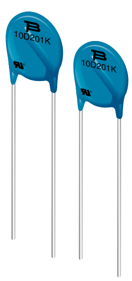
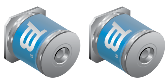
APPLICATION NOTE

Designing Effective Surge Protection for AC and DC Powered Systems

GMOV™ / IsoMOV™ Hybrid Protection Components



Metal Oxide Varistors (MOVs)



Gas Discharge Tubes (GDTs)

Power TVS Products (PTVS Products)

INTRODUCTION

Lightning strikes and electrical switching can inject harmful transients into today's electrical equipment and sensitive electronics. Surges can potentially cause permanent damage to products, data loss, equipment downtime, or in a worst-case scenario, a product recall and associated liability. To protect equipment, it is highly recommended that a Surge Protective Device (SPD) be part of the design.

In a typical SPD, an integrated Surge Protective Component (SPC) is built into an assembly or system that provides the necessary protection functionality. These devices are designed to divert excess current from transients and surges to the ground, thus preventing it from flowing through the electrical equipment.

To help designers find the right surge protection for their AC and DC powered systems, this white paper outlines various protectors and overvoltage technologies currently available. And, since no single protection solution can fit all applications, a list of common trade-offs will also be provided.

SURGE PROTECTIVE DEVICES

There are several Options of technologies or solutions from which a designer can choose to help guard against these types of risks. Choosing a solution that is not a good fit for the application can lead to a costly replacement. Savvy designers consider the cost of "truck rolls" or downtime if a design is not adequately protected against surges. The table below shows the general pros and cons of each option of SPC:

Table 1. Surge Protective Devices

Protector Option	Technology	Current Rating	Peak Pulse Current (8/20 µs)	Typical Voltage Clamping Speeds	Component Lifetime
GDT	Crowbar	Very High	100 kA	Slow	Long
PTVS Diode	Clamp	High	15 kA	Very Fast	Very Long
Varistor (MOV)	Clamp	Medium	80 kA[1]	Fast	Medium
GMOV™ / IsoMOV™ Hybrid Protection Components	Hybrid	Medium	10 kA	Medium	Long

Note 1: *Lists the MOV current rating comparison relative to size is used.*
Although, The MOV can have a peak pulse current up to 80 kA, the size of the MOV will be 5 to 10 times the size of a typical PTVS diode.

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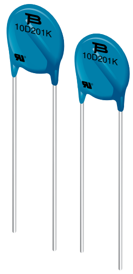

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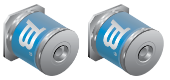

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OVERVOLTAGE PROTECTION TECHNOLOGIES - THREE MAIN OPTIONS

There are three main option of overvoltage protection (OVP) technologies that a designer must consider:

Option 1 - Voltage Switching (Crowbar)

When the transient reaches the breakdown voltage level, the protection device will switch from high impedance to a very low impedance (see Figure 1). This change will temporarily short out the line until the fault extinguishes. It is not recommended to have a single GDT across an AC line. This is due to the GDT being unable to extinguish the follow-on current without some sort of circuit to assist. Follow-on current is defined as current that continues to flow even after the fault has been extinguished. Sometimes it is also referred to as "Holdover."

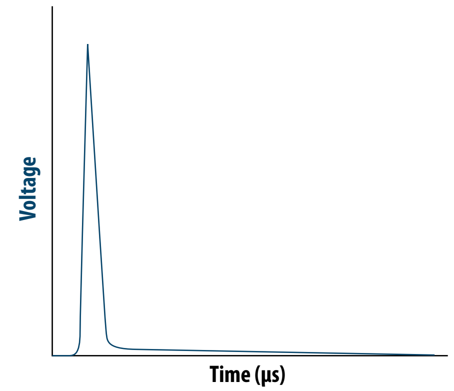

Figure 1. Voltage switching from high impedance to a very low impedance

A GDT is commonly used in DC circuits, telecommunication circuits and signal circuits. In most cases, these circuits are very low current (below 1 A). A simple schematic illustrating the use of a GDT is shown below in Figure 2.

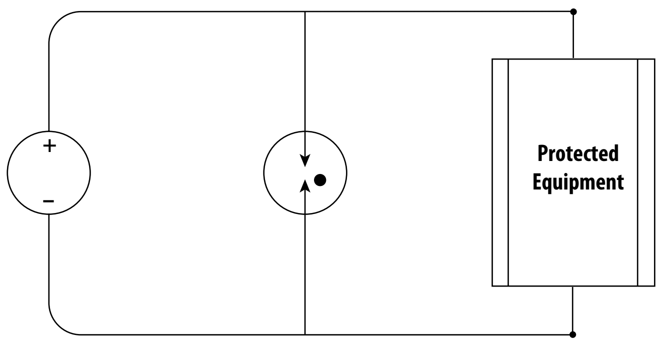

Figure 2. Schematic illustrating the use of a GDT

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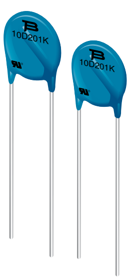
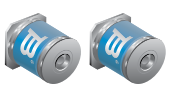


Metal Oxide Varistors
(MOVs)



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Option 1 - Voltage Switching (Crowbar) - Continued

When protecting an application that uses more than 1 A of current, a stacked GDT might be required (see Figure 3). Because a GDT will not fully crowbar (fully short), it has what is called "arc voltage", which is nominally around 10 to 20 V. So, if the operating voltage is higher than this arc voltage and is capable of currents greater than 1 A, a stacked GDT (or multiple GDTs in series) would be required. For example, a 48 V system with 10 A of operating current may need to stack five GDTs, which would have about 60 V of "arc voltage" (five GDTs x 12 V of arc). An ideal solution for this example is the Bourns® Model 2033-80 (800 V) or 2033-140 (1400 V) GDT. These stacked GDTs are designed for surge currents up to 20 kA.

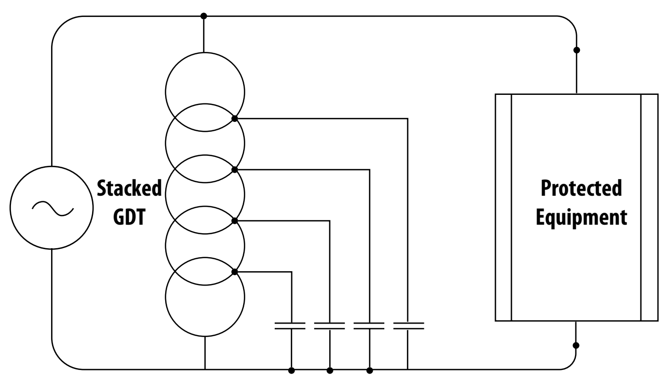

Figure 3. Schematic illustrating the use of a Stacked GDT

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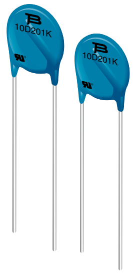

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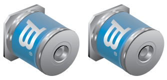

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Option 1 - Voltage Switching (Crowbar) - Continued

Impulse voltage is defined as a fast rate of voltage rise that is in the microsecond range (i.e., 1 kV/µs). In order to keep the impulse voltage low and maintain let-through voltage at a low breakdown level, a capacitor scheme may need to be installed. Let-through voltage is defined as the voltage level experienced by the equipment. Without an installed capacitor scheme, the stacked GDT let-through voltage would be in excess of 2 kV. With the capacitor scheme, the let-through voltage can be reduced to the 1 kV level. Further information can be found in this Bourns datasheet (https://www.bourns.com/docs/product-datasheets/2033.pdf). If the current requirement exceeds 20 kA, it is recommended that discrete GDTs be installed in series to act as a discrete stacked GDT. Bourns offers GDTs with ratings from 40 kA (Bourns® Model 2047) to 100 kA (Bourns® Model 2063).

For an AC application, a stacked GDT with the capacitor scheme may be employed (see Figure 3). The zero-crossings of the AC voltage will extinguish the follow-on current. Since the arc voltage can be as high as 100 V, it has sufficient time to extinguish. In contrast, a single GDT has an arc voltage of approximately 20 V and by the time the GDT is ready to extinguish, the next half-cycle is already present, so the single GDT is not sufficient to stop the continuation of the follow-on current. (see Figure 4).

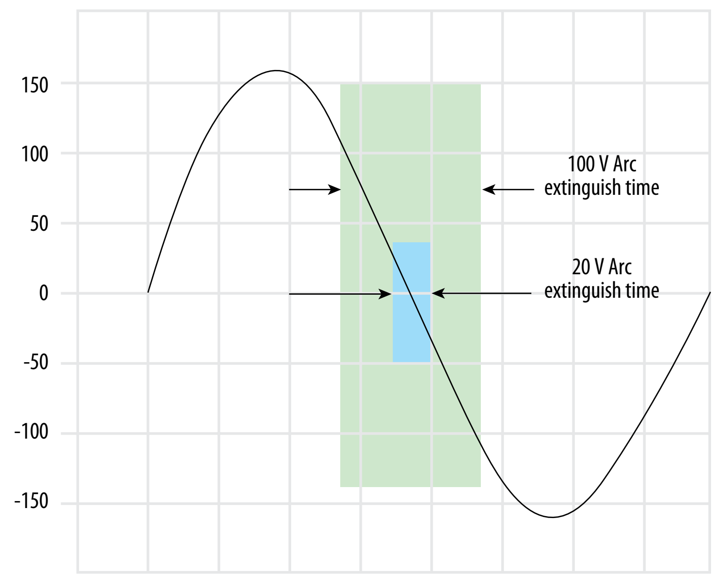

Figure 4. Arc extinguishing times: 20 V vs. 100 V

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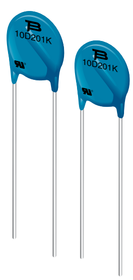

Metal Oxide Varistors
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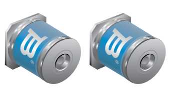

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Option 2 - Voltage Limiting (Clamping)

When the transient voltage reaches the limiting level, the protection device will clamp the voltage (see Figure 5) until the fault extinguishes. Once the transient is extinguished, the line will return to normal operation. It is important to choose devices with a clamping voltage higher than the normal operating voltage. A Power TVS diode (PTVS diode) or a Metal Oxide Varistor (MOV) are commonly used for high current protection in both AC and DC circuits, motors, communication liines and sensing circuits. A PTVS diode typically has a very long lifespan when operated within its specified rating. Varistors, however, are known to deteriorate over time when subjected to a bias voltage as well as variations in temperature.

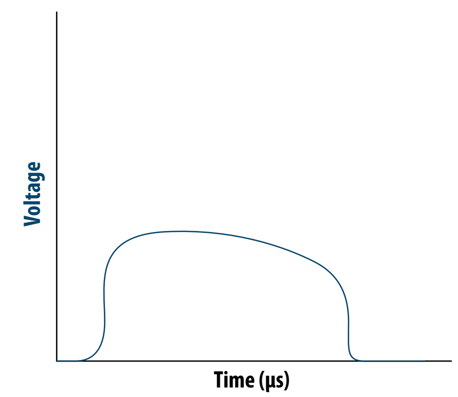
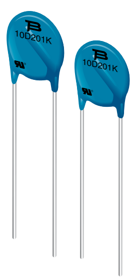


Figure 5. | Transient voltage limit level

While both PTVS diodes and MOV devices have leakage current which typically exceeds 1 µA, the MOV is more susceptible to issues arising from increases in the leakage current. As the MOV's effectiveness deteriorates due to bias voltage and temperature, its leakage current will start to increase until a thermal runaway condition occurs, creating a hazardous situation. The PTVS diode is very stable and does not typically exhibit the aging effect that is common with an MOV.

GMOV™ / IsoMOV™ Hybrid Protection Components



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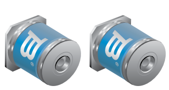

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Option 2 - Voltage Limiting (Clamping) - Continued

PTVS Diodes

Bourns offers a PTVS diode that features up to a 15 kA voltage rating (Bourns® Model PTVS15), and an MOV is available with an 80 kA voltage rating (Bourns® Model ZOVxxxK60). Because an MOV's voltage rises with current (as shown in Figure 9), it can be placed in parallel to increase the surge rating. Keep in mind, though, that the MOVs will not share current equally. The MOV that clamps first will sustain more current until the voltage rises higher than the next MOV's voltage clamping limit. In contrast, a PTVS diode, since it clamps and holds at a designated level, will sustain the full surge current up to the designated level while the parallel unit will not experience enough voltage to clamp.

The schematic below in Figure 6 illustrates shows how a PTVS diode or MOV can be used to protect equipment.

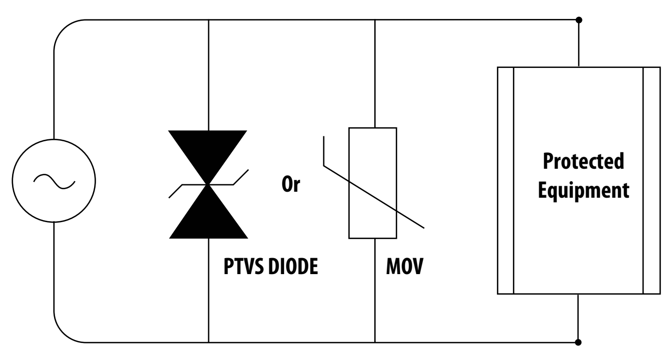

Figure 6. | *Schematic illustrating the use of a PTVS Diode or MOV*

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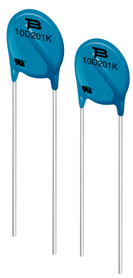

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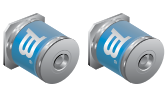

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Option 3 - Voltage Crowbar/Clamping Hybrid

Using a hybrid solution (a combination of a crowbar and clamping solution) allows for virtually no leakage current and a longer operational life. The hybrid device combines two discrete components (series connected GDT and MOV) to achieve this result.

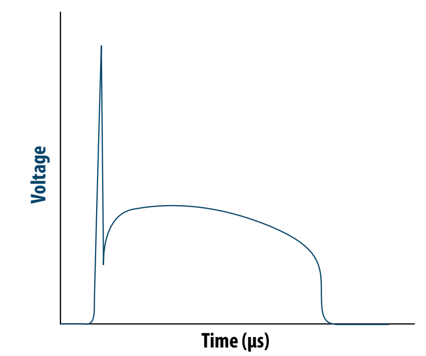

Figure 7. | Initial hybrid combination voltage

Bourns is an industry leader for integrated circuit protection solutions such as the GMOV™ hybrid protection component and Bourns' latest IsoMOV™ device. Both devices have been designed to offer much longer operational life than a varistor alone and without the follow-on current problems of a GDT. Bourns® GMOV™ and IsoMOV™ surge protectors are excellent solutions for AC and DC circuits, motors, or high-speed communication lines for both low and high current circuits. The GMOV™ and IsoMOV™ protectors have very low inherent capacitance, which allows a Power Line Communication (PLC) or high speed circuit to be utilized.

In the hybrid combination, the initial voltage (referred to as Front Protection Voltage (or Vfp) on the Bourns data sheet) may be high (see Figure 7), although the current flow during that initial rise is very low. This Vfp is typically seen when the component is surged by itself as a standalone device. The peak subsides substantially when there is a load (i.e., equipment) connected to it.

Bourns® GMOV™ and IsoMOV™ protectors have the same footprint as a standard MOV and are drop-in replacement, eliminating the need to re-spin the PCB. In the Figure 8 schematic below, two discrete components are shown in the circuit. These can be replaced by a single GMOV™ or IsoMOV™ protector. The GMOV™ and the IsoMOV™ surge protectors feature peak current ratings of 10 kA and 12 kA, respectively.

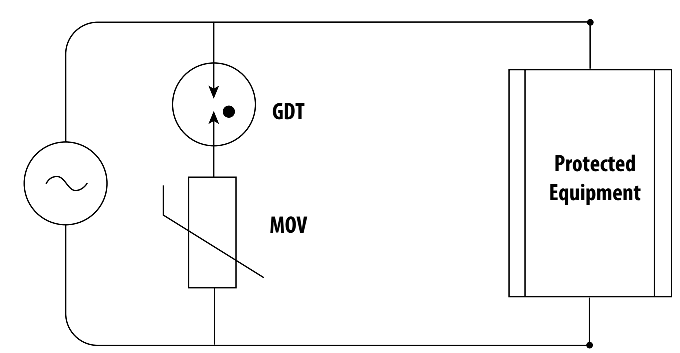

Figure 8. | Schematic illustrating two discrete components in a circuit

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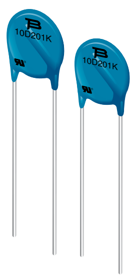

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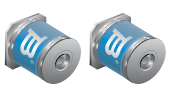

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SURGE PROTECTION COMPONENT TRADE-OFFS

Designers have come to realize that not all protection circuits are equal, and compromises are often necessary when choosing any one of the solutions previously discussed. Table 2 lists the common trade-offs of each technology.

Table 2. Surge Protective Device Common Trade-offs

Protector Option	Effectiveness	Availability	Pricing
GDT	Medium	Now	Low
PTVS Diode	Best	Now	High
Varistor (MOV)	Medium	Now	Low
GMOV™ Hybrid Protection Components	Best	Now	Medium
IsoMOV™ Hybrid Protection Components	Best	Now	Medium

SELECTING THE RIGHT SURGE PROTECTION COMPONENT

A GDT has high let-through voltage, but as long as the equipment's insulation breakdown voltage is higher than the impulse voltage of the GDT, the circuit will not experience a high surge current. The GDT will crowbar and divert the current away from the main circuit.

PTVS devices offer very quick response times and can absorb relatively high current. These devices are well-suited to protect very sensitive equipment where cost is of lesser concern. An MOV, too, has a very quick response time, but its clamping voltage will rise with current (see Figure 9). Unlike a PTVS device, an MOV will deteriorate when experiencing bias voltage across the device.

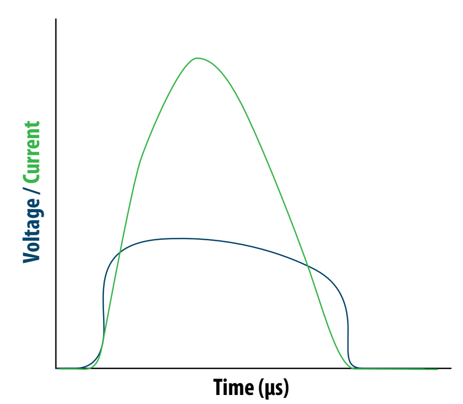
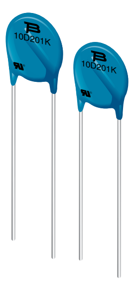


Figure 9. MOV Response time

Hybrid protectors such as the Bourns® GMOV™ and IsoMOV™ devices have been innovatively designed with an MOV and GDT in series. Offering long life solutions with virtually no leakage current, the latest protectors from Bourns take advantage of each component's strong attributes while reducing their inherent weaknesses.

GMOV™ / IsoMOV™
Hybrid Protection Components



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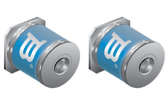
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CONCLUSION

Choosing the right protection solution may seem simple, but with so many standards to review for compliance, it can be confusing. Look to Bourns for support in helping to select the right protection option or technologies to use. Please contact one of Bourns' FAEs for further details. Bourns has the expertise to assist you in meeting your protection requirements.

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