Training Agenda

– MLV Definition and Circuit Protection
– MLV Basic Characteristics and Related Physics
– Typical MLV Types and Related Segments
– MLV Selection Concepts
– Littelfuse MLV Brands and Future Development
– Frontiers of MLV Technology
MLV Definition
– A Multi-Layer Varistor (MLV) is a voltage suppression device that filters and clamps transients in an electrical circuit.

Circuit Protection Concepts
– Protects human body generated ESD threats to sensitive IC and circuitry
  • Protect external threats from the environment such as ESD

– Regulatory requirements related to Circuit Protection
  • IEC 61000-4-2

– Method of circuit protection
  • Passive, Symmetric, Line to ground, Line to Line, and Rail Clamp configuration to fit various protection needs
  • Clamping the transients to rated voltage or less, depending on application
  • Surface mount such as 0402 and other various package to meet stringent board space requirements
MLV Definition

– The MLV surge suppressor is a compact, surface mountable chip that is voltage dependent, nonlinear, and bidirectional.

– The sharp, symmetrical breakdown characteristics of the device provides excellent protection from damaging voltage transients. The MLV impedance changes many orders of magnitude from a near open circuit to a highly conductive state in the presence of a transient.

– The MLV is constructed by forming a combination of alternating electrode plates and semi-conducting ceramic layers into a single ceramic chip. Each alternate layer of electrode is connected to opposite end terminations.

– The MLV surge suppressor is a leadless chip device that is much smaller in size than the components it is designed to protect. Its robust construction makes it ideally suitable to endure the thermal stresses encountered in the soldering, assembling and manufacturing steps involved in surface mount applications.
ESD Threats in Consumer Electronics Systems
Besides short circuit and overload conditions, interference susceptibility is a common and major threat to the consumer electronics. The IEC 61000 standard test has categorized this threat as the following:

- "Soft" failure
  - Data corruption or system latch up

- Latent damage
  - The circuit is still functional, but components have been damaged and can degrade with time or have shortened life span. A typical result is increased leakage current.

- Permanent damage or catastrophic failure
  - Junction burnout
  - Oxide punch-through
  - Melted trace
ESD Modeling - Human Body Model

IEC Model
• Based on Metal to Metal Contact Method
• Used in IEC 61000-4-2 Test Standard for ESD Events

Ansí Model
• Based on Skin to Metal Contact Method
• Used in Military Standard for ESD Events
**IEC 61000-4-2**
- Most commonly referenced standard
- CE Marking certifies compliance to testing to 61000-4-2 guidelines
- Most severe, in terms of current delivered to DUT
- “Pass” is achieved if system suffers no upset or damage
- 10 pulses are applied to the Device Under Test, in the polarity that the DUT is most sensitive to

<table>
<thead>
<tr>
<th>Severity Level</th>
<th>Discharge Voltage</th>
<th>Initial Current</th>
<th>30 ns Current</th>
<th>60 ns Current</th>
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<tbody>
<tr>
<td>1</td>
<td>2 kV</td>
<td>7.5 A</td>
<td>4A</td>
<td>2A</td>
</tr>
<tr>
<td>2</td>
<td>4 kV</td>
<td>15.0 A</td>
<td>8A</td>
<td>4A</td>
</tr>
<tr>
<td>3</td>
<td>6 kV</td>
<td>22.5 A</td>
<td>12A</td>
<td>6A</td>
</tr>
<tr>
<td>4</td>
<td>8 kV</td>
<td>30.0 A</td>
<td>16A</td>
<td>8A</td>
</tr>
</tbody>
</table>
MLV Characteristics as an ESD Suppressor

• MLV devices are offered in different designs to accommodate different suppression requirements.
  – MLVs are most often applied to low voltage (less than 50VDC) systems on power supply, signal, or control lines.

• MLV devices offer high peak surge current ratings.
  – The internal, interleaved dielectric electrode layers form essentially parallel devices so the effective surface area is much larger than the Multilayer size would suggest.

• MLV allows various types of package to meet the board layout needs.
  – The varistor voltage is determined by the thickness of the inter-electrode ceramic and the size of the ZnO grains. This property allows the MLV package design flexibility in meeting ever shrinking board space requirements.

• Inherent filtering capability and bidirectional nature.
  – Due to the intrinsically large capacitance, MLV device can be used as filtering device.
  – An MLV device can be modeled as two zener diodes back to back. It requires no external power to operate. It can be connected in single phase, three phase, and DC circuitry.
Section 2  MLV Characteristics and Device Physics

Basic MLV Characteristics
– Electrical Characteristics
  • Trigger voltage
  • Clamping voltage
  • Response time
  • Leakage current
– Maximum ratings
  • Continuous/Transient
  • ESD Pulse withstand
– Thermal Characteristics
  • De-rating

MLV Construction and Effect on Related MLV Characteristics
– MLV structure vs. electrical characteristics
– MLV structure vs. maximum ratings
– MLV de-rating and physics
MLV Characteristics and Device Physics

Electrical Characteristics

MLV VI Curve characteristic
The sharp, symmetrical breakdown characteristic of the device provides excellent protection from damaging voltage transients. When exposed to high voltage transients, the MLV impedance changes many orders of magnitude from a near open circuit to a highly conductive state.

The MLV Device Families
Since voltage transients have numerous sources and characteristics, Littelfuse Multilayer Suppressors are offered in three separate series:

The ML supports the broadest range of applications with operating voltages from 3.5 to 120VDC. It offers high peak current ratings and is designed for board-level surge, EFT, ESD and other specific transient events.

The MLE is designed for lower energy transients and is rated for ESD suppression in order to protect sensitive components. It is specifically characterized for capacitance and impedance for combined suppressor and high frequency attenuation applications.

The MLN device is a multilayer array to reduce part count and space savings. The standard MLN may be operated at voltage up to 18VDC and is primary intended for the ESD or other low energy transients.
**Electrical Characteristics**

**Speed of Response**
The clamping action of the MLV suppressor depends on a conduction mechanism similar to that of other semiconductor devices.

The actual response time of a MLV suppressor is 1ns to 5ns. This response time is more than sufficient for the transients which are likely to be encountered by a component on a printed circuit board.

**Clamping Voltage**
The clamping voltage of a suppresser is the peak voltage appearing across the device when measured under the conditions of a specified pulse current and specified waveform. The clamping voltage of the MLV should be the level at which a transient must be suppressed to ensure that system or component failure does not occur.
MLV Characteristics and Device Physics

**Electrical Characteristics**

Temperature dependence at lower voltage

**Temperature Dependence**

In the off state, the VI characteristics of the MLV suppressor approaches a linear relationship and shows a temperature dependent effect at current levels below 1mA.

The temperature variation of the clamping voltage is minimal over the full peak current and energy range.
Device Construction

An MLV is constructed by forming a combination of alternating electrode plates and semi-conducting ceramic layers into a block.

Each alternate layer of electrode is connected to opposite end terminations. The interdigitated block formation greatly enhances the available cross-sectional area for active conduction of transients.

The paralleled arrangement of the inner electrode layers represents significantly more active surface area than the small outline of the package may suggest.

The breakdown voltage of the device is dependent on the dielectric thickness between the electrode layers. Changing the dielectric thickness will change the breakdown voltage of the device.
Section 3  MLV Consumer Electronics Applications Examples

MLV devices are most often applied to low voltage systems on power supply, signal, or control lines in order to suppress ESD, EFT, surge, or other transients at the circuit board level for component protection such as the following:

- Computers and their associated peripheral device interfaces
- Office equipment such as keypads/controllers for copiers, fax, and printers
- Portable/hand-hand held devices
- Consumer portable devices
- Digital communication devices including MODEMs, wireless LAN adapters, and interfaces
- Mobile phones and cordless phones
Protection of Integrated Circuits and Low Voltage Circuits

A low voltage MLV device may be used to protect integrated circuits requiring 5V on the input.

The suppressor should be connected upstream from the IC to be protected. The maximum clamping voltage of the suppressor depends on the maximum transient current.

System to system and system to sensor protection
**CMOS protection**

A MLV suppressor connected from $V_{CC}$ to ground will eliminate most of the latch-up problems caused by input over voltage.

A MLV suppressor connected from input to ground will help to protect the input from damaging transients.

![Protection of CMOS devices](image-url)
**Discrete MOSFET Protection**

The MLV suppressor is connected between the drain and source. This MLV must have a steady state voltage capability which exceeds the worst case possible maximum supply voltage. Its clamping voltage at a peak transient current must be less than the minimum breakdown voltage of the MOSFET.

The MLV suppressor can be use to protect the input of a discrete MOSFET from the threat of an ESD transient or other transients by inductive loads.

![Discrete MOSFET protection circuit](image-url)
Global Lab Capabilities

- Qualification of all LF products
- UL-Approved Customer Testing in ISO 17025 Lab (Des Plaines)
  - High power (AC/DC up to 1KV/50KA) UL approvals available in DP
  - Telcordia approvals in DP planned (2008)
- Verification of Telcordia, ITU, IEC, FCC, and other industry, regulatory, and safety standards
  - Verification to various OC and OV standards
    - Insure application meets standards before submitting for approval
- Customer Application testing
  - Assistance with design-in and performance verification
    - Help with selection of appropriate technology and rating
  - Application troubleshooting
    - Assistance insuring proper OV/OC and primary/secondary protection coordination
  - Competitive evaluations
    - Competitive or technology performance comparisons
  - Reliability & Tin Whisker data/testing

Typical IEC 61000-4-2 ESD Waveform Response for V5.5MLA0603 @ 15KV Contact Discharge (Enlarged View)
Section 4  ML Consumer Electronics Application Product Selection

– MLV Feature Comparison

– MLV Circuit Protection Techniques
  • Working voltage (maximum system voltage)
  • Type of transient that is to be suppressed and its energy level
  • What circuit or component requires protection and to what level must be transient be suppressed

– MLV Board Placement
  • Must be placed close to I/O interface
  • Must be placed directly between the dataline and the chassis ground
### Input terminals connected to signal lines requiring protection

<table>
<thead>
<tr>
<th>Input/Output</th>
<th>ESD</th>
<th>Lightning</th>
<th>Transients (other)</th>
<th>Power Cross</th>
<th>Overcurrent</th>
<th>Overvoltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Input</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>Fuse</td>
<td>MOV, MLA, MLE</td>
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<tr>
<td>Display (Optional)</td>
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<td></td>
<td></td>
<td></td>
<td>MLA, MLE, SP72X</td>
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<tr>
<td>Keyboard</td>
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<td></td>
<td>PPTC (Polymer Positive Temperature Coefficient)</td>
<td>PulseGuard® suppressors</td>
<td>MLA, MLE</td>
</tr>
<tr>
<td>Expansion Port</td>
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<td>X</td>
<td></td>
<td></td>
<td>PPTC</td>
<td>PulseGuard® suppressors</td>
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<tr>
<td>PCMCIA</td>
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<td>MLA, MLE</td>
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<tr>
<td>Audio Output</td>
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<td></td>
<td>MOV, Gas Discharge, PulseGuard® suppressors</td>
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<tr>
<td>RF Input</td>
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<td></td>
<td></td>
<td>Tubes, PulseGuard® suppressors</td>
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<tr>
<td>RF Output</td>
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<td></td>
<td></td>
<td></td>
<td>PulseGuard® suppressors</td>
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<tr>
<td>Video Output</td>
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<td>MLN, MLA, PulseGuard® suppressors</td>
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<tr>
<td>S-Video</td>
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<td>MLN, MLA, PulseGuard® suppressors</td>
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<tr>
<td>USB(2.0)</td>
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<td>MLA, PulseGuard® suppressors</td>
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<tr>
<td>Telephone Connection</td>
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<td></td>
<td>Fuse</td>
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</tbody>
</table>
Section 5  Consumer Electronics MLV Product Road Map

Products

- SMD
- 0402
- 0805 Array
- 0405 Array
- IPD Chip
- IPD Array

Technology

- Std Ag/Pt Termination
- Plated Ni/Sn termination

Timeline:
- 2005
- 2006
- 2007
Section 6  Consumer Electronics MLV Technology Challenges

- Higher Surge Ratings in a Smaller Package
- Multiple MLV Elements in a Single Package
- MLV Technology Combined with Other Technologies in One Package
- High Operating Temperature