Varistor Products Overview

CIRCUIT PROTECTION SOLUTIONS

Littelfuse Technologies: Power Thyristors • Protection Arrays • Fuses • PTCs • Varistors • TVS Diodes • GDTs • ESD Suppressors • SIDACtor Devices

Expertise Applied | Answers Delivered
Agenda

1. MOV (Metal Oxide Varistor) fundamentals
   - Mechanism of operation
   - Electrical Characteristics

2. MOV / MLV (Multi-Layer Varistor) types and applications
Transient Surges are Everywhere

- COMPUTERS
  - ESD
  - EFT
  - SURGES

- TELECOM EQUIPMENT
- AUTOMOTIVE
  - LOAD DUMP
  - INDUCTIVE LOADS
  - TRANSIENT BURSTS

- WHITE GOODS

- INDUSTRIAL PANELS

- PORTABLE ELECTRONIC EQUIPMENT
  - ESD

- HOME ENTERTAINMENT

Littelfuse
MOV Definition

- An **MOV**, or **Metal Oxide Varistor**, is a voltage suppression device that clamps a transient in an electrical circuit. It is also called a **Varistor**, or **variable resistor**, because its resistance changes with applied voltage. Sometimes they are referred to as a **VDR**, or **Voltage Dependant Resistor**, by some manufacturers.

- An MOV is a voltage dependent device which has an electrical behavior similar to back to back zener diodes.

- When exposed to high voltage transients, the MOV’s resistance changes from a near open circuit to a very low value, thus clamping the transient voltage to a safe level.

- The potentially destructive energy of the incoming transient pulse is absorbed by the Varistor, thereby protecting vulnerable circuit components.
Terms

- Voltage Transients
- Surges
- Voltage Spikes
- Overvoltage events (short duration)

All mean the same thing.
Lightning

70 Volts at 1 mile
10,000 Volts at 500 feet

Electromagnetic coupling into overhead and buried wires
ESD  Electro-Static Discharge

Walking across a carpet:
35,000 Volts @ RH = 20%
500 Volts @ RH = 65%

Walking across a vinyl floor:
12,000 Volts @ RH = 20%
250 Volts @ RH = 65%
Clamping action

Transient on Line

V_{line}

Energy Dissipated

Clamp Voltage

V_{line}

Line

MOV

Ground
## MOV Electrical Parameters

<table>
<thead>
<tr>
<th>Voltage Rating, Continuous</th>
<th>Energy</th>
<th>Peak Current</th>
<th>Varistor Voltage at 1mA</th>
<th>Clamp Voltage 8x20µS</th>
<th>Capacitance (typical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAC 130</td>
<td>VDC 170</td>
<td>Joules 100</td>
<td>Amps 10000</td>
<td>VDC 185 min</td>
<td>Capacitance 340 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Vpeak 225 max</td>
<td>pF 1900</td>
</tr>
</tbody>
</table>

- **Operating Voltage**
- **1 Pulse Energy Rating**
- **1 Pulse Current Rating**
- **Varistor Voltage**
- **Clamp Voltage at Specific Current**
- **Typical Capacitance**

After only 1 hit of these two max limits, the MOV will need to be replaced.
1. **Leakage/Low current region**
   Acts as a large resistor until reaching the clamping region.

2. **Clamping Region**
   Acts as a conductor in this region. Conducts large amount of current for a small increase in voltage.

3. **High Current/Upturn region**
   Lower lifetime when used in this region.
V-I curve characteristics

1. **Leakage/Low current region**
   Acts as a large resistor until reaching the clamping region.

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   Lower lifetime when used in this region.
V-I curve characteristics

1. **Leakage/Low current region**
   Acts as a large resistor until reaching the clamping region.

2. **Clamping Region**
   Acts as a conductor in this region. Conducts large amount of current for a small increase in voltage.

3. **High Current/Upturn region**
   Limited lifetime when used in this region.
For the same MOV voltage rating:

- Small diameter parts have a higher clamp voltage.
- Large diameter parts have higher current capability.
MOV Characteristics

Continuous Power Dissipation
MOVs are only used for transient suppression, and **not** continuous voltage regulation. Their power rating for continuous current is very low. Their power rating for brief millisecond transients is very high.

**Leakage Current**
Leakage current will increase as the temperature rises.
Pulse Rating Curve

- Guaranteed lifetime, meaning less than a 10% shift in Varistor Voltage.
- High current events will rapidly decrease lifetime.
- Wide transients such as 100mS should be avoided.
MOV selection

1. **Continuous Voltage Rating**, RMS or DC, should be >110% of the maximum expected voltage.

2. **Device size** depends on the *transient energy or current* expected or on the required *clamping voltage*.

3. **Energy** and **Peak Current** ratings are a measure of capability.

4. Max **Clamping voltage** is a reference point on the V-I curve and is a measure of the protection level.

5. **Varistor voltage** can be used for Incoming Inspection and internal manufacturing test purposes.
## MOV Selection Table

<table>
<thead>
<tr>
<th>Voltage range</th>
<th>Energy</th>
<th>Normal use</th>
<th>Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>130 - 1000</td>
<td>11 - 360</td>
<td>AC Power Lines, PCB through-hole mounting</td>
<td>LA, CIII, UltraMOV - TMOV</td>
</tr>
<tr>
<td>130 - 275</td>
<td>11 - 40</td>
<td>Low Energy, Surface Mount</td>
<td>CH, SM7</td>
</tr>
<tr>
<td>130 - 750</td>
<td>270 - 1050</td>
<td>High Energy, Chassis and Board Mount</td>
<td>DA, DB, HA, HB, DHB</td>
</tr>
<tr>
<td>130 - 880</td>
<td>450 - 3200</td>
<td>Primary Power Line, Heavy Industrial, Chassis Mount</td>
<td>BA</td>
</tr>
<tr>
<td>1100 - 2800</td>
<td>3800 - 10000</td>
<td>Motors, Switch Gear, Heavy Industrial, Chassis Mount</td>
<td>BB</td>
</tr>
<tr>
<td>5.5 - 460</td>
<td>.1 - 52</td>
<td>Low Voltage, PCB through-hole mounting</td>
<td>ZA</td>
</tr>
</tbody>
</table>
MOV Radial Portfolio

## 5 Series of Leaded MOVs

<table>
<thead>
<tr>
<th>Type</th>
<th>Energy Level</th>
<th>Voltage Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>Lowest energy</td>
<td>130V - 1000V</td>
</tr>
<tr>
<td><strong>UltraMOV</strong></td>
<td>Medium energy</td>
<td>130V - 625V</td>
</tr>
<tr>
<td>C-III</td>
<td>Highest energy</td>
<td>130V - 320V</td>
</tr>
<tr>
<td>ZA</td>
<td>Low energy</td>
<td>5V – 460V</td>
</tr>
<tr>
<td></td>
<td>Low voltage</td>
<td></td>
</tr>
<tr>
<td><strong>TMOV</strong></td>
<td>Medium Energy</td>
<td>115 – 750V</td>
</tr>
<tr>
<td></td>
<td>Thermally protected</td>
<td></td>
</tr>
</tbody>
</table>
# MOV Radial Sizes

## Disc Diameter (mm)

<table>
<thead>
<tr>
<th>Type</th>
<th>Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>5, 7, 10, 14, 20</td>
</tr>
<tr>
<td>UltraMOV</td>
<td>7, 10, 14, 20, 25</td>
</tr>
<tr>
<td>C III</td>
<td>14, 20</td>
</tr>
<tr>
<td>ZA</td>
<td>5, 7, 10, 14, 20</td>
</tr>
<tr>
<td>TMOV</td>
<td>14, 20, 25, 34</td>
</tr>
</tbody>
</table>
## MOV Radial Ratings

### Peak Current

<table>
<thead>
<tr>
<th>Series</th>
<th>7mm</th>
<th>10mm</th>
<th>14mm</th>
<th>20mm</th>
<th>25mm</th>
<th>34mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>1.2kA</td>
<td>2.5kA</td>
<td>4.5kA</td>
<td>6.5kA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C III</td>
<td></td>
<td></td>
<td>6.0kA</td>
<td>9.0kA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UltraMOV</td>
<td>1.75kA</td>
<td>3.5kA</td>
<td>6.0kA</td>
<td>10.0kA</td>
<td>22kA</td>
<td></td>
</tr>
<tr>
<td>ZA</td>
<td>100-1.2kA</td>
<td>250-2.5kA</td>
<td>1-4.5kA</td>
<td>2-6.5kA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMOV</td>
<td></td>
<td></td>
<td>6kA</td>
<td>10kA</td>
<td>20kA</td>
<td>40kA</td>
</tr>
</tbody>
</table>

### Energy

<table>
<thead>
<tr>
<th>Series</th>
<th>7mm</th>
<th>10mm</th>
<th>14mm</th>
<th>20mm</th>
<th>25mm</th>
<th>34mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>11-35</td>
<td>20-70</td>
<td>38-220</td>
<td>70-360</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C III</td>
<td></td>
<td></td>
<td>45-130</td>
<td>90-220</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UltraMOV</td>
<td>12.5-48</td>
<td>25-100</td>
<td>50-200</td>
<td>100-400</td>
<td>230-890</td>
<td></td>
</tr>
<tr>
<td>ZA</td>
<td>.4-10</td>
<td>.8-18</td>
<td>3.5-35</td>
<td>7-52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMOV</td>
<td>35-6000</td>
<td>52-480</td>
<td>170-670</td>
<td>235-1050</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What is the **TMOV™ Varistor**?

- The **TMOV** Varistor is a Metal Oxide Varistor with an integrated thermally activated element.
- The device will automatically and permanently open-circuit when overheating occurs due to certain sustained over-voltages thereby providing additional thermal safety for the circuit. The MOV will become permanently disconnected.
- The integrated thermal element means it will not flame, fragment or scorch when subjected to an abnormal sustained over-voltage condition defined in UL Standard 1449.
**TMOV and iTMOV**

**TMOV**
- Thermal Fuse
- MOV

**iTMOV**
- Monitor Lead

**Circuit Diagrams:**
- TMOV: Line → Fuse → To Protected Circuit → Neutral
- iTMOV: Line → iTMOV → Diode → LED (Normally On) → R → To Protected Circuit
Typical TMOV body temperature during UL1449 limited current abnormal overvoltage test
Application solutions

Typical installation for plug-in or permanently wired equipment

- AC Power Input
- Fuse
- Washing Machine
  - Microwave
  - TV
  - Set Top Box
  - Radio
  - PC
  - etc
Application solutions

Typical MOV placement at power supply input

Line
Neutral
Ground
Application solutions

MOV placement with line-to-ground isolation

Line

Neutral

Ground

GDT in series with MOV
Set Top Box Power Supply

- Fuse provides overcurrent protection.
- Primary protection provided by MOVs.
- Further protection can be provided by including additional MOVs on the secondary side.
MOV Industrial Series

Description

- Leaded and Packaged Devices for Hi Energy applications.
- Several mounting variations are available.
- Technology is similar to the Radial leaded devices.
- All series are in the range 130VAC and up.
# Industrial Series Summary

<table>
<thead>
<tr>
<th>Series</th>
<th>Size</th>
<th>Voltage</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>60mm</td>
<td>250 - 2800VAC</td>
<td>Bare disc</td>
</tr>
<tr>
<td>HA</td>
<td>32mm</td>
<td>130 - 750VAC</td>
<td>Bolt or thru-slot board mount</td>
</tr>
<tr>
<td></td>
<td>40mm</td>
<td>130 - 750VAC</td>
<td></td>
</tr>
<tr>
<td>HB/DHB</td>
<td>34mm</td>
<td>130 - 750VAC</td>
<td>Bolt or thru-slot board mount</td>
</tr>
<tr>
<td>DA/DB</td>
<td>40mm</td>
<td>130 - 750VAC</td>
<td>Box, upright or flat.</td>
</tr>
<tr>
<td>BA</td>
<td>60mm</td>
<td>130 - 880VAC</td>
<td>Box, upright</td>
</tr>
<tr>
<td>BB</td>
<td>60mm</td>
<td>1100 - 2800VAC</td>
<td>Box, upright</td>
</tr>
</tbody>
</table>
HA Series

Solderable contacts

Voltage range | Size (Dia)
---|---
130VAC - 750VAC | 32 / 40mm

Part Number: V321HA40

VAC where 1 = x10
i.e. 321 = 320VAC

A=Bolt on terminal
C= PCB mount

Disc Diameter
HB Series

Solderable contacts

<table>
<thead>
<tr>
<th>Voltage range</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>130VAC - 750VAC</td>
<td>34mm square</td>
</tr>
</tbody>
</table>

Part Number: **V321HB34**

VAC where 1 = x10
i.e. 321 = 320VAC

Disc Diameter
### Industrial Series

**DA/DB Series**

- **Screw contacts**
- **Voltage range**: 130VAC - 750VAC
- **Size (Dia)**: 40mm

**Part Number**: V321DA40

Vrms where 1 = x10
i.e. 321 = 320VAC

**Disc Diameter**

**Different box style, A or B**
## BA/BB Series

**Screw contacts**

<table>
<thead>
<tr>
<th>Style</th>
<th>Voltage range</th>
<th>Size (Dia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA</td>
<td>130VAC - 750VAC</td>
<td>60mm</td>
</tr>
<tr>
<td>BB</td>
<td>1100VAC – 2800VAC</td>
<td>60mm</td>
</tr>
</tbody>
</table>

**Part Number:** V321BA60

VAC where 1 = x10
2 = x100
i.e. 321 = 320VAC

- Disc Diameter
- Different box style A and B
Test Levels

- All standards attempt to apply levels of severity to the described waveforms, example: **ANSI 62/UL1449**

<table>
<thead>
<tr>
<th>Waveform</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5ms-150kHz</td>
<td>6kV 200A</td>
<td>6kV 500A</td>
<td></td>
</tr>
<tr>
<td>1.2 / 50us 8 / 20us</td>
<td>6kV 3kA</td>
<td>10kV 10kA</td>
<td></td>
</tr>
</tbody>
</table>
Industrial Applications

- Industrial Controls
- Motor Drives
- Generator Protection
- Industrial Distribution Panels
- Electric Locomotives
- Thyristor Power Switching Protection
- Din Rail Circuit Breaker Box Protection
- Base station protection
Applications

Power Input

Motor Drive Controller

Electric Motor Drive

To ensure Input Power is “clean”

May include to protect against transients from the Motor
Surface Mount MOVs

7mm and 20mm disc sizes inside.
Multilayer Varistor

Nicknamed **ML** or **MLV**

- Leadless, Surface Mount Chip Form
- Combine Surge, ESD, and Filtering Functions
- Rugged, Robust, Reliable
- *Four distinct versions:*
  - **ML** - supports the broadest application range
  - **MHS** - low capacitance, high speed ML
  - **MLE** - intended for ESD while providing filter functions
  - **AUML** - automotive load dump transient protection
Multilayer Varistors

What is an MLV?

- MLV’s are voltage dependant, non-linear devices used in overvoltage transient suppression.
- MLV’s are fabricated by wet stack printing layers of Zinc-Oxide (ZnO) and metal inner electrodes, sintering, terminating, glassing & finally plating.
- MLV’s are available in sizes 0402 up to 2220
- MLV’s are available in voltages 3.5Vdc up to 120Vdc
Multilayer Varistor

What does an MLV look like inside?

**End Termination**
Standard finish is Tin (Sn) plated over Nickel (Ni) plated over Silver (Ag)

**Fired Zinc Oxide Black Ceramic**
Glass is porous and is put on before Ni & Sn Termination,

**Metal Inner Electrodes**
Platinum (Pt) or Silver-Palladium (AgPd)
Multilayer Varistors (MLV)

What does an **MLV** look like inside? *continued*

**End Termination**

**Metal Inner Electrodes**

<table>
<thead>
<tr>
<th>Metal Inner Electrodes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Offset Direction**

(Side view)

**Stack Direction**

(End view)
## MLV Electrical Parameters

<table>
<thead>
<tr>
<th>Voltage Rating, Continuous</th>
<th>Energy</th>
<th>Peak Current</th>
<th>Varistor Voltage at 1mA</th>
<th>Clamp Voltage 8x20μS</th>
<th>Capacitance (typical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAC</td>
<td>VDC</td>
<td>Joules</td>
<td>Amps</td>
<td>VDC</td>
<td>Vpeak</td>
</tr>
<tr>
<td>14</td>
<td>18</td>
<td>0.4</td>
<td>150</td>
<td>22 min</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28 max</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1100</td>
</tr>
</tbody>
</table>

- **operating voltage**
- **1 pulse energy rating**
- **1 pulse current rating**
- **Varistor voltage**
- **clamp voltage at specific current**

After only 1 hit of these two max limits, the MOV will need to be replaced.
V-I curve characteristics

For the same MOV voltage rating:

- Smaller parts have a higher clamp voltage at a higher currents.
- Larger parts have a higher energy capability.
## Multilayer Products

<table>
<thead>
<tr>
<th>Series</th>
<th>Voltage</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLA</td>
<td>3.5v – 30VDC</td>
<td>0603 - 1210</td>
</tr>
<tr>
<td></td>
<td>30v – 120VDC</td>
<td>1206 - 1210</td>
</tr>
<tr>
<td>MLE</td>
<td>18VDC</td>
<td>0603 - 0805 - 1206</td>
</tr>
<tr>
<td>MHS</td>
<td>9V – 42 VDC</td>
<td>0402 - 0603</td>
</tr>
<tr>
<td>MLN</td>
<td>5.5v – 18VDC</td>
<td>1206 4X array</td>
</tr>
<tr>
<td>AUMLA</td>
<td>18VDC</td>
<td>1206-1210-1812-2220</td>
</tr>
</tbody>
</table>
Five Sizes

0402
- Width: 0.5mm
- Height: 1mm

0603
- Width: 0.8mm
- Height: 1.6mm

0805
- Width: 1.3mm
- Height: 2.0mm

1206
- Width: 1.5mm
- Height: 3.0mm

1210
- Width: 2.5mm
- Height: 3.2mm

Multilayer Series
SurgeArray™ MLN

- A network of four independent multilayer varistors in a single 1206 surface mount package.
- 5.5, 9, 14, 18 VDC available.
- The inherent capacitance provides filtering capability to eliminate the need for an additional capacitor.
- Reduces board space and assembly placement cost while increasing assembly capacity and system reliability.
Multilayers for Automotive applications

**AUMLA** Used to handle *load dump* requirements

Four sizes

- **1206**
  - 1.6mm
  - 3.2mm

- **1210**
  - 2.5mm
  - 3.2mm

- **1812**
  - 3.2mm
  - 4.5mm

- **2220**
  - 5.0mm
  - 5.7mm

AUMLA logo and red car illustration
MLA Performance

ESD Test Voltage

Peak Clamp Voltage

Peak Impulse Current

V18MLA0805

V5.5MLA0805

0.5kV

1kV

2kV

4kV

8kV

0.1

1.0

10.0

100.0

10

100
Transient Suppression Performance

Voltage vs Time curves for contact discharge ESD

![Graph showing Voltage vs Time curves for contact discharge ESD](image-url)
CH Series

Original surface mount Varistor series using Disc Press Technology

- Voltage range 14VAC - 275VAC
- Large 5x8mm package
- Advantage over ML
  - Higher voltages to 275VAC
  - Higher energy capability
  - Higher peak current capability
- Standard color is dark blue. Multilayers are black.