

As integrated circuit chipsets become more sensitive to damaging electrostatic discharge (ESD) and other transient voltage surges, the choice of circuit protection device becomes all the more important. Surge protection devices suppress voltage transients and divert excessive current away from sensitive electronic components. The challenge is that there are many different types of devices for the designer to choose from. This application note gives guidance on how to select the ideal circuit protection device for a given application.

## Voltage Surge Threats

Voltage surges can result from a variety of sources, typically associated with the handling of an end product, or its connection to power and communications lines. These threats can be understood further by identifying the likely source of an over-voltage condition, and the circuit or components that need to be protected. Table 1 provides an overview of these threats and the types of protective devices that are typically used to avoid damage.

## Protection Device Selection Considerations

ESD is a big concern for hand-held electronics in particular. A study in 20011 revealed that American children aged 8-18 spend an average of 7.5 hours per day using a cell phone, computer, television or other electronic device. Every time they touch a screen, push a button, or plug/unplug a data cable, there is an opportunity for potentially damaging ESD and transient surges. The same threats exist for other consumer electronics (LCD/LED TVs, set top boxes, MP3/PMP players and many others).

ESD is caused by the transfer of static electrical charge from a body to an electronic circuit, and in environments where the relative humidity is very low, the ESD event may have a peak voltage as high as 15,000 volts. At 6,000 volts, an ESD event will be painful to a person. Lower voltage discharges may go unnoticed, but can still cause catastrophic damage to electronic components and circuits. In less severe cases, ESD may result in faulty circuit operation or latent defects that later progress to outright failure. Fortunately, properly applied circuit protection will help avoid these problems.

Type of Threat	Typical Applications	Typical Protection Devices Used	Main Selection Criteria
Lightning	Equipment connected to external power and communication lines	Protection Thyristors, Varistors, TVS* Diodes, Gas Discharge Tubes	Operating voltage, breakover/clamping voltage, surge energy/power/current ratings
Electrostatic Discharge (ESD)	Electronic equipment with a human interfaces and data ports	Polymer ESD Suppressors, TVS Diode Arrays, Multilayer Varistors (MLVs), LED protectors	Uni/bi directional, ESD voltage rating, low dynamic resistance, low clamping voltage, capacitance
Electrical Fast Transient (EFT)	Equipment that has, or is connected to, a system or circuit with switched inductive loads or mechanical relays	Individual TVS Diodes, Metal Oxide Varistors, LED Protectors	Fast rise time response and recovery for repetitive pulses
Inductive load switching and commutative spikes	Equipment associated with large motors, pumps, compressors, relays, and AC power distribution	Metal Oxide Varistors, TVS Diodes, Gas Discharge Tubes	Energy/peak current rating, operating voltage, surge current rating,
Current switching/diversion	Wide range of electrical and electronic circuits	Switching Thyristors, LED Protectors	Proper blocking voltage, and current carrying capacity

\*Transient Voltage Suppressor

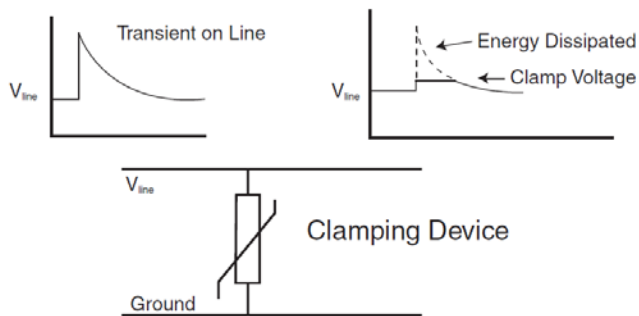
**Table 1.** Typical circuit threats, protection devices, and selection criteria

The type of threat determines the characteristics of the protection device. For ESD protection, suppression devices need very fast response times and to be able to repeatedly handle high peak voltages and currents for short durations. As shown in Table 1, the most appropriate protective devices are generally polymer ESD Suppressors, silicon TVS Diode Arrays, and Multilayer Varistors. If the circuit to be protected includes LEDs, then special protective devices designed specifically for that application may also be needed.

Lightning surge protection, on the other hand, requires crowbar devices, such as Gas Discharge Tubes and Protection Thyristors. These circuit protection devices can be used on communication lines where the short circuit current of the system is less than the holding current of the crowbar device (protection thyristor), or where the operating voltage of the circuit is much lower than the holdover voltage of the crowbar device (GDT).

A clamping device (Figure 1) essentially limits the transient voltage to a set value (above the operating voltage of the circuit being protected). When the applied voltage reaches the device's breakdown value, it will switch to a much lower resistance value to minimize the transient energy that the circuit will experience. This value is typically referred to as the dynamic resistance.

A clamping device will stop conducting as soon as the transient voltage drops below the device's breakover voltage, and the circuit will then be able to operate normally. Polymer ESD suppressors, TVS Diode Arrays, and MLVs are clamping devices.



**Figure 1.** Operation of a clamping device for transient voltage protection.

If the application is a high-speed digital I/O lines or high-frequency RF line, then the protection device should not add capacitance that could distort the signal. Polymeric ESD Suppressors have ultra-low capacitance (typically around 0.05pF), are fast-acting, and have good voltage clamping capabilities. They cannot be used on power supply lines.

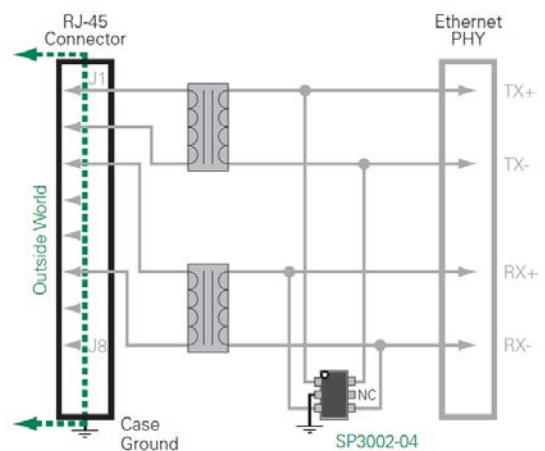
As a rule of thumb, Polymeric ESD Suppressors are used when:

- Protection is required on data, signal, and control lines
- The circuit is not a power supply line
- Signal distortion can occur with very little added capacitance (i.e., high speed data lines or RF circuits)
- ESD is the only transient threat

A different type of ESD protection device, the TVS Diode Array, is used on analog and digital signal lines, such as USB, HDMI, and Ethernet, and other signal lines associated with LCD modules, keypads, and electronic switch assemblies. Compared to other ESD protection devices, TVS Diode Arrays provide the lowest peak and clamp voltages available, due to their low dynamic resistance values. They are available as discrete devices (0402, 0202, etc.) or in packages containing multiple devices to protect multiple lines (see example in Figure 2) within a small space. Generally, TVS Diode Arrays are used when:

- The circuits being protected require the lowest possible clamp voltage (need low dynamic resistance in the protector)
- Low capacitance (typically, 0.40pF – 30pF) and low leakage (around 0.02μA – 10μA) are required
- Multiple lines must be protected and board space is limited, or when small discrete devices are preferred
- Transients other than ESD, such as EFT or lightning, must also be considered

TVS Diode Arrays can safely absorb repetitive, severe (up to 30kV) ESD events without performance degradation. They employ multiple semiconductor technologies, allowing them to provide optimum protection. In order to maintain both low capacitance and low clamping voltage, the Diode Arrays use steering diodes to direct the ESD transient into a central TVS Diode. The steering diodes only operate in the forward bias direction to add minimal resistance, and to also decrease the overall capacitance of the solution.



**Figure 2.** Example of ESD multi-line protection using a TVS Diode Array (SPA™ Family) for an indoor network and equipment.

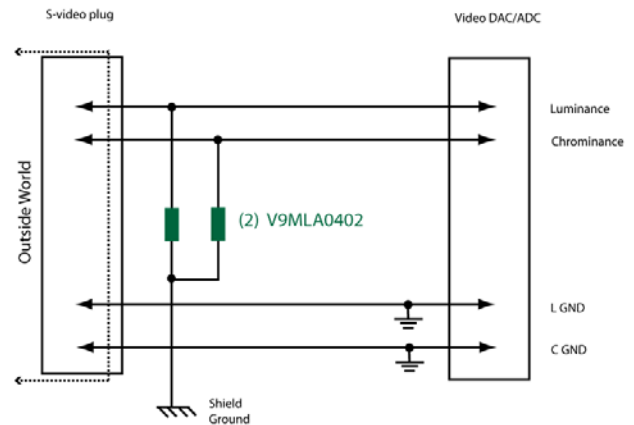
Multilayer Varistors (MLVs) are another class of clamping devices, which are fabricated from ceramic-based materials (zinc oxide). MLVs are generally used for board level protection against ESD, EFT, and other transients that can occur on power supply, data, and control lines if the lines can tolerate higher capacitance. MLVs offer a cost effective solution in a range of popular industry-standard discrete component sizes (0201, 0402, 0603, etc.). Limited multi-line array configurations are also available. Some MLVs also offer low band-pass characteristics that filter high frequency noise from the circuit being protected. MLVs are typically used when:

- Power supply line or low/medium speed data and signal lines are to be protected
- Transient currents or energy beyond ESD is expected (i.e., EFT and lightning induced surges)
- Designers looking to replace high wattage TVS Zener Diodes (300W – 1500W)
- Added capacitance is desirable for EMI filtering (3pF – 4500pF)
- The operating voltage (up to 120VDC) is above Silicon or Polymer ESD Suppressor ratings

An example of a Multilayer Varistor application is shown in Figure 3. The characteristics and location of these devices will protect the video system from most over-voltage surges that might occur on the S-video input lines.

### Location in the Circuit

In addition to selecting the ideal circuit protection device, it is important to install the device in the most appropriate location to ensure effective ESD protection. The selected suppressor should be placed as close as practicable to the connector or button/switch as possible. This will ensure that the ESD transient is clamped as soon as it enters the application. Also, the suppressor should be installed as close as possible to the data/signal line as possible. This will eliminate the potential for an inductive overshoot voltage that would result in a peak voltage that could damage the circuitry – even though the proper protection device may have been selected.



**Figure 3.** Example of MLV surge protection that clamps the S-video input line to 26VDC.

### Other Considerations

Of course, there are considerations that this application note has not addressed. Criteria such as parasitic capacitance, standoff voltage, ESD withstand, etc. are usually not enough to evaluate all possible choices for a suitable protection device. Designers also must consider the clamping voltage and the nature of typical voltage and current surge waveforms. Then the dynamic resistance of each device should be identified to determine which one offers the lowest shunt resistance to ground. Littelfuse offers a wealth of product and application support to help in making these selection decisions at [www.littelfuse.com/designsupport](http://www.littelfuse.com/designsupport).

### Conclusion

A properly selected overvoltage protection device, properly placed in the circuit, confers a number of benefits ranging from increased design reliability and lower warranty costs to stronger brand protection. Armed with a basic understanding of transient overvoltage threats, and knowing the characteristics of different protection devices, the designer can make an informed decision.

*Written by Jim Colby*

**Littelfuse, Inc.**  
8755 West Higgins Road, Suite 500  
Chicago, IL 60631 USA  
Phone: (773) 628-1000

[www.littelfuse.com](http://www.littelfuse.com)