2010

Protection Design Guide for

Computer, Set Top Box, HDTV/Monitor Interfaces

www.semtech.com

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Computer & Digital Video Protection

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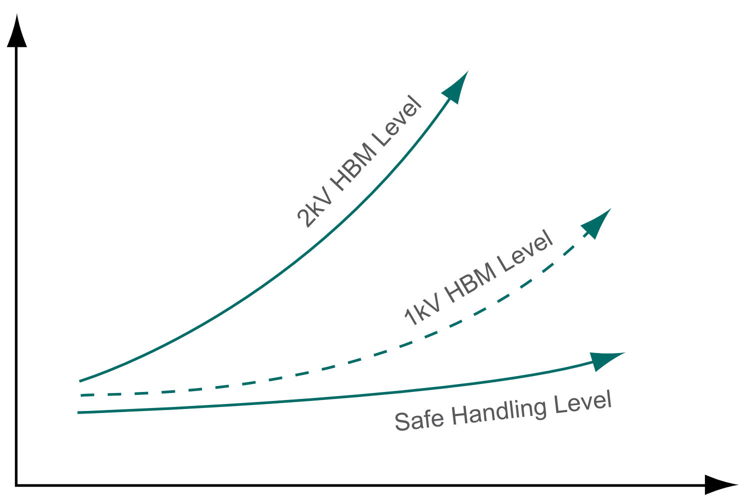
The Need for Robust Circuit Protection

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 trade off: increased susceptibility to damage from ESD, cable discharge and lightning. Not only are transistor geometry sizes scaling down 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.

Cost of ESD design dependent on:

- Chip area
- Respins
- Resources
- Circuit performance
- Time-to-market



ESD Association's Recommended
Safe-Handling Level for On-Chip Protection

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 processing technology. This process technology enables the production of 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 low working voltage protection devices is a critical component for protecting today's systems.

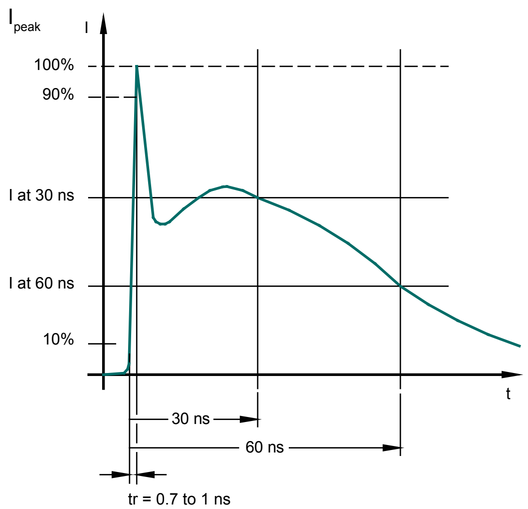
Threat Environment

Computer and high end consumer electronics 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 ESD events. 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 330Ω 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 61000-42

ESD Discharge Levels per IEC61000-4-2					
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: IEC61000-4-2 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 ±8kV 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 destructive risk to telecommunications equipment.

The EMC community models surge transients using a combinational waveform which describes the basic surge wave shape 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 8x20μs waveform. This waveform represents a pulse of 20μs in duration from t=0 to the 50% decay point. The rise time is 8μs to the peak pulse current (Ipp), 25A in this case (see figure below).

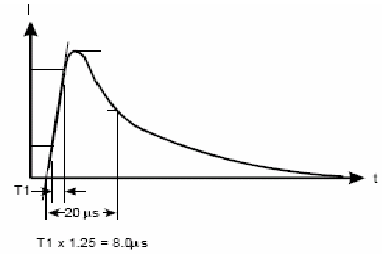
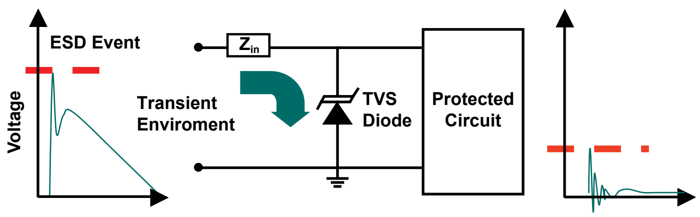


Figure 4 – IEC 61000-4-5 Current Impulse

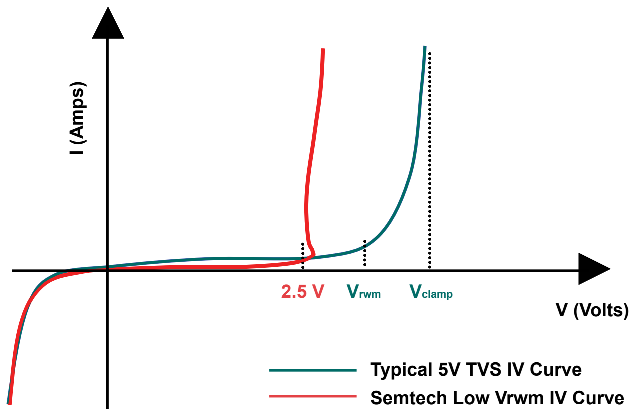
TVS Basics

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



IV Curve for Semtech Low Working Voltage Process

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 Vrwm, is the maximum rated DC voltage for the TVS device. At the Vrwm 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.

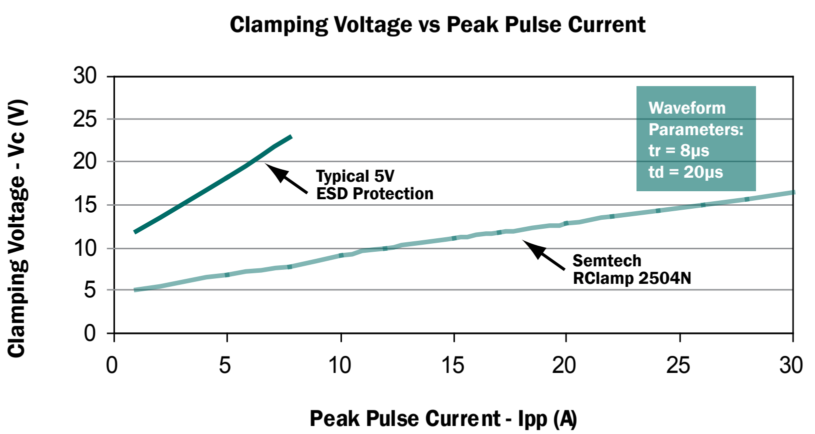
Finally, the TVS needs to offer **high-surge handling**. For systems in the communications infrastructure, components rated only for ESD transient levels will not provide sufficient protection. The TVS component must also be able to handle the higher energy contained within cable discharges and the variety 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.

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.



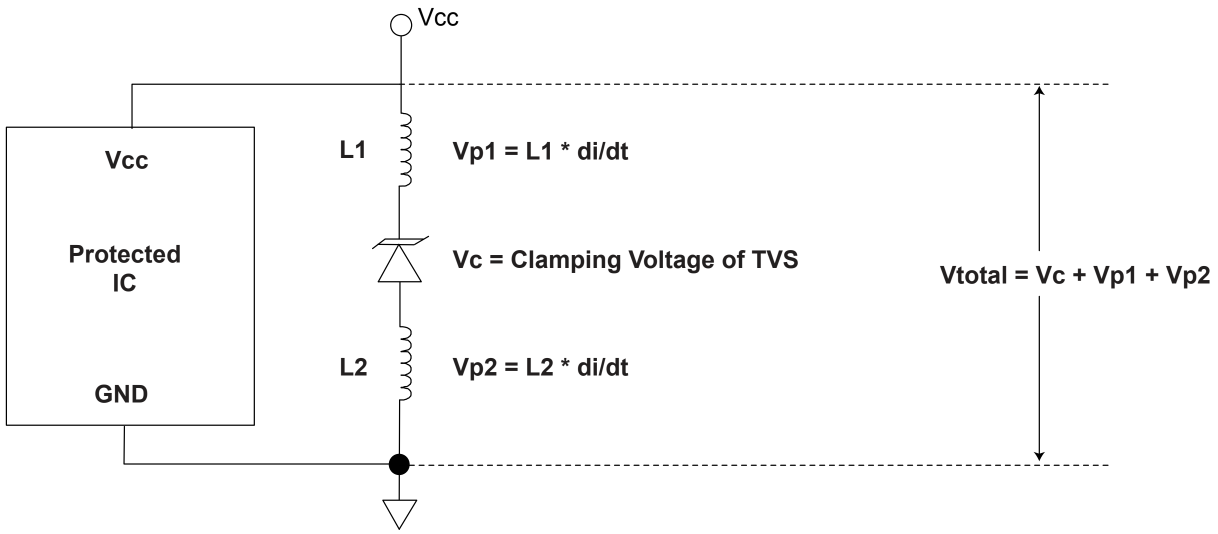
Clamping Performance for RClamp 2504N

Layout Guidelines

PC board layout is an important part of transient immunity design. This is especially critical in computer and digital video applications, where protecting the constant threat of ESD and CDE from normal use is further complicated by the high speed of the link rates. Parasitic inductance in the protection path can result in significant voltage overshoot and may exceed the damage threshold of the protected IC. This is especially critical in the case of fast rise-time transients such as ESD or EFT. Recall that the voltage developed across an inductive load is proportional to the time rate of change in current (V = L di/dt). An ESD induced transient reaches a peak in less than 1ns (per IEC 61000-4-2). Assuming a trace inductance of 20nH per inch and a quarter inch trace, the voltage overshoot will be 50 volts for a 10A pulse.

The primary rule of thumb is to minimize the effects of parasitic inductance by making the shunt paths as short as possible. All inductive paths must be considered including the ground return path, the path between the TVS and the protected line, and the path from the connector to the TVS device. Additionally, The TVS device should be placed as close to the entry point of ESD as possible to reduce transient coupling into nearby traces.

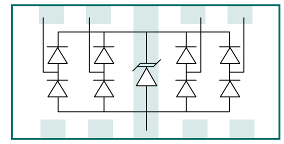
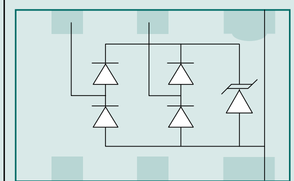
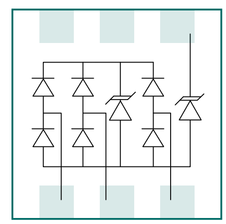
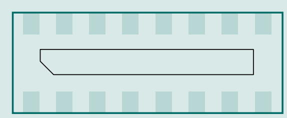
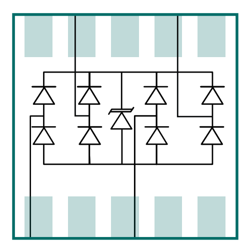
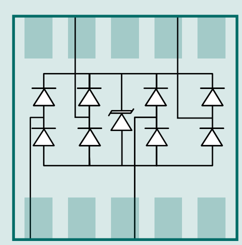
The secondary effects of radiated emissions can cause upset to other areas of the board even if there is no direct path to the connector. Long signal traces will act as antennas to receive energy from fields that are produced by the ESD pulse. By keeping line lengths as short as possible, the efficiency of the line to act as an antenna for ESD related fields is reduced. Minimize interconnecting line lengths by placing devices with the most interconnects as close together as possible. Finally, avoid running critical signal lines near board edges or next to protected lines.

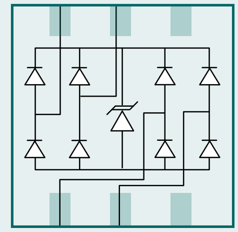
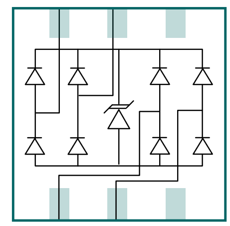
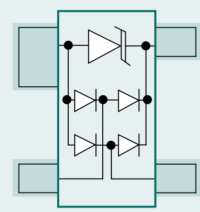
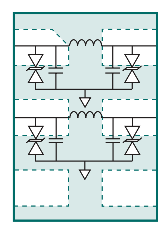
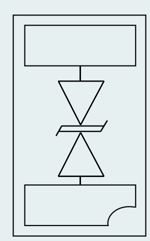


*** L1 represents the parasitic inductance of the trace between TVS and Vcc**
*** L2 represents the parasitic inductance of the trace between TVS and GND**
*** Vtotal represents the voltage that will be see between Vcc and GND of the IC during a transicent.**

Parts & Features

High-speed data transmission interfaces such as HDMI, DisplayPort and USB are widely adopted on computer and consumer electronics systems. Semtech's industry leading low-clamping voltage, low capacitance, 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 computer & digital video devices within the Semtech protection portfolio.

Part Number	Lines	Vrwm	Cap I/O to I/O (typ)	Ipp max (8x20µs)	Application	Circuit Diagram
RClamp0544T	4	5V	0.3pF	5A	HDMI DisplayPort LVDS	 2.0 x 1.0 x 0.4 mm
RClamp0522T	2	5V	0.3pF	5A	HDMI 1.3/1.4 DisplayPort LVDS USB 2.0	 1.6 x 1.0 x 0.4 mm
RClamp0854P	3 1	5.5V 5.5V	0.5pF max	3A 16A	USB 2.0 V_{BUS}	 1.6 x 1.6 x 0.6 mm
EClamp2410P	6	5V	-	-	MicroSD	 4.0 x 1.6 x 0.58 mm
RClamp2504N	4	2.5V	2pF	25A	1000BASE-T 100BASE-T LVDS	 2.6 x 2.6 x 0.6 mm
RClamp3304N	4	3.3V	2pF	25A	1000BASE-T 100BASE-T LVDS	 2.6 x 2.6 x 0.6 mm

Part Number	Lines	Vrwm	Cap I/O to I/O	Ipp max (8x20μs)	Application	Circuit Diagram
RClamp2504P	4	2.5V	0.4pF	5A	1000BASE-T 100BASE-T LVDS Multimedia Card	 1.6 x 1.6 x 0.6 mm
RClamp3304P	4	3.3V	0.4pF	5A	1000BASE-T 100BASE-T LVDS Multimedia Card	 1.6 x 1.6 x 0.6 mm
SR12	2	12V	3pF	16A	xDSL	 2.9 x 2.37 x 1.0 mm
EClamp2422N	2	5V	-	-	Audio	 1.45 x 1.0 x 0.58 mm
RClamp0531T	1	5V	0.5pF	4A	Antenna	 1.0 x 0.6 x 0.4 mm

RClamp® 0544T

ESD Protection for HDMI and other High Speed Interfaces

Features

- 5V working voltage
- 4-line protection
- Capacitance: typical 0.3pF Line-to-Line
- Low-clamping voltage
- No impedance matching required
- No Insertion loss up to 3.0 GHz
- Ultra-small leadless package (2.0 x 1.0 x 0.4 mm)

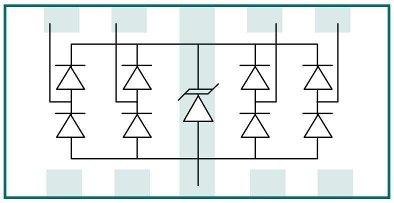
Applications

- Mini HDMI
- HDMI 1.3 / 1.4
- LVDS
- DisplayPort
- USB 2.0

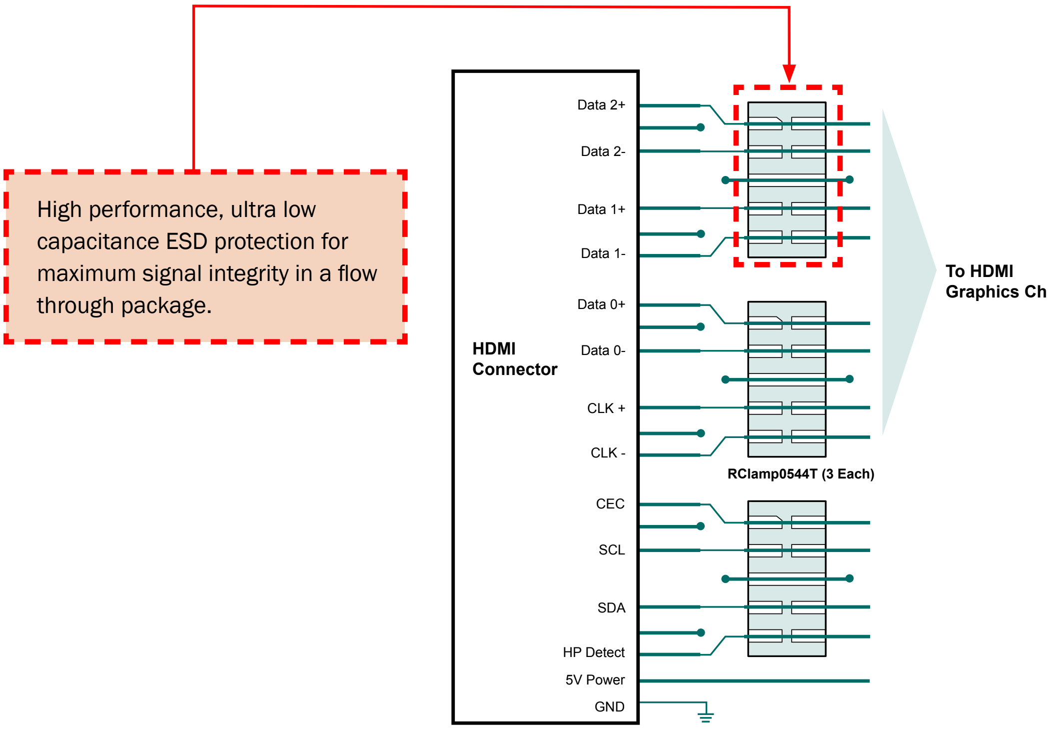
Description

The RClamp0544T is a 4-line protection device operating at 5V. It has a typical capacitance of only 0.30pF between I/O pins. This allows it to be used on circuits operating in excess of 3GHz without signal attenuation. They may be used to ESD immunity requirements of IEC 61000-4-2, Level 4 (±15kV air, ±8kV contact discharge).

The RClamp0544T is in a 8-pin, RoHS/WEEE compliant, SLP2010P8T package. It measures 2.0 x 1.0 x 0.4 mm. The leads are spaced at a pitch of 0.4mm and are designed for easy PCB layout by allowing the traces to run straight through the device.



RClamp0544T



Protection for HDMI Interface

RClamp® 0522T

ESD Protection for USB 2.0 and other High Speed Interfaces

Features

- 5V working voltage
- 2-line protection
- Capacitance: typical 0.3pF Line-to-Line
- Low-clamping voltage
- No insertion loss up to 3.0 GHz
- Small leadless package (1.6 x 1.0 x 0.4 mm)

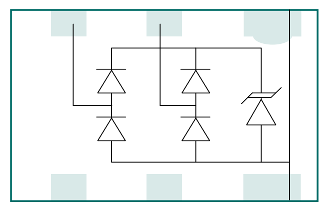
Applications

- USB 2.0
- HDMI 1.3 / 1.4
- LVDS
- DisplayPort

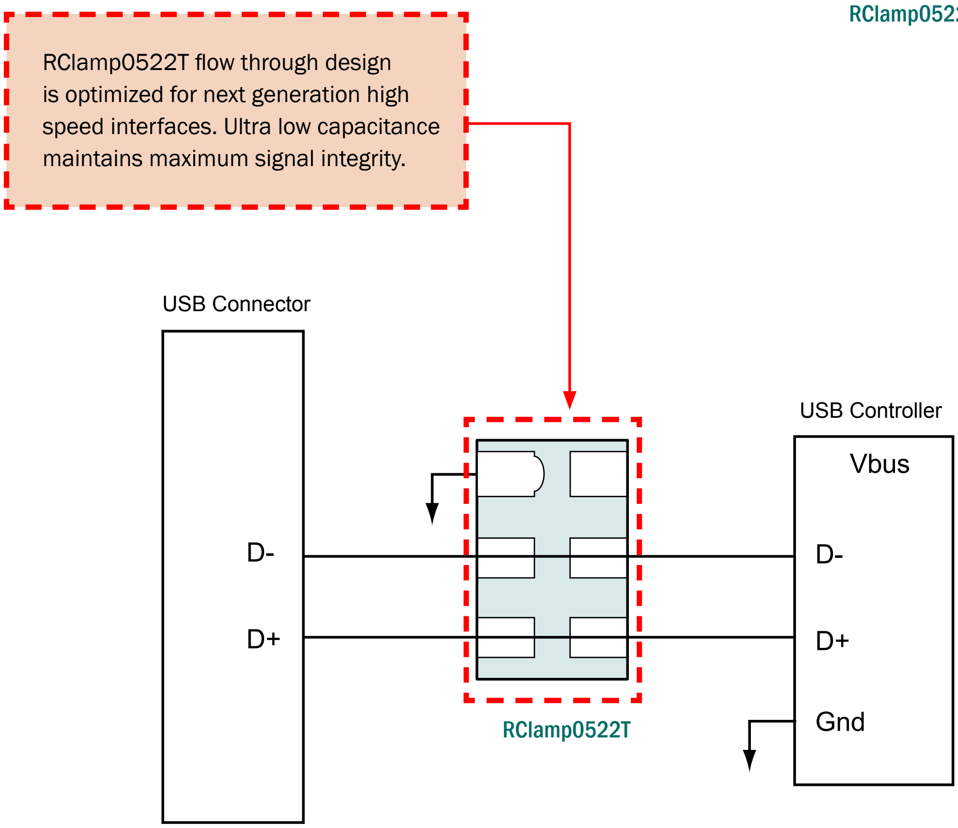
Description

The RClamp0522T has typical capacitance of only 0.3pF (line-to-line). This means it can be used on circuits operating in excess of 3GHz without signal attenuation. They may be used to meet the ESD immunity requirements of IEC 61000-4-2, Level 4 (±15kV air, ±8kV contact discharge). Each device can be configured to protect 1 bidirectional line or two unidirectional lines.

The RClamp0522T is in a 6-pin SLP1610P4T package. It measures 1.6 x 1.0 x 0.4 mm. The leads are spaced at a pitch of 0.5 mm and are finished with lead-free NiPdAu. They are designed for easy PCB layout by allowing the traces to run straight through the device.



RClamp0522T



Protection for USB 2.0 Interfaces

RClamp® 0854P

ESD Protection for USB 2.0 with Integrated 5V VBus Protection

Features

- Protects three I/O lines operating up to 5.5V
- Protects one Vbus line operating up to 5.5V
- Capacitance: typical 0.8pF line-to-ground
- Low clamping voltage
- No insertion loss up to 2.0GHz
- Large ground for increased ESD performance
- Small package (1.6 x 1.6 x 0.6 mm)

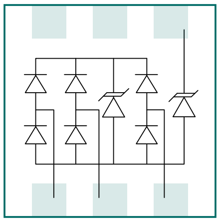
Applications

- USB 2.0
- USB OTG

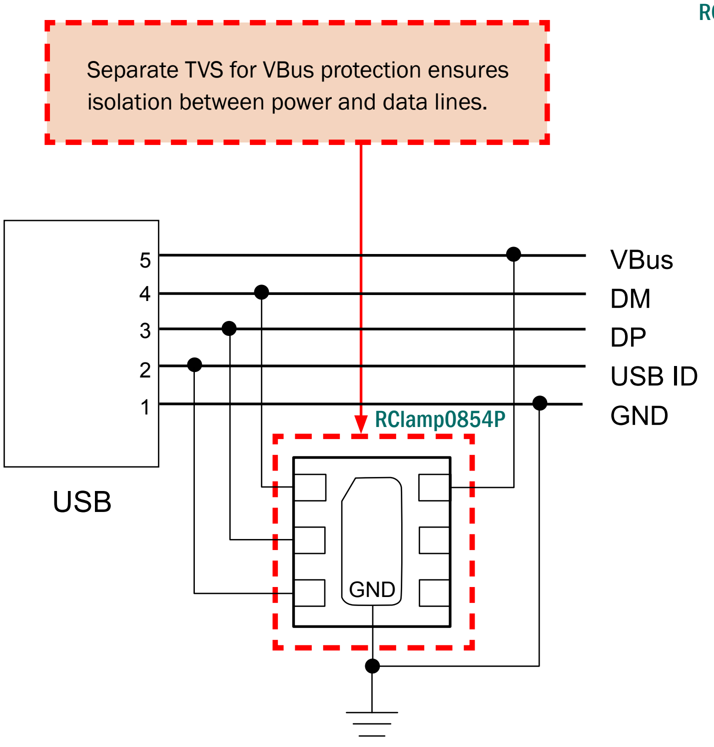
Description

The RClamp0854P is specifically designed to protect the USB port. The unique design of this device features low capacitance TVS diodes for protection of the USB data (DP, DM) and USB ID pins operating up to 5.5 volts. Loading capacitance on these lines is <1pF for maximum signal integrity. An integrated 5.5 volt TVS diode is used for protection of the USB voltage bus, which ensures isolation between power and data lines. Leakage current of the Vbus protection is <50nA when operating at 5.5 volts.

The RClamp0854P is in a 6-pin, RoHS compliant, SLP1616P6 package. It measures 1.6 x 1.6 x 0.6 mm. The leads are spaced at a pitch of 0.5 mm and are finished with lead-free NiPdAu. They may be used to meet the ESD immunity requirements of IEC61000-4-2, Level 4 (15kV air, 8kV contact discharge).



RClamp0854P



Protection for USB 2.0 Interface

EClamp® 2410P

ESD/EMI Protection for Multimedia Cards

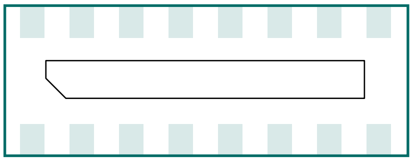
Features
- 5V working voltage
- Protection & termination for six lines & Vdd
- Capacitance: typical 12pF per line
- Termination resistors: 45Ω
- Pull up resistors: 15kΩ (3 each) and 50kΩ
- 16 Pin leadless package (4.0 x 1.6 x 0.58 mm)

Applications
- T-Flash / MircoSD interfaces
- MMC interfaces

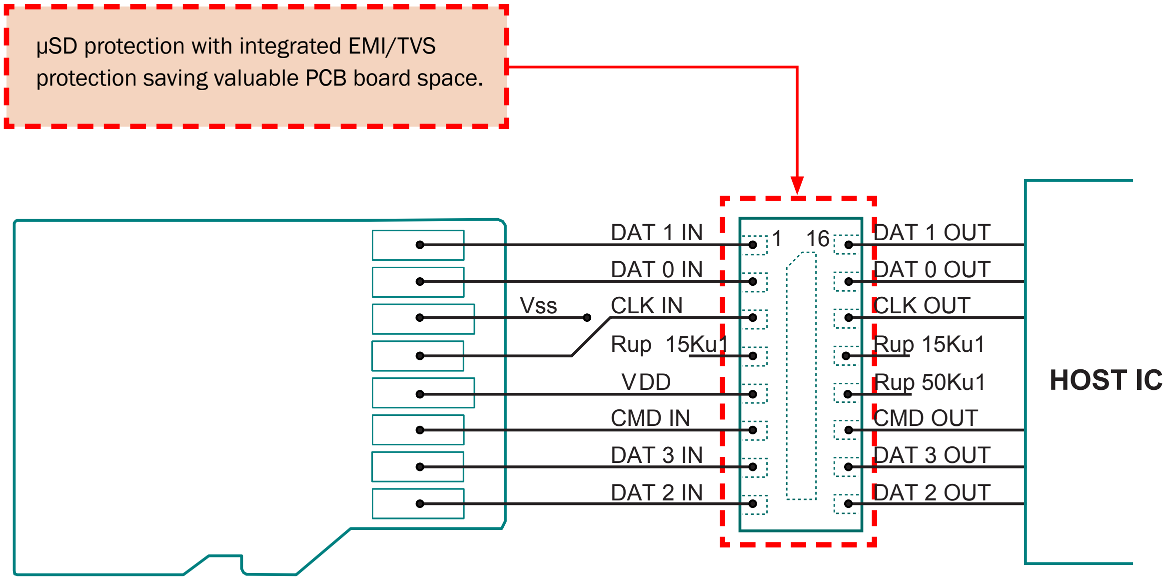
Description

The EClamp2410P is a combination EMI filter and line termination device with integrated TVS diodes for use on Multimedia Card Interfaces. They have been optimized for protection of T-Flash/ MicroSD interfaces in cellular phones and other portable devices. The device consists of six circuits that include series impedance matching resistors and pull up resistors as required by the SD specification. TVS diodes are included on each line for ESD protection.

An additional TVS diode connection is included for protection of the voltage (Vdd) bus. Termination resistor value of 45kΩ is included on the DAT0, DAT1, DAT2, DAT3, CMD, and CLK lines. Pull up resistors of 15kΩ are included on DAT0, DAT1, DAT 2, and CMD lines while a 50kkΩ pull up resistors included on the DAT3 line. These may be configured for devices operating in SD or SPI mode.



EClamp2410P



Protection for MicroSD Interface

RClamp® 2504N

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

Features

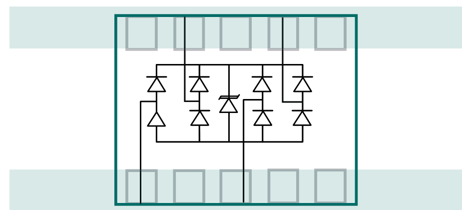
- 2.5V working voltage*
- 4-line protection
- Low-clamping voltage
- 25A (8x20μs) surge rating
- Very small package (2.6 x 2.6 x 0.6 mm)

Applications

- Gigabit Ethernet
- 10/100 Ethernet
- LVDS

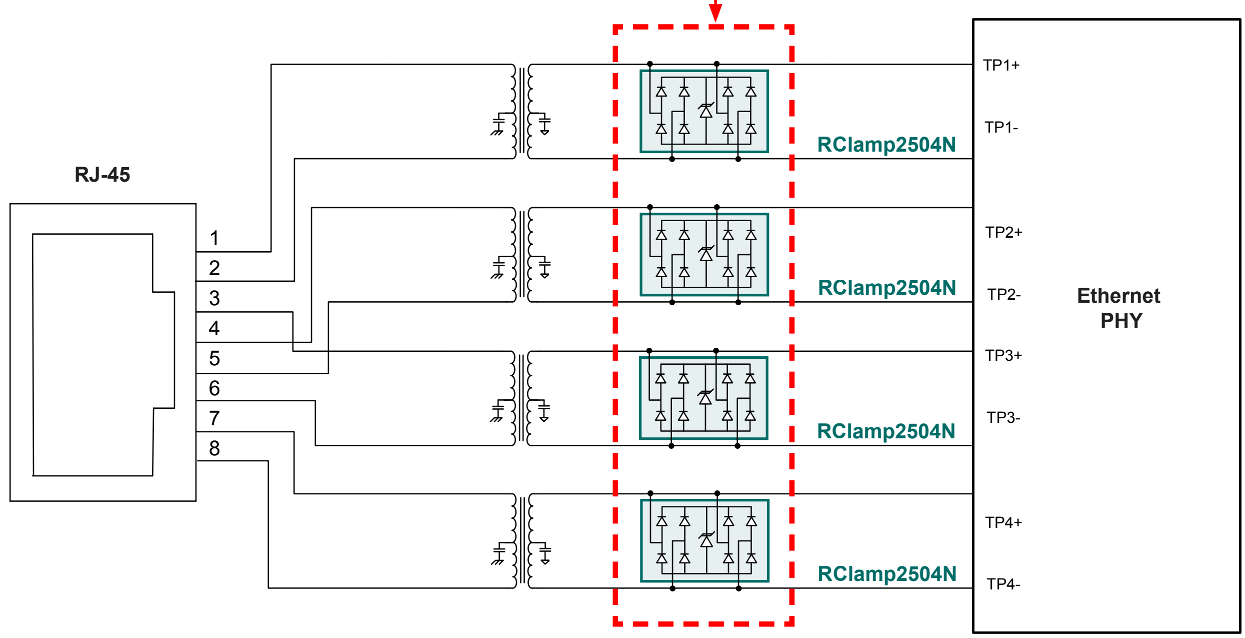
Description

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.



RClamp2504N

The 2.5V working voltage (Vrwm) 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© 3304N is footprint compatible, but with 3.3V Vrwm

RClamp® 2504P

ESD & Cable Discharge Protection for High-Density Ethernet Interfaces

Features

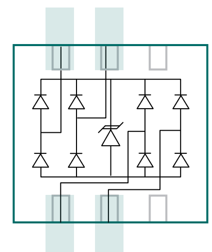
- 2.5V working voltage*
- 4 lines of protection
- Low capacitance (<0.8pF)
- Excellent ESD clamping
- Ultra-small package (1.6 x 1.6 x 0.6 mm)

Applications

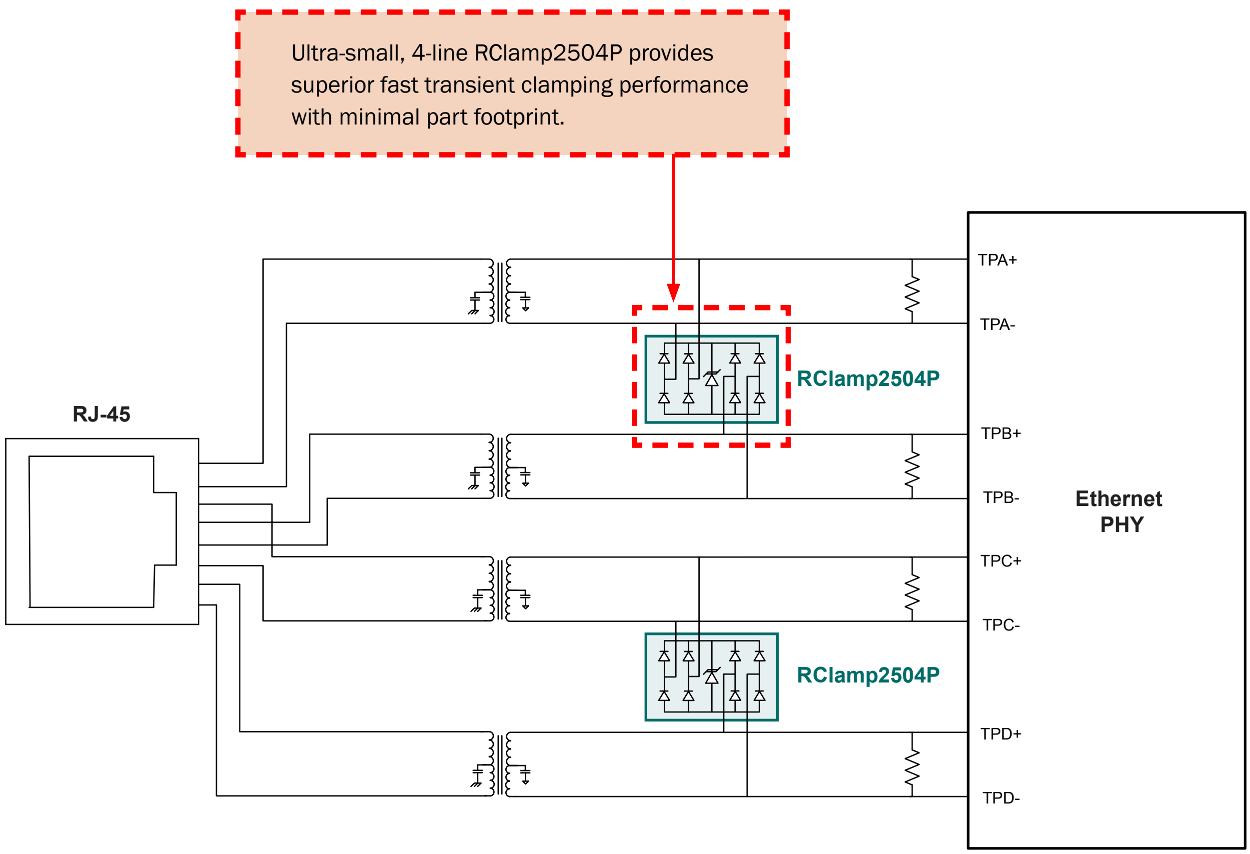
- 1000BASE-T ethernet
- 100BASE-T ethernet
- Multimedia card interfaces

Description

The RClamp2504P is a 4-line, 2.5V (Vrwm) 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 consistent 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 (±15kV air, ±8kV contact discharge).



RClamp2504P



Protection for High-Density Ethernet Interface

* RClamp© 3304P is footprint compatible, but with 3.3V Vrwm

SR12

ESD & Surge Protection for ADSL & VDSL Interfaces

Features

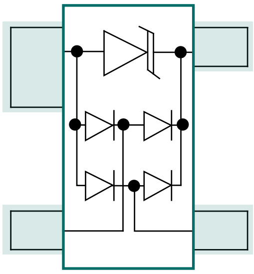
- 12V working voltage
- 2-line protection array
- Low-clamping voltage
- SOT-143 package (2.9 x 2.37 x 1.0 mm)

Applications

- ADSL interfaces
- VDSL interfaces
- Industrial interfaces

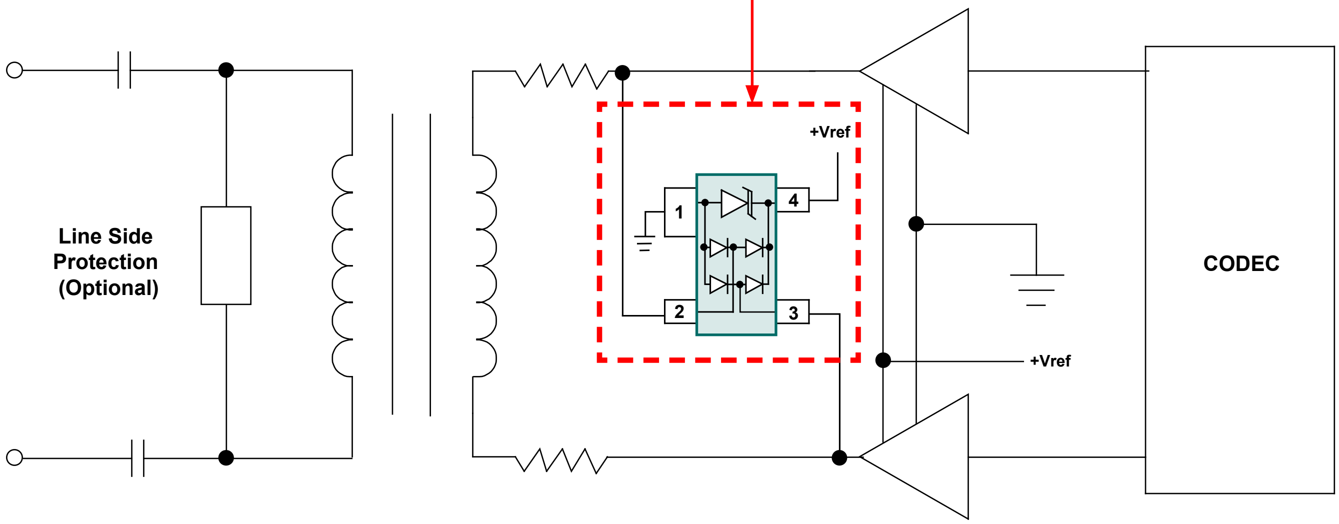
Description

The unique design of the SR12 incorporates four surge rated, low capacitance steering diodes and a TVS diodes 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

EClamp® 2422N

ESD/EMI Protection for Audio Interfaces

Features

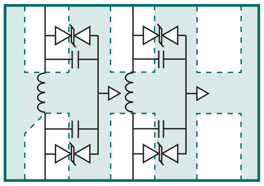
- 5V working voltage
- Protection and filtering for two lines
- Capacitors: 100pF (Typical VR=0v)
- Inductor: 2nH (Typical)
- Small leadless package (1.45 x 1.0 x 0.58 mm)

Applications

- Speaker ports
- Microphone ports

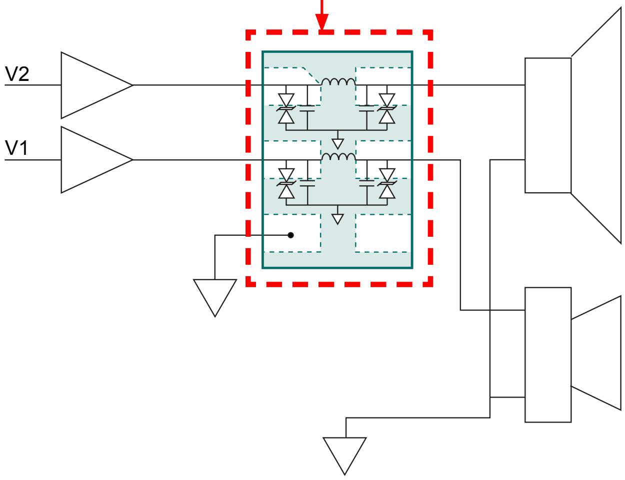
Description

The EClamp2422N is a (C-L-C) low pass filter array with integrated TVS diodes. It is designed to suppress unwanted EMI/RFI signals and provide ESD protection for audio interfaces. Two identical circuits consisting of an inductor of 2nH and capacitor value of 100pF, which are used to achieve 10dB minimum attenuation from 800MHz to 2.7GHz. It has a very low series resistance of 2.0Ω, making it ideal for use on speaker/microphone interfaces.

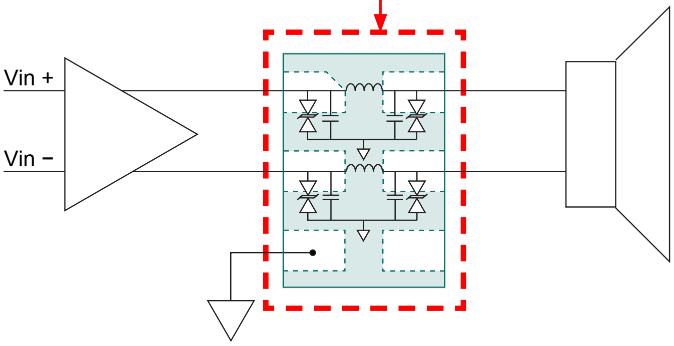


EClamp2422N

Flow through design allows for efficient PCB layout.
Integrated low pass filter reduces part count.



Protection of Single-Ended Mode Microphone with Speaker Output



Differential Mode Protection with Speaker Output

RClamp® 0531T

ESD Protection for Low Frequency Antenna

Features

- 5V working voltage
- 1-line bidirectional
- Capacitance: typical 0.5pF
- Low clamping voltage
- No insertion loss up to 2.5GHz
- Ultra small package (1.0 x 0.6 x 0.4 mm)

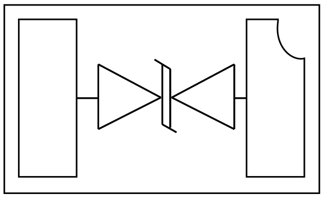
Applications

- GPS antennas
- FM antennas
- LVDS
- High speed data lines

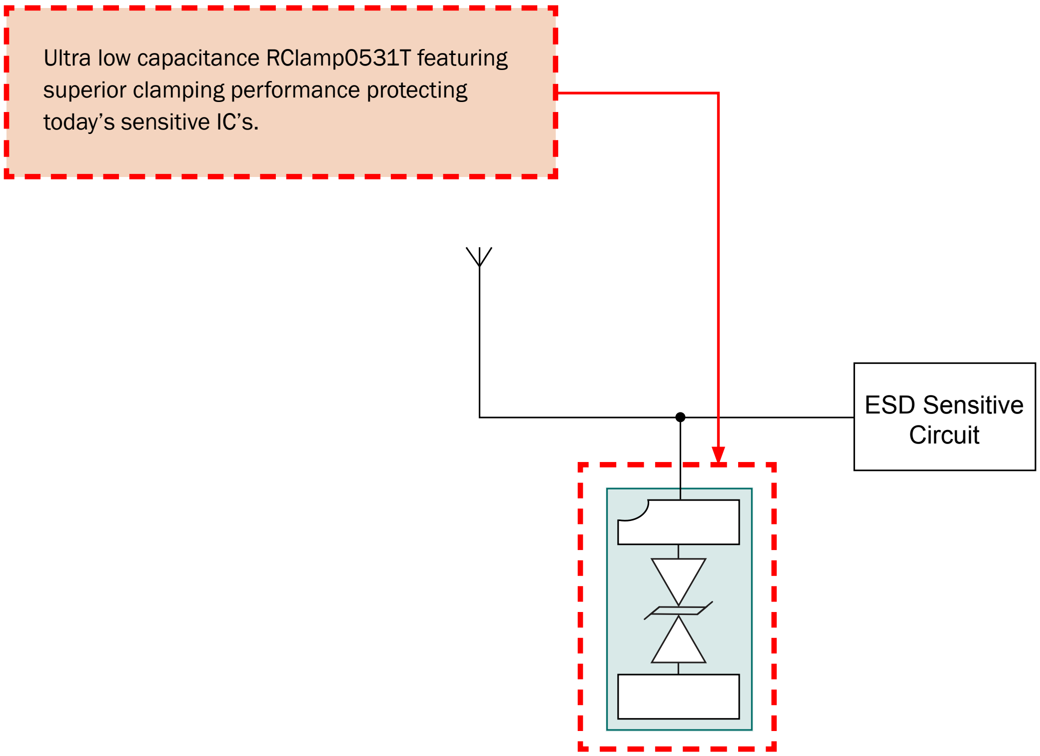
Description

The RClamp0531T is a bidirectional single line protection device offering a maximum capacitance of 0.80pF. This allows it to be used on circuits operating in excess of 2.5GHz without signal attenuation. They may be used to meet the ESD immunity requirements of IEC 61000-4-2, Level 4.

This device is packaged in a 2-pin, RoHS/WEEE compliance, SLP1006P2T package measuring 1.0 x 0.6 x 0.4 mm. Each device protects one high-speed line operating at 5 volts. It gives the designer the flexibility to protect single lines in applications where arrays are not practical.



RClamp0531T



High speed single line ESD protection

Circuit Protection Applications

As high speed 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 in deeper detail 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: ±8kV contact discharge, ±15kV air discharge. IEC 61000-4-2 also specifies the ESD current waveform and parameters shown in Figure 1 & Table 1.

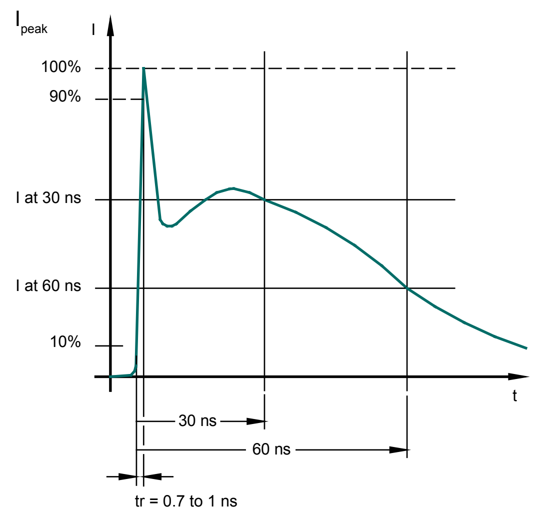


Figure 1 - ESD Waveform per IEC 61000-42

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.

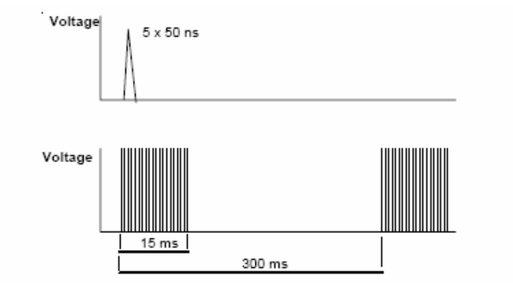


Figure 2 – EFT Burst

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).

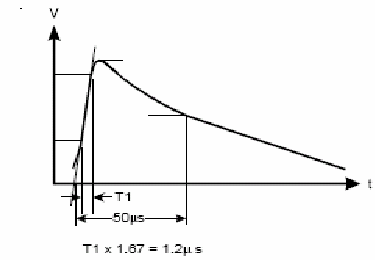


Figure 3 – IEC 61000-4-5 Voltage Impulse

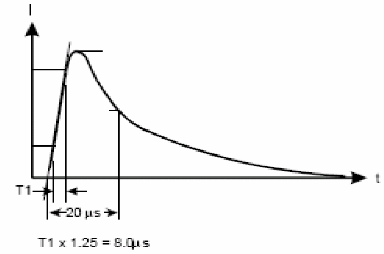


Figure 4 – IEC 61000-4-5 Current Impulse

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 = 2 Ω	Line-GND Zs = 12 Ω	Line-Line Zs =42 Ω	Line-GDN Zs =42 Ω	Line-GDN Zs =42 Ω	Line-GND Zs = 42 Ω
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 – IEC61000-4-5 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

ESD Protection Solutions for DisplayPort

The DisplayPort standard is an uncompressed, open digital communication interface that represents a cost reduction opportunity for PC makers by consolidating the internal and external interconnect. When used internally, it is an interface within a PC or monitor. Externally, it connects a PC to a monitor or projector, or TV. When used as an external interface, the DisplayPort plug is frequently exposed to Electrostatic Discharge (ESD) directly from the user or Cable Discharge (CDE) from hot plug cable.

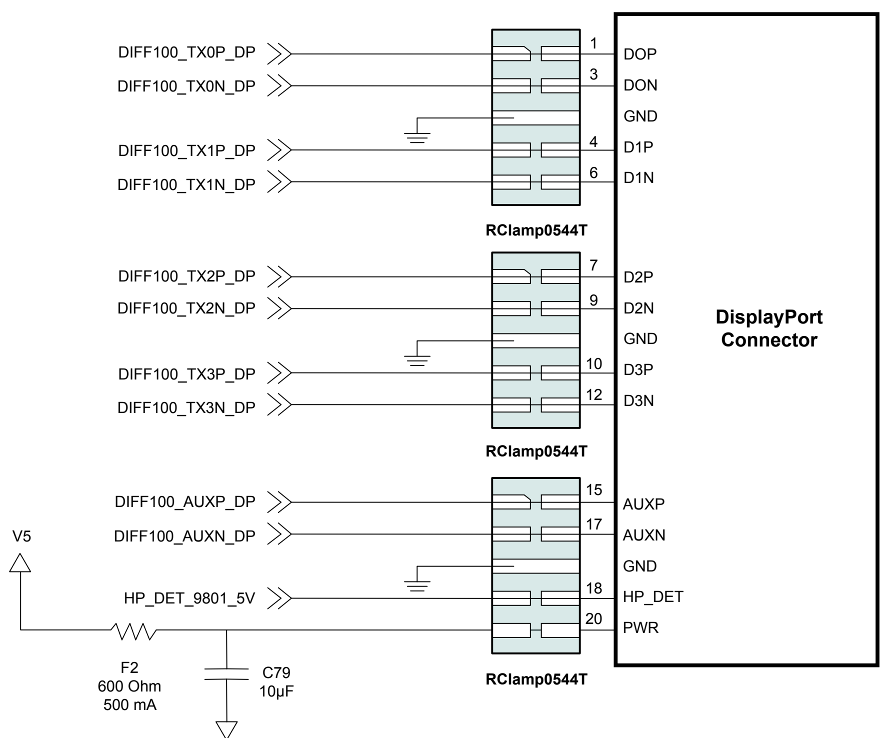
To ensure proper functionality, DisplayPort-based systems must protect all potentially exposed interface signals and power pins to meet or exceed the EOS (electrical over stress) specification of IEC 61000-4-2, Level 4 (±15kV Air, ±8kV Contact) without damage. In most cases, the on-chip ESD protection is no longer sufficient to meet this EOS requirement, making off chip ESD protection circuitry necessary. Providing external protection is further complicated by the high-speed of the link rates; both 2.7Gbps and 1.62Gbps are supported in the standard. At such a high data rate, signal integrity and impedance requirements are given more focus than ever before, as put forth in the DisplayPort Compliant Test Specification (CTS).

Protecting DisplayPort interface from ESD presents several challenges. A low working voltage, and low clamping voltage device is required to minimize stress on the protected IC during an ESD event. At typical transmission speed of 2.7Gbps, an ultra low capacitance ESD devices is necessary to maintain signal integrity.

Semtech's RClamp0544T is the latest addition to the high speed interface protection family. It provides reliable ESD protection in excess of IEC 61000-4-2 Level 4, without the need for capacitive compensation.

RClamp0544T responds quickly in an event of ESD and its low clamping voltage ensures the stress voltage seen by sensitive ICs are well below the destructive threshold.

RClamp0544T has a typical capacitance of 0.3pF between I/O pins which allows it to be used on circuits operating in excess of 3GHz without signal degradation. From a mechanical point of view, the RClamp0544T is housed in a leadless SLP2010P8T package that measures only 2.0 x 1.0 mm. Its unique design allows the traces to run straight through the device thus simplifying PCB design.



Protection for DisplayPort Interface

ESD Protection Solutions for HDMI

High Definition Multimedia Interface (HDMI) is an uncompressed, all-digital audio/video interface. It provides a high speed interface between audio/video source devices, such as DVD players, and sink devices, such as digital displays. The HDMI plug is frequently exposed to Electrostatic Discharge (ESD) directly from the user or Cable Discharge (CDE) from hot plug cable.

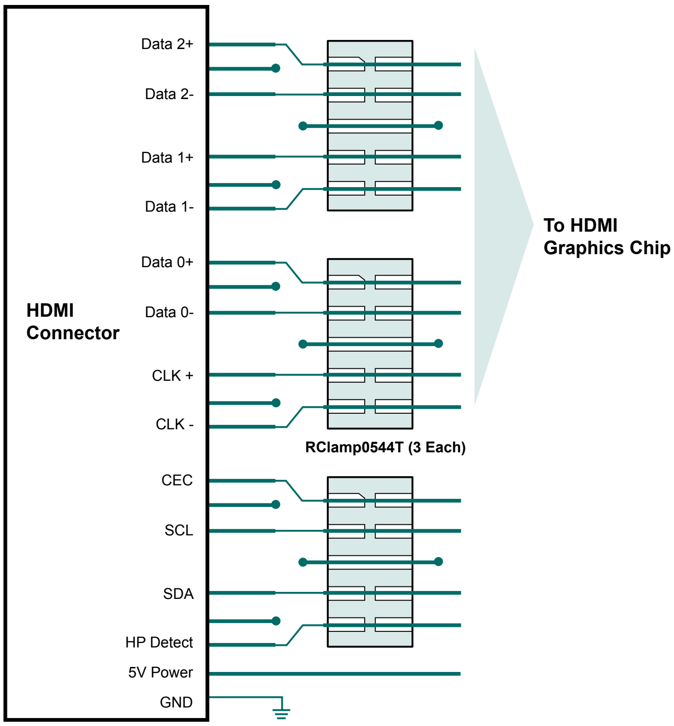
To ensure proper functionality, HDMI-based systems must protect all potentially exposed interface signals and power pins to meet or exceed the EOS (electrical over stress) specification of IEC 61000-4-2, Level 4 (+/-15kV Air, +/-8kV Contact) without damage. Current HDMI silicon runs at 2.25Gbps with 3.4Gbps in the near future. At such a high data rate, signal integrity and impedance requirements are given more focus than ever before, as put forth in the HDMI Compliant Test Specification (CTS). The HDMI CTS requires all HDMI sink devices to maintain the differential impedance of the high speed lines at 100Ω ±15%.

Semtech's RClamp0544T has a typical capacitance of 0.3pF between I/O pins which allows it to be used on HDMI running at a typical transmission speed of 2.25Gbps. Furthermore, this ultra low capacitance eliminates the need to add capacitive compensation while maintaining signal integrity.

From a mechanical point of view, the RClamp0544T is housed in a leadless SLP2010P8T package that measures only 2.0 x 1.0 mm. Its unique design allows the traces to run straight through the device further simplifying PCB design.

RClamp0544T features a very low clamping voltage and low turn on voltage, which means RClamp0544T will respond quickly in an event of ESD and instantly clamp the stress voltage seen by sensitive ICs to well below the destructive threshold.

RClamp0544T provides reliable ESD protection in excess of IEC 61000-4-2 Level 4 (+/- 8kV Contact, +/-15kV Air) as well as IEC61000-4-4 EFT(40A, 5/50ns) and IEC61000-4-5 lightning (5A, 8/20us).



Protection for HDMI Interface

ESD Protection Solutions for LVDS

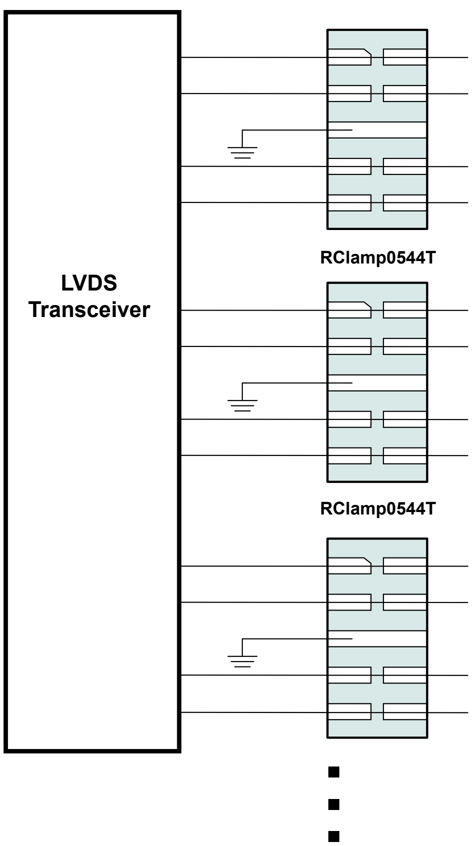
Low-voltage differential signaling (LVDS), is now pervasive in communications networks and used extensively in applications such as laptop computers, office imaging, industrial vision, test and measurement, medical, and automotive. It provides an attractive solution - A small-swing differential signal for fast data transfers at significantly reduced power and with excellent noise immunity.

LVDS uses high-speed analog circuit technique to provide multi-gigabit data transfers on copper interconnects and is a generic interface standard for high-speed data transmission. The American National Standards Institute (ANSI)/Telecommunications Industry Association (TIA)/Electronic Industries Alliances(EIA)-644-1995 standard specifies the physical layer as an electronic interface. It recommends a maximum data rate of 655Mbits/s over twisted-pair copper wire, but predicts a theoretical 1.9Gbits/s on an ideal transmission medium.

Semtech's RClamp0544T is a 5V TVS array that offers low capacitance and low clamping voltage, which makes it an ideal solution for transmission speed of 500Mbps and above. The typical differential mode capacitance of the Semtech RClamp0544T is less than 0.3pF. The ultra low capacitance ensures that the signal integrity will be maintained at 655Mbits/s, the maximum data rate recommended, without the need for capacitive compensation. Further more, RClamp0544T provides reliable ESD protection in excess of IEC 61000-4-2 Level 4 (+/- 8kV Contact, +/-15kV Air) as well as IEC61000-4-4 EFT(40A, 5/50ns) and IEC61000-4-5 lightning (5A, 8/20μs).

Regardless of the level of threat environment, Semtech's RClamp0544T responds quickly to an ESD event and its low clamping voltage ensures the stress voltage seen by sensitive ICs are well below the destructive threshold.

From a mechanical point of view, the RClamp0544T is housed in a leadless SLP2010P8T package that measures only 2.0 x 1.0 mm. Its unique design allows the traces to run straight through the device simplify PCB design.



Protection for LVDS Interface

ESD Protection Solutions for USB

USB stands for universal serial bus. It is the most successful interface in the history of PC and has been virtually adopted 100% in PC and peripherals.

Even though ESD protection requirement is not explicitly called out in USB specifications, USB is susceptible to ESD as a hot insertion and removal system. The high speed data transfer rate of 480Mbps and ever increasing complexity of USB2.0 controllers make its ESD protection quite a challenge. The variations between different manufacturers further complicate the situation.

The selection criteria for protecting most advanced USB2.0 ports are:

1. Low capacitance for minimal signal degradation at 480Mbps
2. Fast response time and low turn on voltage to allow device to turn on and limit the current going into protected IC in an event of ESD
3. Low clamping voltage to limit the voltage across sensitive IC
4. Low leakage current for minimal power consumption

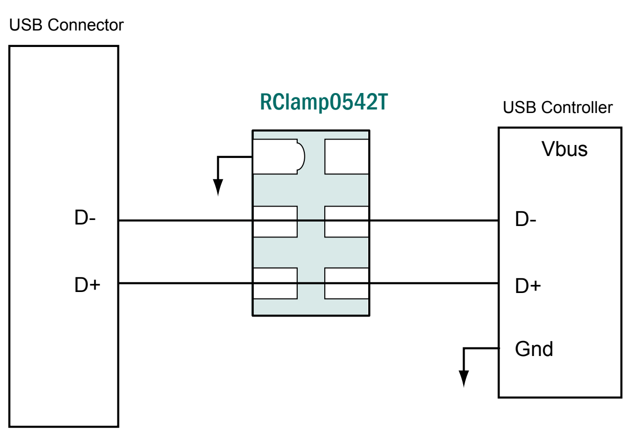
Semtech offers two options for USB2.0 protections depending on whether VBUS protection is required.

RClamp0542T:

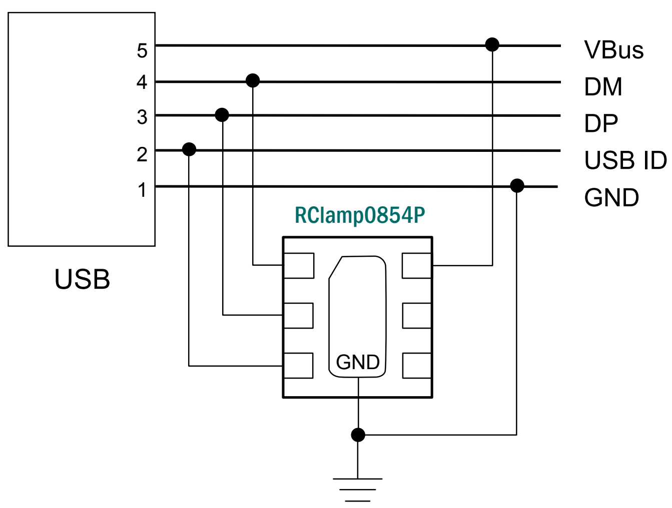
- Provide one pair of high speed datalines with reliable ESD protection in excess of IEC 61000-4-2 Level 4, without the need for capacitive compensation
- Responds quickly in an event of ESD and its low clamping voltage ensures the stress voltage seen by sensitive ICs is well below the destructive threshold
- Has a typical capacitance of 0.3pF between I/O pins which has minimum electrical effects on the high speed signal lines and allows it to be used on circuits operating in excess of 3GHz without signal degradation

RClamp0854P:

- Offers Vbus protection as well as data line protection in excess of IEC 61000-4-2 Level 4
- Has a separate TVS to protect VBus therefore provides isolation between power and datalines
- Has a maximum capacitance of 0.5pF between I/O pins which allows it to be used on circuits operating in excess of 3GHz without signal degradation



Protection for USB 2.0 Interface



Protection for USB 2.0 Interface

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 paper 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 2μs and a decay time of 10μs 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.

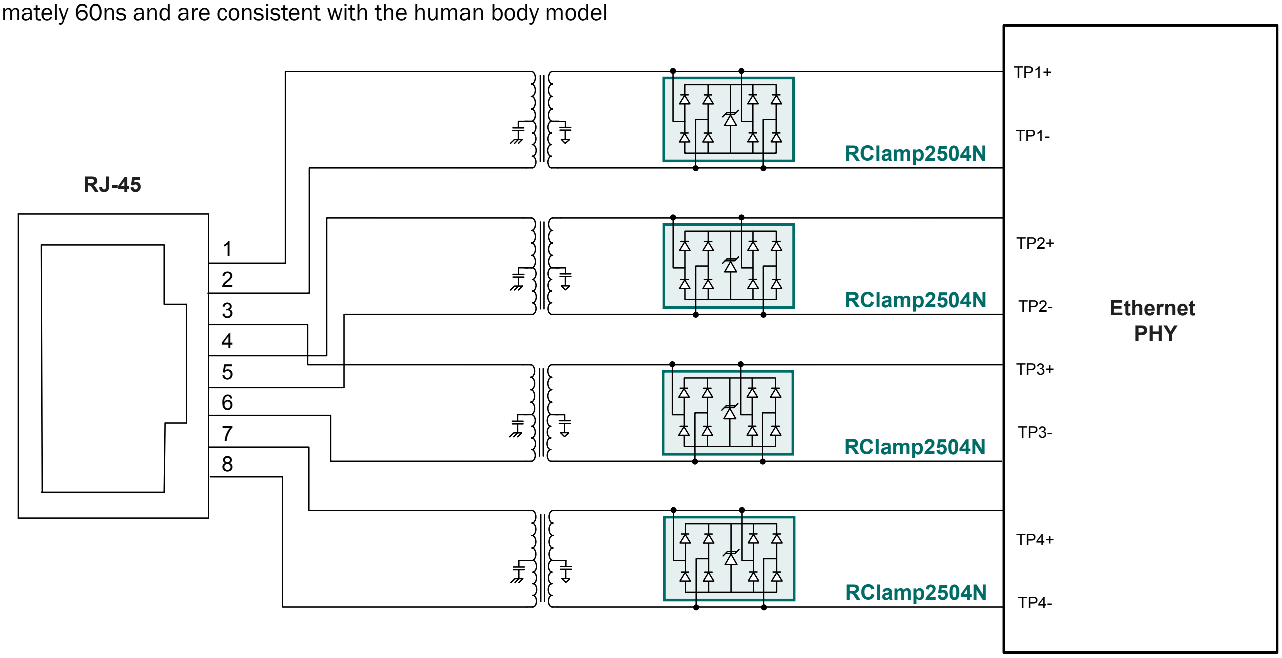


Figure 1 - Protection for Gigabit Ethernet Interfaces

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 0.6 mm. 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 (Ipp=100A, tp=2/10μs).

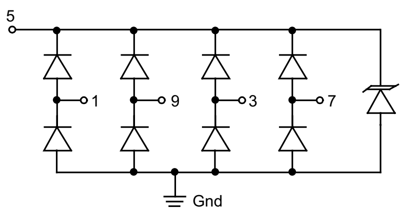


Figure 2 – RClamp2504N Circuit Diagram

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) 2/10μs 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 65ºC 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.

Ethernet Traffic Test Data and Surge Results

The following data shows an example of traffic and surge performance results using Semtech's RClamp2504N TVS array per the circuit diagram shown in Figure 1. The data was captured at elevated temperature using a widely used four-port gigabit ethernet PHY in a representative ethernet system. The multi-ports accessible on the system board enabled using the loop back mode to send and monitor signal data for error count monitoring. A traffic generation evaluation board was used to generate, and transmit, pseudo random Ethernet traffic. Temperature testing was initiated at room temperature and was increased until frame errors were detected. Traffic testing was performed over 100m of Cat 5/5e and Cat6 cable.

Table 1 records the results of the traffic testing. As shown, the gigabit ethernet transmission with the RClamp2504N protection scheme implemented showed no frame errors up to 75ºC across 100 meters of Cat 5 cable and up to 95ºC across 100 meters of Cat 6 cable. Surge testing was also performed using the circuit configuration shown in Figure 1. The results of the surge testing are summarized in Table 2. As shown, the RClamp2504N protects the PHY under test to Telecordia 2x10µs 100A and 1.2 x50µs 100A surges and ITU K.21 10x700µs 25A surge.

Test	Circuit Config	Cable Type	@ 25°C CRC/ Symbol Error		@ 65°C CRC/ Symbol Error		@ 75°C CRC/ Symbol Error	
Traffic Test	Figure 1	Cat 5/5e	PASS	PASS	PASS	PASS	PASS	PASS
Traffic Test	Figure 1	Cat 6	PASS	PASS	PASS	PASS	PASS	PASS
IEEE Template	Figure 1	Cat 5/5e	PASS					
IEEE Template	Figure 1	Cat 6	PASS					

Table 1 - Summary of Traffic Results

Standard	Test	Current	Voltage	Circuit Config	Test Results
Telcordia	2x10µs	100A	800	Figure 1	PASS
Telcordia	1.2x50µs	100A	800	Figure 1	PASS
ITU K.21	10x700µs	25A	1000	Figure 1	PASS

Table 2 - Summary of Surge Test Results

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 that can a 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 (Vc) for a peak pulse current (Ipp) of 1A. Its Vc increases linearly to about 10V for an Ipp 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.

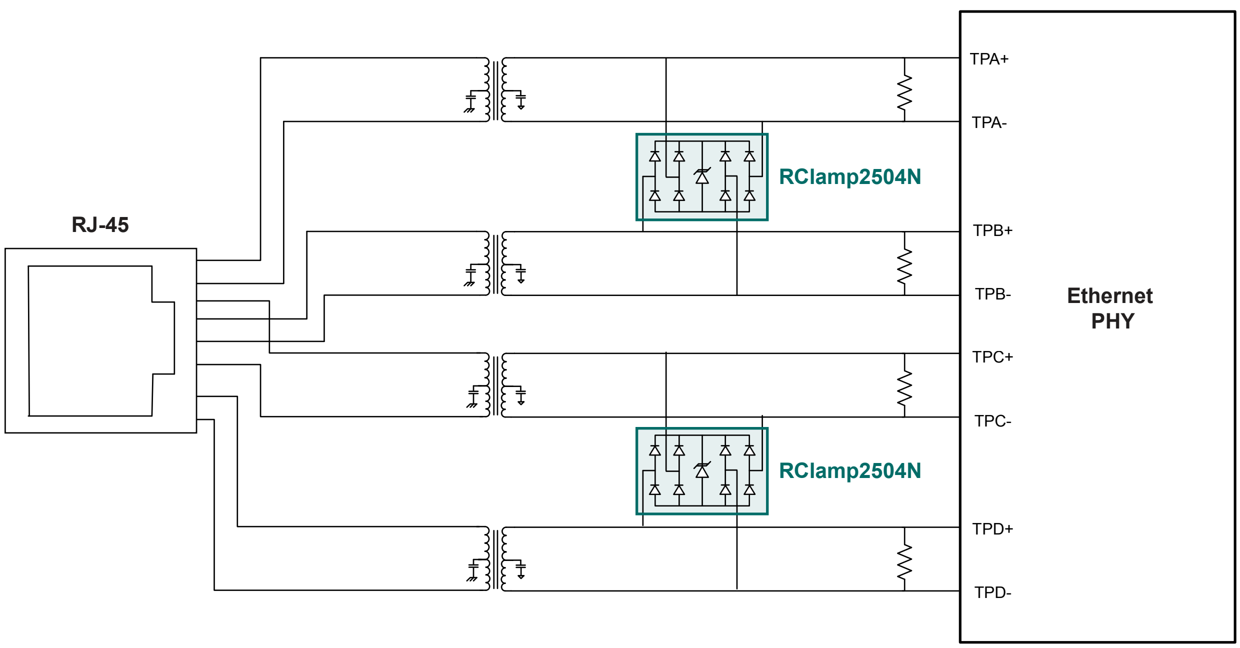


Figure 1 – Cable Discharge Ethernet Protection with RClamp2504N

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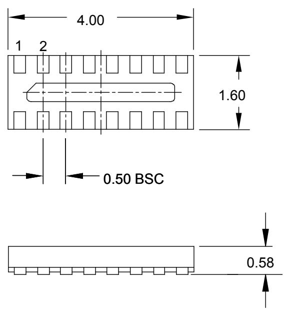

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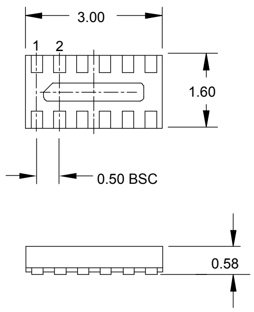

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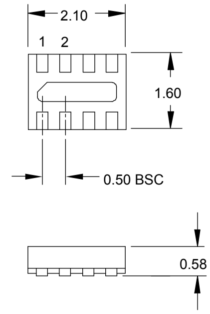

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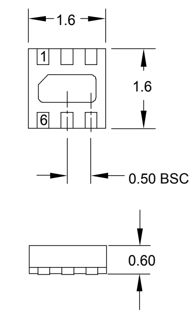

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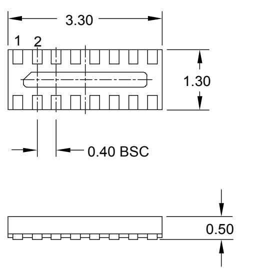

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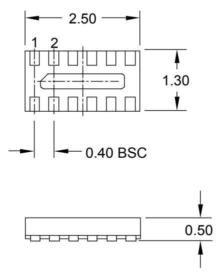

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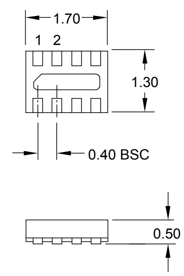

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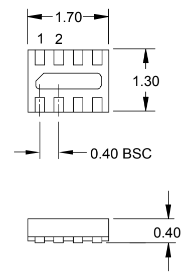

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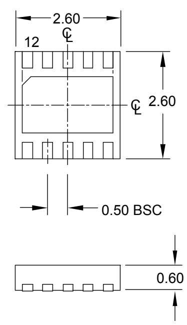

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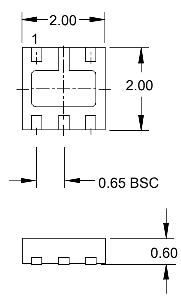

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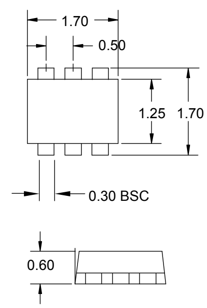

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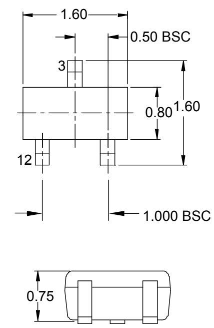

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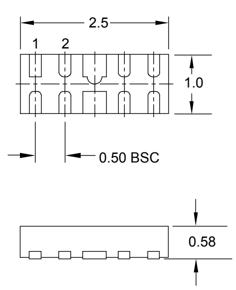

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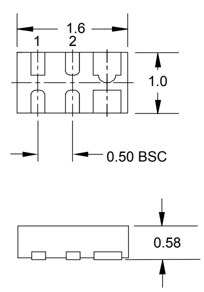

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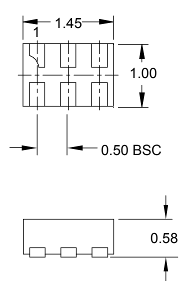

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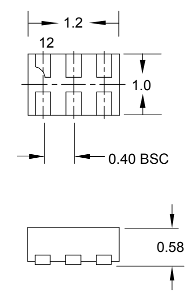

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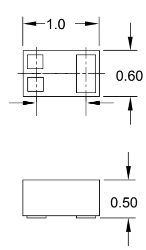

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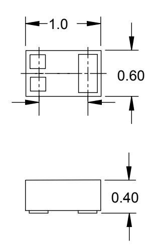

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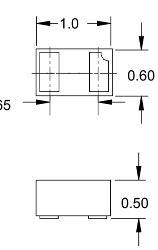

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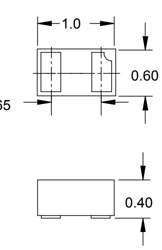

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