Factory Automation Use Case for Daisy Chain Power Delivery

Dayin Xu, David Brandt
Rockwell Automation

Supporters

- Steffen Graber, Pepperl+Fuchs
- Lennart Yseboodt, Philips Lighting
- Mattias Wendt, Philips Lighting

Purpose

- Support objective
  - Specify an optional power distribution technique for use over the 10 Mb/s single twisted pair link segments in conjunction with 10Mbps single-pair PHYs

- This presentation elaborates factory automation use case for daisy-chain power delivery over 10SPE data links

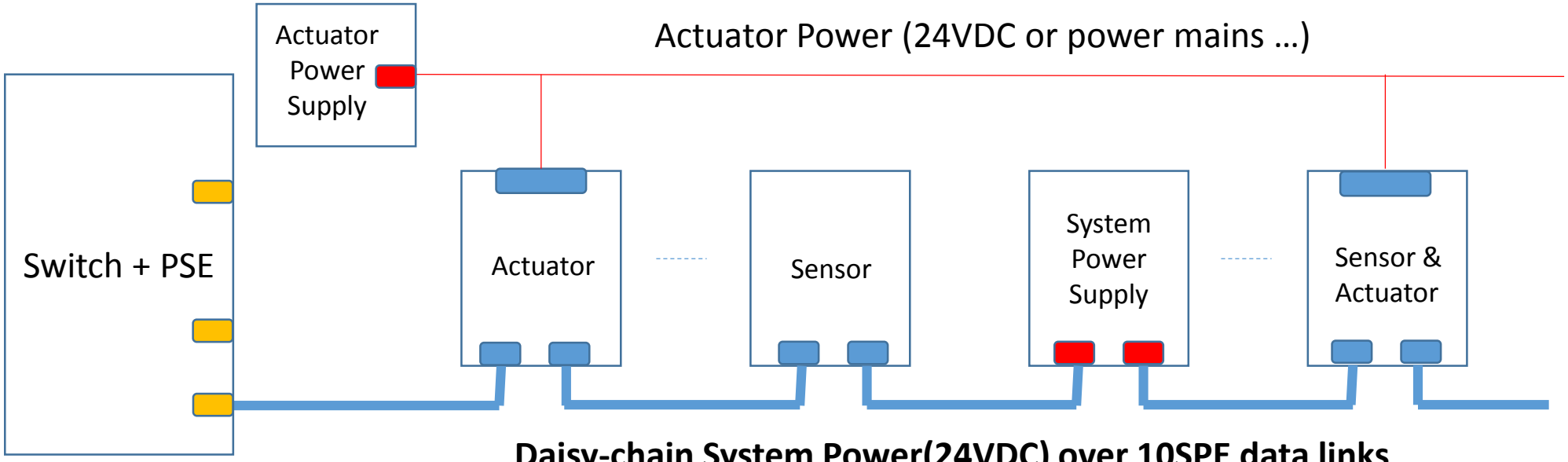
- This presentation also provides considerations on the technical feasibility for daisy-chain power delivery over 10SPE data links

Reference

- Page9-12 of brandt_083116_10SPE_01_adhoc.pdf tell in-cabinet and on-machine use cases
  - On-machine devices are usually daisy-chained
  - In-cabinet components are usually connected in a fieldbus bus or hardwired
- Page 6 of brandt_10SPE_02_0916.pdf tells the Ethernet topology
  - Ethernet Bus matches today's fieldbus topology, but facing technical challenges
  - **Linear topology might have to be an alternative solution**

System Diagram

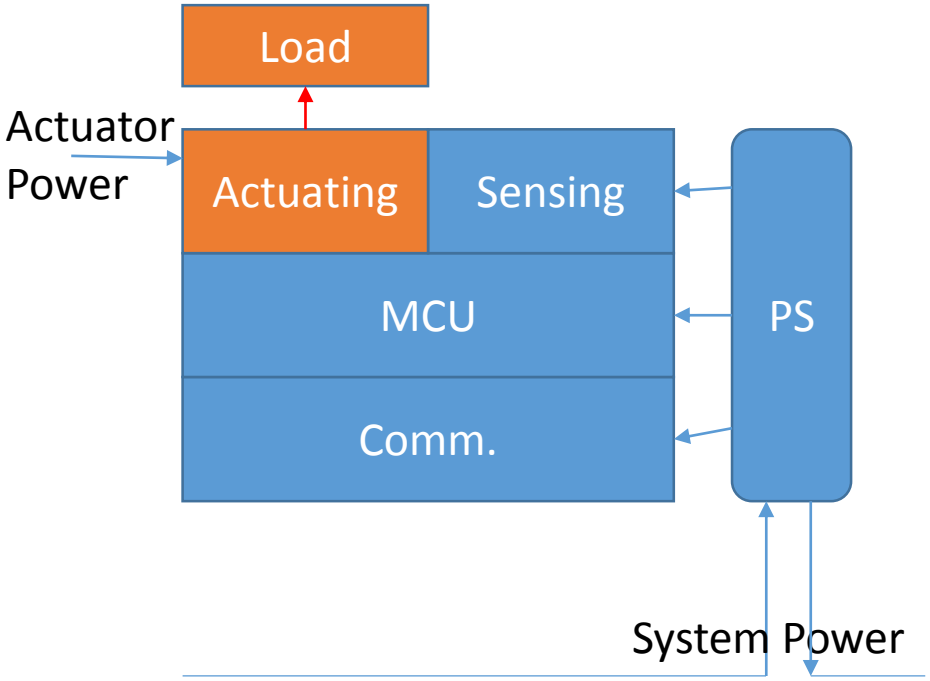
- Daisy-chain system power over 10SPE data links
  - Device-to-device link length: up to 15m, total length: up to 50m
  - 24VDC, up to 4A, up to 64 devices
- System Power capability could be boosted by a power supply equipment
- Actuator Power might be the second pair of the same cable



Daisy-chain System Power(24VDC) over 10SPE data links

Power Types

- **System power**
  - Un-switched power for communication and sensor electronics to monitor industrial process status
  - **DC power (24VDC),** sometimes AC power
- Actuator power
  - Switched power for actuators to control industrial process
  - DC (24VDC) or AC power (MAINs power)



Requirements

- Daisy-chain System Power delivery over 10SPE data links
  - 24VDC, up to 4A, up to 64 devices
  - Device-to-device link length: up to 15m, total length up to 50m
- System Power capability can be boosted by additional Power Supply Equipment as needed
- Power budget and power structure are prearranged
- Simple passive power delivery, no power detection and classification
- No special power configuration, plug and play
- Cost effective implementation

Other Use Cases

- Graber_10SPE_05a_1016.pdf discussed the process automation use case
  - Daisy-chain power delivery from field switch to field switch
  - Power decoupling circuit in devices

- yseboodt_sg10t1_01_powerdata.pdf discussed the lighting use case
  - Daisy-chain power delivery from luminaires to luminaires
  - DC Pass (Passive Bus) vs DC block (PoDL)

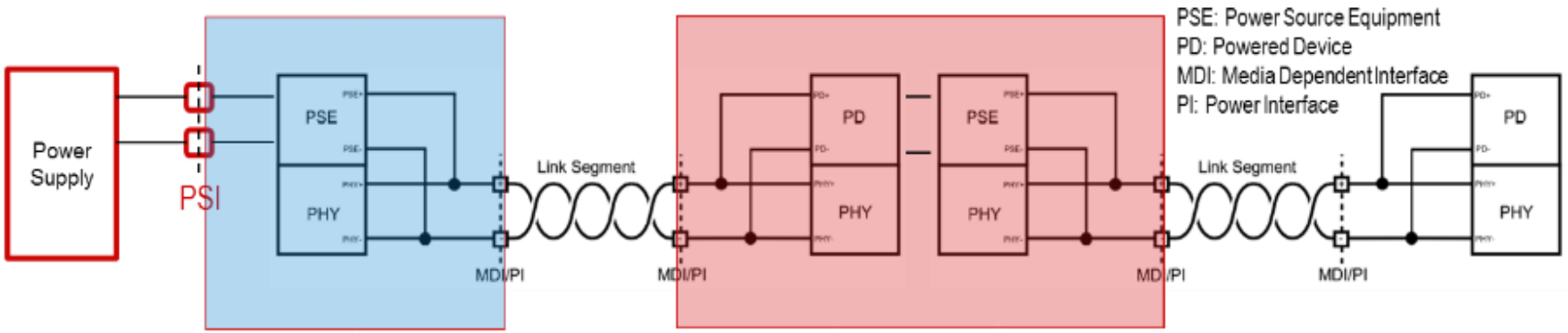
Daisy-chain PoDL

Concept:

- The first device (Switch) provides power to all downstream devices via PI interface
- The middle device has one PD receiving power from the upstream PSE and one PSE powering the downstream PD

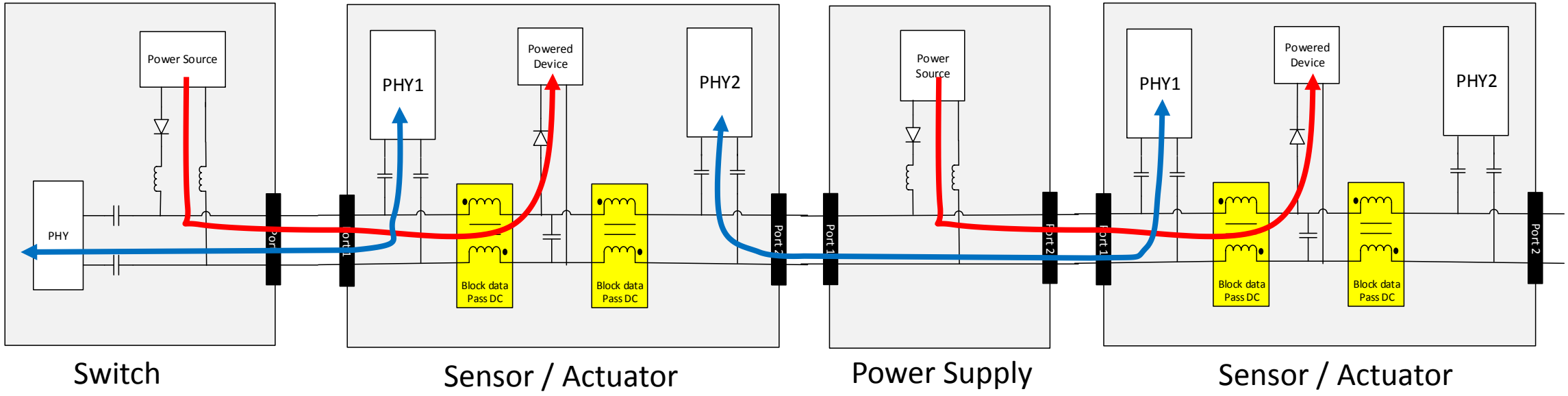
Challenge

- Technical feasibility: Complex or even impossible PD detection and classification
- Efficiency: Power conversion loss in devices
- Cost: High current PD and PSE implementation in devices



Alternative Way?

- 10SPE is daisy-chained
- System power is physically daisy-chained but acts as a bus logically
  - Trunk inductors in devices isolate data and PD noise, but pass DC power
  - To minimize the power loss, trunk inductors' DCR should be as small as possible



Power Distribution Model

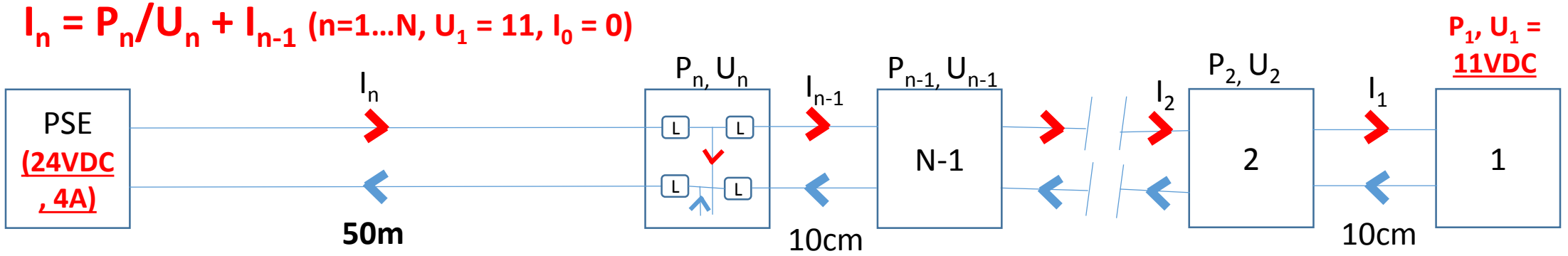
System Configuration

- All PDs are on the far end, the first link length is 50m, all others are 0.1m
- All PDs consume the same power
- PSE has stable 24V output voltage
- PD needs at least 11V input voltage

Variable	Unit	Description
U_{pse}	V	PSE voltage, 24VDC
I_{pse}	A	PSE current, maximum value = 4A
U	V	PD voltage, minimum value = 11V
P	W	PD power
R_L	Ohm	Trunk Inductor's DCR, each PD has 4 inductors
R_c	Ohm	Cable loop DCR per meter
N		Number of device
I	A	Current on the data link segment

$$U_n = U_{n-1} + I_{n-1} * (4*R_L + 0.1*R_c) \quad (n=2...N)$$

$$I_n = P_n/U_n + I_{n-1} \quad (n=1...N, U_1 = 11, I_0 = 0)$$



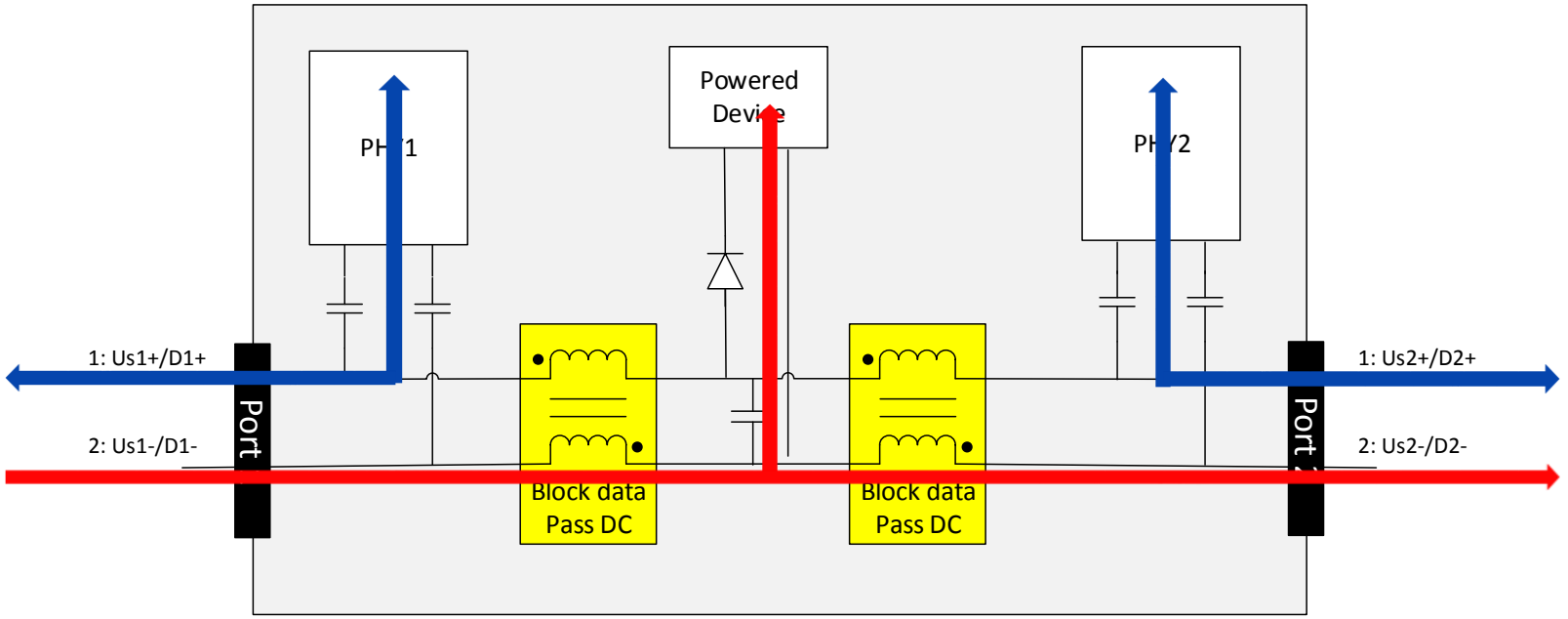
Case Study

- Number of PDs is limited by the voltage drop on the trunk inductor and cable
- 24V, 2A PSE could power one network
- %40-50% power loss in the trunk inductor and cable

Cable	PD Power (W)	Trunk Inductor (ohm)	Number of PDs	PSE ouput current (A)	PSE output power (W)	Inductor Loss (W)	Inductor Loss %	Cable Loss (W)	Cable Loss %	limitation
AWG18, 0.044ohm/m	1	0.4	13	0.923	22.144	8.415	38%	1.894	8.55%	Voltage drop
		0.2	18	1.286	30.86	10.752	34.85%	3.692	11.97%	Voltage drop
		0.1	24	1.746	41.912	12.675	30.24%	6.842	16.32%	Voltage drop
	0.5	0.4	19	0.666	15.98	6.114	38.24%	0.992	6.20%	Voltage drop
		0.2	26	0.921	22.116	7.704	34.84%	1.909	8.63%	Voltage drop
		0.1	36	1.284	30.815	10.061	32.65%	3.734	12.12%	Voltage drop
AWG24, 0.184ohm/m	1	0.1	13	1.086	26.066	2.659	10.20%	10.963	42.06%	Voltage drop
	0.5	0.1	22	0.891	21.383	2.86	13.38%	7.427	34.74%	Voltage drop

Device's System Power and Data Coupling/Decoupling

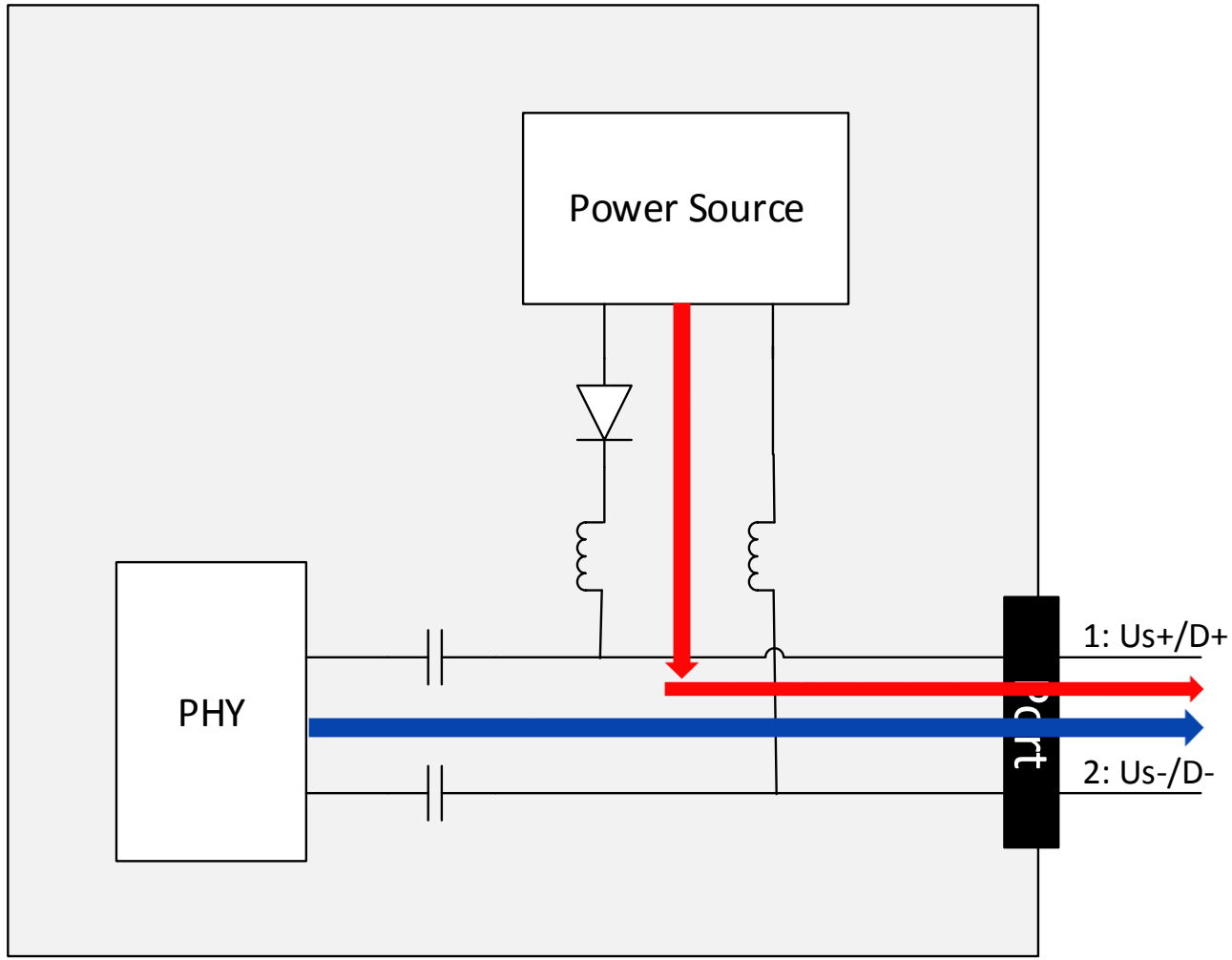
- Isolate 10SPE data and load noise
- Pass through DC power
- Not Intrinsic safety
- High current inductors risking high cost and big size
  - Lower DCR, less power loss
- …



Refer to Graber_10SPE_05a_1016.pdf

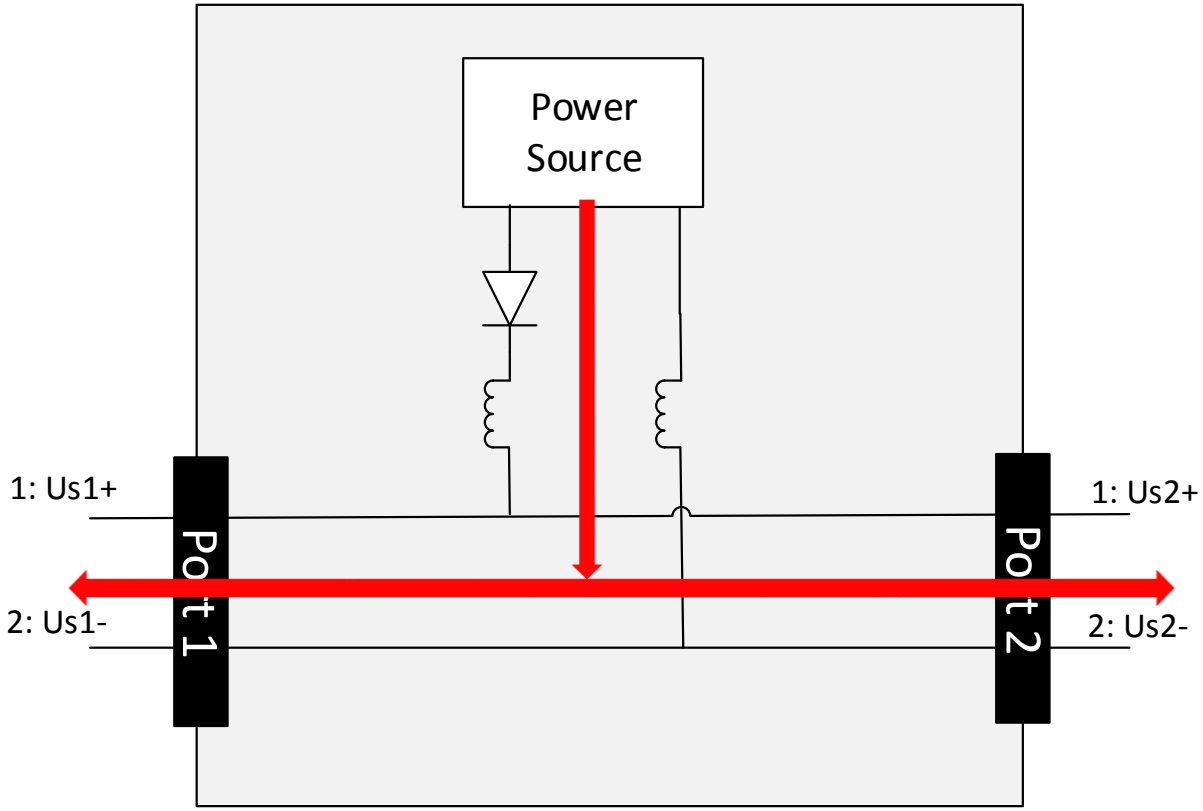
Switch Injection

- Provide system power to network
- Have no PD detection and classification function
- Isolate 10SPE data from power source noise
- …



Mid-span Boost

- Boost system power capability at any position
- Extend reach and/or increase number of PDs by compensating voltage drop in the trunk inductor and cable
- Isolate 10SPE data from power source noise
- …



Conclusion

- Discussed the factory automation use case for daisy-chain power delivery over 10SPE data links
- Consider the technical feasibility for daisy-chain power delivery over 10SPE data links
- Factory automation use case plus other use cases (process automation and lighting) clarify the daisy-chain power delivery requirement for the below objective

Specify an optional power distribution technique for use over the 10 Mb/s single twisted pair link segments in conjunction with 10Mbps single-pair PHYs

Thank You!

Cable Reference

- Horrmeyer_10SPE_01_0916.pdf

Table 8-3.7 Thick Cable: Data Pair Specification

Physical Characteristics	Specification
Conductor pair size	#18 Copper (minimum); 19 strands min (individually tinned)
Insulation diameter	0.150 inches (nominal)
Colors	Light Blue White
Pair Twist/ft	3 (approx.)
Tape shield over pair	2 mil / 1 mil, Al / Mylar Al side out w/shorting fold (pull-on applied)
Electrical Characteristics	**Specification**
Impedance	120 Ohms +/- 10% (at 1 MHz)
Propagation delay	1.36 nSec/ft (maximum)
Capacitance between conductors	12 pF / ft. at 1 kHz (nominal)
Capacitance between one conductor and other conductor connected to shield.	24 pF / ft. at 1 kHz (nominal)
Capacitive unbalance	1200 pF/1000 ft at 1 kHz (nominal)
DCR - @ 20 deg C	6.9 Ohms/1000 ft (maximum)
Attenuation:	0.13 db/100 ft @ 125 kHz (maximum) 0.25 db/100 ft @ 500 kHz (maximum) 0.40 dB/100ft@1.00MHz (maximum)

Table 8-3.12 Thin Cable: Data Pair Specifications

Physical Characteristics	Specification
Conductor pair size	#24 Copper (minimum); 19 strands minimum (individually tinned)
Insulation diameter	0.077 inches (nominal)
Colors	Light Blue White
Pair Twist/ft	5 (approximately)
Tape shield over pair	1 mil / 1 mil, Al / Mylar Al side out w/shorting fold (pull-on applied)
Electrical Characteristics	**Specification**
Impedance	120 Ohms +/- 10% (at 1 MHz)
Propagation delay	1.36 nSec/ft (maximum)
Capacitance between conductors	12 pF / ft. at 1 kHz (nominal)
Capacitance between one conductor and other conductor connected to shield.	24 pF / ft. at 1 kHz (nominal)
Capacitive unbalance	1,200 pF/1000 ft at 1 kHz (maximum)
DCR - @ 20 C	28 Ohms/1000 ft (maximum)
Attenuation:	0.29 db/100 ft @ 125 kHz (maximum) 0.50 db/100 ft @ 500 kHz (maximum) 0.70 dB/100 ft @1.00 MHz (maximum)