IEEE-IAS – Atlanta Chapter

Instrumentation & Controls Issues in Industrial Electrical Design

January 19th, 2016

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Project Sales Engineer

PHOENIX CONTACT
INSPIRING INNOVATIONS

Agenda

- Set the Stage
- Analog Signals
  - Surge Protection
  - Signal Conditioning
- Fieldbus Networks

Set the Stage

- **I&C Design Engineer\Manager for 13 years at major consulting firm in the Water/Wastewater Treatment Industry**
  - Developing P&IDs, control system network diagrams, basic panel layouts, instrumentation details, specifications for instruments, control systems and panel components

- **Coordination with other design disciplines**
  - Civil and process groups
  - Electrical – power requirements, network layouts, area classifications,

Agenda

- Set the Stage
- Analog Signals
  - Surge Protection
  - Signal Conditioning
- Fieldbus Networks

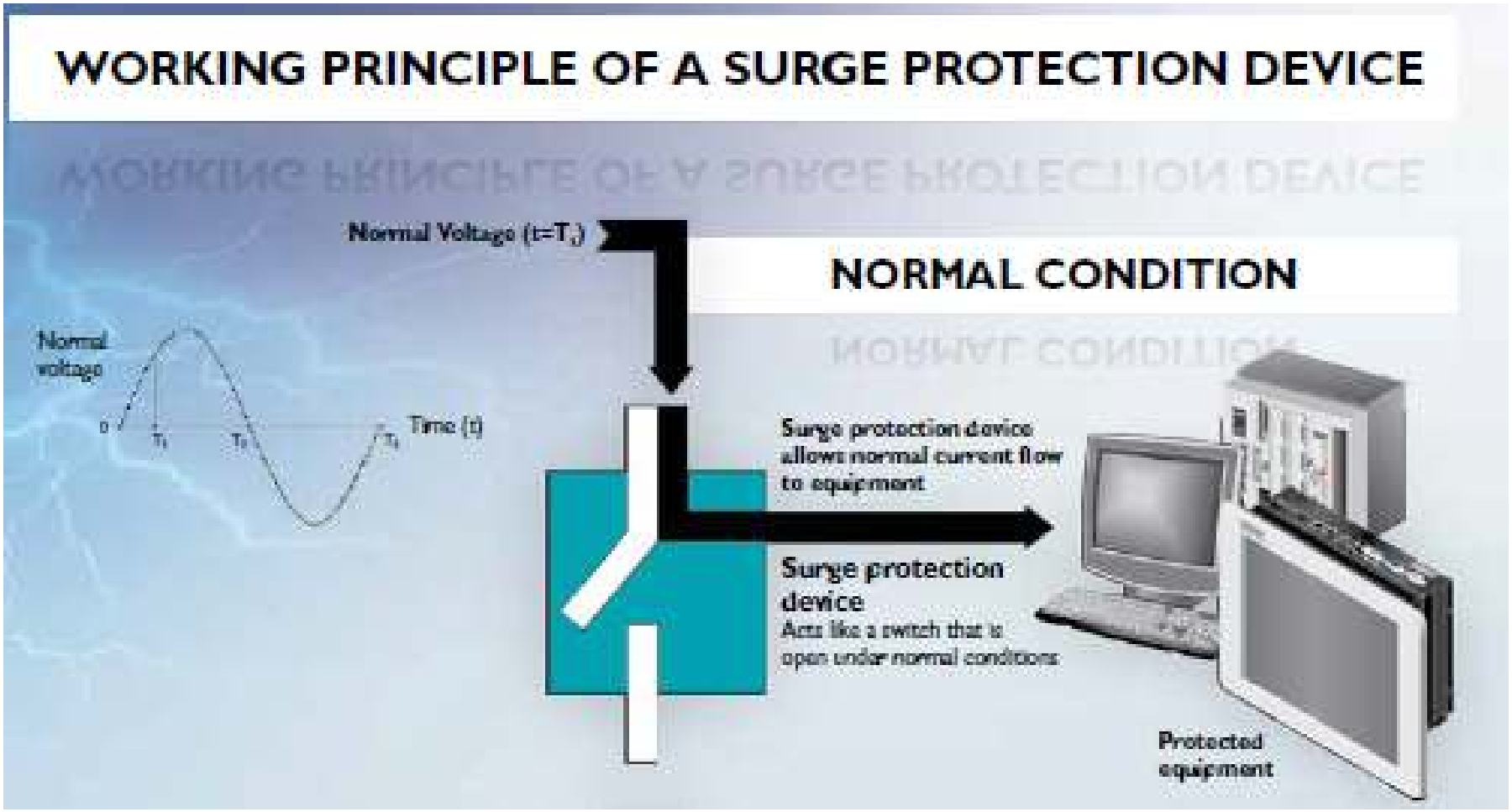
Analog Signals

- Water/Wastewater Industry
  - Pressure, Level, Flow, Temperature
  - Speed, Valve Position/Control
  - Chlorine Residual, Dissolved Oxygen, Nutrients, Suspended Solids, Conductivity, pH
- Analog Signals
  - 4-20 mA DC
  - Loop powered
  - 120 VAC powered devices
- Maintain high availability of signals through surge protection and/or signal conditioning

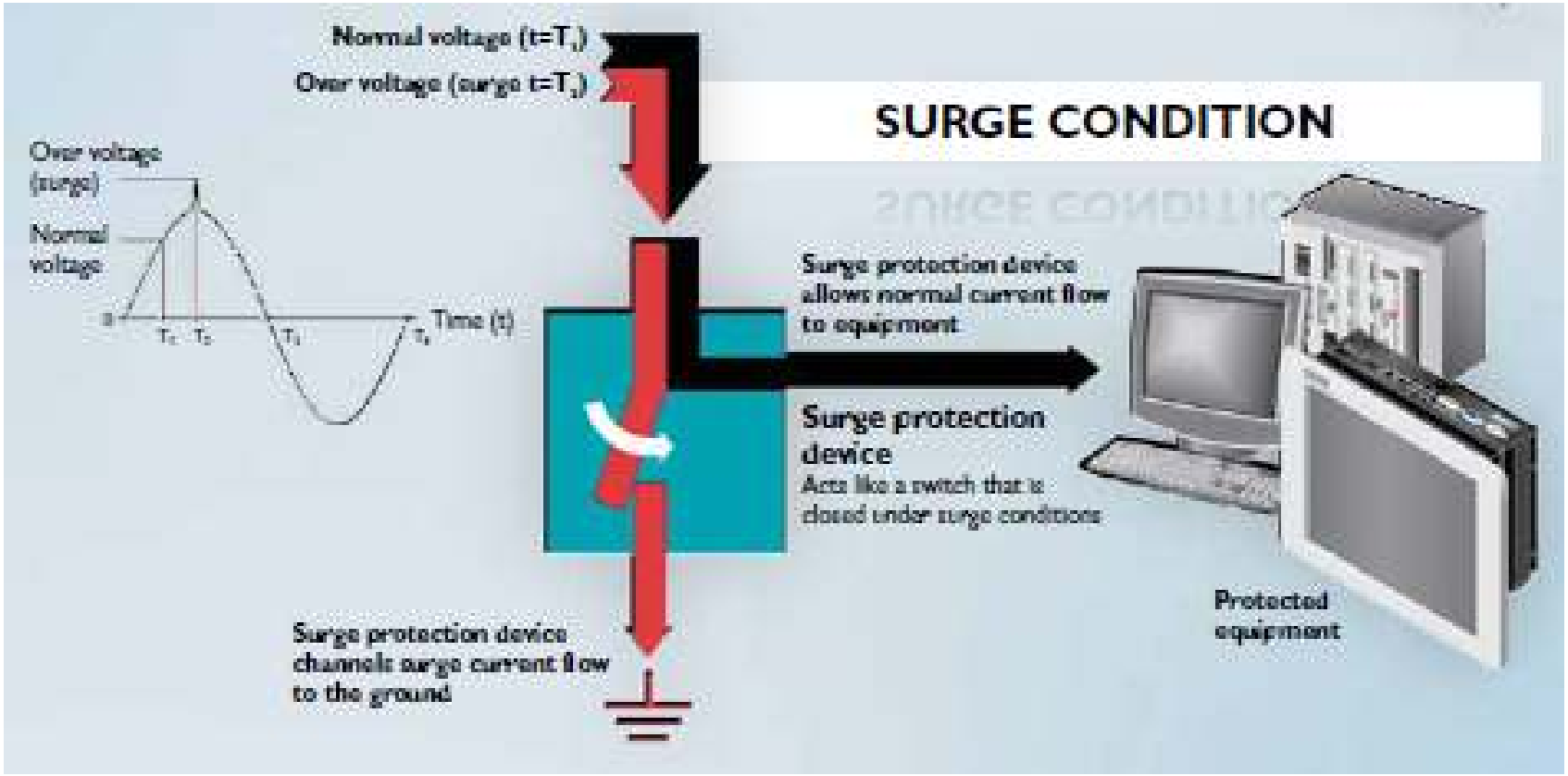
What is Surge Protection?

- Function of Surge Protective Device (SPD) is to divert transient voltage and current away from sensitive equipment, without interruption of the normal circuit operation.

What is Surge Protection?



What is Surge Protection?



Why Surge Protection?

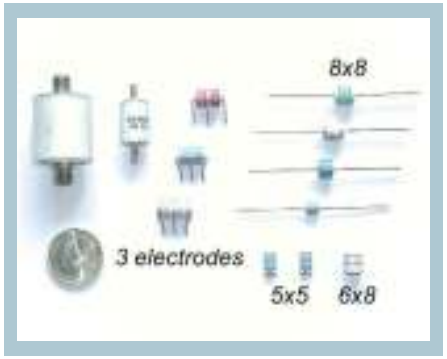
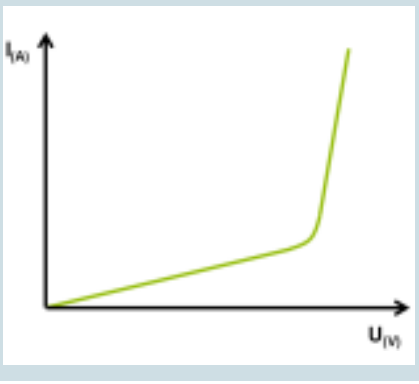
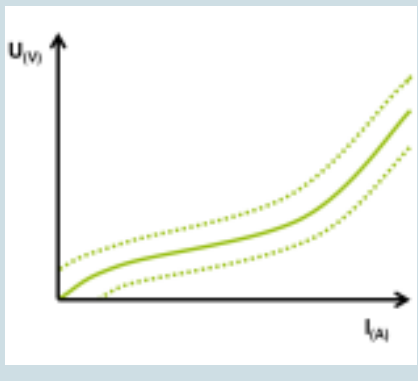
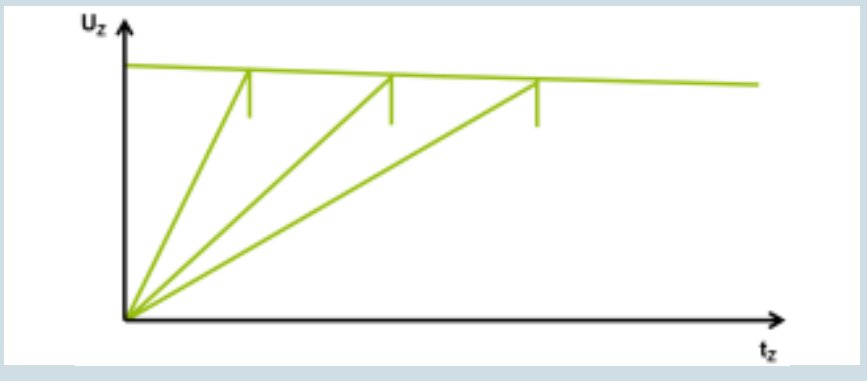
Source of disturbances

LEMP	SEMP	ESD
		
Lightning **E**lectro**m**agnetic **P**ulse	**S**witching **E**lectro**m**agnetic **P**ulse	**E**lectrostatic **D**ischarge
Extremely high surge voltages	Switching of high-capacity machines	Discharge between bodies
Occur only rare as compared to other types	Short circuits in the power supply network	Generally not harmful to human beings
	Occurrence of extremely high current changes	

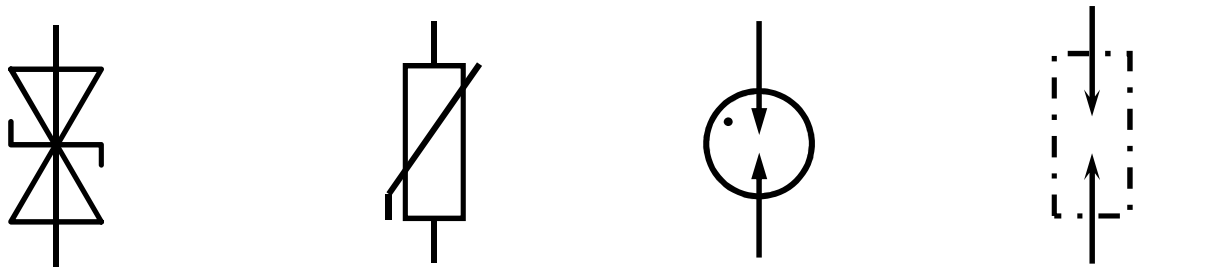
Lessons Learned – Surge Protection

- Proper selection of the surge protective devices
- Detailing where it is required and installation of components
- Understanding shield concepts and detailing shield connections

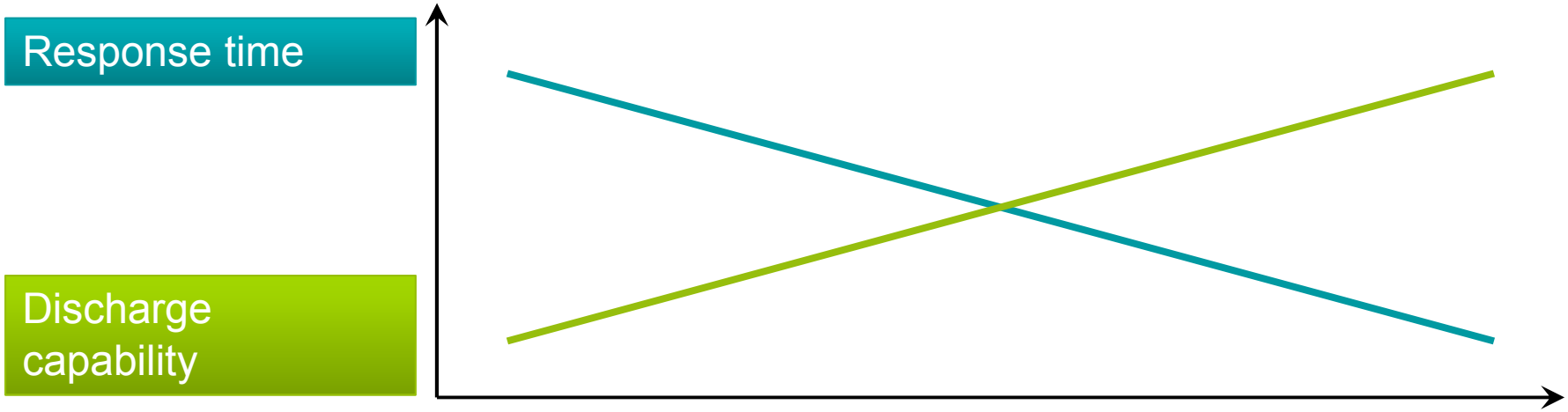
Selecting the Right Surge Protection

Suppressor diode	Varistor	Gas discharge tube (GDT)	Spark gap
			
			
Voltage limiting behaviour		Voltage switching behaviour	

Selecting the Right Surge Protection

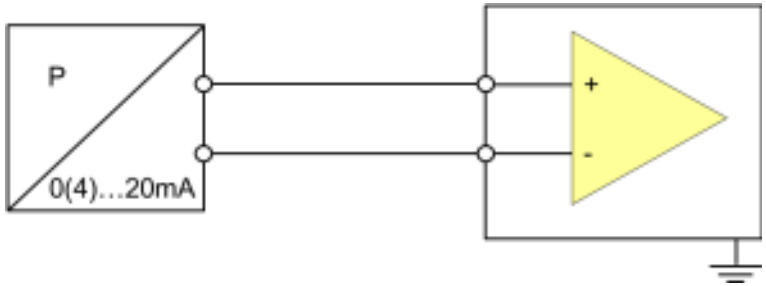


Suppressor diode | Varistor | Gas-discharge tube | Spark gap

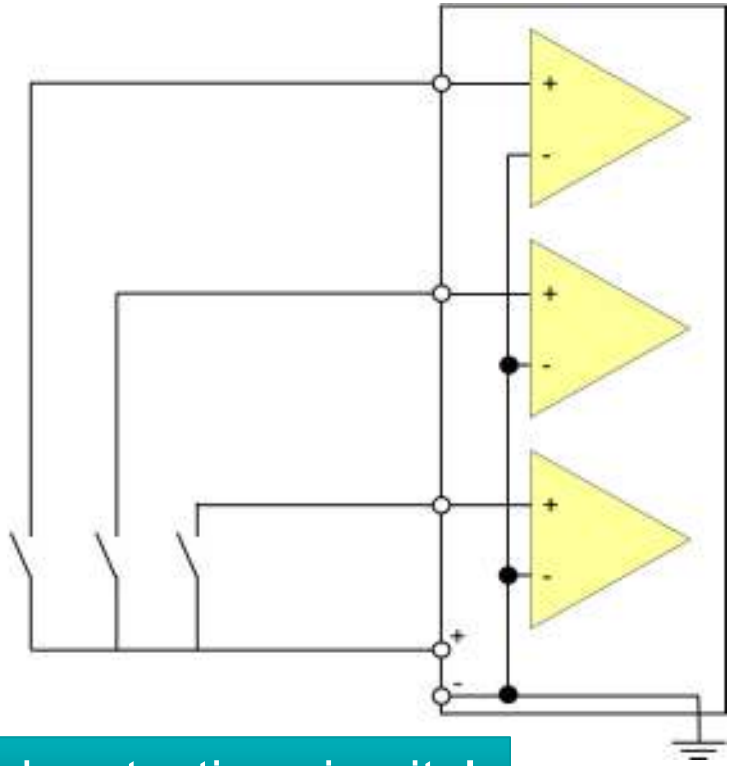


Selecting the Right Surge Protection

Signal loops for Analog-Signals



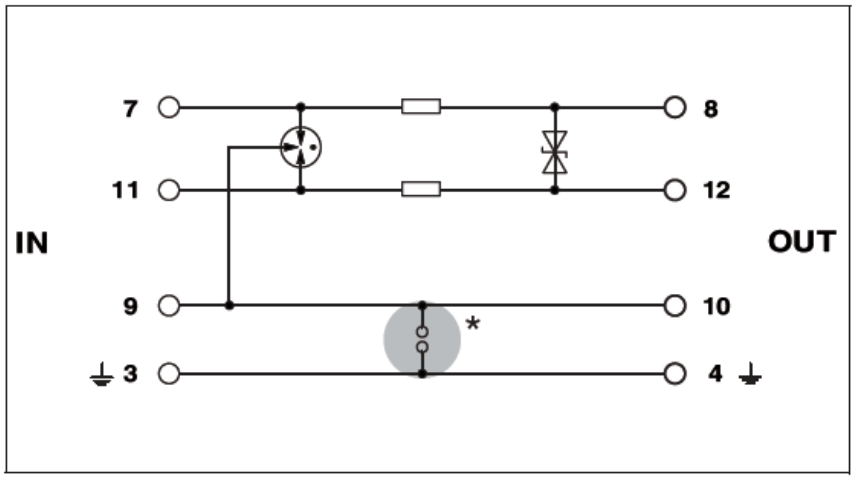
Circuits with common reference for Binary-Signals



Different signal circuits requires adapted protection circuits!

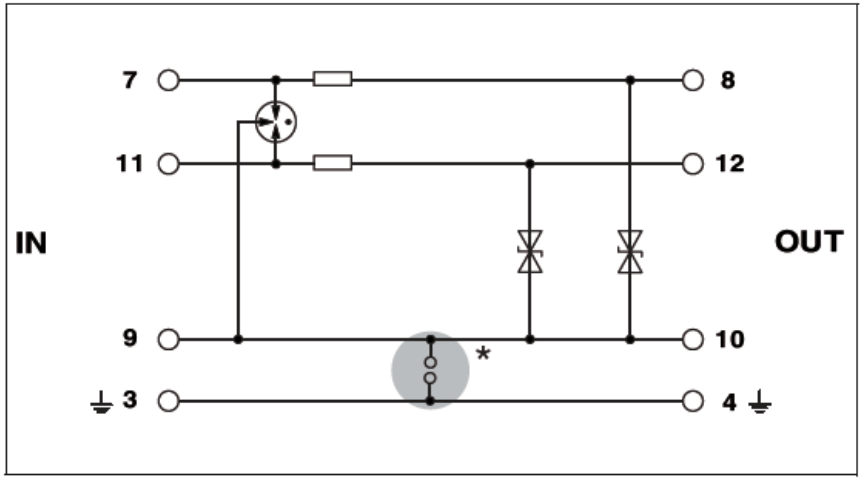
Selecting the Right Surge Protection

isolated



- For isolated circuits
- Low protection level between the lines
- High protection level to ground

grounded



- For grounded circuits or circuits with common reference
- Low protection level to reference (ground)
- Higher protection level between the lines

protection for analog signals

protection for binary signals

Lessons Learned – Surge Protection

- Proper selection of the surge protective devices
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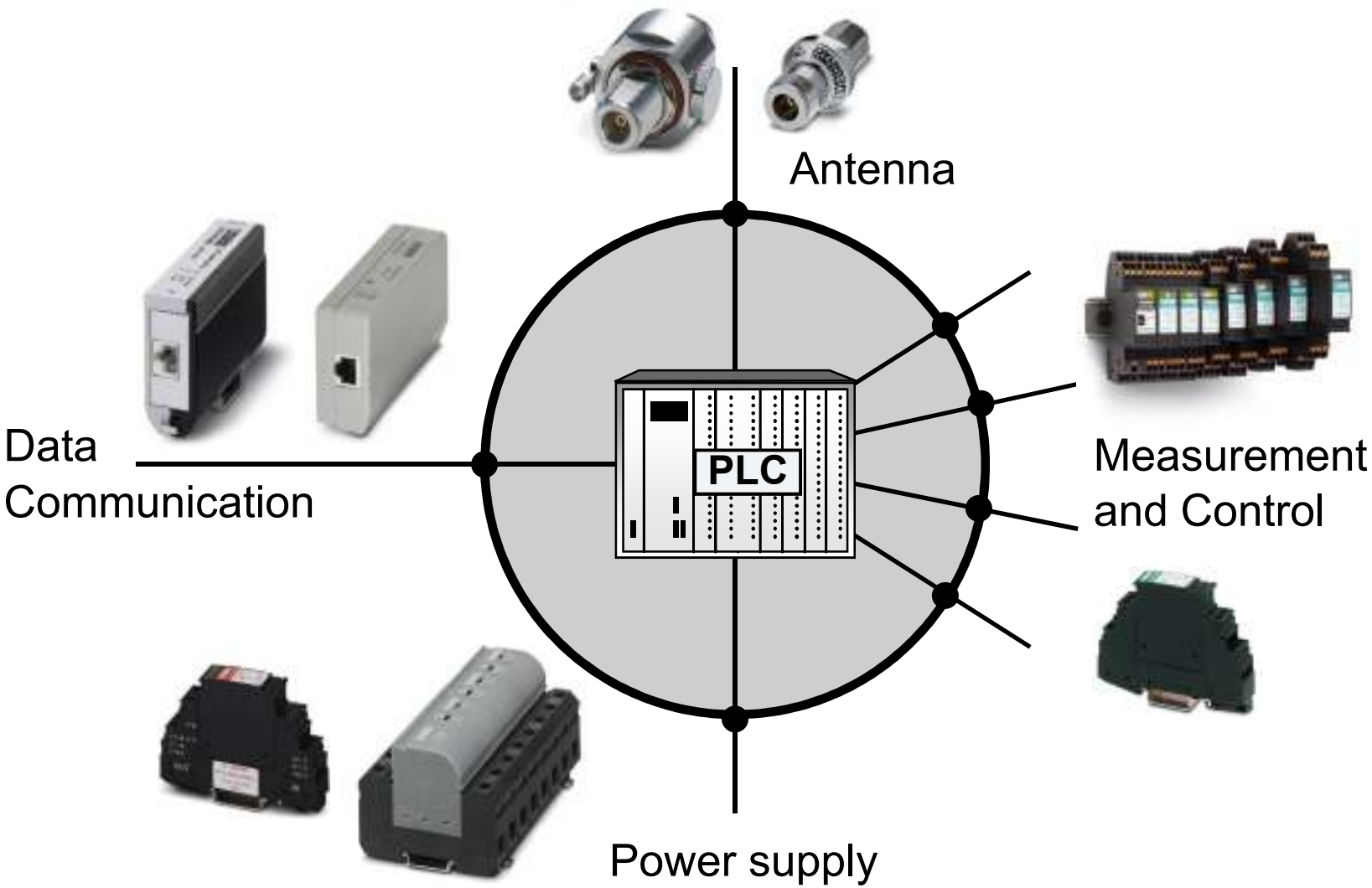
- Understanding shield concepts and detailing shield connections

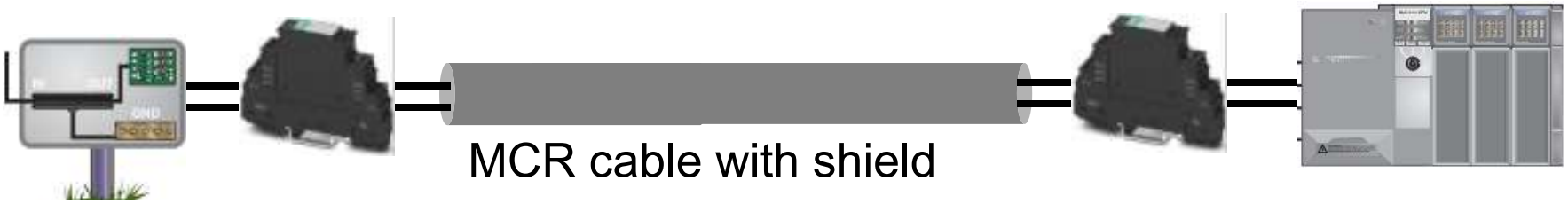
Where to Place Surge Protection



Where to Place Surge Protection

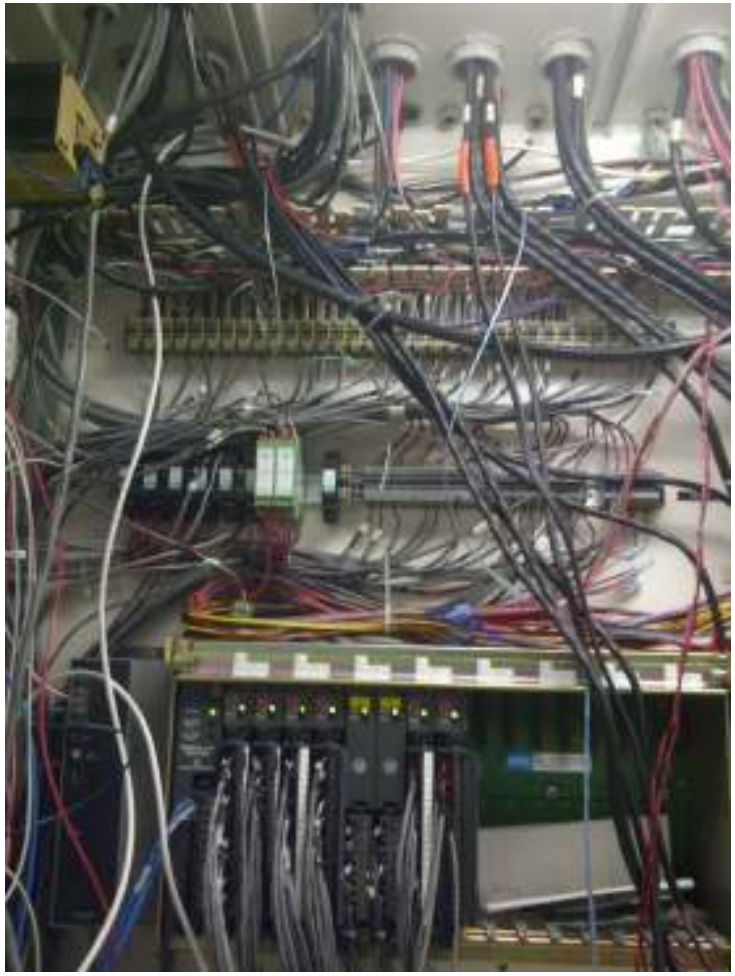
Protected device in the field

Protected device in the control panel



**To protect the complete system,
surge protection on both sides of the cable is necessary!!!**

Wiring is part of a good or bad installation



Lessons Learned – Surge Protection

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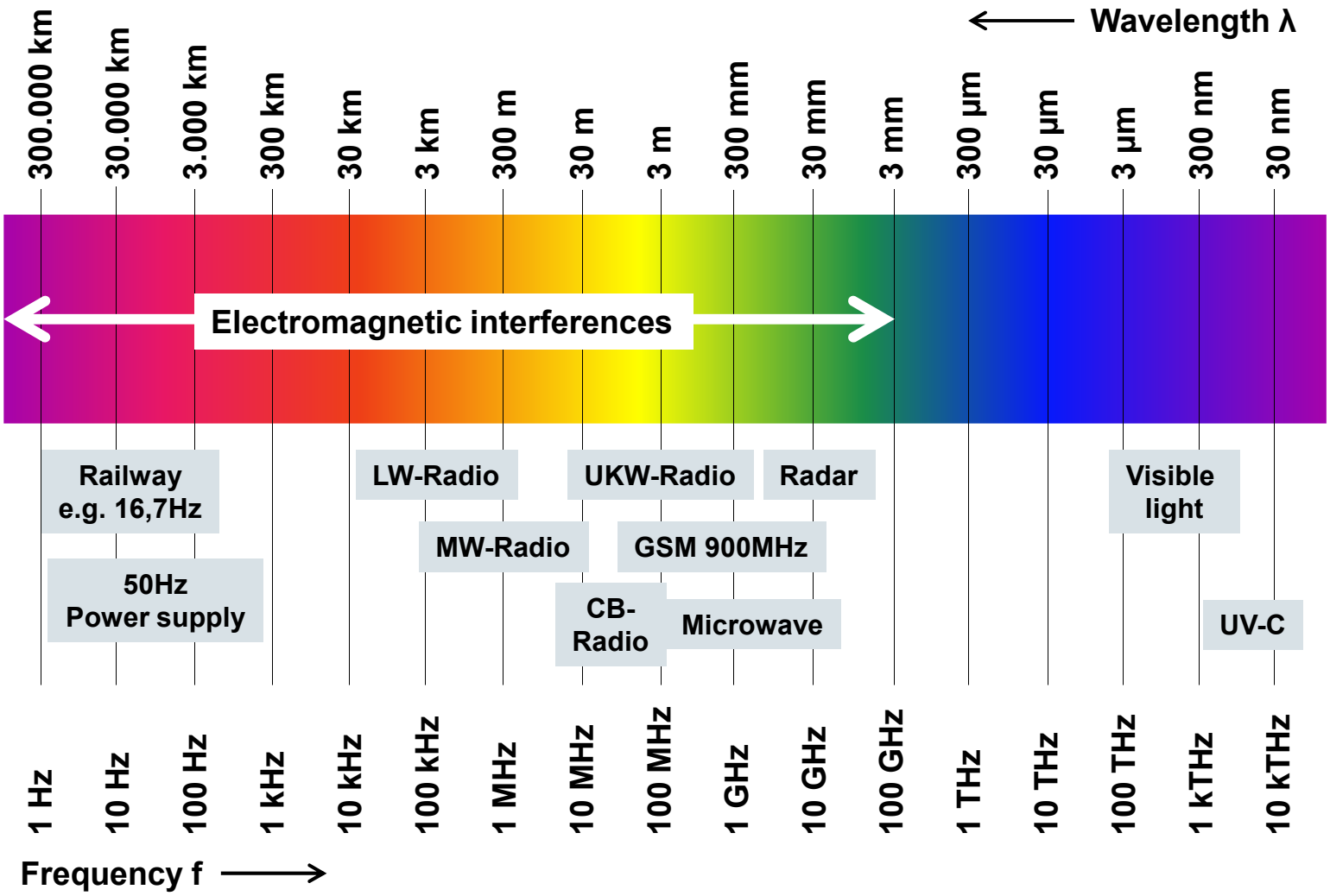
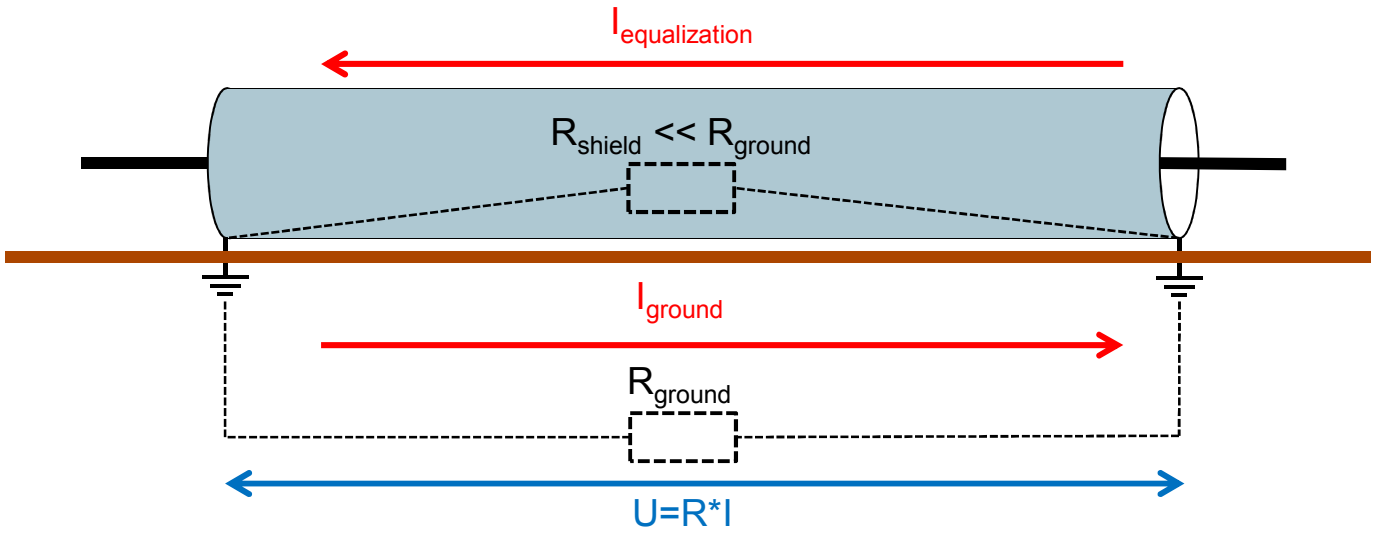
Shielding

Why is a shield needed?



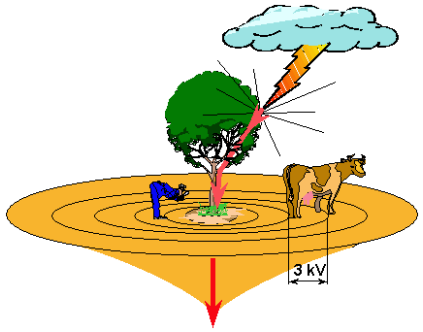
Shielding
Grounding concepts and their behaviour

- Both ends grounded
  - + protection against capacitive coupling
  - + reducing inductive coupling
  - - equalization currents on shield

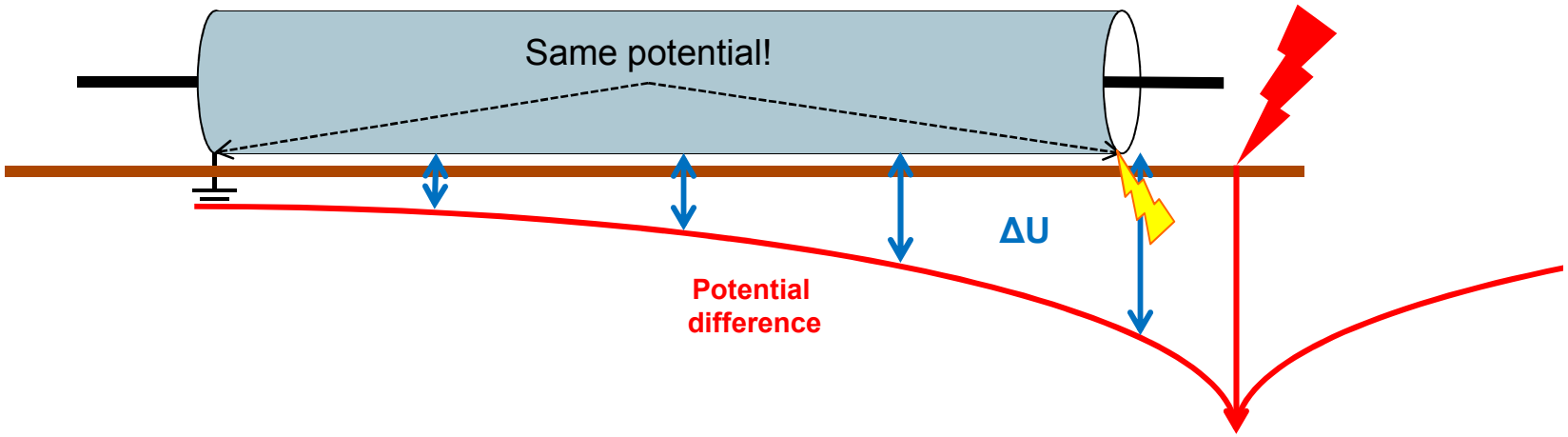


Shielding
Grounding concepts and their behaviour

- One end grounded
  - + protection against capacitive coupling
  - + no equalization currents on shield
  - - not reducing inductive coupling
  - - danger of spark over due lightning impact



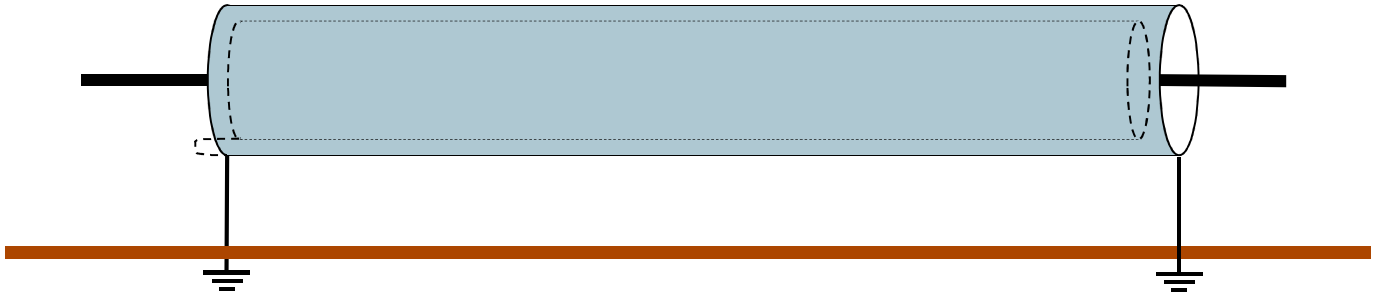
Step - voltage



Shielding
Grounding concepts and their behaviour

- Double shielded
  - Inner shield one side grounded
  - Outer shield both sides grounded

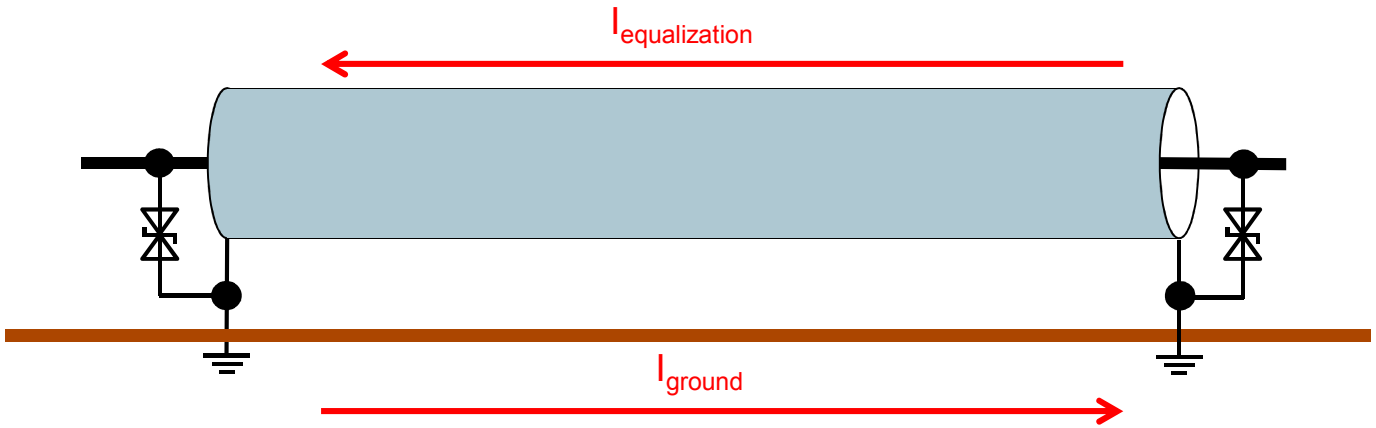
+ protection against capacitive coupling
+ reducing inductive coupling
+ no equalization currents on inner shield
- danger of spark over due lightning impact
  - caused by partial lightning currents on outer shield



Potential differences can lead to a spark over!
Shield should be included to the surge protection concept!

Shielding
Integrating in surge protecting concept

- Non-isolated system, both ends grounded, SPD on both ends
  - SPDs on both sides
  - Shield on both sides grounded
  - Equalization currents on shield



Shielding
Integrating in surge protecting concept

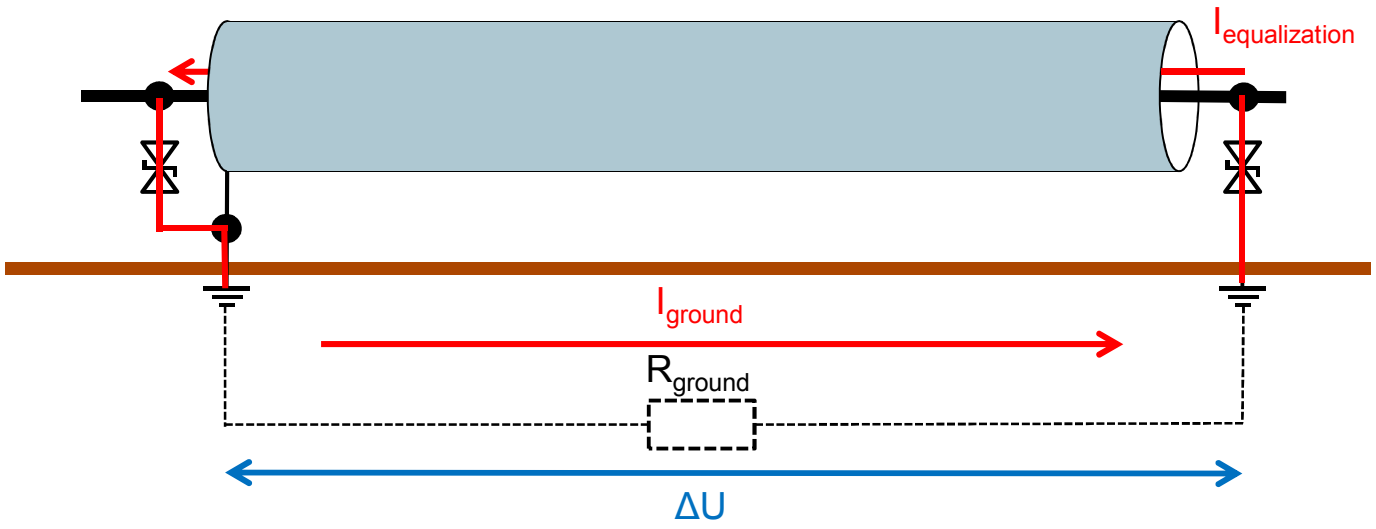
- Non-isolated system, one end grounded, SPD on both ends
  - SPDs on both sides
  - Better solution?
  - High voltage drop in ground possible
  - Diodes became conductive!
  - Equalization currents on line!

$$R_{wet\ pebbles} = 500\frac{\Omega}{m}$$

$$d = 25m$$

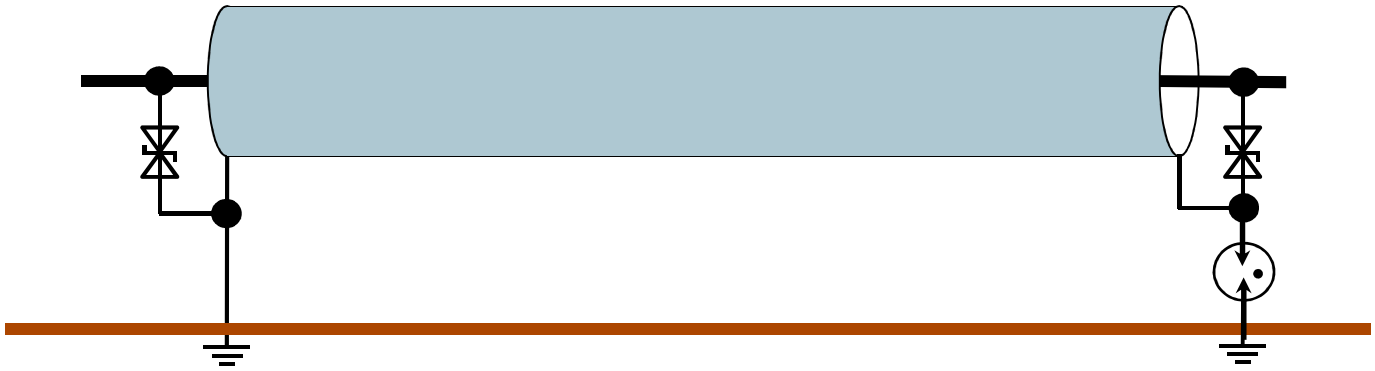
$$I_{ground} = 1mA$$

$$\Delta U = 25m * 500\frac{\Omega}{m} * 1mA = \mathbf{12,5V}$$



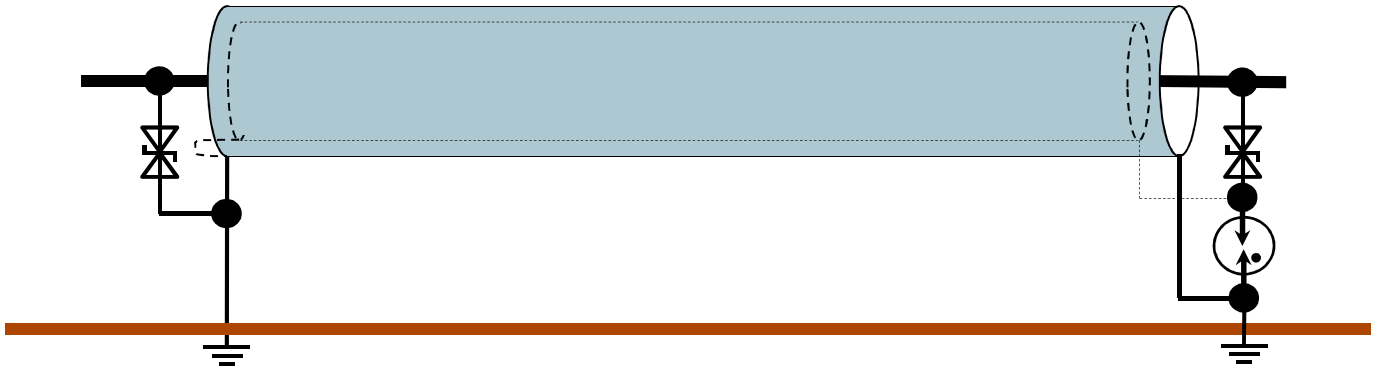
Shielding
Integrating in surge protection concept

- Non-isolated system, one end grounded, SPD on both ends
  - SPD on both ends but slight difference in design
  - Indirect grounded!
  - No equalization currents
  - Partial lightning current on shield in case of lightning



Shielding
Integrating in surge protecting concept

- Non-isolated system, double shielded, SPD on both ends
  - SPD on both ends but slight difference in design
  - Indirect grounded!
  - No equalization currents
  - Partial lightning current on outer shield in case of lightning



Agenda

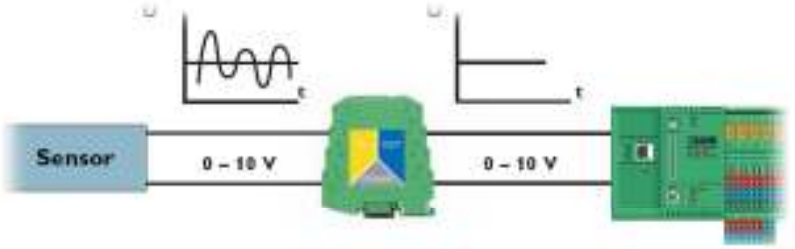
- Set the Stage
- Analog Signals
  - Surge Protection
  - Signal Conditioning
- Fieldbus Networks

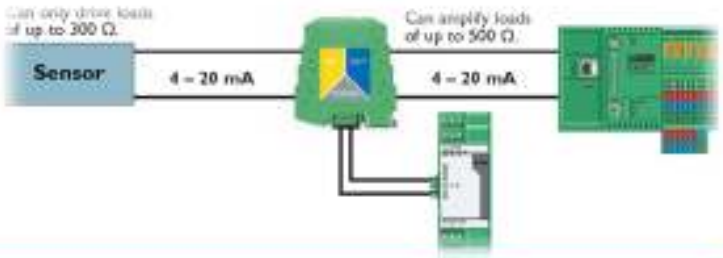
Goals of Analog Signal Conditioning and Protection

- Improve Accuracy
- Increase Quality
- Reduce Installation Costs
- Reduce down time
- Safe Control
- Improve reliabiltity
- Protect expensive equipment

Interface Analog
Why signal conditioners are used?

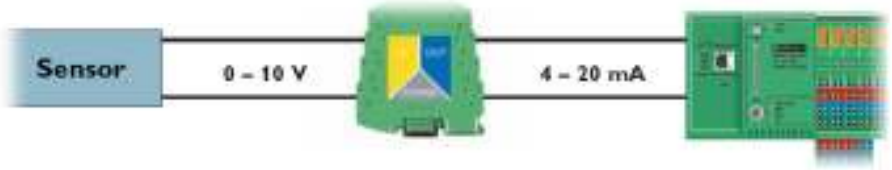
Filtering

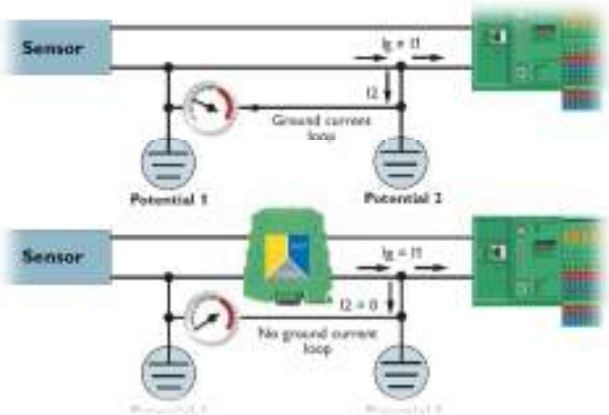




Amplifying

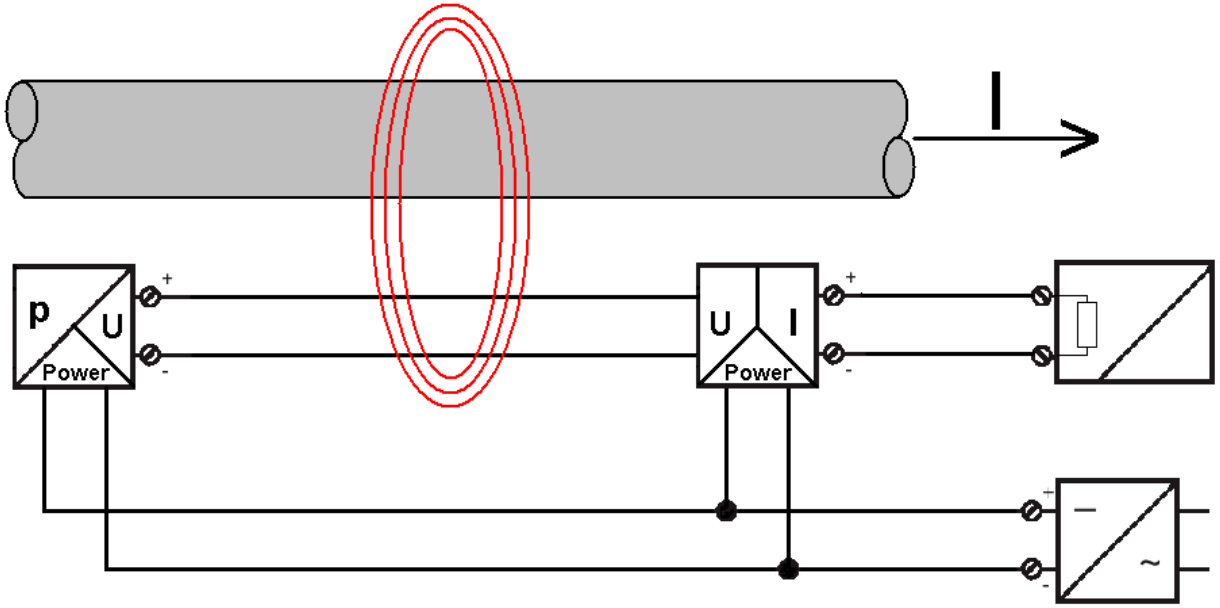
Converting

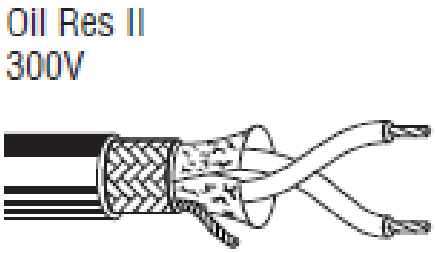




Isolating

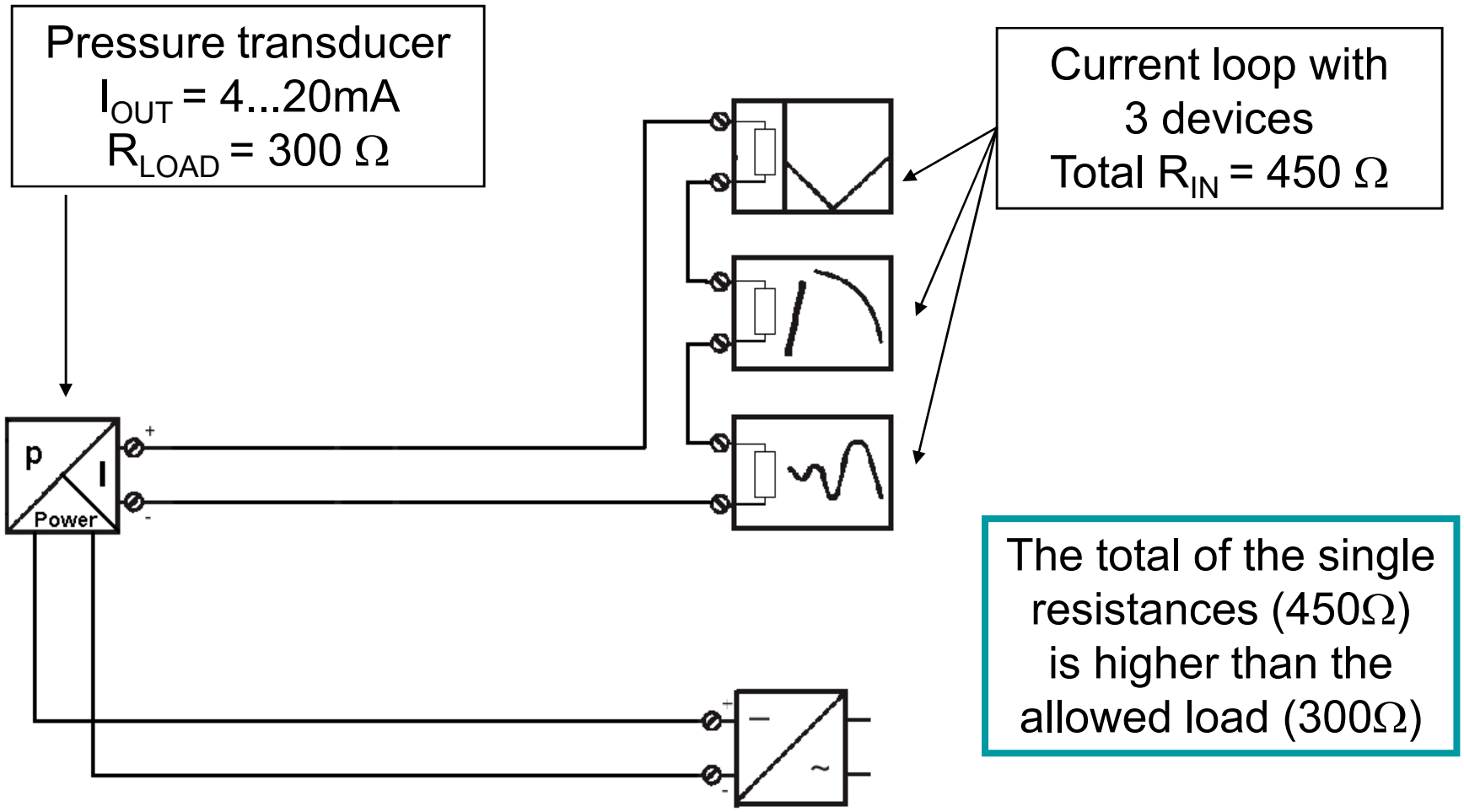
Signal filtering





- High currents influencing the signal transmission
- Signal filtering and conversion to a current signal can help eliminate and avoid interferences
- **Low Pass limit filtering best < 50HZ**

Signal Amplification



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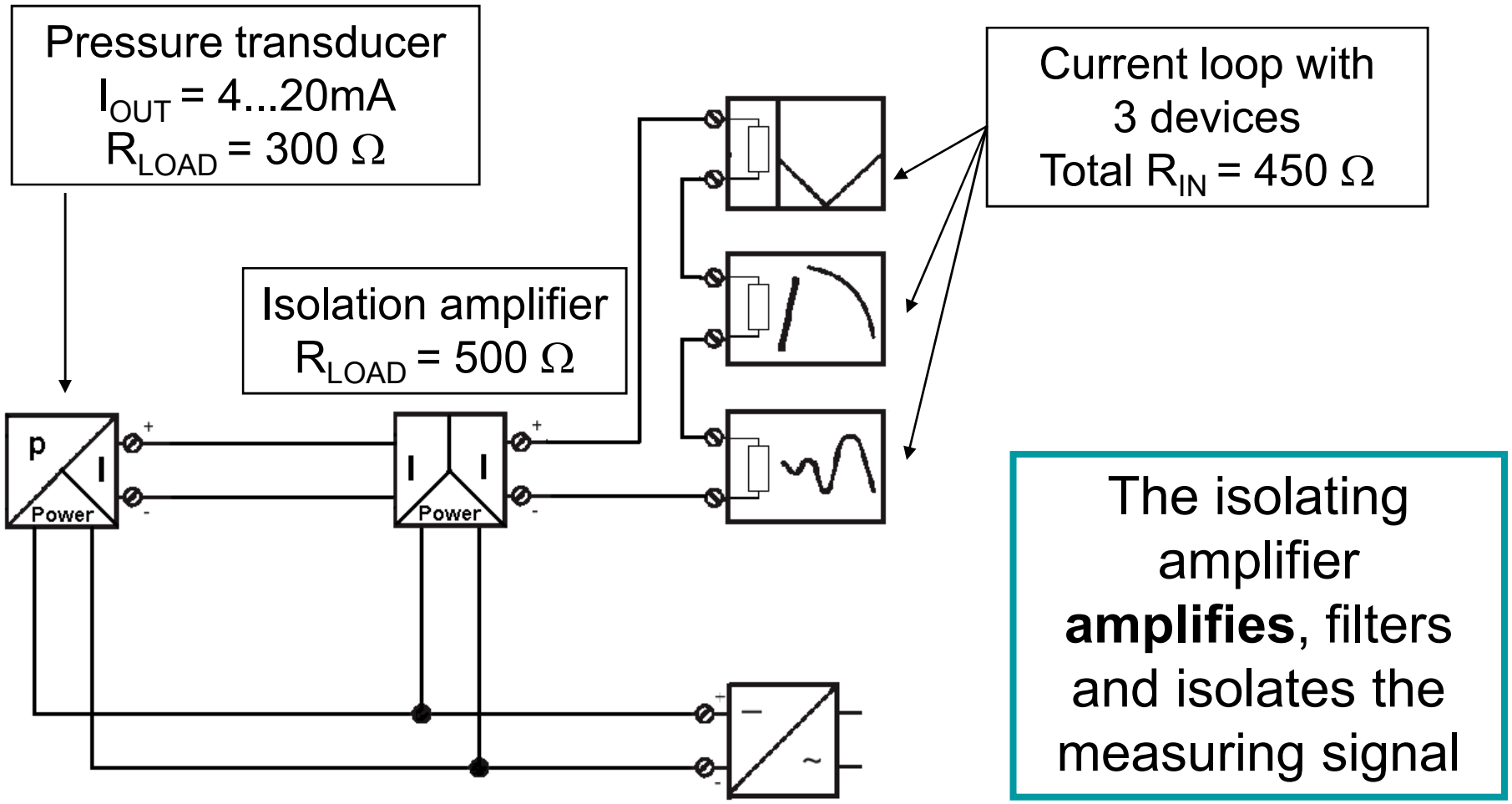
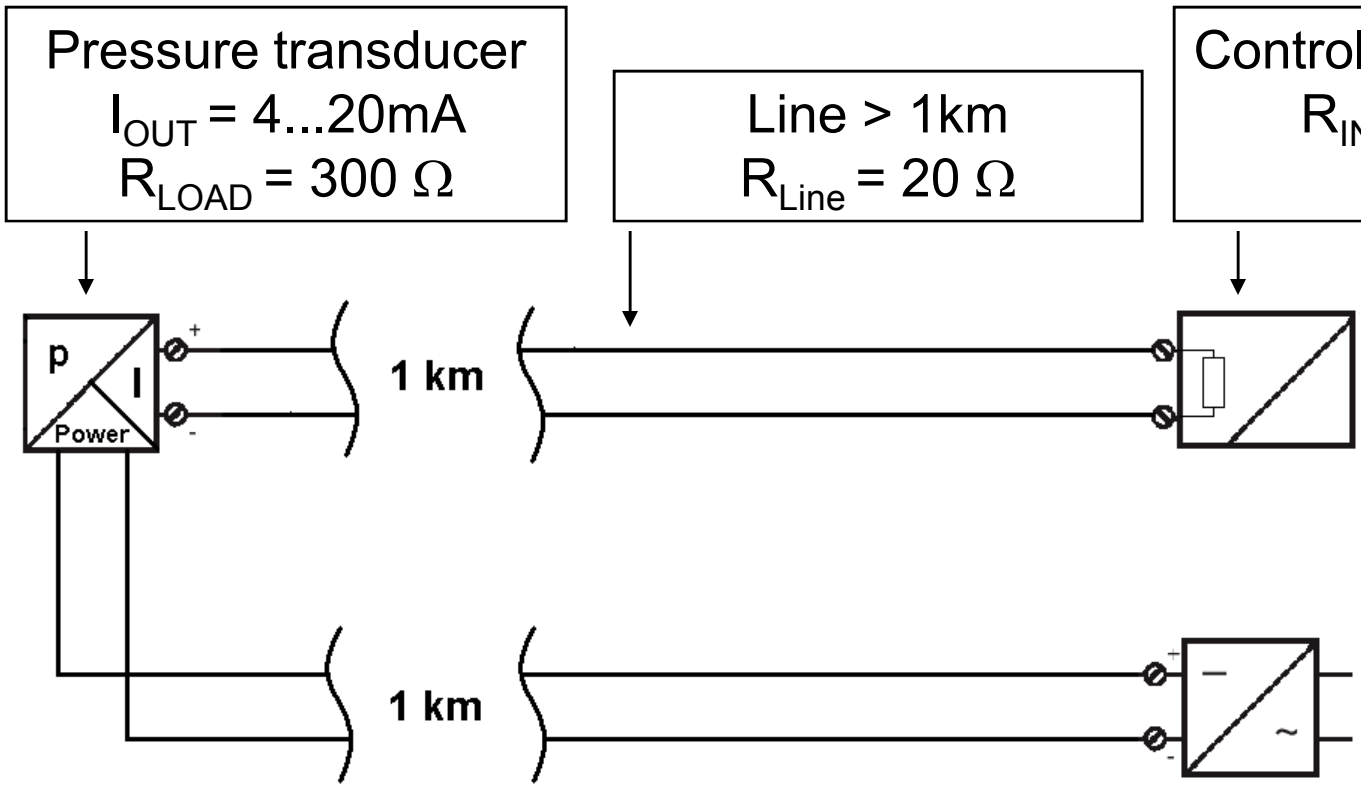
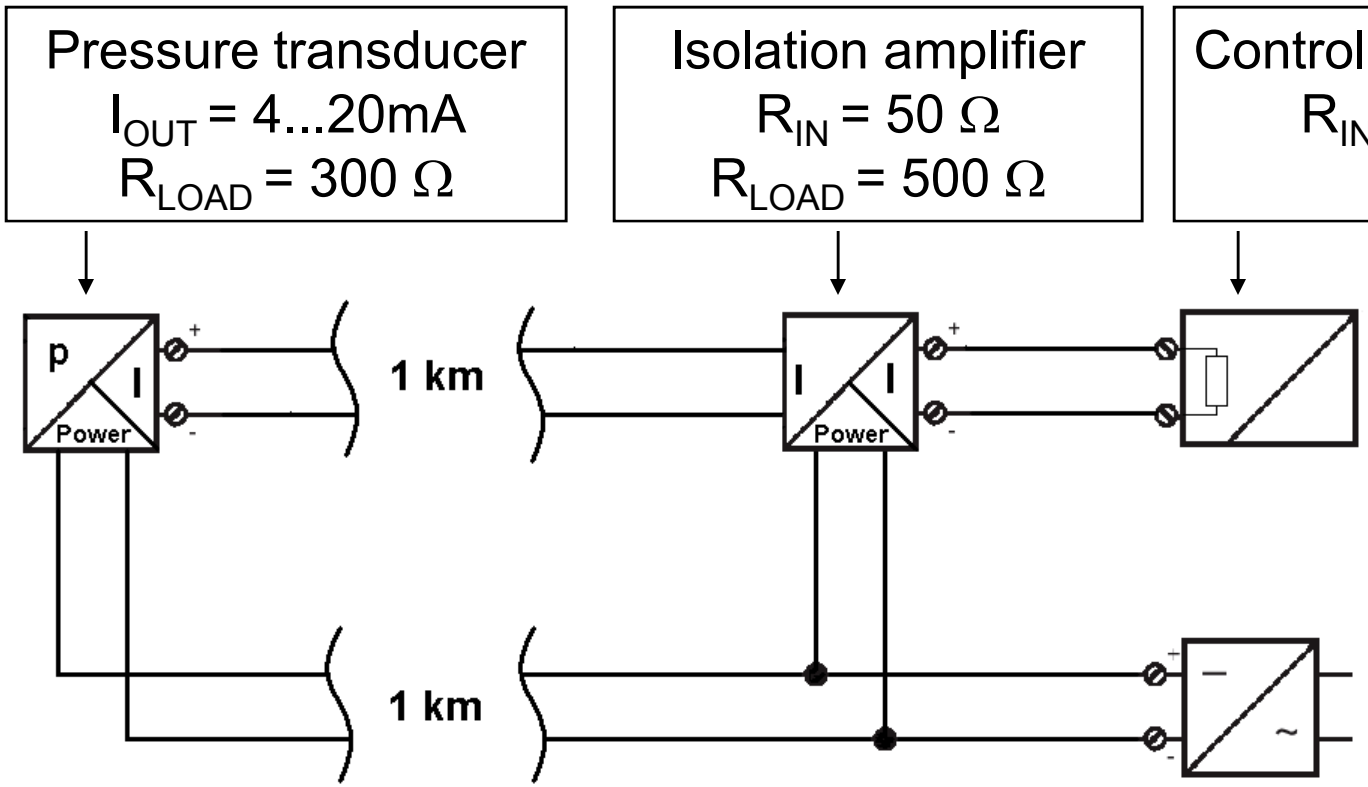


Signal Amplification



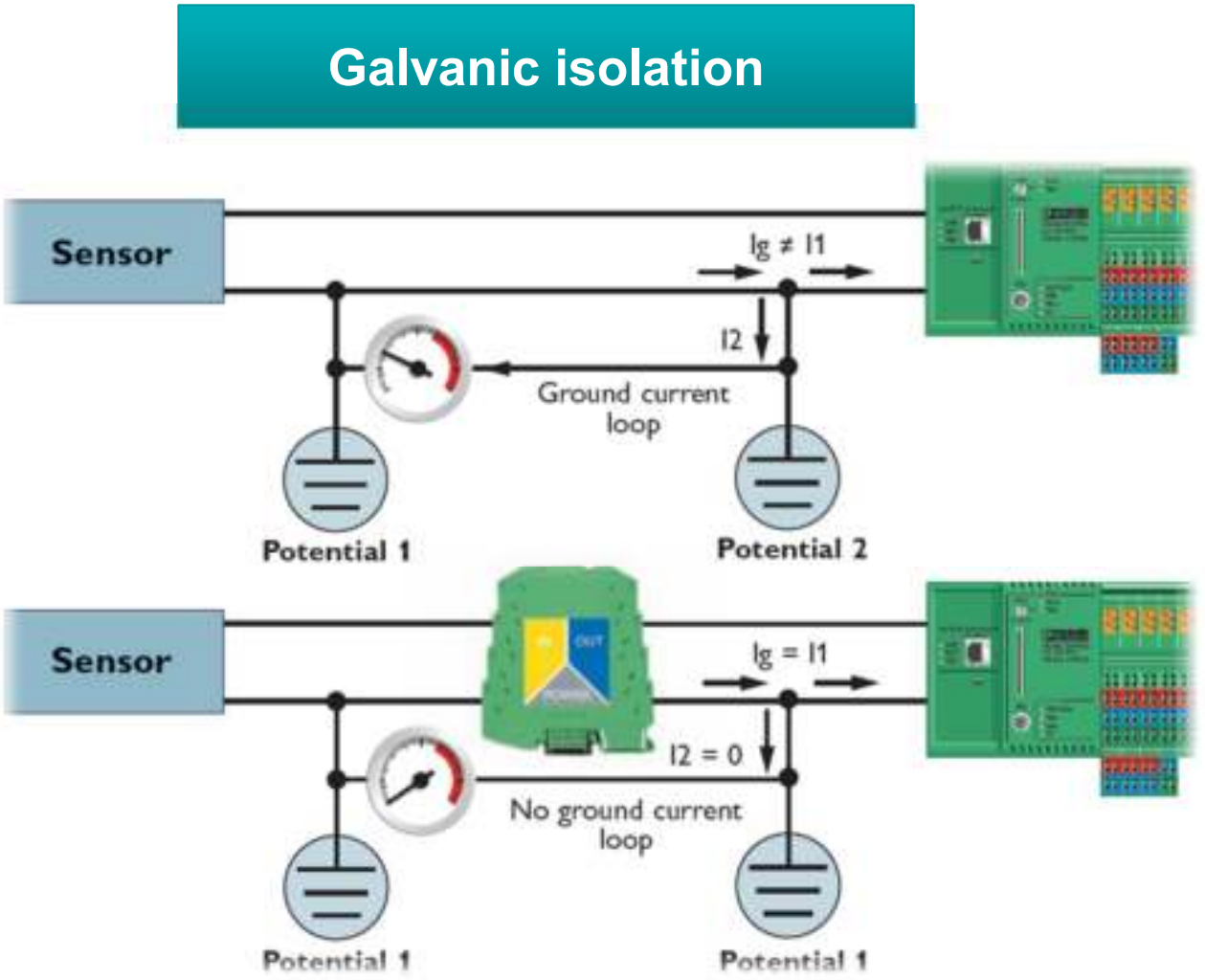
The total of the single resistances (320Ω) is higher then the allowed load (300Ω)

Signal Amplification

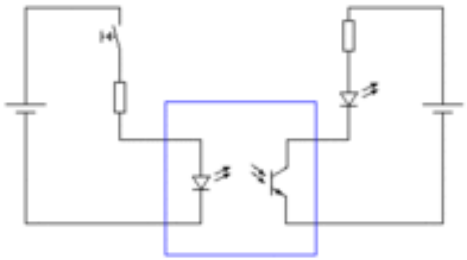


The isolation amplifier **amplifies**, filters and isolates the measuring signal

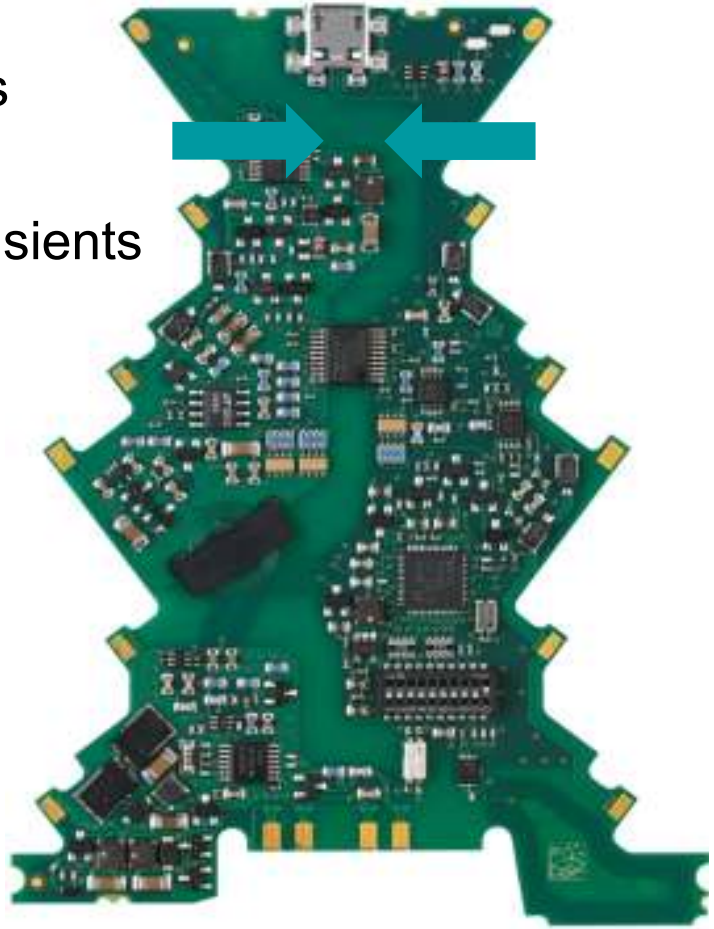
INTERFACE Analog
Why signal conditioners are used?



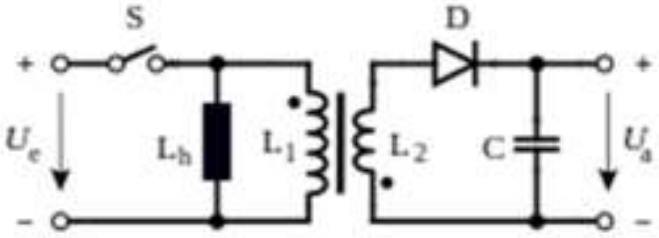
Signal Isolation
Types of Isolation



- **Optical Isolation**
  - Uses light emitting diodes
  - Higher resolution – Faster response times
  - Lower cost
  - More sensitive to static discharge and transients



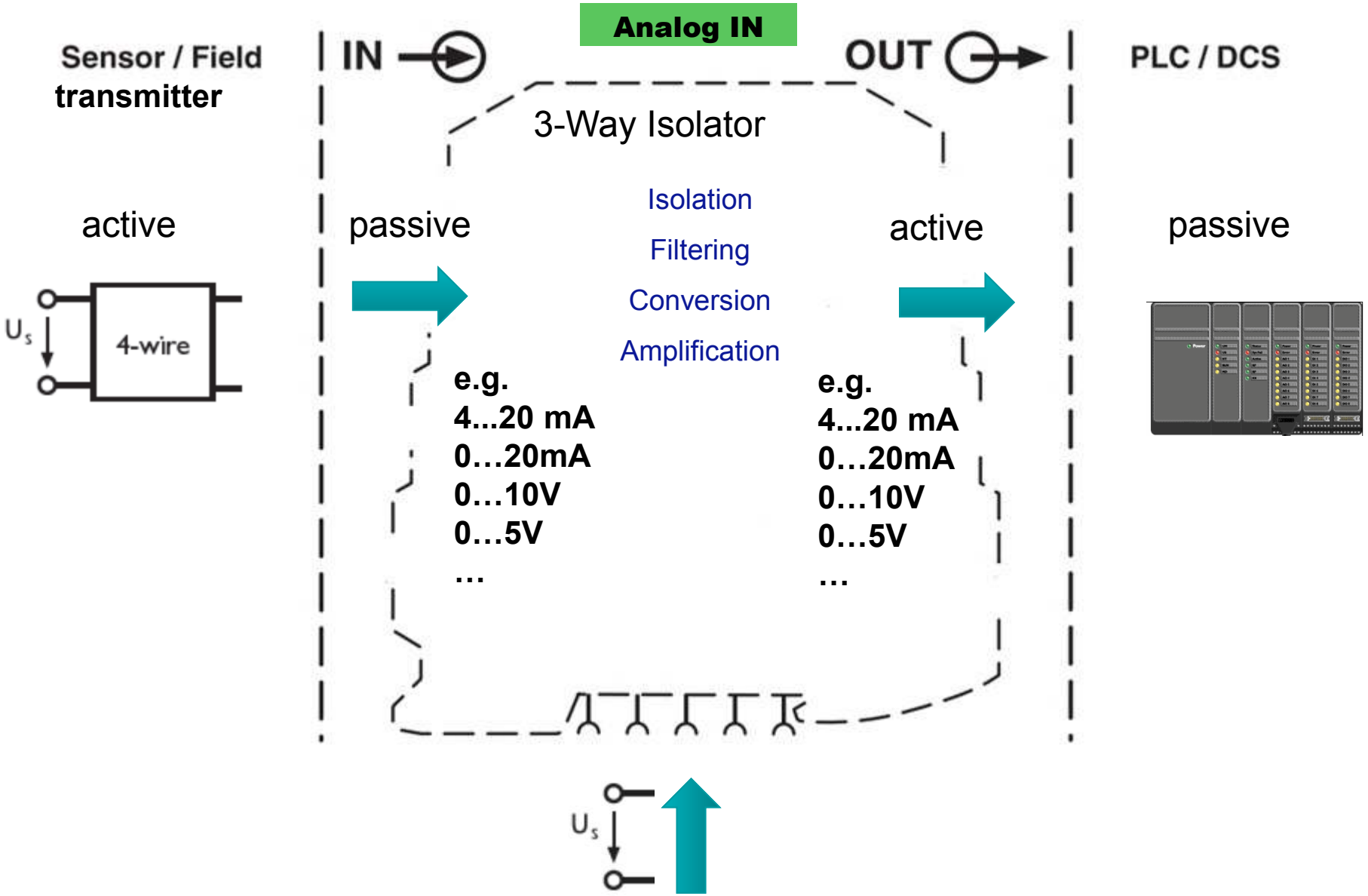
- **Magnetic Isolation**
  - Uses transformer
  - More robust
  - Higher cost



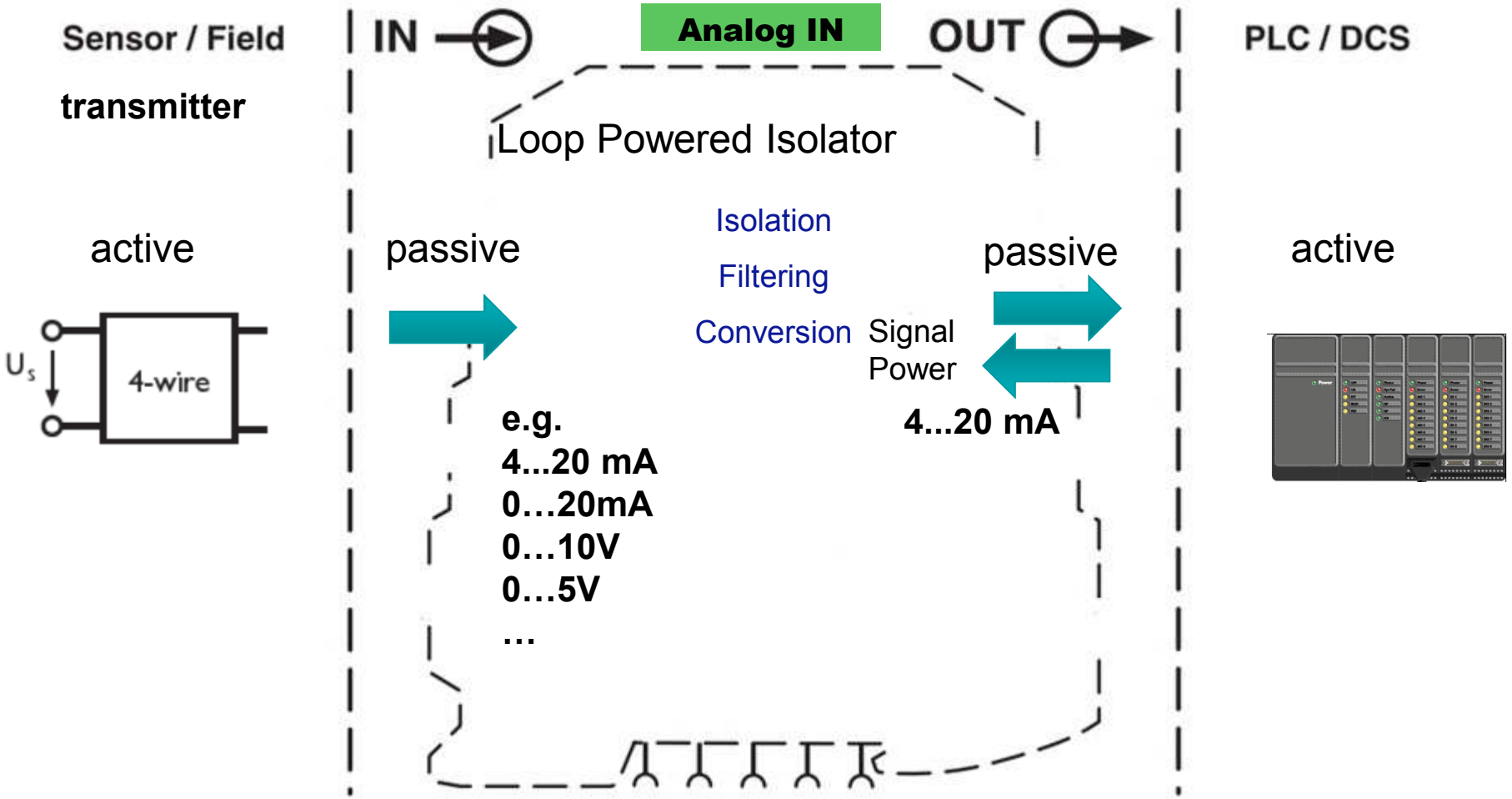
Lessons Learned – Signal Conditioning

- Proper selection of the signal conditioning devices and interfacing with the control system
- Signal conditioners are not surge protective devices

INTERFACE Analog
Isolation technologies / active vs. passive



INTERFACE Analog
Isolation technologies / active vs. active



Lessons Learned – Signal Conditioning

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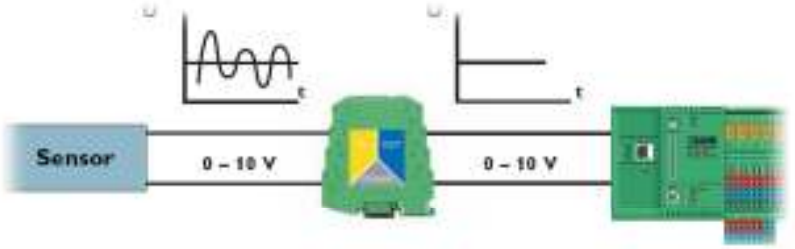
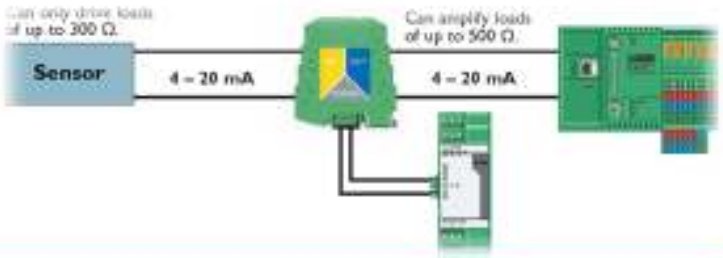
Interface Analog
Why signal conditioners are used?

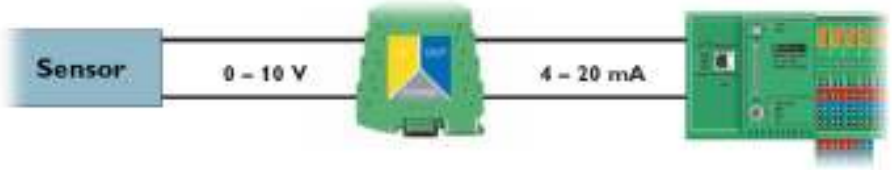
Filtering

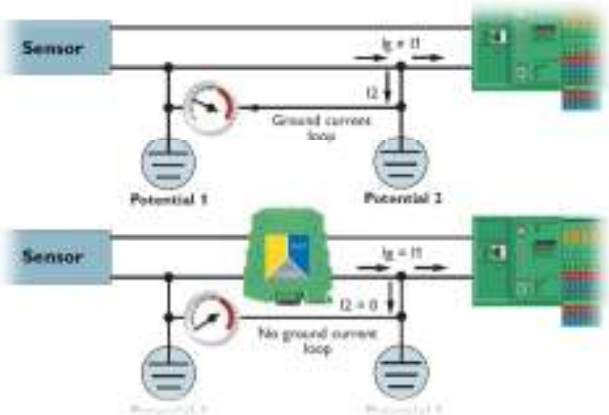




Amplifying

Converting





Isolating

Signal Conditioners/Isolators are NOT Surge Protective Devices

- Isolation/test voltage – 3 kV
- Not designed to handle high current, short duration surges
- If surge is needed, install SPD in front of isolator

Agenda

- Set the Stage
- Analog Signals
  - Surge Protection
  - Signal Conditioning
- Fieldbus Networks

What is Fieldbus?

- **Fieldbus interconnects “field” equipment such as sensors, actuators and I/O to a control system on a single pair of wires**
- **Fieldbus Systems – IEC 61158-2 Specification**
  - Fieldbus is an all-digital, serial, two-way communication system with a data rate of 31.25 kbit/s
    - Profibus PA & Foundation Fieldbus
    - Manchester II coding

Fieldbus Protocols

Foundation Fieldbus & Profibus PA

- **Foundation Fieldbus and Profibus PA are physically identical**
  - Twisted pair cables
  - Balanced power conditioning
  - Device Couplers
  - Two terminators required
  - 9 – 32 Vdc
  - 1900 Meter total segment length (120 meter spur length maximum)

Primary Differences

Profibus PA

- Polling – Master/Slave
- Bus Master
- Addressing instruments individually
- Device only communicates w/ master
- Communication loss – fail safe

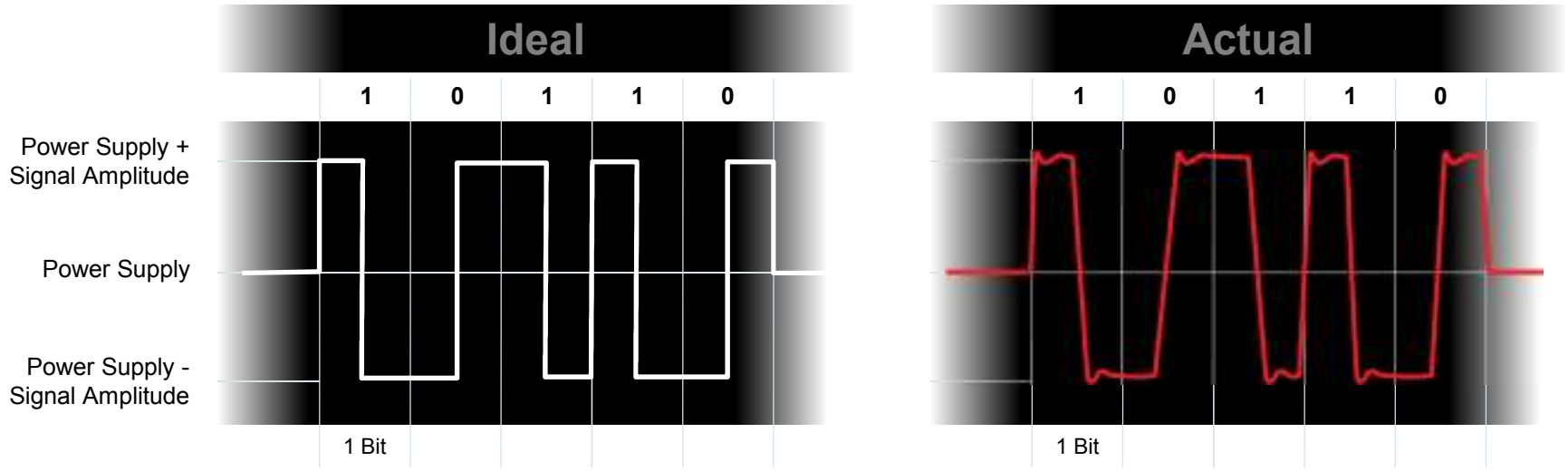
Foundation Fieldbus

- Cyclic transmission – Publisher/Subscriber
- Link Active Scheduler (LAS)
- FF Devices automatically present on bus
- Peer to Peer communication possible
- Communication loss – backup LAS

Fieldbus Protocols

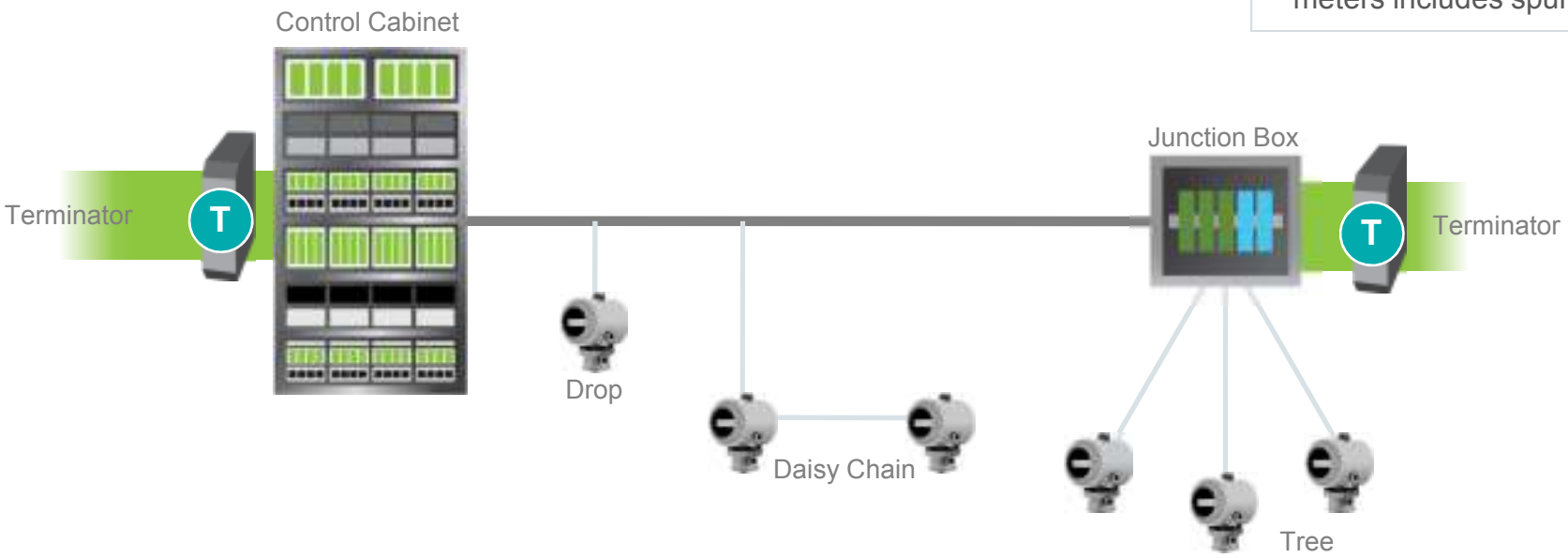
Foundation Fieldbus and Profibus PA

- **What does the signal look like?**
- Manchester II coding is used for both protocols
- 31.25 kbit/s means each bit has a period of 32 µs
  - An ideal signal spends 50% of the time positive and 50% of the time negative



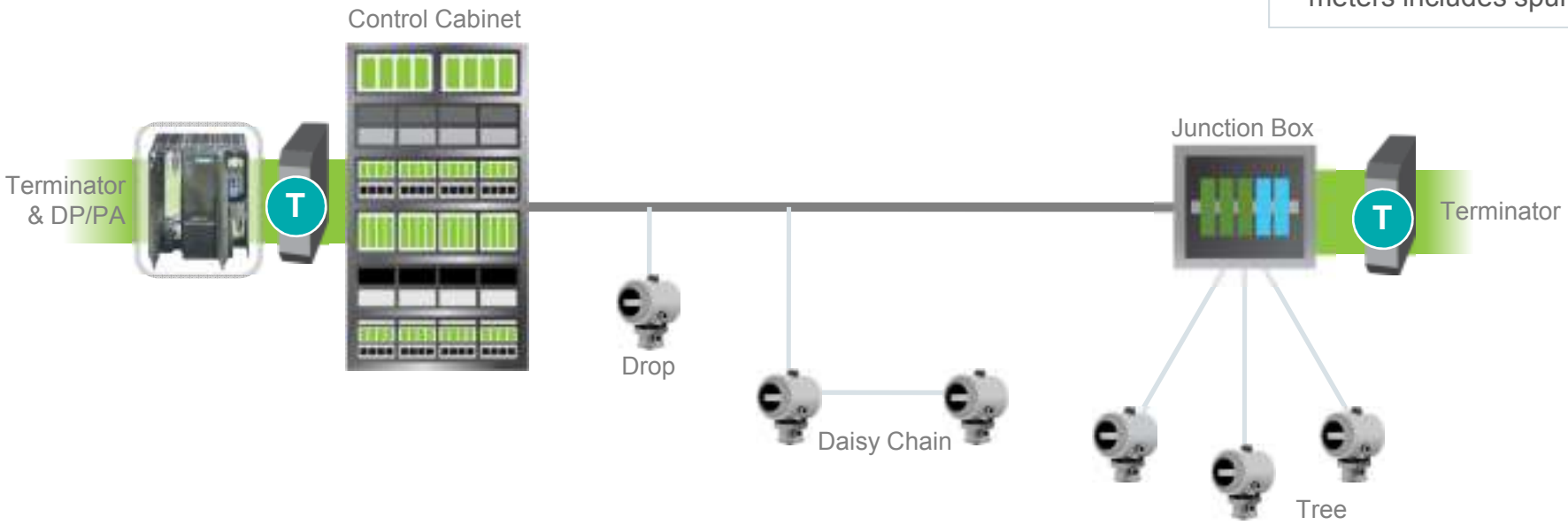
Foundation Fieldbus Topology

- 31.25 kb/s
- Powered Bus
- 9-32 Vdc
- Max length 1900 meters includes spurs



Profibus PATopology

- 31.25 kb/s
- Powered Bus
- 9-32 Vdc
- Max length 1900 meters includes spurs



Why Fieldbus?

- Saving IO cards
- Saving cables
- Saving cabinets
- Access to data
- Ease of planning / installation and startup
- Enabling fully digital communication
- Still being highly reliable
- .....

→Saving money

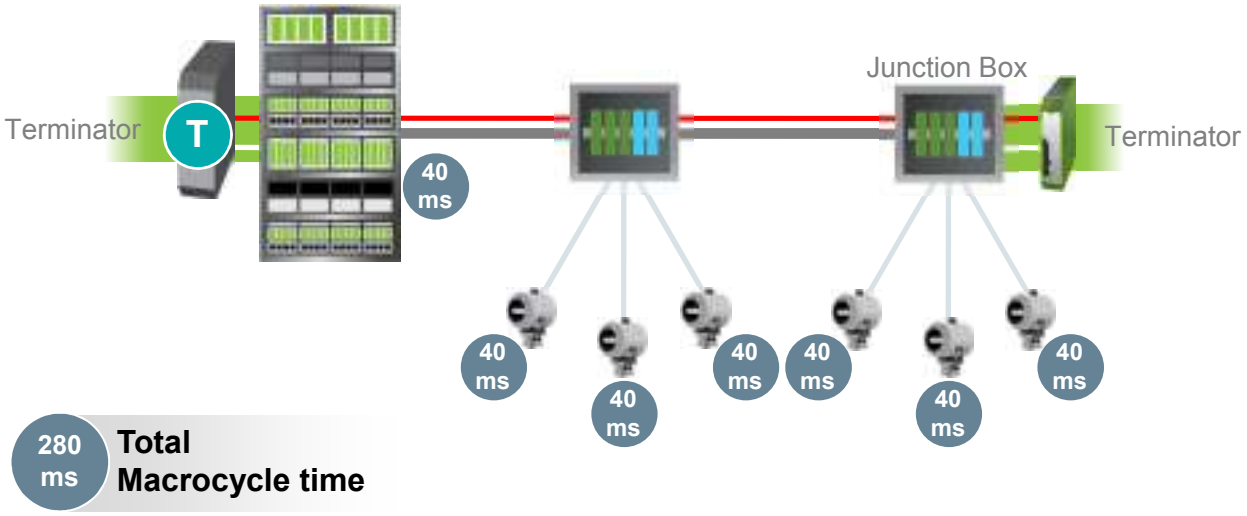
Lessons Learned – Fieldbus Networks

- Understanding the process, process control timing, and number of devices per trunk
- Properly detailing network layout and wiring restrictions; making sure Electrical Contractor adheres to design
- Understanding shield concepts and detailing shield connections

Communication Structure

Token Passing Network

Macrocycle: The repetitious scheduling of the Function Block within all the devices on a segment. The LAS is responsible for scheduling of the segment macrocycle



Token Passing Network

- For loops requiring **1s** macrocycle time, limit segment to **12 devices** including **3 valves** maximum
- For loops requiring **0.5s** macrocycle time, limit segment to **6 devices** including **2 valves** maximum
- For loops requiring **0.25s** macrocycle time, limit segment to **3 devices** including **1 valve** maximum

Lessons Learned – Fieldbus Networks

- Understanding the process, process control timing, and number of devices per trunk
- Properly detailing network layout and wiring restrictions; making sure Electrical Contractor adheres to design
- Understanding shield concepts and detailing shield connections

Fieldbus Wire Specification

Cabling

Cable Type and Description	Max Segment Length
Type A: Multi or single-twisted-pair, individually shielded	1,900 (6,232)
Type B: Multi-twisted-pair, with an overall shield	1,200 (1,200)
Type C: Multi-twisted-pair, without shield	400 (1,312)
Type D: Multi-core, without twisted pairs, without a shield	200 (656)

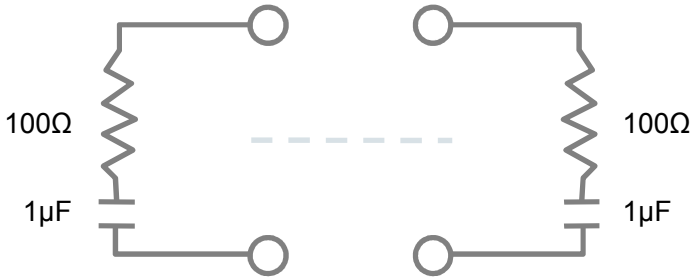
Meters (Feet)

Total Devices	1 Device per Spur	2 Devices per Spur	3 Devices per Spur	4 Devices per Spur
25-32	1 (3)	1 (3)	1 (3)	1 (3)
19 – 24	30 (98)	1 (3)	1 (3)	1 (3)
15 - 18	60 (197)	30 (3)	1 (3)	1 (3)
13 - 14	90 (295)	60 (197)	30 (98)	1 (3)
1 - 12	120 (394)	90 (295)	60 (197)	30 (98)

Additional Specifications:

- Attenuation
- Wire Resistance / Km
- Shield construction
- Wire-to-Shield capacitance
- Shield coverage
- Wire Twists per Meter
- Minimum Bend Radius
- Jacket Resistance

Fieldbus Terminator



- **Exactly 2 terminators are required for each segment**
- **RC network creates a 50 Ohm equivalent load for the network**
- **Prevents signal reflections**
- **Signal level should be between 0.75V and 1.0V pp @ 50 Ohm**

Signal Amplitude	Status
If peak-to-peak level is **> 1 V**	Missing terminator
If peak-to-peak level is between **0.75 V** and **1 V**	**Properly terminated**
If peak-to-peak level is between **0.15 V** and **0.75 V**	Too many terminators

Fieldbus Cabling

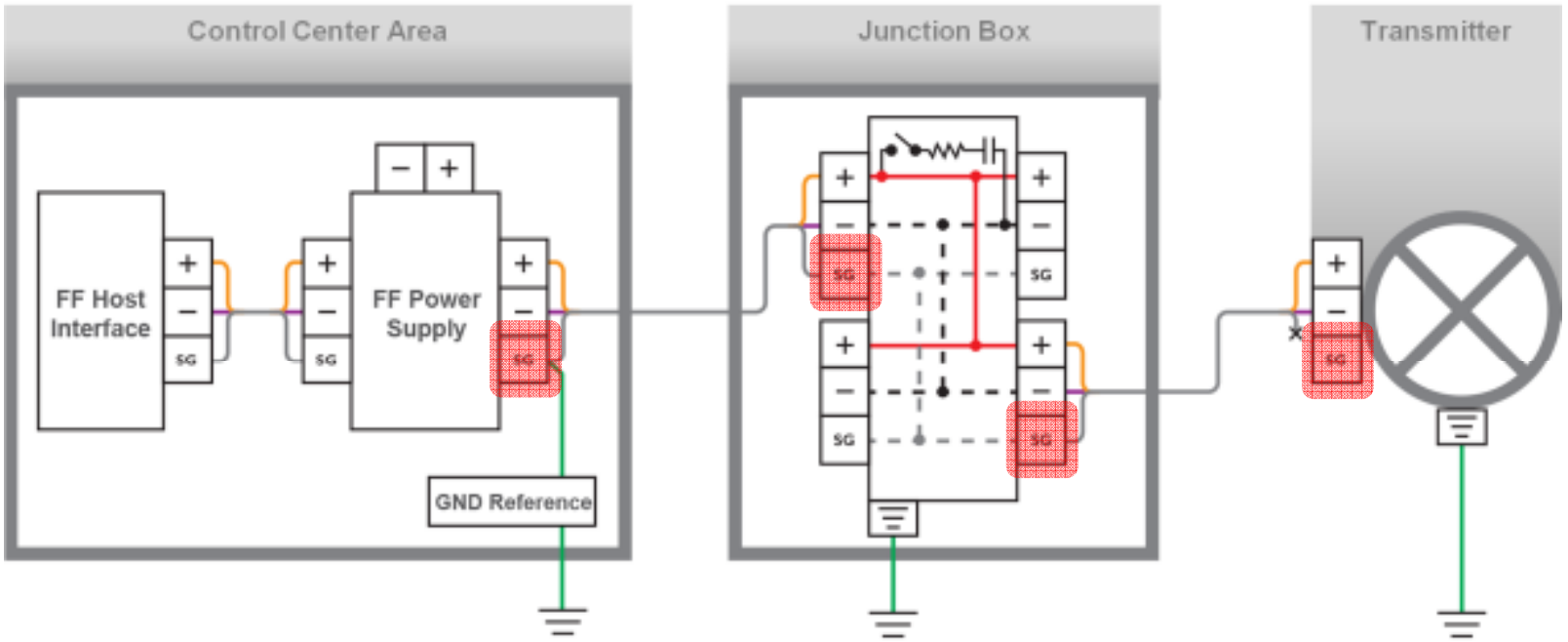
- Minimize loops and maintain proper bend radius

Lessons Learned – Fieldbus Networks

- Understanding the process, process control timing, and number of devices per trunk
- Properly detailing network layout and wiring restrictions; making sure Electrical Contractor adheres to design
- Understanding shield concepts and detailing shield connections

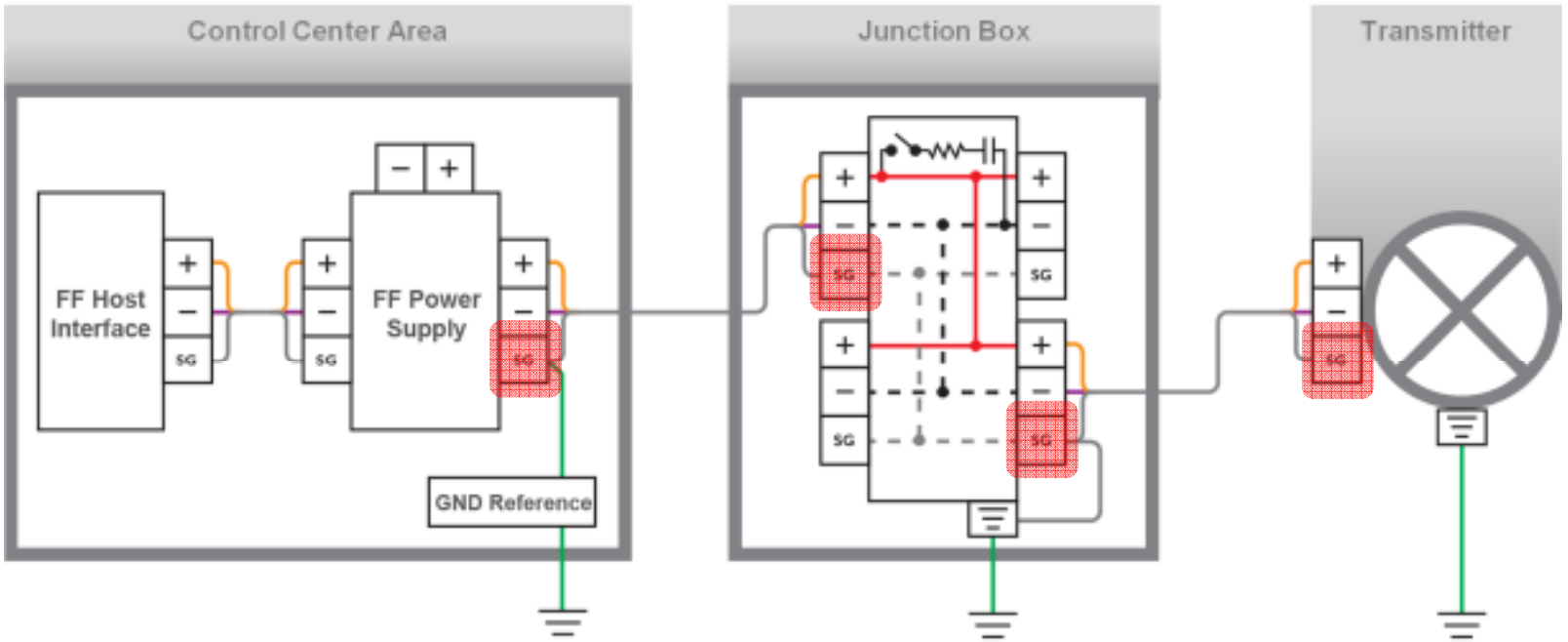
Shield Grounding

Class A: Single Point Shielding



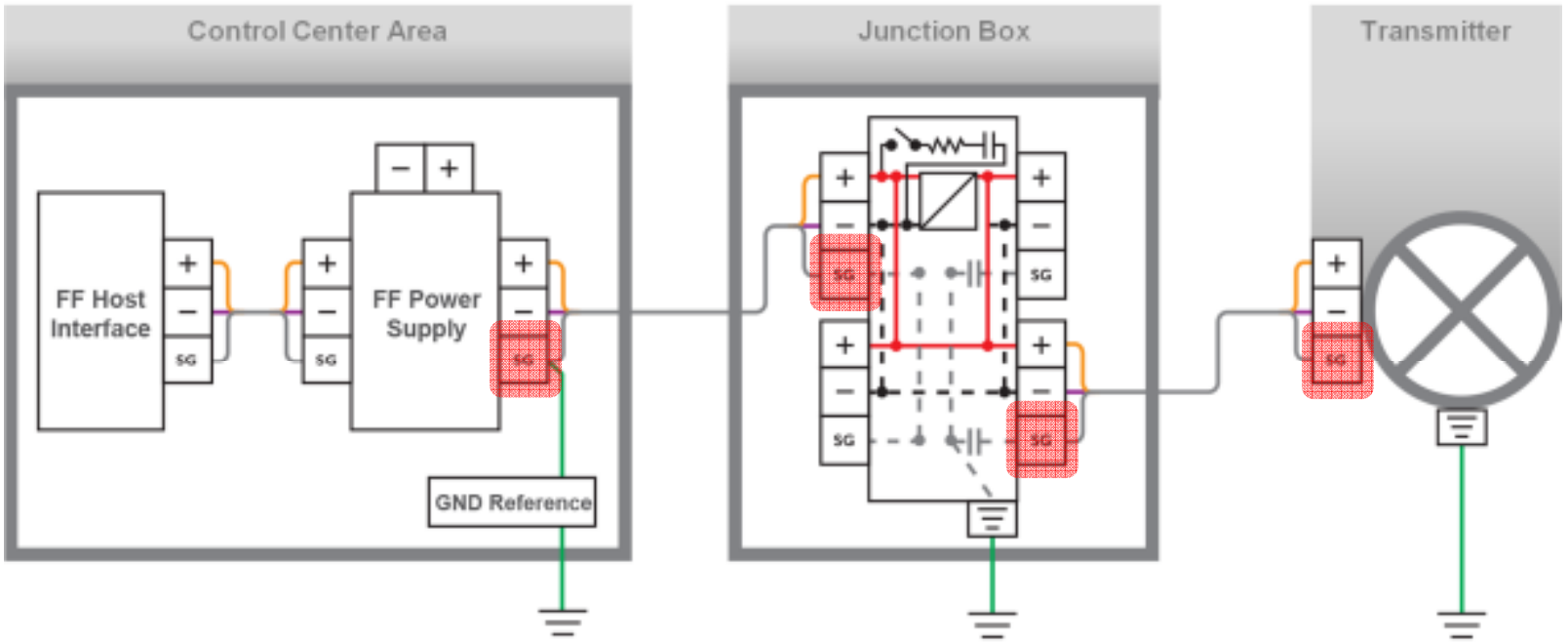
Shield Grounding

Class B: Multi Point Shielding



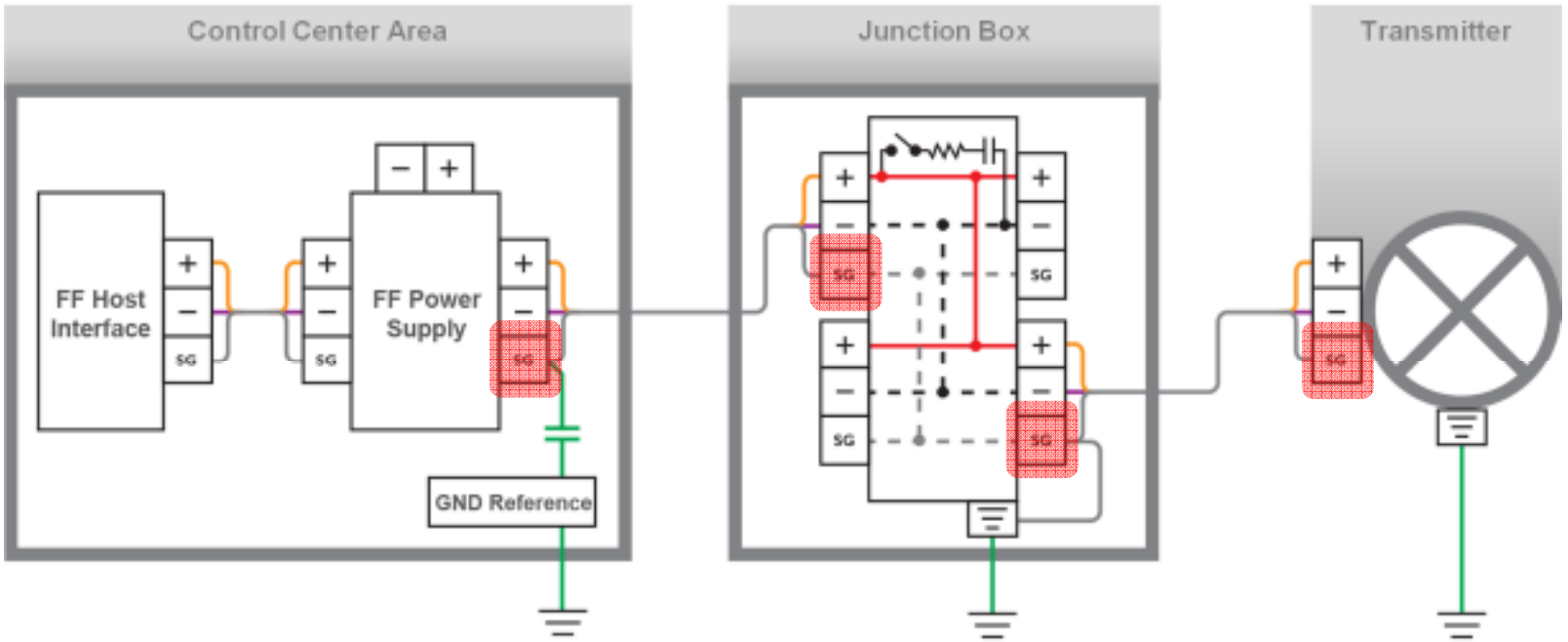
Shield Grounding

Class C: Shielding Using Isolated Device Couplers



Shield Grounding

Class D: Multi Point Shielding Using Capacitive Coupling



Summary

- Regardless, if it is analog or digital…control is only as good as the instrumentation and the signal
- Little more effort on the design details can alleviate a lot of field headaches

IEEE-IAS – Atlanta Chapter

Questions?

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INSPIRING INNOVATIONS