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

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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

**Communications**
- IP Call Stations
- WAP
- IP Call Tower

**Physical Security**
- Badge Readers
- Cameras
- Biometric Door Locks
- Facial Recognition
- Entry Barriers & Turnstiles
- Horns & Sirens

**Sustainability & Wellness**
- Environmental Sensor Hubs
- Power Meters
- Status Signs
- Temperature Sensors

**Tenant Improvements**
- Curtain & Blind Motors
- Ceiling Fans
- Meeting Room Nameplate
- Touchscreen PC’s
- Power over Ethernet Displays

**Electrical**
- HVAC VAV’s
- Light Fixtures
- Ceiling Fans
- HVAC VAV’s
- Lighting Fixtures

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Digital Building: Power & Data

- **HIGH DATA LOW POWER**
  - Ex: Security Cameras, VoIP

- **LOW DATA LOW POWER**
  - Ex: A/V, Environmental Sensors

- **HIGH DATA HIGH POWER**
  - Ex: WiFi, AP Video Conferencing

- **LOW DATA HIGH POWER**
  - Ex: LED Lighting, A/V, Shade Controls
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

25,000 SQ Feet

112'-9"

222'-10"
Power-over-Ethernet
Related Standards & Codes

Cabling, performance, premises & best practices

Applications

• IEEE 802.3

Codes

• TIA / TSB 184-A

• BICSI 005--2013
• BICSI 007--2017

• NEC 2017
# Power-over-Ethernet (IEEE802.3)

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

### DC Loop Resistance of Channels at 60°C

<table>
<thead>
<tr>
<th></th>
<th>Cat 5e 100m</th>
<th>Cat 6 100m</th>
<th>Cat 6A 100m</th>
<th>Cat 8 100m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max dc loop resistance</strong></td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>7.22</td>
</tr>
<tr>
<td><strong>Nominal dc loop resistance</strong></td>
<td>24.38</td>
<td>20.09</td>
<td>20.09</td>
<td>6.81</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>AWG table</th>
<th>Ohms per 100m solid</th>
<th>Ohms per 100m stranded</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>7.32</td>
<td>6.92</td>
</tr>
<tr>
<td>24</td>
<td>9.38</td>
<td>8.76</td>
</tr>
<tr>
<td>26</td>
<td>14.8</td>
<td>14</td>
</tr>
</tbody>
</table>

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

Heating in cabling related to dc resistance per unit length.
# TSB-184-A DC requirements

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

<table>
<thead>
<tr>
<th>Current per pair</th>
<th>Number of Pairs</th>
<th>Category 5e (mW)</th>
<th>Category 6 (mW)</th>
<th>Category 6A (mW)</th>
<th>Category 8 (mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 mA</td>
<td>2</td>
<td>39.08</td>
<td>30.49</td>
<td>30.49</td>
<td>30.49</td>
</tr>
<tr>
<td>600 mA</td>
<td>4</td>
<td>78.15</td>
<td>60.99</td>
<td>60.99</td>
<td>60.99</td>
</tr>
<tr>
<td>720 mA</td>
<td>4</td>
<td>112.54</td>
<td>87.82</td>
<td>87.82</td>
<td>87.82</td>
</tr>
<tr>
<td>1000 mA</td>
<td>4</td>
<td>217.09</td>
<td>169.41</td>
<td>169.41</td>
<td>169.41</td>
</tr>
</tbody>
</table>

DC Resistance directly impacts efficiency!
TSB-184 Addendum 1 (draft)
Installation guidelines to support the delivery of power over 28 AWG cord cable

<table>
<thead>
<tr>
<th>Number of Cables in bundle</th>
<th>Temperature Rise (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600mA per pair</td>
</tr>
<tr>
<td>Air</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.86</td>
</tr>
<tr>
<td>7</td>
<td>2.67</td>
</tr>
<tr>
<td>19</td>
<td>5.05</td>
</tr>
<tr>
<td>24</td>
<td>5.91</td>
</tr>
<tr>
<td>37</td>
<td>7.96</td>
</tr>
<tr>
<td>48</td>
<td>9.58</td>
</tr>
<tr>
<td>52</td>
<td>10.15</td>
</tr>
<tr>
<td>61</td>
<td>11.41</td>
</tr>
<tr>
<td>64</td>
<td>11.82</td>
</tr>
<tr>
<td>74</td>
<td>13.16</td>
</tr>
<tr>
<td>91</td>
<td>15.38</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Current per pair</th>
<th>Number of cables in bundle</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 °C Ambient</td>
<td>45 °C Ambient</td>
</tr>
<tr>
<td>600mA</td>
<td>88</td>
</tr>
<tr>
<td>720mA</td>
<td>53</td>
</tr>
<tr>
<td>1000mA</td>
<td>21</td>
</tr>
</tbody>
</table>
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
• 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

<table>
<thead>
<tr>
<th>Maximum permanent link length m(ft)</th>
<th>Maximum length of 28 AWG cord cable m(ft)</th>
<th>Maximum channel length m(ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.0 (295.3)</td>
<td>6.2 (20.2)</td>
<td>96.2 (315.5)</td>
</tr>
<tr>
<td>82.5 (270.7)</td>
<td>10.0 (32.8)</td>
<td>92.5 (303.5)</td>
</tr>
<tr>
<td>72.8 (238.7)</td>
<td>15.0 (49.2)</td>
<td>87.8 (287.9)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Maximum permanent link length m(ft)</th>
<th>Maximum length of 28 AWG cord cable m(ft)</th>
<th>Maximum channel length m(ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75.0 (246.1)</td>
<td>6.2 (20.2)</td>
<td>81.2 (266.4)</td>
</tr>
<tr>
<td>68.8 (225.7)</td>
<td>10.0 (32.8)</td>
<td>78.8 (258.5)</td>
</tr>
<tr>
<td>60.7 (199.1)</td>
<td>15.0 (49.2)</td>
<td>75.7 (248.4)</td>
</tr>
</tbody>
</table>

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 (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
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 ambient temperature + 15°C
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

• 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)
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

<table>
<thead>
<tr>
<th></th>
<th>Cat 5E</th>
<th>Cat 5E+</th>
<th>Cat 6A</th>
<th>Cat 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AWG</strong></td>
<td>22</td>
<td>22</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td>UTP</td>
<td>UTP</td>
<td>F/UTP</td>
<td>UTP</td>
</tr>
<tr>
<td><strong>Energy Savings (W)</strong></td>
<td>300</td>
<td>300</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td><strong>Temperature Increase (°F)</strong></td>
<td>+13</td>
<td>+10</td>
<td>+13</td>
<td>+20</td>
</tr>
</tbody>
</table>

- 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.
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)**

<table>
<thead>
<tr>
<th>Test</th>
<th>Power Source (W)</th>
<th>Power Received (W)</th>
<th>Power Efficiency (%)</th>
<th>NEXT (dB)</th>
<th>RL (dB)</th>
<th>IL (dB) @100 MHz</th>
<th>ACR (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
<td>10.09</td>
<td>5.54</td>
<td>6.68</td>
<td>11.62</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>90.24</td>
<td>90.24</td>
<td>10.27</td>
<td>5.6</td>
<td>7.02</td>
<td>12.41</td>
</tr>
</tbody>
</table>

**Margin Differences**

<table>
<thead>
<tr>
<th></th>
<th>IEEE 802.3bt PoE</th>
<th>TIA 568-C.2 Margins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.79</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Test</th>
<th>Power Source (W)</th>
<th>Power Received (W)</th>
<th>Power Efficiency (%)</th>
<th>NEXT (dB)</th>
<th>RL (dB)</th>
<th>IL (dB) @100 MHz</th>
<th>ACR (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
<td>10.64</td>
<td>6.88</td>
<td>5.82</td>
<td>12.34</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>89.22</td>
<td>89.22</td>
<td>10.63</td>
<td>6.35</td>
<td>4.92</td>
<td>12.32</td>
</tr>
</tbody>
</table>

**Margin Differences**

<table>
<thead>
<tr>
<th></th>
<th>IEEE 802.3bt PoE</th>
<th>TIA 568-C.2 Margins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.02</td>
</tr>
</tbody>
</table>
Verify Components and Test Channels
CASE STUDIES
Example based on 25,000 sq. ft.

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

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

Wire Gauge Size

Fast Fact:
Wire Gauge Size Drives Energy Efficiency
Conclusions

• Know Application

• Work with manufacturing partner
The Real Impact of High-Power PoE on Your IP Network

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