TVS Device Selection & Placement for Optimal EMC Design

By: ProTek Devices

Compliance with the Electromagnetic Compatibility (EMC) directive is mandatory for nearly all electronics imported into the European Union (EU). The EMC directive requires that products meet both radiated emission and transient immunity standards of protection.

Optimal protection from radiated emissions and transients can be achieved through good engineering practices, such as shielding, grounding, bonding and applying transient voltage suppressors (TVS) at key interface locations.

SELECTION

There are three TVS selection criteria for any given application that must be observed in order to meet EMC standards - Stand-Off Voltage, Peak Pulse Current and Capacitance.

Stand-Off Voltage (V_{WM})

Stand-Off Voltage (V_{WM}) - the maximum continuous dc or peak voltage which may be applied over the standard operating temperature range. V_{WM} is normally 10% below the breakdown voltage (V_{BR}). A TVS device is chosen according to its Stand-Off Voltage, which should be equal to or greater than the circuit operating voltage.

For those applications where the signal is unidirectional (i.e., +5V to 0V), a unidirectional TVS device is appropriate. A unidirectional TVS can protect in both directions if necessary. However, the clamping voltage in the forward direction will be approximately 1 Volt.

A bidirectional TVS device is suitable for applications in which the signal is both positive and negative (i.e., +12V, -12V).

Although, the transient threat can be positive, negative or both in nature, the operating voltage range of the data line signal should dictate the selection of the TVS instead of the nature of the transient threat.

Peak Pulse Current (I_{PP})

The maximum Peak Pulse Current rating (I_{PP}), defines the maximum current handling capability for a give pulse duration (td). The current handling capability is referenced to a specific waveshape (i.e., 8/20µs, 10/1000µs) and is not constant over time.

A pulse duration is defined as the front time plus its fall time. Front time is characterized by the length of time needed for the peak pulse current to reach its peak value as shown in Figure 1. The fall time is characterized as the length of time needed for the peak pulse current to reach 50% of its peak value as shown in Figure 1.

The TVS maximum peak pulse current rating must be higher than the anticipated surge current. These parameters are important in that a TVS must be capable of diverting the transient current without shorting and also providing a low clamping voltage for the protection of the circuit/IC component. If the failure threshold voltage verse time is unknown for a specific component, circuit testing is advised in order to determine the correct TVS device.

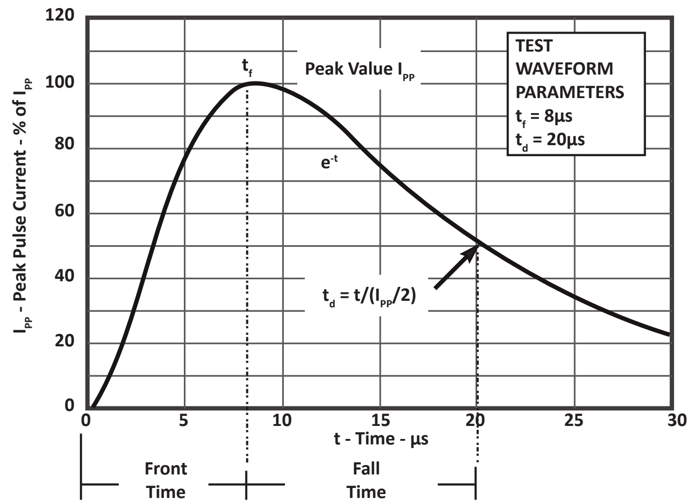

Figure 1. 8/20µs Pulse Waveshape

Capacitance

Capacitance can cause signal loss or be the cause of signal reflection. High-speed data applications seek to minimize capacitance. TVS devices that are low in capacitance are ideal for these types of applications.

PLACEMENT

Before placing the TVS on the board/system it is important to determine whether the transient threat is differential or common-mode. For example, direct contact ESD events are either line-to-line or line-to-ground events. Air discharged ESD events are generally line-to-ground. Surge testing on the circuit/system should help to determine the line-to-line or line-to-ground connections for TVS placement.

The next step is placement of the TVS device(s) within the circuit/system. The placement of a TVS must have the correct ground connection for the return path of the peak pulse transient current. A correct ground connection may be an earth-ground for systems, chassis-ground for equipment and ground-planes(power bus, analog or digital) for printed circuit boards.

To avoid voltage differentials between circuits or other grounds, the return path must be of low impedance. A low impedance path can be achieved through a ground plane or a wide braided wire strap depending upon the interface location of the TVS device and the source of the transient threat.

Inductance on the ground plane or return path will cause a damped sinusoidal voltage in excess of the incident pulse for fast transient events (ESD or EFT). This voltage can cause upset or damage to the IC component when it exceeds the rated pulsed withstand voltage.

Factors that influence the design of a low impedance return path are trace width, trace length and ground planes. A typical inductance of a PCB trace is approximately 20nH per inch; which is a good rule of thumb when measured values are not available. An example of a low impedance return path is shown in Figure 2.

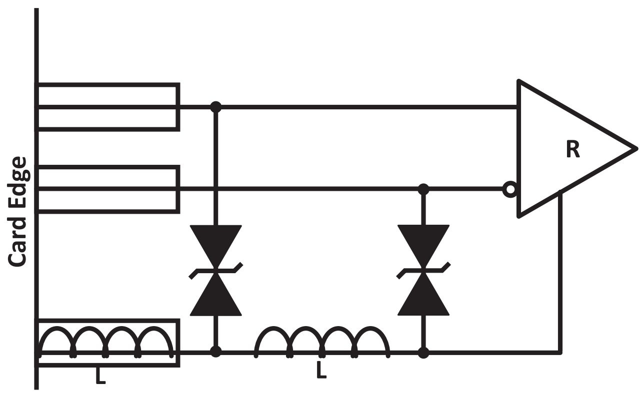

Figure 2. Card Edge TVS Connection. R=Receiver, L=Lead Inductance

Optimal Placement for System Protection

The typical interface location(s) for a system would be the exterior wall at the cable entrance to a building, where an earth-ground is essential. A low impedance ground is also necessary due to the high transient currents associated with lightning. The grounds running from the interface enclosure/panel should be as short as possible to the earth-ground system, which minimizes the secondary effects of radiated energy.

Both power-ground and data-ground connections should be at the same location to lessen the chance of high voltage differentials that can exist between power, data or phone lines due to lightning transients. Where data lines extend off-premise equipment, they require protection at a higher level due to the fact that long lines are subject to increased levels of both radiated (induced) and direct (nearby) strikes of lightning.

Optimal Placement for Equipment Protection

Another common interface location is the equipment chassis, where the metallized surface acts as the largest area for a low impedance single ground point. Similar to a building interface, the equipment chassis serves as a common connection point for both power and data lines as well as a barrier to radiated emissions. A TVS will divert conducted transient currents back to the point of contact (entry). However a TVS cannot prevent radiated EMI/RFI emissions. It is important to eliminate the effects of radiated emissions at the equipment interface by shielding rather than allowing radiated fields to effect the sensitive IC components. A TVS can be used in conjunction with a filter to help protect against EMI/RFI threats.

Optimal Placement for Board Level Protection

Transient voltage suppressors should be placed along the card edge of a printed circuit board. ESD, switching transients and tertiary lighting threats can be induced by the interconnecting cables and wires to the PCB. A TVS along the card edge prevents transients from entering the card or having the ability to create secondary radiated EMI/RFI effects within the board. This applies to both data and power buses.

Placement along the card edge is preferred over installing a protection device in the connector cable assembly. It is more efficient to have a low impedance ground point and single point of ground for both power and data lines at the card edge of the PCB. However, it is important to keep in mind that a TVS alone cannot protect against radiated emissions.

For those applications where EMI/RFI is a consideration, the TVS should be physically placed in close proximity to the individual component that requires protection. Where multiple lines are being protected the TVS device should be located at a point where there is a low impedance ground return path back to the PCB edge from each line. This is usually through a via (hole) to the ground plane on a mulitlayer PCB.

As with the first three protection locations, both power bus and data line inputs should be protected. In this case, the component is the item being isolated from the transient environment and voltage differentials that can upset or cause component failure. It is important that there is a low impedance ground plane for the transient current even at this location.

SUMMARY

Selection and placement of a TVS is a matter of knowing the circuit operating conditions, understanding the source of the transient threat and determining the best interface location. Consideration of these factors will provide a cost-effective EMC complaint solution while optimizing circuit performance during normal circuit operations and during transient events.

COMPANY INFORMATION

COMPANY PROFILE

ProTek Devices, based in Tempe, Arizona USA, is a manufacturer of Transient Voltage Suppression (TVS) products designed specifically for the protection of electronic systems from the effects of lightning, Electrostatic Discharge (ESD), Nuclear Electromagnetic Pulse (NEMP), inductive switching and EMI/RFI. With over 25 years of engineering and manufacturing experience, ProTek designs TVS devices that provide application specific protection solutions for all electronic equipment/systems.

ProTek Devices Analog Products Division, also manufactures analog interface, control, RF and power management products.

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