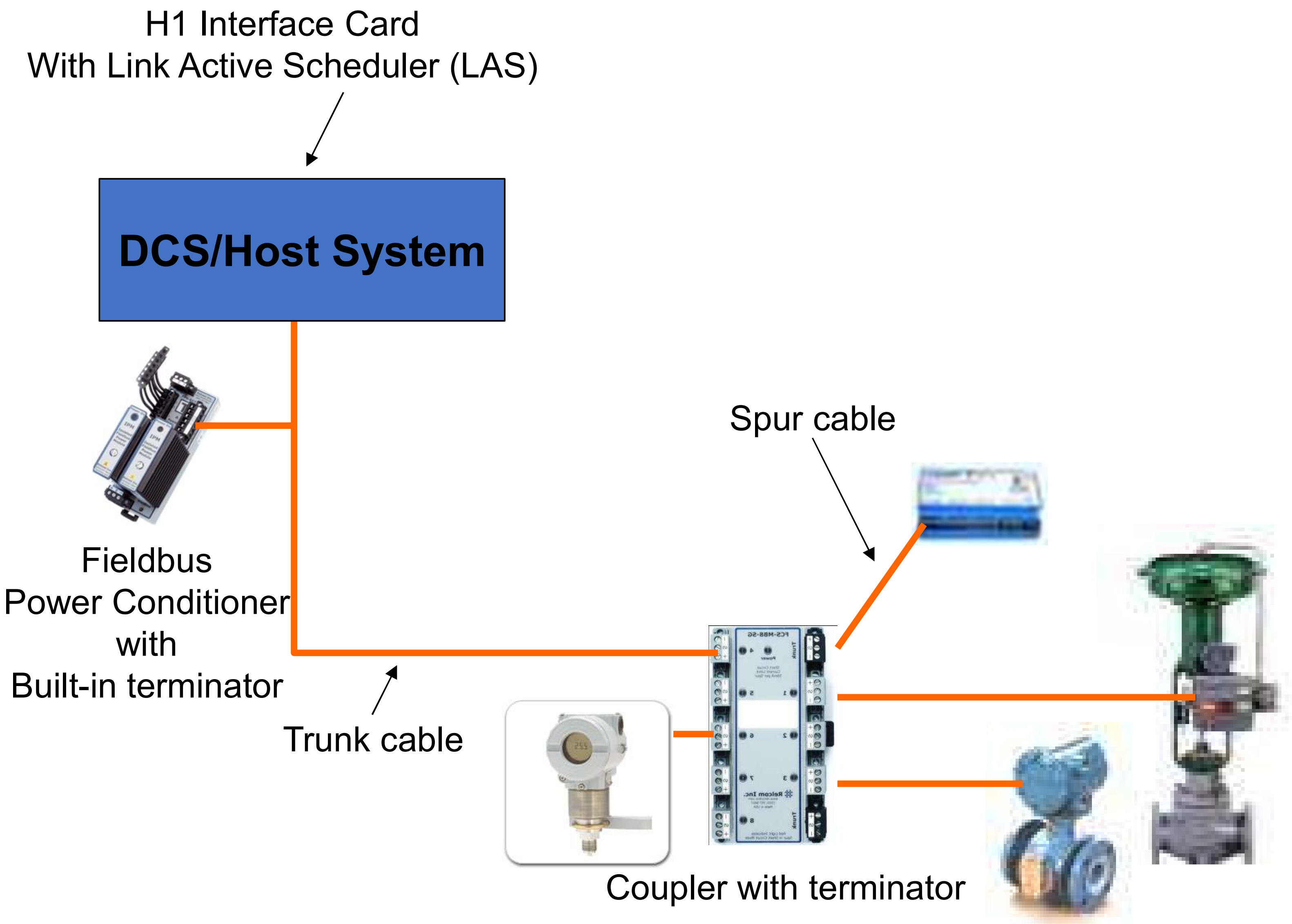
formed in 2015 • global organization • 370+ members

H1 Fieldbus

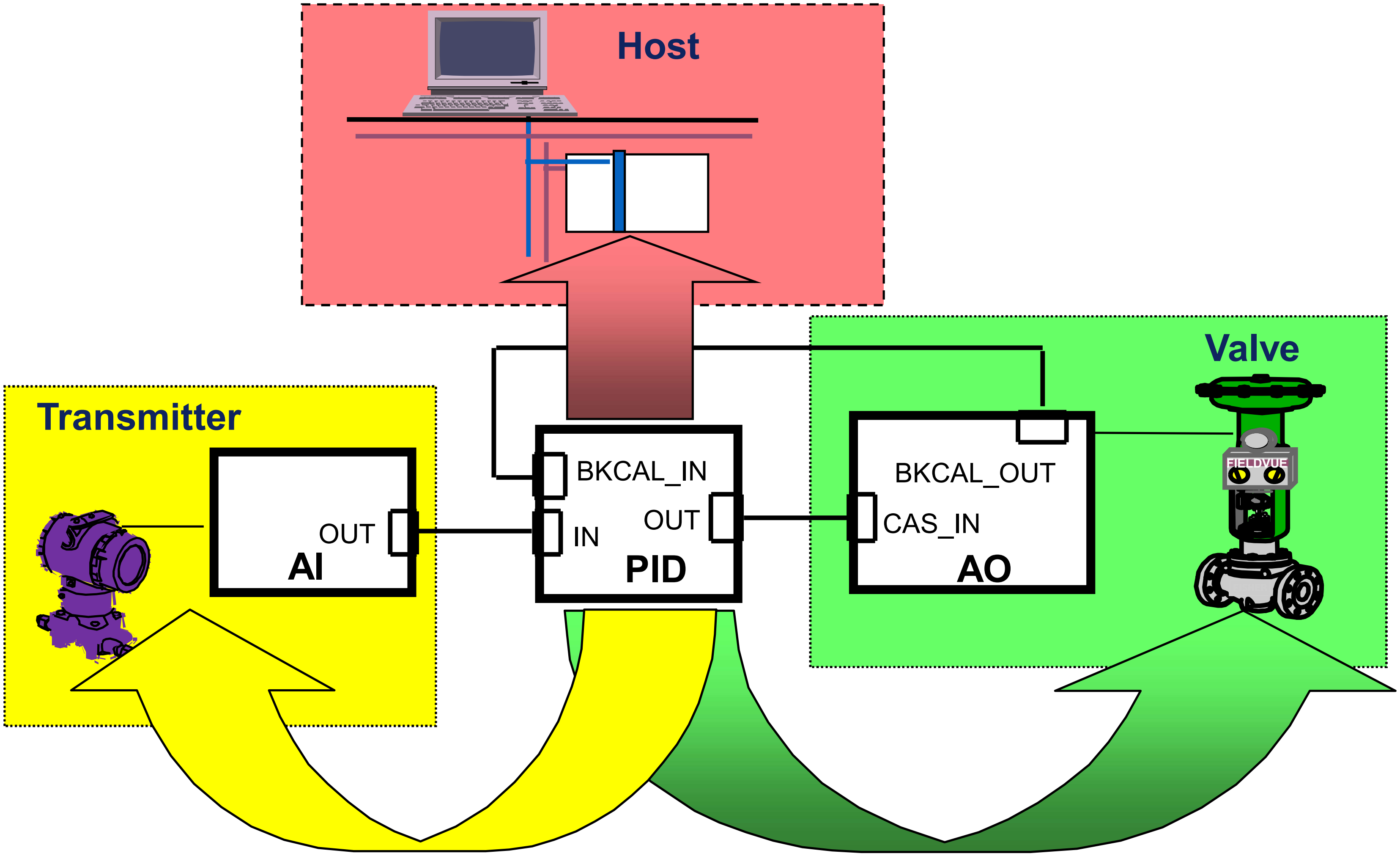
- Powered directly from the fieldbus segment
- Can operate on wiring previously used for 4-20 mA devices



Components of Ff Segment

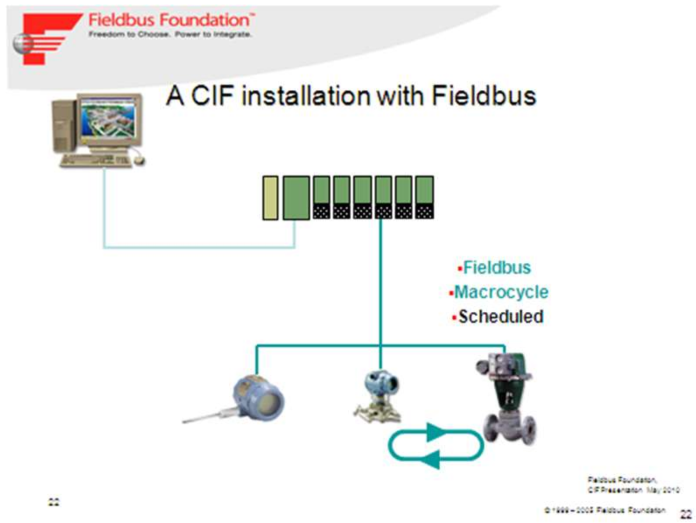


PID Control Options



Control In the Field (CIF) Benefits

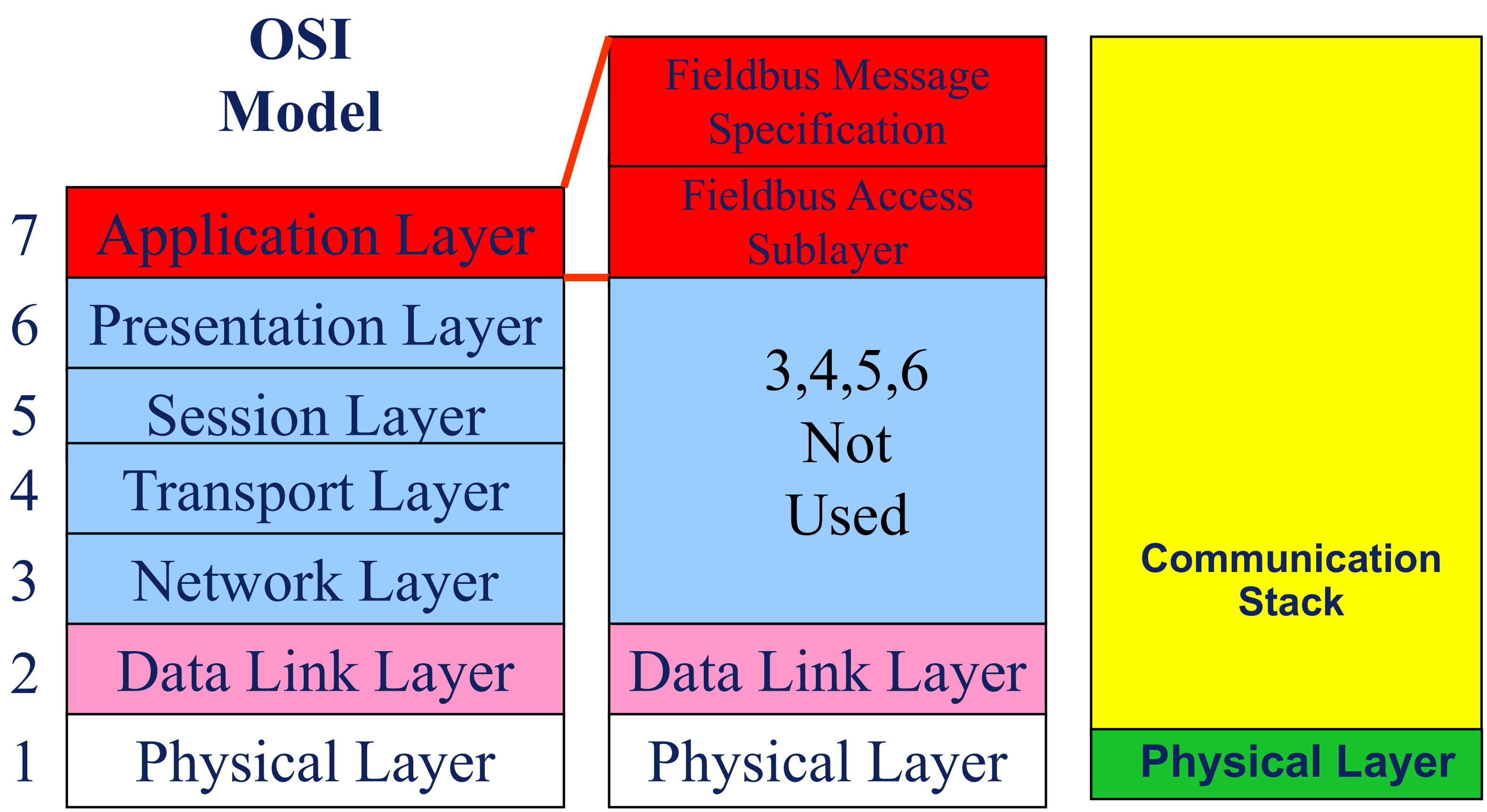
- Improved Control Loop Performance
- Increased reliability and availability
- Improved loop integrity
- Reduced loading on DCS/PLC and network
- Lower capital and installation costs
- Reduced Operating costs



CIF Control Performance Benefits

- Improvements in control loop performance for CIF arise from:
  - Faster sample times
  - Shorter latency (delays) in the read-execute-write cycle
  - Guaranteed determinism
- For control in the DCS, sample time and latency are typically longer
  - Also, DCS and FF segment updates can be asynchronous leading to significantly longer and potentially variable latencies
- Delays in a control loop limit the performance

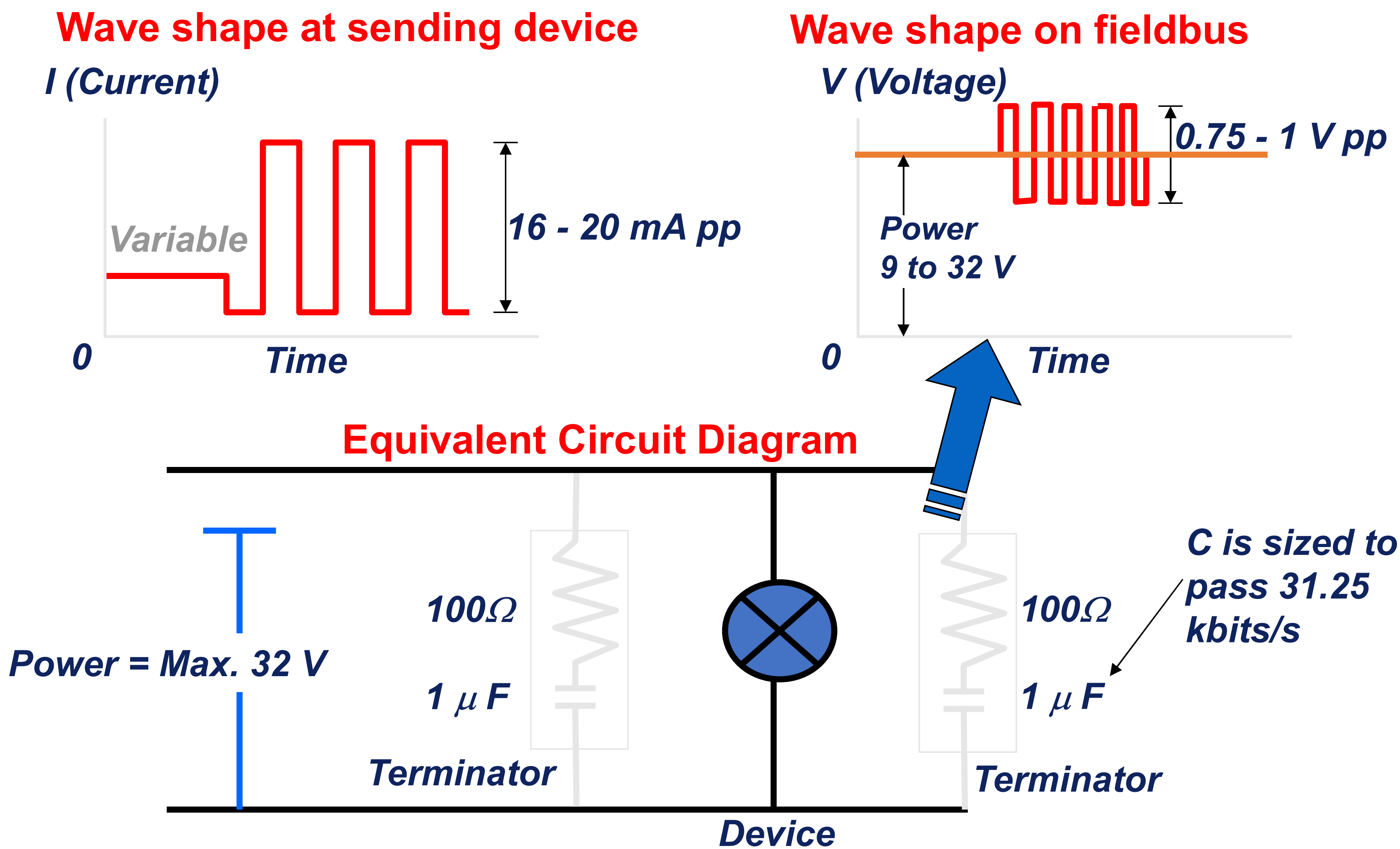
OSI (Open System Interconnect) Model



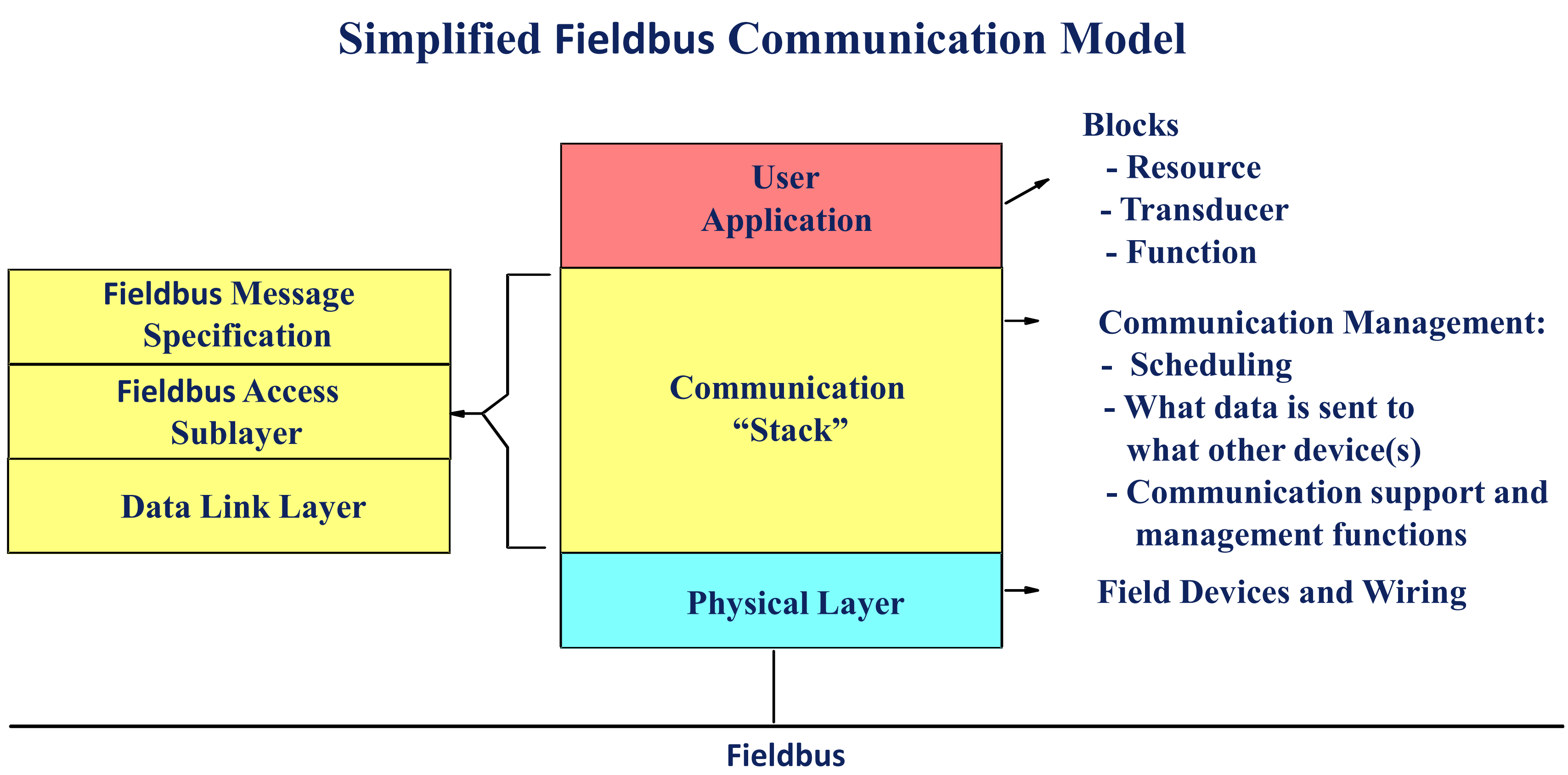
FOUNDATION fieldbus™ Physical Layer

- Transmitting device delivers 16 - 20 mA peak-to-peak signal at 31.25 kbit/s
- Thru a 50 ohms equivalent load (terminators)
- Creates 0.75 - 1.0 V peak-to-peak voltage signal
- Modulates on top of the direct current (DC) supply voltage.
- The DC supply voltage range from 9 to 32 volts
- Supply voltage depends on barrier rating for I.S. applications

Signal Transmission on H1 Fieldbus

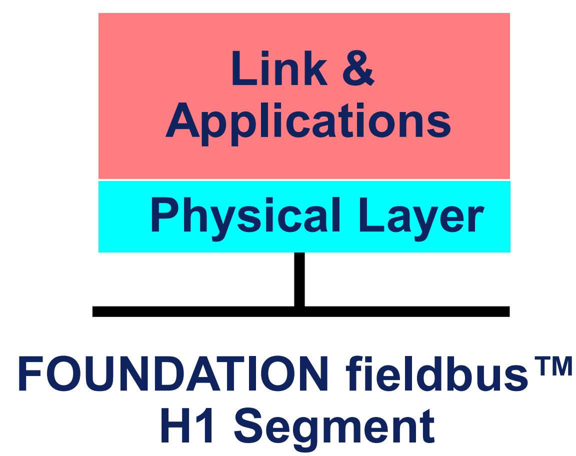


Communication Technology



FOUNDATION fieldbus™ Communications Stack

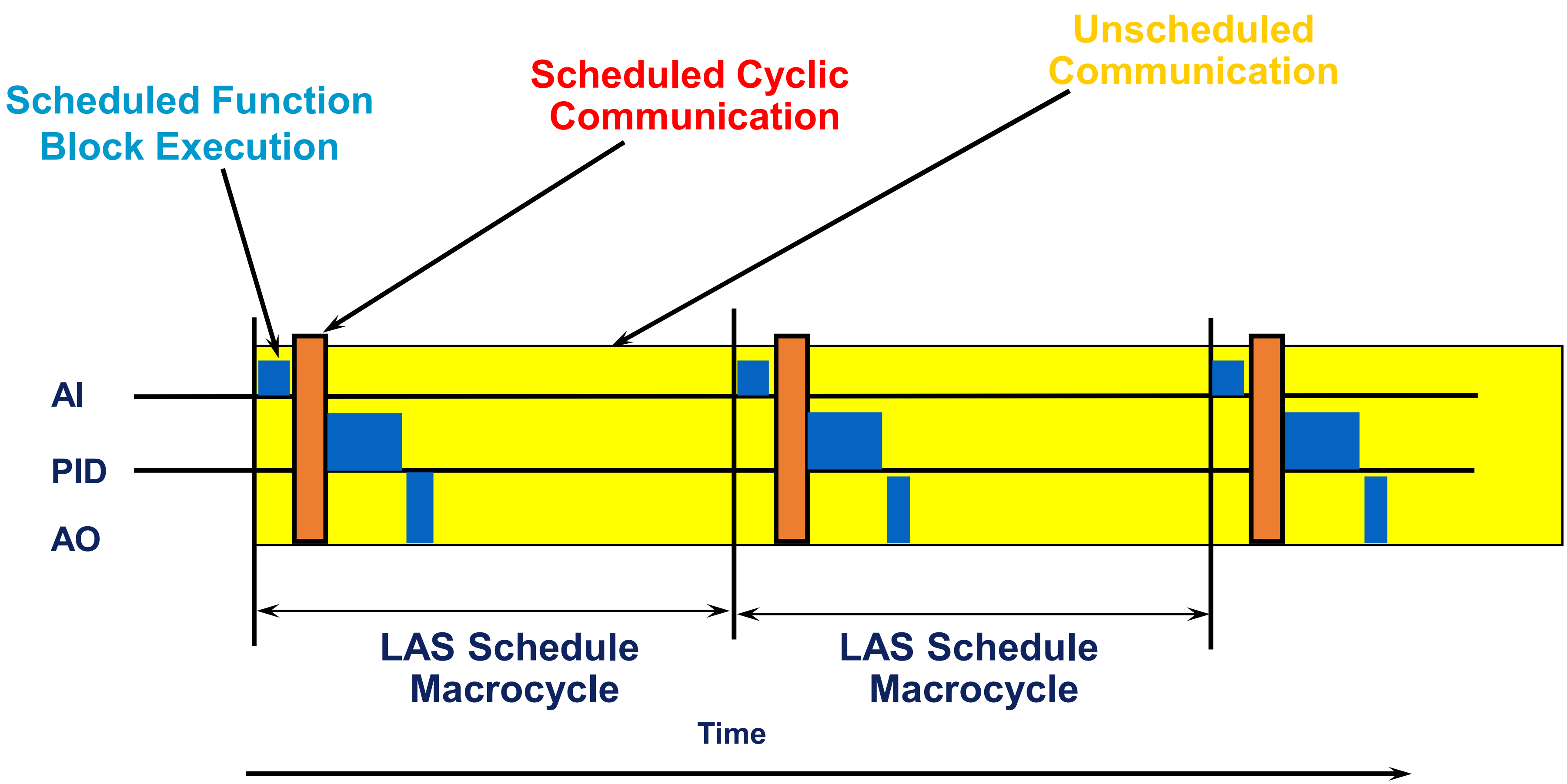
- Link and Application layers
  - Acyclic communications
    - Communications non-control data
  - Cyclic communications
    - Communicates function block data
  - Coordinates function block execution across the bus



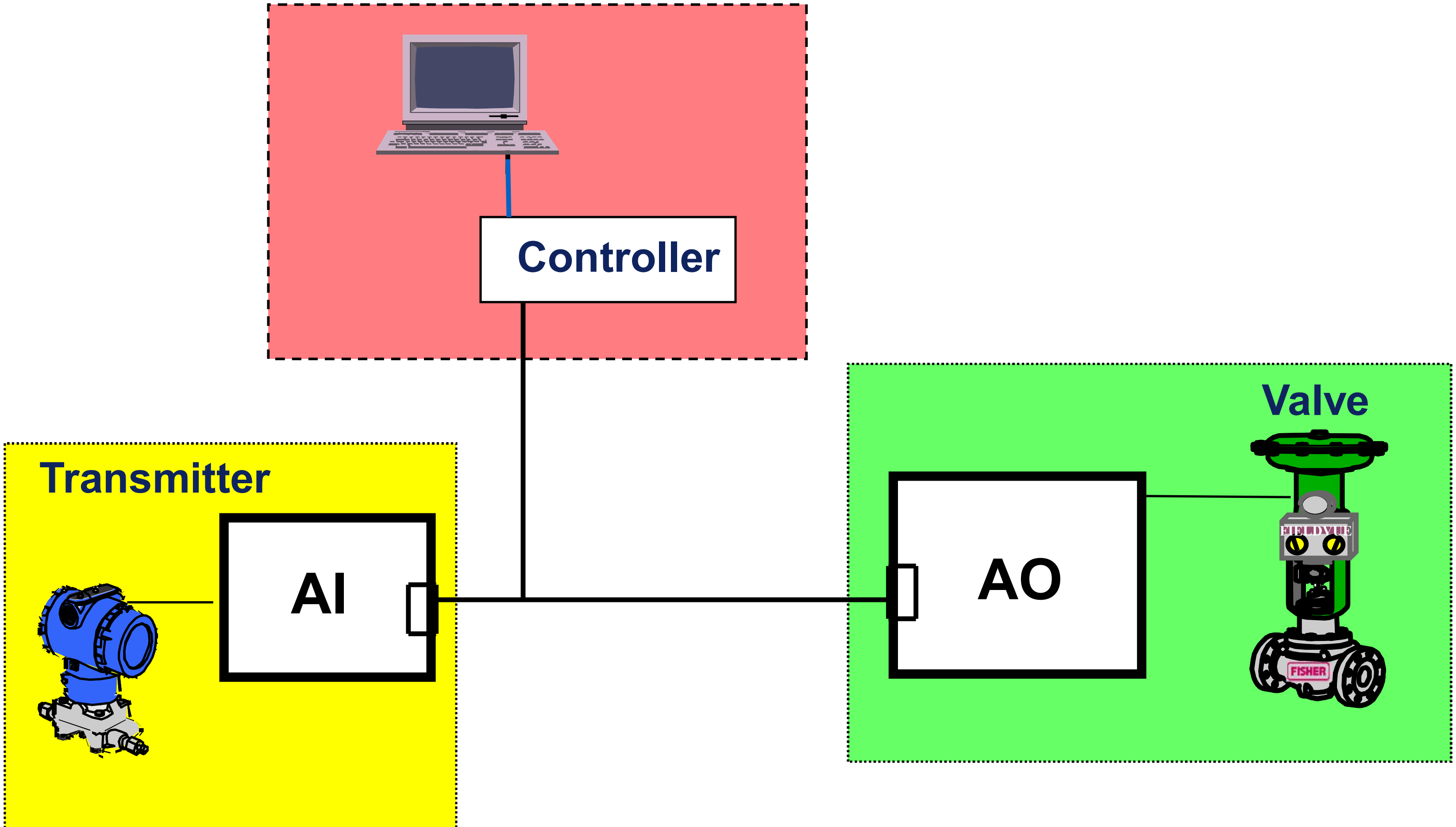
Communications Processing

- LAS - Link Active Scheduler
- The LAS schedules data transfer between function blocks which have been assigned to a segment
- At least one device on a segment must have LAS capability (Usually H1 card)
- LAS devices must have a link master communication stack

FUNCTION BLOCK SCHEDULING



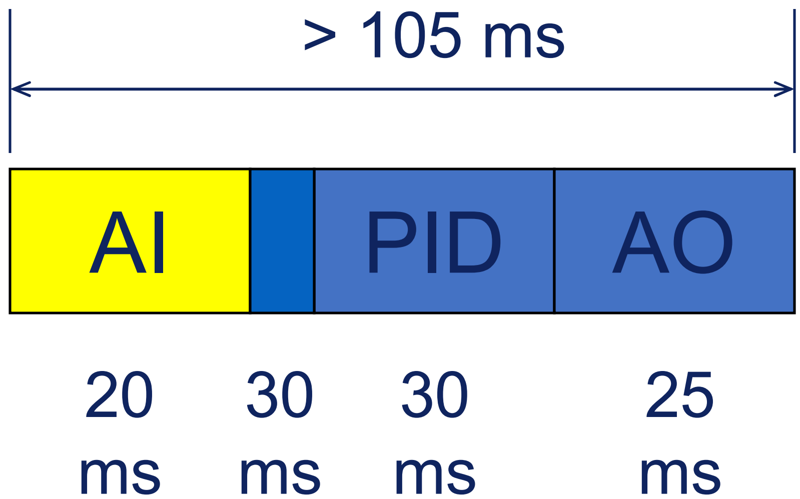
FOUNDATION Fieldbus Projects: Software Engineering — Function Blocks



Communications Processing

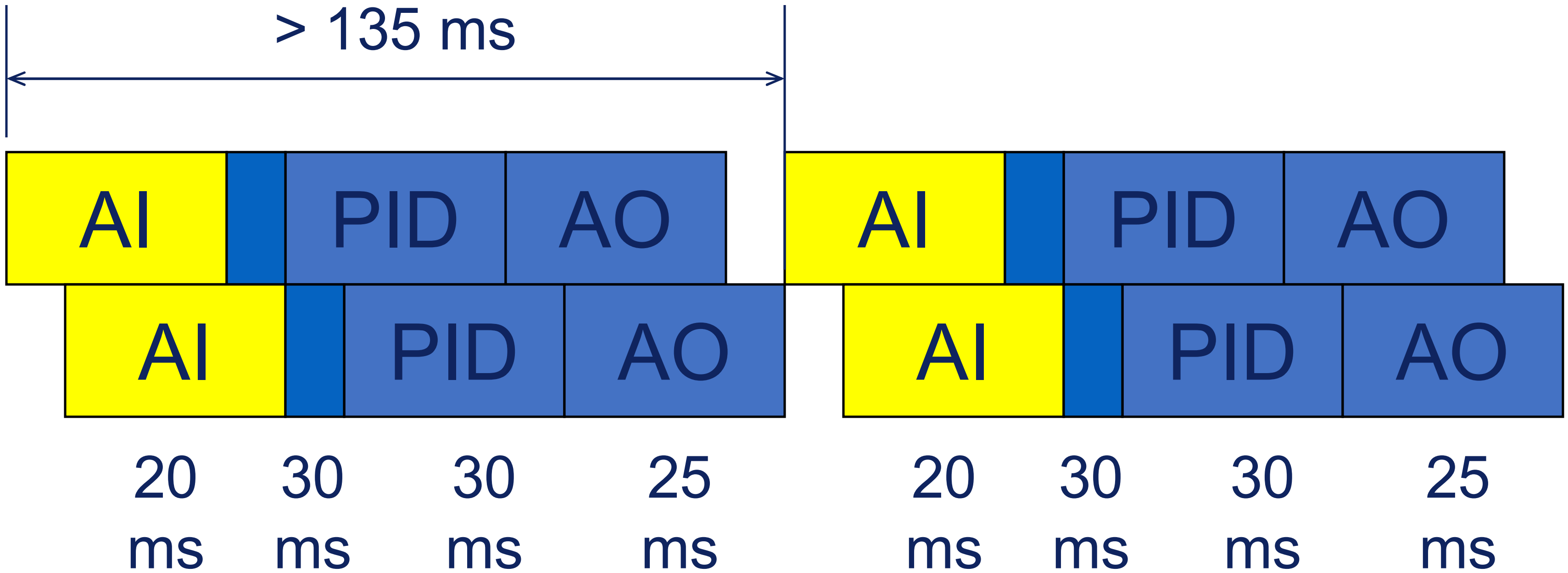
- The LAS allocates both scheduled and unscheduled time on the bus
- Approximately 50% of the time is reserved for asynchronous data
- Macrocycle time depends on block execution speed, number of blocks, communications between blocks, etc.

Communications Processing



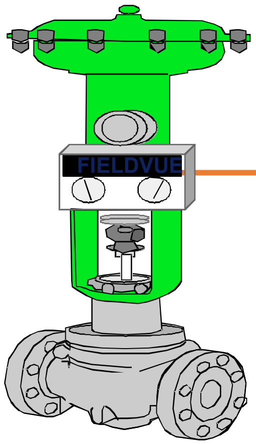
This sample loop on a segment results in a minimum 105 ms macrocycle time.

Communications Processing



Adding a second loop on the segment results in a longer macro-cycle time, but not twice as long (30ms compelled data time).

Fieldbus Blocks



Transducer (Servo) Block
Interface to Sensors

- Calibrate Information
- Configure Information

Function Block
Define Control System Behavior

- AI, AO, DI, DO, PID, etc.
- Approximately 30 Blocks Defined
- Blocks Configured by Host to Implement a Control Strategy

Resource Block
Device Characteristics

- Name
- Manufacturer
- Serial Number
- Enable Features

Fieldbus

Device Descriptor (DD)

- a “driver” for the fieldbus device
  - New devices are added to the fieldbus by simply connecting the device to the fieldbus segment and providing the control system or host with the DDs.
- to achieve interoperability
  - allows operation of devices from different suppliers on the same fieldbus network with only one version of the host human interface
- provides
  - an extended description of each object in the VFD
  - information needed for a control system or host to understand the meaning of the data in the VFD including functions such as calibration and diagnostics.

Device description methods

- Host based sequence of commands that causes certain operations to run in a device on specific conditions.
- Examples of methods:
  - Calibrations – Diagnostics
  - Trim operations – Setup operations
- FOUNDATION fieldbus and HART have standard methods defined that can be used by any host.
  - FOUNDATION fieldbus and HART support this functionality
  - Profibus does not.

What is EDDL?
International Standard for Interoperability

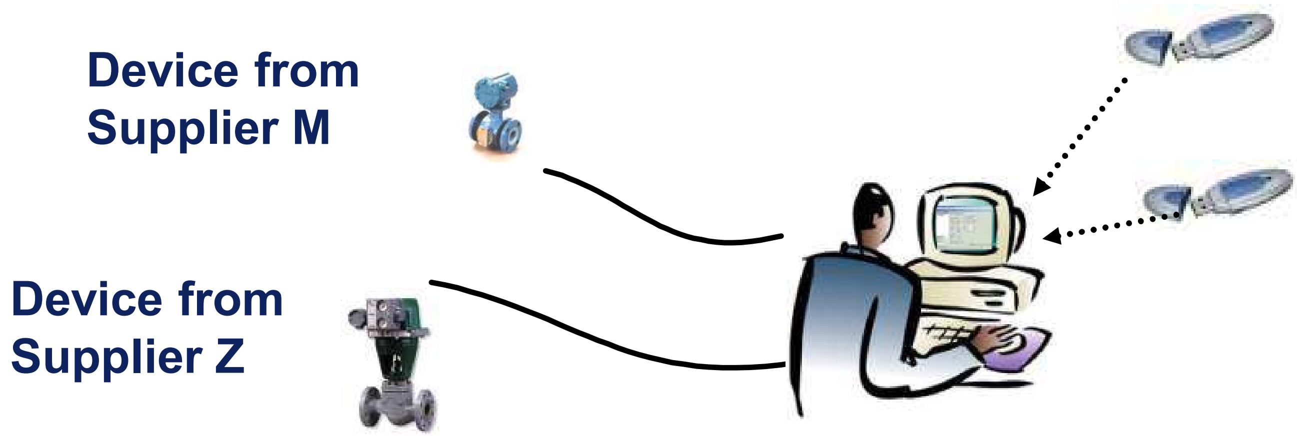
- EDDL is an Electronic Device Description Language
- EDDL is an **international standard**
  - Endorsed by IEC (IEC 61804)
- EDDL is endorsed by the three major digital busses
  - Fieldbus Foundation
  - HART Communication Foundation
  - Profibus Nutzerorganisation e.V (PNO)

EDDL

- EDDL is a descriptive technology
  - designed to avoid the need for special, proprietary, and operating system-specific host application files
- It allows a host system to both configure as well as monitor devices on-line
- Consists of two parts
  - A file (EDD) that describes the device and the information that it contains
  - A host application (EDD Services) that reads the file to learn how to retrieve the device information

EDD’s and Interoperability

EDD’s enable :
- Devices from different suppliers to interoperate with a single Host
- The same device to interoperate with different Hosts.



Describes

How the device functions

Menus

Field Device Tool/Device Type Manager

What is it?

- FDT/DTM is a software technology used to integrate field devices and software applications into host systems.
- Primary purpose is to configure devices
- It consists of two parts:
  - A Field Device Tool (FDT) software application that supports communication with the field device
    - Maintained by the host supplier.
  - A Device Type Manager (DTM) written and maintained by the field device manufacturer or host supplier

Field Device Tool (FDT)

- A FDT is a host based software application that provides interfaces to peripherals and communication protocols
  - Any type of device can be added to the software
  - The FDT has no knowledge of the device; it only provides software services
  - Think of it as an empty Windows Explorer waiting for devices to be added
- FDT is a software Interface

Device Type Manager (DTM)

- A DTM is a software program that enables the user to configure the device
- The DTM interfaces to the FDT to exchange **all** required information from/to a field device
  - All device operations are executed by the DTM
  - The graphical interface is dictated by the DTM
- A DTM is a custom Windows software driver
- DTM's must include install and uninstall software. They are programs

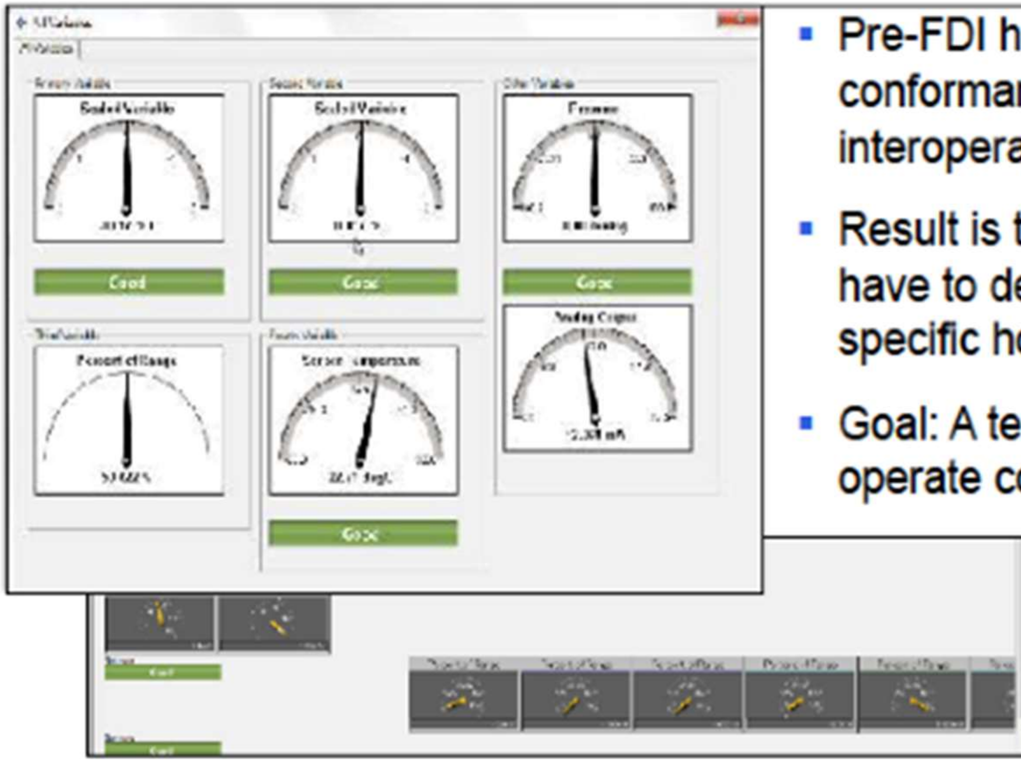
What is the Motivation Behind FDI?

1. Reduce lifecyle costs

- Currently EDDL and FDT technologies are recognized and widely used in the process management industry.
- Result is that the industry typically has to implement solutions for each technology, duplicating work. This also requires a variety of toolsets and skill sets be maintained.
- Goal: A single technology that leverages the best of both existing technologies. **ONE Device – ONE Package – ALL Tools**

Motivation

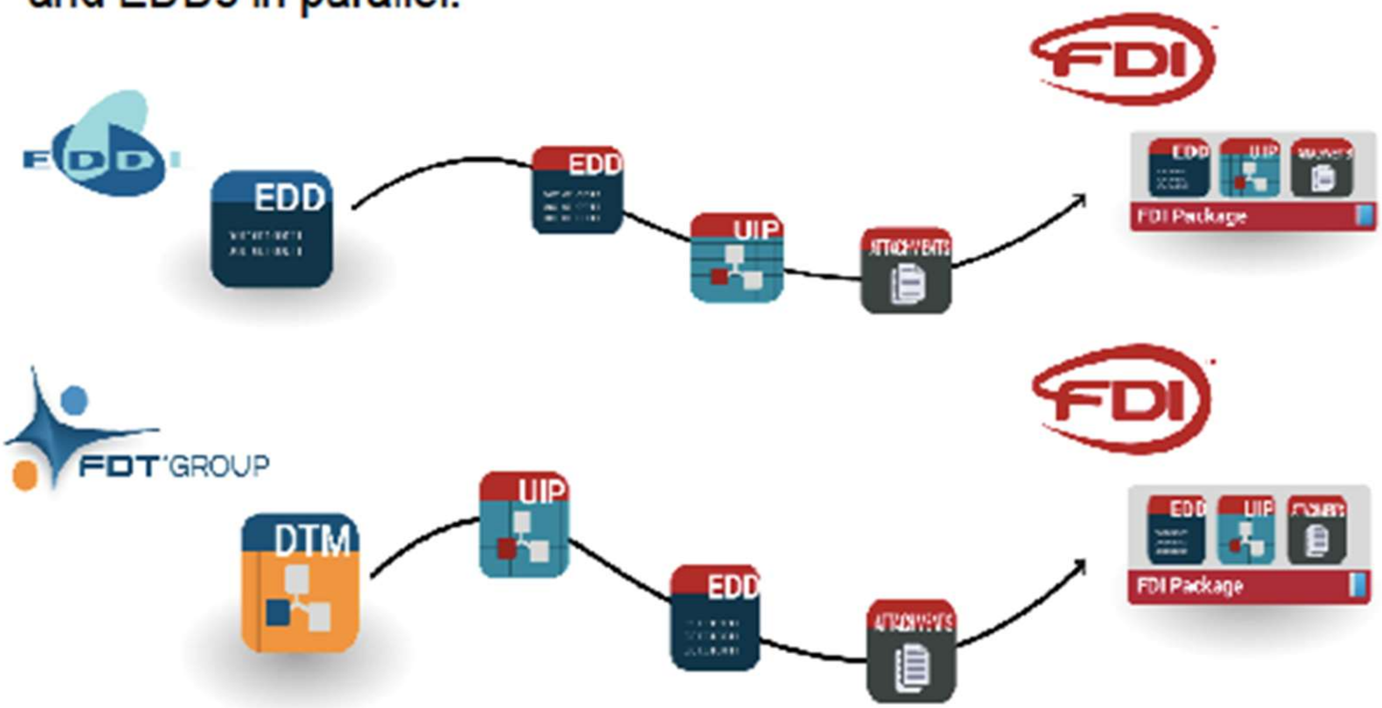
2. Standardize Interfaces



- Pre-FDI host requirements and conformance tests did not drive interoperability
- Result is that device vendors often have to develop custom DDs for specific hosts
- Goal: A technology where DDs will operate consistently on every host

Forward Focused – Backward Compatible

- Millions of devices worldwide are currently installed, configured, operated, and maintained by control systems and tools that support either the EDDL or FDT standards.
- FDI is designed to support FDI Device Packages as well as DTMs and EDDs in parallel.



Compliance Testing & Registration

- A Product bearing the Registered Mark undergo a rigorous testing process
- FieldComm Group governs the overall process – for all supported communication protocols

REGISTERED

Designing Fieldbus Segments

Designing Fieldbus Segments

- Segment Design Considerations
- Constraint Checks
- Communications Processing
- Wiring Design
- Component Selection

Assigning Fieldbus Devices to a Segment

- Maximum 16 devices per segment
- Recommended loading
  - Total of 12 devices per segment
  - Total of 4 control loops per segment
- Devices should be placed on segments based on location, control function, and reliability requirements

Segment Design Considerations

- Instrument Functionality
  - Pick the right instrument for the application
  - Find out which function blocks are available with an instrument
  - Most common function blocks are AI, AO, PID, DI, DO
- Instrument Location
- Process Control Requirements
  - How are the measurements being used?
  - Monitor only or used in PID control?
  - Required update time?
  - Input processing, such as P-T compensation?
  - Output processing, such as split-range?
- Reliability Requirements
  - Redundancy requirements
  - Equipment segregation
  - Distribution of critical loops
  - Component redundancy – LAS, Power Supply, H1 interface

Process Safety Levels (Client Driven)

Level 1 Valves

Failure of this valve will result in a total system trip, causing a shutdown of the entire unit, or other unavoidable losses in excess of $100M. Level 1 valves and their associated measurement shall reside on H1 segments with no other devices. The ISD shall show the criticality rating and shall prominently display that no additional devices shall be loaded on this segment.

Level 2 Valves

Failure of a level 2 valve will result in an emergency situation, where prompt operator action would be required to "save" the unit from immanent total shutdown. The material and energy capacity of associated vessels, geographic location, and elevation/accessibility of such valves should be considered. Failure of a level 2 valve will result in a total system trip, causing a shutdown of the entire unit, or other unavoidable losses in excess of $100M. However, the level 2 valve's process dynamics allow time for quick recovery from the failure, either by quickly fixing a fault or by taking manual control. Level 2 valves and their associated measurement shall reside on H1 segments with no other level 1 or 2 valves. The ISD shall show the criticality rating.

Level 3 Valves

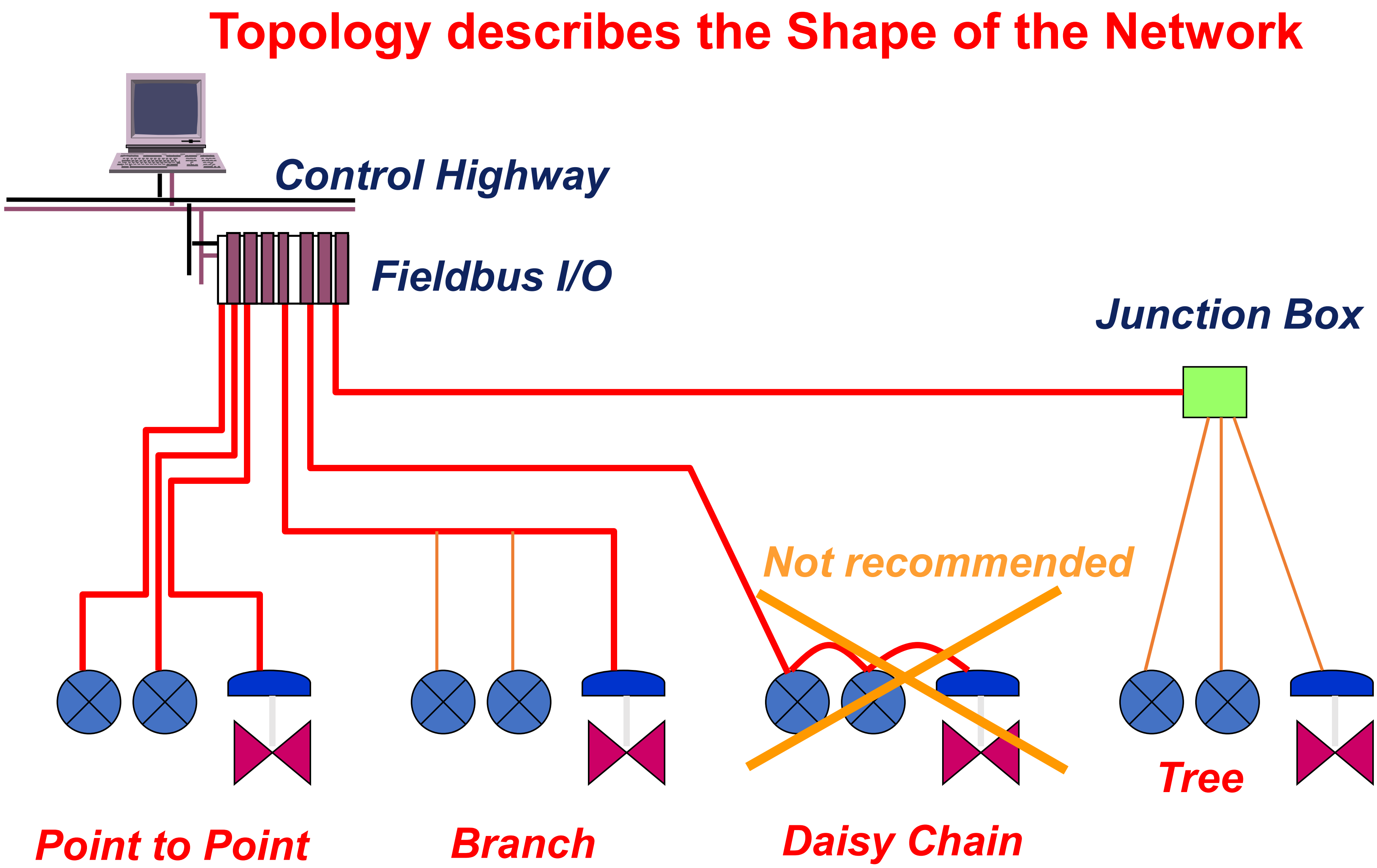
Failure of this valve will not result in any short-term risk of total unit shutdown. Level 3 valves can go to their fail position without requiring any immediate operator action. Level 3 valves can reside on cards or segments with other level 3 valves, or on a segment with a level 2 valve. Consideration should be given to the impact of common mode failures among level 3 and level 2 & 3 valves on the same segment.

EXAMPLE ONLY – VARIES WITH CUSTOMER

Constraint Checks

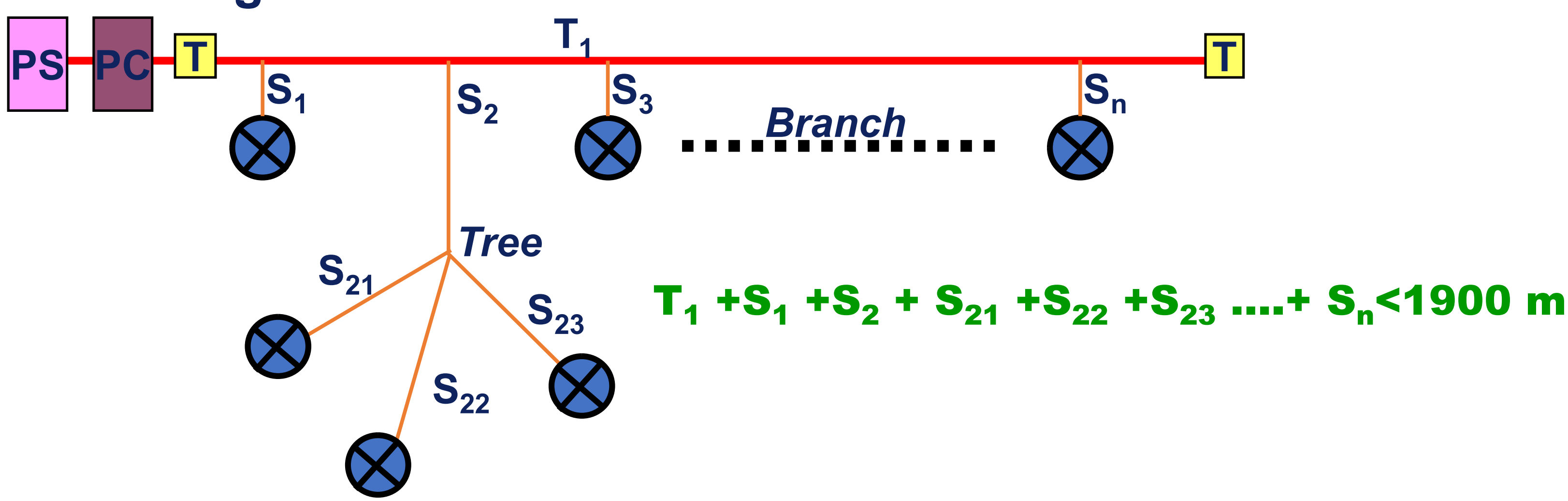
- Distance Limits
- Spur Length
- Power Consumption
- Voltage Drop
- Communications Processing

Foundation Fieldbus supports multiple Topology



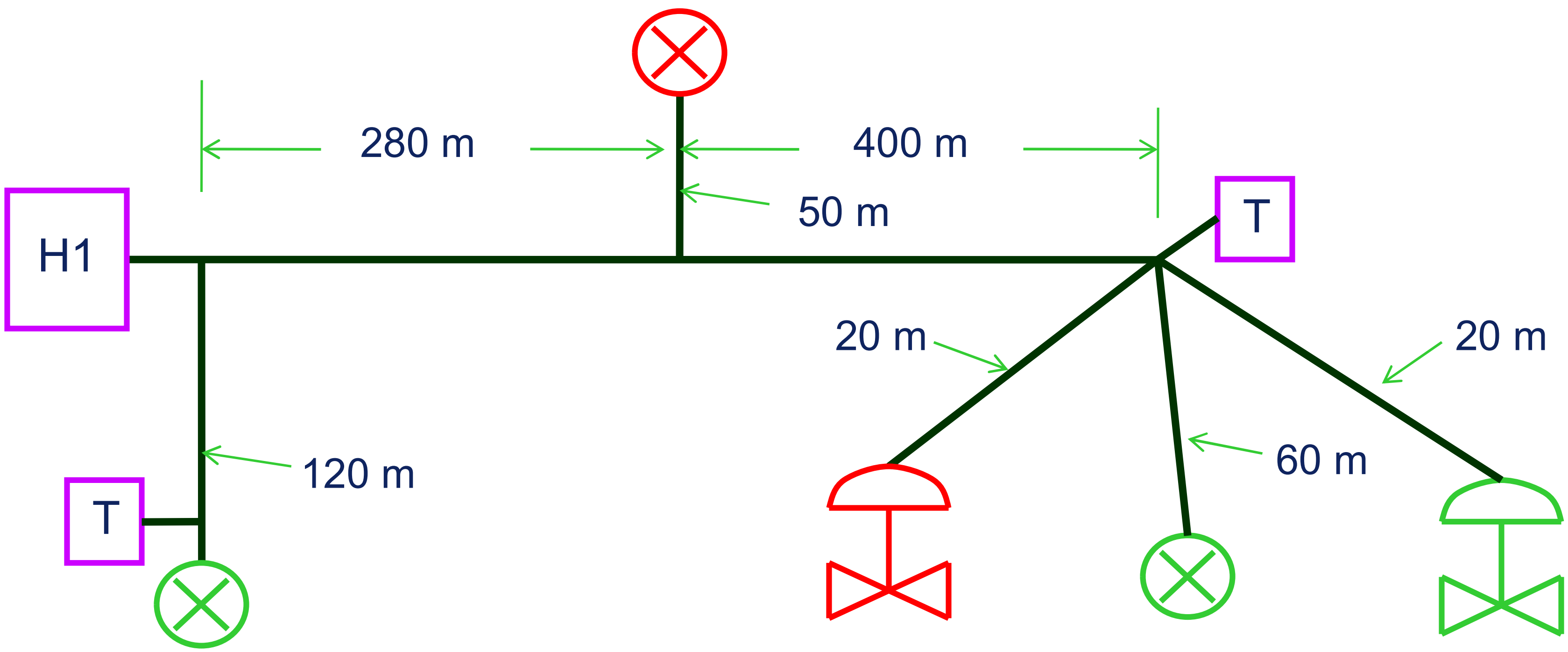
Fieldbus Network Components (non-IS)

- **Segment / Trunk**
  - **The section of the fieldbus that is terminated.**
  - **Max. 1900 m per segment**
  - **Max. 32 devices per segment**
- **Spur**
  - **Branch line from Segment**
  - **Distribute devices along the Segment**
  - **Final Circuit**
  - **Max. length 120 m**



Distance Limits

Total Segment Length = Trunk + All Spurs



Trunk = 800 m
Spurs = 50+20+60+20 = 150 m

=> Total Segment = <u>950 m</u>

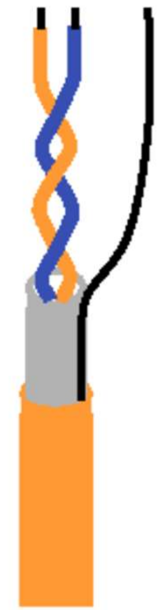
Field Cabling

- **Max. Cable Segment Lengths & Elements per Segment**

Cable Type	Gauge No.	Max. Length
A: Twisted-pair with Shield	#18 AWG	1900 m
B: Multi-twisted pair with Shield	#22 AWG	1200 m
C: Multi-twisted pair without Shield	#26 AWG	400 m
D: Multi-core with Shield	#16 AWG	200 m

Fieldbus cable

Example: Type A cable: Shielded twisted pair



- Recommended
- “Type A” does not specify the diameter; You can get type A cable in AWG 22, AWG 18, AWG 16, etc
- “Type A” is also available as multi-pair:
  as long as individual pairs are twisted and shielded, it is “type A”

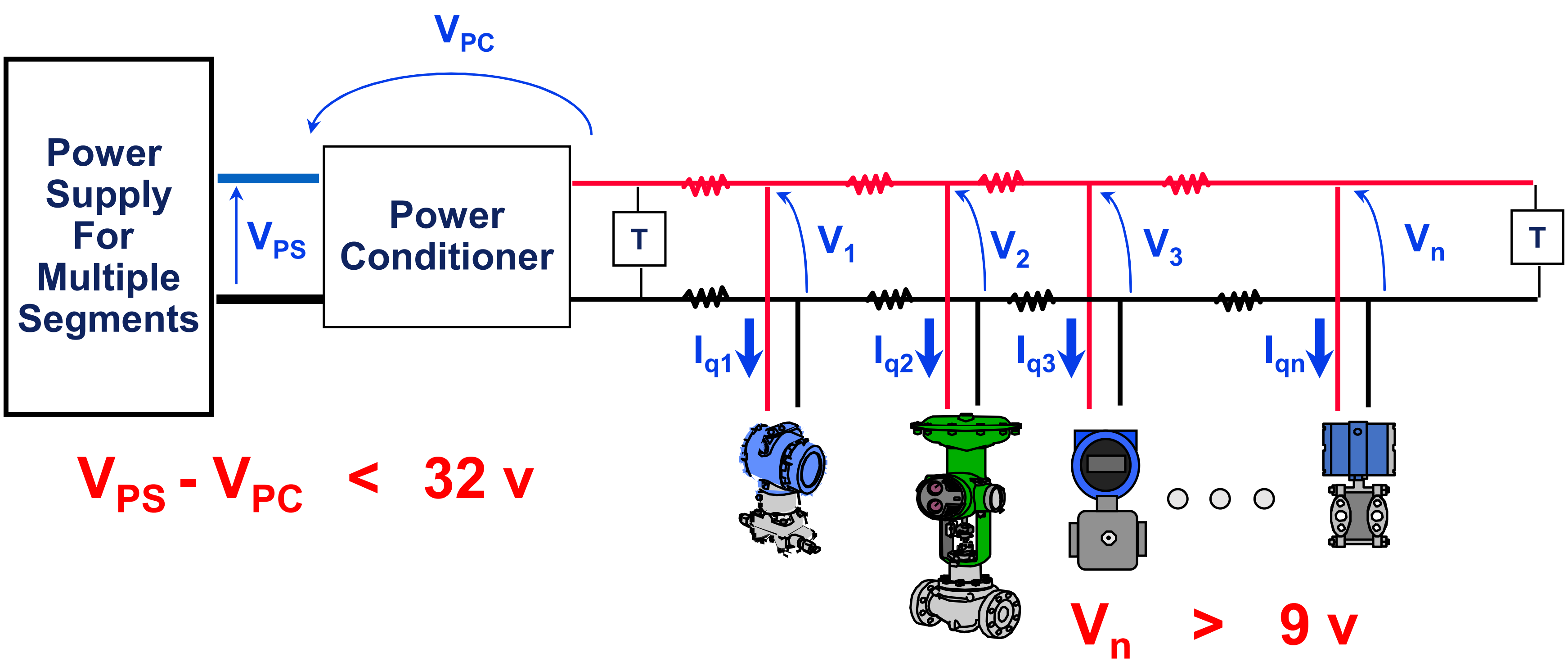
Fieldbus Power Supply

- Isolates fieldbus segments
- Provides power to the bus
- Prevents bulk power supply from “absorbing” digital signal
- Also known as power conditioners or power isolators

Foundation Fieldbus Segment Power

The voltage supplied to the fieldbus cable can be as high as 32 V.

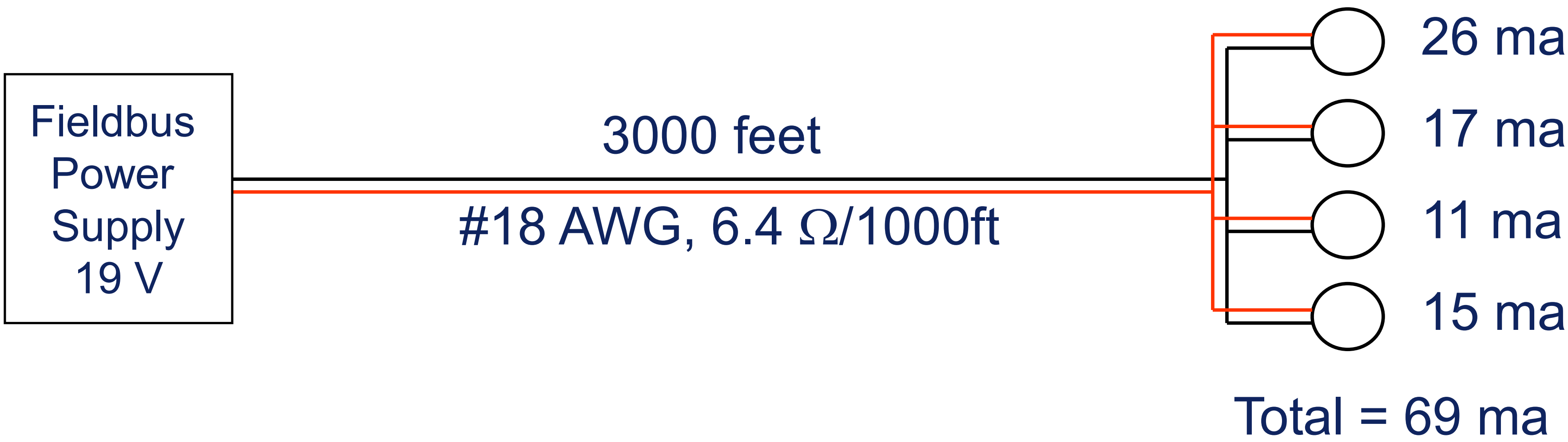
The voltage at any device can be as low as 9 V for the device to operate correctly.



Power Consumption

- Segment limited to power rating of fieldbus power supply
- Power supply rating is 500 ma for non-IS installations
- Most devices will use some bus power, even 4-wire devices
- Typically devices power consumption ranges between 17 to 25 mA
- Fieldbus devices require between 9 and 32 volts for operation
- Heavily loaded segments with long runs can result in low voltage at devices

Voltage Drop



Voltage = 19 - [(3000 x 6.4/1000 x 69/1000) x 2]

Voltage = 19 - 2.65

Voltage = 16.35

DesignMATE

A segment design tool for FOUNDATION™ fieldbus H1

Fieldbus Foundation™

Freedom to Choose. Power to Integrate.

MTL Foundation Fieldbus Segment Calculator V3.04

Use Mass Calculation file | Save Project File as… | Print

Segment OK: 0 errors, 0 warnings.

Project Name	Name of project		
Segment Name	Name of Segment		
Date	30-Aug-2020	Name	
Comments			

Host Control System

Type	Emerson Ovation
Host Current	34 mA

Fieldbus Power Supply

Type	918x-91 (28V 500mA)
Voltage	28 V
Max Current	500 mA
Total Current	284 mA

Segment Properties

Default trunk cable type	28 Ω/km	1.3mm² - AWG 16
Default spur cable type	28 Ω/km	1.3mm² - AWG 16
Max ambient cable temperature	25 C	
Default field device current	17 mA	
Default spur length	30 m	
Field device minimum voltage	10 V	
Spur short circuit test	Yes	Coupler 1 Spur 12
Total trunk and spur length	360 m	
Max spur length	120 m	

Length 0 m 28 Ω/km

Device Coupler 1

Type F312

Voltage 28.0 V

Current 250 mA

	Load	Length	Resistance	Tag	Voltage
Spur 1	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 1	26.74 V
Spur 2	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 2	26.74 V
Spur 3	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 3	26.74 V
Spur 4	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 4	26.74 V
Spur 5	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 5	26.74 V
Spur 6	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 6	26.74 V
Spur 7	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 7	26.74 V
Spur 8	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 8	26.74 V
Spur 9	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 9	26.74 V
Spur 10	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 10	26.74 V
Spur 11	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 11	26.74 V
Spur 12	17 mA	30 m	28 Ω/km	Device Coupler 1 spur 12	26.74 V

Length 0 m 28 Ω/km

Device Coupler 2

Type None

Length 0 m 28 Ω/km

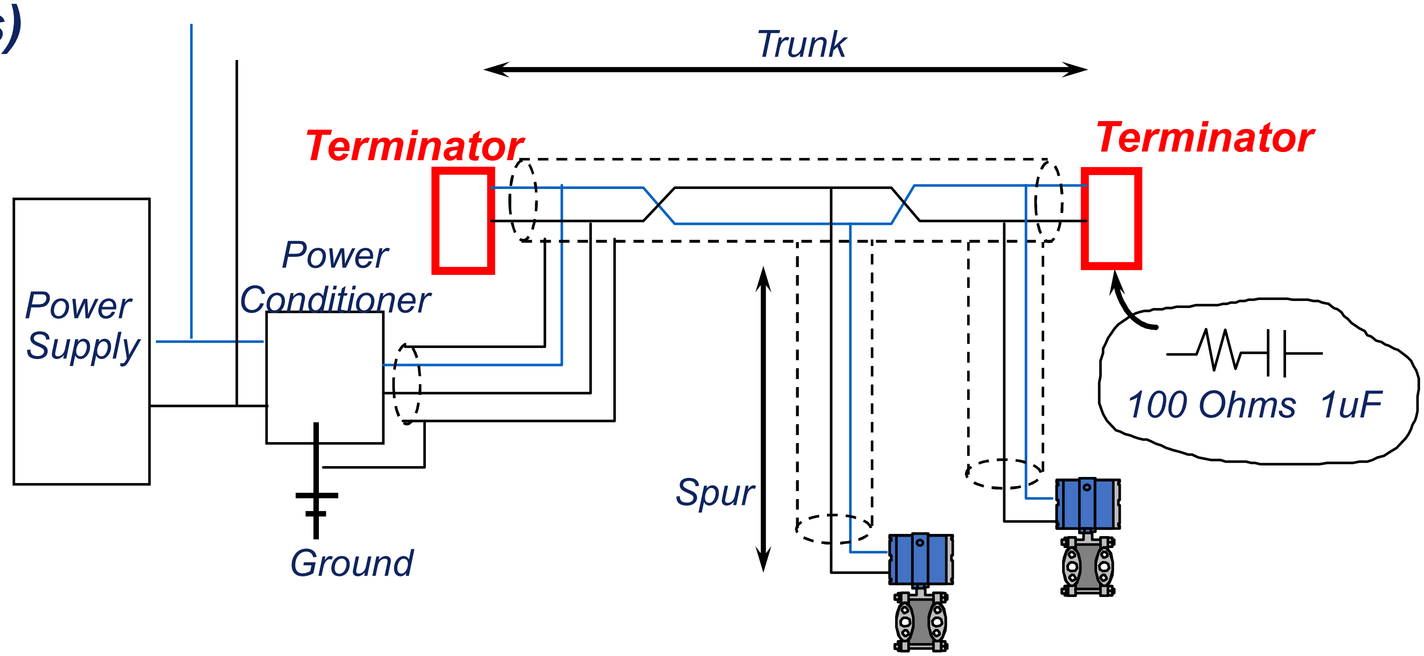
Device Coupler 3

Type None

Approved		Date	

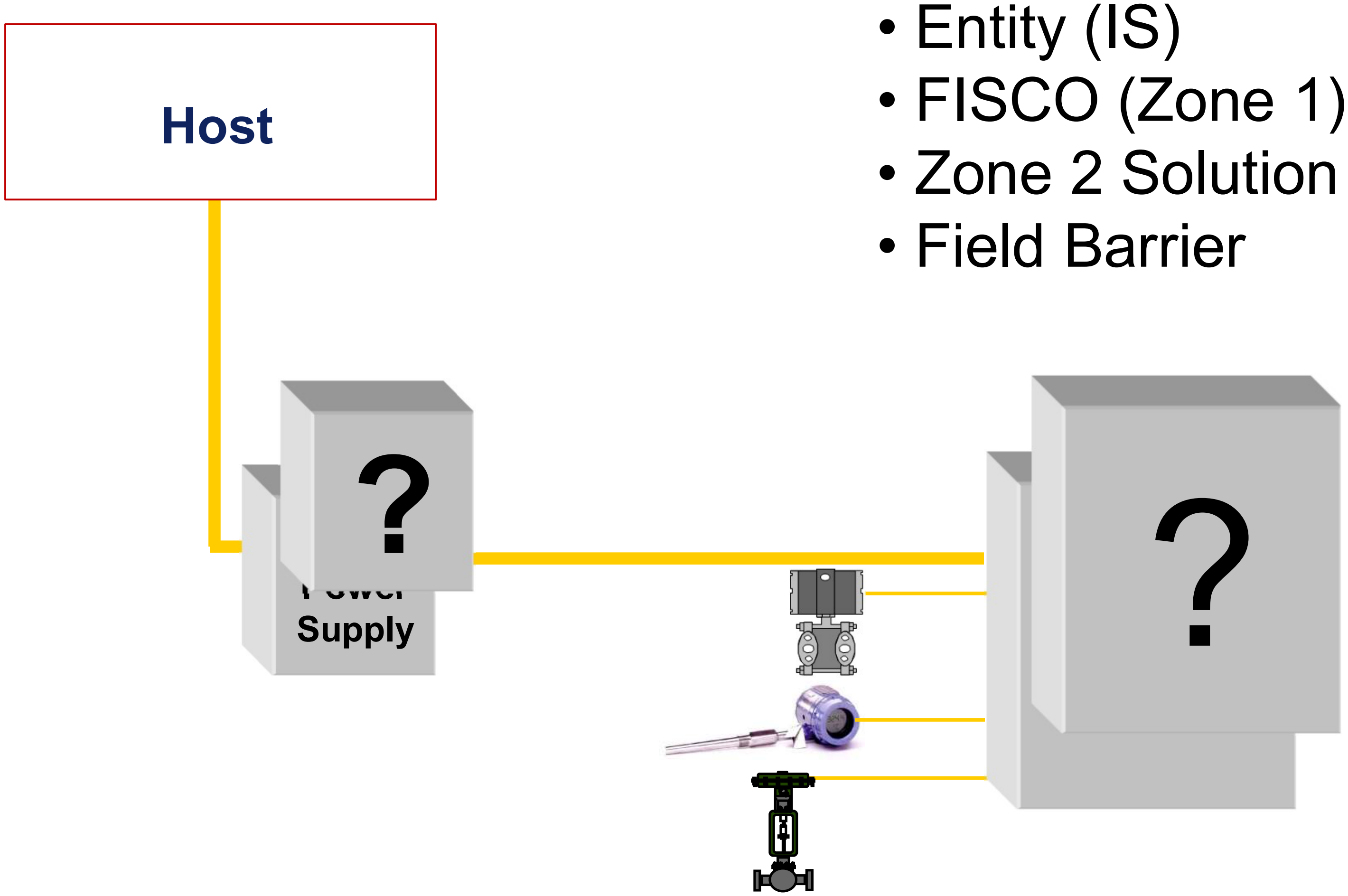
Foundation Fieldbus Network Components

- **Terminator**
  - ***R-C circuit***
  - ***impedance matching module***
  - ***to prevent distortion & signal loss due to reflection at the ends of fieldbus cable***
  - ***for voltage mode signal on the segment***
  - ***capacitor rating determine transmission speed (eg. H1= 31.25 kbit/s)***



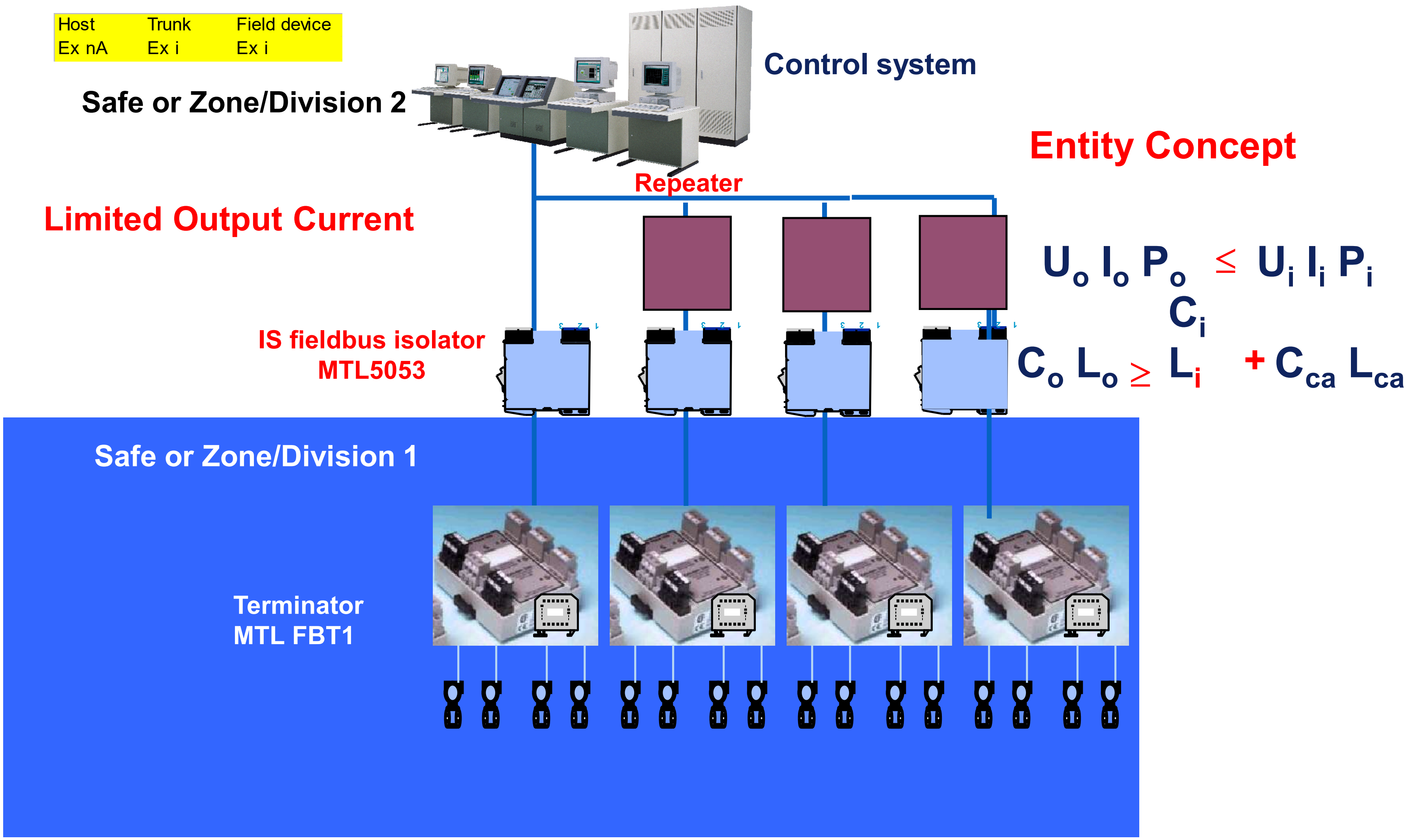
Segment Power Considerations

- Non-IS Application (Safe)
- Intrinsic Safety Models
  - Entity (IS)
  - FISCO (Zone 1)
  - Zone 2 Solution
  - Field Barrier



Conventional Approach
(Entity Concept)

Intrinsically safe protection



Intrinsic Safety - Conventional Approach (Entity Model)

Recommended I.S. parameters (F.F.)

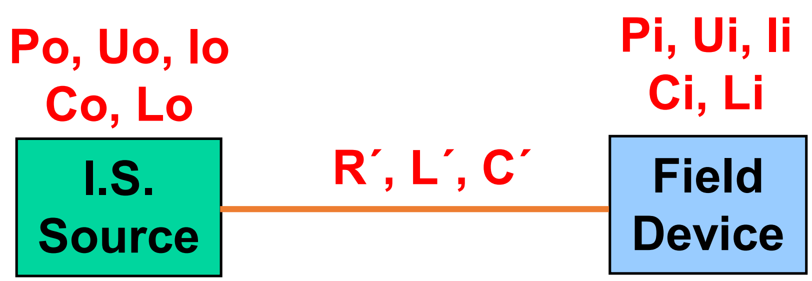
Fieldbus I.S power sources

Parameter	Value
Location of hazardous area apparatus	Zone 0 (US Div. 1)
Gas group	IIC (US Groups A & B)
Open circuit output voltage	24 V max
Short circuit output current	250 mA max
Matched output power	1.2 W max

Hazardous area devices

Parameter	Value
Device approval voltage	24 V min
Device approval current	250 mA min
Device input power	1.2 W min
Device residual capacitance	< 5nF
Device residual inductance	< 20μH
I.S classification	Ex ia, IIC (gas groups A & B), T4

Intrinsic Safety - Conventional Approach (Entity Model)



C	= Capacitance
L	= Inductance
R	= Resistance
I	= Current
U	= Voltage
P	= Power

- Selection of required field devices
- Selection of suitable power supply
- Record I.S. parameters of all devices
- Compliance check = Uo < Ui, Io < Ii, Po < Pi ... For each device

  Uo (max. Open circuit output), Io (max short circuit output), Po (max output), Ui, Ii and Pi (max input)
- Evaluation of network capacitance and inductance = Ci+Ccable < Co, Li+Lcable < Lo
- Calculation of maximum cable parameters = Ccable < Co - Ci, Lcable < Lo - Li

Example of a System Safety Analysis

Example of a system safety analysis

Associated Apparatus (Safe Area)

Man	Type Ref.	Certn. Auth.	Cert. No.	Certn. Cat.	Gas Group
ABC Ltd	B791	BAS	BAS27	ia	IIC

Uo (Voc)	Io (Isc)	Po (Pm)	Co (Ca)	Lo (La)	Lo/Ro (L/R)
22.0V	214 mA	1.19 W	165 nF (IIC) 1.14mF (IIB)	0.35 mH (IIC) 1.04 mH (IIB)	31 mH/ (IIC) 93 mH/ (IIB)

Hazardous Area

Man	Type Ref.	Certn. Auth.	Cert. No.	Certn. Cat.	Gas Group	Temp. Class	Ui (Vmax)	Ii (Imax)	Pi (Pmax)	Ci	Li
ABC Ltd	FBT1	BAS	BAS45	ia	IIC	T4 at 60°C Amb	30.0V	300 mA	1.2W	0	0
DE Inc	DP 04	LCIE	L9506	ia	IIC	T4 at 60°C Amb	25.0V	300 mA	1.2W	2 nF	10 µH
FGH GmbH	TT9	PTB	PTB92	ia	IIC	T4 at 60°C Amb	24.0V	350 mA	1.6W	5 nF	10 µH
JJ inc	IP956	PTB	PTB97	ia	IIC	T4 at 60°C Amb	24.0V	300 mA	1.2W	5 nF	20 µH
KL Ltd	Valve type 7P	BAS	BAS72	ia	IIC	T4 at 60°C Amb	25.0V	250 mA	1.2W	3 nF	10 µH

Complete System

Certn. Auth.	Cert. No.	Certn. Cat.	Gas Group	Temp. Class	Uo (Voc)	Io (Isc)	Po (Pm)	Max C for cable	Max L for cable or	Max L/R for cable
		ia	IIC	T4 at 60oC Amb	22.0V	214 mA	1.19 W	150 nF (IIC) 1.12 mF (IIB)	0.30 mH (IIC) 0.99 mH (IIB)	31 mH/ (IIC) 93 mH (IIB)/

Entity Drawback

Summary:

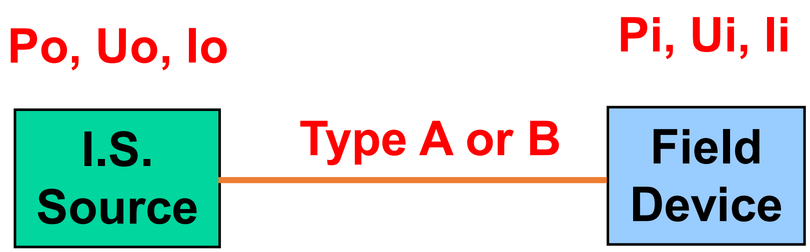
- Since max. current available was around 80 mA, number of field instruments was around 3 or 4
- IS calculations are required on initial design and when adding or removing a device.

FISCO Approach

What is FISCO

- Fieldbus Intrinsically Safe Concept
  - Research project undertaken by PTB in the early 1990’s
  - Determined that cable capacitance and inductance is distributed in the throughout the system wiring.
    - Does not appear at one point
  - Also that Ci and Li of Field devices can be ignored if:
    - Ci is equal to or less than 5nF
    - Li is equal to or less than 10uH

FISCO Based Procedure

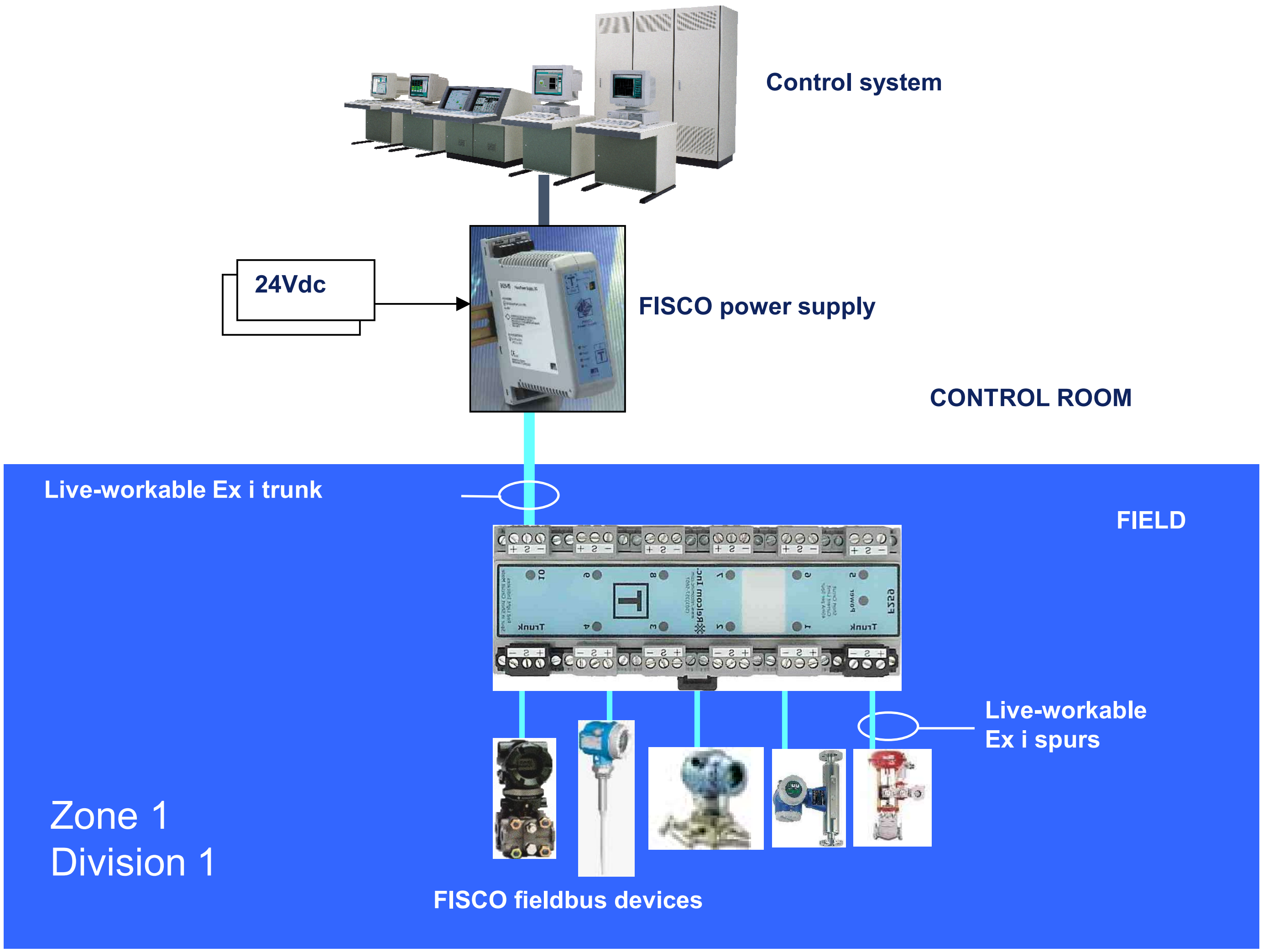


- Selection of FISCO approved devices
- Selection of FISCO approved segment power supply
- Compliance check:
  Uo < Ui, Io < Ii, Po < Pi ... for each device
- The bus cable must have the following values:
  - R´= 15 ... 150 W /km (resistance)
  - L´= 0.4 ... 1 mH/km
  - C´= 80 ... 200 nF/km including shield
- No calculation of C and L values for segment or cable required

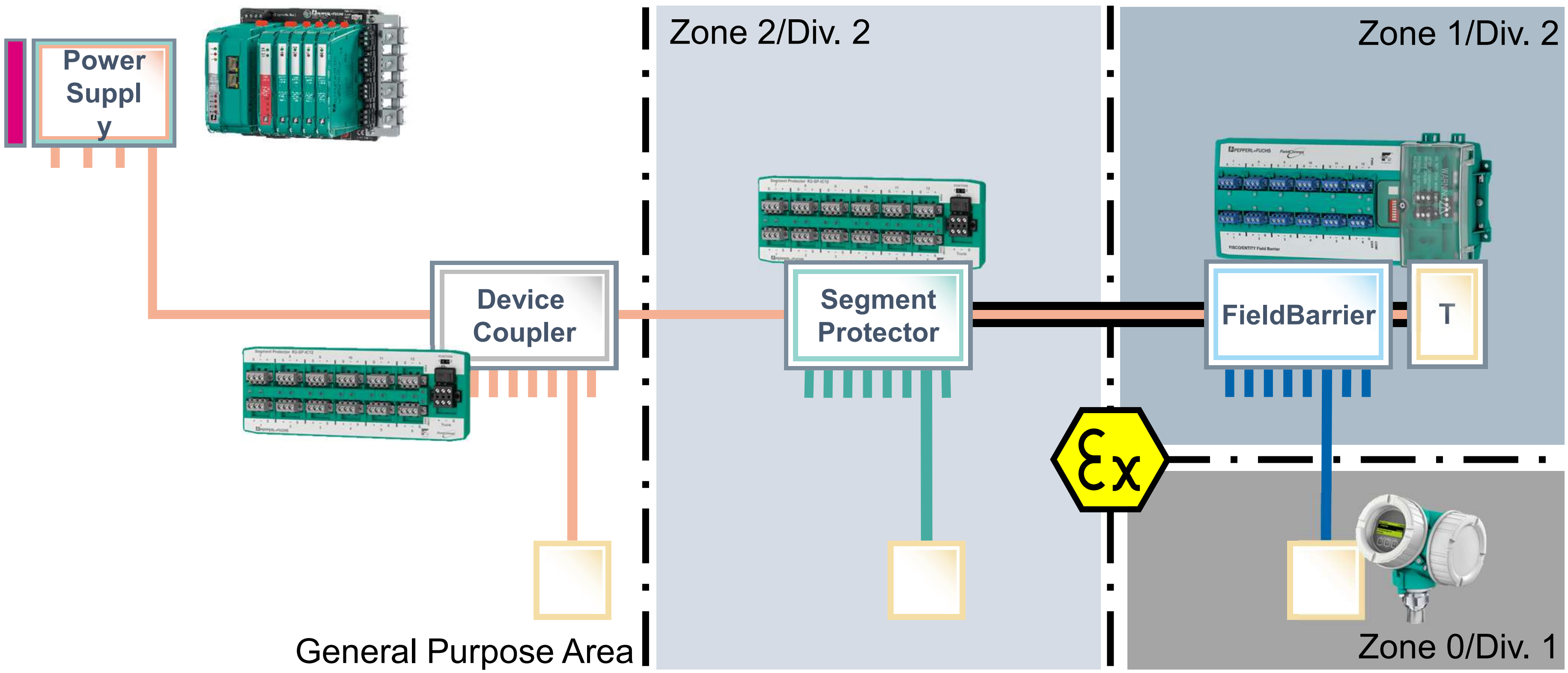
FISCO Cable Parameters

- Cable parameters
  - Loop resistance 15 to 150 ohms / km
  - Inductance per unit length 0.4 to 1mH / km
  - Capacitance per unit length 80 to 200nF
- Length of cable
  - Trunk up to 1000 m
  - Spur up to 60m
  - Splice up to 1m

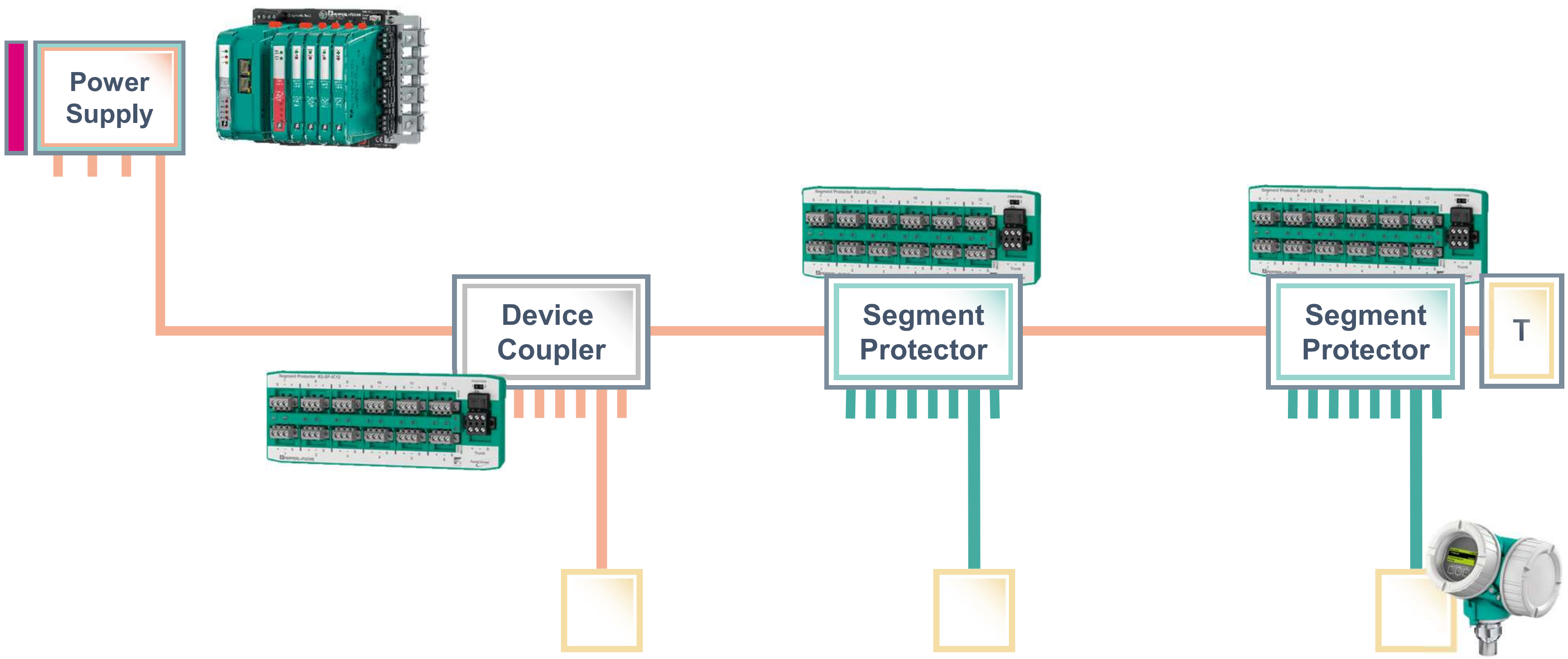
FISCO installation for Zone 1 and Division 1



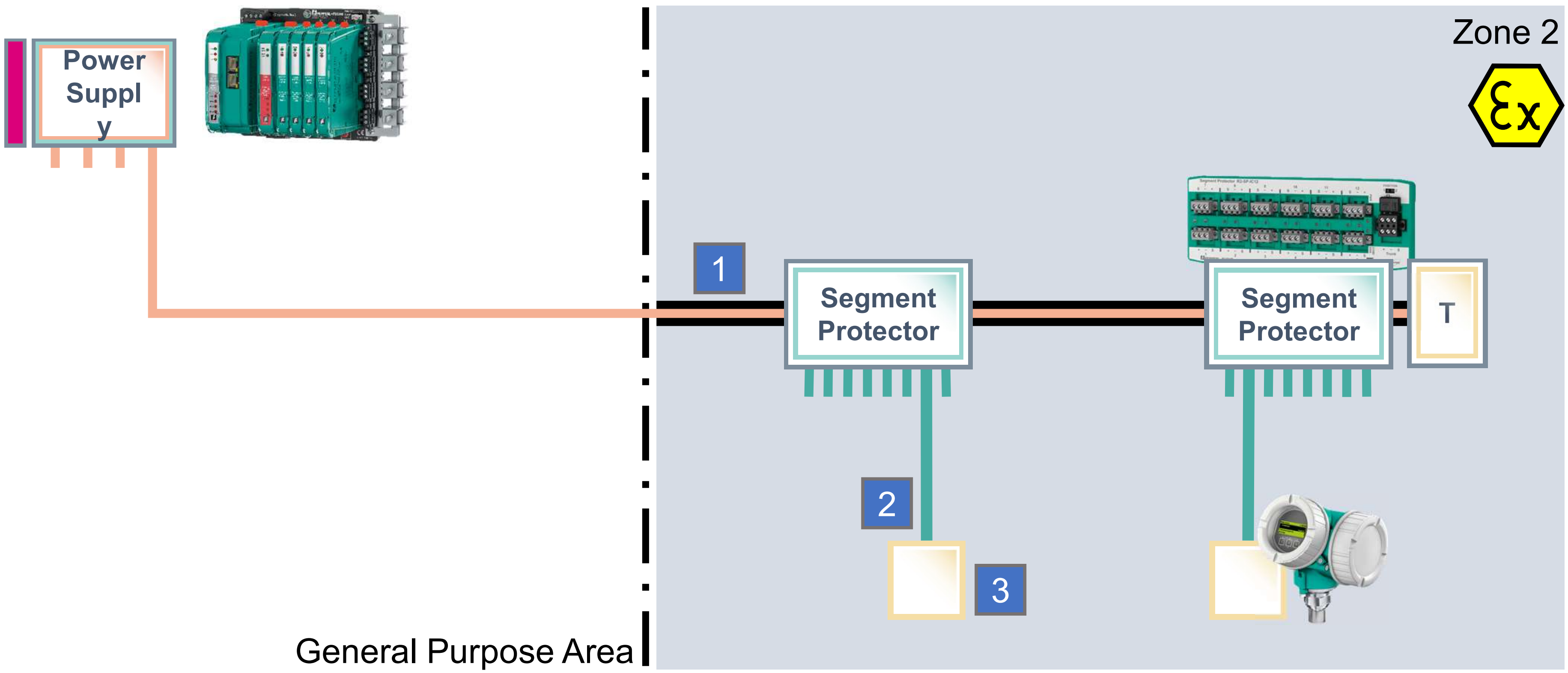
Areas for Fieldbus Installations



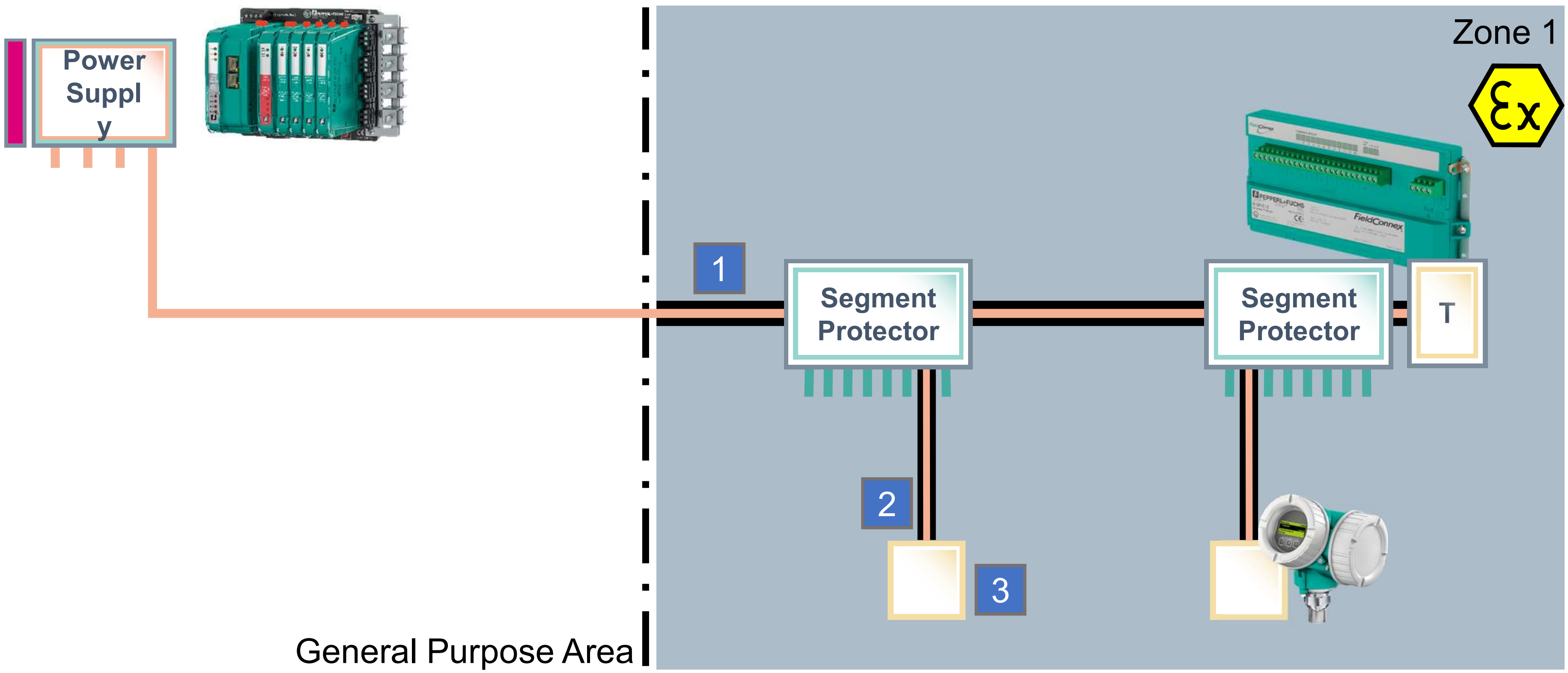
General Purpose Process Plant



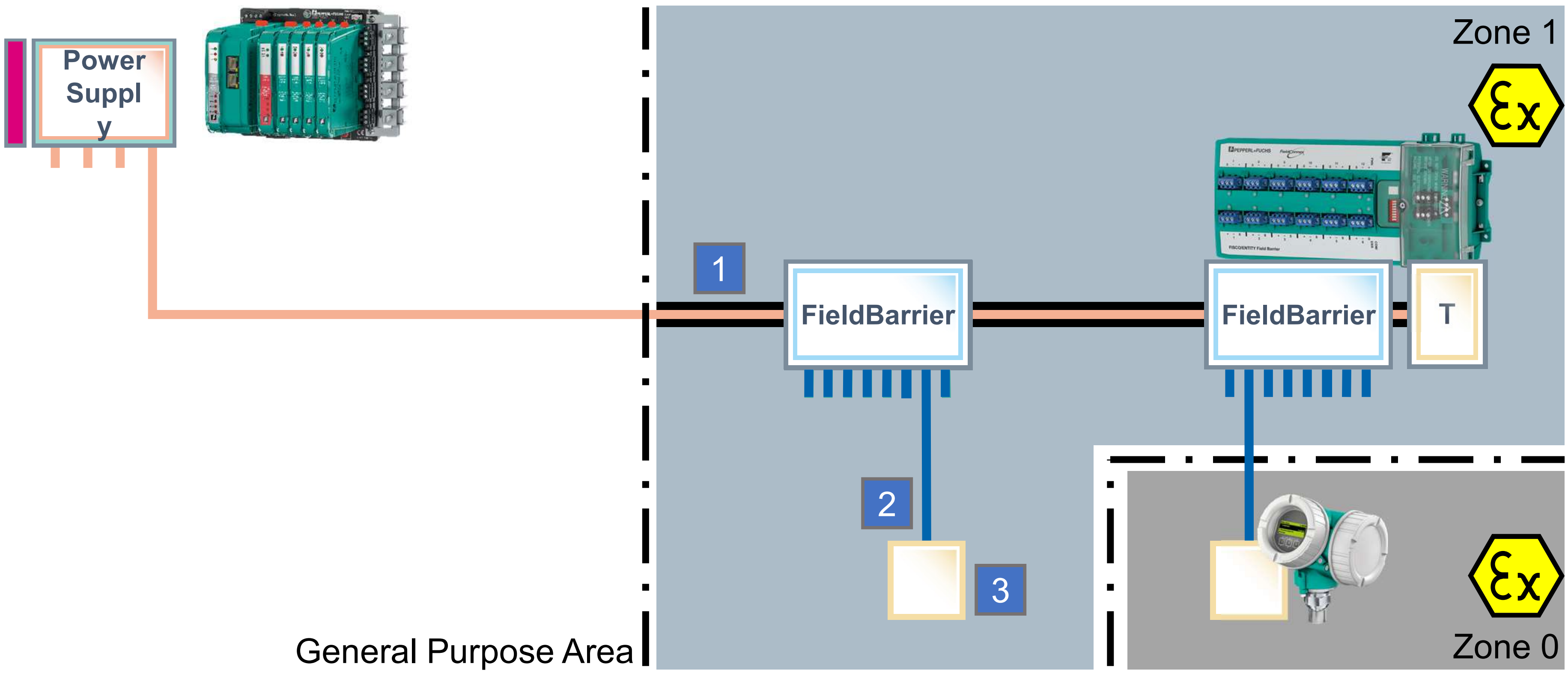
Spurs Ex ic / Zone2



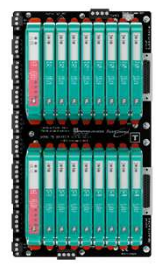
Spurs mechanically protected / Zone 1



FieldBarrier Zone 1 / Instruments Zone 0...1



Power Supplies and Segment Couplers



FieldBarrier and Segment Protector

Fieldbus Device Commissioning and Maintenance Tools

Basic life support: bus powered
>9V 3, signal 3, polarity 3

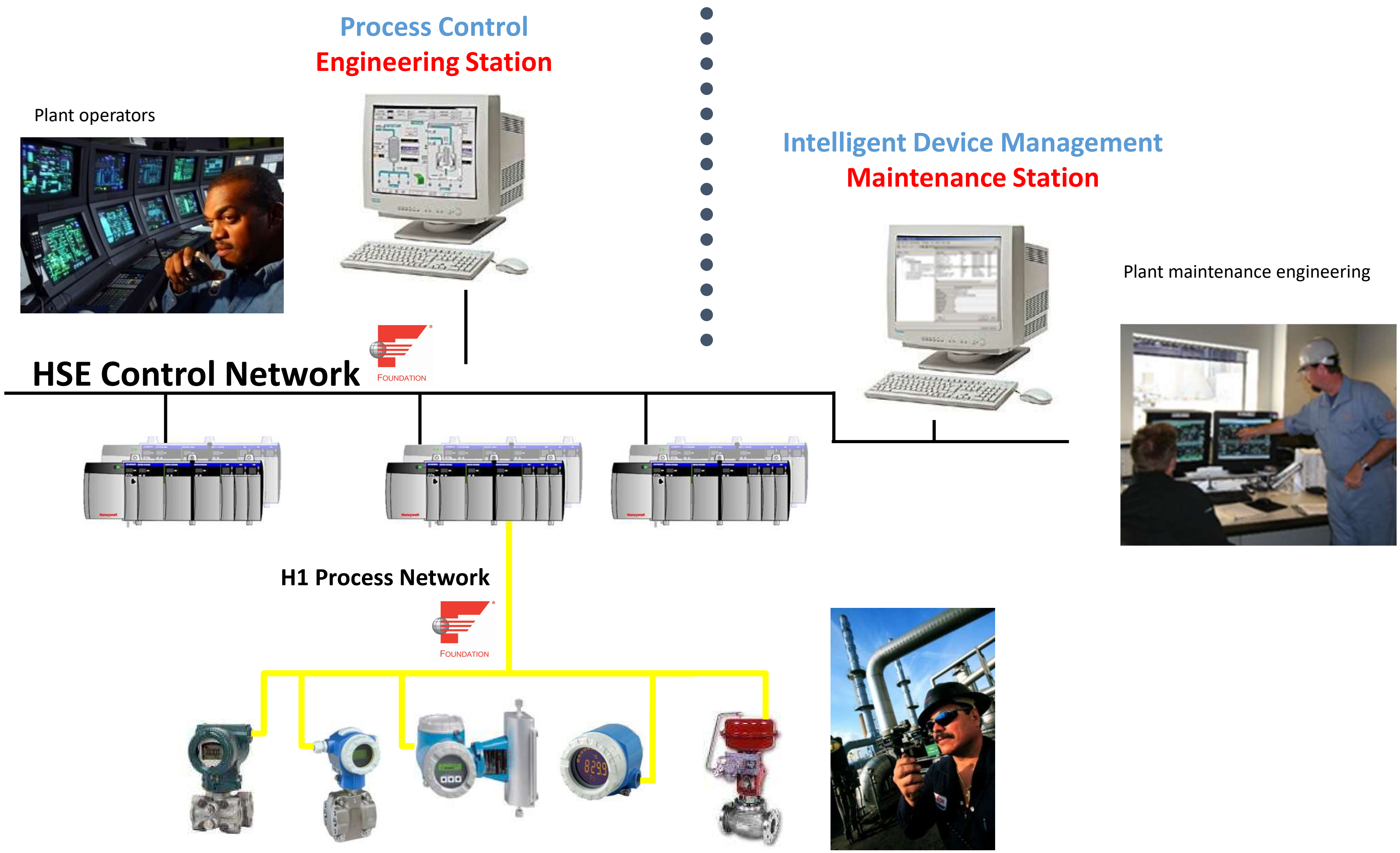
Signal generator for wire testing

Fieldbus monitor: bus powered
measures: DC volts, signal, noise
device count, new device
communication errors

CAPEX Benefits of Foundation Fieldbus

- Control room space, and installation costs such as wiring cost
- Construction & engineering costs
- Startup & commissioning costs

Role Based Diagnostics



The Promise of Bus Technologies:
- Intelligent Device Management

Live Device Data

- Monitoring
  - Identification
  - Information
- Diagnostics
- Configuration/Setup
  - Parameterization
  - Range
  - Calibration Trim
  - Simulation & Override
  - Device Security

Accessing Information

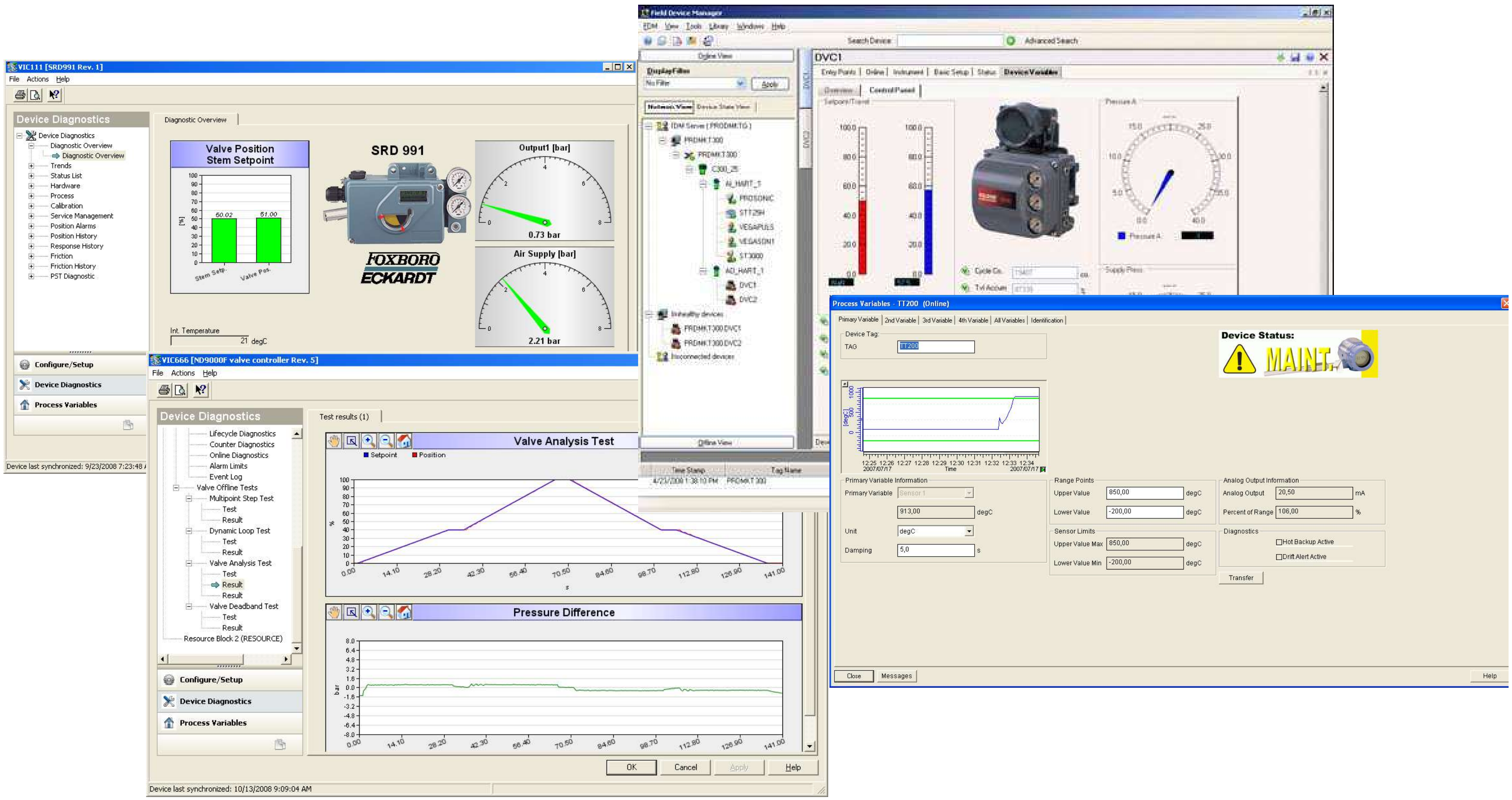
Database

- Service Notes
- Audit Trail and Reporting
  - Configuration changes
  - Maintenance
- Device List
- Calibration Scheduling
- Documentation
- Maintenance Log Entry
  - Calibration
  - Inspection/service

EDDL™

EDDL and Field Diagnostics

- EDDL visualizes device diagnostics to assist in maintenance troubleshooting.

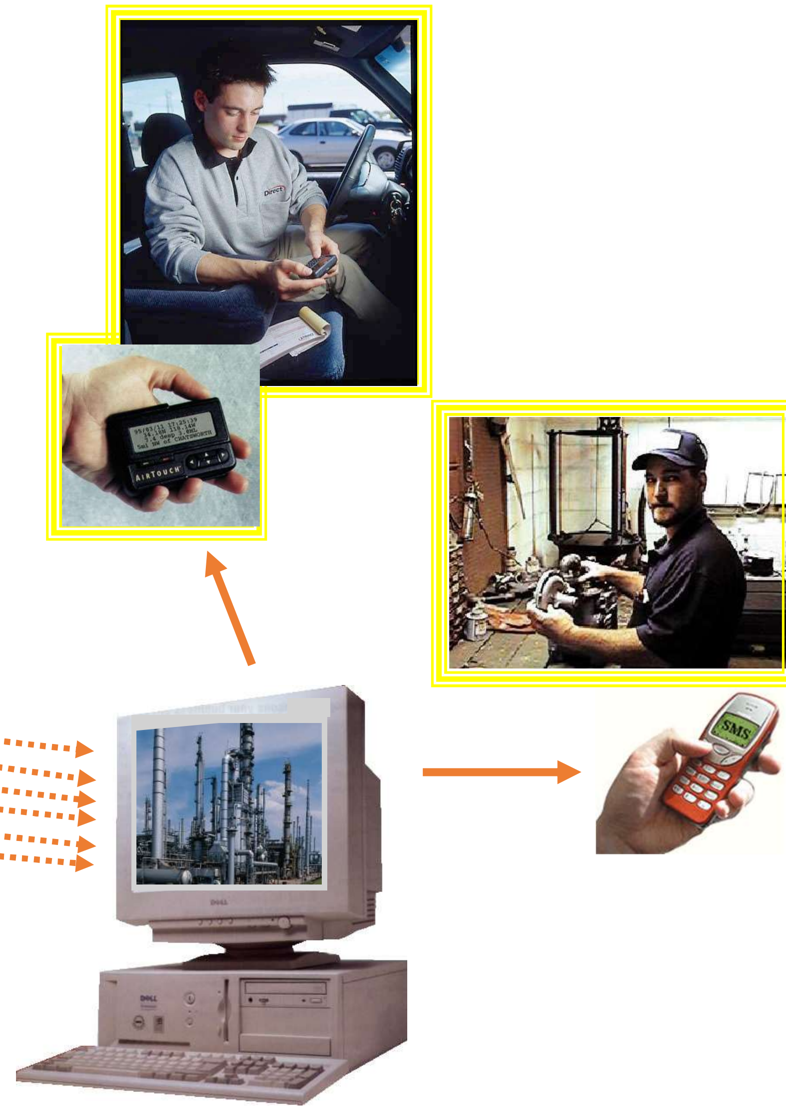


Traditional Maintenance Route

- Every month the routine is repeated
- Check transmitters, <u>listen</u> to rotating equipment

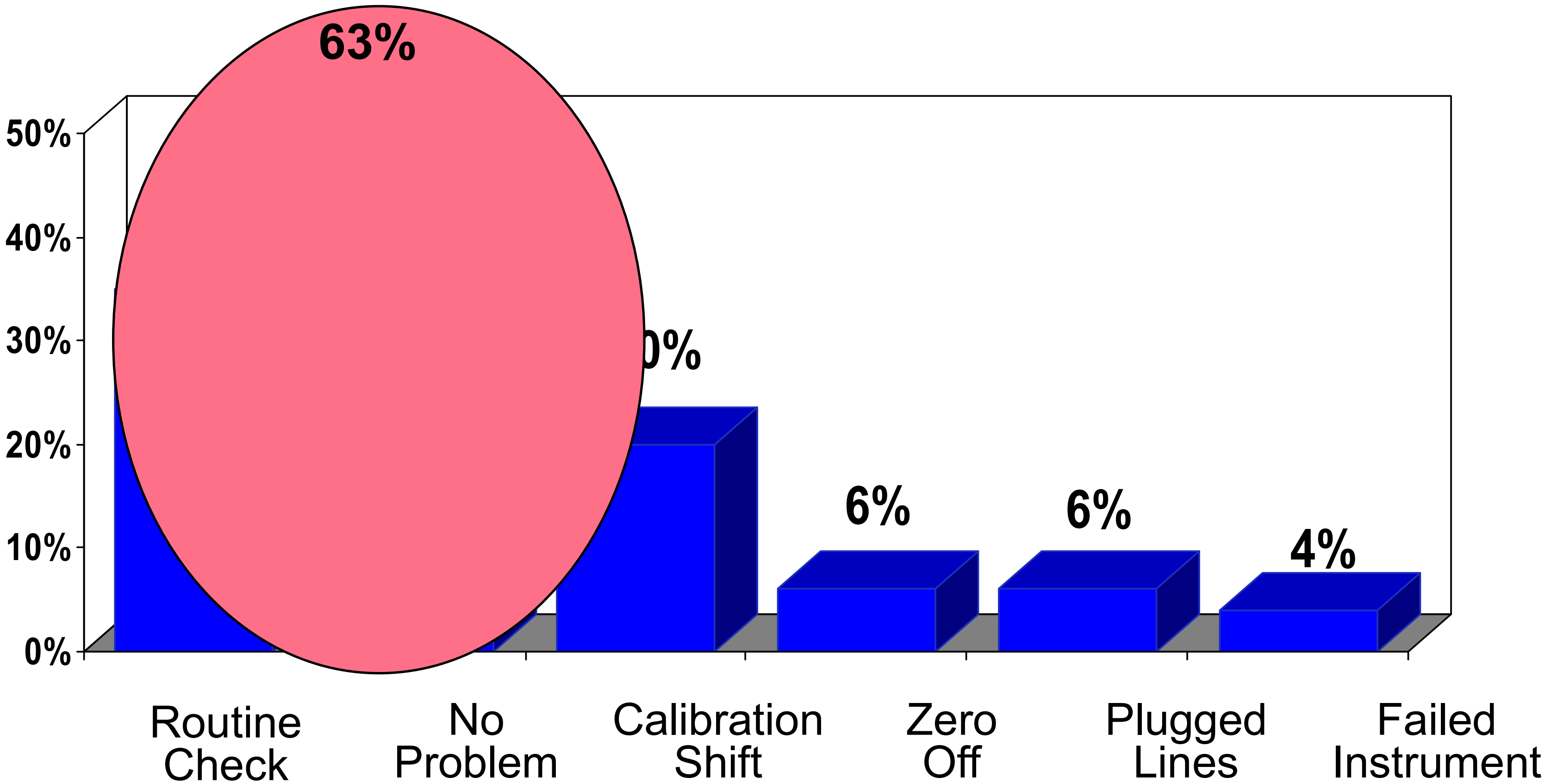
BEFORE

Eyes Into Your Plant
- Proactive/Predictive Plants



Changing Plant Work Practices!

“Unneeded” Trips To The Field - Avoided Through Remote Diagnostics



Source: Dow Chemical Company

The Opportunity

- Improved plant stability and reliability
- Improved asset utilization
- Reduced operating and maintenance fixed cost
- Improved Variable Cost

Savings- End User Survey

- Did FOUNDATION deliver CAPEX savings? Yes
- Savings in engineering & design…………….50%
- No additional cost in documentation……….85%
- Savings due to reduced footprint…………..77%
- Achieved return on investment in *less than two years*……………………………………….75%

- Did FOUNDATION deliver OPEX savings? Yes
- Enhanced device diagnostics……………….90%
- *Tighter control of the process*……………….60%
- *Enhanced effectiveness of system*…………61%
- *Increased system availability*……………….59%
- *Enhanced operator effectiveness*…………..85%
- Ease of device replacement…………………85%

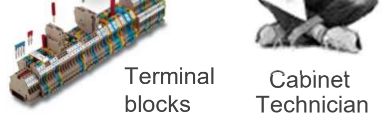
Source Automation Research Corporation

Savings -Engineering Contractor Survey

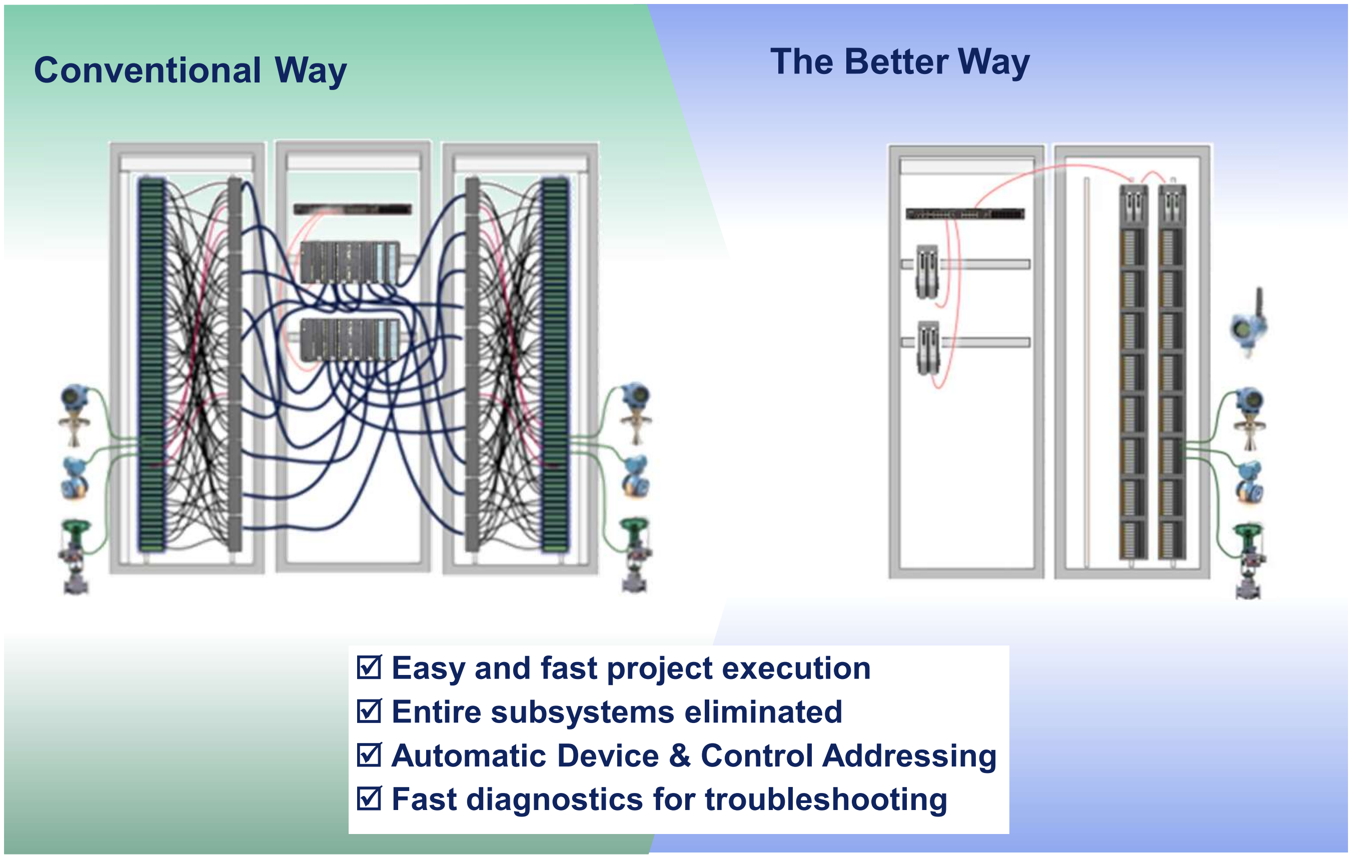
- 90% perceive FOUNDATION fieldbus as leading technology
- 84% believe CAPEX costs are equal to or lower than conventional I/O
- 91% believe FOUNDATION technology delivers OPEX savings
  - Easier maintenance 67%
  - Increased availability 63%
  - Increased efficiency 28%
  - Improved product quality 20%
  - Situation prevention 20%
  - MES connectivity 15%

Source: survey of Engineering Contractors in London, 2007
54 respondents

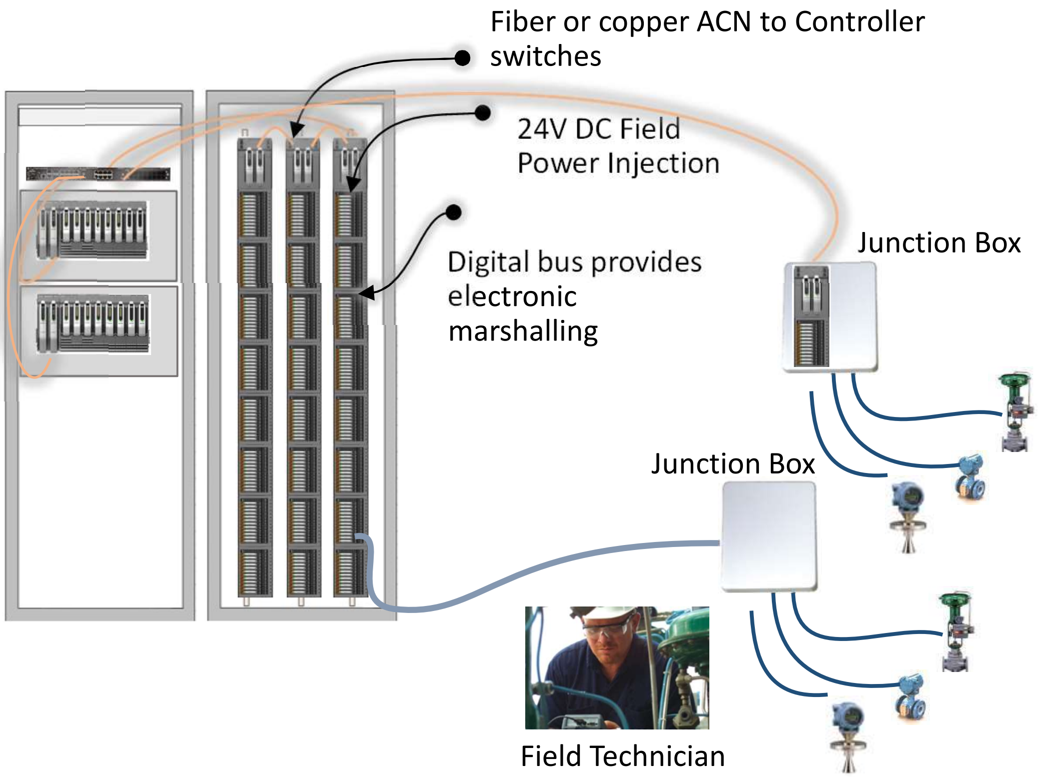
Traditional Practice – Classic I/O



- The challenge of conventional practice
  - Inflexible to change
  - Many components, cabinets and wiring
  - Lots of documentation


Conventional Way
The Better Way
☑ Easy and fast project execution
☑ Entire subsystems eliminated
☑ Automatic Device & Control Addressing
☑ Fast diagnostics for troubleshooting

Configurable I/O; Smart I/O; Electronic Marshalling



- The advantages of configurable I/O
  - Fewer components – more done via software configuration and electronic selection
  - Fewer cabinets and connections
  - Ethernet based instead of multi-core electrical cables
  - Reduced Documentation
  - Flexible and Easy to changes
  - Concurrent engineering