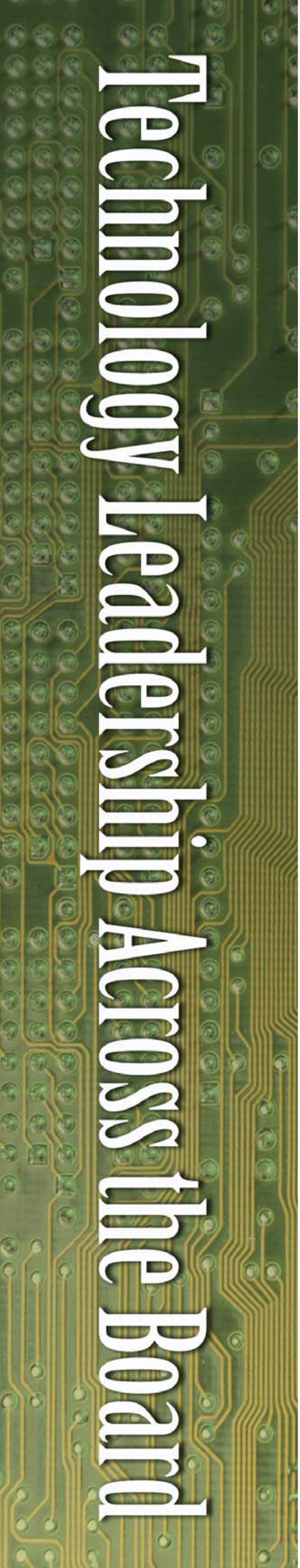

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High Temperature MLVs and Low Capacitance MLVs Improve Auto Designs and Reliability

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Abstract

Multilayer varistors (MLVs) have long been an ideal solution for low power circuitry and sensor applications due to their inherent low current leakage characteristic, which can be as low as a few nanoamps. MLV off state capacitance is also a compelling advantage to designers since it provides a broad range of EMI filtering. Automobile designs are some of the most stringent in the world. Recently two technology developments have broadened the MLV family of products:

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- The operating temperature range of MLVs has been expanded to a range of -55°C to +150°C.
- The capacitance of an MLV has been reduced to <1pF. This results in multilayer varistors with self-resonant frequencies in the 9000MHz range. Expanding the range of available capacitance down to <1pF and upwards to 16nF is of particular interest to the automobile community.

With these advancements, MLVs can now be used throughout a wide variety of under hood automotive applications as well as virtually all the conceivable RF modules in any transport system.

Additionally, 150°C MLVs offer a predictable off state EMC capacitance and large energy strike capability at high temperatures.

Two specific applications demonstrate the advantages of 150°C rated MLVs in automobile circuitry – under hood module interfaces and under hood sensors.

Under Hood Module Interface Protection

Many automotive modules use an integration capacitor placed at the connector PCB interface to provide some level of ESD suppression to the modules sensitive internal components. Typically, integration capacitor values range from 100pF to 10nF depending upon the individual circuits ability to withstand capacitive loading.

To understand the advantages of high temperature MLVs we must first understand the limitations of integration capacitors.

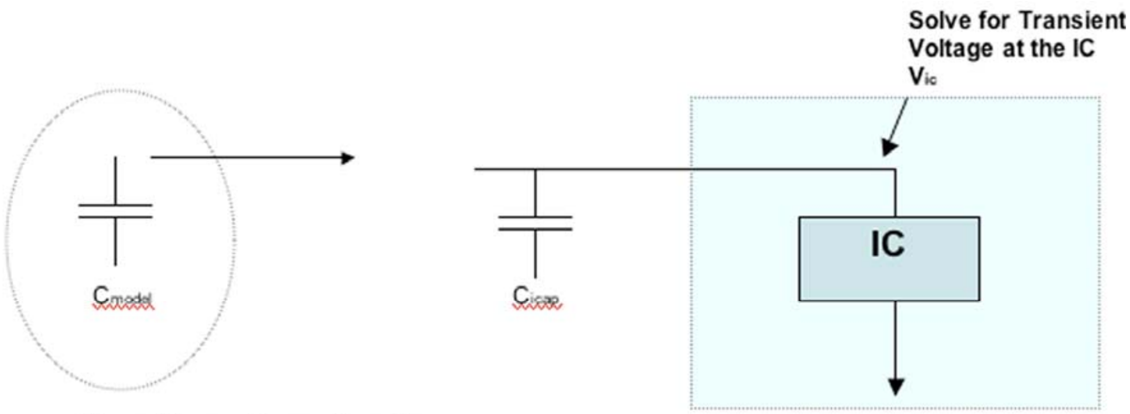
Though MLCC capacitors used as a transient integration capacitor are inexpensive, their selection, implementation and performance can have severe limitations.

First, the capacitor doesn't actually clamp anything, it simply shares the transient charge by dividing the voltage from the source and itself proportional to conservation of charge rules. That is, the capacitor will provide voltage protection to the load according to the equations of Figure 1.

What is important to note is that the integration capacitors value will drop dramatically during the incoming transient event. That means the voltage that is expected based upon calculations of Figure 1 is actually a best-case scenario. Further, the amount of capacitance drop varies by manufacturer, ceramic dielectric within a particular manufacturer, and the speed and magnitude of the applied transient pulse. It is not impossible to experience a 50% (or larger) decrease in capacitance value from the capacitors purchased value. If we compound that transient capacitance variation with temperature related decrease we can experience as 150°C is approached its not inconceivable to have a 75% to 80% drop in capacitance from purchased values.

As an example, if an 8kV ESD strike were injected to the trace of a PCB utilizing a 100pF integration capacitor the best case transient voltage the IC would be subjected to would be 4.8kV assuming 100% transfer of charge of the ESD pulse to the PCB, zero transmission line effects from the circuit trace and zero variation of integration capacitors value during the pulse or temperature range. In the real world 100% coupling doesn't always occur and traces will act as a transmission line. There is no way to give an accurate generalization on the exact voltage at the IC without measuring or modeling for each specific PCB design, waveform type, capacitance value and capacitance manufacturer.

<u>Integration Capacitor Charge Calculations</u> - Figure 1



$$C_{model} \cdot V_{model} = (C_{model} + C_{icap}) \cdot V_{ic}$$

Where:
C_{model} = capacitance of the ESD model
V_{model} = voltage to which the model is charged
Cicap = the capacitance value of the integration capacitor
Vic= voltage that the IC (or device to be protected) sees

If the most common auto grade MLV were used on the same under hood module described in the above example and if an 8kV transient were injected onto the pins a transient voltage of <100V would be seen on the IC.

There is a significant amount of added transient protection offered by the MLV versus the capacitor. Also, the above example is for a single transient event. Though outside the scope of the article, transients by their very nature tend to be random. It is possible that a repetitive transient could enter onto the pin or a transient of much greater magnitude (thus degrading the amount of protection from the capacitor. Possibly even destroying the parallel integration capacitor or creating a latent failure).

MLVs exhibit another significant advantage over the capacitor – stable capacitance. Typically, a 150°C rated MLV will exhibit a capacitance variation of 25% versus the combined capacitance variation of up to 80% on the capacitor.

Under Hood Sensor Protection

It is common to see MLVs utilized in a variety of automobile sensors because of standard MLV products which off leakage currents <2uA. Additionally, source control drawings have been created that result in leakage currents of <50nA. Leakage currents this low allow the sensors, which the MLV is commonly placed across, to have greater accuracy that systems that utilize TVS diodes.

The leakage of an MLV is greatly dependant upon its operating voltage, the voltage at which it operates and its temperature. Graphs 2a and 2b illustrate leakage current for a family of commonly used MLVs in auto circuits (12V, 24V, and 48V lines).

A commonly used set of design rules is to choose an MLV for sensor protection follows:

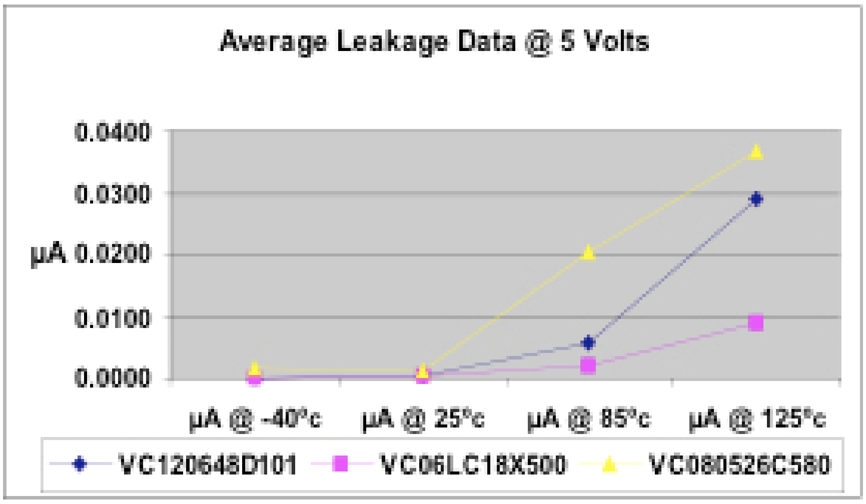
- Double the DC voltage rating, add the ripple voltage present, and use that number as the minimum operating voltage of the MLV on the sensor. Be certain this device clamping voltage is less than the transient damage level of the device in need of protection.

- Once that operating voltage range is determined, choose a MLV with energy content =/> the applied transient energy. Be certain the peak current of the MLV is =/> that than of the applied transient.

- If the capacitance of the devices resulting from steps one and two are too high, increase the DC operating voltage. Pay attention to the devices clamping voltage and be certain it is less than the transient damage level of the device in need of protection.

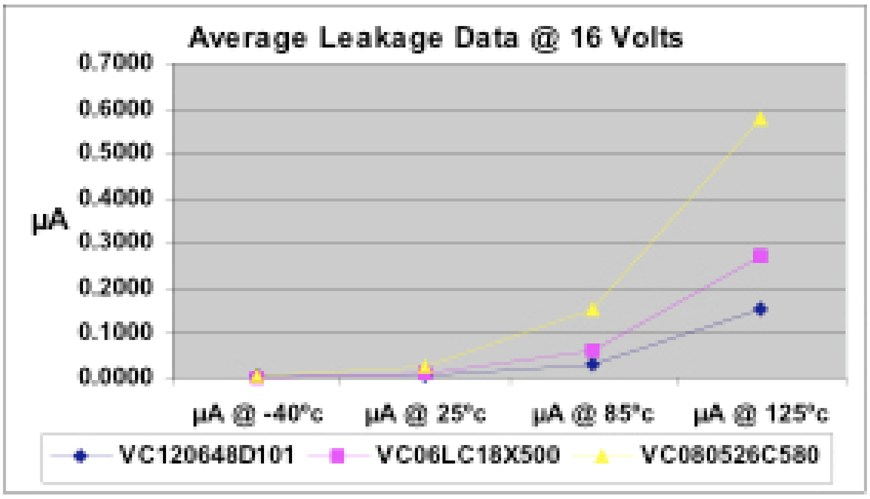
- Choose the case size desired within the offering supplied by steps one, two and three.

<u>Effect of 5V bias on auto grade MLVs</u> - Figure 2a



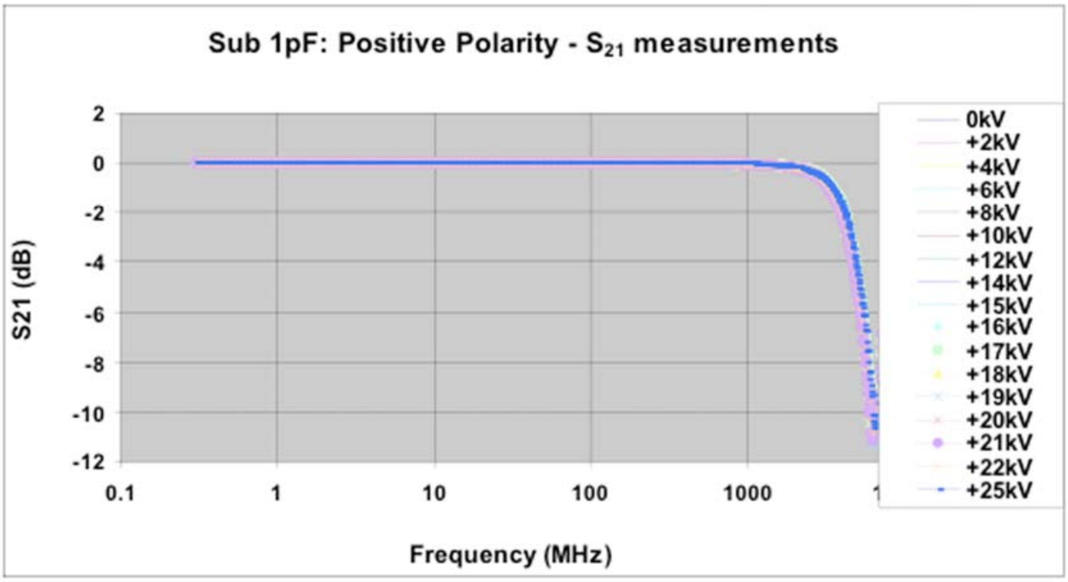
Product Key
VC06LC18X500 = 18v device
VC080526C580 = 26v device
VC120648D101 = 48v device

<u>Effect of 16V bias on auto grade MLVs</u> - Figure 2b



The impact of sub pF MLVs in RF module protection has been significant, as they provide even lower leakage currents when compared to other MLV offerings. Sub pF MLVs are also very consistent in S21 curves prior to, and after ESD strikes, as shown in Figure 3. This makes them easily implemented as band reject filters as well as providing high voltage ESD protection. Its implementation is simple, as shown in Figure 4.

<u>ESD effect on Sub pF Vi curve – pre post data</u> - Figure 3



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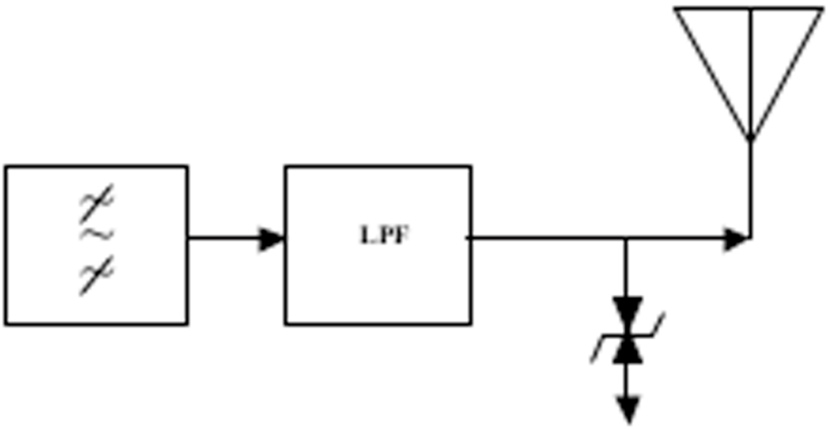
<u>Antennas / RF Decks</u> - Figure 4



Summary

MLVs offer many advantages within automobile circuitry. They are an accepted, essential component in CAN and other communication bus interfaces. New series of MLVs can now provide cost effective alternatives to integration capacitors in demanding interface applications.

MLVs can offer some of the lowest leakage protection available – ideal for sensor applications. MLVs capable of sensor and interface protection are available in case sizes as small as 0201.