Littelfuse

Expertise Applied | Answers Delivered

Electrostatic Discharge (ESD) Suppression

Design Guide

A Guide to Selecting the Right ESD Solution for Your Application

Electrostatic Discharge (ESD) Suppressors
Ideal for Protecting High-Speed Data Line Applications

About This Guide

Electrostatic discharge (ESD) is an electrical transient that poses a serious threat to electronic circuits. Choosing the most appropriate suppressor technology requires balancing between equipment protection needs and operating requirements, while taking into account the anticipated threat level. The form factor/package style of suppression devices must also be considered in addition to their electrical characteristics. This guide is designed to summarize some of the comprehensive ESD solutions that Littelfuse offers, and help designers narrow to technologies appropriate to their end application.

Specifications, descriptions, and illustrative materials in this guide are as accurate as known at the time of publication. However, they are subject to changes without notice. Visit **Littelfuse.com** for more information.

Littelfuse: Everywhere, Everyday

Founded in 1927, Littelfuse is a diversified industrial technology manufacturing company empowering a more sustainable, connected, and safer world. We partner with customers across more than 20 countries and with approximately 16,000 global associations to design and deliver innovative and reliable solutions.

Littelfuse offers an extensive technology portfolio featuring fuses, semiconductors, polymers, ceramics, relays, sensors, switches, and more. Our products serve over 100,000 end customers and are found in a variety of industrial, transportation, and electronics end markets—everywhere, everyday.

Your Design Challenges, Solved

Our history of innovation, combined with our customer-first culture, drives us to collaborate with you to develop safer, more reliable products that are energy efficient and compliant with global regulations. We will partner with you to solve complex problems wherever electrical energy is used, bringing together design, engineering, and technical expertise to deliver business results.

Our product designs are backed by experts committed to delivering the best solutions for your specific needs. Our global organization provides:

- Custom sensor designs per customer specifications
- Vertically integrated manufacturing
- In-house magnetic sensing simulation support
- Quick turnaround for custom sensor prototypes

Customer Focus

A customer-first approach is at the heart of our company-wide culture, driving us to build long-lasting relationships and exceed expectations. Our employees make the difference for your business every day. They listen to your needs and understand your challenges, and they use their knowledge and expertise to develop the best solutions and solve your problems.

Application Expertise

At Littelfuse, we partner with customers to design, manufacture, and deliver innovative solutions for a wide range of markets, including automotive and commercial vehicles, industrial applications, data and telecommunications, medical devices, consumer electronics, appliances, and transportation.

Our experts apply reliable and efficient product solutions, innovative technologies, and global resources to address technical challenges in a variety of applications. Moreover, our worldwide network of research teams focuses on product development and support, design-in programs, and application testing in our global labs.

Global Support

Through our network of global labs in China, Germany, Italy, Japan, Lithuania, Mexico, the Philippines, and the United States, we design innovative solutions and provide customer application support and testing. Our unique capabilities include performance testing, material analysis, and regulatory compliance testing. The dedication of our global labs ensures the outstanding performance, safety, and reliability of our products and support services for our worldwide customer base.

We have over 50 locations throughout the Americas, Europe, and Asia, enabling us to provide products, application knowledge, and technical support around the globe. Our network of regional customer support offices and hundreds of authorized distributors work to help you solve problems quickly.

Operational Excellence

Littelfuse is firmly committed to manufacturing quality products at a competitive price, while lowering our global manufacturing footprint. We build quality into our products and services and strive to have zero defects in everything we do, thereby reducing costs and increasing your total satisfaction. We strive to exceed your expectations every day.

Quality Assurance

Our global manufacturing facilities abide by strict quality assurance requirements and hold the following quality management system registrations:

- ISO 9001
- ISO14001
- IATF 16949

ESD Suppression Technologies

Protection Technology	PULSE-GUARD® ESD Suppressors	XTREME-GUARD™ ESD Suppressors	Multilayer Varistors (MLVs)	TVS Diode Arrays (SPA® Diodes)
				
Data Rate Span	0–10 GHz	0–10 GHz	< 125 mbps	0–40 Gbps
Peak/Clamp (8 kV)	Good	Good	Good	Excellent
ESD Level	Good	Excellent	Good	Excellent
Discrete Options	0201; 0402; 0603	0402; 0603	0402; 0603; 0805; 1206	0805 (SOD323), 0603 (SOD523); 0402 (SOD882, SOD-883, SOD723); 0201 (Flipchip; µDFN-2); 01005 (Flipchip); DFN1610
Array Options	SOT23	—	1206	SOIC-8; SOT143; SOT23, SC70, SOT523; SOT553; SOT563; SOT723; SOT953; MSOP 8; MSOP 10; µDFN; TDFN; DFN-3810
Applications and Circuits	USB2.0; FireWire 1394; HDMI/USB3.0; USB3.1; Type-C; GPIO; keypad/switch; RF antenna	USB2.0; FireWire 1394; HDMI/ USB3.0; USB3.1; Type-C; GPIO; keypad/switch- RF antenna; Automotive	Keypad/switch, audio; analog video; USB1.1; RS232	Keypad/switch; USB1.1; USB2.0; USB3.0; USB4.0; LVDS; thunderbolt; audio; analog video; FireWire 1394; HDMI; Ethernet; MMC interface; LCD module; RS232; RS485; CAN; LIN; Automotive (CAN; LIN; Ethernet; GMSL; FPD-link; Open Alliance; Daisy Chain)
Key Advantages	Lowest capacitance	Lowest capacitance; excellent ESD performance	Lowest cost; broad discrete offering	No wear-out mechanism and clamp voltages; excellent surge and ESD performance

When to Choose?

PULSE-GUARD® ESD Suppressors

- The application tolerates very little added capacitance (high-speed data lines or RF circuits)
- ESD is the only transient threat
- Protection is required on data, signal, and control lines (not power supply lines)

XTREME-GUARD™ ESD Suppressors

- The XGD series protects sensitive electronics against electrostatic discharges as high as 30 kV and is suitable for high-voltage applications up to 32 V dc
- When correctly integrated into a circuit design, the XGD Series can safely absorb repeated ESD strikes nearly four times the maximum level specified in the IEC61000-4-2 international standard without any hit to performance
- Even after multiple ESD strikes, the XGD series exhibits ultra-low current leakage (<1 nA), ensuring minimal power losses; thus, it is suited for protecting battery-powered electronics such as wearables

Multilayer Varistors (MLVs)

- Surge currents or energy beyond ESD are expected in the application (EFT, lightning)
- High-wattage TVS Zener diodes (300 W–1500 W)
- Added capacitance is desirable for EMI filtering (3 pF–6000 pF)
- Power supply lines or low- or medium-speed data and signal lines need to be protected
- Operating voltage is above silicon or PULSE-GUARD® ESD suppressor ratings

TVS Diode Arrays (SPA® Diodes)

- The device being protected requires the lowest possible clamp voltage, low capacitance (0.09 pF–400 pF), and low leakage (0.01 µA–1.5 µA)
- Board space is at a premium and space-savings multi-line protection is necessary
- Transients other than ESD surge, such as EFT or lightning, must also be considered

ESD Damage, Suppression Requirements, and Considerations

ESD Damage

ESD is characterized by fast rise times, high peak voltages, and currents up to 30 amps (per IEC 61000-4-2, level 4), which can melt silicon and conductor traces. However, ESD effects can be subtle as well. The three types of ESD damage are detailed below.

1. Soft Failures

Electrical currents due to ESD can change the state of internal logic, causing a system to latch up or behave unpredictably, thereby potentially corrupting data streams. While this failure is temporary, it may slow down communications, or require a system reboot in the case of lockup.

2. Latent Defects

A component or circuit may be damaged by ESD and have its function degraded, although the system will continue to work. This type of defect often progresses to premature failure.

3. Catastrophic Failures

Of course, ESD can damage a component to the point where it does not function as intended or does not work at all.

ESD Suppression Requirements

The likelihood of electronic circuit damage increases as integrated circuit (IC) dimensions shrink to nanometer sizes. Most ICs operate at low voltages and have structures and conductive paths that cannot survive the high currents and voltages associated with ESD transients.

The migration to higher-frequency communication devices to transmit more information in less time is another significant trend in the field. This means that ESD solutions must not compromise stringent signal integrity requirements at higher data rates. Therefore, ESD suppressors must have low internal capacitance to ensure that data communication signals are not distorted.

IC designers add a limited amount of ESD suppression to their chips to help prevent damage during manufacturing and assembly processes. However, the level of protection added may not be sufficient to protect ICs and other semiconductor devices from ESD during actual usage. Many electronic products, especially portable ones, are used in uncontrolled environments. Portable devices can build up charge as they are carried by users on their person or in a purse. This energy can then be discharged to another device as the two are connected—this usually occurs when a user touches I/O pins on a cable connector. Therefore, designers of end products should consider adding ESD suppressors to their circuits.

ESD Suppression and Circuit Design Considerations

The proper use of ESD circuit protection helps prevent these failures. Suppression devices must be selected in consideration of the fact that has very short rise and fall times—less than one nanosecond (1 ns) in most cases. The International Electrotechnical Commission (IEC) has developed a specification (IEC 61000-4-2) for ESD testing that helps determine whether products are susceptible to ESD events.

Littelfuse device engineers use specifications such as these to design ESD suppressors with the speed, clamping voltage, and residual current levels needed to protect today's sensitive semiconductors and electronic circuitry. Many of these designs have the low internal capacitance required for high bandwidth communications.

When selecting ESD suppressors, circuit designers must consider potential coupling paths that would allow ESD to enter their equipment and circuits. These weak points identify areas that should be considered for ESD suppressor installation. Ultimately, designers must select ESD suppressors with characteristics appropriate to their type of equipment, the component sensitivity, and the environment in which it will be used.

We have developed a robust web-based tool to help circuit designers identify the optimal electronic fuses for their products.

Please visit https://www.littelfuse.com/design-center/design-tools to access the Littelfuse iDesign tool.

Characteristics of Transient Voltage Spikes

Transient Threats—What are Transients?

Voltage transients are defined as short-duration surges of electrical energy that are the result of a sudden release of energy previously stored or induced by other means, such as heavy inductive loads or lightning. In electrical or electronic circuits, this energy can be released in a predictable manner via controlled switching actions, or randomly induced into a circuit from external sources.

Repeatable transients are frequently caused by the operation of motors or generators and the switching of reactive circuit components. Random transients, on the other hand, are often caused by lightning and ESD, which generally occur unpredictably and may require elaborate monitoring to be accurately measured, especially if induced at the circuit board level. Numerous electronics standards groups have analyzed transient voltage occurrences using accepted monitoring or testing methods. The key characteristics of several transients are shown in the table below.

Table 1: Examples of Transient Sources and Magnitude

	VOLTAGE	CURRENT	RISE-TIME	DURATION
Lighting	25 kV	20 kA	10 µs	1 ms
ESD	15 kV	30 A	<1 ns	100 ns

Characteristics of Transient Voltage Spikes

Transient voltage spikes generally exhibit a double exponential wave, as shown below for lightning and ESD.

Figure 1. Lightning Transient Waveform

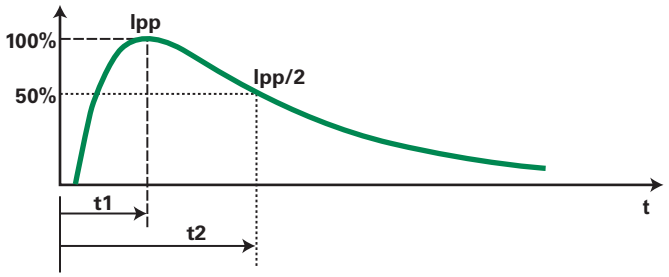
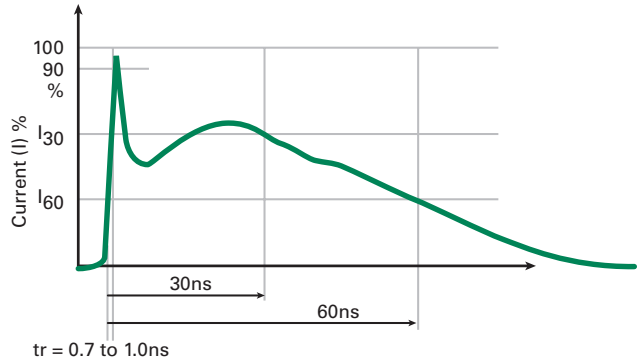


Figure 2. ESD Test Waveform



The exponential rise time of lightning is in the 1.2 µsec to 10 µsec range (essentially 10% to 90%), and the duration ranges from 50 µsec to 1000 µsec. (50% of peak values). ESD on the other hand, is an event with a much shorter duration. The rise time has been characterized at less than 1.0ns. The overall duration is approximately 100 ns.

TVS Diode Transient Voltage Scenarios

Electrostatic Discharge (ESD)

Electrostatic discharge is characterized by fast rise times and high peak voltages and currents. This energy is the result of an imbalance of positive and negative charges between objects.

ESD that is generated by everyday activities can greatly surpass the vulnerability threshold of standard semiconductor technologies.

Following are a few examples:

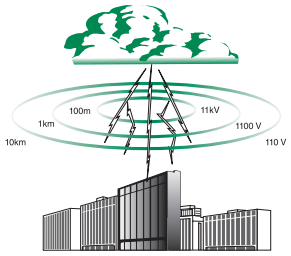
Walking across a carpet:	35 kV @ RH = 20%; 1.5 kV @ RH = 65%
Walking across a vinyl floor:	12 kV @ RH = 20%; 250 V @ RH = 65%
Worker at a bench:	6 kV @ RH = 20%; 100 V @ RH = 65%
Vinyl envelopes:	7 kV @ RH = 20%; 600 V @ RH = 65%
Poly bag picked up from desk:	20 kV @ RH = 20%; 1.2 kV @ RH = 65%

Port Protection from Electrical Hazards

Lightning Induced Transients

Although direct strikes are clearly destructive, transients induced by lightning are not the result of direct strikes.

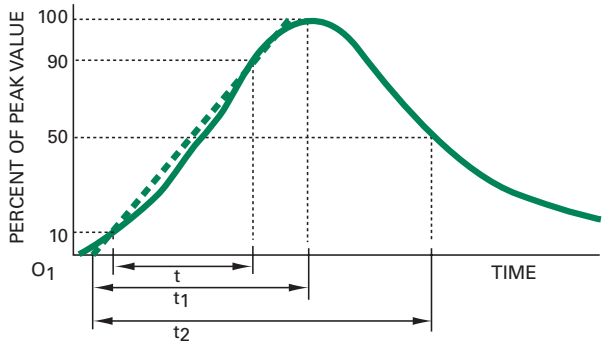
Lightning strikes create magnetic fields that can induce transients of large magnitude in nearby electrical cables.



Cloud-to-cloud strikes affect not only overhead cables but also buried cables. Strikes just 1.6 km away can generate 70 volts in electrical cables.

The transient-generating effect is far greater in cloud-to-ground strikes relative to cloud-to-cloud strikes, as shown in the diagram to the right.

This diagram depicts a typical current waveform for induced lightning disturbances.



Ports Need Protection from Electrical Hazards

Lightning Surges

Induced lightning surges can be coupled to industrial data line, causing damage to sensitive ICs.

Power Cross

Miswiring during assembly or insulation damage can cause cables to be exposed to AC line voltage.

Induced Power Surge

Lightning and power grid switching can induce power surges and cause damage.

Electrical Fast Transient

Electrical fast transients (EFTs) can result from the switching of inductive loads or the bouncing of relay contacts.

Electrostatic Discharge

ESD passing through connecter can damage ICs.

Wire Aging and Installation Faults

RS-485 and ethernet often share the same conduits with DC or AC, gradually resulting in cracks in the insulation due to sharp bends and tight wiring ties.

Data Protocol, Application, and Product Selection

The chart below details the relationships among data rates (protocol), applications, and Littelfuse ESD suppression products.

The top of the chart shows the standard data protocols, associated data rates, and example end applications that may use the protocols, while the body of the chart indicates the applicable Littelfuse ESD suppressors for the various data rates, protocols and applications.

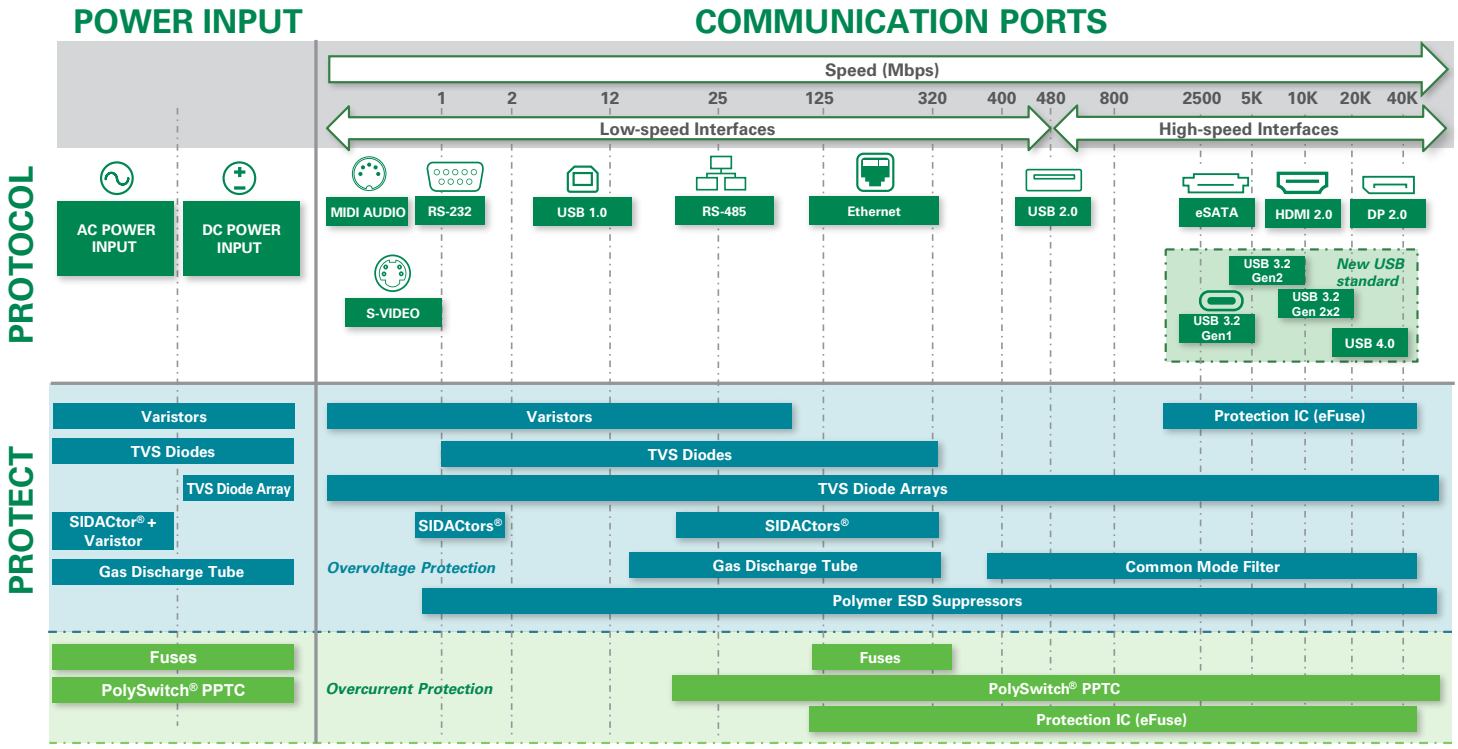
Capacitance is the characteristic of concern. High-capacitance suppression devices tend to add signal distortion as signal frequencies increase, whereas low-capacitance devices maintain signal integrity at high data rates.

Note that an application may use several different data protocols and many different ESD suppressor products. For example, a laptop computer could have RS232, USB 2.0, video, and PS2 mouse ports, among others.

The RS232 and mouse ports use relatively slow data rates and could utilize any Littelfuse suppressor (although higher capacitance multi-layer or silicon parts are preferred for EMI filtering capabilities). The appropriate protector for the video port is determined by data rate, and since the USB 2.0 port requires an extremely low-capacitance suppression device, PULSE-GUARD® ESD Suppressor or TVS Diode Array (SPA® Diodes) devices should be considered.

If you require further assistance in selecting the appropriate Littelfuse ESD suppressor for your specific circuit, please contact your local Littelfuse product representative.

Product Series and Applicable Data Rates and Protocols

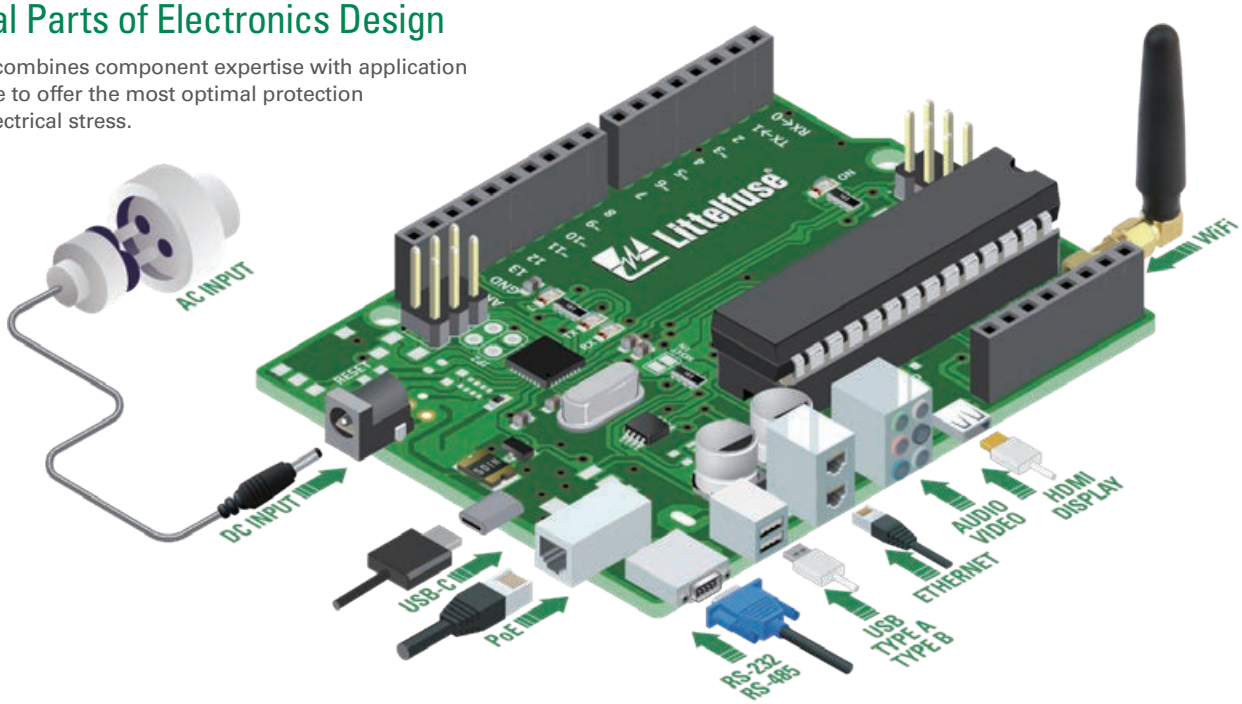


The information above is intended to help circuit designers determine which Littelfuse ESD suppressors are applicable for given data protocols and data rates. Other key characteristics, such as clamping voltage, leakage current, number of lines of protection and ESD capabilities, must be considered as well, especially where there are overlaps in the recommended Littelfuse ESD suppressor line.

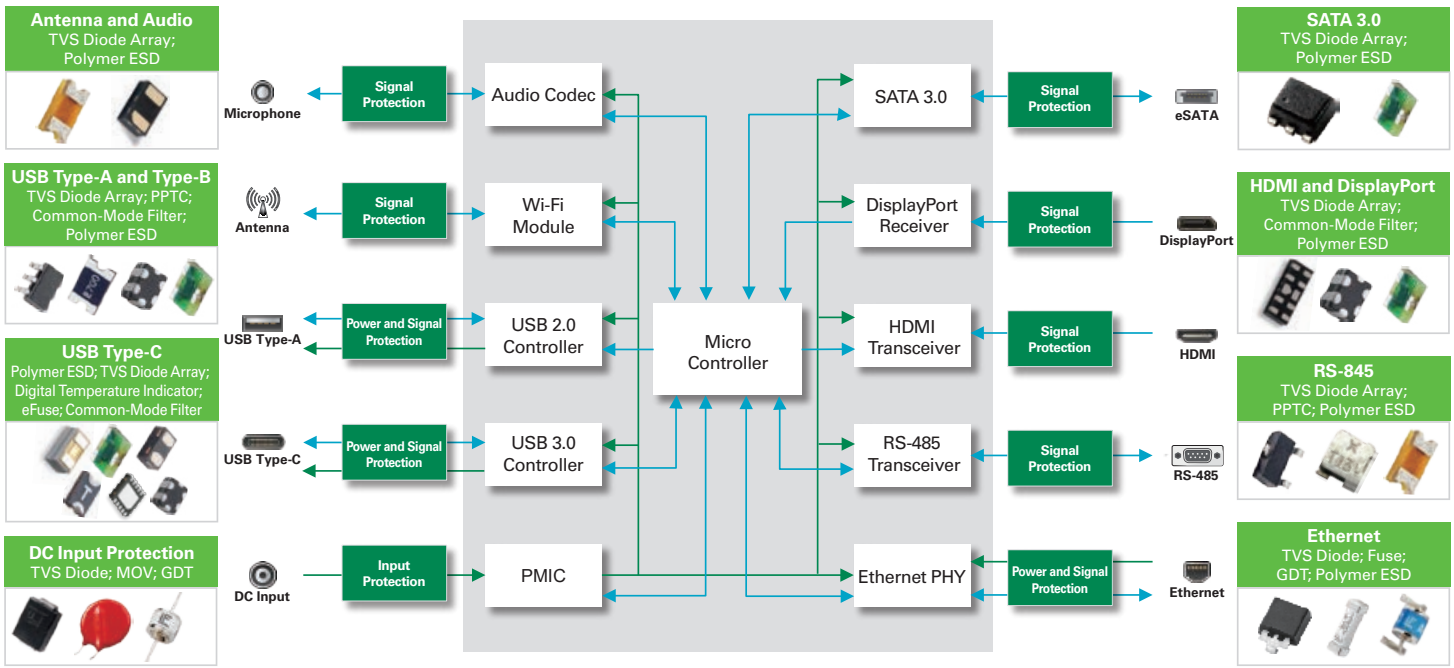
The capacitances of the suppression device and the circuit board at the upper data rate bounds of the products included above need to be taken into account in order to maintain the signal integrity of the overall system.

Power Input and High-speed Communication Ports are Integral Parts of Electronics Design

Littelfuse combines component expertise with application knowledge to offer the most optimal protection against electrical stress.



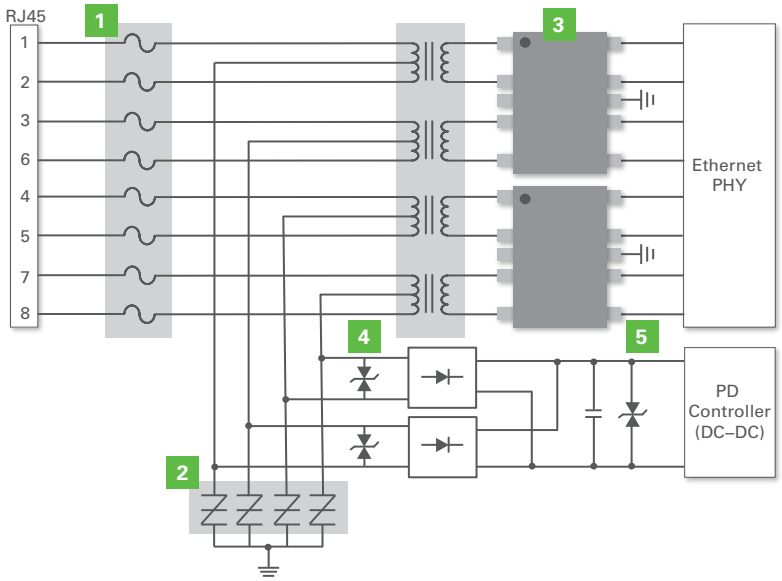
Recommended Solutions for General Port Protection



Broadband Network Port Protection

Lightning, ESD, and Power Fault Protection: PoE++

TeleLink® fuses can help protect electrical devices from power fault overcurrents. They are designed specifically for high-speed telecom applications. A single bi-directional TVS diode is used across the center tap data pair with a second TVS diode across the center tap spare pair. Fuses are offered for surge requirements ranging from 400 W to 8000 W.

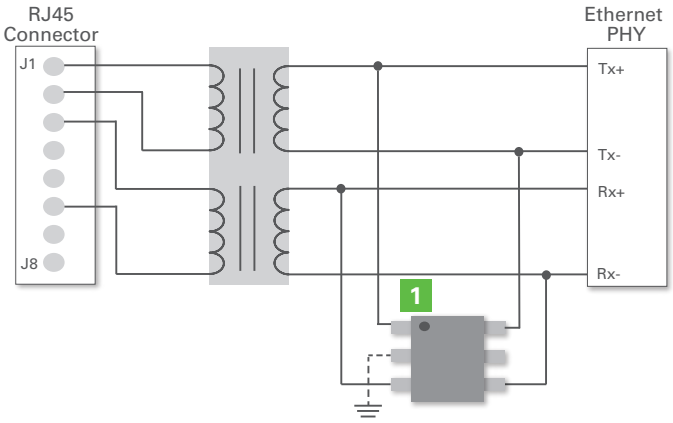


	Technology	Function in Application	Series Name	Features
1	Fuse (x8)	Overcurrent protection from power crosses and lightning surges	461xxx	Surface mount; surge-tolerant fuse designed specifically for high-speed telecom applications
2	SIDACtor® (x4) *OR* GDT (x4)	Protects baseband equipment against damage from overvoltage surges	P4500SCLRP	Low-voltage overshoot; low on-state voltage; low capacitance
		Protects baseband equipment against damage from overvoltage surges	SG75 / SG90	Excellent stability on multiple pulse duty cycles; SMD with ultra-small size
3	TVS Diode Array (x2)	Protects protection against ESD, CDE, EFT, and lightning-induced surges or high-speed data lines	SP2555NUTG	µDFN-10 package; low leakage current (0.1 µA) and low clamping voltage; protects up to four channels up to 45 A
			SP2525NUTG	µDFN-10 package; low capacitance and low clamping voltage; protects up to four channels up to 30 A
			SP3025-04HTG	SOT23-6L package; low capacitance and low clamping voltage; protects up to four channels up to 30 A
4	TVS Diode (x2)	Protects sensitive electronic equipment from voltage surges induced by lightning and other surge events	SMCJ58CA; SMTOAK2	1500 W peak pulse capability; compatible with the lead-free solder reflow temperature profile; 2 kA (8/20 µs) surge current capability for protecting power ports in harsh and/or outdoor environments
5	TVS Diode (x1)			

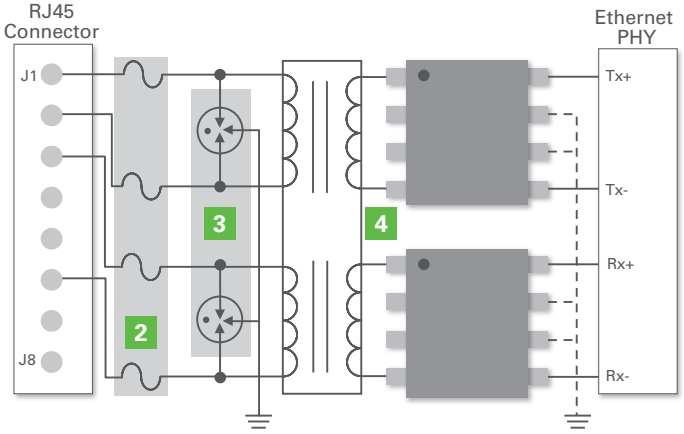
Ethernet Port Protection Solutions

This page contains examples of ESD implementation and lightning suppression for Ethernet ports (RJ-45 connectors). Note that speeds of 1 Gbps or greater will require two additional twisted pairs and that the diode array solution should be replicated. The diagrams below illustrate typical implementations for indoor/ outdoor network lines and equipment applications.

Intra-building Environments



Outdoor and Harsh Environments

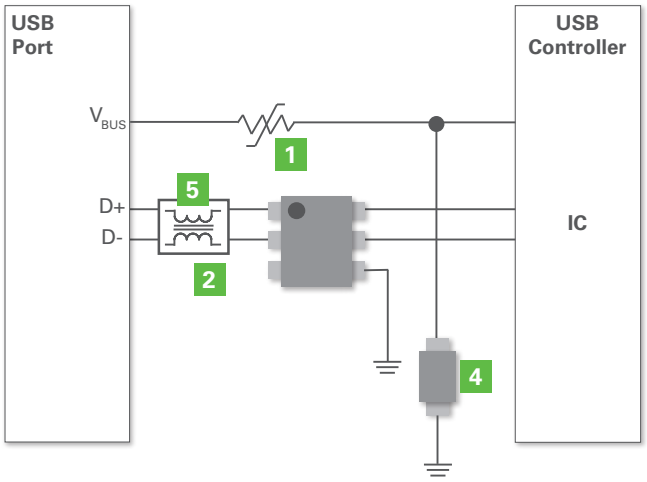


	Technology	Function in Application	Series Name	Features
1	**TVS Diode Array**	Protection from ESD and EFT	SRV05-04HTG-D	Low capacitance; low leakage current; small design; four lines of protection
2	**Fuse**	Overcurrent protection	461xxx	Surface mount; surge-tolerant fuse designed specifically for high-speed telecom applications
3	**GDT**	Lightning protection through the use of GDT with diode array to meet standard requirements	SG; CG6; CG5; SL1010	High surge rating; low capacitance; UL recognition
4	**TVS Diode Array**		LC03xx; SP40xx	Low capacitance; low leakage current

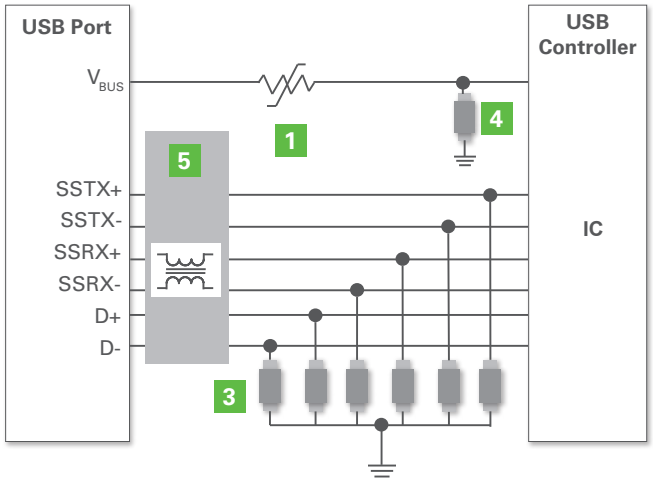
USB Type-A and Type-B Protection Solutions

This page details examples of ESD suppression for high-speed data ports such as USB2.0 and USB3.2 Gen 1x1. For additional design examples, guidance, and application assistance, please contact Littelfuse.

USB 2.0 (480 Mbps)



USB 3.2 Gen 1x1 (5 Gbps)

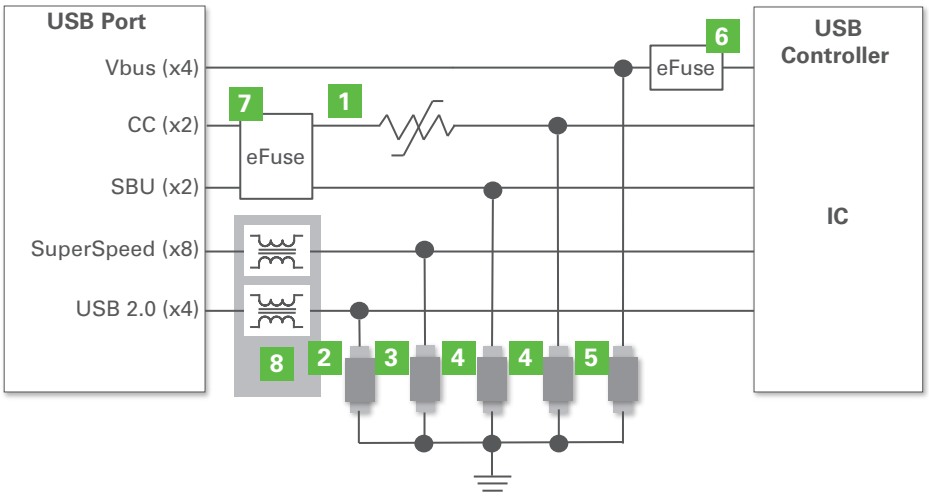


	Technology	Function in Application	Series Name	Features
1	**PPTC**	Protects 5 V dc power supply from overcurrent and overtemperature	Low Rho	Ultra-low internal resistance; higher current capacity in smallest SMD package
2	**TVS Diode Array**	Protection of data lines against ESD	SP3019-04HTG; SP3400-02UTG	Low capacitance (0.3 pF) and leakage current (0.01 µA); small form factor µDFN
3	**TVS Diode Array (6x) *OR* Polymer ESD Suppressor**	Protection of data lines against ESD	SP3213-01UTG	Very low capacitance of 0.09 pF; small formfactor µDFN
			PulseGuard®	Very low capacitance; low leakage current; small form factor
4	**TVS Diode Array**	Protection of power bus against ESD	SP1006-01UTG	Low leakage current of 100 nA; small form factor
5	**Common-Mode Noise Filter**	Suppresses common-mode noise and provides ESD protection	LCFA; LCFE	Ultra-low profile; CMF combined with ESD functions; high cut-off frequency

USB Type-C Protection Solutions

The following are examples of ESD suppression for high-speed data ports such as USB3.2 Gen and USB4.0. For additional design examples, guidance, and application assistance, please contact Littelfuse.

USB 3.2 Gen 2x1 (10 Gbps); USB 3.2 Gen 2x2 (20 Gbps); and USB 4.0 (40 and 80 Gbps)

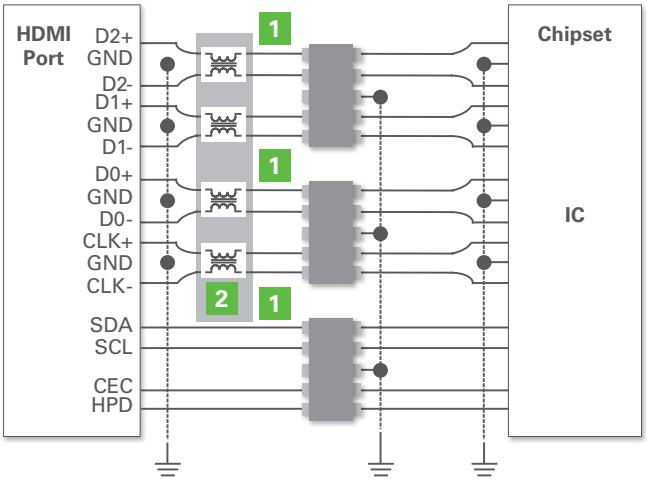


	Technology	Function in Application	Series Name	Features
1	**Digital Temperature Indicator**	Senses overheating of USB-C connector	setP™	Fully compliant with USB Type-C plugs and USB-IF
2	**TVS Diode Array**	Protects against ESD on USB 2.0-speed data lines	SP3530-01UTG	0201 footprint; extremely low dynamic resistance
3	**TVS Diode Array**	Protects against ESD on high-speed data lines	SP3213-01UTG, SP00R6, SP33R6	Low parasitic capacitance
4	**TVS Diode Array**	Protects against ESD	SP1224-01UTG	AEC-Q101-qualified; small footprint
5	**TVS Diode**	Protects power bus against ESD	SMAJ20CA	400 W Peak Pulse Power; excellent clamping capability; low package profile
6	**eFuse**	Protects against 5 V or 5 A dc shorting and hot-plug surge voltage	LS0505EVD22	28 V 6 A rated current limit switch; integrates a 24 mΩ ultra-low protection switch
		Used for 5 V~20 V with PD function	LS2406ERQ23	
7	**eFuse**	Type-C 20 V Vbus short to CC or SBU	LS05006VPQ33	Supports fast OVP response time (80 ns); integrated ESD protection with CC dead battery function
8	**Common-Mode Noise Filter**	Suppresses common-mode noise and protects from ESD	LCFA, LCFE	Ultra-low profile; combined with ESD functions; high cut-off frequency

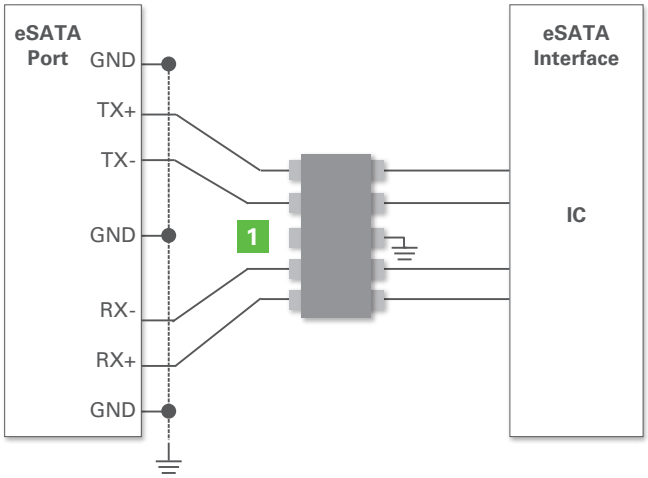
HDMI Port, DisplayPort, and eSATA Port Protection Solutions

This page lists examples of ESD suppression for high-speed data ports such as High-Definition Multimedia Interface (HDMI), DisplayPort, and eSATA. For additional design examples, guidance, and application assistance, please contact Littelfuse.

HDMI and DisplayPort

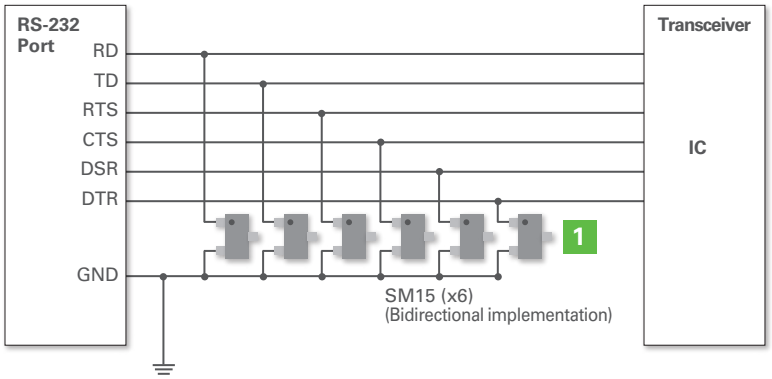


eSATA



	Technology	Function in Application	Series Name	Features
1	**TVS Diode Array *OR* Polymer ESD Suppressor**	Protection of data signal lines from ESD	SP1004U-ULC-04UTG	Low capacitance of 0.2 pF; low clamping voltage of 9.2 V @ IPP = 2.0 A (tP = 8/20 µs); industry standard DFN footprint
			PulseGuard®	Low capacitance; low leakage current; small form factor
2	**Common-Mode Noise Filter**	Suppresses common-mode noise and protects from ESD	LCFA; LCFE	Ultra-low profile; Combined with ESD functions; high cut-off frequency

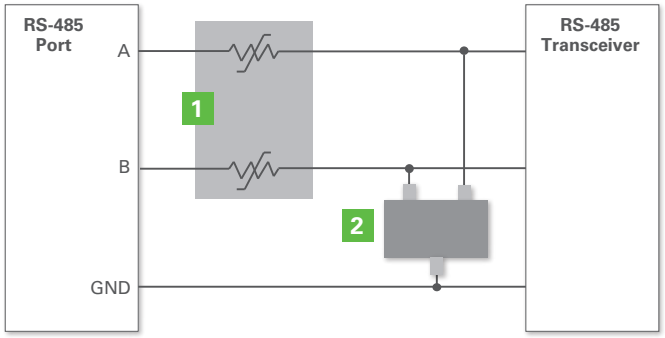
RS-232 Port Protection Solutions



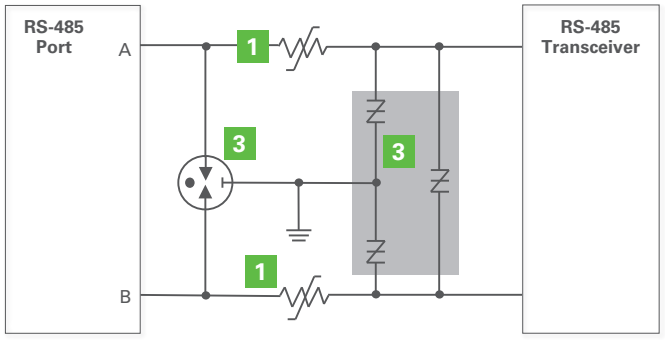
	Technology	Function in Application	Series Name	Features
1	TVS Diode Array	Protection of data signal linefrom ESD	SM15-02HTG	Low dynamic resistance of 0.30 Ω; low leakage current and clamping voltage
			SD15C-01FTG	Low dynamic resistance of 0.46 Ω; low leakage current and clamping voltage

RS-485 Port Protection Solutions

Intra-building Environments



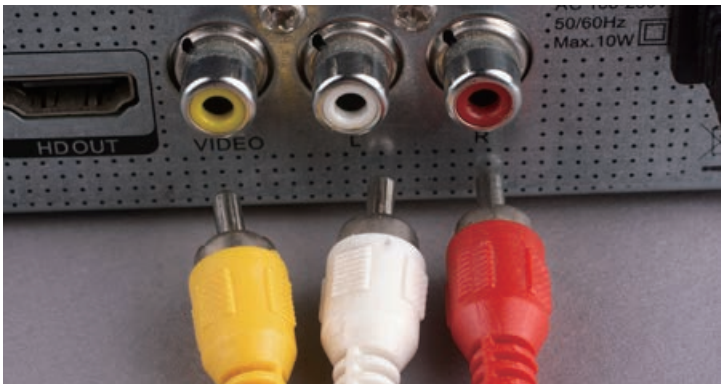
Outdoor and Harsh Environments



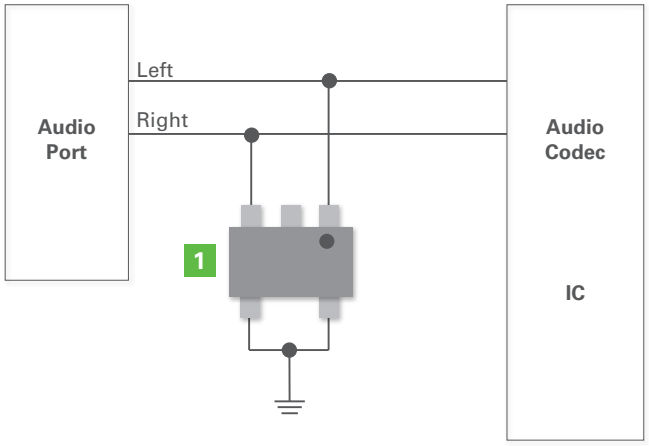
	Technology	Function in Application	Series Name	Features
1	PPTC	Protects equipment from short circuits and power crosses	TSV250	Available in various form factors; low parasitic capacitance
2	TVS Diode Array *OR* Polymer ESD Suppressor	Protects from ESD, EFT, and lightning-induced surges	SP712	Specifically designed for RS-485 with asymmetrical working voltages of 7 V to 12 V
			PulseGuard®; Xtreme-Guard™	Very low capacitance; low leakage current; small form factor
3	GDT + SIDACtor®	Reacts first when lightning occurs, causing the voltage to increase across PPTC until GDT fires	GTCxx; PxxxxS4xLRP	Wide range of voltages and form factors; low capacitance and insertion loss; low voltage overshoot; low on-state voltage
	SIDACtor®	Protection against lightning	Pxxx0S3N	Capable of 3 kA surges exceeding IEC61000-4-5 Level 4, K.20/21 Basic and Enhanced, GR1089, and UL60950 requirements

Audio and Video Line Protection Solutions

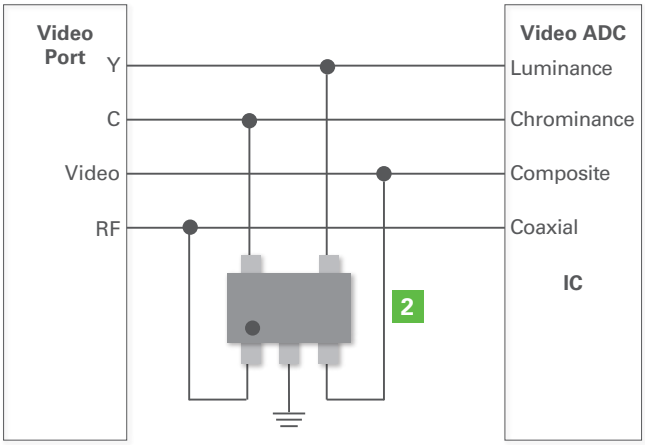
Examples of ESD suppression for ports common in entertainment electronics are listed here. For additional design examples, guidance, and application assistance, please contact Littelfuse.



Audio Line



Video Line

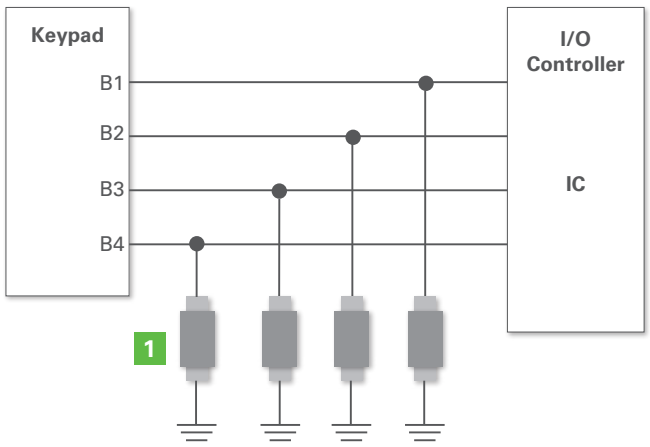


	Technology	Function in Application	Series Name	Features
1	**TVS Diode Array *OR* Polymer ESD Suppressor *OR* Multilayer Varistor**	Protects audio codecs from ESD damage	SP1002	Low capacitance of 5 pF; low leakage current of 0.5 µA; small package
			PulseGuard®	Very low capacitance; low leakage current; small form factor
			MLA	Standard low capacitance; leadless 0402, 0603, 0805, 1206, and 1210 chip sizes
2	**TVS Diode Array *OR* Polymer ESD Suppressor *OR* Multilayer Varistor**	Prevents video analog-to-digital converters from ESD damage	SP3019-04HTG	Low capacitance of 0.3 pF; low leakage current
			PulseGuard®	Very low capacitance; low leakage current; small form factor
			MLA	Standard low capacitance; leadless 0402, 0603, 0805, 1206, and 1210 chip sizes

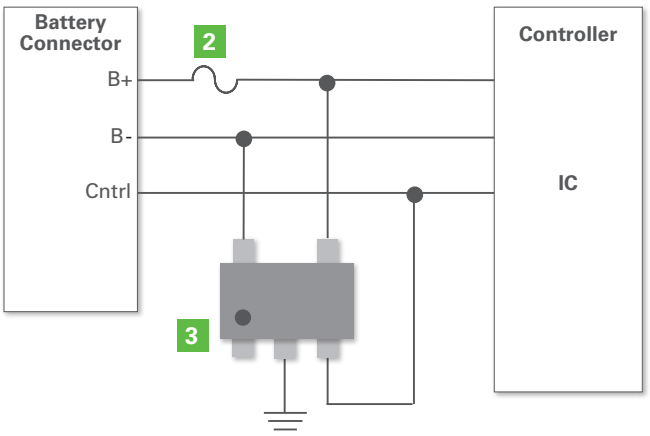
Protection Solutions for Keypads, Buttons, Switches, and Battery Packs

The following are examples of ESD suppression for power buses and control lines in entertainment electronics. For additional design examples, guidance, and application assistance, please contact Littelfuse.

Keypad Protection



Battery Packs Protection



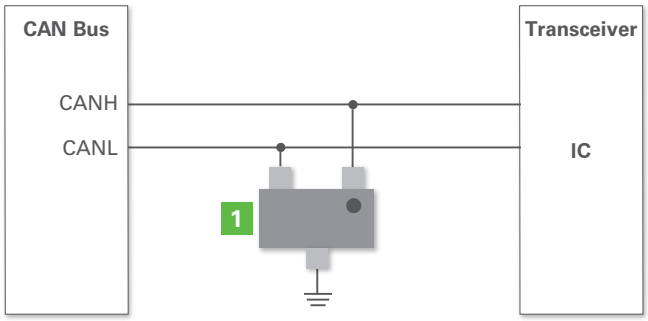
	Technology	Function in Application	Series Name	Features
1	**Multilayer Varistor**	Provides ICs and other components circuit board–level protection against ESD	V5.5MLA0402	AEC-Q200-compliant; standard low capacitance
2	**Fuse**	Overcurrent protection for power buses	435	35 A interrupt rating at 32 V dc; compact footprint (0402)
3	**TVS Diode Array**	ESD protection for power buses and control lines	SP3019-04HTG	AEC-Q101-qualified; low input capacitance; fast response time (<1 ns)

CAN/LIN BUS and SIM/µSIM Socket Protection Solutions

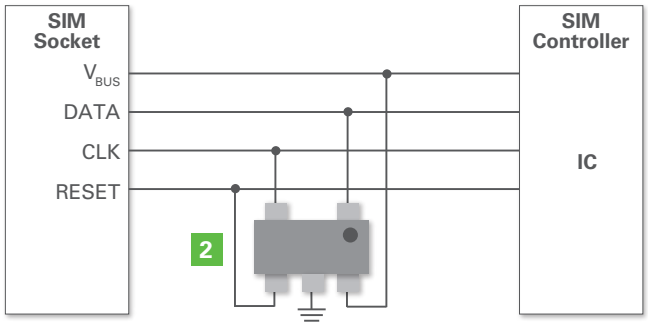
Automotive AEC-Q101-Qualified ESD Protection

This page contains examples of ESD suppression for automotive electronics. For additional design examples, guidance, and application assistance, please contact Littelfuse.

CAN/LIN BUS



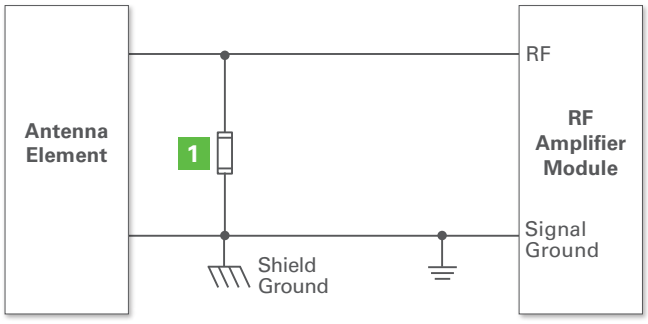
SIM/µSIM Socket



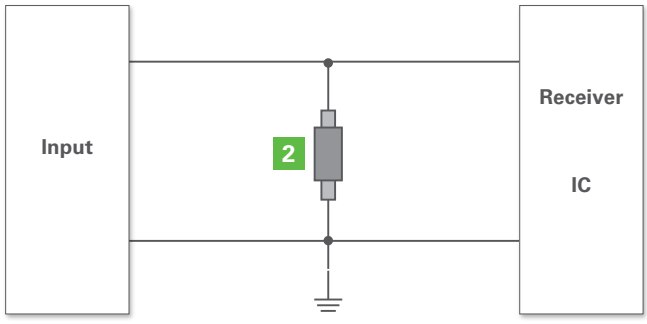
	Technology	Function in Application	Series Name	Features
1	TVS Diode Array	Protects against ESD and surges	AQ24COM-02HTG	AEC-Q101-qualified; low clamping voltage and leakage current
2	TVS Diode Array	Protects against ESD	SP1012-05WTG	Provides elite ESD protection for data lines; very low dynamic resistance of 0.48 Ω

Antenna and Sensor Input Protection Solutions

Antennas



Sensor Inputs



	Technology	Function in Application	Series Name	Features
1	Polymer ESD Suppressor	Protection against ESD	XGD10603	Extremely low capacitance (0.09 pF); high ESD withstand rating (30 kV)
2	TVS Diode Array	Protection against ESD	SP3522-01ETG	High ESD withstand rating; low leakage current; AEC-Q101-qualified parts available

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About Littelfuse

Littelfuse is a trusted partner to engineers worldwide who seek our technical expertise to accurately conduct and analyze test results. Our global vision, team, and leadership collectively form the strategic foundation necessary to deliver innovations that help bolster businesses and align with global megatrends.

Littelfuse offers leading technologies in circuit protection, power control, and sensing. We continue to expand our broad and diverse portfolio of products into adjacent markets, including power semiconductors; heavy-duty switches; magnetic, optical, electromechanical, and temperature sensors; and other products that facilitate the safe control and distribution of electrical power.

Littelfuse offers a wide variety of product technologies, which are listed below.

Overcurrent Protection

- Fuses
- Protection ICs
- Resettable Positive Temperature Coefficient (PPTC) Devices

Overvoltage Suppression

- Gas Discharge Tubes (GDTs)
- Open LED Protectors
- PulseGuard® ESD Suppressors
- SIDACtor® Protection Thyristors
- TVS Diodes
- TVS Diode Arrays
- Varistors
- Wafer and Bare Die

Power Semiconductors

- Bare Die Devices
- Bipolar Devices
- Discrete and Module Solutions
- Fully Engineered Subsystems
- IGBTs
- MOSFETs
- Power Semiconductors and ICs
- Power Control
- Switching Thyristors
- Silicon Carbide Technology
- TRIAC Thyristors

Integrated Circuits and Solid-State Relays

- Gate Drivers
- High-Voltage ICs
- Solid-State Relays

High Reliability Connectors

- D-Sub Connectors
- Harness Solutions
- Micro-D Connectors
- Wire to Wire connectors

Electromechanical Switches

- Dip Switches
- Detect Switches
- Keyswitch Switches
- Navigation Switches
- Pushbutton Switches
- Rocker Switches
- Rotary Switches
- Snap-Acting Switches
- Slide Switches
- Switchlock Switches
- Tactile Switches
- Toggle Switches

Magnetic Sensing

- Hall Effect Sensors
- Magnetic Actuators
- Reed Switches
- Reed Sensors
- Reed Relays

Temperature Sensing

- Digital Temperature Indicators
- RTDs
- Thermistors
- TTape™ Temperature Indicators

Industrial and Transportation Technologies

- Arch-Flash Relay
- Automotive Sensor
- Contactor
- DC Solinoid Relays
- Ground-Fault Relay
- Motor & Pump Protection
- Power Distribution Module
- Residual Current Monitor

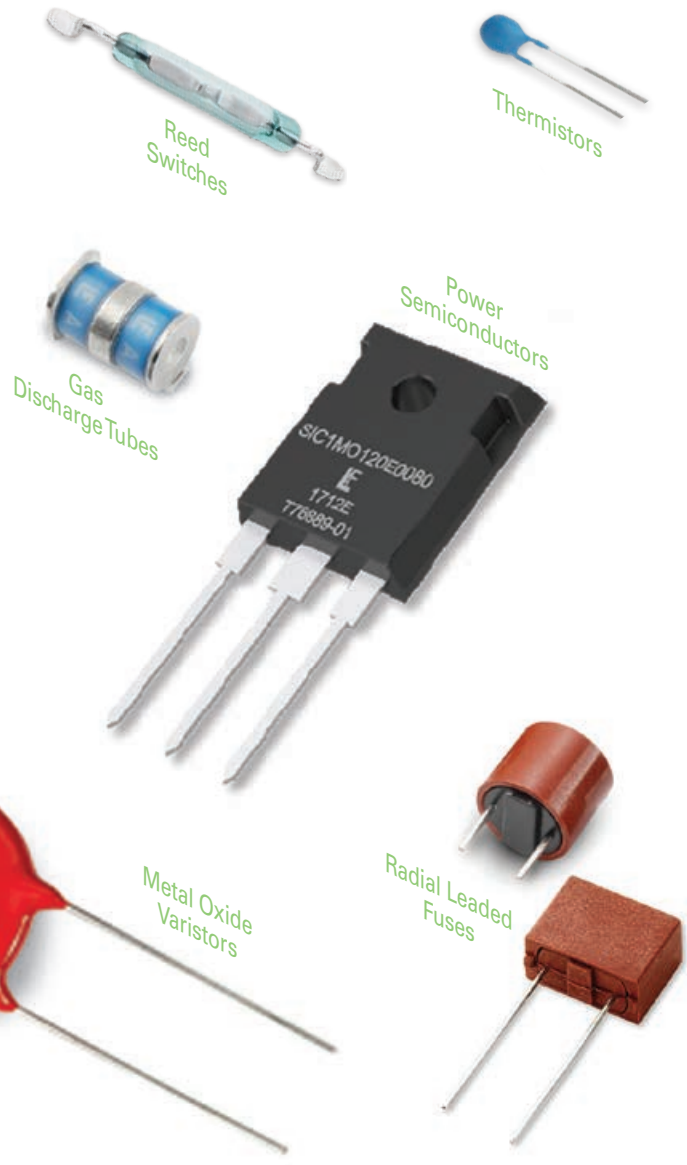
Global Footprint

The Littelfuse mission is to develop innovative circuit protection, power control, and sensing solutions that meet our customers' unique needs. This customer-focused philosophy has helped us become the top circuit protection brand in the world.

Our industry-leading product portfolio includes reliable circuit protection, power control, and sensing products designed for a variety of markets and applications. We have assembled unparalleled expertise and developed a global footprint that puts our facilities close to our customers and target markets. As our global manufacturing and R&D teams objectively recommend the best circuit protection, power control, or sensing solutions for each customer application, they form partnerships that will lead to the development of the next generation of advanced products.

Littelfuse provides:

- Application expertise
- Global support
- Operational excellence
- Technology innovation
- Collaboration
- Customer focus



Additional Resources

Circuit Protection Products Selection Guide

Scan or Click to Download

This guide provides a summary of key circuit protection consideration factors and descriptions of the circuit protection technologies Littelfuse offers product selection tables designed to help you quickly find protection solution suited to your applications.

Sensing Products Selection Guide

Scan or Click to Download

This guide provides an overview of magnetic and temperature-sensing technologies, key consideration factors, descriptions of the technologies Littelfuse offers, and product selection tables to help you quickly identify the sensing solution appropriate for your application.

Power Semiconductor and IC Selection Guide

Scan or Click to Download

This selection guide offers a comprehensive look at the breadth and depth of the Littelfuse power semiconductor and control IC portfolio.

View Technical Resources at Littelfuse.com

Technical information is only a click away. Littelfuse Technical Resources contains datasheets, product manuals, white papers, application guides, demos, on-line design tools, and more.

An Extension of Your Team

Littelfuse engineers are a phone call away to help identify potential issues and provide product recommendations to solve problems.

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Asia Technical Support: **+86 512 67613189**
North America Technical Support: **(800) 999-9445**
South America Technical Support: **+55 11 2844-4395**
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Global Lab Capabilities

You need to be certain that your products live up to the highest standards for performance, reliability, safety, and regulatory compliance. Working with Littelfuse provides you access to dedicated application engineers who partner with you to provide expert design consultation, perform comprehensive tests simulating the harshest environments, and confidentially evaluate the results with you.

TESTING CAPABILITIES

Environmental

- Autoclave
- Dust
- H3TRB
- HAST
- High- and Low-Temperature Storage
- High-Temperature Loading
- Ingress Protection (IP)
- HTGB
- HTRB
- Temperature and Humidity
- Temperature Cycling
- Thermal Shock
- Salt Fog

Physical-Mechanical Characteristics

- Acceleration
- Die Shear
- Leak Detection
- Mechanical Shock
- Resistance to Soldering Heat (Dip, Reflow, Wave)
- Resistance to Solvents
- Solderability
- Terminal Strength (Push, Pull, Bend)
- Vibration
- Wetting Balance
- Wire Pull

Electrical

- BCI
- Capacitance
- EFT
- ESD
- Impedance
- Insulation Resistance
- I-V
- Life
- Lightning Surge
- Overload
- Parametric Tests
- Power-Cross
- Power Cycling
- Ring Wave
- R-T
- S-Parameter Measurements (Insertion Loss, Isolation, Reflection)
- Short Circuit
- Step Current
- Surface Resistivity
- Surge
- TDR (Eye Diagram)
- Telecom
- Thermal Cut-Off
- Time-to-Trip
- TLP
- Transient
- Trip Cycle
- Trip Endurance
- Voltage Drop

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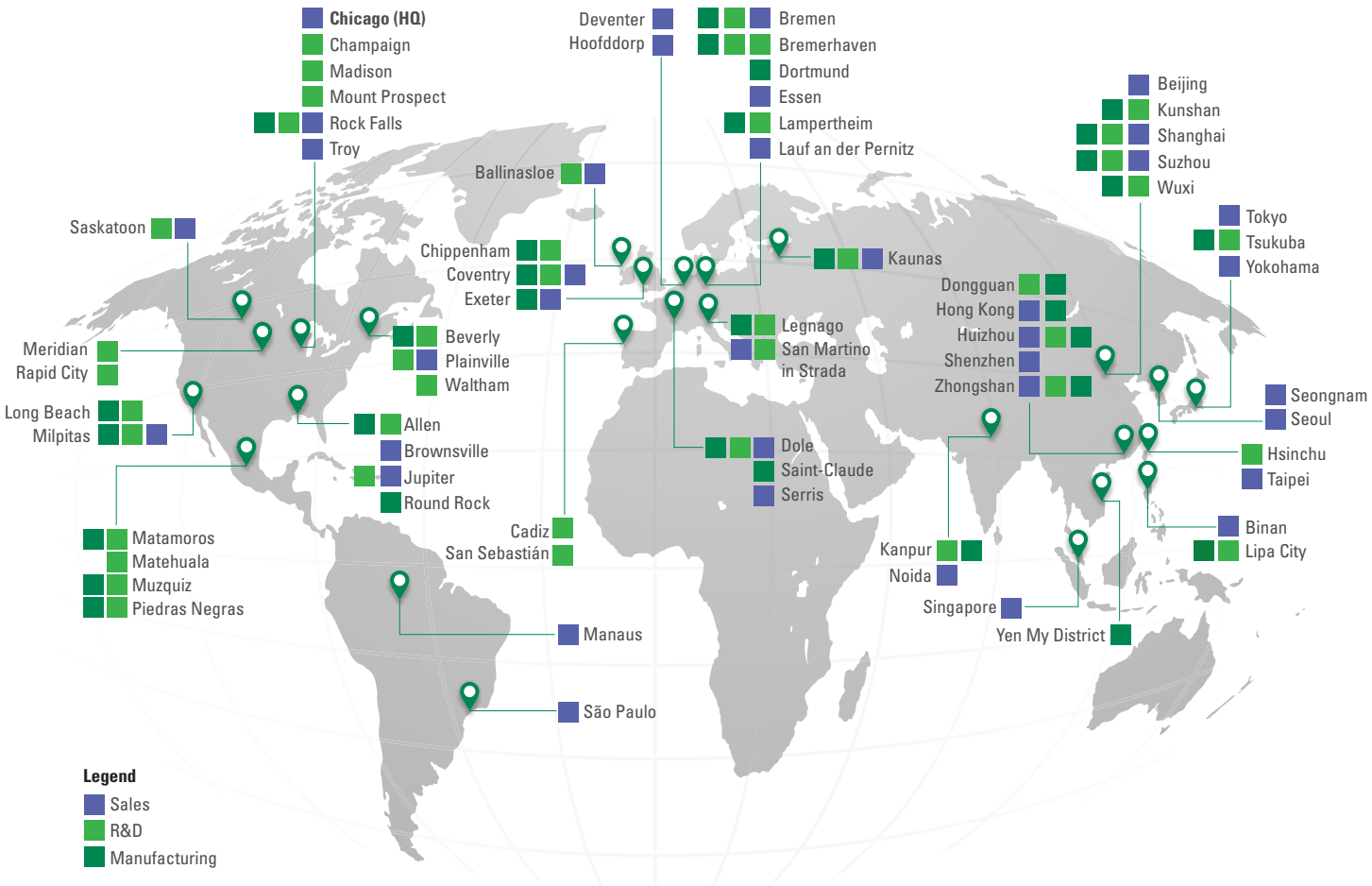
LOCAL RESOURCES FOR A **GLOBAL** MARKET



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