

USB 2.0 and USB 3.0 Circuit Protection Considerations for Hard Disc Drives

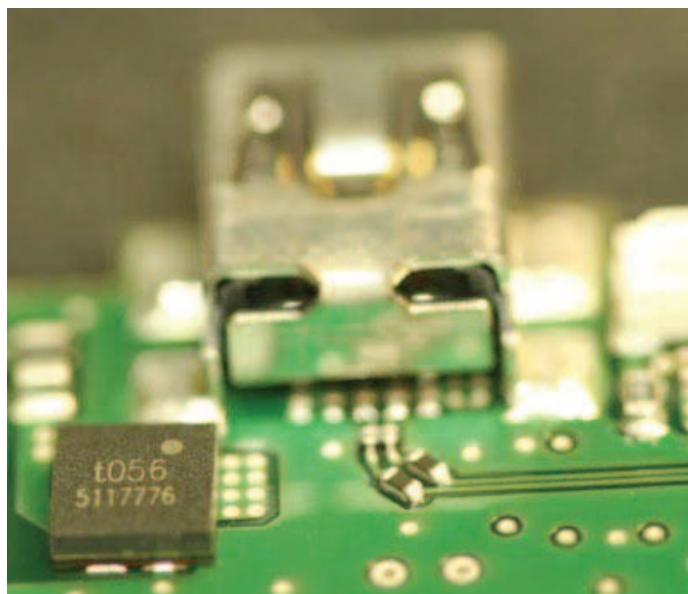
Although power via USB has been in use for some time, the growing use of USB-based external Hard Disc Drives (HDDs), including external-powered-type, USB-powered-type and now the adoption of Solid State Drives (SSDs), poses new challenges in USB port protection designs. This is true not only for end applications, such as the HDD/SDD, but also for the host USB applications that provide power and data via USB.

Continuing improvements in the 2.5" HDD designs include decreasing draw on power and increasing data storage capacity. The majority of HDDs in use today are connected to desktop/laptop computers and USB hubs, although they are finding wider use in gaming units and automotive infotainment systems.

External HDDs can be powered by either an external power supply or by a host USB port. The USB specification allows users to plug and unplug (hot plug) USB devices while the PC or end USB host is in operation. During a hot connect or disconnect the inrush current from a USB hub to the USB device can create both current and voltage transients that are orders of magnitude above the operating power-consumption specification of a USB-connected device.

Overcurrent Protection Considerations

Overcurrent protection for USB-powered devices is required per UL60950 and the USB specification, which requires that overcurrent protection be used in the design of USB power delivery. In a short circuit situation external to the USB host port the overcurrent protection device limits the amount of current that the USB device can draw from the USB host port. Overcurrent protection should not be used to enforce the current limits USB devices are required to meet, which is 500mA for USB 2.0 and 950mA for USB 3.0. When designing in USB port protection the protection devices also must not limit the input power requirements of the connected device.



The USB 3.0 standard dramatically increases the amount of energy that can flow to a USB connected device - to a minimum current rating of 1.5A. High-current applications, such as USB HDD devices, require more reliable and robust circuit protection to help prevent damage caused by overvoltage and overcurrent conditions.

When selecting the proper overcurrent device for USB-supplied power, the designer must consider conditions such as start-up inrush current and supply voltage when the application is connected. Improper selection may cause voltage droops or unwanted nuisance tripping; and, in the case of fuse protection, may result in a permanently open circuit. A popular solution for meeting USB safety requirements is using a polymeric positive temperature coefficient (PPTC) device for overcurrent protection. A major benefit of PPTC devices in host/device USB applications is their ability to reduce the potential of nuisance tripping that can be caused by inrush currents.

To ensure that the PPTC device functions properly, the power carrying trace or traces should be designed to handle twice the current of the protection device so that the trace itself does not become the fusing element. Figure 1 shows the placement of a PPTC device in the circuit, which should be between the power source and the bypass capacitor. Placing the protection device between the USB port and bypass capacitor could indeed add more Equivalent Series Resistance (ESR) and limit the effectiveness of the overcurrent protection device.

Note: Increasing the number of ports raises the energy absorbing-capacity requirement of the PolySwitch device.

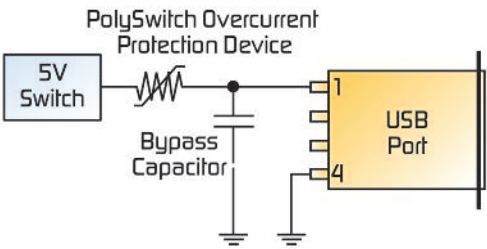


Figure 1: Typical PolySwitch PPTC device overcurrent protection solution for USB port applications.

Overvoltage Protection Considerations

Overvoltage events can be caused by a variety of fault conditions, including user error, poorly regulated third-party power supplies, hot disconnect events, and EMI (electromagnetic interference). The interface and charging systems may also generate negative voltage, resulting in damage to unprotected peripherals.

Placing overvoltage protection devices, such as TE's PolyZen polymer-protected Zener diodes on the power inputs of all USB-powered devices, specifically on the VBUS port, can help protect against damage caused by overvoltage events. Figure 2 shows where the PolyZen device should be placed on a USB HDD design. For protection against ESD-related transients on the data bus, TE's Polymer ESD (PESD) and Silicon ESD (SESD) devices help provide protection against damage from ESD transients of up to 15kV contact surges.

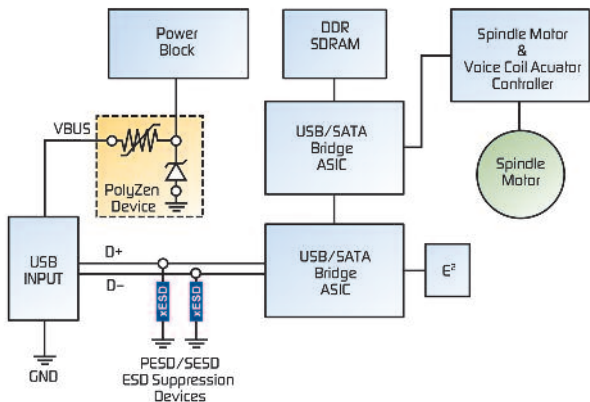
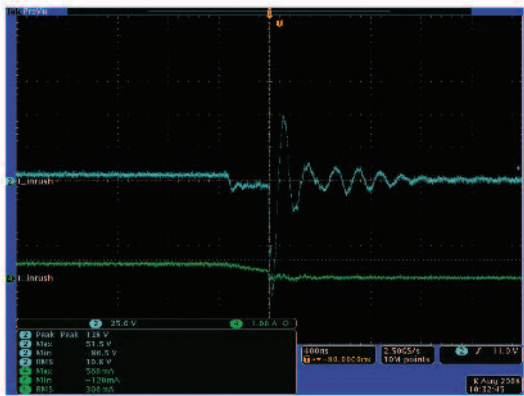


Figure 2: Block Diagram of USB HDD utilizing PolyZen and xESD (e.g., PESD or SESD) devices for USB port power/data line protection.

Recent tests conducted by TE Circuit Protection, as shown in Figures 3a and 3b, demonstrate that higher currents can increase overvoltage risks in ganged ports as well as a single port. Such conditions may arise either from the load or from external faults, including line faults, poor regulation and grounding defects.

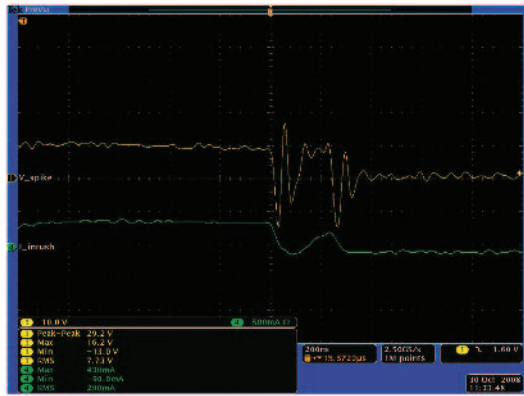
Figure 3a shows an overvoltage condition in a USB 2.0 application. The 4-port ganged configuration is rated at a maximum of 5V and 2A (0.5 A for each port). In the event of an overvoltage fault, and if only a single port is connected, that port may receive the full 10W power instead of a rated 2.5W during a hot connect/disconnect. The resulting voltage spike may be much higher than the rated 5V, enough to damage the IC in the portable device during charging.



1 port = 0.9A max.;
Vpeak = 51.5V

2 ports = 1.8A max.

Figure 3a. Typical overvoltage event in a USB 2.0, 4-port ganged application.



1 port = 0.5A max.;
Vpeak = 16.2V

4 ports = 2A max.

Figure 3b. Typical overvoltage event in a USB 3.0, 2-port ganged application.

Figure 3b shows an overvoltage condition in a USB 3.0 application. Here the 2-port ganged configuration is rated at a maximum of 5V (0.9A per port). Again, if only a single port is connected it may receive up to 9W input power during a hot connect/disconnect event instead of the rated 4.5W. The USB 3.0 specification addresses the issues of overcurrent and overvoltage protection, but because both hosts and peripheral

devices will most often be backward compatible, they must be protected from potential damage caused by overcurrent and overvoltage conditions, regardless of the specification level. Internal testing by TE Circuit Protection has shown that transients caused by hot connects and disconnects, although very short, can reach up to 16V and even exceed 50V levels.

ESD Considerations

To meet and pass EMI requirements for USB port protection, a common mode choke can provide the required noise suppression. PESD and SESD devices are frequently used to help provide robust, reliable ESD suppression. When using PESD and SESD components in conjunction with common mode chokes, proper placement of the ESD devices is on the data lines between the common mode choke and data pins on the USB connector (Figure 4).

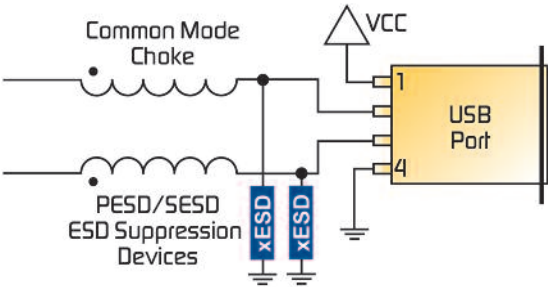


Figure 4: ESD protection device placement with common mode choke option.

Coordinated Protection Solutions

A coordinated protection scheme can be used to enhance protection against overcurrent, overvoltage and ESD transients in USB applications. Figures 5a through 5d

illustrate the circuit protection devices that are recommended by TE for USB 2.0, USB 3.0 and Powered-B connector designs.

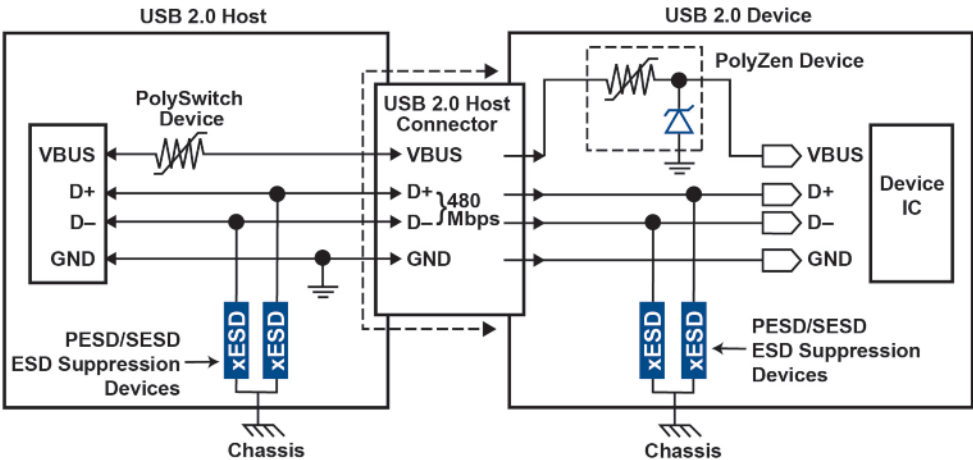


Figure 5a: A coordinated circuit protection approach for USB 2.0.

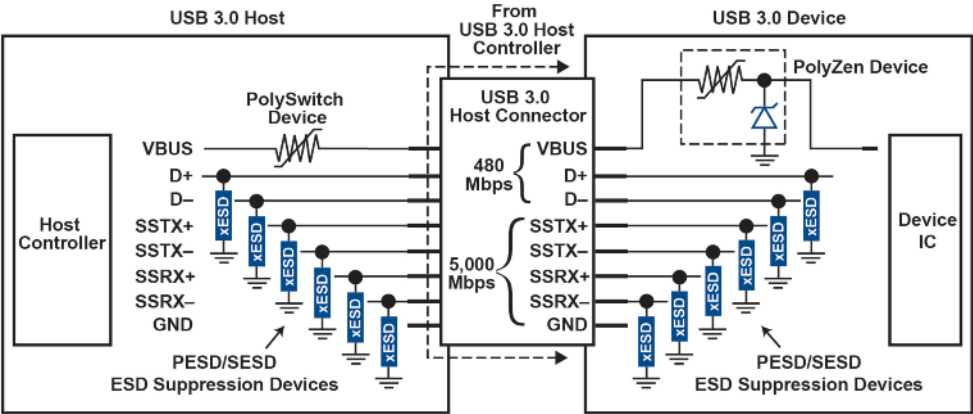


Figure 5b: A coordinated circuit protection approach for USB 3.0.

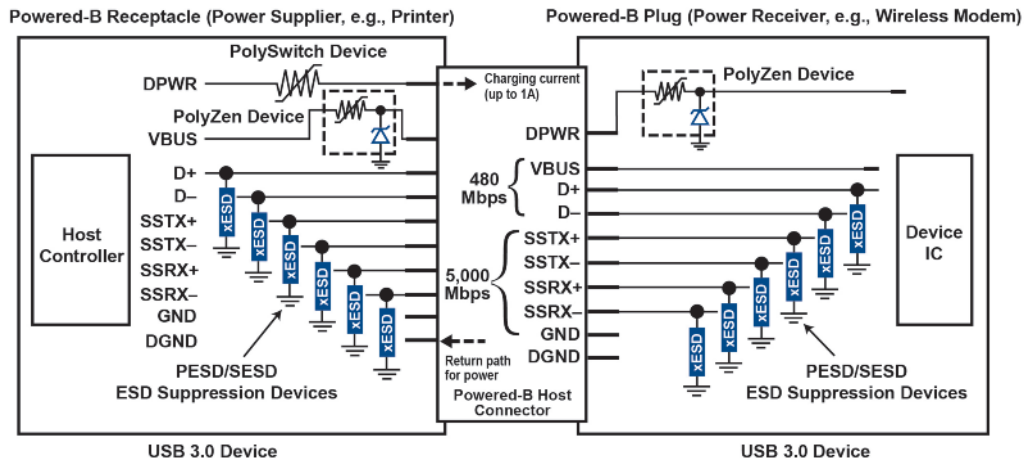


Figure 5c: Bus-powered device with Powered-B plug (e.g., Standard Wireless Modem).

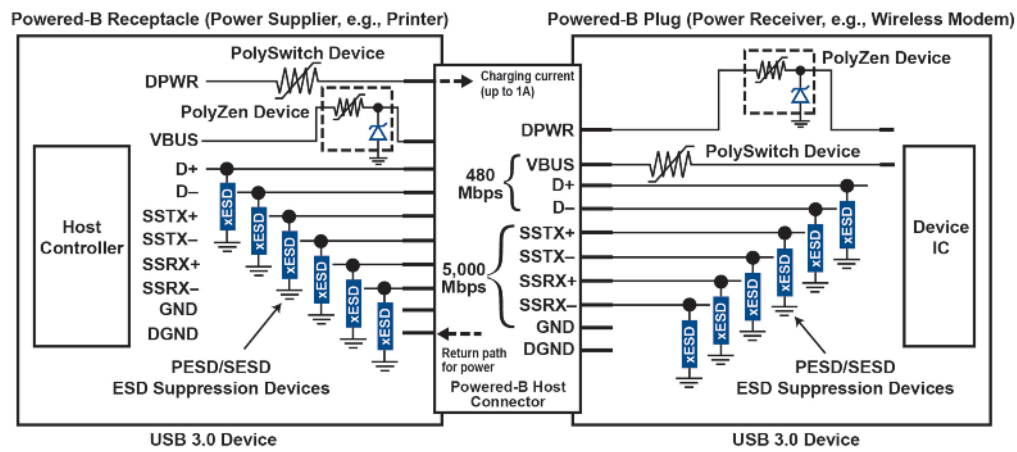


Figure 5d: Battery-powered device charged from DPWR pins and supplying power through VBUS.

Device Recommendations

PolySwitch overcurrent protection devices help designers meet the high-current requirements of the new USB 3.0 or the former USB 2.0 specifications, and provide a simple, space-saving current limiting solution. PESD and SEDS devices provide the low capacitance (typically 0.2pF) required for high-speed data transmission applications, and are available in the electronics industry's most popular form

factors. PolyZen devices help provide protection against damage caused by the use of improper power supplies, voltage transients, and other user-generated errors. These devices offer designers the simplicity of a traditional clamping diode while helping to obviate the need for significant heat sinking in the event of sustained overvoltage.

TE recommends the following devices for ESD protection.

Capacitance	USB 2.0 (2 Data Lines)	USB 3.0 (6 Data Lines)
0.25pF	PESD0603-240	PESD0603-240
0.25pF	PESD0402-140	PESD0402-140
0.5pF	SESD0402S-005-054	SESD0402S-005-054
0.6pF	SESD0201C-006-058	SESD0201C-006-058

TE recommends the following PolySwitch devices for USB overcurrent protection.

		Recommended Parts			
		Ganged Ports per PolySwitch Device			
USB Host Protocol	Max allowed current per port	1	2	3	4
USB 1.0 or 2.0	0.5A	nanoSMDC075F	miniSMDC160F	miniSMDC200F	miniSMDC260F
USB 3.0	0.9A	nanoSMDC150F	miniSMDC260F	N/A	N/A
USB Charging Enabled Port	1.5A	miniSMDC260F	N/A	N/A	N/A

TE recommends placing PolyZen overvoltage protection devices on all USB-powered equipment, specifically on the VBUS port, as shown in the following table.

USB VBUS Overvoltage Protection Recommendations			
USB 2.0	USB 3.0	USB Charging	Notes
PolyZen Device ZEN056V130A24LS	PolyZen Device ZEN056V130A24LS	PolyZen Device ZEN056V230A16LS	Lower Voltage Clamping
PolyZen Device ZEN059V130A24LS	PolyZen Device ZEN059V130A24LS		Low Voltage and Low Power consumption in suspend mode
PolyZen Device ZEN065V130A24LS	PolyZen Device ZEN065V130A24LS	PolyZen Device ZEN065V230A16LS	Lower Leakage Current

TE Circuit Protection

308 Constitution Drive
Menlo Park, CA USA 94025-1164
Tel : (800) 227-7040, (650) 361-6900
Fax : (650) 361-4600

www.circuitprotection.com
www.circuitprotection.com.hk (Chinese)
www.te.com/japan/bu/circuitprotection (Japanese)

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