White Paper | PoE

Power over Ethernet

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Content

Document Identification

White Paer - PoE Power over Ethernet
Document No: NWP11
Version: 2021/11 V1

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Language: English

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1. INTRODUCING THE POE TECHNOLOGY

PoE = Power over Ethernet

A definition of power and data on the same cabling which has been standardized by the IEEE 802.3 working group started in 2003.

PoE technology is used to power remotely connected devices and simultaneously transmit information using an Ethernet cable support consisting of 4 pairs of twisted copper wire.

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 provides significant benefits such as

- **quick installation and flexibility:**
  ease of installation and relocation of the powered device without the need to consider the location of the power source
- **safety:**
  PoE uses relatively low voltages, so there is low risk of electrical hazard
- **reliability:**
  Since data and the power supply pass in the same Ethernet cable, there is only one cable to be pulled per connected device. Compared to an external power supply, the number of connectors and adapters is reduced.
- **scalability:**
  easy to add new equipment to a network (PoE devices are plug-and-play)

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

2. POE NOMENCLATURE

PoE systems consist of three main elements:

- PSE: Power Sourcing Equipment
- PD: Powered Device
- infrastructure Cabling

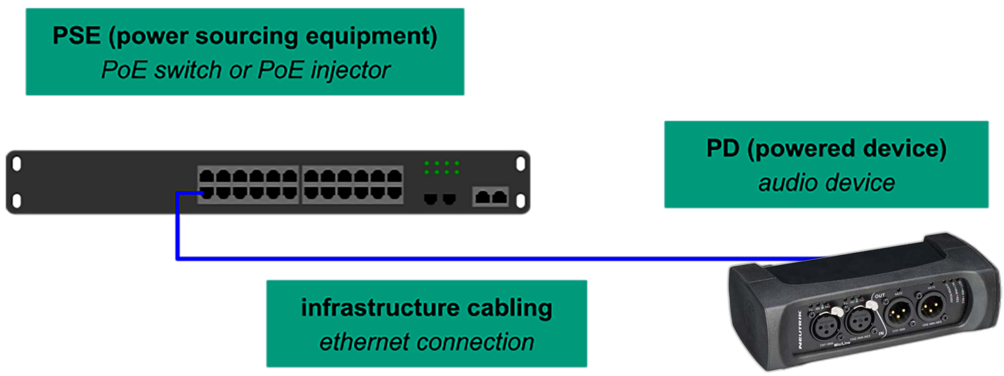


figure 1: PoE nomenclature

The principle of PoE power supply is based on the use of twisted copper pairs of the Ethernet cable to power from the source called PSE (Power Sourcing Equipment), the remote equipment called PD (Power Device).

An Ethernet cable can carry information (voice, data, images, etc.) at a rate up to 40 Gbit/s depending on the type of cable and the active devices (router, switch) used and is made up of four pairs of wires. When the connection is 10 or 100 Mbit/s, the data travels on only two pairs, namely wires 1, 2, 3 and 6; the other two spare parts, namely the wires 4, 5, 7 and 8, can be used to convey the electric current (type A). It is however possible to use the wires 1, 2, 3 and 6 to convey the data and the power (type B), leaving the free pairs unused. When the connection is above 100 Mbit/s, the four pairs are used to carry the data. In this case, the power can be transmitted on the pairs 1/2 and 3/6 or 4/5 and 7/8. The IEEE 802.3af (15 W), 802.3at (30 W) and 802.3.bt (90 W) PoE standards describe these two scenarios. According to the standard, PDs must support power transmission capabilities in both types A and B. On powerup, the PSE needs to determine how much power it needs to supply the PD to avoid damaging it. For this there are two methods: either by a HW protocol (Physical Layer Classification) or by using the LLDP protocol (Link Layer Discovery Protocol) for data exchange between the two devices PSE and PD.

Category 5e cable should be the minimum to use in AV projects for any version of PoE and to support data up to 10Gbps.
A minimum of **AWG 26** is required.

3. THE STANDARDS

PoE has been in use in different forms for over 20 years. The IEEE has standardized four versions. The first PoE standard IEEE 802.3af-2003 allowed for the powering of devices up to 15.4 W. The second standard IEEE 802.3at 2009, so called PoE plus or PoE+, was specified a maximum powering of 30 W. The latest standard (as of May 2021) IEEE 802.3bt-2018 specifies PoE type 3 and type 4 (sometimes referred to as PoE++) to deliver a maximum of 60 W and 90 W respectively.

The voltage at the PSE is defined in all standards (IEEE 803.2 af/at/bt) between 44 V and 57 V.
Due to the worst-case scenario (a voltage drop of 7 V), the PD must also accept 37 V.

3.1 PoE Type 1

- Name: PoE, 2-pair PoE
- Standard: IEEE 802.3af
- Maximum port power: 15.4 W

PoE was originally designed to power low-power devices such as IP telephones. The IEEE 802.3af was standardized in 2003 to use two of the four twisted pairs of wires in standard (at the time) Cat3 Ethernet wire runs.

Examples of devices that PoE Type 1 can support include static surveillance cameras, wireless access points and VoIP phones.

3.2 PoE Type 2

- Name: PoE, 2-pair PoE
- Standard: IEEE 802.3af
- Maximum port power: 15.4 W

PoE Type 2 also utilizes 2-pair PoE, like PoE Type 1. Its basis is the PoE+ or IEEE 802.3at Ethernet standard. It delivers up to 30 W of power at the port level over an Ethernet twisted pair cable.
Because it is backward compatible, it can support the types of devices typically supported by PoE Type 1 as well as devices supported by PoE Type 2.

It connects higher-powered devices to a network such as PTZ cameras, RFID readers, video IP phones, and alarm systems.

3.3 PoE Type 3

- Name: 4-pair PoE, 4P PoE, PoE++, UPOE
- Standard: IEEE 802.3bt
- Maximum port power: 60 W

Also known as 4-pair PoE, 4PPoE, PoE++, or UPoE, PoE Type 3 uses all four pairs in a twisted-pair copper cable to deliver power to the PD - unlike Type 1 and 2 which only use two pairs. This higher level of PoE adheres to the IEEE 802.3bt standard which came out in 2011.
It delivers 60 W of power to each PoE port.
Examples of devices that these higher levels of power support include multi-radio wireless access points, PTZ cameras, building management devices, and video conferencing equipment.

3.4 PoE Type 4

- Name: Higher-Power PoE
- Standard: IEEE 802.3bt
- Maximum port power: 100 W

Type 4 PoE, commonly known as Higher Power PoE, offers the highest capabilities of any currently existing PoE type (May 2021) . This PoE type helps to meet the growing power requirements of network devices. Conforming to the newest IEEE 802.3bt standard, Type 4 PoE de-livers 90 W of power from the PSE.
It has the potential to supply a maximum of 100 W of power per port if necessary.
Type 4 PoE can support extremely power-hungry devices such as laptops and flat screens.

3.5 Maximum Power per Port

One of the objectives of the standard is to comply with the limited power source and Safety Extra Low Voltage (SELV) requirements as defined in ISO/IEC 60950. However, this compliance means that power cannot exceed 90 W per port. Despite this power ceiling, 100 W per port is still sufficient for applications previously unsupportable under the prior IEEE standards, expanding the potential number of PoE ports deployments.

The table below summarizes the different types of IEEE 802.3 standards:

Standard (IEEE)	Type	Max. number of energized pairs	Max. Data rate	Max. current per device	Class	Sourced Power at PSE (W)	Requested Power at PD (W)
802.3af	1	2	1000 BASE-T	350 mA	1	4	3.84
					2	7	6.49
					3	15.4	12.95
802.3at	2	2	1000 BASE-T	600 mA	4	30	25.5
802.3bt	3	4	1000 BASE-T	600 mA	5	45	40
					6	60	51
	4	4		960 mA	7	75	62
					8	90	71.3

figure 2: IEEE 802.3 PoE standards

While these values are the reported maximum powers that can be provided by the power source equipment (PSE), it is not the actual power that is ultimately delivered to the powered device (PD). The small conductor cross-sections, the long cable lengths and the low system voltage as well as the losses in the power supply units of PSE and PD contribute to a noteworthy power loss.

Efficiencies of less than 70 % are not uncommon in such applications. The power delivered by the PSE (sourced power) and the power received by the PD (requested power) therefore differ.

4. SOURCE (PSE) CONFIGURATIONS

4.1 PSE endspan configuration

The endspan configuration is used to connect a PoE power supply, usually a switch, to a PoE compatible PD device. Endspans have internal or external power supplies and provide data and power to connected PD devices via RJ45 ports. Endspans provide policy management and enforce PoE budgets through negotiation as well as perform PD scheduling, and PD maintenance

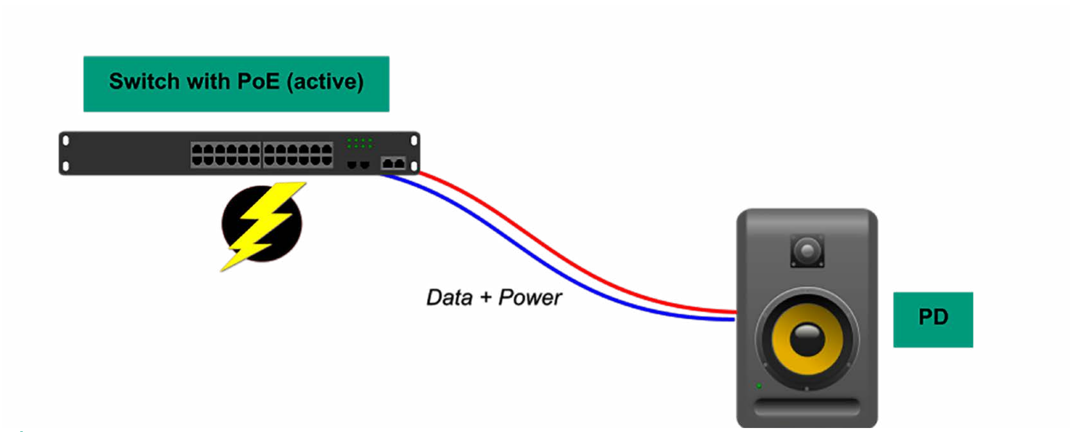


figure 3: PSE endspan

4.2 PSE midspan configuration

Midspans have internal or external power supplies and combine Ethernet data with power typically on a one-to-one relationship. Midspans typically do not have the same kinds of management options as endspans do, but they do still negotiate with PD devices for power needs.

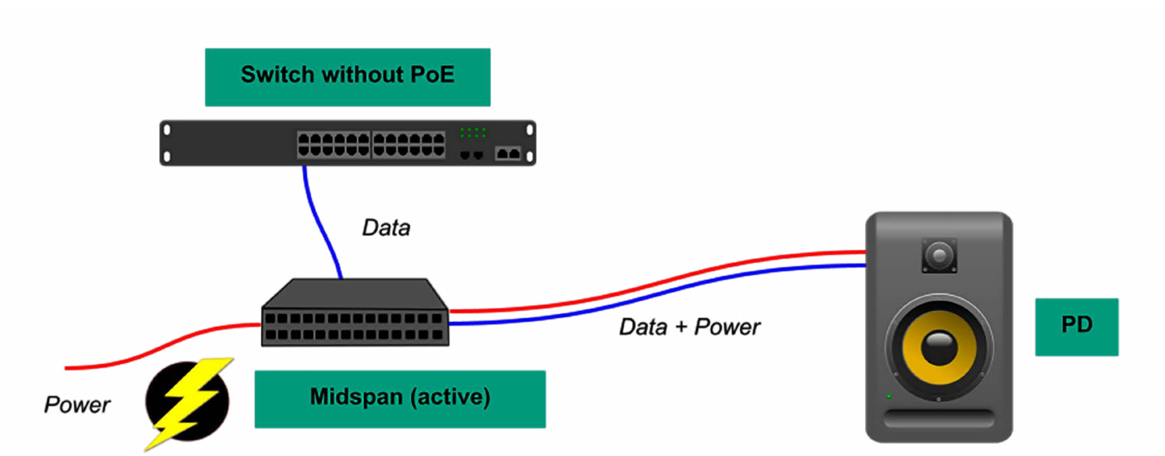


figure 4: PSE midspan

4.3 PoE injector configuration

PoE injectors (also known as Passive PoE - see 5.3 for details about passive PoE) typically have an internal power supply. They also usually have data in, and data/power out connections to allow Ethernet pass-through.

They do not negotiate (see 5.2 power negotiation) with the PD for power class and they do not have any way to scale power back from the PD for PoE budgeting purposes.

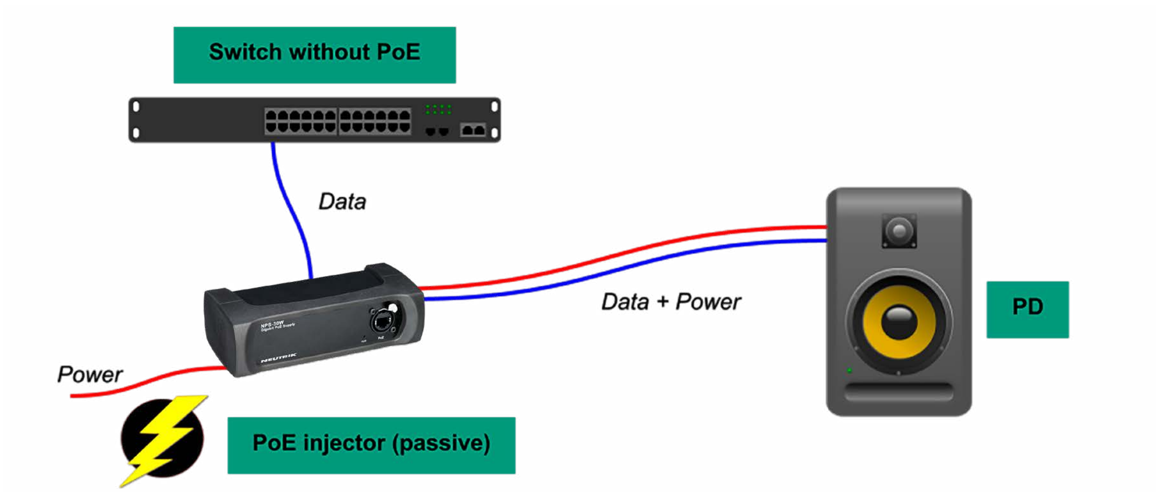


figure 5: PoE injector

Since PoE injectors do not negotiate with the PD, care must be used when specifying this kind of power supply. (see 5.3 passive PoE)

5. ACTIVE AND PASSIVE POE

5.1 Active PoE

Active PoE is also known as standard PoE, which refers to any type of PoE that negotiates the power requirements between the PSE and the PD device. Active PoE switch is a device that complies with standard PoE, so it is also named standard PoE switch. This type of switch is rated to be IEEE 802.3af, IEEE 802.3at or IEEE 802.3bt compliant.

Before powering up, the active PoE switch will test and check to ensure the electrical power is compatible between the switch and the remote device. If it isn't, the active PoE switch will not deliver power, preventing any potential damage to the non-PoE device.

5.2 Power negotiation (handshake)

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 the power is 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.

Typical voltage waveform at the Ethernet port when the PD is powered by a PSE
(Type 4 - Class 8)

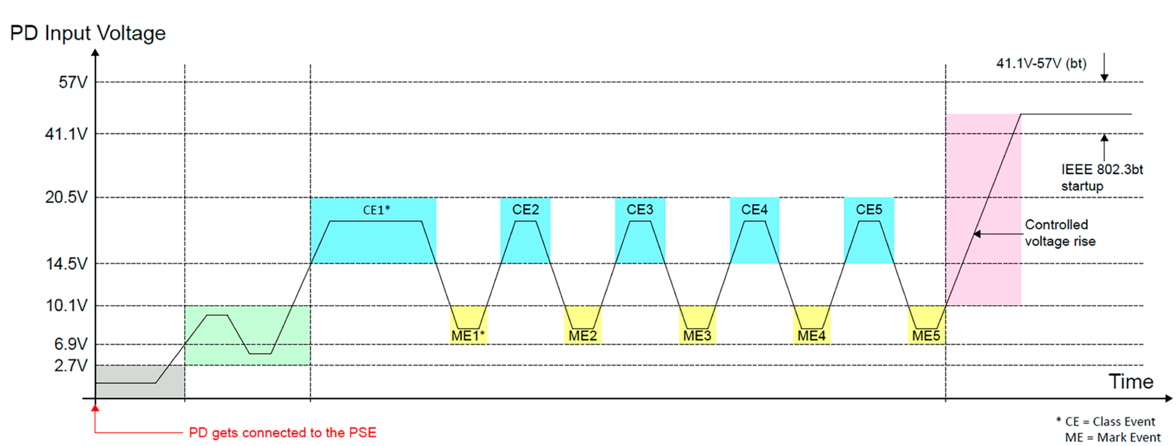


figure 6: power up - active

5.3 Passive PoE

Passive PoE is a non-standard PoE. It can also deliver power over Ethernet, but without the negotiation process. Passive PoE switch/injector does not conform to any IEEE standard. When using passive PoE switches or injectors, the power supply is "alwayson". This means that it always sends current with a certain voltage via the Ethernet cable, regardless of whether the PD supports PoE or not.

When connecting a non-PoE device to a passive PoE supply, the supply is short circuited due to the low resistance of the magnetics used in the non-PoE device.

For example, the NPS-30W detects this low resistance as a short circuit and stops delivering power. In most cases this avoids damage to the non-PoE device.

The PSE (NPS-30W) then tries cyclically to supply the device and remains in supply mode when the short circuit is removed (hick-up mode).

In any case, damage cannot be ruled out 100 %, as this short impulse can be sufficient to damage the device. It may be possible to destroy a device that is not PoE compatible by supplying it with passive PoE.

Typical Voltage Waveform at the Ethernet Port when PD is Powered by a passive, PoE injector

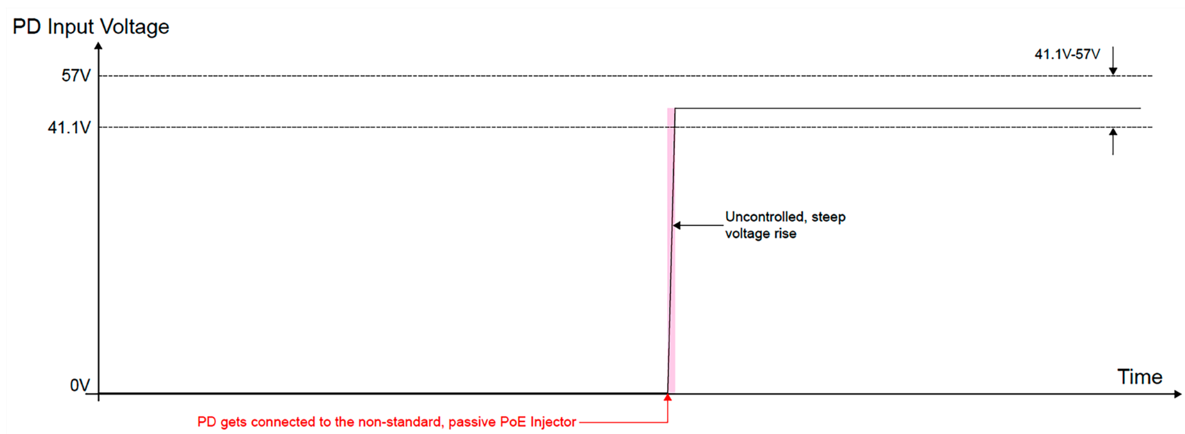


figure 7: power up - passive

Since the internal surge protection is designed for high-voltage, low-energy surge events, it cannot handle the massive amount of power delivered by the passive PoE injector, which can lead to a malfunction of the device.

5.4 Power disconnect

It may happen that a user swaps a connection from a powered to a non-powered device. When the connection is established to the nonpowered device, the 48 V power source could damage it. The 802.3af standard specifies the PSE to disconnect power to a device when it stops receiving a power signature from the PD. When the connection is terminated, power will be cut around 250 ms later.

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 discharge between the removed plug and socket on one or more of the contacts.

6. POWER DELIVERY METHOD

In addition to the four present power levels that are deliverable using PoE, there are numerous power delivery methods. However, only two power delivery methods have been standardized 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 figure 8 to figure 13.

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 10BASE-T and 100BASE-T Ethernet where only the orange and green pairs are used. However, this is not so for 1000BASE-T and 10GBASE-T where all four pairs are used for data transmission.

Figure 8 shows the endpoint PSE location of Alternative A for 10BASE-T/100BASE-TX using the data pairs and Figure 9 shows the endpoint PSE location of Alternative B for 10BASE-T/100BASE-TX using the unused (blue and brown) pairs.

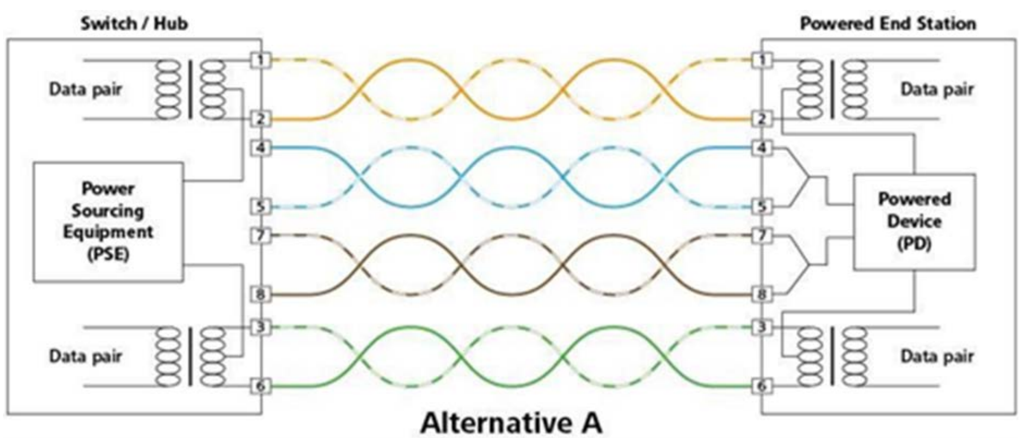


figure 8

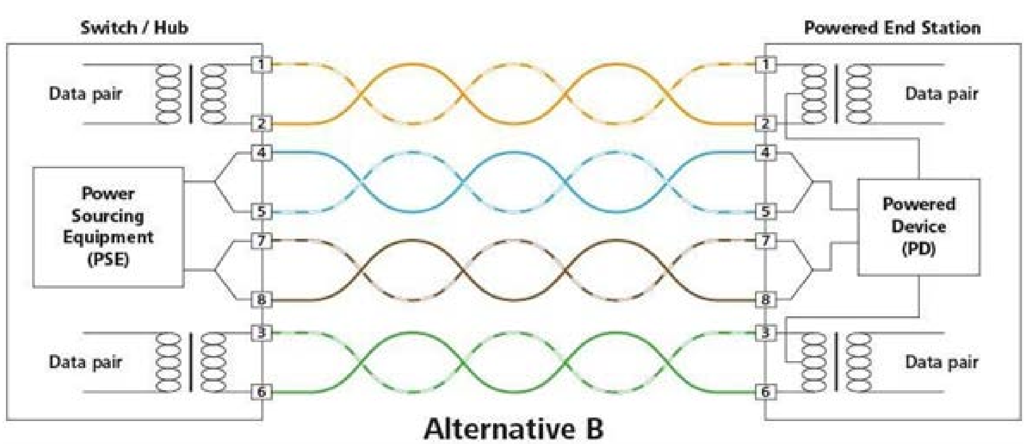


figure 9

For the four-pair signalling of 1000/2.5G/5G/10GBASE-T, the two alternatives simply determine which two pairs deliver the power. Figure 10 and Figure 11 show the endpoint PSE location of Alternative A and Alternative B respectively, with Figure 10 using the orange and green pairs, and Figure 11 using blue and brown.

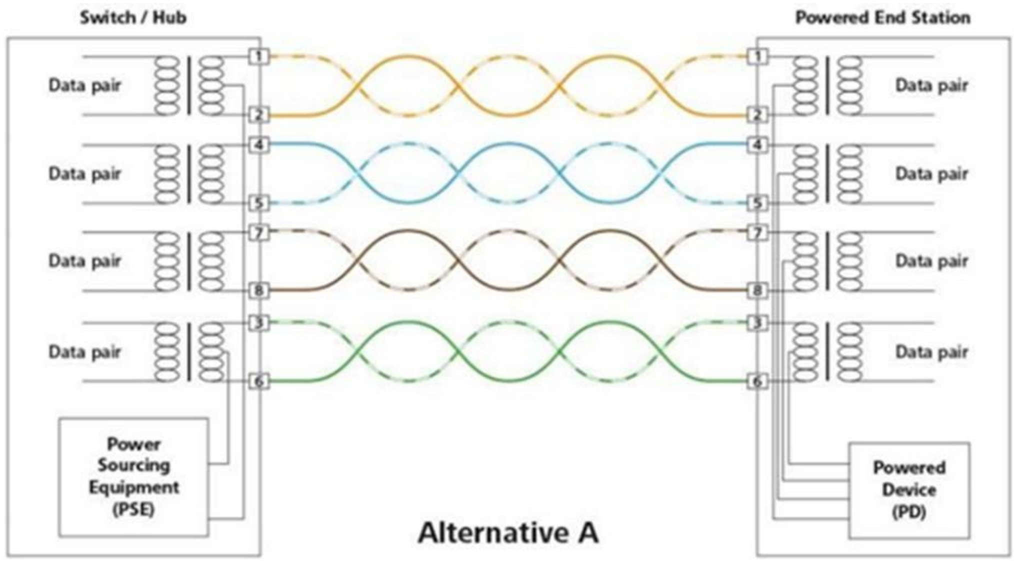


figure 10

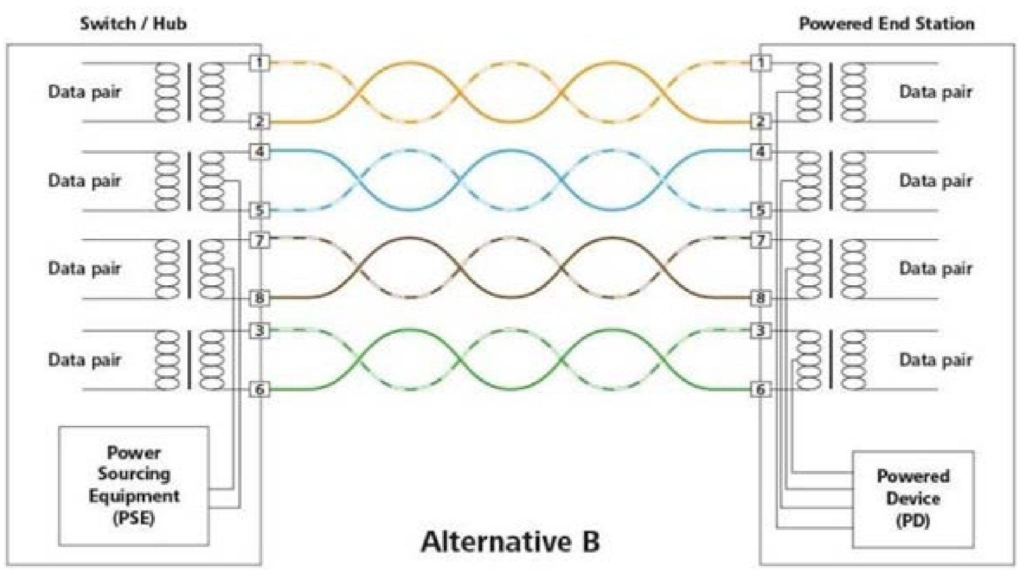


figure 11

PoE type 3 and type 4 allow all four pairs to carry a certain amount of current. Figure 12 and Figure 13 show the endpoint PSE locations for 4-pair PoE for 10BASE-T/ 100BASE-TX and 1G/2.5G/5G/10GBASE-T respectively.

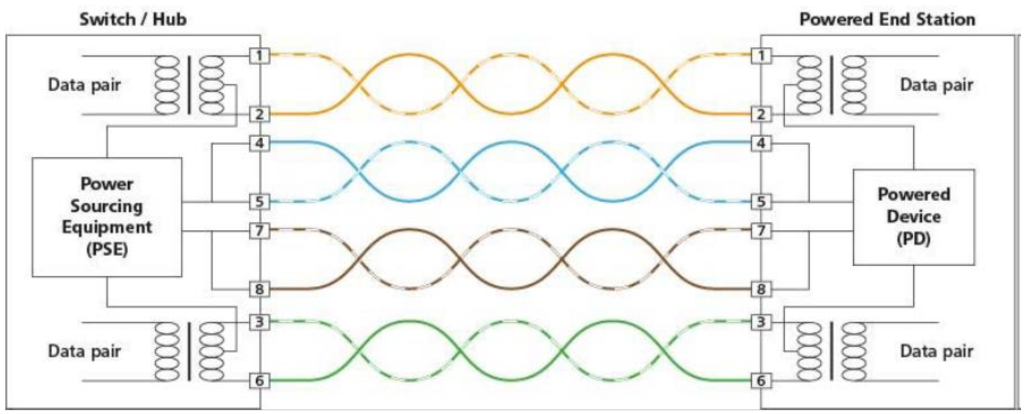


figure 12

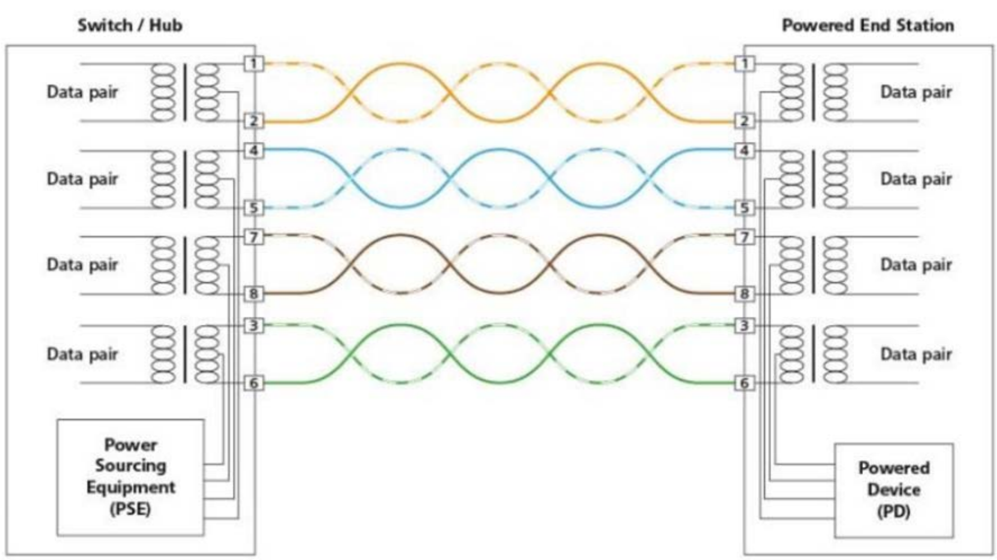
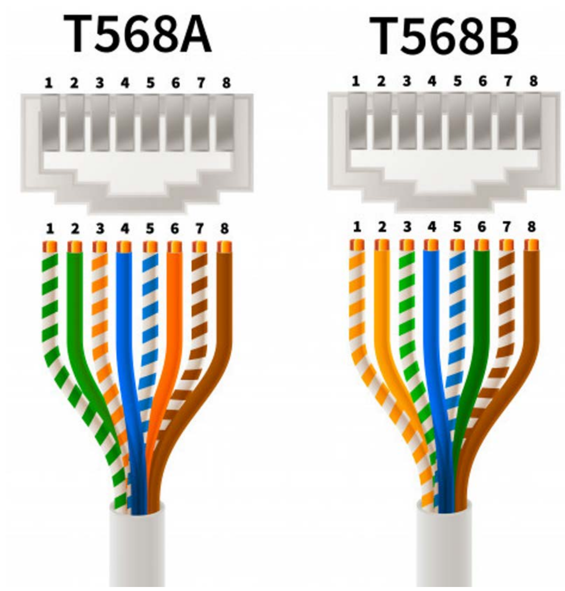


figure 13

7. IEEE STANDARD PIN ASSIGNMENTS



Pin at switch	TIA/EIA-568 T568B Termination	TIA/EIA-568 T568A Termination	10/100 Mode B DC on Spares		10/100 Mode A Mixed DC and Data		1000 (1 gigabit) Mode B DC and Bi-Data		1000 (1 gigabit) Mode A DC and Bi-Data	
1	White/Orange	White/Green	Rx+		Rx+	DC+	TxRx A+		TxRx A+	DC+
2	Orange	Green	Rx-		Rx-	DC+	TxRx A-		TxRx A-	DC+
3	White/Green	White/Orange	Tx+		Tx+	DC-	TxRx B+		TxRx B+	DC-
4	Blue	Blue		DC+	Not Used	Not Used	TxRx C+	DC+	TxRx C+	
5	White/Blue	White/Blue		DC+	Not Used	Not Used	TxRx C-	DC+	TxRx C-	
6	Green	Orange	Tx-		Tx-	DC-	TxRx B-		TxRx B-	DC-
7	White/Brown	White/Brown		DC-	Not Used	Not Used	TxRx D+	DC-	TxRx D+	
8	Brown	Brown		DC-	Not Used	Not Used	TxRx D-	DC-	TxRx D-	

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