PEG PROTECTION ENGINEERS GROUP

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Single twisted pair Ethernet and powering to 1 km and more

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Session 3: *Changing Standards and Codes and How They Impact You*
February 24, 2021

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- Overview of Ethernet two-pair and four-pair reach, data rates, connections and IEEE 802.3bt Class code matrix for Power over Ethernet (PoE)
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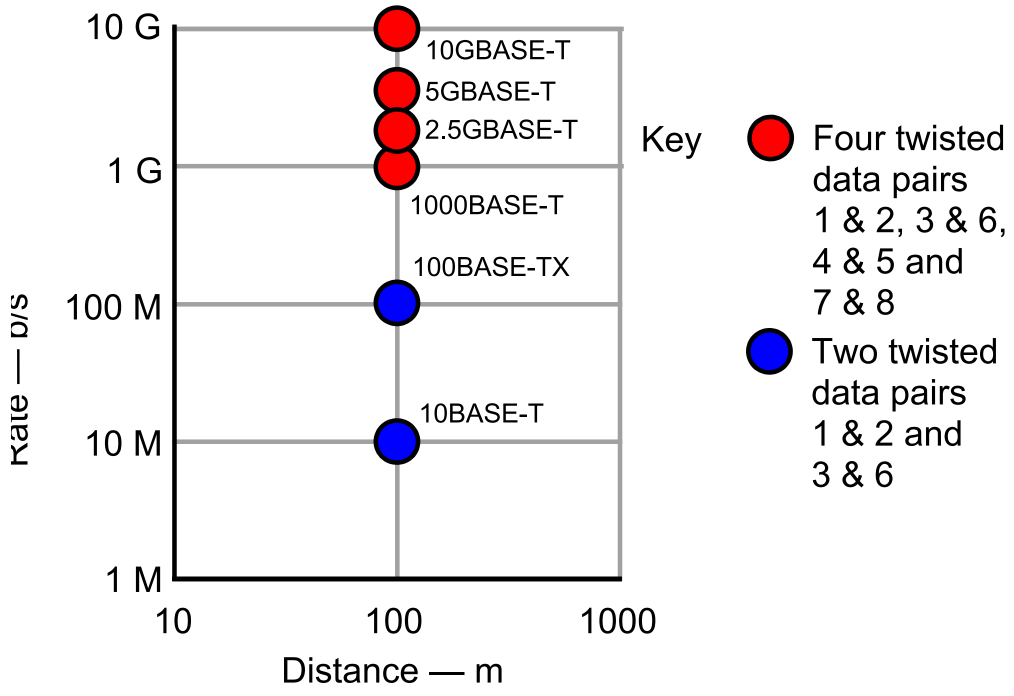
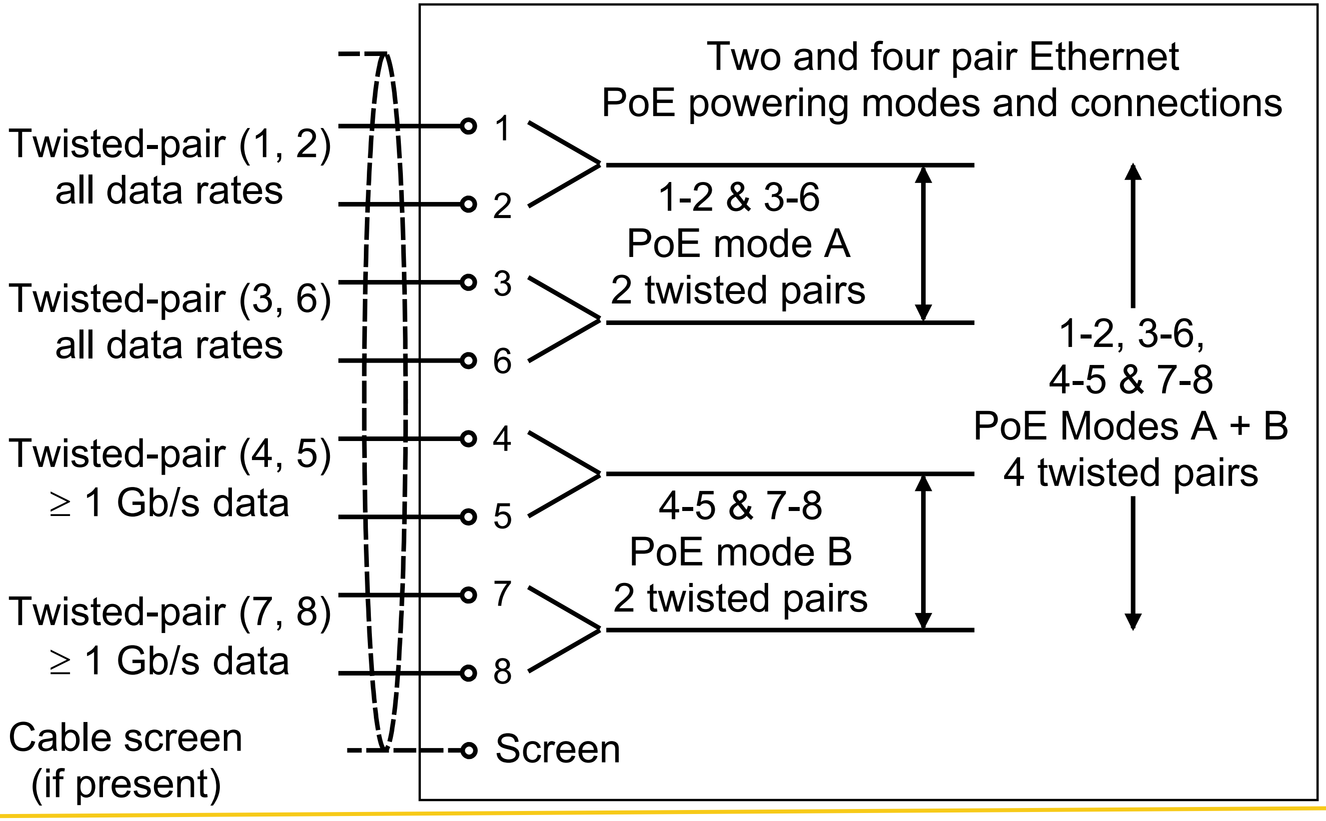
- SPE Industrial (10BASE-T1L) configuration, Class power versus segment length, supporting hardware, protection needs and approaches.
- Bibliography of presentation topics (not presented)

Overview of Ethernet two-pair and four-pair reach, data rates and connections





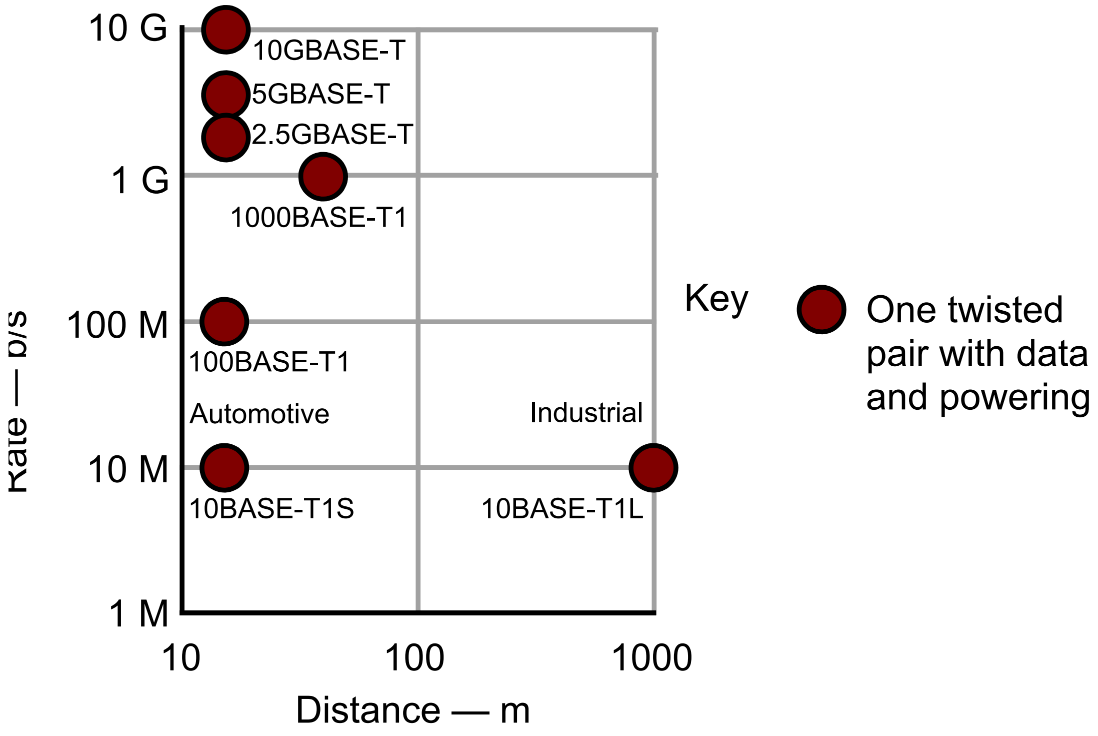
IEEE 802.3bt Class code matrix for Power over Ethernet (PoE)

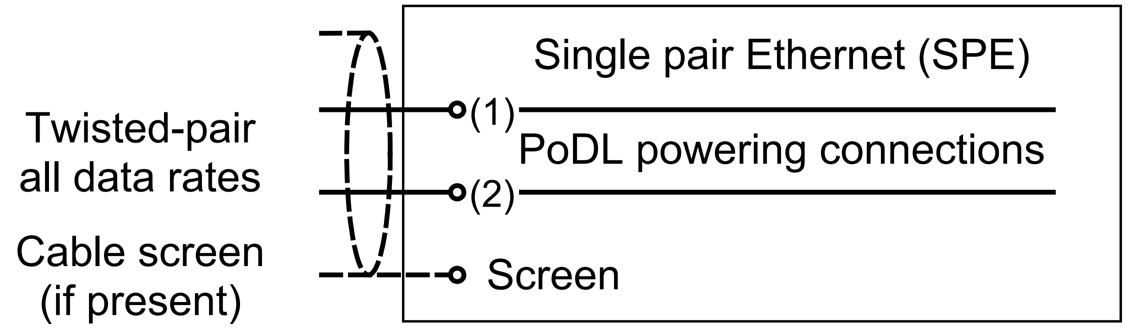
Table complied from IEEE 802.3 Tables 33–11, 145–16, 145–26, 145–27 and 145–29

PoE Class code	PSE Type	PSE maximum voltage V	PSE Type minimum voltage V	PSE nominal power W[c]	Powering pairs used	Total current A	PD minimum voltage V	PD maximum power W[c]	Loop Resistance maximum Ω [a]
0	No PD Type signature, defaults to Class 3								
1	1, 2, 3, 4	57	44, 50, 50, 52	4	2	0.09	42.8	3.84	20
2	1, 2, 3, 4	57	44, 50, 50, 52	7	2	0.15	42	6.49	20
3	1, 2, 3, 4	57	44, 50, 50, 52	14	2	0.33	39.9	13	20
4	2, 3, 4	57	50, 50, 52	30	2	0.60	42.5	25.5	12.5
5[b]	3, 4	57	50, 52	45, 43	4, 2×2	0.90, 0.87 (2×2)	44.3, 41.1 (2×2)	40, 35.6 (2×2)	6.25, 2×12.5
6	3, 4	57	50, 52	60	4	0.87	42.5	51	6.25
7	4	57	52	75	4	1.20	42.9	62	6.25
8	4	57	52	90	4	1.45	41.1	71.3	6.25

[a] Maximum DC twisted-pair loop resistance from IEEE 802.3 Table 33–1 (Types 1 & 2) and IEEE 802.3cg Annex 145C (Types 3 & 4)
[b] Class 5 power feeds can be 4 pairs or 2×2 pairs operation
[c] Power Sourcing Equipment (PSE) allocated power values and Powered Device (PD) requested power values may be software adjusted

Overview of single-pair Ethernet (SPE) reach, data rates and connections (power over data line = PoDL)



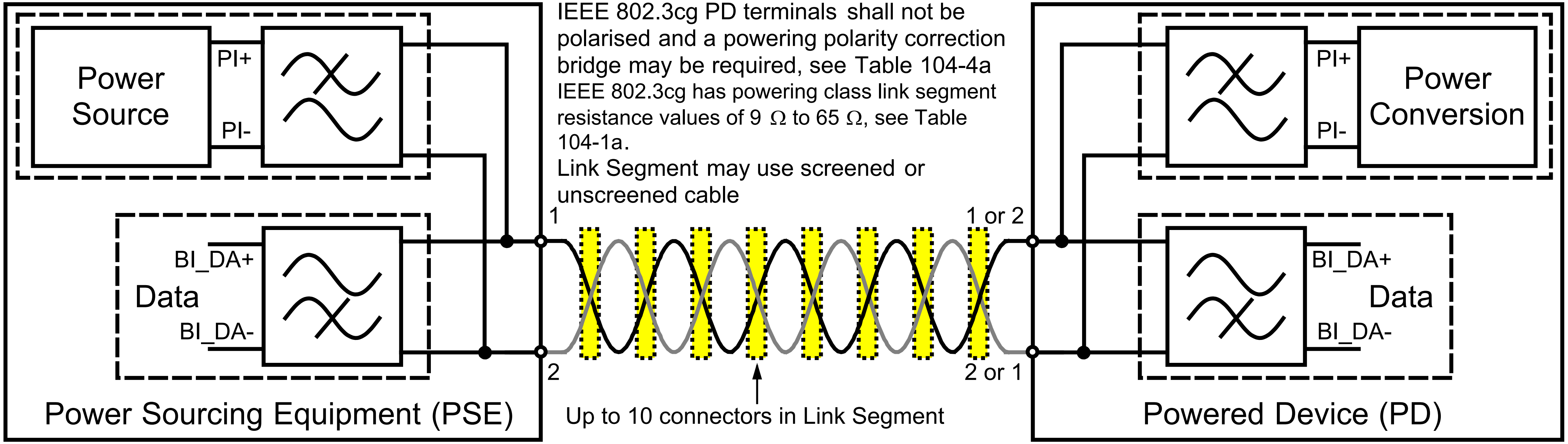


SPE Class code matrix for Power over Data Line (PoDL)

Table complied from IEEE 802.3 Table 104–1 and Table 104–1a

PoDL Class Code	PSE (max) V	PSE (min) V	Current mA	PD (min) V	PD W	Loop Resistance maximum Ω	PSE Notes	Standard
0	18	5.6	101	4.94	0.5	6	12 V unregulated	IEEE 802.3cg 104.2 Link segment for resistance IEEE 802.3-2018 Table 104–1
1	18	5.77	227	4.41	1	6		
2	18	14.4	249	12	3	6.5	12 V regulated	
3	18	14.4	471	10.6	5	6.5		
4	36	11.7	97	10.3	1	6.5	24 V unregulated	
5	36	11.7	339	8.86	3	6.5		
6	36	26	215	23.3	5	6.5	24 V regulated	
7	36	26	461	21.7	10	6.5		
8	60	48	735	40.8	30	6.5	48 V regulated	
9	60	48	1360	36.7	50	6.5		
10	30	20	92	14	1.23	65	25 V nominal	IEEE 802.3cg 104.2 Link segment for resistance IEEE 802.3cg-2019 Table 104–1a
11	30	20	240	14	3.2	25		
12	30	20	632	14	8.4	9.5		
13	58	50	231	35	7.7	65	54 V nominal	
14	58	50	600	35	20	25		
15	58	50	1579	35	52	9.5		

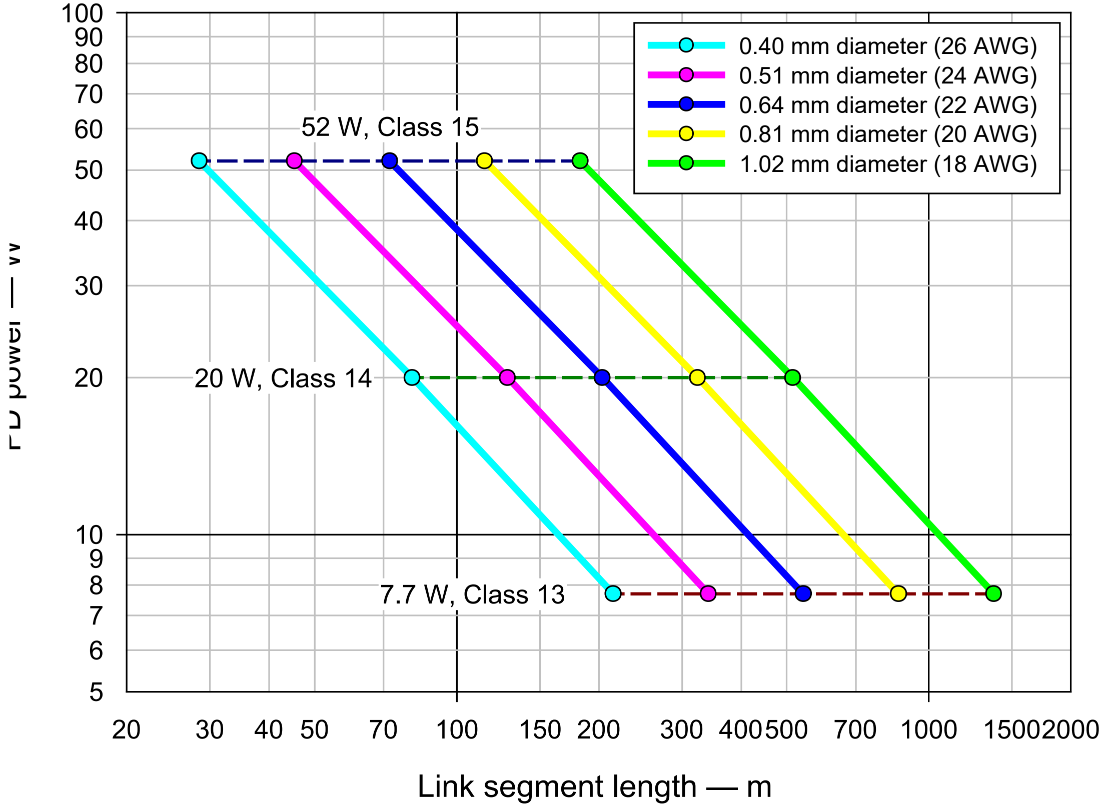
SPE Industrial (10BASE-T1L) configuration



Power Source may be floating or earthed/grounded

SPE Industrial (10BASE-T1L) Class power versus segment length

PSE voltage 50 V to 58 V



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SPE Industrial (10BASE-T1L) supporting hardware

Connectors,
(screened, unscreened)
Cable
(screened, unscreened)

SPE Equipment — mainly for short distance automotive applications

Physical Layer Transceiver (PHY) — Several announced, some using the 2.4 $V_{pk\text{-}pk}$ signal level of the 1 $V_{pk\text{-}pk}$/2.4 $V_{pk\text{-}pk}$ options claim over 1 km reach

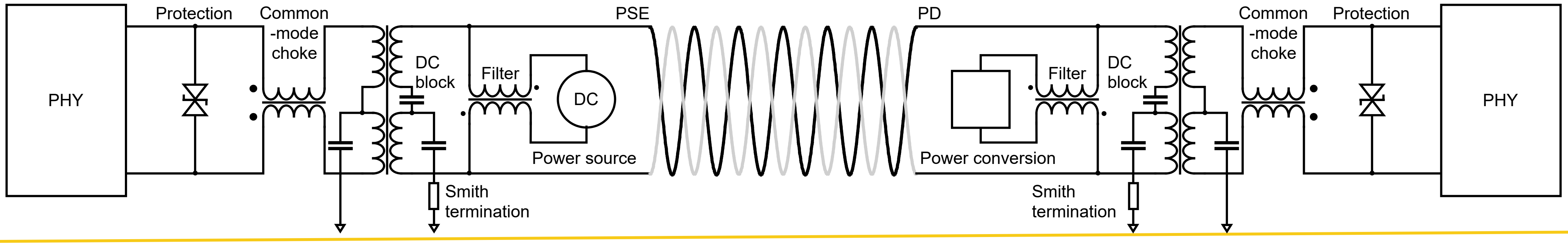
Surge Protection — Where shown only the PHY is protected, suitable link segment SPDs are not in evidence

SPE (10BASE-T1L) Surge Protection

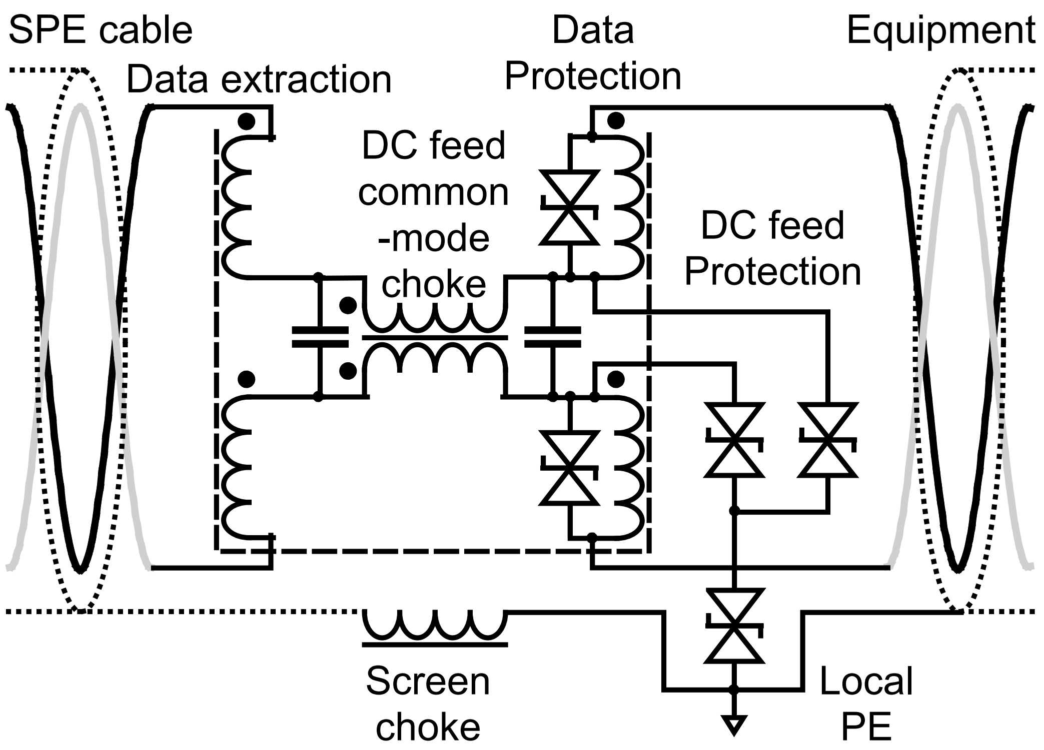
- Surges can couple to a system in four ways; directly (Earth potential rise (EPR), flashover, SPD operation), by magnetic induction, electrical fields (capacitively) and electromagnetically. These are described in ITU-T Recommendation K.147: *Ethernet port resistibility testing for overvoltages and overcurrents*.
- The 2016 ATIS PEG presentation *Loop Currents Caused by Lightning-Induced Induction and GPR* (A. Martin) gave examples EPR and magnetically induced voltage levels
- Pretorius, P.H. *Behaviour of surge protective devices under lightning ground potential rise: Findings from a desk-top study* gave EPR values of 60 kV for high resistivity soil.
- Sekioka et al., *Lightning Overvoltages on Low Voltage Circuit Caused by Ground Potential Rise*, gave induced transient values of 6 kV and 4 kA.
- At 1 km link segment length, industrial SPE values of 10 kV EPR and 6 kV magnetically induced transient voltage are possible.

SPE (10BASE-T1L) use of chokes

- IEEE standard 1692 observes that when there is a transient EPR event, an SPD can conduct providing a connection to the communication path in the reverse direction from which the SPD was intended to operate. This action increases the possibility of equipment damage in communications and power installations. Series protection chokes can increase the transient loop impedance and mitigate voltage and current stress levels.
- Common-mode chokes (two winding cokes) mitigate common-mode surge events.
- Series filter chokes can be used to stop the SPE PoDL power feeds from loading the Ethernet signal path.
- SPE system block diagram from Harting with common-mode and filter chokes shown below:

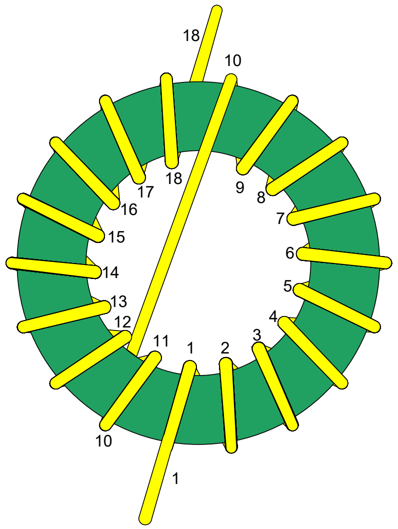


SPE Industrial (10BASE-T1L) SPDs



Left is a proposed SPD that has voltage limiting for data and the DC feed. Common-mode surges are mitigated by the chokes and the isolation transformer. A single voltage limiter to PE prevents differential surge generation

Right is a quick and dirty common-mode choke SPD can made by winding the Ethernet cable around a suitable magnetic toroid. Note the example winding position change on turn 10 to minimise capacitance



SPE Industrial (10BASE-T1L)

Thank you for viewing this presentation on Industrial Single twisted pair Ethernet (IEEE 802.3cg, 10BASE-T1L)

In summary, by having a reach capability of 10× the normal 100m, long reach SPE technology is developing fast, far beyond it's original short-distance automotive roots, into many different application areas.

The following unpresented Bibliography pages provide more information on the topics of SPE general, IEEE Standards, Papers & ITU-T Recommendations, EPR materials, SPE cable standards, SPE connector standards, Chokes and 2007-2021 ATIS PEG Ethernet presentations.

Bibliography – SPE General

- SPE Industrial Partner Network, https://www.single-pair-ethernet.com/en
- IEEE P802.3cg 10Mb/s Single Pair Ethernet: A guide, https://www.ieee802.org/3/cg/public/Jan2019/Tutorial_cg_0119_final.pdf
- Commscope, Single balanced twisted-pair cabling infrastructure for IoT (Internet of Things) and M2M (Machine to Machine) connectivity, https://www.commscope.com/globalassets/digizuite/3288-single-twisted-pair-ethernet-white-paper-wp-111821-en.pdf
- Texas Instruments, Leveraging Single-Pair Ethernet in Building Automation, https://www.ti.com/lit/wp/snla360/snla360.pdf
- Texas Instruments, (SPE Automotive) Daisy-Chained Power and Data Over Single Pair Ethernet (T1) Reference Design, https://www.ti.com/lit/ug/tiduet1/tiduet1.pdf
- Single Pair Ethernet, https://www.weidmueller.com/int/solutions/single_pair_ethernet/index.jsp

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- IEEE Std 1692-2011: *IEEE Guide for the Protection of Communication Installations from Lightning Effects*.
- IEEE 802.3-2018 - *IEEE Standard for Ethernet*.
- IEEE 802.3cg-2019: IEEE Standard for Ethernet - *Amendment 5: Physical Layer Specifications and Management Parameters for 10 Mb/s Operation and Associated Power Delivery over a Single Balanced Pair of Conductors.*
- IEEE C62.42.0-2016: *IEEE Guide for the Application of Surge-Protective Components in Surge-Protective Devices and Equipment Ports—Overview*
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- Dr. A. R. Martin, "*Effects of Lightning on ICT Circuit — Induction and GPR/GCR*" 2016 ATIS Protection Engineers Group (PEG): Electrical Protection of Communications Networks Conference
- ITU-T Recommendation K.147: *Ethernet port resistibility testing for overvoltages and overcurrents*.
- ITU-T Recommendation K.117: *Primary protector parameters for the surge protection of equipment Ethernet ports*
- ITU-T Recommendation K.96: *Surge protective components: Overview of surge mitigation functions and technologies*
- ITU-T Recommendation K.95: *Surge parameters of isolating transformers used in telecommunication devices and equipment*
- K Suppl. 23: Ethernet port surge voltages and currents

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- ISO 11801-3 amendment 1 containing additional single pair requirements for industrial environments like factory automation and process control.
- ISO 11801-6 amendment 1 with additional guidelines for single-pair cabling supporting distributed services such as building automation systems, alarms and access control
- IEC 61156-11 horizontal cables specified up to 600 MHz (26 AWG to 22 AWG)
- IEC 61156-12 drop cables specified up to 600 MHz (26 AWG to 22 AWG)
- IEC 61156-13 horizontal cables specified up to 20 MHz (20 AWG to 16 AWG)
- IEC 61156-14 drop cables specified up to 20 MHz (20 AWG to 16 AWG)

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  - IEC 63171-4: Part 4: Detail specification for 2-way, shielded or unshielded, free and fixed connectors: mechanical mating information, pin assignment and additional requirements for type 4
  - IEC 63171-6:2020, Part 6: Detail specification for 2-way and 4-way (data/power), shielded, free and fixed connectors for power and data transmission with frequencies up to 600 MHz.

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- KF7P Metalwerks, Ferrite choke kits for coax, USB, and Ethernet, https://www.kf7p.com/KF7P/RF_chokes.html
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  Latest ITU-T Surge Protection K Recommendations: Michael "Mick" Maytum
  Direct Lightning Strike Surge Propagation in Customer Premises Wiring: Michael "Mick" Maytum
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  Protecting PoE PSE and Ethernet to the Latest International OSP Standards: Tim Ardley
- **ATIS PEG Conference 2017 Papers**
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  Voice Protection for ONTs Using ECL and Crowbar Devices: Victor Wong

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  Considerations and Pitfalls of External Ethernet and PoE Protection Devices: Jim Wiese
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