WHITE PAPER

# Considerations for the Design & Field Testing of an Optimized High-Power PoE Cabling System

## Why Comprehensive Testing for DCR Unbalance is Critical


*The Fluke Networks DSX Series of CableAnalyzers can certify the DCR performance of installed cabling systems and includes limits for the Powerwise + Clarity system.*

As Power-over-Ethernet (PoE) becomes the preferred method for simultaneously delivering power and data to endpoints, technology companies are introducing new power efficient and PoE specific systems and devices to better serve businesses, enterprise organizations and consumers in general. In order to work properly and at its fullest potential, this new technology requires installers and end users alike to take into consideration:

- The need to thoroughly protect their investment in new devices, including passive infrastructure hardware, like plugs and jacks
- The longer lifespan of usage compared to existing network systems
- The importance of future-proofing devices in accordance with emerging requirements
- That components may reach and will need to withstand higher temperatures
- The need to justify the capital expenditure of installation by calculating expected power efficiency

Now, more than ever, users are seeking access to quality, data-proven components, so that they may be assured of the value of investing in new technology that will meet and surpass their expectations and meet the standards set forth by governing bodies. Industry leaders Fluke Networks, Legrand, and Superior Essex have partnered to create a line of standard-compliant products that are in accordance with the new direct current resistance (DCR) requirements introduced by IEEE 802.3bt.


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## What is PoE?

In recent years, devices which were once strictly analog have become digital, functioning more like computers and utilizing an IP network. One of the first examples of PoE to be found in commercial buildings was the Voice over IP (VoIP) telephone network, and the applications for PoE integrations have only grown. As devices become increasingly digital or "smart," PoE technology simplifies device installation and allows users to better monitor and control their environments. For example, the proliferation of digital devices that can be incorporated into homes, offices, and other buildings give building owners and maintenance teams the ability to monitor and control the building's functions, simplifying operations and improving the environment for tenants.

While in the past, devices required separate cables for AC power and network connections, PoE allows both power and data to be delivered over a single Ethernet cable, also known as a twisted pair cable. The twisted pair cable functions as a pipeline that delivers up to 10 Gbps of data and up to 100W of power to smart devices on the network, including applications such as lighting, IP phones, digital building systems, wireless access points and more.

Although PoE technology is developing, the concept of safe, low-voltage power supply provided via twisted pair communication cabling has existed since the earliest forms of cabled communication. In the past, automated central offices supplied ring voltages of 30V + 15V via 1 or 2 pairs to residential or business land line telephones. More recently technology has progressed from data signaling voltages of 5V or less to PoE power piggybacking over the same twisted 4 pair structured cabling in almost all commercial building communication cabling infrastructures. The goal of Power over Ethernet is to provide a low voltage delivery technology method that can efficiently power an end device from a central location, such as a telecom closet or communication cabinet, while simultaneously using the same transmission path and cabling as Ethernet data transmission. PoE powering eliminates the need to run or utilize separate cabling or AC outlets for the purpose of powering end devices.

## Safety Concerns and Measures

As technology progresses and offers users better tools for asset control and monitoring, PoE becomes increasingly relevant. PoE devices don't require an electrician for installation and virtually eliminate the risk of electrocution, making installation significantly easier. As PoE technology continues to develop, cables become equipped to handle greater transmission burdens safely and potential applications for PoE compatible products increase, as does value for both manufacturers and end users.

Furthermore, the Institute of Electrical and Electronics Engineers (IEEE) approved model for PoE is safe because:

- The technical foundation is built around the National Electric Code (NEC) thresholds for low voltage cabling, similar to what has been used for years for phone systems.
- Power is only supplied by the power sourcing equipment (PSE) onto cabling that has a valid powered device (PD) connected and following an authorization negotiation. When a PD is removed or channel continuity is interrupted, power is no longer supplied to that cable channel.

## PoE and the Digital Building

The Cisco Digital Building laid the groundwork for a PoE cabling system to act as the central nervous system for tomorrow's smart buildings. Cisco has created an ecosystem of partners that pairs "connected device" manufacturers with PoE/Internet of Things (IoT) infrastructure manufacturers. By using PoE as the medium to deliver power and data to connected devices, it becomes possible to create a digital building. Cisco has also designed switching equipment to distribute this signal throughout the building. This equipment supports both centralized and decentralized topologies.

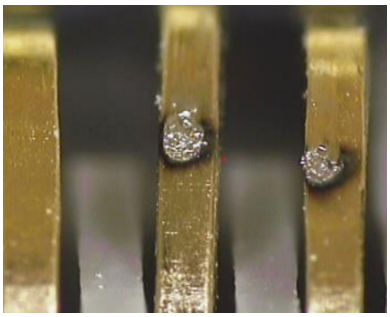
## Standards and Requirements

PoE applications and the cables that power them are governed by several standards organizations: the IEEE, which governs and defines all Ethernet (802.3) applications, including PoE, and the Telecommunications Industry Association (TIA) and International Organization for Standardization (ISO)/ International Electrotechnical Commission (IEC), whose commercial cabling standards set forth installation and testing guideliness and release subsequent standards.

While PoE applications are typically run over structured cabling defined by TIA and ISO/IEC, the PoE standard is controlled entirely by IEEE. The IEEE solicits input from the cabling standards bodies regarding cabling recommendations and initiates liaison discussions on joint technology topics and concerns. The TIA and ISO/IEC define and own the dominant version of structured communication cabling design, installation and testing guidelines. These standards, namely TIA568C and ISO/IEC11801, have been embraced, both in the United States and internationally, since the late 1990s. Both TIA and ISO/IEC now consider the power impact of PoE when assembling or updating cabling standards and practices. The first official Power over Ethernet standard (IEEE 802.3af) was introduced in 2003 and targeted applications that were already served by twisted pair copper cabling. An early targeted application for PoE was IP telephony which, along with subsequent IEEE PoE applications, was designed for deployment over 4 pair cabling via both the building or campus infrastructure (TIA-568 and ISO/ IEC11801) and structured cabling, as well as application specific 4 pair cabling infrastructure.

## Legrand Clarity Cords and HDJ Connectivity: Why Connectivity Choice Matters

Legrand's line of Clarity connectivity, specifically the High Density Jack, or HDJ, is designed with PoE applications in mind. When it comes to safely powering electronics, connection degradation and arcing are two common concerns. A condition known as spark gap erosion can be caused by un-mating the plug jack connection under a PoE load. Legrand's jack contacts are specifically designed to address this concern, separating the area of contact away from the fully mated position of the plug and jacks, protecting the 50 micro-inch gold plated area of the fully mated position and ensuring a high quality contact connection for the life of these products. This is an effective way to protect against connection degradation that could compromise network performance or increase bit error rates.



*Spark Gap erosion shown located away from the critical contact area. Arcing is inevitable, but in a fully mated connection, the plug makes contact with the jack in the critical contact area, away from any spark gap erosion.*

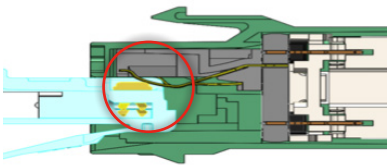


***Fig. 1***
*Arcing, or the "Spark Gap" takes place at the last point of contact between the plug and the jack, as shown here.*

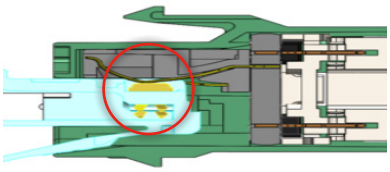


***Fig. 2***
*Legrand's jacks are designed to locate the critical contact area away from any erosion caused by electrical arcing.*

Although jacks and panels have little attenuation impact, largely because circuits within such parts are very short, these connectors can still influence power throughput. Many of today's jacks and panel connectors utilize printed circuitry to control and cancel noise and elevate readable digital signal performance. The emphasis on the data transmission as it pertains to designing printed circuit board (PCB) traces did not cause concerns when the initial lower power PoE standards were released, but it's important to note that PCB circuit paths (total surface area, trace widths and cross sectional content) can differ with each variation, making it important to be aware of differences in current carrying capacities. Connectors that utilize printed circuit boards designed to IEC 60512-99 recommendations are already designed to support 1 amp on each circuit path. Since a complete circuit is a loop, typically containing 2 traces, this requirement can sometimes be listed as 1 amp per pair. A 1 amp design is sufficient to support the max 350mA of 802.3af and the max 600mA of 802.3at, but allowing for the projected 960mA for 802.3bt types 3 and 4 puts total levels dangerously close to the 1 amp capability and design protection recommended by the IEC. To ensure some level of margin, connectivity with PCBs would benefit from circuit traces designed to handle more than 1 amp.

Legrand's line of Clarity connectivity is designed to handle 1.5 amps or more per circuit trace, offering additional margin over and above IEC recommendations. Additionally, all products are manufactured in full compliance with the standards put forth by IEC 60512-99. Because larger cable trace widths on the printed circuit board disseminate heat better, Clarity jacks and cables with thicker wire gauges (typically 22 or 24 AWG) are best optimized for PoE applications.

When choosing devices for PoE connectivity, consider that:

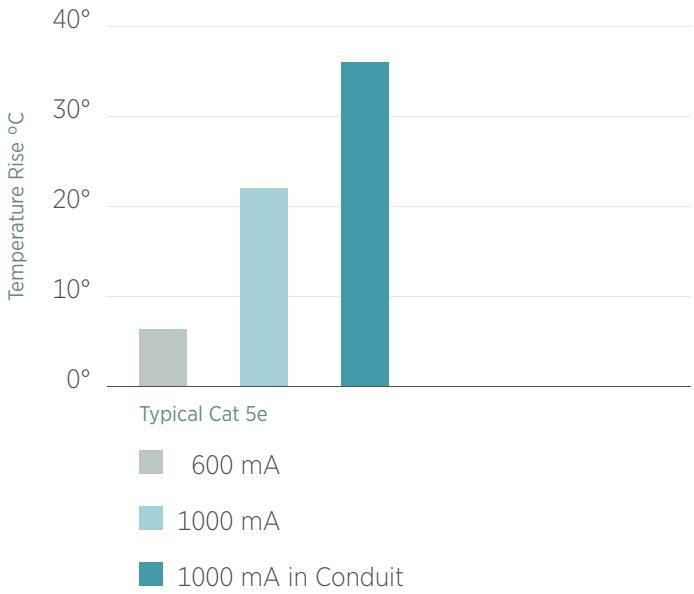
- If connectivity products are not compliant with IEC 60512-99, that connectivity should not be described as able to support all levels of PoE
- By depending on the only standards body recommendation to date (IEC 60512-99), compliant connectivity might be very close to its design limits when supporting the pending high power PoE applications. To eliminate risk, look to connector manufacturers like Legrand who are designing connectivity products with capacities beyond the 1 amp minimum
- Connectivity products designed with or specified as having a capacity of 1.5 amp or greater offer larger power path capacity and margin

## PowerWise® by Superior Essex: Why Cable Choice Matters

As users expect PoE technology to be suitable for up to 100 Watts energized over 4 pairs, a new set of concerns regarding standards, safety, installation, energy efficiency, data transmission performance and lifetime of cable installations has emerged. By implementing a set of dedicated standards to determine how 4 pair PoE systems should be designed to minimize heat generation, maximize power efficiency, and minimize operating costs, Superior Essex has created PowerWise, a line designed to ensure safety and expand and guarantee each product's expected lifetime.

High temperatures generated by PoE operations over category cables call into question the safety of the building and the impact on data transmission. As a result, both the NEC and TIA regulate the maximum heat increase for cables while in operation. The following figure demonstrates the relationship between temperature increases and transmission wattage.

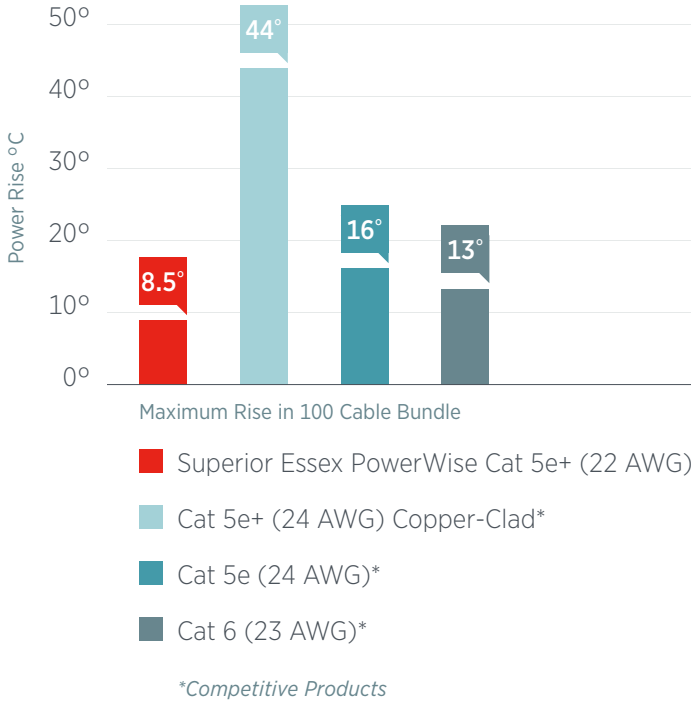
## TEMPERATURE RISE COMPARISON CHART OF 91 CABLE BUNDLE




The next figure shows the difference of temperature increase depending on the design of the cable.

## LOWEST TEMPERATURE RISE

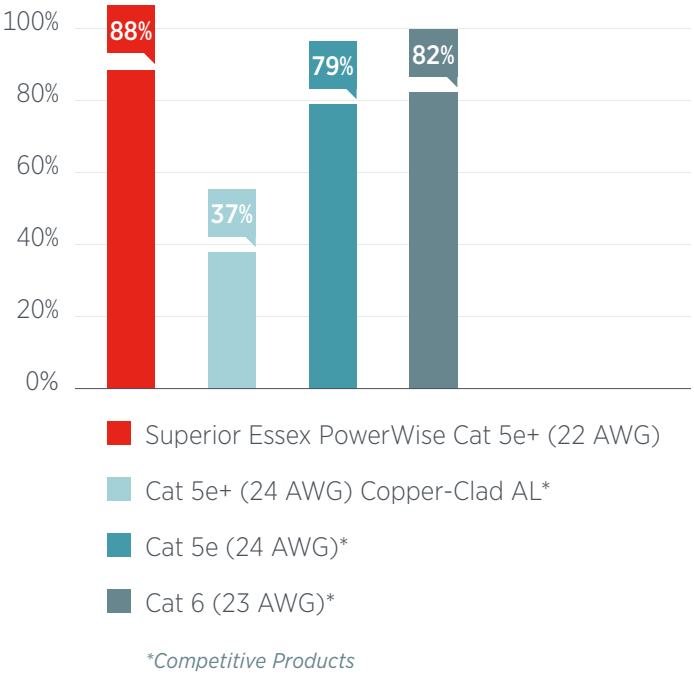
via 22 AWG Conductors



The below chart demonstrates scaled power efficiency among different cables.

POWER EFFICIENCY PER 100 METER LENGTH

AWG




*Competitive Products

For the first time, PoE is being applied to applications like lighting which will need to withstand decades of use in a high heat and high power environment. These harsh conditions have significant implications for the materials used for insulation and jacketing. The introduction of 4PPoE operations means that PoE cables will see higher temperatures for longer periods of time, promoting studies that seek to estimate the service lifetime of category cable insulation by the Oxidative Induction Time (OIT) approach. This is a practical, first-look method that helps researchers to understand the impact of temperature increases on insulation materials. When tested, FEP and PE insulation materials showed, based on the first cable sample examined, that the cable should meet the industry life expectancy of 20 years at normal operating conditions, but not at the lowest UL temperature rating. At lower temperatures, the insulation is more prone to thermal degradation at 60°C and exhibited an estimated lifetime of less than 5 years. In contrast, the data for the second cable sample suggested that the cable will not meet the life expectancy targets even at the typical environmental operating temperature of 40°C. Per visual inspection, the second cable sample shows severe insulation degradation after just 10 days at 120°C, as pictured below.

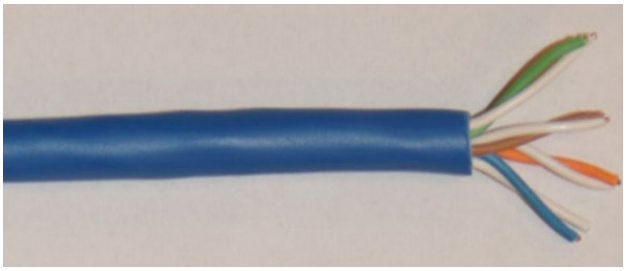


***Fig. 1***
*Figure 1: Sample cable under normal conditions.*

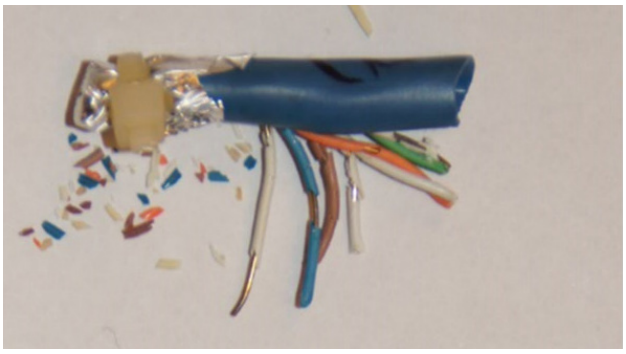


***Fig. 2***
*Cable damage and insulation degradation after 10 days at 120 degrees C.*

In contrast, the Superior Essex PowerWise product line was developed to offer a line of efficient cables able to withstand the challenges of high heat, high power environments. The power efficiency of the cabling system is directly related to the DC resistance of the cable, which has a direct impact on the total cost of operation due to the energy consumption of the system and its relationship to the power loss generated by the cable. The cost of the cabling system of a 100W 4PPoE operation system would be the right balance between the cost of the cable design and the power efficiency of the cable. Cables which minimize heat generation and power loss have a positive impact on the operating cost of the facility, allowing the cooling system to operate less and use less energy. In conclusion, using cables dedicated to PoE systems guarantees the safety of installation, minimizes heat generation, maximizes temperature dissipation, minimizes power loss, and optimizes manufacturing costs.

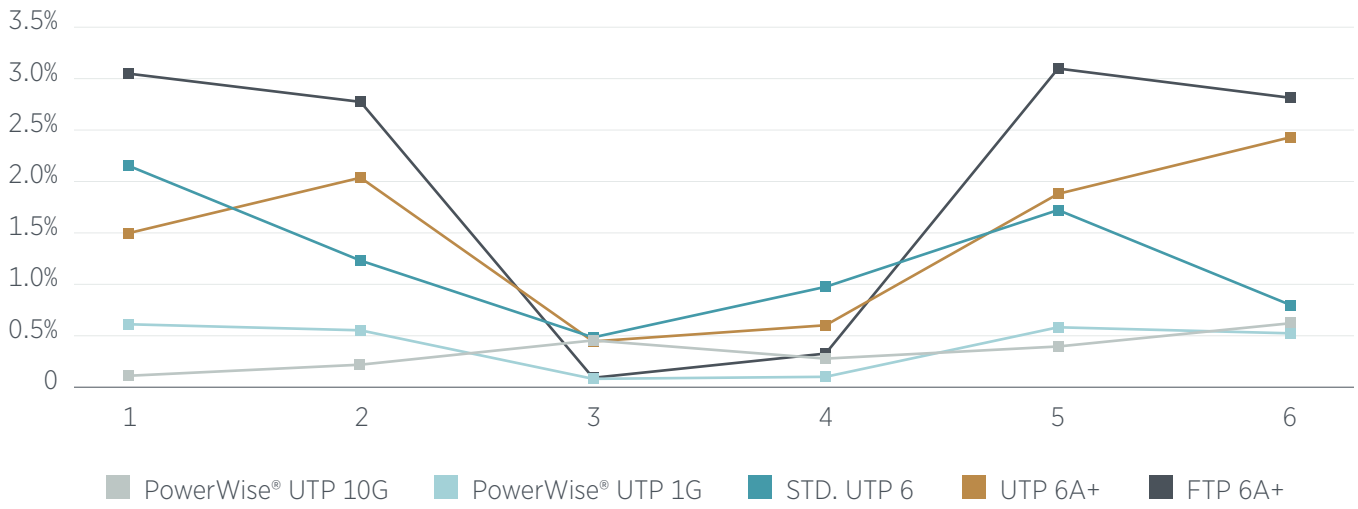
## Synergistic Cabling Systems: Why cabling channel matters

Compliance to Direct Current Resistance (DCR) ensures requirements that power delivery does not degrade data performance, while maintaining a consistent voltage between two pairs. In order to meet the requirements outlined in IEEE 802.3bt Draft 3, DCR should not exceed 21 ohms. The difference in resistance between two pairs must not exceed 200 milliohms or 7.0% and the difference between two conductors of the same pair may not exceed 100 milliohms or 3.0%. The standard also recognizes that field measurements may have accuracy limitations below 200 milliohms. These standards exist to prevent DCR Unbalance, which can be caused by faulty cable manufacturing or poor installation practices, and sometimes even by a cable's specific wire gauge. DCR testing measurements are conducted by the cable manufacturer; lower DCR ratings indicate that a system is better protected than one with a higher rating. Products manufactured with attention to DCR tend to have longer lifespans and lower costs because balancing power and data delivery prevents an excess of power on a single trace and offers more power efficiency without data degradation

When evaluating a PoE system, it's important to analyze DCR Unbalance within a pair, pair to pair, and overall DCR to ensure the optimum delivery of power and data. The nCompass product line, created out of a partnership between Superior Essex and Legrand, is the first and only channel solution designed to pass DCR limits, meeting the Pair to Pair DC Resistance Unbalance requirements as defined by IEEE 802.3bt draft 3.0. Clarity connectivity combined with PowerWise 1G cable offers premium channel performance with even more headroom than Category 6 and 6A systems, maximizing performance while keeping costs low.

## PAIR-TO-PAIR UNBALANCE COMPARISON (nCOMPASS 100M4C CHANNELS)

Percentage

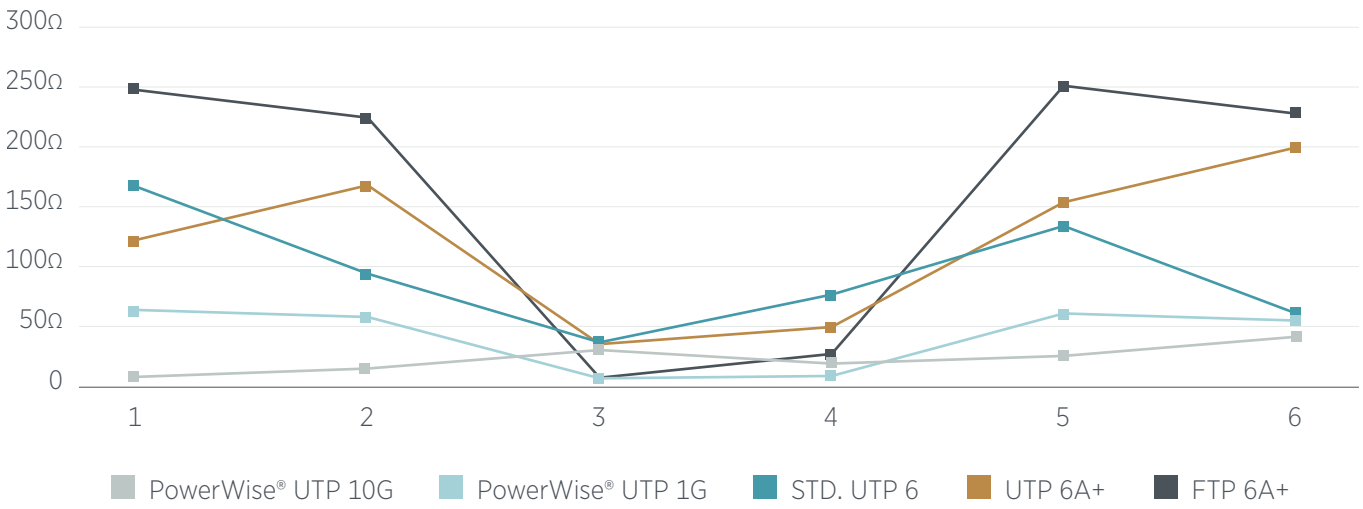



| Pair-to-Pair Unbalance | Wire Pairs (Percentage) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Channel Type** | **1,2–3,4** | **1,2–3,6** | **1,2–7,8** | **3,6–4,5** | **3,6–7,8** | **4,5–7,8** | **Max** |
| PowerWise® UTP 10G | 0.06% | 0.17% | 0.41% | 0.23% | 0.35% | 0.58% | 0.58% |
| PowerWise® UTP 1G | 0.06% | 0.17% | 0.41% | 0.23% | 0.35% | 0.58% | 0.58% |
| Std. UTP 6 | 2.14% | 1.20% | 0.44% | 0.94% | 1.70% | 0.76% | 2.14% |
| UTP 6A+ | 1.47% | 2.02% | 0.40% | 0.56% | 1.86% | 2.42% | 2.42% |
| FTP 6A+ | 3.05% | 2.77% | 0.04% | 0.28% | 3.10% | 2.81% | 3.10% |

*Lower numbers indicate superior performance.*

## PAIR-TO-PAIR UNBALANCE COMPARISON (nCOMPASS 100M4C CHANNELS)

mOhms




| Pair-to-Pair Unbalance | Wire Pairs (mOhms) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Channel Type** | **1,2–3,4** | **1,2–3,6** | **1,2–7,8** | **3,6–4,5** | **3,6–7,8** | **4,5–7,8** | **Max** |
| PowerWise® UTP 10G | 4.2 | 11.3 | 27.0 | 15.5 | 22.8 | 38.2 | 38.2 |
| PowerWise® UTP 1G | 61.0 | 55.0 | 3.0 | 5.0 | 58.0 | 52.0 | 61.0 |
| Std. UTP 6 | 165.7 | 91.7 | 33.5 | 74.0 | 132.2 | 58.2 | 165.7 |
| UTP 6A+ | 120.3 | 166.7 | 32.0 | 46.5 | 152.3 | 198.7 | 198.7 |
| FTP 6A+ | 247.6 | 224.0 | 3.5 | 23.7 | 251.1 | 227.5 | 251.1 |

*Lower numbers indicate superior performance.*

## Fluke Testing: Why PoE field testing matters

For years, cabling specifications have been formulated for high performance data communications. Installed cabling systems certified to meet appropriate requirements for loss and near end crosstalk, for example, can be trusted to support data rates of 10 Gbps or even higher. However, requirements for assuring the performance of high power PoE systems have only recently appeared as the technology has developed. During this time, standards organizations have determined that the relevant measurements for ensuring PoE performance are:

- DC loop resistance
- DC resistance unbalance between pairs
- DC resistance unbalance within a pair

Measured in ohms (Ω), DC loop resistance is the sum of the DC resistance of two conductors in a pair looped at one end of the link. A higher resistance means more loss along the length of the cable, defining the amount of power that can be delivered by a specific length of cable.

DC resistance unbalance within a pair impacts data transmission in PoE cables, and excessive unbalance causes saturation of the receiver's transformer and distorts the waveforms of Ethernet data signals, causing bit errors, retransmits and even nonfunctioning data links. Further, in four-pair Type 3 and Type 4 PoE systems, it is no longer just the resistance unbalance on each pair that matters. Excessive resistance unbalance between multiple pairs can cause PoE to stop functioning.

While it is not uncommon for vendors to list DC resistance unbalance values on specifications for cable, the TIA standards do not require any form of loop resistance or resistance unbalance testing as a field measurement. Unlike DC loop resistance testing, the lack of a requirement to perform field testing for DC resistance unbalance has been in part due to the inability of older testers to perform these measurements. It has therefore remained primarily as a laboratory measurement done by cabling vendors.

While PowerWise and Clarity solutions are is designed and manufactured to meet all the required resistance performance requirements, errors in workmanship or even counterfeit cabling can render an installation inoperable. Field testing of DC resistance unbalance is the only way to guarantee equal resistance between conductors or pairs after installation.

Fluke Networks DSX Series CableAnalyzers can quickly test all three critical parameters: DC resistance, DC resistance unbalance within a pair and DC resistance unbalance between pairs. Working with Legrand and Superior Essex, Fluke Networks developed a set of limits based on TIA and IEEE requirements for testing installed PowerWise and Clarity systems. These testers measure DC loop resistance as a sum of the resistance of two conductors in a pair, as well as DC resistance unbalance—the measure of the difference in resistance between the two conductors.

Since the additional DC resistance testing adds little additional time to a standard "Category" test, it is recommended that DC resistance unbalance testing be performed on the PowerWise and Clarity solutions. It's the only way to be truly sure that the installed system will not only meet or exceed all IEEE-mandated PoE requirements but also provide the benefits of lower heat rise and operational costs.

## Conclusion

Emerging Power-over-Ethernet technology has exciting applications for managing a new breed of digital buildings and creating safe, comfortable environments for their tenants and inhabitants. In order to maximize the benefits of PoE technology, Fluke, Legrand, and Superior Essex have joined their respective industry expertise and offerings to create a system that conserves resources, prioritizes safety, and increases product lifetimes and will withstand the test of time.