



2011 Protection Design Guide for Telecom & Networking Interfaces



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Telecom & Networking Protection



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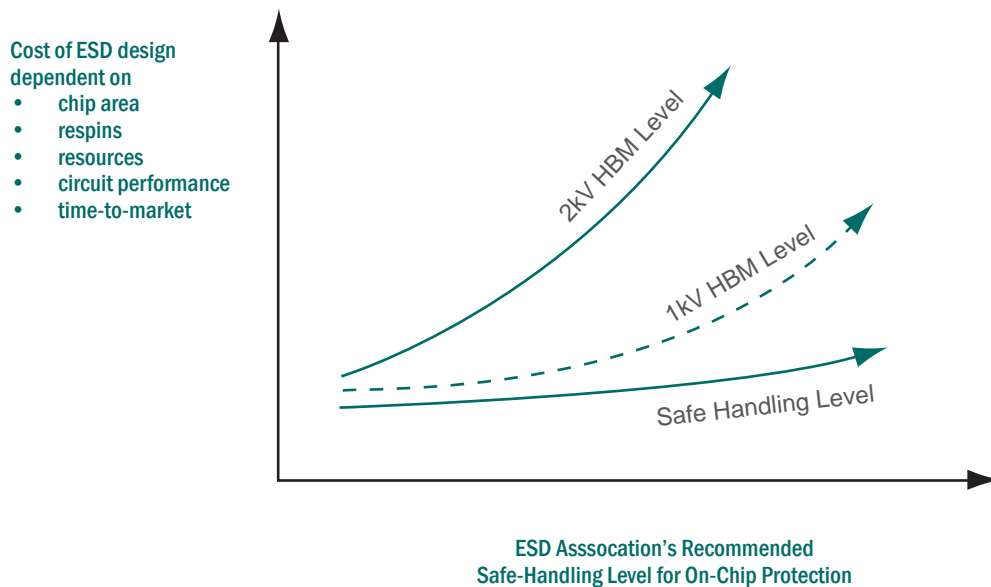
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The Need for Robust Circuit Protection

Today's digital communication integrated circuits (ICs) and transceivers are faster, more efficient, consume less power, and are smaller than ever before. Yet the advances in IC technology and enhanced chip performance has come with a notable tradeoff: increased susceptibility to damage from ESD, cable discharge and lightning. Not only are transistor geometry sizes scaling at a remarkable pace, leading to more sensitive circuits, but the on-chip protection is increasingly being sacrificed in favor of accommodating greater performance in the chip. As this trend progresses, high performance system level transient voltage protection will be needed more than ever before.



Semtech Advantages Process & Technology

The Semtech protection portfolio offers key advantages over industry standard TVS protection devices. These performance advantages are achieved with Semtech's advanced process technology. This process technology enables TVS diode arrays with sub 5 volt working voltage, low clamping voltage, and sub-picofarad capacitance. The compact design of the Semtech process allows devices to be housed in low-profile, space-saving packages. Lower working voltage means that the protection device can respond more quickly, shunt transient voltage spikes at a lower threshold, and thus provide a lower clamping voltage. As the transient voltage sensitivity of transceivers increases, designing with low working voltage protection devices is critical for protecting today's systems.

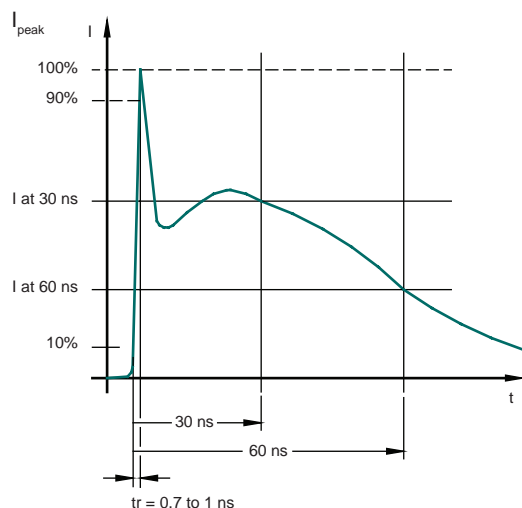
Threat Environment

Telecom and Networking interfaces are vulnerable to a variety of different transient voltage threats. These threats include electrostatic discharge (ESD), cable discharge events (CDE) and lightning surge. Interfaces that are accessible to human contact, such as RJ-45 ports, are vulnerable to transient voltage threats from ESD and cable discharge transients. Additionally, Ethernet Physical Layer Chips (PHYs) within the networking infrastructure are highly vulnerable to lightning threats. When choosing and designing an appropriate protection scheme, you should consider these transients and their inherent electrical characteristics.

Electrostatic Discharge (ESD)

Several models exist to simulate the ESD event. Each is designed to describe the threat in a real world environment. The discharge model is typically a voltage source feeding a resistor/capacitor network. Resistor and capacitor values vary depending upon the standard. Today the most internationally recognized ESD standard is IEC 61000-4-2. IEC 61000-4-2 is a system level standard used by manufacturers to model ESD events from human contact. The test is performed by discharging a 150pF capacitor through a 330 ohm resistor. Discharge into the equipment may be through direct contact (contact discharge) or just prior to contact (air discharge).

IEC 61000-4-2 divides the ESD into four threat levels. Test voltages at the threat levels range from 2kV to 15kV with peak discharge currents as high as 30A. Most manufacturers adhere to the most stringent level, level 4, which defines a +/-15kV air discharge test and a +/-8kV contact discharge test. However, many manufacturers test their equipment beyond these levels. The ESD waveform as defined by IEC 61000-4-2 reaches peak magnitude in 700ps to 1ns and has a total duration of only 60ns. While the ESD pulse contains little energy, the resulting effect can be devastating to sensitive semiconductor devices. Sensitive points of the equipment are to be tested with a combination of positive and negative discharges.



ESD Waveform per IEC 61000-4-2

ESD Discharge Levels per IEC 61000-4-2					
Level	Test Voltage Air Discharge (kV)	Test Voltage Contact Discharge (kV)	First Peak Current (A)	Peak Current at 30 ns (A)	Peak Current at 60 ns (A)
1	2	2	7.5	4	2
2	4	4	15	8	4
3	8	6	22.5	12	6
4	15	8	30	16	8

ESD Immunity: System Level vs. Device Level

For ESD immunity, it is important to distinguish between system level immunity and device level immunity. The JEDEC JESD22-A114E which is equivalent to the earlier Mil-Std-883 is a device level standard appropriate for the level of ESD threat seen in the manufacturing environment. The IEC 61000-4-2 standard is intended to describe the level of ESD threat seen in the system environment. In the case of transceiver ICs, most are rated to 2kV human body model (HBM) according to the JEDEC Standard/Mil-Std 883. This is not the same as 2kV for the system level standard (IEC 61000-4-2). In fact, the IEC pulse, for a given voltage level, will render over 5 times higher current levels than the JEDEC standard. The chart illustrates this difference: a 2kV ESD pulse for the Mil-Std 883 renders a peak current of approximately 1.33A. For the system level, that same 2kV charge level corresponds to a peak current of 7.5A.

Peak Current IEC vs JEDEC			
IEC Level (Contact discharge)	ESD Voltage (kV)	JEDEC JESD-A114E Ipp (kV)	IEC 61000-4-2 Ipp (A)
1	2	1.33	7.5
2	4	2.67	15
3	6	4.00	22.5
4	8	5.33	30

ESD Immunity Standards: IEC 61000-4-2 vs. JESD22-A114E

To achieve high system level ESD immunity, you should adhere to the IEC 61000-4-2 standard. The IEC standard is more closely representative of the real world ESD threats seen by electronic systems. Most commercial designs require passing minimum of $\pm 8\text{kV}$ for the Human Body Model of IEC (level 4) contact discharge.

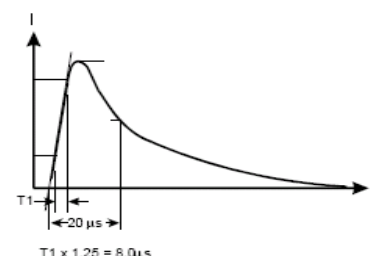
Cable Discharge

Cable Discharge (or CDE) is a real and frequent phenomenon in the Ethernet environment. CDE can be viewed as a type of electrostatic discharge, but should be treated as a separate transient event from ESD. An Ethernet cable, generally unshielded Cat-5 or Cat-6 twisted pair, can be modeled as a capacitor element capable of storing significant charge build up. As defined in the IEEE 802.3 standard, an Ethernet cable can be as long as 100m. The cable becomes charged by means of triboelectric charging or induction. Since Cat-5 and Cat-6 twisted pair cables exhibit very low leakage properties, the charge stored on the cable can remain on the twisted pair for up to several hours before discharging to the port during a plug event. This frequently poses a particularly dangerous threat to Ethernet ports. The high peak voltage and current of the CDE can cause the Ethernet transceiver to become overstressed resulting in intermittent malfunctions. In many cases, the transceiver can also fail catastrophically.

Lightning

Interfaces connected to the telecommunications network are exposed to lightning surges. Electromagnetic coupling of lightning energy can induce large transient pulses in nearby telecommunications lines. Lightning, or surge transients, are sometimes described as “slow” transients because unlike the fast, nanosecond rise times of ESD and Cable Discharge, a lightning pulse is generally on the order of microseconds in duration. However, the energy contained within the pulse is orders of magnitude higher, posing a significant destructive risk to telecommunications equipment.

The EMC community models surge transients using a combinational waveform which describes the basic surge waveshape and characteristics: rise time duration, fall time duration, and peak pulse current (Ipp) or peak pulse voltage. The lightning waveform can be either characterized as a voltage waveform with respect to time or a current waveform with respect to time. For example, the IEC 61000-4-5 calls for a 25A 8x20 μs waveform. This waveform represents a pulse of 20 μs in duration from $t=0$ to the 50% decay point. The rise time is 8 μs to the peak pulse current (Ipp), 25A in this case (see figure below).

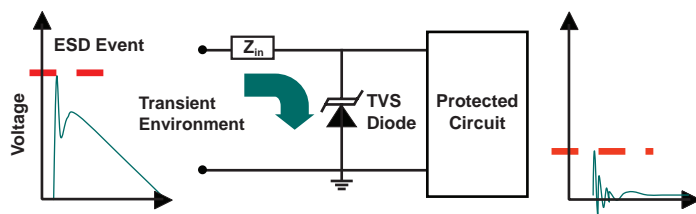


IEC 61000-4-4 Current Impulse

TVS Diode Basics

Transient Voltage Suppression (TVS) Diodes

Transient Voltage Suppressor (TVS) diodes have long been used to provide robust circuit protection. As shown in the following diagram, TVS diodes are generally connected as shunt elements across a transmission line. Under normal operating conditions the TVS diode presents a high impedance to the protected circuit. During a transient event, the TVS achieves breakdown, presents a low impedance shunt path, and the transient current is shunted through the TVS diode. A good TVS protection circuit must divert transient current and clamp transient voltage below the failure threshold of the protected IC.



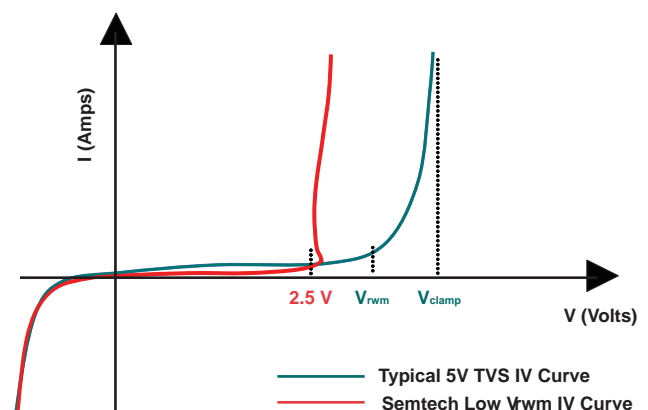
TVS Diode Operation

Parameters for Effective Circuit Protection

A good TVS device for protecting dataline communications interfaces must have some key parameters. First, **low working voltage** is a critical TVS parameter for safeguarding submicron integrated circuits. The working voltage, or V_{rwm} , is the maximum rated DC voltage for the TVS device. At the V_{rwm} voltage, the TVS is still a non-conducting device. Once the transient voltage rises above the working voltage, the TVS quickly achieves breakdown and presents a low impedance path to divert the transient. Thus, a low working voltage is essential for clamping a transient to a level well below the damage threshold of the IC that the TVS is protecting. The I-V curve illustrates the advantage of a lower working voltage. The green line represents a typical I-V curve for a standard TVS device while the red I-V curve illustrates the Semtech's low working voltage technology. The lower working voltage means the transient voltage is arrested more quickly and thus can be clamped to a lower voltage. Using TVS devices with lower working voltage is critical to reducing the stress energy seen by the communications transceiver. To address this need, Semtech has designed a family of 2.5V working voltage protection devices for safeguarding next generation high-speed transceivers.

Secondly, the TVS should present **low capacitance** to preserve signal integrity on the high-speed interface. If the capacitance of the TVS diodes is too high, adding excessive loading to the circuit, signal distortion and data errors will result.

Finally, the TVS needs to offer **high-surge handling**. For systems in the communications infrastructure, components rated only for ESD transient levels will not provide sufficient protection. The TVS component must also be able to handle the higher energy contained within cable discharges and the variety of lightning threats common to Ethernet interfaces. As a general guideline, the TVS should at least provide 25A of surge handling for an 8x20 microsecond pulse.



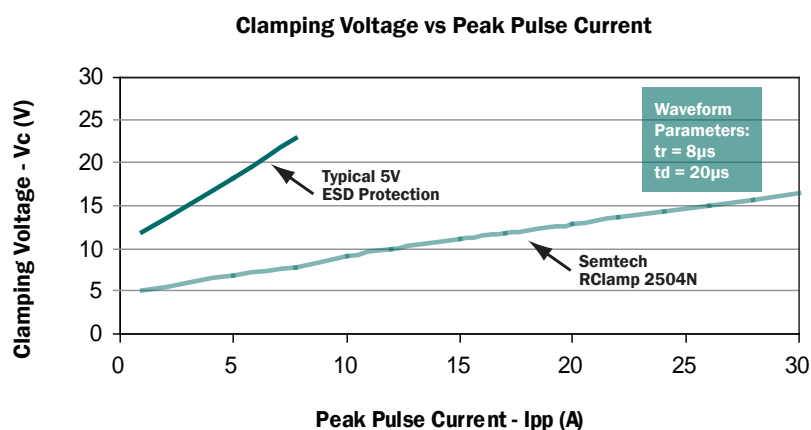
IV Curve for Semtech Low Working Voltage Process

Clamping Voltage

Clamping voltage, by definition, is the maximum voltage drop across the protection device during a transient event, which is also the stress voltage seen by the protected IC. The clamping voltage is the most critical parameter to consider when choosing a TVS device.

It is important to note that a device rated at IEC 61000-4-2 does not guarantee the system will pass ESD testing. This is because the IEC is a system level standard that was originally intended to be applied as pass/fail criteria for showing system level ESD immunity. The purpose of a protection device is to reduce a transient voltage spike down to a safe voltage for the protected IC, and the best way to insure that your TVS protection device adequately protects your interface circuitry is by choosing components that offer the lowest clamping voltage performance.

To illustrate the unique protection benefits of Semtech's proprietary EPD technology, the following chart compares the clamping voltage of an industry standard 5V TVS device with the clamping voltage of the Semtech RClamp2504N device. Built on the EPD platform, the RClamp2504N offers a very low 2.5V working voltage. Notice that the Semtech RClamp2504N provides a nice low, flat clamping voltage over a wide range of peak pulse current values. As a 2.5V working voltage device, the clamping performance of the RClamp2504N is significantly lower than the typical 5V TVS protection device. As the sensitivity on next generation PHYs increases, selecting TVS devices with a lower clamping voltage as illustrated in the chart can impact the difference between safeguarding an Ethernet PHY or resulting in catastrophic damage.

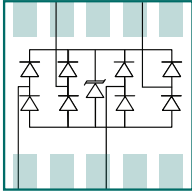
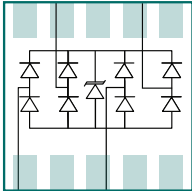
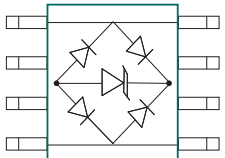
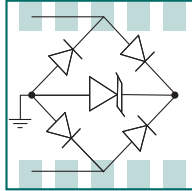
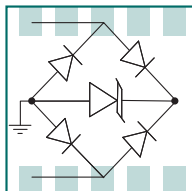
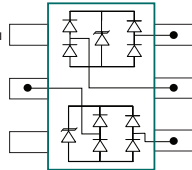


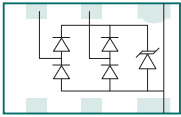
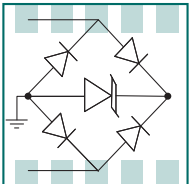
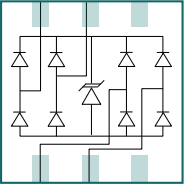
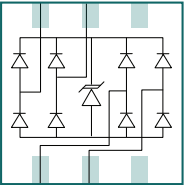
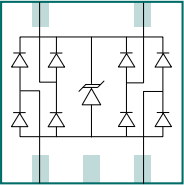
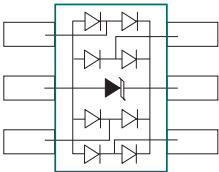
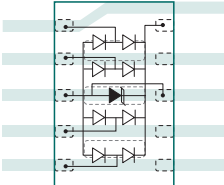
Clamping Performance for RClamp 2504N

Protection Solutions

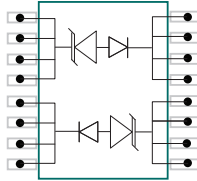
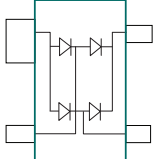
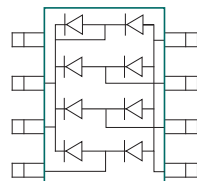
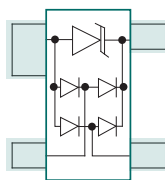
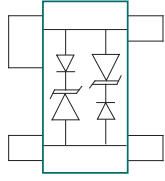
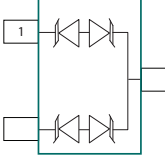
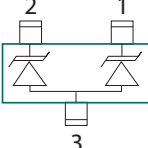
High-speed copper transmission interfaces are used on a wide variety of telecommunications systems including 3G base stations, GPON and EPON systems, enterprise routers, switches, DSLAM equipment, digital surveillance cameras, VoIP telephony and much more. Semtech's industry leading low-clamping performance and innovative packaging provide advanced performance solutions to safeguard your systems from transient voltage threats. This section will highlight some of the newly released key telecom & networking devices within the Semtech protection portfolio.



Part Number	Lines	V _{rw}	Cap I/O to I/O	I _{pp} max (8x20μs)	Application	Circuit Diagram
RClamp® 2504N	4	2.5V	2pF typ	25A	1000BASE-T 100BASE-T LVDS	 <p>2.6 x 2.6 x 0.6mm</p>
RClamp® 3304NA	4	3.3V	2pF typ	25A	1000BASE-T 100BASE-T LVDS	 <p>2.6 x 2.6 x 0.6mm</p>
RClamp® 2502L	2	2.5V	5pF max	40A	1000BASE-T 100BASE-T Industrial	 <p>6.0 x 5.0 x 1.5mm</p>
TClamp® 2502N	2	2.5V	8pF	95A	100BASE-T	 <p>2.6 x 2.6 x 0.6mm</p>
TClamp® 3302N	2	3.3V	8pF	95A	100BASE-T	 <p>2.6 x 2.6 x 0.6mm</p>
RClamp® 0524S	4	5V	1.5pF typ	6A	Power Over Ethernet	 <p>2.9 x 2.8 x 1.2mm</p>

Part Number	Lines	V _{rw}	Cap I/O to I/O	I _{pp} max (8x20μs)	Application	Circuit Diagram
RClamp® 0542T	2	5V	0.25	5A	10GBaseT LVDS	 <p>1.6 x 1.0 x 0.4mm</p>
TClamp® 0602N	2	6V	8pF	95A	T1/E1 T3/E3 100BASE-T	 <p>2.6 x 2.6 x 0.6mm</p>
RClamp® 2504P	4	2.5V	0.4pF	5A	1000BASE-T 100BASE-T LVDS Multimedia Card	 <p>1.6 x 1.6 x 0.6mm</p>
RClamp® 3304P	4	3.3V	0.4pF typ	5A	1000BASE-T 100BASE-T LVDS Multimedia Card	 <p>1.6 x 1.6 x 0.6mm</p>
RClamp® 0504N	4	5V	1.5pF typ	12A	1000BASE-T 100BASE-T LVDS	 <p>2.0 x 2.0 x 0.6mm</p>
RClamp® 0554S	4	5V	3pF	25A	10/100 Ethernet	 <p>2.90 x 2.80 x 1.10mm</p>
RClamp® 0534N	4	5V	1.5pF	25A	10/100 Ethernet	 <p>3.0 x 2.0 x 0.60mm</p>

Note 1: surge data taken with 10/160μs waveform

Part Number	Lines	V _{rw}	Cap I/O to I/O	I _{pp} max (8x20μs)	Application	Circuit Diagram
LC01-6	2	6V	50pF (max)	200A ¹	T1/E1 T3/E3	 <p>10.20 x 10.30 x 2.5mm</p>
SR70	2	3.3V - 70V	10pF	70A	xDSL	 <p>2.9 x 2.37 x 1.0mm</p>
SRDA70-4	4	3.3V - 70V	4pF (typ)	20A	High-speed xDSL lines	 <p>6.0 x 5.0 x 1.5mm</p>
SR12	2	12V	3pF	16A	xDSL	 <p>2.9 x 2.37 x 1.0mm</p>
LCDAxxC-1	2	12V, 24V	8pF (typ)	15A	xDSL	 <p>2.9 x 2.37 x 1.0mm</p>
SM712	2	12V, -7V	75pF (max)	17A	RS-485	 <p>2.90 x 2.37 x 1.0mm</p>
RClamp® 0582B	2	5V	1.2pF	12A	USB 2.0 Serial Interfaces	 <p>1.60 x 1.60 x 0.75mm</p>

RClamp® 2504N

ESD & Surge Protection for 1000BASE-T (Gigabit Ethernet) Interfaces

Features

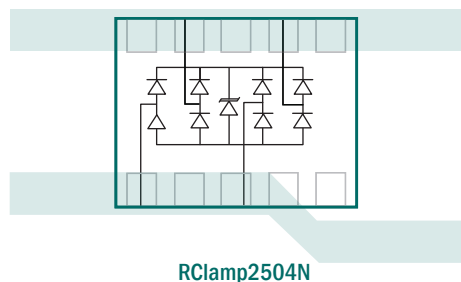
- 2.5V working voltage
- 4-line protection
- Low clamping voltage
- 25A (8x20μs) surge rating
- Very small package (2.6 x 2.6 x 0.6mm)

Applications

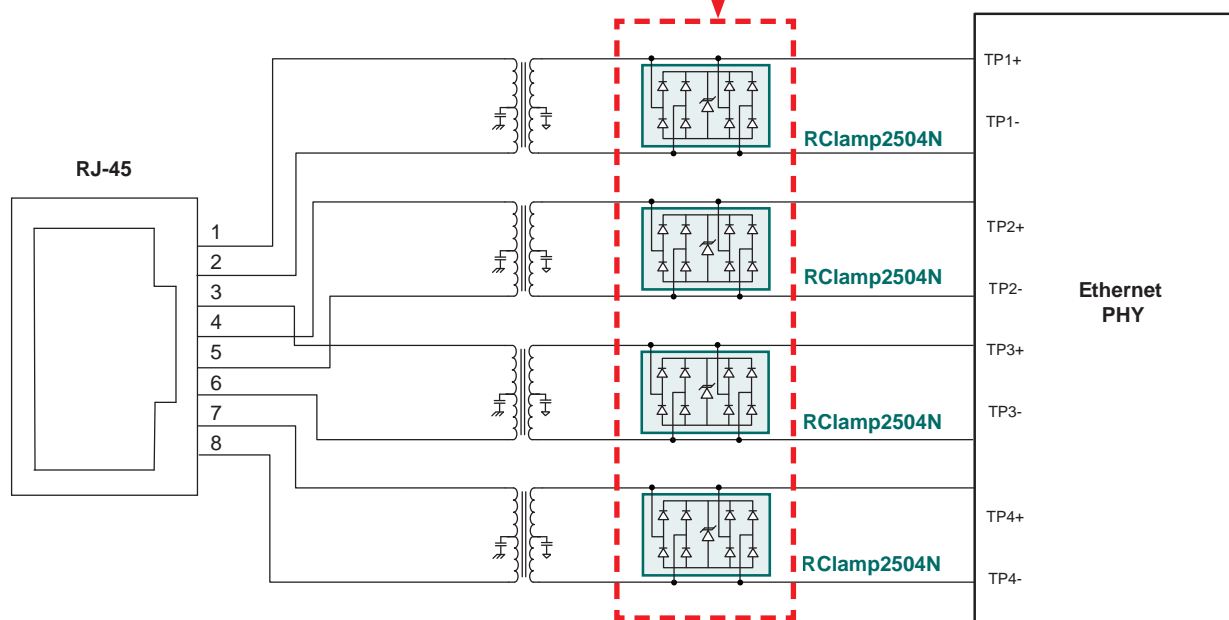
- Gigabit Ethernet
- 10/100 Ethernet
- LVDS

Description

The RClamp2504N uses Semtech's enhanced Punch-Through Diode (EPD) technology process to achieve a low working voltage of 2.5 volts. The low working voltage enables superior clamping voltage performance for safeguarding submicron silicon PHY architectures. The 4-line RClamp2504N can be configured to meet the intra-building surge requirements of Telcordia GR-1089. The low clamping voltage and high surge rating of this device also make it an ideal part for protecting against dangerous ESD and cable discharge threats. The RClamp2504N presents minimal line-to-line capacitance for preserving signal integrity and is housed in a small leadless, RoHS compliant package.



The 2.5V working voltage (V_{rwm}) means that the TVS can achieve breakdown quickly during a transient event. Next generation PHYs are best protected by 2.5V working voltage TVS.



Protection for Gigabit Ethernet Interface

RClamp® 3304NA

ESD & Surge Protection for 1000BASE-T (Gigabit Ethernet) Interfaces

Features

- 3.3V working voltage
- 4-line protection
- Low clamping voltage
- 25A (8x20μs) surge rating
- Very small package (2.6 x 2.6 x 0.6mm)

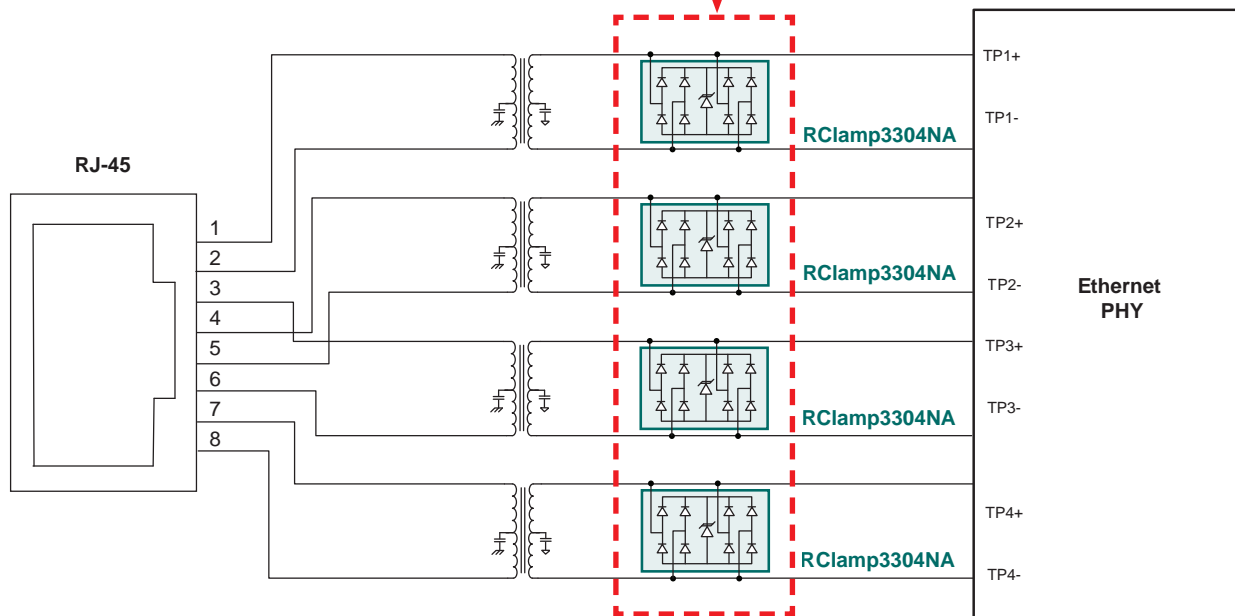
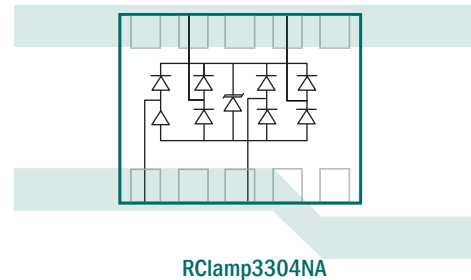
Applications

- Gigabit Ethernet
- 10/100 Ethernet
- LVDS

Description

The RClamp3304NA uses Semtech's advance Punch-Through technology process to achieve a low working voltage of 3.3 volts. The low working voltage enables superior clamping voltage performance for safeguarding submicron silicon PHY architectures. The 4-line RClamp3304NA can be configured to meet the intra-building surge requirements of Telcordia GR-1089, while the low clamping voltage and high surge rating of this device also make it an ideal part for protecting against dangerous ESD and cable discharge threats. The RClamp3304NA presents minimal line to line capacitance for preserving signal integrity and is housed in an ultra-small leadless, RoHS compliant package.

The 2.5V working voltage (V_{rwm}) means that the TVS can achieve breakdown quickly during a transient event. Next generation PHYs are best protected by 2.5V working voltage TVS.



Protection for Gigabit Ethernet Interface

RClamp® 2502L

ESD & Surge Protection for Industrial and Harsh Environment Ethernet Interfaces

Features

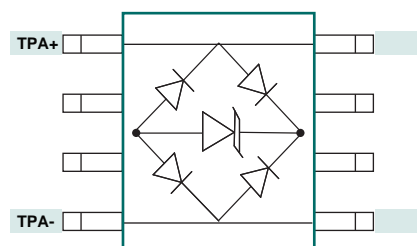
- 2.5V working voltage
- 2-line protection
- 40A (8x20μs) surge rating
- Low clamping voltage
- Flow-through package

Applications

- 10/100 Ethernet
- Gigabit Ethernet
- LVDS
- Analog video
- Industrial interfaces

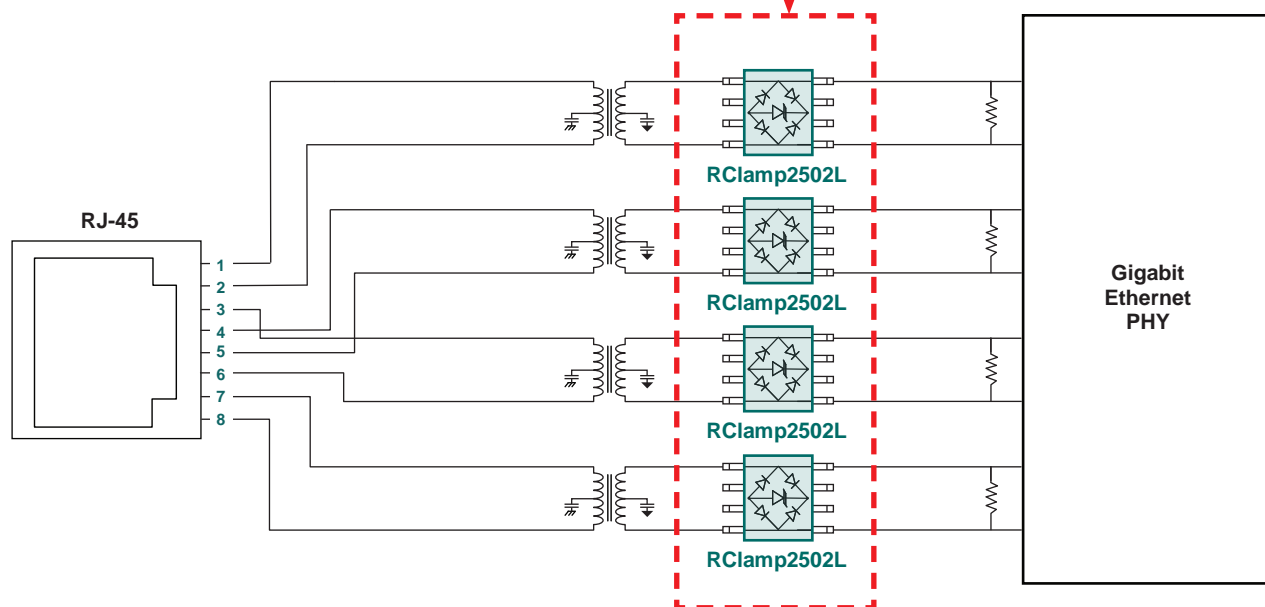
Description

The RClamp2502L is a 2-line, 2.5V (V_{rwm}) low capacitance protection array for safeguarding Ethernet interfaces from ESD, cable discharge and lightning surge transients. The RClamp2502L offers a very robust surge rating for secondary lightning protection (40A, $t_p=8/20\mu s$) and is housed in an industry standard SO-8 package. The SO-8 package accommodates a simple, efficient layout for the board designer, allowing the differential pair traces to run straight under the package.



RClamp2502L

Industry standard SO-8 package facilitates ease of layout on Ethernet interfaces. The 2.5V working voltage and high-surge handling provides optimal protection in harsher industrial environments.



Protection for Gigabit Ethernet Interface to Telcordia GR-1089

TClamp® 2502N

ESD & Surge Protection for 100BASE-T (10/100 Ethernet) Interfaces

Features

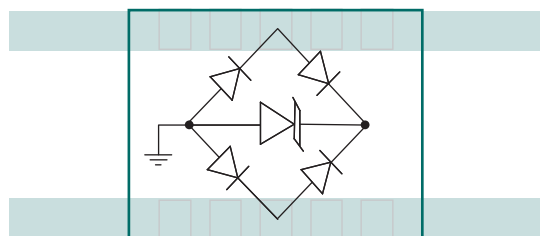
- 2.5V working voltage
- 2-line protection
- Low clamping voltage
- 95A (8x20 μ s) surge rating
- Very small package (2.6 x 2.6 x 0.6mm)

Applications

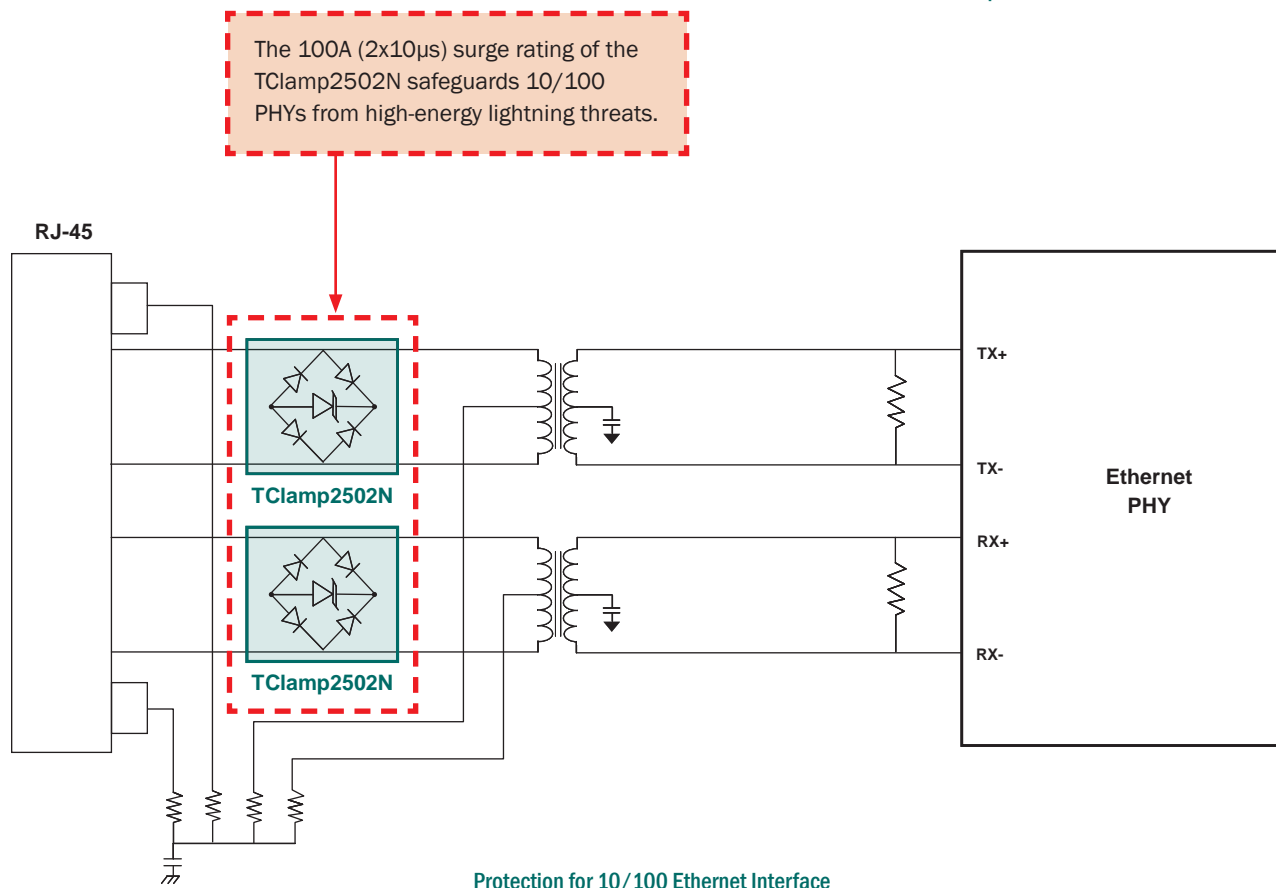
- 10/100 Ethernet
- Video surveillance interfaces
- LVDS interfaces

Description

The TClamp2502N is a 2-line TVS protection device compliant with the Telcordia GR-1089 Intrabuilding surge standard. With its low capacitance (10pF), small size (2.6 x 2.6 x 0.6mm), and low operating voltage (2.5V), the TClamp2502N is the industry's first 2.5V silicon TVS device rated to meet GR-1089 Intra-building surge. The TClamp2502N is packaged in a very small, leadless SLP package, giving designers a remarkable level of surge handling protection for a fraction of the board real estate required by traditional surge rated devices.



TClamp2502N



TClamp® 3302N

ESD & Surge Protection for 100BASE-T (10/100 Ethernet) Interfaces

Features

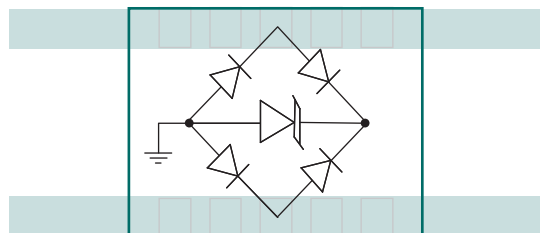
- 3.3V working voltage
- 2-line protection
- Low clamping voltage
- 95A (8x20μs) surge rating
- Very small package (2.6 x 2.6 x 0.6mm)

Applications

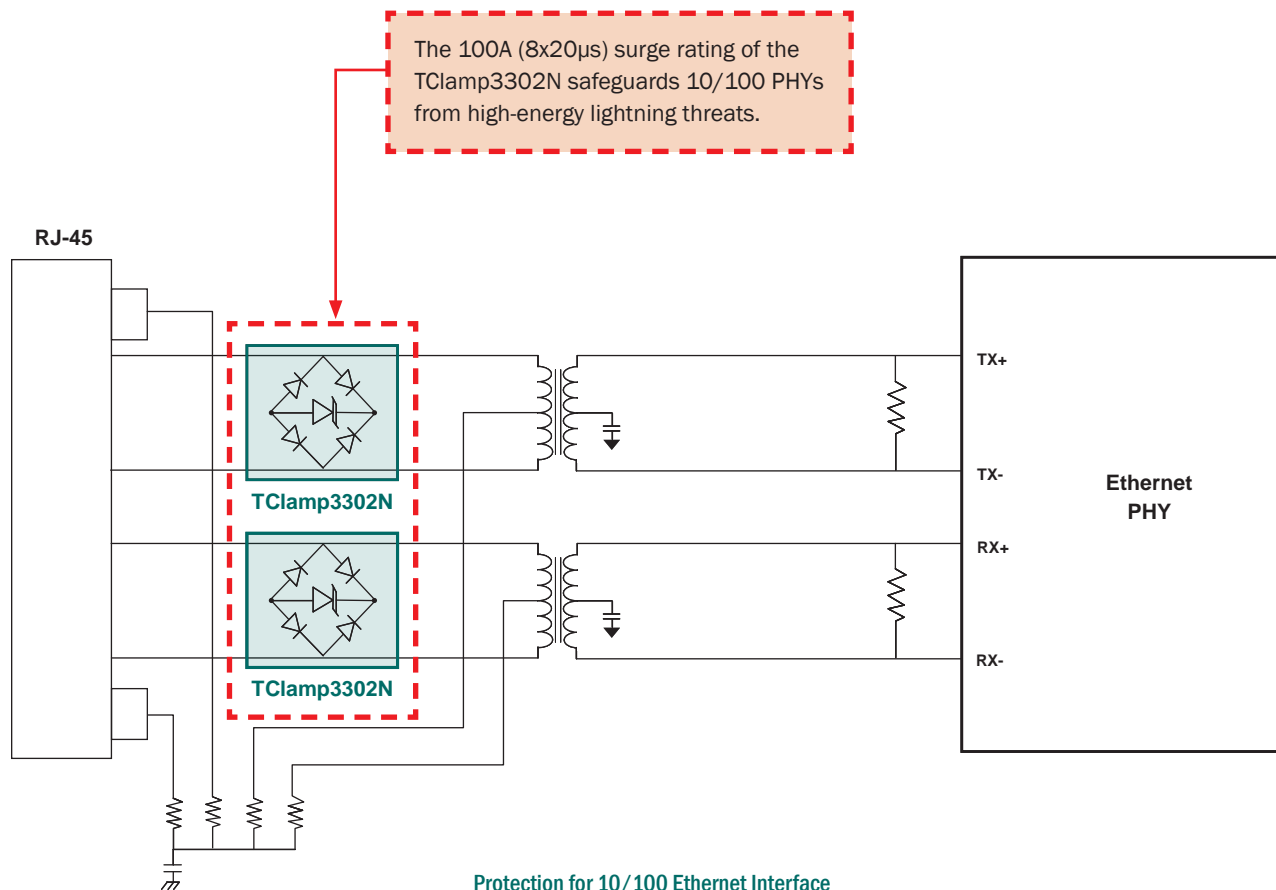
- 10/100 Ethernet
- Video surveillance interfaces
- LVDS interfaces

Description

The TClamp3302N is a two line TVS protection device compliant with the Telcordia GR-1089 intra building surge standard. With its low capacitance (<12pF), small size (2.6 x 2.6 x 0.6mm), and low operating voltage (3.3V), the TClamp3302N offers the industry's first 3.3V silicon TVS device to meet GR-1089 Intra-building surge. The TClamp3302N is packaged into a very small, leadless SLP package.



TClamp3302N



RClamp® 0524S

ESD & Cable Discharge Protection for Power Over Ethernet Interfaces

Features

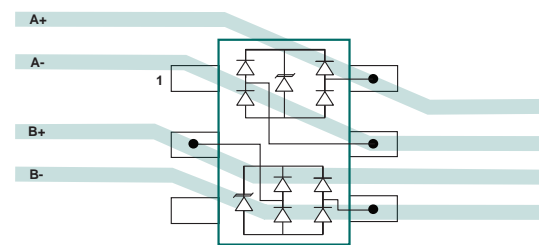
- 5V working voltage
- Split-pad TVS arrays
- Low clamping voltage
- Flow-through package (2.9 x 2.8 x 1.2mm)

Applications

- Power-Over-Ethernet
- Industrial equipment

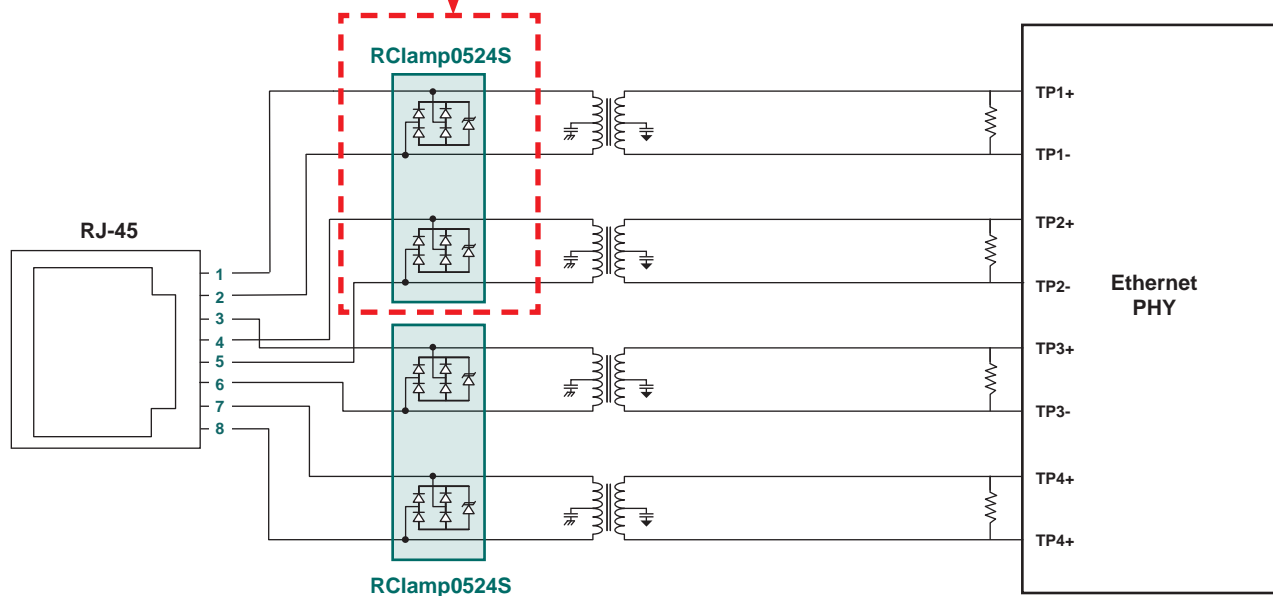
Description

The RClamp0524S is a 4-line, 5V (V_{rwm}) low capacitance protection array designed to safeguard Power-Over-Ethernet interfaces from ESD and cable discharge transients. The split-pad architecture of the RClamp0524S protects PoE signal pairs from dangerous transient spikes while isolating the diode arrays so as to prevent a DC power connection between the pairs. The RClamp0524S offers a simple package layout to facilitate a clean, flow-through design.



RClamp0524S

Dual isolated TVS arrays provide highly integrated transient protection solution while maintaining DC potential separation on PoE line pairs.



Protection for Power-Over-Ethernet Interface

RClamp® 0542T

ESD & Cable Discharge Protection for High Speed Ports

Features

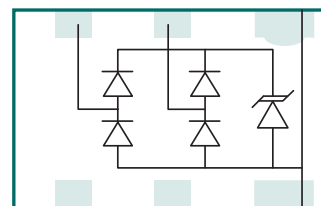
- Protects 2-lines operating at 5V
- Low capacitance: 0.25pF typical (I/O to I/O)
- Low leakage current: < 5nA typ @ $V_{rwm}=5V$
- Innovative package allows for flow-through layout, eliminates stubs
- Small package (1.6 x 1.0 x 0.4mm)

Applications

- Protects 2-lines operating at 5V
- Low capacitance: 0.25pF typical (I/O to I/O)
- Low leakage current: < 5nA typ @ $V_{rwm}=5V$

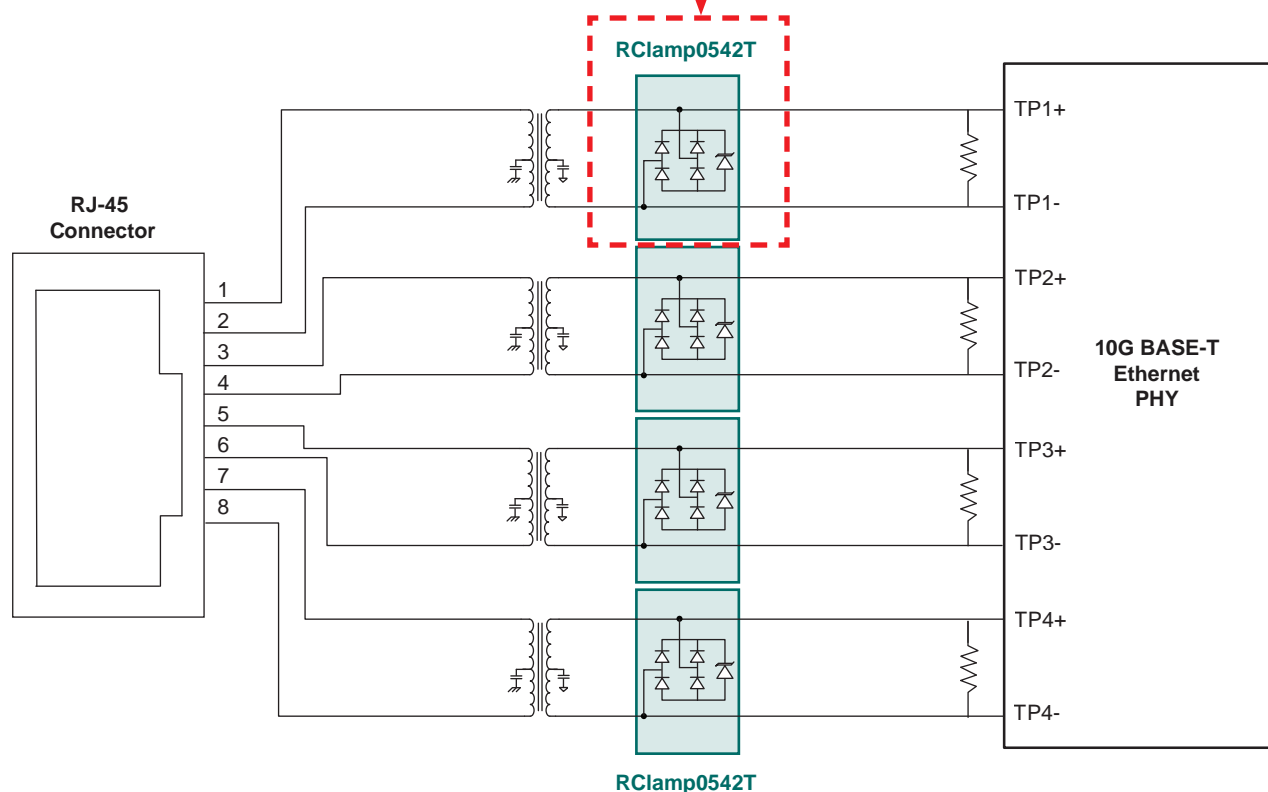
Description

The RClamp0542T is designed to protect high-speed differential pair in emerging interfaces such as 10GBASE-T and USB 3.0. The RClamp0542T is an improvement over the RClamp0522P in terms of ESD clamping performance and the leakage current is considerably lower than previous generation parts.



RClamp0542T

The 2-line RClamp0542T lays out cleanly to facilitate flow-through traces on high-speed interfaces.



Protection for 10G BASE-T Ethernet

TClamp® 0602N

GR-1089 Lightning Protection for T-Carrier Interfaces

Features

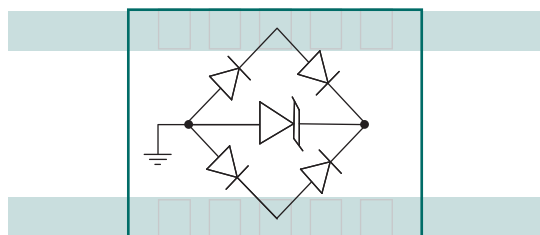
- 6V working voltage
- Low clamping voltage
- Flow-through package
- High-surge rating: 100A (2x10 μ s)

Applications

- T1/E1 interfaces
- T3/E3 interface
- Analog video interfaces
- Digital surveillance cameras

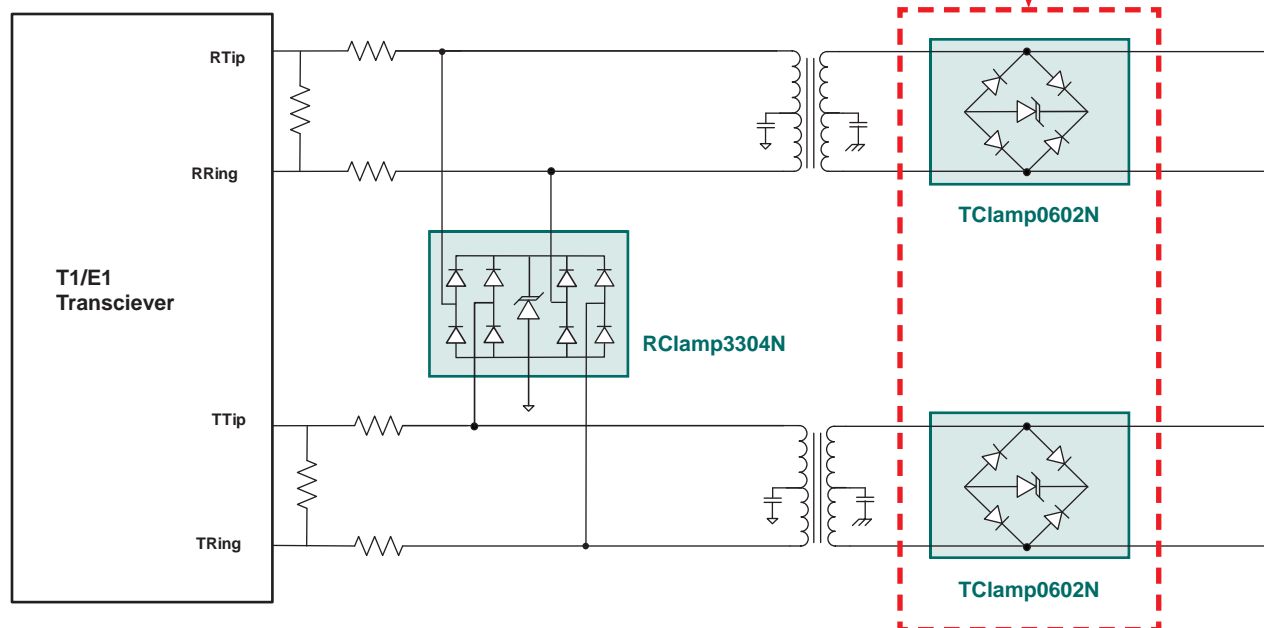
Description

The TClamp0602N is a 2-line 6V working voltage device rated for 100A 2/10 μ s surge per Telcordia GR-1089. With its fast response time and low working voltage, the TClamp0602N will provide the initial lightning surge defense by clamping the lightning impulse to a low voltage. An enhanced diode bridge configuration is used to provide the low capacitance of the TVS diode protection circuit.



TClamp0602N

Line side GR-1089 Intra-building protection. The TClamp0602N is a 100A 2x10 μ s rated device packaged in ultra small 2.6 x 2.6 x 0.6mm package.



Protection for T1/E1 Interface

RClamp® 2504P

ESD & Cable Discharge Protection for High-Density Ethernet Interfaces

Features

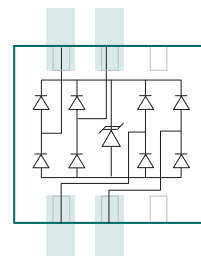
- 2.5V working voltage
- 4 lines of protection
- Low capacitance (<0.8pF)
- Excellent ESD clamping
- Ultra-small package (1.6 x 1.6 x 0.6mm)

Applications

- 1000BASE-T Ethernet
- 100BASE-T Ethernet

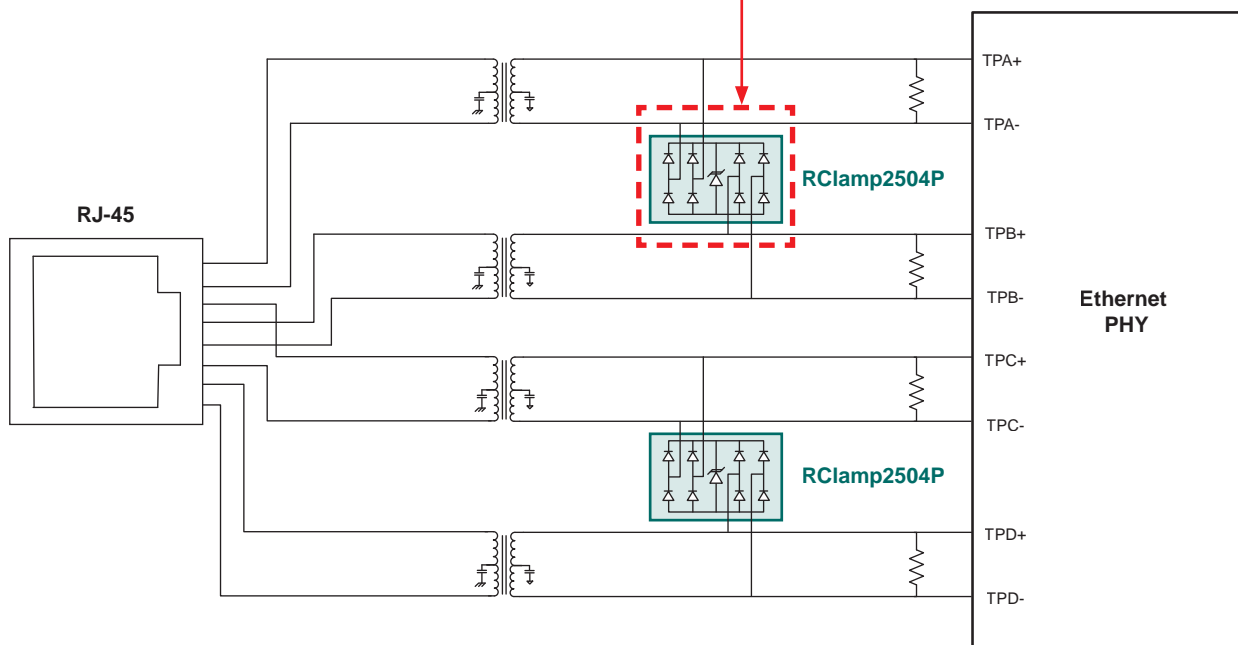
Description

The RClamp2504P is a 4-Line, 2.5V (V_{rwm}) low capacitance protection array for safeguarding Ethernet interfaces from ESD and cable discharge transients. The innovative design incorporates surge rated, low capacitance steering diodes and a TVS diode in a single package. Each line has a maximum capacitance of < 0.8pF line-to-ground. The capacitance of each line is well matched for constant signal balance. This device is optimized for ESD protection of sensitive electronics. It may be used to meet the ESD immunity requirements of IEC 61000-4-2, Level 4 ($\pm 15kV$ air, $\pm 8kV$ contact discharge).



RClamp2504P

Ultra-small, 4-line RClamp2504P provides superior fast transient clamping performance with minimal part footprint.



Protection for High-Density Ethernet Interface

RClamp® 3304P

ESD & Cable Discharge Protection for High-Density Ethernet Interfaces

Features

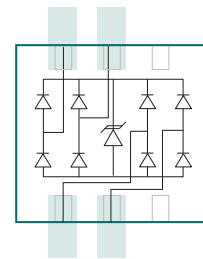
- 3.3V working voltage
- 4 lines of protection
- Low capacitance (<0.8pF)
- Excellent ESD clamping
- Ultra-small package (1.6 x 1.6 x 0.6mm)

Applications

- 1000BASE-T Ethernet
- 100BASE-T Ethernet

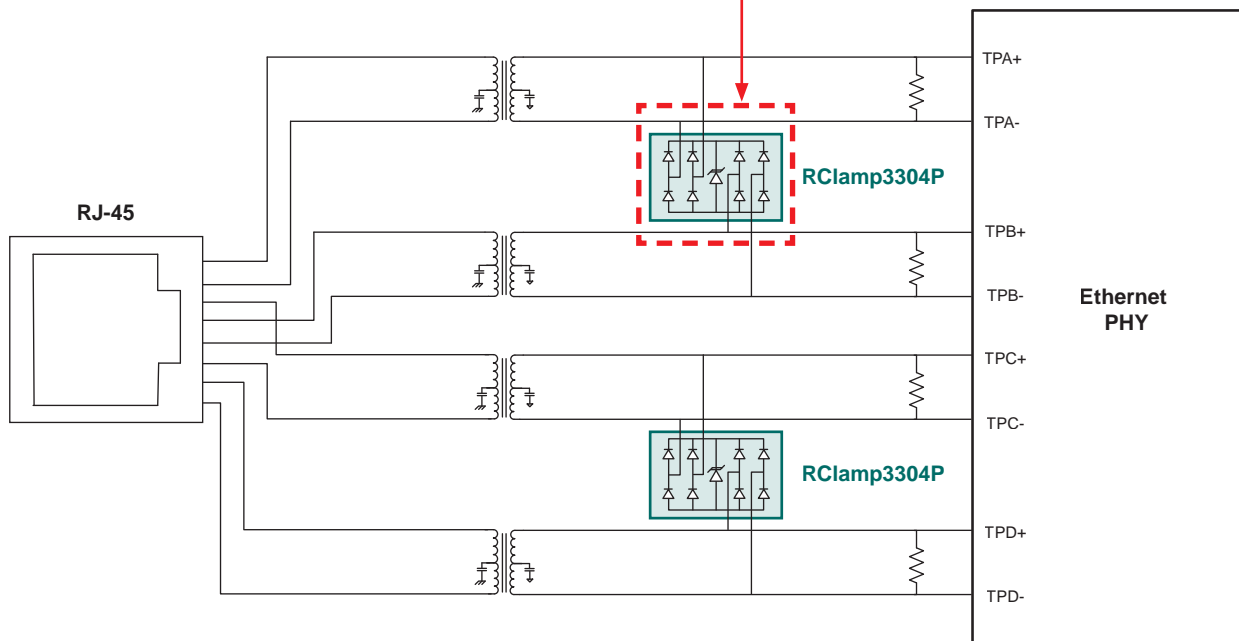
Description

The RClamp3304P is a 4-Line, 3.3V (V_{rwm}) low capacitance protection array designed to safeguard Ethernet interfaces from ESD and Cable Discharge transients. The monolithic design incorporates surge rated, low capacitance steering diodes and a TVS diode in a single package. Each line has a maximum capacitance of < 0.8pF to ground. The capacitance of each line is well matched for constant signal balance. This device is optimized for ESD protection of portable electronics. It may be used to meet the ESD immunity requirements of IEC 61000-4-2, Level 4 ($\pm 15\text{kV}$ air, $\pm 8\text{kV}$ contact discharge).



RClamp3304P

Ultra-small, 4-line RClamp3304P provides superior fast transient clamping performance with minimal part footprint.



ESD Protection for Ethernet Interfaces

RClamp® 0504N

High-Surge, 5V Protection Array

Features

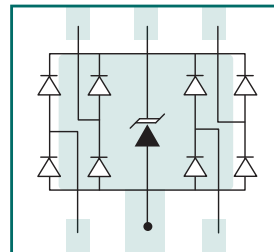
- 5V working voltage
- 4-line protection
- Surge immunity: 12A (8x20μs)
- Low clamping voltage
- Small SLP package

Applications

- 10/100 Ethernet
- USB 2.0
- IEEE 1394

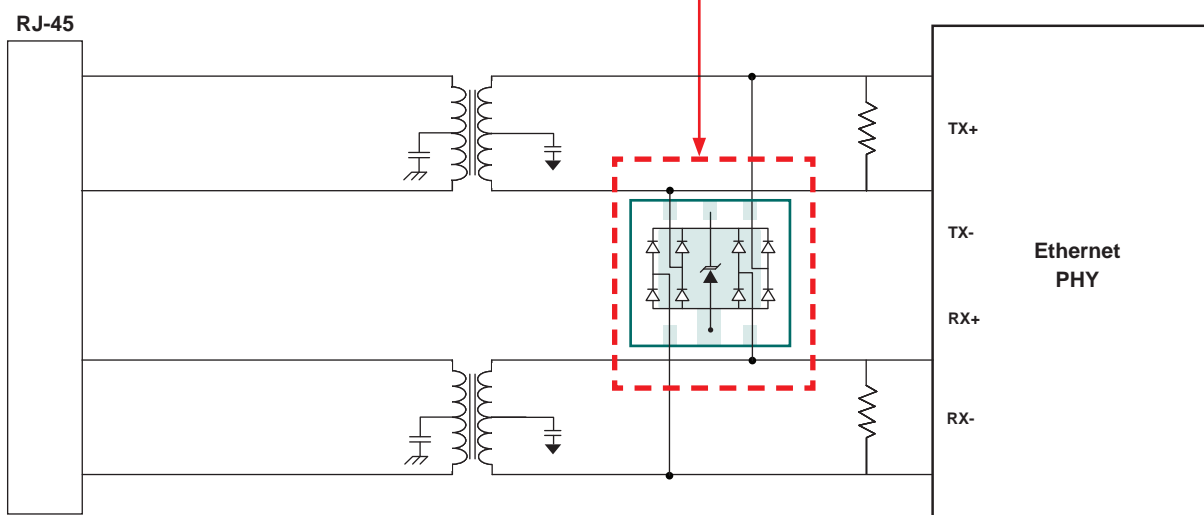
Description

The RClamp0504N has a low typical capacitance of 3pF and operates with virtually no insertion loss to 1GHz. This makes the device ideal for protection of high-speed data lines such as USB2.0, IEEE-1394, and Ethernet.



RClamp0504N

The small size of the RClamp0504N makes it an ideal part to use where board space is at a premium.



TVS Protection for 10/100 Ethernet Interface

RClamp® 0554S

High-Surge, 5V Protection Array

Features

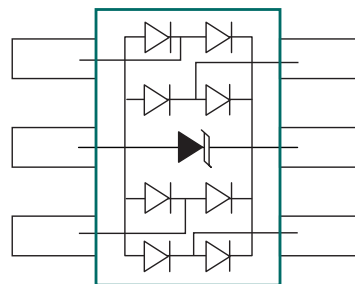
- 5V working voltage
- 4-line protection
- Surge immunity: 25A (8x20μs)
- Low clamping voltage
- Industry standard SOT-23 package

Applications

- 10/100 Ethernet
- USB 2.0
- Analog video

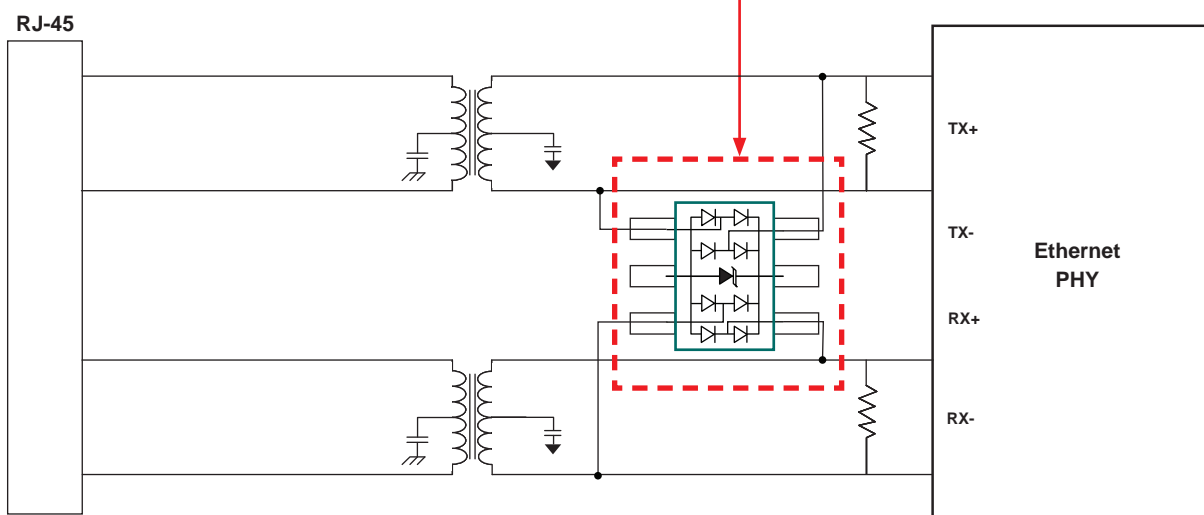
Description

The RClamp0554S is a 5V, 4-line TVS array designed to provide robust protection from ESD, cable discharge and lightning surge. The RClamp0554S is also in a footprint compatible package with the popular SRV05-4, yet with higher surge handling to position it at the high surge end of this market.



RClamp0554S

The RClamp0554S is pin-to-pin compatible with the existing SRV05-4 devices, but offers a higher surge rating (25A, 8x20μs).



TVS Protection for 10/100 Ethernet Interface

RClamp® 0534N

Flow-Through Surge Protection for 10/100 Ethernet

Features

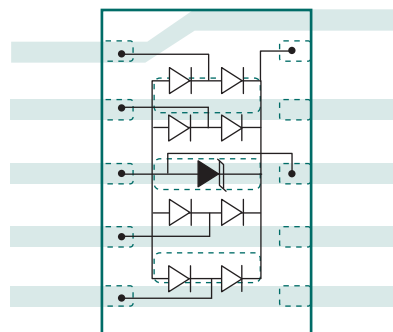
- 5V working voltage
- 4-line, flow-through layout
- Routing possible on one signal layer
- Low clamping voltage performance
- Low leakage current

Applications

- 10/100 Ethernet
- USB 2.0
- IEEE-1394
- Analog video
- Industrial control lines

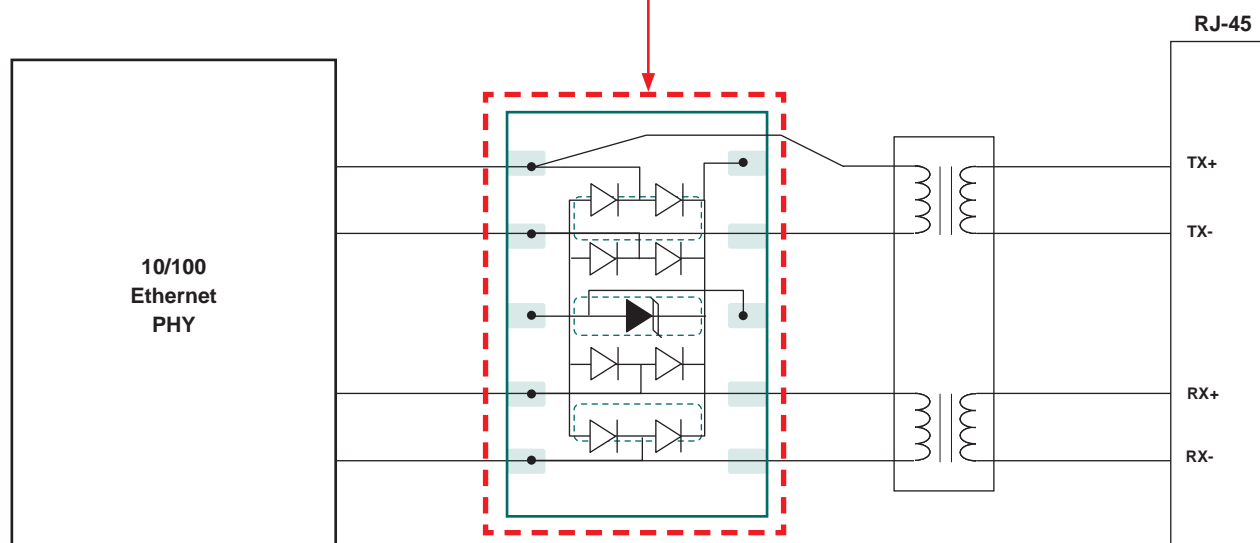
Description

The RClamp0534N is a 4-line 25A (8x20μs) surge rated protection array designed to address the protection needs of fast Ethernet ports. The RClamp0534N provides a very high surge immunity level in a flow-through package that allows routing all the traces on one signal layer.



RClamp0534N

The RClamp0534N's flow-through layout enhances the flexibility and effectiveness of protecting 5V interfaces.



Flow-through TVS Protection Array for 10/100 Ethernet

LC01-6

GR-1089 Lightning Protection for T-Carrier Interfaces

Features

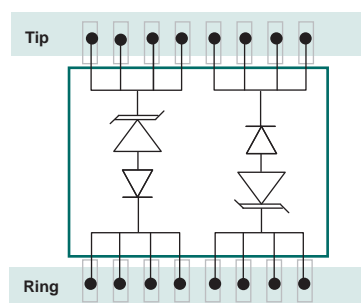
- 6V working voltage
- High-surge rating: 500A (2x10 μ s)
- Protects one tip/ring pair
- Low clamping voltage

Applications

- T1/E1 interfaces
- Base stations
- WAN interfaces
- xDSL interfaces

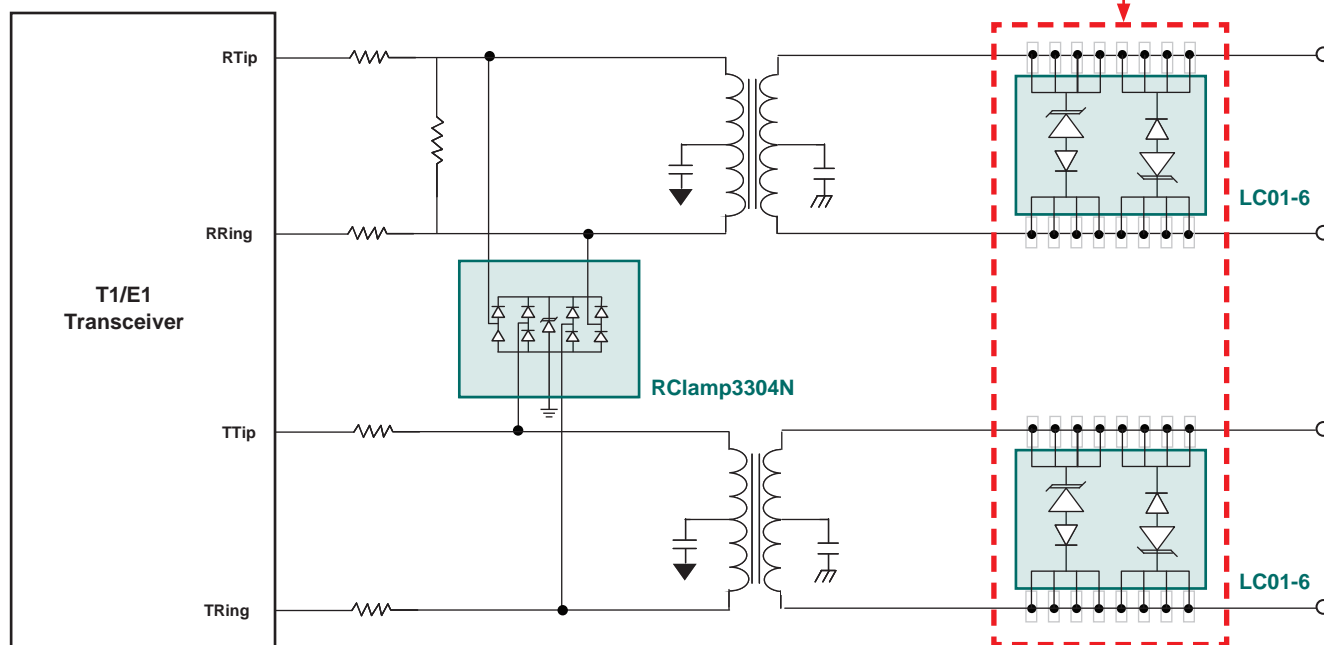
Description

The LC01-6 is a 2-line 6V working voltage device rated for protecting telecom interfaces according to the GR-1089 Outerbuilding requirements: 500A 2/10 μ s surge or 100A (10/1000 μ s) surge. The LC01-6 is commonly used to safeguard T1/E1 interfaces from very high energy lightning surge transient events. The low clamping voltage performance of the LC01-6 provides superior protection response time to transient than traditional thyristor and “crowbar” surge protectors.



LC01-6

Line Side GR-1089 Outer-building protection. The LC01-6 is rated for 100A 10x1000 μ s (500A 2x10 μ s) to provide maximum surge protection.



Outer-building GR-1089 Protection for T1/E1 Interface

SR70

3.3V – 70V, 2-line Protection Array for
High-Speed Protection

SRDA70-4

3.3V – 70V, 4-line Protection Array for
High-Speed Protection

Features

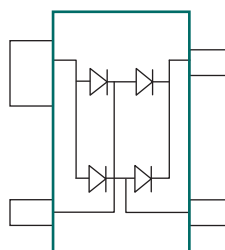
- 12V working voltage
- Low clamping voltage
- 24A (8x20μs) surge rating
- Flexible layout

Applications

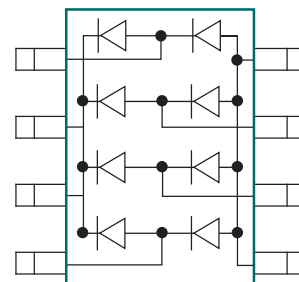
- ADSL interfaces
- VDSL interfaces
- Industrial interfaces

Description

The SR70 and SRDA70-4 are surge rated diodes designed for protection of telecom interfaces. These devices are unique because they do not have a fixed voltage reference. This affords the designer the flexibility to use the protection on a wide range of interfaces. The Vcc and Gnd pins can be configured for the unique design needs by allowing a voltage clamp reference from 3.3V to 70V.

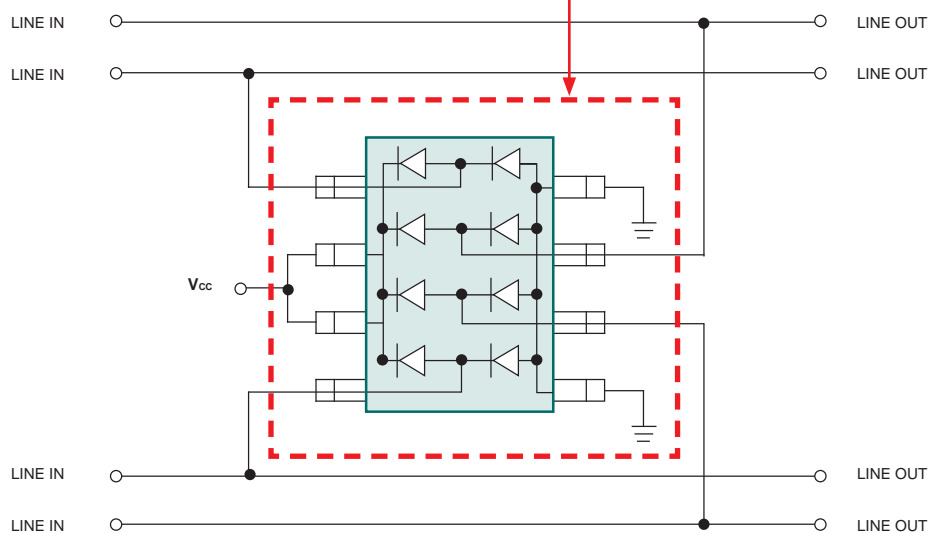


SR70



SRDA70-4

Surge rated diodes afford the flexibility of using the supply rails for clamp reference. The SR70 and SRDA70-4 can be used from 3.3V to 70V.



Protecting Differential Transmission Line with SRDA70-4

SR12

ESD & Surge Protection for ADSL & VDSL Interfaces

Features

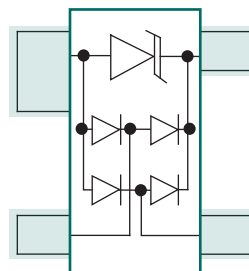
- 12V working voltage
- 2-line protection array
- Low clamping voltage
- SOT-143 package

Applications

- ADSL interfaces
- VDSL interfaces
- Industrial interfaces

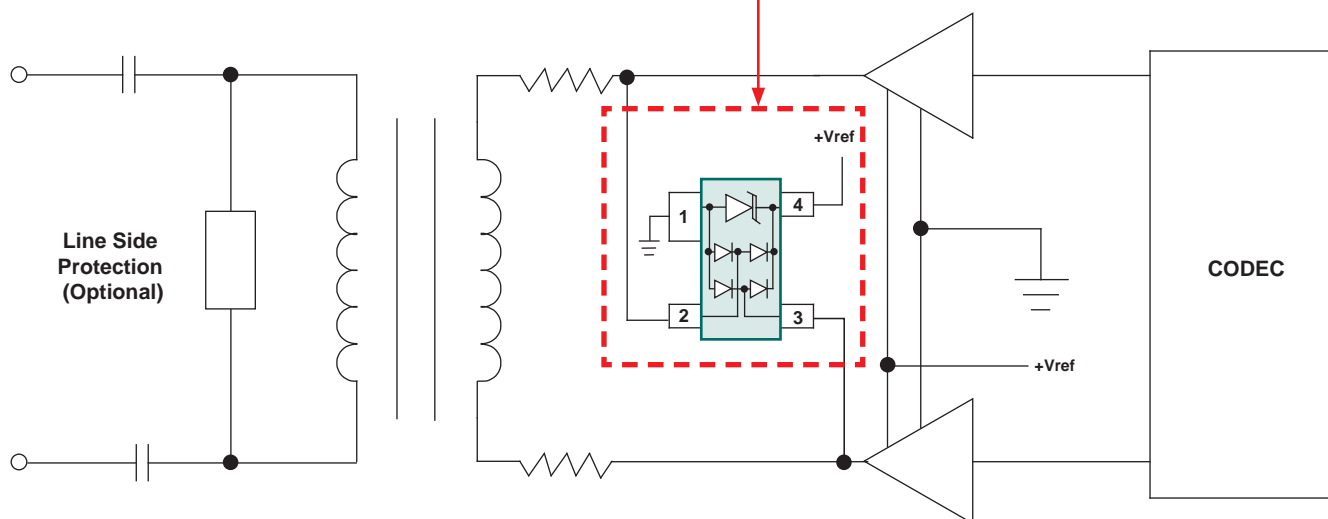
Description

The unique design of the SR12 incorporates four surge rated, low capacitance steering diodes and a TVS diode in a single package. During transient conditions, the steering diodes direct the transient to either the positive side of the power supply line or to ground. The internal TVS diode prevents over-voltage on the power line, protecting any downstream components.



SR12

The SR12 can protect an ADSL or VDSL tip/ring pair, providing very low clamping voltage and minimal capacitive load.



Protecting XDSL Interface with SR12

LCDA12C-1 and LCDA15C-1

ESD & Surge Protection for ADSL & VDSL Interfaces

Features

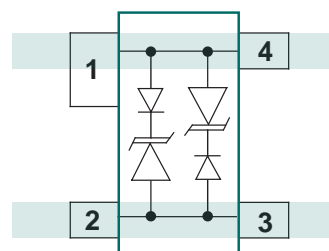
- 12V & 15V working voltage
- 2-line protection array
- Low clamping voltage
- Low leakage current
- Flow-through package

Applications

- ADSL interfaces
- VDSL interfaces
- RS-232, RS-422

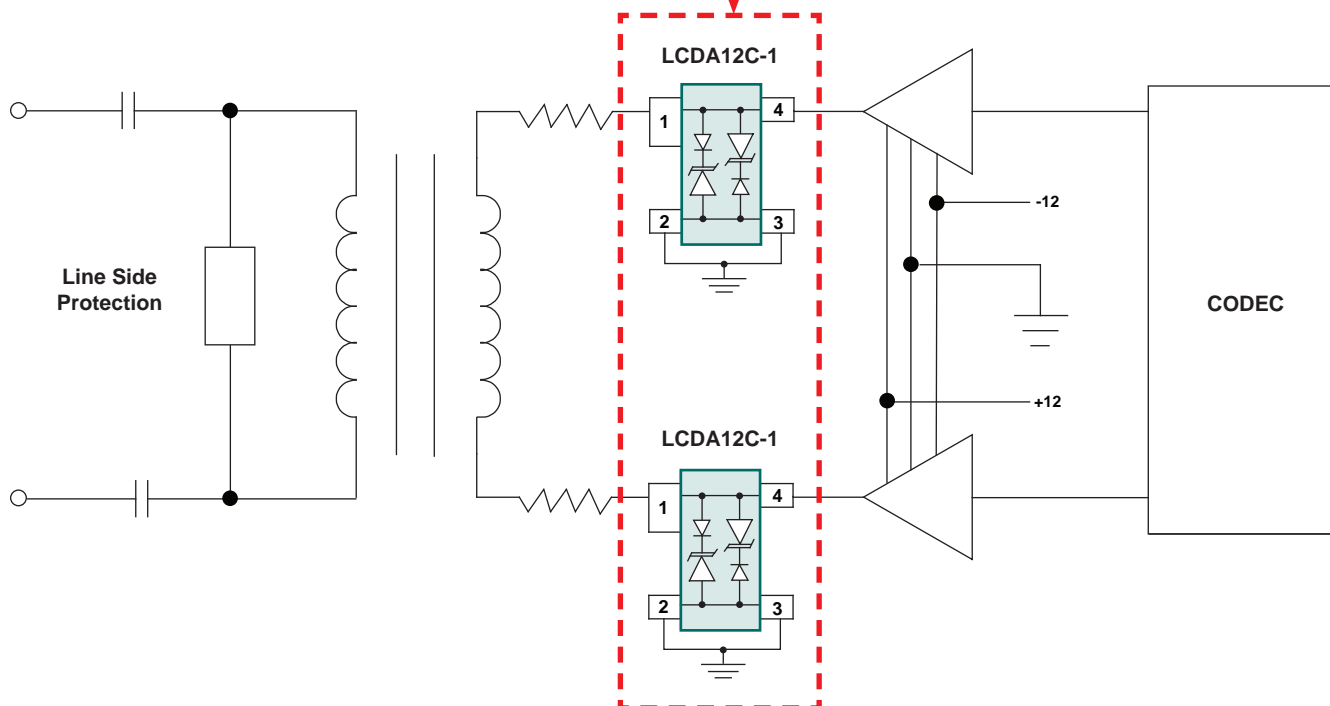
Description

The LCDAxxC-1 is a low capacitance transient voltage suppressor (TVS) diode array. These devices protect sensitive CMOS ICs from dangerous ESD and secondary lightning transient threats. The LCDAxxC-1 will protect one line in common mode (line-to-ground) or one line in metallic mode (line-to-line). The low capacitance of these devices (<15pF) makes them suitable for use on high-speed telecom and datacom interfaces. The LCDAxxC-1 may be used to protect ADSL interfaces, multi-protocol serial transceivers, and wireless systems.



LCDA12C-1

The low clamping LCDAxxC-1 provides robust surge protection for sensitive xDSL circuitry.



ADSL Protection Circuit with LCDAxxC-1

SM712

ESD & Surge Protection for RS-485 Interfaces

Features

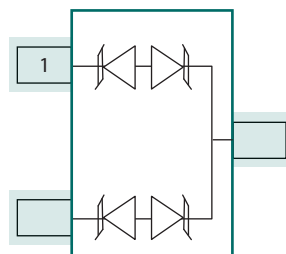
- Protection +12V to -7V lines
- Low capacitance
- Low clamping voltage
- 12A (8/20 μ s) surge rating

Applications

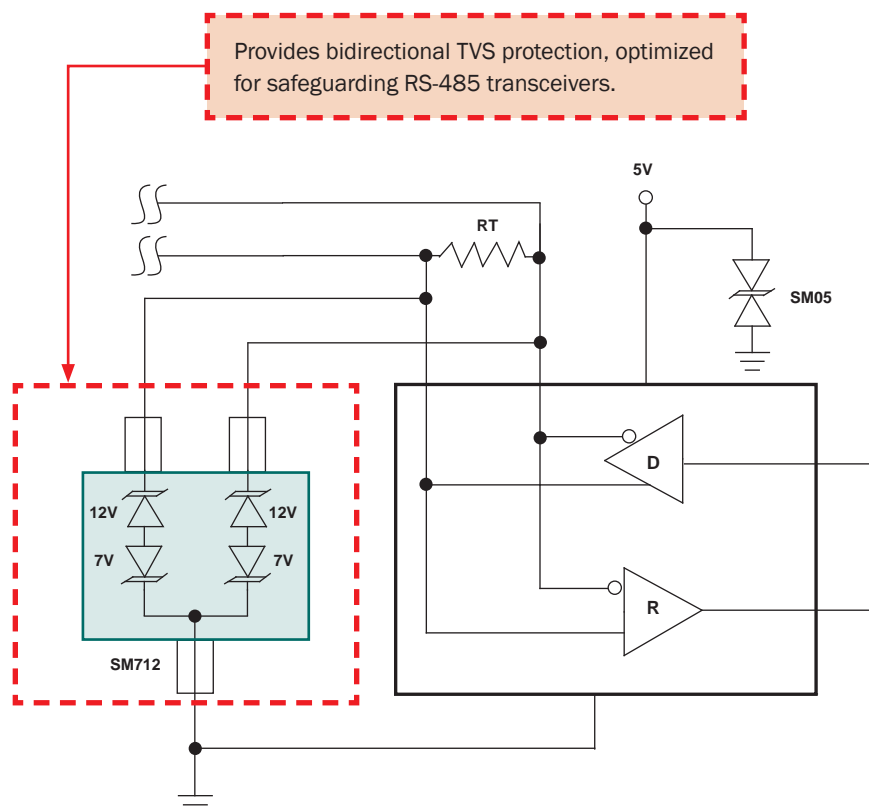
- RS-485 systems
- Security systems
- Enterprise switching

Description

The SM712 TVS is designed for asymmetrical (+12V to -7V) protection in multi-point RS-485 systems. The SM712 will protect devices from transient voltages resulting from electrostatic discharge (ESD), electrical fast transients (EFT) and lightning surge. The device is designed with asymmetrical operating voltage for optimal protection. The TVS diodes at pins 1 and 2 have a working voltage of 12 volts. These pins are connected to the differential data line pairs. The TVS diodes at pin 3 have a working voltage of 7V. Pin 3 can be connected to ground in RS-485 applications.



SM712



Protection for RS-485 Interface with SM712

RClamp®0582B

2-line High speed and USB Port Protection

Features

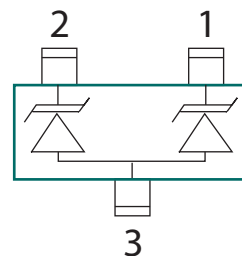
- Protects 1 high-speed interface
- Ideal for USB data lines
- Low capacitance <1.2pF line to line
- Small package size

Applications

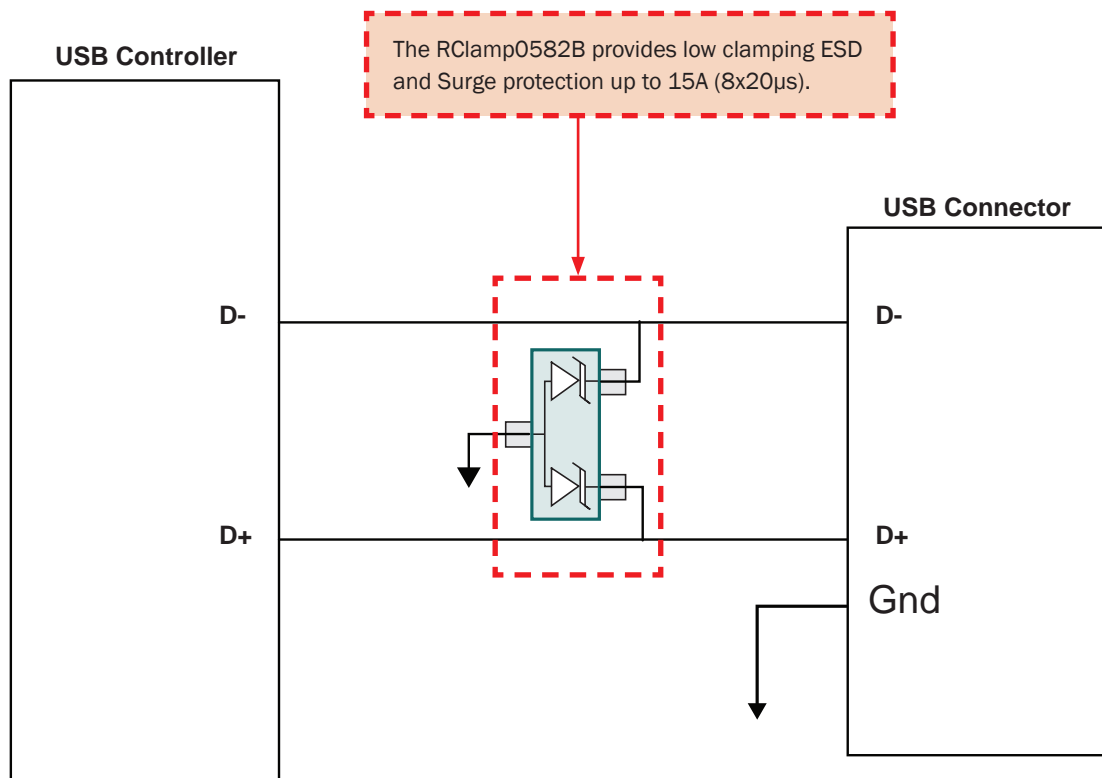
- USB 2.0
- IEEE 1394
- Analog video

Description

The RClamp0582B is an ultra low capacitance device that is designed to protect up to two high speed data interfaces. It has a typical line-to-line capacitance of only 0.7pF, making it ideal for use on lines operating in excess of 2.5GHz. The device is housed in a small, RoHS/WEEE compliant SC-75 package.



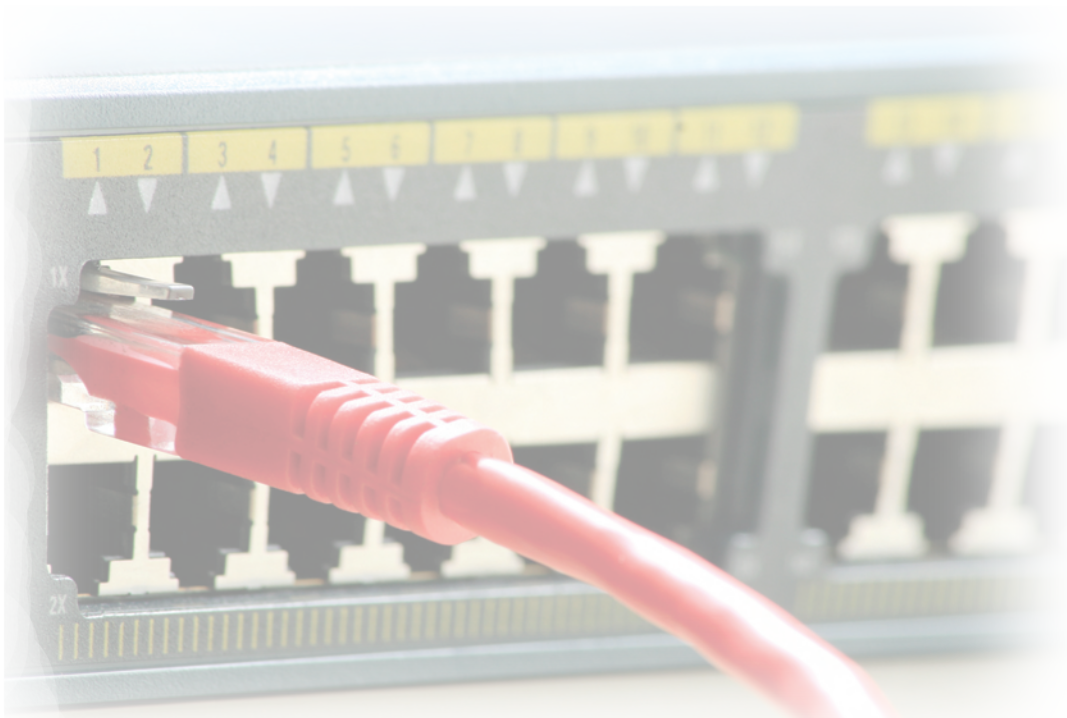
RClamp0582B



Robust Protection for USB2.0 Interfaces

Circuit Protection Applications

As telecommunication interfaces can be subject to wide variety of transient conditions and operating environments, the need for good circuit protection solutions are often unique to the application. This section will examine some of the more subtle aspects of protecting circuit interfaces from overvoltage threats.



IEC 61000-4-x Transient Immunity Standards

The International Electrotechnical Commission (IEC), a worldwide organization promoting international cooperation on questions concerning standardization in electrical & electronic fields, has developed transient immunity standards which have become minimum requirements for manufacturers wanting to do business in the European Community (EC).

Three of the IEC standards deal with transient immunity:

- IEC 61000-4-2 : Electrostatic Discharge (ESD)
- IEC 61000-4-4 : Electrical Fast Transient/Burst (Electrical Fast Transients)
- IEC 61000-4-5 : Surge Immunity

The following sections provide a summary of each of the transient immunity standards.

IEC 61000-4-2 – Electrical Discharge (ESD) Standard

IEC 61000-4-2 addresses one of the most common forms of transients in electronic systems: Electrostatic discharge (ESD). ESD results from conditions which allow the build up of electrical charge from contact and separation of two non-conductive materials. When the charged body is brought in proximity of another object of lower potential, energy is released in the form of electrostatic discharge.

The standard defines immunity requirements for ESD which can be coupled into the equipment directly or through radiated effects. Direct coupling includes any user accessible entry points such as I/O ports, switches, computer keyboards, panel displays, and equipment housings. Radiated coupling results from the discharge between two bodies which are external to the system.

Because the human body is one of the most common generators of ESD, the IEC standard defines a test set up which is designed to simulate an ESD event from a human body. The “Human Body Model” (HBM) as it is referred to, is considered a valid representation of worst case ESD stresses. Discharge into equipment may be through direct contact (contact discharge method) or just prior to contact (air discharge method). Contact discharge is the preferred test method, but air discharge is used where contact discharge cannot be applied.

The ESD threat is divided into four threat levels. Threat level 1 is considered the least severe while threat level 4 is the most severe. Most manufacturers will adhere to level 4: $\pm 8\text{kV}$ contact discharge, $\pm 15\text{kV}$ air discharge. IEC 61000-4-2 also specifies the ESD current waveform and parameters shown in Figure 1 & Table 1.

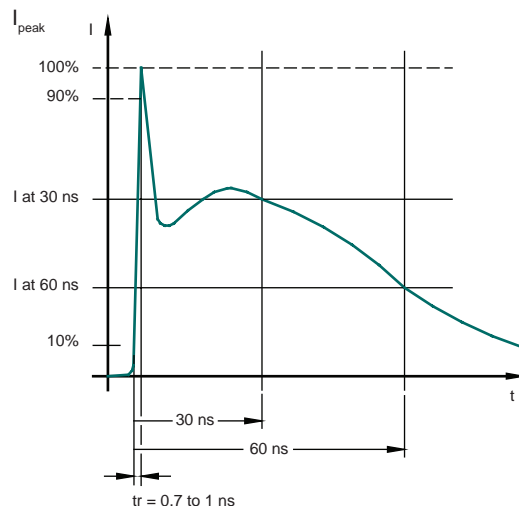


Figure 1 - ESD Waveform per IEC 61000-42

The rise time is extremely fast, defined as 0.7 to 1ns, with a second peak at 30ns and a total duration of only 60ns. The total energy contained within the pulse is approximately a few hundred microjoules.

Transient Voltage Suppression (TVS) diodes are an ideal choice for meeting the ESD transient immunity requirements of IEC 61000-4-2 and are proven solutions for suppressing system level ESD events. The extremely fast response time of the TVS diode is essential for responding to the 1ns rise time of the ESD pulse. Additionally, TVS diodes are capable of clamping the incoming transient to a low enough level as not to cause damage to the protected semiconductor. All TVS diode devices and families offered by Semtech may be used to suppress ESD to level 4 of IEC 61000-4-2. The fast response and low clamping levels make TVS diodes suitable for ESD suppression on data and I/O ports.

Level	Indicated Voltage	First peak current of discharge +/- 10%	Rise time (tr) with discharge switch	Current (+/- 30% at 30 ns)	Current (+/- 30% at 60 ns)
	kV	A	ns	A	A
1	2	7.5	0.7 to 1	4	2
2	4	15	0.7 to 1	8	4
3	6	22.5	0.7 to 1	12	6
4	8	30	0.7 to 1	16	8

Table 1 – IEC61000-4-2 Waveform Parameters

IEC 61000-4-4 – Electrical Fast Transients (EFT) Immunity Standard

Electrical fast transients occur as a result of arcing contacts in switches and relays. EFT disturbances are common in industrial environments where electromechanical switches are used to connect and disconnect inductive loads. IEC 61000-4-4 specifies the EFT threat in both power and data lines. The electrical fast transient is described in terms of a voltage across a 50Ω load from a generator having a nominal dynamic source impedance of 50Ω. The output occurs as a burst of high voltage spikes at a repetition rate ranging from 2kHz to 5kHz. The burst length is defined as 15ms with bursts repeated every 300ms.

Each individual burst pulse is a double exponential waveform with a rise time of 5ns and a total duration of 50ns. A diagram showing the EFT waveform and the EFT burst repetition rate and burst period is shown in Figure 2. Four severity levels are defined in terms of an open circuit voltage as a function of installation environment.

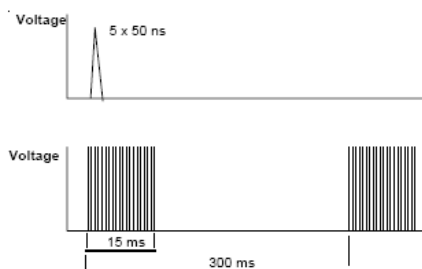


Figure 2 – EFT Burst

The installation environments are defined as :

- 1 - Well protected
- 2 - Protected
- 3 - Typical industrial
- 4 - Severe industrial

Table 2 provides the open-circuit voltages for each threat level and for both power supply and data lines. Short circuit current values are estimated by dividing the EFT open-circuit voltage by its 50Ω source impedance. This represents the worse case stresses seen by the suppression element. Like ESD, EFT can be especially fatal on data and I/O lines. The fast rise time of the EFT pulses demands a suppression element with the same characteristics as that which are required for suppression of an ESD pulse. Again TVS diodes offer the best solution for suppressing the expected transient energy while keeping clamping voltages across the protected elements to a minimum.

Additionally, the extremely fast response time of TVS diodes is essential for responding to the 5ns rise time of the EFT pulse. Due to the repetitive nature of the EFT pulses, TVS diodes with slightly higher power handling capability will be required for protection at threat level 4.

Level	Peak Amplitude			
	Power Supply Port		I/O Signal, Data & Control Lines	
	V _{OC} (kV)	I _{SC} (A)	V _{OC} (kV)	I _{SC} (A)
1	0.5	10	0.25	5
2	1	20	0.5	10
3	2	40	1	20
4	4	80	2	40

Table 2 – IEC61000-4-4 Severity Levels

IEC 61000-4-5 – Surge Standard

IEC 61000-4-5 addresses the most severe transient conditions on both power and data lines. These are transients caused by lightning strikes and switching. Switching transients may be the result of power system switching, load changes in power distribution systems, or short circuit fault conditions. Lightning transients may result from a direct strike or induced voltages and currents due to an indirect strike. The IEC 61000-4-5 standard defines a transient entry point and a set of installation conditions. The transient is defined in terms of a generator producing a given waveform and having a specified open circuit voltage and source impedance. Two surge waveforms are specified : The 1.2 x 50μs open-circuit voltage waveform and the 8 x 20μs short-circuit current waveform (Figures 3 & 4 respectively).

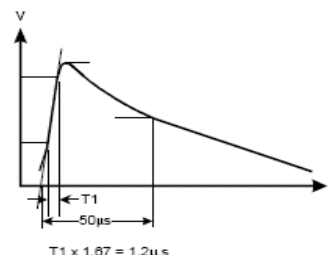


Figure 3 – IEC 61000-4-5 Voltage Impulse

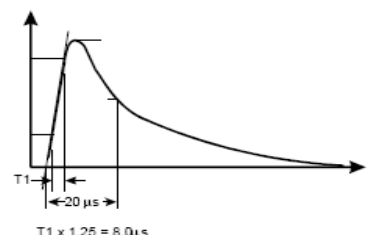


Figure 4 – IEC 61000-4-5 Current Impulse

Transient stress levels for each entry point into the system are defined by installation class. The six classes are defined as :

- Class 0 : Well protected environment
- Class 1 : Partially protected environment
- Class 2 : Well separated cables
- Class 3 : Cables run in parallel
- Class 4 : Multi-wire cables for both electronic & electrical circuits
- Class 5 : Connection to telecommunications cables and overhead power lines (Low density populated areas)

A class 0 environment is considered the lowest threat level and has no transient stress requirements. The class 5 environment is the most severe and requires the highest transient stress level testing. Table 3 summarizes threat levels as a function of installation class. Values of voltage stress using the 1.2 x 50µs waveform are given. Corresponding current values are calculated by dividing the open-circuit voltages by the source impedances. The short-circuit current values are more useful in choosing a suppression element.

The short circuit current stress levels are defined with the 8 x 20µs waveform for power supply applications with a 2Ω source impedance. For data lines requiring a 42Ω source impedance, the short-circuit current waveform is defined as 8 x 20µs. For telecommunications applications, the open-circuit voltage is defined as 10 x 700µs and the short-circuit current is a 5 x 300µs waveform. The source impedance is given as 40Ω.

The type of suppression element needed for IEC 61000-4-5 class surges depends upon the threat level and installation class. For power supply applications high power devices are required. A discrete device or an assembly may be required depending on the application. TVS diodes are the best choice for data line applications and secondary board level protection because of their superior clamping voltage characteristics and fast response time.

Class	Voltage Current	Power Supply		Unsym Lines (Long Distance Bus)		Sym Lines	Data Bus (Short Distance)
		Coupling Mode		Coupling Mode		Coupling Mode	Coupling Mode
		Line-Line Zs = 2Ω	Line-GND Zs = 12Ω	Line-Line Zs = 42Ω	Line-GDN Zs = 42Ω	Line-GDN Zs = 42Ω	Line-GND Zs = 42Ω
0	Voltage	NO REQUIREMENT					
	Current						
1	Voltage	(n/a)	0.5KV	(n/a)	0.5KV	1.0KV	(n/a)
	Current		42A		12A	24A	
2	Voltage	0.5KV	1.0KV	0.5KV	1.0KV	1.0KV	0.5KV
	Current	250A	83A	12A	24A	24A	12A
3	Voltage	1.0KV	2.0KV	1.0KV	2.0KV	2.0KV	(n/a)
	Current	500A	167A	24A	48A	48A	
4	Voltage	2.0KV	4.0KV	2.0KV	4.0KV	(n/a)	(n/a)
	Current	1KA	333A	48A	95A		
5	Voltage	(Note 1)	(Note 1)	2.0KV	4.0KV	4.0KV	
	Current			48A	95A	95A	
WAVE FORMS	Voltage	(1.2 x 50µs)	(1.2 x 50µs)	(1.2 x 50µs)	(1.2 x 50µs)	(1.2 x 50µs)	(1.2 x 50µs)
	Current	(8 x 20µs)	(8 x 20µs)	(8 x 20µs)	(8 x 20µs)	(8 x 20µs)	(8 x 20µs)

Note 1: Depends on class of local power supply system.

Table 3 – IEC 61000-4-5 Severity Levels

Summary

Any OEM equipment manufacturer who plans to sell in the European market will have to meet the requirements of IEC 61000-4. IEC defines three transient immunity standards which provide equipment suppliers with a susceptibility level. Designing in accordance to the IEC standard enables manufacturers to produce more reliable products. Each of the transient immunity standards defines transient sources, entry paths into a system, severity levels, and test methods. Equipment application will determine what level of transient protection is needed. Transient suppression devices must be carefully chosen for each of the standards.

References

Makowski, Leo P., "IEC 1000-4-X (801) Series of Standards," EMC Test & Design, October 1994
Clark, O.M., "Electrical-Transient Immunity: A Growing Imperative for System Design," Electronic Design, January 23, 1992

IEC Publication 1000-4-2 "Electromagnetic Compatibility for Industrial Process Measurement and Control Equipment - Part 4, Electrostatic Discharge Requirements," International Electromechanical Commission, 1995

IEC Publication 1000-4-4 "Electromagnetic Compatibility for Industrial Process Measurement and Control Equipment - Part 4, Electrical Fast Transient/ Burst Requirements," International Electromechanical Commission, 1995

IEC Publication 1000-4-5 "Electromagnetic Compatibility for Industrial Process Measurement and Control Equipment - Part 4, Surge Immunity Test," International Electromechanical Commission, 1995

Lightning Surge Immunity per Telcordia GR-1089

Telephone companies and exchange carriers have long recognized the disruption and equipment damage that lightning induced transients can cause to equipment connected to their networks. To insure safe and continued network operation, telecommunications carriers have required the equipment that they purchase to undergo surge immunity testing designed to emulate the worst case conditions that can be expected in the field. Telcordia GR-1089 is the immunity standard which applies to telecommunications equipment in North America. Telcordia GR-1089 represents the most stringent of lightning immunity standards used for equipment compliance. The GR-1089 standard contains immunity requirements for both inside and outside plant network equipment and customer premises equipment which will be used in carriers networks.

Lightning Immunity

Lightning immunity tests are performed for equipment which is installed either on inside lines only or outside lines. These tests are the result of more than 30 years of field studies measuring actual lightning events in the United States. The studies found that lightning strikes in close proximity produced the fastest rise times, while distant strikes produced slower, longer lasting strikes. The actual shape of the waveforms also varied but Telcordia settled on a double exponential waveform as being representative of lightning surges. The double exponential surge waveform is shown in Figure 1. The double exponential waveform is defined as having an exponential rate of rise to the peak and an exponential decay from that peak.

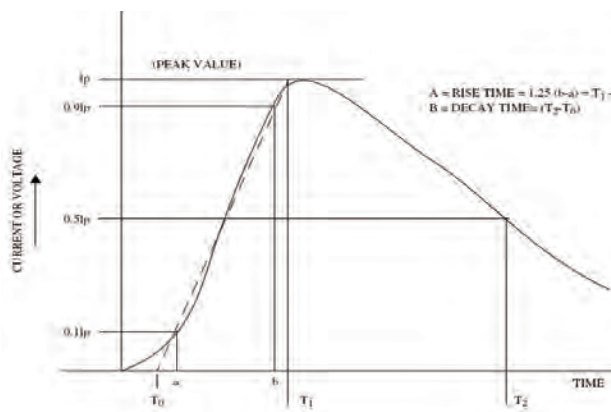


Figure 1 – Double Exponential Surge Waveform

First Level & Second Level Criteria

GR-1089 specifies two levels of surge immunity. First level tests call for metallic (line-to-line) and longitudinal (line-to-ground) surges. After the first level test, the equipment must function correctly and should not have any degraded performance.

Depending upon the equipment port type, second level surge testing may also be applied. Compliance to the second level criteria requires that the EUT may be damaged but must not become a fire, fragmentation, or safety hazard.

GR-1089 Port Types

GR-1089 categorizes telecommunications ports into various port types based upon the equipment location electrically within the network. As the surge threat is a function of the port location within the network, different levels of immunity testing may be required depending upon the port type. The latest revision of the GR-1089 standard (Issue 4) calls for 8 different port types as shown in Table 1:

Type Number	Definition	Example
Type 1	Directly connected to metallic outside plant (OSP)	Broadband coax
Type 2	Not directly connected to metallic outside plane (OSP)	Ethernet
Type 3	Ports directly connected to metallic OSP cable conductors	Remote terminals
Type 4	Equipment port(s) not directly connected to metallic outside-plant	NIUs, ONTs, broadband coax communication
Type 5	Cable conductors	DSL, remote terminals
Type 6	Ports directly to connected to external antennas	Cellular service equipment
Type 7	Connection to AC power systems	
Type 8	Connection to DC power source	

Table 1 – GR-1089 Port Types

To see how the surge test would be applied, consider the case of testing a system with port types 2 & 4 defined by GR-1089. Examples for port types 2 or 4 would include Intrabuilding Ethernet or T1/E1 lines that run within the central office building environment. For this case, there is only a first level lightning surge requirement; the second level surges would not apply.

For a T1/E1 interface, an $\pm 800\text{V}$ (100A) 2/10 μs line-to-line pulse and a $\pm 1500\text{V}$ (100A) 2/10 μs line-to-ground pulse per the standard is required. It is worth noting, GR-1089 Issue 4 makes a subtle distinction between one or two port systems and multi-port interfaces. For instance, 100Base-T Ethernet would be classified as a two port interface while 1000Base-T Ethernet would be a four-port interface. The surges for these respective cases are shown in the Tables 2 & 3. The following section on Gigabit Ethernet will explore protecting Gigabit Ethernet PHYs against GR-1089.

First Level Intra-Building Surge - One or Two Pair Ports				
Surge	Minimum Peak Voltage (Volts)	Minimum Peak Current (Ampere)	Pulse Waveshape	Line-to-Line Surge or Line-to-Ground Surge?
1	$\pm 800\text{V}$	100A	2/10 μs	Line to Line
2	$\pm 1500\text{V}$	100A	2/10 μs	Line to Ground

Table 2 – First Level Intrabuilding Surge – One or Two Port (Port Types 2 & 4)

First Level Intra-Building Surge - Multi-Pair Ports					
Number of Pairs	Surge	Minimum Peak Voltage (Volts)	Value for External Non-Inductive Resistors	Pulse Waveshape	Line-to-Line Surge or Line-to-Ground Surge?
1 or 2	1	$\pm 800\text{V}$	6 Ω	The combination of 1.2/50 μs open-circuit voltage waveshape and 8/20 μs short circuit current waveshape with a 2 Ω internal impedance	Line to Line
	2	$\pm 1500\text{V}$	10 Ω		Line to Ground
3 or 4	1	$\pm 800\text{V}$	6 Ω		Line to Line
	2	$\pm 1500\text{V}$	20 Ω		Line to Ground
Greater than 4	1	$\pm 800\text{V}$	6 Ω		Line to Line
	2	$\pm 1500\text{V}$	40 Ω		Line to Ground

Table 3 – First Level Intra-building Surge – Multiport (Port Types 2 & 4)

Transient Voltage Protection for Gigabit Ethernet PHYs

Ethernet systems within the communications infrastructure are subject to high-level transient threats. This type of equipment may even need to meet the surge immunity requirements of Telcordia GR-1089. Reliable protection of the Ethernet transceiver requires a device that can absorb the expected transient energy, clamp the incoming surge to a safe level, and yet remain transparent to the system under normal operation. Additionally, each new generation of Ethernet deployment yields higher-density boards that demand protection solutions that occupy less board space. Exacerbating the problem, Gigabit Ethernet systems must be rated to operate at high temperatures, making application of external protection even more challenging. This section will discuss a solution for providing reliable protection of GbE systems. This solution is designed to meet the surge requirements of GR-1089. If designed properly, this solution can be used without causing transmission errors.

Transient Threats

The small geometries of GbE transceivers make them particularly susceptible to upset or damage from transient events. One of the most common threats is a Cable Discharge Event (CDE). A CDE occurs when an Ethernet cable becomes charged (due to interaction with its environment) and subsequently discharges into the circuit when the cable is plugged into the connector. In general, the waveforms last for a few hundred nanoseconds with rapid polarity changes. Electrostatic discharges (ESD) that originate from the user are also common. These types of waveforms last for approximately 60ns and are consistent with the human body model

as defined by immunity standards such as IEC 61000-4-2. For outside connections, lightning can also induce high voltage surges onto the communication lines that connect to the Ethernet PHY IC. These events are high energy pulses, lasting several microseconds. The Telcordia Technologies GR-1089-CORE specification defines a set of requirements for lightning and ESD immunity for intra-building equipment. The lightning tests are applied as metallic (line-to-line) or longitudinal (line-to-ground) waveforms. The waveforms are defined with a rise time of 2 μ s and a decay time of 10 μ s with an open circuit (metallic) voltage of 800 volts short circuit current of 100A. Positive and negative polarity surges are applied. To pass, the equipment must continue to operate after the test.

Ethernet Magnetics

An Ethernet port includes transformers and common mode chokes for connecting the PHY to the outside world. Transformers and chokes can be discrete components, but integrated solutions that include the RJ-45 connector, resistors and capacitors are becoming increasingly popular. In either case, the transformer will provide a high level of common mode isolation to external voltages, but no protection for metallic surges. For a metallic (Line-to-Line) surge, current will flow into one line, through the transformer and back to the source. As the current flows, it charges the windings of the transformer on the line side (RJ45 side). Once the surge is removed, the windings on the line side will stop charging and will transfer its stored energy to the IC side where the PHY IC is located. Regardless, the pulse will most certainly be destructive to the PHY chip.

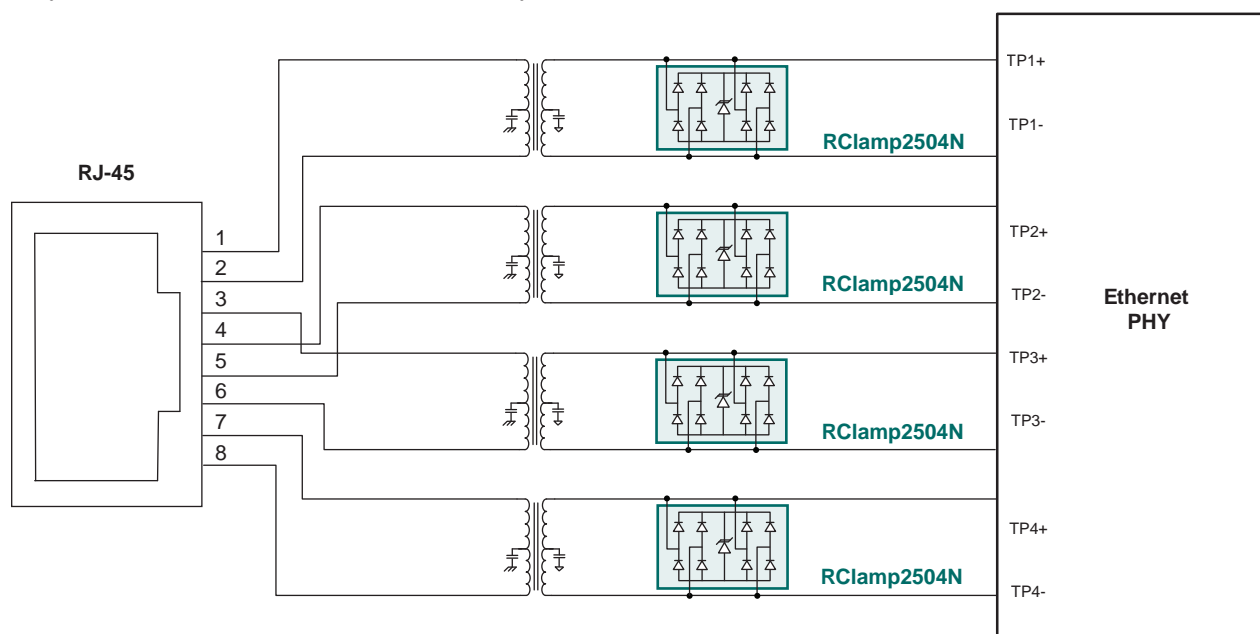


Figure 1 - Protection for Gigabit Ethernet Interfaces

Protection Solutions

As the feature sizes on performance PHYs are scaling smaller along with thinner oxide layers, using low working voltage TVS is critical to safeguarding Ethernet PHYs. Semtech's RClamp2504N is a low capacitance, transient voltage suppressor (TVS) designed to protect Gigabit Ethernet ports while maintaining traffic performance over temperature. The RClamp2504N is constructed using Semtech's low-voltage EPD process technology to achieve a low working voltage of 2.5 volts. The RClamp2504N circuit diagram is shown in Figure 1. The device is in a leadless, RoHS compliant package measuring 2.6 x 2.6 x 0.6mm. The RClamp2504N's low 2.5V working voltage results in a low clamping voltage for maximum protection of the GbE PHY. The RClamp2504N may be used on the PHY side of the transformer to meet the Intra-building surge requirements of Telcordia GR-1089 ($I_{pp}=100A$, $t_p=2/10\mu s$).

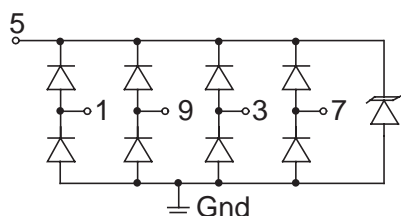


Figure 2 - RClamp2504N Circuit Diagram

Figure 1 illustrates a protection solution using the RClamp2504N TVS device for protecting a Gigabit Ethernet PHY. The four line pairs are protected using the RClamp2504N connected in differential mode (line-to-line) on the PHY side of the transformer. For optimal performance, parasitic inductance should be minimized by placing the device as close to the magnetics as possible and on the same side of the board as the PHY. The clamping voltage, measured at 10.8V, for a metallic mode 800V (100A) 2/10 μs surge provides sufficient clamping margin to minimize electrical stress and prevent latent failure.

GbE System Operation over Temperature

Depending upon the operating environment, Telecom and Datacom systems may be exposed to harsh temperatures extremes. Ethernet ports within these systems are required to operate at very high temperatures. In addition, the IEEE 802.3 specification requires that the Ethernet interface supports data transmission on cable lengths of up to 100 meters. A long cable length will present an additional load to the system transmission, and at elevated temperature, symbol or CRC (Cyclical Redundancy Check) errors can result. Thus, an Ethernet protection circuit must provide the clamping performance to arrest the GR-1089 surge, while also residing on the Ethernet interface without introducing traffic errors.

Generally, the Ethernet interface should provide error free transmission up to 65°C with a 100m cable attached to the port. This presents several challenges. First, the high temperature means the margin of operation of the PHY will be reduced. Secondly, the 100 meter cable presents a large load on the receiving end. Finally, the protection component will present non-linear impedance over temperature. The GbE PHY can account for some impedance variations or discontinuities on the line by performing a forward error correction (FEC). However, large non-linear impedance changes across the differential pair can not always be accounted. The amount of variation in the protection device will depend on leakage current and capacitance; factors dictated primarily by the junction area of the device.

Semtech TVS devices have been shown to operate on Gigabit Ethernet interfaces without introducing packet errors.

Safeguard Ethernet Interfaces from Cable Discharge Threats

Protecting Ethernet interfaces from transient discharges can create a challenge for engineers because good protection must meet two criteria:

1. A protective device must effectively clamp a transient to a safe voltage.
2. The protection device must present an acceptable capacitive load on high-speed differential transmission lines.

Good planning and careful selection of transient voltage-suppression devices can ensure adequate circuit protection from electrostatic discharge (ESD) and cable discharge events. Designing a system for both high-speed communication and transient immunity requirements is nontrivial. Newer Ethernet transceivers run faster, consume less power and use less PCB space. But these advances have contributed to a reduction of on-chip transient-voltage protection levels. Thus, designers need advanced system-level circuit protection to ensure Ethernet systems remain immune to ESD and cable discharge threats.

CDE is a real and frequent phenomenon in the Ethernet environment. Moreover, while cable-discharge (CDE) can be thought of as a type of electrostatic discharge (ESD), designers should treat CDEs as a separate type of transient event. An Ethernet cable – generally unshielded, twisted-pair Cat-5 or Cat-6 – can be simply modeled as a capacitive element that can store a significant charge. That cable, which can run as long as 100m, can accumulate charge via triboelectric or induction effects. Simply dragging a cable along a carpet or removing it from a package will lead to a stored charge. Inductive transfer from a user also can charge a cable. Because Cat-5 and Cat-6 twisted pair cables have low-leakage properties, the charge may remain stored on a twisted pair for several hours and it can discharge into an Ethernet port when a user connects it to equipment. The latter type of discharge occurs directly into the communication interface and poses a particularly dangerous threat to the communication interface such as Ethernet ports. The high peak voltage and current during a CDE can overstress an Ethernet transceiver and lead to intermittent malfunctions or total failure.

The semiconductor industry has recognized the need for a standard method for testing CDE and Working Group 14, ESD Simulators, within the Electrostatic Discharge Association (ESDA) is currently defining a standard method for CDE testing. This work will define a testing method that uses an ESD waveform specified in IEC 61000-4-2, but the new method will account for energy transfer through a cable rather than a human body. Unlike a human-body-model ESD, CDE has an initial current spike followed by a characteristic plateau and then a ringing signal with rapid polarity changes. In many cases, cable discharges can deliver more damaging energy to CMOS structures than human-body-model ESD. Thus it is essential for Ethernet ports to add good system-level protection circuits. Unfortunately, some protection circuits negatively affect signal integrity and others offer inadequate protection. We recommend engineers consider the following characteristics when they review Ethernet-port protection needs:

- Fast response time
- Low clamping voltage
- Low leakage current
- Low capacitance
- High energy handling capacity
- Optimal PCB layout

First, an effective Ethernet-protection device must offer a response time faster than the transient events the system will experience. Thus to safely attenuate a fast discharge during ESDs and CDEs, the protection device must respond within hundreds of picoseconds, faster than the ESD rise time. Figure 1 shows an example of a protection circuit scheme with a sub-nanosecond response time. Placing the protection devices “behind” the Ethernet transformer further reduces surges.

Second, a well devised protection circuit must provide a low clamping voltage for a transient pulse. A transient voltage suppressor (TVS) such as the RClamp2504N (Shown in Figure 1) diode array offers a 4V clamping voltage (V_c) for a peak pulse current (I_{pp}) of 1A. Its V_c increases linearly to about 10V for an I_{pp} of 25A. This type of low-voltage clamping response provides a large protection margin for an Ethernet transceiver.

Finally, the capacitance of a protection circuit must have minimal effect on Ethernet signal integrity. At Gigabit Ethernet speeds you can no longer treat the interface as a lumped-element system but must consider it as a transmission line in which the effect of capacitance elements on signal performance becomes consequential. Excess capacitance loading can cause signal reflections and an impedance mismatch on the transmission line. Choosing components with minimal line-to-line and line-to-ground capacitance can help to ensure a small and acceptable level of signal distortion.

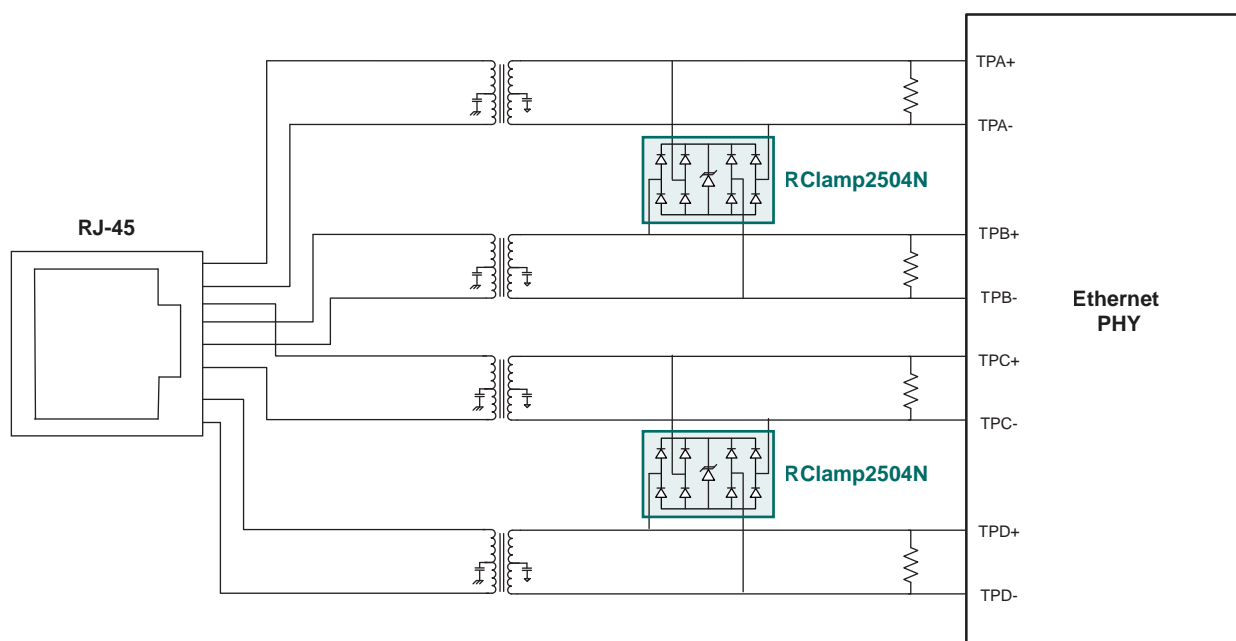


Figure 1 – Cable Discharge Ethernet Protection with RClamp2504N

Power-Over-Ethernet Protection

As Ethernet proliferates in the networking space, the adoption of Power-over-Ethernet (PoE) is rapidly spreading in both 10/100 and Gigabit Ethernet ports. The benefits and cost advantages of powering remote devices over Ethernet cable enables a wide range of applications, including IP telephony, digital video surveillance, wireless LAN access points and other low voltage network connected systems. A typical PoE system utilizes power-sourcing equipment (PSE) to send DC voltage over Ethernet twisted pair to a remote powered device (PD) (Figure 1).

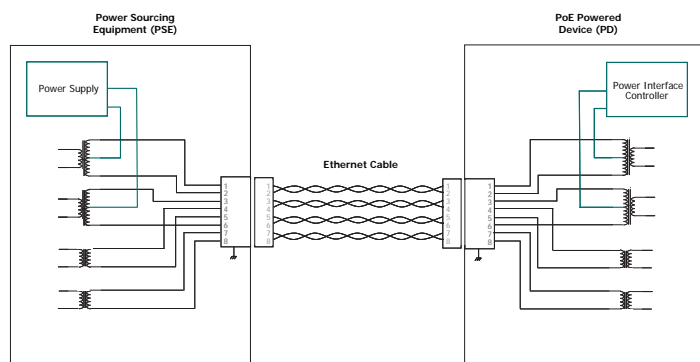


Figure 1 – Power-over-Ethernet (PoE) Typical Circuit

As PoE systems are frequently exposed to transient voltage threats, protecting the Ethernet physical layer transceiver (PHY) from over-voltage stress is an important design consideration.

While PoE applications are increasing, the Ethernet PHY geometries are shrinking at a remarkable pace. At the writing of this paper, 90nm technology is common and silicon vendors are unveiling Ethernet PHYs on 65nm process technology with a view towards even smaller geometries. Implementing effective chip-level ESD on CMOS proves impractical at these advanced transistor geometries. The silicon area required for system level robustness is not only deficient, but implementing effective chip level protection is uneconomical. Consequently, today's Ethernet based system designs increasingly require better off-chip circuit protection to meet worldwide compliance standards and to ensure system reliability.

Transient voltage threats

Ethernet interfaces are vulnerable to many different types of transient over-voltage events. Most common among these are ESD, cable discharge and lightning surges. In addition, the application of DC power over twisted pair cable on Power-over-Ethernet systems can introduce some unique differential-mode connection fault transients. ESD is a fast transient pulse. The rise time of the ESD waveform

as modeled by IEC61000-4-2 is 700 picoseconds to 1 nanosecond while the pulse duration is 60 nanoseconds to 50% decay from the peak pulse current. The high current spike and the energy contained within the transient can easily render damage to the submicron input structures of silicon ICs. Cable discharge (CDE), also known as cable ESD (CESD), occurs when an Ethernet cable becomes charged through routine interaction with the environment through the triboelectric effect or induction. The danger is present when the charged cable is plugged into the system interface. It has been shown that the discharge to the Ethernet port will present differential mode surge through the Ethernet magnetics ^[1]. Similar to ESD, cable discharge exhibits a fast rise time (less than 1 nanosecond); however, unlike ESD, the ensuing waveform presents a long period of ringing with rapid polarity changes. Thus, the energy within a cable discharge waveform can pose more significant and problematic threat for an Ethernet designer than human body ESD.

Differential Mode Transients on Power-over-Ethernet Applications

As mentioned above, protecting Power-over-Ethernet interfaces can be especially challenging because in addition to transients from ESD and surge, there are several scenarios that frequently occur where connecting DC power can result in a differential surges on the Ethernet transmission line. This, of course, can cause catastrophic failure to the PHY or, a more subtle problem, severe stresses leading to latent IC failure.

Most PoE circuit designers will design some form of common-mode protection to protect the PoE circuitry. This usually involves the use of common-mode capacitors connected to earth ground, or possibly a TVS transient voltage suppressor across the power source with a very fast Schottky diode to direct the current flow to ground. Unfortunately, many designers make the mistake of overlooking differential mode protection. Ethernet differential pair, utilize transformers and sometimes common mode chokes to isolate the PHY from the outside environment. The transformer provides a high level of common mode isolation to external voltages, but will provide no protection for metallic or differential (line-to-line) surges.

As shown in Figure 1, in a PoE system +48V or -48V will be present on the differential pairs. This DC voltage is common within a signal pair hence resulting in a 0 DC voltage differentially. However, in some cases it is possible to introduce transients when power is connected. For instance, when the RJ-45 pin-connection is established between the power source equipment and the powered device, the pin-to-pin mating may not occur simultaneously. At the instant the pins make contact to the RJ-45, it is possible to establish contact to pin 1 at an instance just prior or after contact is made to pin 2. This can result in a 48V differential transient with respect to the line pair, thus causing

disruption or damage the PHY of the PoE circuit. A similar example may arise when a user switches connection from a powered device to a non-powered device on the same power source port. When the power source device detects that a non-powered device is now connected, there can exist some latency for the power source device to disable power to that port. In this case, power can be present for sufficient duration that a non simultaneous connection of the pins results in a 48V differential potential. This resulting differential-mode transient poses potential disruptive or destructive effects to the PHY.

Transient Voltage Suppression Diodes (TVS)

Clearly PoE structures are exposed to harsh threat environments and thus will need off-chip circuit protection. Low voltage TVS diodes are a proven protection technology to safeguard Ethernet transceivers. With sub-nanosecond response time, low capacitance and low clamping voltage, they are well suited to guard against a wide variety of transient surges.

For providing differential protection on PoE circuits, a good TVS diode protection scheme must clamp the transient/surges while presenting minimal loading capacitance on the interface. The TVS should offer a low clamping voltage performance and, as a general rule, should provide no more than a few picofarads of line-to-line capacitance. As an additional unique requirement for PoE circuits, the TVS configuration must account for the presence of the +/-48V DC between line pairs. The high DC voltage on separate pairs will prohibit using any integrated diode array or bridge TVS devices that establishes an electrical path between line pairs. The differential pairs must be electrically isolated.

Figure 2 shows an example of a PoE TVS solution for differential mode transient protection using the Semtech RClamp0524S. In implementing a PoE protection circuit, there are some advantages to putting protection on the line side. Not only does this protect the downstream power switch circuitry, but it also keeps transient current from flowing through the transformer. As any additional inductance can add to the ESD clamping of the TVS diodes, it is beneficial to place the TVS as closely as possible to the connector. The TVS array in this example offers a low line-to-line capacitance and provides the necessary line isolation as the diode pairs are separated within the package to isolate the 48V between the differential pair. Additionally, the flow-through layout of the RClamp0524S minimizes the overall inductance in the transient path and facilitates ease of layout on the PCB.

Summary

Power over Ethernet systems require good transient voltage protection to protect against ESD, Cable Discharge and surge transients. In addition, PoE systems must be able to withstand differential mode transients induced from DC power connection faults. With careful design, TVS diodes can be effectively implemented to safeguard PoE circuits from differential mode transients.

[1] "ESD Transfer Through Ethernet Magnetics", Pischl, Neven, December 1, 2006

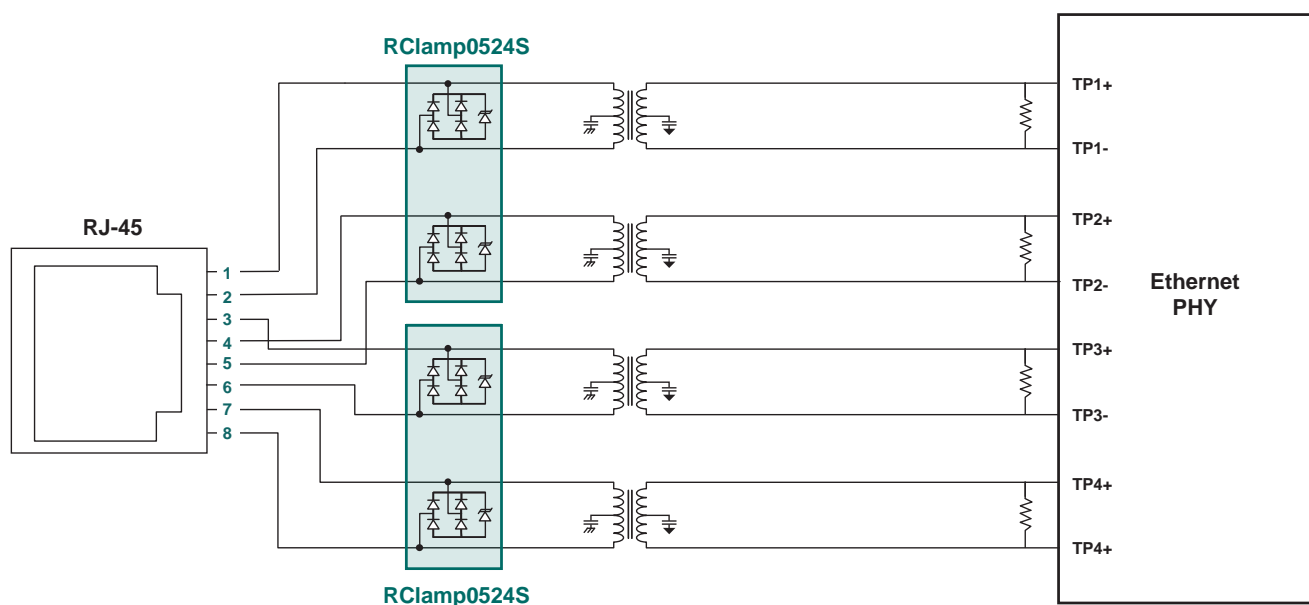


Figure 2 - ESD Protection for Power Over Ethernet Interface

T1/E1 Circuit Protection

T1/E1 digital interfaces have been used commonly as a telecom carrier interface. The technology was introduced to carry multiple voice channels on a frame based digital interface. As a common telecom interface used in the central office environment, T1/E1 tip and ring pairs need to be protected from ESD and Lightning transients.

Due to the high surge current threat for T1/E1 transmit and receive differential pair, a multistage protection scheme is often used. A proven solution to protecting intra-building T1/E1 lines is shown in the circuit diagram below. The design will meet the intrabuilding lightning surge requirements of Telcordia GR-1089 and also provides ESD protection to IEC 61000-4-2 level 4.

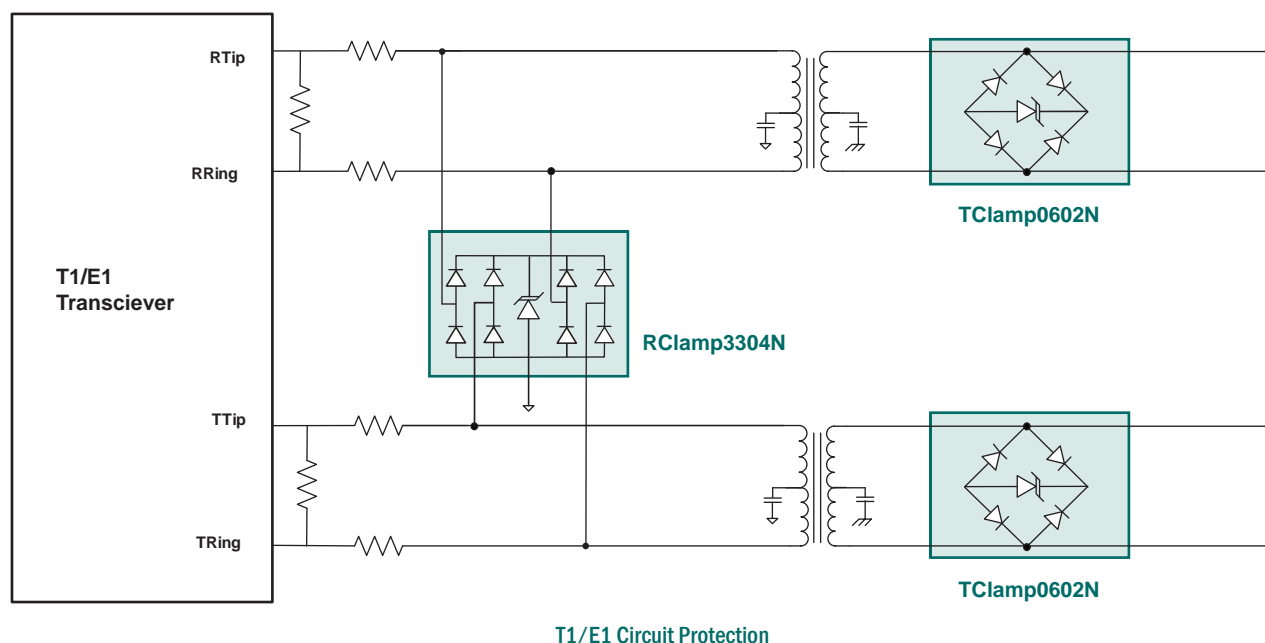
Intra building Protection

On the line-side stage of the protection scheme, the TClamp0602N provides an initial defense by clamping the 100A, 2/10 μ s intra-building lightning surge. The TClamp0602N is a two-line 6V working voltage device rated for 100A 2/10 μ s surge per Telcordia GR-1089. An enhanced diode bridge configuration is used to provide the low capacitance of the TVS diode protection circuit.

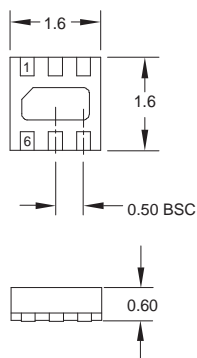
Common mode surge protection will not be necessary if the line transformers are rated for a minimum isolation voltage of 1500V. As T1/E1 systems can present a high port concentration on a line card, the size of the TClamp0602N is ideal for providing high-level surge immunity in a small space. The transceiver side of the transmission line is protected with the RClamp3304N. The RClamp3304N is four-line, 3.3V working voltage device that offers low clamping performance over a wide spectrum of peak pulse current ratings. The secondary side of the T1/E1 interface is protected to provide robust protection against residual lightning pulses and ESD pulses.

Outer building Protection

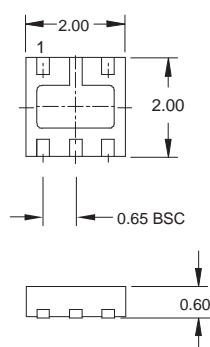
For outer building TVS protection, a similar approach is used to that of the intra-building protection circuitry. In the case of outer-building surge, higher surge immunity is required on the front end of the interface to arrest the 500A 2/10 μ s surge pulse per GR-1089. The LC01-6 is a high surge rated TVS device used in telecom infrastructure protection. The device is surge rated to arrest a 500A pulse for 2/10 μ s. The device is also rated to protect against a 100A surge for 10/1000 μ s. For the case of outer building protection, the Semtech LC01-6 can be used in place of the TClamp0602N per the diagram below. While some may choose to use thyristors on the line side, the superior clamping voltage provided by the LC01-6 in comparison is essential to protection today's more sensitive transceivers.



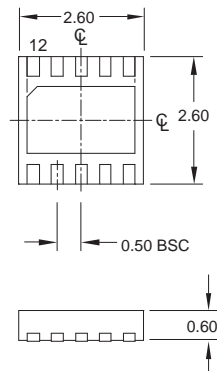
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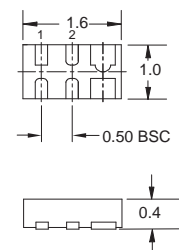
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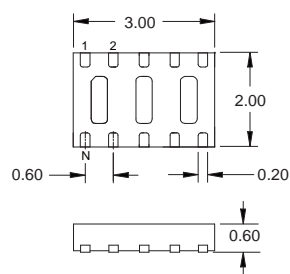
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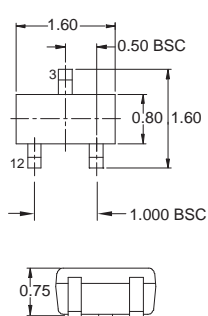
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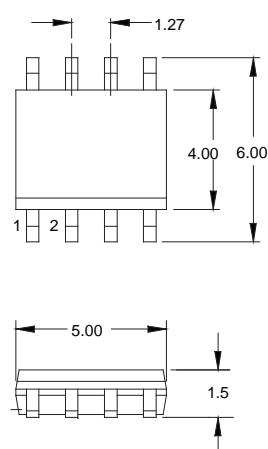
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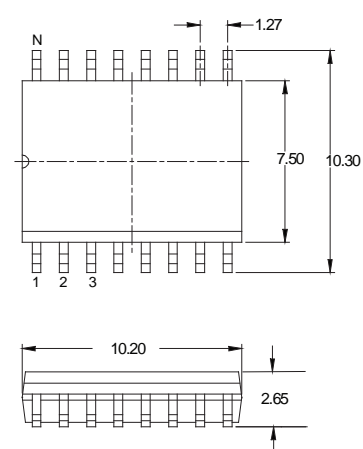
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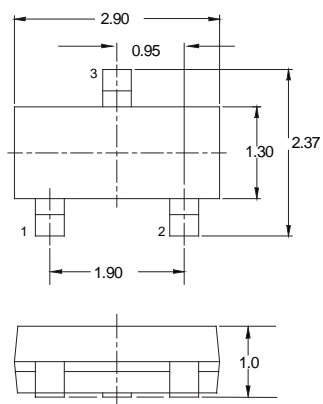
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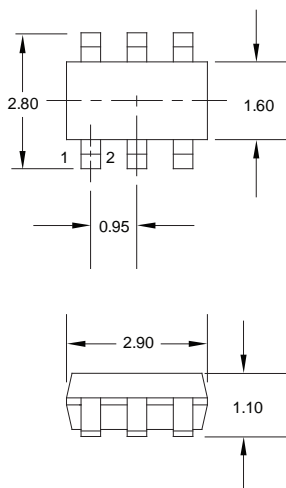
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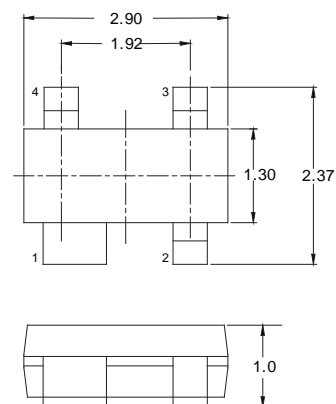
SOT23-3

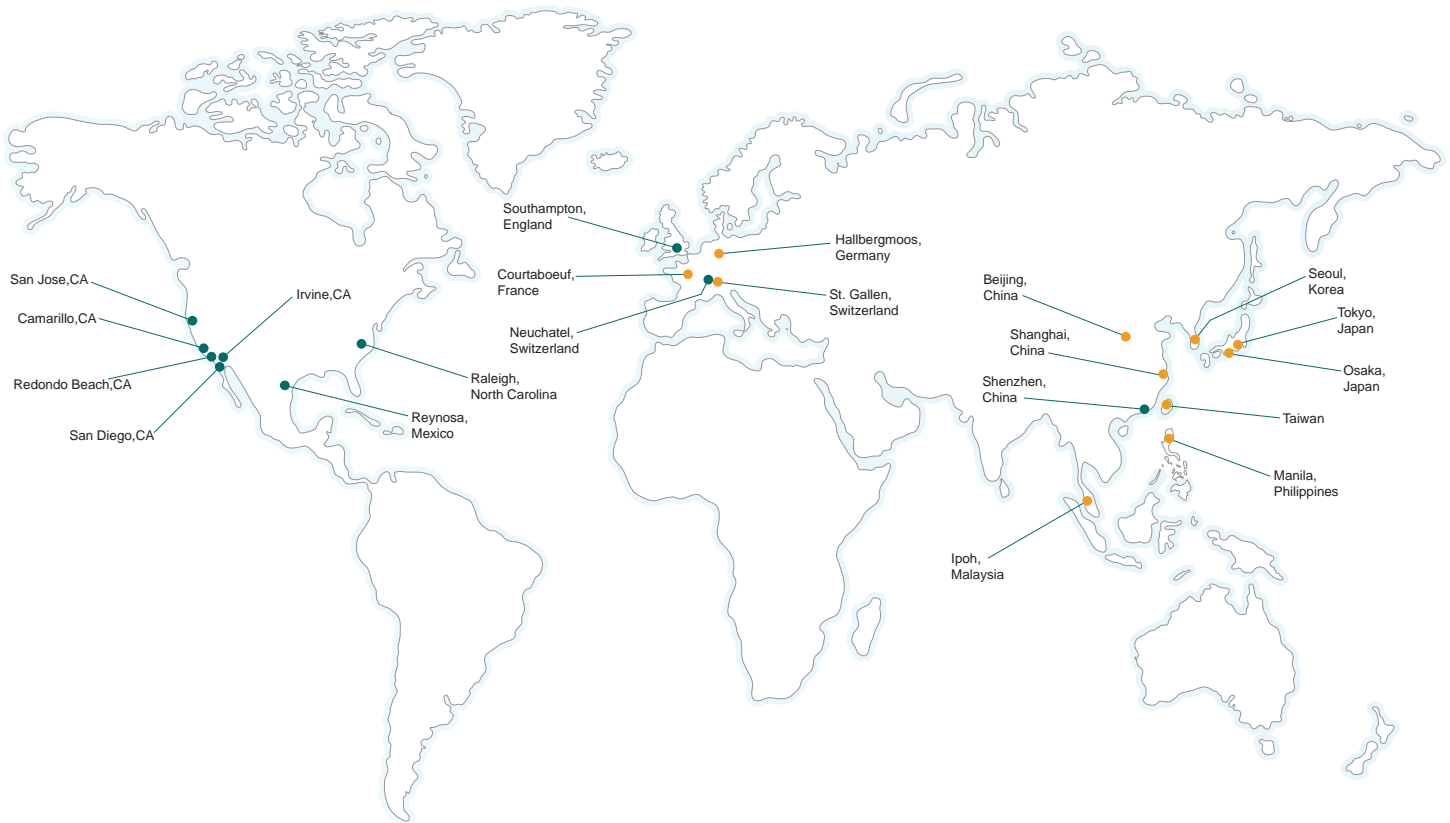


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SOT-143





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