TVS Voltage Characteristics for an Electrostatic Discharge Pulse

The most significant transient threat to IC components connected directly to I/O ports is Electrostatic discharge (ESD). Typical sources of ESD include Human Body Model (HBM), Machine Model (MM), and Charge-Device Model (CDM). The difference between these sources exist in their transient voltage (kilovolts) and peak current (10s of amperes) levels. For instance, a Human Body Model-ESD transient can occur in excess of 40 kilovolts with a current greater than 80 amperes. Any one of these sources can cause an upset in performance or degradation to a sensitive IC component. Generally, transient currents affect the performance of the IC component; whereas excessive voltage transients tend to damage the device. Therefore, it is important to provide some type of protection to clamp the incident voltage and divert the transient current away from the IC component.

Transient voltage suppressors (TVS) are universally known for effectively clamping voltage levels well within the withstand limits of the IC component. However, the withstand limits of an IC component are often unknown due to the lack of published information from the IC manufacturer. In fact, IC components can withstand a higher voltage level than their continuous operating voltage. Again, this information is often unavailable because IC chip design is constantly changing. Many IC component manufacturers do not identify this voltage parameter, but only caution the designer about the steady state condition. Thus, for circuit design engineers, it can be a trial and error process in determining the IC component's withstand levels, which are dependent upon the pulse duration (pulse waveshape) of the transient threat.

TVS Device Characteristics

The TVS device parameters that affect clamping voltage are on-resistance, temperature, and packaging. The on-resistance of a low voltage device (less than 30 volts) is generally less than 500 milliohms. Higher voltages can have an on-resistance from 2 to 4 ohms. Temperature effects include junction heating due to high transient currents and a temperature coefficient of the breakdown (avalanche) voltage. In addition, TVS devices with a breakdown voltage of 5 volts or higher will always have a positive temperature coefficient.

Depending upon the transient current values, temperature effects should be taken into account with standard test waveshapes, such as 8/20 µs and 10/1000 µs, when specifying a maximum clamping voltage of a device. For pulse waveshapes in the nanosecond region, additional criteria must be considered. Internal packaging designs and lengths of lead wires will have an effect on both the overshoot voltage (due to transient dv/dt characteristics) and the actual clamping of the TVS device (due to the transient di/dt characteristics) to a lesser degree.

Overshoot voltage is defined as the voltage that appears on the leading edge of the voltage waveform. This characteristic is attributed to the internal package design which has some finite inductance and the rate of a fast rise time pulse. It is possible to measure the overshoot voltage with a gigahertz oscilloscope. An overshoot voltage is generally clamped within 10 to 20 nanoseconds. Peak voltage measurements beyond this time are the result of the decaying peak pulse current of an ESD event. Although overshoot voltage can vary from test to test as a result of package design, the clamping voltage is a constant value[1]. Clamping voltage is characteristic of the TVS device's response to the peak pulse current, pulse duration, and on-resistance.

Test Results

A Schafner ESD gun, type NSG432, with a discharge voltage capability of 25 kilovolts was used for the following tests. The ESD simulator generates a Human Body Model pulse waveshape of less than 1/60 ns. It appears that the gun is designed to have a fixed voltage rise pulse independent of the charge voltage. The two devices tested were an LCD05C and an SMDA05LCC. Their electrical specifications are shown in Table 1.

Figures 1 and 2 represent the voltage response of an LCD05C for a 10 kilovolt ESD pulse duration of 1/30 ns. Likewise, Figures 3 and 4 represent the voltage response of an LCD05C for a 20 kilovolt ESD pulse duration of 1/30 ns. Figures 1 and 3 take a closer look at the overshoot voltage of the TVS at 5.0 nanosecond per division. From these two figures, it appears that the rate of rise is similar for the 10 kilovolt and 20 kilovolt pulse. They are similar as a result of the fixed rate of rise of the ESD pulse, test equipment, and the fixed package lead inductance but not the turn on time of the TVS. Generally, the turn on time of a TVS is less than 1 ns.

Figures 2 and 4 shows the overshoot voltage, clamping voltage, and the breakdown voltage of the TVS at 50.0 nanoseconds per division. As expected, the 20 kilovolt ESD pulse has a higher current value and a longer pulse duration than the 10 kilovolt ESD pulse. Although the waveshapes are somewhat different, the clamping voltage appears to be similar due to the design of the TVS device. Also, both devices show breakdown voltages of 6.9 volts due to the ex-

Table 1
Electroical Specifications for Transient Voltage Suppressor (TVS) Arrays

ProTek Part Number	Peak Pulse Power Rating (8/20 µs) P_{PP} Watts	Stand-Off Voltage V_{WM} Volts	Leakage Current @ V_{WM} I_D µA	Breakdown Voltage @ 1 mA $V_{BR(Max)}$ Volts	Clamping Voltage V_C Volts	Clamping Voltage @ I_{PP} V_C Volts	Maximum Peak Pulse Current I_{PP} Amps.
SMDA05LCC	300	5.0	100	6.0	12.5 @5 A	14	26
LCA05C	500	5.0	100	6.0	12.5 @10 A	22	40

[1] Clamping voltage may vary depending on temperature.

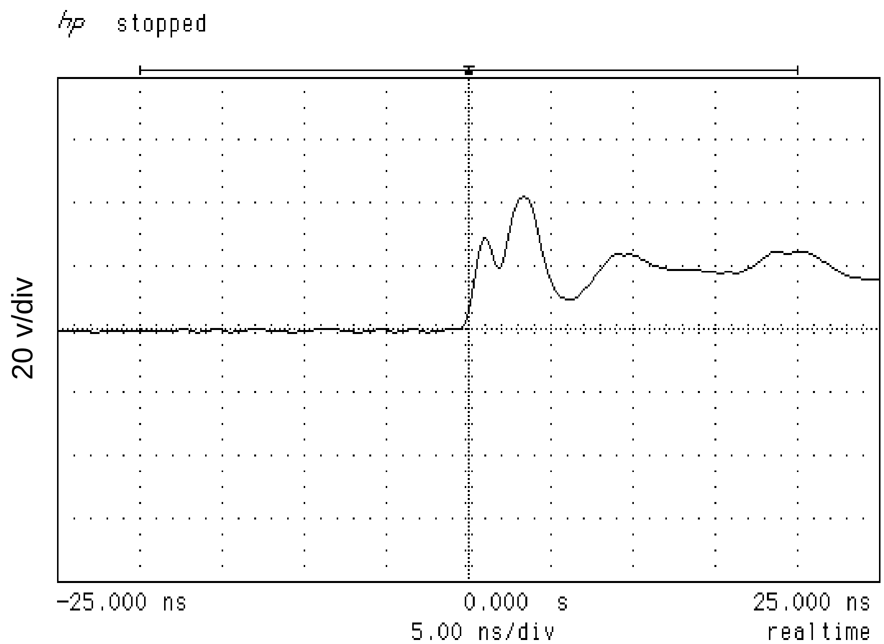

Figure 1
Overshoot & Clamping Voltage of LCA05C
ESD Test Pulse: 10 kV, 1/30 ns (waveshape)
Peak Voltage: 38 V, 3 ns

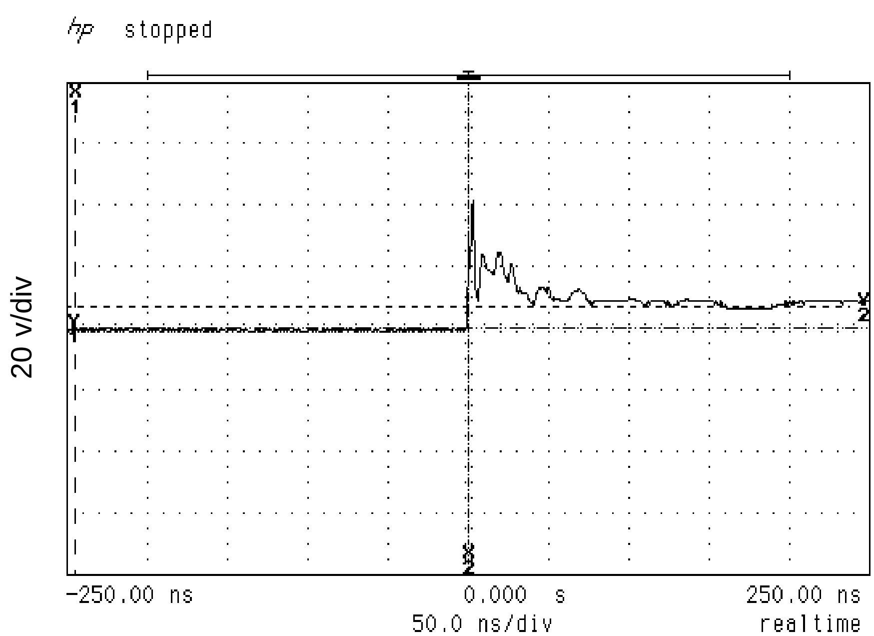

Figure 2
Overshoot & Clamping Voltage of LCA05C
ESD Test Pulse: 10 kV, 1/30 ns (waveshape)
(------ is a 6.9 volt marker)
Peak Voltage: 38 V, < 5 ns

tended trailing edge of the ESD pulse. The dotted line, shown in Figures 2 and 4, represents the actual breakdown voltage of the TVS device when measured at 1 milliamperes.

The second TVS device measured was the SMDA05LCC. Figures 5 and 6 show the voltage characteristics of the above device with an ESD pulse duration of 1/30 ns at 20 kilovolts. Figure 5 represents the overshoot voltage of the device at 5.0 nanoseconds per division and the resulting effects of package lead inductance. The higher voltage is attributed to a much longer wire length due to the multiple bonds. The reflected signal responses are due to a mismatch in device equipment impedance. Figure 6 represents the overshoot voltage, clamping voltage, and the breakdown voltage at 50.0 nanoseconds per division. As a result of the smaller diode junction in comparison to the LCD05C, the SMDA05LCC has a higher clamping voltage during the ESD event. Within 200 nanoseconds the device breaks down to another voltage level simulating a reduction in the ESD current.

Summary

As the results suggest, the device characteristics display three significant voltage levels: overshoot voltage, clamping voltage, and breakdown voltage. Most importantly, it is the clamping voltage that provides the level of protection for the IC component. Transient voltage suppressors are effective in clamping voltage levels well within the withstand limits of the IC component. Currently, TVS devices are successfully being used in I/O port applications. These devices can prevent IC component failure and malfunctions caused by ESD pulses in excess of 20 kilovolts.

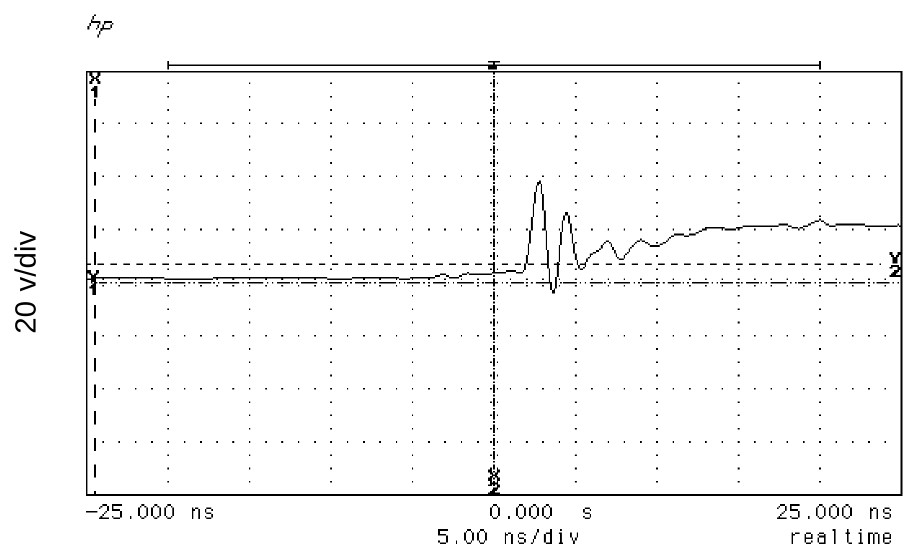

Figure 3
Overshoot & Clamping Voltage of LCA05C
ESD Test Pulse: 20 kV, 1/30 ns (waveshape)
(------ is a 6.9 volt marker)
Peak Voltage: 38 V, 3 ns

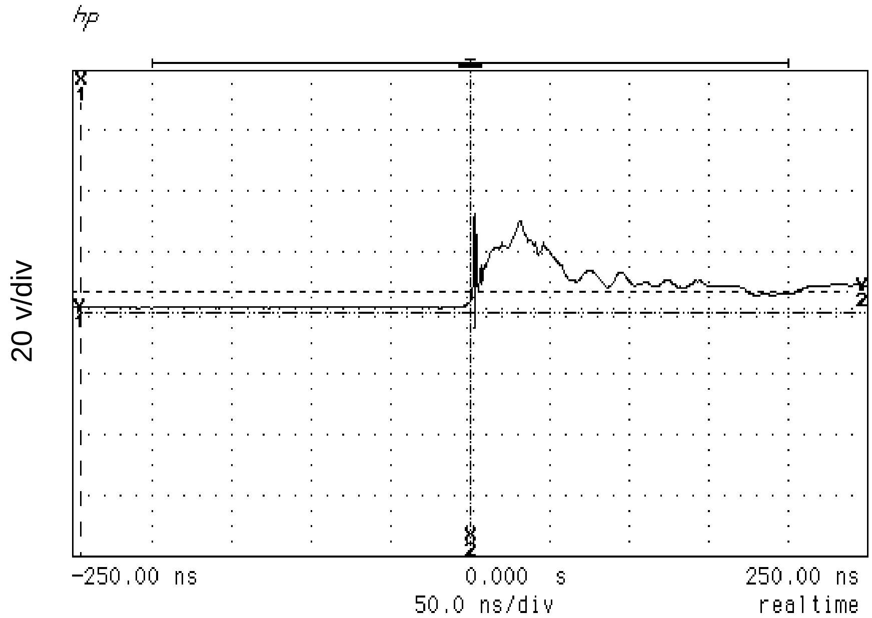

Figure 4
Overshoot & Clamping Voltage of LCA05C
ESD Test Pulse: 20 kV, 1/30 ns (waveshape)
(------ is a 6.9 volt marker)
Peak Voltage: 32.5 V, < 5 ns

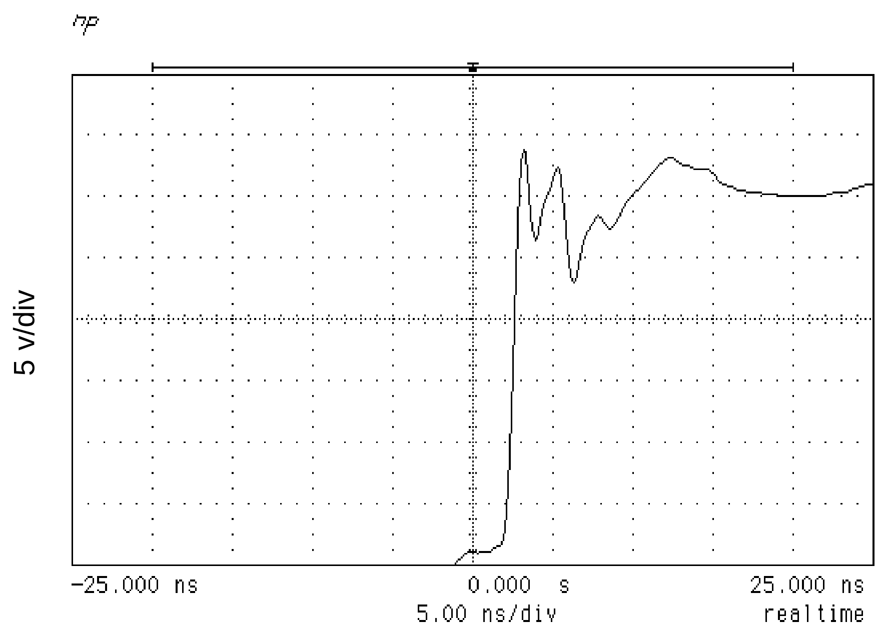

Figure 5
Overshoot & Clamping Voltage of SMDA05LCC
ESD Test Pulse: 20 kV, 1/30 ns (waveshape)
Peak Voltage:33.7 V, 3 ns

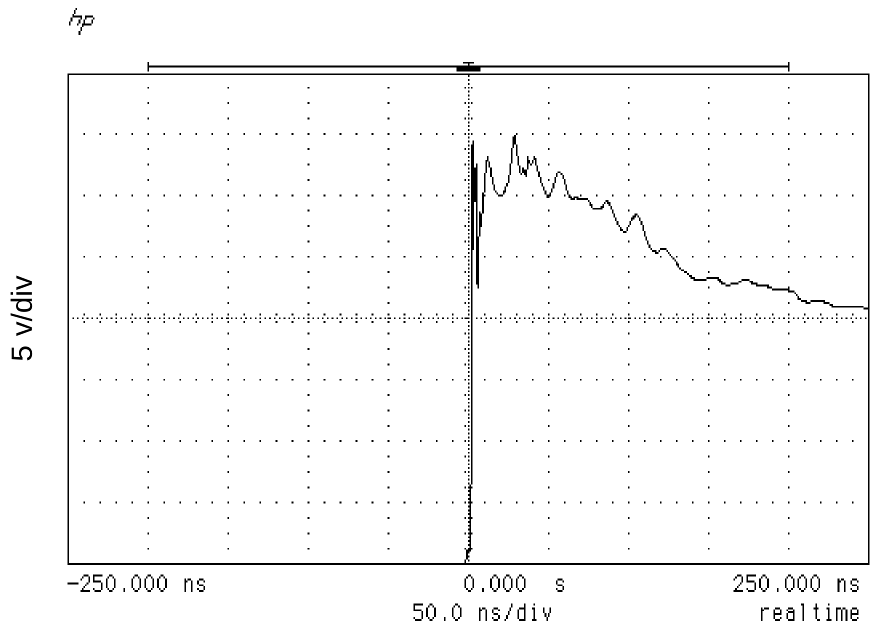

Figure 6
Overshoot & Clamping Voltage of SMDA05LCC
ESD Test Pulse: 20 kV, 1/30 ns (waveshape)
Peak Voltage: 34.8 V, < 5 ns