MicroNote 110

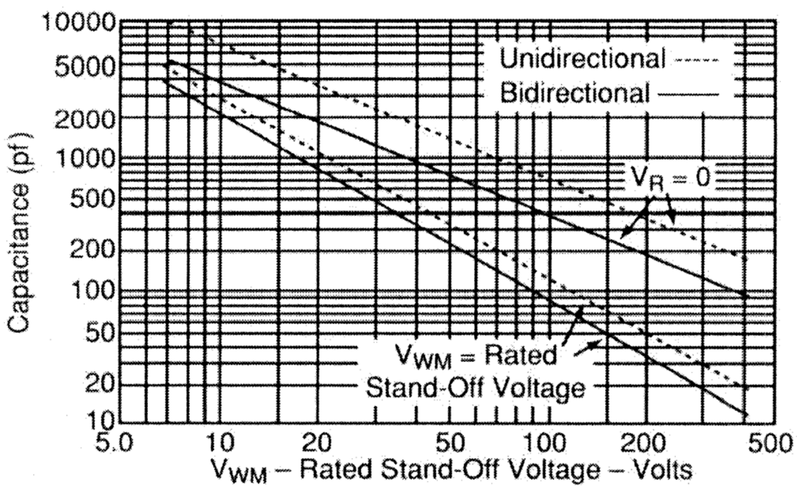
Parasitic Capacitance in Transient Voltage Suppressors and Low-Capacitance Options

By Kent Walters

A silicon transient voltage suppressor (TVS) has an inherent capacitance, resulting from mobile electrons and holes on opposite sides of the p-n junction and depletion layer. This is equivalent to parallel plates having an intervening dielectric layer of silicon in between them, thus providing all the elements of a capacitor. When a reverse bias is applied, the depletion region widens and decreases the capacitance as the voltage bias is increased.

Low-voltage TVS devices have a high concentration of dopant, resulting in a narrow depletion region and thus producing higher capacitance values. Progressively higher voltage devices have exponentially decreasing levels of dopant and wider depletion regions with a corresponding reduction in capacitance. Figure 1 (see page 1) depicts capacitance versus rated working standoff voltage (V_{WM}) for both unidirectional and bidirectional devices in an example of 1500 W-rated series of TVSs. The bidirectional TVSs have two p-n junctions in series that further reduce capacitance.

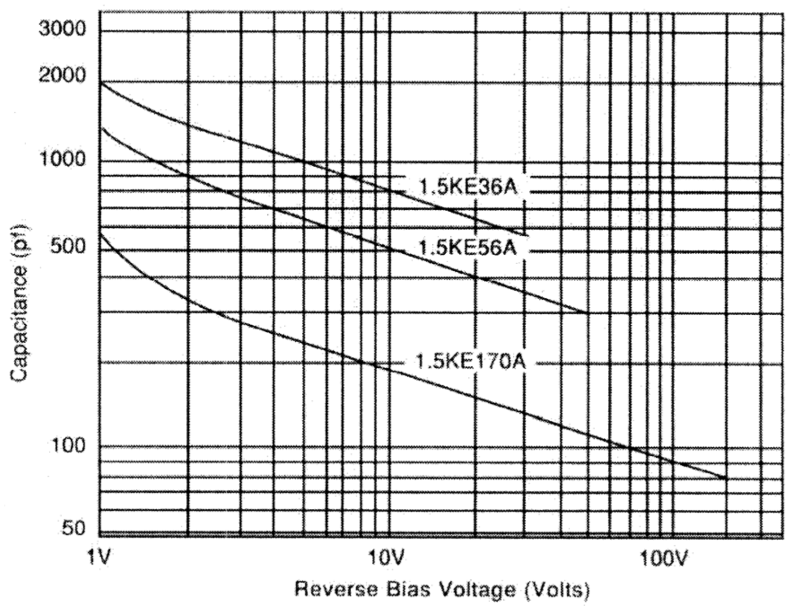
Figure 1: Capacitance vs. Stand-Off Voltage for 1500 W TVSs



Similar capacitance graphs for different power-rated TVS devices will vary proportionally to their rated peak pulse power (P_{PP}), or effective area of p-n junction. For example, a 500 W device will typically have one-third the capacitance of a 1500 W device, while a 7500 W will have five times the capacitance when comparing the same standoff voltage rating selections of TVS devices.

Typical values for capacitance versus bias voltage are shown in Figure 2 (see page 2) for three device types in the 1500 W series: 1.5KE36A, 1.5KE56A, and 1.5KE170A. Capacitance drops exponentially as bias voltage is increased, because the depletion layer widens as reverse bias is increased.

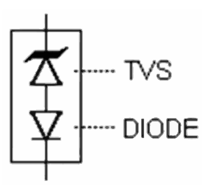
Figure 2: Capacitance vs. Reverse Bias Voltage



At dc operating voltage and low frequencies, the capacitance of a silicon TVS does not affect performance. However, at frequencies of 100 kHz and above, there is a risk of signal attenuation.

For high-frequency or high-data-rate applications, capacitance can be effectively reduced by placing a low-capacitance rectifier chip within the same package in series, but opposite polarity to the TVS chip as shown in Figure 3 (see page 2). With both diodes in series, the total capacitance of both diodes is as low as the capacitance of the rectifier chip. For optimum results in TVS clamping performance during a transient, the rectifier should be ultrafast in forward and reverse recovery characteristics. These low-capacitance configurations are available in one packaged devices by Microsemi. They include the older, but well-established LC and LCE series of TVS devices in metal and plastic axial-leaded packages with 100 pF maximum for 1500 W transient protection, as well as the SAC series with 30 pF maximum for 500 W P_{PP} ratings at 10/1000 µs. There are also plastic surface mount versions available with identical ratings and voltage selections.

Figure 3: Low Capacitance TVS

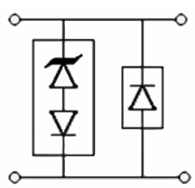


Before this configuration can provide low capacitance, the high capacitance of the TVS avalanche diode has to be charged up with the first signal or data pulses. This is usually not a problem for digital signals like USB or other data ports.

Newer low-capacitance TVS designs using PIN or NIP chips for the low-capacitance rectifier in Figure 3 (see page 2) are also now being introduced in voidless glass packages in both axial-leaded and surface mount for hi-rel applications. With this patented technology, there is lower capacitance relative to package size and P_{PP} ratings, as well as low transient clamping voltage. For example, the 500 W and 1500 W ratings for P_{PP} at 10/1000 µs can be provided with capacitance values of 12 pF and 15 pF respectively. There is also a smaller, newer 150 W–rated low capacitance TVS series at 10/1000 µs with only 4 pF maximum that protects from ESD threats, as well as low-level secondary lightning threats in a smaller glass package with
1N8149 -1N8182(US) part numbers.

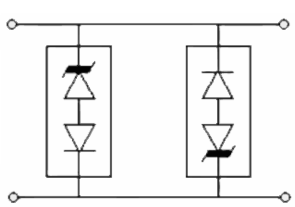
A signal or data line can only be protected from positive transients in Figure 3 (see page 2). For negative transients, an optional unidirectional configuration is recommended, as shown in Figure 4 (see page 3), with a separate low-capacitance rectifier in parallel similar to the low-capacitance rectifier chip inside the low-capacitance TVS except in the opposite direction. This also protects the low-capacitance diode chip inside the low-cap TVS from reverse high-voltage transients. The overall capacitance of this combination will be twice that of the low-cap TVS shown in Figure 3 (see page 2). Consult the factory for the separate low-capacitance rectifier diode if it is not already described in the applicable low-capacitance TVS datasheet.

Figure 4: Optional Unidirectional Low-Capacitance TVS (Low Capacitance TVS and Separate Low-Capacitance Diode in Parallel)



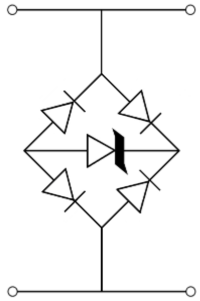
For bidirectional protection involving both positive and negative standoff voltages, two of the-low capacitance TVS devices in Figure 3 (see page 2) are required back-to-back in parallel or what is also often described as an anti-parallel configuration as shown in Figure 5 (see page 3). The capacitance will also be twice that of the individual low-capacitance TVS in Figure 3 (see page 2).

Figure 5: Bidirectional Low Capacitance TVS configuration (2 Low capacitance TVS devices in anti-parallel)



In some bidirectional applications requiring low-capacitance where there are positive and negative signal or data pulses affecting the charging and discharging of the avalanche TVS chip, it is recommended that a low-capacitance steering diode bridge be used for a single TVS to keep it charged (biased) in the same direction as shown in Figure 6 (see page 4) to avoid signal attenuation. These separate steering diodes (4) should also be similar to that used inside the low-capacitance TVS in Figure 3 (see page 2) for the applicable P_{PP} rating. The overall capacitance of this combination in Figure 6 (see page 4) will be approximately the same value as that of the low-cap TVS in Figure 3 (see page 2) when using the same low-capacitance rectifier diodes. Consult the factory for these separate low-capacitance rectifier (steering) diodes. It should also be noted that this low-capacitance TVS bridge configuration also inherently protects the steering diodes from the polarity of high-voltage transients.

Figure 6: Optional Bidirectional configuration (Low Capacitance steering diode bridge with TVS)



All of these described options for 500 W and 1500 W low-capacitance TVS can be used for lightning protection, including aircraft, as may be applicable to the RTCA/DO-160 and “Lightning Induced Transient Susceptibility” in Section 22 as also described in our MicroNotes 130 and 132. Also, special higher power TVS combinations can be generated for low capacitance beyond 1500 W ratings as may be applicable for Waveforms 4 and 5A identified in RTCA/DO-160 for aircraft. Consult the factory for further details on these extended low-capacitance TVS capabilities.

Further options similar to those configurations shown in Figures 4, 5, and 6 are also available in smaller TVS diode arrays with significantly lower P_{PP} and capacitance ratings that are primarily intended for ESD protection.

Support

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