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**USB-6003**

# USER GUIDE

# NI USB-6001/6002/6003

## Low-Cost DAQ USB Device

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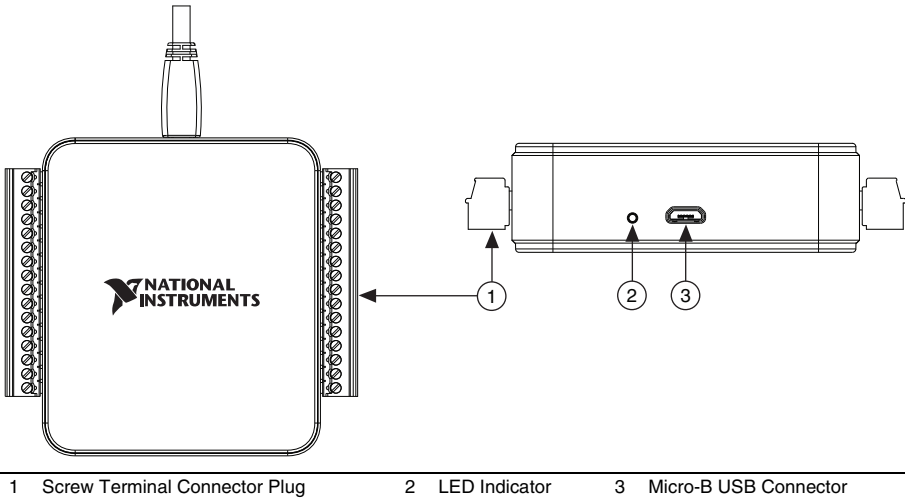
This user guide describes how to use the National Instruments USB-6001/6002/6003 data acquisition (DAQ) devices. For device specifications, go to [ni.com/manuals](http://ni.com/manuals) and search by device name.

The NI USB-6001/6002/6003 is a full-speed USB device that provides eight single-ended analog input (AI) channels, which may also be configured as four differential channels. It also includes two analog output (AO) channels, 13 digital input/output (DIO) channels, and a 32-bit counter.

**Table 1.** Differences Between the NI USB-6001, NI USB-6002, and NI USB-6003

Feature	NI USB-6001	NI USB-6002	NI USB-6003
<b>Analog Input</b>			
Analog-to-digital converter (ADC) Resolution	14-bit	16-bit	16-bit
Maximum Sample Rate (aggregate)	20 kS/s	50 kS/s	100 kS/s
<b>Analog Output</b>			
DAC Resolution	14-bit	16-bit	16-bit
Absolute Accuracy, Typical, at full scale	9.1 mV	8.6 mV	8.6 mV

**Figure 1. NI USB-6001/6002/6003 Top and Side Views**



## Safety Guidelines

Operate the NI DAQ device only as described in this document.



**Caution** Refer to the *NI USB-6001/6002/6003 Safety, Environmental, and Regulatory Information* document included with your kit for important safety and electromagnetic compatibility information. To obtain a copy of this document online, visit [ni.com/manuals](http://ni.com/manuals) and search for the document title.



**Caution** Do *not* operate the device in a manner not specified in this document. Misuse of the device can result in a hazard. You can compromise the safety protection built into the device if the device is damaged in any way. If the device is damaged, contact National Instruments for repair.



**Caution** Do *not* substitute parts or modify the device except as described in this document. Use the device only with the chassis, modules, accessories, and cables specified in the installation instructions.



**Caution** Do *not* operate the device in an explosive atmosphere or where there may be flammable gases or fumes. If you must operate the device in such an environment, it must be in a suitably rated enclosure.



**Caution** You must have all covers and filler panels installed during operation of the device. Do *not* operate the device without verifying that the cover is correctly attached and the device is completely closed.

# Electromagnetic Compatibility Guidelines

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This product was tested and complies with the regulatory requirements and limits for electromagnetic compatibility (EMC) stated in the product specifications. These requirements and limits provide reasonable protection against harmful interference when the product is operated in the intended operational electromagnetic environment.

This product is intended for use in industrial locations. However, harmful interference may occur in some installations, when the product is connected to a peripheral device or test object, or if the product is used in residential or commercial areas. To minimize interference with radio and television reception and prevent unacceptable performance degradation, install and use this product in strict accordance with the instructions in the product documentation.

Furthermore, any modifications to the product not expressly approved by National Instruments could void your authority to operate it under your local regulatory rules.



**Caution** To ensure the specified EMC performance, the length of any wire or cable connected to the screw terminal connector must be no longer than 0.5 m (20 in.).

## Unpacking

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The NI DAQ device ships in an antistatic package to prevent electrostatic discharge (ESD). ESD can damage several components on the device.



**Caution** *Never* touch the exposed pins of the connectors.

To avoid ESD damage in handling the device, take the following precautions:

- Ground yourself with a grounding strap or by touching a grounded object.
- Touch the antistatic package to a metal part of your computer chassis before removing the device from the package.

Remove the device from the package and inspect it for loose components or any other signs of damage. Notify NI if the device appears damaged in any way. Do not install a damaged device in your computer.

Store the device in the antistatic package when the device is not in use.

## Packing List

The NI DAQ device is shipped in a box that contains:

- NI USB-6001/6002/6003
- Two screw terminal connector plugs
- Hi-Speed Micro USB cable
- NI-DAQmx DVD
- *NI USB-6001/6002/6003 Quick Start* document
- *NI USB-6001/6002/6003 Safety, Environmental, and Regulatory Information* document

# Setting Up the NI USB-6001/6002/6003

Complete the following steps to get started with the NI USB-6001/6002/6003.

## Installing the Software

1. Install the application software (if applicable), as described in the installation instructions that accompany your software.
2. Install NI-DAQmx. NI USB-6001/6002/6003 devices are supported by NI-DAQmx 9.9 and later.



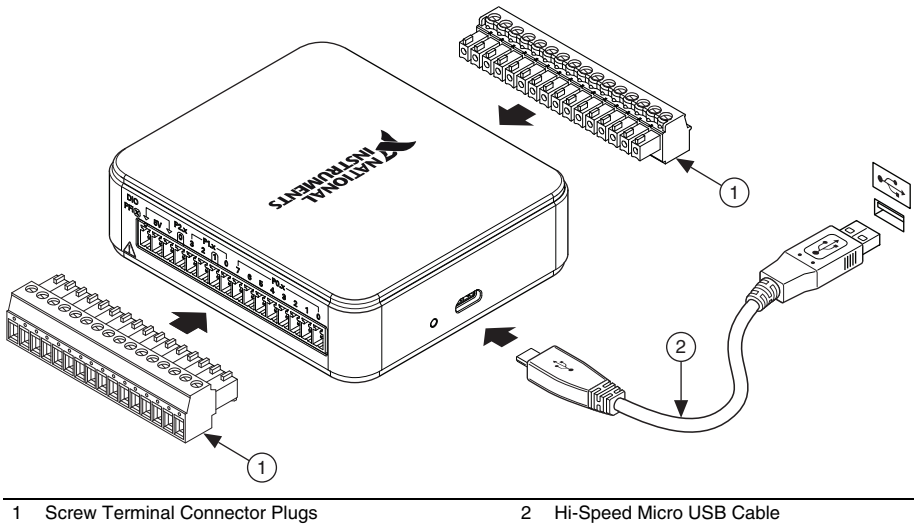
**Note** The NI-DAQmx software is included on the disk shipped with your kit and is available for download at [ni.com/support](http://ni.com/support). The documentation for NI-DAQmx is available after installation from **Start»All Programs»National Instruments»NI-DAQmx**. Other NI documentation is available at [ni.com/manuals](http://ni.com/manuals).

3. Register your products when the NI Product Registration Wizard appears.

## Preparing the Hardware

1. Insert the screw terminal connector plugs into the connector jacks on the device. Refer to Figure 2.
2. The Hi-Speed Micro USB cable has two different connectors. Plug the smaller connector into the device, and plug the larger connector into the USB port on the computer where NI-DAQmx is installed.

**Figure 2.** Hardware Setup for NI USB-6001/6002/6003



## Verifying the Installation

1. Complete the following to launch NI Measurement and Automation Explorer (NI MAX):
  - **(Windows 7/Vista)**—Double-click the **NI MAX** icon on the desktop.
  - **(Windows 8)**—Click **NI Measurement & Automation Explorer** from NI Launcher.
2. Expand **My System»Devices and Interfaces** and verify that the NI USB-6001/6002/6003 is listed. If your device does not appear, press <F5> to refresh the view in NI MAX. If your device is still not recognized, refer to [ni.com/support/daqmx](http://ni.com/support/daqmx) for troubleshooting information.
3. To self-test your device in NI MAX, right-click your device and select **Self-Test**. Self-test performs a brief test to determine successful device installation. When the self-test finishes, a message indicates successful verification. If an error occurs, refer to [ni.com/support/daqmx](http://ni.com/support/daqmx).



**Caution** To ensure the specified EMC performance, operate this product only with shielded cables and accessories.

4. Connect the wires (0.08 to 1.31 mm<sup>2</sup> [28 to 16 AWG]) of a shielded, multiconductor cable to the screw terminals by stripping 6 mm (0.25 in.) of the insulation, inserting the stripped wires into the screw terminals, and securely tightening the screws with a flathead screwdriver to a torque of 0.22 to 0.25 N · m (2.0 to 2.2 lb · in.). Refer to Figure 4 for the NI USB-6001/6002/6003 pinout.

If using a shielded cable, connect the cable shield to a nearby GND terminal.

5. Run a test panel in NI MAX by right-clicking your device and selecting **Test Panels**. Click **Start** to test the device functions, or **Help** for operating instructions. If an error message occurs refer to [ni.com/support/daqmx](http://ni.com/support/daqmx). Click **Close** to exit the test panel.

## Using the NI USB-6001/6002/6003 in an Application

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### Example Programs

NI-DAQmx driver software includes example programs to help you get started programming with the NI USB-6001/6002/6003. You can modify example code and save it in an application, use examples to develop a new application, or add example code to an existing application.

To locate NI software examples, go to [ni.com/info](http://ni.com/info) and enter the Info Code `daqmxexp`. To run examples without the device installed, use an NI-DAQmx simulated device. For more information, open NI Measurement & Automation Explorer (NI MAX), select **Help»Help Topics»NI-DAQmx»MAX Help for NI-DAQmx**, and search for simulated devices.

# NI-DAQ Assistant

You can use the NI-DAQ Assistant through many NI application software programs to configure virtual and measurement channels. Table 2 lists NI-DAQ Assistant tutorial locations for NI applications.

**Table 2.** NI-DAQ Assistant Tutorial Locations

NI Application Software	Tutorial Location
LabVIEW	Go to <b>Start»All Programs»National Instruments»NI-DAQmx»NI-DAQmx Help»Getting Started.</b>
LabWindows™/CVI™	Go to <b>Help»Contents.</b> Next, go to <b>Using LabWindows/CVI»Data Acquisition»Taking an NI-DAQmx Measurement in LabWindows/CVI.</b>
Measurement Studio	Go to <b>NI Measurement Studio Help»Getting Started with the Measurement Studio Class Libraries»Measurement Studio Walkthroughs»Walkthrough: Creating a Measurement Studio NI-DAQmx Application.</b>
SignalExpress	Go to <b>Help»Taking an NI-DAQmx Measurement in SignalExpress.</b>

## ANSI C without NI Application Software

The *NI-DAQmx Help* contains API overviews and general information about measurement concepts. Select **Start»All Programs»National Instruments»NI-DAQmx»NI-DAQmx Help.**

The *NI-DAQmx C Reference Help* describes the NI-DAQmx Library functions. Select **Start»All Programs»National Instruments»NI-DAQmx»Text-Based Code Support»NI-DAQmx C Reference Help.**

## .NET Languages without NI Application Software

With the Microsoft .NET Framework version 2.0 or later, you can use NI-DAQmx to create applications using Visual C# and Visual Basic .NET without Measurement Studio. You need Microsoft Visual Studio .NET 2005 or later for the API documentation to be installed.

The installed documentation contains the NI-DAQmx API overview, measurement tasks and concepts, and function reference. To view the NI-DAQmx .NET documentation, go to **Start»All Programs»National Instruments»NI-DAQmx»Text-Based Code Support.** For function reference, refer to the *NationalInstruments.DAQmx Namespace* and *NationalInstruments.DAQmx.ComponentModel Namespace* topics. For conceptual help, refer to the *Using the Measurement Studio NI-DAQmx .NET Library* and *Developing with Measurement Studio NI-DAQmx* sections.

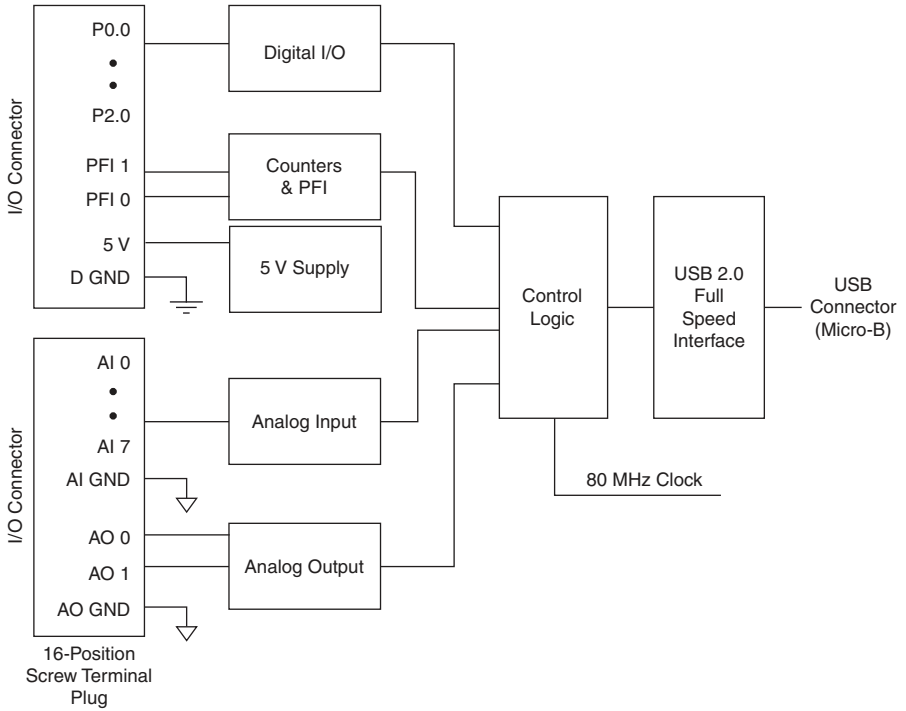
To get to the same help topics from within Visual Studio 2005 or 2008, go to **Help»Contents** and select **Measurement Studio** from the **Filtered By** drop-down list. To get to the same help topics from within Visual Studio 2010, go to **Help»View Help** and select **NI Measurement Studio Help** from the **Related Links** section.

# Features

## Block Diagram

Figure 3 shows key functional components of the NI DAQ device.

**Figure 3.** NI USB-6001/6002/6003 Block Diagram





# LED Indicator

The NI DAQ device has a blue LED that indicates device status, as listed in Table 3.

**Table 3.** LED State/Device Status

LED State	Device Status
Off	Device is not connected or is in suspend mode.
On, not blinking	Device is connected and functioning normally.
Blinking	Device has encountered an error. Wait 10 seconds to allow the device to attempt to recover from the error. If the LED continues blinking, disconnect and reconnect the device. If the error persists, contact National Instruments. Refer to the <a href="#">Worldwide Support and Services</a> section for contact information.

## Screw Terminal Connector Plugs

The NI USB-6001/6002/6003 ships with two detachable screw terminal connector plugs: one for analog signals and one for digital signals. These screw terminal connectors provide 16 connections that use 0.08 to 1.31 mm<sup>2</sup> (28 to 16 AWG). Refer to the [Pinout and Signal Descriptions](#) section for the device pinout and signal descriptions.

## Cables and Accessories

Table 4 contains information about cables and accessories available for the NI USB-6001/6002/6003. For a complete list of accessories and ordering information, refer to the pricing section of the NI DAQ device product page at [ni.com](#).

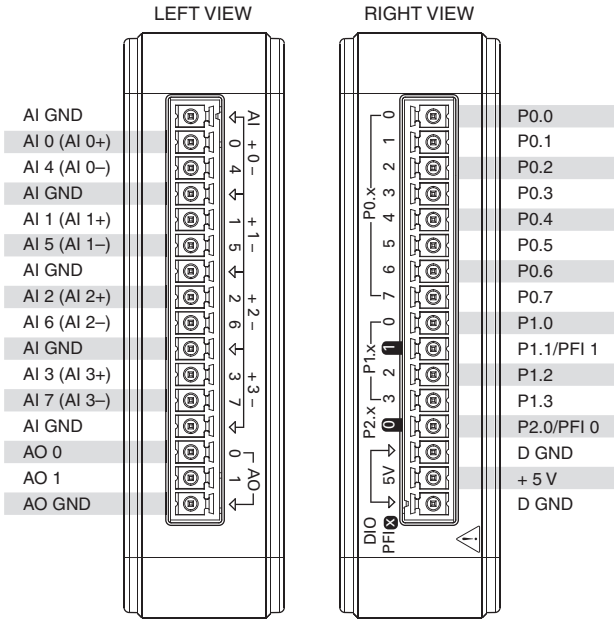
**Table 4.** NI USB-6001/6002/6003 Cables and Accessories

Accessory	Part Number	Description
USB-600x Accessories	782703-01	Four additional screw-terminal connectors and a screwdriver.
USB-600x Series Prototyping Accessories	779511-01	Unshielded breadboarding accessory for custom-defined signal conditioning and prototyping. You can use up to two accessories per device.
Hi-Speed Micro USB Cable, A to Micro-B	782909-01, 782909-02	1 m and 2 m lengths
<b>Caution:</b> To ensure the specified EMC performance, the length of any wire or cable connected to the screw terminal connector must be no longer than 0.5 m (20 in.).		

# Pinout and Signal Descriptions

Figure 4 shows the NI DAQ device pinout. Analog input signal names are listed as single-ended analog input name, AI  $x$ , and then the differential analog input name, (AI  $x+/-$ ). Refer to Table 5 for a detailed description of each signal.

**Figure 4.** NI USB-6001/6002/6003 Pinout



**Table 5.** Signal Descriptions

Signal Name	Reference	Direction	Description
AI GND	—	—	<b>Analog Input Ground</b> —The reference point for single-ended analog input measurements.
AI <0..7>	AI GND	Input	<b>Analog Input Channels 0 to 7</b> —For single-ended measurements, each signal corresponds to one analog input voltage channel. For differential measurements, AI 0 and AI 4 are the positive and negative inputs of differential analog input channel 0. The following signal pairs also form differential input channels: AI <1,5>, AI <2, 6>, and AI <3, 7>. Refer to the <a href="#">Analog Input</a> section for more information.

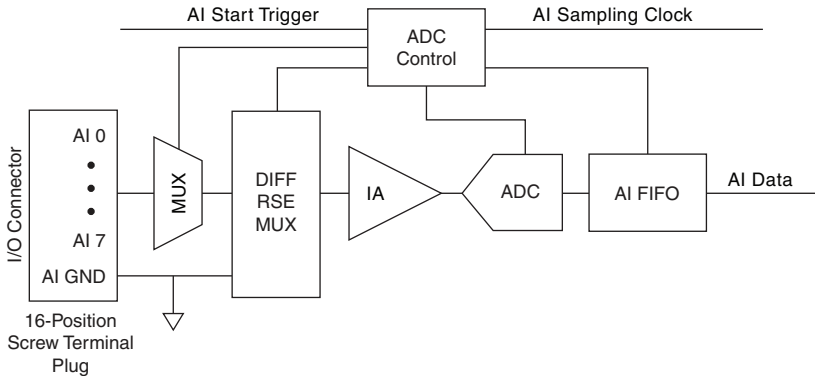
**Table 5.** Signal Descriptions (Continued)

Signal Name	Reference	Direction	Description
AO GND	—	—	<b>Analog Output Ground</b> —The reference point for analog output.
AO <0, 1>	AO GND	Output	<b>Analog Output Channels 0 and 1</b> —Supplies the voltage output of the AO channels. Refer to the <i>Analog Output</i> section for more information.
P0.<0..7>	D GND	Input or Output	<b>Port 0 Digital I/O Channels 0 to 7</b> —You can configure each signal individually as an input or output. Refer to the <i>Digital I/O</i> section for more information.
P1.<0..3>	D GND	Input or Output	<b>Port 1 Digital I/O Channels 0 to 3</b> —You can configure each signal individually as an input or output. Refer to the <i>Digital I/O</i> section for more information.
P2.0	D GND	Input or Output	<b>Port 2 Digital I/O Channel 0</b> —You can configure each signal individually as an input or output. Refer to the <i>Digital I/O</i> section for more information.
PFI 0, 1	D GND	Input	<b>Programmable Function Interface or Digital I/O Channels</b> —An edge counter input or digital trigger input. Refer to the <i>PFI 0 and PFI 1</i> section for more information.
D GND	—	—	<b>Digital Ground</b> —The reference point for digital signals.
+5 V	D GND	Output	<b>+5 V Power Source</b> —Provides +5 V power up to 150 mA. Refer to the <i>+5 V Power Source</i> section for more information.

# Analog Input

The NI USB-6001/6002/6003 has eight analog input channels that you can use for four differential analog input measurements or eight single-ended analog input measurements. Figure 5 shows the analog input circuitry of the NI DAQ device.

**Figure 5.** NI USB-6001/6002/6003 Analog Input Circuitry



The main blocks featured in the analog input circuitry are as follows:

- **MUX**—The multiplexer (MUX) routes one AI channel at a time to the mode selector multiplexer (DIFF/RSE MUX).
- **DIFF/RSE MUX**—The mode selector multiplexer selects between differential mode (DIFF) and referenced single-ended (RSE) measurement mode.
- **IA**—The instrumentation amplifier (IA) removes the common mode signal and buffers the analog input signal before it is sampled by the analog-to-digital converter (ADC).
- **ADC**—The analog-to-digital converter (ADC) digitizes the AI signal by converting the analog voltage into digital code.
- **AI FIFO**—The NI DAQ device can perform both single and multiple analog-to-digital conversions of a fixed or infinite number of samples. A first-in-first-out (FIFO) buffer holds data during AI acquisitions to ensure no data is lost.
- **ADC Control**—The ADC control circuitry sets the conversion rate of the ADC, sets the input configuration, drives the scanning sequence, and starts acquisitions synchronous with PFI 0 or PFI 1.

# Analog Input Modes

You can configure the analog input channels on the NI DAQ device to take up to four differential (DIFF) or eight referenced single-ended (RSE) measurements.

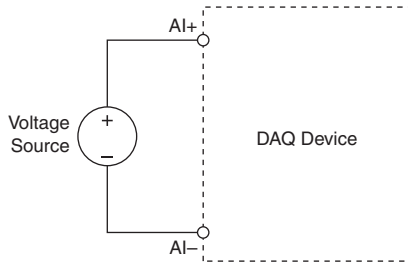
- **Differential mode**—In DIFF mode, the NI DAQ device measures the difference in voltage between two AI signals.
- **Referenced single-ended mode**—In RSE mode, the NI DAQ device measures the voltage of an AI signal relative to AI GND.

Analog input modes are programmed on a per-channel basis. For example, you can configure the device to scan two channels in differential mode and four channels on single-ended mode. The AI settings determine how you connect your AI signals to the NI DAQ device.

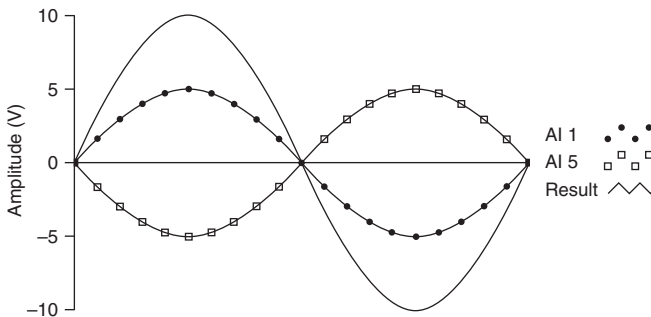
## Taking Differential Measurements

For differential signals, connect the positive lead of the voltage signal or source to the AI+ terminal, and the negative lead to the AI- terminal.

**Figure 6.** Connecting a Differential Voltage Signal



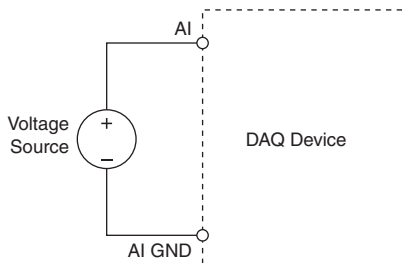
**Figure 7.** Example of a Differential  $\pm 10$  V Measurement



## Taking Referenced Single-Ended Measurements

To connect referenced single-ended (RSE) voltage signals to the NI DAQ device, connect the positive voltage signal to an AI terminal, and the ground signal to a AI GND terminal, as shown in Figure 8.

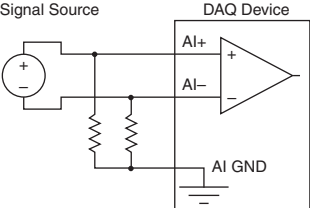
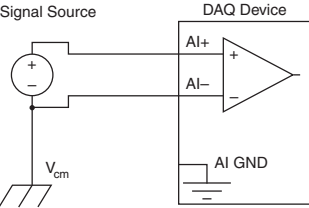
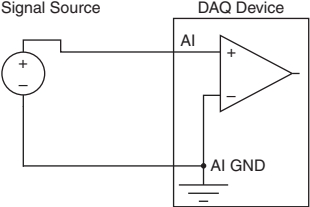
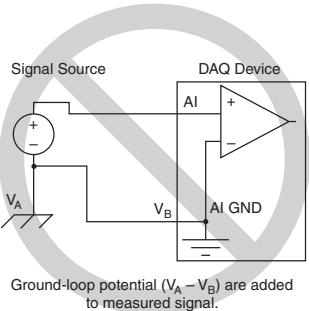
**Figure 8.** Connecting a Referenced Single-Ended Voltage Signal



# Signal Sources and Recommended Input Configuration

Table 6 summarizes the recommended analog input mode(s) for floating signal sources and ground-referenced signal sources.

**Table 6.** NI USB-6001/6002/6003 Analog Input Configuration

	Signal Source Type	
Analog Input Mode <sup>†</sup>	Floating Signal Source (Not Connected to Building Ground)	Ground-Referenced Signal Source <sup>†</sup>
	Examples: <ul style="list-style-type: none"> <li>• Ungrounded thermocouples</li> <li>• Signal conditioning with isolated outputs</li> <li>• Battery devices</li> </ul>	Example: <ul style="list-style-type: none"> <li>• Plug-in instruments with non-isolated outputs</li> </ul>
Differential (DIFF)		
Referenced Single-Ended (RSE)		 <p>Ground-loop potential (<math>V_A - V_B</math>) are added to measured signal.</p>
<p>* Refer to the <a href="#">Taking Differential Measurements</a> section for descriptions of the RSE and DIFF modes and software considerations.</p> <p>† Refer to the <a href="#">Ground-Referenced Signal Sources</a> section for more information.</p>		

## Floating Signal Sources

An instrument or device that has an isolated output is a floating signal source. A floating signal source is not connected to the building ground system, but has an isolated ground-reference point. Some examples of floating signal sources are outputs of transformers, thermocouples, battery-powered devices, optical isolators, and isolation amplifiers.

For more information about field wiring and noise considerations for analog signals, go to [ni.com/info](http://ni.com/info) and enter Info Code `rdfwn3`.

### When to Use Differential Connections with Floating Signal Sources

Use DIFF input connections for any channel that meets any of the following conditions:

- The input signal is low level and requires greater accuracy.
- The leads connecting the signal to the device are greater than 3 m (10 ft).
- The input signal requires a separate ground-reference point or return signal.
- The signal leads travel through noisy environments.
- Two analog input channels, AI+ and AI-, are available for the signal.

DIFF signal connections reduce noise pickup and increase common-mode noise rejection. DIFF signal connections also allow input signals to float within the working voltage of the device. With this type of connection, the instrumentation amplifier (IA) rejects both the common-mode noise in the signal and the ground potential difference between the signal source and the device ground.

Refer to the [Taking Differential Measurements](#) section for more information about differential connections.

### When to Use Referenced Single-Ended (RSE) Connections with Floating Signal Sources

Only use RSE input connections if the input signal meets all of the following conditions:

- The input signal can share a common reference point, AI GND, with other signals that use RSE.
- The leads connecting the signal to the device are less than 3 m (10 ft).

DIFF input connections are recommended for greater signal integrity for any input signal that does not meet the preceding conditions.

In the single-ended modes, more electrostatic and magnetic noise couples into the signal connections than in DIFF configurations. The coupling is the result of differences in the signal path. Magnetic coupling is proportional to the area between the two signal conductors. Electrical coupling is a function of how much the electric field differs between the two conductors.

Refer to the [Taking Referenced Single-Ended Measurements](#) section for more information about RSE connections.



## Ground-Referenced Signal Sources

A ground-referenced signal source is a signal source connected to the building system ground. It is already connected to a common ground point with respect to the device, assuming that the computer is plugged into the same power system as the source. Non-isolated outputs of instruments and devices that plug into the building power system fall into this category.

The difference in ground potential between two instruments connected to the same building power system is typically between 1 and 100 mV, but the difference can be much higher if power distribution circuits are improperly connected. If a grounded signal source is incorrectly measured, this difference can appear as measurement error. Follow the connection instructions for grounded signal sources to eliminate this ground potential difference from the measured signal.

For more information about field wiring and noise considerations for analog signals, go to [ni.com/info](http://ni.com/info) and enter Info Code `rdfwn3`.

### When to Use Differential Connections with Ground-Referenced Signal Sources

Use DIFF input connections for any channel that meets any of the following conditions:

- The input signal is low level and requires greater accuracy.
- The leads connecting the signal to the device are greater than 3 m (10 ft).
- The input signal requires a separate ground-reference point or return signal.
- The signal leads travel through noisy environments.
- Two analog input channels, AI+ and AI-, are available for the signal.

DIFF signal connections reduce noise pickup and increase common-mode noise rejection. DIFF signal connections also allow input signals to float within the working voltage of the device.

Refer to the [Taking Differential Measurements](#) section for more information about differential connections.

### When to Use Referenced Single-Ended (RSE) Connections with Ground-Referenced Signal Sources

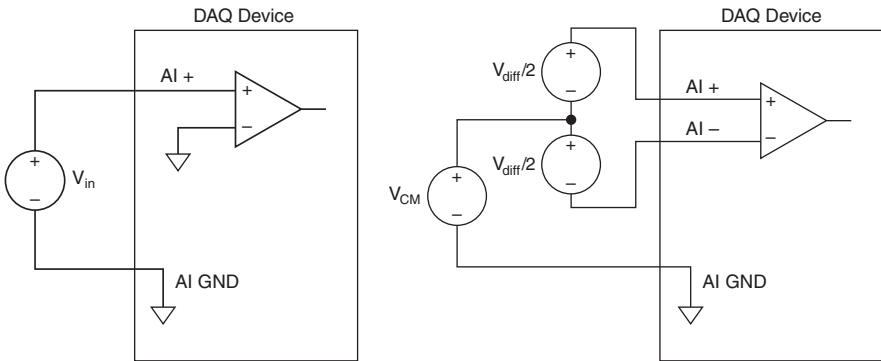
Do *not* use RSE connections with ground-referenced signal sources. Use differential connections instead.

As shown in the bottom right cell of Table 6, there can be a potential difference between AI GND and the ground of the sensor. In RSE mode, this ground loop causes measurement errors.

# Input Range

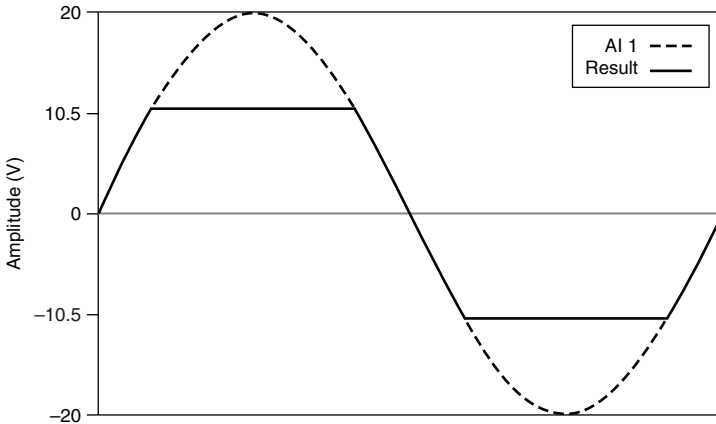
The NI DAQ device has an input range of  $\pm 10$  V. For differential mode, each AI should stay within  $\pm 10$  V with respect to AI GND, and the voltage between positive and negative inputs should be lower or equal to  $\pm 10$  V. For RSE mode, signals of  $\pm 10$  V at any analog input terminal with respect to AI GND are accurately measured.

**Figure 9.** Analog Input Range



Beyond  $\pm 10$  V, the input signal begins clipping as shown in Figure 10. Typically, this clipping begins at  $\pm 10.5$  V.

**Figure 10.** Exceeding  $\pm 10$  V on AI Returns Clipped Results



When no signals are connected to the analog input terminal, the input could be anywhere between  $+10.5$  V and  $-10.5$  V or may rail to  $\pm 10.5$  V. This behavior is normal and does not affect the measurement when a signal is connected. For more information about field and wiring noise considerations for analog signals, go to [ni.com/info](http://ni.com/info) and enter Info Code `rdfwn3`.

# Multichannel Scanning Considerations

The NI DAQ device can scan multiple channels at high rates and digitize the signals accurately. However, you should consider several issues when designing your measurement system to ensure the high accuracy of your measurements.

- **Use Low Impedance Sources**—To ensure fast settling times, your signal sources should have an impedance of  $<1\text{ k}\Omega$ . Large source impedances increase the settling time of the NI DAQ device and decrease the accuracy at fast scanning rates. For more information about decreasing the source impedance of an analog signal, go to [ni.com/info](http://ni.com/info) and enter the Info Code `rdbbis`.
- **Use Short High-Quality Cabling**—Using short high-quality cables can minimize several effects that degrade accuracy including crosstalk, transmission line effects, and noise. The capacitance of the cable also can increase the settling time.
- **Avoid Scanning Faster Than Necessary**—Design your system to scan at slower speeds to give the NI DAQ device more time to settle to a more accurate level when switching between channels.

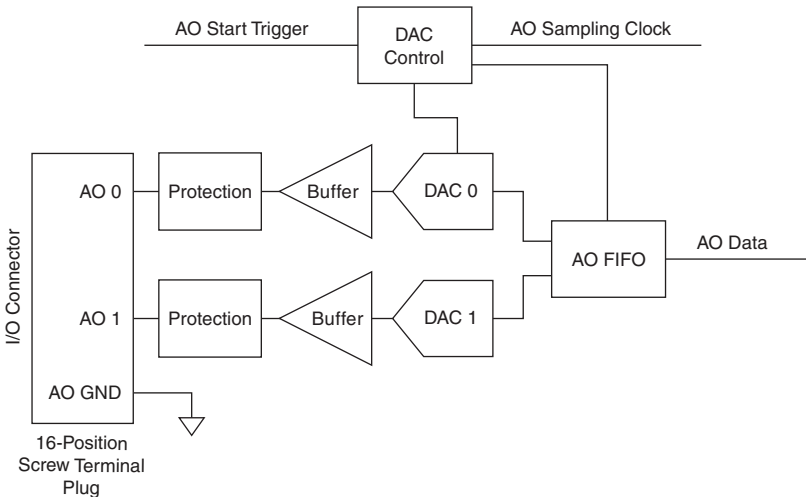
## AI Start Trigger

You can configure PFI 0 or PFI 1 as the AI Start Trigger for analog input tasks. Refer to the [Using PFI to Trigger an Analog Input Acquisition](#) section for more information.

## Analog Output

Figure 11 shows the analog output circuitry of the NI USB-6001/6002/6003.

**Figure 11.** Analog Output Circuitry



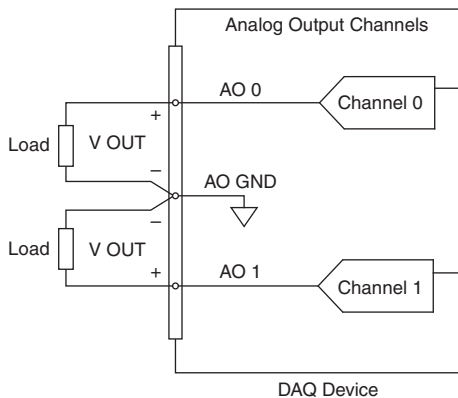
The main blocks of the AO circuitry are as follows:

- **Protection**—The protection circuit prevents damage of the buffers in case of a short circuit or an overvoltage condition.
- **Buffer**—The buffer amplifies the analog signal to the  $\pm 10$  V range and ensures the driving capability for the external load.
- **DAC 0 and DAC 1**—The Digital to Analog Converters (DAC) convert the digital signals into low-level analog signals.
- **AO FIFO**—The AO FIFO (first-in-first out) ensures that data is transferred to the DACs in a timely manner without being affected by USB latencies.
- **DAC Control**—The DAC control sets the DAC data rate and the startup condition, which could be triggered by PFI 0 or PFI 1.

## Connecting Analog Output Signals

The analog output signals are referenced to AO GND. Connect the loads between AO 0 or AO 1 and AO GND.

**Figure 12.** Connecting the Analog Output Loads



## Power-On State

The AO exhibits a short glitch when the device is powered on and when the NI DAQ device exits suspend mode. After power-up, the AO is reset to 0 V.

## AO Range

The AO range is  $\pm 10$  V.

## Minimizing Glitches on the Output Signal

When using a DAC to generate a waveform, you may observe glitches on the output signal. These glitches are normal; when a DAC switches from one voltage to another, it produces glitches due to released charges. The largest glitches occur when the most significant bit of the DAC code changes. You can build a lowpass deglitching filter to remove some of these glitches, depending on the frequency and nature of the output signal. Visit [ni.com/support](http://ni.com/support) for more information about minimizing glitches.

## Analog Output Data Generation Methods

When performing an analog output operation, you can perform software-timed or hardware-timed generations:

- **Software-Timed Generations**—Software controls the rate at which data is generated. Software sends a separate command to the hardware to initiate each NI DAQ conversion. In DAQmx, software-timed generations are referred to as on-demand timing. Software-timed generations are also referred to as immediate or static operations. They are typically used for writing a single value out, such as a constant DC voltage.
- **Hardware-Timed Generations**—A digital hardware signal controls the generation rate. This signal is generated internally on your device. Hardware-timed generations have several advantages over software-timed acquisitions:
  - The time between samples can be much shorter.
  - The timing between samples can be deterministic.

Hardware-timed operations are buffered. During hardware-timed AO generation, data is moved from a PC buffer to the onboard FIFO on the NI DAQ device using USB signal streams before it is written to the DACs one sample at a time. Buffered generations allow for fast transfer rates because data is moved in large blocks rather than one point at a time.

One property of buffered I/O operations is the sample mode. The sample mode can be either finite or continuous:

- Finite sample mode generation refers to the generation of a specific, predetermined number of data samples. After the specified number of samples is written out, the generation stops.
- Continuous generation refers to the generation of an unspecified number of samples. Instead of generating a set number of data samples and stopping, a continuous generation continues until you stop the generation.

## AO Start Trigger

You can configure PFI 1 or PFI 0 as the AO Start Trigger for analog output tasks. Refer to the [Using PFI to Trigger an Analog Output Generation](#) section for more information.

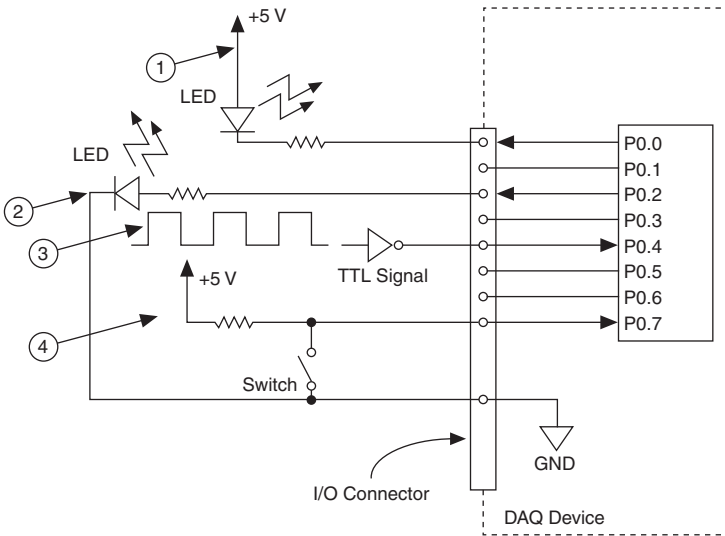
# Digital I/O

The NI USB-6001/6002/6003 has 13 digital lines: P0.<0..7>, P1.<0..3>, and P2.0. D GND is the ground-reference signal for digital I/O. You can individually program each line as input or output.

All digital input and digital output updates and samples are software-timed.

Figure 13 shows P0.<0..7> connected to example signals configured as digital inputs and digital outputs. You can configure P1.<0..3> and P2.0 similarly.

**Figure 13.** Example of Connecting a Load



- 1 P0.0 configured as an open collector **digital output** driving a LED
- 2 P0.2 configured as an **active drive digital output** driving an LED
- 3 P0.4 configured as a **digital input** receiving a TTL signal from a gated inverter
- 4 P0.7 configured as an **digital input** receiving a 0 V or 5 V signal from a switch



**Caution** Exceeding the maximum input voltage ratings or maximum output ratings, which are listed in the specifications document for the device, can damage the device and the computer. National Instruments is *not* liable for any damage resulting from such signal connections. For more information, refer to the device specifications available at [ni.com/manuals](http://ni.com/manuals).

## Power-On States

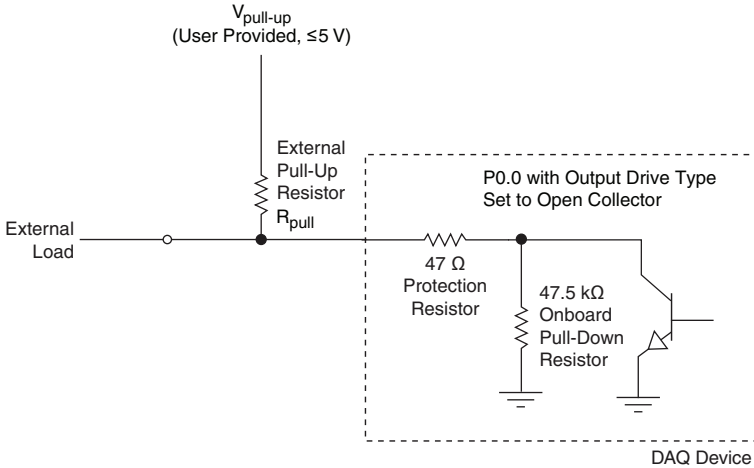
At system startup and reset, the hardware sets all DIO lines to high-impedance inputs. The NI DAQ device does not drive the signal high or low. Each line has a weak pull-down resistor connected to it.

# Source/Sink Information

When used in output mode, the default configuration of the digital ports is active drive, allowing 3.3 V operation with a source/sink current limit of  $\pm 4$  mA.

The ports can be configured as open collector using the NI-DAQmx API, allowing operation with a different voltage level when used in conjunction with an external user-provided pull-up resistor. Figure 14 shows an example of this connection.

**Figure 14.** Example of Connecting an External User-Provided Resistor



**Note:** Ensure that the current flowing across  $R_{pull}$  does not violate the maximum sinking current specifications (4 mA).

For more information about configuring NI devices to be open-drain (open collector) or push-pull (active drive), go to [ni.com/info](http://ni.com/info) and enter Info Code `ex52sp`.

## I/O Protection

To protect the NI DAQ device against overvoltage, undervoltage, and overcurrent conditions, as well as ESD events, you should avoid these fault conditions by using the following guidelines:

- If you configure a DIO line as an output, do *not* connect it to any external signal source, ground signal, or power supply.
- If you configure a DIO line as an output, understand the current requirements of the load connected to these signals. Do *not* exceed the specified current output limits of the NI DAQ device. National Instruments has several signal conditioning solutions for digital applications requiring high-current drive.
- If you configure a DIO line as an input, do *not* drive the line with voltages outside of its normal operating range. The DIO lines have a smaller operating range than the AI signals.
- Treat the NI DAQ device as you would treat any static-sensitive device. Always properly ground yourself and the equipment when handling the NI DAQ device or connecting to it.

# PFI 0 and PFI 1

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## Using PFI as a Counter Source

You can configure PFI 0 or PFI 1 as a source for counting digital edges. In this mode, either rising- or falling-edges are counted using a 32-bit counter. For more information, refer to the device specifications document available at [ni.com/manuals](http://ni.com/manuals).



**Note** Edges can only be counted up from either 0 or an initial value such as 1, 2, 3...or 1001, 1002, 1003. Counting down is not supported; you cannot set the initial count to 100 and count down 99, 98, 97.

## Using PFI to Trigger an Analog Input Acquisition

You can configure an analog input task to wait for an edge on PFI 0 or PFI 1 before starting the acquisition. To do this, configure the AI Start Trigger source to be PFI 0 or PFI 1 and specify either rising or falling edge.

## Using PFI to Trigger an Analog Output Generation

You can configure an analog output task to wait for an edge on PFI 0 or PFI 1 before starting the acquisition. To do this, configure the AO Start Trigger source to be PFI 0 or PFI 1 and specify either rising- or falling-edge.

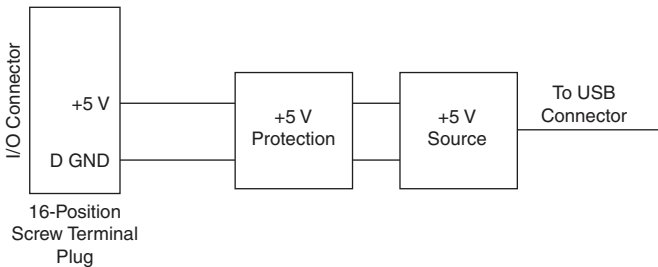
## +5 V Power Source

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Figure 15 shows the +5 V power source circuitry of the NI USB-6001/6002/6003.

**Figure 15.** +5 V Power Source Circuitry

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The main blocks featured in the +5 V power source circuitry are as follows:

- **+5 V Source**—Regulated 5 V supply.
- **+5 V Protection**—Circuit for overvoltage, over current, and short circuit protection.

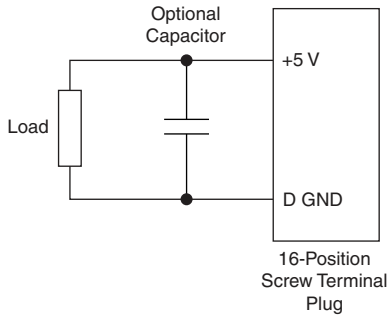
The +5 V source is limited at 200 mA typically. In case of hard short circuit to ground, this limit is further reduced to avoid excessive power dissipation.



# Connecting the Load

The return terminal for the +5 V source is the D GND terminal. +5 V load should be connected between the +5 V terminal and D GND. The current delivered by the NI DAQ device at the +5 V terminal is sourced from the USB connector. To meet the USB specifications, a maximum of 150 mA can be used from the +5 V terminal.

**Figure 16.** Connecting +5 V Power Source Load



## Enable +5 V Power Source

The +5 V power is always enabled and the voltage is present at the +5 V terminal when the device is in active mode. The +5 V power source is not available for about one second after the NI DAQ device is first connected to the USB connector or when the device is in suspend mode.

## Related Documentation

The most recent versions of documents are available from [ni.com/manuals](http://ni.com/manuals).

The following references to documents assume you have NI-DAQmx 9.9 or later and, where applicable, version 8.5 or later of the NI application software.

## Examples

To locate NI software examples, go to [ni.com/info](http://ni.com/info) and enter the Info Code `daqmxexp`.

## NI USB-6001/6002/6003

The *NI USB-6001/6002/6003 Quick Start* packaged with your NI DAQ device describes how to install the device and confirm that your device is operating properly.

The *NI USB-6001 Specifications*, *NI USB-6002 Specifications*, and *NI USB-6003 Specifications* are available for download from [ni.com/manuals](http://ni.com/manuals).

## NI-DAQmx

The *NI-DAQmx Readme* lists which devices, Application Development Environments (ADEs), and NI application software are supported by your version of NI-DAQmx. To access the *NI-DAQmx Readme*, select **Start»All Programs»National Instruments»NI-DAQmx»NI-DAQmx Readme**.

The *NI-DAQmx Help* contains API and NI-DAQmx concepts, and applications. To access the *NI-DAQmx Help*, select **Start»All Programs»National Instruments»NI-DAQmx»NI-DAQmx Help**.

## LabVIEW

If you are a new user, go to [ni.com/gettingstarted](http://ni.com/gettingstarted).

Use the *LabVIEW Help*, available by selecting **Help»LabVIEW Help** in LabVIEW, to access information about LabVIEW programming concepts. Refer to the following locations on the **Contents** tab of the *LabVIEW Help* for information about NI-DAQmx:

- **Start»National Instruments»NI-DAQmx»NI-DAQmx Help»Getting Started**—Includes overview information and a tutorial about how to take an NI-DAQmx measurement in LabVIEW using the NI-DAQ Assistant.
- **VI and Function Reference»Measurement I/O VIs and Functions»DAQmx - Data Acquisition VIs and Functions**—Describes the LabVIEW NI-DAQmx VIs and functions.
- **Property and Method Reference»NI-DAQmx Properties** contains the property reference.
- **Taking Measurements**—Contains the conceptual and how-to information you need to acquire and analyze measurement data in LabVIEW.

## LabWindows/CVI

The **Data Acquisition** book of the *LabWindows/CVI Help* contains *Taking an NI-DAQmx Measurement in LabWindows/CVI*, which contains instructions about creating a measurement task using the NI-DAQ Assistant. In LabWindows/CVI, select **Help»Contents**, then select **Using LabWindows/CVI»Data Acquisition**.

The **NI-DAQmx Library** book of the *LabWindows/CVI Help* contains API overviews and function reference for NI-DAQmx. Select **Library Reference»NI-DAQmx Library** in the *LabWindows/CVI Help*.

## Measurement Studio

If you program your NI-DAQmx-supported device in Measurement Studio using Visual C# or Visual Basic .NET, you can create channels and tasks by launching the NI-DAQ Assistant from NI MAX or from within Visual Studio. You can use Measurement Studio to generate the configuration code based on your task or channel. Refer to the *DAQ Assistant Help* for additional information about generating code.

To view the *NI Measurement Studio Help* in Visual Studio, select **Measurement Studio»NI Measurement Studio Help**. For information related to developing with NI-DAQmx, refer to the following topics within the *NI Measurement Studio Help*:

- To create an NI-DAQmx application using the Measurement Studio Application Wizard and the NI-DAQ Assistant, refer to *Walkthrough: Creating a Measurement Studio NI-DAQmx Application*.
- For help with NI-DAQmx methods and properties, refer to *NationalInstruments.DAQmx Namespace* and *NationalInstruments.DAQmx.ComponentModel Namespace*.
- For conceptual help with NI-DAQmx, refer to *Using the Measurement Studio NI-DAQmx .NET Library* and *Developing with Measurement Studio NI-DAQmx*.
- For general help with programming in Measurement Studio, refer to *Getting Started with the Measurement Studio Class Libraries*.

To create an application in Visual Basic .NET or Visual C#, follow these general steps:

1. In Visual Studio, select **File»New»Project** to launch the New Project dialog box.
2. In the Project types pane, expand the **Visual Basic** or **Visual C#** node, depending on which language you want to create the project in, and select **Measurement Studio**.
3. Choose a project type. You add NI DAQ tasks as a part of this step.

## ANSI C without NI Application Software

The *NI-DAQmx Help* contains API overviews and general information about measurement concepts. Select **Start»All Programs»National Instruments»NI-DAQmx»NI-DAQmx Help**.

The *NI-DAQmx C Reference Help* describes the NI-DAQmx Library functions, which you can use with National Instruments data acquisition devices to develop instrumentation, acquisition, and control applications. Select **Start»All Programs»National Instruments»NI-DAQmx»Text-Based Code Support»NI-DAQmx C Reference Help**.

## .NET Languages without NI Application Software

With the Microsoft .NET Framework version 2.0 or later, you can use NI-DAQmx to create applications using Visual C# and Visual Basic .NET without Measurement Studio. You need Microsoft Visual Studio .NET 2005 or later for the API documentation to be installed.

The installed documentation contains the NI-DAQmx API overview, measurement tasks and concepts, and function reference. To view the NI-DAQmx .NET documentation, go to **Start»All Programs»National Instruments»NI-DAQmx»Text-Based Code Support**. For function reference, refer to the *NationalInstruments.DAQmx Namespace* and *NationalInstruments.DAQmx.ComponentModel Namespace* topics. For conceptual help, refer to the *Using the Measurement Studio NI-DAQmx .NET Library* and *Developing with Measurement Studio NI-DAQmx* sections.

To get to the same help topics from within Visual Studio 2005 or 2008, go to **Help»Contents** and select **Measurement Studio** from the **Filtered By** drop-down list. To get to the same help topics from within Visual Studio 2010, go to **Help»View Help** and select **NI Measurement Studio Help** from the **Related Links** section.

## Training Courses

If you need more help getting started developing an application with NI products, NI offers training courses. To enroll in a course or obtain a detailed course outline, refer to [ni.com/training](http://ni.com/training).

## Technical Support on the Web

For additional support, refer to [ni.com/support](http://ni.com/support).

Many NI DAQ specifications and user guides are available as PDFs. You must have Adobe Reader 7.0 or later (PDF 1.6 or later) installed to view the PDFs. Refer to the Adobe Systems Incorporated Web site at [www.adobe.com](http://www.adobe.com) to download Acrobat Reader. Refer to the National Instruments Product Manuals Library at [ni.com/manuals](http://ni.com/manuals) for updated documentation resources.

## Worldwide Support and Services

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The National Instruments website is your complete resource for technical support. At [ni.com/support](http://ni.com/support) you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

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