Types of Electrical Overstress Protection

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APPLICATION NOTE

Introduction

ON Semiconductor makes a variety of silicon based protection products, including standard and Zener diode based Transient Voltage Suppressors (TVS), Thyristor Surge Protection Devices (TSPD) and Electronic Fuses (eFuse). TVS devices are also included as built in protectors in our line of single ended filters and common mode filters. Protection devices are made in a variety of other technologies, however. This application note will describe some of the most popular components used to protect systems from electrical over stress and will begin with a general discussion of the general classes of protection products and how they work. That will be followed by sections on voltage limiting and current limiting protection and descriptions of the various technologies available along with a summary of their strengths and weaknesses.

Protecting Electrical Systems

Sensitive electrical components in electronic systems are protected from electrical overstress in a number of ways. The first line of defense is the system's case which provides physical protection. The second line of defense is proper grounding which shunts excess voltages and currents away from sensitive nodes. Systems, however, need inputs and outputs such as keyboards, video outputs and data interfaces such as USB ports. These input and output ports often provide an easy path for electrical overstress during normal use. Protection products are used on input and output lines to limit electrical stress from the most commonly occurring stresses, which range from electrostatic discharge through lightning.

Protection components fall into two categories, voltage suppression and current limiting. These are illustrated in Figure 1 in which a voltage limiting device is represented by a diode and a current limiting device is represented by a fuse. Voltage limiters are placed between a sensitive node and a low impedance voltage, usually ground. During normal operation of the system the voltage limiting component must have high impedance. Outside of normal operating voltages the voltage limiting device must switch to a low impedance to shunt stress current to ground, limiting the voltage on the sensitive node. Current limiting devices must be placed in line with the signal. Current limiters must have low resistance during normal system operation but switch to a high impedance state during a stress condition.
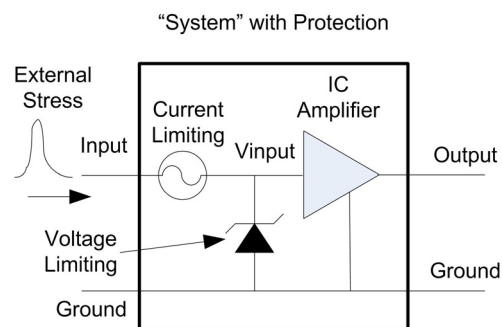

Figure 1. Illustration of How Protection Devices Limit Stress to Sensitive Components

Voltage Suppressors

All integrated circuit pins have a range of voltage and current over which they are designed to operate. Above the normal operating voltage is a region of safe overvoltage, which will not cause damage to the circuit. At higher voltages the integrated circuit will be damaged. These regions are illustrated in Figure 2. The boundary between safe overvoltage and device damage is not sharp. Higher voltages can often be tolerated if the voltage excursion is of short time duration. Voltage suppressors need to work in the region of safe overvoltage of the circuit they are protecting by preventing voltage from entering the device damage region, but not degrade system performance within the range of normal operation.

Voltage suppressors are classified by protection behavior and by their directionality. The protection behavior differentiates between voltage clamping and snapback while directionality differentiates between unidirectional and bidirectional.

Voltage suppressor devices fall into two categories of behavior, voltage clamping and snapback protection as illustrated in Figure 2. A voltage clamping device has high resistance up to a turn on voltage, above which the resistance drops dramatically. For a voltage clamping device it is important that the turn on voltage is above the normal

operating voltage of the system but low enough to ensure the clamping voltage is well below the damage voltage for the node being protected. The on state resistance must also be extremely low to ensure low clamping voltages across a range of conditions that the electrical threat can present to the circuit.

A snapback device behaves differently. A snapback device also has high resistance at low voltage and turns on at a voltage above the normal operating voltage of the circuit being protected. In a snapback device however, the turn on voltage initiates a new conduction mechanism which creates a low resistance and the voltage drops well below the turn on voltage. In some instances the voltage may actually drop into the normal operation range. As illustrated in Figure 2 snapback devices may allow brief transients into the device damage region before returning to the safe voltage range. For many circuits such brief transients are acceptable since the onset of damage is often very time dependent.
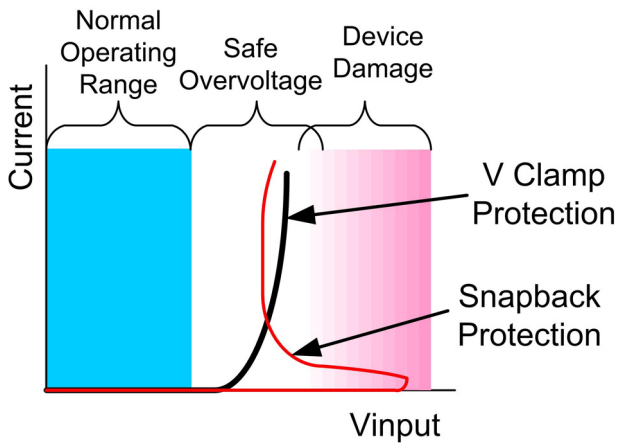
Some snapback type devices are referred to as crowbar devices. A crowbar device has a snapback type of I−V curve but has a very low on state resistance and can carry large currents making them suitable for surges caused by lightning and power line disturbances. Thyristor Surge Protection Devices (TSPD) and Gas Discharge Tubes (GDT) are often called crowbar devices. Polymer surge protection devices do not have a very low on state resistance and cannot be classified as crowbar devices.

Voltage limiting devices are also classified as bidirectional or unidirectional. Sample I−V curves for bidirectional and unidirectional voltage clamping protection components are shown on the left side of Figure 3. A bidirectional protection device has symmetrical protection properties centered at zero volts. As illustrated in the upper right part of Figure 3 a bidirectional protection structure is ideal for protecting nodes whose voltage normally extends symmetrically above and below zero volts, such as audio line applications. A unidirectional device has asymmetric behavior around zero volts. A classic unidirectional protection device is a Zener diode. In the forward direction the Zener begins to conduct strongly at about 0.7 V. In the reverse bias direction the Zener begins to conduct at its reverse bias breakdown voltage. As shown in the lower right part of Figure 3, a unidirectional protection device is ideal for protecting voltage nodes whose voltage is either always positive or always negative, such as data line applications. It is a common mistake to assume that bidirectional protection components protect for both positive and negative stress while unidirectional protection elements only protect for one stress polarity. This is not true, both unidirectional and bidirectional protection products can protect stress with either polarity.

Figure 2. I−V Curves for Voltage Clamping and Snapback Voltage Limiting Devices and How They Relate to the Properties of the Circuits They are Protecting
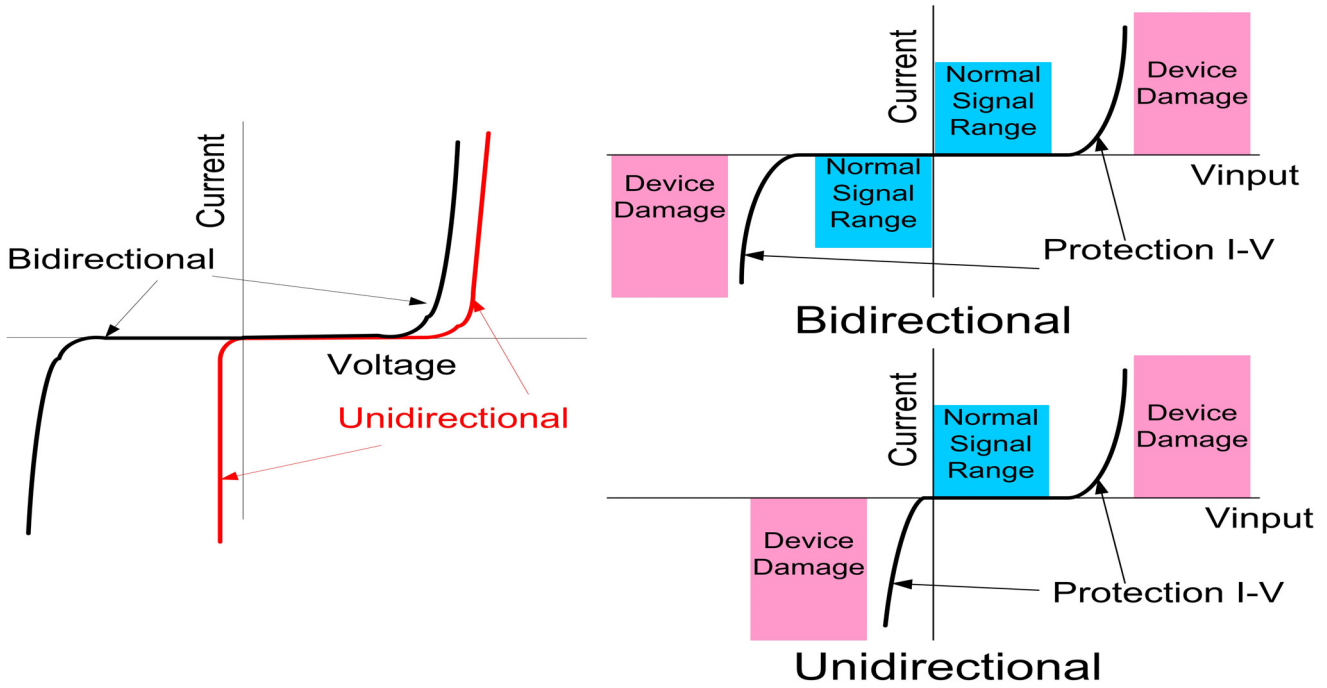
Figure 3. Bidirectional and Unidirectional Voltage Clamping Protection Devices With the Range of Safe and Unsafe Conditions for the Circuit Being Protected

Diode Transient Voltage Suppressors

Diodes are two terminal circuit elements which conduct current easily in one polarity and have a high resistance, up to some breakdown voltage, in the opposite polarity. Today most diodes are solid state devices made from Silicon.
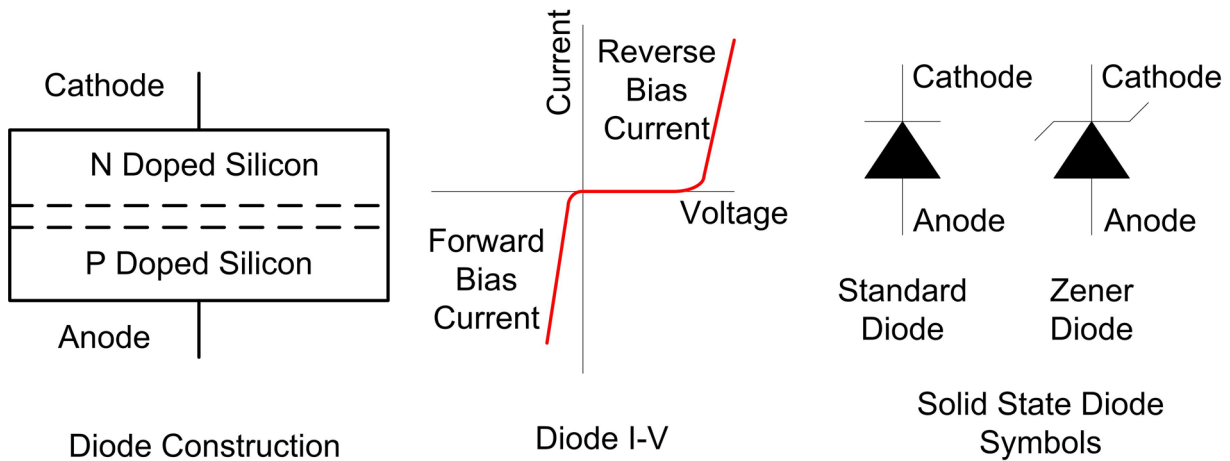

Figure 4. Diode Protection

Silicon diodes are formed at an interface between n doped and p doped regions of silicon as illustrated in Figure 4. At the junction the electric fields between the n and p doped regions create a depleted region without either n or p carriers when there is no externally applied voltage. If a negative voltage is applied from the cathode to the anode both n and p carriers are pushed across the junction (in opposite directions) and current begins to flow at about 0.7 V. If a positive voltage is applied from the cathode to the anode the n and p carriers are pulled further apart and very little current

flows. At a high enough voltage either avalanche breakdown or Zener tunneling will result in high currents. A basic diode's I–V curve is shown in Figure 4. Diodes are inherently unidirectional devices and protect by voltage clamping. The properties of the diode depend on the doping levels of the n and p regions both near the junction and far from the junction. Despite the simple nature of the basic diode structure variations in doping profiles can create a very wide range of diode properties. Diodes designed for

protection have benefited from all of the advances used in state of the art silicon technology development.

One of the most important diode properties is the breakdown voltage. Reverse bias diode breakdown voltages can vary widely from just a few volts up to hundreds of volts. Most silicon based diodes with a well defined breakdown voltage are referred to as Zener diodes. The circuit symbols for standard and Zener diodes are shown in Figure 4. (Reverse bias conduction by Zener tunneling is only significant for diodes with breakdowns of 6 V and less. Diodes with breakdown voltages above 6 V usually begin to conduct in the reverse bias direction by avalanche breakdown. The use of the term Zener diode for these higher breakdown voltage devices is standard in the industry, however.)

In the past silicon based TVS devices had a disadvantage protecting low voltage, high speed signal lines. Lowering the turn on voltage of a protection diode requires higher doping levels in the silicon which results in a high capacitance. This made them unsuitable for high speed applications. Recent technology advances have eliminated that disadvantage.

New products such as the ESD9L5.0 combine the advantages of silicon based protection with the low capacitance required for high speed applications. The ESD9L5.0 behaves as if it were a simple Zener diode. In fact the ESD9L5.0 includes a low breakdown Zener diode and a pair of high breakdown, and therefore low capacitance, standard diodes as shown in Figure 5. The DC I–V characteristics of the ESD9L5.0 are the same as for a low voltage Zener diode. For a negative cathode to anode voltage the single diode in the right branch provides forward bias diode conductivity. For positive cathode to anode voltages the right branch of the ESD9L carries little current, but the left branch will have a breakdown voltage equal to the Zener diode's breakdown plus a forward bias diode drop. The ESD9L5.0 obtains its low capacitance from the low capacitance of the two standard diodes. The right branch of the circuit has the low capacitance characteristic of the high breakdown diode, while in the left branch the series diodes will have a capacitance no higher than the capacitance of the low capacitance high breakdown diode.
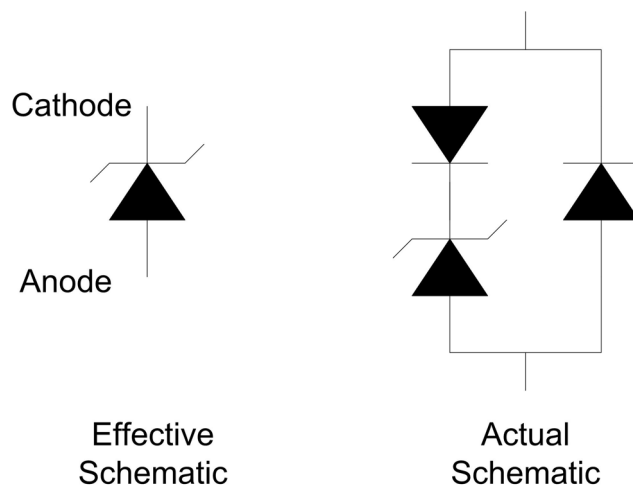

Figure 5. Effective and Actual Schematic of ON Semiconductor's ESD9L5.0, Ultra Low Capacitance Diode Based TVS Device

Zener diode based Transient Voltage Suppressors are a very effective products for protection. They have high conductivity in their on state, their turn on voltage can be controlled accurately, and they do not degrade with repeated stresses below their maximum current limits. They can also be manufactured in a variety of configurations on a single silicon substrate using integrated circuit processing techniques, as illustrated in Figure 6. Products such as

ON Semiconductor's ESD9L3.3 provide protection to unidirectional signals while bipolar signal lines can be protected by products such as ON Semiconductor's ESD7951. Single package solutions to protect multiple signal lines are also available with products such as ON Semiconductor's ESD7004 which is ideal for USB 3.0 and HDMI applications.
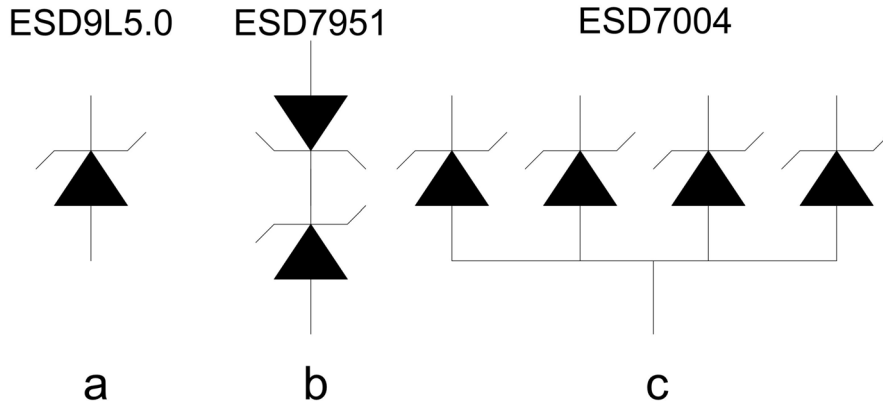
ESD9L5.0   ESD7951   ESD7004

a   b   c

Figure 6. Variety of Diode Based Protection Products Combining Multiple Diodes

Thyristors

Thyristor surge protection devices are based on a pair of interconnected bipolar transistors created by a 4 layer stack of n and p doped silicon regions as shown Figure 7. The n doped region N1, p doped region P1, and n doped region N2 form the emitter, base and collector of an npn transistor while p doped region P2, n doped region N2, and p doped region P1 form the emitter, base and collector of a pnp transistor. With this arrangement the collector of each transistor provides the base of the other transistor as in the center of Figure 7. In this way any emitter to collector current of one transistor provides the base current for the other transistor, thereby powering it into the conduction regime. For a positive Anode to Cathode voltage, both emitter−base junctions, J1 and J3, are forward biased. Only the reverse biased junction J2 prevents current flow. If the

Anode to Cathode voltage is increased to the breakdown voltage of the J2 junction, currents begin to flow directly into the bases of the two bipolar transistors. This turns both transistors on. With both transistors on, the thyristor's resistance drops, and the voltage across the thyristor also drops. The resulting I−V curve for forcing a positive current from the Anode to the Cathode of a thyristor is shown in Figure 7. A protection element with this form of I−V curve can provide excellent protection; when triggered the voltage drops well below the trigger condition and considerable current can be carried with very little power dissipation in the protection element. The protection properties have a snapback behavior for positive voltage. The low on state resistance of a thyristor makes it appropriate to call them crowbar devices.
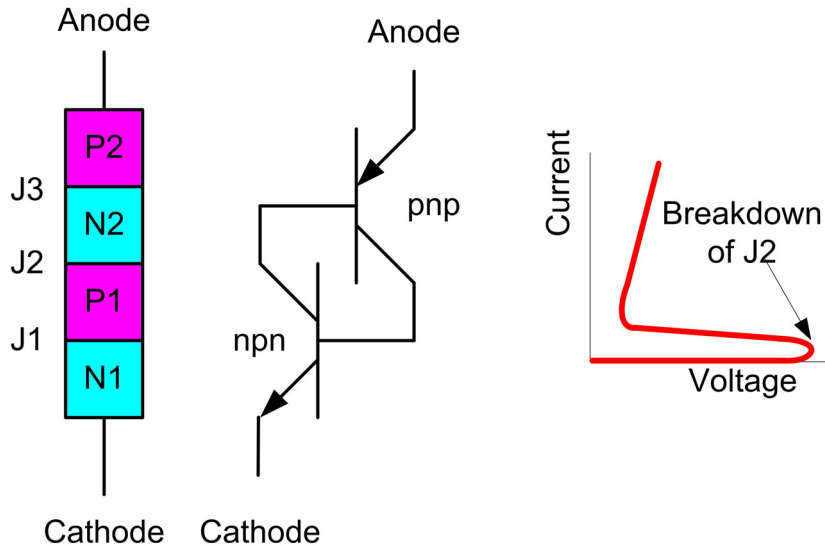
Figure 7. Basic Thyristor Structure and Behavior

Under a negative Anode to Cathode voltage the situation is very different. Only the junction J2 is forward biased. This forward bias junction could be considered the emitter base junction of a pair of bipolar transistors as shown in an unconventional depiction in Figure 8. Since the same junction is providing the emitter for both transistors no regenerative behavior is possible. For negative Anode to Cathode bias the Thyristor breakdown looks similar to a reverse biased diode, as shown in the I–V curve in Figure 8.
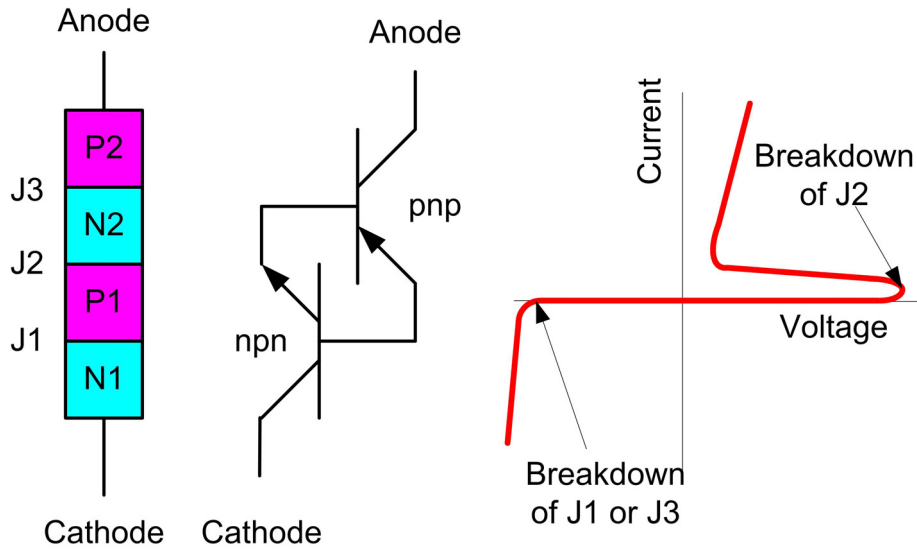
Figure 8. Thyristor Under Negative Voltage

To provide symmetrical snapback behavior it is necessary to use two anti parallel thyristors. This can be achieved with a pair of discrete thyristors, as shown in Figure 9a, or it can be done with an integrated structure on a single piece of silicon including five doping levels, as illustrated in Figure 9b. The integrated device is usually called a Thyristor Surge Protection Device (TSPD), although some companies refer to them as SIDACTORs. The I–V characteristic of a TSPD is shown in Figure 9c.
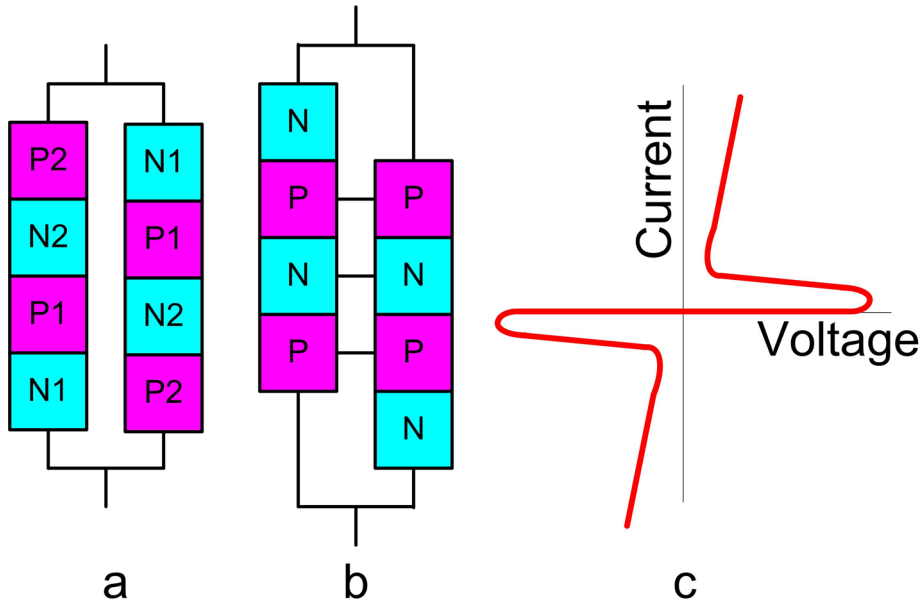
Figure 9. Creation of a Bidirectional Thyristor Protection Device

There are some design constraints that must be considered when using TSPDs. The holding voltage and current of a TSPD are defined in Figure 10. The holding voltage is often below the operating voltage of the circuit being protected. If the power source for the protected node can supply the holding current it is possible for a system to go into a latch−up state after a stress. This condition can be avoided by choosing a TSPD with holding currents greater than the system's power supply can source or by adding a small amount of resistance in the circuit to lower the current that can be supplied to a TSPD after a stress event.
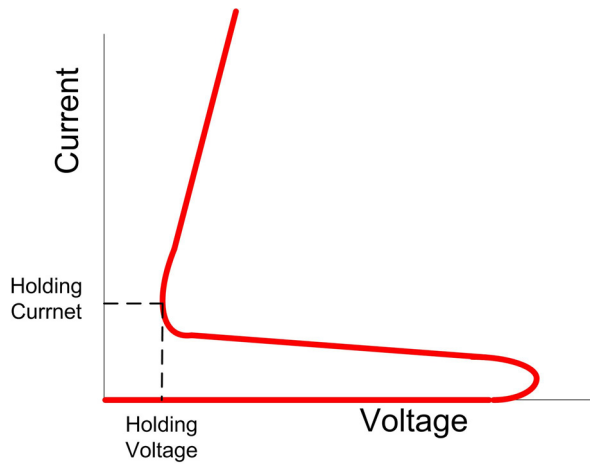
Figure 10. Holding Voltage and Current of a TSPD

TSPDs are excellent protection elements under electrical surge conditions since they can carry large amounts of current without being damaged and are very popular for telecommunication protection. They have low leakage and they come with a wide range of turn on voltages to match a variety of applications. Recent technology advances have produced low capacitance TSPDs that can be used to protect telecommunications circuits carrying high speed xDSL data.

Metal Oxide Varistors (MOV)

The metal oxide varistor is the first of the non−silicon−based voltage limiting devices discussed in this document. The term varistor is a combination of *variable* and *resistor*. At low currents and voltages varistors have a high resistance, but at higher voltages and currents the resistance drops significantly as shown in Figure 11a. Varistors are usually made of a ceramic of zinc oxide grains in a matrix of other oxides as illustrated in Figure 11b. The grains form diodes with the surrounding matrix, creating a complex array of parallel and anti−parallel diodes. At low voltage each miniature diode has a very low voltage across it and very little current flows. At higher voltages individual diodes begin to conduct and the resistance of the varistor drops significantly. Factors such as grain size, the nature of the matrix material between the grains, the thickness of the ceramic and the attachment of leads to the ceramic determine the properties of the varistor. To obtain low voltage turn on and improve conductivity most MOV varistors are constructed as a multi layer structure as shown in Figure 11c.
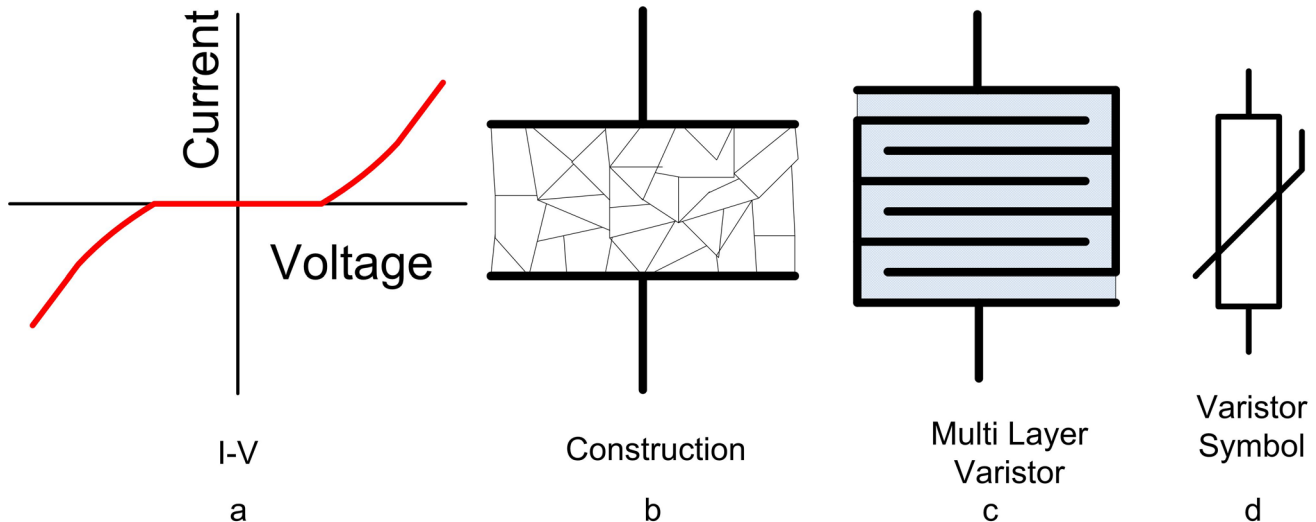

Figure 11. Metal Oxide Varistor and a Symbol Often Used for a Varistor

Varistors are always bidirectional devices but are manufactured with a very wide range of current and voltage capacities for applications ranging from lightning protection for high voltage transmission lines to small surface mount devices intended for ESD protection. Varistors, however, have a relatively high capacitance relative to their conductivity. These limitations of varistors result in much higher on state resistance compared to silicon devices and

thus much higher clamping voltages. Varistors therefore have limited application in the protection of high speed signal lines against ESD threats. Varistor performance can degrade with stresses well below their rated values. In addition, since the performance of the varistor is dependent on the material composition within the product, which can vary from part to part and from stress to stress, the clamping voltage performance is inconsistent and unreliable during the electrical stress. A commonly used circuit symbol for a varistor is shown on the right side of Figure 11.

Polymer Surge Suppressors

Polymer protection is formed by a volume of polymer surrounding an array of conducting particles as illustrated in

Figure 12. At low voltages the polymer has a very high resistance. At higher voltages arcs form between the conducting particles, thereby forming a lower resistance path and the voltage across the device drops. The breakdown voltage will depend on the nature of the polymer, the sizes of the conducting particles and the separation between them. Polymer surge suppression devices are snapback devices and are always bidirectional as illustrated by their I−V curve in Figure 12.

Figure 12. Polymer Surge Suppressor

Polymer devices have very low capacitance, which can be attractive for maintaining signal integrity of high speed applications. They have several down sides, however. They have high trigger voltages that can exceed 1000 V leaving sensitive components unprotected for low voltage stress events. Their on state resistance is poor, which can allow 100s of volts across sensitive circuits during an ESD event even after the protection device triggers. Polymer surge suppressors can also degradation under multiple stresses.

Gas Discharge Tubes (GDT)

Gas discharge tubes are usually formed with a ceramic body filled with a gas mixture containing neon and argon and two or more electrodes as shown in on the left of Figure 13. When the voltage across the electrodes exceeds a specified value a glow discharge is formed and this is followed by an arc if sufficient current is available, thereby

providing a low current path. This is illustrated in the I−V curve in Figure 13. GDTs are snapback devices and are always bidirectional. The on state resistance of GDTs is very low and they are a classic crowbar device.

Gas Discharge Tubes with three or more electrodes can be constructed with a single volume of gas by having holes in the inner electrodes. The result is that an arc formed by a trigger voltage between any two adjacent electrodes will result in a low resistance path between all of the electrodes as the ionized gas fills the entire gas chamber. This can be an important feature for multi line signal ports which might be sensitive to large voltages imbalances between the lines. Gas discharge tubes have a bidirectional snapback I−V similar to a bidirectional thyristor. The I−V curve is somewhat more complex due to glow regions which form between the initial breakdown and a full arc regime.
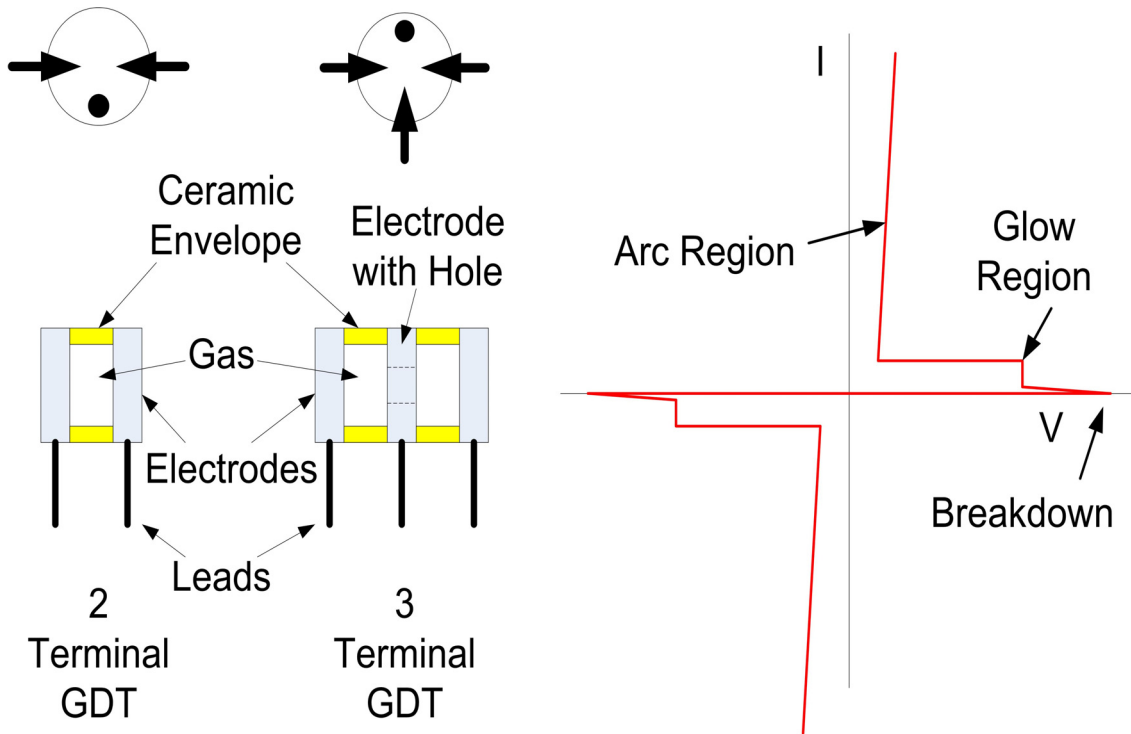
Figure 13. Gas Discharge Tube Construction, Electrical Symbols and I–V Curves

Gas discharge tubes can carry very large amounts of current and have very low capacitance resulting in very little signal loading. On the downside, the lowest turn on voltage for a GDT is about 75 V and the turn on time is relatively long. GDTs are also relatively large and more expensive than other surge protection devices. They excel as primary protection devices in coordination with other faster turn on and lower voltage secondary protection elements.

Summary of Voltage Suppressors

Table 1 provides a summary of voltage limiting protection devices and their properties while Table 2 outlines each devices advantages and disadvantages.

Table 1. SUMMARY OF VOLTAGE SUPPRESSION DEVICES

Type	Protection Mechanism	Application	Directionality	Strategy
Transient Voltage Suppressors (TVS)	Mix of forward bias, and avalanche and Zener breakdown silicon diodes	Surge and ESD	Unidirectional or Bidirectional	V Clamp
Thyristor (TSPD)	Turn on of coupled bipolar transistors (SCR)	Lightning & Surge	Usually Bidirectional	Snapback (Crowbar)
Metal Oxide Varistor (MOV)	Metal Oxide non linear resistance	Lightning, Surge & ESD	Bidirectional	V Clamp
Polymer	Arcs in Polymer w. Conductive Particles	ESD	Bidirectional	Snapback
Gas Discharge Tube (GDT)	Arc in Gas	Lightning & Surge	Bidirectional	Snapback (Crowbar)

Table 2. ADVANTAGES AND DISADVANTAGES OF VARIOUS VOLTAGE LIMITING DEVICES

Type	Advantage	Disadvantage
Transient Voltage Suppressors (TVS)	Well controlled turn on voltage Low resistance in on state Unidirectional and bidirectional versions Low capacitance versions available Low leakage Fast response	Limited power ratings
Thyristor (TSPD)	High current carrying capability Low capacitance versions available	Care needed in selection & design to avoid latch−up; otherwise power reset needed after surge event. Slower turn on than TVS − not fast enough for ESD protection
Metal Oxide Varistor (MOV)	Low cost Fast response	High capacitance High resistance in on state; poor power dissipation capability
Polymer	Very low capacitance Low cost	High turn on voltage High resistance in on state
Gas Discharge Tube (GDT)	Very high current carrying capability Low capacitance High off state impedance	Large size Slow response Expensive

Current Limiting Devices

There are four major types of current limiting devices, fuses, circuit breakers, PTC or positive temperature coefficient devices and electronic fuses (eFuse). The goal of each of the devices is to stop current flow if it gets too high. Each device has its strengths and weaknesses.

Electronic Fuse (eFuse)

An electronic fuse is an active electronic component which can limit current applied to a load as well as remove power from the load entirely. Additional features present in ON Semiconductor eFuses include voltage−clamping of transients. A block diagram of a basic electronic fuse is shown in Figure 14. The central element is a large power FET connecting the power source to the load. The use of a charge pump for the gate allows the FET to have a very low series resistance between the power source and the load during normal operation. Control circuits adjust the charge pump voltage supplied to the FET during normal, over−voltage, over−current and turn−on conditions.

Three circuits control the charge pump voltage; current limit, voltage limit (clamp) and thermal shutdown circuits. The current limit circuit monitors the voltage across the current sense resistor R_S in Figure 14. The current sense resistor is connected to a small section of the large FET. Since the sense resistor is monitoring only a fraction of the total current it can be a low power surface mount resistor placed on the board. The value of the sense resistor sets the "overload current" level above which current will be clamped; the clamped level is known as the "short−circuit current". For a given sense resistor value, the short−circuit current limit is generally lower than the corresponding overload−current level, as a result of which the clamping event leads to a downward transient in the current.

During normal operation the output voltage tracks the input voltage (V_{CC}), less the drop across the low−RDSON FET. If the VCC voltage gets too high and exceeds a preset value, the voltage limit circuit senses the source voltage of

the FET and adjusts the FET gate voltage to maintain the output voltage at a specified maximum value.

Finally the thermal shutdown circuit monitors the temperature of the FET. If the FET temperature exceeds a preset value the FET is turned off, removing power from the load. ON Semiconductor eFuses can be set to automatically restore power to the load after cool down, or require a power cycle or toggling of the enable pin to restore current flow.
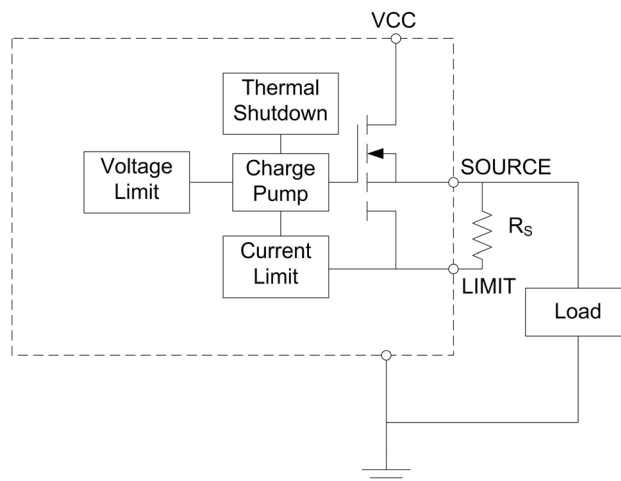

Figure 14. Basic Block Diagram of Primary Electronic Fuse Functions

There are a number of advantages to electronic fuses over other current limiting options. Current can be limited to a preset value, without removing all power to the load. ON Semiconductor electronic fuses can also limit overvoltage in the absence of high current conditions and do so without shutting the system down. Both the voltage and current limit functions work at the speed of an electronic circuit, rather than the slower thermal times characteristic of fusible conductor fuses and positive temperature coefficient (PTC) devices or the mechanical cycle times of a circuit

breaker. Finally the thermal function will remove power from the load in the situation of a long term (sub−millisecond range) over−current condition. ON Semiconductor eFuses have additional features such as under voltage lock out, dV/dt control on power up, logic controlled enable functions and outputs to signal fault conditions. The enable function is sometimes used to combine and coordinate multiple eFuses in parallel and thereby control multiple voltage buses and achieve higher DC−currents (and correspondingly higher trip currents). These advantages make them ideal for high reliability systems that require protection from over−voltage and over−current conditions with a minimum of system down time and with high precision.

Non−resettable Fuses

The primary element of a traditional non−resettable fuse is a fusible conductor that melts when current gets too high, as shown in Figure 15 for a cylindrical fuse. The nature of non−resettable fuses dictates that they will operate only once and must be replaced after operation. There are several parameters which define the capability of fuses. First of all is the amount of current that the fuse is designed to carry without opening. Next is the fuse's rated voltage. After the melting of the fusible element the fuse must be able to sustain the full voltage of the electrical supply without arcing or carrying excess leakage. Less well understood by people not familiar with non−resettable fuses is the maximum interrupt current. When a fusible element melts an arc is usually formed between the two terminals of the fuse. If the current is high enough this arc may continue to conduct current, even without the presence of a conductor between the two fuse terminals. This is especially an issue for DC circuits where there is no zero voltage crossing to help extinguish the arc. Another important parameter for fuses is the time to open. The time to open for a fuse will vary depending on how high the fault current is. Very high fault current will cause very quick action but lower fault currents can take considerable time for the fuse element to melt.
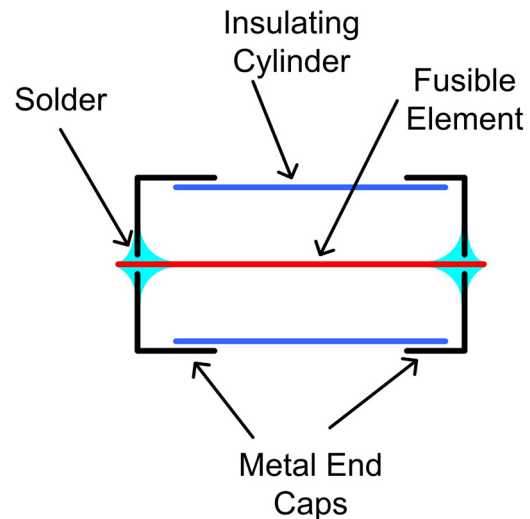
Figure 15. Construction of a Cylindrical Fuse

Circuit Breakers

Circuit breakers are the next class of current limiters. Circuit breakers employ a mechanical switch that automatically opens when current is too high. The mechanical switch can be operated by an electromagnetic device, as in the conceptual example in Figure 16, with a bimetallic strip, a combination of the two or more complex electronic high current sensing circuits. Typically circuit breakers, once they have been activated, require a manual reset to return power to the circuit. Circuit breakers typically can also be used as a power switch in the absence of an overload current. Parameters that are important for circuit breakers are similar to fuses, even though their operation is very different. First of all is a maximum current for operation without activation, the maximum voltage that the breaker is intended to block, a maximum interrupt current and parameters for speed of activation.
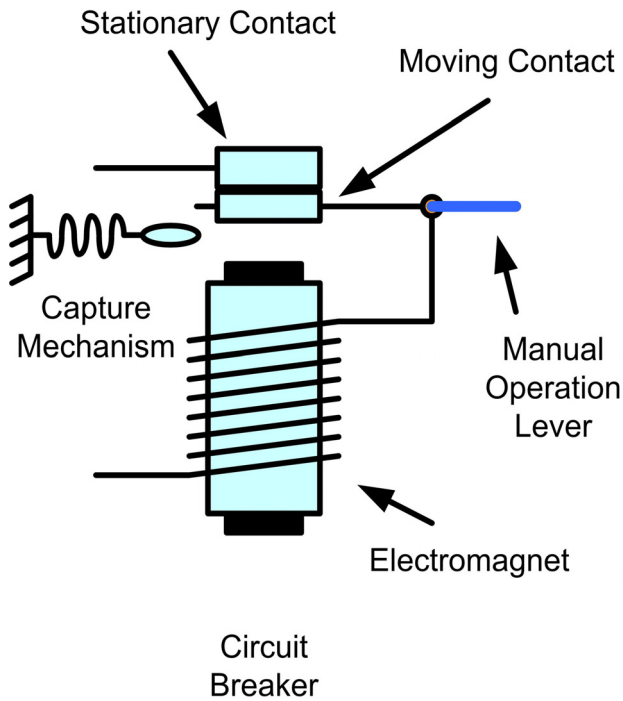
Figure 16. Conceptual Drawing of a Circuit Breaker

Positive Temperature Coefficient (PTC) Device

The final common current limiting device is the PTC or positive temperature coefficient device. A PTC has low resistance at low temperature but its resistance rises very rapidly above a particular current due to self heating of the resistor. Lowering the temperature returns the PTC to a low resistance state. Most PTC devices are made from a polymer containing a high density of conducting particles, often carbon black as illustrated in Figure 17. The density of particles is high enough that the conducting particles either touch or are so close together that conduction occurs through tunneling. During an over−current event, the current through the PTC leads to resistive heating and the polymer goes through a phase change, increasing in volume. The increase in volume pulls the conducting particles apart, resulting in a large increase in resistance. Unlike fuses and circuit breakers PTCs need to continue to carry some current to maintain the high resistance state. When the current is removed the PTC cools and returns to a low resistance state. PTCs provide a self resetting current limiting device. PTCs are characterized by the current they are intended to carry in normal operation, the maximum voltage that they can block, and the maximum current they can interrupt. PTCs are affected more by ambient temperature changes than are non−resettable fuses or circuit breakers.
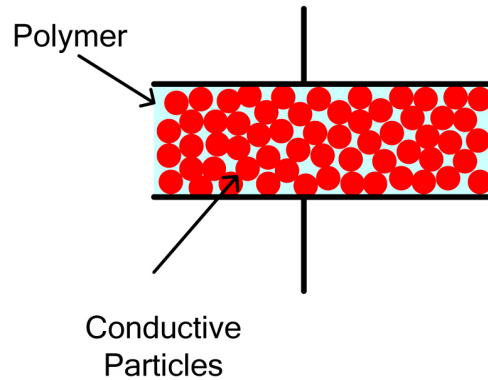
Figure 17. PTC Construction

Summary of Current Limiting Devices

Table 3 provides a summary of the four types of current limiting devices and their advantages and disadvantages.

Table 3. SUMMARY OF CURRENT LIMITING DEVICES

Type	Advantages	Disadvantages
eFuse	Precision Automatically or manually re−settable Fast acting Limits current without removing power for short duration over−current Limits overvoltage	Requires external resistor Moderate cost
Fuse	Wide range of parameters Slow response	Single use device
Circuit Breaker	Can be reset Can double as switch	Large size Expensive Slow
PTC	Self resetting Inexpensive	Slow acting Sensitive to ambient temperature Slow to regain low resistive state

Summary

This application note has summarized the basic properties of some of the most widely used circuit protection elements in use today. ON Semiconductor's silicon based solutions play an important role in both voltage suppression and current limiting protection. Diode based TVS devices are the solution of choice for a range of low to medium energy stresses such as Electrostatic Discharge (ESD) where ON Semiconductor's TVS devices have unequalled capability to combine low capacitance, excellent clamping and high reliability, all of which are ideal and necessary for today's most demanding high speed interfaces. Thyristor Surge Protection Devices (TSPD) excel in telecommunication protection and ON Semiconductor's new low capacitance products are ideal for the higher speed versions of Ethernet. For current limiting protection ON Semiconductor's eFuse line offers current limiting functions with a range of other features such as current limiting without shutdown for short duration over−current excursions, shutdown for longer duration over−current situations, voltage limiting, low voltage shutdown and auto reset, and non auto reset options.