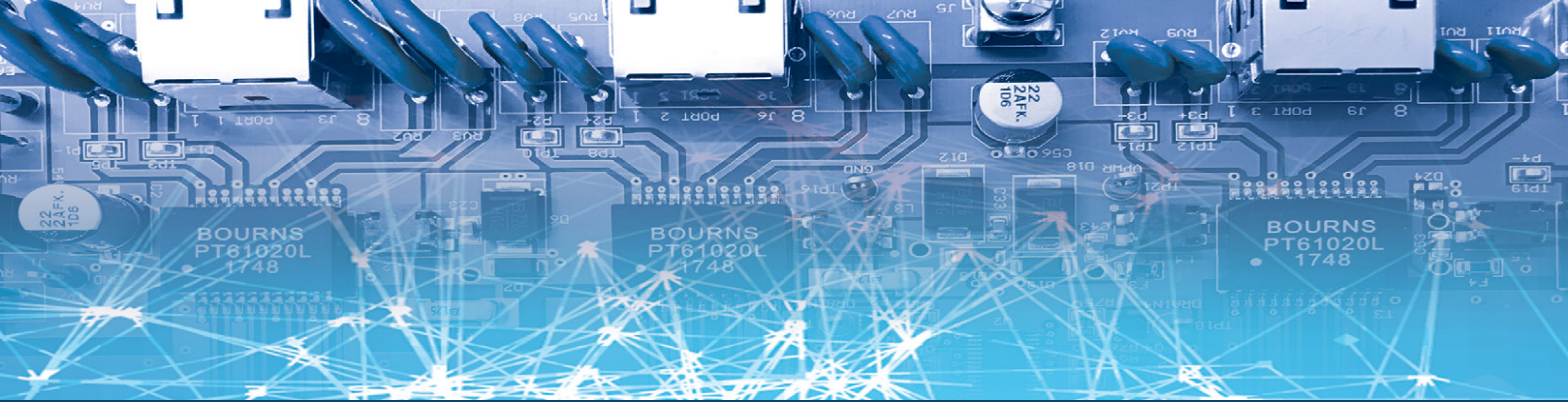
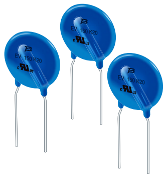


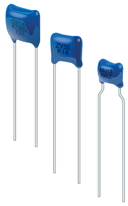
# Tips on Selecting the Right MOV Surge Suppressor

WHITE PAPER

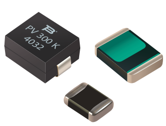
Bourns® Through-Hole Metal Oxide Varistors (MOVs)



Bourns® EdgMOV™ Components



Bourns® Through-Hole Multilayer Varistors (MLVs)



Bourns® Surface Mount Multilayer Varistors (MLVs)

## INTRODUCTION

Metal Oxide Varistors (MOVs) are bidirectional and non-linear surge suppressor devices that are widely used for limiting voltage during a surge or transient event in a broad variety of applications. These highly reliable and robust overvoltage protection devices are available in multiple form factors and surge protection ranges. To help designers select the right MOV that meets their application requirements, this white paper provides tips on the features and specifications to help them narrow down their search.

## MOV OPERATIONAL BASICS

As stated above, an MOV is non-linear device, which means its characteristics will not vary gradually, but instead suddenly when the voltage is at or exceeds its parameters.

An MOV also features non-ohmic current-voltage characteristics that are similar to that of a diode. In contrast to a diode, however, an MOV has the same characteristic for both directions of traversing current.

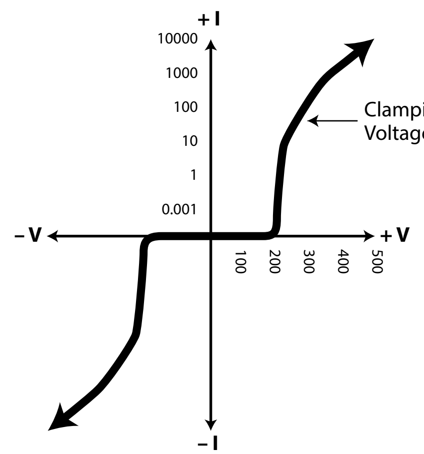
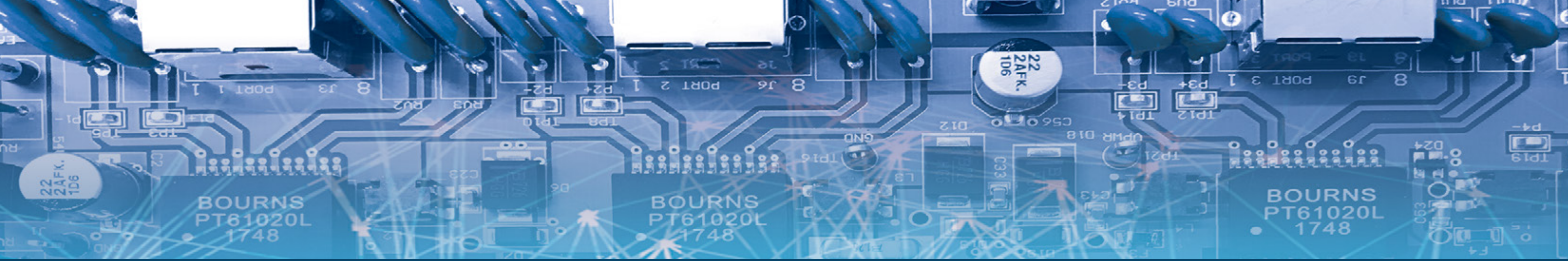
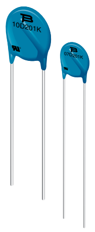


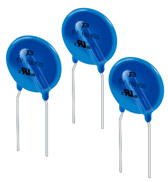

*Figure 1 - This graph shows the sudden voltage clamping during a surge event that exceeds the MOV's parameters.*



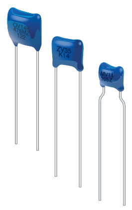




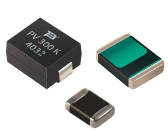
Bourns® Through-Hole Metal Oxide Varistors (MOVs)



Bourns® EdgMOV™ Components



Bourns® Through-Hole Multilayer Varistors (MLVs)



Bourns® Surface Mount Multilayer Varistors (MLVs)

## MOV OPERATIONAL BASICS (Continued)

The MOV is known for handling surge current effectively, but not for long durations. The surge rating for MOVs is measured in microseconds. The industry standard for an MOV is 8/20 µs where the current rises to a minimum of 90 percent of peak (T1) within 8 µs and 50 percent of current decay at 20 µs (T2) as shown in Figure 2 below.

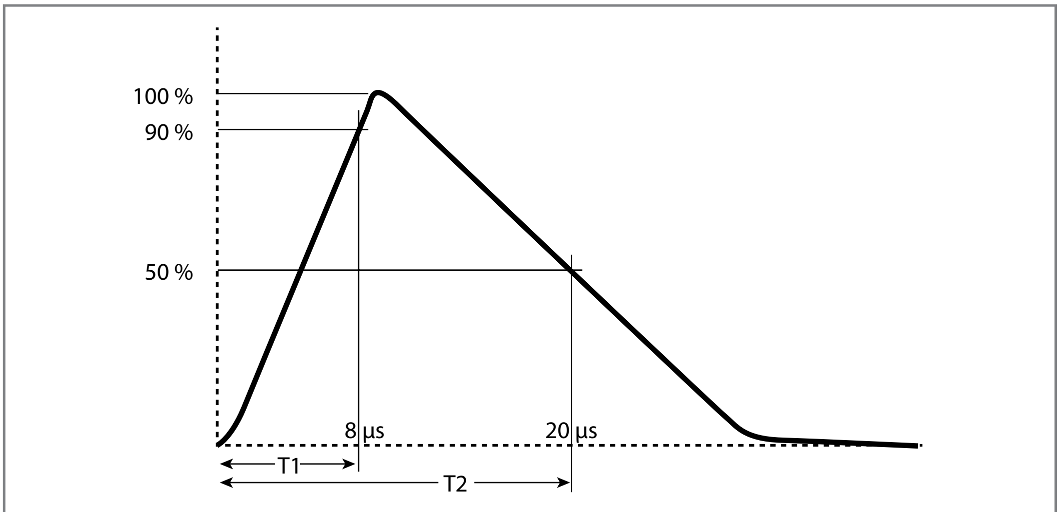
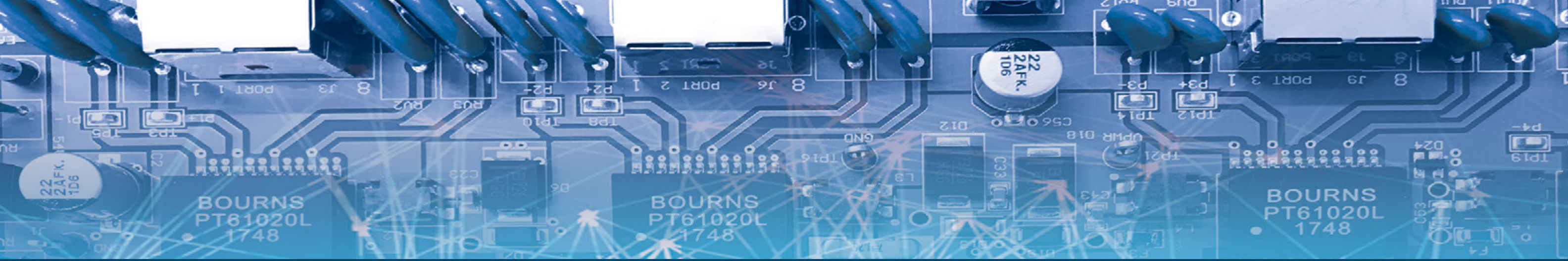



*Figure 2 - For an industry standard MOV with a surge rating of 8/20 µs, the current rises to a minimum of 90 % of peak (T1) within 8 µs and 50 % of current decay at 20 µs (T2).*

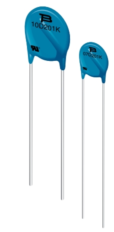
If the overvoltage event is long-lasting, the MOV will start to heat up, which can lead to a thermal runaway condition. A thermal runaway situation can cause the internal grains of the MOV to fuse together and could burn or damage the component. For this reason, a fuse, thermal disconnect, or Gas Discharge Tube (GDT) in series to protect the MOV is recommended.

The impedance of an MOV is nominal between megohms to hundreds of megohms until the voltage reaches the parameter threshold. For example, a 300 Vdc rated clamping voltage ($V_C$) will have virtually no current flowing (impedance in hundreds of megohms) until the source voltage reaches near the boundary of 300 Vdc. Once the voltage reaches approximately 300 Vdc, the MOV will start to conduct approximately 1 mA (impedance roughly 300 kOhms). As the voltage increases, the MOV starts to clamp the voltage. The current also increases as the impedance of the MOV starts to drop. The MOV does not clamp the voltage on a constant basis. As the current through the device rises, so does the clamping voltage.

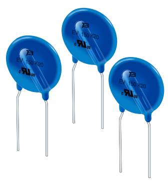
MOV manufacturers rate their MOV either AC, DC, and/or Maximum Continuous Operating Voltage (MCOV). However, MOV manufacturers list their varistor voltage using 1 mA DC based on regulatory standards such as IEC 61643-331.



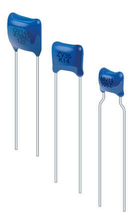
# Tips on Selecting the Right MOV Surge Suppressor



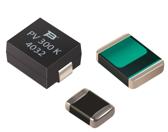
[Bourns® Through-Hole Metal Oxide Varistors (MOVs)](#)



[Bourns® EdgMOV™ Components](#)



[Bourns® Through-Hole Multilayer Varistors (MLVs)](#)



[Bourns® Surface Mount Multilayer Varistors (MLVs)](#)

## WHAT IS THE BEST APPROACH IN SELECTING AN MOV?

**First Step:** Determine the application's surge requirement.
Typically, the MOV data sheet will state the $I_{max}$ (Maximum Current). For example, a 10 mm MOV disc is rated about 3 kA based on the 8/20 µs, a 14 mm MOV disc is rated about 6 kA and a 20 mm MOV disc is rated about 10 kA. The higher the surge rating requirement, the larger the MOV diameter needs to be.

In a square MOV, the surge rating is a little higher. For example, a 10 mm square MOV will be rated at about 3.5 kA, a 14 mm square MOV is rated about 8 kA and so on. The square MOV can handle more current as it has a larger area.

But instead of looking at $I_{max}$, a designer should focus on the $I_{nom}$ (Nominal Current) as most regulatory standards require testing the device based on this rating. For instance, UL 1449 does not require a test of $I_{max}$. To be considered a Type 1 Surge Protection Device (SPD), the SPD must be rated at a minimum of 10 kA $I_{nom}$. A Type 2 SPD needs to have an $I_{nom}$ of 5 kA.

**A good rule of thumb for selecting an MOV is for the $I_{nom}$ to be typically half of its $I_{max}$ rating.**

So, if a 20 mm MOV has a rated $I_{max}$ at 10 kA, the MOV probably has a rated 5 kA $I_{nom}$. It is important to note that not every manufacturer rates their MOVs in the same way. For example, size categories may differ where some manufacturers may offer 18 mm MOVs and others may offer 21 mm MOVs, yet both MOVs are classified in the 20 mm category.

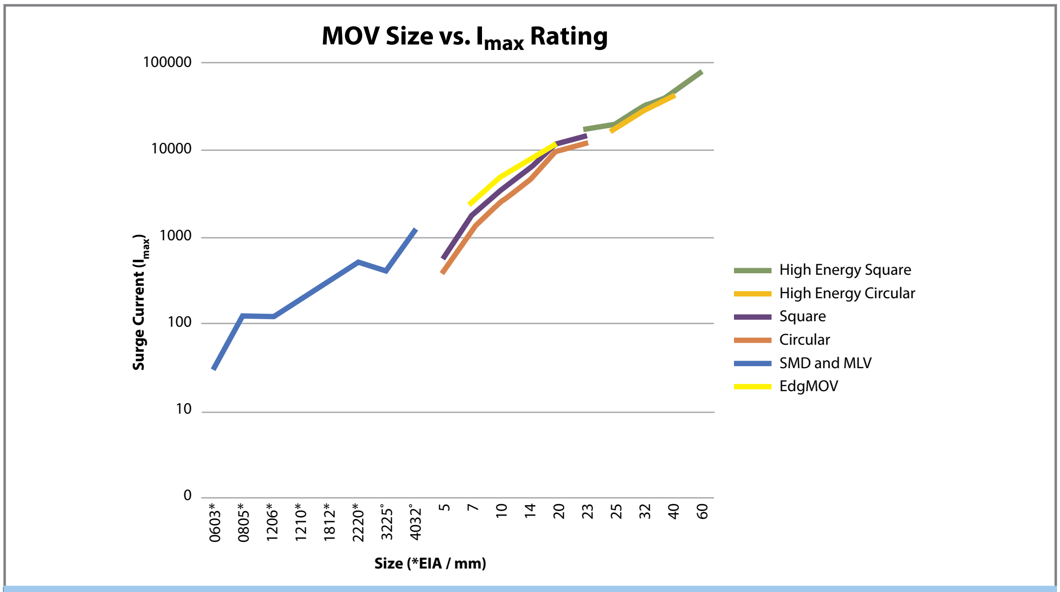
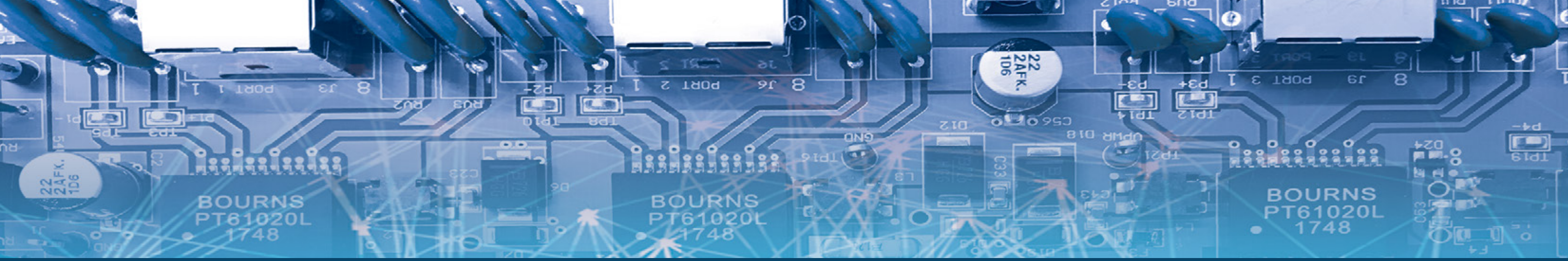
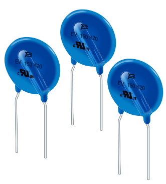



*Figure 3- The graph shows the various ratings for different types and sizes of MOVs.*



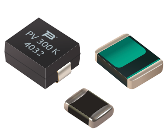

# Tips on Selecting the Right MOV Surge Suppressor

[Bourns® Through-Hole Metal Oxide Varistors (MOVs)]



[Bourns® EdgMOV™ Components]

[Bourns® Through-Hole Multilayer Varistors (MLVs)]



[Bourns® Surface Mount Multilayer Varistors (MLVs)]

## WHAT IS THE BEST APPROACH IN SELECTING AN MOV? (Continued)

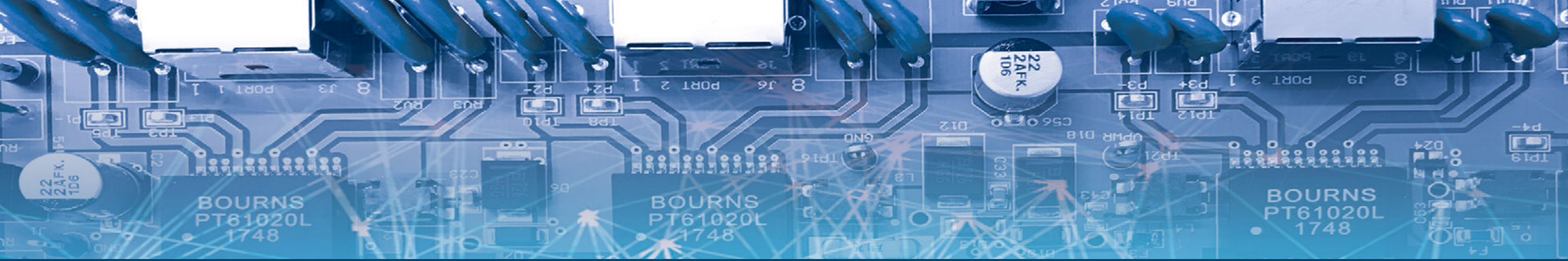
**Example:**
A designer wants to protect equipment that normally plugs into the 120 Vac outlet for residential use. The Bourns website lists multiple varistor product options: Through-Hole, SMD, High Energy, Hybrid, and AEC-Q compliant components. The basic selection is a through-hole MOV, and Bourns offers a wide variety to choose from. In this example, the equipment needs to pass a regulatory requirement of 3 kA. Therefore, designers should look at all the available peak single pulse $I_{max}$ ratings of a minimum of 6 kA (remember the rule of thumb for $I_{nom}$?). The list of possible MOV choices is now smaller.

**Second Step:**
Determine the operating voltage and the application's maximum peak voltage.
Using an example of equipment rated for 120 Vac (170 $V_{peak}$) and given that the typical temporary or swell voltage may go up to 20 percent (144 Vac), then a minimum of a 150 Vac or 220 Vdc rated MOV would be appropriate in these circumstances. As the MOV voltage is proportional to the thickness of the material, the thicker the MOV, the higher the voltage rating.

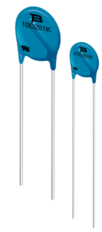
**Third Step:**
Determine if there are any special requirements such as operating temperature.
Using the equipment example above that is built for residential use, an MOV with an operating temperature between -40 °C and +85 °C would be adequate. Higher temperature environments will require higher temperature ratings.

**Fourth Step:**
How high of a clamping voltage ($V_c$) can the protected equipment tolerate?
Manufacturers of MOVs, by default, rate their clamping voltage at 1 mA. The metal zinc oxide in an MOV starts to conduct at 1 mA.

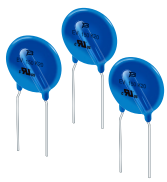
The metal zinc oxide in an MOV starts to conduct at 1 mA. Some manufacturers also give the rating based on IEC 61051-1 for Class Current Rating which is typically 10 % of the peak current ($I_{max}$). Since most data sheets do not list the clamping voltage at either $I_{nom}$ or $I_{max}$, it is up to the customer to conduct their own due diligence and review the graph (example in Figure 4) when determining their clamping voltage requirement.



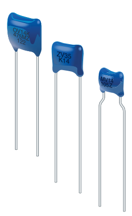




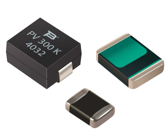
Bourns® Through-Hole Metal Oxide Varistors (MOVs)



Bourns® EdgMOV™ Components



Bourns® Through-Hole Multilayer Varistors (MLVs)



Bourns® Surface Mount Multilayer Varistors (MLVs)

## WHAT IS THE BEST APPROACH IN SELECTING AN MOV? (Continued)

As the current increases, so does the clamping voltage as shown in the figure 4 graph below. MOVs are traditionally assigned a nominal rating at the voltage where the current achieves a 1 milliampere level. At voltages below this rating, the currents are considered leakage currents. Above this voltage rating, the MOV is considered to be in a protecting state and exhibiting a clamping voltage. As can be seen in figure 4, increasing currents result in increasing clamping voltages.

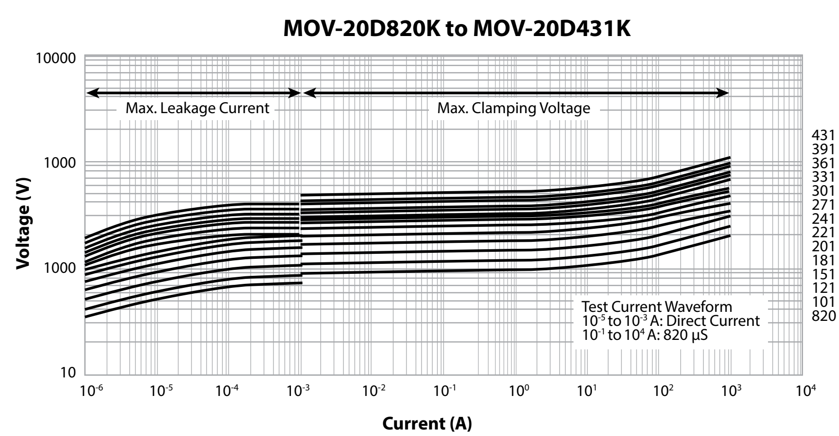



*Figure 4- MOV-20D820K to MOV-20D431K*

Since figure 4 is populated it may be difficult to discern the clamping voltage results. To make it easier to view, figure 5 shows an MOV that is 10 mm with a rating of 200 Vdc.

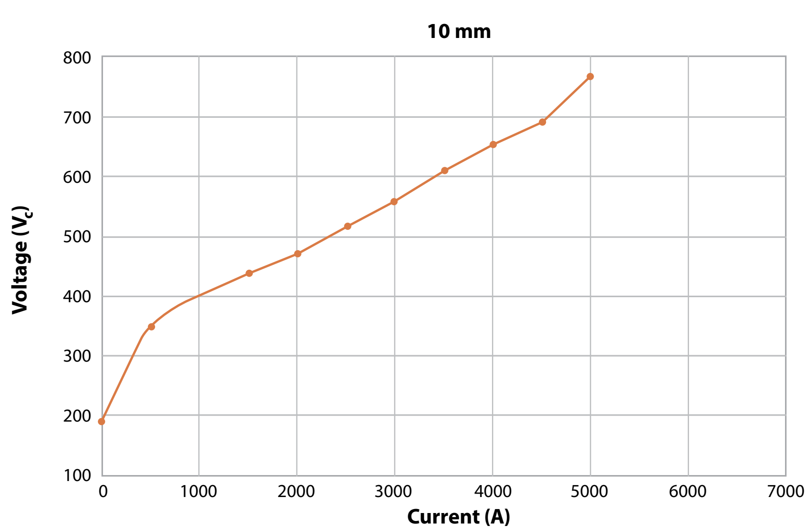
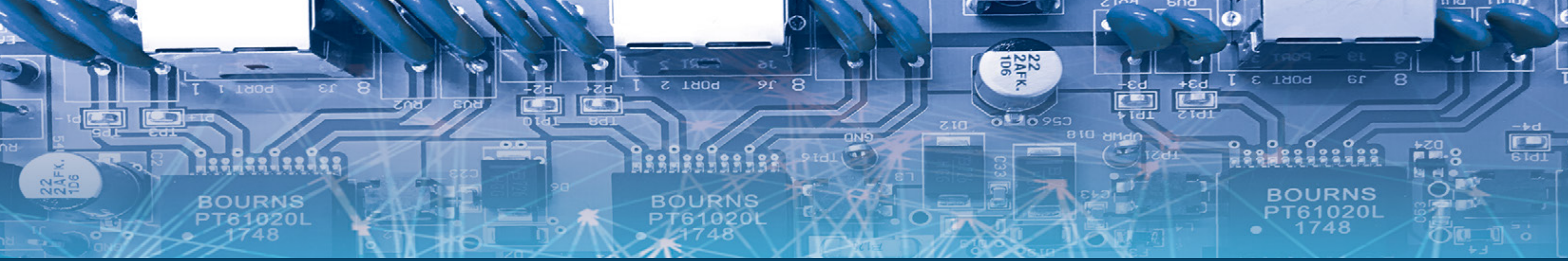
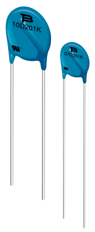


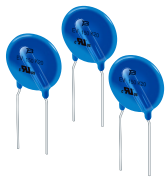

*Figure 5- This graph shows the clamping voltage of a 10 mm MOV with a rating of 200 Vdc.*



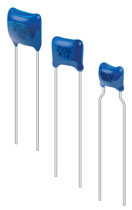
# Tips on Selecting the Right MOV Surge Suppressor



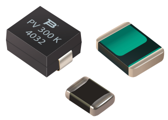
[Bourns® Through-Hole Metal Oxide Varistors (MOVs)]



[Bourns® EdgMOV™ Components]



[Bourns® Through-Hole Multilayer Varistors (MLVs)]



[Bourns® Surface Mount Multilayer Varistors (MLVs)]

## WHAT IS THE BEST APPROACH IN SELECTING AN MOV? (Continued)

When measured at 1 mA, the component is measured at 188 V. With 500 A, the component now clamps at 350 V. At 5000 A, the component clamps at 750 V. The questions a designer needs to ask are: Would the protected equipment be able to tolerate current at that level? Would this level of clamping voltage cause any premature dielectric breakdown within the equipment?

To reduce the clamping voltage, a larger disc or higher rated MOV can be used. In figure 6, we find three MOVs (10 mm standard MOV, 20 mm standard MOV, and 20 mm EdgMOV™ varistor) which were selected to be around 450 V at 1 mA. At 3500 A (maximum rating of 10 mm MOV), the 10 mm standard MOV is clamping over 1100 V while the 20 mm standard MOV is clamping at 950 V and the EdgMOV™ device is clamping at 850 V. At 6500 A (maximum rating of most 20 mm MOVs), the 20 mm MOV is clamping over 1100 V while the EdgMOV™ varistor is below 1000 V. While there are some specialty 20 mm MOVs that have a high maximum rating of 10000 A, the 20 mm EdgMOV™ component has an $I_{max}$ rating of 12000 A.

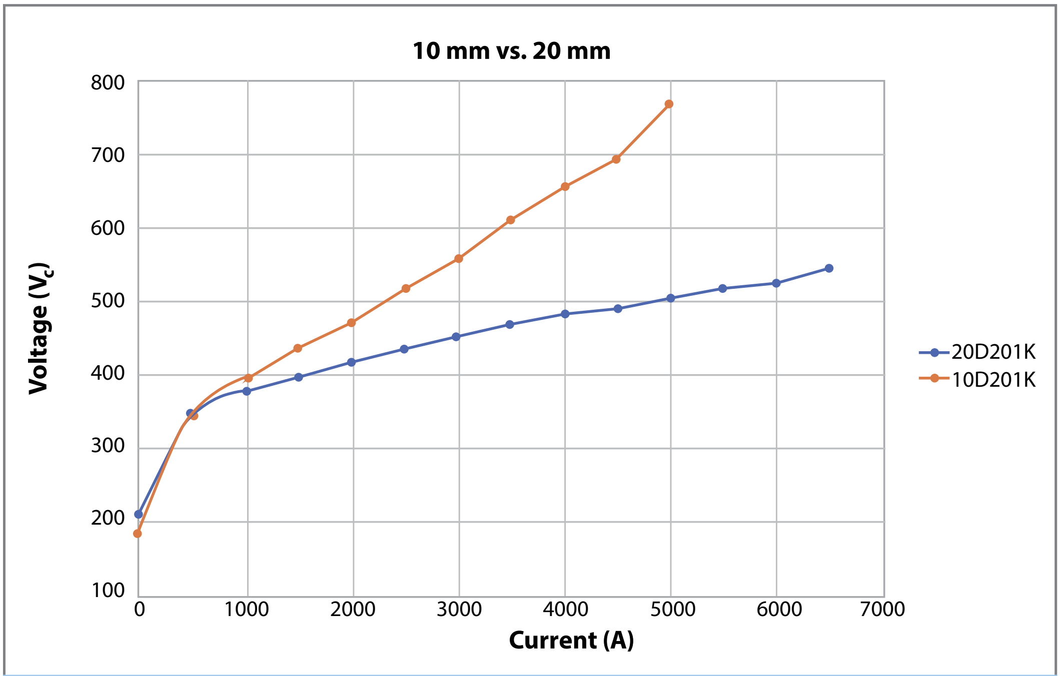
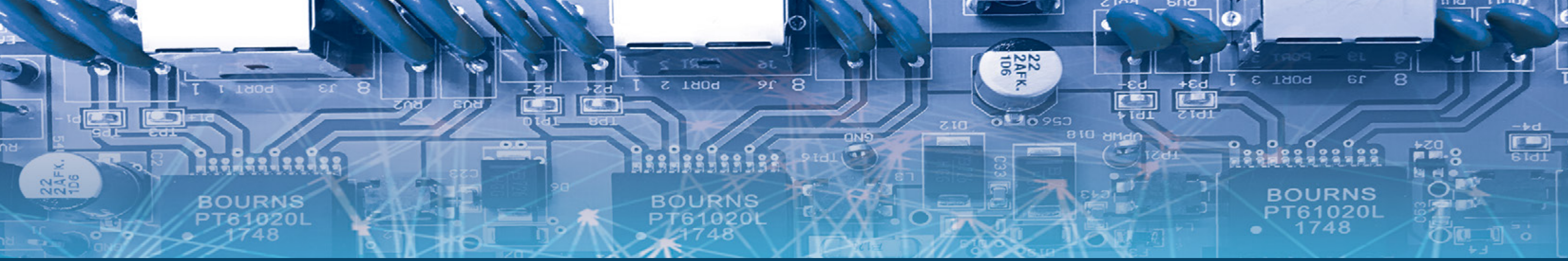
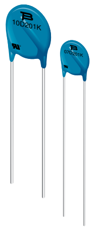


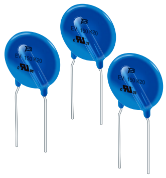

*Figure 6- Shows that at 5000 A, the 20 mm disc is only clamping at approximately 500 V.*





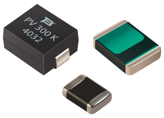


Bourns® Through-Hole Metal Oxide Varistors (MOVs)



Bourns® EdgMOV™ Components

Bourns® Through-Hole Multilayer Varistors (MLVs)



Bourns® Surface Mount Multilayer Varistors (MLVs)

## WHAT ABOUT PUTTING MOVS IN PARALLEL?

When putting MOVs in parallel, they decrease the clamping voltage and they do increase the surge rating, but it is not always double. That result is because the two MOVs do not share the surge current equally. A good designer tip is to start with the 60/40 rule, which means that the first MOV that reacts to a surge probably needs to handle 60 percent of the total surge. For example, when placing two 20 mm MOVs in parallel where each has an $I_{nom}$ rating of 5 kA, in order for the MOVs not to exceed their ratings and using the 60/40 rule, the maximum surge of the parallel rating is 8.3 kA (5 kA / 60 %). Based on this analysis, the first MOV in the parallel model will most likely sustain the 5 kA while the second MOV will sustain the remaining 3.3 kA for a very short period of time before they are eventually equally shared. If the MOV's voltages are matched, a 55/45 rule can typically be applied. This would give them roughly a 9 kA rating, but that would increase the cost due to extra binning of the MOV, affecting the yield.

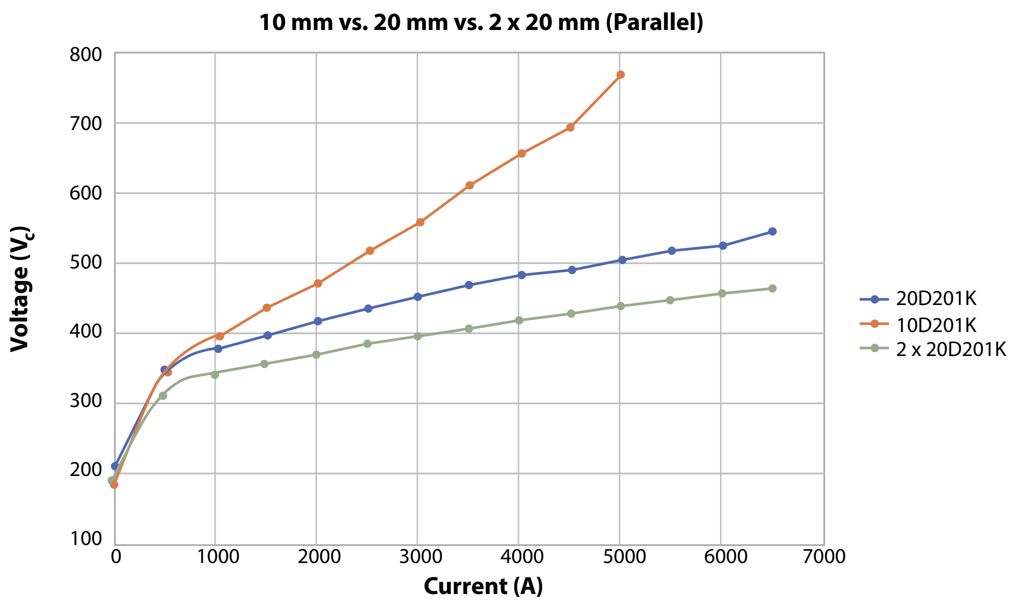
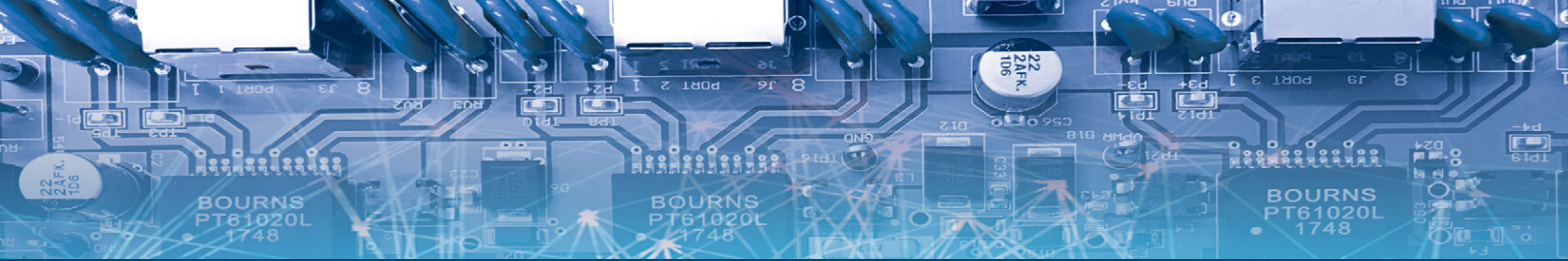
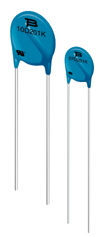


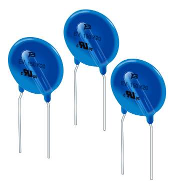

*Figure 7- The graph demonstrates an improvement to the clamping voltage when two MOVs are put in parallel (green line).*



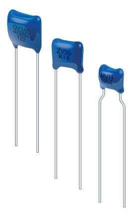




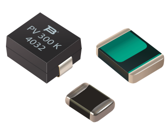
Bourns® Through-Hole Metal Oxide Varistors (MOVs)



Bourns® EdgMOV™ Components



Bourns® Through-Hole Multilayer Varistors (MLVs)



Bourns® Surface Mount Multilayer Varistors (MLVs)

## WHAT ABOUT MLVS?

A good alternative to putting MOVs in parallel is to use an MLV (Multi-Layer Varistor). MLVs are constructed of many layers of MOVs stacked on top of one another. They inherently provide matched voltage. Here is an example of the structure:

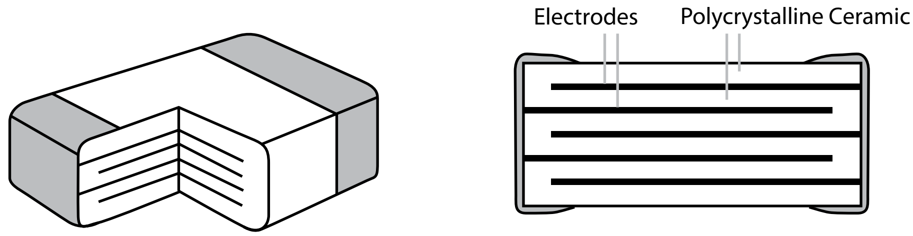



*Figure 8- The structure of an MLV stacks MOVs on top of one another. This diagram shows six MOVs in parallel.*

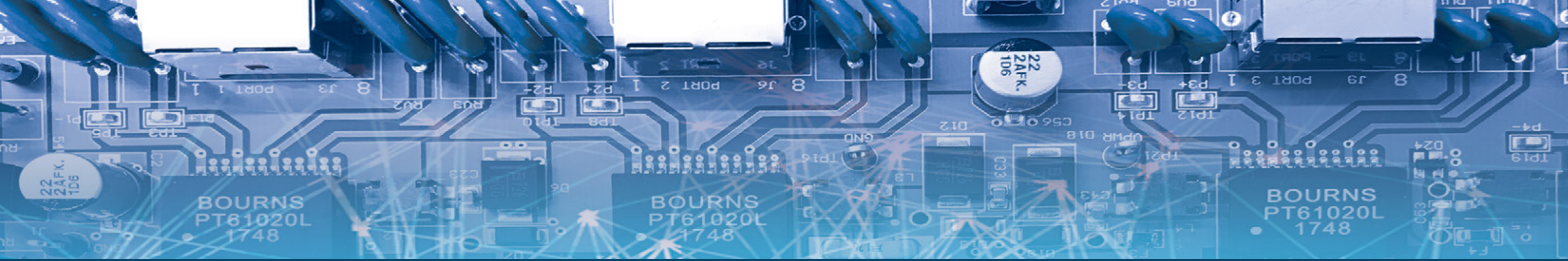
An MLV is typically offered in the 2220 size package. With an $I_{max}$ rating of 2 kA, an MLV can easily outperform a single layer MOV in a 4032 package that is twice its size ($I_{max}$ rating = 1200 A). Due to their small size, most MLVs are low voltage; typically rated under 200 V at 1 mA.

**Example:**
Continuing to use the residential equipment application example, it requires a minimum of 3 kA on a 120 Vac line with normal operating temperature between -40 °C to +85 °C. An optimal solution would be the Bourns® EdgMOV™ Model EV Series with AC voltage of 150 $V_{rms}$.

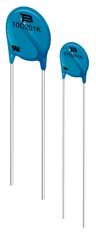
**Another example:**
A designer requires a UL listed Type 2 SPD with a 10 kA rating. By using two 150 Vrms 20 mm EdgMOV™ devices with 8 kA nominal current ratings, the rating can easily handle 13 kA when considering the 60/40 rule of thumb.

Or, two model CVQ series MOVs with 150 $V_{rms}$, with a 10 percent tolerance in a 20 mm diameter package in parallel.

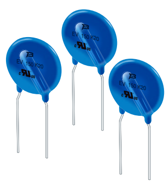
Each has an $I_{max}$ of 12 kA, which when put in parallel and using the rule of thumb for $I_{nom}$ (6 kA / 60 %), each solution would pass the 10 kA rating.



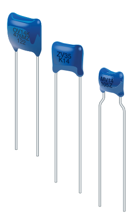




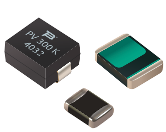
Bourns® Through-Hole Metal Oxide Varistors (MOVs)



Bourns® EdgMOV™ Components



Bourns® Through-Hole Multilayer Varistors (MLVs)



Bourns® Surface Mount Multilayer Varistors (MLVs)

## AVOIDING FAILURE MODE

A catastrophic failure occurs from not successfully limiting a very large surge from an event like a lightning strike, where the energy involved is many orders of magnitude greater than the varistor can handle. Follow-through current resulting from a strike may melt, burn, or even vaporize the varistor. This thermal runaway is due to a lack of conformity in individual grain-boundary junctions, which leads to the failure of dominant current paths under thermal stress when the energy in a transient pulse is too high (i.e., significantly exceeds the manufacturer's "Absolute Maximum Ratings").

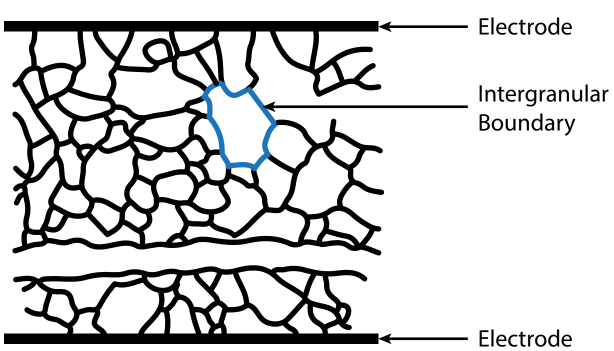
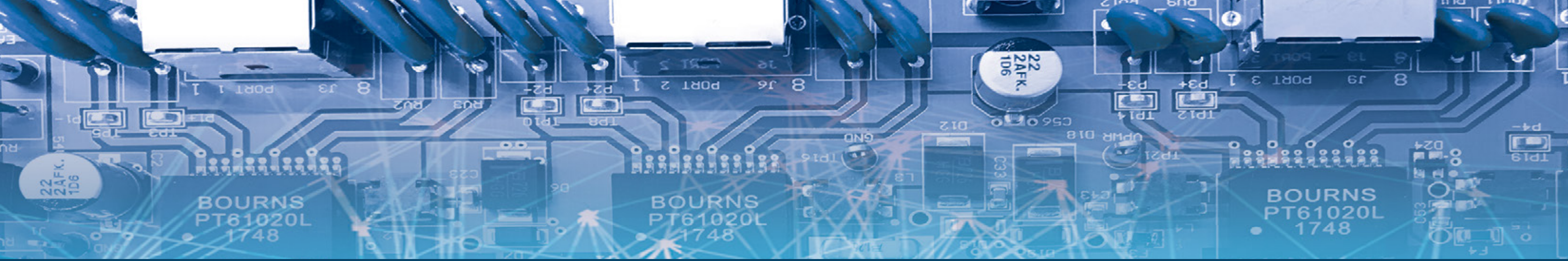



*Figure 9- Individual Grain-boundary Junctions of an Elecctrode*

Cumulative degradation occurs as more surges or frequent voltage swells happen. In this condition, the varistor is not visibly damaged and outwardly appears functional, but it no longer offers protection. Eventually, it will proceed into a short circuit condition as the energy discharges, creating a conductive channel through the oxides.

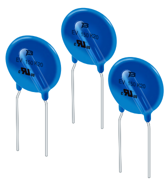
While an MOV is designed to conduct significant power for very short durations (about 8 to 20 microseconds), such as caused by lightning strikes, it typically does not have the capacity to conduct sustained energy. Under normal utility voltage conditions, this is not a problem. However, certain types of faults on the utility power grid can result in sustained overvoltage conditions. Examples include a loss of a neutral conductor or shorted lines on the high voltage system. Application of sustained overvoltage to an MOV can cause high dissipation, potentially resulting in the MOV device catching fire.

The probability of catastrophic failure can be substantially reduced by increasing the rating (using a larger size MOV) or using specially selected MOVs in parallel.

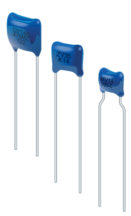


# Tips on Selecting the Right MOV Surge Suppressor

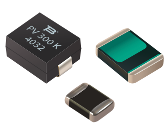
[Bourns® Through-Hole Metal Oxide Varistors (MOVs)]



[Bourns® EdgMOV™ Components]



[Bourns® Through-Hole Multilayer Varistors (MLVs)]



[Bourns® Surface Mount Multilayer Varistors (MLVs)]

## PUTTING MOVS TO WORK

When a well-known company designed an evaluation board for different ITU-K.21 tests, Bourns provided multiple MOVs that matched their rating and voltage requirements. The MOVs were selected based on Bourns' MOV performance in meeting 1 kV, 2 kV, 4 kV, and 6 kV surge requirements.

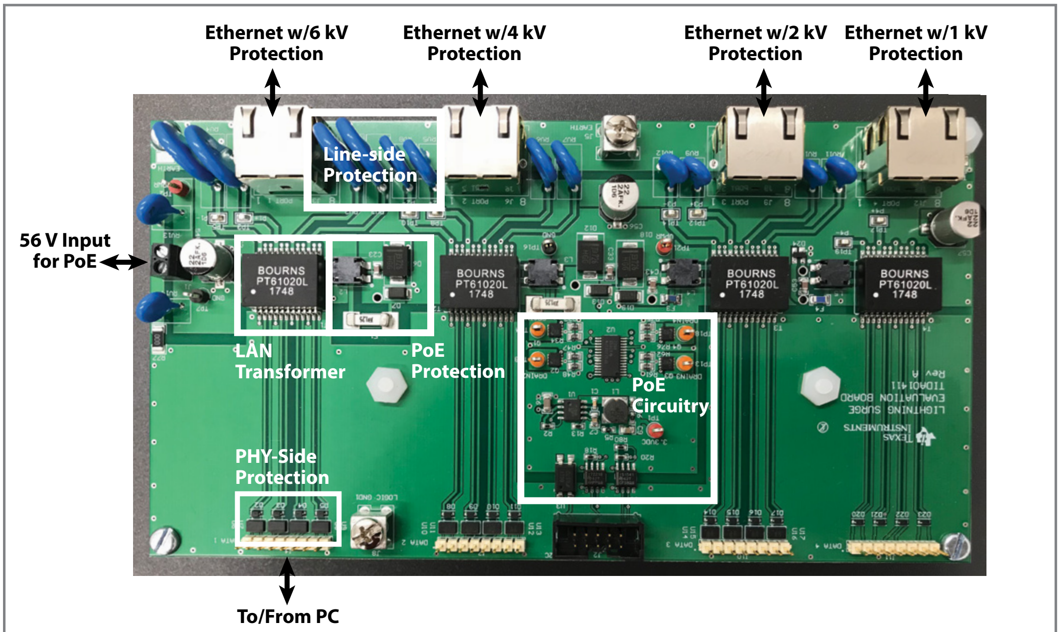



*Figure 10- MOVs on a PCB*

Bourns has one of the industry's most comprehensive lines of MOVs — from space-saving SMT to high energy disc and harsh environment AEC-Q compliant devices as well as the ability to offer customized MOVs.

## ADDITIONAL RESOURCES

Bourns® Varistor Products Technical Library
Bourns® Varistor Components Brochure
Bourns® MOV, MLV and Hybrid Component Product Guide
White Paper: Specifying Bourns® Surge Protection Components for UL/IEC 62368-1 Compliance
White Paper: Designing Effective Circuit Protection for RS-485 and RS-422 Applications
White Paper: The Effect of Surge Testing Live Online for Surge Protective Devices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