



**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.

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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](http://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;<br>0402;<br>0603                                                                       | 0402;<br>0603                                                                                             | 0402;<br>0603;<br>0805;<br>1206                                                    | 0805 (SOD323), 0603 (SOD523);<br>0402 (SOD882, SOD-883, SOD723);<br>0201 (Flipchip; $\mu$ DFN-2);<br>01005 (Flipchip); DFN1610                                                                                                                                      |
| Array Options             | SOT23                                                                                        | —                                                                                                         | 1206                                                                               | SOIC-8; SOT143; SOT23, SC70, SOT523;<br>SOT553; SOT563; SOT723; SOT953;<br>MSOP 8; MSOP 10; $\mu$ DFN; TDFN; DFN-3810                                                                                                                                               |
| Applications and Circuits | USB2.0; FireWire 1394;<br>HDMI/USB3.0; USB3.1;<br>Type-C; GPIO; keypad/switch;<br>RF antenna | USB2.0; FireWire 1394; HDMI/<br>USB3.0; USB3.1; Type-C; GPIO;<br>keypad/switch- RF antenna;<br>Automotive | Keypad/switch, audio;<br>analog video; USB1.1; RS232                               | Keypad/switch; USB1.1; USB2.0; USB3.0;<br>USB4.0; LVDS; thunderbolt; audio;<br>analog video; FireWire 1394; HDMI; Ethernet;<br>MMC interface; LCD module; RS232; RS485;<br>CAN; LIN; Automotive (CAN; LIN; Ethernet;<br>GMSL; FPD-link; Open Alliance; Daisy Chain) |
| Key Advantages            | Lowest capacitance                                                                           | Lowest capacitance;<br>excellent ESD performance                                                          | Lowest cost;<br>broad discrete offering                                            | No wear-out mechanism and clamp voltages;<br>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  $\mu$ A–1.5  $\mu$ A)
- 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 | ☒☒☒     | ☒☒☒     | ☒☒☒s      | ☒ms      |
| ESD      | ☒☒☒     | ☒☒☒     | ☒☒☒s      | ☒☒☒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

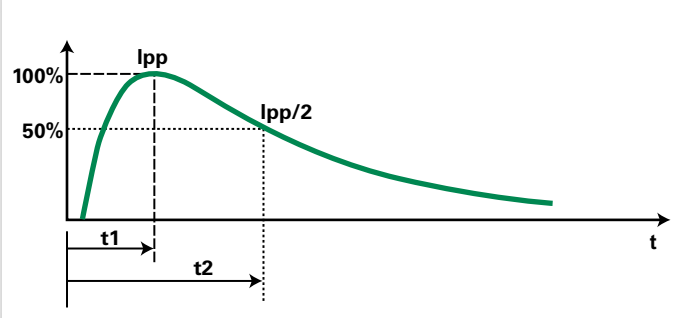
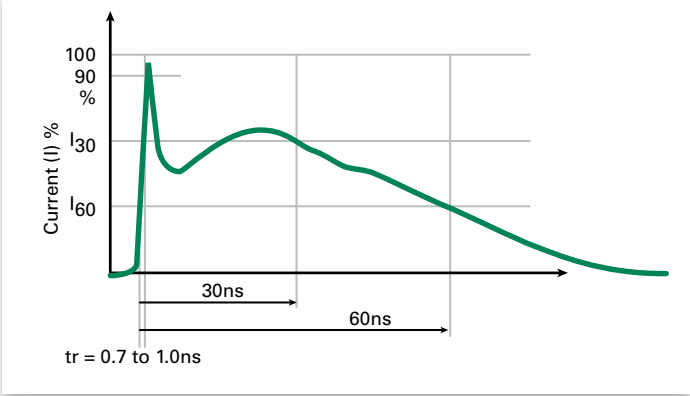


Figure 2. ESD Test Waveform



The exponential rise time of lightning is in the 1.2  $\mu$ sec to 10  $\mu$ sec range (essentially 10% to 90%), and the duration ranges from 50  $\mu$ sec to 1000  $\mu$ sec. (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:

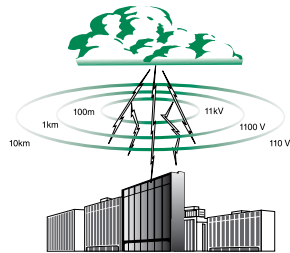
|                               |                                        |
|-------------------------------|----------------------------------------|
| Walking across a carpet:      | 35 kV @ RH = 20%;<br>1.5 kV @ RH = 65% |
| Walking across a vinyl floor: | 12 kV @ RH = 20%;<br>250 V @ RH = 65%  |
|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

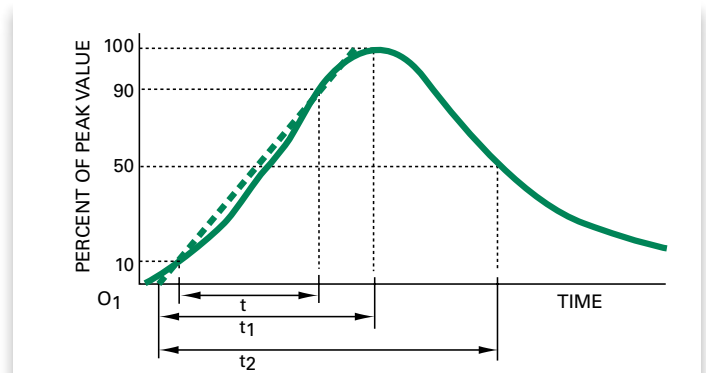
Lightning strikes create magnetic fields that can induce transients of large magnitude in nearby electrical cables.



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 connector 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.

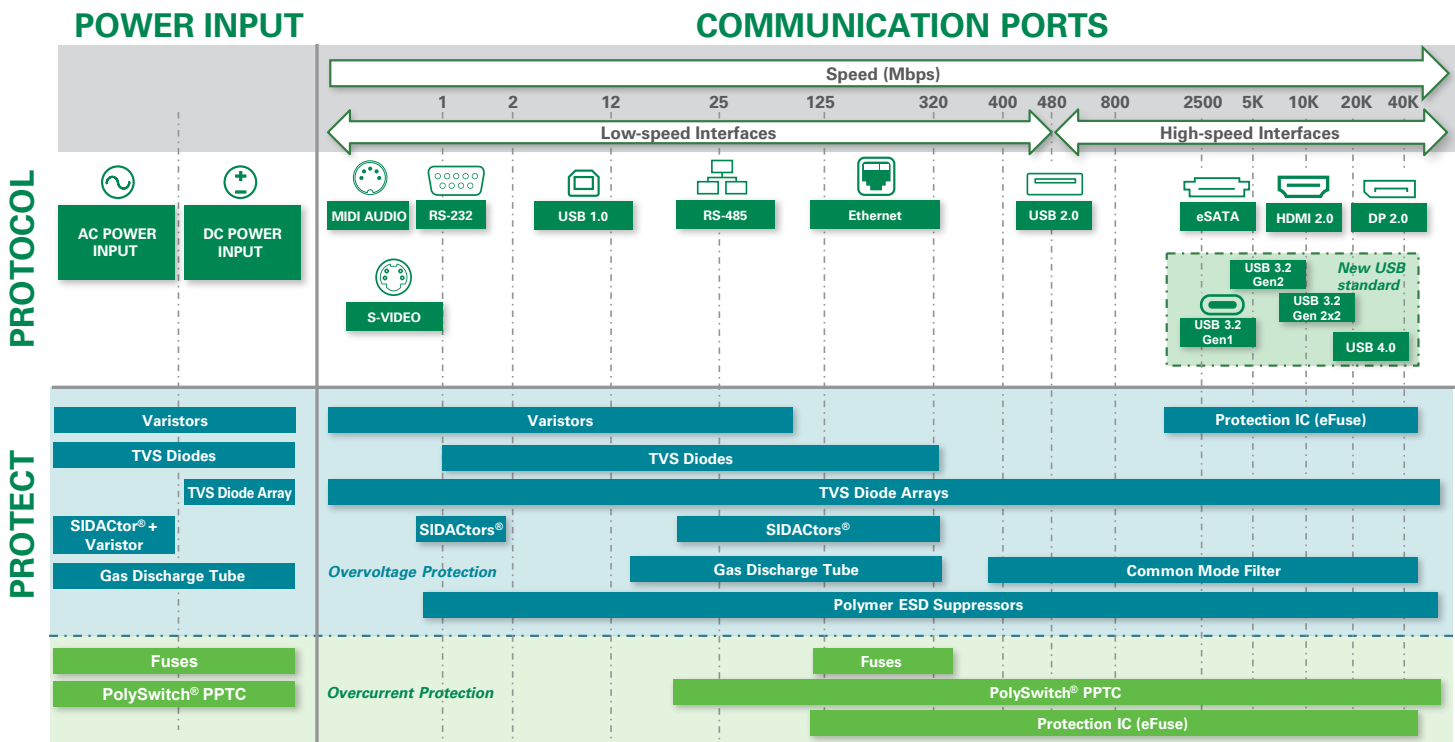
Capacitance is the characteristic of concern. High-capacitance suppression devices tend to add signal distortion as signal frequencies increase, whereas low-capacitance devices maintain signal integrity at high data rates.

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



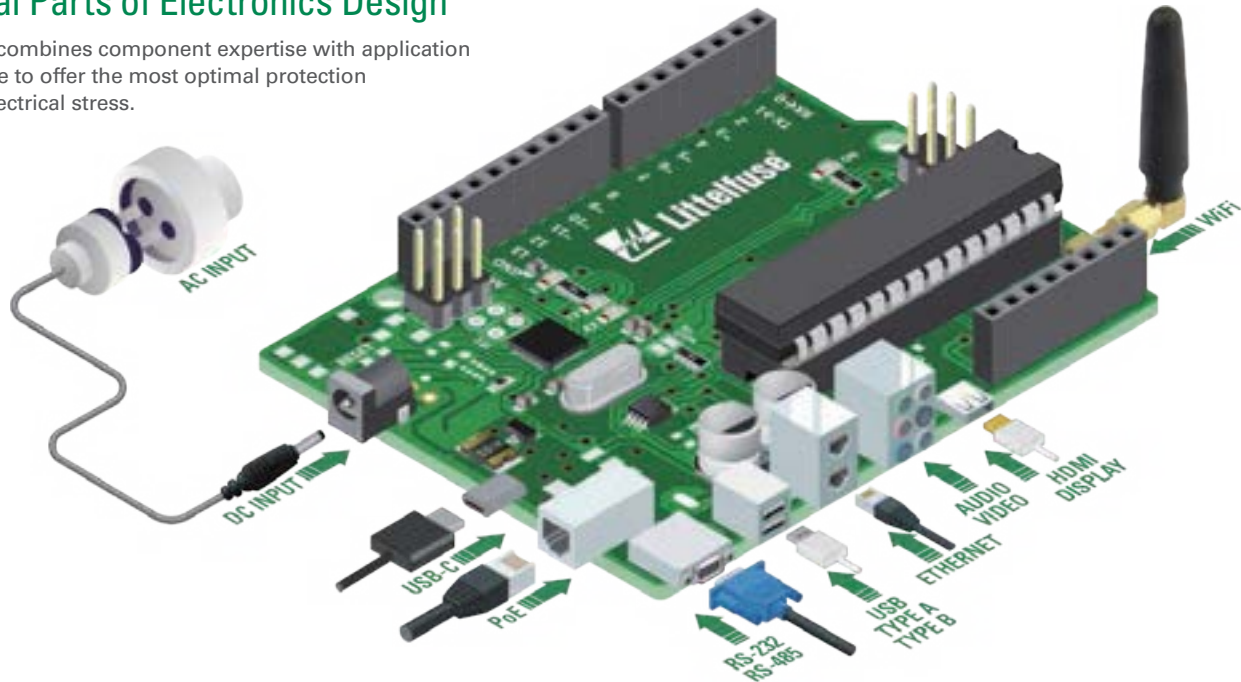
The information above is intended to help circuit designers determine which Littelfuse ESD suppressors are applicable for given data protocols and data rates. Other key characteristics, such as clamping voltage, leakage current, number of lines of protection and ESD capabilities, must be considered as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

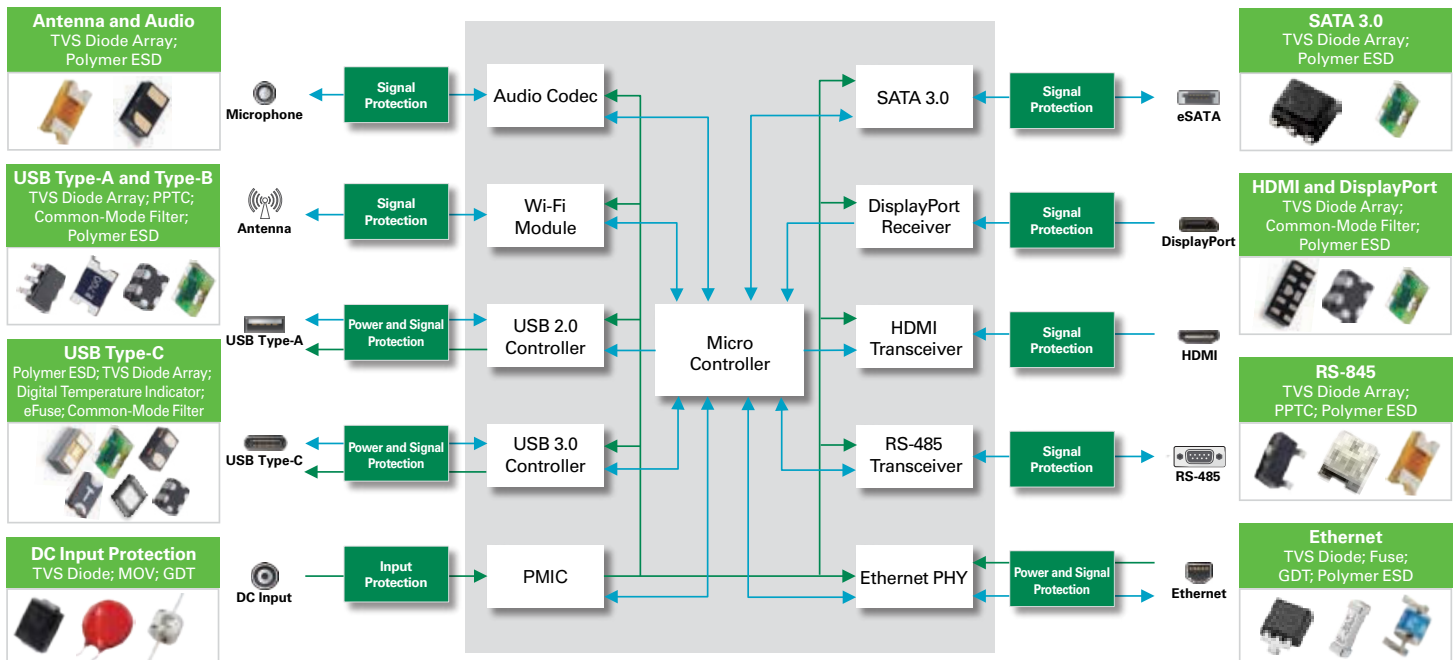
## Solutions for Power and Communication Ports

### 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.



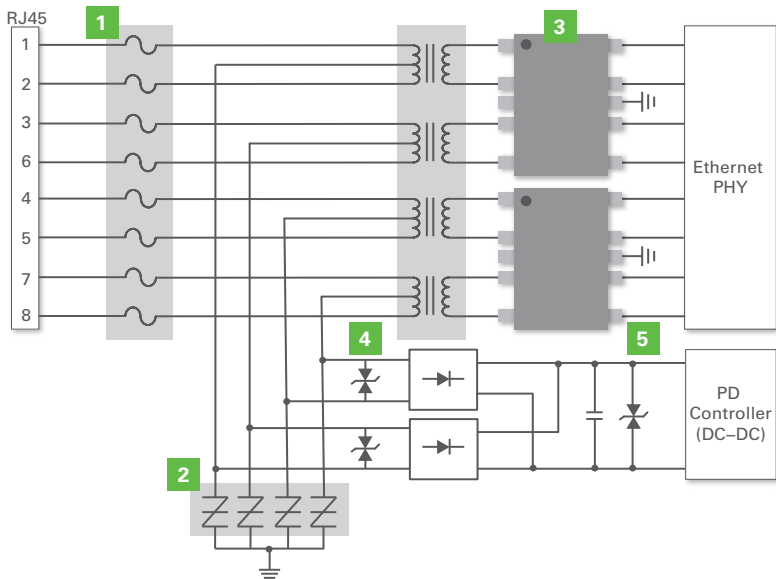
### Recommended Solutions for General Port Protection



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.



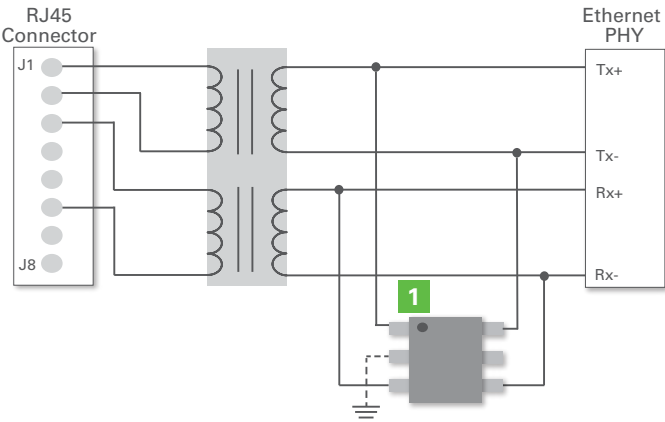
|   | Technology                       | Function in Application                                                               | Series Name | Features                                                                                       |
|---|----------------------------------|---------------------------------------------------------------------------------------|-------------|------------------------------------------------------------------------------------------------|
| 1 | Fuse (x8)                        | Protects network from overcurrents and lightning surges                               | TeleLink    | Available in 8-pin configuration, fuse design specifically for high-speed telecom applications |
| 2 | SIDACTor® (x4)<br>OR<br>GDT (x4) | Protects sensitive equipment from overvoltage surges                                  | TeleLink    | Low inductance, low profile, and high voltage rating                                           |
|   |                                  | Protects sensitive equipment from overvoltage surges                                  | TeleLink    | Excellent stability, multiple pulse capability, and ultra-small size                           |
| 3 | TVS Diode Array (x2)             | Protects network from overvoltage surges and lightning strikes                        | TeleLink    | Available in 8-pin configuration, low inductance, and high voltage rating                      |
|   |                                  | Protects network from overvoltage surges and lightning strikes                        | TeleLink    | Available in 8-pin configuration, low inductance, and high voltage rating                      |
|   |                                  | Protects network from overvoltage surges and lightning strikes                        | TeleLink    | Available in 8-pin configuration, low inductance, and high voltage rating                      |
| 4 | TVS Diode (x2)                   | Protects sensitive electronic equipment from overvoltage surges and lightning strikes | TeleLink    | Available in 8-pin configuration, low inductance, and high voltage rating                      |
| 5 | TVS Diode (x1)                   | Protects sensitive electronic equipment from overvoltage surges and lightning strikes | TeleLink    | Available in 8-pin configuration, low inductance, and high voltage rating                      |

## Ethernet Port Protection Solutions

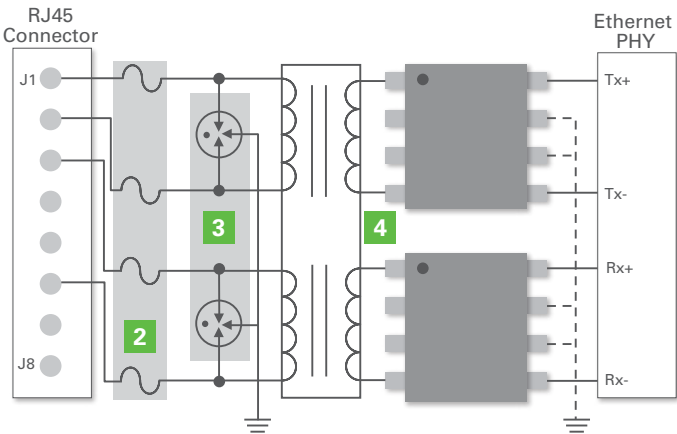
This page contains examples of ESD implementation and lightning suppression for Ethernet ports (RJ-45 connectors). Note that speeds of 1 Gbps or greater will require two additional twisted pairs and that the diode array solution should be replicated. The diagrams below illustrate typical implementations 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                          | ESD010-01   | Low capacitance, low leakage current, small footprint, fast response time          |
| 2 | Fuse            | Overcurrent protection                       | F100        | Surface mount, self-resetting, fuse designed specifically for telecom applications |
| 3 | GDT             | Lightning protection through the use of GDTs | GDT010-01   | High surge voltage, low capacitance, low inductance                                |
| 4 | TVS Diode Array | Protection from ESD                          | ESD010-01   | Low capacitance, low leakage current                                               |

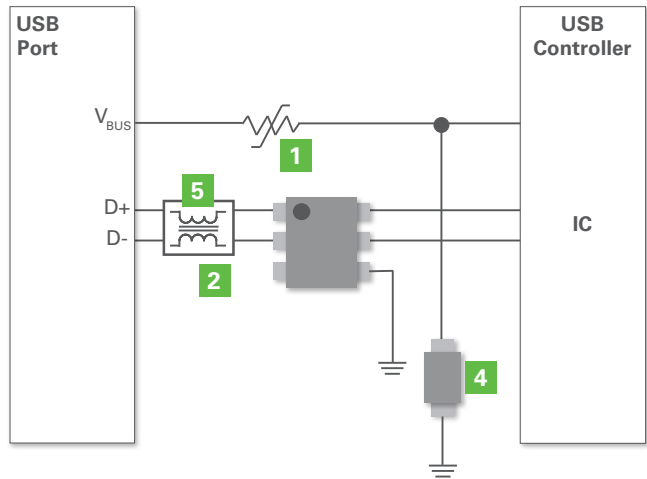
Peripheral/Storage Data  
Port Protection

USB Type-A and Type-B  
Protection Solutions

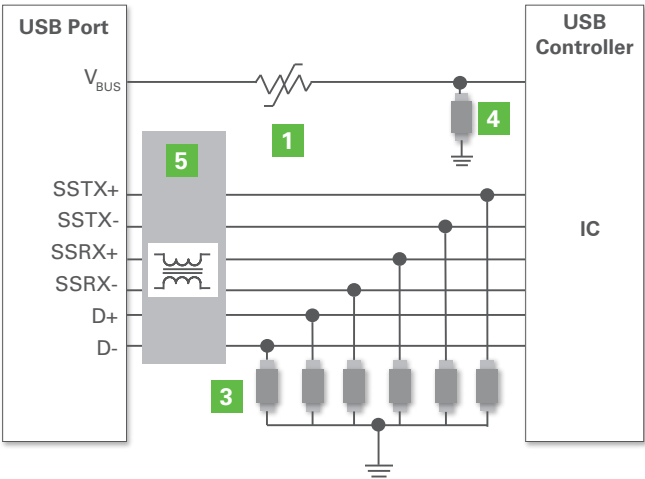
This page details examples of ESD suppression for high-speed data ports such as USB2.0 and USB3.2 Gen 1x1. For additional design examples, guidance, and application assistance, please contact Littelfuse.



USB 2.0 (480 Mbps)



USB 3.2 Gen 1x1 (5 Gbps)



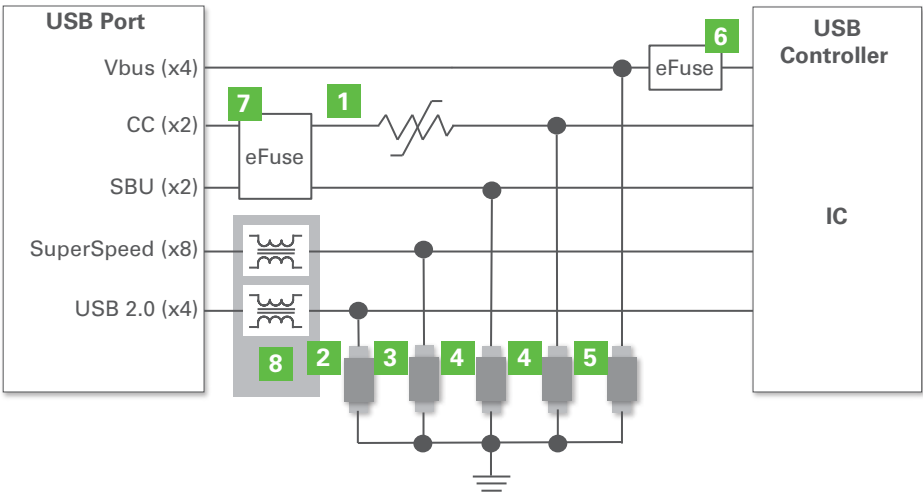
|   | Technology                                     | Function in Application                           | Series Name                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Features                                                          |
|---|------------------------------------------------|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| 1 | PPTC                                           | Protects ICs from overvoltage and overtemperature | LoXn                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | It has a low resistance and a small footprint                     |
| 2 | TVS Diode Array                                | Protection of lines from ESD                      | 6x1, 6x2, 6x3, 6x4, 6x5, 6x6, 6x7, 6x8, 6x9, 6x10, 6x11, 6x12, 6x13, 6x14, 6x15, 6x16, 6x17, 6x18, 6x19, 6x20, 6x21, 6x22, 6x23, 6x24, 6x25, 6x26, 6x27, 6x28, 6x29, 6x30, 6x31, 6x32, 6x33, 6x34, 6x35, 6x36, 6x37, 6x38, 6x39, 6x40, 6x41, 6x42, 6x43, 6x44, 6x45, 6x46, 6x47, 6x48, 6x49, 6x50, 6x51, 6x52, 6x53, 6x54, 6x55, 6x56, 6x57, 6x58, 6x59, 6x60, 6x61, 6x62, 6x63, 6x64, 6x65, 6x66, 6x67, 6x68, 6x69, 6x70, 6x71, 6x72, 6x73, 6x74, 6x75, 6x76, 6x77, 6x78, 6x79, 6x80, 6x81, 6x82, 6x83, 6x84, 6x85, 6x86, 6x87, 6x88, 6x89, 6x90, 6x91, 6x92, 6x93, 6x94, 6x95, 6x96, 6x97, 6x98, 6x99, 6x100 | Low capacitance and low leakage current for fast signal rise time |
| 3 | TVS Diode Array (6x) OR Polymer ESD Suppressor | Protection of lines from ESD                      | 6x1, 6x2, 6x3, 6x4, 6x5, 6x6, 6x7, 6x8, 6x9, 6x10, 6x11, 6x12, 6x13, 6x14, 6x15, 6x16, 6x17, 6x18, 6x19, 6x20, 6x21, 6x22, 6x23, 6x24, 6x25, 6x26, 6x27, 6x28, 6x29, 6x30, 6x31, 6x32, 6x33, 6x34, 6x35, 6x36, 6x37, 6x38, 6x39, 6x40, 6x41, 6x42, 6x43, 6x44, 6x45, 6x46, 6x47, 6x48, 6x49, 6x50, 6x51, 6x52, 6x53, 6x54, 6x55, 6x56, 6x57, 6x58, 6x59, 6x60, 6x61, 6x62, 6x63, 6x64, 6x65, 6x66, 6x67, 6x68, 6x69, 6x70, 6x71, 6x72, 6x73, 6x74, 6x75, 6x76, 6x77, 6x78, 6x79, 6x80, 6x81, 6x82, 6x83, 6x84, 6x85, 6x86, 6x87, 6x88, 6x89, 6x90, 6x91, 6x92, 6x93, 6x94, 6x95, 6x96, 6x97, 6x98, 6x99, 6x100 | Low capacitance of 6x100 for fast signal rise time                |
|   |                                                |                                                   | PulseGuard                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Low capacitance and low leakage current for fast signal rise time |
| 4 | TVS Diode Array                                | Protection of ICs from ESD                        | 6x1, 6x2, 6x3, 6x4, 6x5, 6x6, 6x7, 6x8, 6x9, 6x10, 6x11, 6x12, 6x13, 6x14, 6x15, 6x16, 6x17, 6x18, 6x19, 6x20, 6x21, 6x22, 6x23, 6x24, 6x25, 6x26, 6x27, 6x28, 6x29, 6x30, 6x31, 6x32, 6x33, 6x34, 6x35, 6x36, 6x37, 6x38, 6x39, 6x40, 6x41, 6x42, 6x43, 6x44, 6x45, 6x46, 6x47, 6x48, 6x49, 6x50, 6x51, 6x52, 6x53, 6x54, 6x55, 6x56, 6x57, 6x58, 6x59, 6x60, 6x61, 6x62, 6x63, 6x64, 6x65, 6x66, 6x67, 6x68, 6x69, 6x70, 6x71, 6x72, 6x73, 6x74, 6x75, 6x76, 6x77, 6x78, 6x79, 6x80, 6x81, 6x82, 6x83, 6x84, 6x85, 6x86, 6x87, 6x88, 6x89, 6x90, 6x91, 6x92, 6x93, 6x94, 6x95, 6x96, 6x97, 6x98, 6x99, 6x100 | Low leakage current of 6x100 for fast signal rise time            |
| 5 | Common-Mode Noise Filter                       | Suppresses common-mode noise and ESD protection   | LCX, LCX2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | It has a low impedance and a fast signal rise time                |

# 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 | Monitors operating temperature of connected components | set000      | Full compliance with USB specification                                             |
| 2 | TVS Diode Array               | Protects against static discharge events               | ESD000      | Low footprints, low inductance, low dynamic resistance                             |
| 3 | TVS Diode Array               | Protects against static discharge events               | ESD000      | Low parasitic capacitance                                                          |
| 4 | TVS Diode Array               | Protects against static discharge events               | ESD000      | High-voltage, low-leakage, low-footprint                                           |
| 5 | TVS Diode                     | Protects against static discharge events               | ESD000      | Low pulse-to-pulse recovery time, low capacitance, low inductance                  |
| 6 | eFuse                         | Protects against overcurrent and overvoltage           | Littelfuse  | Programmable current limit settings, integrates multiple protection settings       |
| 7 | eFuse                         | Monitors and controls power to components              | Littelfuse  | Monitors first response time, integrates protection settings, integrates functions |
| 8 | Common-Mode Noise Filter      | Suppresses common-mode noise, protects from EMI        | Littelfuse  | Integrates common-mode and differential functions, low cutoff frequency            |

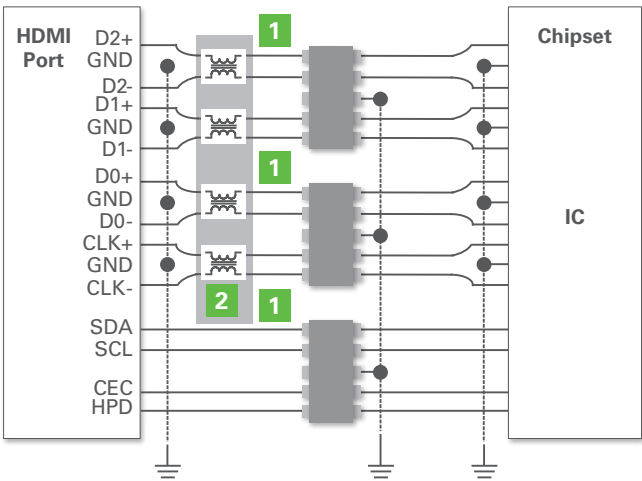
Peripheral/Storage Data  
Port Protection

HDMI Port, DisplayPort, and eSATA Port  
Protection Solutions

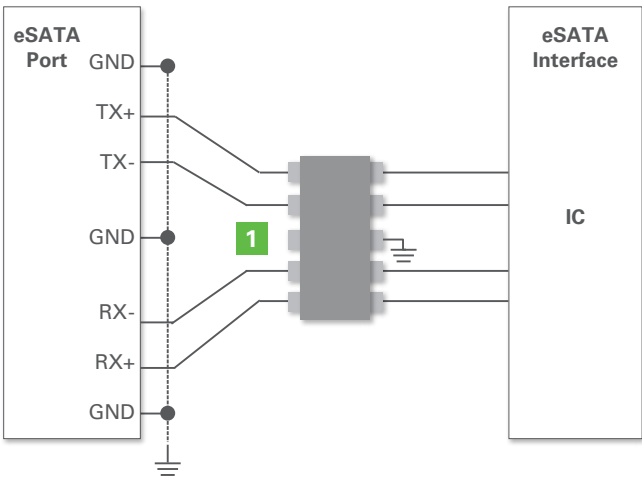
This page lists examples of ESD suppression for high-speed data ports such as High-Definition Multimedia Interface (HDMI), DisplayPort, and eSATA. For additional design examples, guidance, and application assistance, please contact Littelfuse.



HDMI and DisplayPort

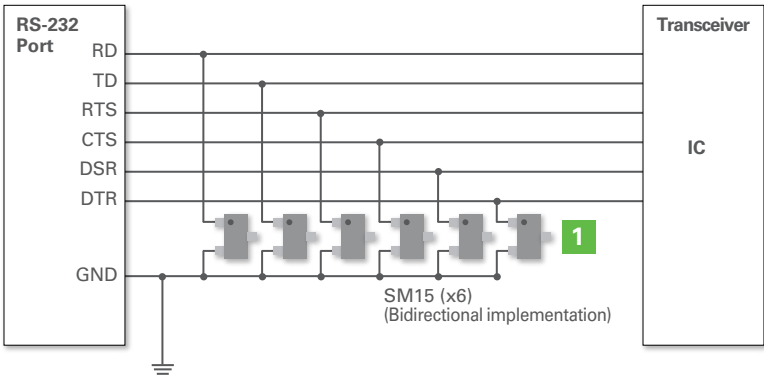


eSATA



|   | Technology                                         | Function in Application                    | Series Name | Features                                                                      |
|---|----------------------------------------------------|--------------------------------------------|-------------|-------------------------------------------------------------------------------|
| 1 | TVS Diode Array<br>OR<br>Polymer ESD<br>Suppressor | Protection of signal lines from            | ESD010-01   | Low capacitance of 1pF<br>Low clamping voltage of 10V<br>Must standstill foot |
|   |                                                    |                                            | ESD010-02   | Low capacitance of 1pF<br>Low clamping voltage of 10V<br>Must standstill foot |
| 2 | Common-Mode<br>Noise Filter                        | Reduces common mode noise<br>Protects from | LF010-01    | Highly efficient<br>Common mode noise<br>functionality cutoff frequency       |

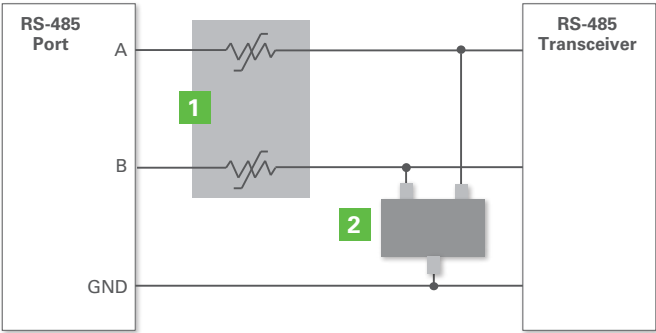
RS-232 Port Protection Solutions



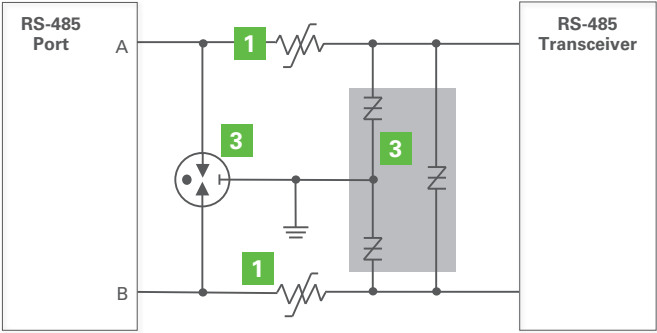
|   | Technology      | Function in Application         | Series Name | Features                                                             |
|---|-----------------|---------------------------------|-------------|----------------------------------------------------------------------|
| 1 | TVS Diode Array | Protection of signal lines from | ESD10E01    | Low dynamic resistance of 100Ω or less, low capacitance 10pF or less |
|   |                 |                                 | ESD10E02    | Low dynamic resistance of 100Ω or less, low capacitance 10pF or less |

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 overcurrents                                      | ESD10E01                | Available in various form factors and resistive capacitance                                                |
| 2 | TVS Diode Array<br>OR<br>Polymer ESD Suppressor | Protects from electrostatic discharge induced surges                                         | ESD10E01                | Excellent resistance for high-voltage ESD immunity of 8kV to 15kV                                          |
|   |                                                 |                                                                                              | PulseGuard<br>TimeGuard | Excellent capacitance of less than 10pF or less, low inductance                                            |
| 3 | GDT + SIDActor®                                 | Protects against lightning induced surges and voltage to increase dissipation until it fails | ESD10E01<br>ESD10E02    | At the end of life, the form factor, capacitance, and resistance loss of the overvoltage protection device |
|   | SIDActor®                                       | Protection against lightning                                                                 | ESD10E01                | Available of 10 surges above 1000V Level 1<br>Excellent basic and surge protection performance             |

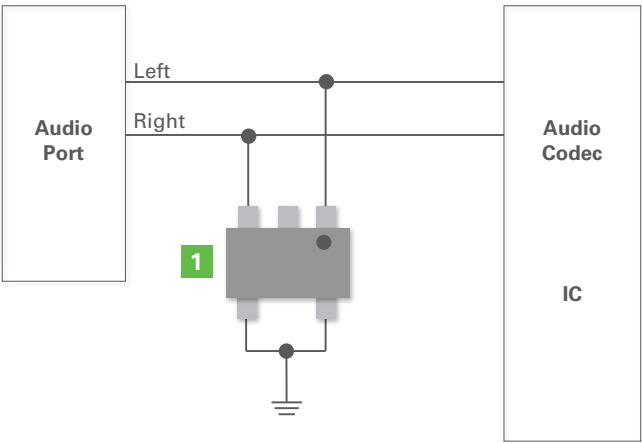
Entertainment Electronics  
Port Protection

Audio and Video Line  
Protection Solutions

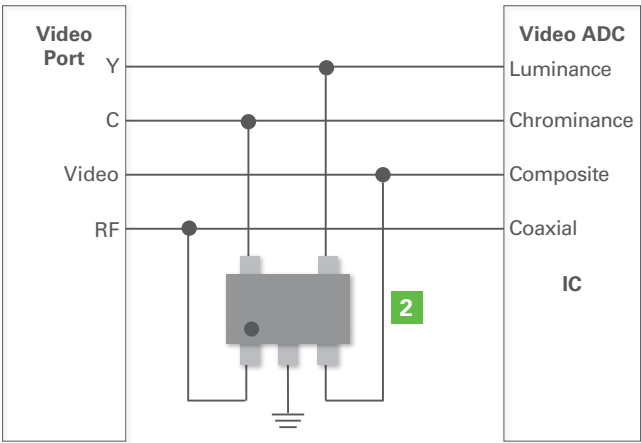
Examples of ESD suppression for ports common in entertainment electronics are listed here. For additional design examples, guidance, and application assistance, please contact Littelfuse.



Audio Line



Video Line



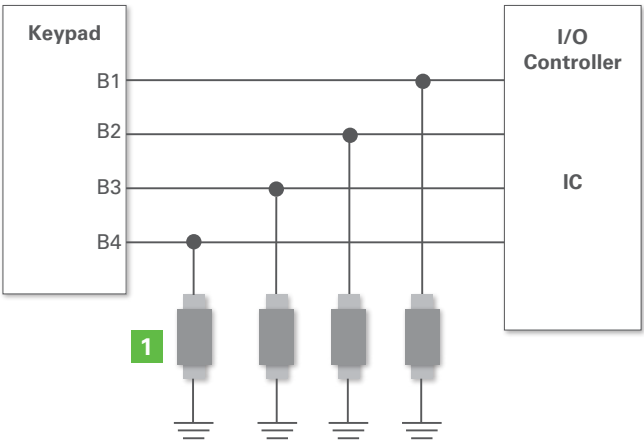
|   | Technology                                                                   | Function in Application               | Series Name | Features                                                 |
|---|------------------------------------------------------------------------------|---------------------------------------|-------------|----------------------------------------------------------|
| 1 | TVS Diode Array<br>OR<br>Polymer ESD Suppressor<br>OR<br>Multilayer Varistor | Protects audio codecs from ESD damage | 16V05       | Low capacitance of 100pF or less, current of 1000A, 100V |
|   |                                                                              |                                       | PulseGuard  | 100V or 1000V, 100pF or less, current of 1000A, 100V     |
|   |                                                                              |                                       | 16V05       | 100V or 1000V, 100pF or less, current of 1000A, 100V     |
| 2 | TVS Diode Array<br>OR<br>Polymer ESD Suppressor<br>OR<br>Multilayer Varistor | Protects video ADCs from ESD damage   | 16V05       | Low capacitance of 100pF or less, current of 1000A, 100V |
|   |                                                                              |                                       | PulseGuard  | 100V or 1000V, 100pF or less, current of 1000A, 100V     |
|   |                                                                              |                                       | 16V05       | 100V or 1000V, 100pF or less, current of 1000A, 100V     |

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

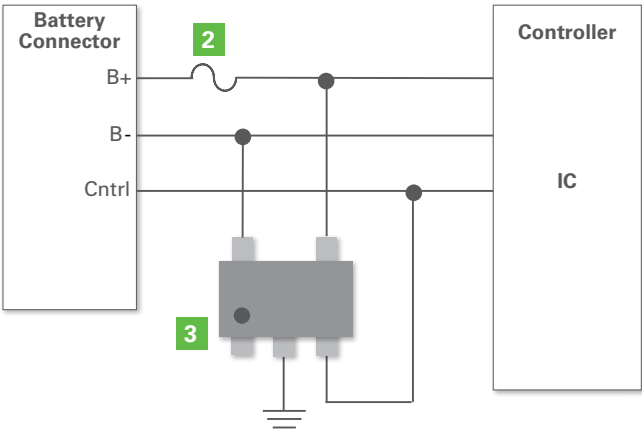
The following are examples of ESD suppression for power buses and control lines in entertainment electronics. For additional design examples, guidance, and application assistance, please contact Littelfuse.



Keypad Protection



Battery Packs Protection



|   | Technology          | Function in Application                                                          | Series Name | Features                                 |
|---|---------------------|----------------------------------------------------------------------------------|-------------|------------------------------------------|
| 1 | Multilayer Varistor | Protects sensitive electronic circuits from electrostatic discharge (ESD) damage | MLV Series  | High energy dissipation, low capacitance |
| 2 | Fuse                | Protects power lines from overcurrent                                            | Microfuse   | Small footprint, high reliability        |
| 3 | TVS Diode Array     | Protects power lines from electrostatic discharge (ESD) damage                   | ESD Series  | Low capacitance, fast response time      |

Automotive Electronics  
Port Protection

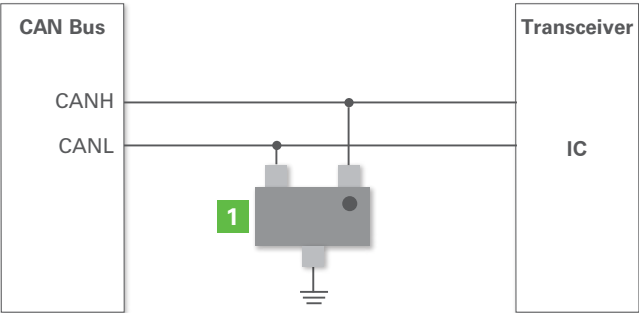
CAN/LIN BUS and SIM/μSIM Socket  
Protection Solutions

Automotive AEC-Q101-Qualified ESD Protection

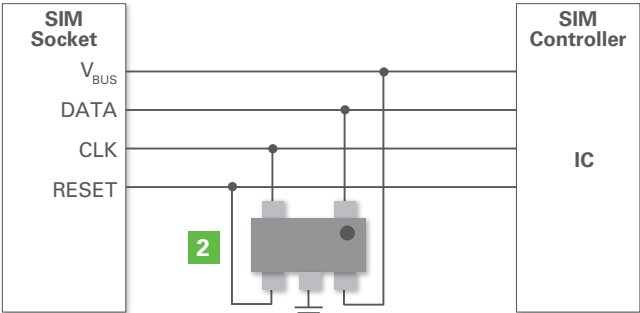
This page contains examples of ESD suppression for automotive electronics. For additional design examples, guidance, and application assistance, please contact Littelfuse.



CAN/LIN BUS



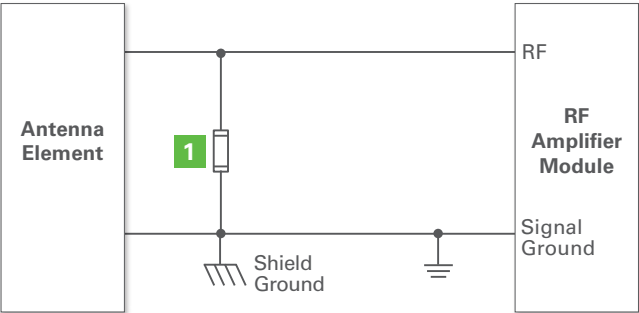
SIM/μSIM Socket



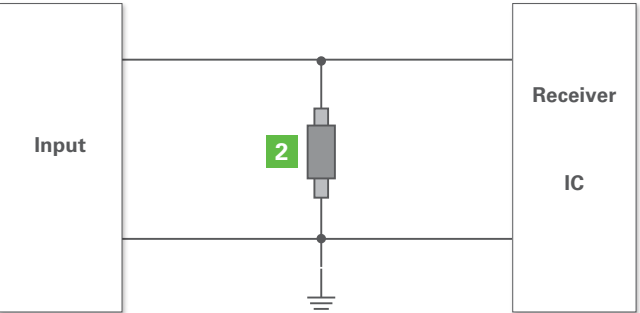
|   | Technology      | Function in Application | Series Name | Features                                         |
|---|-----------------|-------------------------|-------------|--------------------------------------------------|
| 1 | TVS Diode Array | Protects sensitive ICs  | ESD10V010   | Low capacitance, low inductance, high efficiency |
| 2 | TVS Diode Array | Protects sensitive ICs  | ESD10V010   | Low capacitance, low inductance, high efficiency |

Antenna and Sensor Input Protection Solutions

Antennas



Sensor Inputs



|   | Technology             | Function in Application | Series Name | Features                                         |
|---|------------------------|-------------------------|-------------|--------------------------------------------------|
| 1 | Polymer ESD Suppressor | Protects sensitive ICs  | ESD10V010   | Low capacitance, low inductance, high efficiency |
| 2 | TVS Diode Array        | Protects sensitive ICs  | ESD10V010   | Low capacitance, low inductance, high efficiency |

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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
- Keypress 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 Solenoid 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

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.

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to Download



### Sensing Products Selection Guide

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.

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### Power Semiconductor and IC Selection Guide

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

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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.

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

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[Littelfuse.com](http://Littelfuse.com)

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## Global Lab Capabilities



You need to be certain that your products live up to the most stringent standards for performance, reliability and safety before you can move forward. At Littelfuse, we give you access to the latest technology and expertise to help you to make the right design decisions before you commit to costly tests. Simulate the most demanding conditions, evaluate the results and move forward.

### 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

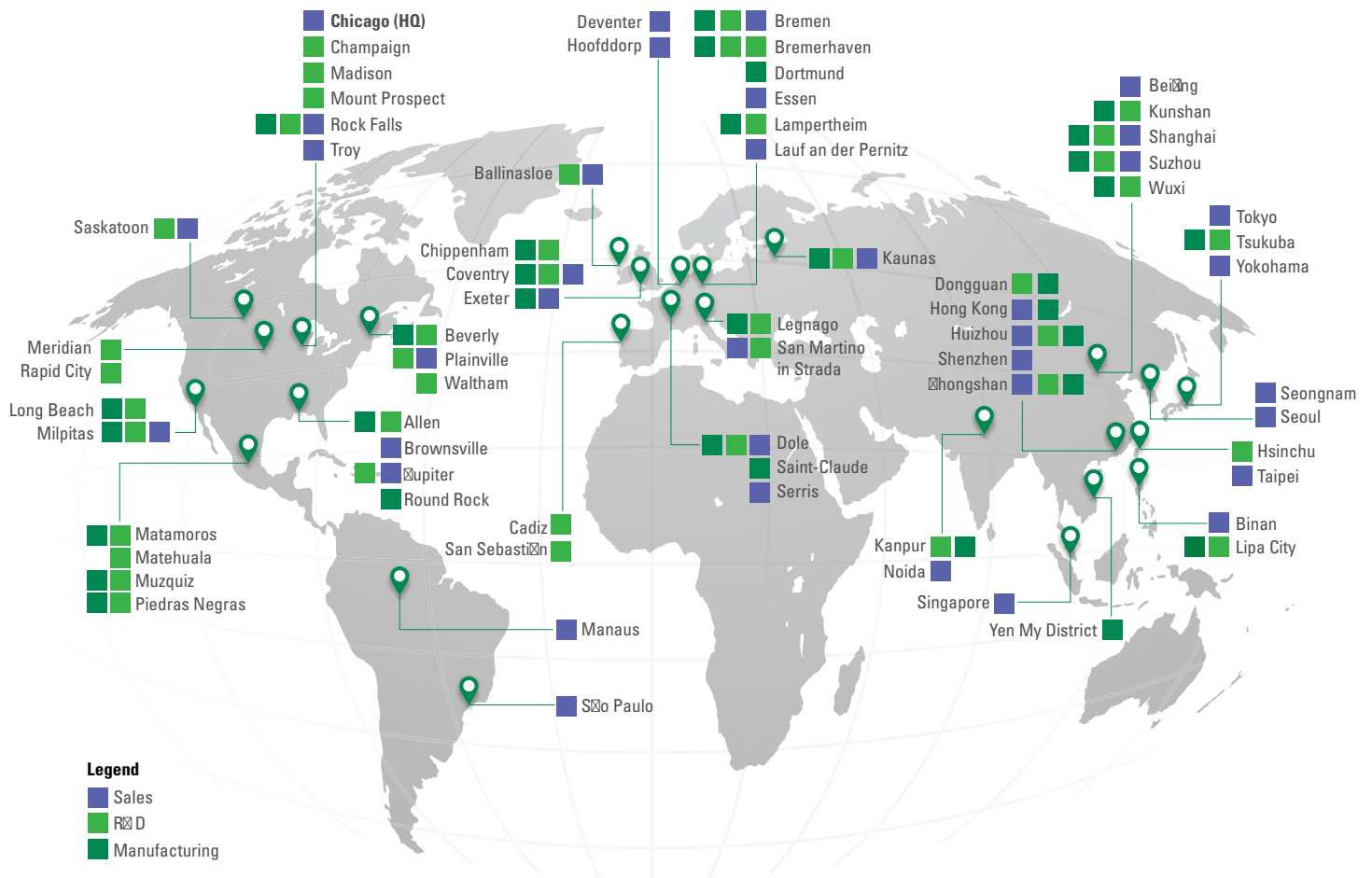
#### Electrical

- 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





## LOCAL RESOURCES FOR A GLOBAL MARKET



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Expertise Applied | Answers Delivered