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Application Note:
Designing Protection Solutions for 10GbE/1GbE & PoE Using SP4044-04ATG/SP4045-04ATG TVS Diode Arrays

Overview

Ethernet is a Local Area Network (LAN) technology that was standardized as IEEE 802.3. Today, there are four dominant forms of wired Ethernet in the marketplace, with additional types in development. The four dominant forms are:

- 10Base-T (10 Mbps, Baseband signaling, twisted pair)
- 100Base-T (100 Mbps, Baseband signaling, twisted pair)
- 1000Base-T or 1GbE (1000 Mbps, Baseband signaling, twisted pair)
- 10GbE (10 Gbps, Baseband signaling, twisted pair)

Voltage Surge and Overcurrent Threats

Ethernet is increasingly being used in applications located in harsh environments that are subject to overvoltage events such as electrostatic discharges (ESD), electrical fast transients (EFT), cable discharge events (CDE) and lightning-induced events. These overvoltage and overcurrent events are defined in various industry standards such as:

- IEC 61000-4-2 ESD
- IEC 61000-4-4 EFT
- IEC 61000-4-5 lightning induced surges
- GR-1089-CORE Issue 6 (USA related withstand level for NEBS compliance)
- ITU K.20/21/45 (World-wide compliance recommendation)
- IEEE 802.3 (Ethernet requirements)
- UL/EN/IEC 60950-1 Safety Standard

NOTE: A comprehensive summary of these various standards can be found in the Regulatory Requirements section of the SIDACtor catalog.

The 10GbE and 1GbE versions of Ethernet are very sensitive to any additional line loading; therefore, any protection components and circuits must be carefully considered to avoid degrading Ethernet's intrinsic high data rates and 100-meter reach capability.

Littelfuse Solutions

The Littelfuse SP4044 and SP4045 Series TVS (Transient Voltage Suppressor) Diode Arrays (Figure 1) offer circuit designers overvoltage solutions for 10GbE or 1GbE interfaces in small form factor SMT (Surface Mount Technology) MSOP-10 packages. These components combine the advantages of low off-state capacitance load and low dynamic resistance with a robust surge rating. The low off-state capacitance minimizes negative effects on the signal of interest, the low dynamic resistance provides a superior clamping value over other industry protection solutions, and the robust surge rating provides a tertiary protection solution that is compliant with most worldwide surge resistibility standards.

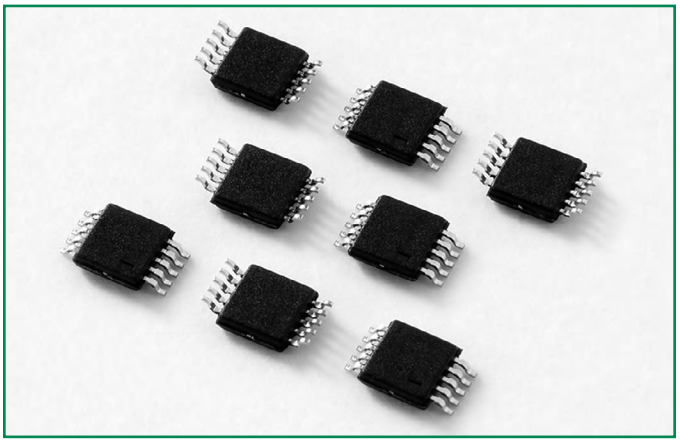

Figure 1: Littelfuse SP4044 & SP4045 Series TVS Diode Arrays (SPA® {Silicon Protection Array} Diodes)

Both the SP4044-04ATG (for Ethernet PHY voltage references ≤ 2.8V) and SP4045-04ATG (for Ethernet PHY voltage references ≤ 3.3V) provide a flow-through solution that does not require "stub" connections. This simplifies the PCB layout process and reduces EMI concerns associated with PCB trace stubs. Trace stubs can cause line balancing issues, which can lead to higher radiated energy and potentially cause the

application to exceed an acceptable level of EMI radiation. These PCB trace stubs can also cause signal reflections that have a negative impact on the original signal, which can reduce the data transmission rate and reach. These stubs can reduce the effectiveness of the circuit protection component by adding another voltage drop between the protection component and the protected circuit.

These two overvoltage protection components have an off-state capacitance of 1.5pF with a surge rating of 24A based on the 8/20µs surge current waveform (Figure 2). This off-state capacitance is compatible with both the 10GbE and 1GbE baseband signaling and does not cause the "eye" diagram (Figure 3) to close. One way to characterize the protection loading effects on the Ethernet signal integrity is to conduct eye diagram testing. This test involves repetitively sampling a digital signal and displaying the resulting eye pattern on an oscilloscope. A mask is often used to define acceptable signal qualities and compliance as seen in the eye diagram below. This "eye" diagram is a method of measuring the integrity of the Ethernet signal.

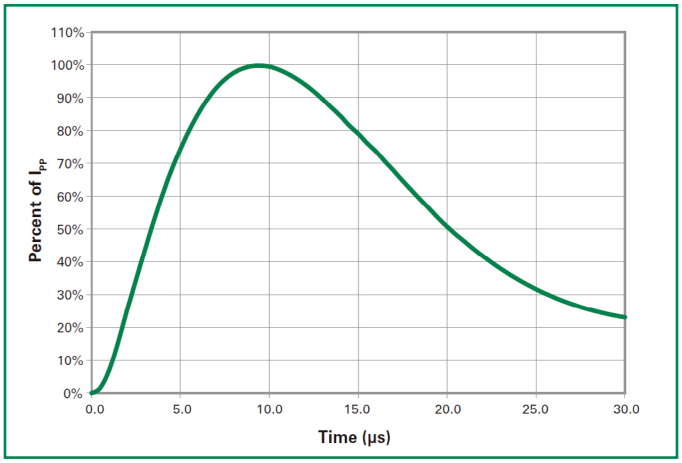

Figure 2: Current Surge waveshape

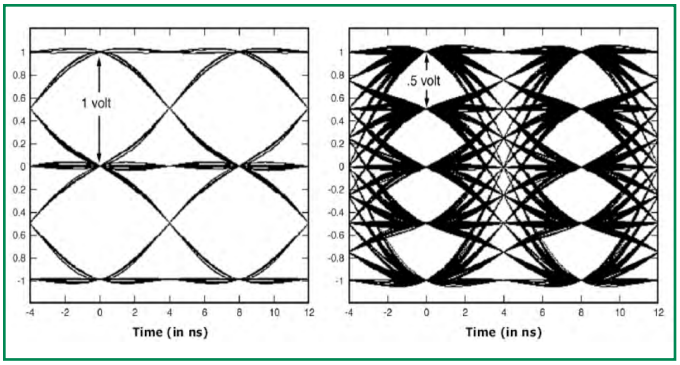

Figure 3. Eye Diagram

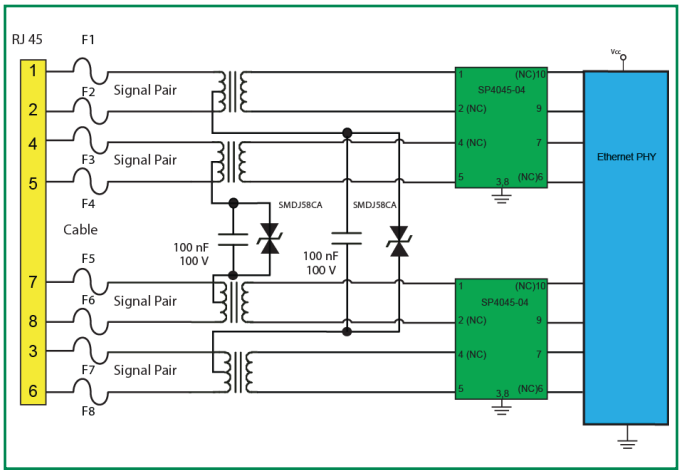

Figure 4. Compliant protection solution for an Ethernet PHY voltage ≤ 3.3V that employs two SP4045-04ATG TVS Diode Arrays

Figure 4 illustrates a comprehensive solution that is compliant with the standards listed in the section on voltage surge threats. On the right side of the schematic, near the Ethernet PHY (Physical Layer Device), note the two SP4045-04ATG clamping components. Two of these flow-through components are required because 10GbE and 1GbE versions of Ethernet use all eight wires of the CAT5e bundle. The transformer provides the first level of protection by limiting the coupling of any surge energy as a result of its saturation characteristics and its inter-winding capacitance parameters. Any surge energy that manages to get through the transformer barrier is clamped by the SP4045-04ATG, ensuring protection of the sensitive Ethernet PHY IC. (If the Ethernet PHY voltage is ≤ 2.8V, the SP4044-04ATG can be substituted for the SP4045-04ATG.)

Best practices would dictate employing a clamping component with a stand-off voltage as close as practical to (or greater than) the Vcc Ethernet PHY voltage level. The low dynamic resistance ratings of the SP4044-04ATG/SP4045-04ATG TVS Diode Arrays (0.220 Ω/0.3Ω) provide clamping action that is superior to that of other industry protection components and ensure highly effective protection for the Ethernet PHY. These TVS Diode Arrays provide both differential protection and common mode protection for the Ethernet PHY. The TVS ground reference must be the same as the Ethernet PHY ground reference.

For a comprehensive Ethernet solution, the designer will often see a need for Power over Ethernet (PoE) protection and overcurrent safety protection. The center tap connections provide the means for delivering and receiving PoE. The SMDJ58CA is a bi-directional TVS diode for these center-tap connections so an additional polarity guard (diode bridge) is not needed. For a lower surge withstand capability and a slightly

lower cost, the SMAJ58CA, SMBJ58CA, or SMCJ58CA can also be considered. The Power Supply Equipment (PSE) end will only need a single bi-directional TVS diode because the mode type will be known. However, the Powered Device (PD) end must protect both Mode A and Mode B PoE (also known as Alternate A and Alternate B), so two di-directional TVS components are required. If PoE is not being implemented, then the two 100nF capacitors and the two SMDJ58CA components can be eliminated.

The 04611.25 TeleLink fuses (F1-F8) provide overcurrent protection compliant with GR-1089 Issue 6, UL/EN/IEC 60950-1, and both the Basic and Enhanced levels of ITU K20/21/45. A TeleLink fuse on each wire is recommended for 10GbE and 1GbE links rather than a single fuse on one wire of each data pair. This helps to maintain the line balance on these high-speed interfaces. Fuses have an inherent inductance value: therefore, a fuse must be placed on each wire to maintain the differential balance of each wire pair.

A complete protection solution for an Ethernet interface has been reviewed in this application note. This application note addresses exposure to:

1) Lightning surges
2) ESD
3) CDE
4) EFT
5) Power fault events

This application note initially concentrated on solving the ESD/EFT/CDE/ lightning surge exposure of the Ethernet data interface by offering a low capacitance clamping TVS diode array solution (SP4044/4045-04). The center tap connected PoE interface was then reviewed for potential exposure and the DO214 SMT SMXJ58CA and SMxJ58A solutions were offered. Finally safety related over current issues were then addressed by offering the TeleLink fuse, which protects the twisted pair wires if a power fault event occurs. Littelfuse has world-wide lab testing capabilities to assist our customers is designing the appropriate protection solutions for compliance to world-wide standards, regulations, and recommendations. We invite our customers to request this design assistance for their application designs. For further information, please visit our website at www.littelfuse.com.

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