Isolate, Convert, Extend, & Connect

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Exploit the benefits of USB while eliminating its weaknesses.

USB was a great leap forward. Its convenience, flexibility, and interoperability have simplified everything from cabling to device installation. Engineers can now connect up to 127 devices using a single port and add new peripherals without opening a computer to insert an expansion card. Devices are hot swappable; cables are interchangeable; and USB will even supply power to a downstream device.

As good as it is, USB was designed with safe office and IT environments in mind. When it moves into the real world, as it is currently doing in industries ranging from manufacturing to health care, USB reveals a number of inherent weaknesses:

- It has an effective range limitation of only 30 meters, even when using hubs.
- It is highly susceptible to ground loops, electromagnetic interference (EMI), and electrostatic discharges (ESD).
- It can provide 500 mA power to downstream devices, but that capability can lead to arcing and fire when cables come loose. It’s not designed to communicate with older protocols.

When taking USB off the desktop, each of these issues must be considered.

Range Limitation: Conversion & Extension

In a straight line, a USB’s 30-meter range is roughly the height of a nine-story building. At first glance, that sounds pretty good, but data communication cables rarely travel in a straight line. Normally, they're laid above, below, and around working spaces, so it can easily require 30 meters of cable to connect two pieces of equipment that are only 10 meters apart. Thirty meters may be adequate for home and/or office environments, but it isn’t enough for industry.

The USB range limitation can be addressed through extension and conversion. For example, in situations where installing a local PC would be impractical, as in kiosks or security applications, a USB-over-Ethernet server would let you connect multiple USB devices at a remote location, convert the data stream for TCP/IP transmission over Ethernet, and then control the devices from a central office (**Figure 1**). The intervening Ethernet connection can be Cat 5 cable, fiber optics, or radio. In each case the data stream will be converted to a different protocol, but the data itself will move smoothly.

If, as often happens, a legacy coax or telephone cable system is in place, the labor and material costs of a Cat5 cable installation can be eliminated by deploying a pair of Ethernet extenders. Ethernet extenders use DSL technology to convert data for

transmission over the legacy copper cable (**Figure 2**). The savings with this method can be substantial.

Although serial communication protocols pre-date USB by decades, legacy serial devices don't need to be left out of the loop. USB-to-serial converters can be acquired for virtually any application, from heavy-duty, multi-port, DIN-rail-mounted converters to simple inline converters that USB-enable a single device (**Figure 3**).

Spikes, Surges & Ground Loops

USB cables behave well enough in the home office, but in industrial environments they’re the weakest link in the USB specification. For example, a powerful magnetic field like those found around industrial motors can induce current on the USB cable and burn out expensive components in connected PLCs and machinery. Ordinary surge suppressors will not suffice. 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 is powerless to intervene.

The answer is USB isolation.

A USB cable contains four wires: two for data and two that carry 5 VDC power for downstream devices. Isolation works by changing the nature of the signal on the 2 USB data lines and transforming the 5 VDC power on the other pair. The isolator protects the data lines by converting the signal to either pulses of light or an electrical field, then back to an electrical signal again. It allows data to pass through, but it stops power surges and ESDs at the isolation zone. The isolator controls surges and ESD on the power line by transforming the 5 VDC USB power to AC, then back to DC (**Figure 4**).

Remember, isolators will limit the USB data rate to full speed or 12 Mbps. This happens because USB devices default to full speed until they are able to negotiate a higher connection rate with the USB hub. The negotiation is initiated by the device, which drives 17.78 mA into the D- data line for at least a millisecond, creating a "K-chirp". If the hub is high-speed (480 Mbps) capable, it will respond by alternately injecting 17.78 mA into the D- and the D+ lines. When the device has detected at least three of these chirp pairs it will decide that the hub is hi-speed capable, and it will establish the connection at the higher data rate. Unfortunately, isolators interfere with this negotiation when they convert the DC signal to AC at the isolation zone, the negotiation for a higher data rate fails, and the connected devices default to full speed. That’s more than ample for most industrial applications, but it does mean that unprotected, non-isolated high-speed USB connections will normally be faster.

The Right Way to Connect

Older cables were once connected with exposed pins that could be bent or broken. USB cables, however, protect the pins inside the connector housing. The design has

proven to be quite reliable in desktop applications, but industrial environments are less benign.

Vibration can cause USB cables to work loose, and minor tugging will do the same thing. When that happens in a home office, a typical result might be that the printer stops working. It’s an easy fix at home, but in industrial applications it can mean serious data loss and downtime. If flammable substances are present, USB’s 5 VDC power is enough to pose a risk for fire and explosion.

It would be impractical to abandon USB, so some manufacturers are addressing the problem by developing high-retention USB ports. The ports closely resemble the ports in office equipment — and plugging in a USB cable feels effortless — but the difference in industrial safety is enormous. A typical high retention port can grip a cable firmly enough to resist 3.4 lbs of force (**Figure 5**).

USB may have been designed for the office environment, but it doesn’t have to stay in the cube. Isolate, convert, extend, and connect and it's possible to take USB all the way out to the network edge.

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