# Power over Ethernet (PoE): Power Delivery through Network Cables

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## Introduction

Power over Ethernet (PoE) is a technology that supports powering of network devices through its network connection. PoE allows both data and electrical power to be transmitted over a single Ethernet cable, eliminating the need for separate power supplies and additional cable installation.

## PoE Standards

Several PoE standards have been developed over the years, each with different power delivery capacities. The most prevalent standard in public transport applications is IEEE 802.3af. Its power delivery capability is sufficient for powering a wide range of devices commonly found in public transport applications.

| | Type 3 (802.3bt) | | | | | | Type 4 (802.3bt) | |
|---|---|---|---|---|---|---|---|---|
| | Type 1 (802.3af) | | | Type 2 (802.3at) | | | | |
| **PSE** | Class 1 4 W | Class 2 7 W | Class 3 15.4 W | Class 4 30 W | Class 5 45 W | Class 6 60 W | Class 7 75 W | Class 8 90 W |
| | 2-pairs only (Class 0-4) | | | 2-pairs (Class 5-8) | | | | |
| **PD** | Class 1 3.84 W | Class 2 6.49 W | Class 3 13 W | Class 4 25.5 W | Class 5 40 W | Class 6 51 W | Class 7 62 W | Class 8 71.3 W |

IEEE 802.3af (PoE): This was the first standardized PoE implementation, providing up to 15.4 watts of DC power per port. Operating voltage is 44-51 Vdc.

IEEE 802.3at (PoE+): Also known as PoE Plus (PoE+), this standard offers increased power delivery, providing up to 30 watts of DC power per port. PoE+ is backward compatible with IEEE 802.3af. Operating voltage 50-57V

IEEE 802.3bt (4PPoE): The latest and most robust PoE standard, 802.3bt, introduces four different power classes, capable of delivering up to 90 watts of DC power.

| Type | Standard | PSE min. input power | PD Guaranteed min. power | Cable category | Max. cable lenght | Number of pairs |
|---|---|---|---|---|---|---|
| Type 1 | IEEE 802.3af | 15.4 W | 12.95 W | Cat. 5e | 100 m | 2 pairs |
| Type 2 | IEEE 802.3at | 30 W | 25.5 W | Cat. 5e | 100 m | 2 pairs |
| Type 3 | IEEE 802.3bt | 60 W | 51 W–60 W | Cat. 5e and above | 100 m | 2 pairs class 0–4<br>4 pairs class 0–4<br>4 pairs class 5–6 |
| Type 4 | IEEE 802.3bt | 90 W | 71 W–90 W | Cat. 5e and above | 100 m | 4 pairs class 7–8 |

**PoE Classes**

| Class | PSE Output Power[W] | PD Input Power[W] | PD Type | Standard |
|---|---|---|---|---|
| 0 | 15.4 | 12.95 | 1 | IEEE 802.3af |
| 1 | 4 | 3.84 | 1 | |
| 2 | 7 | 6.49 | 1 | |
| 3 | 15.4 | 12.95 | 1 | |
| 4 | 30 | 25.5 | 2 | IEEE 802.3at |
| 5 | 45 | 40 | 3 | IEEE 802.3bt |
| 6 | 60 | 51 | 3 | |
| 7 | 75 | 62 | 4 | |
| 8 | 90 | 73 | 4 | |

Power over Ethernet (PoE) classes are used to define the power requirements and capabilities of Powered Devices (PDs) in a PoE network. These classes help Power Sourcing Equipment (PSE) determine how much power to allocate to each connected PD. The PoE classes are defined within the IEEE 802.3af, IEEE 802.3at, and IEEE 802.3bt standards, and they specify the maximum power consumption a PD can draw from the PSE. The classes are denoted by a numerical value from 0 to 8.

**How PoE Works**

PoE operates by injecting DC power into the Ethernet data line. This process occurs in PoE capable Ethernet switches, which deliver power over standard Category 5 (CAT5) or higher Ethernet cables. Devices that can receive power through PoE are typically remote devices like video equipment, sensors, monitors, card readers, and edge devices.

The PoE defines two components as:

- Power Sourcing Equipment (PSE): The PSE is responsible for delivering power to the remote devices
- Powered Devices (PD): These are remote devices that receive power from the PSE

**PoE over Two Pairs**

Each pair consists of 2 twisted wires. Power is injected on the isolated side of the Ethernet transformer.
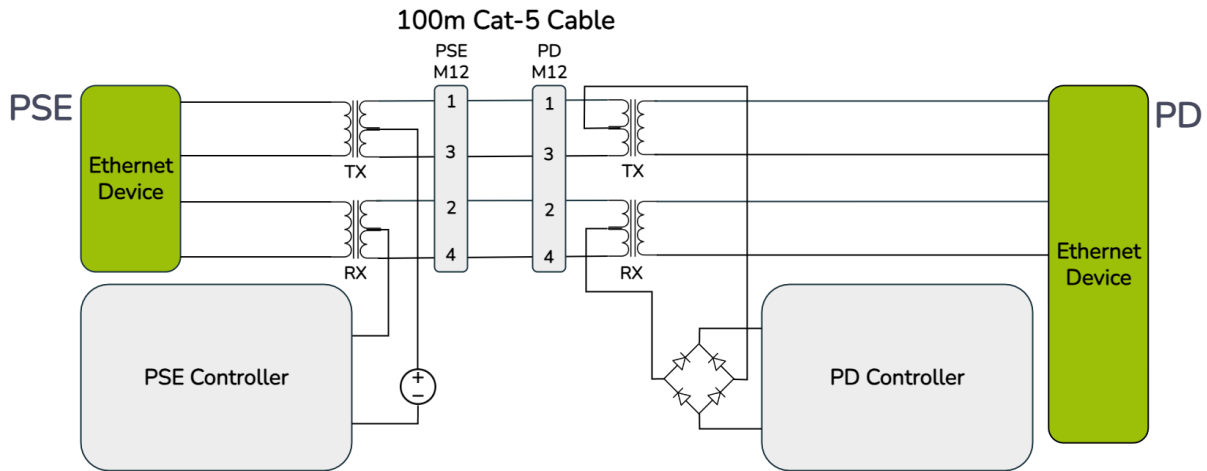


**PoE Detection and Classification**

PoE standard defines exactly the power up process. The procedure ensures that only valid PoE devices are powered. The process starts with detection, then classification and if both are valid, then PSE will apply power to the cable.

Detection: PSE periodically probes the connection for a detection of a PD. During detection PSE applies low voltage and low current to cable and measures dV/dI. Valid detection is given if PSE measures a value of typically 25 kOhms.

Classification: PSE sends a voltage signal in a range of 14.5V to 20.5V to detected PD. Valid PD then will draw pre-defined, class specific current. PSE measures the current drawn on cable and determines through this value the class of PD. Then PSE turns on the power on the port.
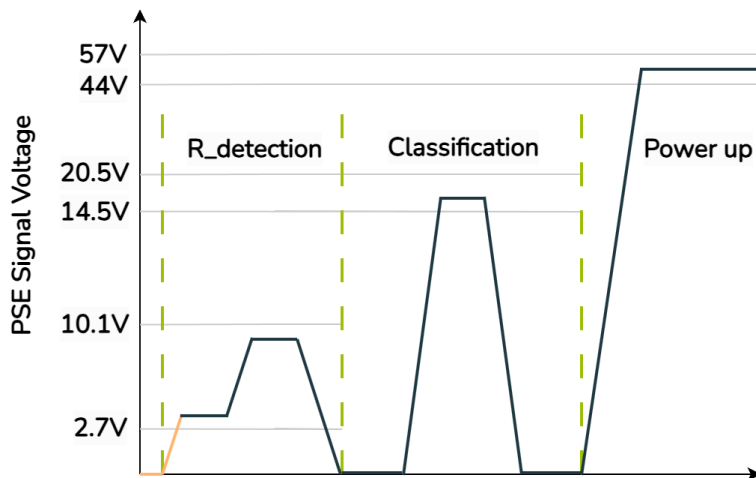


| Class Level | Class Range Current (mA) |
|---|---|
| 0 | 0–4 |
| 1 | 9–12 |
| 2 | 17–20 |
| 3 | 26–30 |
| 4 | 36–44 |

**PoE Operation**

After PSE turned on the power on the port, the inrush current phase occurs before normal operation. During this phase, the capacitors of PD will be charged to the PoE voltage. The PoE standard allows a gentle overcurrent for a short period of time (50ms - 75ms). If the PD draws more current beyond this time, the PSE will turn off the power on the port to protect the internal circuit.

After the inrush current phase, both PSE and PD operate normally. During normal operation, the PSE continuously monitors the current drawn by the PD. Depending on the PD Class, the PSE will set up a current limit for the port to provide protection against fault conditions. The PoE standard defines two limiting mechanisms for overcurrent conditions: ICUT and ILIM. If the rising current on a port reaches ICUT and persists for TCUT time, the PSE may shut down the port. If the port current reaches ILIM, the PSE will immediately shut down the port. After a cooldown period, the PSE will restart the detection procedure again.

**Benefits of PoE**

Simplified Deployment: PoE eliminates the need for separate power supplies for networked devices, reducing clutter and simplifying installation. This streamlined approach saves time and effort during network deployment.

Flexibility and Mobility: PoE-enabled devices are not tied to power outlets, granting greater flexibility in device placement. This mobility is especially beneficial for devices like access points and cameras, allowing for optimal positioning without concerns about proximity to power sources.

Centralized Power Management: PoE networks allow for centralized power management and control. PSEs can monitor power usage and manage power allocation to different devices, optimizing power consumption and troubleshooting potential issues remotely.