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Understanding the IEEE 802.3bt PoE Standard

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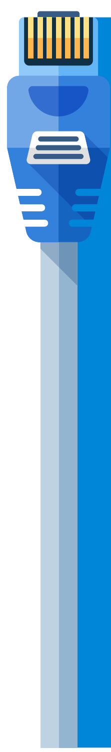
Introduction

With the introduction of the IEEE 802.3bt Power over Ethernet (PoE) standard, Ethernet cables can now carry up to 90 W of power, enabling a broad range of new applications. Yet, despite being in the market for over a decade, PoE technology can still be very confusing and misunderstood. The latest standard adds additional features beyond just increased power delivery, and it is also more complex than previous standards. In this white paper we will go over the basics of how PoE works, and then look the key features in the new 802.3bt standard.



- Power over Ethernet provides both data and power over a single Ethernet cable.
- The latest IEEE PoE standard, 802.3bt, provides up to 90 W of power onto an Ethernet cable while maintaining backwards compatibility with older IEEE PoE standards.

Sending Power Down a Standard Cat 5e Ethernet Cable

As the name implies, PoE injects power onto a cable designed for data without disrupting the high-speed traffic the cable is carrying. The Ethernet standard and the Ethernet cable design make this a reasonably straightforward endeavor, and PoE uses standard Ethernet cables. As shown in Figure 1, inside the Ethernet cable itself are four twisted pairs of wires. Ethernet is an isolated network, so each twisted pair connects to a data transformer. PoE simply injects a DC voltage (~54 V) onto the twisted pairs of the Ethernet cable through center taps on the data transformers. Because the wires are small, a higher voltage is chosen to reduce the current flowing through the wires. In a two-pair power configuration (802.3af, 802.3at), one twisted pair is positive, and the other is negative. In a four-pair power configuration (802.3bt), two twisted pairs are positive, and two are negative. The power sourcing equipment (PSE) puts power onto the cable, and the powered device (PD) takes power off the cable. In addition, the IEEE PoE standards allow the PSE to power the twisted pairs in any polarity, so the PD must have input bridges (diodes or actively controlled FETs) to set the polarity of the incoming voltage.

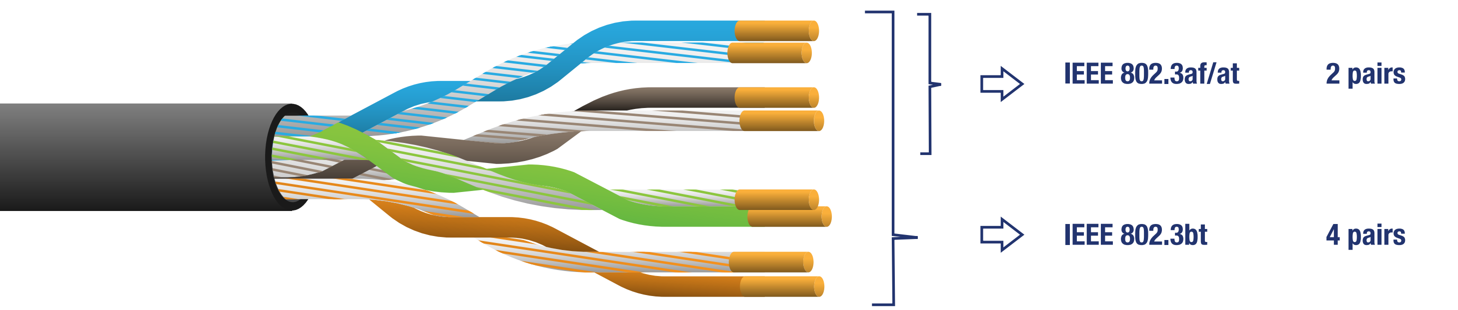


Figure 1: Ethernet cabling contains four twisted pairs of wires. IEEE 802.3af/at powers two of the four twisted pairs, and IEEE 802.3bt powers all four twisted pairs for 30 W and above.

The Detection Phase

If power is applied to a non-PoE device it may be damaged. Therefore, the first step in the PoE protocol is a detection phase in which the PSE determines if a PD is connected. There are many different algorithms PSEs use to detect a valid PD. Regardless of what method is used, the PD must present a 25k Ω resistance when a voltage between 2.7 and 10.1 V is applied, as shown in Figure 2. Silicon Labs' latest 802.3bt PSEs, the Si3471 and Si3474, use a robust multi-point detection algorithm to reliably detect a connected PD.

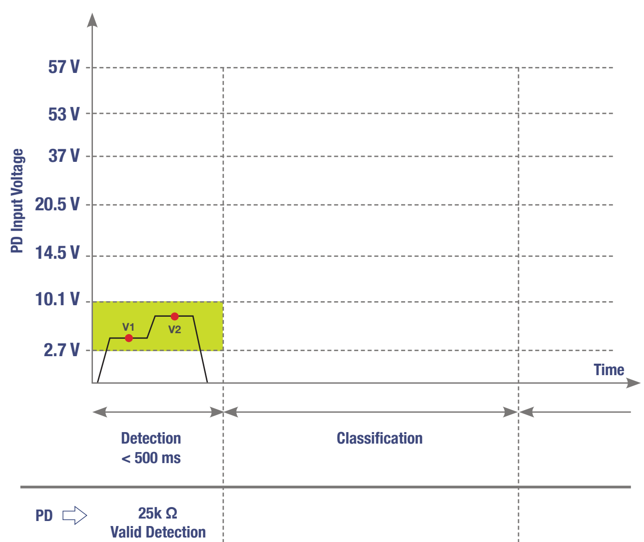


Figure 2: The PSE injects between 2.7 V and 10.1 V onto the Ethernet cable and looks for a resistance of 25k Ω, indicating a PD is connected.

The Classification Phase

With a valid PD detected, the PSE begins the classification phase. During classification, the PSE and PD do an analog handshake in which the PD requests a power “class”, and the PSE responds with the class the PD is granted. Type defines the kind of analog handshake from the PSE to the PD. Class refers to the minimum power the PSE guarantees the PD will receive, and the maximum power the PD is allowed to draw from the cable. Just like standard Ethernet, the cable can be up to 100 meters in length, so a fair amount of power is lost in the cable. See Table 1 for the various PoE types and classes.

	Type 1 802.3af			Type 2 802.3at	Type 3 802.3bt		Type 4 802.3bt	
Power Class	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
Power from PSE	4 W	7 W	15.4 W	30 W	45 W	60 W	75 W	90 W
Power delivered to PD	3.84 W	6.49 W	13 W	25.5 W	40 W	51 W	62 W	71.3 W

Table 1: The IEEE PoE standards, the minimum power from the PSE, and maximum power delivered to the PD.

The simplest classification handshake is type 1, which is shown in Figure 3. The PSE puts 15.5-20.5 V onto the cable and measures the PD’s current draw. Due to cable loss, the PD will see 14.5-20.5 V from the PSE during classification. Based on the PD’s current draw, the PSE determines the PD’s requested class. If the PSE has sufficient power, it proceeds to power the PD. If it does not have enough power available, a type 1 PSE simply does not power the PD. The current drawn by the PD during classification is called the classification signature or classification current. As shown on Table 2, the IEEE PoE specification defines five classifications signatures the PD is allowed to draw during classification.

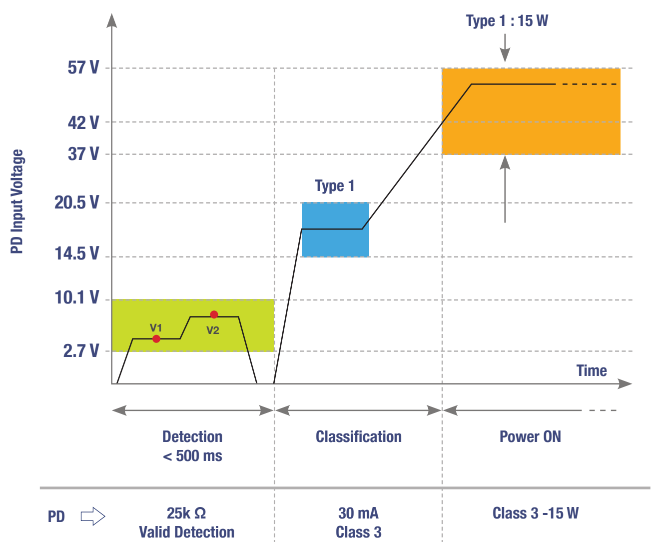


Figure 3: The voltage waveforms from the PD’s perspective during type 1 detection, classification, and power on.

Type 2 classification builds upon type 1 by adding a second pulse to the classification phase, as shown in Figure 4. During classification, a type 2 PD draws 40 mA (classification signature 4) to signal to the PSE it is requesting class 4 power and is a type 2 PD. A type 1 PSE sees this as a request for class 3 power and proceeds to power the PD. A type 2 PSE detects the higher current and then lowers the classification voltage to a “mark” voltage to create a pulse. Next it repeats this procedure to create a second classification pulse and powers the PD. The two classification pulses signal to the PD class 4 power has been granted by the PSE.

A PD requesting class 4 power might not get it from the PSE. It might receive less than it asked for, and the PD design will need to operate with only class 3 power. This process is called power demotion. Silicon Labs Si34061 type 2 PD includes a dedicated pin (nT2P) to signal to the PD system that type 2 power was granted by the PSE.

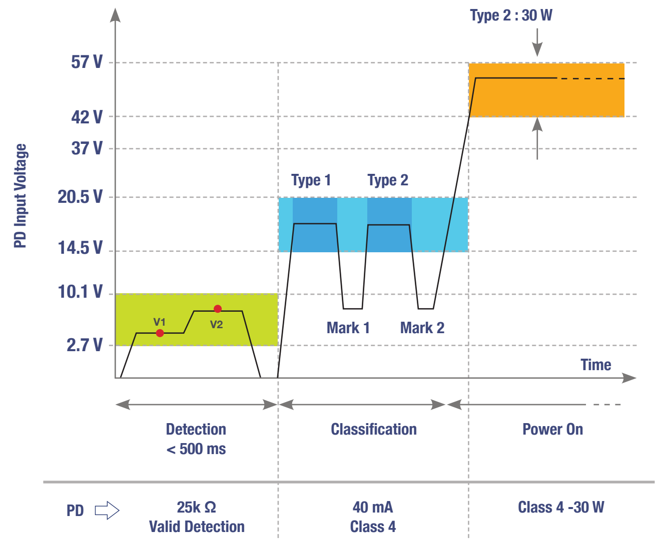


Figure 4: The voltage waveforms from the PD’s perspective during type 2 detection, classification, and power on.

The 802.3bt classification process builds upon type 1 and 2 and is shown in Figure 5. A type 3 PSE presents 4 classification pulses, and a type 4 PSE produces five pulses. When a PD requests type 3 or 4 power, it draws 40 mA (classification signature 4 current) for the first two pulses, and then lowers its current draw to the classification signature 3, 2, 1 or 0 level for the subsequent pulses. Table 2 shows the class signature current values. The lower current draw on the third pulse tells the PSE how much power the PD is requesting. The fourth and fifth pulses indicate to the PD how much power the PSE is granting. Four classification pulses from the PSE indicate type 3 power, and five classification pulses signal type 4 power has been granted to the PD. For example, if the PD requests class 7 or 8 power and the PSE indicates type 4, then the PD gets the power it requested. Likewise, if the PD requests class 5 or 6 and the PSE indicates type 3, then the PD receives the power it requested.

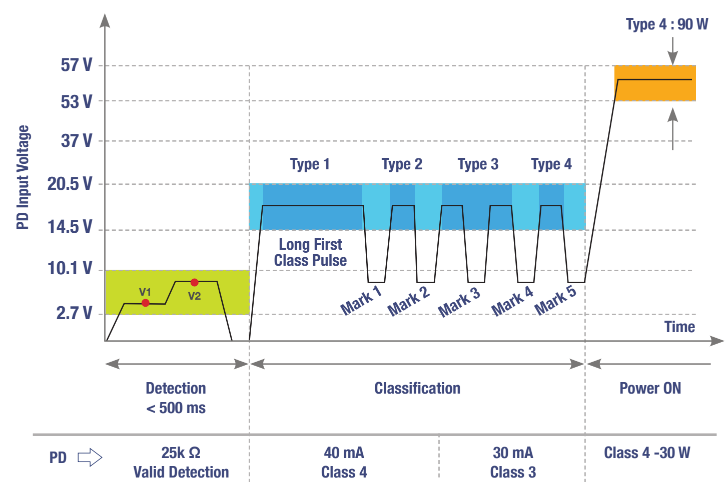


Figure 5: The voltage waveforms from the PD’s perspective during type 4 detection, classification, and power on.

Classification Signature	Current Drawn by PD	Current Draw Seen by the PSE
Class signature 0	1 to 4 mA	0 to 5 mA
Class signature 1	9 to 12 mA	8 to 13 mA
Class signature 2	17 to 20 mA	16 to 21 mA
Class signature 3	26 to 30 mA	25 to 31 mA
Class signature 4	36 to 44 mA	35 to 45 mA

Table 2: Classification Signature Current Values

The Power On Stage

Power on is the final stage of the PSE providing power to a PD. The IEEE PoE specification calls out the inrush current a PD may draw during power up. Silicon Labs' PD products, such as the Si3404, Si34061, and Si34071 all include built-in inrush current limiting.

Power Demotion and Why it Matters

Many PoE-enabled Ethernet switches are not designed to provide full power on each PoE Ethernet port to reduce cost. The PoE standard allows for power demotion, where the PSE still powers a PD but with less power than the PD requested. During power demotion, the PSE assigns the PD a lower type than the PD requested. Due to the classification handshake, PSEs can only grant type to a PD. A PD that is demoted to a lower type is automatically assigned the highest power class within that type. The following two examples illustrate how power demotion works.

Example 1: A PD requests class 8 power, and the PSE has class 6 power available. In this situation, the PSE demotes the PD to type 3, and the PD receives class 6 power.

	Type 1 802.3af			Type 2 802.3at	Type 3 802.3bt		Type 4 802.3bt	
Power Class	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
Power from PSE	4 W	7 W	15.4 W	30 W	45 W	60 W	75 W	90 W
Power delivered to PD	3.84 W	6.49 W	13 W	25.5 W	40 W	51 W	62 W	71.3 W

Example 1: A PSE with class 6 power available demotes a PD requesting class 8 to type 3, and the PD receives class 6 power.

Example 2: A PD requests class 8 power, and the PSE only has class 5 power available. The PSE can only demote the PD by type, so the PD cannot be granted class 5 power. If the PSE granted the PD type 3 power, the PD would be granted class 6 power. Instead, the PSE must grant the PD type 2 power.

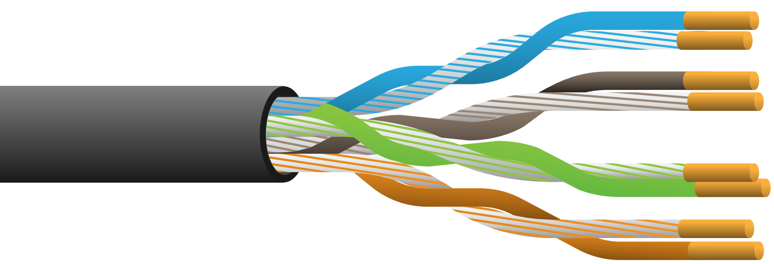
	Type 1 802.3af			Type 2 802.3at	Type 3 802.3bt		Type 4 802.3bt	
Power Class	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
Power from PSE	4 W	7 W	15.4 W	30 W	45 W	60 W	75 W	90 W
Power delivered to PD	3.84 W	6.49 W	13 W	25.5 W	40 W	51 W	62 W	71.3 W

Example 2: A PSE with class 5 power available demotes a PD requesting class 8 to type 2, resulting in the PD receiving class 4 power.

To ensure operation when connected to any PSE, the PD system must be able to operate at the various power levels the PSE may grant. Without this capability, the PD will draw too much power, and the PSE will shut it down. The vast majority of type 2, 3, and 4 PD devices on the market include some method for communicating the received type back to the main PD system controller. For example, Silicon Labs Si34071 PD includes a UART port to enable the PD system controller to easily read back the power class granted by the PSE.

Low Power and PoE: Maintain Power Signature

The 802.3at PoE standard includes a feature called Maintain Power Signature (MPS). As per the IEEE standard, if a PD draws less than 10 mA of current, the PSE may disconnect the PD. The MPS feature allows the PD to maintain the connection to the PSE by drawing short bursts of current. This enables the PD system to enter a low power state in which the PSE would otherwise disconnect it. 802.3bt introduces a shorter MPS pulse width to enable PDs to enter an even lower power state. The long first class pulse from the type 3 or 4 PSE signals to the connected PD that the PSE supports short MPS. Just like with inrush, Silicon Labs Si34071 802.3bt PD automatically switches to short MPS when connected to a PSE that supports the feature.



Autoclass and LLDP

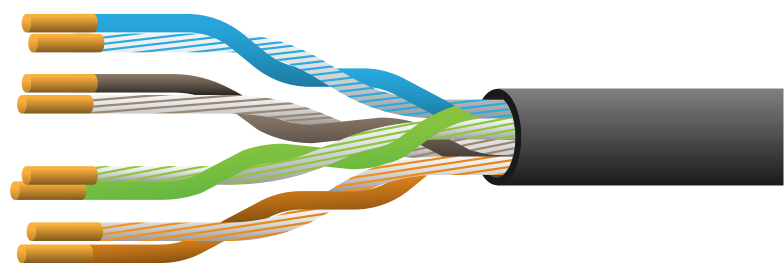
In addition to short MPS, 802.3bt introduces another new feature called autoclass. Autoclass allows a PD to draw the maximum power it will ever consume shortly after power up. The PSE measures the actual power the PD will consume and adjusts power allocation accordingly. For example, a PD may request class 8 (90 W) of power, but only draw 80 W in the actual application. By using autoclass, the PSE measures the actual PD power consumption and has 10 W of additional power to provide to other PDs in the system.

Although introduced in previous PoE standards, link layer discovery protocol (LLDP) is even more useful when using the higher power 802.3bt standard. For many years, Ethernet networks have used LLDP to enable switches and routers to discover various system details through communicating over the data layer with special LLDP packets. PoE adds an extension to LLDP for the PSE and PD to also communicate information via LLDP packets. One key LLDP feature is the ability of the PSE and PD to re-negotiate power in one-tenth of a watt increments, possibly freeing up power for the PSE or granting the PD slightly more power.

Managing Maximum System Power

In a typical multiport PoE PSE implementation like switches, not all PDs will require maximum power, allowing the use of a smaller and lower cost power supply. When the PDs are requesting more power than is available, the host controller can use the PSE's typical I2C registers to manage power priorities. If the system power supply is adequate to provide maximum power to all ports, then the PSE can be used in an autonomous mode. The Si3474 802.3bt PSE has a complete I2C register map for power management and an autonomous mode to support either use case.

Applications like injectors/midspans that typically power only one PoE port can be easily setup for complete autonomous operation without any host interface. The 5 x 7 mm Si3471 single port 802.3bt PSE device uses 3 I/O pins to indicate the maximum power of the system power supply. Upon boot, these pins configure the Si3471 to automatically handle all PD requested classes up to the maximum power available. This use case does not require isolators for host I2C control, saving system space and BOM cost.



Power the Future

The 802.3bt standard brings unprecedented levels of power to PoE systems. In addition, many new features bring more flexibility to PoE connected systems. Many systems need to be connected and powered reliably. PoE offers the ability to do both with a single cable. With the expanded power of 802.3bt, even more systems can take advantage of the ease of use and simplification enabled through PoE.

Charlie Ice is a Senior Product Manager at Silicon Labs focusing on the company's Power over Ethernet (PoE) product line. Charlie joined Silicon Labs in 2018 with more than 10 years managing products in the technology industry. His experience includes microcontrollers, digital motor control, digital power supply control, and test and measurement equipment. Prior to joining Silicon Labs, Charlie managed the hardware resell program at National Instruments after marketing digital motor control MCUs at Texas Instruments and Microchip Technology. Charlie holds a Master and Bachelor of Science in Electrical Engineering, both from Rice University in Houston, Texas.

Kevin Kilbane serves as a Senior Product Manager for Silicon Labs' isolation and access products. Kevin joined Silicon Labs in 2010 and holds two patents. Prior to joining Silicon Labs, Kevin was the audio Marketing Director at IDT and MCU Strategic Marketing and Systems Manager at Freescale. Kevin holds a Bachelor of Science in Electrical Engineering from Cornell University.

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