

## A Guide For Using Multilayer Suppressors in TVS Zener Applications

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Simply stated, it is the role of the transient suppressor to reduce voltage spikes to a magnitude that will not cause damage to susceptible integrated circuits, transistors, and other sensitive components. The sources of these transients might be externally induced such as ESD, EFT, or lightning surge that reach the circuit board level, or generated in the application itself such as through inductive load switching. A third source is the intentional testing of a product in order to achieve a specific EMC compliance level.

The Multilayer Suppressor is one such category of devices used address these situations at the circuit board level. A specially fabricated Metal Oxide Varistor ceramic chip in leadless surface mount form, these components add versatility for the circuit designer by providing a wide range of surge capability in a small outline and can be produced in styles to fit specific application needs.

Circuit designers planning for or currently using discrete TVS Zeners may want to consider the Multilayer Suppressor ( or "ML" ) device as an alternative technology as it has its own set of attributes.

Since the Zinc Oxide ML differs from the silicon TVS Zener suppressor in both physical and electrical characteristics it does not universally replace all TVS Zeners in all circuits. Likewise, then a direct cross-reference of these two different technologies is not practical. Below are the pertinent questions for Zener substitution with Multilayer Suppressors for comparison by the designer.

### **Which TVS Zener types might be replaced by "MLs"?**

The applicable types are typically the discrete TVS power Zeners such as the 300 to 1500 Watt types with common industry prefix designations. Table I provides examples of industry prefix nomenclature. Since the Multilayer Varistor is designed as a transient suppressor, it would not be used to replace voltage regulator type zeners.

Table I – Common TVS Zener types

	<b>300W</b>	<b>400W</b>	<b>600W</b>	<b>1500W</b>	
<b>Through-Hole</b>	SA	SA, P4KA	P6KE	1.5KE	
<b>Surface-Mount</b>	SMAJ	SM4 , TPSMA	1SMB, SMBJ, SM6, P6SMB	1SMC, SMCJ, SM15, 1.5SMC, TPSMC	

### **How do the form factors differ between MLs and Zeners?**

Mandates for board size reduction or conversion to surface-mount production are often the first reasons for the selection of the small ML which is manufactured in leadless, surface mount form. The construction resembles MLC chip capacitors and is offered in industry EIA PDP-100 sizes of "0402" to "2220".

The sizes usually chosen for TVS Zener substitution are the 0805, 1206 or 1210. Since the ML body is ceramic, flammability ratings required of plastic encapsulated devices are not applicable. TVS Zeners are typically the larger plastic package types: J-Bend surface mount (DO-214, etc. ) Gull Wing surface mount ( DO-215, etc.) Axial Lead through hole ( DO-13, DO-41,etc.)

Therefore, board layout changes would be required in retrofit situations.

### **How does the terminology of key parameters compare?**

Table II lists the basic electrical parameter nomenclature. Essentially, two sets of terms are used to describe the same parameters. The Zener's Working Peak Reverse Voltage ( VRWM or VWM ) is normally compared to the ML's Maximum Continuous Working Voltage ( VM [DC] ). Presently, this range is from 3.5 to 120 Volts (DC) for the ML, applicable for much of the sensitive on-board silicon devices it's meant to protect.

TABLE II – Nomenclature comparisons

<b>Parameter</b>	<b>Zener terms</b>	<b>Equivalent Multilayer terms</b>
Maximum Working or Reverse Standoff Voltage	VWM, VR, VRM	VM (DC)
Breakdown Voltage	VBR	VN (Nominal Voltage)
Peak Pulse Power	Ppk (WATTS)	WTM (Joules)
Maximum Surge Current or Peak Pulse current	IPP, IRSM, IPPM, IFSM	ITM

### **How do the V-I characteristics compare?**

The metal oxide formulation and sintering process result in the familiar, inherent bi-directional clamping characteristic. This is usually desirable as transients are typically both positive and negative in nature. Zener Suppressors use two diffusions to create the bidirectional characteristic or two die can be mounted in the same package and electrically connected back to back. (When a uni-directional Zener is used in an existing application, it must be determined if forward current flow through the Zener is required for normal circuit operation, precluding the use of the ML in rare cases.)

The ML exhibits a more "rounded" knee V-I characteristic in the region where it transitions to its low resistance "conduction" state. Zeners generally have a sharper avalanche characteristic. The Zener's Breakdown Voltage ( VBR ) relates to the Multilayer's Nominal Voltage ( VN ), both of which are measured at the 1mA level as an initial indication of the clamping transition region. (Except for the very lowest voltage Zeners which are sometimes measured at 10mA.)

The "Clamping Factor" relates to the V-I curve in the clamping region and is calculated from the clamping voltage observed at a specified transient current divided by the voltage at initial breakdown (  $VC \div VN$  ). Zeners can have a lower Clamping Factor at certain currents due to low Zener impedance.

Most designers create a safety margin between the circuit's working voltage and the absolute maximum voltage rating of its components. In those applications where the over voltage susceptibility of a component is very close to the circuit's operating voltage, for example, an IC that operates at 15 VDC and is damaged at 18V, the maximum surge current should be known to determine if an ML is a suitable replacement

To consider the ML in an existing Zener circuit, the ML's V-I characteristics should be reviewed. Where the maximum allowable clamping voltage is known, the designer would find this voltage level on the data sheet V-I curves and relate it to the maximum Peak Transient Current in the ML. A first approximation for this current is often the short circuit current or, the Peak Transient Voltage expected divided by the source impedance at that point in the circuit.

### **Are operating temperature and derating similar?**

The MLs produced by Littelfuse match the operating temperature ratings of the Zener's -40° C to +125 °C specification. Importantly, the ML has no derating of Energy or Peak Current over this entire range. Depending upon the Zener, derating typically starts between 25°and 40°C. Graph 1 compares these curves. Additionally for the ML, the clamping region of operation is essentially

immune to temperature variation for this technology, having a coefficient of  $< 0.01\%$  / deg. C, the ML provides the same protection level over the temperature range.

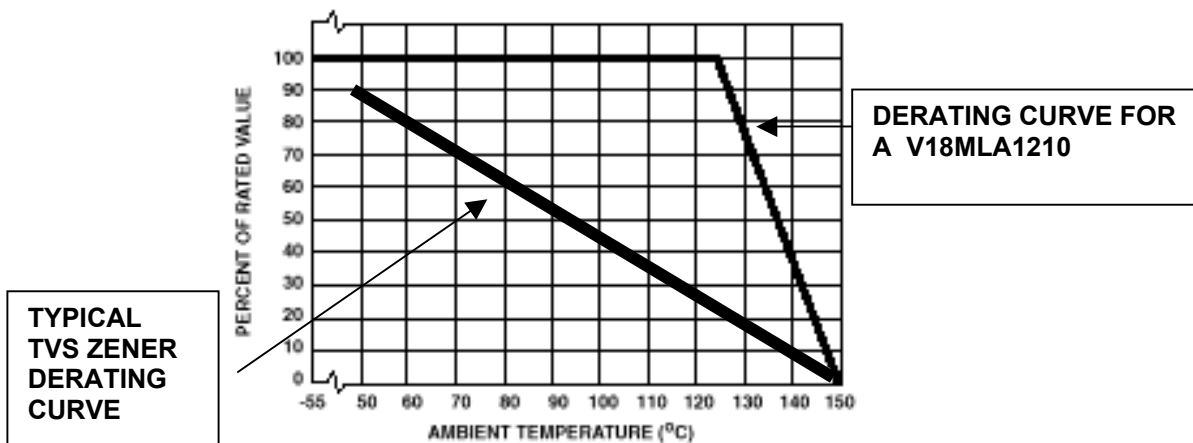


FIGURE 1. CURRENT, ENERGY AND POWER DERATING CURVE

### How is the ML size chosen?

The suppression device must meet or exceed the expected transient energy induced by a surge. The transient's peak voltage and waveshape along with the circuit source impedance should be known to determine the appropriate suppressor. The Energy dissipation capability of the ML primarily depends upon the volume of Zinc Oxide material (or physical size). Much of the electrical transient it suppresses is converted to heat. Energy (E) in Joules dissipated within the ML is calculated from the product of Clamp Voltage (V), ML Peak Current (I), transient duration (t), and an integrating factor (k) appropriate for the waveshape.  $[E = (V) (I) (t) k]$ . Both Multilayer and TVS Zeners base their ratings on the 10x1000 uS double exponential waveform. The Zener expresses this as Watts at a maximum Peak Current usually for that specific duration. An advantage of the ML is that the energy is dissipated throughout the volume of the Zinc Oxide material and is not focussed within the small P-N junction as in the case of a Zener. As a result, the smaller ML can often replace the larger Zener. Similarly, the multilayer construction of the Littelfuse ML offers an effectively large active area in this small foot print, allowing for Peak Transient Current levels that might otherwise damage a comparable Zener junction, especially at elevated ambient temperatures such as +125C.

Table III converts three Zener Wattage types of 18VRM, in terms of Joules to relate it to a potential ML size depending upon the application. The values have been derated for operation at 85°C in this example. Determining the actual dissipation required in the application, of course, ensures that the proper device will be selected, avoiding either too large or too small of a device.

TABLE III – ML size determination

TVS Zener Wattage Rating	Common Zener Prefix Designation	18V Zener Joule Rating <sub>1</sub> (10x1000)	Suggested 18V ML Size	ML Joule Rating <sub>2</sub> (10x1000)
500W	SA	0.56 J	0805 or 1206	0.3 to 1.0
600W	1SMB, P6KE	0.67 J	1206 or 1210	0.3 to 1.2
1500W	1SMC, 1.5KE	1.67 J	1210	0.3 to 1.2

1. Derated for operation at +85°C.
2. Depending on voltage rating and device size.  
No derating required up to +125°C ambient.

### **How does capacitance compare?**

The ML capacitance can range from tens to hundreds of picoFarads. Like the Zener, it is essentially inversely proportional to its voltage rating ( In general, the ML Zinc oxide material thickness increases with voltage). Capacitance values are generally higher for the lower voltage MLs, but can be lower than theTVS Zener's, depending on which types are compared. In practice, if a TVS rated Zener of the types mentioned above is currently in use in a particular application, then an ML may often be used without effecting AC circuit operation. Some standard versions of the ML offer reduced amounts of capacitance by having fewer number of interelectrode layers. The reader is referred to the data sheet for specific types and values. Littelfuse also can tailor the capacitance for specific circuit needs.

Capacitance can also be put to good use as MLs have been applied as combination suppressor / low pass filters on power supply lines or to attenuate noise on control lines while still protecting it from transients. In cases where transients have very high  $dV/dT$  edges the capacitance of the ML helps by skewing the sharp wave front and reducing ringing.

### **How does the Speed of Response Compare?**

Both the ML and Zener exhibit excellent response to fast rising voltage edges of "real world" transients which most often range in rise times from a few of nanosecond to tens of microseconds. The Littelfuse ML Zinc oxide material itself responds in a nanosecond. In practice, the total response time will depend upon circuit parameters and the magnitude of the surge current. The leadless ML chip effectively does not add lead inductance of its own. Consider the IEC human body model for ESD transients. In this extreme case of  $di/dt$  wavefront there is sometimes misunderstanding between the 1 nanosecond current rise time requirement of the calibration wave into a 2 Ohm load and that of the resultant  $dv/dt$  voltage wave form observed when induced in a circuit of interest by that same generator.

### **What about Zener or Diode arrays substitution?**

Zener (or Diode arrays such as SM, SMDA, LCD, or ITA types) are really in a different application category than the high power TVS discretes since they are typically rated at much lower wattage and primarily designed for ESD events. For example, the wattage ratings are often given in the 8x20 microsecond condition rather than with the 10x1000 microsecond wave. They are often supplied in IC packages such as 6 - 18 Lead DIP, SOP, and SOT versions. Most applicable for substitution may be the Littelfuse V18MLN41206, a 4-line multilayer in a 1206 sized array.

Other technologies suited to replace Zener or diode arrays and offering specific application advantages are the Littelfuse "PulseGuard" type such as the PGB002ST23, a voltage variable

polymer material in SOT-23 footprint and the 4-line SP724 ( silicon SCR/Doide array family ) also in SOT-23 package.

### **Conclusion**

Attributes of Multilayer Suppressors add real value for transient protection solutions in terms of space savings, surge energy ratings and robustness, and can offer an alternative to TVS Zeners. The key steps to review when considering a Littelfuse Multilayer for use in a Zener application are simply:

1. Matching the Working voltage
2. Confirming bi-directional clamping for the application
3. Acceptance of a leadless chip form factor
4. Appropriate sizing for the surge energy expected
5. Clamping performance
6. Capacitance

Where a TVS Zener is currently applied, consideration of ML usage may hinge primarily on the acceptance of form factor and a higher Clamping Factor.