AN 17.18

# SMSC Design Guide for Power Over Ethernet Applications

## 1 Introduction

### 1.1 Power Over Ethernet

Power over Ethernet (POE) has emerged as a practical method of providing power to Ethernet devices without the need for an external power supply, defined by the IEEE802.3af specification. POE systems include two major components, the Power Sourcing Equipment (PSE), and the Powered Device (PD). The PSE puts a 48V differential voltage on either the data pair or the spare pair of the twisted pair medium, and the PD takes the 48V differential off the center tap of the transformer of the device to be powered. In theory, the Ethernet PHY should not see this 48V differential, as a balanced transformer allows only the AC portion of the Ethernet signalling to be induced across the transformer windings.

### 1.1.1 PSE Injection Options

The PSE can be located either within the Ethernet switch/hub in Endpoint PSE systems, or in between the switch/hub and the powered end station in Midspan PSE systems. A diagram of the injection alternatives are shown below in Figure 1.1, taken from the IEEE802.3af specification document. Endpoint PSE systems inject 48V onto either the data pair of the Ethernet twisted pair medium (Endpoint PSE, Alternative A), the spare pair of the twisted pair medium (Endpoint PSE, Alternative B), or both data pair and spare pair of the twisted pair medium (not shown). Midspan PSE systems inject 48V onto the spare pair of the twisted pair medium only (Midspan, Alternative B). For the discussion of this application note, Endpoint PSE alternative A will only be considered, as this is the only configuration where 48V is placed directly onto the data pair of the twisted pair medium.

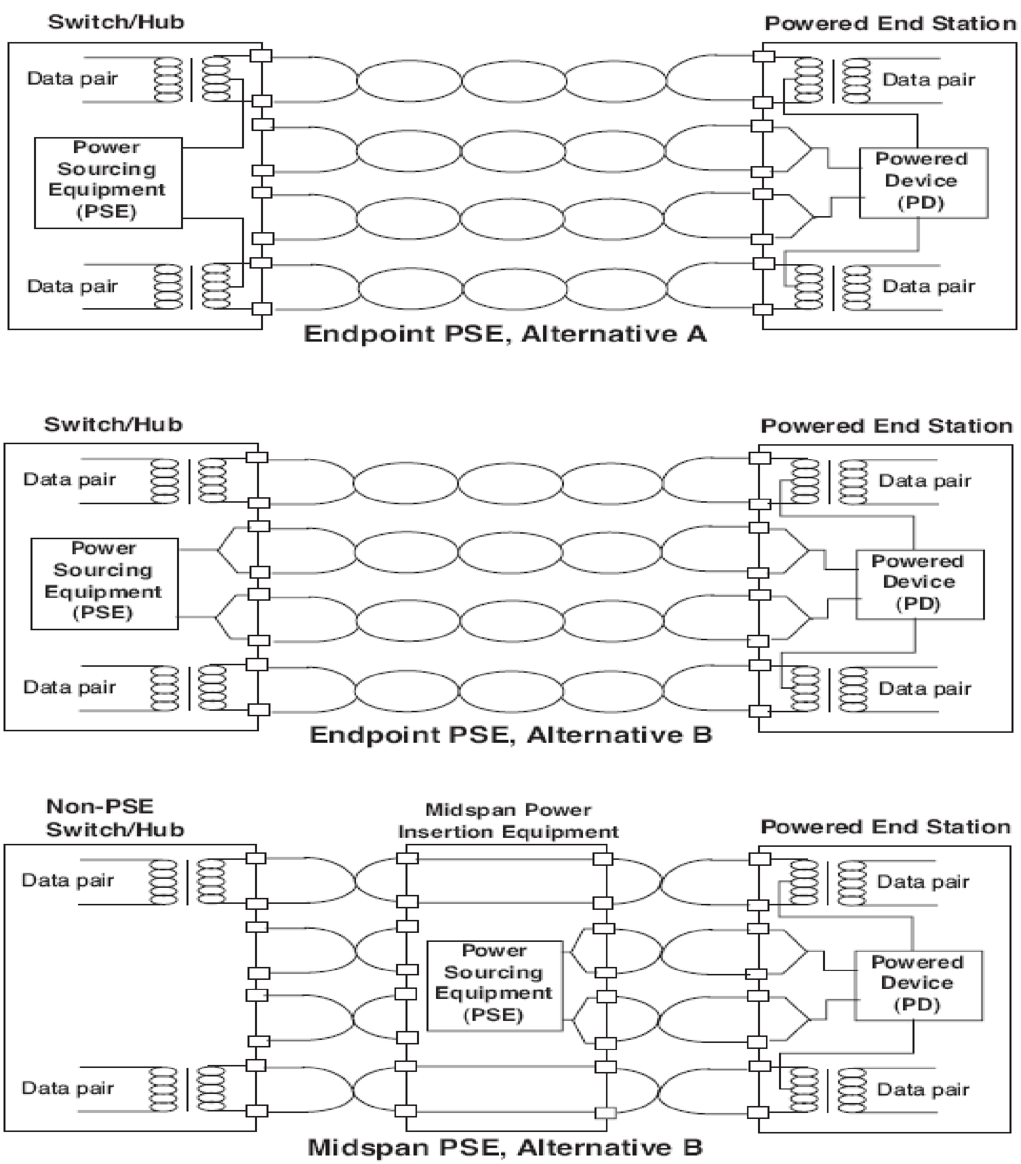


**Figure 1.1 POE Injection Configurations**

### 1.1.2 Endpoint Injection Alternative A

In the endpoint injection alternative A, the 48V differential is injected onto the center taps of the two TX and RX transformers on the PSE side of the twisted pair medium, and is taken from the center taps of the transformer on the PD side of the twisted pair medium as shown below in Figure 1.2. In an ideal POE system, the transformer is always balanced, and no DC offset is induced across to the Ethernet PHY side of the transformer.

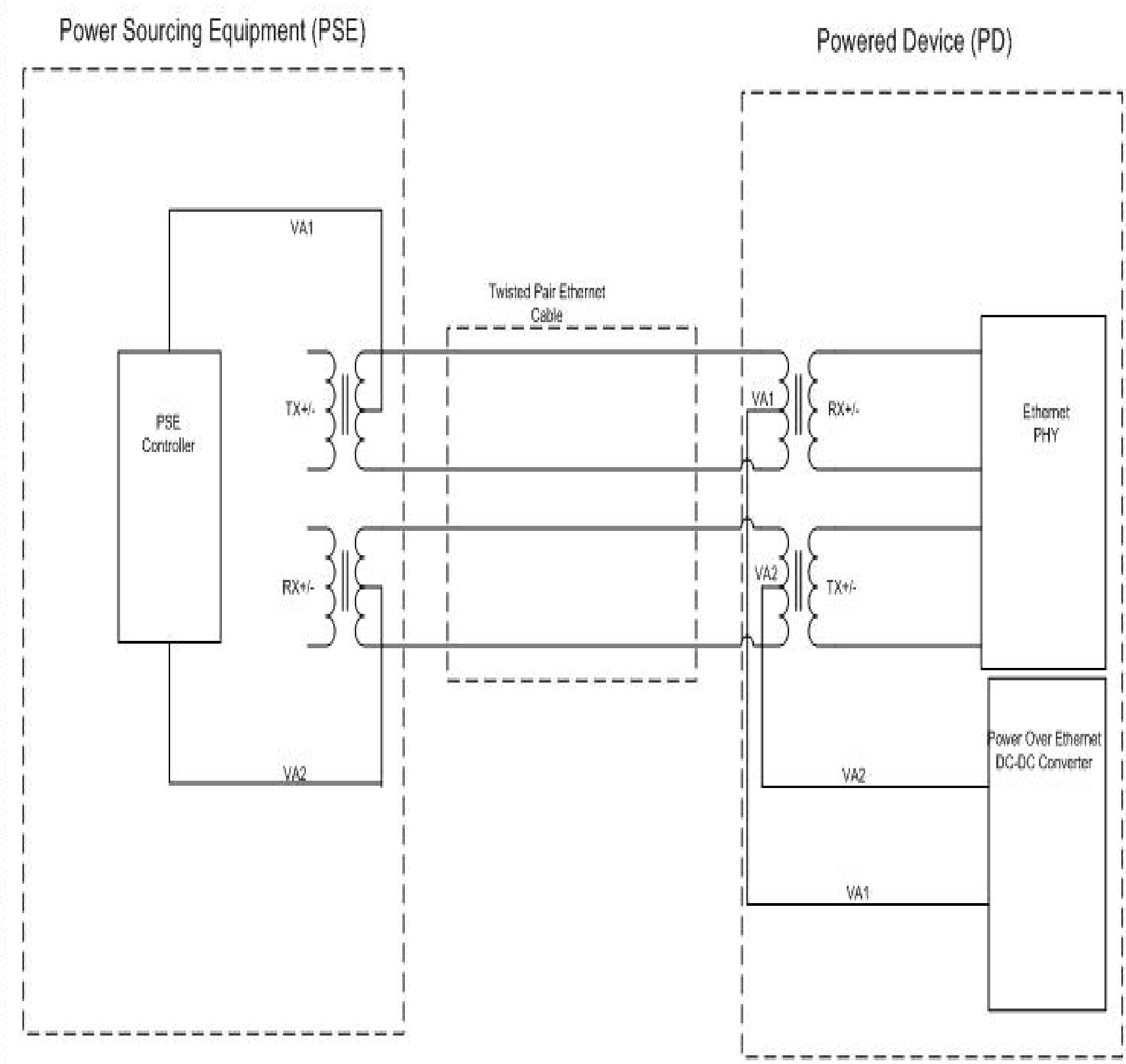


**Figure 1.2 Endpoint Injection Alternative A**

### 1.1.3 PD Detection and Classification

When the PSE and PD are connected by the twisted pair medium, a detection and classification event occurs, where the PSE injects a small differential voltage (Vport) onto the center taps of the PSE side of the transformer and looks for a valid PD detection signature of a characteristic capacitance and resistance value to classify the device as a valid POE device. If the device is characterized as a valid PD device, the PSE increases Vport and measures the current draw, which sets the classification current that the PSE will be allowed to source. Once these two detection and classification events occur, the PSE ramps its differential voltage up to the 48V desired operation range. The detection and classification sequence is shown below in Figure 1.3.

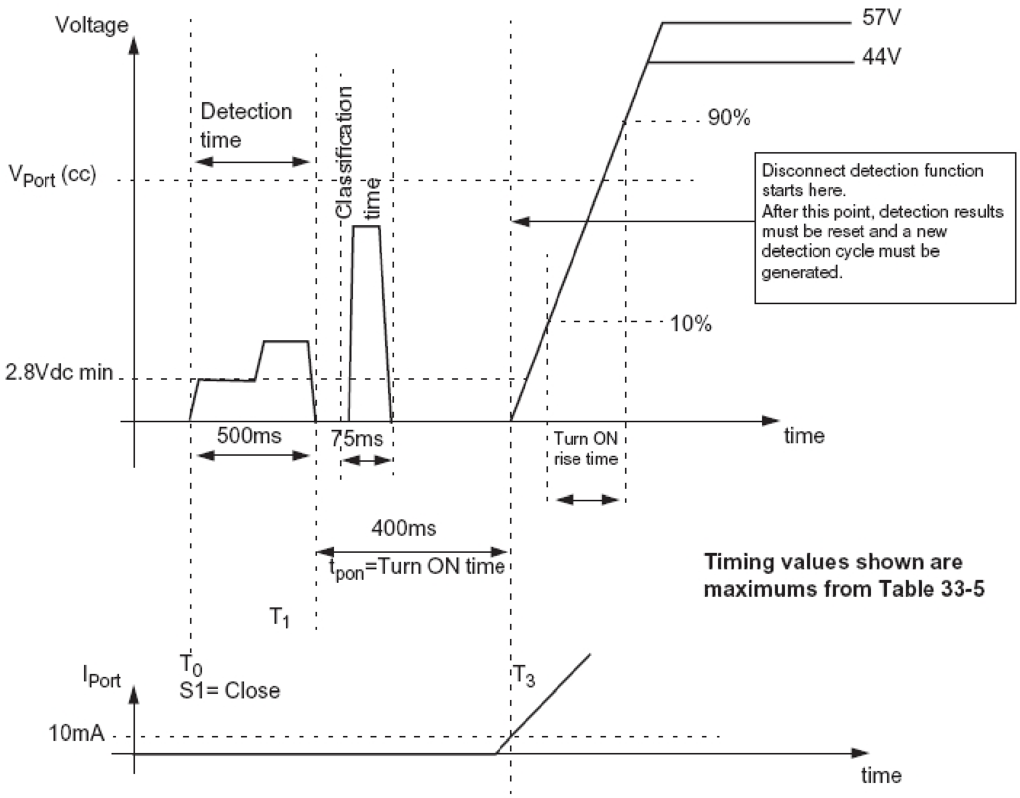


**Figure 1.3 IEEE 802.3af Power Over Ethernet Detection and Classification Sequence**

# 2 Cable Transient Event and PHY Protection

## 2.1 Cable Transient Event

Cable transient events are + and - DC surges that are induced across the transformer onto the PHY side of the TX+/- and RX+/- signals as shown below in Figure 2.1. The PHY side of the transformer should not contain any DC component other than the typical 3.3V pull-up on the center tap of the transformer for analog signal biasing. In Power Over Ethernet applications, there are two main reasons why cable transient events occur, negative rail PSE switching, and hot unplug/plug-in events. The following section explains these two situations in detail.

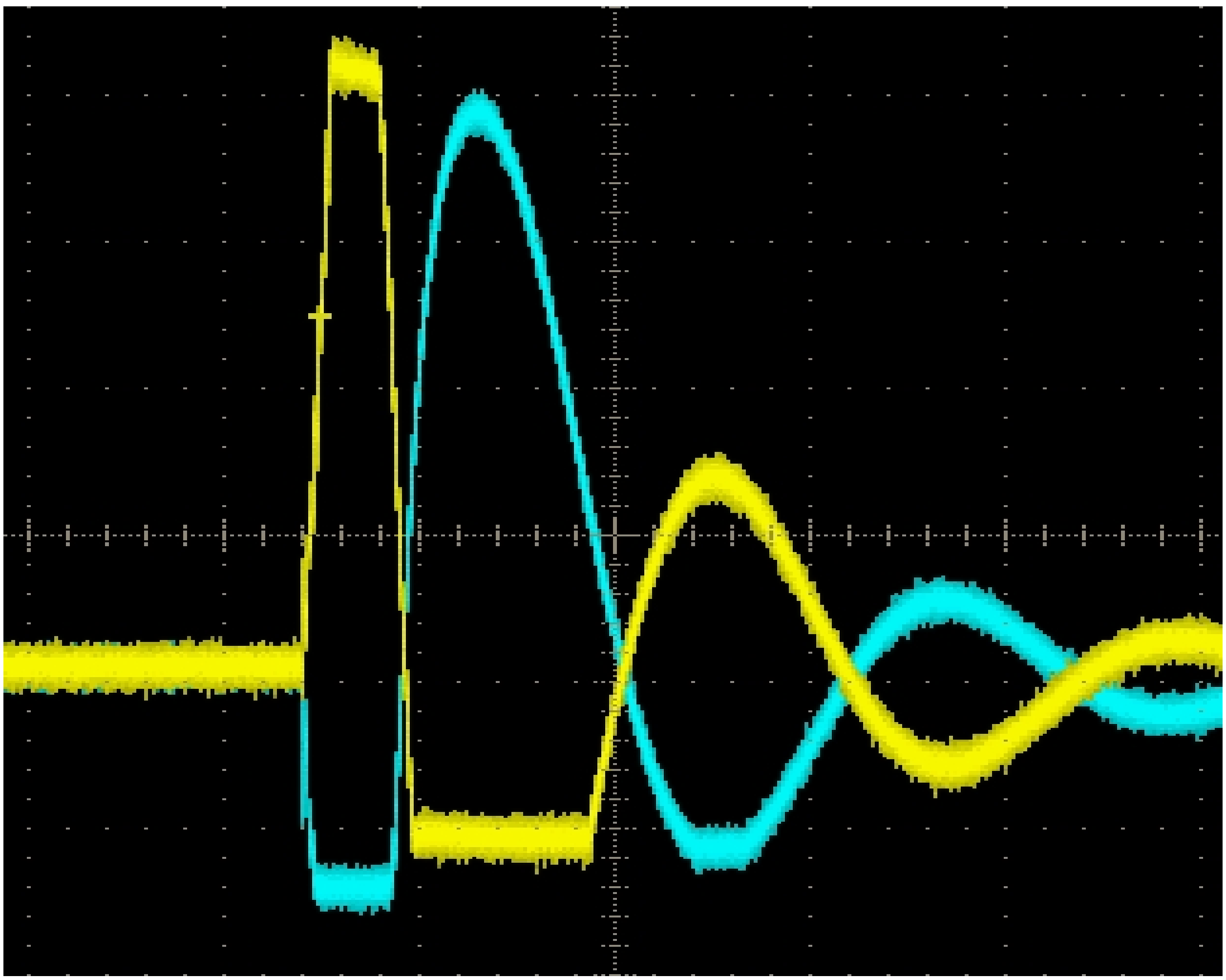

**Figure 2.1 Transient Observed on the PHY Side of Ethernet Magnetics. Scale: X=1uS/div, Y= 5V/div**

### 2.1.1 Negative Rail 48V Switching

Most PSE controllers utilize a negative rail switching system. +48V is initially applied to both the TX transformer center tap and RX transformer center tap, giving a 0V differential between the two center taps. Once detection and classification is complete, and a valid PD device has been recognized, one of the rails switches to 0V, yielding a 48V differential used to power the PD device. When there has not been a valid PD device detected, there is still +48V present on both the TX and RX pairs. In an ideal condition, the RJ-45 connector pins of the twisted pair Ethernet cable would make contact with the RJ-45 jack terminals simultaneously upon plug in, and this would keep the transformers balanced. However, due to the mechanical nature of the RJ-45 jack, contact bounce makes it nearly impossible for the transformer to remain balanced. The TX and RX differential pairs of the transformer see +48V at slightly different times, inducing a large amount of energy onto the PHY side of the transformer. The RLC nature of the PSE and PD combinations causes high energy oscillations seen on the PHY side of the transformer.

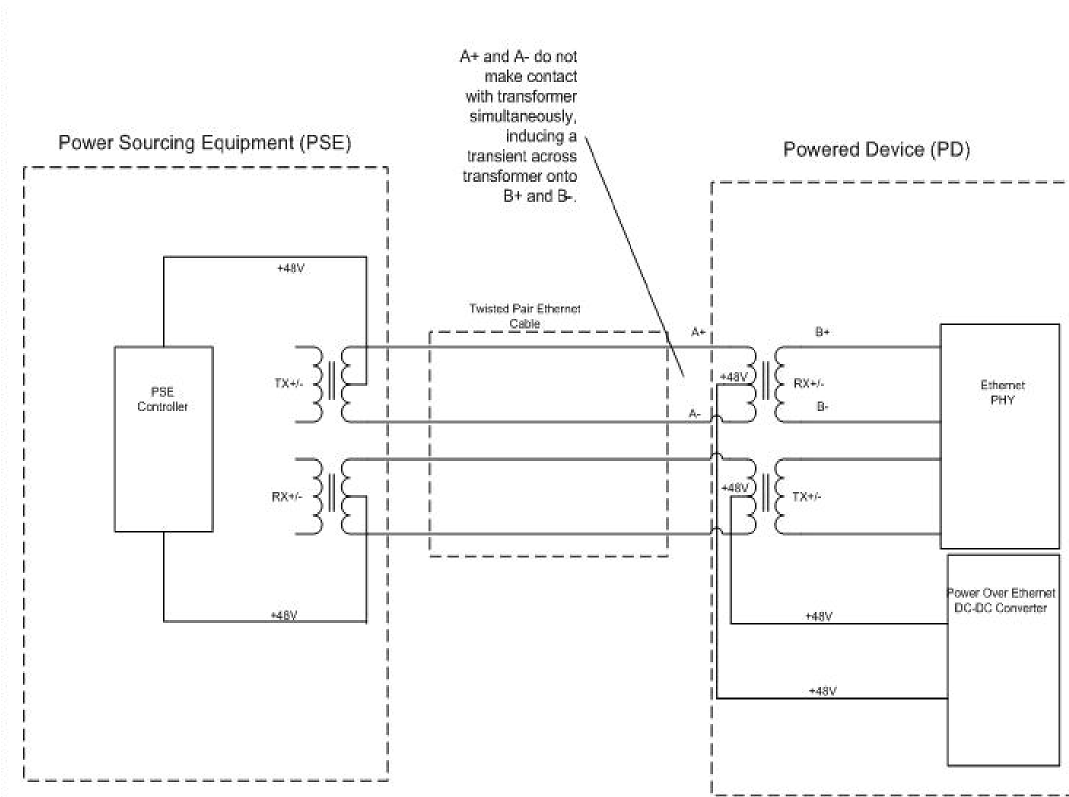


**Figure 2.2 Negative Rail PSE Plug-In**

## 2.1.2 Hot Unplug/Plug Event

When the PSE is disconnected from the PD, there is a time where it has not determined that it has been disconnected, and the 48V differential remains across the PSE side of the twisted pair cable. If the twisted pair cable is then plugged back into the PD device, there is a +48V differential hot-plugged into the RJ-45 connector. Due to contact bounce, and other mechanical contact issues, the 4 TX and RX pairs are not simultaneously connected, inducing a large amount of energy onto the PHY side of the transformer. The RLC nature of the PSE and PD combinations causes high energy oscillations seen on the PHY side of the transformer.

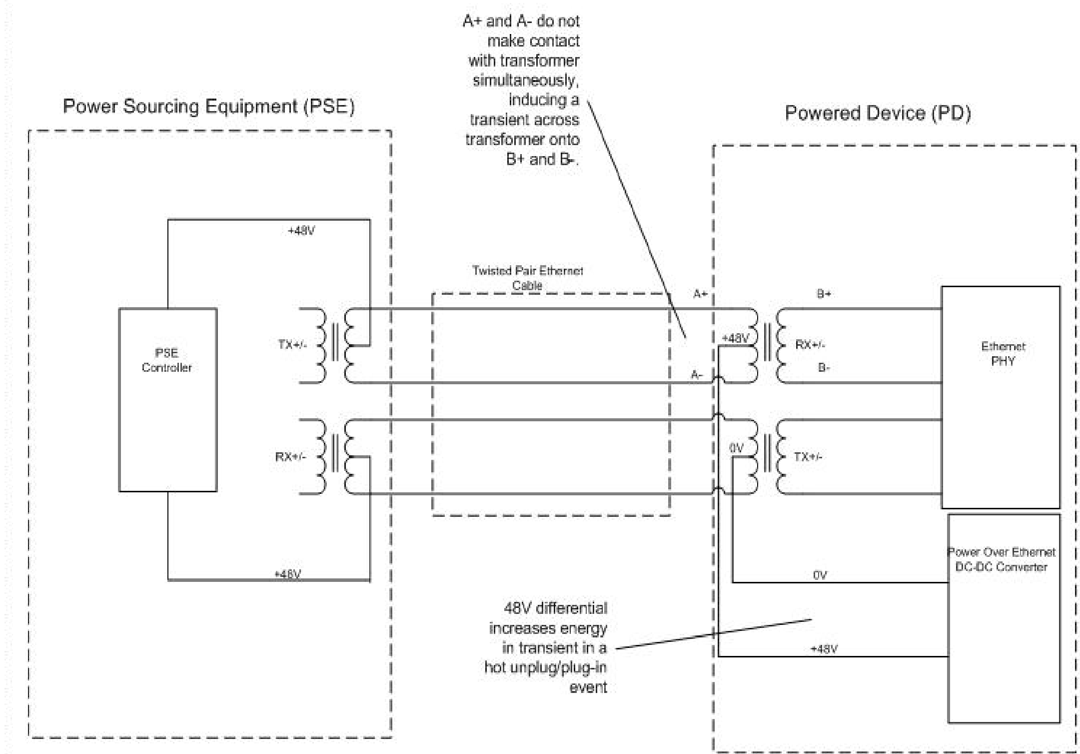


**Figure 2.3 Hot Unplug/Plug-In Event**

## 2.2 PHY Protection

When using an SMSC device in Power Over Ethernet applications, external transient protection is recommended as shown below in Figure 2.4. The schematic below shows an example of a TVS suppression solution. This solution couples the energy differentially into the two TVS diodes on each differential pair. For cases when the transient is across the TX+/- pair in the figure below, the voltage is clamped at a value equivalent to the forward bias voltage across D1, plus the zener voltage of D2. This transient voltage must be clamped at a voltage no greater than 5V. D3 and D4 act the same way when the transient is across the RX+/- differential pair. The total capacitance seen by each differential pair must not exceed 50pF (25pF single ended).

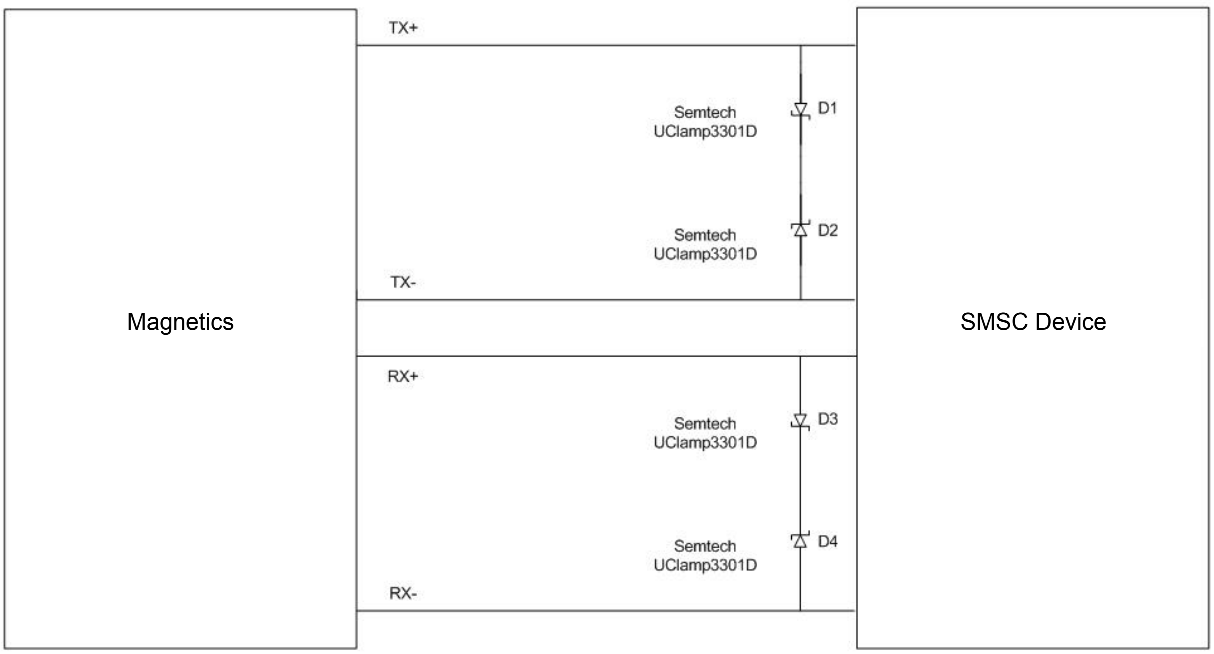


**Figure 2.4 Transient Protection Using TVS Devices**

### 2.2.1 Qualified TVS Solutions

The Semtech device listed below is just one example of a TVS solution that will provide PHY protection in POE applications, however other devices that meet the clamping requirements above may also be used. There are also integrated RJ45 and magnetics modules on the market that integrate these TVS devices inside of them.

The following is a link to the Semtech documentation:

Semtech UClamp3301D

80 ARKAY DRIVE, HAUPPAUGE, NY 11788 (631) 435-6000, FAX (631) 273-3123