

# DAQ

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## 6023E/6024E/6025E User Manual

Multifunction I/O Devices for PCI, PXI™,  
CompactPCI, and PCMCIA Bus Computers

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# About This Manual

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The 6023, 6024, and 6025 E Series boards are high-performance multifunction analog, digital, and timing I/O boards for PCI, PXI, PCMCIA, and CompactPCI bus computers. Supported functions include analog input, analog output, digital I/O, and timing I/O.

This manual describes the electrical and mechanical aspects of the PCI-6023E, PCI-6024E, DAQCard-6024E, PCI-6025E, and PXI-6025E boards from the E Series product line and contains information concerning their operation and programming.

## Conventions Used in This Manual

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The following conventions are used in this manual:

<>	Angle brackets containing numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, DBIO<3..0>.
◆	The ◆ symbol indicates that the text following it applies only to a specific product, a specific operating system, or a specific software version.
	This icon denotes a note, which alerts you to important information.
	This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash.
<b>bold</b>	Bold text denotes items that you must select or click on in the software, such as menu items and dialog box options. Bold text also denotes parameter names.
CompactPCI	CompactPCI refers to the core specification defined by the PCI Industrial Computer Manufacturer's Group (PICMG).
<i>italic</i>	Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text that is a placeholder for a word or value that you must supply.
monospace	Monospace font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories,

programs, subprograms, subroutines, device names, functions, operations, variables, filenames and extensions, and code excerpts.

**NI-DAQ** NI-DAQ refers to the NI-DAQ driver software for PC compatible computers unless otherwise noted.

**PXI** PXI stands for PCI eXtensions for Instrumentation. PXI is an open specification that builds off the CompactPCI specification by adding instrumentation-specific features.

## Related Documentation

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The following documents contain information you may find helpful:

- *DAQ-STC Technical Reference Manual*
- National Instruments Application Note 025, *Field Wiring and Noise Considerations for Analog Signals*
- *PCI Local Bus Specification Revision 2.2*
- *PICMG CompactPCI 2.0 R2.1*
- *PXI Specification Revision 2.0*
- *PC Card (PCMCIA) 7.1 Standard*

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# Introduction

This chapter describes the 6023E, 6024E, and 6025E devices, lists what you need to get started, gives unpacking instructions, and describes the optional software and equipment.

## Features of the 6023E, 6024E, and 6025E

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The 6025E features 16 channels (eight differential) of analog input, two channels of analog output, a 100-pin connector, and 32 lines of digital I/O. The 6024E features 16 channels of analog input, two channels of analog output, a 68-pin connector and eight lines of digital I/O. The 6023E is identical to the 6024E, except that it does not have analog output channels.

These devices use the National Instruments DAQ-STC system timing controller for time-related functions. The DAQ-STC consists of three timing groups that control analog input, analog output, and general-purpose counter/timer functions. These groups include a total of seven 24-bit and three 16-bit counters and a maximum timing resolution of 50 ns. The DAQ-STC makes possible such applications as buffered pulse generation, equivalent time sampling, and seamless changing of the sampling rate.

- ◆ PCI-6023E, PCI-6024E, PCI-6025E, and PXI-6025E only

With many DAQ devices, you cannot easily synchronize several measurement functions to a common trigger or timing event. These devices have the Real-Time System Integration (RTSI) bus to solve this problem. In a PCI system, the RTSI bus consists of the National Instruments RTSI bus interface and a ribbon cable to route timing and trigger signals between several functions on as many as five DAQ devices in your computer. In a PXI system, the RTSI bus consists of the National Instruments RTSI bus interface and the PXI trigger signals on the PXI backplane to route timing and trigger signals between several functions on as many as seven DAQ devices in your system.

These devices can interface to an SCXI system—the instrumentation front end for plug-in DAQ devices—so that you can acquire analog signals from thermocouples, RTDs, strain gauges, voltage sources, and current sources. You can also acquire or generate digital signals for communication and control.

## Using PXI with CompactPCI

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Using PXI compatible products with standard CompactPCI products is an important feature provided by *PXI Specification, Revision 1.0*. If you use a PXI compatible plug-in card in a standard CompactPCI chassis, you cannot use PXI-specific functions, but you can still use the basic plug-in card functions. For example, the RTSI bus on your PXI E Series device is available in a PXI chassis, but not in a CompactPCI chassis.

The CompactPCI specification permits vendors to develop sub-buses that coexist with the basic PCI interface on the CompactPCI bus. Compatible operation is not guaranteed between CompactPCI devices with different sub-buses nor between CompactPCI devices with sub-buses and PXI. The standard implementation for CompactPCI does not include these sub-buses. Your PXI E Series device works in any standard CompactPCI chassis adhering to *PICMG CompactPCI 2.0 R2.1* core specification.

PXI specific features are implemented on the J2 connector of the CompactPCI bus. Table 3-3, *Pins Used by PXI E Series Device*, lists the J2 pins used by your PXI E Series device. Your PXI device is compatible with any Compact PCI chassis with a sub-bus that does not drive these lines. Even if the sub-bus is capable of driving these lines, the PXI device is still compatible as long as those pins on the sub-bus are disabled by default and not ever enabled. Damage can result if these lines are driven by the sub-bus.

## What You Need to Get Started

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To set up and use your device, you need the following:

- One of the following devices:
  - PCI-6023E
  - PCI-6024E
  - PCI-6025E
  - PXI-6025E
  - DAQCard-6024E

- 6023E/6024E/6025E User Manual
- One of the following software packages and documentation:
  - LabVIEW for Windows
  - Measurement Studio
  - VirtualBench
- NI-DAQ for PC Compatibles
- Your computer equipped with one of the following:
  - PCI bus for a PCI device
  - PXI or CompactPCI chassis and controller for a PXI device
  - Type II PCMCIA slot for a DAQCard device



**Note** Read Chapter 2, *Installation and Configuration*, before installing your device. Always install your software before installing your device.

## Software Programming Choices

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When programming your National Instruments DAQ and SCXI hardware, you can use National Instruments application software or another application development environment (ADE). In either case, you use NI-DAQ.

### National Instruments Application Software

LabVIEW features interactive graphics, a state-of-the-art user interface, and a powerful graphical programming language. The LabVIEW Data Acquisition VI Library, a series of virtual instruments for using LabVIEW with National Instruments DAQ hardware, is included with LabVIEW. The LabVIEW Data Acquisition VI Library is functionally equivalent to NI-DAQ software.

Measurement Studio, which includes LabWindows/CVI, tools for Visual C++, and tools for Visual Basic, is a development suite that allows you to use ANSI C, Visual C++, and Visual Basic to design your test and measurement software. For C developers, Measurement Studio includes LabWindows/CVI, a fully integrated ANSI C application development environment that features interactive graphics and the LabWindows/CVI Data Acquisition and Easy I/O libraries. For Visual Basic developers, Measurement Studio features a set of ActiveX controls for using National Instruments DAQ hardware. These ActiveX controls provide a high-level

programming interface for building virtual instruments. For Visual C++ developers, Measurement Studio offers a set of Visual C++ classes and tools to integrate those classes into Visual C++ applications. The libraries, ActiveX controls, and classes are available with Measurement Studio and the NI-DAQ software.

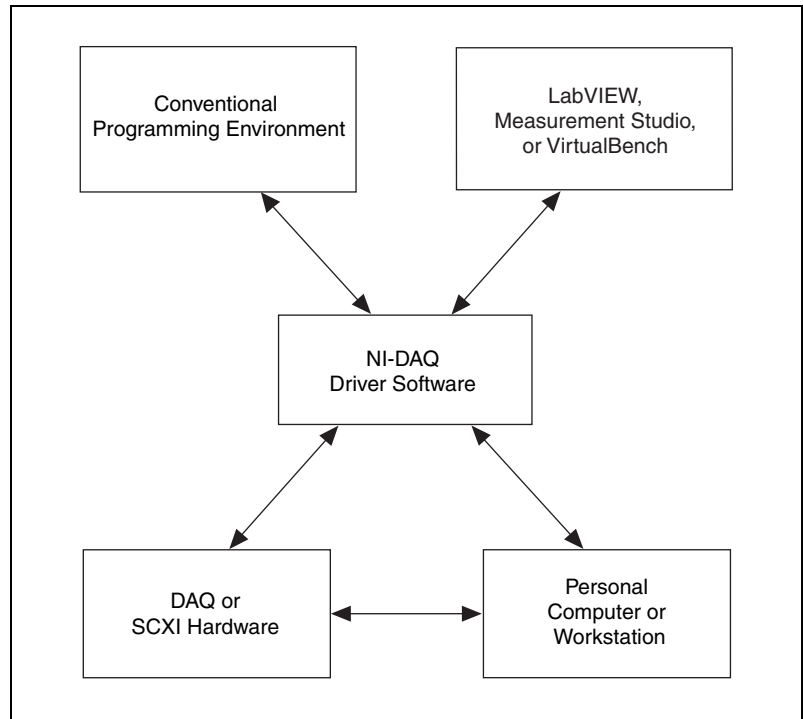
VirtualBench features virtual instruments that combine DAQ products, software, and your computer to create a stand-alone instrument with the added benefit of the processing, display, and storage capabilities of your computer. VirtualBench instruments load and save waveform data to disk in the same forms that can be used in popular spreadsheet programs and word processors.

Using LabVIEW, Measurement Studio, or VirtualBench software greatly reduces the development time for your data acquisition and control application.

## NI-DAQ Driver Software

The NI-DAQ driver software shipped with your 6023E/6024E/6025E is compatible with your device. It has an extensive library of functions that you can call from your application programming environment. These functions allow you to use all features of your 6023E/6024E/6025E.

NI-DAQ addresses many of the complex issues between the computer and the DAQ hardware such as programming interrupts. NI-DAQ maintains a consistent software interface among its different versions so that you can change platforms with minimal modifications to your code. Whether you are using LabVIEW, Measurement Studio, or other programming languages, your application uses the NI-DAQ driver software, as illustrated in Figure 1-1.



**Figure 1-1.** The Relationship Between the Programming Environment, NI-DAQ, and Your Hardware

To download a free copy of the most recent version of NI-DAQ, click **Download Software** at [ni.com](http://ni.com).

## Optional Equipment

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National Instruments offers a variety of products to use with your device, including cables, connector blocks, and other accessories, as follows:

- Cables and cable assemblies, shielded and ribbon
- Connector blocks, shielded and unshielded screw terminals
- RTSI bus cables
- SCXI modules and accessories for isolating, amplifying, exciting, and multiplexing signals for relays and analog output. With SCXI you can condition and acquire up to 3,072 channels.
- Low channel count signal conditioning modules, devices, and accessories, including conditioning for strain gauges and RTDs, simultaneous sample and hold, and relays

For more information about these products, refer to the National Instruments catalogue or web site or call the office nearest you.



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# Installation and Configuration

This chapter explains how to install and configure your 6023E, 6024E, or 6025E device.

## Software Installation

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Install your software before installing your device.

If you are using LabVIEW, LabWindows/CVI, ComponentWorks, or VirtualBench, install this software before installing the NI-DAQ driver software. Refer to the software release notes of your software for installation instructions.

If you are using NI-DAQ, refer to your NI-DAQ release notes. Find the installation section for your operating system and follow the instructions given there.

## Unpacking

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Your device is shipped in an antistatic package to prevent electrostatic damage to the device. Electrostatic discharge can damage several components on the device. To avoid such damage in handling the device, take the following precautions:

- Ground yourself by using a grounding strap or by holding 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 the device for loose components or any other sign of damage. Notify National Instruments if the device appears damaged in any way. Do *not* install a damaged device into your computer.

*Never* touch the exposed pins of connectors.

# Hardware Installation

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After installing your software, you are ready to install your hardware. Your device will fit in any available slot in your computer. However, to achieve best noise performance, leave as much room as possible between your device and other devices. The following are general installation instructions. Consult your computer user manual or technical reference manual for specific instructions and warnings.

◆ PCI device installation

1. Turn off and unplug your computer.
2. Remove the top cover of your computer.
3. Remove the expansion slot cover on the back panel of the computer.
4. Touch any metal part of your computer chassis to discharge any static electricity that might be on your clothes or body.
5. Insert the device into a 5 V PCI slot. Gently rock the device to ease it into place. It may be a tight fit, but *do not force* the device into place.
6. Screw the mounting bracket of the device to the back panel rail of the computer.
7. Visually verify the installation.
8. Replace the top cover of your computer.
9. Plug in and turn on your computer.

◆ PCMCIA card installation

Insert the DAQCard into any available Type II PCMCIA slot until the connector is seated firmly. Insert the card face-up. It is keyed so that you can only insert it one way.

◆ PXI device installation

1. Turn off and unplug your computer.
2. Choose an unused PXI slot in your system. For maximum performance, the device has an onboard DMA controller that you can only use if the device is installed in a slot that supports bus arbitration, or bus master cards. National Instruments recommends installing the device in such a slot. The PXI specification requires all slots to support bus master cards, but the CompactPCI specification does not. If you install in a CompactPCI non-master slot, you must disable the onboard DMA controller of the device using software.
3. Remove the filler panel for the slot you have chosen.

4. Touch any metal part of your computer chassis to discharge any static electricity that might be on your clothes or body.
5. Insert the device into a 5 V PXI slot. Use the injector/ejector handle to fully insert the device into the chassis.
6. Screw the front panel of the device to the front panel mounting rail of the system.
7. Visually verify the installation.
8. Plug in and turn on your computer.

The device is installed. You are now ready to configure your hardware and software.

## Hardware Configuration

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National Instruments standard architecture for data acquisition and standard bus specifications, makes these devices completely software-configurable. You must perform two types of configuration on the devices—bus-related and data acquisition-related configuration.

The PCI devices are fully compatible with the industry-standard *PCI Local Bus Specification Revision 2.2*. The PXI device is fully compatible with the *PXI Specification Revision 2.0*. These specifications let your computer automatically set the device base memory address and interrupt channel without your interaction.

You can modify data acquisition-related configuration settings, such as analog input range and mode, through application-level software. Refer to Chapter 3, *Hardware Overview*, for more information about the various settings available for your device. These settings are changed and configured through software after you install your device. Refer to your software documentation for configuration instructions.

## Hardware Overview

This chapter presents an overview of the hardware functions on your device.

Figure 3-1 shows a block diagram for the PCI-6023E, PCI-6024E, PCI-6025E, and PXI-6025E.

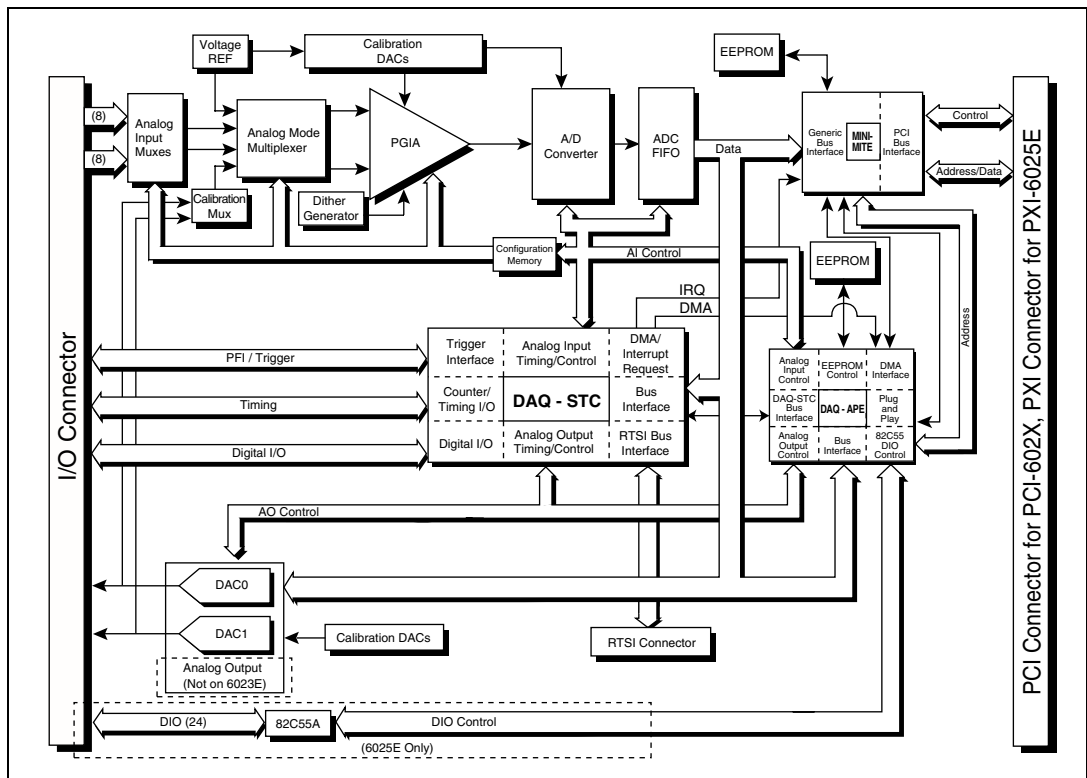


Figure 3-1. PCI-6023E, PCI-6024E, PCI-6025E, and PXI-6025E Block Diagram

Figure 3-2 shows the block diagram for the DAQCard-6024E.

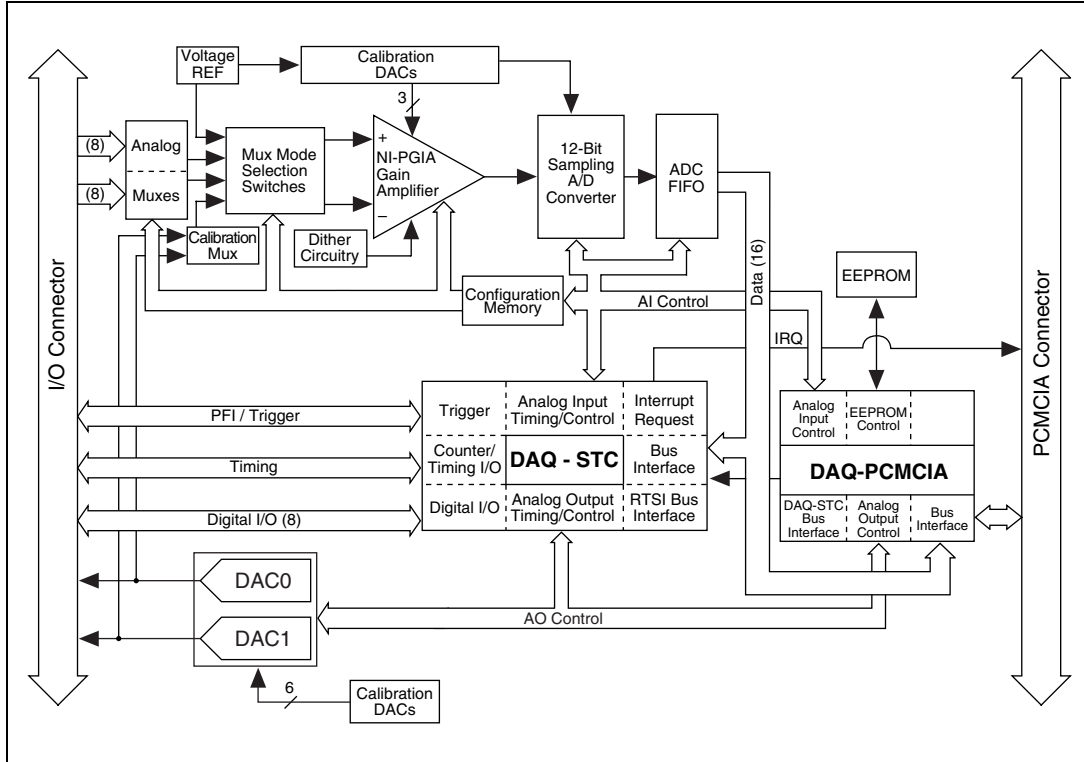


Figure 3-2. DAQCard-6024E Block Diagram

## Analog Input

The analog input section of each device is software configurable. The following sections describe in detail each of the analog input settings.

### Input Mode

The devices have three different input modes—nonreferenced single-ended (NRSE), referenced single-ended (RSE), and differential (DIFF) input. The single-ended input configurations provide up to 16 channels. The DIFF input configuration provides up to eight channels. Input modes are programmed on a per channel basis for multimode scanning. For example, you can configure the circuitry to scan 12 channels—four DIFF channels and eight RSE channels. Table 3-1 describes the three input configurations.

**Table 3-1.** Available Input Configurations

Configuration	Description
DIFF	A channel configured in DIFF mode uses two analog input lines. One line connects to the positive input of the programmable gain instrumentation amplifier (PGIA) of the device, and the other connects to the negative input of the PGIA.
RSE	A channel configured in RSE mode uses one analog input line, which connects to the positive input of the PGIA. The negative input of the PGIA is internally tied to analog input ground (AIGND).
NRSE	A channel configured in NRSE mode uses one analog input line, which connects to the positive input of the PGIA. The negative input of the PGIA connects to analog input sense (AISENSE).

For diagrams showing the signal paths of the three configurations, refer to the *Analog Input Signal Overview* section in Chapter 4, *Signal Connections*.

## Input Range

The devices have a bipolar input range that changes with the programmed gain. You can program each channel with a unique gain of 0.5, 1.0, 10, or 100 to maximize the 12-bit analog-to-digital converter (ADC) resolution. With the proper gain setting, you can use the full resolution of the ADC to measure the input signal. Table 3-2 shows the input range and precision according to the gain used.

**Table 3-2.** Measurement Precision

Gain	Input Range	Precision <sup>1</sup>
0.5	-10 to +10 V	4.88 mV
1.0	-5 to +5 V	2.44 mV
10.0	-500 to +500 mV	244.14 $\mu$ V
100.0	-50 to +50 mV	24.41 $\mu$ V

<sup>1</sup> The value of 1 LSB of the 12-bit ADC; that is, the voltage increment corresponding to a change of one count in the ADC 12-bit count.

**Note:** See Appendix A, *Specifications*, for absolute maximum ratings.

## Dithering

When you enable dithering, you add approximately  $0.5 \text{ LSB}_{\text{rms}}$  of white Gaussian noise to the signal to be converted by the ADC. This addition is useful for applications involving averaging to increase the resolution of your device, as in calibration or spectral analysis. In such applications, noise modulation is decreased and differential linearity is improved by the addition of dithering. When taking DC measurements, such as when checking the device calibration, enable dithering and average about 1,000 points to take a single reading. This process removes the effects of quantization and reduces measurement noise, resulting in improved resolution. For high-speed applications not involving averaging or spectral analysis, you may want to disable dithering to reduce noise. Your software enables and disables the dithering circuitry.

Figure 3-3 illustrates the effect of dithering on signal acquisition. Figure 3-3a shows a small ( $\pm 4 \text{ LSB}$ ) sine wave acquired with dithering off. The ADC quantization is clearly visible. Figure 3-3b shows what happens when 50 such acquisitions are averaged together; quantization is still plainly visible. In Figure 3-3c, the sine wave is acquired with dithering on. There is a considerable amount of visible noise, but averaging about 50 such acquisitions, as shown in Figure 3-3d, eliminates both the added noise and the effects of quantization. Dithering has the effect of forcing quantization noise to become a zero-mean random variable rather than a deterministic function of the input signal.

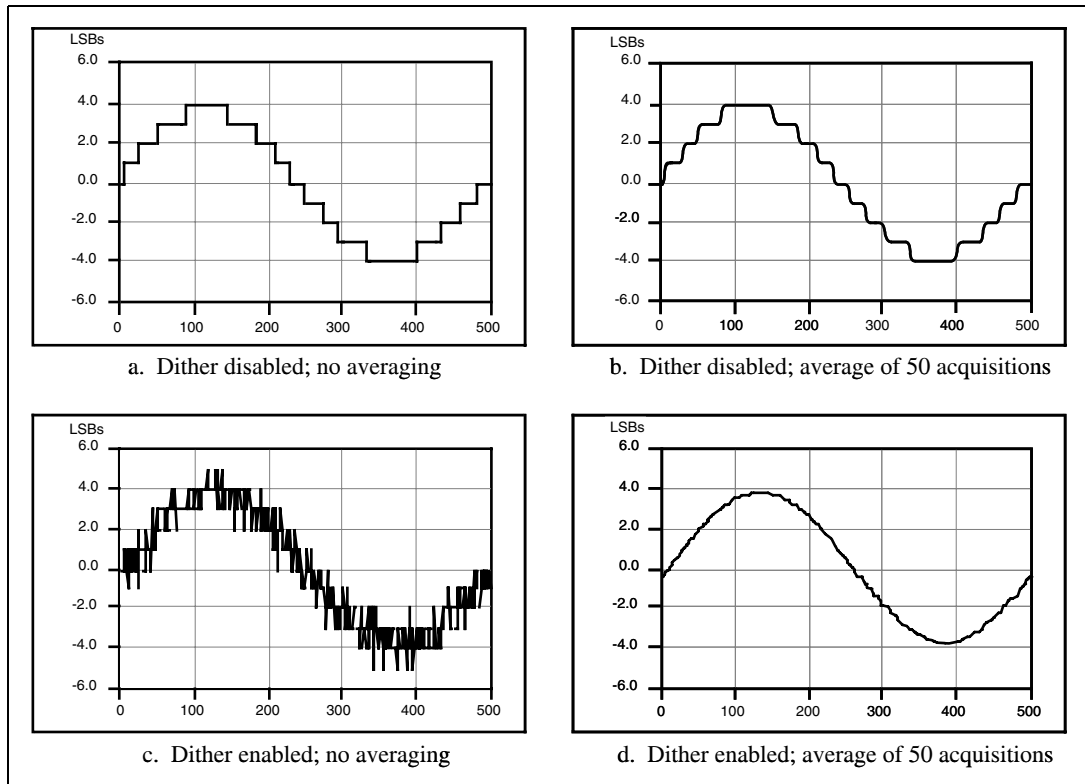


Figure 3-3. Dithering

## Multichannel Scanning Considerations

The devices can scan multiple channels at the same maximum rate as their single-channel rate; however, pay careful attention to the settling times for each of the devices. No extra settling time is necessary between channels as long as the gain is constant and source impedances are low. Refer to Appendix A, *Specifications*, for a complete listing of settling times for each of the devices.

When scanning among channels at various gains, the settling times can increase. When the PGIA switches to a higher gain, the signal on the previous channel can be well outside the new, smaller range. For instance, suppose a 4 V signal connects to channel 0 and a 1 mV signal connects to channel 1, and suppose the PGIA is programmed to apply a gain of one to channel 0 and a gain of 100 to channel 1. When the multiplexer switches to channel 1 and the PGIA switches to a gain of 100, the new full-scale range is  $\pm 50$  mV.



The approximately 4 V step from 4 V to 1 mV is 4,000% of the new full-scale range. It can take as long as 100  $\mu$ s for the circuitry to settle to 1 LSB after such a large transition. In general, this extra settling time is not needed when the PGIA is switching to a lower gain.

Settling times can also increase when scanning high-impedance signals due to a phenomenon called *charge injection*, where the analog input multiplexer injects a small amount of charge into each signal source when that source is selected. If the impedance of the source is not low enough, the effect of the charge—a voltage error—has not decayed by the time the ADC samples the signal. For this reason, keep source impedances under 1 k $\Omega$  to perform high-speed scanning.

Due to the previously described limitations of settling times resulting from these conditions, multiple-channel scanning is not recommended unless sampling rates are low enough or it is necessary to sample several signals as nearly simultaneously as possible. The data is much more accurate and channel-to-channel independent if you acquire data from each channel independently (for example, 100 points from channel 0, then 100 points from channel 1, then 100 points from channel 2, and so on).

## Analog Output

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- ◆ 6025E and 6024E only

These devices supply two channels of analog output voltage at the I/O connector. The bipolar range is fixed at  $\pm 10$  V. Data written to the digital-to-analog converter (DAC) is interpreted in two's complement format.

## Analog Output Glitch

In normal operation, a DAC output glitches whenever it is updated with a new value. The glitch energy differs from code to code and appears as distortion in the frequency spectrum.

## Digital I/O

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The devices contain eight lines of digital I/O (DIO<0..7>) for general-purpose use. You can individually software-configure each line for either input or output. At system startup and reset, the digital I/O ports are all high impedance.

The hardware up/down control for general-purpose counters 0 and 1 are connected onboard to DIO6 and DIO7, respectively. Thus, you can use DIO6 and DIO7 to control the general-purpose counters. The up/down control signals are input only and do not affect the operation of the DIO lines.

- ◆ 6025E only

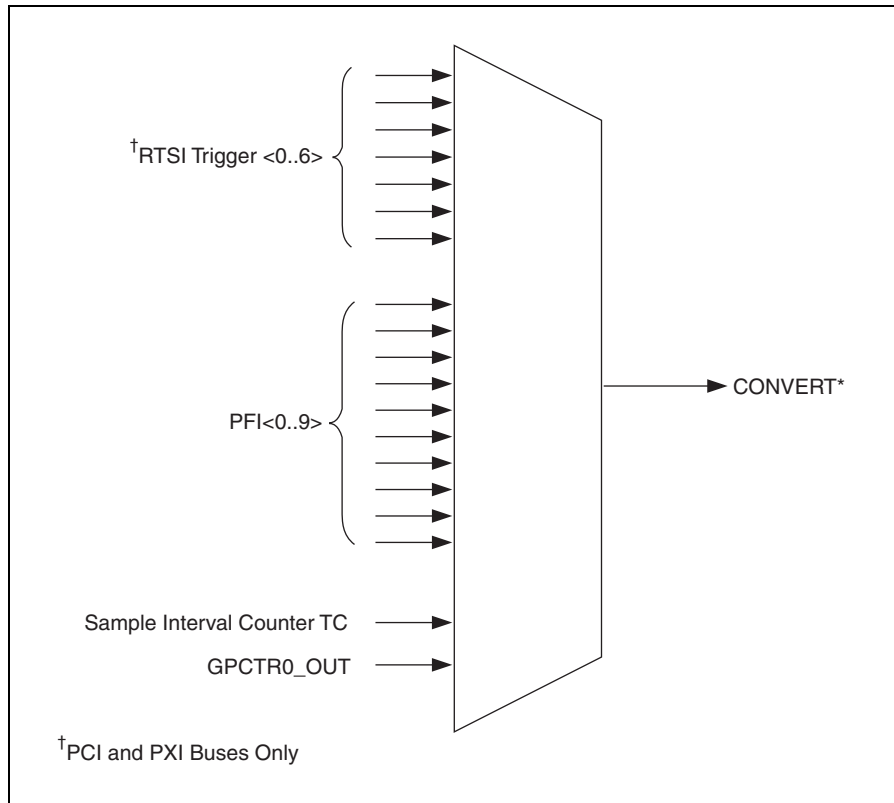
The 6025E device uses an 82C55A programmable peripheral interface to provide an additional 24 lines of digital I/O that represent three 8-bit ports—PA, PB, PC. You can program each port as an input or output port. The 82C55A has three modes of operation—simple I/O (mode 0), strobed I/O (mode 1), and bidirectional I/O (mode 2). In modes 1 and 2, the three ports are divided into two groups—group A and group B. Each group has eight data bits, plus control and status bits from Port C (PC). Modes 1 and 2 use handshaking signals from the computer to synchronize data transfers. Refer to Chapter 4, *Signal Connections*, for more detailed information.

## Timing Signal Routing

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The DAQ-STC chip provides a flexible interface for connecting timing signals to other devices or external circuitry. Your device uses the RTSI bus to interconnect timing signals between devices (PCI and PXI buses only), and the programmable function input (PFI) pins on the I/O connector to connect the device to external circuitry. These connections are designed to enable the device to both control and be controlled by other devices and circuits.

There are a total of 13 timing signals internal to the DAQ-STC that you can control by an external source. You can also control these timing signals by signals generated internally to the DAQ-STC, and these selections are fully software-configurable. Figure 3-4 shows an example of the signal routing multiplexer controlling the CONVERT\* signal.



**Figure 3-4.** CONVERT\* Signal Routing

Figure 3-4 shows that CONVERT\* can be generated from a number of sources, including the external signals RTSI<0..6> (PCI and PXI buses only) and PFI<0..9> and the internal signals Sample Interval Counter TC and GPCTRO\_OUT.

On PCI and PXI devices, many of these timing signals are also available as outputs on the RTSI pins, as indicated in the *RTSI Triggers* section in this chapter, and on the PFI pins, as indicated in Chapter 4, *Signal Connections*.

## Programmable Function Inputs

Ten PFI pins are available on the device connector as PFI<0..9> and connect to the internal signal routing multiplexer of the device for each timing signal. Software can select any one of the PFI pins as the external source for a given timing signal. It is important to note that you can use any of the PFI pins as an input by any of the timing signals and that multiple timing signals can use the same PFI simultaneously. This flexible routing

scheme reduces the need to change physical connections to the I/O connector for different applications.

You can also individually enable each of the PFI pins to output a *specific* internal timing signal. For example, if you need the UPDATE\* signal as an output on the I/O connector, software can turn on the output driver for the PFI5/UPDATE\* pin.

## Device and RTSI Clocks

- ◆ PCI and PXI buses

Many device functions require a frequency timebase to generate the necessary timing signals for controlling A/D conversions, DAC updates, or general-purpose signals at the I/O connector.

These devices can use either its internal 20 MHz timebase or a timebase received over the RTSI bus. In addition, if you configure the device to use the internal timebase, you can also program the device to drive its internal timebase over the RTSI bus to another device that is programmed to receive this timebase signal. This clock source, whether local or from the RTSI bus, is used directly by the device as the primary frequency source. The default configuration at startup is to use the internal timebase without driving the RTSI bus timebase signal. This timebase is software selectable.

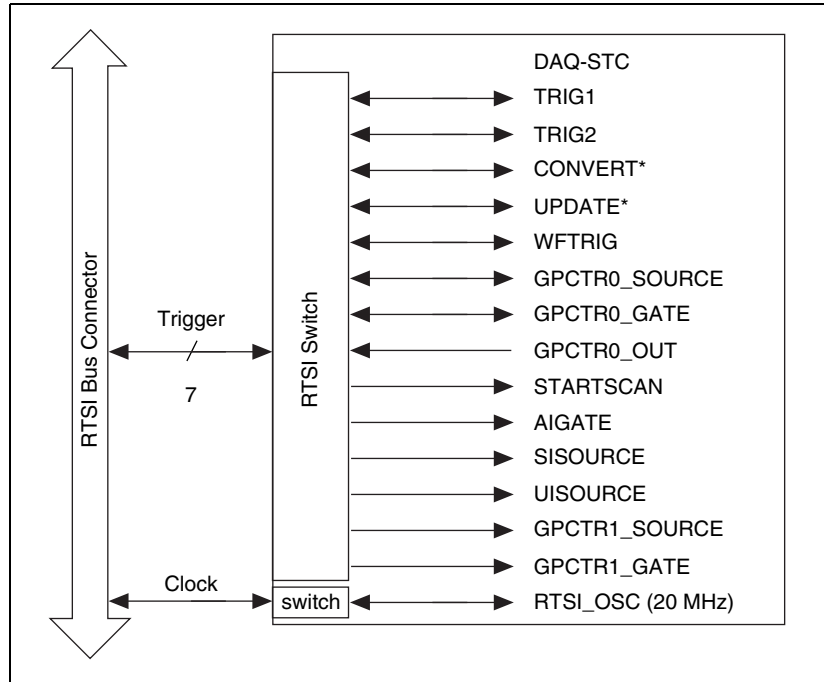
- ◆ PXI-6025E

The RTSI clock connects to other devices through the PXI trigger bus on the PXI backplane. The RTSI clock signal uses the PXI trigger <7> line for this connection.

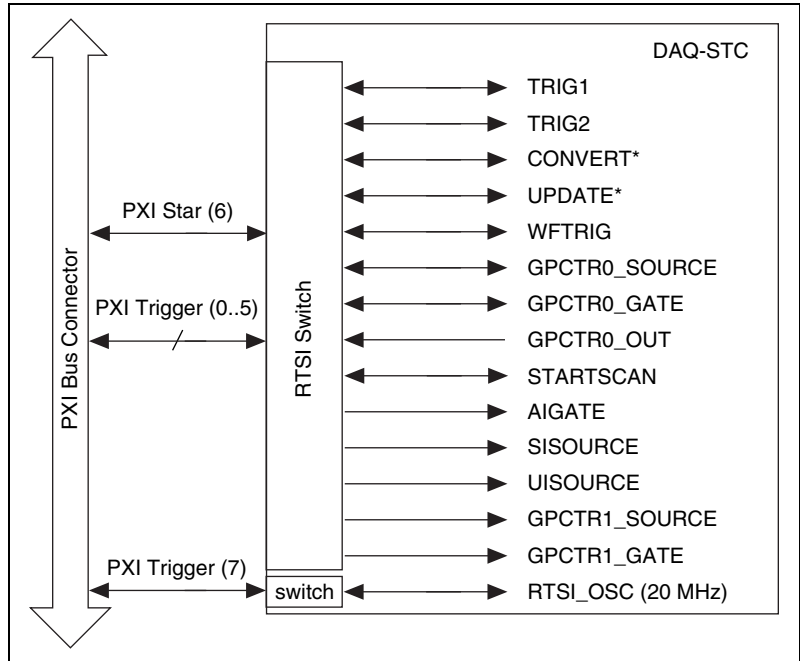
## RTSI Triggers

- ◆ PCI and PXI buses

The seven RTSI trigger lines on the RTSI bus provide a very flexible interconnection scheme for any device sharing the RTSI bus. These bidirectional lines can drive any of eight timing signals onto the RTSI bus and can receive any of these timing signals. This signal connection scheme is shown in Figure 3-5 for PCI devices and Figure 3-6 for PXI devices.



**Figure 3-5.** PCI RTSI Bus Signal Connection



**Figure 3-6.** PXI RTSI Bus Signal Connection

Table 3-3 lists the name and number of pins used by the PXI-6025E.

**Table 3-3.** Pins Used by PXI E Series Device

PXI E Series Signal	PXI Pin Name	PXI J2 Pin Number
RTSI<0..5>	PXI Trigger<0..5>	B16, A16, A17, A18, B18, C18
RTSI 6	PXI Star	D17
RTSI Clock	PXI Trigger 7	E16
Reserved	LBL<0..3>	C20, E20, A19, C19
Reserved	LBR<0..12>	A21, C21, D21, E21, A20, B20, E15, A3, C3, D3, E3, A2, B2

Refer to the *Timing Connections* section of Chapter 4, *Signal Connections*, for a description of the signals shown in Figures 3-5 and 3-6.

# Signal Connections

This chapter describes how to make input and output signal connections to your device through the I/O connector. Table 4-1 shows the cables that can be used with the I/O connectors to connect to different accessories.

**Table 4-1.** I/O Connector Details

Device with I/O Connector	Number of Pins	Cable for Connecting to 100-pin Accessories	Cable for Connecting to 68-pin Accessories	Cable for Connecting to 50-pin Signal Accessories
PCI-6023E, PCI-6024E	68	N/A	SH6868 Shielded Cable, R6868 Ribbon Cable	SH6850 Shielded Cable, R6850 Ribbon Cable
DAQCard-6024E	68	N/A	SHC68-68EP Shielded Cable, RC68-68 Ribbon Cable	68M-50F Adapter when used with the SHC68-68EP or RC68-68
6025E	100	SH100100 Shielded Cable	SH1006868 Shielded Cable	R1005050 Ribbon Cable



**Caution** Connections that exceed any of the maximum ratings of input or output signals on the devices can damage the device and the computer. Maximum input ratings for each signal are given in the *Protection* column of Table 4-3. National Instruments is *not* liable for any damages resulting from such signal connections.

## I/O Connector

Figure 4-1 shows the pin assignments for the 68-pin I/O connector on the PCI-6023E, PCI-6024E, and DAQCard-6024E. Figure 4-2 shows the pin assignments for the 100-pin I/O connector on the PCI-6025E. Refer to Appendix B, *Custom Cabling and Optional Connectors*, for pin

assignments of the optional 50- and 68-pin connectors. A signal description follows the figures.

ACH8	34	68	ACH0
ACH1	33	67	AIGND
AIGND	32	66	ACH9
ACH10	31	65	ACH2
ACH3	30	64	AIGND
AIGND	29	63	ACH11
ACH4	28	62	AISENSE
AIGND	27	61	ACH12
ACH13	26	60	ACH5
ACH6	25	59	AIGND
AIGND	24	58	ACH14
ACH15	23	57	ACH7
DAC0OUT1	22	56	AIGND
DAC1OUT1	21	55	AOGND
RESERVED	20	54	AOGND
DIO4	19	53	DGND
DGND	18	52	DIO0
DIO1	17	51	DIO5
DIO6	16	50	DGND
DGND	15	49	DIO2
+5 V	14	48	DIO7
DGND	13	47	DIO3
DGND	12	46	SCANCLK
PFI0/TRIG1	11	45	EXTSTROBE*
PFI1/TRIG2	10	44	DGND
DGND	9	43	PFI2/CONVERT*
+5 V	8	42	PFI3/GPCTR1_SOURCE
DGND	7	41	PFI4/GPCTR1_GATE
PFI5/UPDATE*	6	40	GPCTR1_OUT
PFI6/WFTRIG	5	39	DGND
DGND	4	38	PFI7/STARTSCAN
PFI9/GPCTR0_GATE	3	37	PFI8/GPCTR0_SOURCE
GPCTR0_OUT	2	36	DGND
FREQ_OUT	1	35	DGND

<sup>1</sup> Not available on the 6023E

**Figure 4-1.** I/O Connector Pin Assignment for the 6023E/6024E



AIGND	1	51	PC7
AIGND	2	52	GND
ACH0	3	53	PC6
ACH8	4	54	GND
ACH1	5	55	PC5
ACH9	6	56	GND
ACH2	7	57	PC4
ACH10	8	58	GND
ACH3	9	59	PC3
ACH11	10	60	GND
ACH4	11	61	PC2
ACH12	12	62	GND
ACH5	13	63	PC1
ACH13	14	64	GND
ACH6	15	65	PC0
ACH14	16	66	GND
ACH7	17	67	PB7
ACH15	18	68	GND
AISENSE	19	69	PB6
DAC0OUT	20	70	GND
DAC1OUT	21	71	PB5
RESERVED	22	72	GND
AOGND	23	73	PB4
DGND	24	74	GND
DIO0	25	75	PB3
DIO4	26	76	GND
DIO1	27	77	PB2
DIO5	28	78	GND
DIO2	29	79	PB1
DIO6	30	80	GND
DIO3	31	81	PB0
DIO7	32	82	GND
DGND	33	83	PA7
+5 V	34	84	GND
+5 V	35	85	PA6
SCANCLK	36	86	GND
EXTSTROBE*	37	87	PA5
PFI0/TRIG1	38	88	GND
PFI1/TRIG2	39	89	PA4
PFI2/CONVERT*	40	90	GND
PFI3/GPCTR1_SOURCE	41	91	PA3
PFI4/GPCTR1_GATE	42	92	GND
GPCTR1_OUT	43	93	PA2
PFI5/UPDATE*	44	94	GND
PFI6/WFTRIG	45	95	PA1
PFI7/STARTSCAN	46	96	GND
PFI8/GPCTR0_SOURCE	47	97	PA0
PFI9/GPCTR0_GATE	48	98	GND
GPCTR0_OUT	49	99	+5 V
FREQ_OUT	50	100	GND

**Figure 4-2.** I/O Connector Pin Assignment for the 6025E

Table 4-2 shows the I/O connector signal descriptions for the 6023E, 6024E, and 6025E.

**Table 4-2.** I/O Connector Signal Descriptions

Signal Name	Reference	Direction	Description
AIGND	—	—	Analog input ground—these pins are the reference point for single-ended measurements in RSE configuration and the bias current return point for DIFF measurements. All three ground references—AIGND, AOGND, and DGND—are connected on your device.
ACH<0..15>	AIGND	Input	Analog input channels 0 through 15—you can configure each channel pair, ACH< <i>i</i> , <i>i</i> +8> ( <i>i</i> = 0..7), as either one DIFF input or two single-ended inputs.
AISENSE	AIGND	Input	Analog input sense—this pin serves as the reference node for any of channels ACH <0..15> in NRSE configuration.
DAC0OUT <sup>1</sup>	AOGND	Output	Analog channel 0 output—this pin supplies the voltage output of analog output channel 0.
DAC1OUT <sup>1</sup>	AOGND	Output	Analog channel 1 output—this pin supplies the voltage output of analog output channel 1.
AOGND	—	—	Analog output ground—the analog output voltages are referenced to this node. All three ground references—AIGND, AOGND, and DGND—are connected together on your device.
DGND	—	—	Digital ground—this pin supplies the reference for the digital signals at the I/O connector as well as the +5 VDC supply. All three ground references—AIGND, AOGND, and DGND—are connected on your device.
DIO<0..7>	DGND	Input or Output	Digital I/O signals—DIO6 and 7 can control the up/down signal of general-purpose counters 0 and 1, respectively.
PA<0..7> <sup>2</sup>	DGND	Input or Output	Port A bidirectional digital data lines for the 82C55A programmable peripheral interface on the 6025E. PA7 is the MSB. PA0 is the LSB.
PB<0..7> <sup>2</sup>	DGND	Input or Output	Port B bidirectional digital data lines for the 82C55A programmable peripheral interface on the 6025E. PB7 is the MSB. PB0 is the LSB.
PC<0..7> <sup>2</sup>	DGND	Input or Output	Port C bidirectional digital data lines for the 82C55A programmable peripheral interface on the 6025E. PC7 is the MSB. PC0 is the LSB.
+5 V	DGND	Output	+5 VDC Source—these pins are fused for up to 1 A of +5 V supply on the PCI and PXI devices, or up to 0.75 A from a DAQCard device. The fuse is self-resetting.

**Table 4-2.** I/O Connector Signal Descriptions (Continued)

Signal Name	Reference	Direction	Description
SCANCLK	DGND	Output	scan clock—this pin pulses once for each A/D conversion in scanning mode when enabled. The low-to-high edge indicates when the input signal can be removed from the input or switched to another signal.
EXTSTROBE*	DGND	Output	External strobe—you can toggle this output under software control to latch signals or trigger events on external devices.
PFI0/TRIG1	DGND	Input  Output	PFI0/Trigger 1—as an input, this is one of the programmable function inputs (PFIs). PFI signals are explained in the <i>Timing Connections</i> section in this chapter.  As an output, this is the TRIG1 (AI start trigger) signal. In posttrigger data acquisition sequences, a low-to-high transition indicates the initiation of the acquisition sequence. In pretrigger applications, a low-to-high transition indicates the initiation of the pretrigger conversions.
PFI1/TRIG2	DGND	Input  Output	PFI1/Trigger 2—as an input, this is one of the PFIs.  As an output, this is the TRIG2 (AI stop trigger) signal. In pretrigger applications, a low-to-high transition indicates the initiation of the posttrigger conversions. TRIG2 is not used in posttrigger applications.
PFI2/CONVERT*	DGND	Input  Output	PFI2/Convert—as an input, this is one of the PFIs.  As an output, this is the CONVERT* (AI convert) signal. A high-to-low edge on CONVERT* indicates that an A/D conversion is occurring.
PFI3/GPCTR1_SOURCE	DGND	Input  Output	PFI3/Counter 1 Source—as an input, this is one of the PFIs.  As an output, this is the GPCTR1_SOURCE signal. This signal reflects the actual source connected to the general-purpose counter 1.
PFI4/GPCTR1_GATE	DGND	Input  Output	PFI4/Counter 1 Gate—as an input, this is one of the PFIs.  As an output, this is the GPCTR1_GATE signal. This signal reflects the actual gate signal connected to the general-purpose counter 1.
GPCTR1_OUT	DGND	Output	Counter 1 Output—this output is from the general-purpose counter 1 output.

**Table 4-2.** I/O Connector Signal Descriptions (Continued)

Signal Name	Reference	Direction	Description
PFI5/UPDATE*	DGND	Input Output	PFI5/Update—as an input, this is one of the PFIs.  As an output, this is the UPDATE* (AO Update) signal. A high-to-low edge on UPDATE* indicates that the analog output primary group is being updated for the 6024E or 6025E.
PFI6/WFTRIG	DGND	Input Output	PFI6/Waveform Trigger—as an input, this is one of the PFIs.  As an output, this is the WFTRIG (AO Start Trigger) signal. In timed analog output sequences, a low-to-high transition indicates the initiation of the waveform generation.
PFI7/STARTSCAN	DGND	Input Output	PFI7/Start of Scan—as an input, this is one of the PFIs.  As an output, this is the STARTSCAN (AI Scan Start) signal. This pin pulses once at the start of each analog input scan in the interval scan. A low-to-high transition indicates the start of the scan.
PFI8/GPCTR0_SOURCE	DGND	Input Output	PFI8/Counter 0 Source—as an input, this is one of the PFIs.  As an output, this is the GPCTR0_SOURCE signal. This signal reflects the actual source connected to the general-purpose counter 0.
PFI9/GPCTR0_GATE	DGND	Input Output	PFI9/Counter 0 Gate—as an input, this is one of the PFIs.  As an output, this is the GPCTR0_GATE signal. This signal reflects the actual gate signal connected to the general-purpose counter 0.
GPCTR0_OUT	DGND	Output	Counter 0 Output—this output is from the general-purpose counter 0 output.
FREQ_OUT	DGND	Output	Frequency Output—this output is from the frequency generator output.
<p>* Indicates that the signal is active low</p> <p><sup>1</sup> Not available on the 6023E</p> <p><sup>2</sup> Not available on the 6023E or 6024E</p>			

Table 4-3 shows the I/O signal summary for the 6023E, 6024E, and 6025E.

**Table 4-3.** I/O Signal Summary

Signal Name	Signal Type and Direction	Impedance Input/ Output	Protection (Volts) On/Off	Source (mA at V)	Sink (mA at V)	Rise Time (ns)	Bias
ACH<0..15>	AI	100 G $\Omega$ in parallel with 100 pF	42/35	—	—	—	$\pm 200$ pA
AISENSE	AI	100 G $\Omega$ in parallel with 100 pF	40/25	—	—	—	$\pm 200$ pA
AIGND	AO	—	—	—	—	—	—
DAC0OUT (6024E and 6025E only)	AO	0.1 $\Omega$	Short-circuit to ground	5 at 10	5 at -10	10 V/ $\mu$ s	—
DAC1OUT (6024E and 6025E only)	AO	0.1 $\Omega$	Short-circuit to ground	5 at 10	5 at -10	10 V/ $\mu$ s	—
AOGND	AO	—	—	—	—	—	—
DGND	DO	—	—	—	—	—	—
VCC	DO	0.1 $\Omega$	Short-circuit to ground	1A fused	—	—	—
DIO<0..7>	DIO	—	V <sub>CC</sub> +0.5	13 at (V <sub>CC</sub> -0.4)	24 at 0.4	1.1	50 k $\Omega$ pu
PA<0..7> (6025E only)	DIO	—	V <sub>CC</sub> +0.5	2.5 at 3.7min	2.5 at 0.4	5	100 k $\Omega$ pu
PB<0..7> (6025E only)	DIO	—	V <sub>CC</sub> +0.5	2.5 at 3.7min	2.5 at 0.4	5	100 k $\Omega$ pu
PC<0..7> (6025E only)	DIO	—	V <sub>CC</sub> +0.5	2.5 at 3.7min	2.5 at 0.4	5	100 k $\Omega$ pu
SCANCLK	DO	—	—	3.5 at (V <sub>CC</sub> -0.4)	5 at 0.4	1.5	50 k $\Omega$ pu
EXTSTROBE*	DO	—	—	3.5 at (V <sub>CC</sub> -0.4)	5 at 0.4	1.5	50 k $\Omega$ pu
PFI0/TRIG1	DIO	—	V <sub>CC</sub> +0.5	3.5 at (V <sub>CC</sub> -0.4)	5 at 0.4	1.5	50 k $\Omega$ pu
PFI1/TRIG2	DIO	—	V <sub>CC</sub> +0.5	3.5 at (V <sub>CC</sub> -0.4)	5 at 0.4	1.5	50 k $\Omega$ pu
PFI2/CONVERT*	DIO	—	V <sub>CC</sub> +0.5	3.5 at (V <sub>CC</sub> -0.4)	5 at 0.4	1.5	50 k $\Omega$ pu
PFI3/GPCTR1_SOURCE	DIO	—	V <sub>CC</sub> +0.5	3.5 at (V <sub>CC</sub> -0.4)	5 at 0.4	1.5	50 k $\Omega$ pu

**Table 4-3.** I/O Signal Summary (Continued)

Signal Name	Signal Type and Direction	Impedance Input/Output	Protection (Volts) On/Off	Source (mA at V)	Sink (mA at V)	Rise Time (ns)	Bias
PFI4/GPCTR1_GATE	DIO	—	$V_{CC} + 0.5$	3.5 at ( $V_{CC} - 0.4$ )	5 at 0.4	1.5	50 k $\Omega$ pu
GPCTR1_OUT	DO	—	—	3.5 at ( $V_{CC} - 0.4$ )	5 at 0.4	1.5	50 k $\Omega$ pu
PFI5/UPDATE*	DIO	—	$V_{CC} + 0.5$	3.5 at ( $V_{CC} - 0.4$ )	5 at 0.4	1.5	50 k $\Omega$ pu
PFI6/WFTRIG	DIO	—	$V_{CC} + 0.5$	3.5 at ( $V_{CC} - 0.4$ )	5 at 0.4	1.5	50 k $\Omega$ pu
PFI7/STARTSCAN	DIO	—	$V_{CC} + 0.5$	3.5 at ( $V_{CC} - 0.4$ )	5 at 0.4	1.5	50 k $\Omega$ pu
PFI8/GPCTR0_SOURCE	DIO	—	$V_{CC} + 0.5$	3.5 at ( $V_{CC} - 0.4$ )	5 at 0.4	1.5	50 k $\Omega$ pu
PFI9/GPCTR0_GATE	DIO	—	$V_{CC} + 0.5$	3.5 at ( $V_{CC} - 0.4$ )	5 at 0.4	1.5	50 k $\Omega$ pu
GPCTR0_OUT	DO	—	—	3.5 at ( $V_{CC} - 0.4$ )	5 at 0.4	1.5	50 k $\Omega$ pu
FREQ_OUT	DO	—	—	3.5 at ( $V_{CC} - 0.4$ )	5 at 0.4	1.5	50 k $\Omega$ pu
AI = Analog Input      DIO = Digital Input/Output      pu = pullup AO = Analog Output      DO = Digital Output <b>Note:</b> The tolerance on the 50 k $\Omega$ pullup and pulldown resistors is very large. Actual value can range between 17 k $\Omega$ and 100 k $\Omega$							

## Analog Input Signal Overview

The analog input signals for these devices are ACH<0..15>, ASENSE, and AIGND. Connection of these analog input signals to your device depends on the type of input signal source and the configuration of the analog input channels you are using. This section provides an overview of the different types of signal sources and analog input configuration modes. More specific signal connection information is provided in the [Analog Input Signal Connections](#) section.

### Types of Signal Sources

When configuring the input channels and making signal connections, you must first determine whether the signal sources are floating or ground-referenced.

## Floating Signal Sources

A floating signal source is not connected in any way 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. An instrument or device that has an isolated output is a floating signal source. You must tie the ground reference of a floating signal to the analog input ground of your device to establish a local or onboard reference for the signal. Otherwise, the measured input signal varies as the source floats out of the common-mode input range.

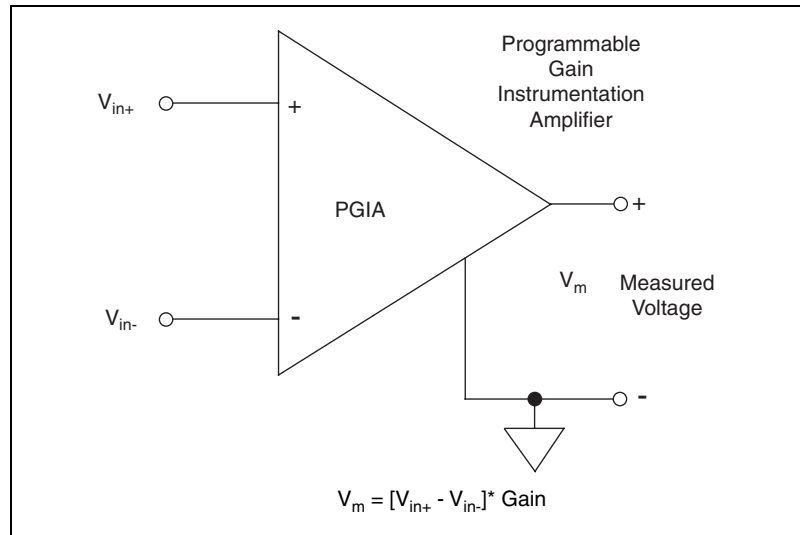
## Ground-Referenced Signal Sources

A ground-referenced signal source is connected in some way to the building system ground and is, therefore, already connected to a common ground point with respect to the device, assuming that the computer is plugged into the same power system. 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 can be much higher if power distribution circuits are not properly connected. If a grounded signal source is improperly measured, this difference can appear as an error in the measurement. The connection instructions for grounded signal sources are designed to eliminate this ground potential difference from the measured signal.

## Analog Input Modes

You can configure your device for one of three input modes—nonreferenced single ended (NRSE), referenced single ended (RSE), and differential (DIFF). With the different configurations, you can use the PGIA in different ways. Figure 4-3 shows a diagram of the PGIA of your device.



**Figure 4-3.** Programmable Gain Instrumentation Amplifier (PGIA)

In single-ended mode (RSE and NRSE), signals connected to ACH<0..15> are routed to the positive input of the PGIA. In DIFF mode, signals connected to ACH<0..7> are routed to the positive input of the PGIA, and signals connected to ACH<8..15> are routed to the negative input of the PGIA.



**Caution** Exceeding the DIFF and common-mode input ranges distorts your input signals. Exceeding the maximum input voltage rating can damage the device and the computer. National Instruments is *not* liable for any damages resulting from such signal connections. The maximum input voltage ratings are listed in the *Protection* column of Table 4-3.

In NRSE mode, the AISENSE signal connects internally to the negative input of the PGIA when their corresponding channels are selected. In DIFF and RSE modes, AISENSE is left unconnected.

AIGND is an analog input common signal that routes directly to the ground connection point on the devices. You can use this signal for a general analog ground connection point to your device if necessary.

The PGIA applies gain and common-mode voltage rejection and presents high input impedance to the analog input signals connected to your device. Signals are routed to the positive and negative inputs of the PGIA through input multiplexers on the device. The PGIA converts two input signals to a signal that is the difference between the two input signals multiplied by the



gain setting of the amplifier. The amplifier output voltage is referenced to the ground for the device. The A/D converter (ADC) of your device measures this output voltage when it performs A/D conversions.

Reference all signals to ground either at the source device or at the device. If you have a floating source, reference the signal to ground by using the RSE input mode or the DIFF input configuration with bias resistors (see the [Differential Connections for Nonreferenced or Floating Signal Sources](#) section). If you have a grounded source, do not reference the signal to AIGND. You can avoid this reference by using DIFF or NRSE input configurations.

## Analog Input Signal Connections

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The following sections discuss the use of single-ended and DIFF measurements and recommendations for measuring both floating and ground-referenced signal sources.

Figure 4-4 summarizes the recommended input configuration for both types of signal sources.

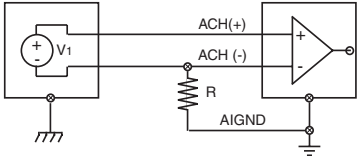
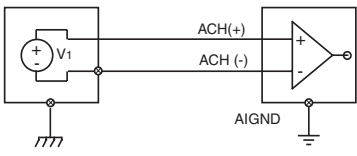
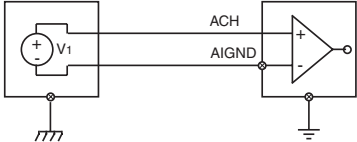
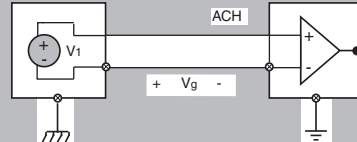
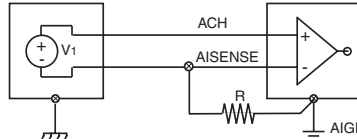
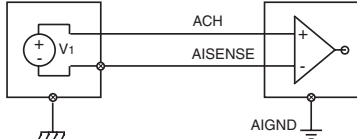
Input	Signal Source Type	
	Floating Signal Source (Not Connected to Building Ground)	Grounded Signal Source
	Examples <ul style="list-style-type: none"> <li>• Ungrounded Thermocouples</li> <li>• Signal conditioning with isolated outputs</li> <li>• Battery devices</li> </ul>	Examples <ul style="list-style-type: none"> <li>• Plug-in instruments with nonisolated outputs</li> </ul>
Differential (DIFF)	 <p>See text for information on bias resistors.</p>	
Single-Ended — Ground Referenced (RSE)		<p style="text-align: center;"><b>NOT RECOMMENDED</b></p>  <p style="text-align: center;">Ground-loop losses, <math>V_g</math>, are added to measured signal</p>
Single-Ended — Nonreferenced (NRSE)	 <p>See text for information on bias resistors.</p>	

Figure 4-4. Summary of Analog Input Connections

## Differential Connection Considerations (DIFF Input Configuration)

A DIFF connection is one in which the analog input signal has its own reference signal or signal return path. These connections are available when the selected channel is configured in DIFF input mode. The input signal is connected to the positive input of the PGIA, and its reference signal, or return, is connected to the negative input of the PGIA.

When you configure a channel for DIFF input, each signal uses two multiplexer inputs—one for the signal and one for its reference signal. Therefore, with a DIFF configuration for every channel, up to eight analog input channels are available.

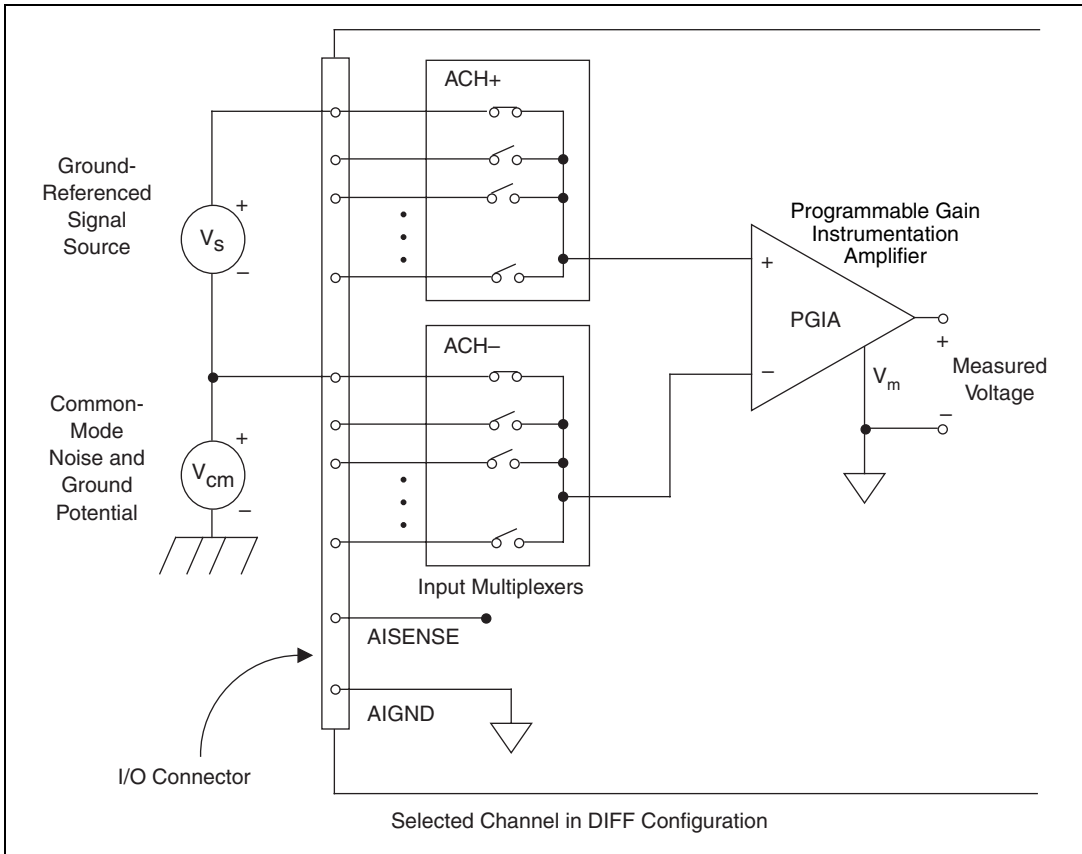
Use DIFF input connections for any channel that meets any of the following conditions:

- The input signal is low level (less than 1 V).
- 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.

DIFF signal connections reduce picked up noise and increase common-mode noise rejection. DIFF signal connections also allow input signals to float within the common-mode limits of the PGIA.

## Differential Connections for Ground-Referenced Signal Sources

Figure 4-5 shows how to connect a ground-referenced signal source to a channel on the device configured in DIFF input mode.

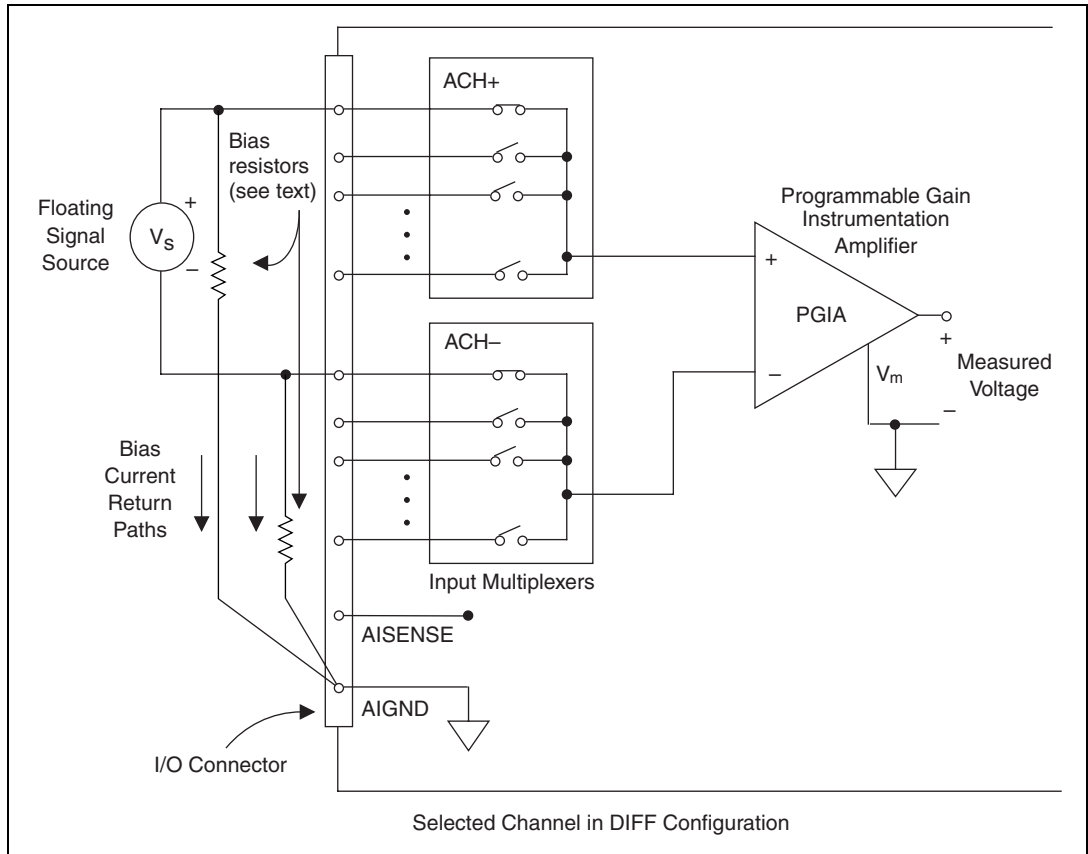


**Figure 4-5.** Differential Input Connections for Ground-Referenced Signals

With this type of connection, the PGIA rejects both the common-mode noise in the signal and the ground potential difference between the signal source and the device ground, shown as  $V_{cm}$  in Figure 4-5.

## Differential Connections for Nonreferenced or Floating Signal Sources

Figure 4-6 shows how to connect a floating signal source to a channel configured in DIFF input mode.



**Figure 4-6.** Differential Input Connections for Nonreferenced Signals

Figure 4-6 shows two bias resistors connected in parallel with the signal leads of a floating signal source. If you do not use the resistors and the source is truly floating, the source is not likely to remain within the common-mode signal range of the PGIA. The PGIA then saturates, causing erroneous readings.

You must reference the source to AIGND. The easiest way is to connect the positive side of the signal to the positive input of the PGIA and connect the negative side of the signal to AIGND as well as to the negative input of the PGIA, without any resistors at all. This connection works well for DC-coupled sources with low source impedance (less than 100  $\Omega$ ).

However, for larger source impedances, this connection leaves the DIFF signal path significantly out of balance. Noise that couples electrostatically onto the positive line does not couple onto the negative line because it is connected to ground. Hence, this noise appears as a DIFF-mode signal instead of a common-mode signal, and the PGIA does not reject it. In this case, instead of directly connecting the negative line to AIGND, connect it to AIGND through a resistor that is about 100 times the equivalent source impedance. The resistor puts the signal path nearly in balance, so that about the same amount of noise couples onto both connections, yielding better rejection of electrostatically coupled noise. Also, this configuration does not load down the source (other than the very high input impedance of the PGIA).

You can fully balance the signal path by connecting another resistor of the same value between the positive input and AIGND, as shown in Figure 4-6. This fully balanced configuration offers slightly better noise rejection but has the disadvantage of loading the source down with the series combination (sum) of the two resistors. If, for example, the source impedance is 2 k $\Omega$  and each of the two resistors is 100 k $\Omega$ , the resistors load down the source with 200 k $\Omega$  and produce a -1% gain error.

Both inputs of the PGIA require a DC path to ground in order for the PGIA to work. If the source is AC coupled (capacitively coupled), the PGIA needs a resistor between the positive input and AIGND. If the source has low impedance, choose a resistor that is large enough not to significantly load the source but small enough not to produce significant input offset voltage as a result of input bias current (typically 100 k $\Omega$  to 1 M $\Omega$ ). In this case, you can tie the negative input directly to AIGND. If the source has high output impedance, balance the signal path as previously described using the same value resistor on both the positive and negative inputs; be aware that there is some gain error from loading down the source.

## Single-Ended Connection Considerations

A single-ended connection is one in which the device analog input signal is referenced to a ground that it can share with other input signals. The input signal is tied to the positive input of the PGIA, and the ground is tied to the negative input of the PGIA.

When every channel is configured for single-ended input, up to 16 analog input channels are available.

You can use single-ended input connections for any input signal that meets the following conditions:

- The input signal is high level (greater than 1 V).
- The leads connecting the signal to the device are less than 10 ft (3 m).
- The input signal can share a common reference point with other signals.

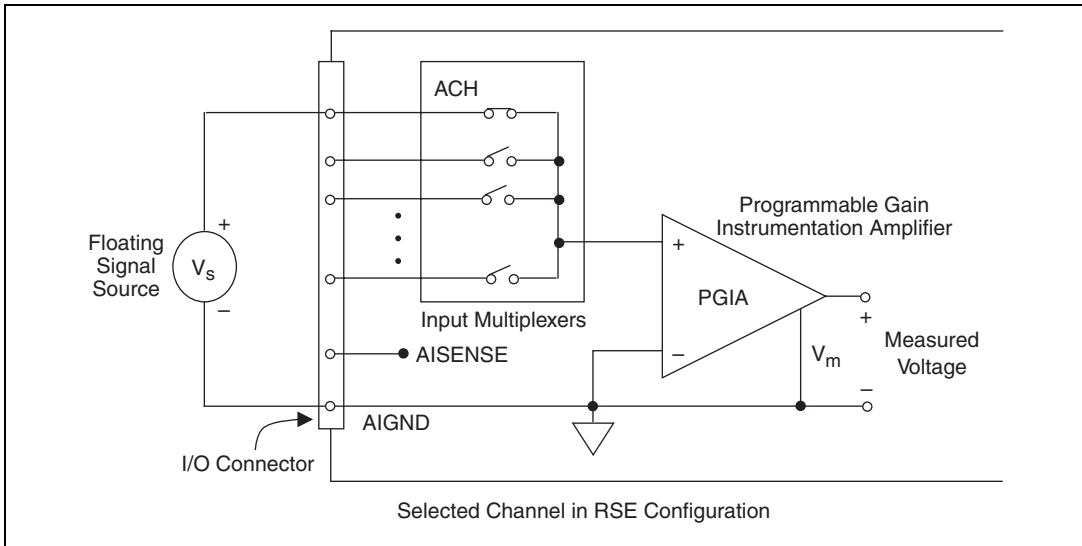
DIFF input connections are recommended for greater signal integrity for any input signal that does not meet the preceding conditions.

Using your software, you can configure the channels for two different types of single-ended connections—RSE configuration and NRSE configuration. The RSE configuration is used for floating signal sources; in this case, the device provides the reference ground point for the external signal. The NRSE input configuration is used for ground-referenced signal sources; in this case, the external signal supplies its own reference ground point and the device should not supply one.

In single-ended configurations, 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.

## Single-Ended Connections for Floating Signal Sources (RSE Configuration)

Figure 4-7 shows how to connect a floating signal source to a channel configured for RSE mode.



**Figure 4-7.** Single-Ended Input Connections for Nonreferenced or Floating Signals

## Single-Ended Connections for Grounded Signal Sources (NRSE Configuration)

To measure a grounded signal source with a single-ended configuration, you must configure your device in the NRSE input configuration. Connect the signal to the positive input of the PGIA, and connect the signal local ground reference to the negative input of the PGIA. The ground point of the signal, therefore, connects to the AISENSE pin. Any potential difference between the device ground and the signal ground appears as a common-mode signal at both the positive and negative inputs of the PGIA, and this difference is rejected by the amplifier. If the input circuitry of a device were referenced to ground, in this situation as in the RSE input configuration, this difference in ground potentials appears as an error in the measured voltage.



Figure 4-8 shows how to connect a grounded signal source to a channel configured for NRSE mode.

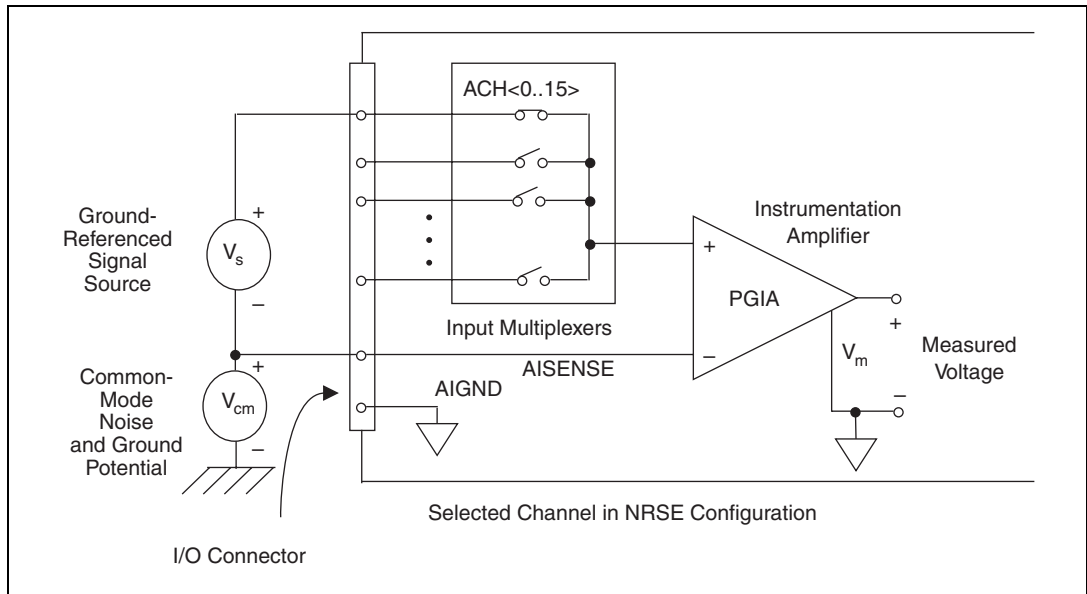


Figure 4-8. Single-Ended Input Connections for Ground-Referenced Signals

## Common-Mode Signal Rejection Considerations

Figures 4-5 and 4-8 show connections for signal sources that are already referenced to some ground point with respect to the device. In these cases, the PGIA can reject any voltage caused by ground potential differences between the signal source and the device. In addition, with DIFF input connections, the PGIA can reject common-mode noise pickup in the leads connecting the signal sources to the device. The PGIA can reject common-mode signals as long as  $V_{+in}$  and  $V_{-in}$  (input signals) are both within  $\pm 11$  V of AIGND.

## Analog Output Signal Connections

- ◆ 6024E and 6025E

The analog output signals are DAC0OUT, DAC1OUT, and AOGND. DAC0OUT and DAC1OUT are not available on the 6023E. DAC0OUT is the voltage output signal for analog output channel 0. DAC1OUT is the voltage output signal for analog output channel 1.

AOGND is the ground reference signal for both analog output channels and the external reference signal. Figure 4-9 shows how to make analog output connections to your device.

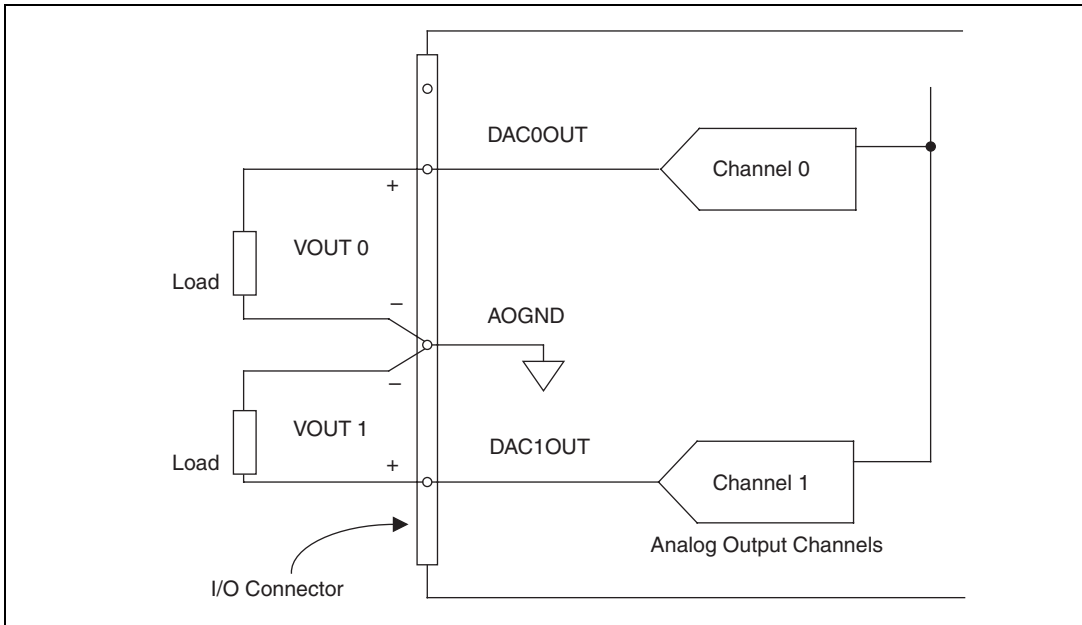


Figure 4-9. Analog Output Connections

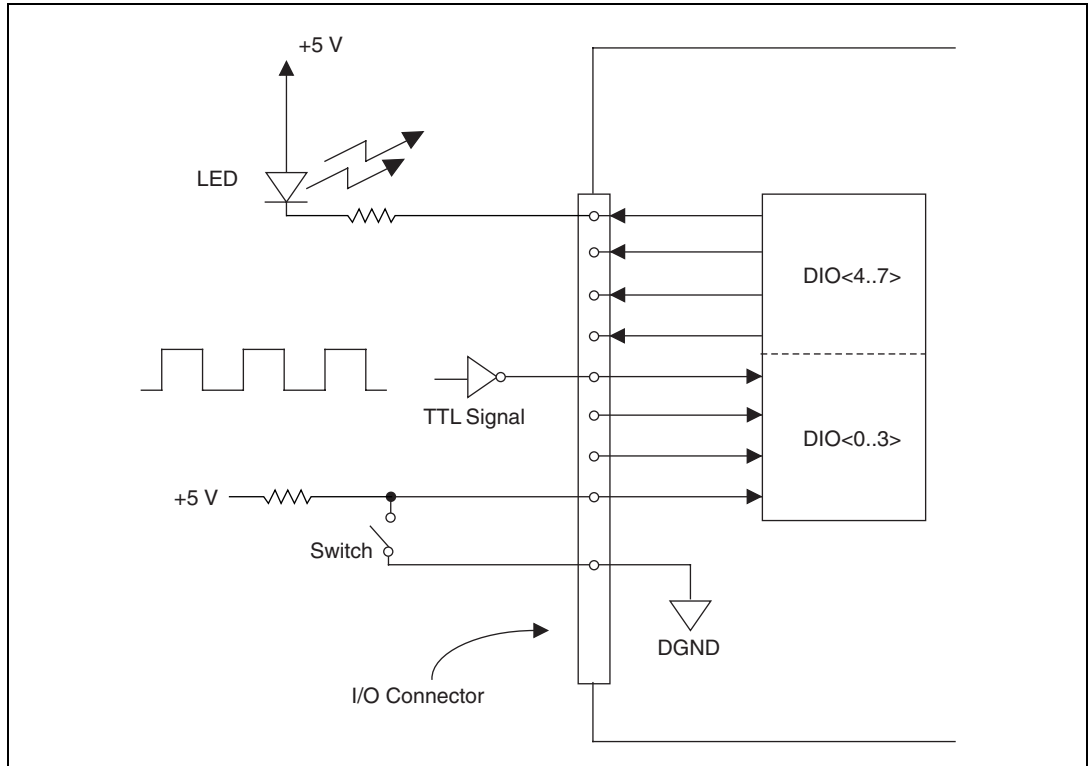
## Digital I/O Signal Connections

### All Devices

All devices have digital I/O signals DIO<0..7> and DGND. DIO<0..7> are the signals making up the DIO port, and DGND is the ground-reference signal for the DIO port. You can program all lines individually as inputs or outputs. Figure 4-10 shows signal connections for three typical digital I/O applications.

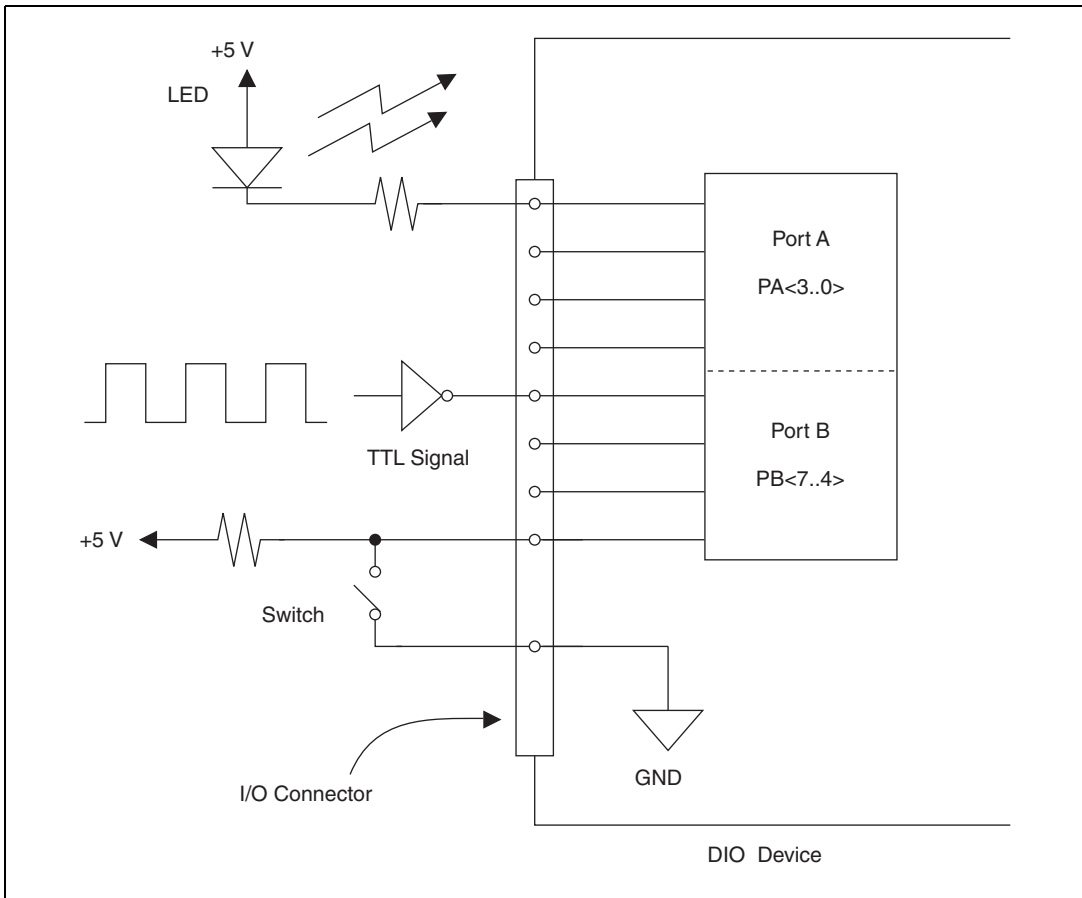


**Caution** Exceeding the maximum input voltage ratings, which are listed in Table 4-2, can damage the DAQ device and the computer. National Instruments is *not* liable for any damages resulting from such signal connections.



**Figure 4-10.** Digital I/O Connections

Figure 4-10 shows DIO<0..3> configured for digital input and DIO<4..7> configured for digital output. Digital input applications include receiving TTL signals and sensing external device states such as the state of the switch shown in the Figure 4-11. Digital output applications include sending TTL signals and driving external devices such as the LED shown in Figure 4-11. Figure 4-11 depicts signal connections for three typical digital I/O applications.



**Figure 4-11.** Digital I/O Connections Block Diagram

## Programmable Peripheral Interface (PPI)

◆ 6025E only

The 6025E device uses an 82C55A PPI to provide an additional 24 lines of digital I/O that represent three 8-bit ports—PA, PB, and PC. You can program each port as an input or output port.

In Figure 4-11, port A of one PPI is configured for digital output, and port B is configured for digital input. Digital input applications include receiving TTL signals and sensing external device states such as the state of the switch in Figure 4-11. Digital output applications include sending

TTL signals and driving external devices such as the LED shown in Figure 4-11.

## Port C Pin Assignments

◆ 6025 only

The signals assigned to port C depend on how the 82C55A is configured. In mode 0, or no handshaking configuration, port C is configured as two 4-bit I/O ports. In modes 1 and 2, or handshaking configuration, port C is used for status and handshaking signals with any leftover lines available for general-purpose I/O. Table 4-4 summarizes the port C signal assignments for each configuration. You can also use ports A and B in different modes; the table does not show every possible combination.



**Note** Table 4-4 shows both the port C signal assignments and the terminology correlation between different documentation sources. The 82C55A terminology refers to the different 82C55A configurations as modes, whereas NI-DAQ, ComponentWorks, LabWindows/CVI, and LabVIEW documentation refers to them as handshaking and no handshaking.

**Table 4-4.** Port C Signal Assignments

Configuration Terminology		Signal Assignments							
<i>6023E/ 6024E/6025E User Manual</i>	National Instruments Software	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0
Mode 0 (Basic I/O)	No Handshaking	I/O	I/O	I/O	I/O	I/O	I/O	I/O	I/O
Mode 1 (Strobed Input)	Handshaking	I/O	I/O	IBF <sub>A</sub>	STB <sub>A</sub> *	INTR <sub>A</sub>	STB <sub>B</sub> *	IBFB <sub>B</sub>	INTR <sub>B</sub>
Mode 1 (Strobed Output)	Handshaking	OBF <sub>A</sub> *	ACK <sub>A</sub> *	I/O	I/O	INTR <sub>A</sub>	ACK <sub>B</sub> *	OBF <sub>B</sub> *	INTR <sub>B</sub>
Mode 2 (Bidirectional Bus)	Handshaking	OBF <sub>A</sub> *	ACK <sub>A</sub> *	IBF <sub>A</sub>	STB <sub>A</sub> *	INTR <sub>A</sub>	I/O	I/O	I/O

\* Indicates that the signal is active low.  
Subscripts A and B denote port A or port B handshaking signals.

## Power-up State

### ◆ 6025E only

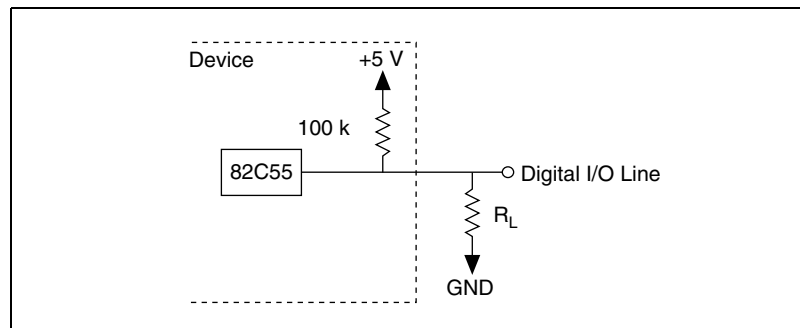
The 6025E contains bias resistors that control the state of the digital I/O lines PA<0..7>,PB<0..7>,PC<0..7> at power up. Each digital I/O line is configured as an input, pulled high by a 100 k $\Omega$  bias resistor.

You can change individual lines from pulled up to pulled down by adding your own external resistors. This section describes the procedure.

## Changing DIO Power-up State to Pulled Low

Each DIO line is pulled to  $V_{cc}$  (approximately +5 VDC) with a 100 k $\Omega$  resistor. To pull a specific line low, connect between that line and ground a pull-down resistor ( $R_L$ ) whose value gives you a maximum of 0.4 VDC. The DIO lines provide a maximum of 2.5 mA at 3.7 V in the high state. Using the largest possible resistor ensures that you do not use more current than necessary to perform the pull-down task.

However, make sure the value of the resistor is not so large that leakage current from the DIO line along with the current from the 100 k $\Omega$  pull-up resistor drives the voltage at the resistor above a TTL-low level of 0.4 VDC. Figure 4-12 shows the DIO configuration for high DIO power-up state.



**Figure 4-12.** DIO Channel Configured for High DIO Power-up State with External Load

### Example

A given DIO line is pulled high at power up. To pull it low on power up with an external resistor, follow these steps:

1. Install a load ( $R_L$ ). Remember that the smaller the resistance, the greater the current consumption and the lower the voltage.

2. Using the following formula, calculate the largest possible load to maintain a logic low level of 0.4 V and supply the maximum driving current:

$$V = I \times RL \Rightarrow RL = V/I$$

where:

$$V = 0.4 \text{ V} \quad \text{Voltage across } RL$$

$$I = 46 \mu\text{A} + 10 \mu\text{A} \quad 4.6 \text{ V across the } 100 \text{ k}\Omega \text{ pull-up resistor and } 10 \mu\text{A maximum leakage current}$$

Therefore:

$$RL = 7.1 \text{ k}\Omega \quad ; 0.4 \text{ V}/56 \mu\text{A}$$

This resistor value, 7.1 k $\Omega$ , provides a maximum of 0.4 V on the DIO line at power up. You can substitute smaller resistor values to lower the voltage or to provide a margin for  $V_{cc}$  variations and other factors. However, smaller values draw more current, leaving less drive current for other circuitry connected to this line. The 7.1 k $\Omega$  resistor reduces the amount of logic high source current by 0.4 mA with a 2.8 V output.

## Timing Specifications

- ◆ 6025E only

This section lists the timing specifications for handshaking with your 6025E PC<0..7> lines. The handshaking lines STB\* and IBF synchronize input transfers. The handshaking lines OBF\* and ACK\* synchronize output transfers. Table 4-5 describes signals appearing in the handshaking diagrams.

**Table 4-5.** Signal Names Used in Timing Diagrams

Name	Type	Description
STB*	Input	Strobe input—a low signal on this handshaking line loads data into the input latch.
IBF	Output	Input buffer full—a high signal on this handshaking line indicates that data has been loaded into the input latch. A low signal indicates the device is ready for more data. This is an input acknowledge signal.

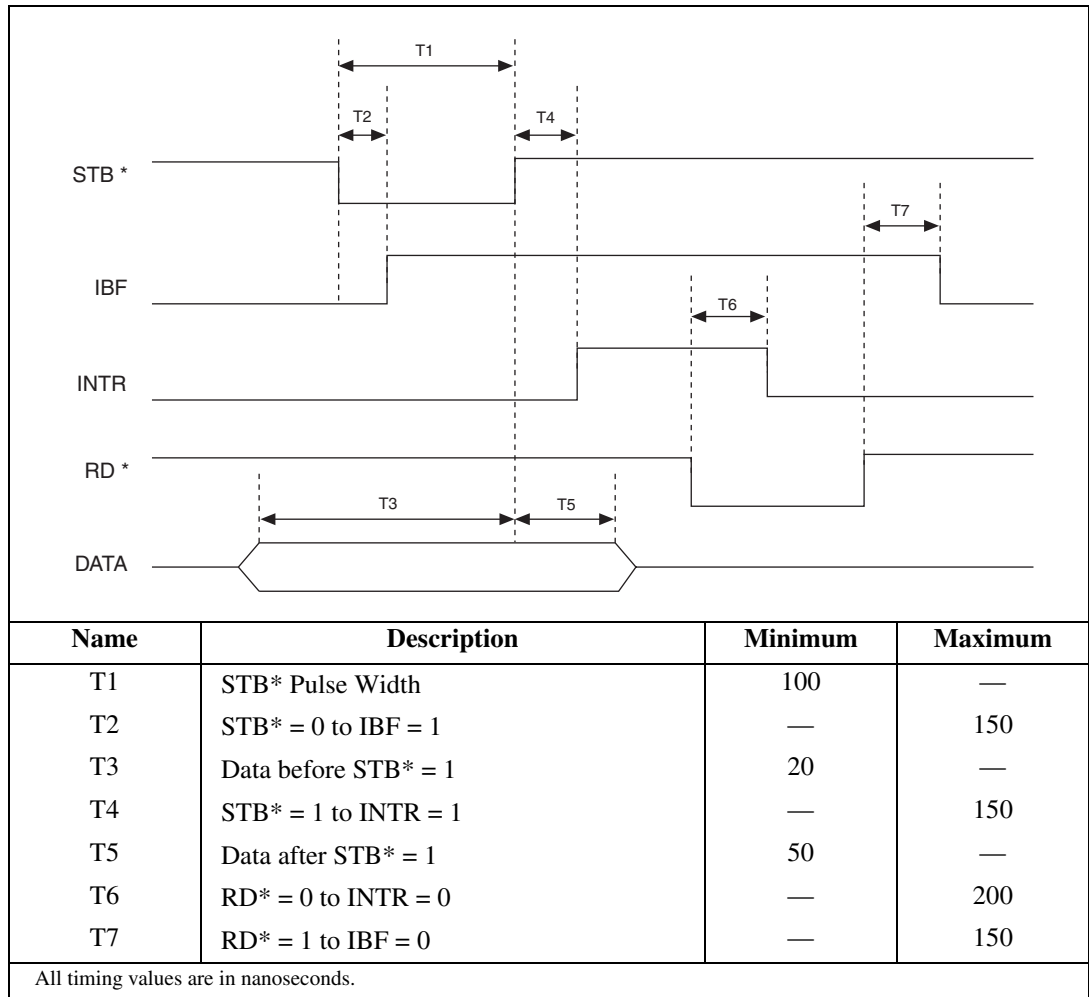
**Table 4-5.** Signal Names Used in Timing Diagrams (Continued)

Name	Type	Description
ACK*	Input	Acknowledge input—a low signal on this handshaking line indicates that the data written to the port has been accepted. This signal is a response from the external device indicating that it has received the data from your DIO device.
OBF*	Output	Output buffer full—a low signal on this handshaking line indicates that data has been written to the port.
INTR	Output	Interrupt request—this signal becomes high when the 82C55A requests service during a data transfer. You must set the appropriate interrupt enable bits to generate this signal.
RD*	Internal	Read—this signal is the read signal generated from the control lines of the computer I/O expansion bus.
WR*	Internal	Write—this signal is the write signal generated from the control lines of the computer I/O expansion bus.
DATA	Bidirectional	Data lines at the specified port—for output mode, this signal indicates the availability of data on the data line. For input mode, this signal indicates when the data on the data lines should be valid.



## Mode 1 Input Timing

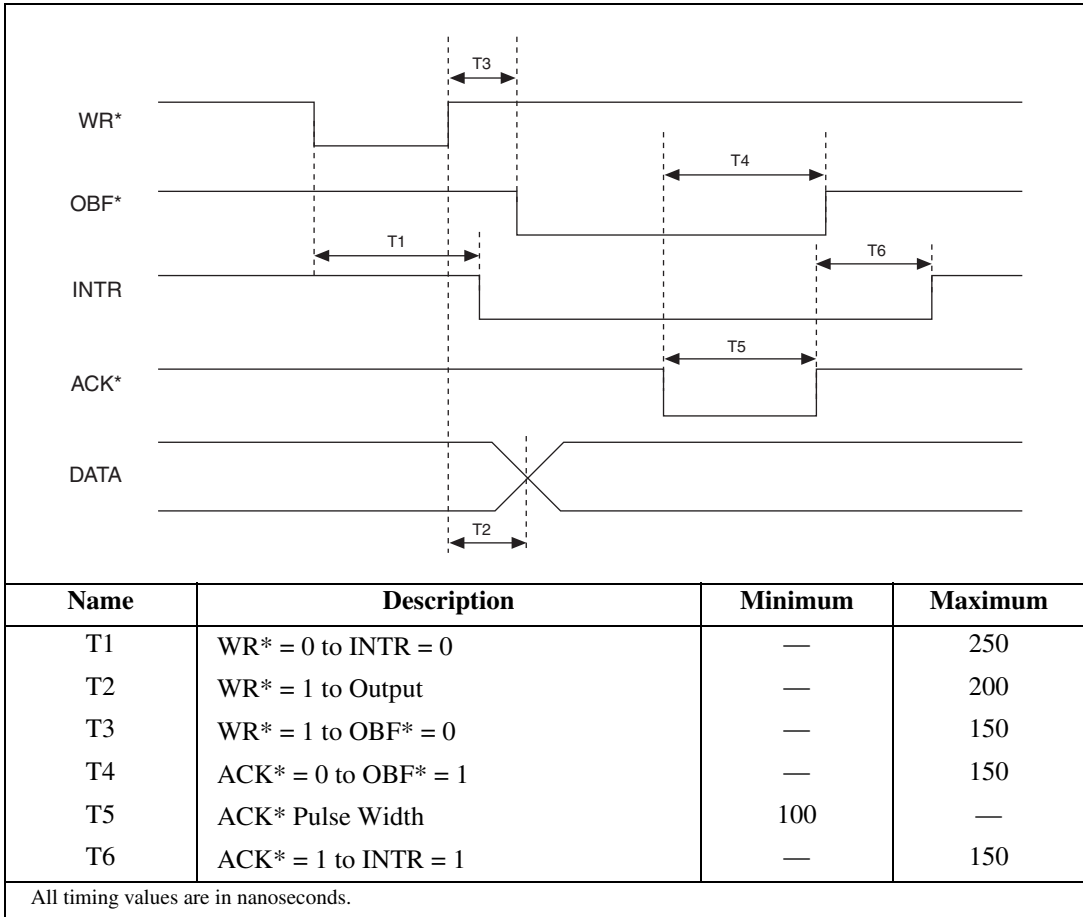
Timing specifications for an input transfer in mode 1 are shown in Figure 4-13.



**Figure 4-13.** Timing Specifications for Mode 1 Input Transfer

## Mode 1 Output Timing

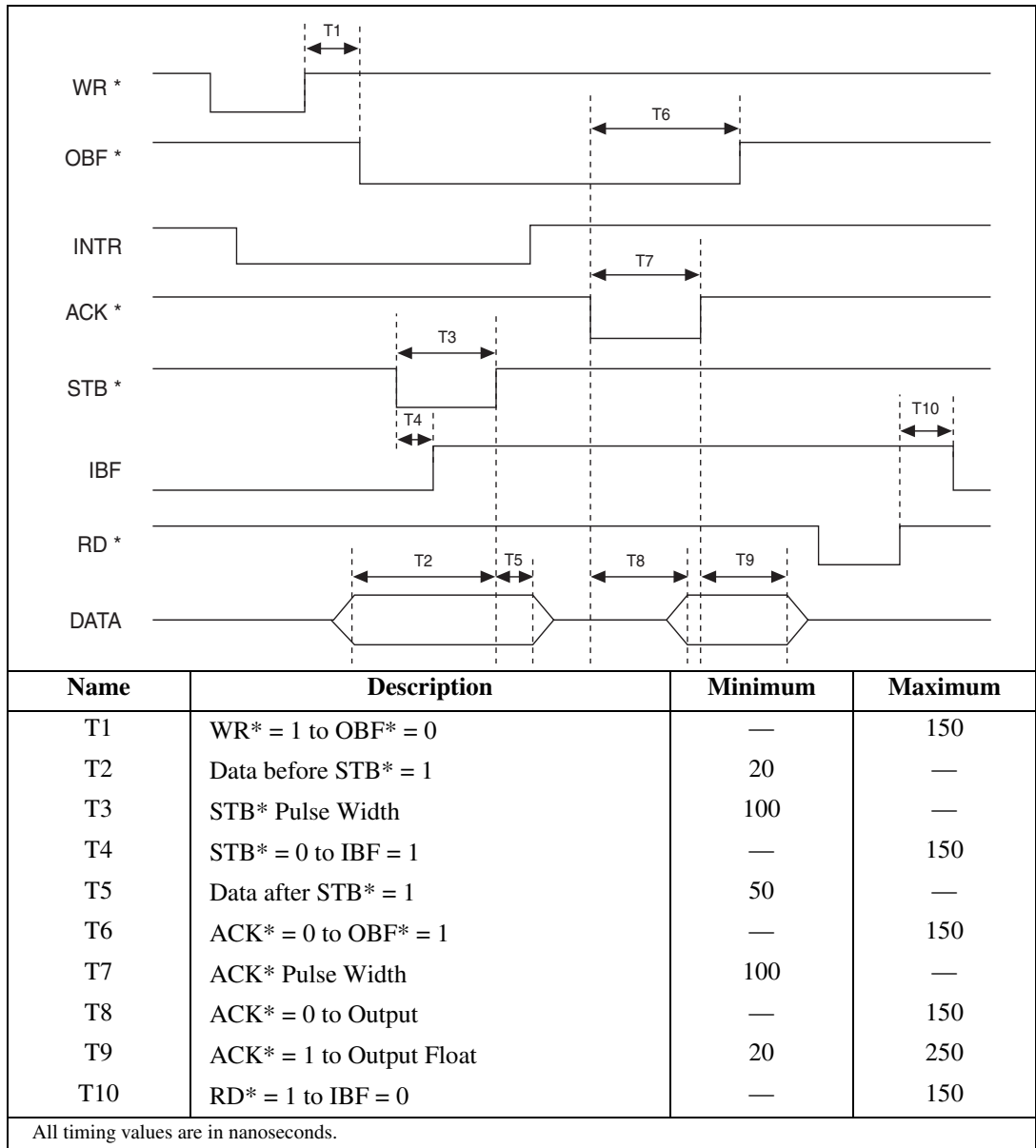
Timing specifications for an output transfer in mode 1 are shown in Figure 4-14.



**Figure 4-14.** Timing Specifications for Mode 1 Output Transfer

## Mode 2 Bidirectional Timing

Timing specifications for a bidirectional transfer in mode 2 are shown in Figure 4-15.



**Figure 4-15.** Timing Specifications for Mode 2 Bidirectional Transfer

## Power Connections

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Two pins on the I/O connector supply +5 V from the computer power supply through a self-resetting fuse. The fuse resets automatically within a few seconds after the overcurrent condition is removed. These pins are referenced to DGND and you can use them to power external digital circuitry. The power rating is +4.65 to +5.25 VDC at 1 A for the PCI and PXI devices, and +4.65 to +5.25 VDC at 0.75A for PCMCIA cards.



**Caution** Under no circumstances connect these +5 V power pins directly to analog or digital grounds, or to any other voltage source on the device or any other device. Doing so can damage the device and the computer. National Instruments is *not* liable for damages resulting from such a connection.

## Timing Connections

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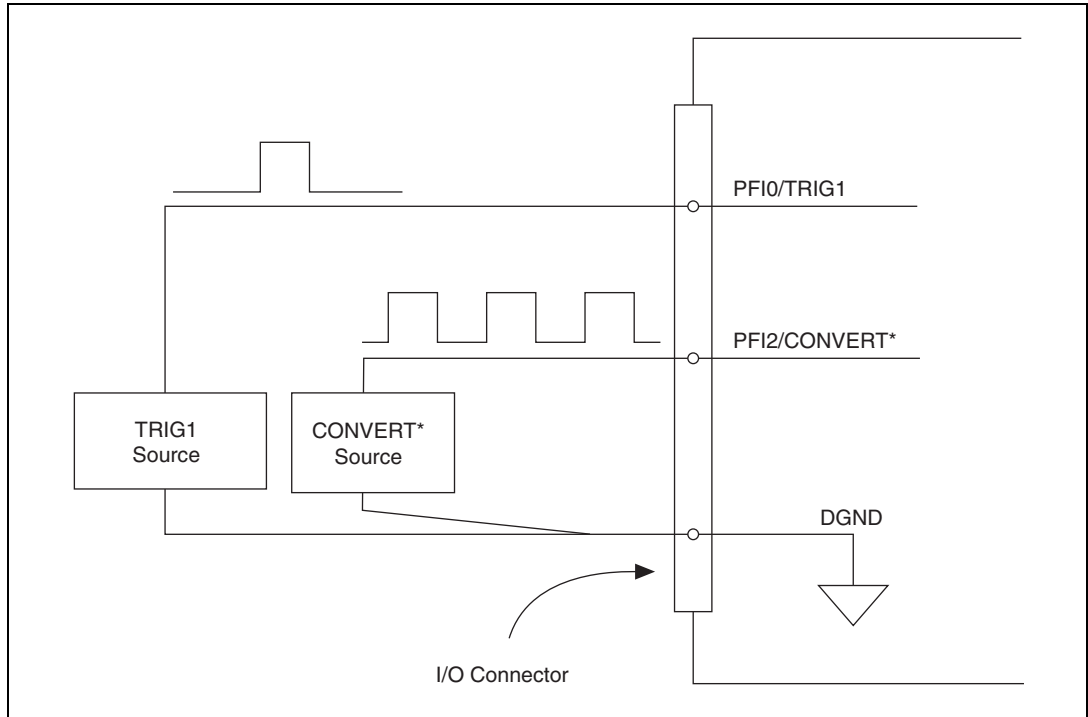


**Caution** Exceeding the maximum input voltage ratings, which are listed in Table 4-3, can damage the device and the computer. National Instruments is *not* liable for any damages resulting from such signal connections.

All external control over the timing of your device is routed through the 10 programmable function inputs labeled PFI<0..9>. These signals are explained in detail in the [Programmable Function Input Connections](#) section. These PFIs are bidirectional; as outputs they are not programmable and reflect the state of many DAQ, waveform generation, and general-purpose timing signals. There are five other dedicated outputs for the remainder of the timing signals. As inputs, the PFI signals are programmable and can control any DAQ, waveform generation, and general-purpose timing signals.

The DAQ signals are explained in the [DAQ Timing Connections](#) section; the waveform generation signals in the [Waveform Generation Timing Connections](#) section, and the general-purpose timing signals in the [General-Purpose Timing Signal Connections](#) section.

All digital timing connections are referenced to DGND. This reference is demonstrated in Figure 4-16, which shows how to connect an external TRIG1 source and an external CONVERT\* source to two PFI pins.



**Figure 4-16.** Timing I/O Connections

## Programmable Function Input Connections

There are a total of 13 internal timing signals that you can externally control from the PFI pins. The source for each of these signals is software-selectable from any of the PFIs when you want external control. This flexible routing scheme reduces the need to change the physical wiring to the device I/O connector for different applications requiring alternative wiring.

You can individually enable each of the PFI pins to output a specific internal timing signal. For example, if you need the CONVERT\* signal as an output on the I/O connector, software can turn on the output driver for the PFI2/CONVERT\* pin. Be careful not to drive a PFI signal externally when it is configured as an output.

As an input, you can individually configure each PFI pin for edge or level detection and for polarity selection, as well. You can use the polarity selection for any of the 13 timing signals, but the edge or level detection

depends upon the particular timing signal you are controlling. The detection requirements for each timing signal are listed within the section that discusses that individual signal.

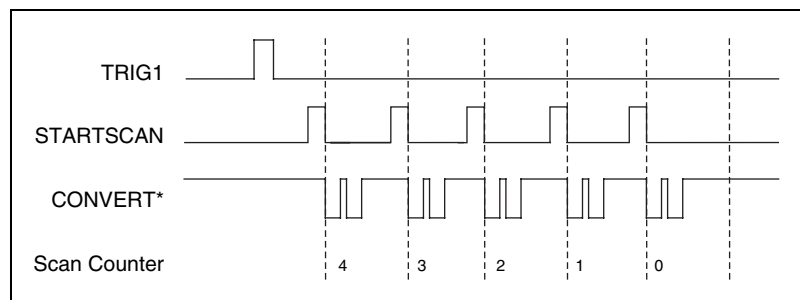
In edge-detection mode, the minimum pulse width required is 10 ns. This applies for both rising-edge and falling-edge polarity settings. There is no maximum pulse-width requirement in edge-detect mode.

In level-detection mode, there are no minimum or maximum pulse-width requirements imposed by the PFIs themselves, but there can be limits imposed by the particular timing signal that is controlled. These requirements are listed in this chapter under the section for each applicable signal.

## DAQ Timing Connections

The DAQ timing signals are SCANCLK, EXTSTROBE\*, TRIG1, TRIG2, STARTSCAN, CONVERT\*, AIGATE, and SISOURCE.

Posttriggered data acquisition allows you to view only data that is acquired after a trigger event is received. A typical posttriggered DAQ sequence is shown in Figure 4-17. Pretriggered data acquisition allows you to view data that is acquired before the trigger of interest in addition to data acquired after the trigger. Figure 4-18 shows a typical pretriggered DAQ sequence. The description for each signal shown in these figures is included in this chapter under the section for each corresponding signal.



**Figure 4-17.** Typical Posttriggered Acquisition

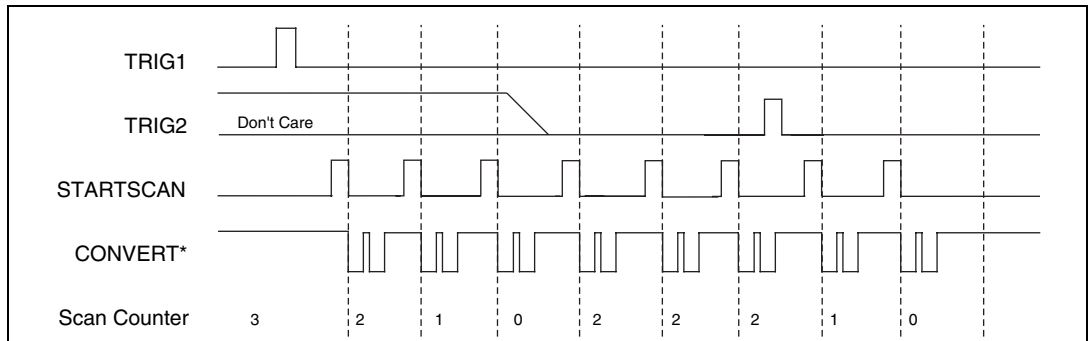


Figure 4-18. Typical Pretriggered Acquisition

## SCANCLK Signal

SCANCLK is an output-only signal that generates a pulse with the leading edge occurring approximately 50 to 100 ns after an A/D conversion begins. The polarity of this output is software-selectable, but is typically configured so that a low-to-high leading edge can clock external analog input multiplexers indicating when the input signal has been sampled and can be removed. This signal has a 400 to 500 ns pulse width and is software-enabled. Figure 4-19 shows the timing for the SCANCLK signal.

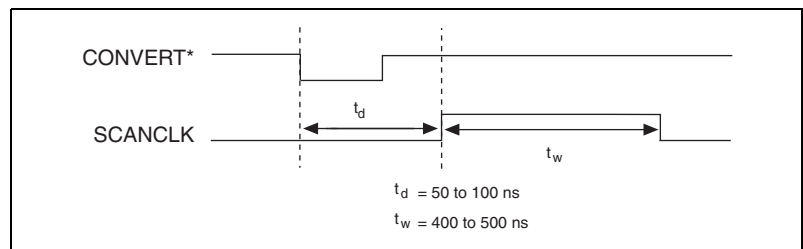
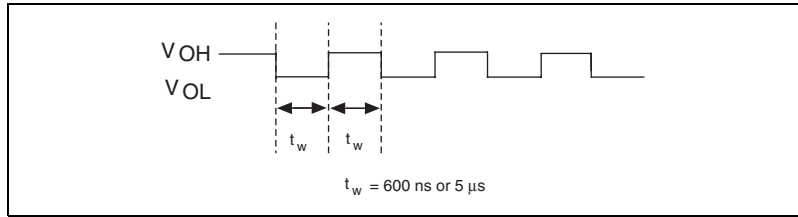


Figure 4-19. SCANCLK Signal Timing

## EXTSTROBE\* Signal

EXTSTROBE\* is an output-only signal that generates either a single pulse or a sequence of eight pulses in the hardware-strobe mode. An external device can use this signal to latch signals or to trigger events. In the single-pulse mode, software controls the level of the EXTSTROBE\* signal. A 10  $\mu$ s and a 1.2  $\mu$ s clock are available for generating a sequence of eight pulses in the hardware-strobe mode. Figure 4-20 shows the timing for the hardware-strobe mode EXTSTROBE\* signal.



**Figure 4-20.** EXTSTROBE\* Signal Timing

## TRIG1 Signal

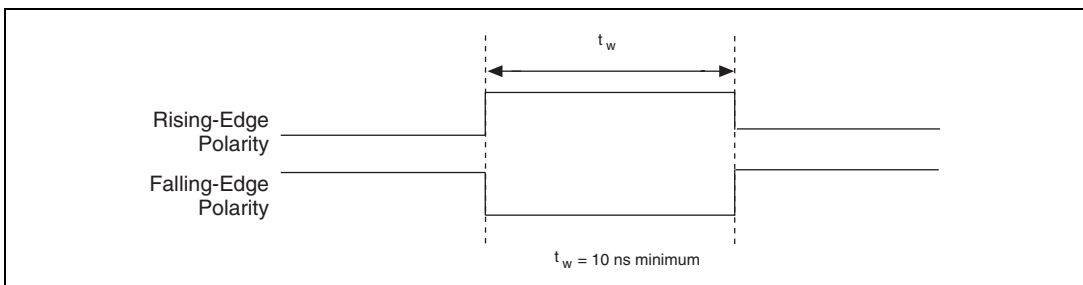
Any PFI pin can externally input the TRIG1 signal, which is available as an output on the PFI0/TRIG1 pin.

Refer to Figures 4-17 and 4-18 for the relationship of TRIG1 to the DAQ sequence.

As an input, the TRIG1 signal is configured in the edge-detection mode. You can select any PFI pin as the source for TRIG1 and configure the polarity selection for either rising or falling edge. The selected edge of the TRIG1 signal starts the data acquisition sequence for both posttriggered and pretriggered acquisitions.

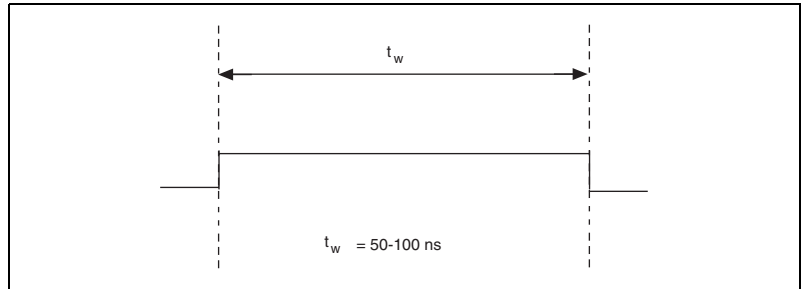
As an output, the TRIG1 signal reflects the action that initiates a DAQ sequence. This is true even if the acquisition is externally triggered by another PFI. The output is an active high pulse with a pulse width of 50 to 100 ns. This output is set to high impedance at startup.

Figures 4-21 and 4-22 show the input and output timing requirements for the TRIG1 signal.



**Figure 4-21.** TRIG1 Input Signal Timing





**Figure 4-22.** TRIG1 Output Signal Timing

The device also uses the TRIG1 signal to initiate pretriggered DAQ operations. In most pretriggered applications, the TRIG1 signal is generated by a software trigger. Refer to the TRIG2 signal description for a complete description of the use of TRIG1 and TRIG2 in a pretriggered DAQ operation.

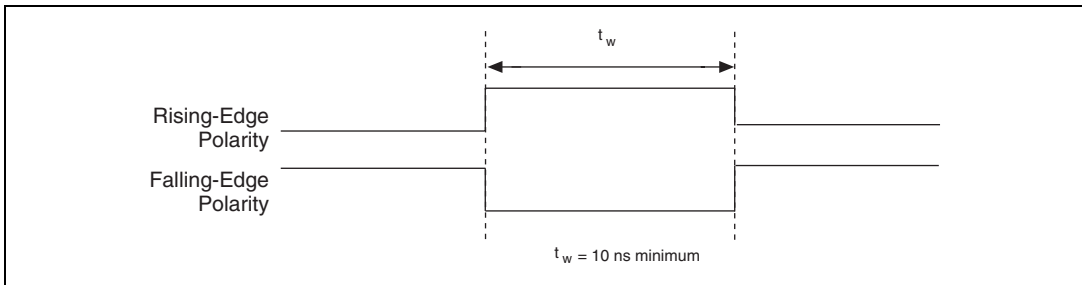
## TRIG2 Signal

Any PFI pin can externally input the TRIG2 signal, which is available as an output on the PFI1/TRIG2 pin. Refer to Figure 4-18 for the relationship of TRIG2 to the DAQ sequence.

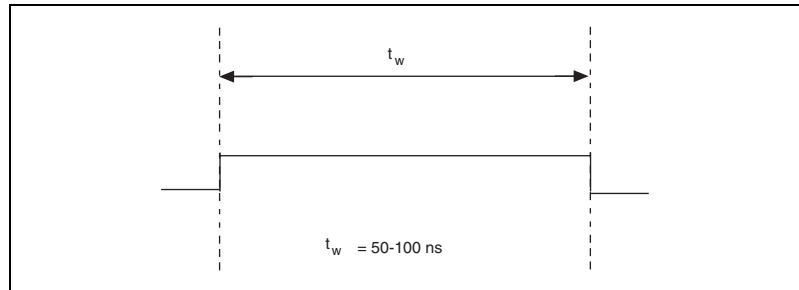
As an input, the TRIG2 signal is configured in the edge-detection mode. You can select any PFI pin as the source for TRIG2 and configure the polarity selection for either rising or falling edge. The selected edge of the TRIG2 signal initiates the posttriggered phase of a pretriggered acquisition sequence. In pretriggered mode, the TRIG1 signal initiates the data acquisition. The scan counter indicates the minimum number of scans before TRIG2 can be recognized. After the scan counter decrements to zero, it is loaded with the number of posttrigger scans to acquire while the acquisition continues. The device ignores the TRIG2 signal if it is asserted prior to the scan counter decrementing to zero. After the selected edge of TRIG2 is received, the device acquires a fixed number of scans and the acquisition stops. This mode acquires data both before and after receiving TRIG2.

As an output, the TRIG2 signal reflects the posttrigger in a pretriggered acquisition sequence. This is true even if the acquisition is externally triggered by another PFI. The TRIG2 signal is not used in posttriggered data acquisition. The output is an active high pulse with a pulse width of 50 to 100 ns. This output is set to high impedance at startup.

Figures 4-23 and 4-24 show the input and output timing requirements for the TRIG2 signal.



**Figure 4-23.** TRIG2 Input Signal Timing



**Figure 4-24.** TRIG2 Output Signal Timing

## STARTSCAN Signal

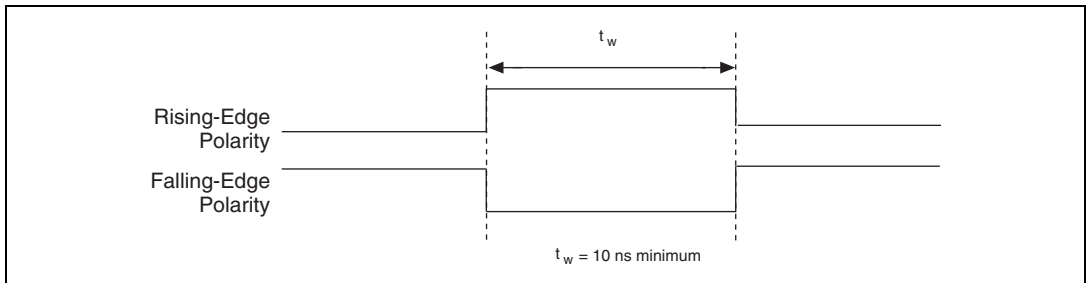
Any PFI pin can externally input the STARTSCAN signal, which is available as an output on the PFI7/STARTSCAN pin. Refer to Figures 4-17 and 4-18 for the relationship of STARTSCAN to the DAQ sequence.

As an input, the STARTSCAN signal is configured in the edge-detection mode. You can select any PFI pin as the source for STARTSCAN and configure the polarity selection for either rising or falling edge. The selected edge of the STARTSCAN signal initiates a scan. The sample interval counter starts if you select internally triggered CONVERT\*.

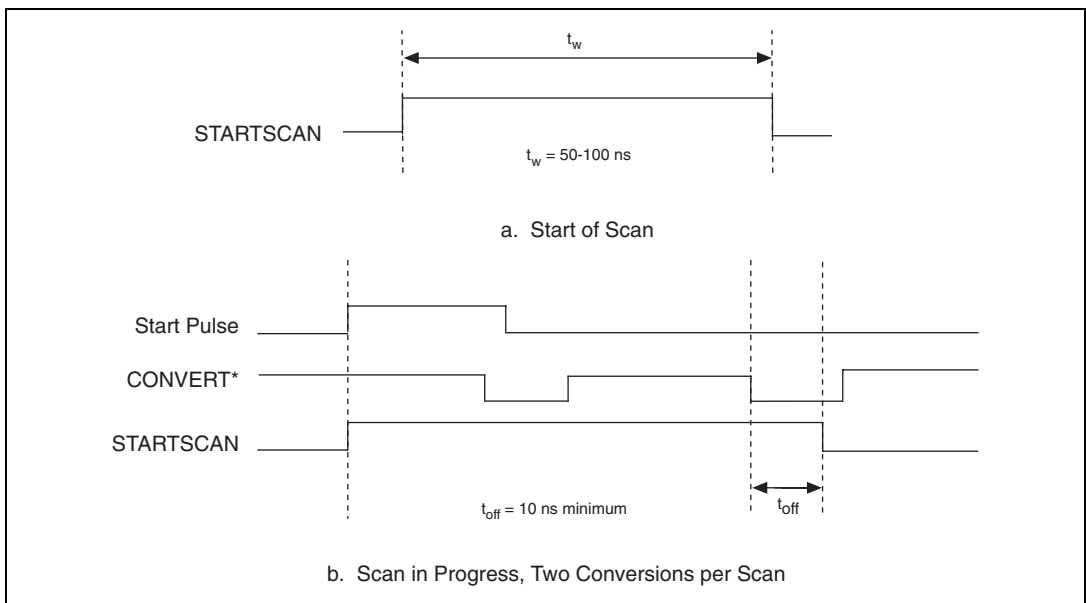
As an output, the STARTSCAN signal reflects the actual start pulse that initiates a scan. This is true even if the starts are externally triggered by another PFI. You have two output options. The first is an active high pulse with a pulse width of 50 to 100 ns, which indicates the start of the scan. The second action is an active high pulse that terminates at the start of the last conversion in the scan, which indicates a scan in progress. STARTSCAN is

deasserted  $t_{\text{off}}$  after the last conversion in the scan is initiated. This output is set to high impedance at startup.

Figures 4-25 and 4-26 show the input and output timing requirements for the STARTSCAN signal.



**Figure 4-25.** STARTSCAN Input Signal Timing



**Figure 4-26.** STARTSCAN Output Signal Timing

The CONVERT\* pulses are masked off until the device generates the STARTSCAN signal. If you are using internally generated conversions, the first CONVERT\* appears when the onboard sample interval counter reaches zero. If you select an external CONVERT\*, the first external pulse after STARTSCAN generates a conversion. Separate the STARTSCAN pulses by at least one scan period.

A counter on your device internally generates the STARTSCAN signal unless you select some external source. This counter is started by the TRIG1 signal and is stopped either by software or by the sample counter.

Scans generated by either an internal or external STARTSCAN signal are inhibited unless they occur within a DAQ sequence. Scans occurring within a DAQ sequence can be gated by either the hardware (AIGATE) signal or software command register gate.

## CONVERT\* Signal

Any PFI pin can externally input the CONVERT\* signal, which is available as an output on the PFI2/CONVERT\* pin.

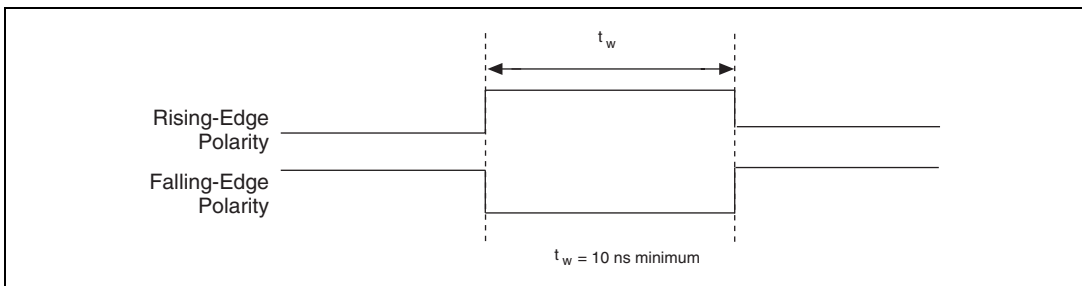
Refer to Figures 4-17 and 4-18 for the relationship of CONVERT\* to the DAQ sequence.

As an input, the CONVERT\* signal is configured in the edge-detection mode. You can select any PFI pin as the source for CONVERT\* and configure the polarity selection for either rising or falling edge. The selected edge of the CONVERT\* signal initiates an A/D conversion.

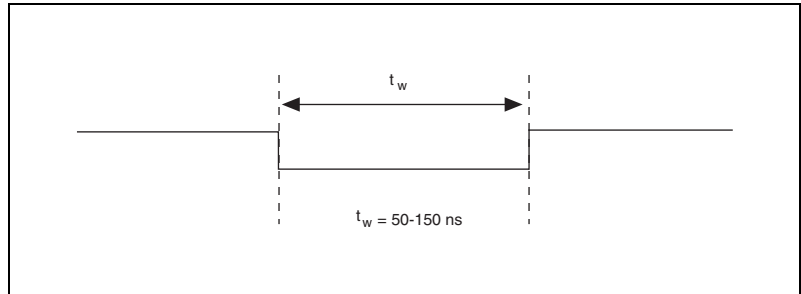
The ADC switches to hold mode within 60 ns of the selected edge. This hold-mode delay time is a function of temperature and does not vary from one conversion to the next. Separate the CONVERT\* pulses by at least 5  $\mu$ s (200 kHz sample rate).

As an output, the CONVERT\* signal reflects the actual convert pulse that is connected to the ADC. This is true even if the conversions are externally generated by another PFI. The output is an active low pulse with a pulse width of 50 to 150 ns. This output is set to high impedance at startup.

Figures 4-27 and 4-28 show the input and output timing requirements for the CONVERT\* signal.



**Figure 4-27.** CONVERT\* Input Signal Timing



**Figure 4-28.** CONVERT\* Output Signal Timing

The sample interval counter on the device normally generates the CONVERT\* signal unless you select some external source. The counter is started by the STARTSCAN signal and continues to count down and reload itself until the scan is finished. It then reloads itself in preparation for the next STARTSCAN pulse.

A/D conversions generated by either an internal or external CONVERT\* signal are inhibited unless they occur within a DAQ sequence. Scans occurring within a DAQ sequence can be gated by either the hardware (AIGATE) signal or software command register gate.

## AIGATE Signal

Any PFI pin can externally input the AIGATE signal, which is not available as an output on the I/O connector. The AIGATE signal can mask off scans in a DAQ sequence. You can configure the PFI pin you select as the source for the AIGATE signal in either the level-detection or edge-detection mode. You can configure the polarity selection for the PFI pin for either active high or active low.

In the level-detection mode if AIGATE is active, the STARTSCAN signal is masked off and no scans can occur. In the edge-detection mode, the first active edge disables the STARTSCAN signal, and the second active edge enables STARTSCAN.

The AIGATE signal can neither stop a scan in progress nor continue a previously gated-off scan; in other words, once a scan has started, AIGATE does not gate off conversions until the beginning of the next scan and, conversely, if conversions are gated off, AIGATE does not gate them back on until the beginning of the next scan.

## SISOURCE Signal

Any PFI pin can externally input the SISOURCE signal, which is not available as an output on the I/O connector. The onboard scan interval counter uses the SISOURCE signal as a clock to time the generation of the STARTSCAN signal. You must configure the PFI pin you select as the source for the SISOURCE signal in the level-detection mode. You can configure the polarity selection for the PFI pin for either active high or active low.

The maximum allowed frequency is 20 MHz, with a minimum pulse width of 23 ns high or low. There is no minimum frequency limitation.

Either the 20 MHz or 100 kHz internal timebase generates the SISOURCE signal unless you select some external source. Figure 4-29 shows the timing requirements for the SISOURCE signal.

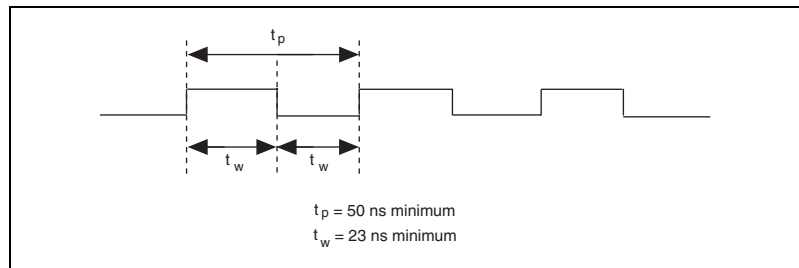


Figure 4-29. SISOURCE Signal Timing

## Waveform Generation Timing Connections

The analog group defined for your device is controlled by WFTRIG, UPDATE\*, and UISOURCE.

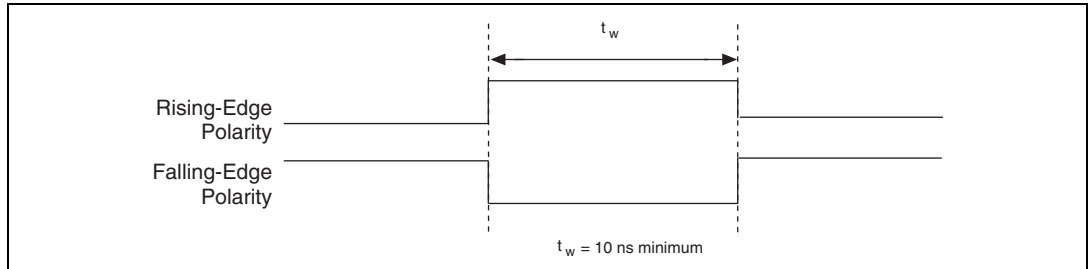
### WFTRIG Signal

Any PFI pin can externally input the WFTRIG signal, which is available as an output on the PFI6/WFTRIG pin.

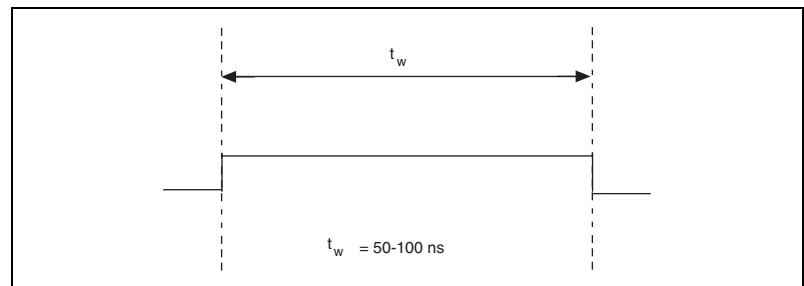
As an input, the WFTRIG signal is configured in the edge-detection mode. You can select any PFI pin as the source for WFTRIG and configure the polarity selection for either rising or falling edge. The selected edge of the WFTRIG signal starts the waveform generation for the DACs. The update interval (UI) counter is started if you select internally generated UPDATE\*.

As an output, the WFTRIG signal reflects the trigger that initiates waveform generation. This is true even if the waveform generation is externally triggered by another PFI. The output is an active high pulse with a pulse width of 50 to 100 ns. This output is set to high impedance at startup.

Figures 4-30 and 4-31 show the input and output timing requirements for the WFTRIG signal.



**Figure 4-30.** WFTRIG Input Signal Timing



**Figure 4-31.** WFTRIG Output Signal Timing

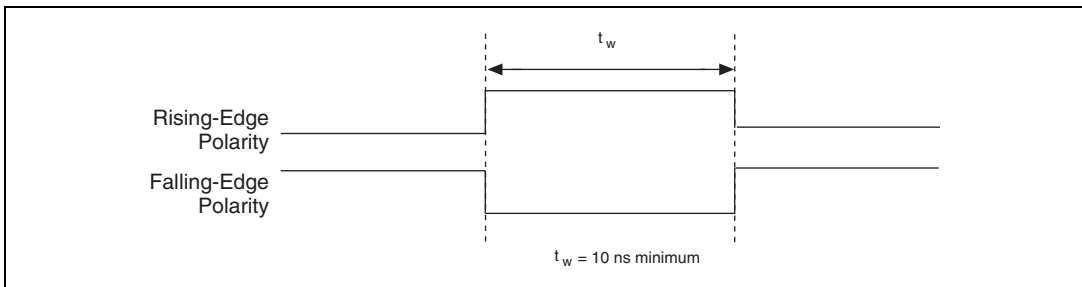
## UPDATE\* Signal

Any PFI pin can externally input the UPDATE\* signal, which is available as an output on the PFI5/UPDATE\* pin.

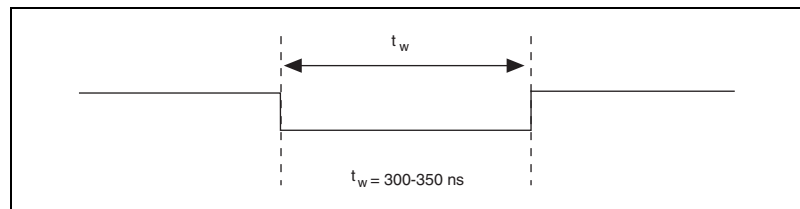
As an input, the UPDATE\* signal is configured in the edge-detection mode. You can select any PFI pin as the source for UPDATE\* and configure the polarity selection for either rising or falling edge. The selected edge of the UPDATE\* signal updates the outputs of the DACs. In order to use UPDATE\*, you must set the DACs to posted-update mode.

As an output, the UPDATE\* signal reflects the actual update pulse that is connected to the DACs. This is true even if the updates are externally generated by another PFI. The output is an active low pulse with a pulse width of 300 to 350 ns. This output is set to high impedance at startup.

Figures 4-32 and 4-33 show the input and output timing requirements for the UPDATE\* signal.



**Figure 4-32.** UPDATE\* Input Signal Timing



**Figure 4-33.** UPDATE\* Output Signal Timing

The DACs are updated within 100 ns of the leading edge. Separate the UPDATE\* pulses with enough time that new data can be written to the DAC latches.

The device UI counter normally generates the UPDATE\* signal unless you select some external source. The UI counter is started by the WFTRIG signal and can be stopped by software or the internal Buffer Counter.

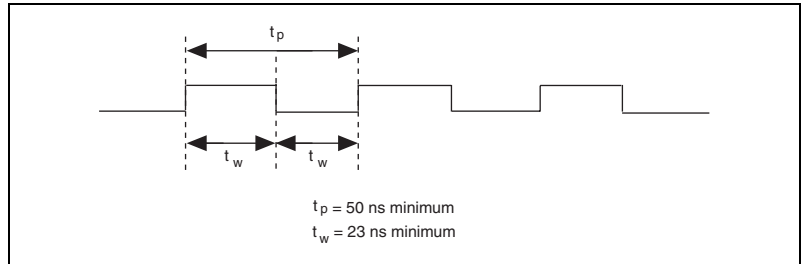
D/A conversions generated by either an internal or external UPDATE\* signal do not occur when gated by the software command register gate.

## UISOURCE Signal

Any PFI pin can externally input the UISOURCE signal, which is not available as an output on the I/O connector. The UI counter uses the UISOURCE signal as a clock to time the generation of the UPDATE\*



signal. You must configure the PFI pin you select as the source for the UISOURCE signal in the level-detection mode. You can configure the polarity selection for the PFI pin for either active high or active low. Figure 4-34 shows the timing requirements for the UISOURCE signal.



**Figure 4-34.** UISOURCE Signal Timing

The maximum allowed frequency is 20 MHz, with a minimum pulse width of 23 ns high or low. There is no minimum frequency limitation.

Either the 20 MHz or 100 kHz internal timebase normally generates the UISOURCE signal unless you select some external source.

## General-Purpose Timing Signal Connections

The general-purpose timing signals are GPCTR0\_SOURCE, GPCTR0\_GATE, GPCTR0\_OUT, GPCTR0\_UP\_DOWN, GPCTR1\_SOURCE, GPCTR1\_GATE, GPCTR1\_OUT, GPCTR1\_UP\_DOWN, and FREQ\_OUT.

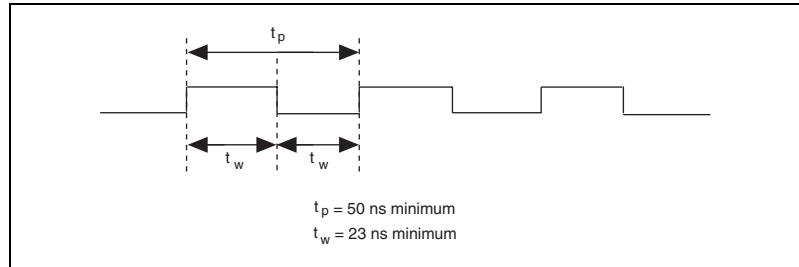
### GPCTR0\_SOURCE Signal

Any PFI pin can externally input the GPCTR0\_SOURCE signal, which is available as an output on the PFI8/GPCTR0\_SOURCE pin.

As an input, the GPCTR0\_SOURCE signal is configured in the edge-detection mode. You can select any PFI pin as the source for GPCTR0\_SOURCE and configure the polarity selection for either rising or falling edge.

As an output, the GPCTR0\_SOURCE signal reflects the actual clock connected to general-purpose counter 0. This is true even if another PFI is externally inputting the source clock. This output is set to high impedance at startup.

Figure 4-35 shows the timing requirements for the GPCTR0\_SOURCE signal.



**Figure 4-35.** GPCTR0\_SOURCE Signal Timing

The maximum allowed frequency is 20 MHz, with a minimum pulse width of 23 ns high or low. There is no minimum frequency limitation.

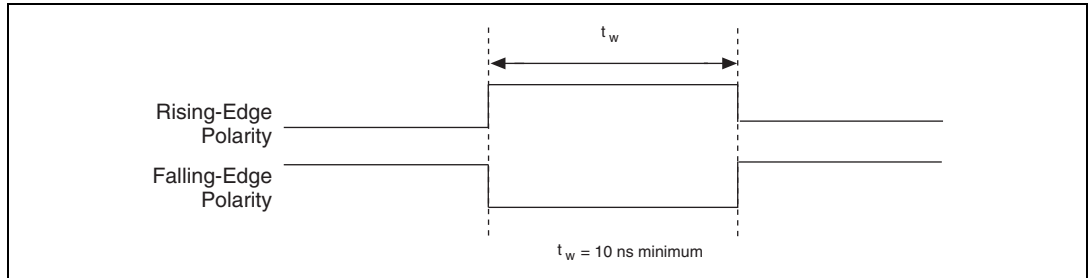
The 20 MHz or 100 kHz timebase normally generates the GPCTR0\_SOURCE signal unless you select some external source.

## GPCTR0\_GATE Signal

Any PFI pin can externally input the GPCTR0\_GATE signal, which is available as an output on the PFI9/GPCTR0\_GATE pin.

As an input, the GPCTR0\_GATE signal is configured in the edge-detection mode. You can select any PFI pin as the source for GPCTR0\_GATE and configure the polarity selection for either rising or falling edge. You can use the gate signal in a variety of different applications to perform actions such as starting and stopping the counter, generating interrupts, saving the counter contents, and so on.

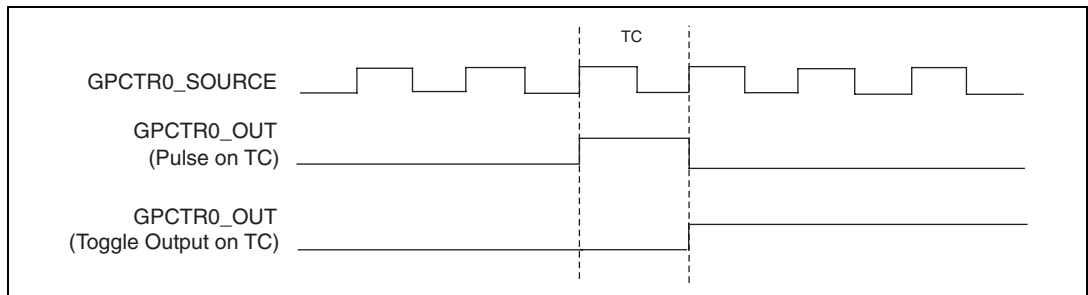
As an output, the GPCTR0\_GATE signal reflects the actual gate signal connected to general-purpose counter 0. This is true even if the gate is externally generated by another PFI. This output is set to high impedance at startup. Figure 4-36 shows the timing requirements for the GPCTR0\_GATE signal.



**Figure 4-36.** GPCTRO\_GATE Signal Timing in Edge-Detection Mode

## GPCTRO\_OUT Signal

This signal is available only as an output on the GPCTRO\_OUT pin. The GPCTRO\_OUT signal reflects the terminal count (TC) of general-purpose counter 0. You have two software-selectable output options—pulse on TC and toggle output polarity on TC. The output polarity is software-selectable for both options. This output is set to high impedance at startup. Figure 4-37 shows the timing of the GPCTRO\_OUT signal.



**Figure 4-37.** GPCTRO\_OUT Signal Timing

## GPCTRO\_UP\_DOWN Signal

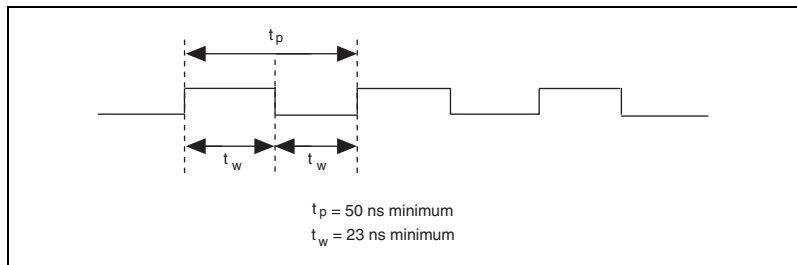
This signal can be externally input on the DIO6 pin and is not available as an output on the I/O connector. The general-purpose counter 0 counts down when this pin is at a logic low and count up when it is at a logic high. You can disable this input so that software can control the up-down functionality and leave the DIO6 pin free for general use.

## GPCTR1\_SOURCE Signal

Any PFI pin can externally input the GPCTR1\_SOURCE signal, which is available as an output on the PFI3/GPCTR1\_SOURCE pin. As an input, the GPCTR1\_SOURCE signal is configured in the edge-detection mode. You can select any PFI pin as the source for GPCTR1\_SOURCE and configure the polarity selection for either rising or falling edge.

As an output, the GPCTR1\_SOURCE monitors the actual clock connected to general-purpose counter 1. This is true even if the source clock is externally generated by another PFI. This output is set to high impedance at startup.

Figure 4-38 shows the timing requirements for the GPCTR1\_SOURCE signal.



**Figure 4-38.** GPCTR1\_SOURCE Signal Timing

The maximum allowed frequency is 20 MHz, with a minimum pulse width of 23 ns high or low. There is no minimum frequency limitation.

The 20 MHz or 100 kHz timebase normally generates the GPCTR1\_SOURCE unless you select some external source.

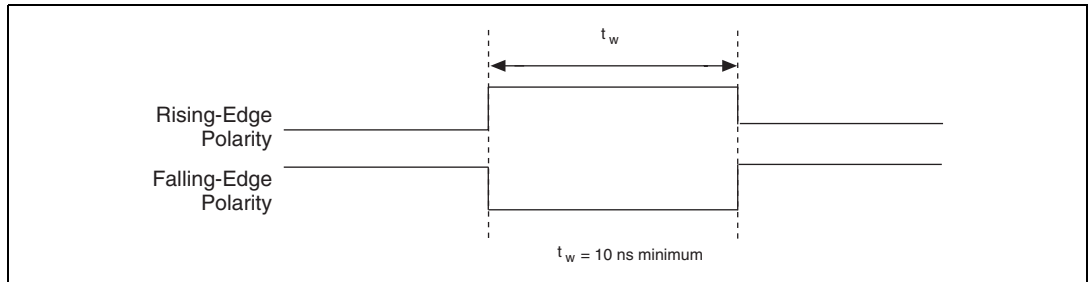
## GPCTR1\_GATE Signal

Any PFI pin can externally input the GPCTR1\_GATE signal, which is available as an output on the PFI4/GPCTR1\_GATE pin.

As an input, the GPCTR1\_GATE signal is configured in edge-detection mode. You can select any PFI pin as the source for GPCTR1\_GATE and configure the polarity selection for either rising or falling edge. You can use the gate signal in a variety of different applications to perform such actions as starting and stopping the counter, generating interrupts, saving the counter contents, and so on.

As an output, the GPCTR1\_GATE signal monitors the actual gate signal connected to general-purpose counter 1. This is true even if the gate is externally generated by another PFI. This output is set to high impedance at startup.

Figure 4-39 shows the timing requirements for the GPCTR1\_GATE signal.

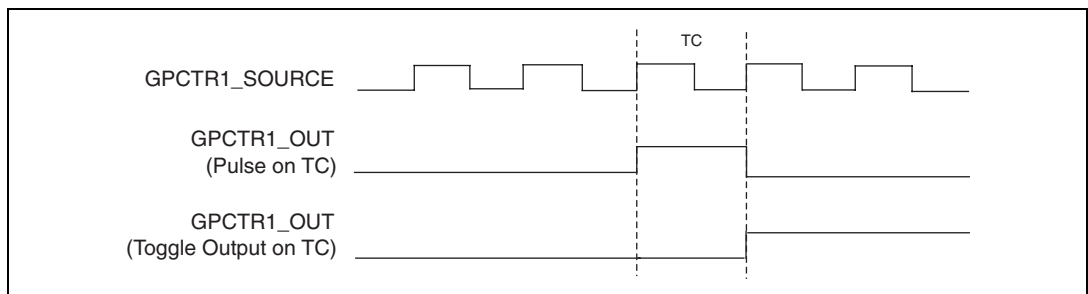


**Figure 4-39.** GPCTR1\_GATE Signal Timing in Edge-Detection Mode

## GPCTR1\_OUT Signal

This signal is available only as an output on the GPCTR1\_OUT pin. The GPCTR1\_OUT signal monitors the TC device general-purpose counter 1. You have two software-selectable output options—pulse on TC and toggle output polarity on TC. The output polarity is software-selectable for both options. This output is set to high impedance at startup.

Figure 4-40 shows the timing requirements for the GPCTR1\_OUT signal.

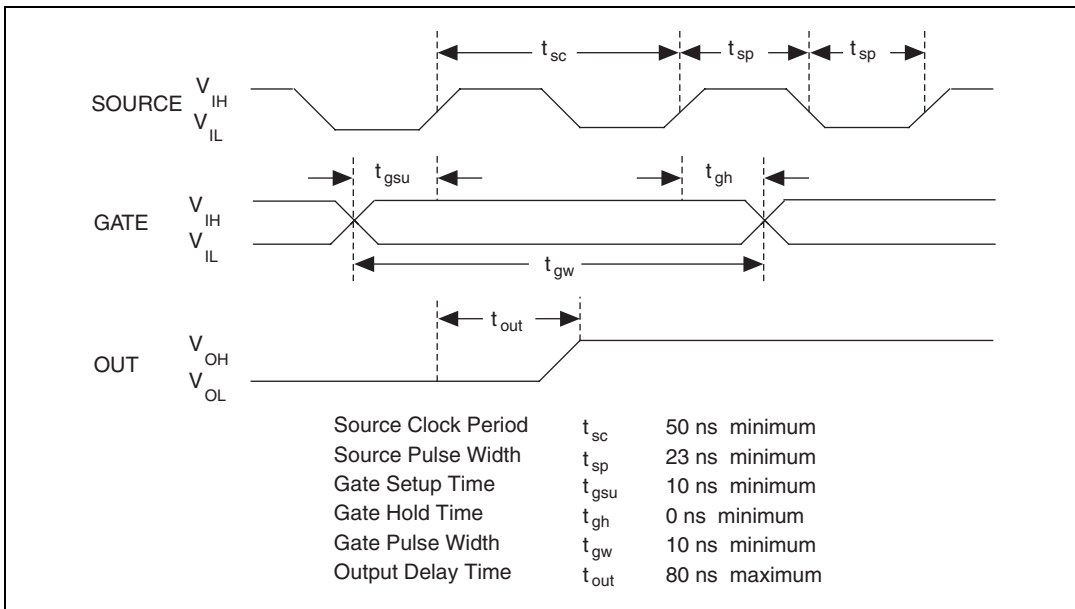


**Figure 4-40.** GPCTR1\_OUT Signal Timing

## GPCTR1\_UP\_DOWN Signal

This signal can be externally input on the DIO7 pin and is not available as an output on the I/O connector. General-purpose counter 1 counts down when this pin is at a logic low and counts up at a logic high. This input can be disabled so that software can control the up-down functionality and

leave the DIO7 pin free for general use. Figure 4-41 shows the timing requirements for the GATE and SOURCE input signals and the timing specifications for the OUT output signals of your device.



**Figure 4-41.** GPCTR Timing Summary

The GATE and OUT signal transitions shown in Figure 4-41 are referenced to the rising edge of the SOURCE signal. This timing diagram assumes that the counters are programmed to count rising edges. The same timing diagram, but with the source signal inverted and referenced to the falling edge of the source signal, applies when the counter is programmed to count falling edges.

The GATE input timing parameters are referenced to the signal at the SOURCE input or to one of the internally generated signals on your device. Figure 4-41 shows the GATE signal referenced to the rising edge of a source signal. The gate must be valid (either high or low) for at least 10 ns before the rising or falling edge of a source signal for the gate to take effect at that source edge, as shown by  $t_{gsu}$  and  $t_{gh}$  in Figure 4-41. The gate signal is not required to be held after the active edge of the source signal.

If you use an internal timebase clock, the gate signal cannot be synchronized with the clock. In this case, gates applied close to a source edge take effect either on that source edge or on the next one. This arrangement results in an uncertainty of one source clock period with respect to unsynchronized gating sources.

The OUT output timing parameters are referenced to the signal at the SOURCE input or to one of the internally generated clock signals on the devices. Figure 4-41 shows the OUT signal referenced to the rising edge of a source signal. Any OUT signal state changes occur within 80 ns after the rising or falling edge of the source signal.

## FREQ\_OUT Signal

This signal is available only as an output on the FREQ\_OUT pin. The frequency generator of the device outputs the FREQ\_OUT pin. The frequency generator is a 4-bit counter that can divide its input clock by the numbers 1 through 16. The input clock of the frequency generator is software-selectable from the internal 10 MHz and 100 kHz timebases. The output polarity is software-selectable. This output is set to high impedance at startup.

# Field Wiring Considerations

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Environmental noise can seriously affect the accuracy of measurements made with your device if you do not take proper care when running signal wires between signal sources and the device. The following recommendations apply mainly to analog input signal routing to the device, although they also apply to signal routing in general.

Minimize noise pickup and maximize measurement accuracy by taking the following precautions:

- Use DIFF analog input connections to reject common-mode noise.
- Use individually shielded, twisted-pair wires to connect analog input signals to the device. With this type of wire, the signals attached to the CH+ and CH- inputs are twisted together and then covered with a shield. You then connect this shield only at one point to the signal source ground. This kind of connection is required for signals traveling through areas with large magnetic fields or high electromagnetic interference.

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# Calibration

This chapter discusses the calibration procedures for your device. If you are using the NI-DAQ device driver, that software includes calibration functions for performing all of the steps in the calibration process.

Calibration refers to the process of minimizing measurement and output voltage errors by making small circuit adjustments. For these devices, these adjustments take the form of writing values to onboard calibration DACs (CalDACs).

Some form of device calibration is required for all but the most forgiving applications. If you do not calibrate your device, your signals and measurements could have very large offset, gain, and linearity errors.

Three levels of calibration are available to you and described in this chapter. The first level is the fastest, easiest, and least accurate, whereas the last level is the slowest, most difficult, and most accurate.

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## Loading Calibration Constants

Your device is factory calibrated before shipment at approximately 25 °C to the levels indicated in Appendix A, *Specifications*. The associated calibration constants—the values that were written to the CalDACs to achieve calibration in the factory—are stored in the onboard nonvolatile memory (EEPROM). Because the CalDACs have no memory capability, they do not retain calibration information when the device is unpowered. Loading calibration constants refers to the process of loading the CalDACs with the values stored in the EEPROM. NI-DAQ software determines when this is necessary and does it automatically. If you are not using NI-DAQ, you must load these values yourself.

In the EEPROM there is a user-modifiable calibration area in addition to the permanent factory calibration area. This means that you can load the CalDACs with values either from the original factory calibration or from a calibration that you subsequently performed.



This method of calibration is not very accurate because it does not take into account the fact that the device measurement and output voltage errors can vary with time and temperature. It is better to self-calibrate the device when it is installed in the environment in which it will be used.

## Self-Calibration

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Your device can measure and correct for almost all of its calibration-related errors without any external signal connections. Your National Instruments software provides a self-calibration method. This self-calibration process, which generally takes less than a minute, is the preferred method of assuring accuracy in your application. Initiate self-calibration to minimize the effects of any offset, gain, and linearity drifts, particularly those due to warmup.

Immediately after self-calibration, the only significant residual calibration error could be gain error due to time or temperature drift of the onboard voltage reference. This error is addressed by external calibration, which is discussed in the following section. If you are interested primarily in relative measurements, you can ignore a small amount of gain error, and self-calibration should be sufficient.

## External Calibration

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Your device has an onboard calibration reference to ensure the accuracy of self-calibration. Its specifications are listed in Appendix A, *Specifications*. The reference voltage is measured at the factory and stored in the EEPROM for subsequent self-calibrations. This voltage is stable enough for most applications, but if you are using your device at an extreme temperature or if the onboard reference has not been measured for a year or more, you may wish to externally calibrate your device.

An external calibration refers to calibrating your device with a known external reference rather than relying on the onboard reference. Redetermining the value of the onboard reference is part of this process and you can save the results in the EEPROM, so you should not have to perform an external calibration very often. You can externally calibrate your device by calling the NI-DAQ calibration function.

To externally calibrate your device, be sure to use a very accurate external reference. Use a reference that is several times more accurate than the device itself.

## Other Considerations

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The CalDACs adjust the gain error of each analog output channel by adjusting the value of the reference voltage supplied to that channel. This calibration mechanism is designed to work only with the internal 10 V reference. Thus, in general, it is not possible to calibrate the analog output gain error when using an external reference. In this case, it is advisable to account for the nominal gain error of the analog output channel either in software or with external hardware. See Appendix A, [Specifications](#), for analog output gain error information.

## Specifications

This appendix individually lists the specifications of each bus type and are typical at 25 °C.

### PCI and PXI Buses

#### Analog Input

##### Input Characteristics

Number of channels ..... 16 single-ended or 8 differential  
(software-selectable per channel)

Type of ADC..... Successive approximation

Resolution ..... 12 bits, 1 in 4,096

Sampling rate ..... 200 kS/s guaranteed

Input signal ranges ..... Bipolar only

<b>Board Gain (Software-Selectable)</b>	<b>Range</b>
0.5	±10 V
1	±5 V
10	±500 mV
100	±50 mV

Input coupling ..... DC

Max working voltage  
(signal + common mode) ..... Each input should remain  
within ±11 V of ground

Overvoltage protection

Signal	Powered On	Powered Off
ACH<0..15>	±42	±35
AISENSE	±40	±25

FIFO buffer size.....512 S

Data transfers .....DMA, interrupts,  
programmed I/O

DMA modes .....Scatter-gather  
(single transfer, demand transfer)

Configuration memory size .....512 words

### Accuracy Information

Nominal Range (V)		Absolute Accuracy						Relative Accuracy		
		% of Reading		Offset (mV)	Noise + Quantization (mV)		Temp Drift (%/°C)	Absolute Accuracy at Full Scale (mV)	Resolution (mV)	
Positive FS	Negative FS	24 Hours	1 Year		Single Pt.	Averaged			Single Pt.	Averaged
10	-10	0.0872	0.0914	6.38	3.91	0.975	0.0010	16.504	5.89	1.28
5	-5	0.0272	0.0314	3.20	1.95	0.488	0.0005	5.263	2.95	0.642
0.5	-0.5	0.0872	0.0914	0.340	0.195	0.049	0.0010	0.846	0.295	0.064
0.05	-0.05	0.0872	0.0914	0.054	0.063	0.006	0.0010	0.106	0.073	0.008

**Note:** Accuracies are valid for measurements following an internal E Series calibration. Averaged numbers assume dithering and averaging of 100 single-channel readings. Measurement accuracies are listed for operational temperatures within ±1 °C of internal calibration temperature and ±10 °C of external or factory-calibration temperature. One-year calibration interval recommended. The Absolute Accuracy at Full Scale calculations were performed for a maximum range input voltage (for example, 10 V for the ±10 V range) after one year, assuming 100 pt averaging of data.

## Transfer Characteristics

Relative accuracy .....	$\pm 0.5$ LSB typ dithered, $\pm 1.5$ LSB max undithered
DNL .....	$\pm 0.5$ LSB typ, $\pm 1.0$ LSB max
No missing codes .....	12 bits, guaranteed
Offset error	
Pregain error after calibration .....	$\pm 12$ $\mu$ V max
Pregain error before calibration .....	$\pm 28$ mV max
Postgain error after calibration .....	$\pm 0.5$ mV max
Postgain error before calibration.....	$\pm 100$ mV max
Gain error (relative to calibration reference)	
After calibration (gain = 1) .....	$\pm 0.02\%$ of reading max
Before calibration .....	$\pm 2.75\%$ of reading max
Gain $\neq 1$ with gain error adjusted to 0 at gain = 1 .....	$\pm 0.05\%$ of reading max

## Amplifier Characteristics

Input impedance	
Normal powered on .....	100 $\Omega$ in parallel with 100 pF
Powered off .....	4 k $\Omega$ min
Overload.....	4 k $\Omega$ min
Input bias current .....	$\pm 200$ pA
Input offset current.....	$\pm 100$ pA
CMRR (DC to 60 Hz)	
Gain 0.5, 1.0.....	85 dB
Gain 10, 100.....	90 dB

## Dynamic Characteristics

Bandwidth

Signal	Bandwidth
Small (-3 dB)	500 kHz
Large (1% THD)	225 kHz

Settling time for full-scale step.....5  $\mu$ s max to  $\pm 1.0$  LSB accuracy

System noise ( $LSB_{rms}$ , not including quantization)

Gain	Dither Off	Dither On
0.5 to 10	0.1	0.6
100	0.7	0.8

Crosstalk .....-60 dB, DC to 100 kHz

## Stability

Recommended warm-up time..... 15 min.

Offset temperature coefficient

Pregain..... $\pm 15 \mu V/^{\circ}C$

Postgain ..... $\pm 240 \mu V/^{\circ}C$

Gain temperature coefficient ..... $\pm 20$  ppm/ $^{\circ}C$

## Analog Output

- ◆ 6024E and 6025E only

## Output Characteristics

Number of channels.....2 voltage

Resolution.....12 bits, 1 in 4,096

Max update rate

DMA.....10 kHz, system dependent

Interrupts.....1 kHz, system dependent

Type of DAC .....Double buffered, multiplying

FIFO buffer size ..... None

Data transfers ..... DMA, interrupts,  
programmed I/O

DMA modes ..... Scatter-gather  
(Single transfer, demand transfer)

## Accuracy Information

Nominal Range (V)		Absolute Accuracy				Offset (mV)	Temp Drift (%/°C)	Absolute Accuracy at Full Scale (mV)
		% of Reading						
Positive FS	Negative FS	24 Hours	90 Days	1 Year				
10	-10	0.0177	0.0197	0.0219	5.93	0.0005	8.127	
<b>Note:</b> Temp Drift applies only if ambient is greater than $\pm 10$ °C of previous external calibration.								

## Transfer Characteristics

Relative accuracy (INL)

After calibration .....  $\pm 0.3$  LSB typ,  $\pm 0.5$  LSB max  
 Before calibration .....  $\pm 4$  LSB max

DNL

After calibration .....  $\pm 0.3$  LSB typ,  $\pm 1.0$  LSB max  
 Before calibration .....  $\pm 3$  LSB max

Monotonicity ..... 12 bits, guaranteed after calibration

Offset error

After calibration .....  $\pm 1.0$  mV max  
 Before calibration .....  $\pm 200$  mV max

Gain error (relative to internal reference)

After calibration .....  $\pm 0.01\%$  of output max  
 Before calibration .....  $\pm 0.75\%$  of output max

## Voltage Output

Range .....	$\pm 10$ V
Output coupling .....	DC
Output impedance .....	$0.1 \Omega$ max
Current drive .....	$\pm 5$ mA max
Protection .....	Short-circuit to ground
Power-on state (steady state) .....	$\pm 200$ mV
Initial power-up glitch	
Magnitude .....	$\pm 1.1$ V
Duration .....	2.0 ms
Power reset glitch	
Magnitude .....	$\pm 2.2$ V
Duration .....	4.2 $\mu$ s

## Dynamic Characteristics

Settling time for full-scale step .....	10 $\mu$ s to $\pm 0.5$ LSB accuracy
Slew rate .....	10 V/ $\mu$ s
Noise .....	200 $\mu$ V <sub>rms</sub> , DC to 1 MHz
Midscale transition glitch	
Magnitude .....	$\pm 45$ mV
Duration .....	2.0 $\mu$ s

## Stability

Offset temperature coefficient .....	$\pm 50 \mu$ V/ $^{\circ}$ C
Gain temperature coefficient .....	$\pm 25$ ppm/ $^{\circ}$ C



## Digital I/O

Number of channels	
6025E .....	32 input/output
6023E and 6024E .....	8 input/output
Compatibility .....	TTL/CMOS

### DIO<0..7>

Digital logic levels

Level	Min	Max
Input low voltage	0 V	0.8 V
Input high voltage	2 V	5 V
Input low current ( $V_{in} = 0$ V)	—	-320 $\mu$ A
Input high current ( $V_{in} = 5$ V)	—	10 $\mu$ A
Output low voltage ( $I_{OL} = 24$ mA)	—	0.4 V
Output high voltage ( $I_{OH} = 13$ mA)	4.35 V	—

Power-on state ..... Input (High-Z),  
50 k $\Omega$  pull up to +5 VDC

Data transfers ..... Programmed I/O

### PA<0..7>, PB<0..7>, PC<0..7>

- ◆ 6025E only

Digital logic levels

Level	Min	Max
Input low voltage	0 V	0.8 V
Input high voltage	2.2 V	5 V
Input low current ( $V_{in} = 0$ V, 100 k $\Omega$ pull up)	—	-75 $\mu$ A
Input high current ( $V_{in} = 5$ V, 100 k $\Omega$ pull up)	—	10 $\mu$ A
Output low voltage ( $I_{OL} = 2.5$ mA)	—	0.4 V
Output high voltage ( $I_{OH} = 2.5$ mA)	3.7 V	—

Handshaking .....	2-wire
Power-on state	
PA<0..7> .....	Input (High-Z), 100 k $\Omega$ pull-up to +5 VDC
PB<0..7>.....	Input (High-Z), 100 k $\Omega$ pull-up to +5 VDC
PC<0..7>.....	Input (High-Z), 100 k $\Omega$ pull-up to +5 VDC
Data transfers .....	Interrupts, programmed I/O

## Timing I/O

Number of channels .....	2 up/down counter/timers, 1 frequency scaler
Resolution	
Counter/timers .....	24 bits
Frequency scalars .....	4 bits
Compatibility .....	TTL/CMOS
Base clocks available	
Counter/timers .....	20 MHz, 100 kHz
Frequency scalars .....	10 MHz, 100 kHz
Base clock accuracy.....	$\pm 0.01\%$
Max source frequency.....	20 MHz
Min source pulse duration .....	10 ns in edge-detect mode
Min gate pulse duration .....	10 ns in edge-detect mode
Data transfers .....	DMA, interrupts, programmed I/O
DMA modes .....	Scatter-gather (single transfer, demand transfer)

## Triggers

### Digital Trigger

Compatibility .....	TTL
Response .....	Rising or falling edge
Pulse width .....	10 ns min

### RTSI

Trigger lines .....	7
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## Calibration

Recommended warm-up time .....	15 min
Interval .....	1 year
External calibration reference .....	> 6 and < 10 V
Onboard calibration reference	
Level .....	5.000 V ( $\pm 3.5$ mV) (actual value stored in EEPROM)
Temperature coefficient .....	$\pm 5$ ppm/ $^{\circ}$ C max
Long-term stability .....	$\pm 15$ ppm/ $\sqrt{1,000}$ h

## Power Requirement

+5 VDC ( $\pm 5\%$ ) .....	0.7 A
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**Note** Excludes power consumed through  $V_{cc}$  available at the I/O connector.

Power available at I/O connector .....	+4.65 to +5.25 VDC at 1 A
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## Physical

Dimensions (not including connectors)	
PCI devices .....	17.5 by 10.6 cm (6.9 by 4.2 in.)
PXI devices .....	16.0 by 10.0 cm (6.3 by 3.9 in.)

I/O connector	
6023E/6024E .....	68-pin male SCSI-II type
6025E.....	100-pin female 0.05D type

## Operating Environment

Ambient temperature .....	0 to 55 °C
Relative humidity .....	10 to 90% noncondensing
◆ PXI-6025E only	
Functional shock.....	MIL-T-28800 E Class 3 (per Section 4.5.5.4.1) Half-sine shock pulse, 11 ms duration, 30 g peak, 30 shocks per face
Operational random vibration.....	5 to 500 Hz, 0.31 g <sub>rms</sub> , 3 axes

## Storage Environment

Ambient temperature .....	-20 to 70 °C
Relative humidity .....	5% to 95% noncondensing
◆ PXI-6025E only	
Non-operational random vibration .....	5 to 500 Hz, 2.5 g <sub>rms</sub> , 3 axes



**Note** Random vibration profiles for the PXI-6025E were developed in accordance with MIL-T-28800E and MIL-STD-810E Method 514. Test levels exceed those recommended in MIL-STD-810E for Category 1, Basic Transportation.

# PCMCIA Bus

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## Analog Input

### Input Characteristics

Number of channels ..... 16 single-ended or 8 differential  
(software-selectable per channel)

Type of ADC..... Successive approximation

Resolution ..... 12 bits, 1 in 4,096

Sampling rate ..... 200 kS/s guaranteed

Input signal ranges ..... Bipolar only

<b>Board Gain (Software-Selectable)</b>	<b>Range</b>
0.5	$\pm 10$ V
1	$\pm 5$ V
10	$\pm 500$ mV
100	$\pm 50$ mV

Input coupling ..... DC

Max working voltage  
(signal + common mode) ..... Each input should remain  
within  $\pm 11$  V of ground

Overvoltage protection

<b>Signal</b>	<b>Powered On</b>	<b>Powered Off</b>
ACH<0..15>	$\pm 42$	$\pm 35$
AISENSE	$\pm 40$	$\pm 25$

FIFO buffer size ..... 2048 S

Data transfers ..... Interrupts, programmed I/O

Configuration memory size..... 512 words

## Accuracy Information

Nominal Range (V)		Absolute Accuracy							Relative Accuracy	
		% of Reading		Offset (mV)	Noise + Quantization (mV)		Temp Drift (%/°C)	Absolute Accuracy at Full Scale (mV)	Resolution (mV)	
		Positive FS	Negative FS		24 Hours	1 Year			Single Pt.	Averaged
10	-10	0.0872	0.0914	8.83	3.91	1.042	0.0010	19.012	5.89	1.37
5	-5	0.0272	0.0314	4.42	1.95	0.521	0.0005	6.517	2.95	0.686
0.5	-0.5	0.0872	0.0914	0.462	0.452	0.052	0.0010	0.972	0.516	0.069
0.05	-0.05	0.0872	0.0914	0.066	0.063	0.007	0.0010	0.119	0.073	0.009

**Note:** Accuracies are valid for measurements following an internal E Series calibration. Averaged numbers assume dithering and averaging of 100 single-channel readings. Measurement accuracies are listed for operational temperatures within  $\pm 1^\circ\text{C}$  of internal calibration temperature and  $\pm 10^\circ\text{C}$  of external or factory calibration temperature.

## Transfer Characteristics

Relative accuracy .....  $\pm 0.5$  LSB typ dithered,  
 $\pm 1.5$  LSB max undithered

DNL .....  $\pm 0.75$  LSB typ,  
 $-0.9$  to  $+1.5$  LSB max

No missing codes ..... 12 bits, guaranteed

### Offset error

- Pregain error after calibration .....  $\pm 12$   $\mu\text{V}$  max
- Pregain error before calibration .....  $\pm 28$  mV max
- Postgain error after calibration .....  $\pm 0.5$  mV max
- Postgain error before calibration .....  $\pm 100$  mV max

### Gain error (relative to calibration reference)

- After calibration (gain = 1) .....  $\pm 0.02\%$  of reading max
- Before calibration .....  $\pm 2.75\%$  of reading max
- Gain  $\neq 1$  with gain error  
 adjusted to 0 at gain = 1 .....  $\pm 0.05\%$  of reading max

## Amplifier Characteristics

### Input impedance

Normal powered on ..... 100 G $\Omega$  in parallel with 100 pF  
 Powered off ..... 4 k $\Omega$  min  
 Overload..... 4 k $\Omega$  min

Input bias current .....  $\pm 200$  pA

Input offset current.....  $\pm 100$  pA

### CMRR (DC to 60 Hz)

Gain 0.5, 1.0..... 85 dB  
 Gain 10, 100..... 90 dB

## Dynamic Characteristics

### Bandwidth

Signal	Bandwidth
Small ( $-3$ dB)	500 kHz
Large (1% THD)	225 kHz

Settling time for full-scale step ..... 5  $\mu$ s max to  $\pm 1.0$  LSB accuracy

### System noise (LSB<sub>rms</sub>, not including quantization)

Gain	Dither Off	Dither On
0.5 to 1	0.10	0.65
10	0.45	0.65
100	0.70	0.90

Crosstalk.....  $-60$  dB, DC to 100 kHz

## Stability

Recommended warm-up time ..... 30 min

### Offset temperature coefficient

Pregain .....  $\pm 15$   $\mu$ V/ $^{\circ}$ C  
 Postgain.....  $\pm 240$   $\mu$ V/ $^{\circ}$ C

Gain temperature coefficient .....±20 ppm/°C

## Analog Output

### Output Characteristics

Number of channels .....2 voltage

Resolution .....12 bits, 1 in 4,096

Max update rate  
 Interrupts .....1 kHz, system dependent

Type of DAC .....Double buffered, multiplying

FIFO buffer size .....None

Data transfers .....Interrupts, programmed I/O

### Accuracy Information

Nominal Range (V)		Absolute Accuracy					Temp Drift (%/°C)	Absolute Accuracy at Full Scale (mV)
		% of Reading			Offset (mV)			
Positive FS	Negative FS	24 Hours	90 Days	1 Year				
10	-10	0.0177	0.0197	0.0219	5.93	0.0005	8.127	
<b>Note:</b> Temp Drift applies only if ambient is greater than ±10 °C of previous external calibration.								

### Transfer Characteristics

Relative accuracy (INL)

After calibration .....±0.5 LSB typ, ±1.0 LSB max

Before calibration .....±4 LSB max

DNL

After calibration .....±0.5 LSB typ, ± 1.0 LSB max

Before calibration .....±3 LSB max

Monotonicity .....12 bits, guaranteed after calibration



## Offset error

After calibration .....	$\pm 1.0$ mV max
Before calibration .....	$\pm 200$ mV max

## Gain error (relative to internal reference)

After calibration .....	$\pm 0.01\%$ of output max
Before calibration .....	$\pm 0.75\%$ of output max

**Voltage Output**

Range .....	$\pm 10$ V
Output coupling.....	DC
Output impedance .....	$0.1 \Omega$ max
Current drive .....	$\pm 5$ mA max
Protection .....	Short-circuit to ground
Power-on state (steady state).....	$\pm 200$ mV
Initial power-up glitch	
Magnitude .....	$\pm 1.5$ V
Duration .....	1.0 s
Power reset glitch	
Magnitude .....	$\pm 1.5$ V
Duration .....	1.0 s

**Dynamic Characteristics**

Settling time for full-scale step .....	10 $\mu$ s to $\pm 0.5$ LSB accuracy
Slew rate.....	10 V/ $\mu$ s
Noise .....	200 $\mu$ Vrms, DC to 1 MHz
Midscale transition glitch	
Magnitude .....	$\pm 20$ mV
Duration .....	2.5 $\mu$ s

## Stability

Offset temperature coefficient .....±50 μV/°C

Gain temperature coefficient .....±25 ppm/°C

## Digital I/O

Number of channels .....8 input/output

Compatibility .....TTL/CMOS

### DIO<0..7>

Digital logic levels

Level	Min	Max
Input low voltage	0 V	0.8 V
Input high voltage	2 V	5 V
Input low current ( $V_{in} = 0$ V)	—	-320 μA
Input high current ( $V_{in} = 5$ V)	—	10 μA
Output low voltage ( $I_{OL} = 24$ mA)	—	0.4 V
Output high voltage ( $I_{OH} = 13$ mA)	4.35 V	—

Power-on state.....Input (High-Z),  
50 kΩ pull up to +5 VDC

Data transfers .....Programmed I/O

## Timing I/O

Number of channels .....2 up/down counter/timers,  
1 frequency scaler

Resolution

Counter/timers .....24 bits

Frequency scalars .....4 bits

Compatibility .....TTL/CMOS

Base clocks available	
Counter/timers .....	20 MHz, 100 kHz
Frequency scalers.....	10 MHz, 100 kHz
Base clock accuracy .....	$\pm 0.01\%$
Max source frequency .....	20 MHz
Min source pulse duration.....	10 ns in edge-detect mode
Min gate pulse duration.....	10 ns in edge-detect mode
Data transfers .....	Interrupts, programmed I/O

## Triggers

### Digital Trigger

Compatibility .....	TTL
Response .....	Rising or falling edge
Pulse width.....	10 ns min

## Calibration

Recommended warm-up time .....	30 min
Interval .....	1 year
External calibration reference .....	$> 6$ and $< 10$ V
Onboard calibration reference	
Level .....	5.000 V ( $\pm 3.5$ mV) (actual value stored in EEPROM)
Temperature coefficient.....	$\pm 5$ ppm/ $^{\circ}$ C max
Long-term stability .....	$\pm 15$ ppm/ $\sqrt{1,000}$ h

## Power Requirement

+5 VDC ( $\pm 5\%$ )..... 270 mA



**Note** Excludes power consumed through  $V_{CC}$  available at the I/O connector.

Power available at I/O connector ..... +4.65 to +5.25 VDC at 0.75 A

## Physical

PC card type.....Type II  
I/O connector .....68-position VHDCI female connector

## Environment

Operating temperature .....0 to 40 °C with a maximum internal device temperature of 70 °C as measured by onboard temperature sensor.  
Storage temperature .....-20 to 70 °C  
Relative humidity .....10 to 95% non-condensing

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# Custom Cabling and Optional Connectors

This appendix describes the various cabling and connector options for the DAQCard-6024E, PCI-6023E, PCI-6024E, PCI-6025E, and PXI-6025E devices.

## Custom Cabling

---

National Instruments offers cables and accessories for you to prototype your application or to use if you frequently change device interconnections.

If you want to develop your own cable, however, use the following guidelines:

- For the analog input signals, shielded twisted-pair wires for each analog input pair yield the best results, assuming that you use differential inputs. Tie the shield for each signal pair to the ground reference at the source.
- Route the analog lines separately from the digital lines.
- When using a cable shield, use separate shields for the analog and digital parts of the cable. Failure to do so results in noise coupling into the analog signals from transient digital signals.

The following list gives recommended connectors that mate to the I/O connector on your device.

- ◆ PCI-6023E and PCI-6024E

Honda 68-position, solder cup, female connector

Honda backshell

- ◆ DAQCard-6024E

Honda 68-Position, VHDCI

◆ 6025E

AMP 100-position IDC male connector

AMP backshell, 0.50 max O.D. cable

AMP backshell, 0.55 max O.D. cable

Mating connectors and a backshell kit for making custom 68-pin cables are available from National Instruments.

## Optional Connectors

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The following table shows the optional connector and cable assembly combinations you can use for each device.

Device	Connector	Cable Assembly
PCI-6023E/6024E	68-Pin E Series	SH6868, R6868
	50-Pin E Series	SH6850, R6850
DAQCard-6024E	68-Pin E Series	SHC68-68-EP, RC68-68
	50-Pin E Series	68M-50F adapter plus SHC68-68-EP or RC68-68 cable
6025E	MIO-16 68-Pin, 68-Pin Extended Digital Input	SH1006868
	50-Pin E Series, 50-Pin Extended Digital Input	RI005050

Figure B-1 shows the pin assignments for the 68-Pin E Series connector.

ACH8	34	68	ACH0
ACH1	33	67	AIGND
AIGND	32	66	ACH9
ACH10	31	65	ACH2
ACH3	30	64	AIGND
AIGND	29	63	ACH11
ACH4	28	62	AISENSE
AIGND	27	61	ACH12
ACH13	26	60	ACH5
ACH6	25	59	AIGND
AIGND	24	58	ACH14
ACH15	23	57	ACH7
DAC0OUT <sup>1</sup>	22	56	AIGND
DAC1OUT <sup>1</sup>	21	55	AOGND
RESERVED	20	54	AOGND
DIO4	19	53	DGND
DGND	18	52	DIO0
DIO1	17	51	DIO5
DIO6	16	50	DGND
DGND	15	49	DIO2
+5 V	14	48	DIO7
DGND	13	47	DIO3
DGND	12	46	SCANCLK
PFI0/TRIG1	11	45	EXTSTROBE*
PFI1/TRIG2	10	44	DGND
DGND	9	43	PFI2/CONVERT*
+5 V	8	42	PFI3/GPCTR1_SOURCE
DGND	7	41	PFI4/GPCTR1_GATE
PFI5/UPDATE*	6	40	GPCTR1_OUT
PFI6/WFTRIG	5	39	DGND
DGND	4	38	PFI7/STARTSCAN
PFI9/GPCTR0_GATE	3	37	PFI8/GPCTR0_SOURCE
GPCTR0_OUT	2	36	DGND
FREQ_OUT	1	35	DGND

<sup>1</sup> Not available on the 6023E

**Figure B-1.** 68-Pin E Series Connector Pin Assignments

Figure B-2 shows the pin assignments for the 68-pin extended digital input connector.

GND	34	68	PC7
PC6	33	67	GND
PC5	32	66	GND
GND	31	65	PC4
PC3	30	64	GND
PC2	29	63	GND
GND	28	62	PC1
PC0	27	61	GND
PB7	26	60	GND
GND	25	59	PB6
PB5	24	58	GND
PB4	23	57	GND
GND	22	56	PB3
GND	21	55	PB2
PB1	20	54	GND
PB0	19	53	GND
GND	18	52	PA7
PA6	17	51	GND
PA5	16	50	GND
GND	15	49	PA4
PA3	14	48	GND
PA2	13	47	GND
GND	12	46	PA1
PA0	11	45	GND
+5 V	10	44	GND
N/C	9	43	N/C
N/C	8	42	N/C
N/C	7	41	N/C
N/C	6	40	N/C
N/C	5	39	N/C
N/C	4	38	N/C
N/C	3	37	N/C
N/C	2	36	N/C
N/C	1	35	N/C

**Figure B-2.** 68-Pin Extended Digital Input Connector Pin Assignments



Figure B-3 shows the pin assignments for the 50-pin E Series connector.

AIGND	1	2	AIGND
ACH0	3	4	ACH8
ACH1	5	6	ACH9
ACH2	7	8	ACH10
ACH3	9	10	ACH11
ACH4	11	12	ACH12
ACH5	13	14	ACH13
ACH6	15	16	ACH14
ACH7	17	18	ACH15
AISENSE	19	20	DAC0OUT <sup>1</sup>
DAC1OUT <sup>1</sup>	21	22	RESERVED
AOGND	23	24	DGND
DIO0	25	26	DIO4
DIO1	27	28	DIO5
DIO2	29	30	DIO6
DIO3	31	32	DIO7
DGND	33	34	+5 V
+5 V	35	36	SCANCLK
EXTSTROBE*	37	38	PFI0/TRIG1
PFI1/TRIG2	39	40	PFI2/CONVERT*
PFI3/GPCTR1_SOURCE	41	42	PFI4/GPCTR1_GATE
GPCTR1_OUT	43	44	PFI5/UPDATE*
PFI6/WFTRIG	45	46	PFI7/STARTSCAN
PFI8/GPCTR0_SOURCE	47	48	PFI9/GPCTR0_GATE
GPCTR0_OUT	49	50	FREQ_OUT

<sup>1</sup> Not available on the 6023E

**Figure B-3.** 50-Pin E Series Connector Pin Assignments

Figure B-4 shows the pin assignments for the 50-pin extended digital input connector.

PC7	1	2	GND
PC6	3	4	GND
PC5	5	6	GND
PC4	7	8	GND
PC3	9	10	GND
PC2	11	12	GND
PC1	13	14	GND
PC0	15	16	GND
PB7	17	18	GND
PB6	19	20	GND
PB5	21	22	GND
PB4	23	24	GND
PB3	25	26	GND
PB2	27	28	GND
PB1	29	30	GND
PB0	31	32	GND
PA7	33	34	GND
PA6	35	36	GND
PA5	37	38	GND
PA4	39	40	GND
PA3	41	42	GND
PA2	43	44	GND
PA1	45	46	GND
PA0	47	48	GND
+5 V	49	50	GND

**Figure B-4.** 50-Pin Extended Digital Input Connector Pin Assignments



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# Common Questions

This appendix contains a list of commonly asked questions and their answers relating to usage and special features of your device.

## General Information

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### What is the DAQ-STC?

The DAQ-STC is the system timing control application-specific integrated circuit (ASIC) designed by National Instruments and is the backbone of the E Series devices. The DAQ-STC contains seven 24-bit counters and three 16-bit counters. The counters are divided into the following three groups:

- Analog input—two 24-bit, two 16-bit counters
- Analog output—three 24-bit, one 16-bit counters
- General-purpose counter/timer functions—two 24-bit counters

You can configure the groups independently with timing resolutions of 50 ns or 10  $\mu$ s. With the DAQ-STC, you can interconnect a wide variety of internal timing signals to other internal blocks. The interconnection scheme is quite flexible and completely software configurable. New capabilities such as buffered pulse generation, equivalent time sampling, and seamless changing of the sampling rate are possible.

### What does sampling rate mean to me?

It means that this is the fastest you can acquire data on your device and still achieve accurate results. For example, these devices have a sampling rate of 200 kS/s. This sampling rate is aggregate—one channel at 200 kS/s or two channels at 100 kS/s per channel illustrates the relationship.

### What type of 5 V protection do the devices have?

The PCI and PXI devices have 5 V lines equipped with a self-resetting 1 A fuse. The PCMCIA cards have 5 V lines equipped with a self-resetting 0.75 A fuse.

## Installation and Configuration

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### **How do I set the base address for my device?**

The base address of your device is assigned automatically through the PCI/PXI bus protocol. This assignment is completely transparent to you.

### **What jumpers should I be aware of when configuring my E Series device?**

The E Series devices are jumperless and switchless.

### **Which National Instruments document should I read first to get started using DAQ software?**

Your NI-DAQ or application software release notes documentation is always the best starting place.

### **What version of NI-DAQ must I have to use my 6023E/6024E/6025E?**

You must have *NI-DAQ for PC Compatibles* version 6.5 or higher to use a PCI a PXI device. To use the DAQCard-6024E you must have NI-DAQ for PC compatibles version 6.9 or higher.

## Analog Input and Output

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### **I'm using my device in differential analog input mode and I have connected a differential input signal, but my readings are random and drift rapidly. What's wrong?**

Check your ground-reference connections. Your signal can be referenced to a level that is considered *floating* with reference to the device ground reference. Even if you are in differential mode, you must still reference the signal to the same ground level as the board reference. There are various methods of achieving this while maintaining a high common-mode rejection ratio (CMRR). These methods are outlined in Chapter 4, [Signal Connections](#).

### **I'm using the DACs to generate a waveform, but I discovered with a digital oscilloscope that there are glitches on the output signal. Is this normal?**

When it switches from one voltage to another, any DAC produces glitches due to released charges. The largest glitches occur when the most significant bit (MSB) of the D/A code switches. You can build a lowpass

deglitching filter to remove some of these glitches, depending on the frequency and nature of your output signal.

### **Can I synchronize a one-channel analog input data acquisition with a one-channel analog output waveform generation on my PCI E Series device?**

Yes. One way to accomplish this is to use the waveform generation timing pulses to control the analog input data acquisition. To do this, follow steps 1 through 4 below, in addition to the usual steps for data acquisition and waveform generation configuration.

1. Enable the PFI5 line for output, as follows:
  - If you are using NI-DAQ, call `Select_Signal(deviceNumber, ND_PFI_5, ND_OUT_UPDATE, ND_HIGH_TO_LOW)`.
  - If you are using LabVIEW, invoke the Route Signal VI with the signal name set to PFI5 and the signal source set to AO Update.
2. Set up data acquisition timing so that the timing signal for A/D conversion comes from PFI5, as follows:
  - If you are using NI-DAQ, call `Select_Signal(deviceNumber, ND_IN_CONVERT, ND_PFI_5, ND_HIGH_TO_LOW)`.
  - If you are using LabVIEW, invoke AI Clock Config VI with clock source code set to PFI pin, high to low, and clock source string set to 5.
3. Initiate analog input data acquisition, which starts only when the analog output waveform generation starts.
4. Initiate analog output waveform generation.

## **Timing and Digital I/O**

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### **What types of triggering can be hardware-implemented on my device?**

Digital triggering is hardware-supported on every device.

### **Will the counter/timer applications that I wrote previously work with the DAQ-STC?**

If you are using NI-DAQ with LabVIEW, some of your applications drawn using the CTR VIs will still run. However, there are many differences in the counters between the E Series and other devices; the counter numbers are different, timebase selections are different, and the DAQ-STC counters are

24-bit counters (unlike the 16-bit counters on devices without the DAQ-STC).

If you are using the NI-DAQ language interface or LabWindows/CVI, the answer is no, the counter/timer applications that you wrote previously will not work with the DAQ-STC. You must use the GPCTR functions; ICTR and CTR functions will not work with the DAQ-STC. The GPCTR functions have the same capabilities as the ICTR and CTR functions, plus more, but you must rewrite the application with the GPCTR function calls.

**I am using one of the general-purpose counter/timers on my device, but I do not see the counter/timer output on the I/O connector. What am I doing wrong?**

If you are using the NI-DAQ language interface or LabWindows/CVI, you must configure the output line to output the signal to the I/O connector. Use the `Select_Signal` call in NI-DAQ to configure the output line. By default, all timing I/O lines except EXTSTROBE\* are high impedance.

**What are the PFIs and how do I configure these lines?**

PFIs are programmable function inputs. These lines serve as connections to virtually all internal timing signals. If you are using the NI-DAQ language interface or LabWindows/CVI, use the `Select_Signal` function to route internal signals to the I/O connector, route external signals to internal timing sources, or tie internal timing signals together.

If you are using NI-DAQ with LabVIEW and you want to connect external signal sources to the PFI lines, you can use AI Clock Config, AI Trigger Config, AO Clock Config, AO Trigger and Gate Config, CTR Mode Config, and CTR Pulse Config advanced level VIs to indicate which function the connected signal serves. Use the Route Signal VI to enable the PFI lines to output internal signals.



**Caution** If you enable a PFI line for output, do not connect any external signal source to it; if you do, you can damage the device, the computer, and the connected equipment.

**What are the power-on states of the PFI and DIO lines on the I/O connector?**

At system power-on and reset, both the PFI and DIO lines are set to high impedance by the hardware. This means that the device circuitry is not actively driving the output either high or low. However, these lines can have pull-up or pull-down resistors connected to them as shown in Table 4-3, *I/O Signal Summary*. These resistors weakly pull the output to either a logic high or logic low state. For example, DIO(0) is in the high impedance state

after power on, and Table 4-3, *I/O Signal Summary*, shows that there is a 50 k $\Omega$  pull-up resistor. This pull-up resistor sets the DIO(0) pin to a logic high when the output is in a high impedance state.

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# Technical Support Resources

## Web Support

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National Instruments Web support is your first stop for help in solving installation, configuration, and application problems and questions. Online problem-solving and diagnostic resources include frequently asked questions, knowledge bases, product-specific troubleshooting wizards, manuals, drivers, software updates, and more. Web support is available through the Technical Support section of [ni.com](http://ni.com)

## NI Developer Zone

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The NI Developer Zone at [ni.com/zone](http://ni.com/zone) is the essential resource for building measurement and automation systems. At the NI Developer Zone, you can easily access the latest example programs, system configurators, tutorials, technical news, as well as a community of developers ready to share their own techniques.

## Customer Education

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National Instruments provides a number of alternatives to satisfy your training needs, from self-paced tutorials, videos, and interactive CDs to instructor-led hands-on courses at locations around the world. Visit the Customer Education section of [ni.com](http://ni.com) for online course schedules, syllabi, training centers, and class registration.

## System Integration

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If you have time constraints, limited in-house technical resources, or other dilemmas, you may prefer to employ consulting or system integration services. You can rely on the expertise available through our worldwide network of Alliance Program members. To find out more about our Alliance system integration solutions, visit the System Integration section of [ni.com](http://ni.com)



## Worldwide Support

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National Instruments has offices located around the world to help address your support needs. You can access our branch office Web sites from the Worldwide Offices section of [ni.com](http://ni.com). Branch office web sites provide up-to-date contact information, support phone numbers, e-mail addresses, and current events.

If you have searched the technical support resources on our Web site and still cannot find the answers you need, contact your local office or National Instruments corporate. Phone numbers for our worldwide offices are listed at the front of this manual.

# Glossary

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Prefix	Meanings	Value
p-	pico-	$10^{-12}$
n-	nano-	$10^{-9}$
$\mu$ -	micro-	$10^{-6}$
m-	milli-	$10^{-3}$
k-	kilo-	$10^3$
M-	mega-	$10^6$
G-	giga-	$10^9$
t-	tera-	$10^{12}$

## Numbers/Symbols

°	degree
>	greater than
<	less than
-	negative of, or minus
$\Omega$	ohm
/	per
%	percent
$\pm$	plus or minus
+	positive of, or plus
$\sqrt{\quad}$	square root of
+5 V	+5 VDC source signal

## A

A	amperes
AC	alternating current
ACH	analog input channel signal
A/D	analog-to-digital
ADC	analog-to-digital converter—an electronic device, often an integrated circuit, that converts an analog voltage to a digital number
ADC resolution	the resolution of the ADC, which is measured in bits. An ADC with 16 bits has a higher resolution, and thus a higher degree of accuracy, than a 12-bit ADC.
AI	analog input
AIGATE	analog input gate signal
AIGND	analog input ground signal
AISENSE	analog input sense signal
ANSI	American National Standards Institute
AO	analog output
AOGND	analog output ground signal
ASIC	Application-Specific Integrated Circuit—a proprietary semiconductor component designed and manufactured to perform a set of specific functions for a specific customer

## B

base address	a memory address that serves as the starting address for programmable registers. All other addresses are located by adding to the base address.
bipolar	a voltage range spanning both negative and positive voltages
breakdown voltage	the voltage high enough to cause breakdown of optical isolation, semiconductors, or dielectric materials. <i>Also see</i> <a href="#">working voltage</a> .

**bus** the group of conductors that interconnect individual circuitry in a computer. Typically, a bus is the expansion interface to which I/O or other devices are connected. Examples of PC buses are the ISA bus and PCI bus.

**bus master** a type of a plug-in board or controller with the ability to read and write devices on the computer bus

## C

**C** Celsius

**CH** channel

**channel** pin or wire lead to which you apply, or from which you read, an analog or digital signal. Analog signals can be single-ended or differential. For digital signals, channels are grouped to form ports.

**CMRR** common-mode rejection ratio—a measure of the ability of a differential amplifier to reject interference from a common-mode signal, usually expressed in decibels (dB)

**CONVERT\*** convert signal

**counter/timer** a circuit that counts external pulses or clock pulses (timing)

**crosstalk** an unwanted signal on one channel due to an input on a different channel

**CTR** counter

**current drive capability** the amount of current a digital or analog output channel is capable of sourcing or sinking while still operating within voltage range specifications

## D

**D/A** digital-to-analog

**DAC** D/A converter—an electronic device, often an integrated circuit, that converts a digital number into a corresponding analog voltage or current

**DAC0OUT** analog channel 0 output signal

**DAC1OUT** analog channel 1 output signal

DAQ	data acquisition—(1) collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures and processing the measurement data using a computer; (2) collecting and measuring the same kinds of electrical signals with A/D and/or DIO boards plugged into a computer, and possibly generating control signals with D/A and/or DIO boards in the same computer
dB	decibel—the unit for expressing a logarithmic measure of the ratio of two signal levels: $dB=20\log_{10} V_1/V_2$ , for signals in volts
DC	direct current
DGND	digital ground signal
DIFF	differential input configuration
differential amplifier	an amplifier with two input terminals, neither of which are tied to a ground reference, whose voltage difference is amplified
differential input	the two-terminal input to a differential amplifier
DIO	digital input/output
dithering	the addition of Gaussian noise to an analog input signal
DMA	direct memory access—a method by which data can be transferred to/from computer memory from/to a device or memory on the bus while the processor does something else. DMA is the fastest method of transferring data to/from computer memory.
DNL	differential nonlinearity—a measure in LSB of the worst-case deviation of code widths from their ideal value of 1 LSB
DO	digital output
drivers/driver software	software that controls a specific hardware device such as a DAQ device

## E

EEPROM	electrically erasable programmable read-only memory—ROM that can be erased with an electrical signal and reprogrammed. Some SCXI modules contain an EEPROM to store measurement-correction coefficients.
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electrostatically coupled propagating a signal by means of a varying electric field

EXTSTROBE external strobe signal

## F

FIFO first-in first-out memory buffer

floating signal sources signal sources with voltage signals that are not connected to an absolute reference or system ground. Also called nonreferenced signal sources. Some common example of floating signal sources are batteries, transformers, or thermocouples.

FREQ\_OUT frequency output signal

ft feet

## G

g grams

gain the factor by which a signal is amplified, sometimes expressed in decibels

GATE gate signal

glitch an unwanted momentary deviation from a desired signal

GPCTR general purpose counter

GPCTR0\_GATE general purpose counter 0 gate signal

GPCTR0\_OUT general purpose counter 0 output signal

GPCTR0\_SOURCE general purpose counter 0 clock source signal

GPCTR0\_UP\_DOWN general purpose counter 0 up down

GPCTR1\_GATE general purpose counter 1 gate signal

GPCTR1\_OUT general purpose counter 1 output signal

GPCTR1\_SOURCE general purpose counter 1 clock source signal

GPCTR1_UP_DOWN	general purpose counter 1 up down
GPIB	General Purpose Interface bus, synonymous with HP-IB. The standard bus used for controlling electronic instruments with a computer. Also called IEEE 488 bus because it is defined by ANSI/IEEE Standards 488-1978, 488.1-1987, and 488.2-1987.
grounded measurement system	See <a href="#">RSE</a> .
<b>H</b>	
h	hour
hex	hexadecimal
Hz	hertz—cycles per second of a periodic signal
<b>I</b>	
INL	integral nonlinearity—a measure in LSB of the worst-case deviation from the ideal A/D or D/A transfer characteristic of the analog I/O circuitry
input bias current	the current that flows into the inputs of a circuit
input impedance	the measured resistance and capacitance between the input terminals of a circuit
input offset current	the difference in the input bias currents of the two inputs of an instrumentation amplifier
instrumentation amplifier	a very accurate differential amplifier with a high input impedance
interrupt	a computer signal indicating that the CPU should suspend its current task to service a designated activity
I/O	input/output—the transfer of data to/from a computer system involving communications channels, operator interface devices, and/or data acquisition and control interfaces
$I_{OH}$	current, output high

$I_{OL}$  current, output low

IRQ interrupt request

## K

k kilo—the standard metric prefix for 1,000, or  $10^3$ , used with units of measure such as volts, hertz, and meters

K kilo—the prefix for 1,024, or  $2^{10}$ , used with B in quantifying data or computer memory

kS 1,000 samples

## L

LabVIEW laboratory virtual instrument engineering workbench

LED light-emitting diode

library a file containing compiled object modules, each comprised of one or more functions, that can be linked to other object modules that make use of these functions. NIDAQMSC.LIB is a library that contains NI-DAQ functions. The NI-DAQ function set is broken down into object modules so that only the object modules that are relevant to your application are linked in, while those object modules that are not relevant are not linked.

linearity the adherence of device response to the equation  $R = KS$ , where  $R$  = response,  $S$  = stimulus, and  $K$  = a constant

LSB least significant bit

## M

MIO multifunction I/O

MSB most significant bit



## N

NI-DAQ	National Instruments driver software for DAQ hardware
noise	an undesirable electrical signal—Noise comes from external sources such as the AC power line, motors, generators, transformers, fluorescent lights, soldering irons, CRT displays, computers, electrical storms, welders, radio transmitters, and internal sources such as semiconductors, resistors, and capacitors. Noise corrupts signals you are trying to send or receive.
NRSE	nonreferenced single-ended mode—all measurements are made with respect to a common measurement system reference, but the voltage at this reference can vary with respect to the measurement system ground

## O

OUT	output pin—a counter output pin where the counter can generate various TTL pulse waveforms
-----	--

## P

PCI	Peripheral Component Interconnect—a high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA. It is achieving widespread acceptance as a standard for PCs and work-stations; it offers a theoretical maximum transfer rate of 132 Mbytes/s.
PFI	programmable function input
PFI0/TRIG1	PFI0/trigger 1
PFI1/TRIG2	PFI1/trigger 2
PFI2/CONVERT*	PFI2/convert
PFI3/GPCTR1_SOURCE	PFI3/general purpose counter 1 source
PFI4/GPCTR1_GATE	PFI4/general purpose counter 1 gate
PFI5/UPDATE*	PFI5/update
PFI6/WFTRIG	PFI6/waveform trigger

PFI7/STARTSCAN	PFI7/start of scan
PFI8/GPCTR0_ SOURCE	PFI8/general purpose counter 0 source
PFI9/GPCTR0_GATE	PFI9/general purpose counter 0 gate
PGIA	programmable gain instrumentation amplifier
port	(1) a digital port consisting of multiple I/O lines on a DAQ device (2) a serial or parallel interface connector on a PC
PPI	programmable peripheral interface
ppm	parts per million
pu	pullup
pulse trains	multiple pulses

## Q

quantization error	the inherent uncertainty in digitizing an analog value due to the finite resolution of the conversion process
--------------------	---

## R

referenced signal sources	signal sources with voltage signals that are referenced to a system ground, such as the earth or a building ground. Also called grounded signal sources.
resolution	the smallest signal increment that can be detected by a measurement system. Resolution can be expressed in bits, in proportions, or in percent of full scale. For example, a system has 12-bit resolution, one part in 4,096 resolution, and 0.0244% of full scale.
ribbon cable	a flat cable in which the conductors are side by side
rise time	the difference in time between the 10% and 90% points of a system's step response
rms	root mean square—the square root of the average value of the square of the instantaneous signal amplitude; a measure of signal amplitude

RSE	referenced single-ended mode—all measurements are made with respect to a common reference measurement system or a ground. Also called a grounded measurement system.
RTSI bus	real-time system integration bus—the National Instruments timing bus that connects DAQ devices directly, by means of connectors on top of the devices, for precise synchronization of functions
<b>S</b>	
s	seconds
S	samples
sample counter	the clock that counts the output of the channel clock, in other words, the number of samples taken. On boards with simultaneous sampling, this counter counts the output of the scan clock and hence the number of scans.
scan	one or more analog samples taken at the same time, or nearly the same time. Typically, the number of input samples in a scan is equal to the number of channels in the input group. For example, one scan, acquires one new sample from every analog input channel in the group.
scan clock	the clock controlling the time interval between scans.
scan rate	the number of scans a system takes during a given time period, usually expressed in scans per second
SCXI	Signal Conditioning eXtensions for Instrumentation
SE	single-ended—a term used to describe an analog input that is measured with respect to a common ground
self-calibrating	a property of a DAQ board that has an extremely stable onboard reference and calibrates its own A/D and D/A circuits without manual adjustments by the user
sensor	a device that converts a physical phenomenon into an electrical signal
settling time	the amount of time required for a voltage to reach its final value within specified accuracy limits
signal conditioning	the manipulation of signals to prepare them for digitizing

SISOURCE	SI counter clock signal
software trigger	a programmed event that triggers an event such as data acquisition
software triggering	a method of triggering in which you simulate an analog trigger using software. Also called conditional retrieval.
SOURCE	source signal
S/s	samples per second—used to express the rate at which a DAQ board samples an analog signal
STARTSCAN	start scan signal
STC	system timing controller
synchronous	(1) hardware—a property of an event that is synchronized to a reference clock (2) software—a property of a function that begins an operation and returns only when the operation is complete

## T

TC	terminal count—the highest value of a counter
THD	total harmonic distortion
THD+N	signal-to-THD plus noise—the ratio in decibels of the overall rms signal to the rms signal of harmonic distortion plus noise introduced
TRIG	trigger signal
trigger	any event that causes or starts some form of data capture
TTL	transistor-transistor logic

## U

UI	update interval
unipolar	a signal range that is always positive (for example, 0 to +10 V)
UISOURCE	update interval counter clock signal

update	the output equivalent of a scan. One or more analog or digital output samples. Typically, the number of output samples in an update is equal to the number of channels in the output group. For example, one pulse from the update clock produces one update which sends one new sample to every analog output channel in the group.
update rate	the number of output updates per second

## V

V	volts
V <sub>cc</sub>	positive supply voltage
VDC	volts direct current
VI	virtual instrument—(1) a combination of hardware and/or software elements, typically used with a PC, that has the functionality of a classic stand-alone instrument (2) a LabVIEW software module (VI), which consists of a front panel user interface and a block diagram program
V <sub>IH</sub>	volts, input high
V <sub>IL</sub>	volts, input low
V <sub>in</sub>	volts in
V <sub>m</sub>	measured voltage
V <sub>OH</sub>	volts, output high
V <sub>OL</sub>	volts, output low
V <sub>ref</sub>	reference voltage
V <sub>rms</sub>	volts, root mean square

**W**

waveform	multiple voltage readings taken at a specific sampling rate
WFTRIG	waveform generation trigger signal
working voltage	the highest voltage that should be applied to a product in normal use, normally well under the breakdown voltage for safety margin. <i>See also</i> <a href="#">breakdown voltage</a> .

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