Power Over Ethernet (PoE)
Part 1
What is it?, How is it used?, and Lightning Field Failure Analysis

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What is PoE?

"Definition"

Power over Ethernet (PoE) describes any of several standardized or proprietary Ethernet systems which carry electrical power along with data on Cat 3 or higher type cable. This allows a single 8 conductor cable to provide both data connection and electrical power to devices such as IP Phones, IP Cameras, IP monitoring equipment, and wireless access points. PoE allows data communications up to 100M (≈330 feet). Power may be carried on the same conductors as the data, or it may be carried on dedicated conductors in the same cable. The system or network circuit consists of a PSE (Power Source Equipment) and a PD (Powered Equipment)

What is PoE?

"Characteristics of PoE"

- Similar topology to traditional T1 "Span Powering"
- Uses 2 Pairs for power (10/100 baseT, GigE)
- Proprietary system might supply power on 4 pairs
- Power can be on unused pairs (10/100 baseT) or data pairs
- Mode A and Mode B Powering schemes
- Voltage limits are always under 60 Vdc (SELV, ES1)
- Current and Power are tightly controlled by IEEE standards (IEEE 802.3af & 802.3at)
- Type 1 – Limits PSE output power to 15.4W (af /at)
- Type 2 (PoE+) – Limits PSE output power of 30.0W (at)

What is PoE?

"Characteristics of PoE"

PD Power Level Classes for PoE

Class	Usage	Power range [Watt]	Class description
0	Default	0.44–12.94	Classification unimplemented
1	Optional	0.44–3.84	Very Low power
2	Optional	3.84–6.49	Low power
3	Optional	6.49–12.95	Mid power
4	Valid for 802.3at (Type 2) devices, not allowed for 802.3af devices	12.95–25.50	High power

What is PoE?

"Schematics of PoE"

Mode A and Mode B Powering for 10/100 baseT

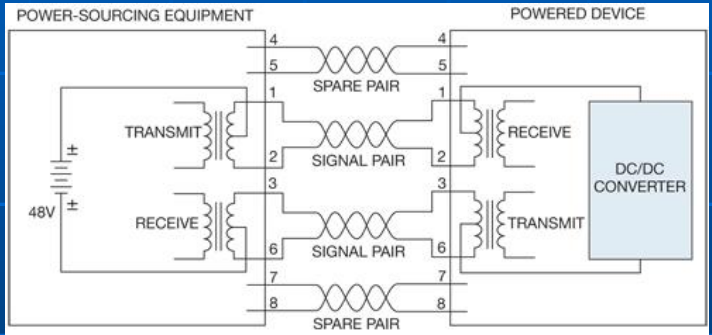


Figure 2 Mode A POE uses the data-signaling pairs 1, 2 and 3, 6, thereby combining the dc voltage with the signal over these data pairs.

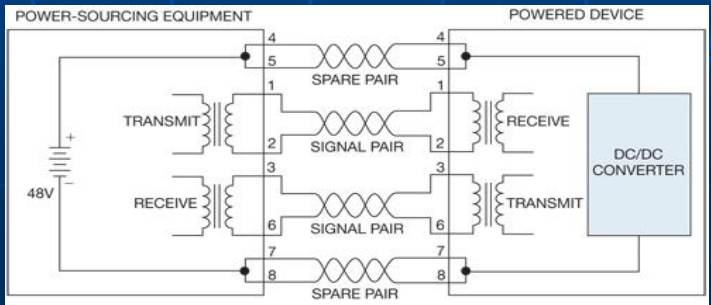
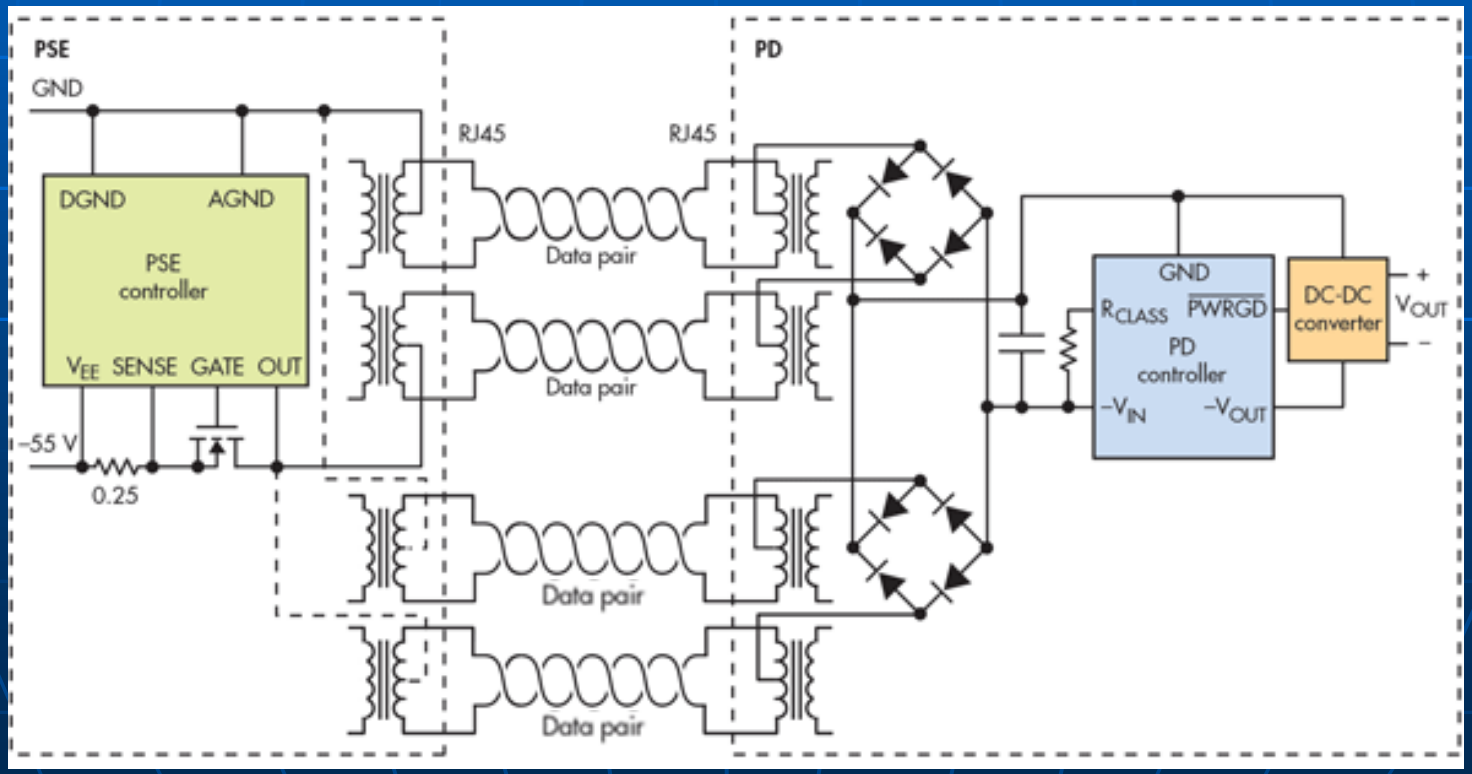


Figure 1 Apply POE Mode B power over the "spare" data pairs in 10 or 100BaseTX systems or over pairs 4 to 5 and 7 to 8 of a 1000BaseT system. POE uses the phantom powering technique so that a pair carries a 0V potential difference between its leads; power-supply voltage is the difference between two wire pairs.

What is PoE?

"Schematics of PoE"

Powering for GigE



What is PoE?

"Wiring of PoE"

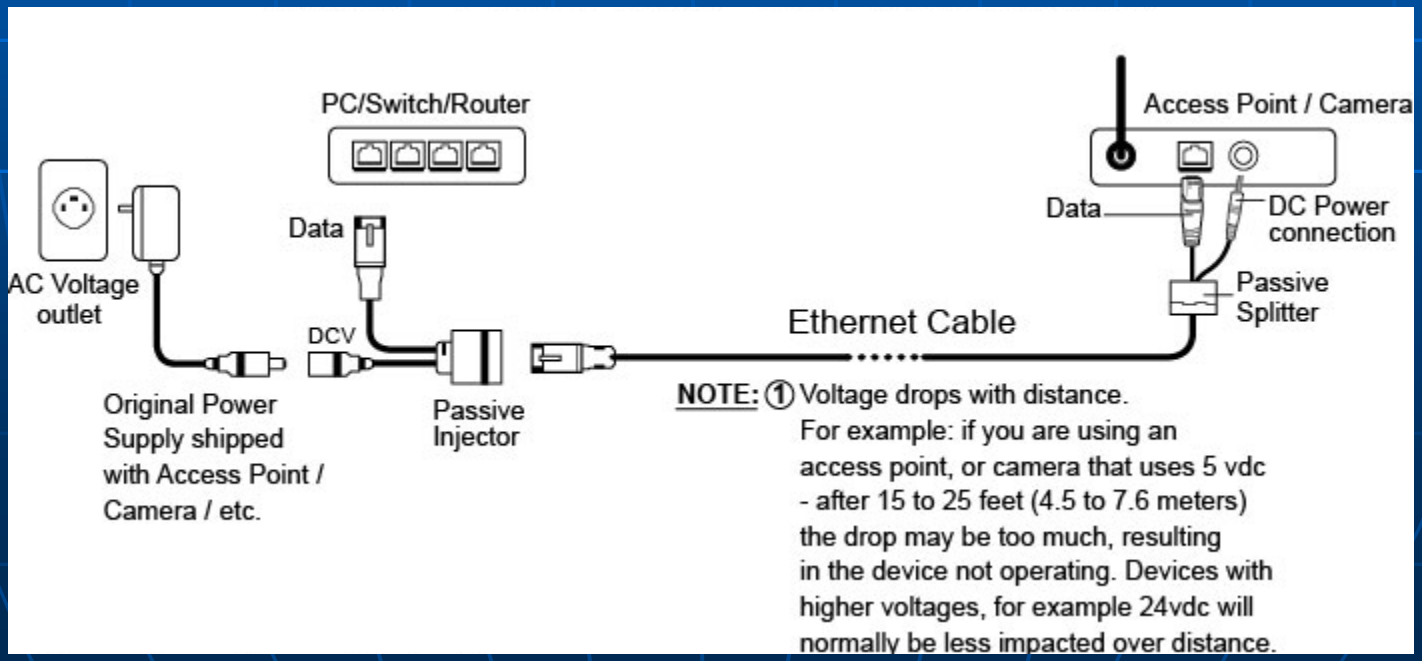
Mode A and Mode B Wiring and Pinouts

802.3af Standards A and B						
PINS on Switch	T568A Color	T568B Color	10/100 DC on Spares (mode B)	10/100 Mixed DC & Data (mode A)	1000 (1 Gigabit) DC & Bi-Data (mode B)	1000 (1 Gigabit) DC & Bi-Data (mode A)
Pin 1	white/green stripe	white/orange stripe	Rx +	Rx + DC +	TxRx A +	TxRx A + DC +
Pin 2	green solid	orange solid	Rx -	Rx - DC +	TxRx A -	TxRx A - DC +
Pin 3	white/orange stripe	white/green stripe	Tx +	Tx + DC -	TxRx B +	TxRx B + DC -
Pin 4	blue solid	blue solid	DC +	unused	TxRx C + DC +	TxRx C +
Pin 5	white/blue stripe	white/blue stripe	DC +	unused	TxRx C - DC +	TxRx C -
Pin 6	orange solid	green solid	Tx -	Tx - DC -	TxRx B -	TxRx B - DC -
Pin 7	white/brown stripe	white/brown stripe	DC -	unused	TxRx D + DC -	TxRx D +
Pin 8	brown solid	brown solid	DC -	unused	TxRx D - DC -	TxRx D -

What is PoE?

"Alternative method of PoE Power injection"

In certain instances, the PC, switch or router only have regular Ethernet ports without PoE. In those cases a PoE midspan injector can be used.



What is PoE?

”Handshaking, Protection and Powering Protocol”

- The PSE, not the PD, decides whether power mode A or B shall be used.
- PDs that implement only Mode A or Mode B are disallowed by the standard.
- The PSE can implement mode A or B or both.
- A PD indicates that it is standards-compliant by placing a 25 kΩ resistor between the powered pairs.
- If the PSE detects a resistance that is too high or too low (including a short circuit), no power is applied. This protects devices that do not support PoE.
- An optional "power class" feature allows the PD to indicate its power requirements by changing the sense resistance at higher voltages.
- To stay powered, the PD must continuously use 5–10 mA for at least 60 ms with no more than 400 ms since last use, or else it will be unpowered by the PSE.

What is PoE?

”Handshaking, Protection and Powering Protocol”

The setup Handshaking and phases are as follows:

- PSE tests PD for physical presence.
- PSE powers up PD.
- PD sends to PSE: I'm a PD, max power = X, max power requested = X.
- PSE sends to PD: I'm a PSE, max power allowed = X.
- PD may now use the amount of power as specified by the PSE.

What is PoE?

”Handshaking, Protection and Powering Protocol”

The rules for this power negotiation are:

- PD shall never request more power than allowed by the physical “class”
- PD shall never draw more than max power rated by PSE
- PSE may deny any PD attempting to draw more power than the maximum allowed by PSE
- PSE shall not reduce power allocated to a PD that is in use
- PSE may *request* reduced power, via conservation mode

What is PoE?

”Cable I²R (power) loss Considerations”

Cable Considerations

- Cat 3 Ethernet cable typically uses 24-26 AWG conductors
- Cat 5 Ethernet cable typically uses 24 AWG conductors
- Cat 6 & 7 Cable typically uses 22-23 AWG
- Beware of new short haul Cat 6 & Cat 7 which can be 26AWG!
- The cable has eight conductors (only half of which are used for power)
- One pair has current going one way and the other pair returns the current
- The absolute allowed maximum power transmitted is
  30W, 50 V × 0.600 A (per 802.3at).
- Maximum resistance per 100 m loop (using 2 conductors) at 25° C
  - 26 AWG ≈ 16Ω
  - 24 AWG ≈ 10Ω
  - 23 AWG ≈ 8Ω
  - 22 AWG ≈ 6.5Ω

Note: these values depend upon strand size, cable vendor, temperature etc.

What is PoE?

”Cable I²R (power) loss Considerations”

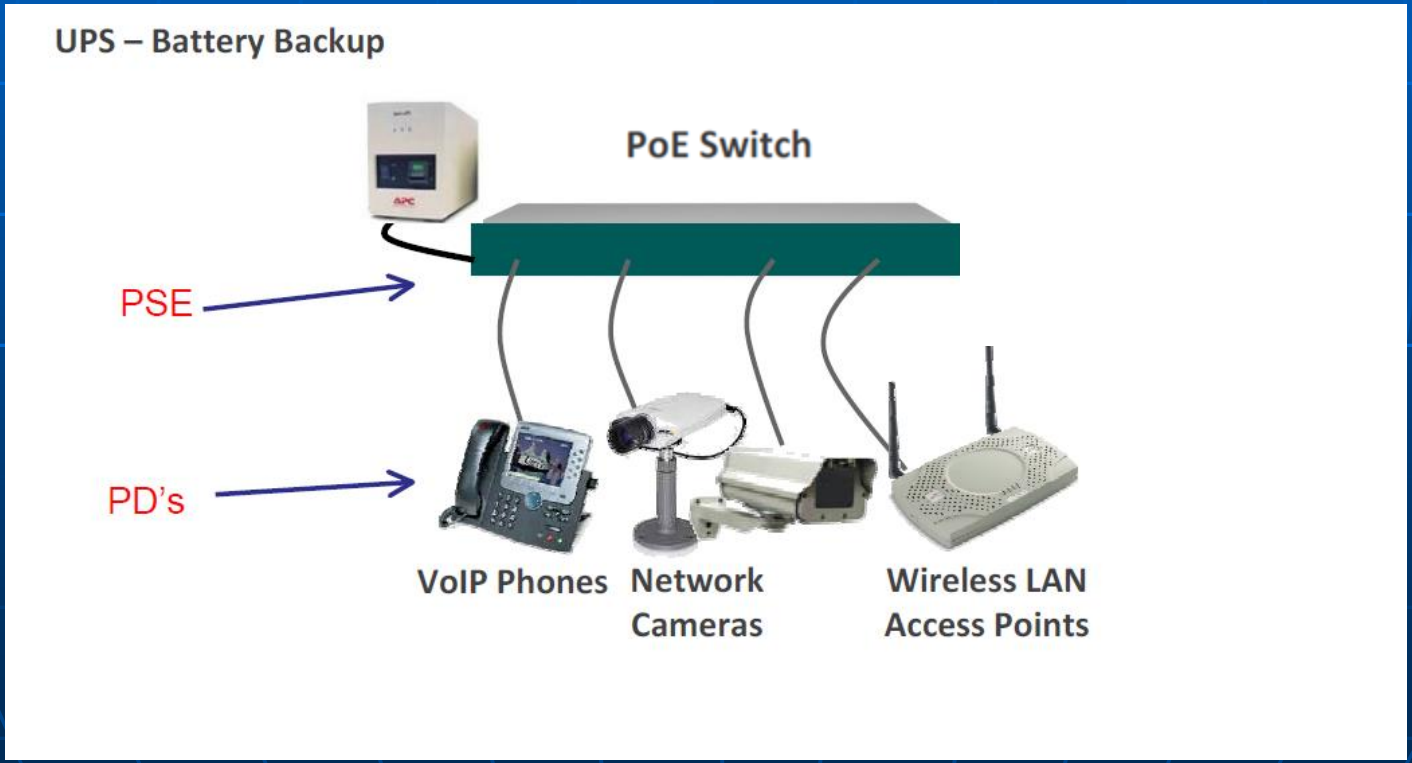
Cable Considerations

- Worst Case Power Loss in Cable
  - 26 AWG = 19Ω x .600 x.600 = 5.76 W
  - 24 AWG = 12.5Ω x .600 x.600 = 4.50 W
  - 23 AWG = 8Ω x .600 x.600 = 2.88 W
  - 22 AWG = 6.5Ω x .600 x.600 = 2.34 W
- This is power that is potentially not available to the PD on long loops.
- This is all based on quality copper conductors, but guess what:
  - there is a proliferation of copper clad aluminum cable being called Cat5 and up.
  - Saves money, but also adds 30-50% more resistance compared to pure copper.
  - More resistance means more cable I²R loss, with less power to the PD!
  - Lots of cheap Chinese knock off cable with fake certifications being reported, with high and inconsistent/un-even resistances in conductor

What is PoE?

”How is PoE used”

Typical Configurations



What is PoE?

”How is PoE used”

Typical PSE’s

What is PoE?

”How is PoE used”

Typical PD’s

What is PoE?

”How is PoE used”

PoE Injector

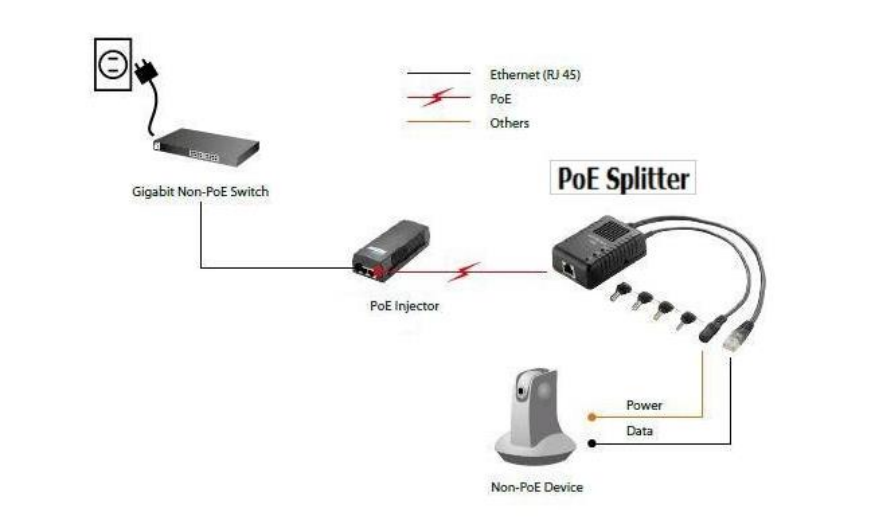
PoE Splitter

PoE Prot/Inj

What is PoE?

”How is PoE used”

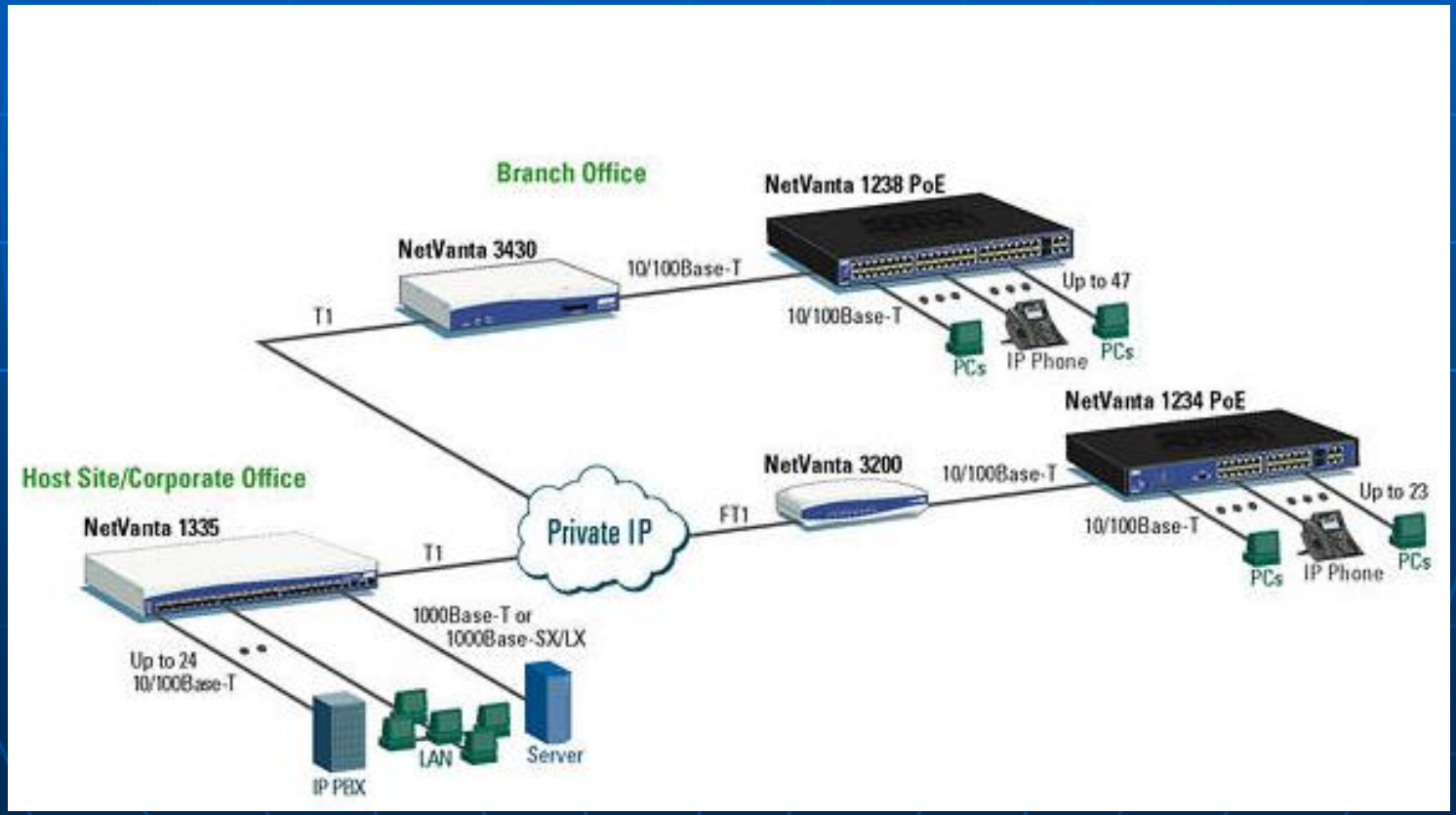
Typical PoE Injector usage



What is PoE?

”How is PoE used”

Typical IP network using PoE



What is PoE?

”Field Problems with PoE”

Background

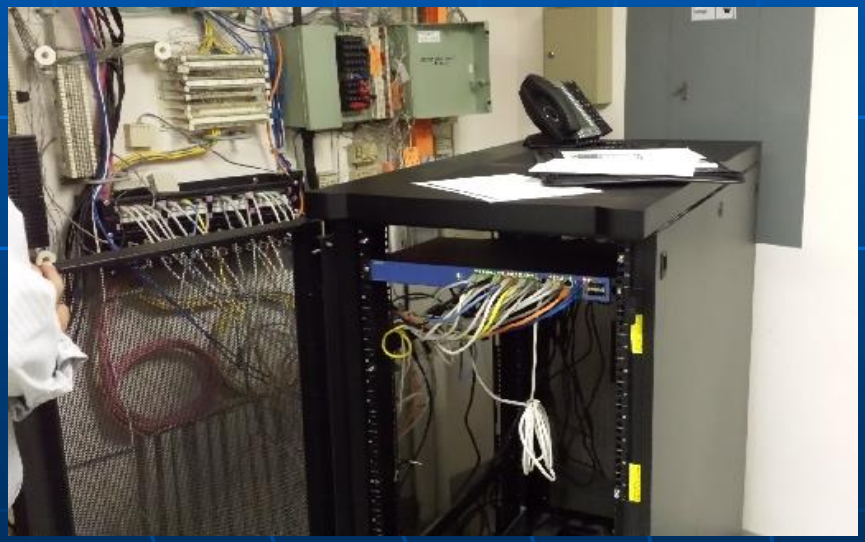
- PoE was intended to stay within a building or structure
- PoE was not intended to have any large electrical voltage potentials or currents from AC Mains switching transients, Induced lightning transients or lightning related GPR imposed on it.
- PoE was intended to be a longitudinally balanced, symmetric, twisted pair, high grade cable insulation system, with at least 2400V impulse isolation to ground (see IEEE 802.3af/at isolation test)
- PoE can be very susceptible to longitudinal impulses, while still complying with options “A” or “B” of the IEEE 802.3 isolation test
- PoE can be very susceptible to electrical impulse transients between powering pairs as well as differentially.
- PoE often has multiple ports, and can be very susceptible to electrical impulse transients between ports (especially GPR’s).

What is PoE?

”Field Problems with PoE”

Problems found in field investigations:

- PoE ports run to out buildings, security shacks, mobile classroom buildings.

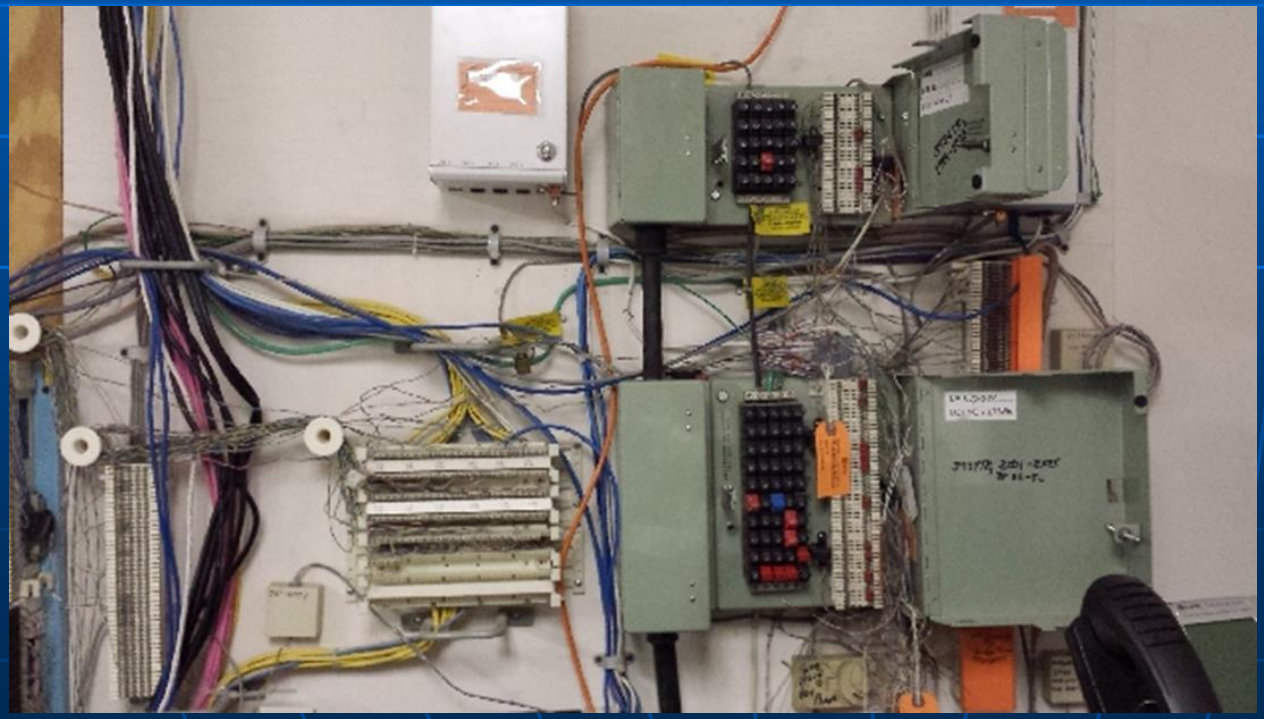


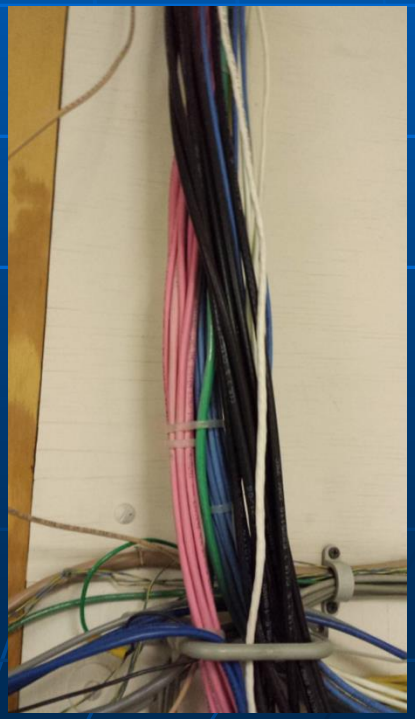
What is PoE?

”Field Problems with PoE”

Problems found in field investigations:

- PoE ports run with cables coupled to Primary Protector Ground wires and OSP Coax cables.





What is PoE?

”Field Problems with PoE”

Problems found in field investigations:

- PoE ports run in close proximity to Electrical Transient Generators (i.e. refrigerator compressor motors).

What is PoE?

”Field Problems with PoE”

Problems found in field investigations:

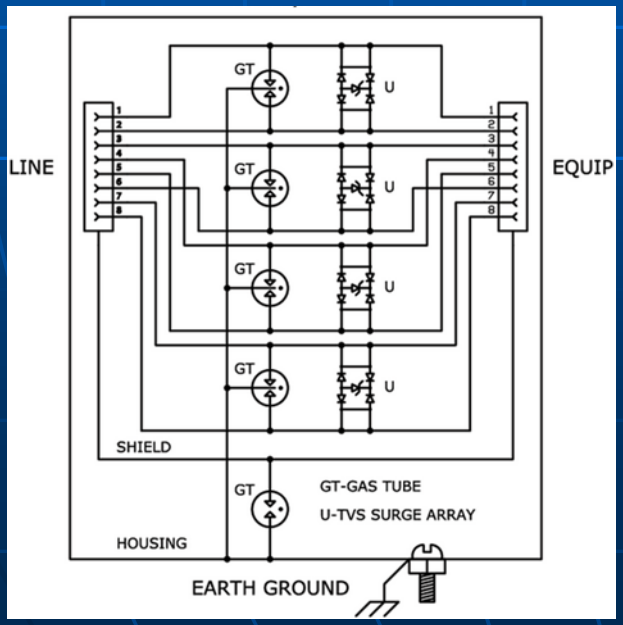
- PoE ports run between buildings (one with welding equipment and also with a grain elevator behind it)

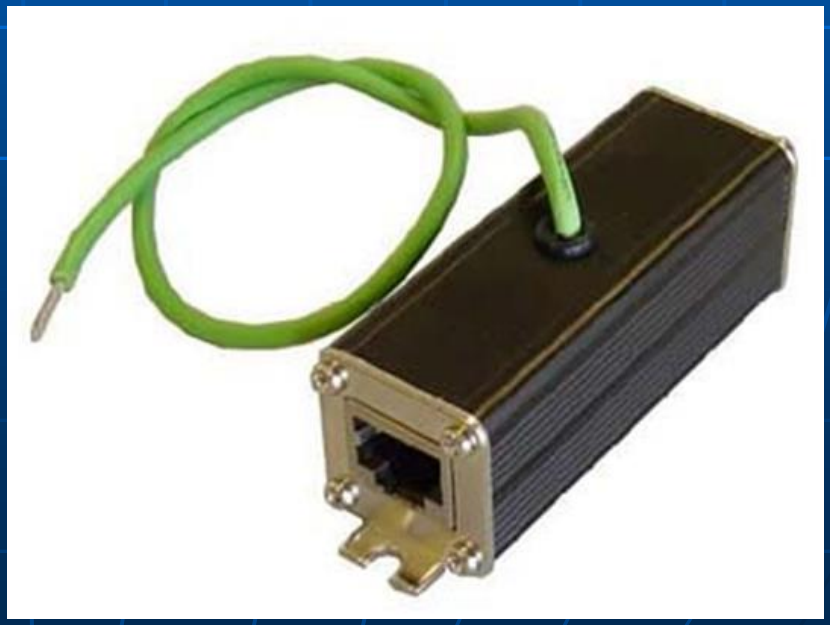
What is PoE?

”Field Problems with PoE”

Problems found in field investigations:

- Customers trying to fix problems or prevent them by adding off the shelf PoE protectors. Most have a ground connection and TVS/Gas tubes that fire to ground and will actually makes things vastly worse



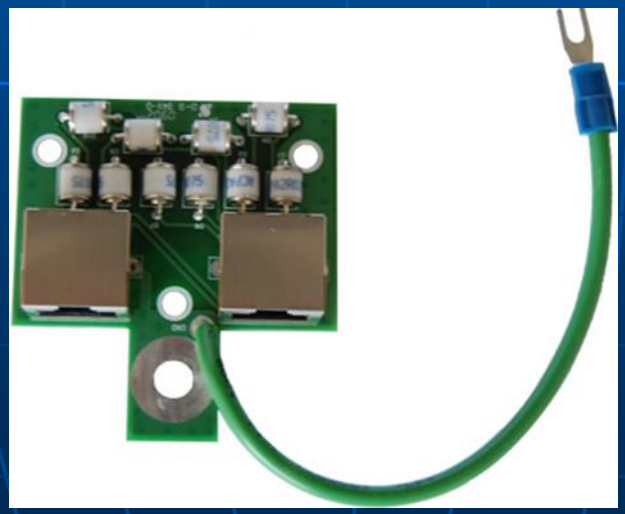


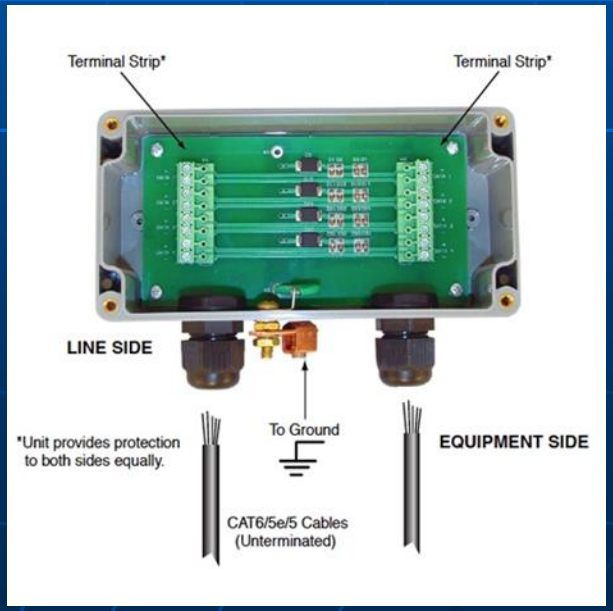
What is PoE?

”Field Problems with PoE”

Problems found in field investigations:

- Customers not realizing they are invalidating the PoE Equipment Listings and potentially violating the NEC.
- Customers unaware they are often using un-Listed or improperly Listed Ethernet or PoE Protectors





What is PoE?

”Field Problems with PoE”

Problems with most PoE Protectors

- Most will cause more damage than they will prevent
- Some don’t protect data pairs, just power pairs
- Most PoE equipment is NRTL safety Listed as “SELV” interfaces (not TNV) and thus MUST be “isolated” from exposure to the OSP or cabling between structures. ADTRAN is only vendor known to offer Ethernet (patented) and PoE (patent pending) protectors that provide true isolation. (>6KV impulse)
- Technically a “non-isolating” protector is not allowed for lightning protection applications.
- If there are electrical transients that could be on a PoE interface the equipment needs to be Listed as TNV. If it is TNV, it would require a UL497A protector . If not TNV the protector would have to have isolation. Only SELV interfaces can have UL497B protectors (no current limiting)
- TVS/gas tube protection to ground, but no current limiting as required by UL-497A.
- Generally no place to connect the ground of the protector
- Most PoE protectors are un-Listed, or listed to the wrong UL-497 standard (typically UL-497B, instead of UL-497A, or UL 497)
- Designed with gas tubes to ground in an OSP enclosure with diagrams showing OSP deployment/exposure and hazardous warnings, yet not Listed to UL-497. How can that meet code???

What is PoE?

”Questions”