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Understanding the Benefits and Potential Hazards of Using USB-Based Data Acquisition Solutions for Test & Measurement Applications

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The Universal Serial Bus (USB) is increasingly gaining favor as an alternative interface for data acquisition and measurement. Computer peripherals such as printers, mice, and digital cameras already use USB as a quick and easy way to connect to a PC. The USB connection simplifies the peripheral installation by eliminating the necessity of "cracking open" the PC to install a plug-in board.

USB was created by a group of manufacturers including Intel, Microsoft, and Compaq to simplify connecting external peripherals to personal computers. Today, nearly all desktop and laptop PCs on the market come equipped with at least one USB port. USB ports can also be added to desktop computers using a plug-in board that installs into a PCI bus slot. Equally important, these USB ports have full software support under Microsoft Windows® 2000 and XP.

For test and measurement applications, USB data acquisition modules offer a number of significant advantages. At the same time, there are also some potential hazards that can cause unsuccessful results depending on the application. This paper describes both the benefits and potential hazards of using USB data acquisition modules for test and measurement applications.

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USB Benefits for Test and Measurement

USB provides users with a simple alternative for developing test and measurement applications by offering the following advantages:

- **True Plug and Play** – Simply connect a data acquisition module to a PC USB port with a standard, low-cost USB cable. The PC automatically identifies the module when it is plugged in and installs the software needed to operate it. This connection scheme greatly reduces start up time.

  Installing a USB DAQ module no longer requires having to open a PC to add a plug-in board, configure DIP switches and IRQ settings, search for the right device driver, or reboot the system. Install the module into any USB port, connect your sensors/signals, and begin acquiring data immediately.

- **Enhanced Noise Immunity** – USB data acquisition modules offer performance benefits for noise-sensitive measurements. Because USB cables are typically 1 to 5 meters long, the I/O circuitry is located further away from the computer's noisy motherboard and power supplies, and closer to the sensors and signals they will be measuring. As a result, there is less potential for noise being introduced into the modules from noise sources inside the PC.

- **Full- and High-Speed Transfer Rates –** Computers with USB 1.1 ports can transfer data to and from a USB data acquisition module at up to 12 Mbits/second. This full-speed rate is useful for data streaming applications and supports data acquisition rates of up to 400kHz.

  PCs with a USB 2.0 port can support high-performance applications with data transfer rates of up to 480 Mbits/second. This increased bandwidth allows multiple I/O operations to perform simultaneously at throughput rates up to 500kHz in each direction, similar to PCI measurement systems.

- **Cost Savings –** Most USB data acquisition modules include removable terminal blocks or BNC connectors that handle a large array of I/O connections. This eliminates the need to buy optional screw terminal accessories and cables.

- **Portable –** USB data acquisition modules are compact and portable. They allow users to move even the most sophisticated test and measurement applications out of the lab and into the field.

- **Easily Expandable –** With low-cost expansion hubs and USB cables, a user can add additional USB modules to scale up the measurement capacity.

- **Hot-swappable –** USB data acquisition modules can be installed or removed while the computer is running. Users can plug modules in, acquire data, and unplug them when data acquisition is complete without the need to power down the PC.

Device drivers load dynamically into the PC when the module is plugged in and dynamically unload when the module is unplugged.

- **Simple Power Connections –** USB data acquisition modules can be powered either directly by the bus or through a simple connection to an external power source. Low-powered modules draw less than 100mA at 5V and use the power supplied by the USB cable. Self-powered modules draw up to 500mA at 5V and use their own power supplies.

Potential Hazards

While USB offers many benefits for data acquisition applications, there are also hidden hazards. Knowing what these hazards are and how to avoid them can prevent unsuccessful results.

Unlike PCI boards, which have short substantial grounding systems built into the PC backplane, USB modules have a ground connection up to 5 meters long and active circuitry at both ends. If the USB module is not designed properly, this setup can cause significant problems for noise-sensitive measurements such as system lockups, erratic performance, and electromagnetic transients.

To avoid these potential problems, consider the type of application and the environment in which the USB module will be used. In general, there are three possibilities to consider:

1. Will the module be exposed to electrostatic discharge (ESD), lightning, or power surges from motors, switching devices, or other equipment?
2. Are there voltages with different ground potentials?
3. Will the module be operated in a safe environment?

If the answer to questions 1 or 2 is "Yes," then the system should be equipped with isolation protection. Isolation protects the PC from damage and preserves data integrity by physically separating the electrical connections between circuits, thereby limiting potentially harmful voltage or current from flowing through the system. Isolation can be provided either by adding signal conditioning accessories to the system, which can be expensive, or by choosing an isolated USB data acquisition module from the start.

Case 1 – ESD, Lightning, or Power Surges

Figure 1 shows a typical application scenario, with a sensor measuring a voltage from a device or system under test. The sensor is connected to a USB data acquisition module, which in turn is connected to a laptop PC.

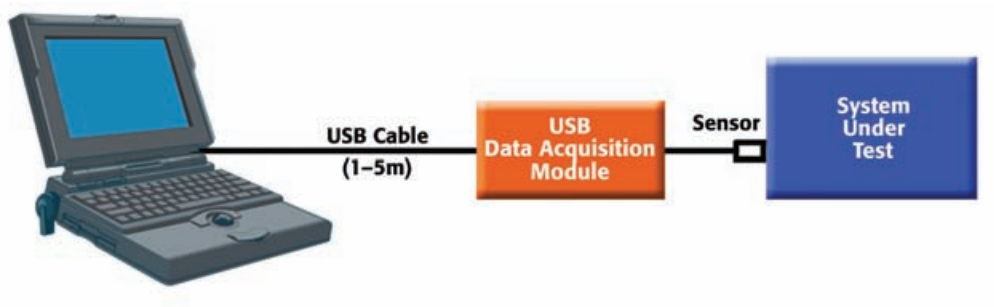

Figure 1. Typical application setup

ESD, lightning, and power surges generate sudden transient over-voltages that can damage the electronic components in the entire system. Typically these transients last only a few milliseconds, but are still enough to cause significant damage to electronic components.

If the USB data acquisition module is not isolated (see ***Figure 2),*** the currents generated by transient overvoltages move through the entire system, eventually reaching and potentially damaging the PC and other system components.

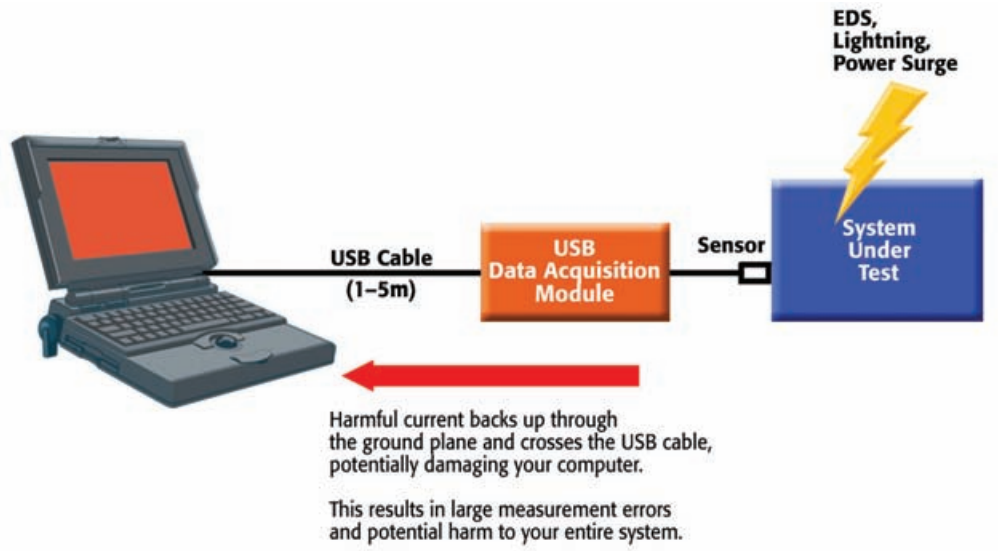

Figure 2. Non-isolated USB data acquisition modules during ESD, lightning, or power surges can potentially damage the system and cause data inaccuracies.

Some non-isolated modules can actually lock up the entire system in response to transient voltages, necessitating a system reboot. In a test and measurement application, this means a potential loss of data, not to mention the time lost to reboot the system and make sure all components are functioning properly. In contrast, isolated modules (shown in ***Figure 3***) dissipate harmful current across the module's ground plane, protecting the entire system.

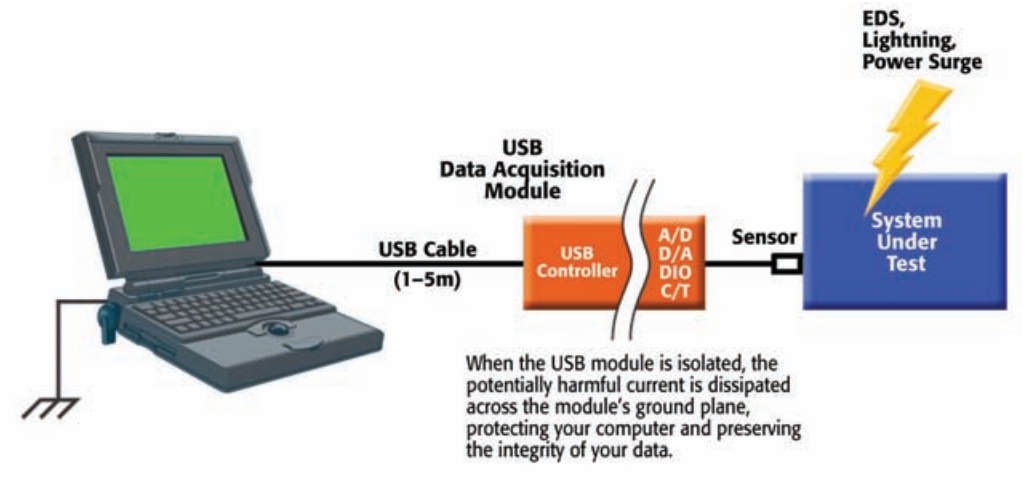

Figure 3. Isolated USB data acquisition modules during ESD, lightning, or power surges protect the PC and preserve signal integrity.

Even if the transient voltage is small enough not to damage the system, collected data may contain large errors, particularly at high resolutions. For example, if a USB module with 16-bit resolution is used to measure a signal in the ±10V range, the LSB value is 0.31mV (see ***Table 1***). Therefore, if the module is non-isolated and a transient voltage is introduced into the system, the measured data could be off by hundreds of millivolts. Even in static environments, the data could be off by tens of millivolts. Such inaccuracies are significant sources of error when measuring low-level signals.

Table 1. Voltage Ranges at Different Resolutions

		16-Bit Resolution	12-Bit Resolution
Voltage Range	**Gain**	**LSB Value**	**LSB Value**
±10 V	1	0.31 mV	4.88 mV
±5 V	2	0.15 mV	2.44 mV
±2.5 V	4	0.08 mV	1.22 mV
±1.25 V	8	0.04 mV	0.61 mV

Isolation is critical for high-accuracy, low-noise measurements. This isolation converts the power from input signals into output signals that dissipate over the ground plane of the module. As a result, the computer is safeguarded from harmful transients and measurements are more accurate.

Figure 4. KUSB-3102

The KUSB-3102 module, for example, provides 500V of isolation using an electronic circuit composed of standard components. These include transformers to convert power from fast clock signals with no delay; optoisolators to convert power from slower control signals with a delay in the tens of microseconds; and differential capacitive coupling which converts power from slow data paths with a delay of 1 microsecond.

Case 2 – Different Ground Potentials

Single-ended analog inputs are non-isolated inputs that are referenced to earth ground. In non-isolated systems, even digital I/O signals are connected to the same ground. If the system under test shares the same ground with the USB data acquisition module (by virtue of being connected to the building's power system), the difference in ground potential between the two devices can be substantial – more than 100mV. Fast switching currents must then travel down the 5 meter USB cable to the PC.

Depending on how single-ended inputs connect to the module, ground loop errors can be introduced. When these errors are added to the signal and other ground potentials that can be generated across five meters of USB cable, the results can be highly inaccurate measurements and potential damage to the system. ***Figure 5*** shows an example of improperly connecting single-ended inputs. A better connection scheme for single-ended inputs that reduces ground-loop errors is shown in ***Figure 6***.

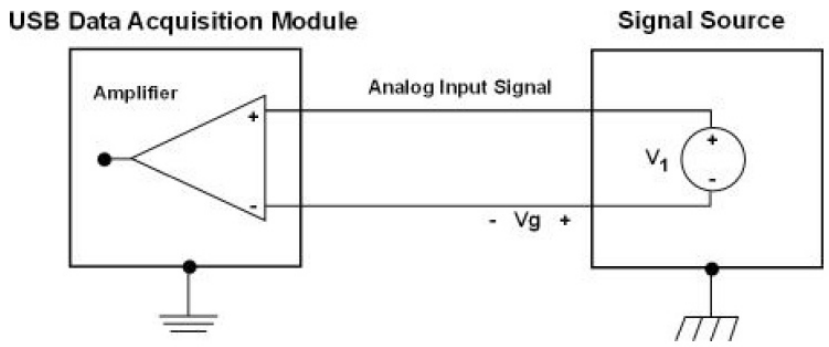

Figure 5. Improperly connecting single-ended inputs can damage the system and result in inaccurate measurements.

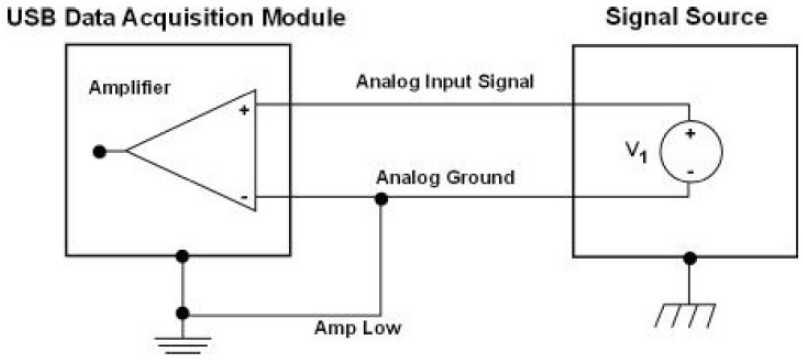

Figure 6. Properly connecting single-ended inputs.

Differential inputs produce the most accurate measurements (shown in ***Figure 7***). Differential inputs are isolated inputs because they are referenced to a ground reference point that is not connected to earth ground. As a result, they eliminate common-mode voltage errors that can occur when differences in ground potentials exist.

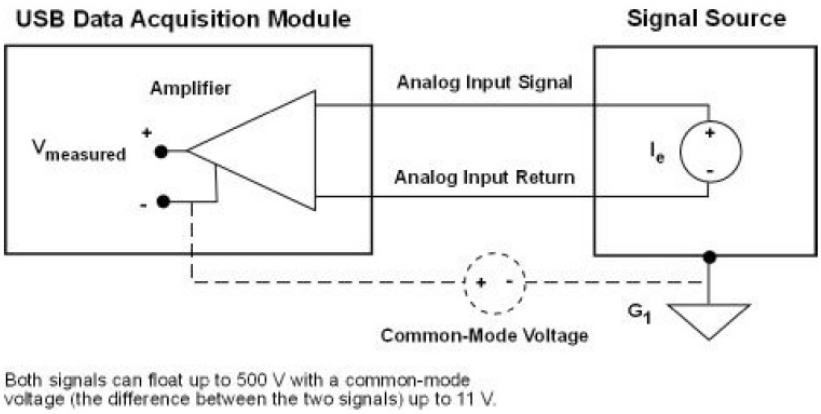

Figure 7. Differential inputs are isolated and eliminate common-mode voltage errors by providing a reference ground source not tied to earth ground.

Therefore, if measuring low-level signals, where noise is a significant part of the measurement, or where common-mode voltage exists, ensure that the USB data acquisition module provides differential input connections.

Case 3 – Benign Conditions

In benign environments, where transient electrical spikes and different ground potentials do not exist, isolation is not required. In non-isolated systems, the PC is tied directly to the ground system of the sensor, so measurements will be accurate as long as no noise or other errors are added to the voltage source.

While non-isolated solutions may be less expensive, test and measurement applications are rarely performed in benign, hazard-free environments. So beware of incurring back-end costs measured in data accuracies or system failures if choosing a non-isolated solution.

Conclusion

The benefits of USB for test and measurement applications are many. But, before choosing a USB data acquisition module, consider the application. If transient voltages or differences in ground potentials exist, protect the PC and preserve signal integrity by choosing an isolated USB data acquisition module.

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