The Real Impact of High-Power PoE on Your IP Network

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BICSI

Agenda

- PoE Drivers
- Relevant Standards
- What to know to ask the right questions
  - Cabling considerations
  - Component considerations
  - Channel considerations
- Case studies
  - Calculating power efficiency
  - Justifying capital expenditure

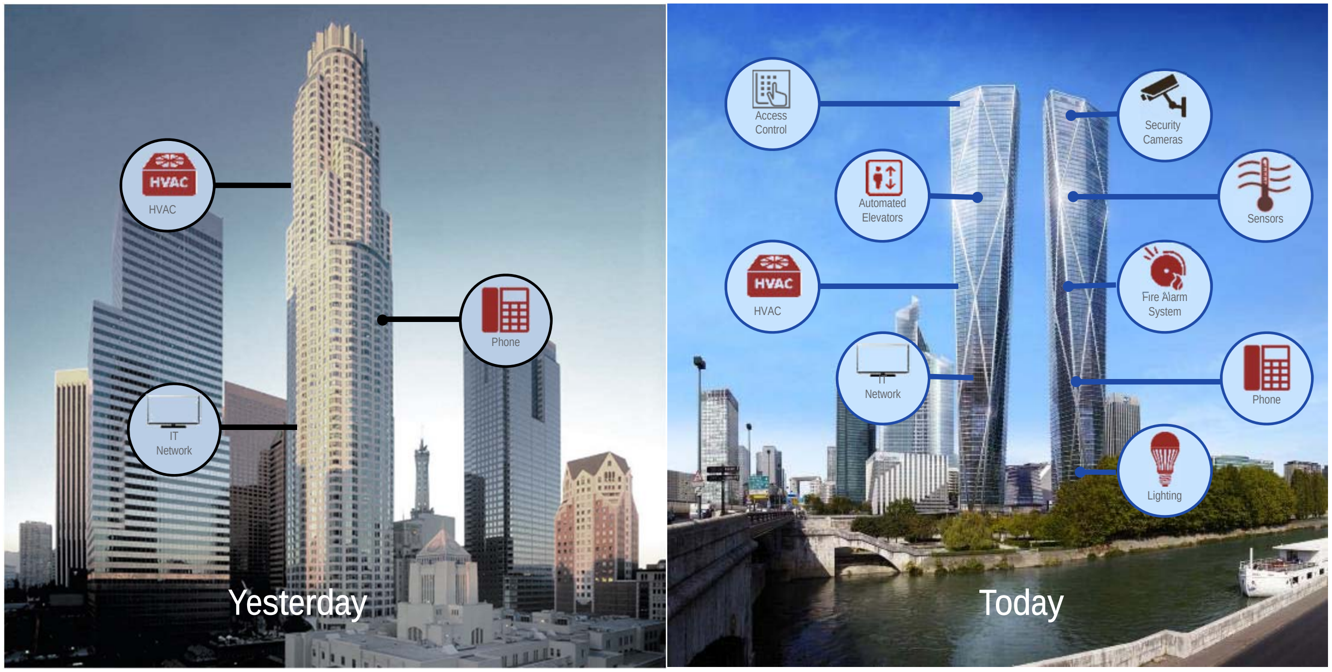
What is Power-over-Ethernet?

Traditional Way

What is Power-over-Ethernet?

Using PoE

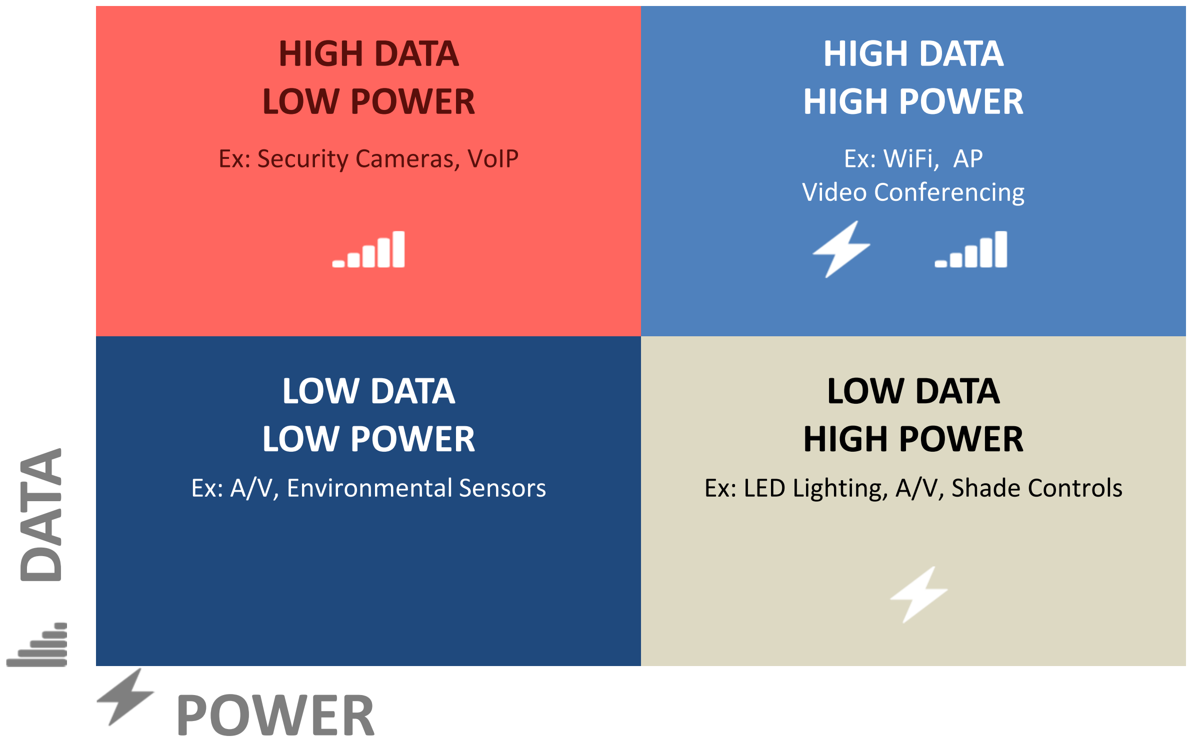
Technology Has Changed Buildings



New customer experiences and innovation demand improved efficiencies

PoE Digital Building Endpoint Examples

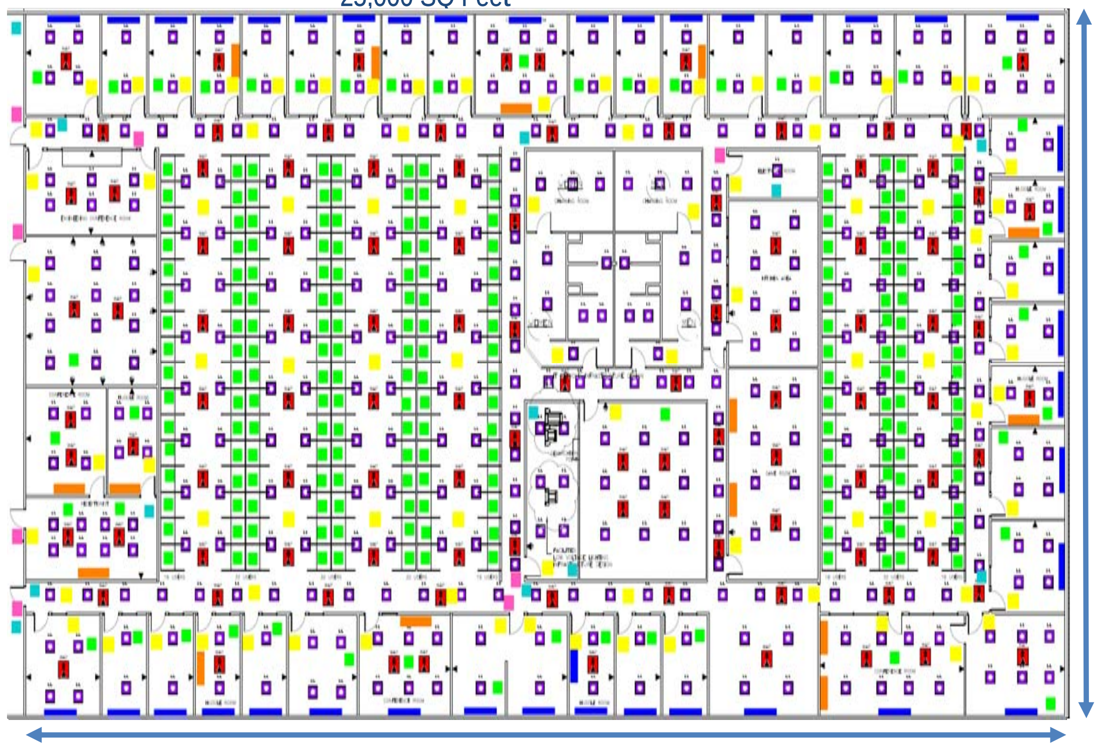
Digital Building: Power & Data



PoE - Commercial Building Applications

PoE Infrastructure

LED Lighting	389
Phone, Client, Monitor	192
Display	16
Occupancy Sensors	89
WAP	107
Shade Control	40
Security Camera	12
Access Controls	8
Total	853



Power-over-Ethernet

Related Standards & Codes

Cabling, performance, premises & best practices

- TIA /TSB 184-A
- BICSI 005--2013
- BICSI 007--2017

Applications

- IEEE 802.3

Codes

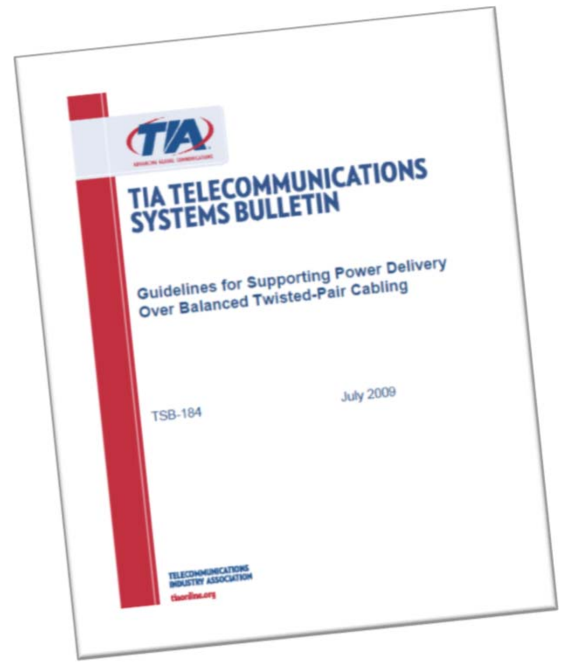
- NEC 2017

Power-over-Ethernet (IEEE802.3)

Standard	IEEE 802.3af	IEEE 802.3at	IEEE 802.3bt		HDBaseT
	PoE	PoE+	PoE++	4PPoE	PoH
Type	1	2	3	4	N/A
Status	2003	2009	Ratified Sept. 2018		Exists today
Maximum number of energized pairs	2	2	4	4	4
Maximum DC current per pair	350 mA	600 mA	600 mA	960 mA	1000mA
Maximum power delivered by the Power Sourcing Equipment (PSE)	15.4 watt	30.0 Watt	60.0 Watt	99.9 Watt	>100W
Minimum required power at the Powered Device (PD)	12.95 Watt	25.5 Watt	51.0 Watt	71.0 Watt	>100W
Maximum Data Rate	1000BASE-T	1000BASE-T	10GBASE-T		Varies

TIA: What is TSB-184?

- Technical Service Bulletin
- Provides guidelines for supporting power delivery over twisted-pair cabling simultaneously with data
  - Twisted-pair cabling defined in ANSI/TIA-568 series
  - Safety Extra Low Voltage (SELV) limited power source (LPS) power
  - Focus on temperature de-rating of cable
  - Comprehensive approach
  - Defines bundle sizes
  - Includes 26 AWG
  - Installation recommendations
- Describes methods to help manage temperature rise (≤15º)
  - Reduce long term cable degradation
  - Minimize negative effect on transmission performance
  - Reduce the amount of heat added to surrounding environment



TIA TSB-184-A

Guidelines for Supporting Power Delivery over Balanced Twisted-Pair Cabling

- Current has been increased to up to 1000 mA/pair.
- Models have been refined to include additional cable properties and installation conditions.
- Temperature rise tables include temperature rise in open air and sealed conduit.
- Bundling recommendations and installation recommendations have been added.
- Measurement procedures to develop models have been refined and included in the document.
- Includes additional specifications for ***pair-to-pair dc resistance unbalance***.

Driven by high-power PoE

TSB-184-A DC requirements

Energy consumption is related to the loop dc resistance -- heating in cabling will be related to the local dc resistance per unit length.

Larger conductor size reduces dc loop resistance improving power delivery efficiency & minimize heating.

DC Loop Resistance of Channels at 60°C

	Cat 5e 100m	Cat 6 100m	Cat 6A 100m	Cat 8 100m
Max dc loop resistance	25	25	25	7.22
Nominal dc loop resistance	24.38	20.09	20.09	6.81

Notes:

1. *Dc loop resistance applies only to pairs that provide dc continuity end-to-end*
2. *All values are at or adjusted to 60° C.*
3. *Max values from ANSI/TIA-568.2-D*

TSB-184-A DC requirements

Heating in cabling related to dc resistance per unit length.

AWG DC Resistance at 20°C

AWG table	Ohms per 100m solid	Ohms per 100m stranded
23	7.32	6.92
24	9.38	8.76
26	14.8	14

Assumptions:

- Category 5e horizontal cable is assumed to be 24AWG solid conductor cable
- Category 6 horizontal cable is assumed to be 23AWG solid conductor cable
- Category 8 horizontal cable is assumed to be 23AWG solid conductor cable
- All categories of cord cable are represented by 26AWG stranded cable

TSB-184-A DC requirements

DC Resistance directly impacts efficiency!

Table A.9 - Nominal power loss per meter of different cable types.

Current per pair	Number of Pairs	Category 5e	Category 6	Category 6A	Category 8
600 mA	2	39.08 mW	30.49 mW	30.49 mW	30.49 mW
600 mA	4	78.15 mW	60.99 mW	60.99 mW	60.99 mW
720 mA	4	112.54 mW	87.82 mW	87.82 mW	87.82 mW
1000 mA	4	217.09 mW	169.41 mW	169.41 mW	169.41 mW

TSB-184 Addendum 1 (draft)

WORK IN PROGRESS

Installation guidelines to support the delivery of power over 28 AWG cord cable

Table 2 - Temperature rise in air of 28 AWG cord cable v. number of cables in bundle for different current levels per pair

Number of Cables in bundle	Temperature Rise (°C)		
	600mA per pair	720mA per pair	1000mA per pair
	Air	Air	Air
1	0.86	1.25	2.40
7	2.67	3.84	7.41
19	5.05	7.27	14.03
24	5.91	8.51	16.41
37	7.96	11.47	-
48	9.58	13.80	-
52	10.15	14.62	-
61	11.41	16.43	-
64	11.82	-	-
74	13.16	-	-
91	15.38	-	-

- Maximum number of 28 AWG cord cables in a bundle for 15 °C temperature rise at 20 °C and 45 °C ambient in air

Current per pair	Number of cables in bundle	
	20 °C Ambient	45 °C Ambient
600mA	88	77
720mA	53	47
1000mA	21	18

TSB-184 Addendum 1 (draft)

Installation guidelines to support the delivery of power over 28 AWG cord cable

- When using high power (PoE Type 4)

Figure 1 - Example of 28 AWG cord cable bundles consisting of 12 cables separated by a minimum of 1.5 inches in an equipment rack using a 10 inch vertical manager

COMPLETED

ANSI/TIA-568.2-D: 28 AWG Cord Addition

- Recognize twisted-pairs of 22 AWG to 28 AWG for cord cable
- 28 AWG cord cables shall comply with the mechanical performance requirements, testing and test methods as 22-26 AWG cord cables (additional requirements listed in Annex G)
- DC resistance of UTP or screened cord cable shall not exceed 23.6 Ω per 100 m (328 ft.) (20 °C) –Annex G
  – 27.3 Ω per 100 m (328 ft.) (60 °C)

Table G.3 – 28 AWG cord cable example use cases at 20 °C

Maximum permanent link length m(ft)	Maximum length of 28 AWG cord cable m(ft)	Maximum channel length m(ft)
90.0 (295.3)	6.2 (20.2)	96.2 (315.5)
82.5 (270.7)	10.0 (32.8)	92.5 (303.5)
72.8 (238.7)	15.0 (49.2)	87.8 (287.9)

At 60 °C the maximum permanent link and channel lengths are decreased due to the increased insertion loss in the horizontal cable as shown in the following equations.

Table G.4 – 28 AWG cord cable example use cases with permanent link at 60 °C

Maximum permanent link length m(ft)	Maximum length of 28 AWG cord cable m(ft)	Maximum channel length m(ft)
75.0 (246.1)	6.2 (20.2)	81.2 (266.4)
68.8 (225.7)	10.0 (32.8)	78.8 (258.5)
60.7 (199.1)	15.0 (49.2)	75.7 (248.4)
NOTE - This table assumes that the patch cords included in the channel are at 20 °C.		

BICSI Standards

BICSI 005-2013 Electronic Safety & Security

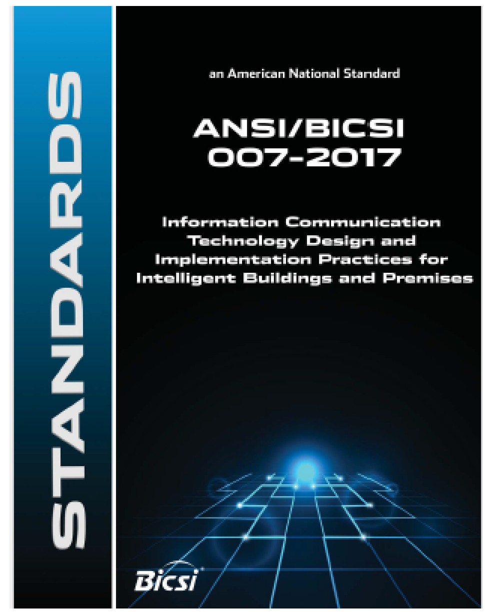
- ➢ Inclusion of IP based architecture
- ➢ Support for PoE
- ➢ Recommends Category 6 or better

BICSI Standards

BICSI 007-2017 Intelligent Buildings

- Equipment cords and coverage area cables used for data and power transmission should have conductors with a minimum size of 0.205 mm^2 (24 AWG).

- For new installations, consider using cabling with 0.326 mm^2 (22 AWG) conductors if:
  - The specific building system (e.g., audio systems, video displays) is expected to require power exceeding 50W during the life cycle of the building
  - Future flexibility is desired in the types of systems that could be supported.



NFPA – NEC 2017 code

NEC is for SAFETY -- not application, power usage or performance

- Section 840.160
  - Nothing required if less than 60 watts is used
  - If more than 60 watts is used
    - Comply to section 725.144 or OPTIONALLY comply to UL LP-Listing

AWG	Numberof 4-Pair Cables in a Bundle																				
	1			2-7			8-19			20-37			38-61			62-91			92-192		
	Temp Rating			Temp Rating			Temp Rating			Temp Rating			Temp Rating			Temp Rating			Temp 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	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.8	1.0	0.5	0.6	0.7	0.4	0.5	0.6	0.4	0.5	0.6	NA	NA	NA
24	2.0	2.0	2.0	1.0	1.4	1.6	0.8	1.0	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	3.0	3.0	3.0	1.4	1.8	2.1	1.0	1.2	1.4	0.7	0.9	1.1	0.6	0.8	0.9	0.6	0.7	0.8	0.5	0.6	0.7

UL LP LISTING…..

UL LP Listing

New UL Limited Power (LP) certification:

1. CMP burn test
2. Cable Heating test
    - Create a bundle of 192 cables
    - Place in a 6ft long non-metallic conduit
    - Inject power
    - Check if the temperature increase is not higher than the cable rating
    - For 75°C rated cable and 45°C ambient temperature / no more than 30°C

UL LP Listing

Issues

- ➢ Based on UL test results only
- ➢ Inconsistent with TIA / IEEE
  - Bundle size different
  - Not same ampacity
  - Temperature reference different
    - UL is vs temperature rating
    - IEEE is temperature rating minus 10°C
    - TIA is ambiant temperature + 15°C

IEEE Advancing Technology for Humanity

TIA ADVANCING GLOBAL COMMUNICATIONS

UL LP Listing

ISSUE

– Temperature rating

- Min 60°C for insulation and jacket
- 75°C marking:
    - ? 75°C insulation and jacket
    - ? 75°C insulation and 60°C jacket
- 90°C marking:
    - ? 90°C insulation and jacket
    - ? 90°C insulation and 75°C jacket
- 105°C marking:
    - ? 105°C insulation and jacket
    - ? 105°C insulation and 90°C jacket

What happens if the cable is at 87°C?

The insulation is good but how is the jacket impacted during the time when it is rated for 75°C…

UL LP Listing

What you need to remember

More work to be done between groups for 2020

- LP simplifies cable choice by pre-testing
  - Large bundle sizes
  - Accounting for temperature rating
  - Accounts for cable design performance
  - Reasonable worst case environmental conditions

- However…
  - The listing is not being enforced by code or any standard
  - The listing is not aligned with current IEEE or TIA standards development
  - Only compares temperature of cable bundle under power to cable temperature rating
  - Does not include aging affects of operation at elevated temperatures
  - Does not consider cable performance verification at elevated temperatures
  - Confusion about who is allowed to install and how to install (the local authority has the final word)

COMPONENT CONSIDERATIONS

Cable: Twisted Pair Cable Factors for PoE

- **Gauge Size**

  Larger copper gauge = less heat and is better at mitigating heat rise

- **Cable Size**

  Larger cables better dissipate heat

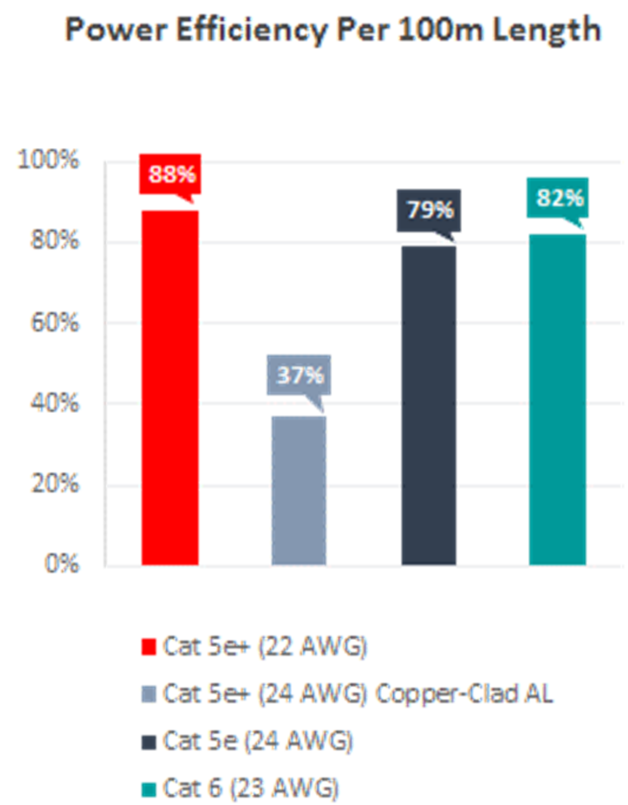
- **Temperature rating**
  - Cables with a higher temp rating = better ability to mitigate heat rise
  - 100% FEP (Plenum) insulation will have a higher rating than partial FEP or polyolefin insulation (Riser)

- **Other elements of cable construction**

  Shielded products dissipate heat down the length of the cable so improve capability

Cable: Power Efficiency

- ➢ Think about the application
  - ➢ High-speed Data vs. High power vs. Mix
  - ➢ AWG more important than performance category?
- ➢ If main application is high power, high-performance category may not provide best ROI



Cable: Temperature Rise

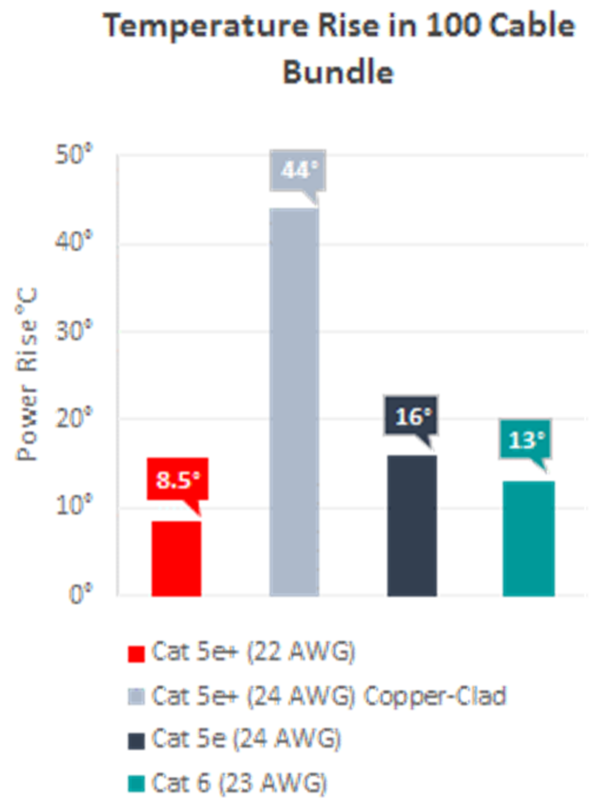
Higher Temp = Higher Attenuation

↓

Higher Attenuation = Signal loss

↓

Signal Loss = Shorter Channel Distance



Cable: Temperature Rise

	Cat 5E	Cat 5E+	Cat 6A	Cat 6
AWG	22	22	23	23
Design	UTP	UTP	F/UTP	UTP
Energy Savings (W)	300	300	90	0
Temperature Increase (°F)	+13	+10	+13	+20

- 100 cables in bundle
- 100 meters
- 100W for 5 days

Cable: Temperature Rise

Energized cable has an impact on lifespan of cable materials

FEP insulation yields **longest system lifespan**

Promotes longest life for powered devices

Top Challenges of Implementing Cost-Efficient 4PPoE (IEEE 802.3bt) Cable Solutions

Cable Sample #2 with Polyolefin insulation after 10 days at 120°C

Connectivity: Design Considerations for PoE

- **Interface contact displacement (spark gap)**
  Prevent arc damage

- **Increase electrical area for power**
  Support higher current

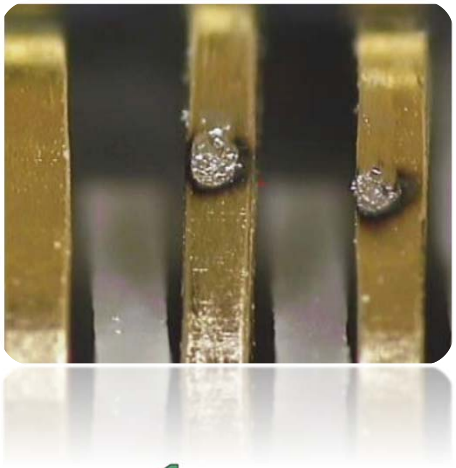
- **Improved housing cavity**
  Withstand usage, extended life cycle, improved electrical performance

- **Improved cavity air flow**
  Heat dissipation

- **Power transfer heat dissipation**
  Support higher current

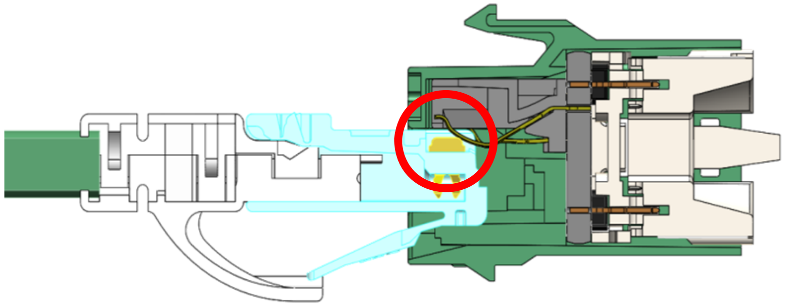
Connectivity Design Considerations

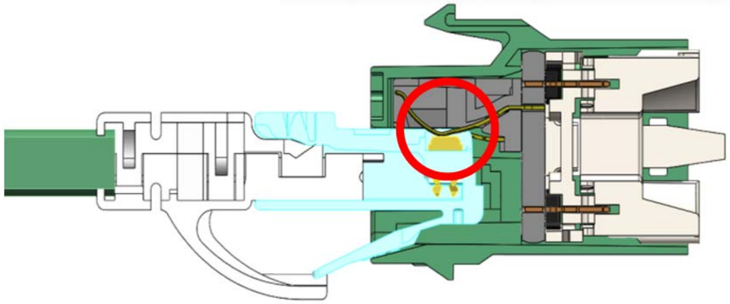
Spark Gap Concerns



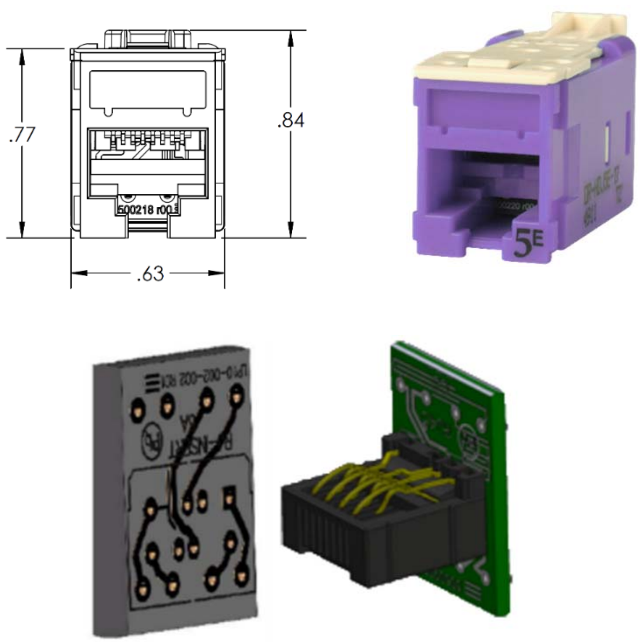
Spark Gap Concerns When Un-mating Under PoE Load

- Connectivity designs that locate the last point of contact away from the fully mated connection protected area of the mated connection from any arch damage





Connectivity Design Considerations



- IEC 60512-99 recommendations support 1 amp on each circuit path

  802.3af supports a max of 350mA
  802.3at supports a max of 600mA
  802.3bt projected max of 960mA

- 960mA is **dangerously close** to 1 amp
  - Connectivity should be designed to support more than 1A

- Pick connectivity ready for emerging devices & designed to withstand the stressors usage and extended life cycles.

IMPACT ON CHANNEL

Challenges for the network

- Delivering up to 100 watts of power while……
  - Maximizing energy efficiency
  - Maintaining data integrity
  - Maximizing life span of cabling
- New Pair to Pair Unbalanced DCR limits required in the standard
- Justifying Capex & ROI

High power impact on data transmission

Cabling Performance Margins under Power Load

TIA 568-C.2 Category 5E performance margins with applied IEEE802.3bt PoE power at Ambient Room Temperature (25° C)

	IEEE 802.3bt PoE			TIA 568-C.2 Margins			
Test	Power Source (W)	Power Received (W)	Power Efficiency (%)	NEXT (dB)	RL (dB)	IL (dB) @100 MHz	ACR (dB)
1	0	NA	NA	10.09	5.54	6.68	11.62
2	100	90.24	90.24	10.27	5.6	7.02	12.41
		Margin Differences		0.18	0.06	0.34	0.79

TIA 568-C.2 Category 5E performance margins with applied IEEE802.3bt PoE power under maximum TSB-184-A Elevated Temperature rating (60° C)

	IEEE 802.3bt PoE			TIA 568-C.2 Margins			
Test	Power Source (W)	Power Received (W)	Power Efficiency (%)	NEXT (dB)	RL (dB)	IL (dB) @100 MHz	ACR (dB)
3	0	NA	NA	10.64	6.88	5.82	12.34
4	100	89.22	89.22	10.63	6.35	4.92	12.32
		Margin Differences		0.01	0.53	0.9	0.02

Verify Components and Test Channels

CASE STUDIES

Example based on 25,000 sq. ft.

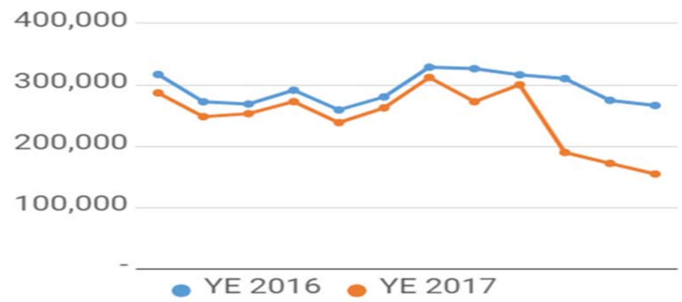
Connected Lighting TCO with controls

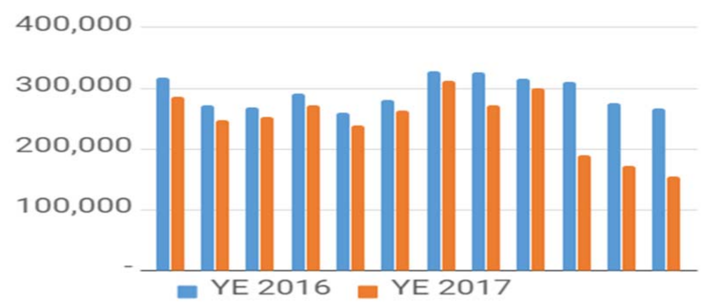
	PoE-LED (Central/Closet)	PoE-LED (De-central/Ceiling)	AC-LED	AC-FL
Total CAPEX	**$193,132**	**$219,304**	**$236,967**	**$188,477**
Per Square Foot	$7.73	$8.77	$9.48	$7.54
Cost Delta (relative to AC-LED)	-18.5%	-7.5%	0.0%	-20.5%
Total OPEX	**$88,177**	**$86,284**	**$88,046**	**$190,369**
Per Square Foot	$3.53	$3.45	$3.52	$7.61
Per Square Foot (per year)	$0.35	$0.35	$0.35	$0.76
Cost Delta (relative to AC-LED)	0.1%	-2.0%	0.0%	116.2%
Total INVESTMENT	**$281,309**	**$305,588**	**$325,012**	**$378,846**
Per Square Foot	$11.25	$12.22	$13.00	$15.15
Per Square Foot (per year)	$1.13	$1.22	$1.30	$1.52
Cost Delta (relative to AC-LED)	-13.4%	-6.0%	0.0%	16.6%

Case Study: The Sinclair Office Building

Case Study: The Sinclair Office Building

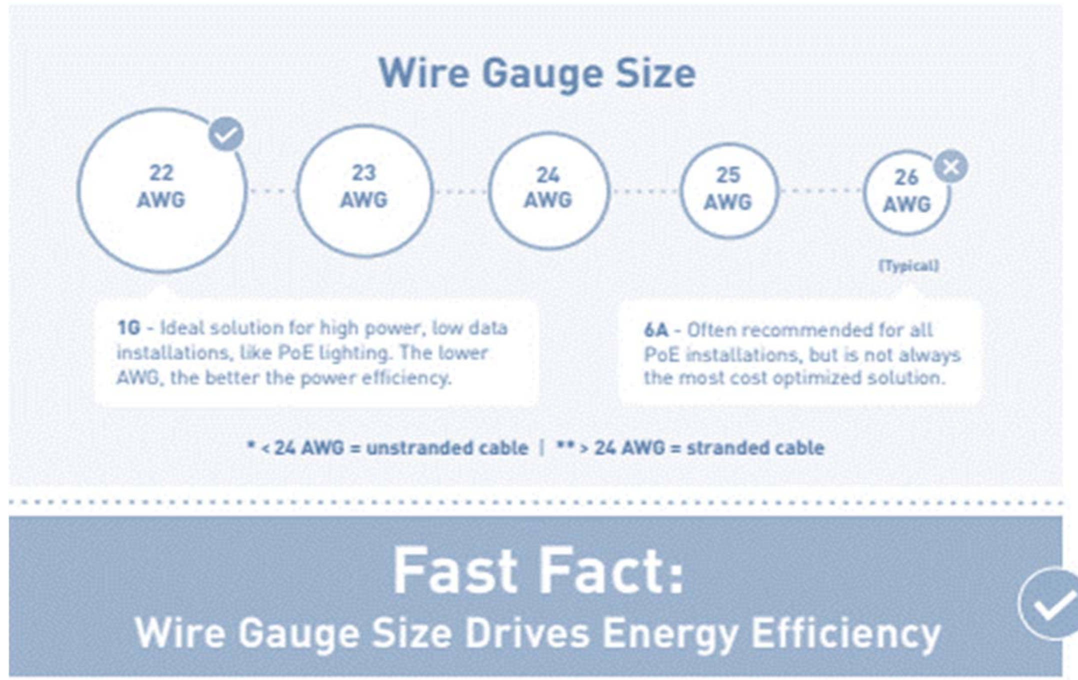
	YE 2016	YE 2017
jan	316,866	286,861
feb	272,376	248,146
mar	268,707	253,063
apr	291,208	272,666
may	259,108	238,546
jun	280,267	262,491
jul	328,715	312,005
aug	326,295	272,527
sep	316,320	300,119
oct	310,155	189,925
nov	274,787	172,121
dec	266,411	154,825





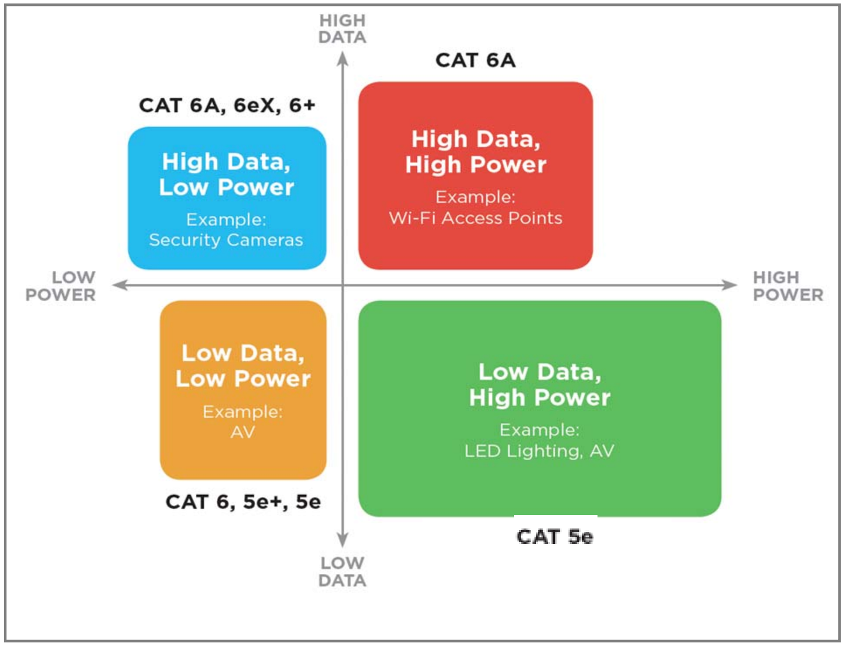
Conclusions

- Think differently
  - What performance do you actually need?
  - 1G vs. 10G
  - CAPEX / ROI



Conclusions

- Know Application
- Work with manufacturing partner



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