A Guide to ThyZorb® Thyristor Surge Protection Devices

Vishay Semiconductors

INTRODUCTION

With the proliferation of sophisticated electronics into an ever-increasing number of wide-range applications, the need to protect against damage from high-energy electrical transients has become of increasing importance. The explosive growth in fast electronic information interchange has meant that the incorporation of highly sensitive electronics in the front end of telecommunications equipment has become commonplace. Telecommunications applications are driving the need for effective and complete over-voltage solutions due to the extreme environments in which these highly sensitive systems are required to operate.

Transient over-voltages and surges are common occurrences in the electrical environment and are generated by many means. The main categories are:

- Power switching, electromechanical and solid state
- EM radiation
- Lightning
- Electrostatic discharge

However, in the context of telecommunications applications, lightning-induced transients pose one of the greatest threats due to the speed and energy magnitude they are capable of delivering. The ThyZorb® TSPD (Thyristor Surge Protective Device) is a semiconductor device that has widespread application in the telecommunications industry protecting the electronic systems from damaging over-voltage transients. These ThyZorb devices are suited to secondary level protection against lightning and power line crossing.

ThyZorbs are ideal protection devices for telecommunication applications because of their high impedance in the off-state and high-current diverting capacity in the on-state.

What is a ThyZorb® TSPD?

A ThyZorb TSPD is an SCR variant used to short circuit (crowbar) high voltage transients, thereby protecting sensitive telecommunications equipment. The ThyZorb switches into a low voltage state of conduction when the voltage across the Anode and Cathode exceeds a predetermined voltage level and the resulting current from the source impedance exceeds the break-over current level. The ThyZorb gate is internal to the device chip. Because the voltage across the ThyZorb collapses, when it has switched on, the power dissipated across the device is low. This makes it an ideal component type to:

- Protect people from hazardous voltages induced by lightning or power line contact.
- Limit the maximum voltage seen by the telecommunications equipment.
- Divert the very high transient currents to ground and away from the equipment.

The ThyZorb is a two terminal bi-directional device. Fig.1 shows the electrical symbol for the bi-directional TSPD. Fig.2 shows the main Electrical Characteristics of the ThyZorb in the standby and on-state modes of operation.

Fig. 1 - ThyZorb Symbol

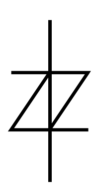
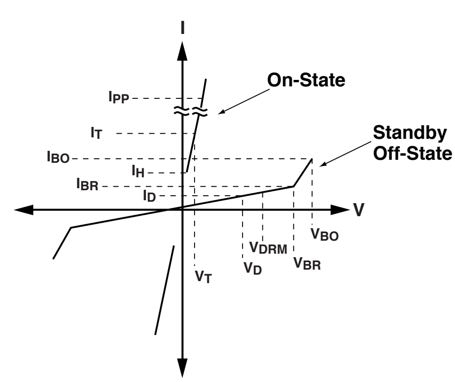


Fig. 2 - Electrical Characteristics



Definitions of Rated Parameters (See Fig. 2):

Breakover Current (I_{BO}): The instantaneous current flowing at the breakover voltage.
Breakover voltage (V_{BO}): The maximum voltage across the device in the breakdown region measured under specified voltage rate of rise and current rate of rise.
Holding current (I_H): The minimum current required to maintain the device in the on-state.
Breakdown voltage (V_{BR}): The voltage across the device in the breakdown region at a specified breakdown current prior to reaching the breakover voltage.
Breakdown current (I_{BR}): The current through the device in the breakdown region.
Off-state voltage (V_D): The dc voltage when the device is in the off-state.
Off-state current (I_D): The dc value of current that results from the application of the off-state voltage.
Repetitive peak off-state voltage (V_{DRM}): Rated maximum (peak) continuous voltage that may be applied in the off-state, including all dc and repetitive alternating voltage components.
Repetitive peak off-state current (I_{DRM}): The maximum (peak) value of off-state current that results from the application of the repetitive peak off-state voltage.
On-state voltage (V_T): The voltage across the device in the on-state at a specified current, I_T
On-state current (I_T): The current through the device in the on-state condition.
Peak pulse impulse current (I_{PPM}): Rated maximum value of peak impulse current (I_{PP}) applied for multiple pulses at specified waveform and maximum duty factor of 0.01% without causing failure.
Off-state Capacitance (C_O): The capacitance in the off-state measured at a specified frequency, f, amplitude, Vd, and dc bias VD.

How does a ThyZorb® TSPD work?

A ThyZorb has two modes of operation, the blocking off-state (standby) mode and the conducting on-state mode. In off-state (normal) operation the ThyZorb behaves similar to a Zener diode, where it presents high impedance and is essentially invisible to the circuit (See Fig. 3). The off-state current, I_D, of the ThyZorb is measured at a voltage, V_D. The breakdown voltage, V_{BR}, of the device is measured at I_{BR}.

Fig. 3 - ThyZorb Standby Characteristics

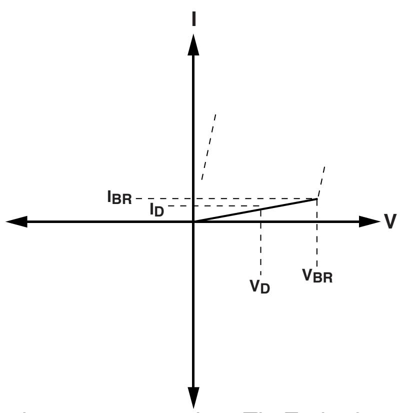
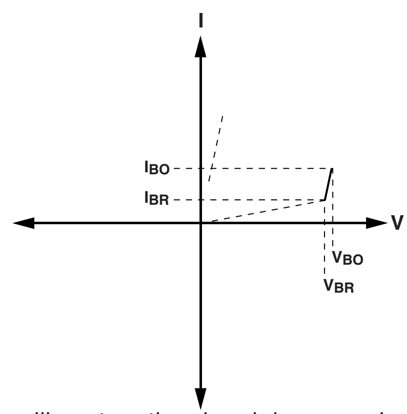


Fig. 4 - ThyZorb Avalanche Characteristics



As the voltage across the ThyZorb increases, the device will enter the breakdown region and clamp the voltage at the V_{BO} limit. (See Fig. 4) As the applied (transient) voltage increases past V_{BR}, the ThyZorb's dynamic impedance drops from about 21GΩ at V_{DM} to a few ohms. This causes the current through the device to increase rapidly. The ThyZorb voltage will remain in this region until the current through the device increases to the I_{BO} level. At I_{BO} the current level causes the device to switch into its low voltage on-state. (See Fig. 5) The switching time is very fast (< 5μs) to prevent high power dissipation (I*V) heating the silicon. The ThyZorb now presents a very low impedance path to ground for any transient voltage and diverts the high current (I_{PP}) away from the equipment to ground. As the energy in the transient dissipates the current reduces towards zero Amps. When the currents falls below the holding current, I_H, the ThyZorb switches back to the high impedance off-state. (See Fig. 6)

Fig. 5 - ThyZorb Breakover & On Characteristics

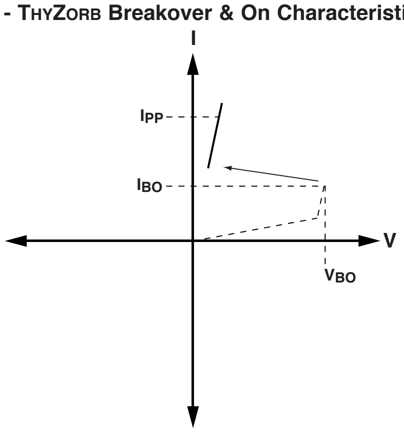
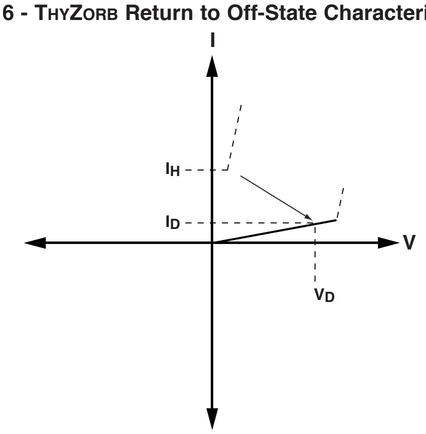


Fig. 6 - ThyZorb Return to Off-State Characteristics



In this standby state the only current through the ThyZorb is I_D and is typically less than 10nA.

ThyZorb® TSPD / TransZorb® ABD Comparison

In the on-state the power dissipated in the ThyZorb device is relatively low when compared to a TransZorb ABD (avalanche breakdown diode) with a similar V_{BR} (V_Z) and chip size (Power = I*V). This is because the voltage across the ThyZorb collapses once the I_{BO} level is exceeded. The decrease in the voltage across the terminals enables the ThyZorb to handle much higher I_{PP} levels than the avalanche diode. When high current combined with low voltage equates with low power, excessive temperatures in the silicon are avoided. Failure due to heat is avoided. Figures 7 and 8 illustrate the different current handling capabilities between a TransZorb and a ThyZorb.

Fig. 7 - TransZorb

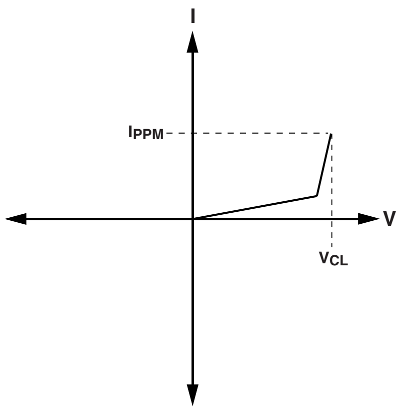


Fig. 8 - ThyZorb

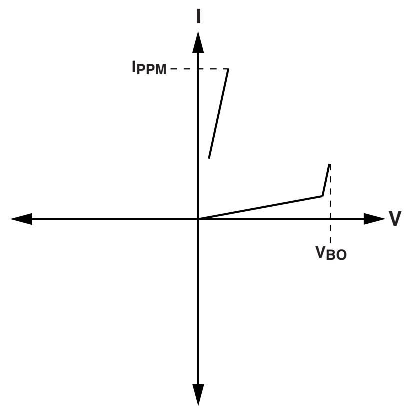


Fig. 9 shows the clamping voltage across a TransZorb TVS, and Fig. 10 shows the clamping voltage using a ThyZorb TVS with the same breakdown voltage. The surge voltage applied to both devices is the same.

Fig. 9

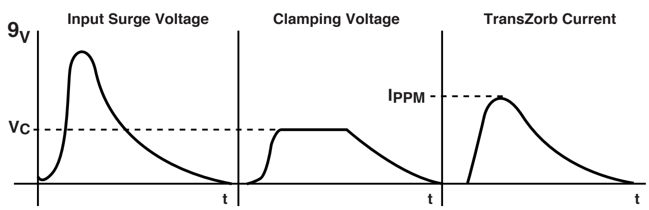
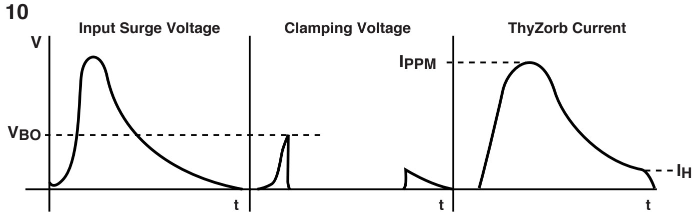


Fig. 10



From the above it can be seen that the current amplitude diverted by the ThyZorb is significantly higher than with the TransZorb. The let-through voltage is also significantly less with the ThyZorb than with the TransZorb. Both devices switch on at the same voltage, but the ThyZorb continues to divert surge current long after the TransZorb stops conducting. The TransZorb stops conducting current when the transient voltage amplitude falls below the V_Z level. The ThyZorb continues to conduct past this point and continues until the transient current falls below the holding level, I_H.

Surge Current Capability* vs. Breakdown Voltage

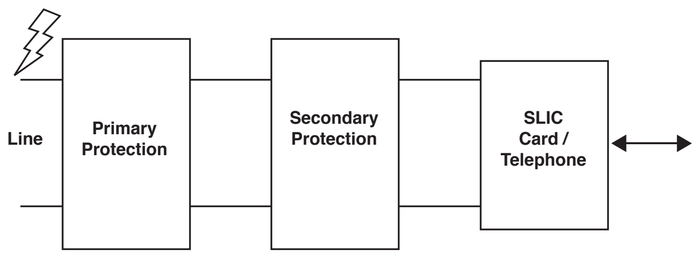
Breakdown Voltage	62V	150V	220V
TransZorb - SMC	17.7A	7.2A	4.6A
ThyZorb - SMTPA	50A	50A	50A

* 10/1000µs

ThyZorb® TSPD Applications

The main application for the of ThyZorb is in providing secondary-level protection to telephone, analog and digital line card circuits from the effects of lightning and accidental cross coupling of the telecommunication lines with the electrical distribution system. See Fig 11.

Fig. 11



Today's semiconductor equipment is not able to withstand these excessive voltages for any length of time. Hence the need for fast response, low clamping factor ThyZorb devices at the front of the equipment to be protected. The voltage limiting and high current-handling capability, make the ThyZorb an ideal protection device. The ThyZorb device is placed in parallel with the equipment to be protected to enable it present a low impedance path to ground for the transient energy.

Fig. 15 - Two Point Protection

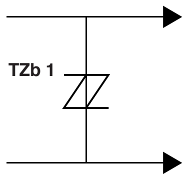
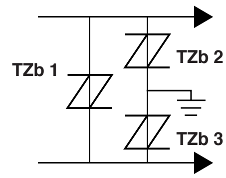


Fig. 16 - Three Point Protection



In Fig. 15 ThyZorb 1 limits the maximum voltage between the two lines to the V_{BO} limit for that ThyZorb . This configuration is usually used to protect circuits without a ground reference. Fig. 16 has additional ThyZorb devices (2&3), which limit the maximum voltage between either line commonly referred to as “tip” and “ring” and ground to a maximum level set by the V_{BO} of the ThyZorbs. ThyZorb 1 limits the maximum voltage between the two lines.

ThyZorb® TSPD Selection

A ThyZorb is selected to be invisible to the circuit operation and at the same time limit any line voltages to a specified maximum level, above which damage may occur to the circuit being protected. To achieve this the V_{DRM} voltage must be greater than any line (signal) voltage and the V_{BO} must be less than the equipment damage threshold level. The holding current must be higher than the maximum operating input current, otherwise the ThyZorb will remain in the on-state after the transient surge is no longer there. Because leakage current, I_D represents additional and unwanted loading on the electronic circuit I_D needs to be kept as low as possible. ThyZorbs typically have I_D in the low nano-Amp range.

The ThyZorb operating temperature range must also be taken into account. The calculated V_{DRM} for the application must not be less than the normal signal voltage levels over the full operating temperature range of the ThyZorb. V_{BO} falls as temperature of the device falls. This reduces the V_{DRM} of the device and the peak signal level that can be applied without getting clipped.

As the data rates increase the importance of capacitance of the protection circuit becomes more significant.

Surge Specifications

Complies with the following standards:	Voltage Waveforms (µs)	Current Waveforms (µs)
(CCITT) ITU-K20	10/700	5/310
(CCITT) ITU-K17	10/700	5/310
VDE043	10/700	5/310
VDE0878	1.2/50	1/20
IEC-1000-4-5	10/700 1.2/50	5/310 8/20
FCC Part 68, lightning surge type A	10/160 10/560	10/160 10/560
FCC Part 68, lightning surge type B	9/720	5/320
BELLCORE TR-NWT-001089 first level	2/10 10/1000	2/10 10/1000
BELLCORE TR-NWT-001089 first level	2/10	2/10
CNET 131-24	0.5/700	0.8/310

ThyZorb® Selector Guide

I_{PPM} (8/20µs) (A)	I_{PPM} (10/1000µs) (A)	PACKAGE		V_{DRM} RANGE (V)	$V_{(BO)}$ RANGE (V)	MINIMUM I_H (mA)
		SMA (DO-214AC)	SMB (DO-214AA)			
200	50	SMP50-62 - SMP50-270	SMTPA62 - SMTPA270	56 - 243	80 - 350	150
		P0640SAA - P3500SAA	P0640SA - P3500SA	58 - 320	70 - 395	150
300	100		SMP100LC-65 - SMP100LC-270	55 - 230	80 - 350	150
			P0640SC - P3500SC	58 - 320	70 - 395	150