“Infrastructure-Grade PoE – Strategies for a Trouble-Free PoE Installation for 2020 and Beyond

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Jason Potterf – Cisco Systems

Agenda – 3.5 Hour Session

- PoE Basics
- Origins and Evolution
- How PoE Works
- IEEE Standard Compliant PoE
  - Break mid-way
- Recognizing PoE as Safe Smart Power vs Non-Compliant PoE
- NFPA 70 – NEC
- PoE and Licensing Legislation - GZ
  - Break
- Designing and Planning for PoE
- Installation and Inspection
- Management and Applications

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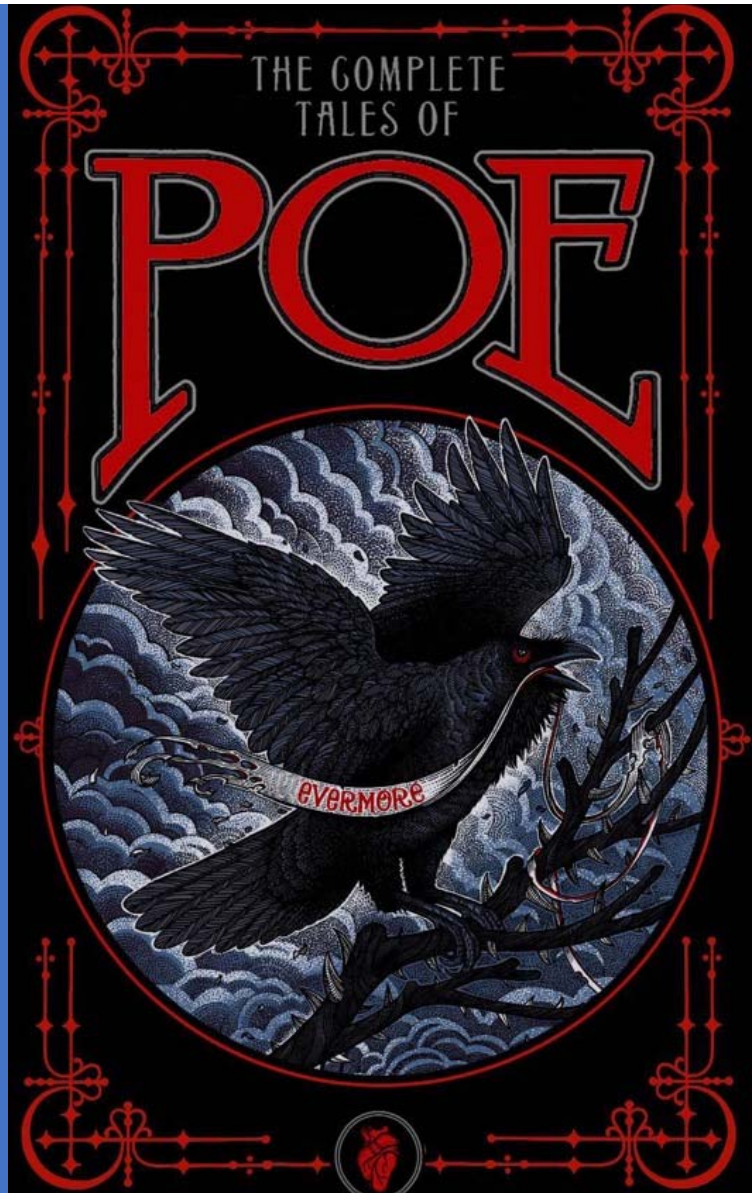
PoE Basics



What is PoE

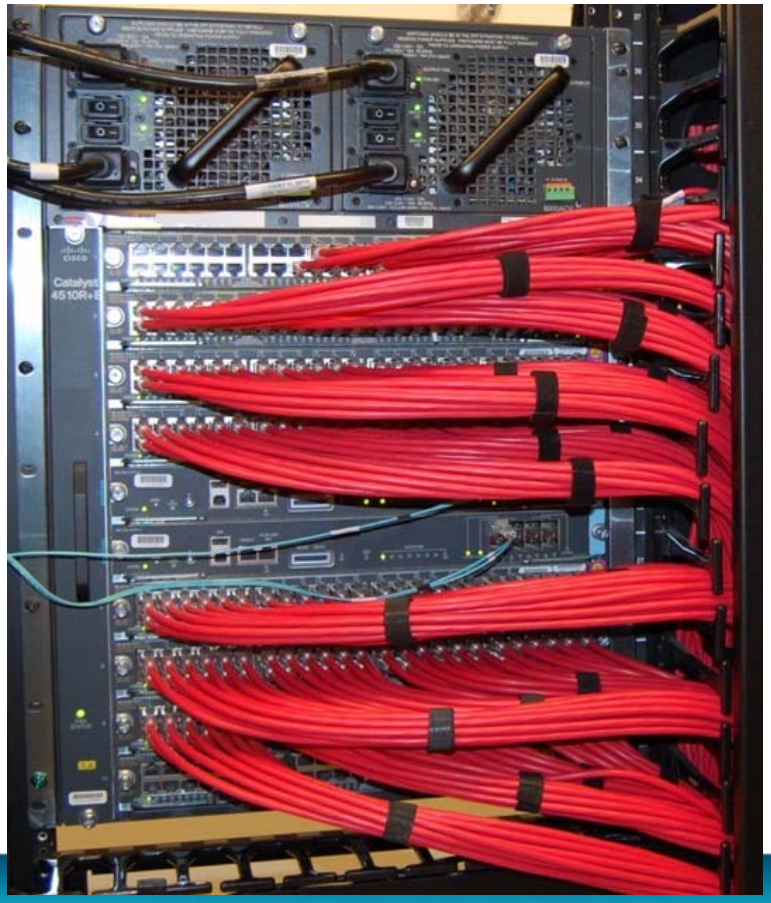
- Simply stated, this is adding power to the same cable that provides Ethernet communications
- Cables that once only carried data now also carry power
- Current will now heat this cable
- These cables are usually bundled and this can exacerbate heating

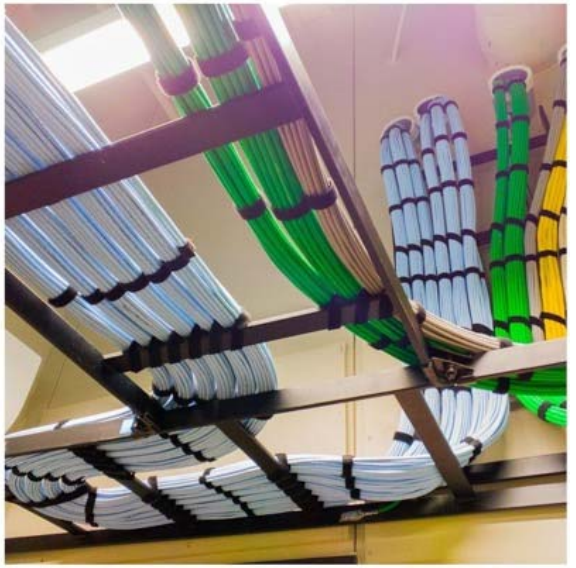
Definitions

- PSE – Power Sourcing Equipment, the power supply
- PD – Powered Device, the load
- Endpoint – PSE integrated into an Ethernet switch
- Midspan – PSE located between a switch and a PD
- Pairset – two complementary pairs in the four-pair Category cable

PoE System

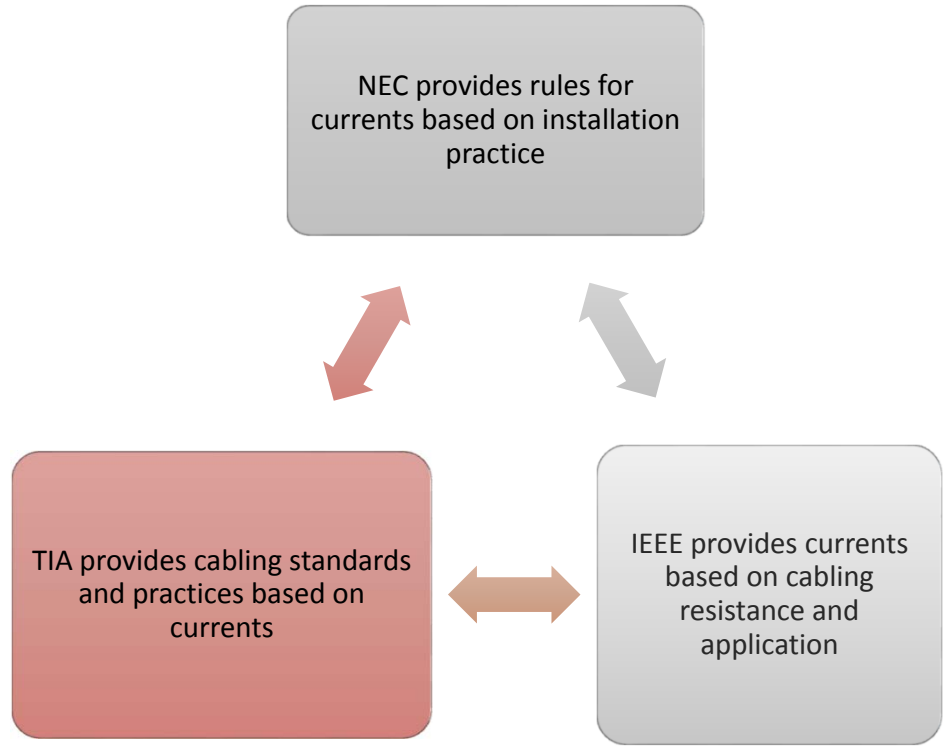
Cable Bundles





PoE related standards

- NEC
  - Defines bundling restrictions, Class 2 Power-Limited Circuits
- TIA TSB-184-A
  - Defines the cabling
- IEEE 802.3
  - Defines interoperability specifications for sources and loads



Origins and Evolution

The IP Phone

PoE, like most innovations, started as a solution to a problem. People were accustomed to a phone being a standalone device – i.e. not needing a separate power supply.

In 1999, Cisco developed a proprietary PoE method to deliver up to 7W for phones.

IEEE 802.3af

- Call for Interest July, 1999
- Ratified 12 June 2003
- 15.4W at the PSE, 12.95W at the PD
- 44V-57V, 350mA
- Classes for 4, 7 and 13W PDs
- Defined over a minimum CAT3 cable system
  - 10/100M Ethernet links
  - 20ohm loop resistance
- 100m maximum distance between PSE and PD

IEEE 802.3at

- Call for Interest November, 2004
- Ratified 30 October 2009
- 30W at the PSE, 25.5W at the PD
- 50V-57V, 600mA
- Introduced Types: Type 1 – 802.3af and Type 2 – 802.3at
- Added Class 4, LLDP, 1000Mbps
- Defined over a minimum CAT5 cable system
  - 10/100/1000 Ethernet links
  - 12.5ohm loop resistance

Cisco UPoE

- Cisco Proprietary method to supply up to 60W from PSE
- Introduced in July 2011
- Uses IEEE 802.3at detection scheme
- Then uses Ethernet communications to negotiate to higher power
- Initial powering is on one pairset. Ethernet negotiation will then enable the second pairset.
- 60W operation is roughly equivalent to two IEEE 802.3at links in one cable

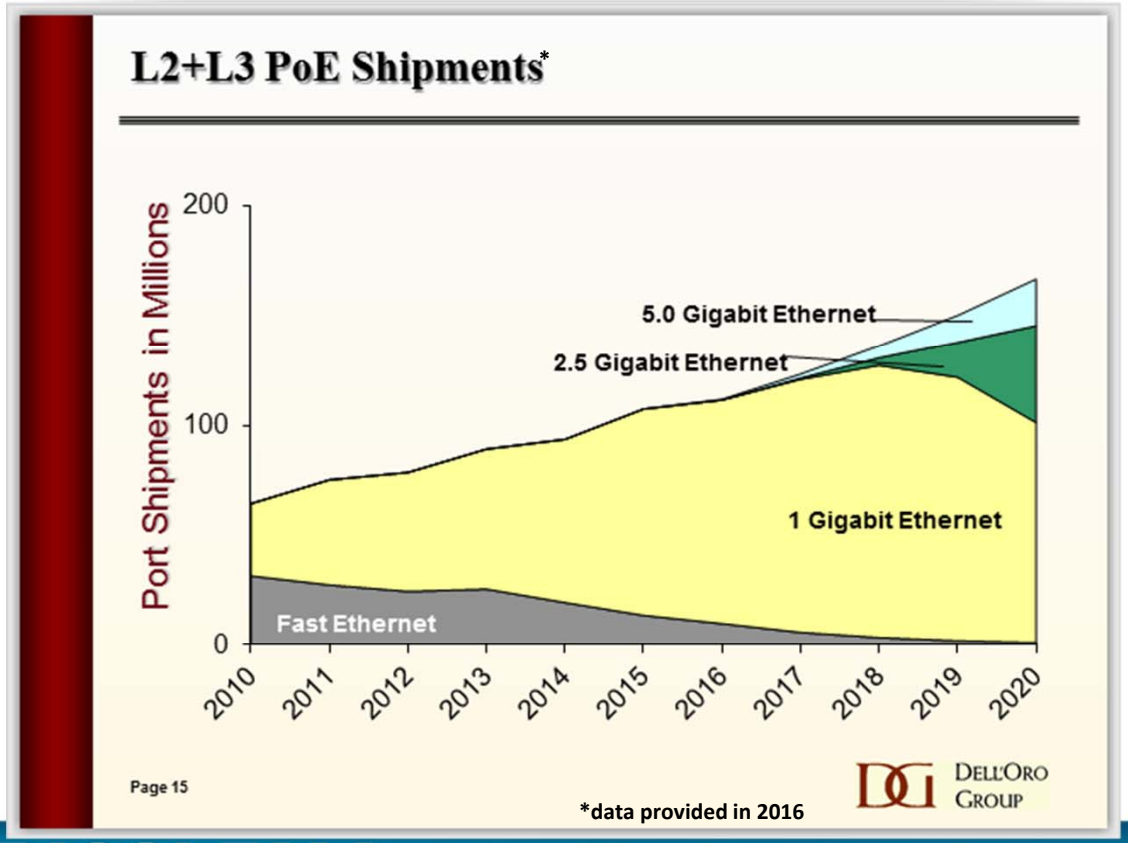
IEEE 802.3bt

- Call for Interest March, 2013
- Ratified 27 September 2018
- Added two additional Types
  - Type 3 – 60W at PSE, 51W at PD
  - Type 4 – 90W at PSE, 71.3W at PD
- Added Classes 5-8, 10Gpbs, introduced connection check, autoclass
- Defined over a minimum CAT5 cable system
  - 12.5ohm pairset loop resistance
- Main focus is to use all 4 pairs in the standard Ethernet cable. 802.3af and 802.3at were intentionally limited to only 2P power.
- Improved standby power: AF/AT: 130mW; BT: 20mW

PoE Development Summary

Standard	Start	Ratified	Classes	Min V	Max V	Max I	PSE Power
IEEE 802.3af	July '99	June '03	0,1,2,3	44V	57V	350mA	15.4W
IEEE 802.3at	Nov '04	Oct '09	0,1,2,3,4	50V	57V	600mA	30W
Cisco UPOE		July '11	NA	50V	57V	1200mA	60W
IEEE 802.3bt	Mar '13	Sep '18	1,2,3,4,5,6,7,8	52V	57V	1732mA	90W

PoE port shipments



- By 2015, port shipments hit 100M ports per year
- 420M ports shipped from 2010 to 2015
- The installed base approaches **ONE BILLION** ports

IEEE 802.3 PSE and PD power by class

Class	PSE Power (W)	PD Power (W)
1	4	3.84
2	7	6.49
3	15.4	13
4	30	25.5
5	45	40
6	60	51
7	75	62
8	90	71.3

How PoE Works

The 1000 foot view

Basic PoE System Diagram, Endpoint

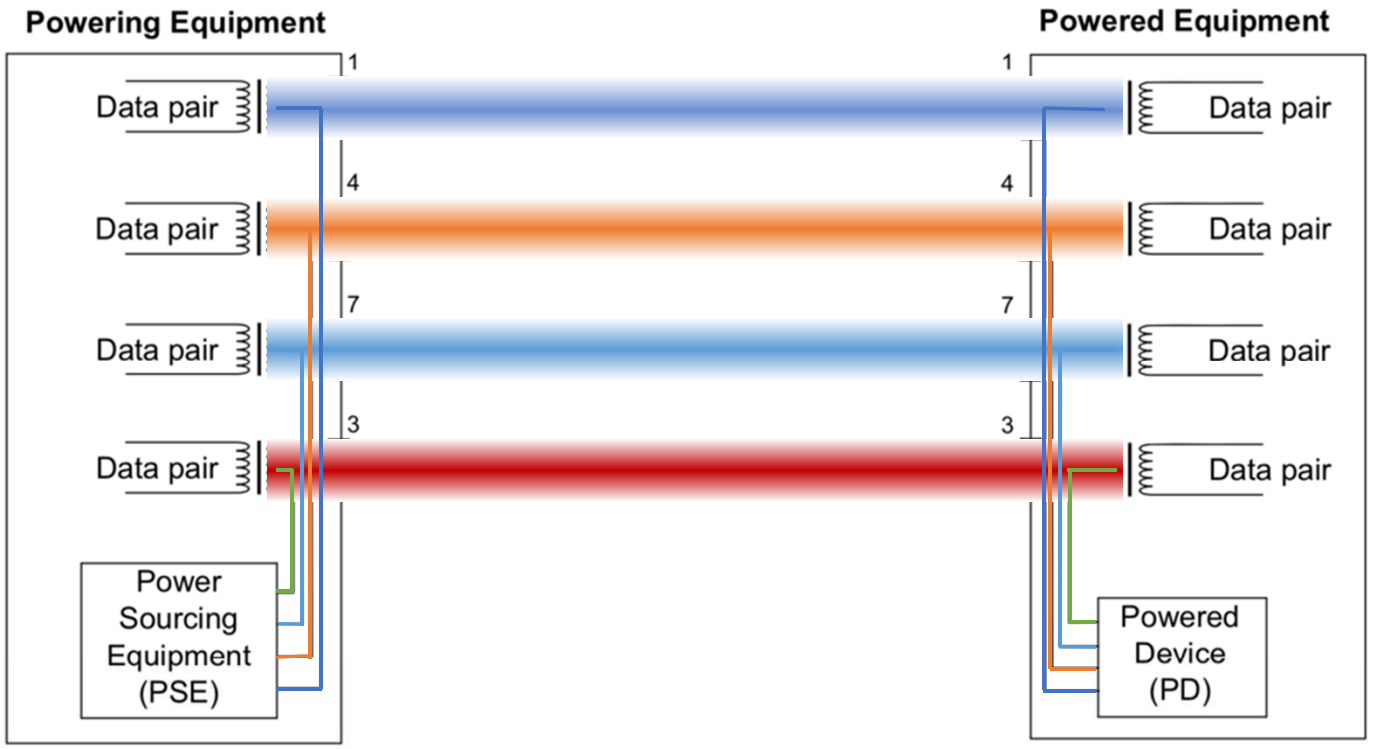


Figure 145–7—1000/2.5G/5G/10GBASE-T 4-pair Endpoint PSE location overview

Power is applied to transformer center taps

This is known as phantom powering

Note there are 4 distinct current paths

Each current path uses two conductors in parallel

Image Source: IEEE 802.3bt

Basic PoE System Diagram, Midspan

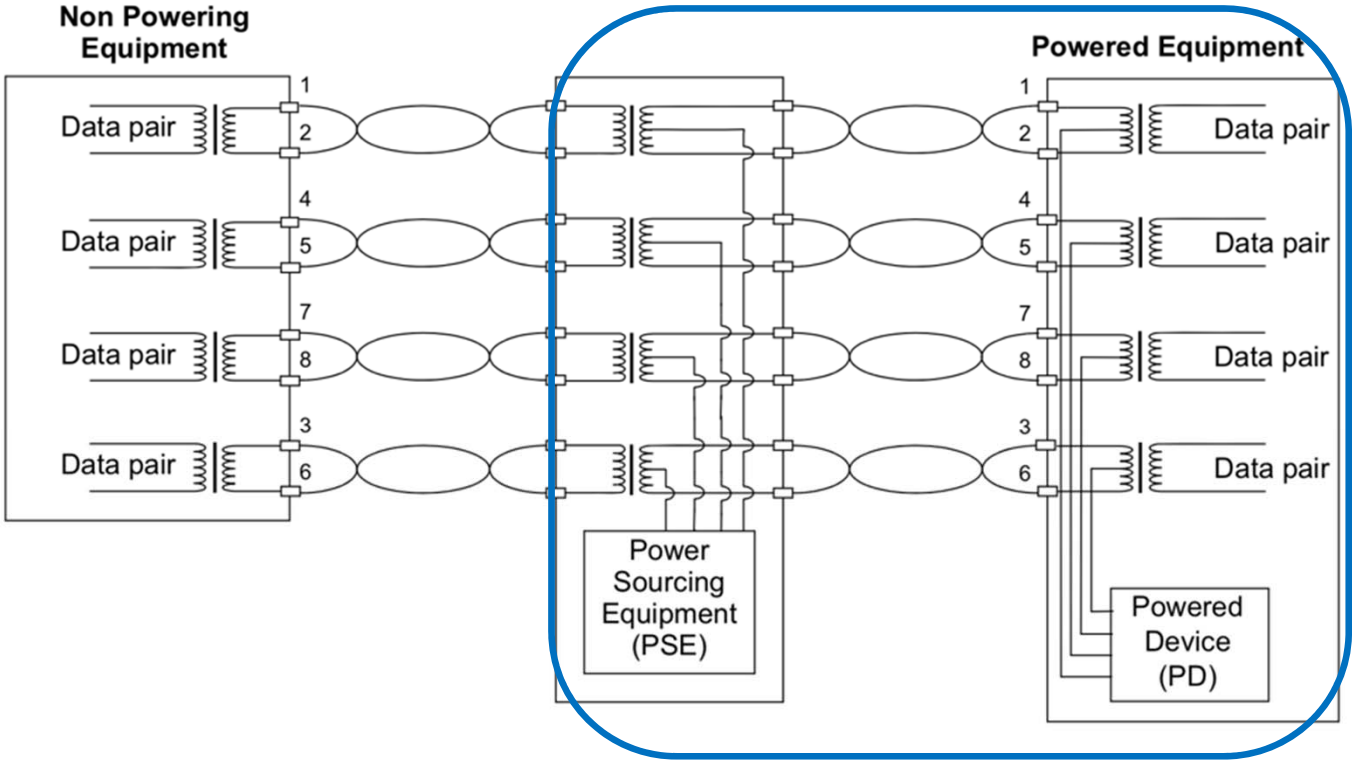


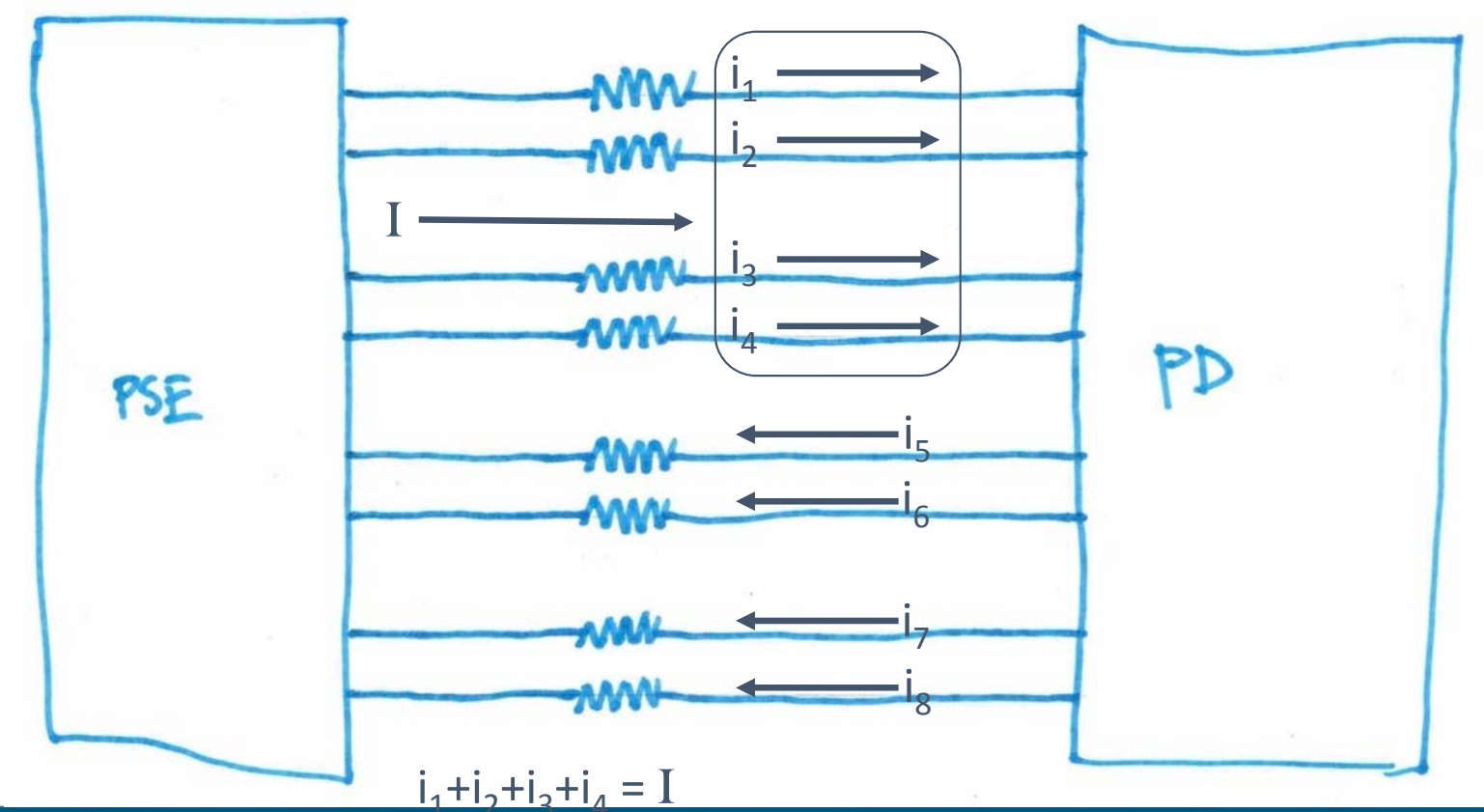
Figure 145–11—1000BASE-T, 2.5G, 5G, or 10GBASE-T 4-pair Midspan PSE location overview

Midspan, as the name implies, is power that is added to an existing network with a PSE that sits between a switch and the PD

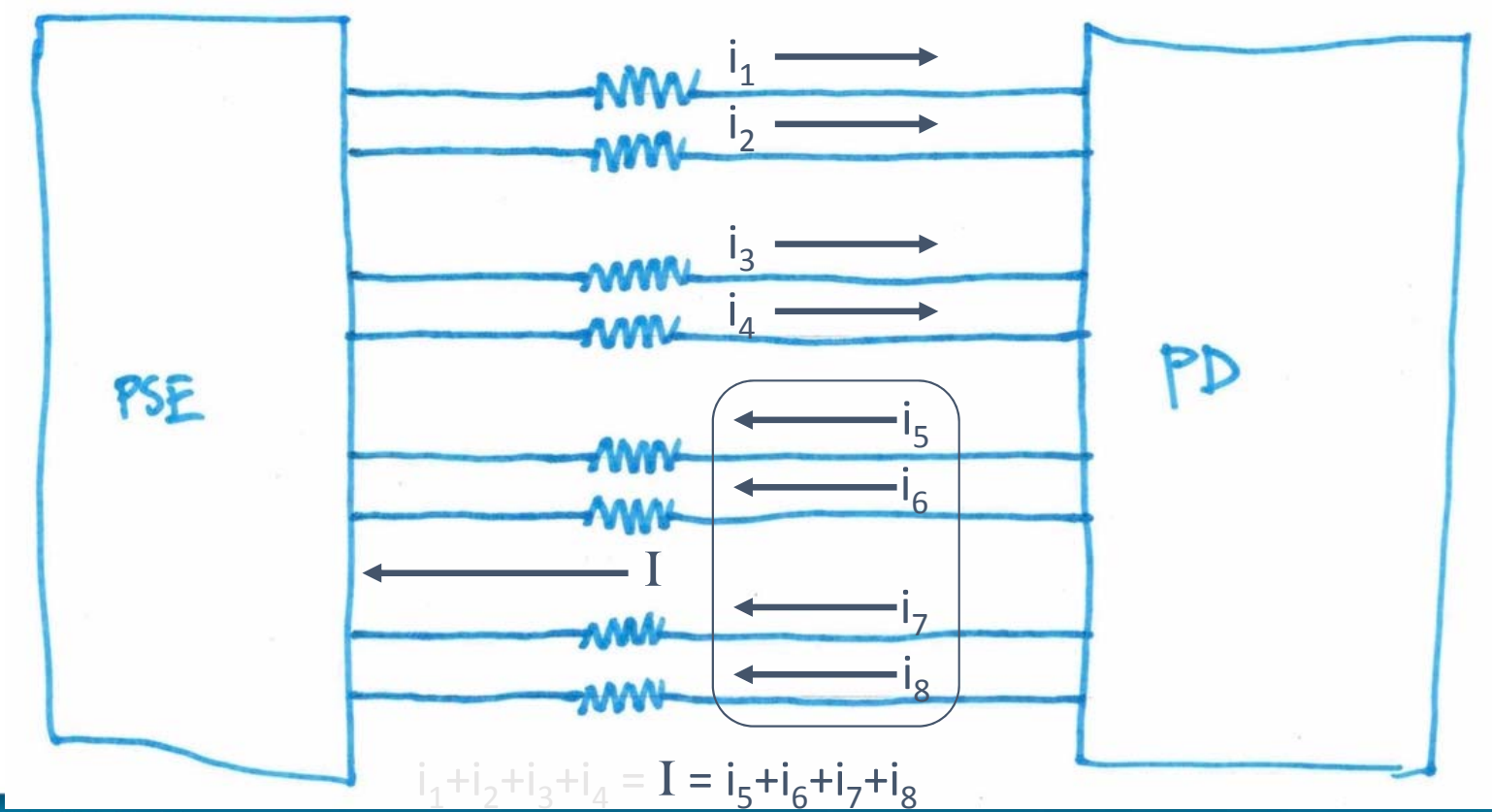
Note that with the exception of the location of the PSE, the diagram is identical to the Endpoint

Image Source: IEEE 802.3bt

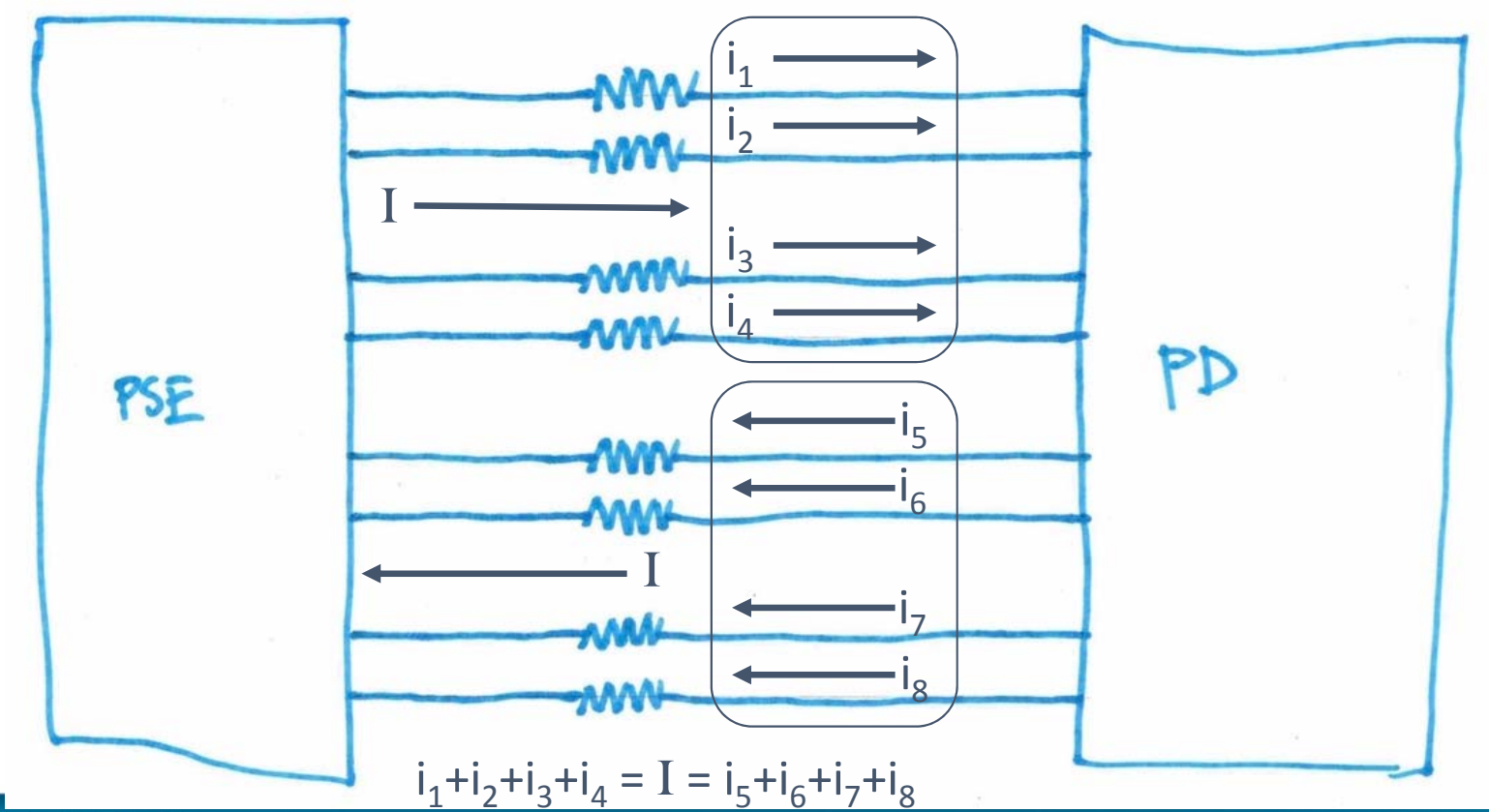
PoE System Diagram



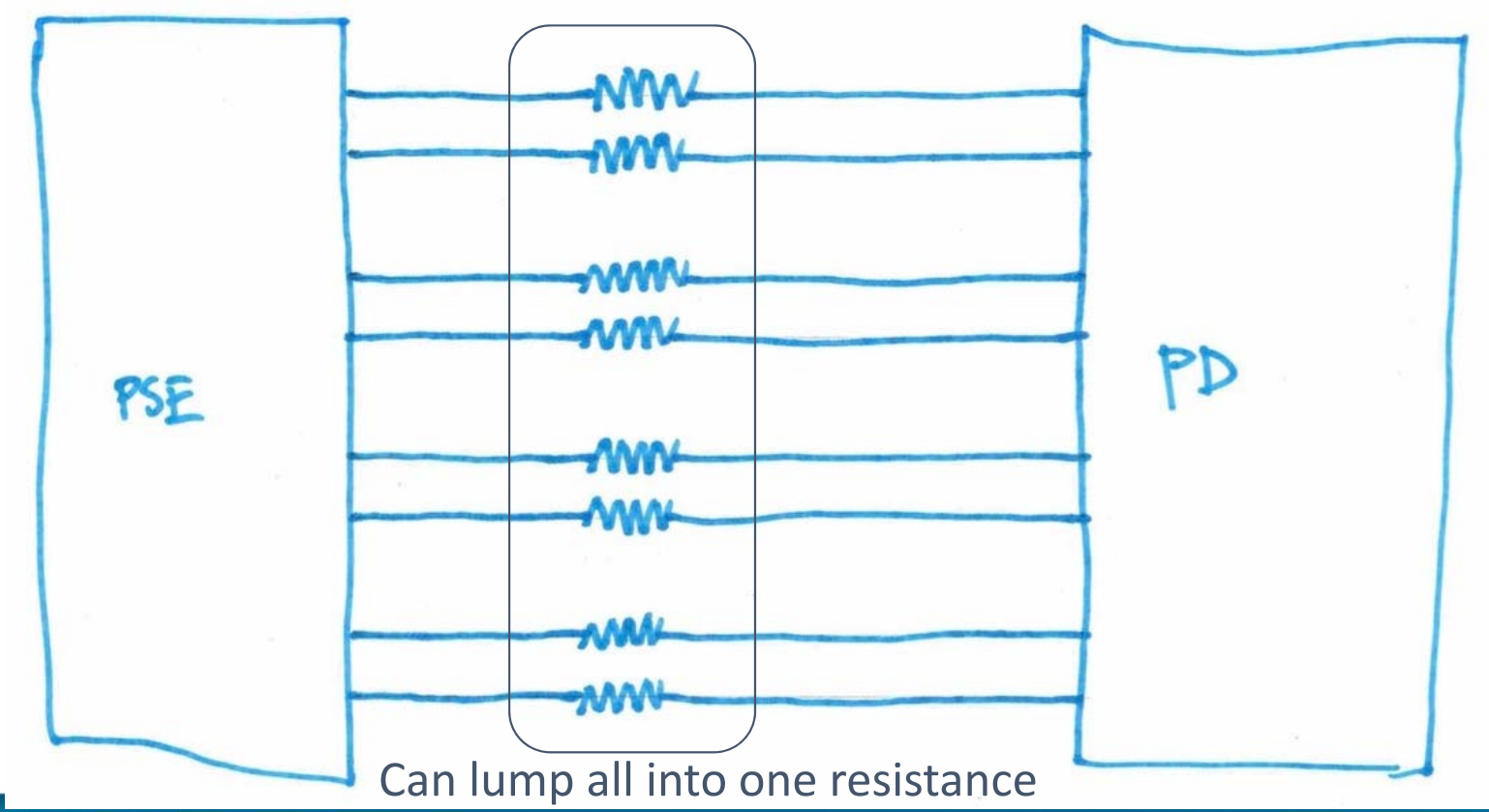
PoE System Diagram



PoE System Diagram

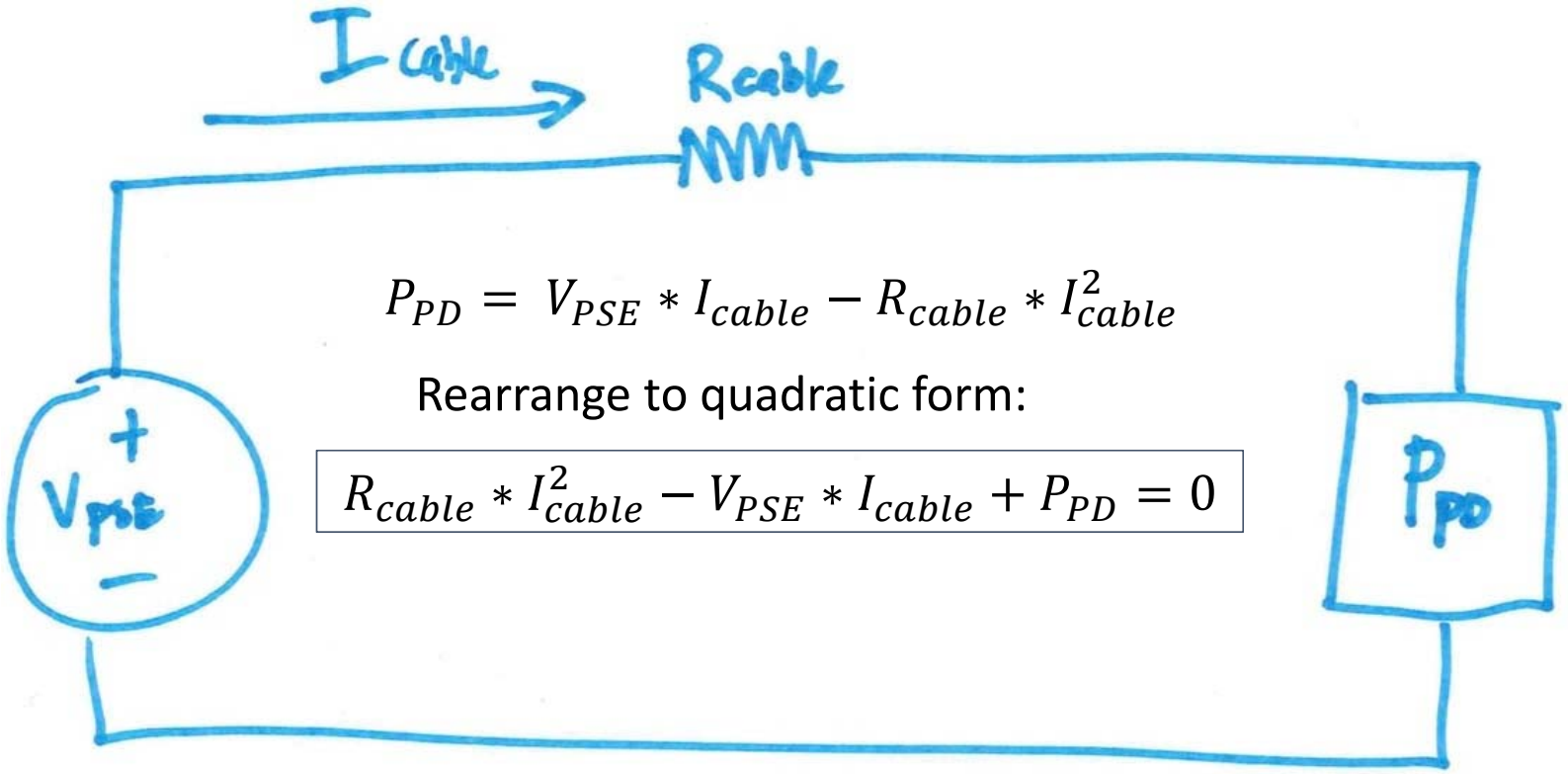


PoE System Diagram



Can lump all into one resistance

PoE System Diagram, Simplified

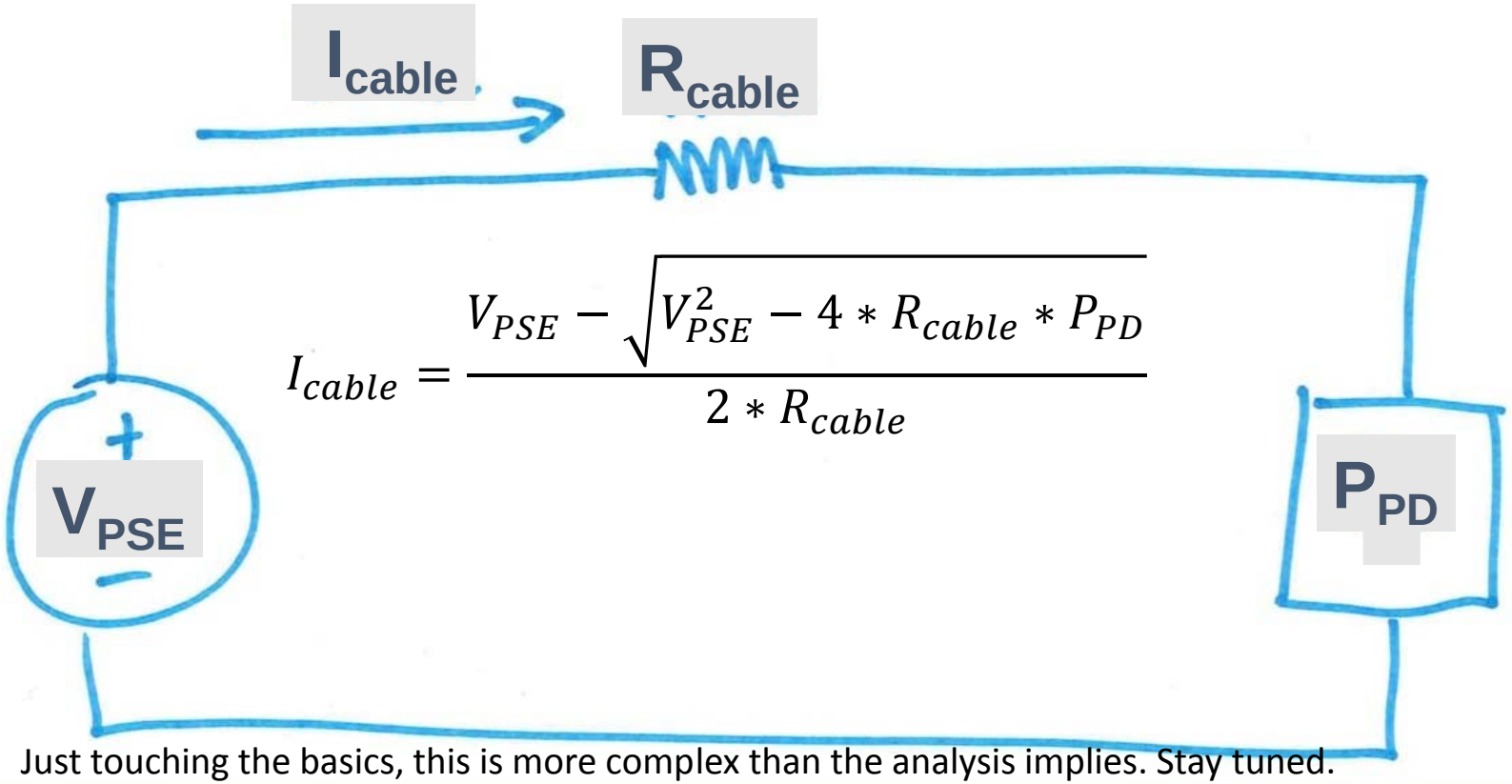


$$P_{PD} = V_{PSE} * I_{cable} - R_{cable} * I_{cable}^2$$

Rearrange to quadratic form:

$$R_{cable} * I_{cable}^2 - V_{PSE} * I_{cable} + P_{PD} = 0$$

PoE System Diagram, Simplified



$$I_{cable} = \frac{V_{PSE} - \sqrt{V_{PSE}^2 - 4 * R_{cable} * P_{PD}}}{2 * R_{cable}}$$

Just touching the basics, this is more complex than the analysis implies. Stay tuned.

2P vs 4P Systems

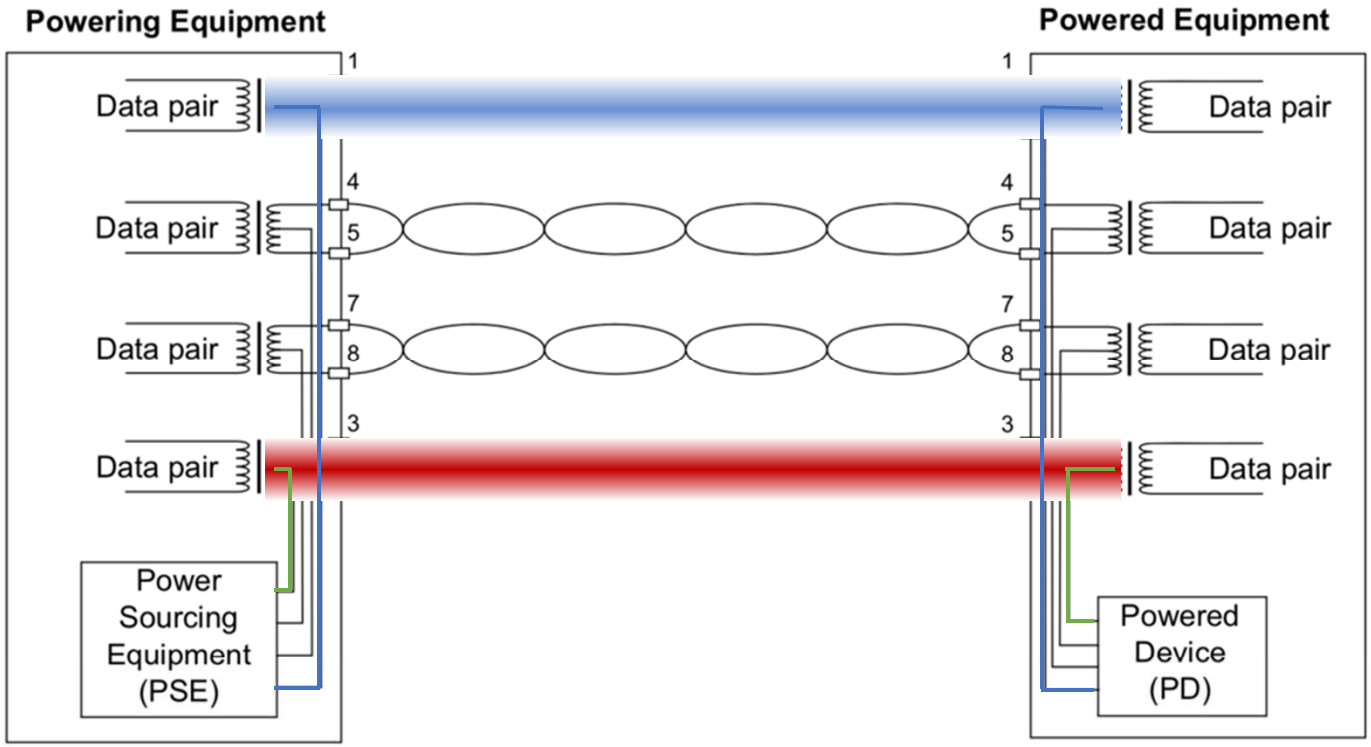


Figure 145–7—1000/2.5G/5G/10GBASE-T 4-pair Endpoint PSE location overview

A 2 pair (2P) system uses only two of the available four pairs in a Category cable. IEEE 802.3af and 802.3at are 2P standards.

Why?

This was the 10/100M days where data was only 2P, therefore PoE had to match.

Image Source: IEEE 802.3bt

2P vs 4P Systems

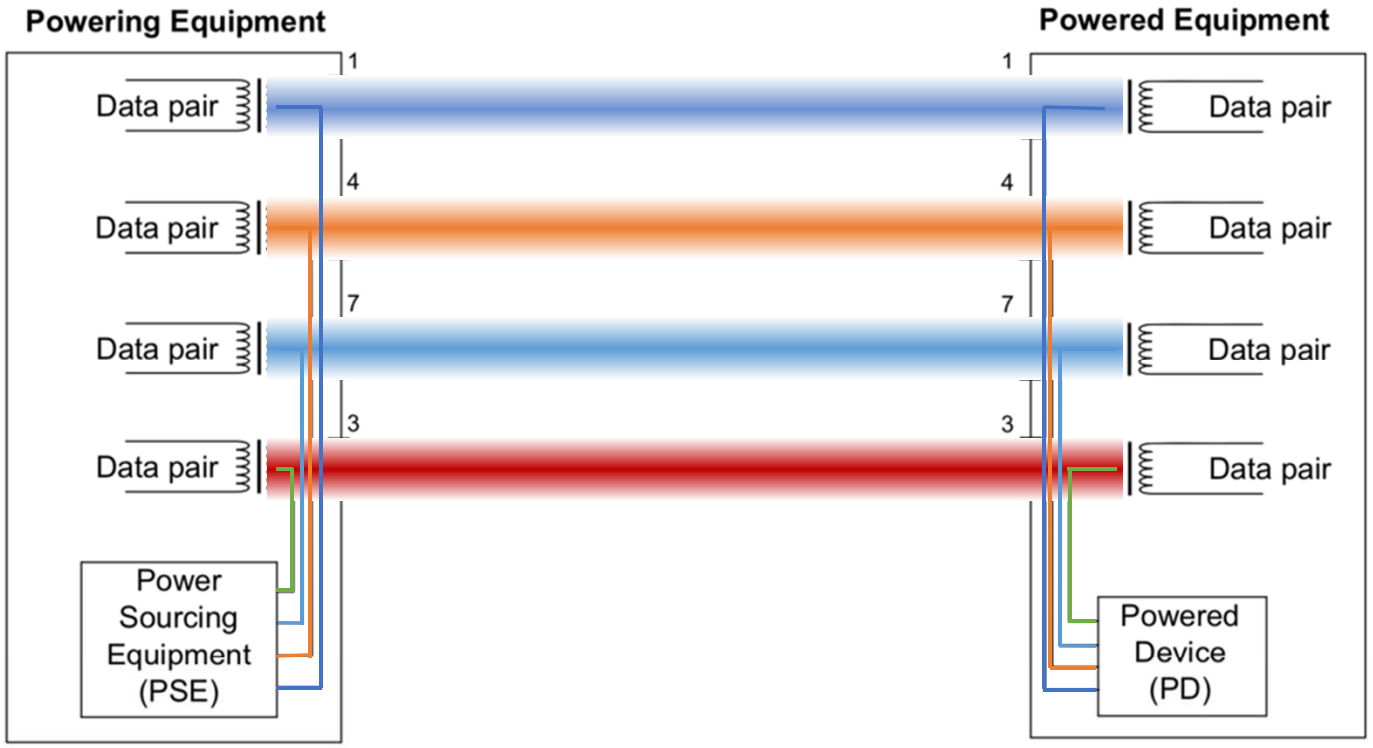


Figure 145–7—1000/2.5G/5G/10GBASE-T 4-pair Endpoint PSE location overview

A 2 pair (2P) system uses only two of the available four pairs in a Category cable. IEEE 802.3af and 802.3at are 2P standards.

A 4 pair (4P) system uses all four pairs in a Category cable. IEEE 802.3bt is a 4P standard. The 4P system will have R_{cable} that is one half of the same system using only 2P.

Image Source: IEEE 802.3bt

IEEE Standard Compliant PoE

IEC60950

Why start a presentation on PoE with a summary of IEC60950 Safety Extra Low Voltage (SELV) and Limited Power Source (LPS)?

- IEEE 802.3 standards are not safety documents
- IEEE 802.3 points to other standards for safety
- IEEE 802.3 compliant PoE was built upon the IEC60950 safety standard
- IEEE 802.3 complies to IEC60950 SELV and LPS

IEC60950 Safety Extra Low Voltage (SELV)

- 2.2.1 SELV CIRCUITS shall exhibit voltages that are **safe to touch** both under normal operating conditions and after a single fault. If no external load is applied to the SELV CIRCUIT, the voltage limits of 2.2.2 and 2.2.3 shall not be exceeded.
- 2.2.2 The voltage between any two conductors of the SELV CIRCUIT or CIRCUITS, and between any one such conductor and earth, shall not exceed 42.4 V peak, or 60 VDC, under normal operating conditions.
- 2.2.3 In the event of a single fault, the voltages between any two conductors of the SELV CIRCUIT or CIRCUITS and between any one such conductor and earth shall not exceed 42.4 V peak, or 60 VDC, for longer than 0.2 s. Moreover, a limit of 71 V peak, or 120 VDC, shall not be exceeded.

Text Source: IEC60950-1 Edition 2.2 2013-05

IEC60950 Limited Power Source (LPS)

- A limited power source shall comply with one of the following:
- – the output is inherently limited in compliance with table 2B; or

Table 2B – Limits for power sources without an overcurrent protective device

Output voltage [a] (U_{oc})		Output current [b d] (I_{sc})	Apparent power [c d] (S)
V a.c.	V d.c.	A	VA
≤ 30	≤ 30	≤ 8,0	≤ 100
–	$30 < U_{oc} \leq 60$	$\leq 150/U_{oc}$	≤ 100

a U_{oc}: Output voltage measured in accordance with 1.4.5 with all load circuits disconnected. Voltages are for substantially sinusoidal a.c. and ripple free d.c. For non-sinusoidal a.c. and d.c. with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

b I_{sc}: Maximum output current with any non-capacitive load, including a short-circuit.

c S (VA): Maximum output VA with any non-capacitive load.

d Measurement of I_{sc} and S are made 5 s after application of the load if protection is by an electronic circuit and 60 s for a positive temperature coefficient device~~, and 60 s~~ or in other cases.

Image Source: IEC60950-1 Edition 2.2 2013-05

NEC Class 2 Circuits

Table 11(B) Class 2 and Class 3 Direct-Current Power Source Limitations

Power Source		Inherently Limited Power Source (Overcurrent Protection Not Required)					Not Inherently Limited Power Source (Overcurrent Protection Required)			
		Class 2				Class 3	Class 2		Class 3	
Source voltage V_{max} (volts) (see Note 1)		0 through 20*	Over 20 and through 30*	Over 30 and through 60*	Over 60 and through 150	Over 60 and through 100	0 through 20*	Over 20 and through 60*	Over 60 and through 100	Over 100 and through 150
Power limitations VA_{max} (volt-amperes) (see Note 1)		—	—	—	—	—	250 (see Note 3)	250	250	N.A.
Current limitations I_{max} (amperes) (see Note 1)		8.0	8.0	$150/V_{max}$	0.005	$150/V_{max}$	$1000/V_{max}$	$1000/V_{max}$	$1000/V_{max}$	1.0
Maximum overcurrent protection (amperes)		—	—	—	—	—	5.0	$100/V_{max}$	$100/V_{max}$	1.0
Power source maximum nameplate rating	VA (volt-amperes)	$5.0 \times V_{max}$	100	100	$0.005 \times V_{max}$	100	$5.0 \times V_{max}$	100	100	100
	Current (amperes)	5.0	$100/V_{max}$	$100/V_{max}$	0.005	$100/V_{max}$	5.0	$100/V_{max}$	$100/V_{max}$	$100/V_{max}$

IEEE compliant PoE ports are NEC Class 2 Limited Power Circuits

Image Source: NFPA 70, 2017 edition

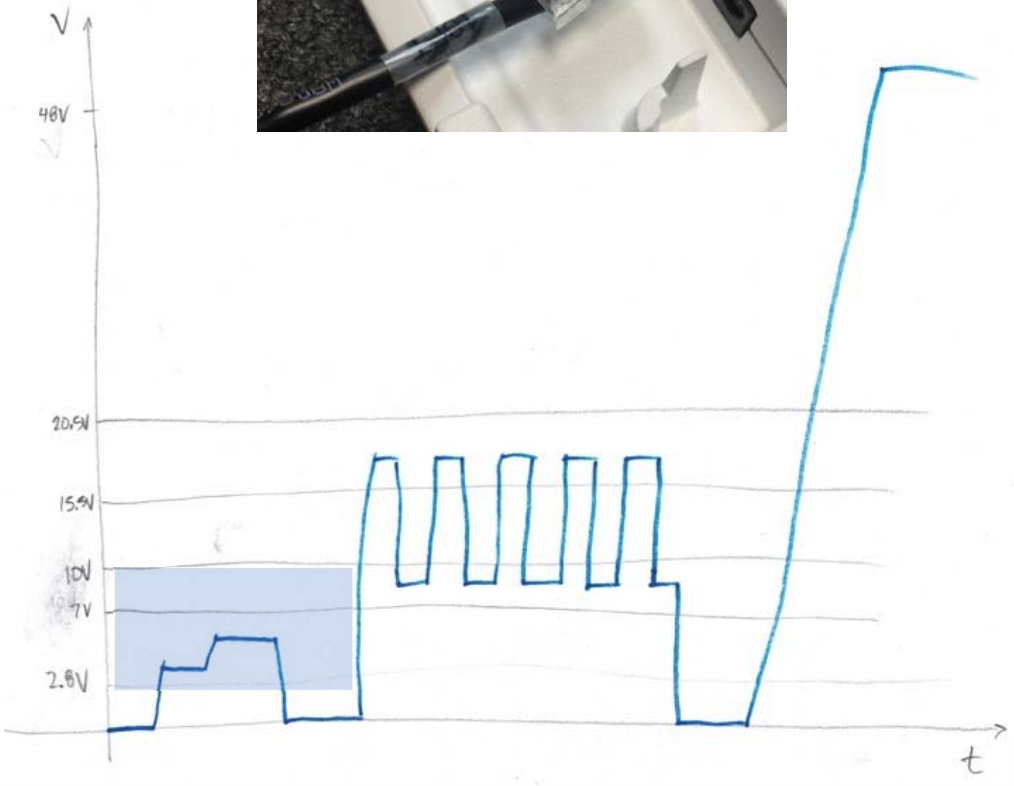
5 Minute Break

IEEE 802.3 PoE

- Detection
- Classification
- Power Up
- Normal Operation
- Power Removal

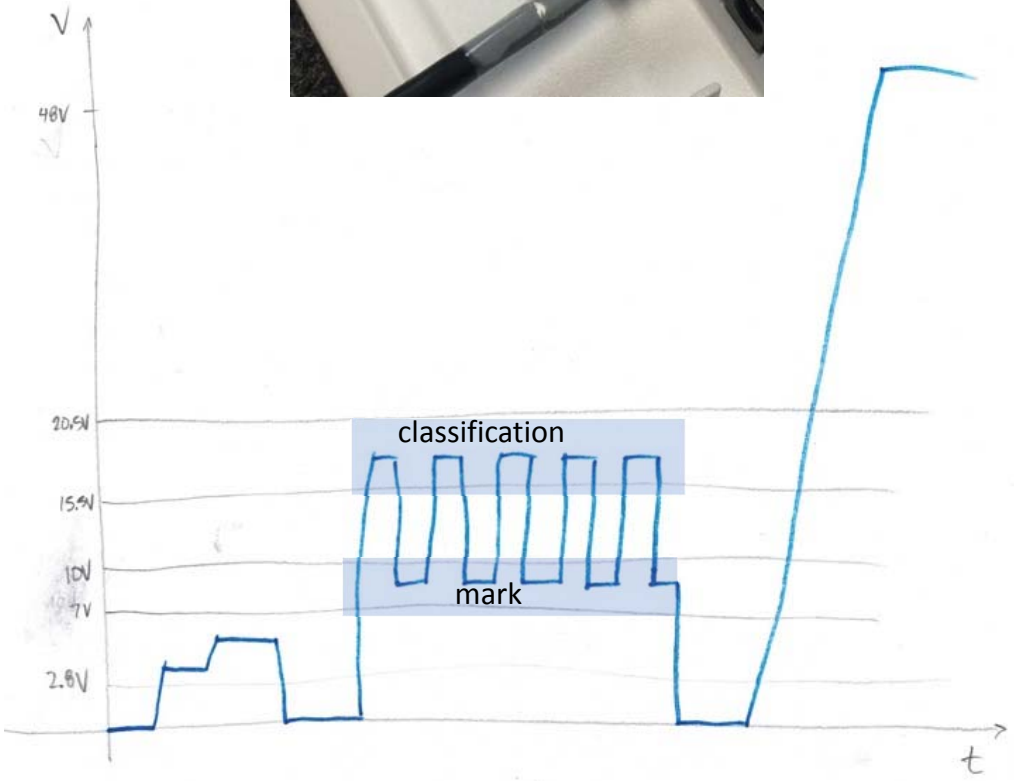
PD Detection

- No power is available at the PSE port without a PD connected
- Detection occurs in a range between 2.8V and 10V
- Open circuit limit of 30V and 5mA for detection
- Detection is looking for a 24.9k resistance



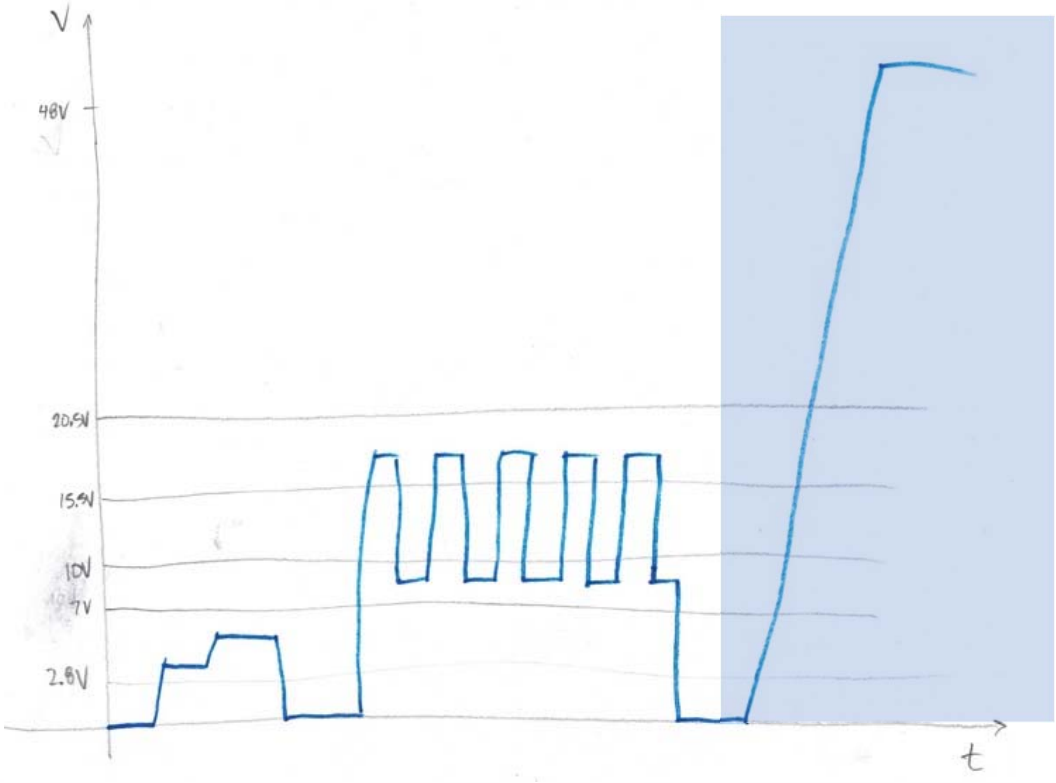
PD Classification

- Once a PD is detected, the PSE moves to classification
- A voltage between 15.5V and 20.5V is applied and the current is measured
- Each classification event is followed by a mark event in the range of 7-10V



PD Power Up

- Only once the PD is successfully detected and classified can power be applied
- PSE port voltage during power on is 44V, 50V, or 52V min (dependent on PSE Type)
- PSE max port voltage is 57V for all Types



Power Removal

- Disconnecting the PD will cause power removal. PSE returns to detection probing.
- Power removal for overcurrent is a complex set of equations and an upper/lower bound template
- Lowerbound template sets the minimums a PSE must provide to guarantee powering compliant PDs
- Upperbound template sets limits to protect the PSE and cabling from overcurrent

Power Removal Continued

- Worst case fault conditions that turn PSE power off:
  - 1.75A per pair for 75ms
  - 1.3A per pair for 4s
  - Greater than 0.96A per pair longer than 4s
    - These numbers are for Class 8 and are per pairset specifications
- Real PSEs will remove power before any of these conditions are met

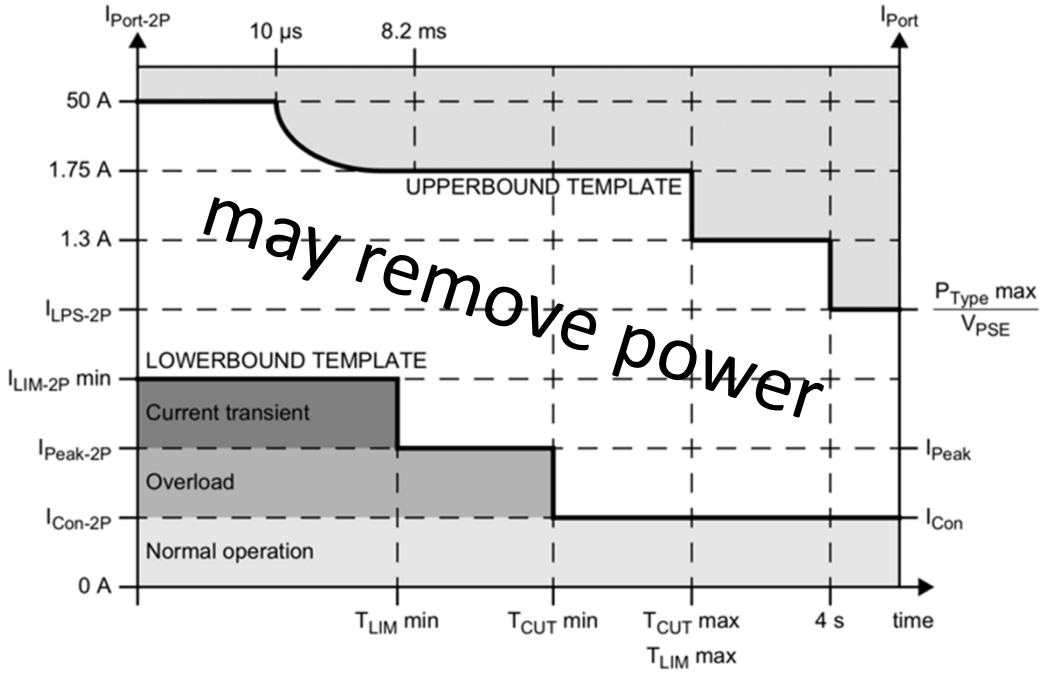
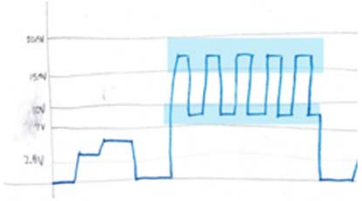
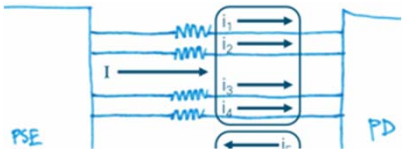


Figure 145–24—Power on states, per pairset operating current template for Type 4 PSEs

Image Source: IEEE 802.3bt



The Classes

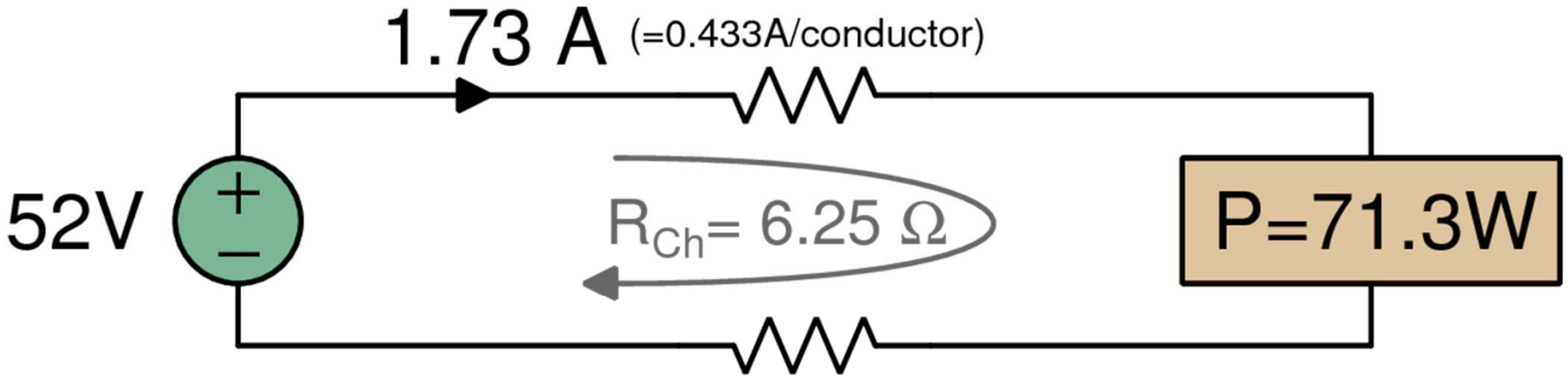


PD Class	# of PD Classification Events	P_{PSE}	P_{PD}	I_{CABLE} MAX	Max Rated Current Per Conductor	
					2 Pair	4 Pair
1	1	4W	3.84W	91mA	45mA	20mA
2	1	7W	6.49W	159mA	80mA	35mA
3	1	15.4W	13W	350mA	175mA	77mA
4	2	30W	25.5W	600mA	300mA	150mA
5	4	45W	40W	900mA	NA	225mA
6	4	60W	51W	1200mA	NA	300mA
7	5	75W	62W	1442mA	NA	361mA
8	5	90W	71.3W	1731mA	NA	433mA

PoE is a Constant Power System

- Recall the equation for $I_{cable} = \frac{V_{PSE} - \sqrt{V_{PSE}^2 - 4 * R_{cable} * P_{PD}}}{2 * R_{cable}}$
- The currents presented on the previous slide are the worst case rated currents
- These are derived from the minimum V_{pse} and max P_{pd} and R_{cable}
- Real systems don't operate at the mins and maxes
- PDs are 'constant power', the power consumption of the PD does not change if any of the three variables change
- A change in any one results in a reduction of cable current

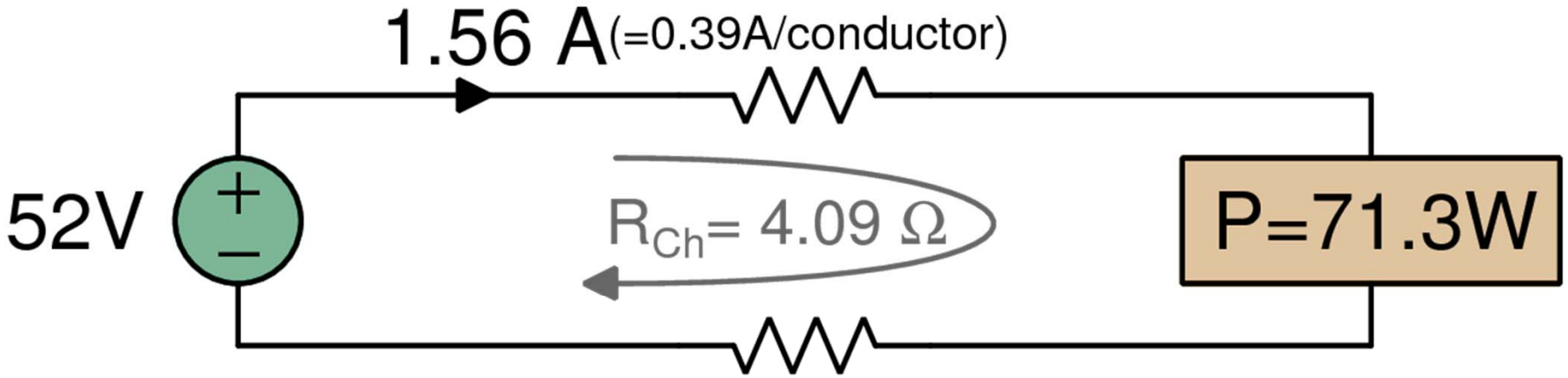
IEEE 802.3bt worst case example



Worst case channel of 6.25 Ω

Load: constant power of 71.3 W (Class 8)

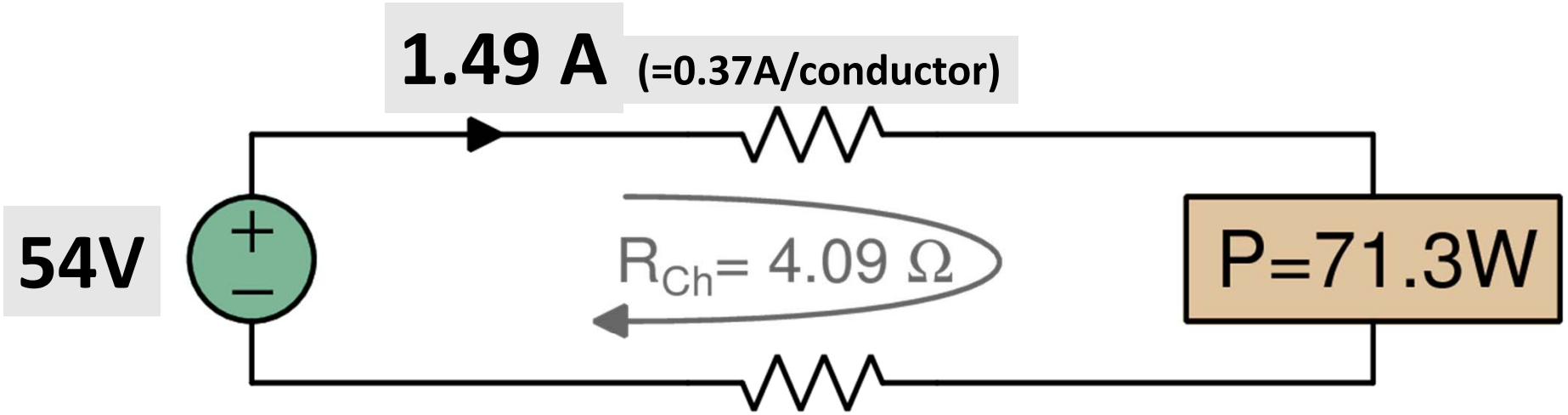
Realistic Cable Resistance



Channel: 24 AWG UTP

Load: constant power of 71.3 W (Class 8)

Realistic PSE Voltage



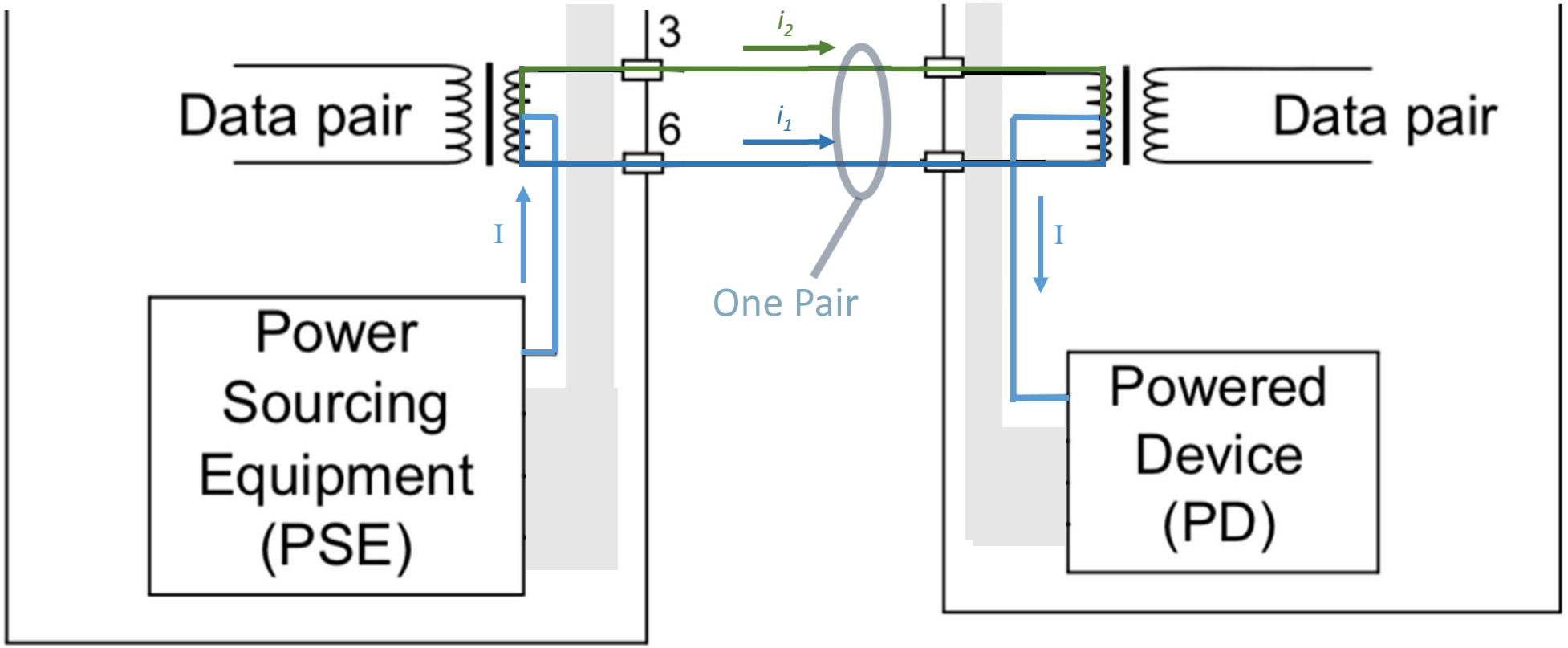
Channel: 24 AWG UTP

Load: constant power of 71.3 W (Class 8)

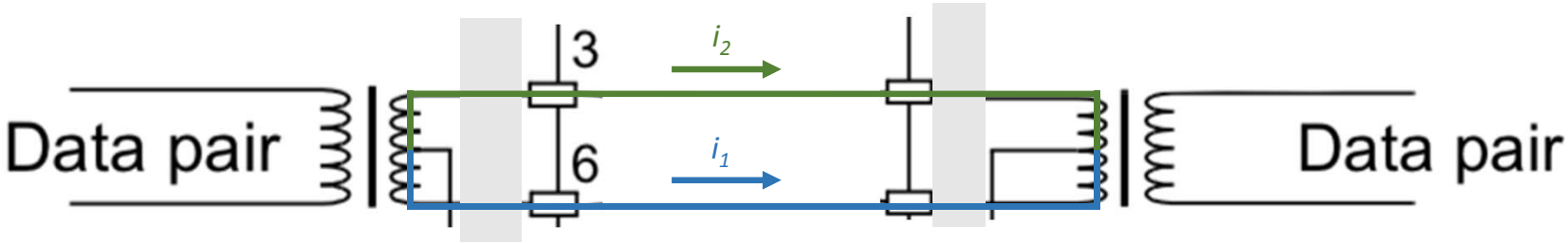
You will never find a PoE system at worst case I_{cable}

-Chad Jones

Current Imbalance (one pairset)



Current Imbalance con’t



- i_1 is not necessarily equal to i_2
- This is due to component and cable tolerance
- The difference can be as high as 3%
- This is known as current imbalance

Current Unbalance (whole cable)

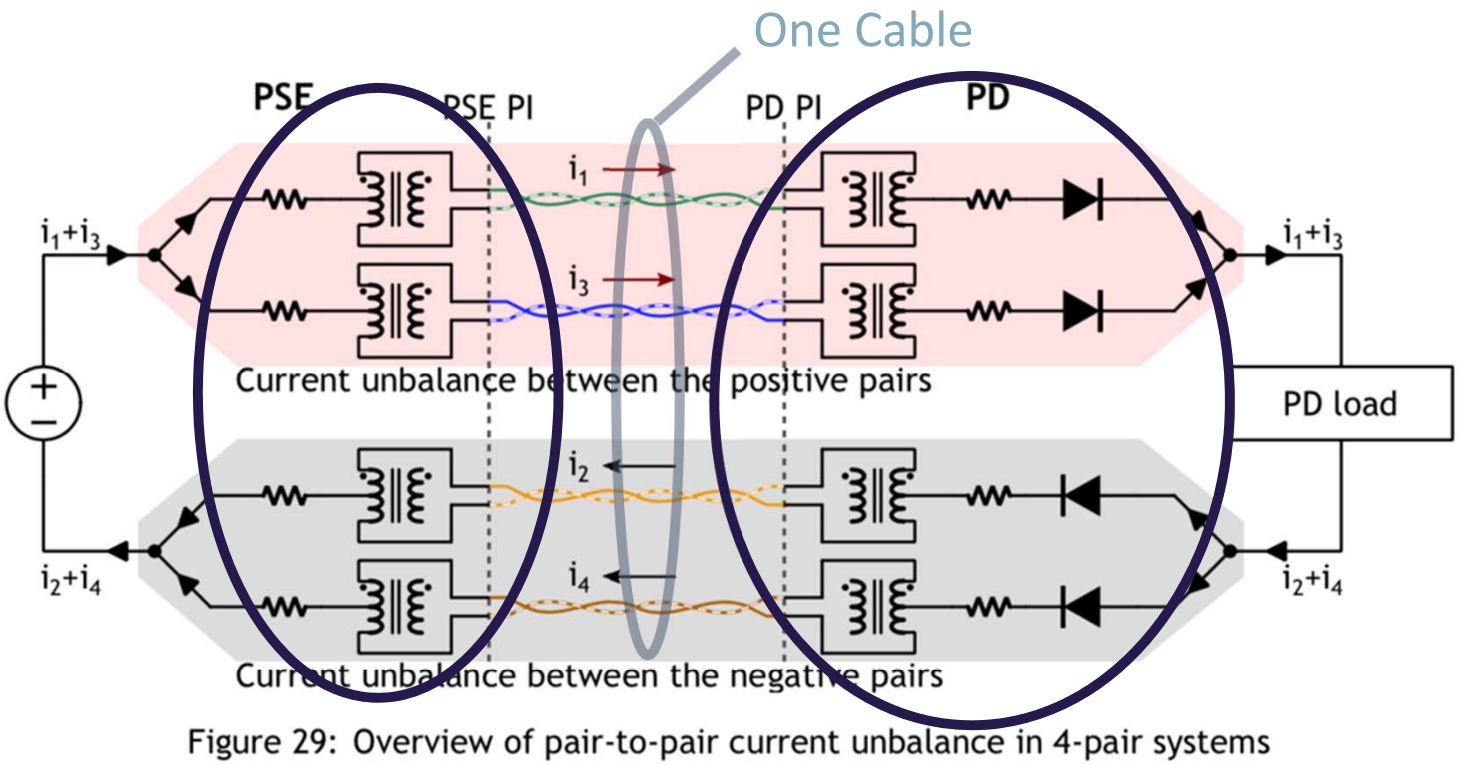


Figure 29: Overview of pair-to-pair current unbalance in 4-pair systems

- $i_1 + i_3 = i_2 + i_4$
- $i_1 \neq i_3 \neq i_2 \neq i_4$
- Due to component and cable tolerance
- More components than for imbalance
- Difference can be as high as 24%
- This is known as current unbalance

Image Source: https://ethernetalliance.org/wp-content/uploads/2018/04/WP_EA_Overview8023bt_V2_FINAL.pdf

The PoE Current

- I_{cable} is the sum of pairset current in any one direction
- Worst case numbers can easily be derived
- Implies three variables all at worst case
- In reality, systems are never at worst case

- Current imbalance is WITHIN a pairset
- Current unbalance is BETWEEN pairsets
- 2P systems deal with imbalance
- 4P systems deal with both unbalance and imbalance

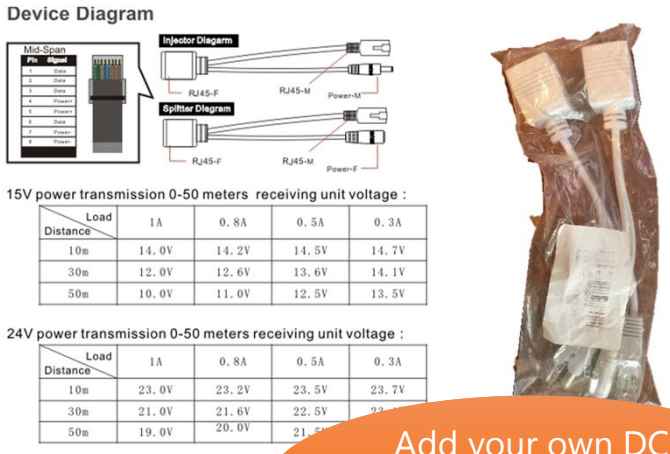
Recap IEEE Standard Compliant PoE

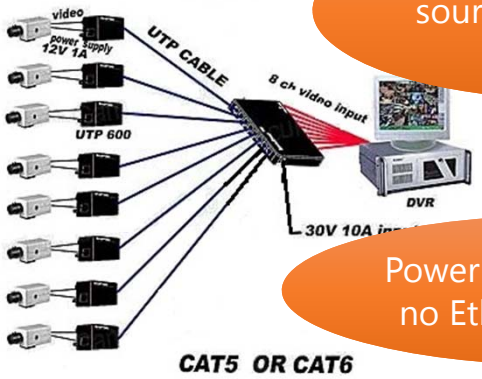
- Based on IEC60950 safety standard
- Which has equivalence to NEC Class 2
- No power is available at a port without a valid PD
- But if power was available, it falls into the safe to touch range
- Once a PD is detected and powered, the PSE monitors power and disconnects within limits imposed under LPS
- Short circuits are disconnected within 75ms, but typically much faster

Recognizing PoE as Safe Smart Power vs Non-Compliant PoE

Success of safe power sources breeds alternatives

- No detection to protect devices not wanting power
- No classification to limit current provided
- No standardization of voltage (Provision of 5V, 12V or 24V saves conversion costs)
- No inherent current/power limiting – direct coupling of any source to a line





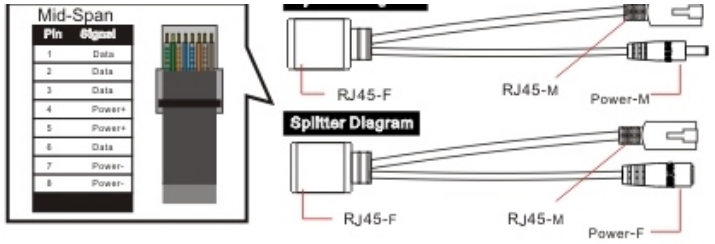
Add your own DC source to a coupler – Not PoE

Power source, Cable, but no Ethernet! – Not PoE

How to tell the difference?

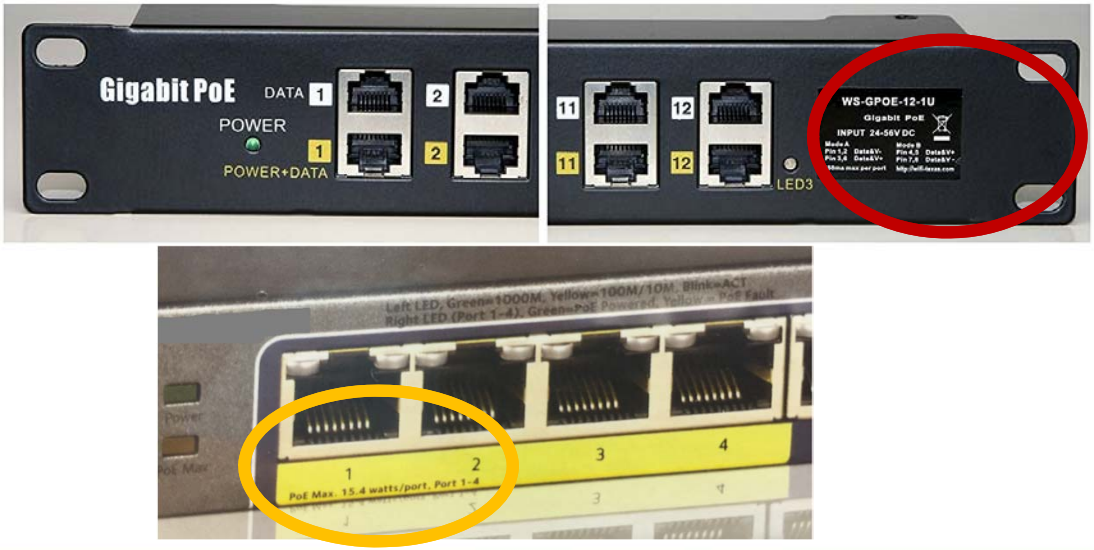
Easy:

- Simple power couplers/splitters
- Look for separate ‘brick’ power supply coupled in or out
- Often not standard PoE

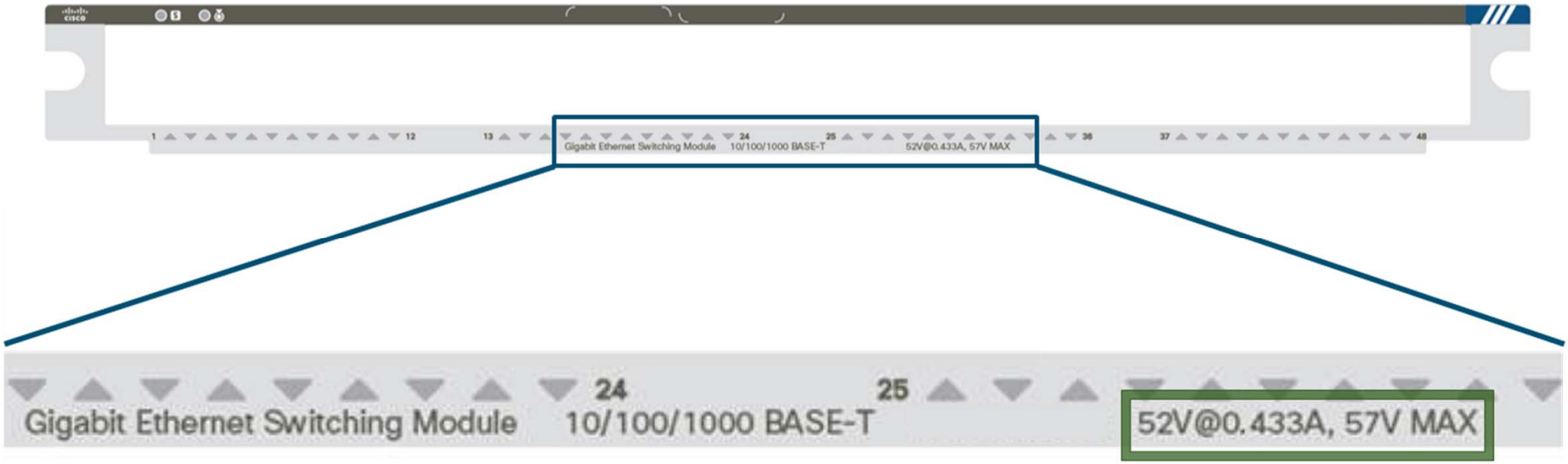


Hard:

- Multi-port sources or Integrated PDs look like standard PoE network equipment
- Misleading labels – READ THE FINE PRINT
  - May need to read datasheets



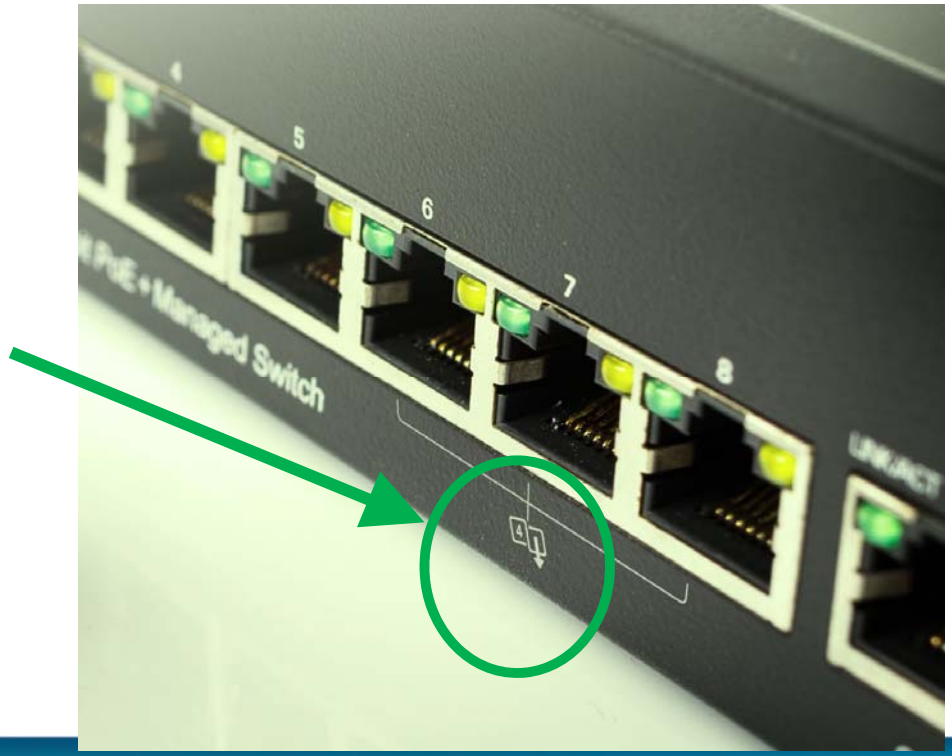
Look for 725.121(C) Required Marking
- But keep your eyes out for more!



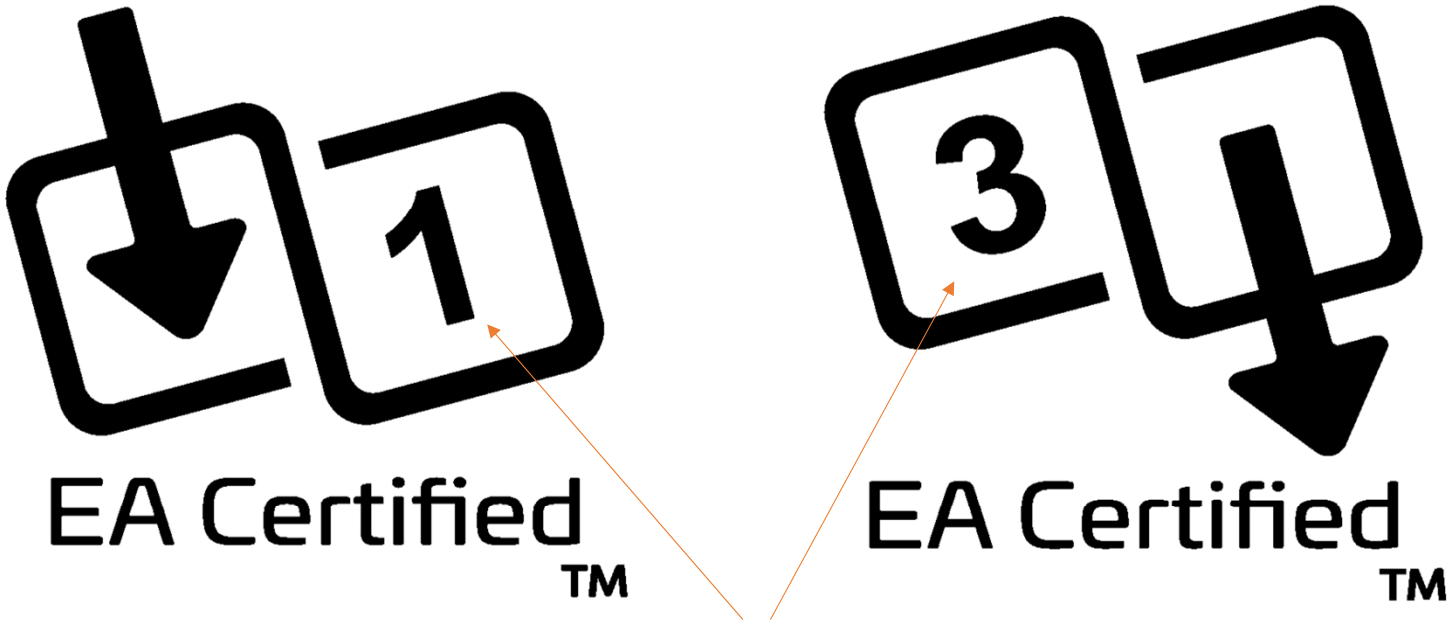
Normalizing the label to look for – Ethernet Alliance PoE Logo

Identifying IEEE 802.3-based PoE

- Beyond labeling current & voltage
- Products tested against IEEE 802.3 PoE standards
  - Includes detection, classification, disconnect and other standard features
- Includes power class (current levels) for PDs & PSEs
- Identifies interoperable PSEs & PDs

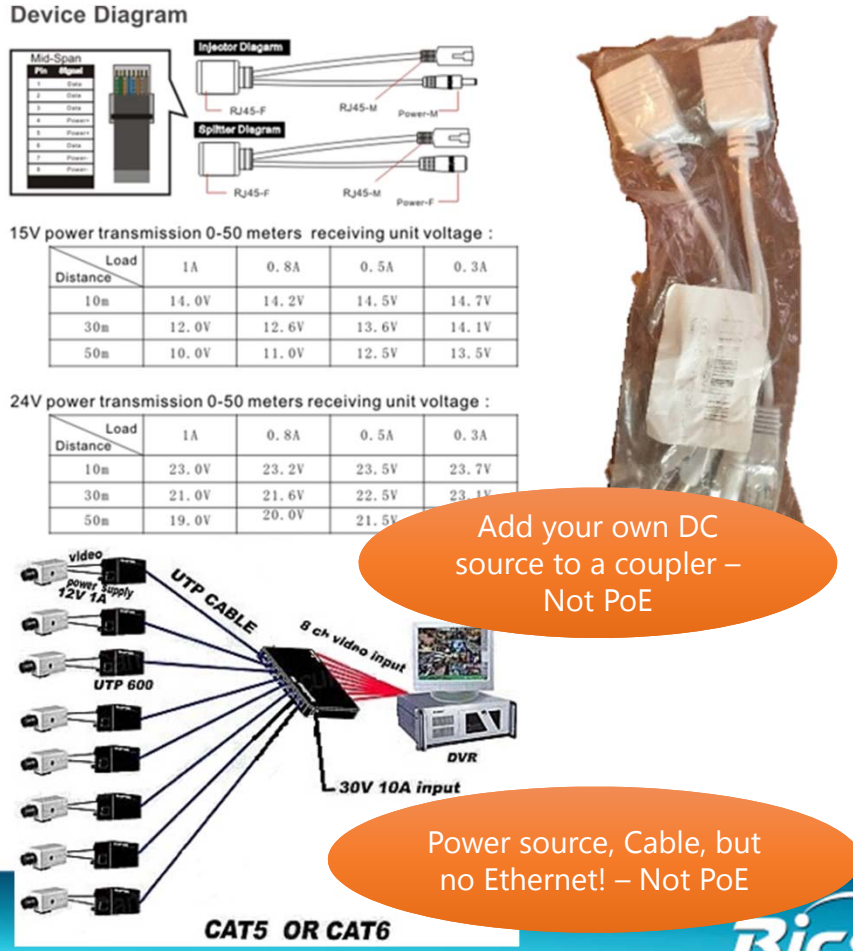


Ethernet Alliance PoE Certification Logo



Non-compliant PoE: Success breeds low-cost imitation

- No detection to protect devices not requesting power
- No classification to set current limits
- No standardization of voltage (Provision of 5V, 12V or 24V saves conversion costs)
- No inherent current/power limiting – direct coupling of any source to a line



Add your own DC source to a coupler – Not PoE

Power source, Cable, but no Ethernet! – Not PoE

NFPA 70 –
The National Electrical Code

PoE Smart Power Advantages

- Safe:
  - Class 2 limits:

Class 2 Circuit. The portion of the wiring system between the load side of a Class 2 power source and the connected equipment. Due to its power limitations, a Class 2 circuit considers safety from a fire initiation standpoint and provides acceptable protection from electric shock.

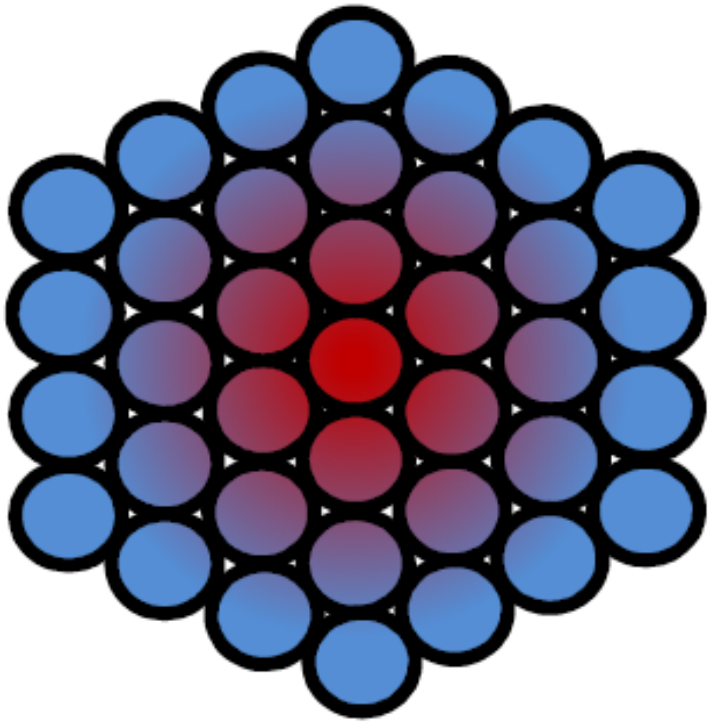
  - PLUS: de-energized until the source detects a proper load
  - PLUS: Removes power on overcurrent fault or load removal
- Efficient:
  - Only provides the power requested
- Protects from faults by policing power supplied relative to what the device asked for

Back to Safety…

- Wasn't there something in the 2017 NEC about PoE and Safety?
  - 725.144: Class 2 and Class 3 circuits – Transmission of Power and Data
  - 840.160: Premises Powering of Communications Equipment over Communications Cables – Powering Circuits.

The basics of bundle heating

- If all the cables in a bundle are carrying current, they will all contribute heat
- Naturally, the cable in the center of the bundle will be the hottest
- PoE has existed since 1999, the industry has taken this into account
- Heating of bundles of cables carrying data and class 2 power entered the NEC in 2017
  - The 2020 NEC refines the 2017 NEC for PoE



840.160 NEC©-2020 Second Revision

840.160 Powering Circuits.

Communications cables listed in accordance with 805.179, in addition to carrying the communications circuit, shall also be permitted to carry circuits for powering communications equipment listed in accordance with 805.170. The power source shall be listed in accordance with 840.170(G). Installation of the listed 4-pair communications cables for a communications circuit or installation where 4-pair communications cables are substituted for Class 2 and Class 3 cables in accordance with 725.154(A) shall comply with 725.144.

Exception: Installing communications cables in compliance with 725.144 shall not be required for listed 4-pair communications cables where the rated current of the power source does not exceed 0.3 amperes in any conductor 24 AWG or larger.

Informational Note: A typical communications cable for this application is a 4-pair cable sometimes referred to as Category 5e (or higher) LAN cable or balanced twisted pair cable. These types of cables are often used to provide Ethernet- and Power over Ethernet (PoE)–type services. A large number of such powering cables bundled together can cause overheating of the wiring if not controlled as described in Table 725.144.

Text Source: NFPA 70 2020 Second Draft Report

840.160 NEC©-2017 to NEC©-2020

- Removed the 60W statement
- Replaced with 0.3A on 24AWG or larger
- Settled on the term ‘rated current’

725.144(A) NEC©-2020 Second Revision

(A) Use of Class 2 or Class 3 Cables to Transmit Power and Data.

Where Types CL3P, CL2P, CL3R, CL2R, CL3, or CL2 transmit power and data, the rated current per conductor of the power source shall not exceed the ampacities in Table 725.144 at an ambient temperature of 30°C (86°F). For ambient temperatures above 30°C (86°F), the correction factors in Table 310.15(B)(1) or in Equation 310.15(B) shall apply.

Exception: Compliance with Table 725.144 shall not be required for installations where conductors are 24 AWG or larger and the rated current per conductor of the power source does not exceed 0.3 amperes.

Informational Note: One example of the use of Class 2 cables is a network of closed-circuit TV cameras using 24 AWG, 60°C rated, Type CL2R, Category 5e balanced twisted-pair cabling.

Text Source: NFPA 70 2020 Second Draft Report

725.144(A) NEC©-2017 to NEC©-2020

- Added an exemption for currents 0.3A and below
- Correlated to the term ‘rated current’ between FR and SR

725.144(B) NEC©-2020 Second Revision

(B) Use of Class 2-LP or Class 3-LP Cables to Transmit Power and Data.

Types CL3P-LP, CL2P-LP, CL3R-LP, CL2R-LP, CL3-LP, or CL2-LP shall be permitted to supply power to equipment from a power source with a rated current per conductor up to the marked current limit located immediately following the suffix "-LP" and shall be permitted to transmit data to the equipment. Where the number of bundled LP cables is 192 or less and the selected ampacity of the cables in accordance with Table 725.144 exceeds the marked current limit of the cable, the ampacity determined from the table shall be permitted to be used. For ambient temperatures above 30°C (86°F), the correction factors of Table 310.15(B)(1) or Equation 310.15(B) shall apply. The Class 2-LP and Class 3-LP cables shall comply with the following, as applicable:

(1) Cables with the suffix "-LP" shall be permitted to be installed in bundles, raceways, cable trays, communications raceways, and cable routing assemblies.

(2) Cables with the suffix "-LP" and a marked current limit shall follow the substitution hierarchy of Table 725.154 and Figure 725.154(A) for the cable type without the suffix "-LP" and without the marked current limit.

(3) System design shall be permitted by qualified persons under engineering supervision.

Informational Note: An example of a limited power (LP) cable is a cable marked Type CL2-LP(0.5A), 23 AWG.

Text Source: NFPA 70 2020 Second Draft Report

725.144(B) NEC©-2017 to NEC©-2020

- Added the reference to 310.15(B)(2)*
- Correlated to the term ‘rated current’ between FR and SR
- Correctly refer to the LP cable marking as a current limit
- Clarified use of LP cable beyond the marking in accordance with Table 725.144

*other changes in 310.15 makes this 310.15(B)(1) and Eq 310.15(B)

725.121(C) NEC©-2020 Second Revision

(C) Marking.

The power sources for limited power circuits in 725.121(A)(3), limited power circuits for listed audio/video equipment, listed information technology equipment, listed communications equipment, and listed industrial equipment in 725.121(A)(4) shall have a label indicating the maximum voltage and rated current output per conductor for each connection point on the power source. Where multiple connection points have the same rating, a single label shall be permitted to be used.

Informational Note: Rated current for power sources covered in 725.144 is the output current per conductor the power source is designed to deliver to an operational load at normal operating conditions, as declared by the manufacturer.

Text Source: NFPA 70 2020 Second Draft Report

725.121(C) NEC©-2017 to NEC©-2020

- Correlated to the term ‘rated current’ between FR and SR
- Added an exemption for marking for currents 0.3A and below; then removed that exemption in SR

*Two new TIAs have been filed for the 2020 code, one to add an effective date of Jan 1, 2021 for marking of the 0.3A and below ports, one to add an informational note suggesting a labeling format for PoE systems of Nominal Voltage @ Max Current, Max Voltage

Table 725.144 NEC©-2020 Second Revision

Table 725.144 Ampacities of Each Conductor in Amperes in 4-Pair Class 2 or Class 3 Balanced Twisted-Pair Cables Based on Copper Conductors at an Ambient Temperature of 30°C (86°F) with All Conductors in All Cables Carrying Current, 60°C (140°F), 75°C (167°F), and 90°C (194°F) Rated Cables

AWG	Number of 4-Pair Cables in a Bundle																	
	1–7			8–19			20–37			38–61			62–91			92–192		
	Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating		
	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C
26	1.00	1.23	1.42	0.71	0.87	1.02	0.55	0.68	0.78	0.46	0.57	0.67	0.45	0.55	0.64	NA	NA	NA
24	1.19	1.46	1.69	0.81	1.01	1.17	0.63	0.78	0.91	0.55	0.67	0.78	0.46	0.56	0.65	0.40	0.48	0.55
23	1.24	1.53	1.78	0.89	1.11	1.28	0.77	0.95	1.10	0.66	0.80	0.93	0.58	0.71	0.82	0.45	0.55	0.63
22	1.50	1.86	2.16	1.04	1.28	1.49	0.77	0.95	1.11	0.66	0.82	0.96	0.62	0.77	0.89	0.53	0.63	0.72

Text Source: NFPA 70 2020 Second Revision

Table 725.144 NEC©-2017 to NEC©-2020

AWG	1			2–7			8–19			20–37			38–61			62–91			92–192		
	Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating		
	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C
26	1	1	1	1	1	1	0.7	0.8	1	0.5	0.6	0.7	0.4	0.5	0.6	0.4	0.5	0.6	NA	NA	NA
24	2	2	2	1	1.4	1.6	0.8	1	1.1	0.6	0.7	0.9	0.5	0.6	0.7	0.4	0.5	0.6	0.3	0.4	0.5
23	2.5	2.5	2.5	1.2	1.5	1.7	0.8	1.1	1.2	0.6	0.8	0.9	0.5	0.7	0.8	0.5	0.7	0.8	0.4	0.5	0.6
22	3	3	3	1.4	1.8	2.1	1	1.2	1.4	0.7	0.9	1.1	0.6	0.8	0.9	0.6	0.8	0.9	0.5	0.6	0.7

AWG		1–7			8–19			20–37			38–61			62–91			92–192		
		Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating		
		60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C
26		1.00	1.23	1.42	0.71	0.87	1.02	0.55	0.68	0.78	0.46	0.57	0.67	0.45	0.55	0.64	NA	NA	NA
24		1.19	1.46	1.69	0.81	1.01	1.17	0.63	0.78	0.91	0.55	0.67	0.78	0.46	0.56	0.65	0.40	0.48	0.55
23		1.24	1.53	1.78	0.89	1.11	1.28	0.77	0.95	1.10	0.66	0.80	0.93	0.58	0.71	0.82	0.45	0.55	0.63
22		1.50	1.86	2.16	1.04	1.28	1.49	0.77	0.95	1.11	0.66	0.82	0.96	0.62	0.77	0.89	0.53	0.63	0.72

Table 725.144 NEC©-2017 to NEC©-2020

- Expanded the entries to two decimal places, using the numbers from the Fact Finding Report and natural mathematical rounding
- Deleted the 'One Cable' columns as that data was derived from a completely different source than the rest of the table, collapsed this in with the old 2-7 column
- Replaced data in the 23AWG row (with new test data) as table analysis revealed an anomaly that traced back to a mistake with the conduit material

725.144 NEC©-2020 New Informational Notes

Informational Note No. 3: The requirements of Table 725.144 were derived for carrying power and data over 4-pair copper balanced twisted pair cabling. This type of cabling is described in ANSI/TIA 568-C.2-2009, *Commercial Building Telecommunications Cabling Standard — Part 2: Balanced Twisted-Pair Telecommunications Cabling and Components*.

Informational Note No. 4: See TIA-TSB-184-A-2017, *Guidelines for Supporting Power Delivery Over Balanced Twisted-Pair Cabling*, for information on installation and management of balanced twisted pair cabling supporting power delivery.

Informational Note No. 5: See ANSI/NEMA C137.3-2017, *American National Standard for Lighting Systems — Minimum Requirements for Installation of Energy Efficient Power over Ethernet (PoE) Lighting Systems*, for information on installation of cables for PoE lighting systems.

Informational Note No. 6: Rated current for power sources covered in 725.144 is the output current per conductor the power source is designed to deliver to an operational load at normal operating conditions, as declared by the manufacturer. In the design of these systems, the actual current in a given conductor might vary from the rated current per conductor by as much as 20 percent. An increase in current in one conductor is offset by a corresponding decrease in current in one or more conductors of the same cable.

Text Source: NFPA 70 2020 Second Draft Report

Summary of PoE Related Changes, 2017 to 2020

- Acknowledged that cable heating is purely about the current
- Replaced 60W exemption with 0.3A in any conductor ≥24AWG
- Expanded Table 725.144 to two decimal places, normalized margin across the table
- Added ambient temperature correction factors for LP cable
- Settled on term ‘rated current’ but added an informational note in 725.121 stating that rated current in 725 isn’t exactly like rated current throughout the rest of the NEC
- Striving for user-friendliness for installers and inspectors

What's next for the NEC

- Every 3 years the code is subject to change
  - Preparation for the 2023 cycle starts now
- Potential for new class of power source to better reflect PoE
- Single pair ethernet and powering will impact the 2023 code
  - New types of signaling wiring
  - New applications
  - Adjustment of existing applications already in the code
  - Data & power – single pair is entirely outside of the 725.144 bundling study
  - Other NFPA documents (NFPA72 – alarms)

5 Minute Break

PoE and Licensing Legislation

A note about Standards vs codes

- This is where ‘standards’ and ‘codes’ differ.
  - NFPA 70 (the NEC) is a code – it gets written into law (when incorporated, everything can be followed)
  - TIA 568, IEEE 802.3, etc. are standards – they are not written in a way compatible to write them into law

- BUT neither is law or regulation until adopted by a piece of legislation or a rule making

Success brings attention

- Legislation related to electrical licensing & permitting targets anything > 50 volts
  - Attempts to write the NEC out of license rules
  - Ensnares PoE as “electrical work”
- Legislative sessions on hold from 2019
  - All known attempts were defeated, withdrawn, or amended
- Underlying issues:
  - Prominence/importance of PoE – presence in the NEC
  - Need for normalization of low voltage licensing

Action in many jurisdictions

- Initially seen in Utah, proposed electrical board rules NPR Rule R156-55b, defining 'electrical work' as greater than 50v and all other work to require a license
  - They didn't expect opposition, no change to the definition of electrical work was made
- This is widespread at both state and local level
  - So far AZ, MD, ND, NY, OK, TX, UT, MD, FL, ND, PA, NJ, CO, New York City, and Houston
- So far, over 15 separate actions tracked, most resolved either by the bills dying or amending with exemptions to cover telecom and/or PoE applications
- Many state legislatures adjourned in June; some full-time legislatures may take up the issue again this fall

Pattern

- Legislation simplifying or unifying licensing
  - Not necessarily unfavorable – lack of uniformity in low voltage credentials can be a problem
  - May delete exemptions that currently allow low-voltage & communications work
- Licensing or Permitting-related legislation may be amended to delete exemptions or delete NEC references
  - Or new exemptions inserted are limited to 50 volts (no good for PoE)
- Result: need to watch all actions which could be amended

Example legislation:
Deleting the NEC - OK SB175 as Introduced

- Replaces reference to class 2/3 circuits in the NEC with another act which requires licensing

> B. Class 2 and Class 3 circuits as provided in the Alarm, Locksmith and Fire Sprinkler Industry Act, shall be exempt from the requirements of ~~electrical licensing of either an electrical contractor or a journeyman electrician,~~ the Electrical License Act; provided, the work is performed in accordance with the National Fire Protection Association 70 requirements for Class 2 and Class 3 circuits.

Example legislation – FIXED??: Follow up – OK SB175 as amended

- A list of exemptions for each interest, but still limited at 50 volts...
- Letters of opposition filed
- Withdrawn by sponsor due to opposition

B. The portion of the wiring system between the load side of a Class 2 and Class 3 ~~circuits shall be~~ power source and the connected equipment utilized for the installation of burglar alarms or security systems, electronic access control, closed circuit television, commercial and residential fire alarm systems, commercial and residential fire sprinkler systems, nurse call systems, and voice, video, audio, data signal and lighting systems fifty (50) volts or less, are exempt from the requirements of electrical licensing ~~of either an electrical contractor or a journeyman electrician,~~ pursuant to the Electrical License Act; provided, the work is performed in accordance with the requirements for Class 2 and Class 3 circuits in the respective articles of the National Fire Protection Association 70 ~~requirements for Class 2 and Class 3 circuits~~ National Electrical Code as adopted by the State of Oklahoma.

Low voltage licensing : MD HB905 & MD HB792

- Both bills sought to unify licensing in MD and establish statewide limited energy licensing
- Both dead now

HB 905 limited to 50 volts

(I) "LOW–VOLTAGE SERVICES" MEANS:

(1) FOR AUDIO SIGNAL PROCESSING, AMPLIFICATION, AND REPRODUCTION EQUIPMENT, ELECTRICAL SERVICES THAT ARE OPERATED AT NOT MORE THAN 80 VOLTS OF ELECTRICAL CURRENT; AND

(2) FOR ALL OTHER ELECTRICALLY OPERATED SERVICES, SERVICES THAT ARE OPERATED AT NOT MORE THAN 50 VOLTS OF ELECTRICAL CURRENT.

HB 792 used the NEC and definitions

(K) "PROVIDING LIMITED ENERGY SERVICES" MEANS TO DESIGN, INSTALL, ERECT, REPAIR, MAINTAIN, OR ALTER ANY OF THE FOLLOWING:

(1) CABLING AND EQUIPMENT FOR VOICE, AUDIO, AND DATA SIGNALS;

(2) CLASS TWO OR CLASS THREE CIRCUITS, AS DEFINED BY THE NATIONAL ELECTRICAL CODE, THAT ARE REMOTE CONTROL, SIGNALING, OR POWER–LIMITED;

(3) FIRE ALARM SYSTEMS;

(4) OPTICAL FIBER CABLES;

(5) COMMUNICATION CIRCUITS;

(6) RACEWAYS;

(7) COMMUNITY ANTENNA TELEVISION OR RADIO DISTRIBUTION SYSTEMS;

(8) NETWORK–POWERED BROADBAND COMMUNICATIONS SYSTEMS;

(9) PREMISES–POWERED BROADBAND COMMUNICATIONS SYSTEMS;

(10) ALARM SYSTEMS;

(11) ACCESS CONTROL SYSTEMS;

(12) VIDEO SURVEILLANCE SYSTEMS;

(13) HOME AUTOMATION AND CONTROL SYSTEMS;

(14) AUDIO VISUAL SYSTEMS;

(15) COMPUTER AND COMMUNICATIONS NETWORKS;

(16) HEATING FURNACES AND ELECTRICALLY OPERATED

Example legislation: ND1157
Inadvertent catching up of PoE in data exemptions

- Tries to protect computer network systems, but ensnares PoE (as introduced)

> 1. A person that does not have a valid license issued by the board may not undertake or offer to undertake with another person to plan, lay out, supervise, install, make additions, make alterations, or make repairs, in the installation of wiring, apparatus, or equipment for electric light, heat, or power~~, shall apply to the board for a license~~. This licensure requirement does not include the planning, laying out, supervising, installing, making of additions to, making of alternations to, or making of repairs to a system, such as an audio system, video system, computer network system, home automation system, or security system, if the system is not for electric light, heat, or power.

Example AZ HB2181 (as introduced)
PoE friendly legislation

- Had broad exemption for low voltage

Be it enacted by the Legislature of the State of Arizona:

Section 1. Section 32-1121, Arizona Revised Statutes, is amended to read:

32-1121. Persons not required to be licensed; penalties; applicability

A. This chapter ~~shall~~ DOES not ~~be construed to~~ apply to:

18. LOW-VOLTAGE COMMUNICATION SYSTEMS COMPANIES OR AGENTS ENGAGING IN ANY WORK TO INSTALL, SERVICE OR REPAIR ANY OF THE FOLLOWING:

(a) TELEPHONE SYSTEMS.
(b) SOUND SYSTEMS.
(c) INTERCOMMUNICATION SYSTEMS.
(d) PUBLIC ADDRESSING SYSTEMS.
(e) TELEVISION OR VIDEO SYSTEMS.
(f) LOW-VOLTAGE SIGNALING DEVICES.
(g) LOW-VOLTAGE LANDSCAPE LIGHTING THAT DOES NOT EXCEED NINETY-ONE VOLTS.
(h) LOW-VOLTAGE WIRING AND EQUIPMENT FOR MASTER AND PROGRAM CLOCKS.

Example AZ HB 2181 – as passed
Not harmful, but less friendly

- Limited exemption to telecommunications providers, will require future legislative action for new technologies.

Be it enacted by the Legislature of the State of Arizona:

Section 1. Section 32-1121, Arizona Revised Statutes, is amended to read:

32-1121. Persons not required to be licensed; penalties; applicability

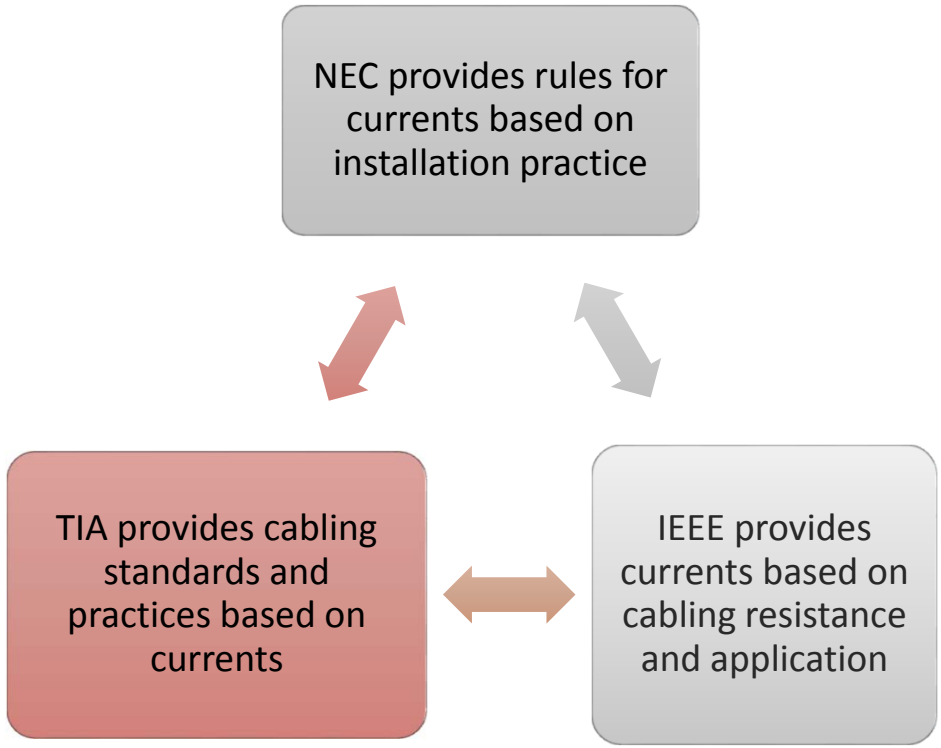
A. This chapter ~~shall~~ DOES not ~~be construed to~~ apply to:

18. CABLE TELEVISION, SATELLITE TELEVISION AND TELECOMMUNICATIONS PROVIDERS, INCLUDING DATA AND RELATED SERVICES OF CABLE TELEVISION, SATELLITE TELEVISION AND TELECOMMUNICATIONS PROVIDERS INCLUDING CONTRACTORS AND SUBCONTRACTORS OF CABLE TELEVISION, SATELLITE TELEVISION AND TELECOMMUNICATIONS PROVIDERS IF THE WORK OF THE CONTRACTORS AND SUBCONTRACTORS IS LIMITED TO INSTALLING LOW-VOLTAGE CABLE, TELEPHONE SERVICES, INTERNET SERVICES AND DATA SERVICE. INSTALLATION DOES NOT INCLUDE DIGGING, TRENCHING, GRADING, HORIZONTAL BORING, COMPACTING OR FILLING EARTHEN OR OTHER MATERIAL BEFORE THE SERVICE DROP OF THE COMMERCIAL OR RESIDENTIAL STRUCTURE.

Designing and Planning for PoE

Multiple documents to guide plans

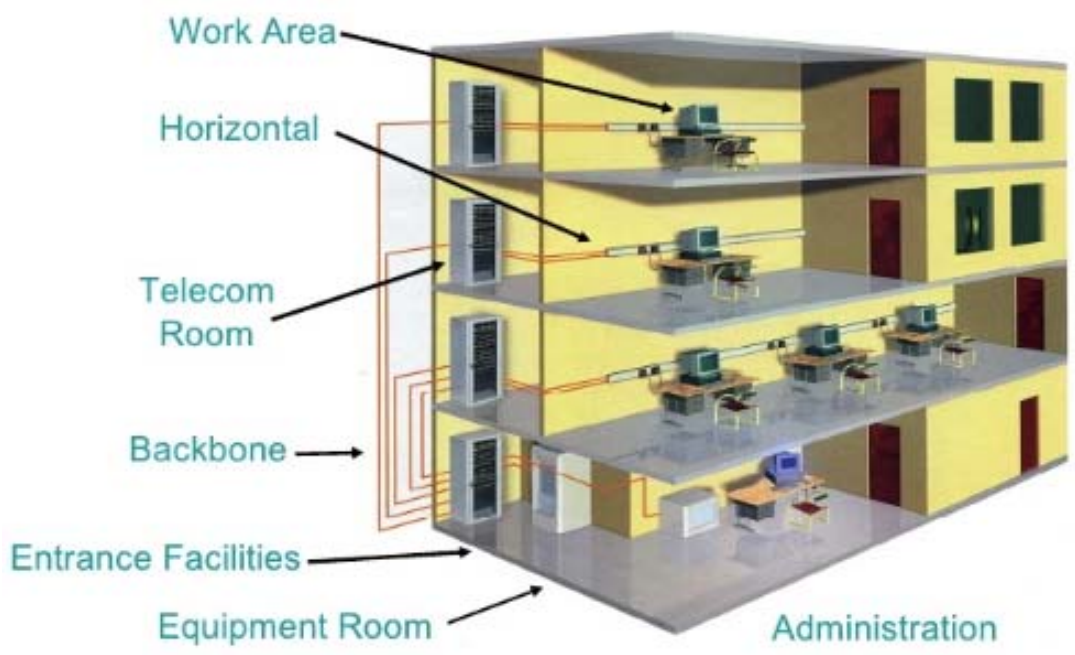
- NEC
  - Exception for < 0.3 A/conductor
  - Bundling tables / LP cabling
- TIA TSB-184-A*
  - Bundling tables & modeling information for engineering supervision
- IEEE 802.3
  - Current levels based on power classification



*here TIA means Telecommunications Industry Association, not to be confused with NFPA's TIA, Tentative Interim Amendment

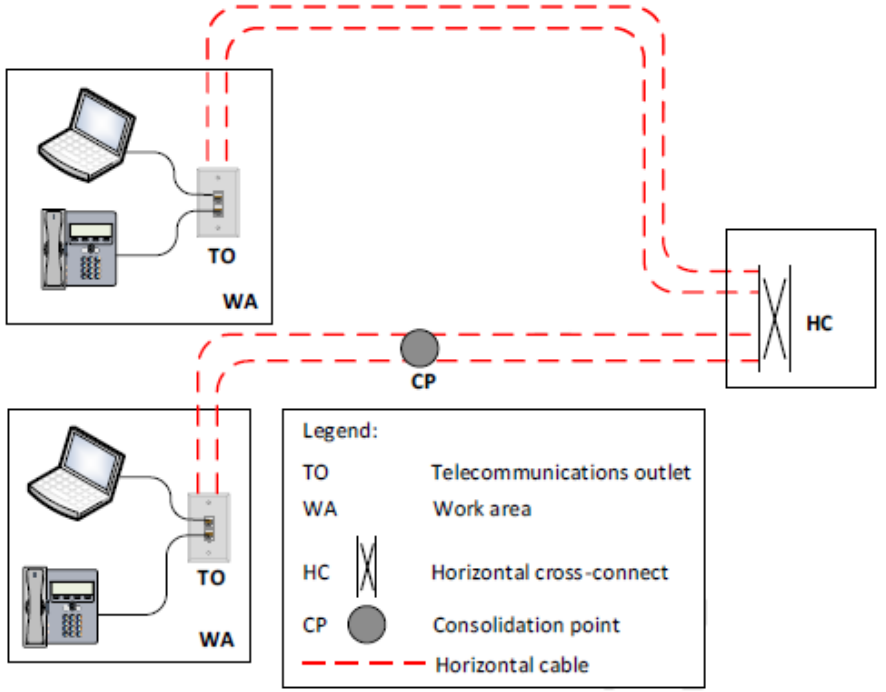
But first... Some structured cabling basics

- "Structured cabling", has been the basis of data cabling since the late 1980s
  - Specified in TIA-568 series of documents
- Low voltage installers are trained on this, and certify installations to TIA-568
- Divides the installation into areas with different characteristics



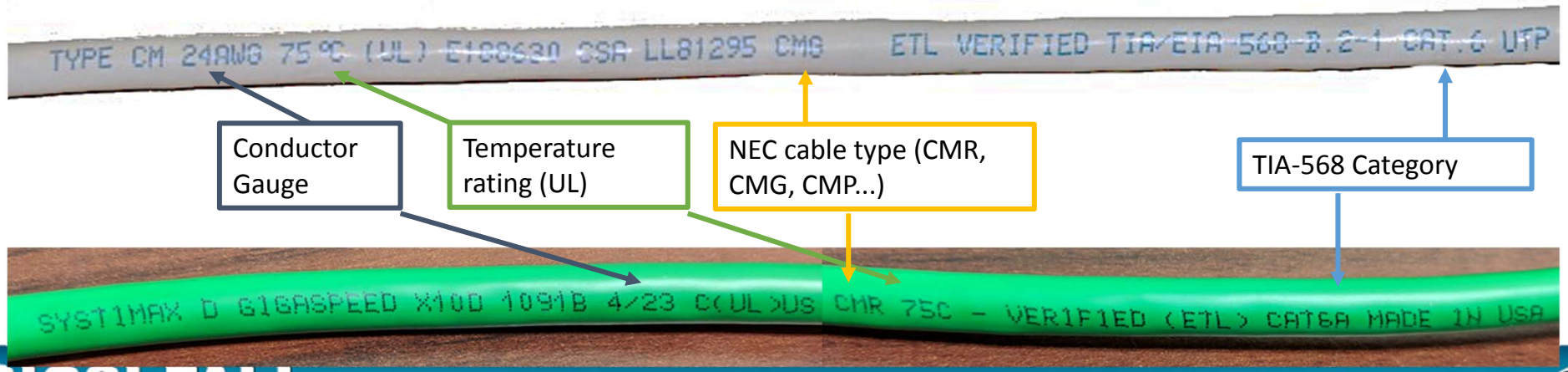
Horizontal Cabling Matters for PoE

- TIA-568-D.2 is the latest specification
- Cabling & components are certified, tested, and labeled to TIA-568 standards
- TIA-568 architecture divides wiring into horizontal cable and cords
  - Permanently installed cabling is called “horizontal cabling”
  - But - what WE often see are cords.



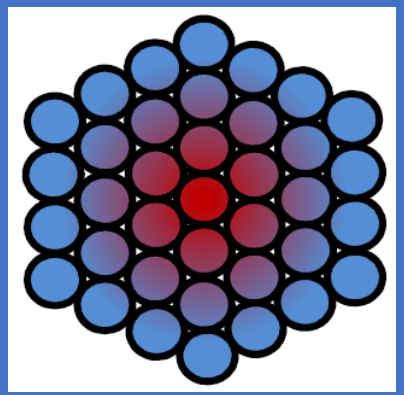
TIA-568-D.2 Specifies copper cabling and components

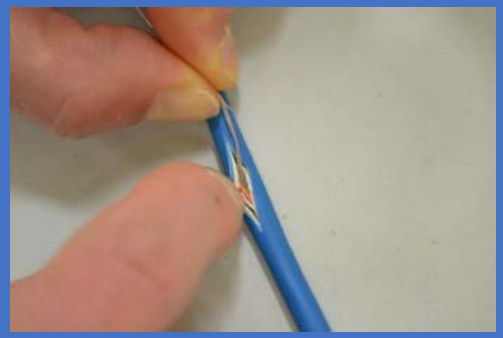
- For data, most installations certify and specify to Category
  - TIA Category (5e, 6, 6a) defines data communications performance
- Most installations today are “Cat” 5e or 6 - trend is away from 5e towards 6 and 6A
  - Growing number of installations are “Cat 6A” - Recommended by many cable & system OEMs for PoE
- Cabling is generally marked as to Gauge and Category



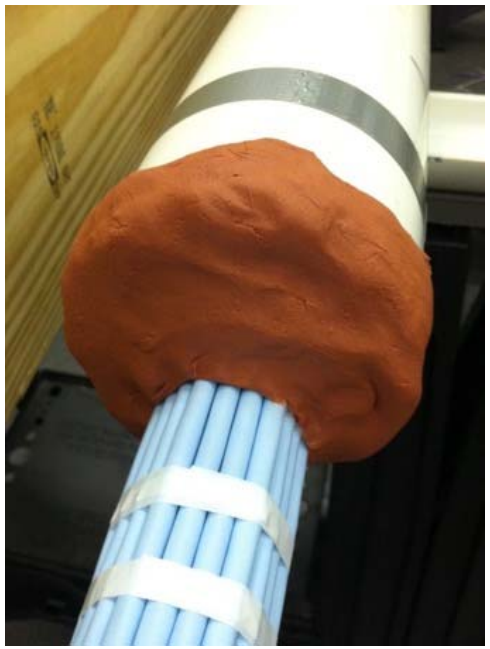
TSB-184-A: Guidelines made with multi-vendor measurements

- Cable bundles measured for maximum heat at center of bundle
  - Assumes all conductors are energized



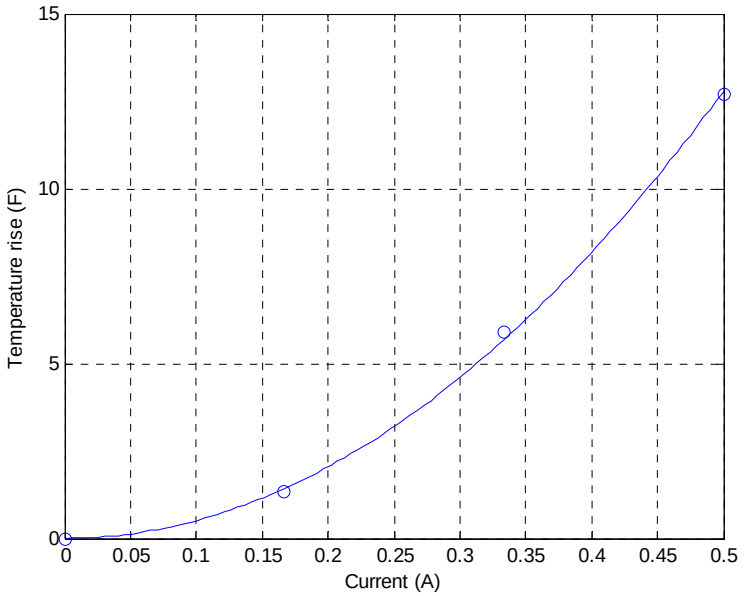


Thermocouples inserted into cables in centers of bundles



Basic approach – Measurements are fitted to a heating curve

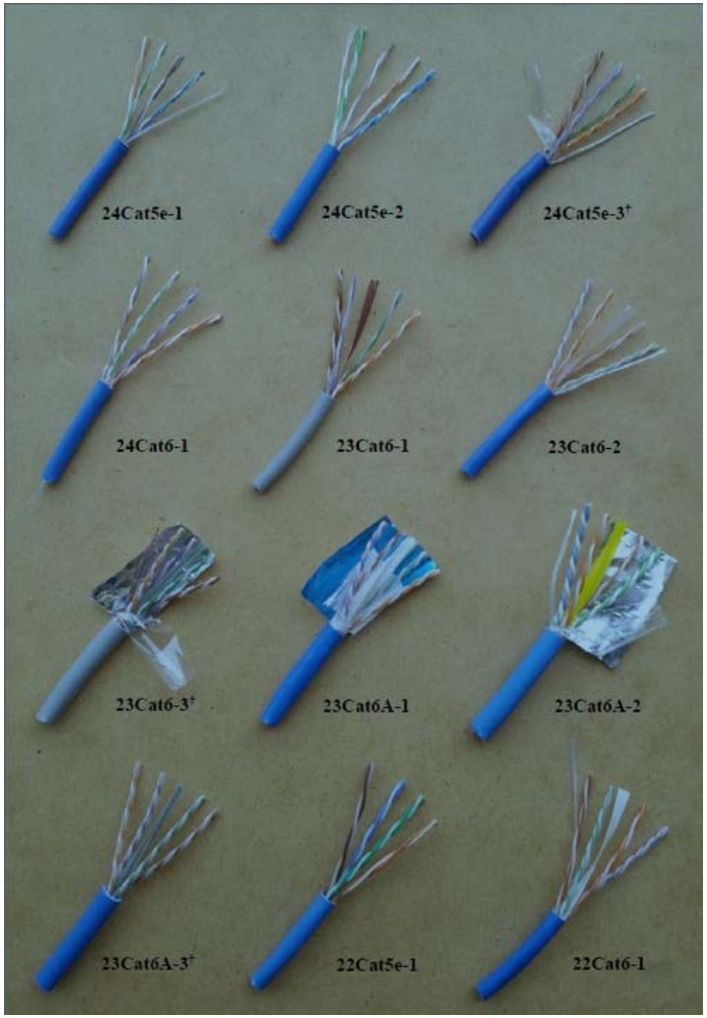
- According to Joule's law, heating is proportional to square of the current
- The point (0,0) corresponds to no temperature rise in the un-energized bundle.
  - This is a BOUNDARY CONDITION – something always true and independent of measurements



Note – TIA TSB-184-A refers to current per PAIR of conductors (2x the current per conductor referred to in the NEC)

TSB-184A models by Category of cabling

- Category is what is specified for most low voltage installations, to ensure data performance
- Category is what low voltage installers usually certify to, per contracts
- Category ROUGHLY corresponds to minimum conductor AWG and to types of construction (there are exceptions)
  - Typically:
    - Cat5e typically 24 AWG, usually unshielded (UTP)
    - Cat6 is 23-24 AWG, UTP or with a foil shield
    - Cat6a is 22-23 AWG either with metal screening or larger diameter jacketing



Source: Jason Tuenge, Karsten Kelly, Michael Poplawski, "Connected Lighting Systems Efficiency Study — PoE Cable Energy Losses, Part 1", US Dept of Energy, Nov 2017 (revised Jan 2019), https://www.energy.gov/sites/prod/files/2019/01/f58/cls_poe-cable-pt1.pdf

TSB-184-A provides guidance in different formats

Example 1:
Table of maximum bundle size for 15°C rise at 45°C ambient

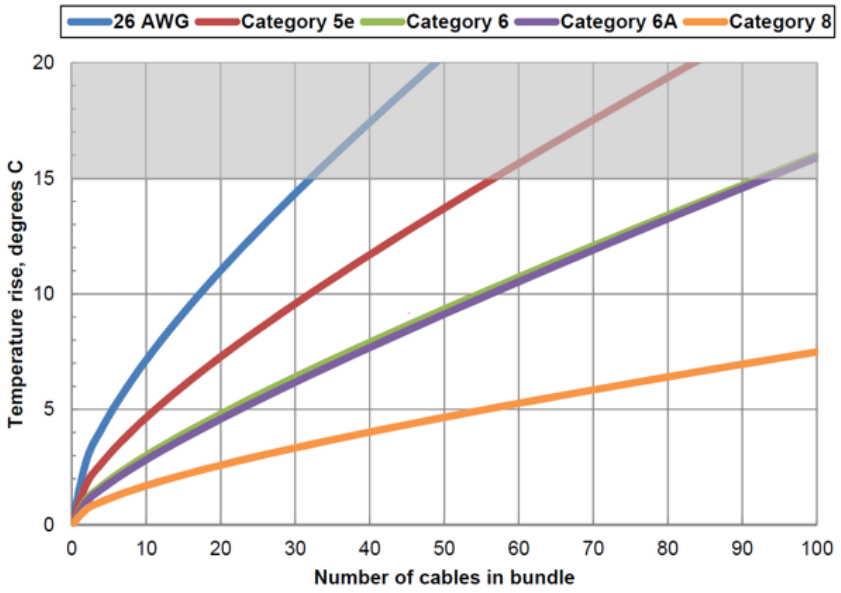
Current per pair	26 AWG		Category 5e 24AWG		Category 6 23AWG		Category 6A 23AWG		Category 8 23AWG	
	Air	Conduit	Air	Conduit	Air	Conduit	Air	Conduit	Air	Conduit
600mA	124	68	191	129	252	182	313	242	918	514
720mA	75	39	121	79	163	114	203	151	581	317
1000mA	28	13	51	31	72	46	90	62	243	125

Example 2:
Equation for ampacity (per pair) vs. bundle size, cable temperature rating, ambient temp, and category (coefficients C1 and C2)

$$i = \sqrt{\frac{T_{rating} - T_{ambient}}{(C_1 N + C_2\sqrt{N})[1 + \alpha(T_{ambient} - 20\ °C)]}}$$

For the case of a Category 5e bundle of cable in open air (C_1=0.1267, C_2=0.9933) described by $T_{ambient}$ = 45 °C, T_{rating}= 60 °C and N = 37. The ampacity is 1.128 Amps per pair.

Example 3:
Temperature rise with 500mA/conductor in air at 45°C



TSB-184- Design guidelines related to Installation

1. Installation design including the type of pathways selected, the pathway fill factor and whether the pathway is sealed at both ends.
2. The pathway environment and whether the pathway goes through insulated areas, in which case the type of insulation will have a significant factor. For optimal thermal performance, pathway design should avoid any insulated areas.
3. Thermal aspects of the entire pathway (e.g. metal, plastic, covered, ventilated, non-ventilated, airflow) should be taken into account when designing for dc power delivery.
4. The number of cables in close proximity or bundled.
5. Grouping and separation of cables (e.g. using compartments or separation in pathways) based on powering levels for optimal power delivery.
6. The geometric arrangements of the cables, or configurations with increased surface area, such as rectangles, improve heat dissipation reducing temperature rise.

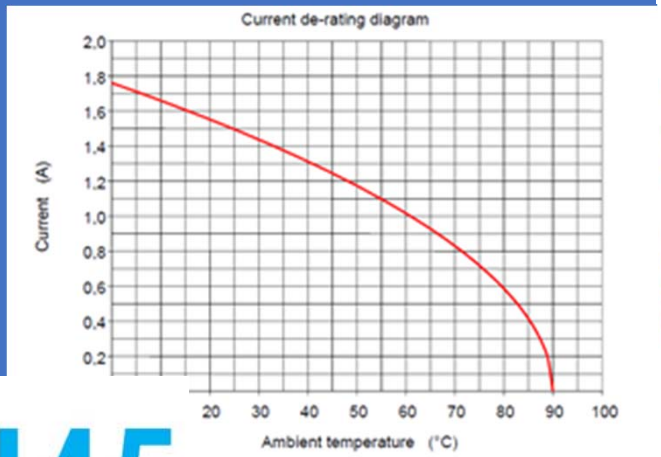
Variations with cable design

- Study measured multiple manufacturers at each category over varying bundle sizes and current
- BUT there is variation in cable design
  - Some cables are made with larger diameter conductors for lower resistance (this means less heating)

    e.g., 22 AWG Cat5e cable vs. typical Cat5e (24 AWG)
  - Physical size of bundles depends on more than just category and conductor size (larger size bundles with the same # of cables also can lessen heating)
  - Construction of cable jacketing / screening may also change heating characteristics

What about connectors?

IEC 60603-7 specifies > 1 Ampere/contact at 60°C

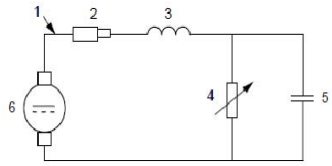


the RJ45

IEC 60512-99-001 specifies unmating under load consistent with 500mA/conductor PoE needs

5.1 General

The values for the circuit components and the details of the test circuit, referenced in IEC 60512-9-3, shall be as shown in Figure 1.



1	Cables in accordance with 4.1
2	Connector under test
3	Inductor 100 µH
4	Variable resistor (e.g. 50 Ω to 300 Ω)
5	Capacitor 5 µF
6	Power source

5.2 Voltage and current

The variable resistor(s) shall be set so that the electrical current in each circuit (mated contacts) of the specimen is 0,6 A. When specimen is unmated, the 'open circuit' voltage, in all circuits, shall be 55 V d.c. See Annex A.

IEEE 802.3 at specifies a maximum current of 0,3 A per conductor and an open circuit voltage of 55 V d.c. The test current has been doubled to 0,6 A in order to represent the high probability that one contact of any given pair will separate before the other. Therefore as in the cited application, where current is carried by pairs of contacts in multiple parallel circuits, the last contact to break will do so carrying all the current (twice the nominal).

An electrical load, current and open circuit voltage, as detailed in Clause 5, shall be applied to each specimen.

For the purpose of this test one connector shall be fixed and the other disengaged at a speed of

150 ± 10 mm/s.

One engagement and one separation constitute one cycle.

25 cycles shall be performed.

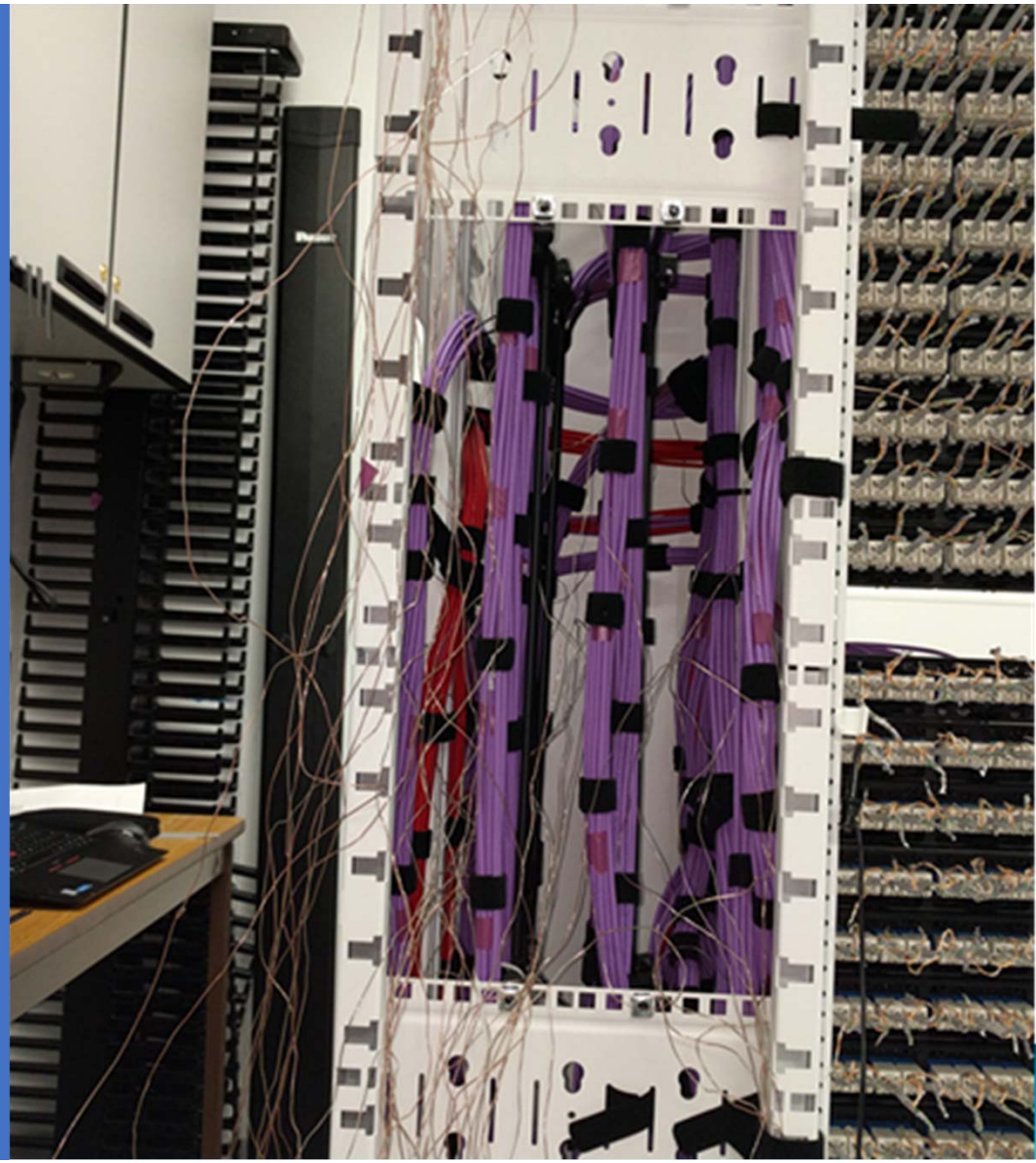
The polarity of the d.c. source (direction of the electrical current) shall be reversed and 25 further cycles performed.

Flowing mixed gas test. Method 1	11g	4 days. Half of the samples mated; half of the samples unmated

Bicsi

Yes, this is complicated –
fortunately, there are shortcuts...

- Easiest way – restricted powering (planning based on power source capability)
  - If PoE currents are less than 300mA/conductor (IEEE 802.3 PoE to 60 Watts) and cables are 24 AWG or larger (usual cables), **no special engineering is required**
- Another easy way – manage small bundles (simple planning for cables)
  - Keep bundle sizes small (24 or fewer per bundle) and PoE within IEEE 802.3 limits (up to 90W, or 0.433A/conductor)
  - Separate bundles of 24 (1.5 in is enough)



Or you can fine-tune the install

- Slightly harder way:
  - Use table-based design
  - Generally go look for category 6a or other 23 AWG or larger conductor cabling, allowing larger bundles without concern to 90W levels

- Fully engineered way:
  - Plan which circuits are powered, and at what levels
  - Use equation-based design and guidance from manufacturer, TIA TSB-184-A and NEC Table 725.144 to pick cable category/gauge and bundle size based on expected current levels and number of circuits

AWG	Number of 4-Pair Cables in a Bundle																	
	1-7			8-19			20-37			38-61			62-91			92-192		
	Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating		
	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C
26	1.00	1.23	1.42	0.71	0.87	1.02	0.55	0.68	0.78	0.46	0.57	0.67	0.45	0.55	0.64	NA	NA	NA
24	1.19	1.46	1.69	0.81	1.01	1.17	0.63	0.78	0.91	0.55	0.67	0.78	0.46	0.56	0.65	0.40	0.48	0.55
23	1.24	1.53	1.78	0.89	1.11	1.28	0.77	0.95	1.10	0.66	0.80	0.93	0.58	0.71	0.82	0.45	0.55	0.63
22	1.50	1.86	2.16	1.04	1.28	1.49	0.77	0.95	1.11	0.66	0.82	0.96	0.62	0.77	0.89	0.53	0.63	0.72

Data Source: National Electrical Code 2020 Second Revision

$$\Delta T_{cable\_type} = \left(C_1 N + C_2 \sqrt{N}\right) \cdot i^2 \qquad \text{(A-1)}$$

Where:

C_1: Represents temperature rise within the bundle from the surface of the bundle to the center of the bundle

C_2: Represents temperature rise from the surface of the bundle to the ambient environment

N: The number of cables in the bundle

i: The current per pair in amps

Source: TIA TSB-184-A

PoE Cabling design Choices

Up to 60W, standard 24 AWG cable?

- Easy design – no bundling requirements

37 cables in a bundle, and nothing less than 24 AWG?

- Easy design – up to full Class 8 IEEE 802.3 PoE

Special needs? – consult tables or engineering supervision

- Beyond standard power levels, OR
- High bundle-count needs, OR
- Small conductor sizes

Installation and Inspection

Table 725.144 NEC©-2020 Second Revision

AWG	Number of 4-Pair Cables in a Bundle																	
	1-7			8-19			20-37			38-61			62-91			92-192		
	Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating		
	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C
26	1.00	1.23	1.42	0.71	0.87	1.02	0.55	0.68	0.78	0.46	0.57	0.67	0.45	0.55	0.64	NA	NA	NA
24	1.19	1.46	1.69	0.81	1.01	1.17	0.63	0.78	0.91	0.55	0.67	0.78	0.46	0.56	0.65	0.40	0.48	0.55
23	1.24	1.53	1.78	0.89	1.11	1.28	0.77	0.95	1.10	0.66	0.80	0.93	0.58	0.71	0.82	0.45	0.55	0.63
22	1.50	1.86	2.16	1.04	1.28	1.49	0.77	0.95	1.11	0.66	0.82	0.96	0.62	0.77	0.89	0.53	0.63	0.72

Text Source: NFPA 70 2020 Second Revision

Table 725.144 NEC©-2020 Second Revision

AWG	Number of 4-Pair Cables in a Bundle																	
	1-7			8-19			20-37			38-61			62-91			92-192		
	Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating		
	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C
26	1.00	1.23	1.42	0.71	0.87	1.02	0.55	0.68	0.78	0.46	0.57	0.67	0.45	0.55	0.64	NA	NA	NA
24	1.19	1.46	1.69	0.81	1.01	1.17	0.63	0.78	0.91	0.55	0.67	0.78	0.46	0.56	0.65	0.40	0.48	0.55
23	1.24	1.53	1.78	0.89	1.11	1.28	0.77	0.95	1.10	0.66	0.80	0.93	0.58	0.71	0.82	0.45	0.55	0.63
22	1.50	1.86	2.16	1.04	1.28	1.49	0.77	0.95	1.11	0.66	0.82	0.96	0.62	0.77	0.89	0.53	0.63	0.72

Highlighted for IEEE Class 8 current, one cell is less than 0.433A

Text Source: NFPA 70 2020 Second Revision

Table 725.144 adjusted to 45°C ambient

AWG	Number of 4-Pair Cables in a Bundle																	
	1-7			8-19			20-37			38-61			62-91			92-192		
	Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating			Temperature Rating		
	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C	60°C	75°C	90°C
26	0.71	1.00	1.23	0.50	0.71	0.88	0.39	0.56	0.68	0.33	0.47	0.58	0.32	0.45	0.55	NA	NA	NA
24	0.84	1.19	1.46	0.57	0.82	1.01	0.45	0.64	0.79	0.39	0.55	0.68	0.33	0.46	0.56	0.28	0.39	0.48
23	0.88	1.25	1.54	0.63	0.91	1.11	0.54	0.78	0.95	0.47	0.65	0.81	0.41	0.58	0.71	0.32	0.45	0.55
22	1.06	1.52	1.87	0.74	1.05	1.29	0.54	0.78	0.96	0.47	0.67	0.83	0.44	0.63	0.77	0.37	0.51	0.62

Currents corrected to a 45℃ ambient using the equation in 310.15(B)(2)

- 45℃ is the max ambient assumed in TIA TSB-184-A

- To be TIA-568 compliant, the horizontal must be 24AWG or larger

Text Source: NFPA 70 2020 Second Revision

The code does offer a way to avoid all this analysis

LP Cable

(B) Use of Class 2-LP or Class 3-LP Cables to Transmit Power and Data.

Types CL3P-LP, CL2P-LP, CL3R-LP, CL2R-LP, CL3-LP, or CL2-LP shall be permitted to supply power to equipment from a power source with a rated current per conductor up to the marked current limit located immediately following the suffix "-LP" and shall be permitted to transmit data to the equipment. Where the number of bundled LP cables is 192 or less and the selected ampacity of the cables in accordance with Table 725.144 exceeds the marked current limit of the cable, the ampacity determined from the table shall be permitted to be used. For ambient temperatures above 30°C (86°F), the correction factors of Table 310.15(B)(1) or Equation 310.15(B) shall apply. The Class 2-LP and Class 3-LP cables shall comply with the following, as applicable:

(1) Cables with the suffix "-LP" shall be permitted to be installed in bundles, raceways, cable trays, communications raceways, and cable routing assemblies.

(2) Cables with the suffix "-LP" and a marked current limit shall follow the substitution hierarchy of Table 725.154 and Figure 725.154(A) for the cable type without the suffix "-LP" and without the marked current limit.

(3) System design shall be permitted by qualified persons under engineering supervision.

Informational Note: An example of a limited power (LP) cable is a cable marked Type CL2-LP(0.5A), 23 AWG.

Text Source: NFPA 70 2020 Second Revision

The Installation Contract

- When the install includes PoE, recommend the contract specifies:

- Category of cable (5e, 6a, etc.)
- AWG of conductors in cable
- Temperature rating of cable
- Max bundle size
- Max PSE Class
- LP cable?

Bundles

- Large, organized bundles are the worst case
- Recommend bundles be limited to 24
- Those bundles are not bundled together
- Can be as large as 37 without any extra consideration

Simple lookup of max bundle size for a given AWG

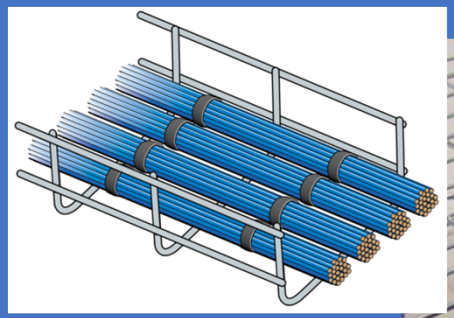
(60°C cable, 45°C ambient)

AWG	Max Bundle Size
24	37
23	61
22	91

For new installations, Cisco recommends Cat6a, 75°C cable

What about cables loose (not bundled) in a tray?

- Can separate bundles in the tray and treat as ‘bundled’
- OR: heating is roughly related to fill depth
- Recommend larger depth tray can be used but filled only to 1” depth



Cat 5e Temperature Rise vs. Cable Quantity

Bundle Data Point and Model Line are for Reference

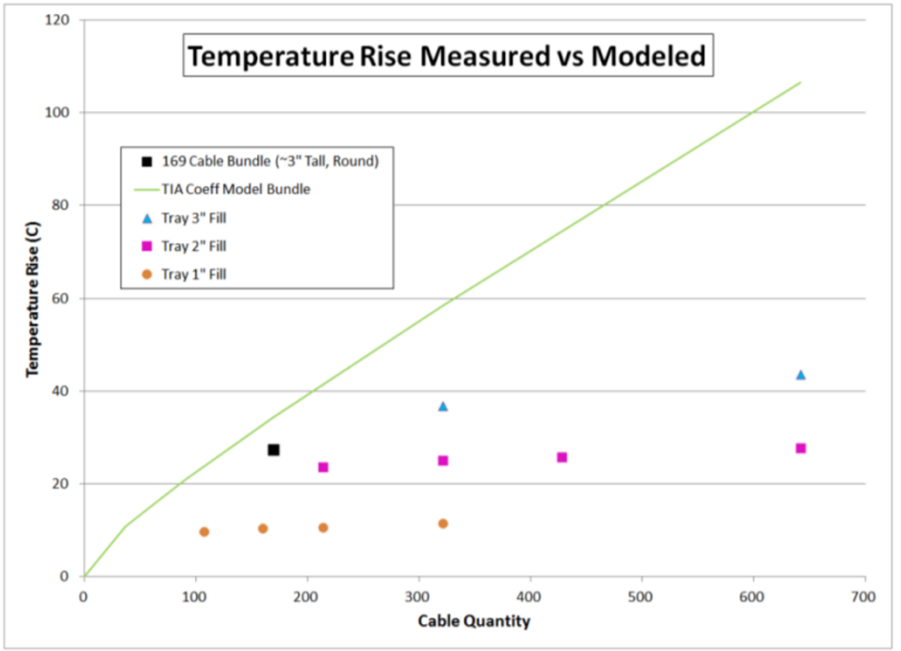
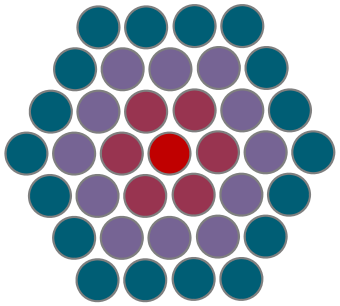


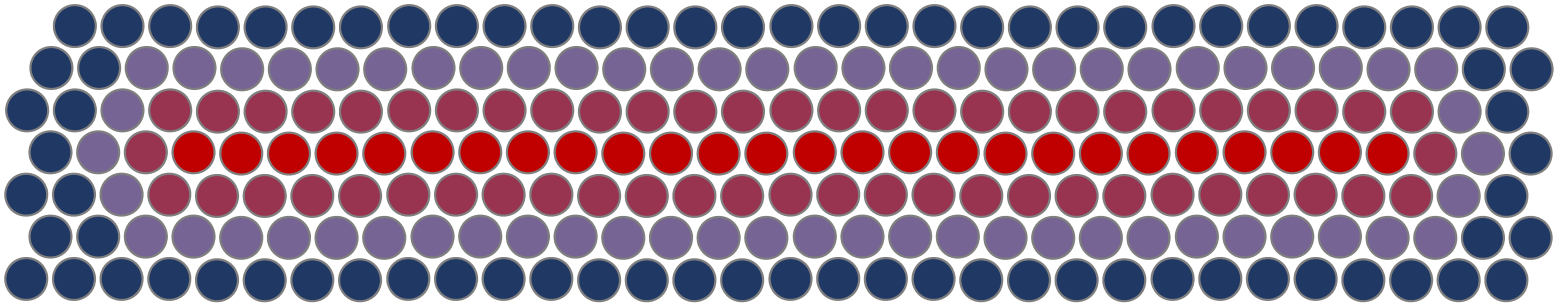
Image Source: TIA TR-42.7 submission “PoE Temp of Cables in Tray, Brian Marchant, Paul Vanderlaan, Berk-Tek

Cable Tray Fill Depth

This is the 37 cable bundle



This is the 37 cable bundle extrapolated out to a cable tray install



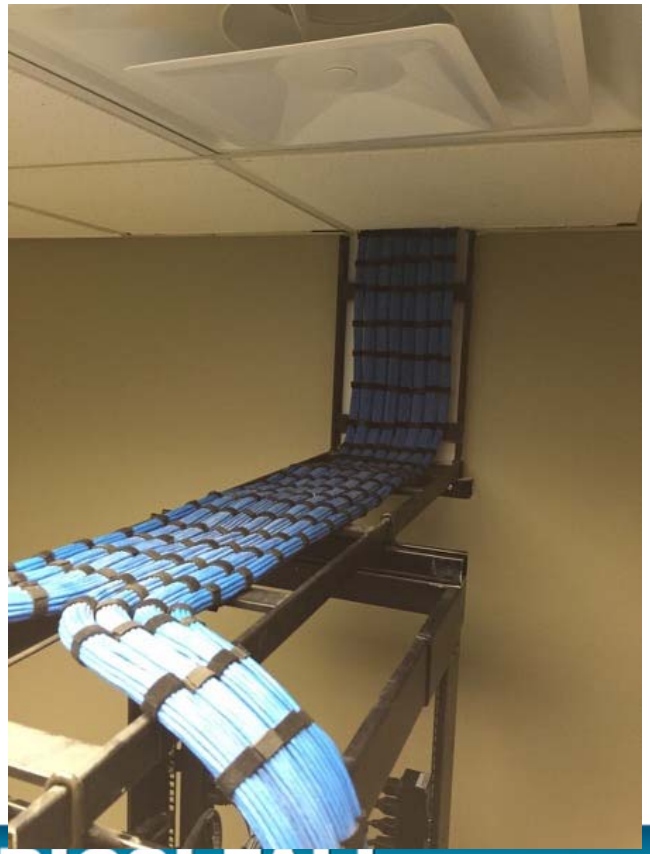
Same thing as 7-layer tray fill

Cable Tray Fill Depth

- Larger AWG can accommodate more fill depth

AWG	Max Layer Count in Cable Tray
24	7
23	9
22	11

Cable Bundles in a Tray

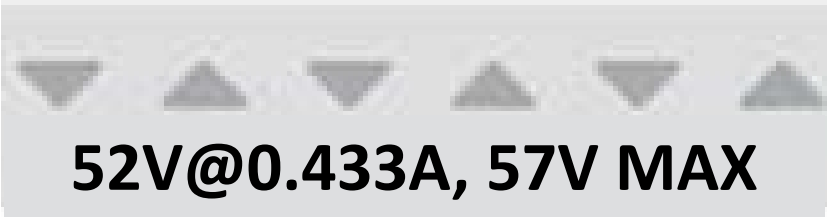


Labeling

- PSEs are required to have a marking under 725.121(C)
- At a minimum the marking SHALL indicate the maximum voltage and rated output current per conductor

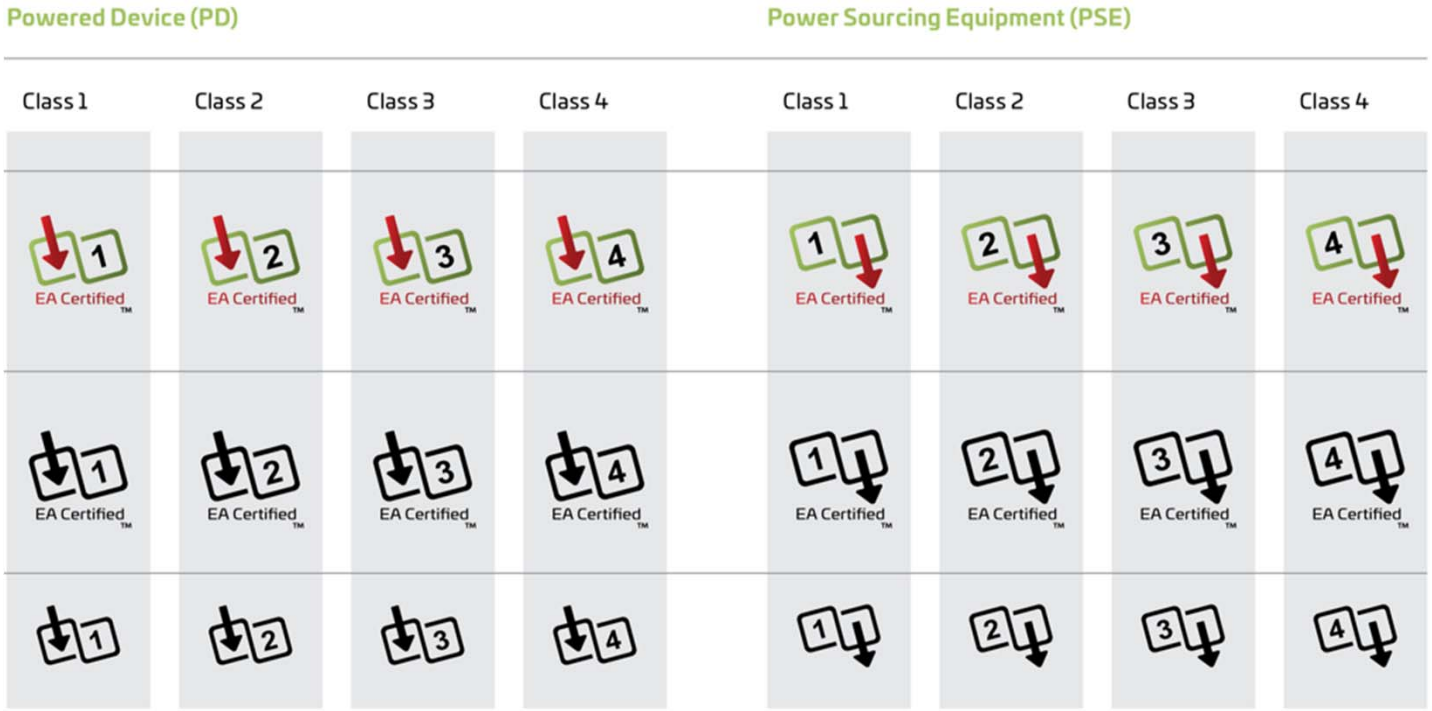
- Cisco suggests:

Nominal Voltage@Rated Current, Max Voltage



- Also, can look for EA logo

EA Logo



- Logo number indicates the IEEE Class
- Currently includes 1-4
- Gen 2 adds 5-8, coming later in 2019
- Logo could be in any of the forms shown
- If logo number is 6 or less, then the 0.3A exemption applies

Inspection

- A section on inspection would look a lot like the preceding slides
- Inspector, installers and designers are all focused on the same restrictions
- What follows is a recommended checklist for PoE inspections

Inspection

- What is the max current per conductor?
  - 0.3A or less? Pass
- How many ports of PoE are available in each location?
  - 37 or less? Pass

Inspection

- Is the cable:
  - Cat6a, 75℃ in bundles 192 or less?
  - Other Cat cable but 23AWG, 75℃ in bundles of 192 or less?
  - LP cable (LP 0.6)?
  - 23AWG, 60℃ cable in bundles of 61 or less
  - In bundles of 37 or less?

- If yes to any of the above, Pass

Inspection

- If the answer was NO to the previous questions, the design engineer should walk the inspector through compliance.

Management and Applications

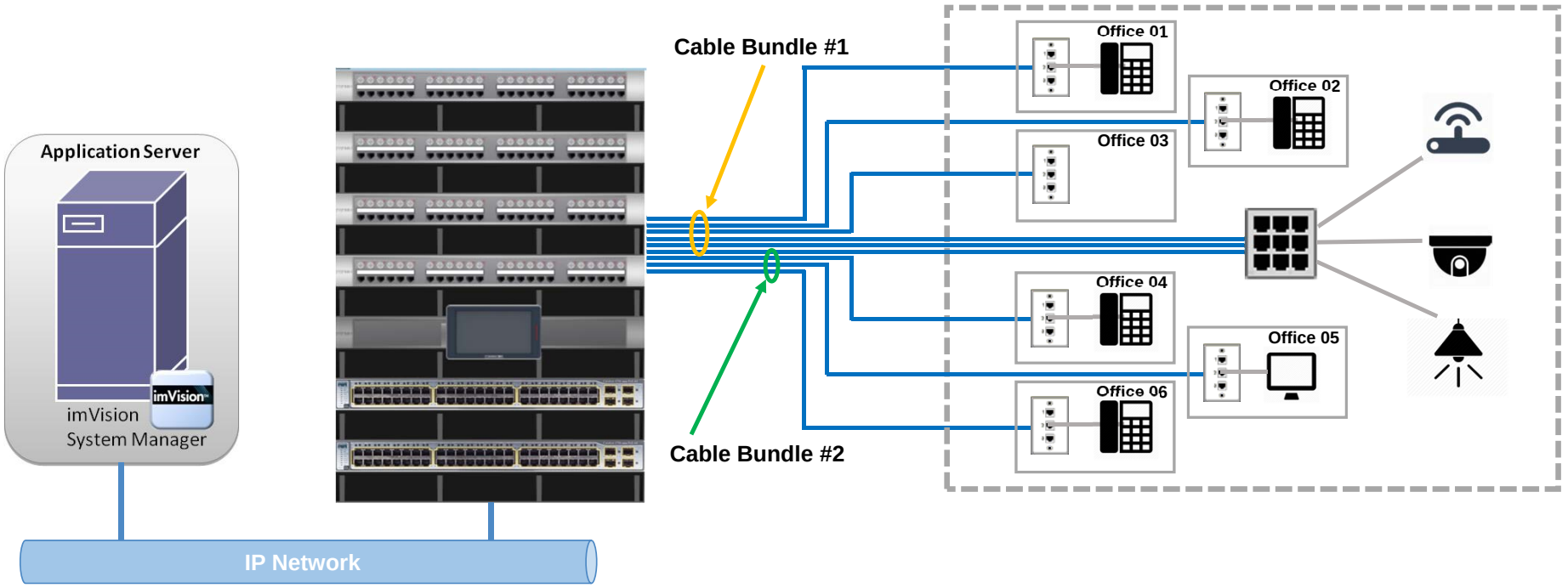
All these cables are Ethernet, but not all are powered… Can we do better?

- Using the network data

Linking power management to the infrastructure

- Automated infrastructure management
  - As-built or auto-sensed configurations
  - Which cable goes to where
  - Managed to a network database
- Linked to the EMS?
  - Controls power to avoid overheating
- Enables safer systems
  - Automatically, On-demand, and without additional inspection
    - Power sources often are installed after the fact

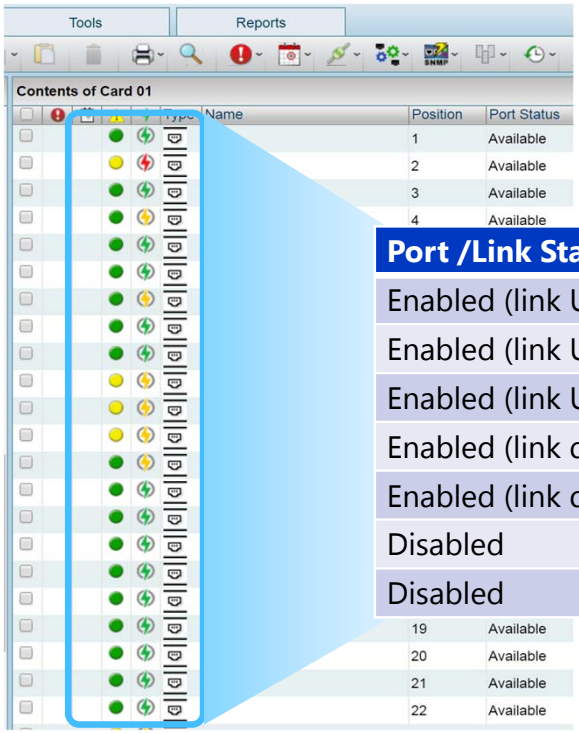
ISO/IEC 18598 – amendment 1 (to be adopted as ANSI/TIA-5048-1)



PoE data from Switches

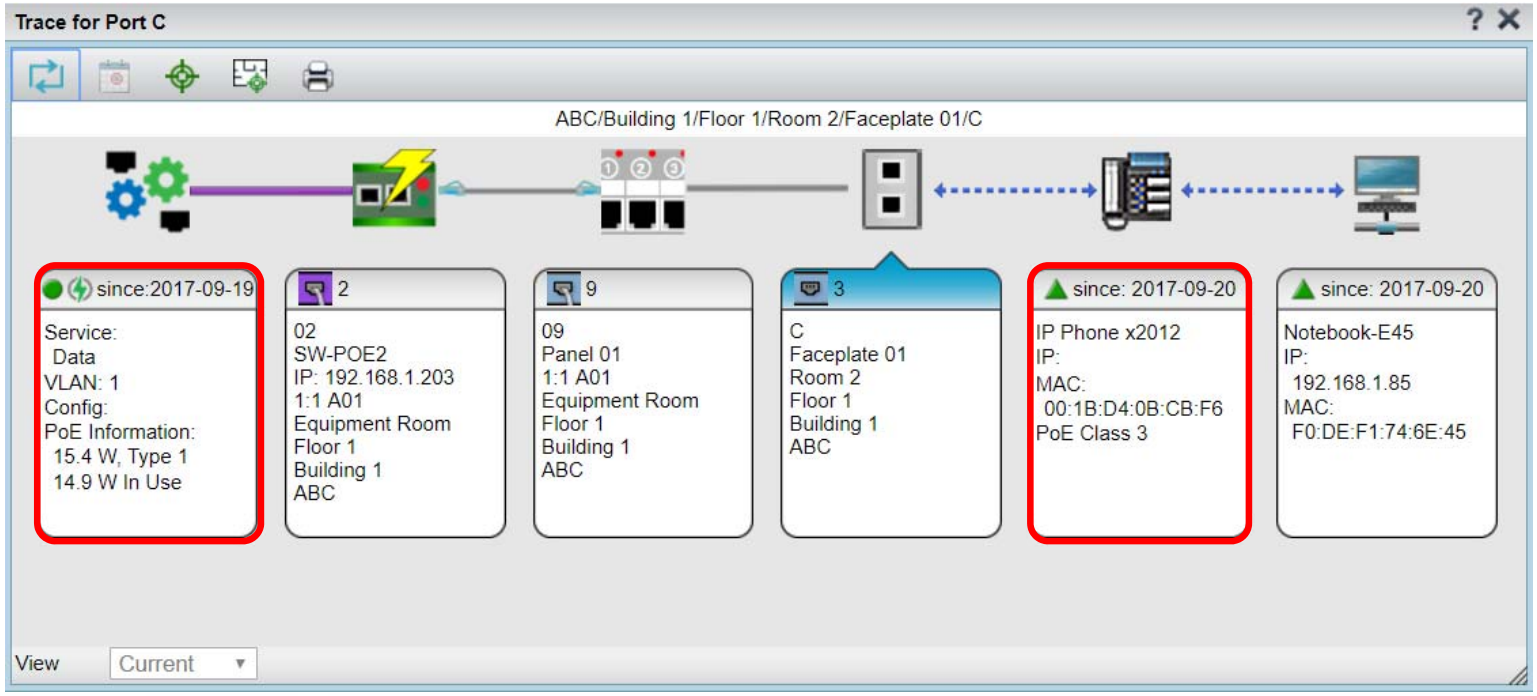
In line with TIA/EIA 606C

- PoE Capable (PS)
- PoE Type
- PoE Ports
- Ports with PoE In Use
- PoE Total Capacity (W)
- PoE Allocated Capacity (W)

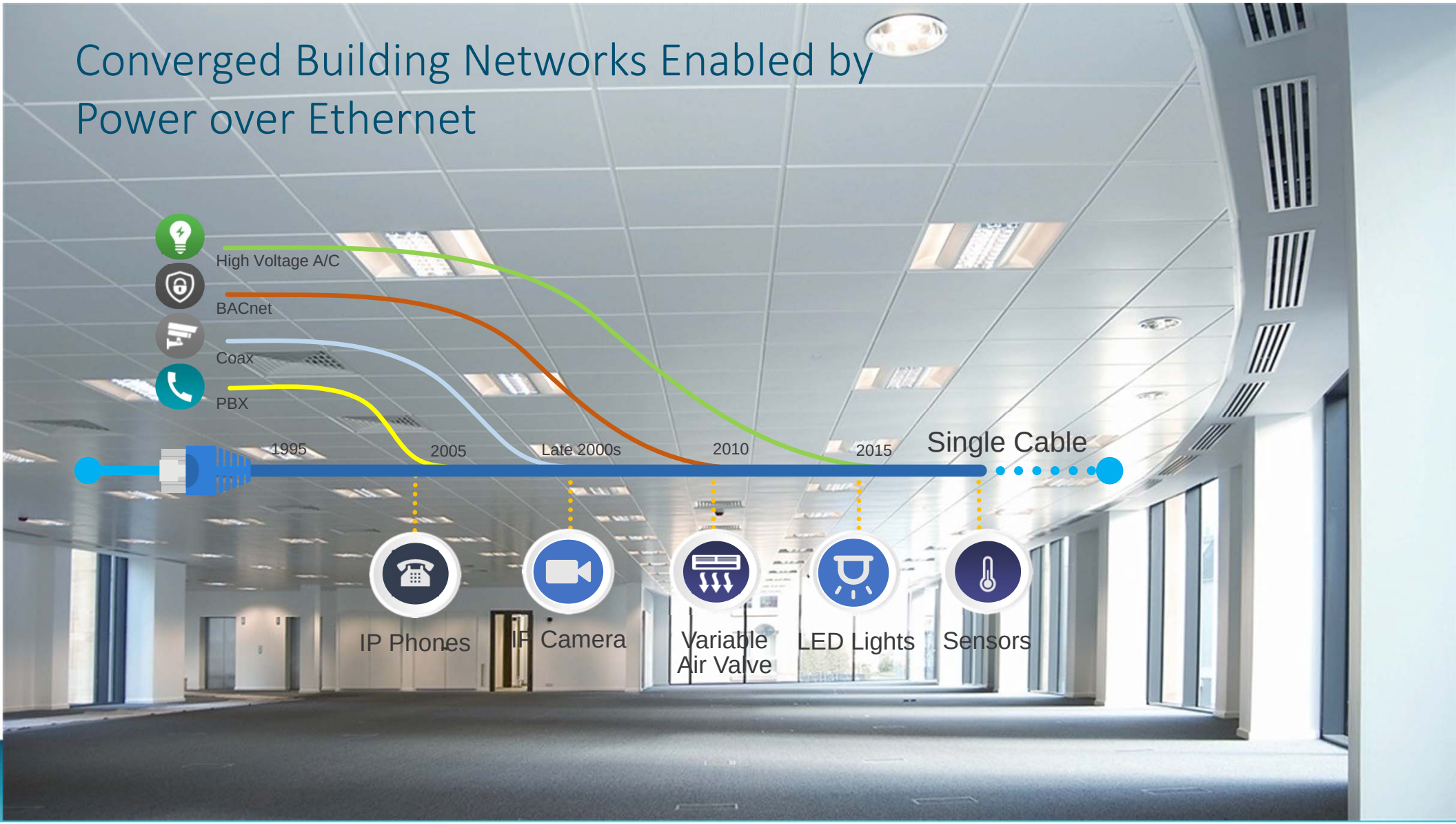


Port /Link Status	PoE Status
Enabled (link Up)	in use
Enabled (link Up)	not in use
Enabled (link Up)	disabled
Enabled (link down)	not in use
Enabled (link down)	disabled
Disabled	Not in Use
Disabled	disabled

Combine PoE Data with Cabling Information



Converged Building Networks Enabled by Power over Ethernet



Lights as a Sensor Platform

Color beacons create pathway lighting or indicate room status

Bluetooth SMART READY

Integrated BTLE for nearby devices

Integrated Speaker modules

One lighting fixture facilitates many applications

Any light can be backed up centrally with a UPS

Integrated CO2 and other gas or particle sensors

Visible Light Communication

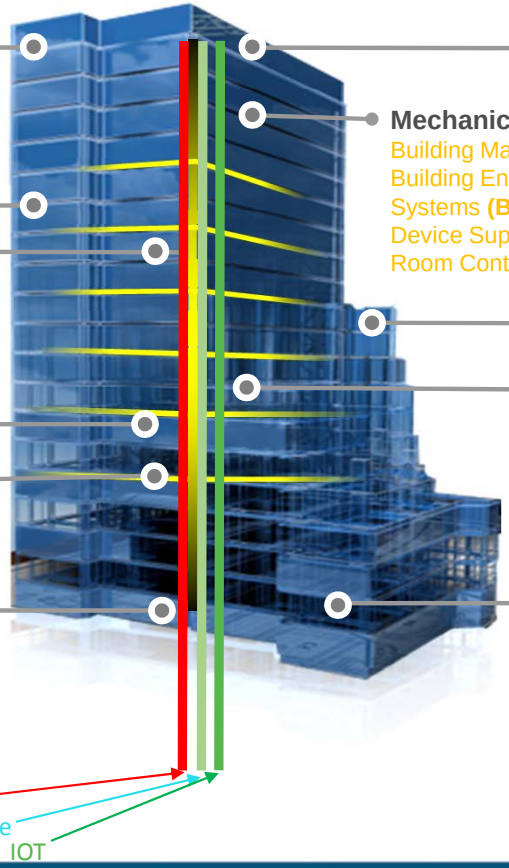
Network Power creates a secure and scalable path for Applications; Connectivity drives new functionality in Light fixtures

IP/POE Digital Building Endpoints:

More Product Diversity Every Day

Intelligent Building Systems Breakout

IP Systems
Transitioning to IP
Monitoring Only



Physical Security
Close Circuit TV
Access Control
Intruder Detection
Key Management

Sustainability / Wellness
Electrical Monitoring
Water Monitoring
Gas Monitoring
Demand Response
Productivity Monitoring
Air Quality

Communications
Base Building Telephone
Public Address / Intercom
Base Building Wi-Fi

Fire / Life Safety
Emergency Warning and Intercommunication System
BMS Integration
Security System Integration
Very Early Smoke Detection Apparatus (VESDA)
Emergency Signage
Emergency Lighting

Building Services
Bathroom Services
Data Access for Services
Plug Load Monitoring

Building Envelope
Steel
Concrete
Glass (Capacitive)
Insulation

Power
Enterprise
IOT

Mechanical
Building Management System **(BMS)**
Building Energy Management Systems **(BEMS)**
Device Supervisory Control
Room Control

Electrical
Low Voltage Control
Load Shedding
Standby Power Systems
High Voltage SCADA
Combined Cooling/Heat/Power (CCHP)
Lighting Control
Micro Grid (DC) Monitoring

Hydraulic
Water Recycling System
Leak Detection
Flow Control / Monitoring
Toilet / Sink Flow

Vertical Transportation
Elevator Management
Elevator Display System
Elevator Security Integration
Elevator Communications
Escalator Management

Car Park Systems
Car Park Management
Park Assist
Car Charging Systems

Tenant Improvements
Window Shades
Digital Signage
Projectors
White Noise Systems
Meeting Room Automation
Audio / Visual System

It’s a Complex Value Chain

Customer
(Final Decision maker)

Architects
(Form concepts)

Lighting Designer

General Contractor

MEP Contracts

Vendors
(Provide compatible product and salesforce)

IT consultant / Cisco SI
(Services and Support)

Influence

Value proposition

Idea’s

General design
Specification Written

Benefits breakout

Lighting design

Bid

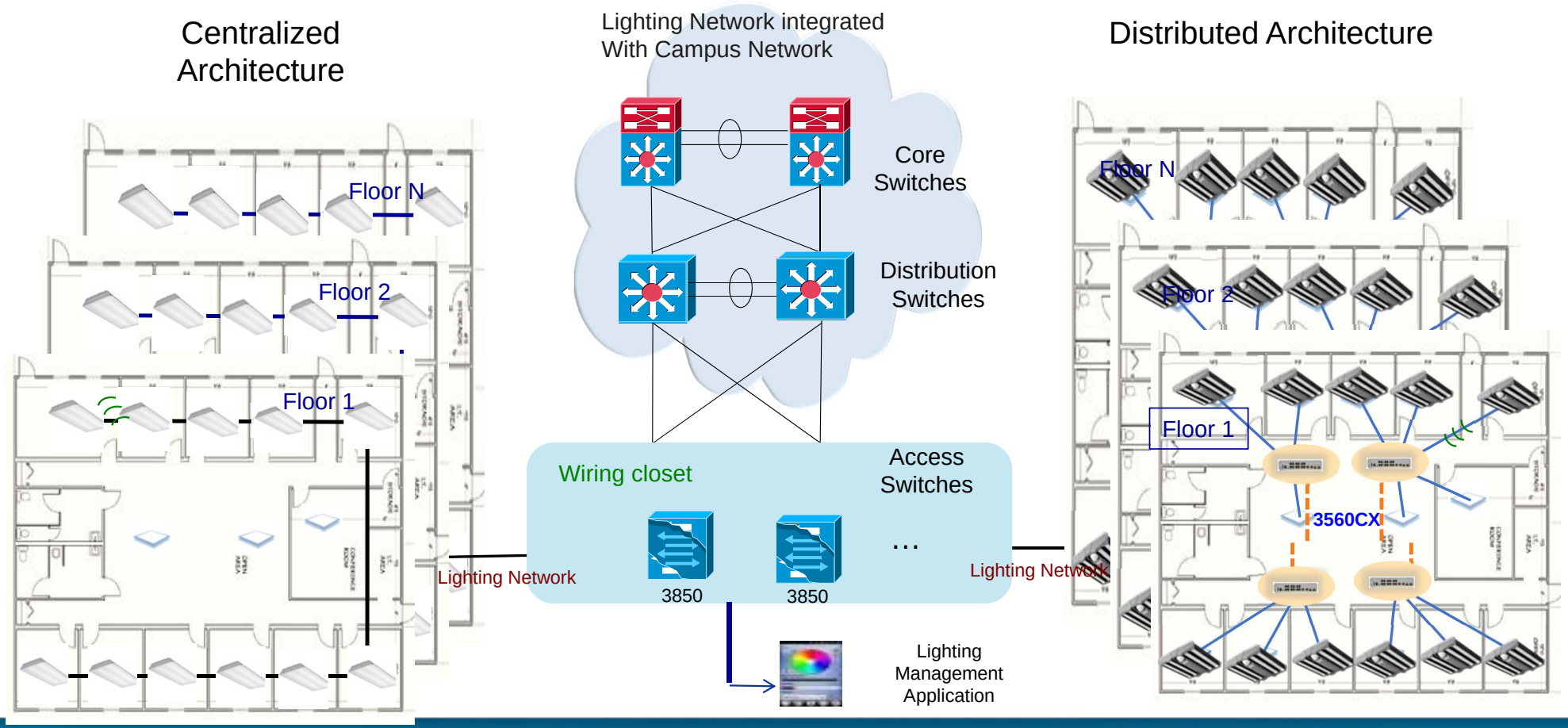
Capex saving

Cost Engineering/Alt Products

Procurement

9 to 36 Months

Reference Architecture With Digital Ceiling



Distributed Building Network

Zone Enclosure

Uplink Data
Remote Power

External
DAS

WiFi AP

WiFi AP

BMS Controllers

Badge
Readers

Light Fixtures

Small Cell/DAS

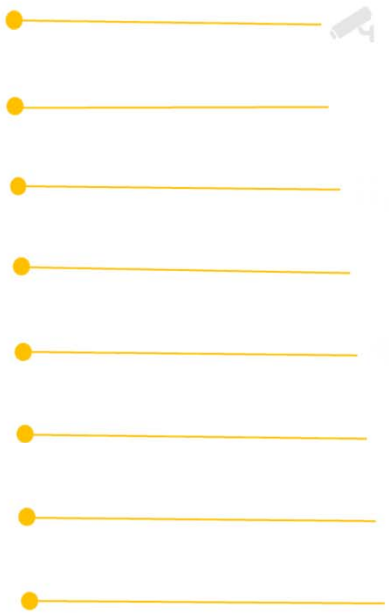
HVAC VAV's

Cameras

Flexible Zone Expansion
Short Patch Cables to Endpoints

Siloed, Complex, and Insecure

Separate Building System Networks…



… evolve independently, reinventing the wheel and hindering holistic innovation

Lighting Technology Advances Lead To Greater Energy Efficiency Savings

Email Share Tweet StumbleUpon Share Like 0 G+1

March 2014 - Lighting Article Use Policy

Reducing energy use is a long-standing goal for most facility managers. Conscientic efforts to trim energy consumption reduce both costs and the size of the organizatio

University attacked by its own vending machines, smart light bulbs & 5,000 IoT devices

A university, attacked by its own malware-laced soda machines and other botnet-controlled IoT devices, was locked out of 5,000 systems.

Mirai IoT Botnet Description and DDoS Attack Mitigation

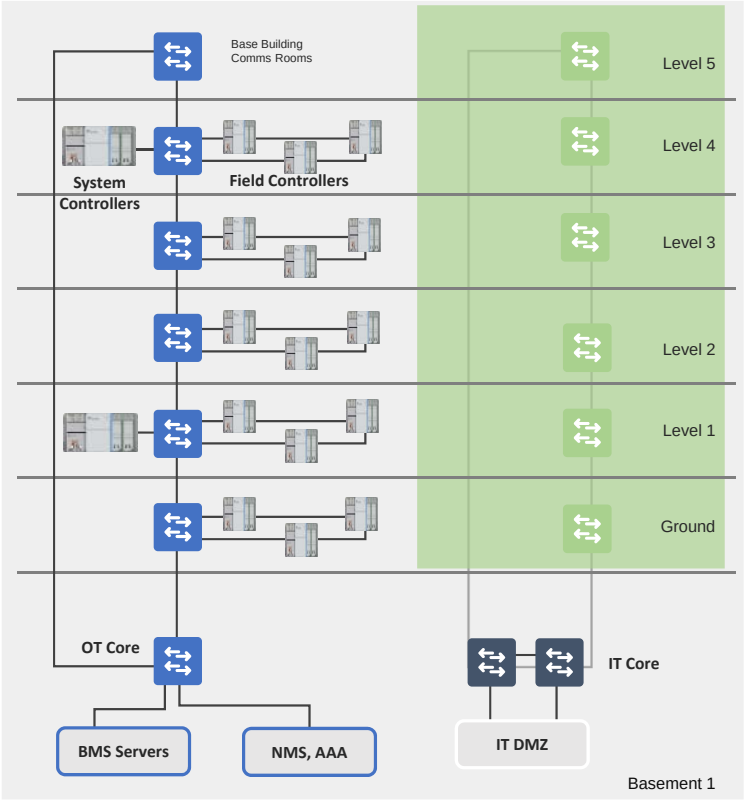
By **Roland Dobbins** on 10/26/2016.
Posted in **Botnets**.

Changes from previous version: Removed erroneous Mirai bot

Complex $ Not cost-optimized Not scalable **Not secure**

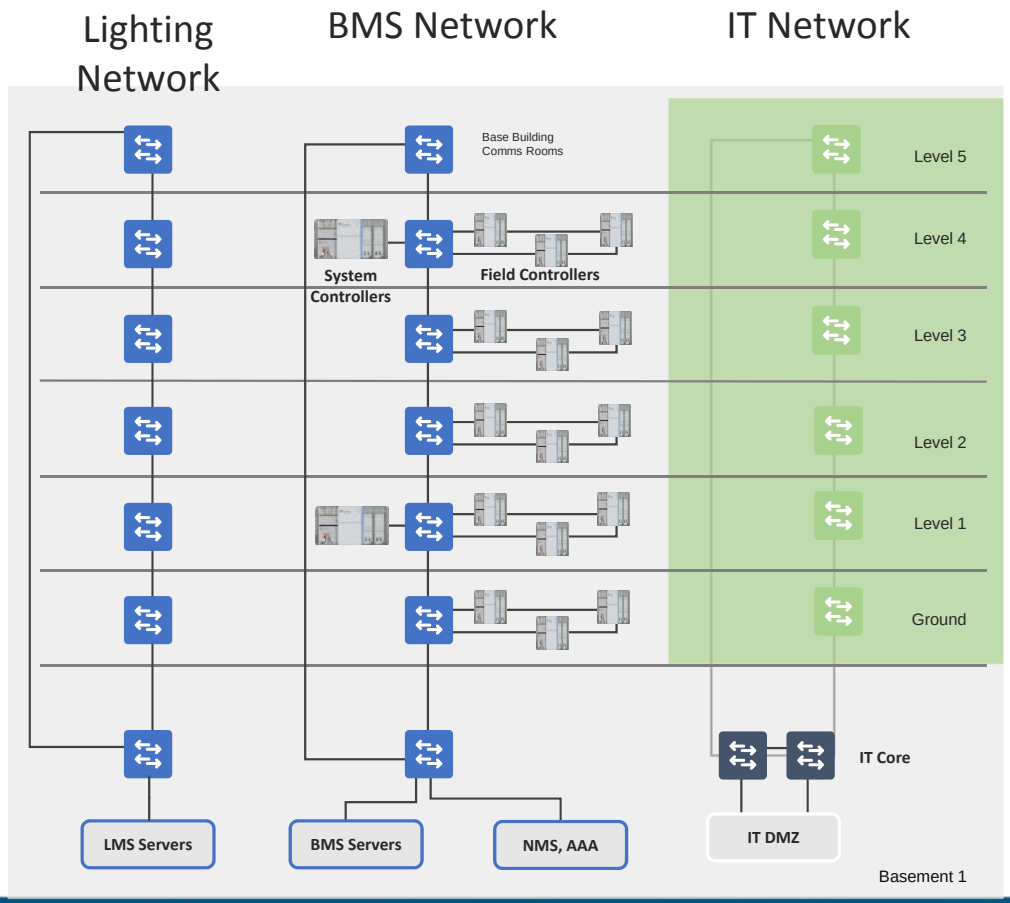
Single Building System + IT

- Separate Network Building Management
- Installed outside the IT equipment closet
- Security is the responsibility of the business owner, who may be the building operator
- Data becomes isolated
- Systems become duplicated

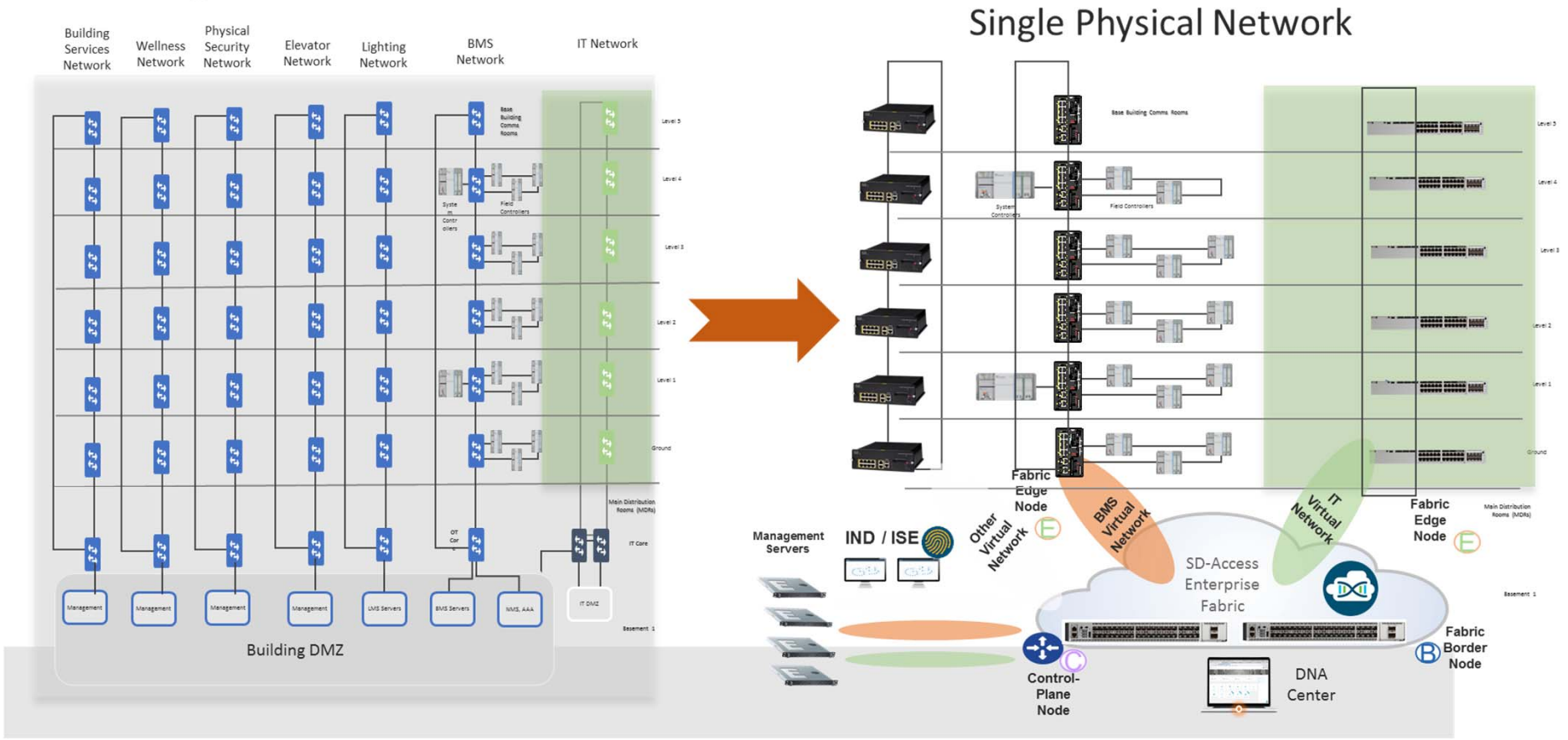


Second Building System + IT

- Increase Cost
- Widens Security Surface
- Increases Complexity
- Strands Data



Evolving Connected Networks



Wrap Up/ Summary/ Q&A