ESD Protection for portable electronic products

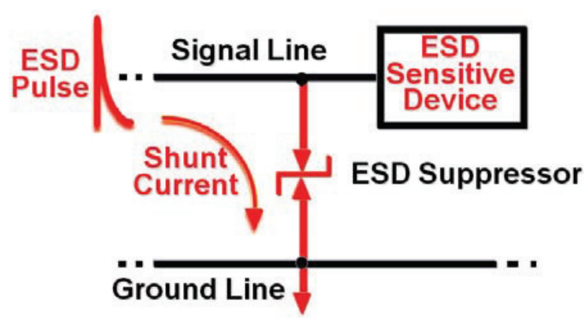
Overview

What is ESD?

Electrostatic discharge (ESD) is a growing problem within the electronic industry due to the sensitivity of high speed circuits and the growth in hand held portable products. The portable products used in everyday life have many input/output ports that connect to different devices. Human interaction with portable equipment ports is the cause of many ESD failures. Eaton offers a variety of ESD protection products that prevent damage to internal components in electronic equipment. Ideally for the best protection, these devices should be placed on the printed circuit board near the input/output ports to shunt ESD energy at the point of entry.

How is ESD Generated?

We experience occurrences of static electricity every day, such as walking across a carpeted room, opening a door or sliding across a car seat will create static electricity. A mild electric shock is often experienced, however this shock does not cause any harm to our bodies, but could cause severe damage to electronic devices. Damage due to ESD is estimated to cost the electronic industry billions of dollars each year, and this damage is not limited to the manufacturing cost, but also impacts machinery downtime and lost man-hours.



ESD function

Two main types of ESD failures

- Soft failure
- Hard failure

Soft failures are temporary failures due to the corruption of data or some other recoverable mechanism. Hard failures result in permanent damage to the system that may require replacement of a part before the equipment operation can be restored. Some hard failures are catastrophic failures which cause the electronic device to be inoperable and the device is permanently damaged.

In some instances the device is still functional, but the life of the device is significantly shortened. This latent damage is difficult to detect. The illustration of this type of damage effect is in shown in Figure 1. A portion of the conductor was damaged by the ESD energy discharge. The weak link is still functioning, but the connection will most likely fail over time.

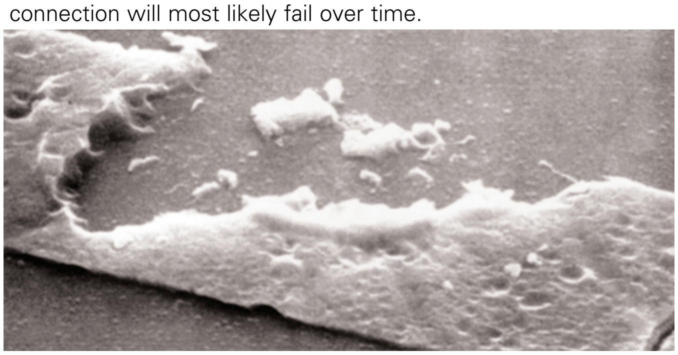


Figure 1. Latent damage due to ESD discharge

ESD event

An ESD event is the transfer of energy between two bodies at different electrostatic voltage potentials. To better understand the ESD event, we need to look at the human body model, which is widely used in the electronic industry.

The human body model is illustrated in Figure 2. In this model, the human body energy is transferred from the person, through the device and completing the path, to ground. The human body is modeled as two parallel capacitors. The capacitor holds energy, much like the stored energy in the body discharges when the path to ground is created.

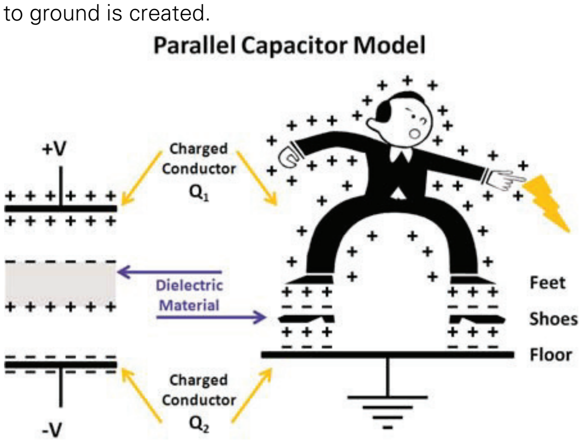


Figure 2. Human Body Model

ESD testing

IEC61000-4-2 is a standard test that was developed to establish a common and reproducible basis for evaluating the effects of ESD on products simulation the Human Body Model. The test circuit is illustrated in Figure 3.

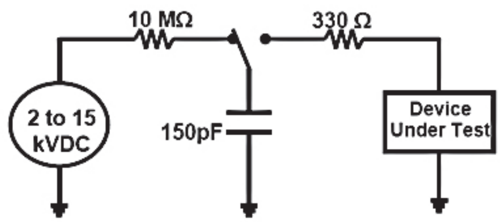


Figure 3. Test setup for Human Body Model

The 150 pf capacitor is charged by the DC voltage generator when the switch is connected to the 10 MΩ resistor. When the switch is moved to the other position, the energy stored in the capacitor will discharge through the device under test. IEC specification of test voltages for different levels of test for contact and air is given in Table 1. Test voltage is selected for different test level requirement.

Contact discharge	Level	Air discharge
2000 V	Level 1	2000 V
4000 V	Level 2	4000 V
6000 V	Level 3	8000 V
8000 V	Level 4	15,000 V

Table 1. Test conditions

ESD pulse

The ESD pulse is an extremely fast rising transient event. The pulse, as characterized in IEC 61000-4-2 (Figure 4), has a rise time of less than 1 ns, peak currents up to 45 A, and voltage levels to 15 kV. Characteristics determined by this test are voltage overshoot, peak voltage, clamping voltage, peak current, and device resistance.

Additionally, wiring inductance and probe capacitance can produce inaccurate readings on the oscilloscope. Considerable care must be taken during the test setup in order to reduce the connection wire length and a low capacitance probe must be used.

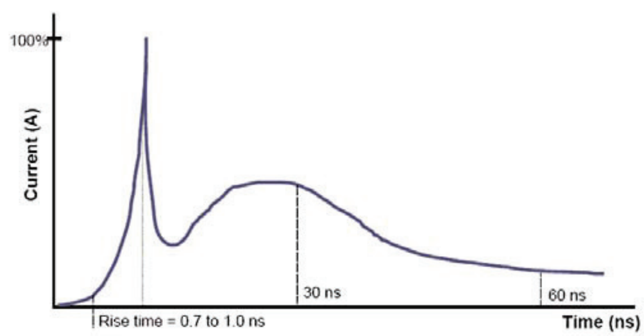


Figure 4. ESD pulse

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Technology options for protection against ESD

Eaton offers three different technologies for ESD protection.

- Voltage variable material
- Multilayer varistor (MLV)
- Transient voltage suppressor diode (TVS)

Voltage variable material

Voltage variable material (VVM) devices are made form a proprietary material mix and have unique properties ideal for ESD suppression applications. The VVM polymer matrix responds to an overvoltage condition by rapidly changing its internal resistance/ impedance from high to low, as illustrated in Figure 5.

Some advantages of this polymeric matrix are fast response, ultra low capacitance, and very low leakage current. Additionally, due to their ultra ow capacitance, the VVM should be used in high frequency, high data rates applications.

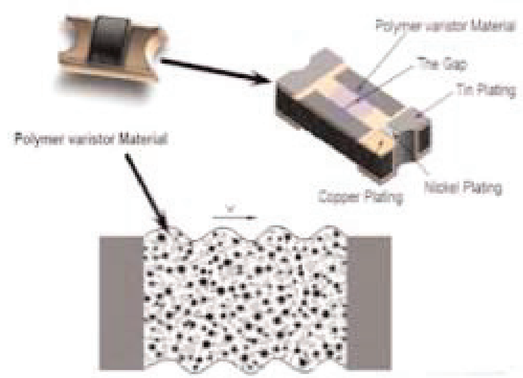


Figure 5. Voltage variable material ESD suppressors

The VVM is board level circuit protection devices designed exclusively for the fast transient overvoltages associated with ESD. When an overvoltage occurs the device exhibits a dramatic change to become more conductive. The nature of the material creates a bi-directional part, and only one device is required to provide complete ESD protection regardless of the input surge polarity.

In a typical application the device is connected between the signal line and ground. The device exhibits minimal capacitance and is practically "invisible" to the circuit during normal operation. Under normal operating voltages (typically to 15 V) the high impedance of the device insulates each signal line from ground, however when an ESD event occurs, the voltage variable material switches to a conductive state- this voltage level is called "trigger voltage"- within nanoseconds. The voltage across signal line drops to the clamping voltage level and current is shunted through the device to the ground. When the overvoltage pulse ends, the circuit returns to its normal operating state and the device switches back to its high resistance state and is again "invisible" to the circuit.

Multilayer varistor (MLV)

MLVs are made of multiple layers of zinc oxidized ceramic that when heated; the zinc oxide forms grains. These grains form boundaries similar to a diode, (i.e. one way operation). During a voltage spike, the high voltage causes the grain boundaries to breakdown and create low resistance for current to flow, shunting the voltage to ground and, hence, providing circuit protection.

Typical Characteristics of the Eaton MLV families are low capacitance, high energy handling capacity, low cost, and compact size. The 0402 and 0603 MLVA families are standard SMT sizes in the industry.

Construction of MLV

MLVs are made of fine grain ceramic layers that are stacked with alternating connections between the two electrodes. Every other layer connects to the same electrode (Figure 6). This configuration allows higher resistances at lower voltages, but also faster response times than MOVs.

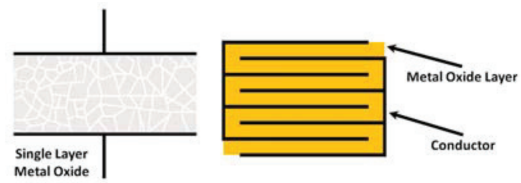


Figure 6. Multilayer varistor construction

Transient Voltage Suppression (TVS) diodes

TVS diodes are another technology designed for protecting electronic circuits against ESD pulses. Silicon-avalanche diodes are well suited for ESD protection, with high impedance at stand-off voltage and low impedance at breakdown voltage.

TVS Diodes are made with parallel opposing silicon avalanche diodes. Each diode is created by a P-N junction. These junctions (see Figure 7) form boundaries, which do not allow current to flow during normal operation and reduce loss through the device.

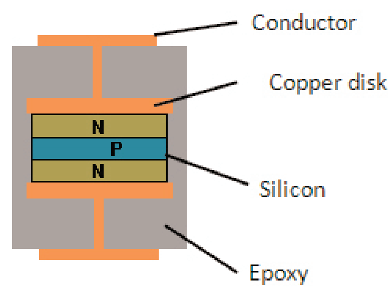


Figure 7. Transient Voltage Suppression construction

Any voltage spike or ESD pulse causes the P-N junction to break down creating a low resistance path for current to flow. This provides protection by shunting the voltage to ground. This is illustrated in Figure 8.

Eaton TVS Diode families provide low clamping voltage, low capacitance, and bidirectional capabilities and they are offered in small 0201 and 0402 packages.

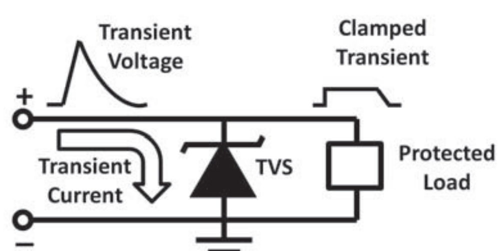


Figure 8. Transient Voltage Suppression operation

Selection of ESD devices

Eaton offers a wide variety of ESD suppressor products to protect electronic equipment against ESD pulses. Some important characteristics to consider when selecting an ESD solution include: IC sensitivity, speed of data transfer, clamping voltage, operating voltage, trigger voltage, peak current handling capacity, low capacitance, size, and the number of strikes the ESD device must withstand.

There are two main reasons ESD sensitivity of most circuits is on the rise. The first reason is the small IC package and the reduction in the die size. The second reason is the increase in the operating frequencies and a resultant sensitivity of the IC. Other factors that contribute to ESD sensitivity are the increase in the number of IC pins and the proximity to other devices. In Some cases, the ICs include an internal ESD protection, but the protection levels are typically very low, (around 2 kV).

The operating voltage of most ICs is getting lower than ever, and 1.5 V to 1.8 V volt devices are now common. To protect the IC's low voltage operation, the ESD device must be able to operate at low voltage and lower clamping voltage. These parameters are typically specified in most data sheets. Another important parameter associated with working voltage is the leakage current - Typically in the nA range when the device is in standby mode.

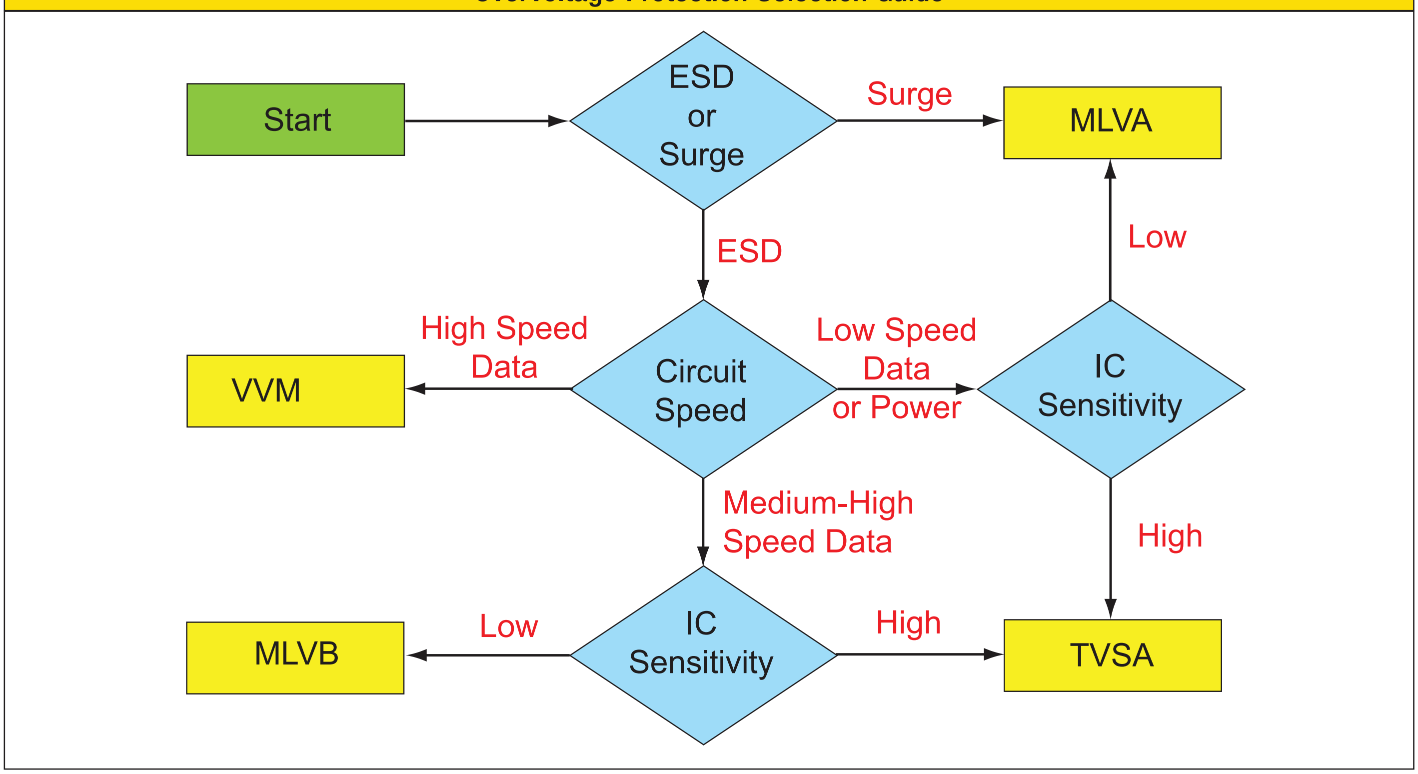
Clamping voltage is defined differently for different ESD suppressor technologies. In the case of MLV and TVS diode, the clamping voltage is defined as the peak voltage measured across the ESD device with 1 A pulse current and 80/20 us waveform. For voltage variable polymer type devices, the clamping voltage is defined as the voltage at which the device stabilizes (clamps) after transition from high impedance to low impedance.

The placement of ESD device in any given circuit is critical in the protection of sensitive devices. The ESD device should be placed very close to the input of the ESD, usually a connector or switch, and the ground plane.

Higher speed data lines require lower capacitance protective devices so that the signal is not attenuated or distorted. Low capacitances ranging from 0.5-5 pF are required for high speed transient voltage protection, depending on the specific signal frequency.

Eaton offers the industry standard packages of 0201, 0402, 0603, 1206 and 2510 in single and arrays. Discrete 0201, 0402, and 0603 SMD designs save precious circuit board space while giving designers flexibility in device placement for superior ESD protection schemes. Please Refer to the selection guide that follows for additional information to select the best ESD solution for your application.

Overvoltage Protection Selection Guide

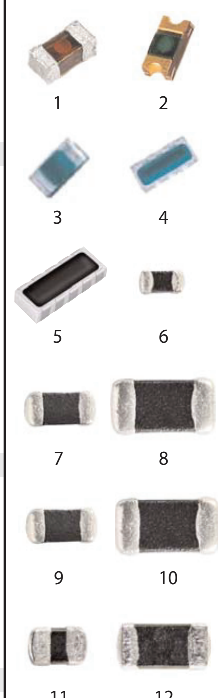


Applications	Technology		Feature / Benefit
High Speed Data Circuits	Voltage Variable Material	 Discrete  Array	• Ultra-low capacitance (0.05 pF typical) maintains signal integrity • 1 ns Reaction time protects ICs from ESD damage • Withstands 1000 ESD strikes for long lasting protection • Small 0402, 0603, 1206 and 2510 arrays meet the demands of many applications
Cost Sensitive Applications	MLVA & MLVB	 Discrete	• Small 0201, 0402, and 0603 SMD footprints save PCB space • Low capacitance (0.5-5pF) delivers superior protection for USB 2.0 • Low leakage currents (<10mA) permit maintaining circuit functionality • Fast response time (<1ns) meets the needs of IEC 61000-4-2
Highly Sensitive ICs	TVS Diodes	 Discrete	• Solid-state silicon-avalanche technology protects against high voltage surges • Bi-directional functionality protects against positive and negative voltage spikes • Small 0201 and 0402 SMD footprints save PCB space • Low leakage currents and clamping voltages reduce power consumption and increase efficiency

ESD Suppressor Selection Guide

Part Number	Image Ref.	Rated Volts Vdc	Clamping Typ Voltage(V) Typical	Capacitance (pF) Typical	Trigger Voltage(V) Typical	Leakage Current	Size (mm) LxWxH	Packaging (pcs/reel)
Voltage Variable Material Ultra-Low Capacitance ESD Suppressors								
0402ESDA-MLP1	1	30	35	0.05pF@1MHz	300	<0.1nA	1.1x0.53x0.36	10000
PS04LTVA1	1	5	25	0.05pF@1MHz	150	<0.1nA	1.1x0.53x0.36	10000
0603ESDA-MLP7	2	30	35	0.05pF@1MHz	300	<0.1nA	1.6x0.8x0.5	5000
0603ESDA-TR1	3	24	35	0.15pF@1kHz~1.8GHz	300	<0.1nA	1.6x0.8x0.5	5000
41206ESDA-TR1	4	12	35	0.15pF@1kHz~1.8GHz	150	<0.1nA	3.2x1.6x0.8	5000
42510ESDA-TR1	5	12	30	0.1pF@1MHz	300	<0.01µA	2.5x1.0x0.5	5000
MLVA Series Standard Capacitance Multi-Layer Varistors								
MLVA02V05C033	6	5.5	30	33pF@1MHz	***	<10µA	0.6x0.3x0.3	15000
MLVA02V05C047	6	5.5	26	47pF@1MHz	***	<10µA	0.6x0.3x0.3	15000
MLVA02V05C064	6	5.5	26	64 pF@1MHz	***	<10µA	0.6x0.3x0.3	15000
MLVA04V05C270	7	5.5	20	270pF@1MHz	***	<10µA	1.0x0.5x0.5	10000
MLVA04V09C130	7	9	32	130pF@1MHz	***	<10µA	1.0x0.5x0.5	10000
MLVA04V14C090	7	14	38	90pF@1MHz	***	<10µA	1.0x0.5x0.5	10000
MLVA04V18C085	7	18	45	85pF@1MHz	***	<10µA	1.0x0.5x0.5	10000
MLVA06V05C270	8	5.5	22	270pF@1MHz	***	<10µA	1.6x0.8x0.8	4000
MLVA06V09C210	8	9	27	210pF@1MHz	***	<10µA	1.6x0.8x0.8	4000
MLVA06V14C150	8	14	35	150pF@1MHz	***	<10µA	1.6x0.8x0.8	4000
MLVA06V18C130	8	18	40	130pF@1MHz	***	<10µA	1.6x0.8x0.8	4000
MLVA06V26C100	8	26	58	100pF@1MHz	***	<10µA	1.6x0.8x0.8	4000
MLVB Series Low Capacitance Multi-Layer Varistors								
MLVB04V18C0R5	9	18	250	0.5pF@1MHz	***	<10µA	1.0x0.5x0.5	10000
MLVB04V18C001	9	18	110	1pF@1MHz	***	<10µA	1.0x0.5x0.5	10000
MLVB04V18C003	9	18	58	3pF@1MHz	***	<10µA	1.0x0.5x0.5	10000
MLVB04V09C005	9	9	35	5pF@1MHz	***	<10µA	1.0x0.5x0.5	10000
MLVB06V18C0R5	10	18	250	0.5pF@1MHz	***	<10µA	1.6x0.8x0.8	4000
MLVB06V18C001	10	18	110	1pF@1MHz	***	<10µA	1.6x0.8x0.8	4000
MLVB06V18C003	10	18	58	3pF@1MHz	***	<10µA	1.6x0.8x0.8	4000
MLVB06V09C005	10	9	35	5pF@1MHz	***	<10µA	1.6x0.8x0.8	4000
TVSA Series Discrete Transient Voltage Suppressors								
TVSA02V05C004	11	5	17	4pF@1MHz	***	<10nA	0.6x0.3x0.3	15000
TVSA04V05C006	12	5	17	6pF@1MHz	***	<10nA	1.0x0.5x0.5	10000

Image References



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Printed in USA
Publication No. 4067
November 2017

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