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Power over Ethernet – The story so far

White Paper

HellermannTyton

Introduction

Power over Ethernet (PoE) does exactly what its name suggests; it delivers usable power over Ethernet (twisted pair) cabling.

Providing both the power and data required by an attached device has significant benefits such as ease of installation and relocation of the powered device without the need to consider the location of the power source. Remote control and monitoring are also easier to achieve with a remote power solution.

Even though there are some obvious benefits to PoE there are some things to know and others to be considered.

The Standards

PoE has been in use in various forms for many years however the IEEE have standardised two versions. The first PoE in 2003 allowed for the powering of devices up to 19.95 watts (W).

The second, so called PoE plus or PoE+, was standardised in 2009 with a maximum powering provision of 34.2W. Whilst these values are the reported maximum powers that can be provided by power source equipment (PSE) it is not the actual power that is ultimately delivered to the powered device (PD).

The resistance of the copper cabling coverts some of the sourced power into heat and as such only 12.95W to 19.95W of power is actually delivered to the PD for PoE and 25.5W to 34.2W for PoE+. The 2009 IEEE 802.3at standard merged PoE and PoE+ into 802.3at:2009 Type 1 (PoE) and Type 2 (PoE+).

Power Delivery Method

In addition to the two present power levels that are deliverable using PoE, there are numerous power delivery methods. However, only two power delivery methods have been standardised by the IEEE; they are referred to as Alternative A and Alternative B and describe the methods employed to deliver the power from the PSE to the PD.

The references to Alternative A and B only apply to the PSE since the PDs are normally designed to support both power delivery techniques as shown in figures 1 to 5.

It is generally understood that the two alternatives simply define whether the power is transmitted via used or unused pairs. This is the case for 10BaseT and 100BaseT Ethernet where only the orange and green pairs are used. However, this is not so for 1000BaseT and 10GBaseT where all four pairs are used for data transmission.

Figure 1 shows Alternative A for 10/100BaseT using the data pairs and Figure 2 shows Alternative B for 10/100BaseT using the unused (blue and brown) pairs.

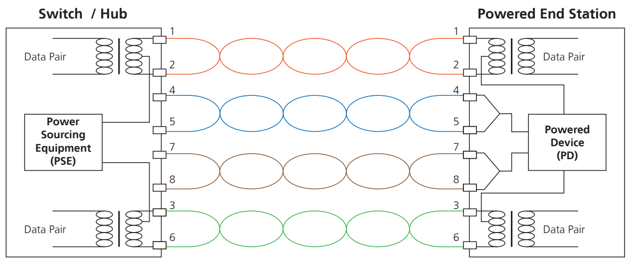

Figure 1 - 2 Pair Data Transmission, Alternative A

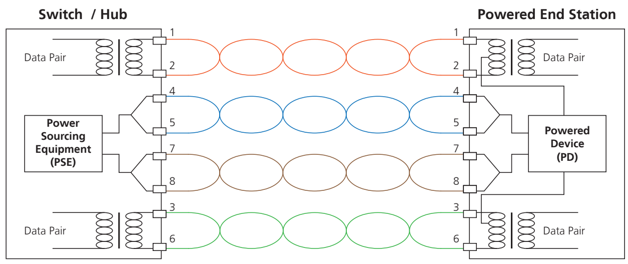

Figure 2 - 2 Pair Data Transmission, Alternative B

For the four-pair signalling of 1G/10GBaseT the two alternatives simply determine which two pairs deliver the power.

Figures 3 and 4 show Alternative A and Alternative B respectively, with Figure 3 using the orange and green pairs, and figure 4 using blue and brown.

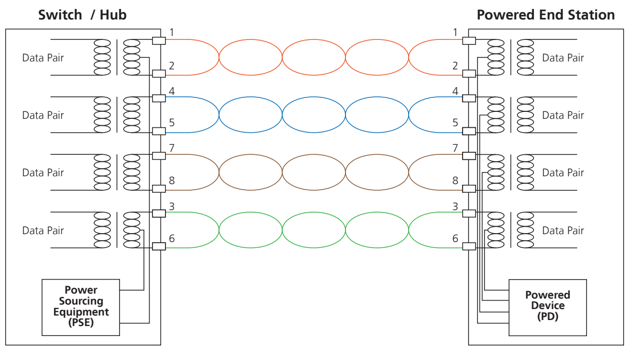

Figure 3 - 4 Pair Data Transmission, Alternative A

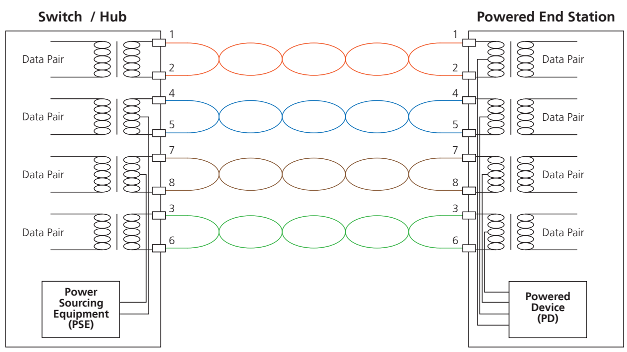

Figure 4 - 4 Pair Data Transmission, Alternative B

Figures 1 through 4 depict the use of power source equipment within the endpoint (switch or hub). The same configurations are also available in a mid-span solution.

Endpoint PSE or Mid-span PSE

Figure 5 shows the mid-span configuration for Alternative A for a four-pair Ethernet system.

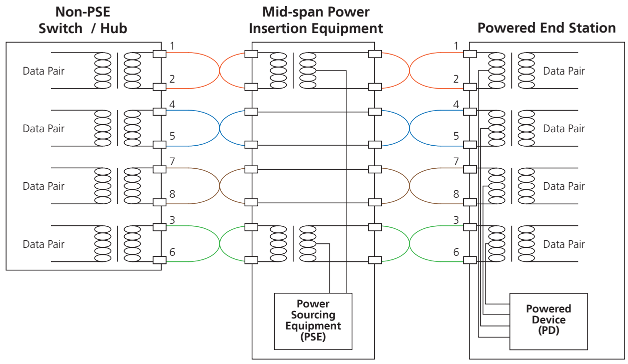

Figure 5 - Mid-span 4 Pair Data Transmission, Alternative A

In this type of powering solution, the switch or hub can be of a standard design without integral power source equipment. Whilst the switch cost will of course be lower, the combined cost of a separate switch and mid-span PSE will likely be greater, and occupy more rack space. The benefits of keeping them separate enable them to be upgraded independently and also to only provide power on those ports where it is needed.

Figure 6 - PoE Switch *Figure 7 - PoE Mid-Span*

Figure 6 shows a typical combined switch and PSE with 24 powered ports. Figure 7 shows a mid-span PSE device that supports 16 incoming Ethernet ports and 16 outgoing Ethernet + PoE ports.

Although referred to as mid-span, these devices are usually situated adjacent to the Ethernet switches.

Types of Powered Devices

Thousands of devices now support remote powering from PSE. These PDs have the benefit of not requiring the installation of both dedicated power and network cables to the same location.

Many domestic and commercial IT devices operate on low voltages and include power transformers to reduce mains voltages down to something more usable. These generally take the form of small power supply units. Delivering power over the cabling reduces the need for this type of power provision and the significant inefficiencies they have in converting from mains voltages to much lower DC voltages.

There are numerous applications for PoE, the most popular of which are wireless access points, IP cameras and IP telephones. Typical examples of which are shown in figure 8.

Figure 8 - PoE Powered Devices

Devices such as IP telephones used in voice over IP (VoIP) networks often incorporate two RJ45 sockets, one used for the incoming powered Ethernet connection, back to the switch, and the other a regular unpowered socket to allow a desktop or laptop computer to be connected, thus eliminating the need for a second RJ45 connection in the wall.

Connector Impact

So, how does PoE work? Is the power always on? How does the PSE know how much power to supply? How do you turn the PSE off? This section will answer all of these questions and more.

The low voltage PoE is not always on. If no device is detected then the power is off. Only when a PD is attached to a PoE enabled source is the power made available to the PD. This addresses any concerns over people receiving electric shocks from Ethernet sockets or patch cords if they are left accessible.

There is a handshake that occurs between the PSE and the PD prior to the power being enabled. This only takes a fraction of a second and during the handshake the PD communicates its powering requirements back to the PSE so that the correct mode can be set in the PSE.

A PSE device can provide power using only one (at a time) four-wire connection, regardless of whether the Ethernet protocol is two- or four-pair. In either type the two conductors of each utilised pair carry the same current. Table 1 below is extracted from IEEE 802.3at.

Conductor	Alternative A (MDI-X)	Alternative A (MDI)	Alternative B (All)
1	Negative V_{PSE}	Positive V_{PSE}	
2	Negative V_{PSE}	Positive V_{PSE}	
3	Positive V_{PSE}	Negative V_{PSE}	
4			Positive V_{PSE}
5			Positive V_{PSE}
6	Positive V_{PSE}	Negative V_{PSE}	
7			Negative V_{PSE}
8			Negative V_{PSE}

Table 1 - IEEE 802.3at Table 33-2

Although the power is off when there is no PD connected to the link and the handshake between the two activates the power, the removal of the PD doesn't benefit from the same degree of control. In other words, the PSE cannot anticipate the removal of the PD through the unplugging of a patch cord and as such the voltage and current are still present when this action occurs.

The net result of unplugging the cord is a small arc between the removed plug and socket on one or more of the contacts. The arcing causes a pitting on the surface of the contacts which in turn increases the contact resistance and over time will cause a connector failure.

Figure 9 shows the contacts in a typical connector after multiple live disconnections.

Figure 9 - Contact Pitting

The arcing only occurs for the initial disconnection within a single link and not any subsequent disconnection on the same link. As such, the decision about which connection to break first requires careful consideration. Whilst it is inconvenient if pitting and deterioration occurs at the telecommunications outlet (TO), it is easier to replace than an RJ45 soldered to the motherboard of a £1000+ laptop.

This deterioration can be avoided but not easily. Whilst the PSE will only provide power to an appropriate PD, the power can be remotely switched off using, for example, a web-style interface, usually provided in the PSE. Using this approach however means that a call to the IT department would be required any time a user wanted to unplug a PD; this is clearly impractical especially in an open environment such as a university.

The second solution to this problem involves the inclusion of a sacrificial connection between the TO and the PD. This through-coupler should be where the initial disconnection takes places since it is the easiest and most cost-effective component to replace. The only requirement is that the user remembers to disconnect at this point before any other, as once the link is broken the power is removed and the risk of arcing and pin damage is eliminated altogether.

Power Delivery Vs Cabling Performance

The effect of passing a current along a copper conductor causes it to heat up; the greater the current the greater the rise in temperature. This is a well-known physical characteristic of copper cables. If the cable is insulated then the heat will not dissipate freely.

The increased amount of heat within a cable adversely affects the resistance of it, which in turn causes more power to be lost as heat. Whilst this chain reaction does reach equilibrium and stabilises, it has been proven that the temperature inside a bundle of cables, all delivering PoE, can rise by 40°C in some circumstances. There are several proprietary PoE solutions that deliver even more remote power than PoE+ for which the impacts are substantially greater. The constant heating and cooling of the cable is undesirable and may cause premature failures either in the copper or the insulation. Operating cables at elevated temperatures and over repeated heating and cooling cycles may have thus far unknown affects.

Fortunately for PoE and PoE+ (IEEE 802.3at Type 1 & 2) elevated cable temperature is not really a problem. However, for IEEE 802.3bt (see section below – "The Future of PoE"), the temperature rise in a 24 cable bundle could be as much as 17°C for a C6 cable bundle. This increase in temperature, and resulting increase in conductor resistance, limits the maximum channel distance that can now be served by over 10m. Figure 10 shows the calculated maximum channel length for different temperature rises based on the temperature rise model documented in CLC TR 50174-99-1.

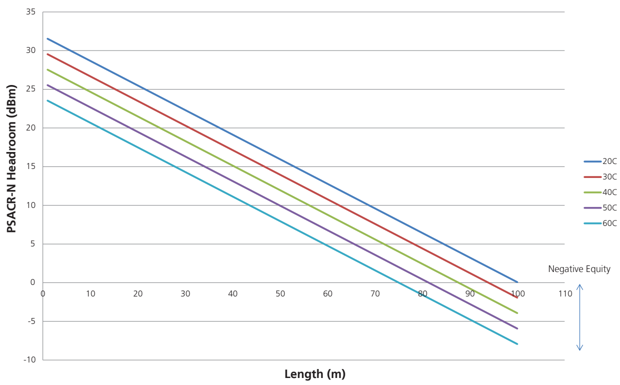

Figure 10 - Maximum Channel Length Vs Temperature

If the temperature goes even higher, the maximum channel length is further reduced. There are PSE devices that claim to deliver in excess of 0.75A per conductor which in a C6 UTP cable could give rise to an increase in temperature of almost 40°C.

A 40°C temperature rise, depending on the installation environment and the amount of ventilation/insulation, would reduce the channel length from 100m to 75m and the possible area served by up to 30%. Figures 11 and 12 show the heat distribution of different cable bundles in different installation environments.

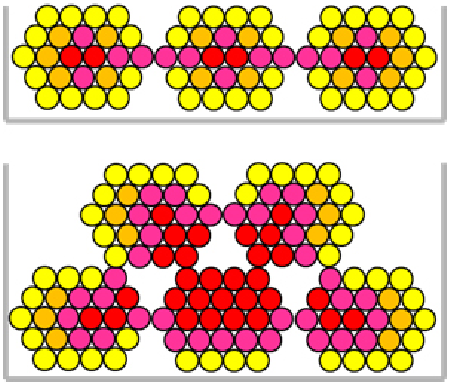

Figure 11 - Partially Ventilated Cable Bundles

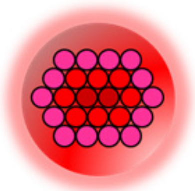

Figure 12 - Insulated Cable Bundle

The Future of PoE

A further PoE standard (IEEE 802.3bt) is currently in development in IEEE which is expected to source between 100W and 114W, delivering a minimum power of 75W with up to 500mA per conductor. This suggests that up to 25W of power could be lost as heat in every PoE circuit.

Today's PDs don't require this degree of power to operate and at present, with the exception of VoIP telephones, they are not deployed in large numbers. However, the significant increase in available power from the next generation of PSE will mean that more applications can take advantage of remote powering. Applications from 10GBaseT wireless access points supporting larger numbers of connected users, to building management and control systems, to LED lighting are all valid reasons for increasing the amount of power that can be delivered using data cabling.

The use of PoE for commercial LED lighting solutions is still in its infancy. Figure 13 shows a typical configuration for such a system where the power and control for the lighting is supplied over standard data cabling. Environmental sensors taking readings of ambient light levels or human activity are also connected to the network such that lights can be intelligently controlled and power consumption minimised.

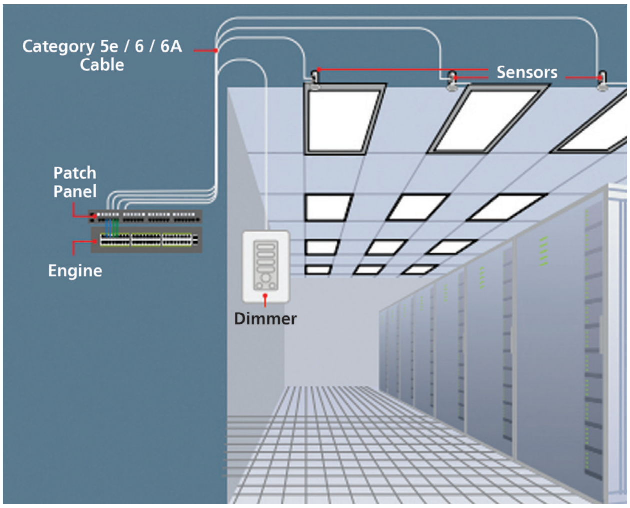

Figure 13 - Example of LED Lighting Configuration

This increased usage of data infrastructure is not without its implications however. With up to 25W of power being lost as heat for every active link, and the utilisation of large numbers of links for non-traditional services such as LED lighting, it is now more important than ever to ensure that the type and performance of the chosen infrastructure products are given careful consideration.

As previously explained, these elevated powers will give rise to elevated temperatures which in turn will reduce the end-to-end performance of the data infrastructure and ultimately reduce either its length or data throughput. Knowing where these circuits are within the building infrastructure and the circuits that they will likely affect as their temperature increases will become ever more important, especially as the lines blur between facilities and IT with respect to physical network design, installation and management.

Managing the cabling used to deliver remote power on a day-to-day basis will be the key to successfully utilising higher-powered Ethernet networks. Careful consideration should be given to those devices that utilise Ethernet cabling to deploy power but do not meet the requirements of the 802.3 range of standards. These non-standardised devices may source even higher power levels and be accompanied by greater temperature rises and reductions in effective channel length which in turn will accelerate the performance decline of the infrastructure.

Further evaluation of the impact of 802.3bt and beyond is needed to determine the long-term effects on twisted pair cabling systems.

HellermannTyton Connectivity

HellermannTyton's C5E, C6 and C6A copper-based networking products have been proven to support both current forms of PoE, as described in IEEE 802.3at, up to a maximum distance of 90m in link and 100m in channel configurations. However, consideration should be given to the installation environment, size of cable bundle and the amount of ventilation available to minimise undesirable temperature rise. Installing in accordance with HellermannTyton's installation guidelines will maintain unwanted temperatures rises within acceptable levels.

Careful consideration should also be made when selecting a method to allow the safe and reliable unplugging process for connected devices, especially those that will be plugged and unplugged on a regular basis, such as hot-desk workers or student laptops, etc. However, the inclusion of a sacrificial connection point, to eliminate connector damage, has the potential to negatively impact the performance of the infrastructure and would not be included in the system warranty due to its limited life expectancy if plugged and unplugged regularly.

Conclusion

PoE has been in existence for several years and is now widely accepted and adopted as an effective means of delivering both power and data to remote devices over twisted pair cabling infrastructure.

The use of PoE is likely see a further upturn in the future as the amount of available power increases to a more useful level and more sophisticated and power-hungry devices utilise it. This increase comes with a greater responsibility to know how much power is being delivered over the cabling system and what routes it takes.

Understanding how the cabling system is ventilated and keeping up to date and accurate records of power consumption will ensure a healthy network infrastructure for all users.

Ensuring that those departments responsible for the distribution of both power and IT services, over what has largely been considered an IT resource, should also be clearly defined to avoid one powered service from disrupting another.

Installing quality cabling infrastructure, adhering to industry standards and HellermannTyton's installation guidelines is an essential first step in ensuring a successful and high-performing remotely-powered building infrastructure.

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