

Ruggedizing USB Connections for Tough Environments

Brian Foster, Product Manager, Serial and USB Product Lines, B&B Electronics

USB is ubiquitous, it's useful and it's here to stay. But it isn't inherently rugged or reliable. It's up to you to make it that way.

When technician John Baker of Premier Resource Services connected his laptop to a customer's piece of industrial machinery he got a nasty surprise. There was a quick puff of smoke, and John lost his hard drive, his USB port and the USB adapter that he'd connected to the machine.

The problem, he soon discovered, was that while his laptop was plugged into the wall, the machine he was servicing was connected to the shop's single-phase power supply and its leads had been reversed to keep it from tripping a GFI switch. As the laptop and the connected device now had different ground potentials, the USB cable became the path to a lower ground state. It was an expensive lesson.

A kiosk manufacturer plugged a card reader into the kiosk's built-in computer. Everything was powered up, and all of the connections looked fine, yet the two devices wouldn't communicate. His natural inclination was to assume that either the card reader or the cable was faulty. But that wasn't the issue. The problem lay in the kiosk's built-in computer. It was a low cost single-board device, and its USB ports were not providing full power.

An injection molding machine manufacturer found a way to enhance part quality and cut material costs by regulating the temperatures of multiple heating elements. The process created a powerful electromagnetic field. The controlling computer could be kept at a safe distance, but the USB hub and cables were inside the field, and the resulting electromagnetic interference was a communications nightmare.

"You can expect all kinds of problems when you're working with USB," says Mike Fahrion, director of product management for B&B Electronics and a specialist in data communications. "It was originally designed as a standard bus for connecting computer peripherals in safe home and office desktop environments. But its cross-platform, hot-swappable interface turned out to be so useful that USB now appears in everything from emergency medical equipment to precision agricultural guidance systems; environments that it was never designed to handle."

A Laundry List of Inherent Weaknesses

USB was intended to connect mild-mannered home and office devices like printers, keyboards, media players, cameras and external disk drives. And it wouldn't just

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connect them; it would carry 5 VDC power as well, in many cases eliminating the requirement that the peripheral devices include their own power supplies. In fact, rechargeable devices would be able to use USB to restore their internal batteries to full power.

Devices would be able to draw up to 5 unit loads from a USB port, with a unit load in USB 2.0 being defined as 100 mA. "Low-power" devices would draw one unit load or less (under 100 mA). "High-power" devices could draw the full 500 mA. Additionally, devices that required more than 500 mA could be equipped with a Y-shaped cable that would enable them to draw power from two USB ports at the same time. Devices with internal power, like printers, would register as "low-power" devices, requiring only 100 mA.

Devices would initially function at low power, but would be able to request high power if needed. That was the specification, at any rate.

Ruggedizing USB Power

In reality, unfortunately, it has turned out that designers and manufacturers don't always rigidly adhere to the USB specification. That single-board computer in the shopping mall kiosk, for example, wasn't providing 500 mA for high-power USB devices to the USB port. It was providing 100 mA, just one unit load. A connected device with internal power would function properly, but a high-power device requiring 500 mA would not. The same weakness appears in a lot of devices; common examples would include some of the cheaper netbooks. As the number of applications calling for USB continues to increase, so will the number of instances in which devices fail to function correctly due to the lack of full 500 mA power at the USB port.

There isn't much you can do to ensure that every manufacturer, everywhere, takes the USB specification seriously. But you can resolve the problems associated with under-powered USB ports by installing devices like powered USB isolators or powered USB hubs. They'll boost the USB signal up to the full 500 mA.

Ruggedizing USB for Ground Loops

It's very useful to be able to connect a remote device via USB. But the greater the distance between the connected devices, the more likely it becomes that communicating devices will be getting their power from different building ground references. When they do, the USB cable's ground wire can create a ground loop path.

In home/office environments the ground loop problem is rarely an issue. The connected devices will normally be quite close, usually sharing a wall outlet and a common ground. But industrial installations will be far more complex. Imagine a situation in which a process control system is powered from a source in one building location, but the front panel is powered somewhere else. When you connect a PC to the front panel via USB, powering the PC at the same location, you can create a ground loop with the process control system, which may be hundreds of meters away. Magnetic flux from motors or other high-power devices can use this ground

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loop to induce current noise on the ground. If you're lucky the only result will be data transmission errors. More extreme events, like surges and voltage overloads, will burn out integrated circuits and connectors.

Your computers and connected devices should be protected with USB isolators. Ordinary surge suppression tries to limit spikes between the signal and ground line. But if the ground line rises, as it does in ground loop situations, then surge suppression won't stop it. Isolation allows the lines to float while keeping the local side at the proper ground and signal level. An isolator controls electrical flows while simultaneously ensuring that your data stream is not interrupted. You can deploy dedicated inline USB isolators as well as USB devices that perform additional functions while including isolation, like isolated hubs or serial converters.

Isolation works by changing the nature of both the data signal and the 5 VDC power carried by the USB cable. The data enters the isolator as an electrical signal, is converted to either pulses of light or an electrical field, then back to an electrical signal again. The data flow is uninterrupted, but power surges and ESD are stopped cold at the isolation zone. The isolator protects against surges and ESD on the power line by briefly transforming the 5 VDC USB power to AC, through an isolation transformer, then back to DC again.

Ruggedizing USB Cables

USB cables have some nice features. For example, the specification deliberately made it very hard to attach a USB connector incorrectly. The host devices that supply power use a type A connector and the devices that receive power use a type B connector. They can't be reversed. Users can't accidentally connect two USB power supplies and create a risk for fire or damage to expensive circuitry.

The specification also required that the power connections in the type A connector should be on the outside, and that the data connections (D+ and D-) would be on the inside, and recessed. This meant that the power connection would be established first, thus preventing data errors.

The connectors themselves were designed for easy insertion and extraction. The connectors would hold the cables in place with no need for thumbscrews or clips. That has proven to be quite handy in office environments, where people are often making connections at awkward angles, like under desks or behind various kinds of office equipment.

It was a wonderful cabling solution for home and office computing.

But the same easy connection and extraction that makes USB so useful in an office environment can be a problem when you take USB off the desktop. Heavy vibration in industrial applications can cause USB cables to work themselves loose. Any accidental tugging on the USB cable will produce the same result. And because USB carries power, a loose USB cable can cause arcing – a serious problem in environments that pose a risk for fire or explosion.

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Manufacturers have started to address the problem. One solution involves connecting USB cables and ports with thumbscrews. But that requires the use of proprietary cables that aren't likely to be available at your neighborhood office supply store. Additionally, the thumbscrews eliminate one of USB's most useful features: the ease with which USB cables can be connected and disconnected.

A more elegant solution employs "high-retention" USB ports. They'll work with any cable, and they retain USB's quick connect/disconnect feature. The difference is that it requires more force to dislodge them. The high-retention ports used by B&B Electronics, for example, hold a cable securely enough that it requires 15 newtons of force (3.4 lbs) to remove one – so securely, in fact, that they will meet UL requirements for Class 1 Division 2 Hazardous Locations.

Ruggedizing for EMI and ESD

Standard USB cables were intended for office environments, so they're not hardened against significant electrostatic discharges (ESD) or electromagnetic interference (EMI). ESD and EMI weren't expected to be serious issues. But as USB moves into places like crowded control panels, factory floors and emergency vehicles crammed with electronics of every description, EMI and ESD become a daily risk. In these tougher environments USB cables can carry unintended spikes and surges that will damage connected equipment. Additionally, standard cables provide very little resistance to things like moisture, dust and temperature.

More reliable USB cable is available in several versions. Options range from shielded plastic cable, which is resistant to EMI, all the way up to IP67-rated metalized plastic cable that resists EMI as well as potential physical damage from harsh environments.

Rugged Range Extension

USB has a range limitation of five meters. That's quite serviceable in office environments but less useful elsewhere. You can extend the range up to 30 meters using USB hubs, which also give you an opportunity to add additional ports. (USB allows a single computer to control as many as 127 different devices.) USB hubs designed for home/office are normally rather flimsy, but you can install industrial-grade, metal-cased USB hubs that feature high-retention connectors, versatile mounting, and resistance to environmental hazards. Industrial-grade hubs with integrated isolation will let you make more efficient use of tight spaces by performing multiple functions in the same unit.

Ruggedizing Installations

Consumer-grade USB devices aren't built for hard use. When you move off the desktop you'll want to deploy better equipment, and you may need to secure it firmly in place. When shopping for industrial grade hubs, isolators, USB-to-serial converters or any other USB device, look for equipment that can be installed in panels or on DIN rail right out of the box.

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USB failures can be expensive in ways that aren't as immediately obvious as a burned out circuit board or connector. Equipment repair has associated labor costs, as does reprogramming. And although it may be hard to quantify, down time costs money, too.

"It's the price of convenience," says Fahrion. "USB is too useful to ignore. But whenever you take it off the desktop you're going to have to employ a few workarounds. USB appears in every industry these days, and there's a good chance that it was never designed for yours."

USB is ubiquitous, it's useful and it's here to stay. But it isn't inherently rugged or reliable. It's up to you to make it that way.

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