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## AN INTRODUCTION TO TRANSIENT VOLTAGE SUPPRESSOR DEVICES

### 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 TVSs and metal oxide varistors (MOVs).

Crowbar devices conduct when threshold voltages are exceeded and then trigger to an on-state voltage drop of only a few volts, hence the name crowbar. These devices restore to nonconduction when the driving voltage and/or current is reduced with the passing of the transient. Gas discharge tubes (GDTs) and thyristors are crowbar devices.

### Suppressor Structures

Metal oxide varistors 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 to 3 volts, 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 multikiloamp, multikilovolt units. MOV parameters are symmetrically bidirectional.

Silicon avalanche junction TVSs contain a pn junction similar to a zener diode but with a larger cross section, proportional to its surge power rating. For longer duration transients, thick metallized contacts are required to absorb the heat produced by the transient. Parts are available as chips, axial lead and surface mount devices. Long duration pulses can be suppressed by increasing chip size and heat dissipation. Both voltage and power capability can be increased by stacking parts in combinations of series and/or

parallel. Devices are available in unidirectional configuration for dc 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 500V/sec. 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 1kA for 8/20 $\mu$ s, up to gallon jug sizes rated at 250kA. The type primarily seen is the telecommunication variety which is about 3/8" diameter and 1/4" thick.

Thyristors used for transient suppression are typically semiconductor four layer (pnpn) 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 6500A for a single surge; however, reducing the surge current to 900A, increases life to 100 surges. This device is also steady state power limited, only 1/4W for a 20mm disc. Clamping factors (ratio of clamping voltage to breakdown voltage) are about 4. Failure mode is with a resistance of 8-10 Ohms.

Silicon avalanche junction TVS devices have subnanosecond clamping times and low clamping factors of 1.33, ensuring optimum protection for sensitive microchips. There is no wear out of a silicon TVS. 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 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. For example, a 12V rated 600W part

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## Series D002

has an 8/20 $\mu$ s surge capability of 140A. Failure mechanism is short circuit.

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

Thyristors are also voltage triggered to the on-state, making the transition through a turn-on resistance slope which can be either positive or negative depending on chip design. On-state voltage drop across the device is but a few volts, allowing large surge current conduction by a relatively small chip. Operating voltages range from 20V up through 250V with current ratings of 50 to 200A for 10/1000 $\mu$ s. When over-surged, thyristors 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.

Silicon TVSs are used extensively for protection across more sensitive data lines on telecommunication and microprocessor based monitoring systems. They are also used on personal computers and peripheral equipment I/O ports, as well as across dc power bus lines. Their subnanosecond turn-on times and low clamping makes them very effective protectors for electrostatic discharge, and other secondary transient sources.

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.

Thyristors 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 provide high current protection for less sensitive systems while silicon thyristors and TVS devices are used in lower voltage applications at the board level.