

# Benefits & Potential Dangers of Using USB for Test & Measurement Applications

Recognized for its ease of use and flexibility, USB is one of the fastest growing busses within the computer and electronics industries today. All new PCs have a number of USB ports, some with as many as six, for connecting external devices. For test and measurement applications, USB data acquisition modules offer a number of significant advantages. But, beware - they also contain some potential dangers that can cause catastrophic results depending on your application.

This document describes both the benefits and potential dangers of using USB data acquisition modules for test and measurement applications.

## Benefits of Using USB for Test and Measurement

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

- **True Plug and Play** - Simply connect your data acquisition module to the USB port of your PC using a standard, low-cost cable. The PC automatically identifies the module when it is plugged in, and installs the software necessary to operate it. This connection scheme greatly reduces your start up time. You no longer have to open your PC to add a board, configure DIP switches and IRQ settings, search for the right device driver, or reboot your system. Simply connect your sensors to the module and go. Within minutes, you're acquiring data: temperature, pressure, sound - whatever you need.
- **Less Noise Sensitivity from the PC** - USB data acquisition modules offer performance benefits for noise-sensitive measurements. Since the USB cable is 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 they will be measuring.
- **Full and High-Speed Transfer Rates** - Computers configured 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 400 kHz. For high-performance applications, ensure that your PC has a high-speed USB 2.0 port. With USB 2.0, you can transfer data between the PC and your USB data acquisition module at up to 480 Mbits/second. This increased bandwidth allows you to perform multiple I/O operations simultaneously at throughput rates up to 500 kHz in each direction, similar to PCI measurement systems.
- **Cost Savings** - Many USB data acquisition modules include removable terminal blocks or BNC connectors that conveniently handle all user I/O connections. This design is not only convenient, but cost-effective, since you don't have to purchase optional screw terminal accessories.
- **Portable** - USB data acquisition modules are compact and portable allowing you to move even the most sophisticated test and measurement applications out of the lab and into the field.

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- **Easily Expandable** - Using low-cost expansion hubs and USB cables, you can connect up to 127 data acquisition modules to a single USB port.
- **Hot-Swappable** - USB data acquisition modules can be installed or removed while the computer is running. Just plug the device in, use it, and unplug it when you're done. There's no need to power down your PC. Because the USB module is self-enumerating and self-identifying, the device driver is dynamically loaded when the module is plugged in and dynamically unloaded 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 100 mA at 5 V and use the power supplied by the USB cable. Self-powered modules draw up to 500 mA at 5 V and use their own power supplies.

### Potential Dangers of Using USB for Test and Measurement

While USB offers many benefits, not all USB data acquisition modules are created equal. There are hidden dangers that depending on your application and the design of your USB module can cause catastrophic results.

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

Before choosing a USB data acquisition module, consider your application:

1. Will your data acquisition module be susceptible to electrostatic discharge (ESD), lightning, or power surges from motors, switching devices, or other equipment?
2. Are you dealing with voltages that have different ground potentials?
3. Will the module be operated in a benign environment?

If you answered "Yes" to questions 1 or 2 above, ensure that your system includes isolation. Isolation protects your PC from damage and preserves the integrity of your data by physically separating the electrical connections between circuits, thereby limiting potentially harmful voltage or current from flowing through your system. You can provide isolation either by adding signal conditioning accessories to your system, which can be expensive, or by choosing an isolated USB data acquisition module from the start.

If you answered "Yes" to question 3, a nonisolated module might be the right choice for you.

Let's look at these application environments in more detail and explore the role of isolation in each case.

## Case One - ESD, Lightning, or Power Surges

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

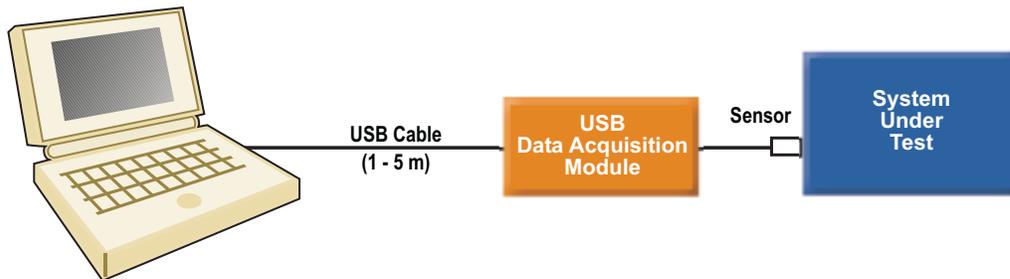


Figure 1. Typical Application Setup

ESD, lightning, and power surges generate sudden transient overvoltages that, even if short-lived, can damage the electronic components in your entire system. If your USB data acquisition module is nonisolated (see Figure 2), the current that is generated by these types of events backs up through the entire system, eventually reaching and potentially damaging your PC and other system components.

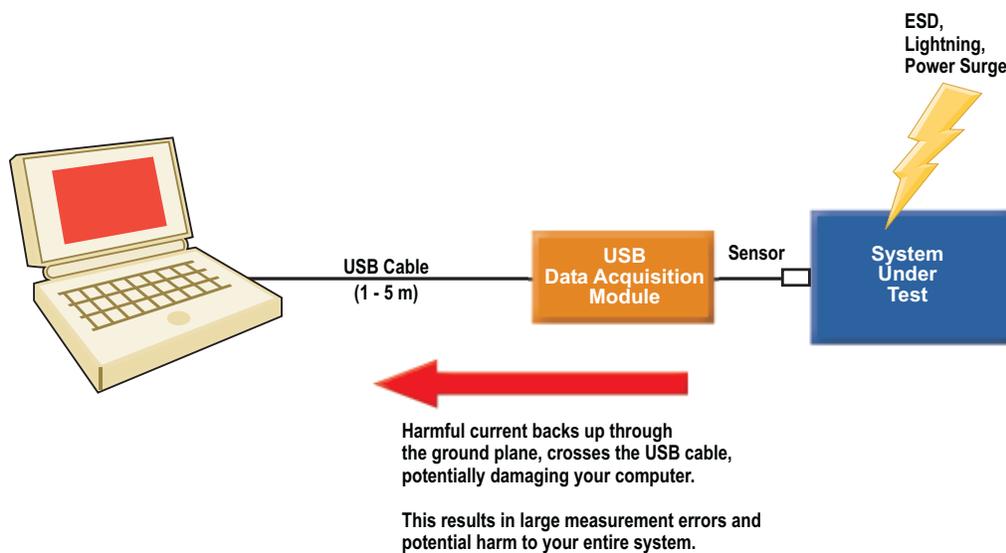
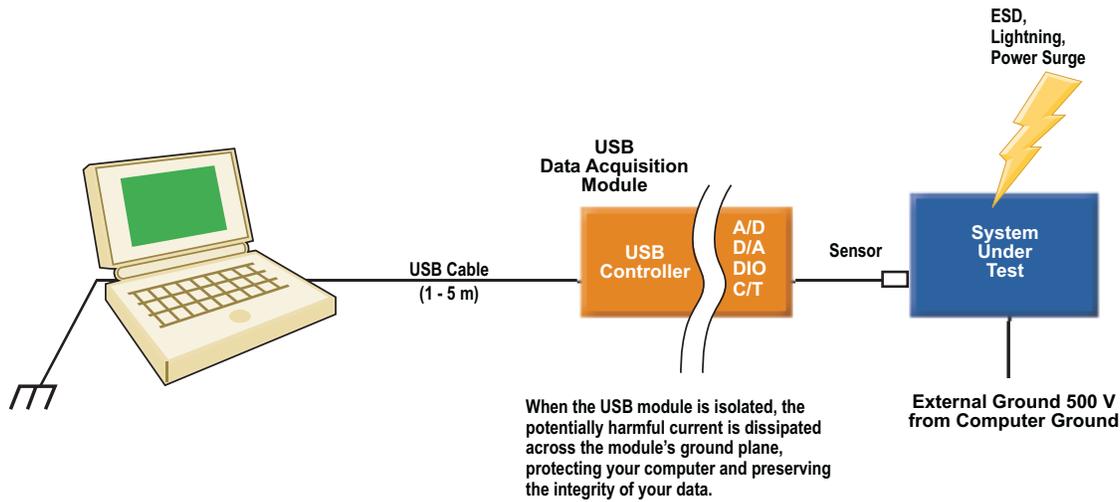


Figure 2. Nonisolated USB Data Acquisition Modules During ESD, Lightning, or Power Surges Can Potentially Damage Your System and Cause Data Inaccuracies

Nonisolated modules from some data acquisition vendors actually lock up the entire system in response to transient voltages, necessitating a system reboot. In test and measurement applications, this kind of behavior is unacceptable.

In contrast, isolated modules (shown in Figure 3) dissipate harmful current across the module's ground plane, protecting your entire system.



**Figure 3.** Isolated USB Data Acquisition Modules During ESD, Lightning, or Power Surges Protect Your PC and Preserve Signal Integrity

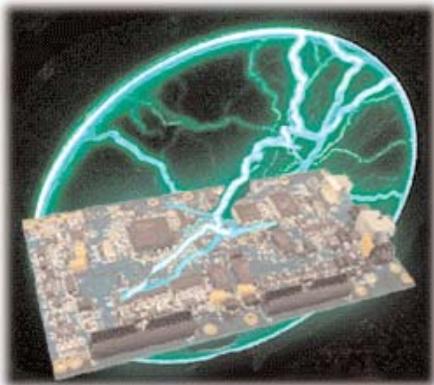
Even if the transient voltage that is introduced is small enough not to damage your system, **be aware that your data can contain large errors, particularly at high resolutions!** For example, if you are using a USB module with 16-bit resolution to measure a signal in the +/-10 V range, the LSB value is 0.31 mV (see Table 1). Therefore, if the module is nonisolated and a transient voltage occurs in the electrical system, your data could be off by hundreds of millivolts. Even in static environments, your data could be off by tens of millivolts - huge inaccuracies when you are measuring low-level signals.

As you can see, if you need high-accuracy, low-noise measurements, **isolation is critical.** Data Translation provides a complete range of USB modules - our isolated DT9801 and DT9834 Series, which provide up to 500 V of galvanic isolation, and our non isolated ECONseries. Galvanic isolation eliminates the physical connection by converting the power from your input signals into output signals that dissipate over the ground plane of the module, as shown in

**Table 1. Voltage Ranges at Different Resolutions**

Voltage Range	Gain	16-Bit Resolution (LSB Value)	12-Bit Resolution (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

Figure 4. As a result, your computer is safe and your measurements are more accurate.



**Figure 4.** Galvanic Isolation Dissipates Transient Voltages Across the Ground Plane of the Module, Protecting Your PC and Preserving Your Data

The DT9801 module, for example, provides 500 V of galvanic isolation using the following components:

- Transformers - Convert power from fast clock signals with no delay.
- Optoisolators - Convert power from slower control signals with a delay in the tens of microseconds.
- Differential capacitive coupling - Converts power from slow data paths with a delay of 1 microsecond.

Table 2 summarizes the isolated USB modules offered by Data Translation.

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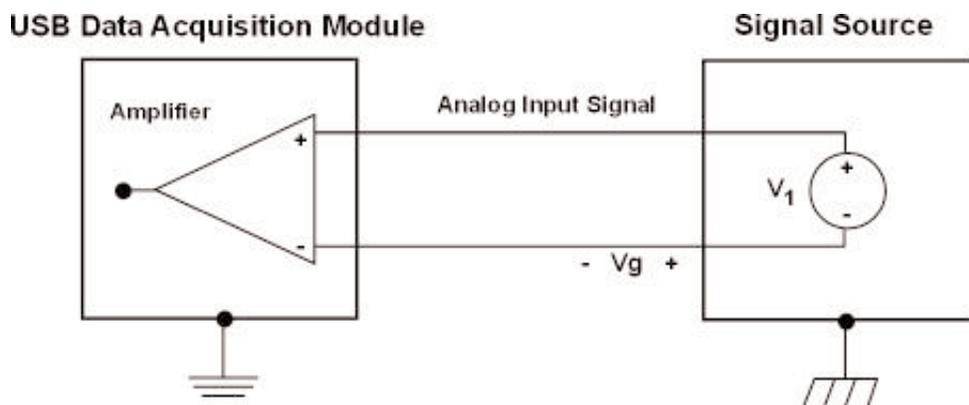
**Table 2. Isolated USB Modules from Data Translation - Selection Guide**

Series Description	Resolution (bits) @ Throughput (kS/s)	Subsystems	Independent Subsystem Operation at Full System Throughput	USB Speed High Speed = 480 Mbs Full Speed = 12 Mbs	PC Ground Isolation	ESD Protection 4 kV Contact 8 kV	Power
Highest Performance DT9834	16/12-bits @ 500 kS/s	AI, AO, DIO, C/T	Yes to 500 kS/s	High Speed	Yes to 500 V	Yes	External
World's Most Accurate DT9821	24-bits @ 0.960 kS/s	AI, AO, DIO	Yes to 1 kS/s	Full Speed	Yes to 500 V	Yes	USB
Programmable DSP Fulcrum II	24-bits @ 100 kS/s	AI, AO, DIO, C/T	Yes to 100 kS/s	High Speed	Yes to 500 V	Yes	External
Thermocouple DT9805	16-bits @ 50 kS/s	AI, AO, DIO, C/T	Yes to 1 kS/s	Full Speed	Yes to 500 V	Yes	USB
General Purpose Multifunction DT9800	16/12-bits @ 100 kS/s	AI, AO, DIO, C/T	Yes to 1 kS/s	Full Speed	Yes to 500 V	Yes	USB
Highest DIO DT9835	96-bits @ 1 kS/s	DIO	Yes to 1 kS/s	Full Speed	Yes to 500 V	Yes	USB

### Case Two - Different Ground Potentials

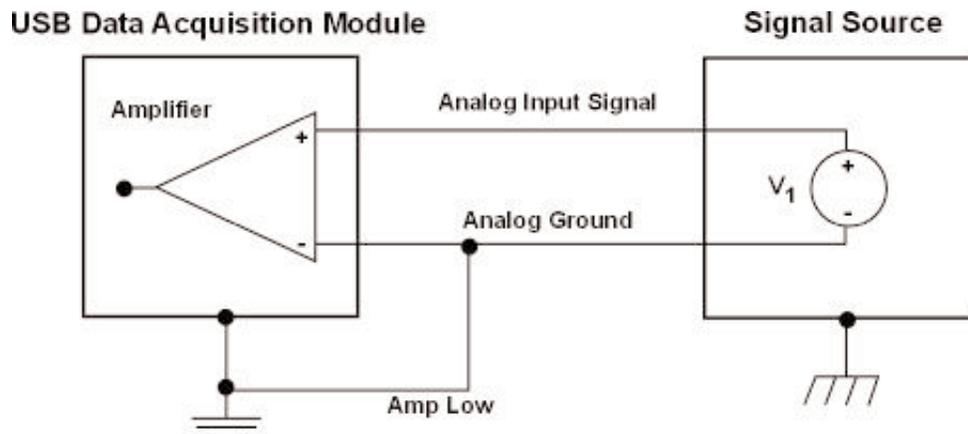
Single-ended analog inputs are nonisolated inputs that are referenced to earth ground. In nonisolated systems, even digital I/O signals are connected to the same ground. If your system under test shares the same ground as your USB data acquisition module (by virtue of being connected to building's power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

Depending on how you connect single-ended inputs to the module, you can introduce ground-loops errors that, when added to your signal and other ground potentials across up to 5 meters of USB cable, can not only provide highly inaccurate measurements, but can also damage your system. Figure 5 shows an example of improperly connecting single-ended inputs.



**Figure 5.** Improperly Connecting Single-Ended Inputs Can Damage Your System and Result in Inaccurate Measurements

A better connection scheme for single-ended inputs that reduces ground-loop errors is shown in Figure 6.



**Figure 6.** Properly Connecting Single-Ended Inputs

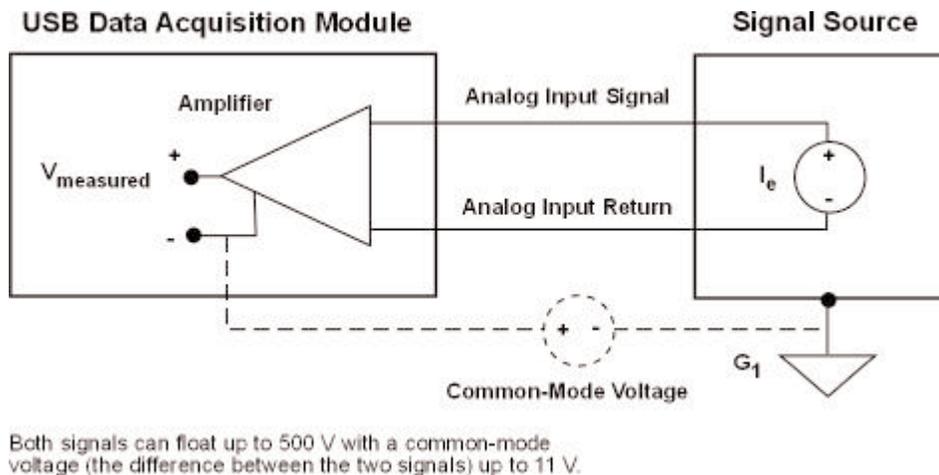
For the most accurate measurements, use differential inputs (shown in Figure 7). Differential inputs are isolated inputs because they are referenced to a ground reference point that is not connected to earth ground. As a result, they eliminate common-mode voltage errors that can occur when differences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

Therefore, if you are measuring low-level signals, signals where noise is a significant part of the measurement, or if common-mode voltage exists, ensure that your USB data acquisition module provides differential input connections. Data Translation's isolated USB modules, from the DT9801 to the DT9834 Series, provide up to 8 or 16 differential input connections for maximum ground-loop protection.

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**Figure 7.** Differential inputs Are Isolated and Eliminate Common-Mode Voltage Errors by Providing a Reference Ground Source Not Tied to Earth Ground

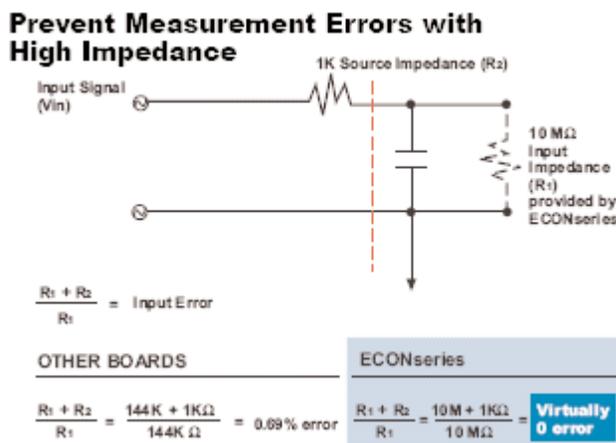
### Case Three - Benign Conditions

In benign environments, where transient electrical spikes and different ground potentials do not exist, nonisolated modules are a good, less expensive choice. A laptop that runs off battery power is a good example of a benign environment. In nonisolated systems, the PC is tied directly to the ground system of the sensor, so your measurements will be accurate as long as no noise or other errors are added to your voltage source.

To ensure that no measurement errors are introduced, it is critical that your module provides high input impedance. Assume, for example, that the source impedance of your analog signal is 1 kOhm (see Figure 8). If your module provides only 144 kOhms of input impedance, as is the case with modules from many vendors, your measurements could be off by 0.69%. Choosing a module with high input impedance, however, minimizes these measurement errors.

Data Translation's ECONseries modules provide 10 MOhms of input impedance for virtually error-free measurements. Table 3 summarizes the nonisolated modules offered by Data Translation.

*“Data Translation's ECONseries modules provide 10 MOhms of input impedance for virtually error-free measurements.”*



**Figure 8.** High Input Impedance is a Critical Specification in Nonisolated Modules

**Table 3. Nonisolated USB Modules from Data Translation - Selection Guide**

Series Description	Resolution (bits) @ Throughput (kS/s)	Subsystems	Independent Subsystem Operation at Full System Throughput	Analog Input FSR	Waveform Analog Output FSR	Clocks & Triggers External/Internal	Power
General Purpose Data Acquisition DT9812-10V	12-bits @ 50 kS/s	8 AI, 2 AO, 16 DIO, 1 C/T	Yes to 50 kS/s	$\pm 10\text{ V}, \pm 5\text{ V},$ $\pm 2.5\text{ V}, \pm 1.25\text{ V}$	$\pm 10\text{ V}$	Yes/Yes	USB < 100 mA
General Purpose Data Acquisition DT9812-2.5V	12-bits @ 50 kS/s	8 AI, 2 AO, 16 DIO, 1 C/T	Yes to 50 kS/s	0 to 2.44 V, 1.22 V, 0.61 V, 0.305 V, 0.1525 V	0 to 2.44 V	Yes/Yes	USB < 100 mA
Lowest Cost Data Acquisition DT9810	10-bits @ 25 kS/s	8 AI, 0 AO, 20 DIO, 1 C/T	Yes to 25 kS/s	0 to 2.44 V	-	No/Yes	USB < 100 mA
Lowest Cost DIO DT9817	-	0 AI, 0 AO, 28 DIO, 1 C/T	Yes	-	-	-	USB < 100 mA

All ECONseries modules are:

- Full-speed USB 2.0 devices operating at 12 Mbps
- Nonisolated, utilizing the same ground as the USB port
- ESD protected up to 4 kV contact and 8 kV arc
- Powered from USB sources - no power supply needed

## Summary

The benefits of USB for test and measurement applications are many. But, before choosing a USB data acquisition module, consider your application. If transient voltages or differences in ground potentials exist, protect your PC and preserve the integrity of your signal by choosing an isolated USB data acquisition module. If, on the other hand, you are operating in benign conditions, where transient electrical spikes and different ground potentials do not exist, choose a nonisolated module with high input impedance for error-free measurements.