

Ethernet Protection - A Whole Solution

By: ProTek Devices

Electronic devices and components are vulnerable to the damaging effects of lightning, electrostatic discharge (ESD) and switching transients. Protecting Ethernet equipment such as switches, routers and network cards, while maintaining performance presents a challenge to design engineers. In addition, high frequencies, low power consumption and a reduction in board space add to the complexity when choosing the proper protection device for these systems.

TRANSIENT PROTECTION DEVICES

Transient Voltage Suppressors (TVS)

Silicon Avalanche Junction TVS devices contain a P/N junction similar to a Zener diode but with a larger cross section, which is proportional to its surge power rating. Longer duration pulses can be suppressed by increasing the die size and head dissipation. Both voltage and power capability can be increased by stacking parts in series or parallel.

Package configurations for silicon TVS devices range from chip size to large module units. Silicon TVS devices can be unidirectional or bidirectional for voltages with positive and negative pulses.

Silicon TVS devices have a sub-nanosecond response time as well as low clamping factors (~1.33). These devices do not wear out like MOVs and are available in a wide voltage range.

Although rated at lower surge current levels than a MOV, silicon TVS devices are more than adequate for use in protecting signal and low voltage DC bus lines. For example, a 12 Volt rated 600 Watt device has a 8/20 μ s surge capability of 140 Amps. Failure mechanism of a TVS device is a short circuit.

Silicon TVS diodes are used across data lines to protect telecommunication and microprocessor based monitoring systems. These devices are used in protecting portable electronics, electronic interface I/Os as well as DC power bus lines. Sub-nanosecond response times and low clamping voltages make these devices effective in protecting electronics from the effects of Electrostatic Discharge and other secondary transient sources.

Gas Discharge Tubes (GDT)

Gas Discharge Tubes (GDT) are glass or ceramic packages, filled with inert gases that are ionized by means of electron collision. This causes the device to conduct large amounts of current. When a transient voltage exceeds the DC breakdown rating of the device, the electrodes of the gas tube will be triggered. The GDT will go into breakdown mode and change from a high-resistance state to a virtual short circuit with a low arc voltage. During this state, the GDT will divert a high level of transient current to protect the equipment. When the transient drops below the DC holdover voltage and current, the gas tube will return to the off-state.

GDTs can conduct very high surge currents (up to several kiloamps) and can have a capacitance as low as 1pF. The disadvantages of gas discharge tubes are a high firing voltage when circuit dV/dt is large and performance degradation after each firing. Typically GDTs are using in combination with other transient voltage suppressors.

Thyristor Surge Suppressors (TSS)

Thyristor Surge Suppressors (TSS) are solid-state components containing three P-N junctions, that switch to a low on-state voltage when triggered. They are small in size compared to their high surge current ratings. Operating voltages range from 20 Volts to 250 Volts with current ratings of 50 Amps to 200 Amps for

a 10/1000 μ s waveform. Package configurations include axial lead, surface mount or cellular discs.

These devices are voltage triggered to the on-state, making the transition through a turn-on resistance slope, which can be either positive or negative depending upon chip design. On-state voltage drops across the device is only a few volts, allowing large surge current conduction by a relatively small chip. Thyristors typically fail when over-surged.

Like GDTs, Thyristors are also used in the telecom sector for protecting subscriber stations and central office exchanges from primary lightning strikes. Thyristors are also used to protect driver controls for both inductive and resistive loads, fluorescent lighting ballasts and primary and secondary telecom lines.

Steering Diodes

Steering diode arrays are low capacitance devices that provide high-speed data line and I/O port protection from transients caused by Electrostatic Discharge (ESD), Electrical Fast Transients (EFT) and other induced voltages. These devices divert the transient to the power-bus or ground and away from sensitive IC components. Typical Leakage Current for a steering diode array is 0.1 μ A, Capacitance 1-5pF and Forward Peak Pulse Current 12-40A.

Overcurrent Protection Components (PTC Resistors or SMD Fuses)

Positive Temperature Coefficient (PTC) resistors are overcurrent protection devices, which function as current limiting components. When an AC power line crosses a data line - as in a power fault situation - a large amount of current flows through the PTC onto the line. The PTC will heat up, causing its resistance to rise. The resistance of the PTC will go back to normal when the circuit fault is cleared. Due to the effects of insertion loss from the PTC to the data signal, the combination of surge rated resistors and fuses are often used to replace PTC resistors.

PROTECTION SOLUTIONS

Lightning Transients

Lightning transients are the most severe threats to electronic systems that are situated outside of buildings or at the building entrance. A lightning strike has a typical peak current of 20 kiloamps and produces intense electric and magnetic fields, which can couple into nearby power lines, data lines and circuit wiring causing catastrophic or latent damage to equipment/systems.

A two-stage network - primary and secondary protection - provides a whole solution for Ethernet systems and equipment that are exposed to lightning transients. In the exposed environment such as building interface, primary protection is used by applying damping resistors and high current-rated crowbar devices like Gas Discharge Tubes to shunt the bulk of the surge current.

In order to meet regulatory requirements (GR974-CORE, ITU K2.8 and UL497A), building entrance protection devices should be able to withstand over-voltage ratings that exceed 5000 Volts and surge currents up to 250 Amps for Thyristor Surge Suppressors and 10~20kA for Gas Discharge Tubes. Figure 1 shows external Ethernet I/O port protection. R1 and R2 represent the resistors used to limit the large current; Z1 and Z2 can be a GDT or a TSS. Both are crowbar devices used for common-mode protection. In this application, the lines of the twisted pair are protected to ground.

Inside the building, near the equipment, secondary protection is applied to suppress the remaining lightning transient and switching transients. At this stage,

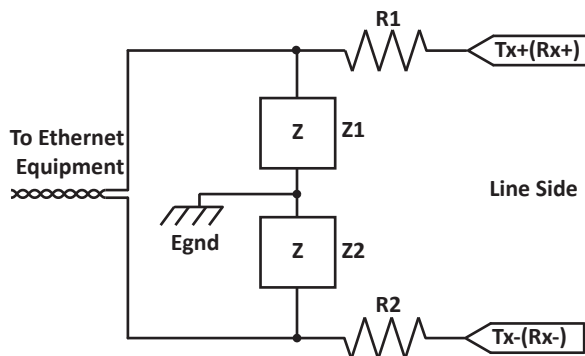


Figure 1. External Ethernet I/O Protection

TVS devices are used to divert the transient current, clamp the voltage and keep the internal circuitry safe. The fast response time and low clamping voltage of the TVS diodes compensates for the high firing voltage of the gas discharge tubes.

Secondary transient protection is recommended for equipment inside the building. In order to meet regulatory requirements (IEC 61000-4-5, GR 1089-CORE, FCC Part 68, UL497B and ITU-T K20 and K21), the protector should be able to withstand over voltages that exceed 1500 Volts and surge currents up to 100 Amps (8/20 μ s, 10/1000 μ s or 10/700 μ s surge waveforms).

Data line protection elements are normally required on both the line side and chip side of the line transformers. Line side suppression diverts the build of the transient currents, thus protecting the transceiver as well as the transformers. Chip side protection protects the transceiver IC from fast transient events that are coupled through the transformer due to parasitic winding capacitance.

There are several solutions for secondary lightning protection for Ethernet systems. Figure 2 shows the circuit using TVS diodes (Z1, Z2 and Z3). Protection is imposed on both sides of the magnetic transformer. On the line side of the isolation transformer, during the metallic lightning surge, a low capacitance TVS (Z1) provides voltage and current limiting to differential mode surges. On the chip side, two TVS devices are shunted to ground to protect the internal IC from any residual transient energy that is coupled through the transformer.

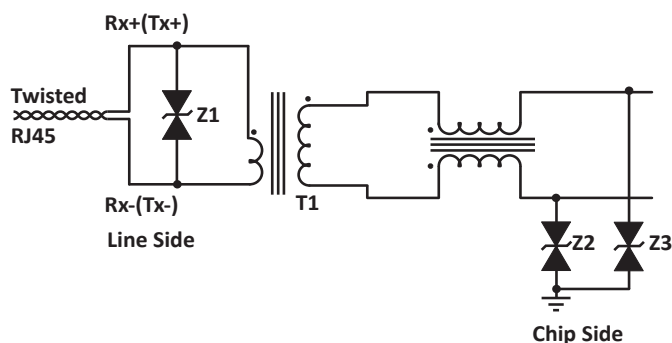


Figure 2. Secondary Lightning Protection at the Equipment

There are several different choices for the TVS devices depending upon how many lines need to be protected (i.e., GBLCxxC Series device versus a SLVDA2.8LC).

Another solution is to use a steering diode array (i.e., SRV05-4, SR2.8 or PSR05) at the chip side. The TVS diode provides protection to the power line and the steering diode directs the transients from the data line to either a power supply line or ground. This will prevent the transceiver IC from latch-up and other dam-

age. Steering diodes are low in junction capacitance, which reduces insertion loss of the signals for high-speed Ethernet applications. Figure 3 shows a TVS diode/Steering Diode combination protection scheme.

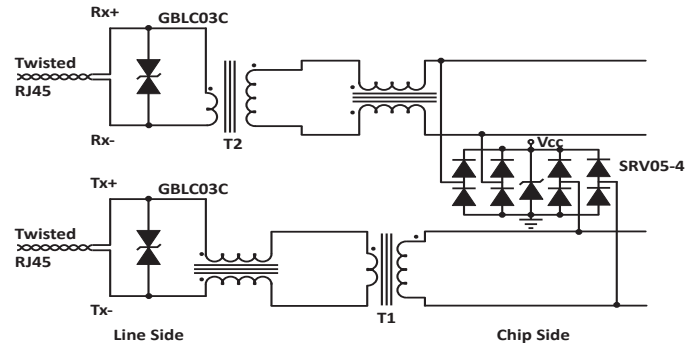


Figure 3. Secondary Lightning Protection at the Equipment

To minimize the path length between the protection devices and the lines, place the TVS diodes close to the RJ45 connector and the terminal of the isolation transformer to restrict transient coupling to nearby traces. The total voltage from the IC chips on the equipment side will be the combination of the TVS clamping voltage and the overshoot voltage due to wire inductance. It is important to make wire traces inductance as small as possible.

Grounding is another concern. Lightning is a common-mode transient, which is reference to a low impedance ground such as a chassis or a PCB ground plane. A low impedance grounding system (less than 0.5 Ohms) with minimum discontinuities is important for optimal design layout.

Electrostatic Discharge

Electrostatic Discharge (ESD) is a significant threat to electronic components. ESD is a single, fast, high voltage and high current event resulting from the near or direct contact of two objects generating both an electric and magnetic field. Electrostatic Discharge is defined by three models; Human Body Model (HBM), Machine Model (MM) and Charged Device Model (CDM).

A static charge can accumulate on a device through handling or contact with packaging materials or work surfaces. This frequently occurs when a device moves across a surface or vibrates in a metal tray. The model used to simulate the transfer of charge between two devices is referred to as the Charged Device Model (CDM).

Similarly, Machine Model (MM) refers to the accumulation and transfer of a charge from equipment to equipment.

The Human Body Model (HBM) is the most prominent source of ESD, where simple human contact or air discharge can cause component or product failure on fixed or handheld equipment. A HBM transient can have a charge greater than 40 kilovolts with a current over 80 Amps.

For low speed I/O (10BaseT) or power supply Ethernet applications flip chip devices are recommended due to their low cost and small size. For high-speed applications (Gigabit Ethernet), low capacitance devices like the SR2.8, SLVU2.8-4, GBLCxxC Series, PLC496 and SRV05-4 would minimize insertion loss. These devices can be placed close to the RJ45 port or close to the transformer, but on the chip side. A TVS/Steering Diode Array combination device such as the SR2.8 is placed on the line side to suppress line-line ESD transients as shown in Figure 4. Another solution is shown in Figure 5 using the PLC496.

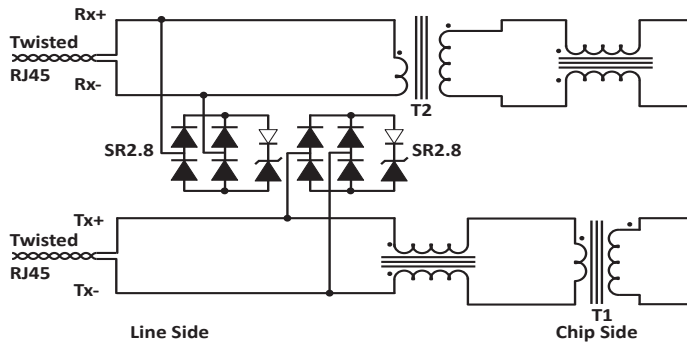


Figure 4. ESD Protection for Ethernet Data Lines

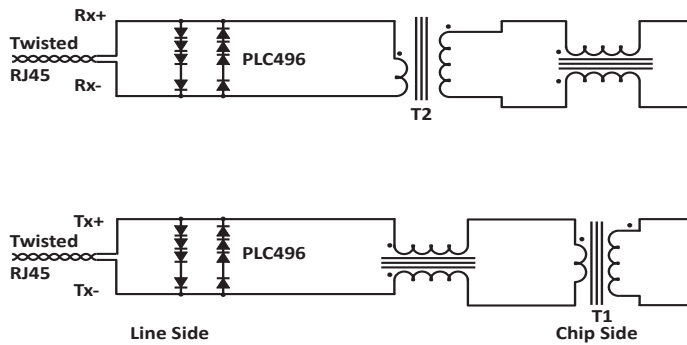


Figure 5. ESD Protection for Ethernet Data Lines

SUMMARY

Lightning and electrostatic discharge transients are threats the Ethernet applications. A variety of protection strategy are available to counter these transients. Transient Voltage Suppressors (TVS) in combination with other devices provide an optimal solution.