IEEE 802.3at PoE Plus Operating Efficiency:

How to Keep a Hot Application Running Cool

The development of the PoE Plus standard brought to light a significant new challenge in delivering power over a structured cabling system. The higher power delivered by PoE Plus devices causes a temperature rise within the cabling, which can negatively impact system performance. The information in this paper will allow readers to be better equipped to make PoE Plus-ready cabling choices that will support reduced current-induced temperature rise and minimize the risk of degraded physical and electrical performance due to elevated temperature.

HIGHLIGHTS AND CONCLUSIONS:

- Although safe for humans, the 600mA currents associated with the PoE Plus application generate heat in the installed cabling plant.
- Excessive temperature rise in the cabling plant cannot be tested or mitigated in the field.
- Excessive temperature rise in the cabling plant can result in an increase in insertion loss and premature aging of jacketing materials.
- Choosing media with improved heat dissipation performance can minimize the risks associated with excessive temperature rise.
- Category 6A F/UTP cabling systems dissipate almost 50% more heat than category 5e cabling.
- Category 7_A S/FTP cabling systems dissipate at least 60% more heat than category 5e cabling.
- It is reasonable to anticipate that category 6A and higher-rated cabling will be the targeted media for the support of tomorrow’s high performance telecommunications powering applications.

MARKET OVERVIEW:

The allure of deploying power concurrent with data over telecommunications cabling is undeniable. The benefits of IEEE 802.3af[1] Power over Ethernet (PoE) equipment include simplified infrastructure management, lowered power consumption, reduced operational costs in the case of applications such as voice over internet protocol (VoIP), and even improved safety due to separation from the building's main AC power ring. Market research indicates that the PoE market is on the cusp of significant growth and the numbers are impressive! According to the market research firm Venture Development Corporation[2], approximately 47 million PoE-enabled switch ports were shipped in 2007. Looking forward, the firm expects PoE-enabled switch port shipments to grow at almost double the rate of overall Ethernet port shipments and reach more than 130 million ports by the year 2012.

With it's capability to deliver 13.0 watts average input power to the powered device (PD) at a safe nominal 48 volts direct current (VDC) over TIA category 3/ISO class C and higher rated structured cabling, IEEE 802.3af PoE, (also known as "Type 1") systems can easily support devices such as:

- IP-based voice and video transmission equipment,
- IP-based network security cameras,
- Wireless access points (WAPs),
- Radio frequency identification (RFID) tag readers,
- Building automation systems (e.g. thermostats, smoke detectors, alarm systems, security access, industrial clocks/timekeepers, and badge readers),
- Print servers, and bar code scanners

INTRODUCING PoE PLUS:

In 2005, IEEE recognized an opportunity to enhance the capabilities of power sourcing equipment (PSEs) to deliver even more power to potentially support devices such as:

- Laptop computers
- Thin clients (typically running web browsers or remote desktop software applications)
- Security cameras with Pan/Tilt/Zoom capabilities
- Internet Protocol Television (IPTV)
- Biometric sensors
- WiMAX[3] transceivers providing wireless data over long distances (e.g. point-to-point links and mobile cellular access), and high volumes of other devices that require additional power

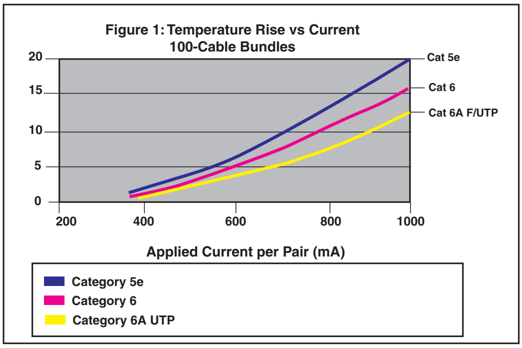
In support of these needs, IEEE 802.3at[4] specifies a PoE Plus or "Type 2" system that can deliver 25.5 watts average input power to the powered device (PD) at a safe nominal 53 VDC over legacy TIA category 5/ISO class D:1995 and higher rated structured cabling (note that, for new installations, cabling should meet or exceed TIA category 5e/ISO class D:2002 requirements). Refer to table 1 for a detailed comparison of the capabilities of Type 1 (PoE) and Type 2 (PoE Plus) systems.

TABLE 1:
Overview of PoE and PoE Plus system specifications

	Type 1 - PoE	Type 2 – PoE Plus
Minimum Category of Cabling	Category 3/Class C	Category 5/Class D:1995 with DC loop resistance < 25Ω
Average Input Power Available to the PD	13.0 W	25.5 W
Minimum Power at the PSE Output	15.4 W	30 W
Allowed PSE Output Voltage	44 – 57 VDC	50 – 57 V
Nominal PSE Output Voltage	48 VDC	53 VDC
Maximum DC Cable Current	350 mA per pair	600 mA per pair
Maximum Ambient Operating Temperature	60° C	50° C
Installation Constraints	None	Maximum 5kW delivered power per cable bundle

POE PLUS CHALLENGES:

The development of PoE Plus requirements brought to light a significant new challenge in the specification of power delivery over structured cabling. For the first time, due to the higher power delivered by Type 2 PSE devices, IEEE needed to understand the temperature rise within the cabling caused by applied currents and subsequently specify the PoE Plus application operating environment in such a way as to ensure that proper cabling system transmission performance is maintained. In order to move forward, IEEE enlisted the assistance of the TIA and ISO cabling standards development bodies to characterize the current carrying capacity of various categories of twisted-pair cables.



After extensive study and significant data collection, TIA was able to develop profiles of temperature rise versus applied current per pair for category 5e, 6, and 6A cables configured in 100-cable bundles as shown in **Figure 1**. Interestingly, these profiles were created primarily based upon analysis of the performance of unshielded twisted-pair (UTP) cables. They were later corroborated by data submitted to the ISO committee. As expected, since category 5e cables have the smallest conductor diameter, they also have the worst heat dissipation performance and exhibit the greatest temperature rise due to applied current. Note that category 5 cables were excluded from the study since category 5 cabling is no longer recommended by TIA for new installations. IEEE adopted the baseline profile for category 5e cables as representative of the worst-case current carrying capacity for cables supporting the PoE Plus application.

Sidebar No. 1

TEMPERATURE DE-RATING OF UTP VERSUS F/UTP AND S/FTP CABLING SYSTEMS:

It is well known that insertion loss increases (signals attenuate more) as the ambient temperature in the cabling environment increases. To address this issue, both TIA and ISO specify a temperature dependent de-rating factor for use in determining the length that the maximum horizontal cable distance should be reduced by to ensure compliance with specified channel insertion loss limits at temperatures above ambient (20 °C).

What is not well known is that the de-rating adjustment that is made for UTP cabling allows for a much greater increase in insertion loss (0.4% increase per°C from 20°C to 40°C and 0.6% increase per °C from 40°C to 60°C) than the de-rating adjustment that is specified for F/UTP and S/FTP systems (0.2% increase per°C from 20°C to 60°C). This means that F/UTP and S/FTP cabling systems have more stable transmission performance at elevated temperatures and are more suited to support applications such as PoE Plus than UTP cabling systems.

Additional TIA guidance recommended that a maximum temperature increase of 10°C, up to an absolute maximum temperature of 60°C, would be an acceptable operating environment for cabling supporting PoE Plus applied current levels. In consideration of this input, IEEE chose to reduce the maximum temperature for Type 2 operation to 50°C, which eliminated the need for complicated power de-rating at elevated temperatures. Next, IEEE had to identify a maximum DC cable current that would not create a temperature rise in excess of 10°C. An analysis of the worst case category 5e current carrying capacity profile led IEEE PoE Plus system specifiers to target 600 mA as the maximum DC cable current for Type 2 devices, which, according to the TIA profile, results in a 7.2°C rise in cable temperature. Although this temperature rise is less than the maximum 10°C value recommended, it provides valuable system headroom that helps to offset additional increases in insertion loss due to elevated temperatures **(See sidebar No. 1)** and minimize the risk of premature aging of the jacketing materials. Operating margin against excessive temperature rise is especially critical because this condition cannot be ascertained in the field.

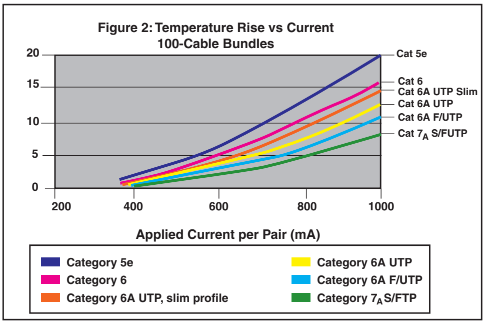
An additional outcome of the TIA investigation was the understanding that higher temperature rises occur as cable bundle size increases. Analysis of the worst case category 5e profile resulted in TIA providing general guidance that the maximum power injected into any cable bundle should not exceed 5kW up to 45°C. Interestingly, while IEEE acknowledges that cable current carrying capacity is a function of cable type and installation practices (e.g. bundling), it is outside the scope of the 802.3at Standard to address these considerations. These issues are addressed in TIA TSB-184[5] and ISO/IEC TR 29125[6]. These documents describe environmental conditions of installed cabling (including bundled cabling and cabling in conduit), heat dissipation profiles of different categories and types of cables, and how these conditions and profiles might impact the capability of telecommunications cabling to support the PoE Plus application.

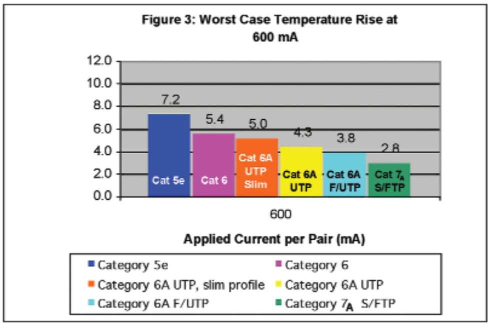
KEEPING IT COOL:
For the first time, managing heat build-up in structured cabling must be taken into consideration in new and retrofit installations. The main challenges in designing PoE Plus-ready cabling plants are:

- Ensuring that operating temperatures do not exceed 50°C and
- Specifying cabling types and installation practices, such as bundling, that support minimal temperature rise due to applied current.

Since there is no easy method to cool down hot pathways (think of a ceiling space in Arizona, India, Argentina, Spain, Israel, or Darwin, Australia) or for monitoring PoE Plus induced temperature rise in the installed cabling, the recommended approach to minimize the risks associated with excessive temperature rise is to select cabling media that has superior heat dissipation performance to start with. While the TIA current carrying capacity profiles are helpful in that they clearly demonstrate relative advantages between select media types (e.g. category 6A UTP cables have better heat dissipation performance than category 5e UTP and category 6 UTP cables), the story that they tell is incomplete. Specifically, they do not address the performance of category 6A screened (F/UTP) and category 7_A fully-shielded (S/FTP) cables.

Siemon Labs investigated the current-carrying capacity of riser (CMR) and plenum (CMP) category 6A F/UTP and category 7_A S/FTP cables, in addition to the new slim-profile category 6A UTP cables. Test cables were arranged in accordance with the TIA 100-bundle cable configuration (**See sidebar No.2**) and the worst case temperature rise for each media type was profiled. Reference category 6A UTP measurements were collected and used to normalize Siemon data to the TIA category 6A data. The resulting heat dissipation profiles are shown in **Figure 2**. The current carrying capacity of category 7 cables is expected to be equivalent to category 7_A cables since their physical construction is so similar. The worst case temperature rise for each media type with 600 mA applied current is shown in **Figure 3**.





Sidebar No. 2

OVERVIEW OF THE SIEMON 100-BUNDLE TEMPERATURE RISE VERSUS APPLIED CURRENT TEST CONFIGURATION:

1. Beginning with a core consisting of a 1.2 meter length of cable, layers of 1.2 meter long cable lengths were carefully applied around the core to create a symmetrical 6-around-1 bundle.

2. The bundle layer was secured with electrical tape and a temperature-sensing thermocouple was embedded into the surface of the cable jacket.

3. Additional 1.2 meter cable lengths were applied, taped, and embedded with thermocouples to grow the bundle size incrementally from an 18-around-1 bundle, to a 36-around-1 bundle, to a 60-around-1 bundle, to a 90-around-1 bundle, and, finally, to a 100-around-1 bundle. Representative bundle configurations are shown in **Photo 1**. An example of an embedded temperature-sensing thermocouple is shown in **Photo 2**.

4. The finished 100-around-1 bundle was suspended in air at a minimum distance of 0.3 m from any object in all directions. The ends of the bundle were covered with insulating foam to eliminate heat dissipation from the ends of the bundle, thereby ensuring worst case heat build-up. Test leads from a continuous current power supply were attached to all 4-pairs in the cable bundle.

5. The current on the power supply was set to 720 mA for each pair, for a total of applied current of 2.88 A. Initial sample temperatures were measured and recorded for each bundle layer. Temperature readings were collected at hourly intervals from each thermocouple. Final temperature readings were collected after the bundle had stabilized for 4 hours. As expected, the highest temperature rise was recorded at the thermocouple closest to the core of the bundle. The thermal resistance of the cable bundle was determined from the measurements, and a heat dissipation profile, including performance at 600 mA, was derived.

6. Measurement accuracy is approximated to be +/- 1°C.

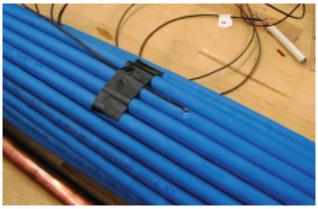
Photo 1. Cable Test Sample Bundle Preparation

6-around-1 bundle

18-around-1 bundle

100-around-1 bundle

Photo 2.
Placement of temperature sensing Thermocouple

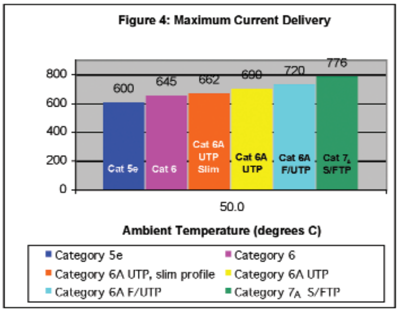


DISPELLING THE HEAT DISSIPATION MYTH:

Since metal has a higher conductivity than thermoplastic jacketing materials, a thermal model can be used to predict that screened and fully-shielded cables have better heat dissipation than UTP cables. Siemon's data substantiates the model and clearly demonstrates that screened cables exhibit better heat dissipation than UTP cables and fully-screened cables have the best heat dissipation properties of all copper twisted-pair media types. ***Unfortunately, the misconception that screened and fully-shielded systems will "trap" the heat generated by PoE and PoE Plus applications still exists in the industry today. This notion is completely false and easily dispelled by models and laboratory data.***

MEDIA SELECTION:

Interestingly, the PoE Plus application is compatible with 10BASE-T, 100BASE-T, and 1000BASE-T, while compatibility with 10GBASE-T is noted as not being precluded by the new Standard. Thus, in an attempt to operate over the largest percentage of the installed cabling base possible, the 802.3at Standard specifies ISO '11801 class D:1995[7] and TIA '568-B.2 category 5[8] compliant cabling systems having DC loop resistances less than or equal to 25 ohms as the minimum grade of cabling capable of supporting PoE Plus. Note that these are legacy grades of 100 MHz cabling; TIA recognizes '568-C.2 category 5e[9] cabling and ISO recognizes class D:2002[10] cabling for new installations. While these objectives represent good news for end-users with an installed base of category 5/category 5e or class D:1995/class D:2002 cabling, these cabling systems typically have poor heat dissipation properties and much better choices exist for those specifying new or retrofit cabling plants today.



To emphasize, specifying cabling with better heat dissipation characteristics means that:

- Operating temperatures are less likely to exceed 50°C,
- Certain common installation practices, such as bundling, are less likely to impact overall temperature rise,
- Undesirable increases in insertion loss due to elevated temperatures will be minimized
- The risk of premature aging of cabling jacket materials is reduced.

Good heat dissipation performance exhibited by the cabling plant is especially critical since no methods exist today for monitoring temperature rise in an installation or mitigating a high-temperature environment. Historically, a comfortable level of performance margin is considered to be 50% headroom to Standards-specified limits (this would be equivalent to 6 dB headroom for a transmission performance parameter). Following these guidelines, ***the solutions that offer the most desirable levels of heat dissipation headroom in support of the PoE Plus application are category 6A F/UTP and category 7$_A$ S/FTP cabling systems.*** In fact, category 7$_A$ S/FTP cabling systems dissipate at least 60% more heat than category 5e cables!

BEYOND PoE PLUS:

With the many functional and cost-savings advantages associated with the PoE Plus application, it's easy to predict that the need to supply even more power to the PD is just a few years away. Fortunately, an element of improved heat dissipation is also the ability to support more current delivery within the IEEE maximum 10°C temperature rise constraint. **Figure 4** shows the maximum current that can be applied over different media types at 50°C without exceeding maximum temperature rise constraints. Based upon their vastly superior current carrying ability, it's a safe bet that category 6A and higher-rated cabling will be the targeted media for the support of tomorrow's high performance telecommunications powering applications.

DEFINITIONS:

Insertion Loss: The decrease in amplitude and intensity of a signal (often referred to as attenuation).
Type 1: PoE delivery systems and devices
Type 2: PoE Plus delivery systems and devices

ACRONYMS:

° C: . . . . .Degrees Celsius
A: . . . . .Ampere or Amp, unit of current
AC: . . . . .Alternating Current
DC: . . . . .Direct Current
dB: . . . . .Decibel
IP: . . . . .Internet Protocol
IPTV: . . . . .Internet Protocol Television
kW: . . . . .Kilowatt
MHz: . . . . .Megahertz
PD: . . . . .Powered Device
PoE: . . . . .Power over Ethernet, IEEE 802.3af
PoE Plus: . . . . .Power over Ethernet Plus, IEEE 802.3at
PSE: . . . . .Power Sourcing Equipment
F/UTP: . . . . . . .Foil around Unshielded Twisted-Pair (applicable to category 6A and lower-rated cabling)
IEEE: . . . . .Institute of Electrical and Electronics Engineers
ISO: . . . . .International Standards Organization
m: . . . . .Meter
mA: . . . . .Milliampere or Milliamp, unit of current
RFID: . . . . .Radio Frequency Identification
S/FTP: . . . . . . .Shield around Foil Twisted-Pair (applicable to category 7 and 7_A cabling)
TIA: . . . . .Telecommunications Industry Association
UTP: . . . . .Unshielded Twisted-Pair
VDC: . . . . .Volts, Direct Current
VoIP: . . . . .Voice over Internet Protocol
W: . . . . .Watt, unit of power
WAP: . . . . .Wireless Access Point

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