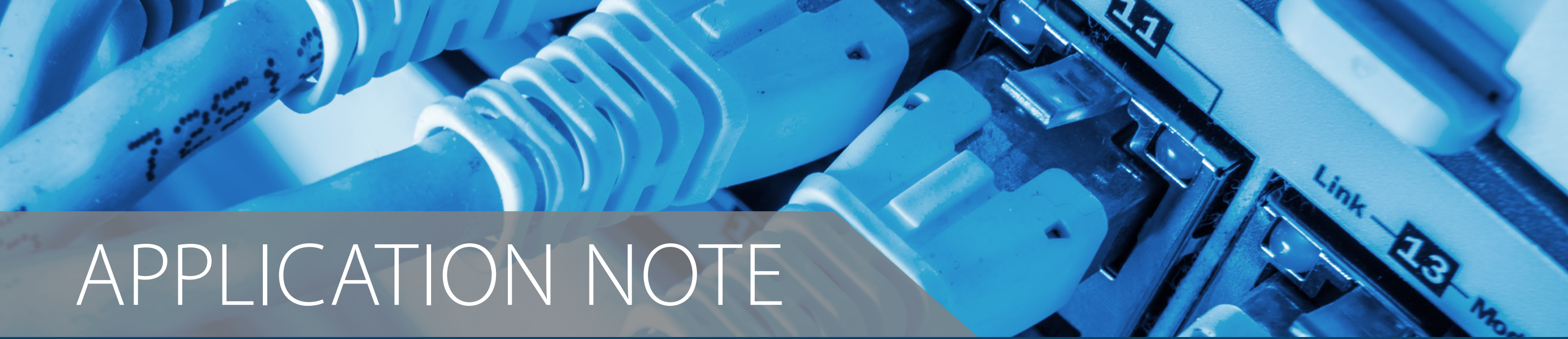

APPLICATION NOTE

How to Apply AC Rectifiers when Designing PoE PD Devices

CD-HD01

CD-HD201

BACKGROUND

Before Power-over-Ethernet (PoE) became a standard, Ethernet system installers developed a variety of ways to send power through an Ethernet cable along with the digital Ethernet signal to power various remotely connected Ethernet devices, such as cameras, smart locks, etc. Since an Ethernet cable needs to be routed to the device anyway, installation becomes much simpler if it can also supply power. Then, a separate power cable would not also be required.

Two Ethernet system installation solutions have appeared in the field, Mode A and Mode B, as shown in Figure 1.

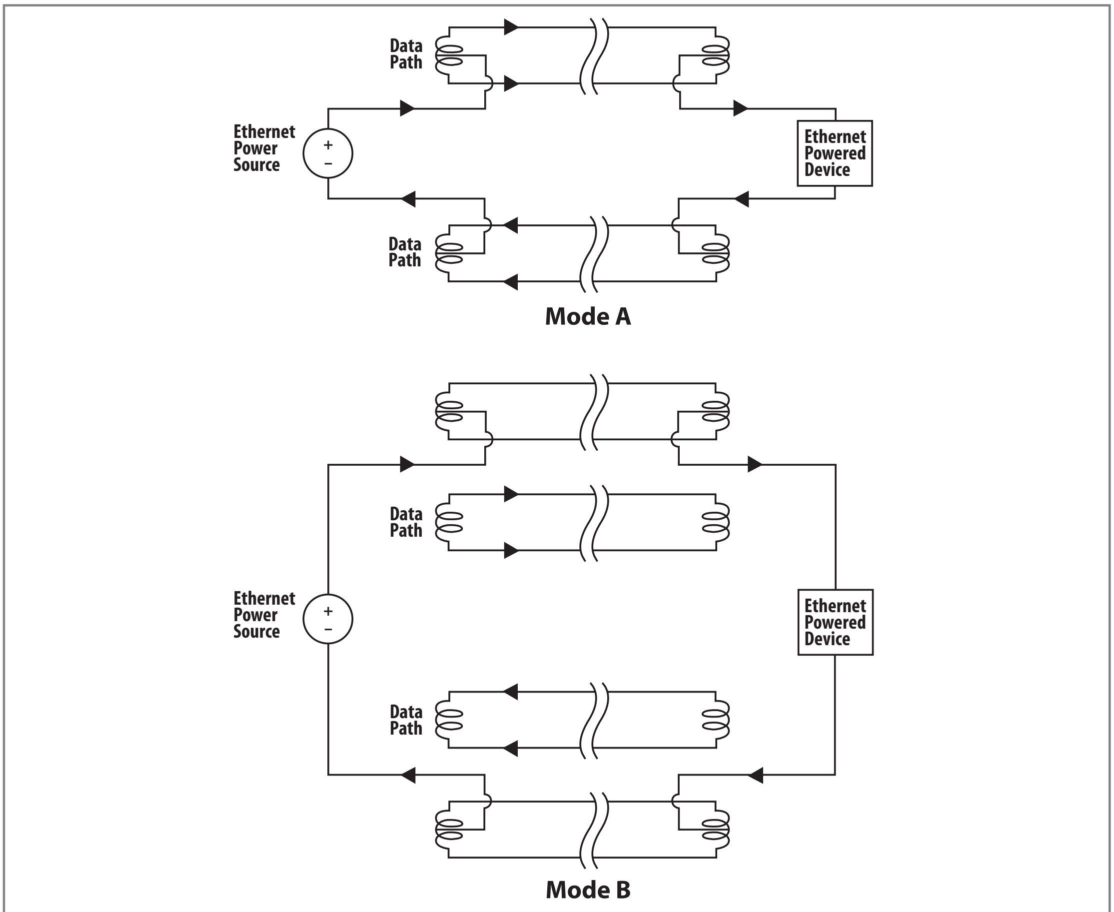

Figure 1 - Mode A and Mode B

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BACKGROUND (CONTINUED)

The advantage of Mode A is that it uses only two differential pairs. The advantage of Mode B is that the Ethernet signal is isolated from the power supply. Power supply disruptions and glitches will not affect the Ethernet signal.

There is another key issue. Since there were no standards at the time, various polarities of the power supply voltage were used. Also, crossover cables were present in the field, which further complicates knowing what appears on which lines. Therefore, to operate correctly in legacy PoE systems, an Ethernet Powered Device (PD) must allow for both Mode A and Mode B connections as well as positive and negative supply polarity.

A common way to handle these issues is to use two bridge rectifier diodes, one for Mode A and one for Mode B, as shown in Figure 2. The diode bridges allow either supply polarity to be accepted for either Mode.

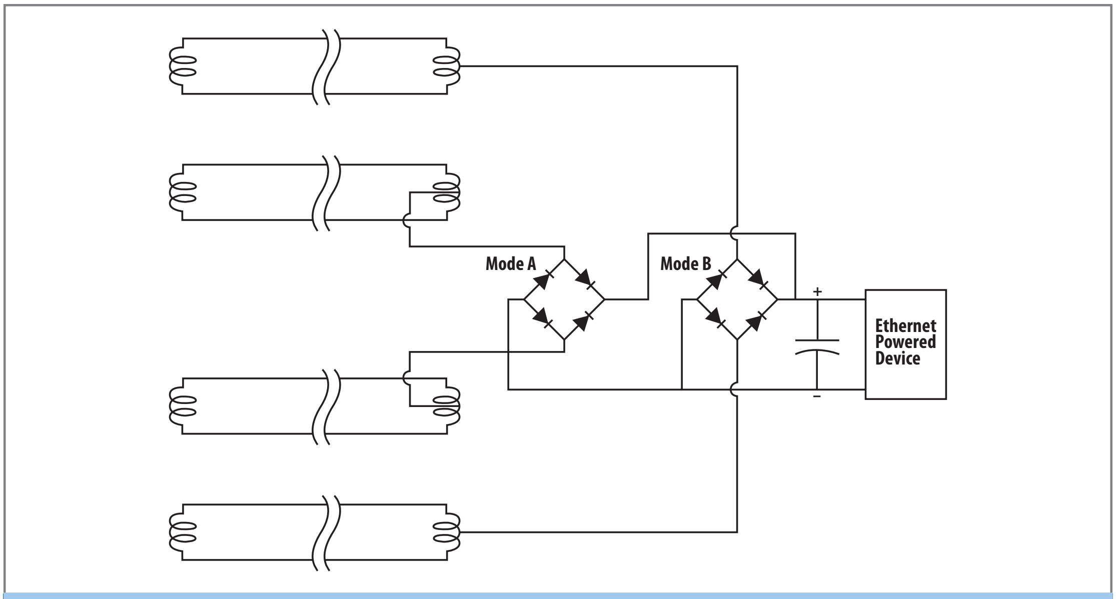

Figure 2 - Typical PD PoE Implementation

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MAIN ISSUE WITH USE OF BRIDGE RECTIFIERS

PoE is a DC source. When the PD is plugged in, the PoE system negotiates the connection by varying the DC level. Once completed, the DC level is constant.

Bridge rectifiers, on the other hand, are typically characterized for AC rectification, which raises questions. How do their data sheet parameters relate to operation in a DC system such as PoE? How should the proper rectifier diodes be chosen for PoE operation?

The latest IEEE 802.3bt standard defines new high-power Type 4 devices that provide up to 90 W of power using all four pairs of wires with a predefined voltage polarity. Since the voltage ambiguity has been removed, diode bridges are not required for Type 4 PDs. The discussion in this paper is only relevant for PD Types 1 through 3.

AC RECTIFIERS

Since efficiency is important in PoE systems, the voltage drop across the rectifier diodes must be small. This requires the use of Schottky bridge rectifiers. PoE systems run at 57 VDC (max.) so a bridge rated at 100 V will provide plenty of margin. A good example is the Bourns® Model CD-HD01 surface mount Schottky Bridge Rectifier Diode, available in a very small 4.75 mm x 6.15 mm package with a 100 V breakdown rating. The maximum ratings from the product data sheet are shown in Table 1.

Parameter	Symbol	CD-HD01	Unit
Maximum Repetitive Peak Reverse Voltage	V_{RRM}	100	V
Maximum Average Forward Rectified Current (T_A = 55 ºC)	$I_{F(AV)}$	1.0	A
Peak Forward Surge Current 8.3 ms Single Half Sine-Wave Superimposed on Rated Load (JEDEC Method)	I_{FSM}	30.0	A
Operating Temperature Range	T_J	-55 to +125	ºC
Storage Temperature Range	T_{STG}	-55 to +125	ºC

Table 1 - Example of Bridge Rectifier Data Sheet Maximum Ratings

But how much PoE current can this bridge rectifier diode support? What is the Maximum Average Forward Rectified Current rating and how is it measured?

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HOW AC RECTIFICATION WORKS

To properly interpret data sheet parameters, it is useful to first examine the application for which these devices were designed. A typical AC rectifier circuit for a 1 A load is shown in Figure 3 along with the voltage waveform seen at the DC output and diode currents. The diodes charge the load capacitor during each half-cycle. The resistive load draws current from the capacitor, reducing the output voltage. At the next half-cycle, the capacitor is charged up again. Thus, the output voltage is a DC level with a ripple voltage superimposed on it.

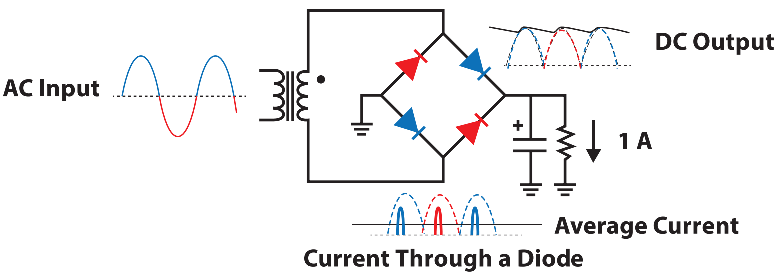

Figure 3 - AC Rectification

The average current through the diodes is what is required to replenish the average current drawn by the load. Since this is a full-wave rectifier, only one pair of diodes conducts during each half-cycle. These are designated as blue and red diodes in Figure 3. The blue diodes conduct during the positive cycles and the red diodes conduct during the negative cycles.

During the positive blue cycle, the red diodes are off and the blue diode pair must supply the current. If the load is drawing 1 A then the blue pair must supply an average current of 1 A. During the next half-cycle, the blue diodes are off and the red diodes must supply 1 A on average. Since each diode is on only half of the time, the long-term average of the current through each diode is only 0.5 A. The bridge, on the other hand, includes all the diodes and supplies the entire 1 A load current all of the time. A 1 A bridge is required to support the 1 A load current in this example.

However, as shown in Figure 3, the diode current is extremely pulse-like as it charges the capacitor back to its peak voltage level. The peak current is very much larger than its average current. It is wise to select a bridge with an average current larger than what is required by the load. The website http://www.skillbank.co.uk/psu/trfrec.htm has some examples and gives an easy-to-follow step-by-step guide on choosing components. The site suggests using a bridge diode rated at two times the load current.

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HOW AC RECTIFICATION WORKS (CONTINUED)

In addition, during turn-on, the capacitor is completely discharged. The diodes must tolerate the resulting huge inrush current. The data sheet example shown in Table 1 lists Peak Forward Surge Current 8.3 ms Single Half Sine-Wave (I_{fsm}) as 30 A. A half cycle of 60 Hz is 8.3 ms so this specification can be used to gauge the inrush current capability of the bridge in an AC power rectifier application. It can supply up to 30 A in a single half-cycle.

Diode current ratings can be shown in either thermal or maximum current limits. As seen in Table 1, the current for this 1 A bridge can be as high as 30 A. This is the maximum current the device can tolerate. The 1 A rating is limited by long-term thermal effects and applies when using averaging in the above discussions.

PoE SUPPLY FOR PD

Receiving power from PoE is very different than receiving power from AC. There is no sinewave. There is no AC to DC rectification. Once the PoE connection has been negotiated, the supply voltage is constant. The current is DC (assuming the load is fixed). This situation is much simpler than the rectified AC case. The Maximum Average Forward Rectified Current is just the expected DC load current. However, in this case only one of the diode pairs is on and always supplies the entire load on its own. The other half of the bridge is always off (because PoE power never changes polarity). Using the example above, the ON diodes are delivering 1 A on average, vs 0.5 A in the AC rectification case. However, since the load current is still 1 A, the entire diode bridge still supplies the same current as before and must be rated to 1 A. The bridge rating has not changed, but the individual diodes must support a higher average current.

Furthermore, since PoE voltage is fixed, diode current is not pulse-like. It constantly supplies the current to the load. The bridge is there to keep voltage polarity consistent regardless of the system into which the PD is plugged. The bridge diodes switch on start-up and remain on (or off) for the remainder of the time the PD is powered. The capacitor will remain charged and mainly acts as a PoE filter.

PoE provides its own soft-start sequence so the PD diodes don't have to be overly concerned with inrush current. Still, there is a large capacitive load, so it is wise to provide for a substantial margin to allow for a more robust design.

CD-HD01

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PoE SUPPLY FOR PD (CONTINUED)

The various PoE classes are listed in Table 2. Examples of bridge diodes for the maximum PoE current are also shown, but bridges with higher current ratings will provide more margin and will tolerate more severe fault and surge conditions. If a particular PD load is less than the maximum PoE current, then bridges with smaller ratings may be suitable.

Type	Power Class	Max. Available PoE Power	Min. Available PoE Power	Max. PoE Current per Pair	Min. Bridge Average Current	Bourns® Suggested Model
1	0	15.4 W	13 W	350 mA	1 A	CD-HD01
1	1	4 W	3.8 W	90 mA	1 A	CD-HD01
1	2	7 W	6.5 W	160 mA	1 A	CD-HD01
1	3	15.4 W	13 W	350 mA	1 A	CD-HD01
2	4	30 W	25.5 W	600 mA*	2 A	CD-HD201
3	5	45 W	40 W	450 mA**	2 A	CD-HD201
3	6	60 W	51 W	600 mA**	2 A	CD-HD201

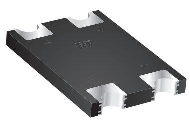
Table 2 - Suggested Bridges for Various PoE Types and Classes

** Only one bridge is needed since Type 2 devices only implement Mode A.*
*** Two bridges are required since Type 3 devices use all 4 pairs. Each bridge handles ½ the current.*

APPLICATION NOTE

How to Apply AC Rectifiers when Designing PoE PD Devices

CD-HD01



CD-HD201

SUMMARY

Bridge diodes in PoE PD designs allow for compatibility with legacy Ethernet installations. It is important to note that bridge diodes are characterized for AC rectification applications, not PoE. A discussion on AC rectification and PoE resulted in the following differences in the diode requirements:

Application	Bridge Average Current (min.)	Diode Average Current (min.)	Diode Repetitive Peak Current	Inrush Current
AC Rectification	I_{load}	1/2 I_{load}	Very High	High
PoE	I_{load}	I_{load}	I_{load}	Low

Table 2 - Suggested Bridges for Various PoE Types and Classes

A summary of the power and current requirements for the various PoE device types and classes was shown, allowing a starting point for choosing appropriate bridge diodes.

FOR ADDITIONAL INFORMATION, PLEASE SEE:

Ethernet Standards: https://standards.ieee.org/standard/802_3-2018.html

Ethernet Transformers: https://www.bourns.com/products/magnetic-products/transformers-signal

Bridge Rectifiers: https://www.bourns.com/products/diodes/rectifier-diodes

Ethernet PortNote® Solutions: https://www.bourns.com/resources/technical-library/portnote-solutions

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