Techniques for ESD Immunity in USB Devices

Martin Rowe - November 01, 2000

If your company manufactures Universal Serial Bus (USB) peripherals, then you know that users expect hot-swappable devices that work flawlessly even after taking an ESD hit. Testing reveals immunity problems, but it’s the design changes that come from those tests that make a reliable product.

Jennifer Banh, an engineer at B&B Electronics (Ottawa, IL, [www.bb-elec.com](http://www.bb-elec.com)) had ESD-related problems—from both direct and from indirect hits—in an early design of a USB-to-RS-485 converter. Darrell Locke, engineer at Advanced Input Devices (Coeur d’Alene, ID, [www.advanced-input.com](http://www.advanced-input.com)) didn’t have a problem with direct ESD hits, but he had a problem with indirect ESD: Current in USB cables from ESD-induced radiated energy caused data errors and system crashes.

![Figure 1. A recessed USB connector protects the cable shield from direct ESD exposure. (Courtesy of B&B Electronics.)](image)

**Figure 1** shows a USB cable’s peripheral end and B&B’s product, a USB-to-RS-485 converter. A metal shield surrounds the cable connector’s plastic housing, which in turn surrounds the two data lines and two power lines. If you plug the cable into most USB peripherals, though, part of the outer shield remains exposed.

The exposed metal shield will pass current from direct ESD hits into both the peripheral device and to the peripheral’s host PC or USB hub at the other end of the cable. When Banh injected a ±4 kV contact ESD pulse into that exposed shield, the resulting current traveled through the cable to the host PC, whereupon the PC’s software froze. Banh had to unplug the USB device and reboot the computer to recover from the error.

Engineers at B&B had essentially two options for increasing a product’s immunity to direct ESD hits. They could add shields, filters, and grounds to the product or cut off ESD at the source. Banh and others chose to mechanically isolate the USB cable connector’s shield from any possible direct ESD hits. They recessed the USB connector into the black box (Fig. 1), so the plastic case will protect the cable connector’s shield from ESD.
Any exposed metal makes a product potentially susceptible to ESD. The black box in Figure 1 has an RS-485 terminal strip at the opposite end (not shown in Fig. 1). The terminal strip has metal contacts. To eliminate ESD hits on those contacts, B&B engineers protect the terminal strip by placing it behind the plastic door.

![Figure 1](image1.jpg)

**Figure 1.** The black box has an RS-485 terminal strip at the opposite end.

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**Indirect Hits**

An ESD event radiates energy that can couple into a circuit through cables, connectors, and PCB traces. Both Banh and Locke had similar problems on USB cables from indirect ESD; after an ESD event, their computers would no longer recognize the USB peripheral. Locke’s product, the custom control panel shown in **Figure 2**, contains a USB trackball, a USB keyboard, several USB switches, and a USB hub all mounted in one housing. The input devices connect to the hub, and a USB cable connects the panel to a PC. Because the panel’s components were enclosed in a plastic case, the case protected the panel’s electronics from direct ESD hits.

Indirect ESD hits can cause problems, too. During initial prototype testing, Locke found that a host PC no longer recognized the panel’s components after a ±3-kV discharge into his test setup’s ground plane. The panel uses a shielded USB cable, as required in chapter 7 of the USB specification.¹ Locke had to find out how current from the radiated EMI was entering the USB cables and traveling to the PC, and then find a way to make the product immune.

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**Immunize**

Bypass capacitors can help immunize a product from induced current. Capacitors between a USB product’s D+ and D– data lines and ground on a PCB will divert high-frequency current to ground. Unfortunately, Section 7.1.6.1 limits the total capacitance of a capacitor, the line driver’s output, and the PCB traces between the two to 100 pF. Capacitors on the D+ and D– data lines can improve ESD immunity, but too much capacitance may violate the USB spec and compromise signal integrity. Locke did add capacitors to the data lines in his product. The capacitors shunted some of the ESD-induced EMI current to ground, which reduced data errors while keeping the product within the USB specification’s capacitance limits.

In some applications, ferrite beads around cables can reduce common-mode currents that disrupt a product’s operation. The USB spec discourages the use of ferrite beads because they may slow a data signal’s edges to where a USB device no longer recognizes bits. Be aware, though, that Intel’s EMI Design Guidelines for USB Components suggests using ferrite beads as a method for reducing interference.² According to Locke, Intel’s design guideline (which is undated) was written early in USB’s life and you shouldn’t use ferrite beads.
Guard traces on a PCB can also improve ESD immunity. A USB product’s guard traces, which connect to ground, isolate the sensitive data lines from radiated emissions. As rules of thumb, Banh and Locke also recommend:

- use as much PCB area as possible for power and ground,
- connect USB shells to ground,
- place oscillators as far away from the USB data lines as possible, and
- position USB connectors as far as possible from the peripheral’s USB controller chip.

While the solutions to ESD problems on USB devices seem easy, both Banh and Locke point out that ESD troubleshooting is a trial-and-error process that can take weeks to perform. Most products go through several iterations before they get the right value components that solve ESD problems. Keep in mind that products need a complete functional test and an ESD test after each design change. T&MW

**FOOTNOTES**


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