
# MLV

## Surface Mount Multilayer Varistors (MLVs) Design Guide

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# Surface Mount Multilayer Varistors (MLVs) Design Guide

Littelfuse Multilayer Varistors (MLA, AUML, MHS, MLA AUTO, MLE, and MLN) are used to suppress high transient voltage and protect circuits. Littelfuse, an industry leader in circuit protection, offers a variety of multilayer varistors constructed with high-quality materials.

Multilayer Transient Surge Suppressors was specifically designed to suppress the destructive transient voltages. The most common transient condition results from large inductive energy discharges. The MLVs are manufactured from semiconducting ceramics which offer rugged protection and excellent transient energy absorption in a small package. The devices are available in ceramic leadless chip form, eliminating lead inductance and assuring fast speed of response to transient surges. These Suppressors require significantly smaller space and land pads than silicon TVS diodes, offering greater circuit board layout flexibility for the designer.

## ABOUT THIS GUIDE

Choosing the most appropriate suppressor technology requires a balance between equipment protection needs and operating requirements, taking into account the anticipated threat level. In addition to the electrical characteristics of suppression devices, the form factor/package style must also be considered. This guide is designed to summarize some of the comprehensive ESD solutions that Littelfuse offers, and help designers narrow to technologies appropriate to their end application:

# Introduction - Common Electrical Transient Events

## Introduction

Over many decades, the demands imposed on electronic systems designers have remained consistent. The challenge to design circuits and systems that include more functionality and capabilities in smaller sizes continues. This ongoing miniaturization trend has given rise to other challenges.

As the size of the components used continues to shrink, their sensitivity to electrical stresses increases. Integrated circuits, especially microprocessors, have become instrumental components in modern electronic systems. However, their vulnerability to common electrical threats, such as electrostatic discharge (ESD) events, has forced circuit designers to take special measures to protect these devices.

Modern vehicles employ many electronic systems to control their various parts, including the engine, climate control, braking and, in some cases, steering systems. Transient electrical threats, such as in-rush currents for starting electric motors or ESD events, can also prove detrimental to sensitive automotive electronic systems.

A Multilayer Varistor (MLV) is a compact, surface-mountable chip that is voltage dependent, nonlinear, and bidirectional. It has an electrical V-I characteristic similar to back-to-back zener diodes, offering symmetrical protection in both forward and reverse directions. The sharp, symmetrical breakdown characteristics of an MLV device provide excellent protection from damaging voltage transients. When exposed to high voltage transients, the impedance of the MLV changes by many orders of magnitude, from a near open circuit to a highly conductive state.

MLV technology has high surge handling capability and exhibits extremely low leakage current, so it is a preferred solution commonly used for protection against ESD events, inductive switching transients, and general surge protection.

## Common Electrical Transient Events

Voltage transients are defined as short-duration surges of electrical energy and are the result of the sudden release of energy previously stored or induced by other means, such as heavy inductive loads or lightning. In electrical or electronic circuits, this energy can be released in a predictable manner through controlled switching actions or randomly induced into a circuit from external sources.

## ESD (Electrostatic Discharge)

Electrostatic discharge is characterized by very fast rise times and very high peak voltages and currents. This energy is the result of an imbalance of positive and negative charges between objects.

Here are some examples of the voltages that can be generated, depending on the relative humidity (RH):

- Walking across a carpet:
  35kV @ RH = 20%; 1.5kV @ RH = 65%
- Walking across a vinyl floor:
  12kV @ RH = 20%; 250V @ RH = 65%
- Worker at a bench:
  6kV @ RH = 20%; 100V @ RH = 65%
- Opening a vinyl envelope:
  7kV @ RH = 20%; 600V @ RH = 65%
- Picking up a polymer bag from a desk
  20kV @ RH = 20%; 1.2kV @ RH = 65%

The level of ESD generated by everyday activities like these can be far higher than the vulnerability threshold of standard semiconductor protection technologies. Following figure illustrates the ESD waveform defined in the IEC 61000-4-2 test specification.

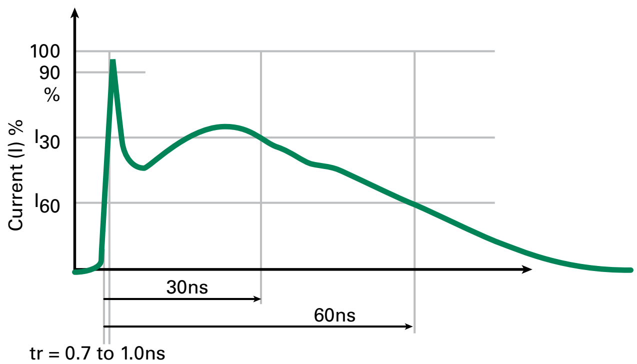



**Figure 1. ESD Test Waveform**

## Inductive Load Switching

The switching of inductive loads generates high energy transients that increase in magnitude with increasingly heavy loads. When the inductive load is switched off, the collapsing magnetic field is converted into electrical energy that takes the form of a double exponential transient

Depending on the source, these transients can be as large as hundreds of volts and hundreds of amps, with durations of 400ms.

Typical sources of inductive transients include:

- Generators
- Motors
- Relays
- Transformers

Sources like these are extremely common in electrical

# Introduction - Common Electrical Transient Events (continued)

and electronic systems. Because the sizes of the loads vary according to the application, the wave shape, duration, peak current, and peak voltage are all variables that exist in real-world transients. Once these variables are approximately calculated or measured, a suitable suppressor technology can be selected.

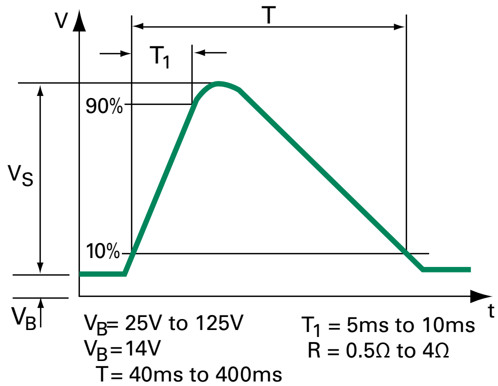



**Figure 2. Automotive Load Dump**

The above figure shows a transient resulting from stored energy within the alternator of an automobile charging system. A similar transient can be generated by other DC motors in a vehicle. For example, DC motors are used to power amenities like power locks, seats, and windows. These DC motor applications can produce transients that do as much damage to sensitive electronic components as transients that occur in the external environment.

## Lightning-Induced Transients

A lightning direct strike is clearly destructive; transients induced by lightning are the result of a strike occurring nearby. When a lightning strike occurs, it creates a magnetic field that can induce transients of large magnitude in nearby electrical cables.

Figure 3 shows how a cloud-to-cloud strike will affect both overhead and buried cables. Even a strike around one mile distance (1.6km) can generate 70V in electrical cables.

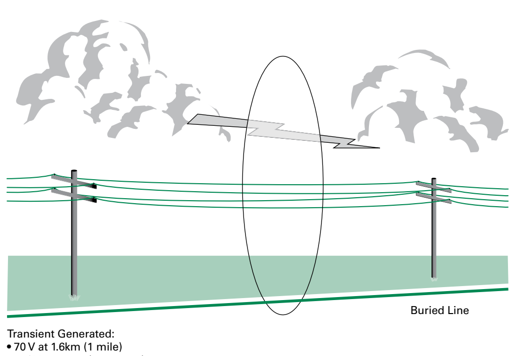



**Figure 3. Cloud-to-Cloud Lightning Strike**

Figure 4 shows the effect of a cloud-to-ground strike; the transient-generating effect is far greater.

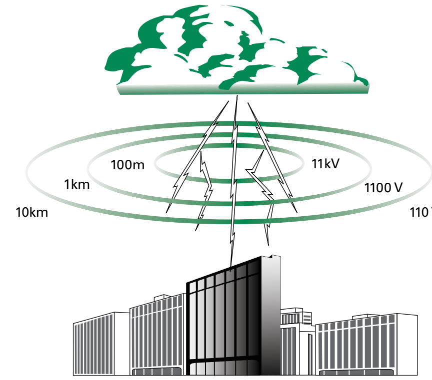



**Figure 4. Cloud-to-Ground Lightning Strike**

Figure 5 shows a typical current waveform for induced lightning disturbances.

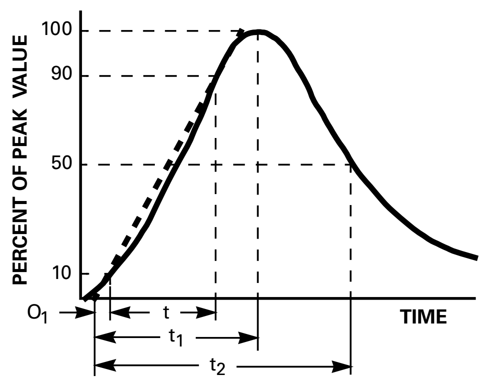



**Figure 5. Peak Pulse Current Test Waveform**

## Transient Threats Vs. Sensitivity of the Electronics System

Even though they occur in a timeframe of nanoseconds, ESD events can be very harmful to sensitive electronics. The high voltage level of an ESD pulse can punch through the $SiO_2$ of the MOSFET and other IC chips and damage the system permanently. Figure 6 shows a circuit board damaged by an ESD event.

# Transient Threats Vs. Sensitivity of the Electronics System

**Figure 6. Circuit Board Damage Due to ESD**

Recurring transients are frequently caused by the operation of motors, generators, or the switching of reactive circuit components. Random transients, on the other hand, are often caused by lightning and ESD, which generally occur unpredictably, and may require elaborate monitoring to be accurately measured, especially if induced at the circuit-board level. Numerous electronics standards groups have analyzed transient voltage occurrences using accepted monitoring or testing methods.

As component sizes shrink, electronic components exhibit increased sensitivity to electrical stresses. Microprocessors, for example, have structures and conductive paths that are unable to handle high currents from ESD transients. Such components operate at very low voltages, so voltage disturbances must be controlled to prevent device interruption and latent or catastrophic failures.

Sensitive microprocessors are prevalent today in a wide range of devices. Everything from home appliances, such as dishwashers, to industrial controls and even toys use microprocessors to improve functionality and efficiency.

Most vehicles now also employ multiple electronic systems to control the engine, climate, braking and, in some cases, steering, traction, and safety systems.

Many of the supporting components, such as electric motors or accessories within appliances and automobiles, present transient threats to the entire system.

Careful circuit design should not only factor in environmental effects but the potential effects of these related components. Table 2 shows the vulnerability of various component technologies.

| Device Type | Vulnerability (Volts) |
|---|---|
| VMOS | 30–1800 |
| MOSFET | 100–200 |
| GaAsFET | 100–300 |
| EPROM | 100 |
| JFET | 140–7000 |
| CMOS | 250–3000 |
| Schottky Diode | 300–2500 |
| Bipolar Transistor | 380–7000 |
| SCR | 680–1000 |
| Power MOSFET | 100–2000 |
| IGBT | 4000–8000 |

**Table 2. Range of Device Vulnerability**

| | Voltage | Current | Rise Time | Duration | Protection Device | Application Area |
|---|---|---|---|---|---|---|
| Lighting | 25kV | 200kA | 10µs | 1ms | MOV/TVS/SIDACtor | Telecom |
| Switching | 600V | 500A | 20µs | 500ms | MOV/TVS/SIDACtor | Industrial/Power System |
| EMP | 1kV | 10A | 20ns | 1ms | MOV/MLV | Industrial/Power System |
| ESD | 15kV | 30A | <1ns | 100ns | MLV/PGB/ Diode Array | Consumer Industrial |

**Table 1. Key Characteristics of Several Common Transients**

## Transient Threats Vs. Sensitivity of the Electronics System (continued)

### Protection Device Selection Considerations

Four different device technologies are designed for transient suppression: TVS diodes, multilayer varistors (MLVs), TVS diode arrays, and polymer ESD suppressors. Table 3 summarizes the various transient protection solutions available.

| Type of Threat | Typical Application | Typical Protection Device Used | Main Selection Criteria |
|---|---|---|---|
| Lightning | Equipment connected to external power and communication lines | Protection thyristors, TVS diodes, gas discharge tubes (GDTs), MOVs | Operating voltage, breakover/ clamping voltage, surge energy/power/ current ratings |
| ESD (Electrostatic Discharge) | Electronic equipment with human interfaces and data ports | MLVs, MOVs, polymer ESD suppressors, TVS diodes | Uni-/bidirectional, ESD voltage rating, low dynamic resistance, low clamping voltage, low capacitance |
| EFT (Electrical Fast Transient) | Equipment that has, or is connected to, a system or circuit with switched inductive loads or mechanical relays | MLVs, MOVs, polymer ESD suppressors, TVS diodes | Energy/peak current rating, operating voltage, surge current rating |
| Inductive load switching and commutative spikes | Equipment associated with large motors, generators, pumps, compressors, relays, and AC power distribution | MLVs, MOVs, polymer ESD suppressors, TVS diodes, GDTs | Proper blocking voltage and current carrying capacity |

**Note: MLV devices are rated at 125°C and suitable for harsh environment applications.**

**Table 3. Protection Technology Comparison**

### Multilayer Varistor as Surge Protection Solution

MLVs are clamping devices used for board level protection from ESDs, EFTs, and other transients that can occur on power supply, data, and control lines if the lines can tolerate higher capacitance.

MLVs offer a cost-effective solution in a range of popular industry-standard discrete component sizes. Some MLVs also offer low band-pass characteristics that filter high frequency noise from the circuit being protected. MLVs are typically used when:

- Power supply line or low/medium speed data and signal lines are to be protected.
- Transient currents or energy beyond ESD is expected (that is, EFT and lightning-induced surges)
- Designers looking to replace high wattage TVS Zener Diodes (300W–1500W).
- Added capacitance is desirable for EMI filtering (3p–4500pF).
- The operating voltage (up to 120VDC) is above silicon or polymer ESD suppressor ratings.

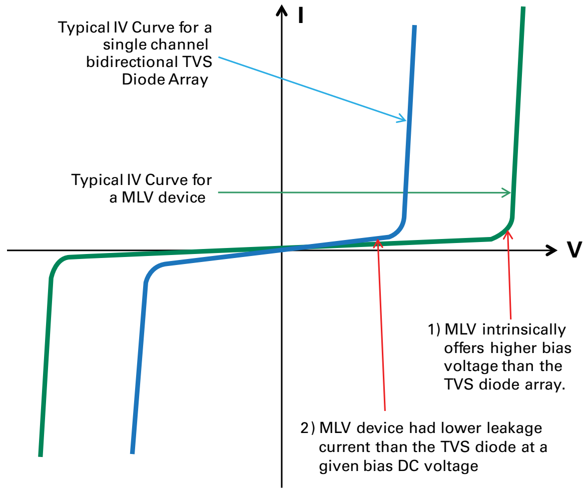



**Figure 7. The IV Curve of Typical MOV Sharp**

# About the MLV Technology

## About the MLV Technology

The MLVs have a multilayer structure to absorb transient energy and maximize the effectiveness of the ZnO2 material of which they are made.

## Structure

The MLVs are made of multiple fine-grain ceramic layers of a specific formulation. The MLV is constructed by forming a combination of alternating electrode plates and semiconducting ceramic layers into a block (Figure 8). Each layer of electrode is connected to the end termination on the opposite side.

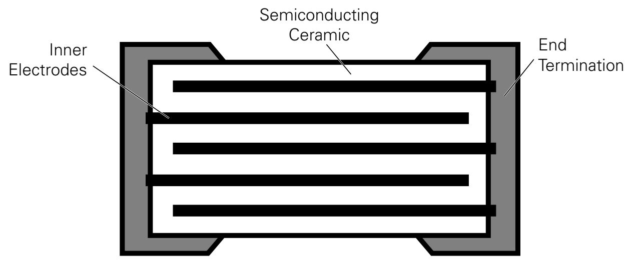



**Figure 8. Cross-section View of Multilayer Suppressor**

## Advantages of MLV Technology

This interdigitated block formation greatly enhances the cross-sectional area available for active conduction of transients. This parallel arrangement of the inner electrode layers represents significantly more active surface area than the small outline of the package would suggest. This increased active surface area results in proportionally higher peak energy capability.

Another advantage of this type of construction is that the breakdown voltage of the device is dependent on the dielectric thickness between the electrode layers, not the overall thickness of the device. Increasing or decreasing the dielectric thickness will change the breakdown voltage of the device.

## How Does a Multilayer Varistor Work?

The crystalline structure of the MLV transient voltage suppressor consists of a matrix of fine, conductive grains separated by uniform grain boundaries, forming many P-N junctions (Figure 9). These boundaries are responsible for blocking conduction at low voltages, and are the source of the nonlinear electrical conduction at higher voltages. Conduction of the transient energy takes place between these P-N junctions. The uniform crystalline grains act as heat sinks for the energy absorbed by the device in a transient condition, and ensures an even distribution of the transient energy (heat) throughout the device. This even distribution results in enhanced transient energy capability and long-term reliability.

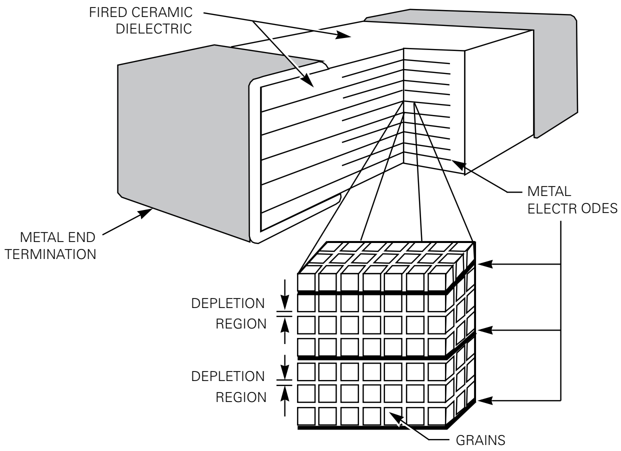



**Figure 9. Crystalline Structure of Multilayer Suppressor**

With MLV technology, energy-handling capability can be significantly increased with a larger overall package outline. The energy-handling capability doubles from 0.6J (10/1000μs waveform) for a 0.120-inch by 0.06-inch device (1206) to 1.2J for a 0.120-inch by 0.100-inch (1210) device.

As a result, MLVs are well-suited for the increasing demand for ESD protection for handheld and wearable devices. As the result of extensive research, Littelfuse can now offer the industry a 0201-size MLV.

# Where Are MLVs Used?

## Where Are MLVs Used?

MLVs are ideal for ESD and surge protection for virtually any application that involves electrical or electronic circuits, including automobiles, white goods, industrial applications, and portable electronics.

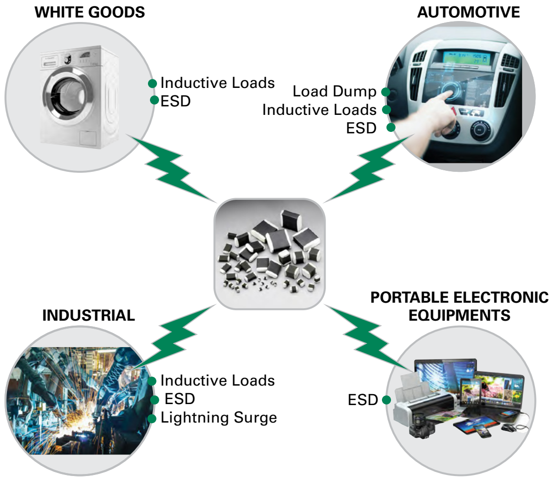



**Figure 10. Applications Using MLVs**

## Power Line Protection with MLV

From a circuit perspective, MLVs are often used to protect the DC port of a power supply from ESD, as well as for EMC protection.

| Protocols | Circuit Characteristics | MLV Advantages |
|---|---|---|
| DC power | DC power for DC at secondary input or output. DC bus for USB or HDMI ports. | • Low leakage current<br>• Additional EMI protection<br>• ESD protection |
| Audio circuit | Analog audio power line with bidirectional power source. | Low leakage current |
| Touch screen | Sensing ICs are vulnerable to ESD events for resistive touch screens | Provides external ESD protection for touch screen |

**Table 4. Power Line Protection Summary**

## MLV Protection in DC Power Line or Audio Circuit

MLV devices can be connected near the I/O port to clamp the ESD or surge event to the DC circuitry (Figure 11). Their smaller size, high temperature at 125°C, and quick response time offer one of the best solutions for industrial applications to provide on-board protection to protect against inductive surges as well as wearable device for audio IC protection.

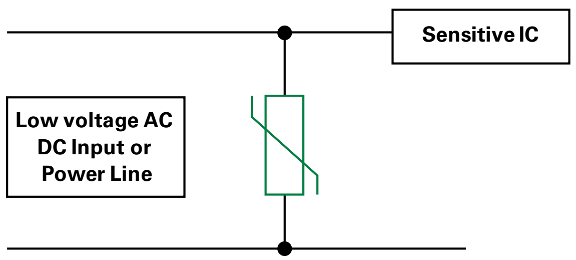



**Figure 11. MLV Protection in DC Power Line**

## MLV Protection in Touch Screen Circuit

Touch screen ICs are vulnerable to ESD events and high energy ESDs may couple to harm the ICs. An MLV provides an ideal solution to clamp ESD voltage to a safe level and enhance the reliability and life cycle for touch screen applications (Figure 12). The low leakage current feature of MLV devices also enhances the battery life of the display devices.

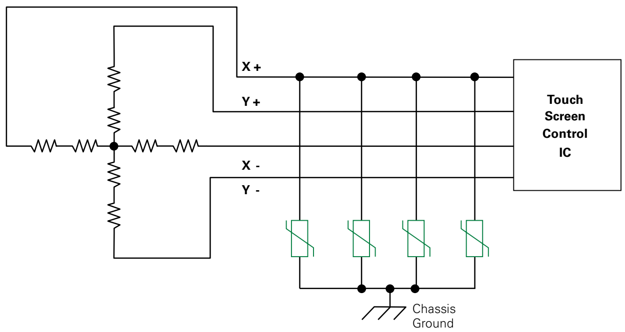



**Figure 12. MLV Protection in Touch Screen Circuit**

# Where Are MLVs Used? (continued)

## Data Line and Control Line Protection by MLV Device

Built with SMD packages and wide capacitance ranges down to as low as 3pF, MLVs are widely used for data line and control line protection.

| Protocols | Speed | Capacitance Requirements | Threats | MLA Device Advantage |
|---|---|---|---|---|
| USB1.1 | 12MHz | 50pF | ESD | MLA |
| USB2.0 | 480MHz | 3pF | ESD | MHS for D+/D- line<br>All MLV for DC line |
| USB3.0 | 5GHz | 0.1pF | ESD | MHS for D+/D- line<br>All MLV for DC line |
| HDMI | 3GHz | 0.2pF | ESD | MLV for DC line |
| CAN bus | 100kHz | 100pF | ESD, Load Dump | Auto grade MLV |
| LIN | 100kHz | 100pF | ESD, Load Dump | Auto grade MLV |
| RS-232 | 10kHz | 1000pF | ESD | All MLV Series |

**Table 5. Port Protection Summary**

Data line transmission requires both signal integrity and safe levels for IC protection. The MLV device structure provides capacitance levels ranging from 3pF to 500pF, depending on product series. This characteristic makes MLV devices ideal for low speed and control line protection (Figure 13). Some MLV Series, such as the MHS Series, can protect data line speed up to 500MHz.

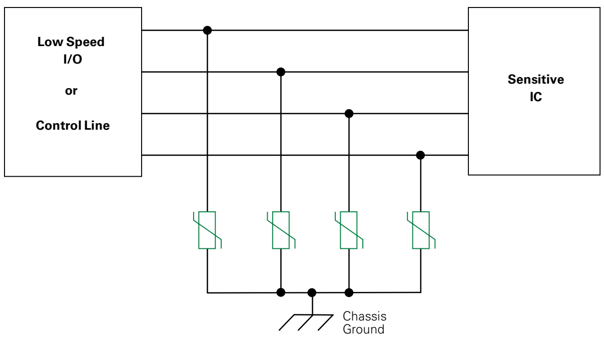



**Figure 13. Data Line or Control Line Protection**

## Application Examples

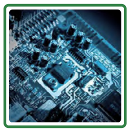
### CASE 1—AUTOMOTIVE TOUCH PANEL AND KEY/BUTTON PROTECTION

### PROTECTION NOTES

To help protect displays and push buttons against ESD threats due to human contacts, overvoltage protection devices should be used to provide clamping, thereby limiting the ESD voltage and preventing control circuitry failure. In general, multilayer varistor (MLA) devices can be used. In this case, an MLA Automotive Series device may be selected. TVS Diode Arrays are another potential alternative.

| Key Parameters | Application Condition | Requirement for MLV |
|---|---|---|
| Continuous Voltage Rating | Typical working voltage at 5VDC or 12VDC | Varistor voltage higher than 6VDC or 14VDC respectively |
| Device size | Customer may need compact design, SMD PCB mounting | 0402 or 0603 based on board space limitation |
| Energy and Peak Current | IEC 61000-4-2 requirement at 8kV Contact Discharge | All Littelfuse MLVs can meet the 8kV contact Discharge |
| Clamping Voltage | Application testing may be needed to determine exact clamping voltage needed | |
| Suggested Series Datasheet Link | MLA Automotive | |

**Note: This example is only for ESD threats; please refer to other example for other types of surges.**



### CASE 2 - AUTOMOTIVE CAN BUS

### PROTECTION NOTES

Load dump event, switching transient from can be power windows, side mirrors and power door lock damaging to control multiple functions. Depending on surge rating, CAN bus or LIN bus DC line or data line.

| Key Parameters | Application Condition | Requirement for MLV |
|---|---|---|
| Continuous Voltage Rating | 12 VDC or 24VDC requirement based on system voltage | Varistor voltage higher than 14VDC or 26VDC respectively |
| Device size | Customer may need compact design, SMD PCB mounting | 1206 up to 2220 |
| Energy and Peak Current | Load Dump | 10 Pulses Load Dump Energy up to 25 joules |
| Clamping Voltage | Application testing may be needed | |
| Suggested Series Datasheet Link | AUML | |

**Note: This example is only for ESD threats; please refer to other example for other types of surges.**

# Application Examples (continued)

## CASE 3 - INDUSTRIAL - SWITCHING INDUCTIVE LOADING PROTECTION NOTES

In an industrial control environment, an electric motor or inductive loading can generate high voltage surges during inductive switching from the energy stored in the winding coil in the motor or relays.

Inductive Switching: 8x20μs model by IEC61000-4-5. Suitable solutions include the MLA and MLE devices.

| Key Parameters | Application Condition | Requirement for MLV |
|---|---|---|
| Continuous Voltage Rating | 12VDC | Varistor voltage higher than 14VDC |
| Device size | Customer may need compact design, SMD PCB mounting | 0603 and up to 1210 size available |
| Energy and Peak Current | IEC 61000-4-5 requirement, Waveform as 8x20μs | Higher surge rating MLV needed up to Ipeak at 150A |
| Clamping Voltage | To meet IC damage level. Application testing may be needed | |
| Suggested Series Datasheet Link | MLA and MLE | |

**Note: This example is only for an 8x20μs inductive surge threat; please refer to other examples for other types of surges.**

## CASE 4 - WHITE GOODS - DISPLAY USER INTERFACE PROTECTION NOTES

ESD Human body model up to 8kV can be harmful to ECU of home appliance through the user interfaces. MLA, MHS, and MLE Series devices can help shunt ESD away from sensitive circuitry in appliance control interfaces.

| Key Parameters | Application Condition | Requirement for MLV |
|---|---|---|
| Continuous Voltage Rating | Typical value at 5VDC | Varistor voltage higher than 6VDC |
| Device size | Customer may need compact design, SMD PCB mounting | 0402 or 0603 typically used |
| Energy and Peak Current | IEC 61000-4-2 requirement at 8kV contact discharge | All Littelfuse MLVs can meet the 8kV contact discharge |
| Clamping Voltage | To meet IC damage level. Application testing may be needed | |
| Suggested Series Datasheet Link | MHS, MLA, and MLE | |

**Note: This example is only for ESD threats; please refer to other example for other types of surges.**

## Application Examples (continued)

### CASE 5 - COMPUTER/MOBILE - AUDIO PROTECTION

### PROTECTION NOTES

An ESD event can result in damage to the device through contact or air discharge through the audio port on the wearable devices. Because audio signals can range from 10Hz to 10kHz, MLA/MHS/MLE devices help shunt ESD away from sensitive circuitry without inducing signal distortion.

| Key Parameters | Application Condition | Requirement for MLV |
|---|---|---|
| Continuous Voltage Rating | 5VDC | Varistor voltage higher than 16VDC |
| Device size | Customer may need compact design, SMD PCB mounting | 0402 or 0603 |
| Energy and Peak Current | IEC 61000-4-2 requirement | 8kV Contact Discharge |
| Clamping Voltage | Application testing may be needed to meet IC damage level. Application testing may be needed | |
| Suggested Series Datasheet Link | MLE | |

**Note: This example is only for ESD threats; please refer to other example for other types of surges.**

# MLV Selection - Examples

## MLV Key Parameters

Although the AUML and MLA Series varistors are used in automotive electrical systems, the MLA, MHS, MLE, and MLN Series can be used in general applications. Refer to the summary in Table 11.

| MLV Series | AUML Series | MLA AUTO Series | MHS Series | MLA Series | MLE Series | MLN Series |
|---|---|---|---|---|---|---|
| **Features** | Auto-motive Grade | Auto-motive Grade | Low Capa-citance | Standard Chip Sizes | ESD | 1206 4X Array |
| **Voltage** | 18VDC | 3.5-48 VDC 2.5-40 VRMS | ≤42VDC (3pF) ≤18VDC (12pF) ≤9VDC (22pF) | 3.5V-30 VDC 30V-120 VDC | ≤18VDC | 5.5-18 VDC |
| **Size** | 1206 -2220 | 0603 -1210 | 0402 -0603 | 0201 -1210 | 0402 -1206 | 1206 |

**Table 11. Voltages and Sizes of Littelfuse MLVs**

These are the most critical parameters used for MLV 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.

The essence of MLV selection is finding the best match for the application in terms of electrical parameters, such as voltage and peak pulsing current, as well as the device size that best fits within the available board space.

| Selection Steps | Protection Notes |
|---|---|
| Continuous Voltage Rating | Continuous Working Voltage Rating DC condition; the operating voltage of the protected equipment or device plus the tolerance of the operating voltage. Tolerance and maximum allowable voltage of normal operating voltage. |
| Device size | Physical size of the MLV to best fit the available board space |
| Energy and Peak Current | Maximum expected surge current and number of hits |
| Clamping Voltage | Maximum voltage level that may be harmful to protected IC |
| Verify the Leakage Current | Leakage current of the selected varistor is appropriate for the circuit |
| Capacitance Requirement | Maximum allowable varistor capacitance |

**Table 12. MLV Selection Table (Worksheet)**

| Part Number | Maximum Ratings (125° C) | | | | | Specifications (25°C) | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum Continuous Working Voltage | | Maximum Non-repetitive Surge Current (8/20μs) | Maximum Non-repetitive Surge Energy (10/1000μs) | Maximum Clamping Voltage at 1A (or as Noted) (8/20μs) | Nominal Voltage at 1mA DC Test Current | | Typical Capacitance at f = 1MHz |
| | $V_{M(DC)}$ | $V_{M(AC)}$ | $I_{TM}$ | $W_{TM}$ | $V_C$ | $V_{N(DC)}$ Min | $V_{N(DC)}$ Max | C |
| | (V) | (V) | (A) | (J) | (V) | (V) | (V) | (pF) |
| V26MLA0603N | 26.0 | 20.0 | 30 | 0.100 | 60.0 | 31.0 | 38.0 | 110 |
| Part Number | Continuous Voltage Rating | | One Pulse Current Rating | One Pulse Energy | Clamping Voltage at Specific Current | Varistor Voltage | | Typical Capacitance |

**Figure 14. MLV Electrical Specifications**

## MLV Selection - Examples (continued)

### EXAMPLE 1 (GENERAL SURGE PROTECTION)

**Circuit conditions and requirements:**

- 20VDC
- Current waveform for surge is 8x20μs
- One-time peak current 100A
- Repetitive peak current at 3A
- Other components (Most vulnerable device to be protected, such as a IC rated at 300V

| Approach to Finding Solution | Compare Requirement to V26MLA1206N |
|---|---|
| **Step 1:** To find the voltage rating of the MLV, allow for 20% head room take into **account voltage variations** (20VDC x 1.2 + 24VDC; So look at 26VDC rated MLVs) (Refer to the summary in Table 13) | Voltage rating of 26VDC |
| **Step 2:** Determine which MLV size to use (Identify those that minimally meet the 100A surge requirement) (Refer to the summary in Table 14) | Device size of 1206 (3.2 x 1.6mm) |
| **Step 3:** Check datasheet or contact factory for pulse withstanding curve (Refer to the summary in Figure 13) | Can meet 10000 time surge pulses |
| **Step 4:** Use V-I Curve of selected MLV to varify that the peak voltage will be **below 300V ceiling** (Refer to the summary in Figure 14) | Peak voltage of 150V |

| Part Number | Maximum Ratings (125° C) | | | | | Specifications (25ºC) | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum Continuous Working Voltage | | Maximum Non-repetitive Surge Current (8/20μs) | Maximum Non-repetitive Surge Energy (10/1000μs) | Maximum Clamping Voltage at 1A (or as Noted) (8/20μs) | Nominal Voltage at 1mA DC Test Current | | Typical Capacitance at f = 1MHz |
| | $V_{M(DC)}$ | $V_{M(AC)}$ | $I_{TM}$ | $W_{TM}$ | $V_C$ | $V_{N(DC)}$ Min | $V_{N(DC)}$ Max | C |
| | (V) | (V) | (A) | (J) | (V) | (V) | (V) | (pF) |
| V18MLA0805N | 18.0 | 14.0 | 120 | 0.300 | 44.0 | 22.0 | 28.0 | 520 |
| V18MLA0805LN | 18.0 | 14.0 | 40 | 0.100 | 44.0 | 22.0 | 28.0 | 290 |
| V18MLA1206N | 18.0 | 14.0 | 150 | 0.400 | 44.0 | 22.0 | 28.0 | 1270 |
| V18MLA1210N | 18.0 | 14.0 | 500 | 2.500 | 44.0 at 2.5 | 22.0 | 28.0 | 2930 |
| V26MLA0603N | 26.0 | 20.0 | 30 | 0.100 | 60.0 | 31.0 | 38.0 | 110 |
| V26MLA0805N | 26.0 | 20.0 | 100 | 0.300 | 60.0 | 29.5 | 38.5 | 220 |
| V26MLA0805LN | 26.0 | 20.0 | 40 | 0.100 | 60.0 | 29.5 | 38.5 | 190 |
| V26MLA1206N | 26.0 | 20.0 | 150 | 0.600 | 60.0 | 29.5 | 38.5 | 720 |
| V26MLA1210N | 26.0 | 20.0 | 300 | 1.200 | 60.0 at 2.5 | 29.5 | 38.5 | 1480 |

Step 1 - Determine the voltage rating of the MLV device

**Table 13. Step 1 Illustration**

| Part Number | Maximum Ratings (125° C) | | | | | Specifications (25ºC) | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum Continuous Working Voltage | | Maximum Non-repetitive Surge Current (8/20μs) | Maximum Non-repetitive Surge Energy (10/1000μs) | Maximum Clamping Voltage at 1A (or as Noted) (8/20μs) | Nominal Voltage at 1mA DC Test Current | | Typical Capacitance at f = 1MHz |
| | $V_{M(DC)}$ | $V_{M(AC)}$ | $I_{TM}$ | $W_{TM}$ | $V_C$ | $V_{N(DC)}$ Min | $V_{N(DC)}$ Max | C |
| | (V) | (V) | (A) | (J) | (V) | (V) | (V) | (pF) |
| V18MLA0805N | 18.0 | 14.0 | 120 | 0.300 | 44.0 | 22.0 | 28.0 | 520 |
| V18MLA0805LN | 18.0 | 14.0 | 40 | 0.100 | 44.0 | 22.0 | 28.0 | 290 |
| V18MLA1206N | 18.0 | 14.0 | 150 | 0.400 | 44.0 | 22.0 | 28.0 | 1270 |
| V18MLA1210N | 18.0 | 14.0 | 500 | 2.500 | 44.0 at 2.5 | 22.0 | 28.0 | 2930 |
| V26MLA0603N | 26.0 | 20.0 | 30 | 0.100 | 60.0 | 31.0 | 38.0 | 110 |
| V26MLA0805N | 26.0 | 20.0 | 100 | 0.300 | 60.0 | 29.5 | 38.5 | 220 |
| V26MLA0805LN | 26.0 | 20.0 | 40 | 0.100 | 60.0 | 29.5 | 38.5 | 190 |
| V26MLA1206N | 26.0 | 20.0 | 150 | 0.600 | 60.0 | 29.5 | 38.5 | 720 |
| V26MLA1210N | 26.0 | 20.0 | 300 | 1.200 | 60.0 at 2.5 | 29.5 | 38.5 | 1480 |

Step 2 - Determine the size of the MLV device

**Table 14. Step 3 Illustration**

## MLV Selection - Examples (continued)

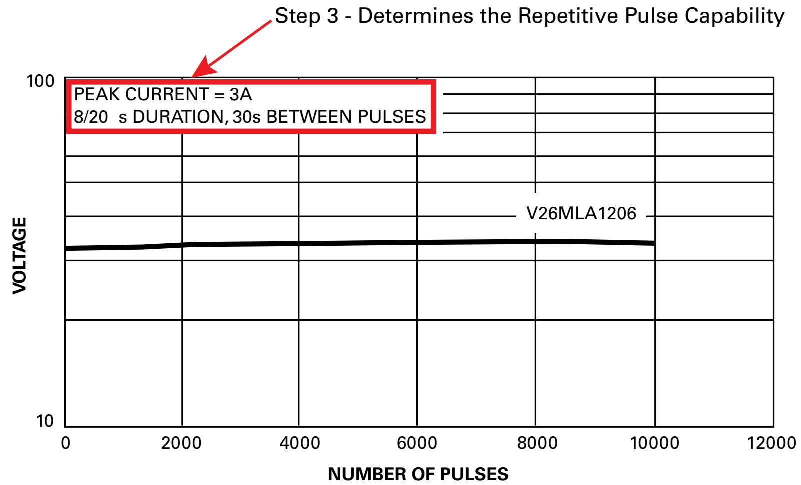



**Figure 14. Step 3 Illustration**

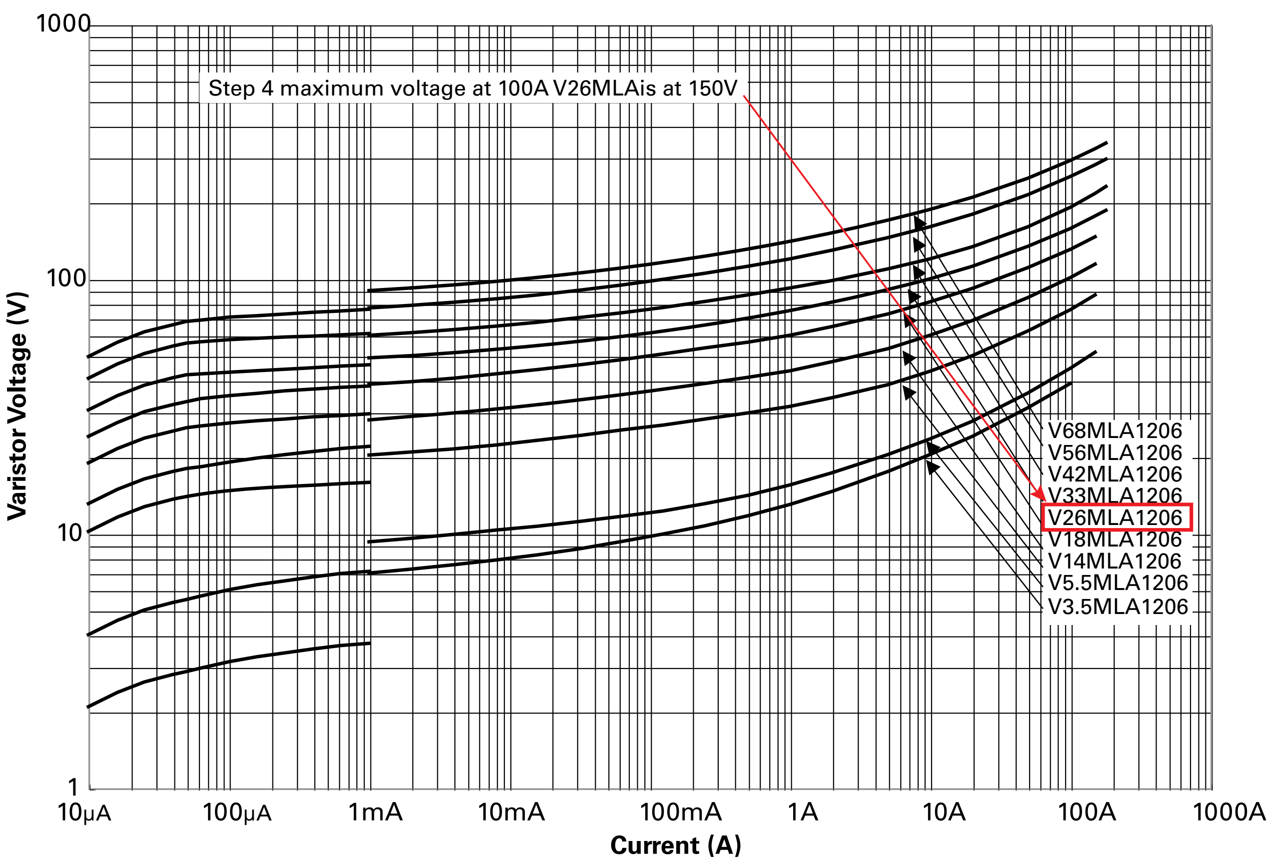



**Figure 15. Step 4 Illustration**

# MLV Selection - Examples (continued)

## EXAMPLE 2 (LOAD DUMP PROTECTION)

**Circuit conditions and requirements:**

- 12VDC
- Current waveform for surge is Load Dump (time of emery input 40ms, interval 60 seconds)
- Load Dump Energy 10J for 10 pulses
- Other components (Most vulnerable device to be protected, such as an IC rated at 150V, typically rated with 8x20µs waveform)

| Approach to Finding Solution | Compare Requirement to V18AUMLA2220 |
|---|---|
| **Step 1:** To find the voltage rating of the MLV, allow for 20% head room take into account voltage variations (12VDC x 1.2 + 14.4VDC; So look at 18VDC rated MLVs) (Refer to the summary in Table 15) | Voltage rating of 18VDC |
| **Step 2:** Determine which MLV size to use (Identify those that minimally meet the 10J (10 Pulses) surge requirement) (Refer to the summary in Table 16) | Device size of 2220 (5.6 x 5.0mm) can meet 10 times Load Dump pulses (10J for each pulse) |
| **Step 3:** Use V-I Curve of selected MLV to verify that he peak voltage will be below 50V ceiling (Refer to the summary in Figure 16) | Peak voltage of 50V |

| Part Number | Maximum Ratings (125℃) | | | Specifications (25℃) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum Continuous DC Voltage | Jump Start Voltage (5 Min) | Load Dump Energy (10 Pulses) | Nominal Varistor Voltage at 10mA DC Test Current | | Maximum Standby Leakage (at 13V DC) | Maximum Clamping Voltage ($V_C$) at Test Current (8/20µs) | |
| | $V_{M(DC)}$ | $V_{JUMP}$ | $W_{LD}$ | $V_{N(DC)}$ Min | $V_{N(DC)}$ Max | $I_L$ | $V_C$ | $I_P$ |
| | (V) | (V) | (J) | (V) | (V) | (µA) | (V) | (A) |
| V18AUMLA1206 | 18 | 24.5 | 1.5 | 23 | 32 | 50 | 40 | 1.5 |
| V18AUMLA1210 | 18 | 24.5 | 3.0 | 23 | 32 | 50 | 40 | 1.5 |
| V18AUMLA1812 | 18 | 24.5 | 6.0 | 23 | 32 | 100 | 40 | 5.0 |
| V18AUMLA2220 | 18 | 24.5 | 25 | 23 | 32 | 200 | 40 | 10.0 |
| V24AUMLA2220 | 24 | 24.5 | 25 | 32 | 39 | 200 | 60 | 10.0 |
| V48AUMLA2220 | 48 | 24.5 | 25 | 54.5 | 66.5 | 200 | 105 | 10.0 |

Step 1 - Determine the voltage rating of the MLV device

**Table 15. Step 1 Illustration**

| Part Number | Maximum Ratings (125℃) | | | Specifications (25℃) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum Continuous DC Voltage | Jump Start Voltage (5 Min) | Load Dump Energy (10 Pulses) | Nominal Varistor Voltage at 10mA DC Test Current | | Maximum Standby Leakage (at 13V DC) | Maximum Clamping Voltage ($V_C$) at Test Current (8/20µs) | |
| | $V_{M(DC)}$ | $V_{JUMP}$ | $W_{LD}$ | $V_{N(DC)}$ Min | $V_{N(DC)}$ Max | $I_L$ | $V_C$ | $I_P$ |
| | (V) | (V) | (J) | (V) | (V) | (µA) | (V) | (A) |
| V18AUMLA1206 | 18 | 24.5 | 1.5 | 23 | 32 | 50 | 40 | 1.5 |
| V18AUMLA1210 | 18 | 24.5 | 3.0 | 23 | 32 | 50 | 40 | 1.5 |
| V18AUMLA1812 | 18 | 24.5 | 6.0 | 23 | 32 | 100 | 40 | 5.0 |
| V18AUMLA2220 | 18 | 24.5 | 25 | 23 | 32 | 200 | 40 | 10.0 |
| V24AUMLA2220 | 24 | 24.5 | 25 | 32 | 39 | 200 | 60 | 10.0 |
| V48AUMLA2220 | 48 | 24.5 | 25 | 54.5 | 66.5 | 200 | 105 | 10.0 |

Step 1 - Determine the size of the MLV device

**Table 16. Step 2 Illustration**

## MLV Selection - Examples (continued)

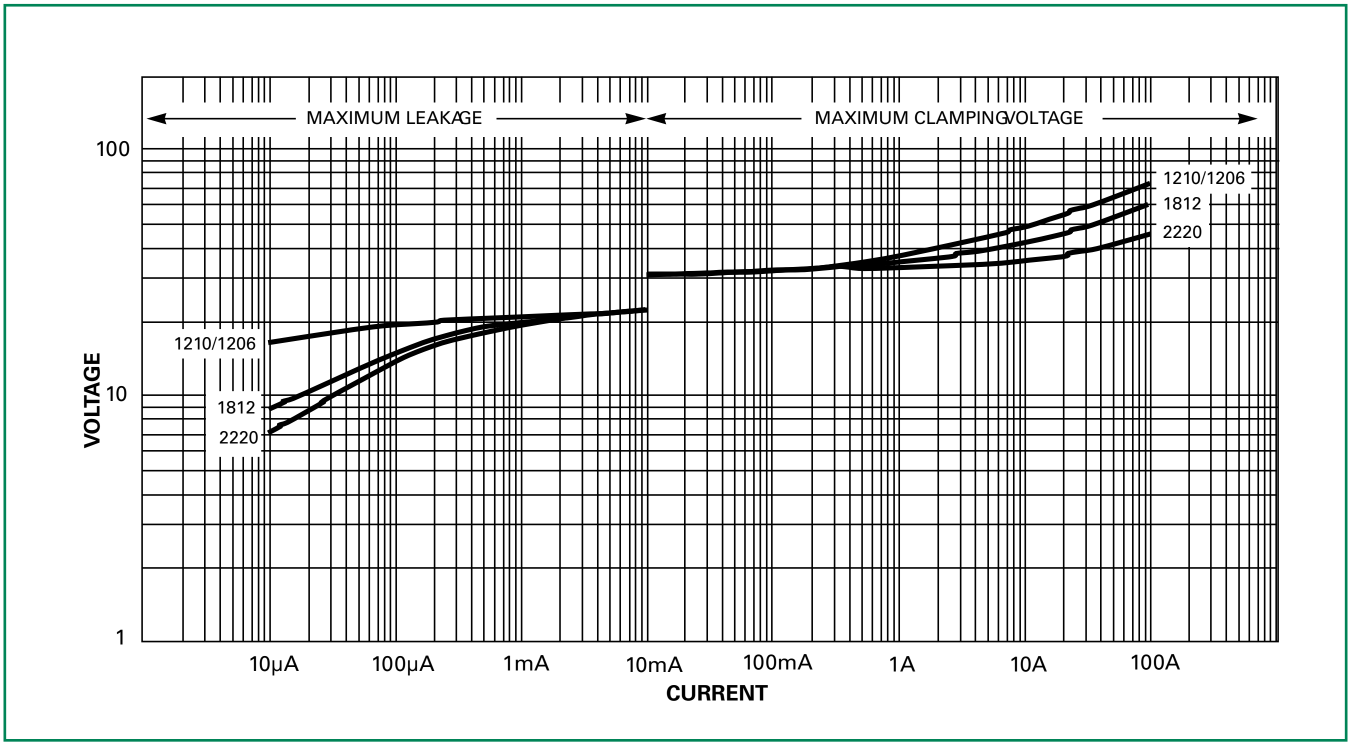



**Figure 16. Step 3 Maximum leakage current/clamping voltage curve for AUML Series at 25°C**

## MLV Selection - Examples (continued)

### EXAMPLE 3 (ESD PROTECTION)

**Circuit conditions and requirements:**

- Circuit operating voltage at 3.0VDC
- Current waveform IEC61000-4-2 ESD waveform
- 30 times at 8kV Contact Discharge
- Signal speed at 500MHz
- Other components (Most vulnerable device to be protected, such as an IC rated at 500V)

| Approach to Finding Solution | Compare Requirement to V0402MMHS03N |
|---|---|
| **Step 1: To find the voltage rating of the MLV, allow for 20% head room take into account voltage variations** (3.0VDC x 1.2 + 3.6VDC; So look at 5.5VDC rated MLVs) (Refer to the summary in Table 17) | Voltage rating of 5.5VDC |
| **Step 2: Determine which MLV size to use** (Identify contact discharge ESD at 8kV and related clamping voltage level at 300V (Refer to the summary in Table 18) | Device size of 0402 (1.0 x 0.5mm) |
| **Step 3: Check signal integrity with Insertion Loss Chart** (Refer to the summary in Figure 17) | Can meet -3dB at 1000GHz |
| **Step 4: Use nominal stability to multiple ESD impulse chart for repetitive ESD withstanding capability** (Refer to the summary in Figure 18) | Able to meet at least 1000 8kV contact discharge human body model ESD pulses |

| Part Number | Performance Specifications (25 °C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum Clamping Voltage At 1A (8X20μs) | Maximum ESD Clamp Voltage (Note 1) | | Typical Leakage Current at Specified DC Voltage | | Typical Capacitance at 1MHz (1V p-p) | | Typical Inductance (from Impedance Analysis) |
| | | 8kV Contact (Note 2) | 15kV AIR (Note 3) | 3.5V | 5.5V | C (Note 4) | | L |
| | | Clamp | Clamp | P | $I_L$ | MIN | MAX | |
| | ($V_c$) | (V) | (V) | (μA) | (μA) | (pF) | (pF) | (nH) |
| V0402MHS03N | 135 | <300 | <400 | 0.5 | 1.00 | 2 | 5 | <1.0 |
| V0603MHS03N | 135 | <300 | <400 | 0.5 | 1.00 | 1 | 6 | <1.0 |
| V0402MHS12N | 55 | <125 | <160 | 0.5 | 1.00 | 8 | 16 | <1.0 |
| V0603MHS12N | 55 | <125 | <160 | 0.5 | 1.00 | 8 | 16 | <1.0 |
| V0402MHS22N | 30 | <125 | <160 | 0.5 | 1.00 | 15 | 29 | <1.0 |
| V0603MHS22N | 30 | <65 | <100 | 0.5 | 1.00 | 15 | 29 | <1.0 |

Step 1 - Determine the voltage rating of the MLV device

**Table 17. Step 1 Illustration**

| Part Number | Performance Specifications (25 °C) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum Clamping Voltage At 1A (8X20μs) | Maximum ESD Clamp Voltage (Note 1) | | Typical Leakage Current at Specified DC Voltage | | Typical Capacitance at 1MHz (1V p-p) | | Typical Inductance (from Impedance Analysis) |
| | | 8kV Contact (Note 2) | 15kV AIR (Note 3) | 3.5V | 5.5V | C (Note 4) | | L |
| | | Clamp | Clamp | P | $I_L$ | MIN | MAX | |
| | ($V_c$) | (V) | (V) | (μA) | (μA) | (pF) | (pF) | (nH) |
| V0402MHS03N | 135 | <300 | <400 | 0.5 | 1.00 | 2 | 5 | <1.0 |
| V0603MHS03N | 135 | <300 | <400 | 0.5 | 1.00 | 1 | 6 | <1.0 |
| V0402MHS12N | 55 | <125 | <160 | 0.5 | 1.00 | 8 | 16 | <1.0 |
| V0603MHS12N | 55 | <125 | <160 | 0.5 | 1.00 | 8 | 16 | <1.0 |
| V0402MHS22N | 30 | <125 | <160 | 0.5 | 1.00 | 15 | 29 | <1.0 |
| V0603MHS22N | 30 | <65 | <100 | 0.5 | 1.00 | 15 | 29 | <1.0 |

Step 2 - Determine the size of the MLV device

**Table 18. Step 2 Illustration**

## MLV Selection - Examples (continued)

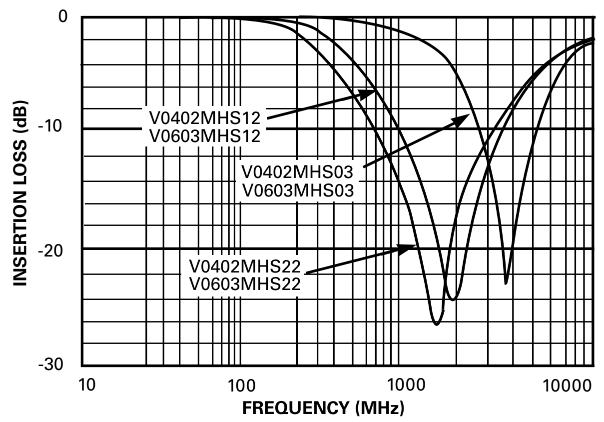



**Figure 17. Step 3 Step 3 Illustration - Insertion Loss (S21) Characteristics**

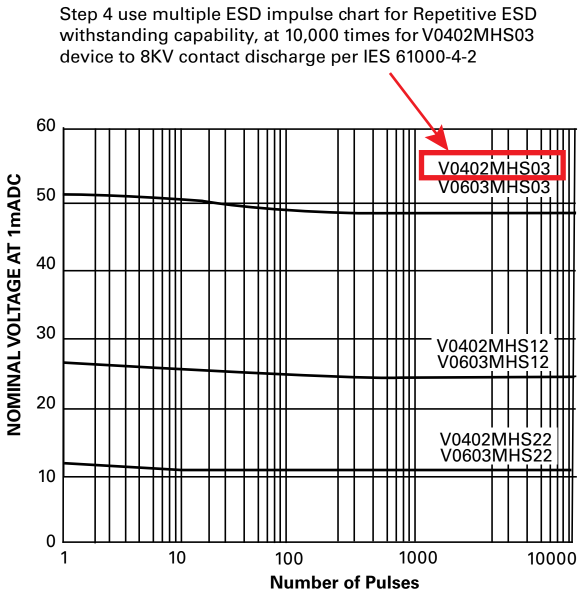


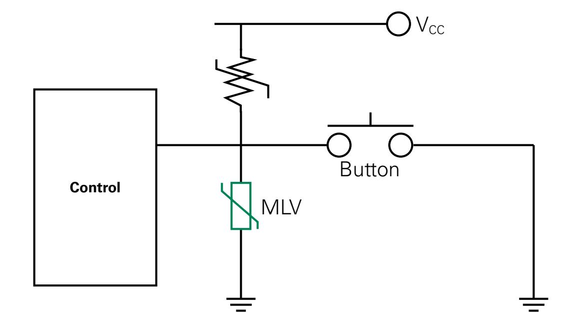

**Figure 18. Step 4 Illustration - Nominal voltage stability to multiple ESD impulses**

# Appendix I - General Application Examples

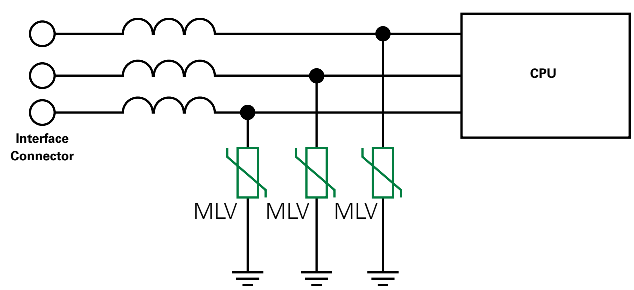
## GENERAL APPLICATIONS

Providing protection against ESDs is a significant concern when designing wearable devices, smart phones, computers, televisions, or other electronics. Every time a user touches a screen, pushes a button, or plugs/unplugs a data cable, there is an opportunity for potentially damaging ESD and transient surges. The same threats exist for other consumer electronics (LCD/LED TVs, set-top boxes, MP3/PMP players, and many others).

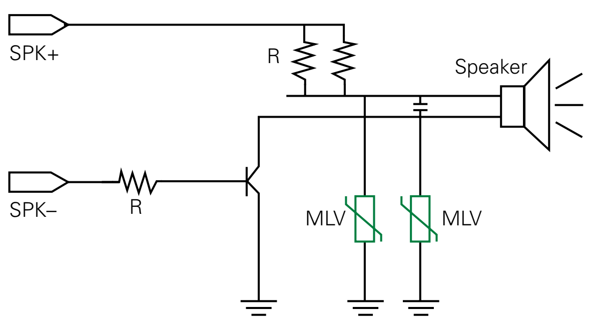
Whether the application is a home appliance, a smart phone, or an industrial panel, as long as there is EMC susceptibility, MLV devices offer a smart way to protect it. The MLV devices can well protect I/O ports like audio lines, USB ports, and RS-232 interfaces where ESD could otherwise gain access.



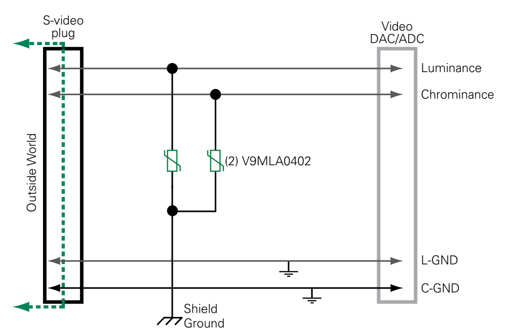

The MLV devices are ideal for ESD protection of buttons, control keys, or anywhere an ESD path can be formed.




The MLV devices can be applied in interface circuits, like a control line for microprocessors.




Audio I/Os like the earphone jack, can allow ESD to penetrate the audio IC and can cause damage due to the low-speed line in nature, MLVs are ideal for such applications.

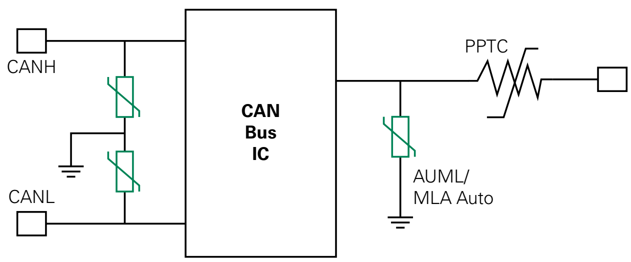



The characteristics and location of an MLV device will protect the video system from most over-voltage surges that might occur on the S-video input lines.

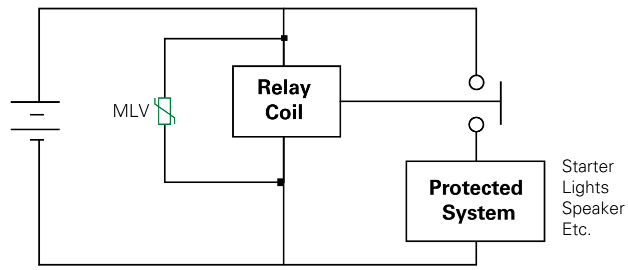
# Appendix II - Automotive Application Examples (continued)

## AUTOMOTIVE APPLICATIONS

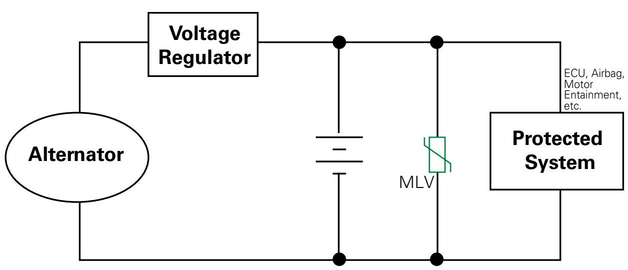
Modern vehicles have many electronic components within them. MLV is mostly used in the signal line and DC bus for ESD and surge protection.



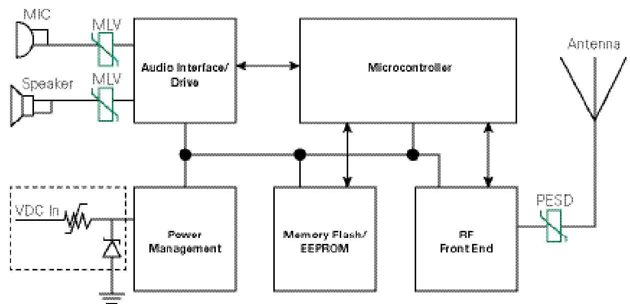

CAN Bus ICs are susceptible to Automotive transients. AUML and MLA Series devices offer protection for both the data and DC lines.




Protect vehicle subsystems (for example, airbag, power train, and climate control) from alternator transients with an Auto MLV. Use it as a shunt for the transient surge to protect the DC power line against the surge.




To protect against automotive relay surges, use an Auto MLV to absorb the arcing energy released by the magnetic fields of the relay.




Automotive subsystems like the audio system are also susceptible to transient-induced surges.

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