MicroNote 102

An Introduction to Transient Voltage Suppressor Devices

By Kent Walters

Suppressor Device Types

Various Transient Voltage Suppressor (TVS) products limit voltage spikes to acceptable levels by either clamping or crowbar action. A clamp device begins conducting when its threshold voltage is exceeded, then restores to the nonconducting mode when voltage drops below threshold level. Voltage spikes are clipped off to safe levels by clamp devices. Examples include silicon p-n junction or Avalanche Breakdown Diodes (ABDs) that Microsemi provides. Clamping devices also include Metal Oxide Varistors (MOVs). In contrast to this, crowbar devices conduct when threshold voltages are exceeded and then trigger to a lower on-state voltage of only a few volts, hence the name crowbar. These devices restore to nonconduction when driving voltage and/or current is reduced with the passing of the transient. Examples include Gas Discharge Tubes (GDTs) and Thyristor Surge Suppressor (TSS) devices.

Suppressor Structures

MOVs are made up of grains of zinc oxide in a matrix of bismuth and other metal oxides. Each grain boundary is the equivalent of a junction with a breakdown voltage of 2 V to 3 V with the net result equivalent to hundreds of diodes in series and parallel. By varying the grain size, thickness, and area, parameters including current and voltage rating can be controlled. Packaging ranges from chips to large multi-kilovolt units. MOV parameters are symmetrically bidirectional.

Avalanche Breakdown Diodes or ABDs contain a p-n junction similar to a Zener diode but typically with a larger cross-sectional area that helps increase its surge power rating. For longer duration transients, thick metalized contacts and adjacent discs are desirable to absorb heat produced by the transient. Parts are available as chips, axial lead, and surface mount devices. Both voltage and power capability can be increased by stacking parts in combinations of series and/or parallel configurations. Devices are available in unidirectional for dc applications and bidirectional for voltages with positive and negative swings.

Most GDTs have two parallel electrodes in a low-pressure inert gas cavity of glass or ceramic. They are dc voltage rated at a rise-time of 500 V/s. The spacing and size of the electrodes determines the voltage and current ratings respectively. The smallest GDTs are the size of neon lamps, rated at 1 kA for 8/20 µs, up to gallon jug sizes rated at 250 kA. The type primarily seen is the telecommunication variety that is about 3/8” diameter and 1/4” thick.

Thyristors Surge Suppressors or TSSs used for transient suppression are typically semiconductor four-layer (p-n-p-n) devices for unidirectional and five-layer for single-chip bidirectional use. They are small in size for their surge current ratings and are available in axial lead, surface mount, cellular discs, or chips.

Performance

An MOV conducts high-current surges for a limited number of events as they wear out. For example, the maximum rating for a 20 mm disc is normally 6500 A for single surge; however, reducing the surge current to 900 A increases its life to 100 surges. This device is also steady-state power limited: only 1/4 W for a 20 mm disc. Clamping factors (ratio of clamping voltage to breakdown voltage) are about 4 (comparatively high). Failure mode is typically a resistance of 8 Ω–10 Ω.

The ABD devices have sub-nanosecond clamping times and low clamping factors of 1.33, ensuring optimum protection for sensitive microchips. There is no wear out of these silicon p-n junction TVS devices unless used beyond their ratings. Both silicon and MOV TVSs are available over a broad voltage range with silicon devices clamping at a much lower voltage compared to an MOV. Although many are rated at lower surge current levels than MOVs, silicon TVSs are more than adequate for their major uses across signal and low-voltage dc bus lines. High power examples of ABDs can be rated at 36 kW with 10/1000 µs waveforms that can also often be used in aircraft protection from induced lightning effects. Many ABDs offered by Microsemi have V_{WM} voltage ratings of 5 to 170 V with some up to 400 V. Failure mechanisms for ABDs is typically a short circuit (see MicroNote 135).

GDTs are voltage triggered and fire at levels well above their dc-rated voltage. A 90 V dc-rated communication protector will fire at about 500 V in 0.5 µs with a 1 kV/µs voltage risetime event. Silicon TVS are often used with GDTs for low-voltage clamping. Communication type GDTs are rated at 10 kA for 8/20 µs. GDT failure symptoms are high-leakage current with increased firing voltage.

The TSS devices are also voltage triggered to the on-state, making the transition through a turn-on resistance slope. These can be either positive or negative depending on chip design. On-state voltage drops across the device is only a few volts, allowing large surge current conduction by a relatively small chip. Operating voltages range from 20 V up through 250 V with current ratings of 50 A to 200 A for 10/1000 µs. When over-surged, TSSs fail short.

Applications

MOVs are most often used on the power mains to protect downstream electronics and electrical equipment from direct and nearby lightning hits. Many are used in consumer appliances for solid state control protection. Chip MOVs are finding increasing use in computer protection for ESD on less sensitive lines where their higher clamping voltages can be tolerated.

ABDs that Microsemi provides as TVSs are used extensively for protection across sensitive data lines on telecommunication and microprocessor-based monitoring systems. They are also used on personal computers, peripheral equipment I/O ports, and across dc power bus lines. Their sub-nanosecond turn-on times and low clamping makes them effective protectors for electrostatic discharge and other secondary transient sources including lightning protection on aircraft.

GDTs are used largely in the telecom sector for protecting subscriber stations and central office exchanges from primary lightning effects on communication lines. However, they are gradually being replaced by some users with high-current thyristors for longer life expectancy.

TSSs are used in a host of applications, including driver controls for both inductive and resistive loads. Growing uses are in fluorescent lighting ballasts and protection across telecom lines at both primary and secondary levels.

Summary

With the growing influence of electronics in our daily lives, communication, transportation, manufacturing, and office computers, we are becoming more dependent on protective devices for their role in reliability enhancement. MOVs are best suited for protection on power mains, GDTs for high-current protection with higher triggering voltages and less sensitive systems, TSSs where crow-bar action is not a problem that may result in latch-up, and ABDs in a variety of voltage applications at board level.

For additional technical information, contact Design Support at: http://www.microsemi.com/designsupport or Kent Walters (kent.walters@microchip.com at 480-302-1144.

Microsemi
2355 W. Chandler Blvd.
Chandler, AZ 85224 USA

Within the USA: +1 (480) 792-7200
Fax: +1 (480) 792-7277

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