Varistor

Design and Characteristics
An Electronic Circuit
Varistors Protect Circuits from Transients
Interferences EMI/RFI

How to remove noise and suppress overvoltage:
Dual components

Standards are:
- CISPR 25
- IEC 61000
- ISO 11452-1
- EN 50 08
Varistors from KEMET

What is it?

• A device that protects sensitive electronic circuits from unwanted transients or stops transients emanating from relays and motors.

Benefits

• Voltage range from 3V to 385V
• Temperature range from -55°C to +150°C
• Available in a variety of surface mount sizes from 0603 to 4032
• Surge current as high as 1200A
• Response time as low as <1ns
• Dual function: Varistor/Capacitor in one leaded package ideal for electric motors
Varistor Construction

- Base electrode (Ag)
  - Intermediate Electrode (Ni)
  - External Electrode (Sn)
- ZnO Layer
- Inner Electrodes (Ag+Pd)

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How Does It Work?

• In normal mode of operation (Non-clamping) the resistance of the MOV (metal oxide varistor – zinc oxide) is very high.

• During transient voltages the MOV resistance drops.

• When the transient has passed the MOV returns to it’s normal mode of operation.

• MOV’s start conducting at specific voltages and stop conducting as transients fall below a threshold voltage.

• Differences between silicon carbide (SiC) varistors and MOV varistors are:
  - MOV’s Leakage current is much lower.
  - MOV’s clamp transients much faster.
How Does It Work?

- As the voltage between the terminals of the varistor increases, the resistance of the varistor decreases.

- In normal operation when the applied voltage is at rated voltage or below the varistors resistance is very high.

- When a voltage transient occurs the voltage exceeds the rated voltage and its resistance drops very rapidly to the point when it has almost no resistance. Thus a majority of energy of the transient is then dissipated in the varistor.
Characteristics
Varistor Functionality

- Resistance
- Clamping Voltage
- Varistor Voltage
- Circuit Voltage

**Graphical Description**
- **Low to High Transition**:
  - Current: x mA
  - Voltage: 1 mA

**Diagrams**
- Resistance direction
- Clamping Voltage direction
- Varistor Voltage direction
- Circuit Voltage direction

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A voltage/current curve will show a step in the line. WHY?
A varistor will have an upper and lower tolerance.
Below 1 mA current point, a varistor does not operate. Lower tolerance, since we want the lowest voltage value.
Above 1 mA current point, the varistor is operating. Higher tolerance, since we want the highest protection voltage.
Advantages Over Other Transient Suppression Techniques
Varistor vs. TVS

**Multilayer Varistor (MLV)**

- **ADVANTAGE**
  - Energy absorption takes place inside the ZnO grains and is provided nearly over the entire volume of the component.

**TVS Diode**

- **DISADVANTAGE**
  - Energy absorption only in the relative small area of the pn junction possible.
**Varistor vs. Diode**

**Replacing a TVS Diode with a MLV**

Same Dimension = 10x Imax

TVS Diode: DO-214AC, 18V, 102A

MLV equivalent over:
the size 2220, 18V, 1200A (10 x ImaxTVS)

MLV equivalent over:
the energy capability 0805, 18V, 120A

**Clamping Voltage**

Multilayer Varistors can significantly clamp the ESD peak pulse lower than TVS diodes.

**Life Test MLV vs. TVS Diode**

<table>
<thead>
<tr>
<th></th>
<th>0h</th>
<th>48h</th>
<th>144h</th>
<th>216h</th>
<th>500h</th>
<th>1000h</th>
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<tbody>
<tr>
<td>MLV 2220</td>
<td></td>
<td></td>
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<tr>
<td>x-bar</td>
<td>0.00</td>
<td>1.09</td>
<td>1.24</td>
<td>1.52</td>
<td>1.49</td>
<td>2.00</td>
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<tr>
<td>σ</td>
<td>0.00</td>
<td>0.18</td>
<td>0.17</td>
<td>0.25</td>
<td>0.19</td>
<td>0.28</td>
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<tr>
<td>TVS Diode</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x-bar</td>
<td>0.00</td>
<td>-0.72</td>
<td>-0.53</td>
<td>0.09</td>
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<td>0.11</td>
<td>0.05</td>
<td>0.03</td>
<td>0.03</td>
<td>0.29</td>
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</tbody>
</table>
Varistor vs. TVS Diode

**ENERGY CAPABILITY**
- VARISTOR: Higher energy capability
- TVS DIODE: Lower energy capability

**RESPONSE TIME**
- VARISTOR: Slower response time
- TVS DIODE: Faster response time

**SURGE CURRENT CAPABILITY**
- VARISTOR: High in all range
- TVS DIODE: Low to moderate especially in high voltage range

**CLAMPING VOLTAGE**
- VARISTOR: Higher clamping voltage
- TVS DIODE: Lower clamping voltage

**POLARITY**
- VARISTOR: Bipolar
- TVS DIODE: Unipolar & Bipolar

**TEMPERATURE DEPENDENCE**
- VARISTOR: Temperature dependent
- TVS DIODE: Temperature dependent

**CONFIGURATION**
- VARISTOR: SMD & Through-hole
- TVS DIODE: SMD & Through-hole

**COST**
- VARISTOR: Lower
- TVS DIODE: Higher

**ADVANTAGES**
- VARISTOR: Wide range of breakdown voltages, Higher surge capabilities, ESD protection, EMI/RFI attenuation, Size
- TVS DIODE: Fast response time (below 1ns), Low clamping voltage

**DISADVANTAGES**
- VARISTOR: Degradation over time of operation, But normal operation should not degrade the varistor
- TVS DIODE: Limited power capability, Typically fail as a short circuit
Application Notes

Timing Behavior
- Varies from 10ns – 20ns for SMD and 20ns – 60ns for leaded
- The higher the voltage type, the slower the response time
- Inductance of leads and mounting method affects response time

Aging
- Premature aging occurs due to surges, momentary over voltages, high operating temperature and high application voltage

Degradation
- Varistor must withstand repeated rated surges
- Constant leakage current and capacitance

Failure Modes
- Open – common for a Varistor with a thermal fuse
- Short/open – common for a Varistor without a thermal fuse
- Caused by a breakdown over insulation or internal breakdown
# Varistor Product Overview

<table>
<thead>
<tr>
<th>KEMET</th>
<th>DUAL FUNCTION</th>
<th>SMD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Series</strong></td>
<td>VM</td>
<td>VA</td>
</tr>
<tr>
<td><strong>Package</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DC voltage range (Vdc)</strong></td>
<td>16 .. 56</td>
<td>16 .. 56</td>
</tr>
<tr>
<td><strong>AC voltage range (Vrms)</strong></td>
<td>14 .. 40</td>
<td>14 .. 40</td>
</tr>
<tr>
<td><strong>Imax(8/20us) (A)</strong></td>
<td>800 .. 1200</td>
<td>150</td>
</tr>
<tr>
<td><strong>Temperature (°C)</strong></td>
<td>-40 .. +125</td>
<td>-40 .. +125</td>
</tr>
<tr>
<td><strong>Typical capacitance</strong></td>
<td>0.47u .. 1.5uF</td>
<td>0.37n .. 10nF</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>7.5x9 / 8x12mm</td>
<td>6x9mm</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Elimination of transients and EMI noise from DC motors in automotive electronics (windscreen wipers, window lifting, seat adjustment etc.), VM/VK is one single component that comprises varistor and capacitor. Protection against overvoltage transients in automotive applications. Suppression of inductive switching or other transient events, ESD protection at the circuit board level. Low values of capacitance, excellent for I/O line protection operating at high speed data transfer, ESD protection for industrial, consumer electronics. Provides on-board transient voltage protection of integrated circuits. Standard SMD varistors for transient surge suppression used for industrial applications, pv systems, telecom, household electronics, inverters, mains/line voltage.</td>
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Thank You!