Computer-Based Instruments

NI 5102 User Manual

Digitizing Oscilloscope

NATIONAL INSTRUMENTS™

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Internet Support
E-mail: support@natinst.com
FTP Site: ftp.natinst.com
Web Address: http://www.natinst.com

Bulletin Board Support
BBS United States: 512 794 5422
BBS United Kingdom: 01635 551422
BBS France: 01 48 65 15 59

Fax-on-Demand Support
512 418 1111

Telephone Support (USA)
Tel: 512 795 8248
Fax: 512 794 5678

International Offices
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National Instruments Corporate Headquarters
6504 Bridge Point Parkway   Austin, Texas 78730-5039   USA   Tel: 512 794 0100

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Contents

About This Manual

Chapter 1
Introduction

Chapter 2
Installation and Configuration

Chapter 3
Digitizer Basics

Chapter 4
Hardware Overview

Appendix A
Specifications

Appendix B
Customer Communication

Glossary

Index

Figures

Tables

About This Manual

This manual describes the mechanical and electrical aspects of the NI 5102 instruments and contains information concerning their installation and operation. The NI 5102 is available in PCI, PXI, ISA, PCMCIA, and USB form factors. These instruments are analog input devices that combine the benefits of digitizers and oscilloscopes.

Organization of This Manual

The *NI 5102 User Manual* is organized as follows:

- Chapter 1, *Introduction*, describes the NI 5102, lists additional equipment, and explains how to unpack your NI 5102.
- Chapter 2, *Installation and Configuration*, describes how to install and configure your NI 5102.
- Chapter 3, *Digitizer Basics*, explains the basic information you need to understand about making measurements with digitizers, including important terminology and how to use your probe.
- Chapter 4, *Hardware Overview*, includes an overview of the NI 5102, explains the operation of each functional unit making up your NI 5102, and describes the signal connections.
- Appendix A, *Specifications*, lists the specifications of the NI 5102.
- Appendix B, *Customer Communication*, contains forms you can use to request help from National Instruments or to comment on our products and manuals.
- The *Glossary* contains an alphabetical list and description of terms used in this manual, including abbreviations, acronyms, metric prefixes, mnemonics, and symbols.
- The *Index* contains an alphabetical list of key terms and topics in this manual, including the page where you can find each one.

Conventions Used in This Manual

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, port, or signal name (for example, ACH<0..7> stands for ACH0 through ACH7).
♦	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 to the left of bold italicized text denotes a note, which alerts you to important information.
	This icon to the left of bold italicized text denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash.
bold	Bold text denotes parameters.
bold italic	Bold italic text denotes a note, caution, or warning.
digitizer	Digitizer refers to a NI 5102 instrument.
italic	Italic text denotes emphasis, a cross reference, or an introduction to a key concept. This font also denotes text from which you supply the appropriate word or value, as in Windows 3.*x*.
NI 5102	NI 5102 is a generic term that denotes one or more of the NI 5102 (PCI), NI 5102 (PXI), NI 5102 (ISA), NI 5102 (PCMCIA), and NI 5102 (USB) instruments.
NI 5102 (ISA)	Refers to the NI 5102 instrument for ISA bus.
NI 5102 (PCI)	Refers to the NI 5102 instrument for PCI bus.
NI 5102 (PCMCIA)	Refers to the NI 5102 instrument for computers with a Type II PCMCIA slot.
NI 5102 (PXI)	Refers to the NI 5102 instrument for PXI bus.
NI 5102 (USB)	Refers to NI 5102 instrument for computers that are USB compatible.
NI-DAQ	NI-DAQ refers to the NI-DAQ software for PC compatibles unless otherwise noted.

Plug and Play — Plug and Play refers to a device that is fully compatible with the industry standard Plug and Play specification. Plug and Play systems automatically arbitrate and assign system resources, freeing the user from manually configuring jumpers or switches to configure settings such as the product base address and interrupt level.

National Instruments Documentation

The *NI 5102 User Manual* is one piece of the documentation set for your measurement system. You could have any of several types of manuals, depending on the hardware and software in your system. Use the manuals you have as follows:

- Your data acquisition (DAQ) hardware user manuals—These manuals have detailed information about the DAQ hardware that plugs into or is connected to your computer. Use these manuals for hardware installation and configuration instructions, specification information about your DAQ hardware, and application hints.
- Software documentation—You may have both application software and NI-DAQ software documentation. National Instruments application software includes LabVIEW, LabWindows/CVI, ComponentWorks, Measure, and VirtualBench. After you set up your hardware system, use the application software documentation to help you write your application. If you have a large and complicated system, it is worthwhile to look through the software documentation before you configure your system.
- Accessory manuals—If you are using accessory products, read the terminal block and cable assembly installation guides. They explain how to physically connect the relevant pieces of the system. Consult these guides when you are making your connections.

Related Documentation

The following documents contain information that you may find helpful:

- National Instruments *PXI Specification*, revision 1.0
- PICMG CompactPCI 2.0 R2.1
- Your computer user manual or technical reference manual

Customer Communication

National Instruments wants to receive your comments on our products and manuals. We are interested in the applications you develop with our products, and we want to help if you have problems with them. To make it easy for you to contact us, this manual contains comment and configuration forms for you to complete. These forms are in Appendix B, *Customer Communication*.

1 Introduction

This chapter describes the NI 5102, lists additional equipment, and explains how to unpack your NI 5102.

About Your NI 5102

Thank you for your purchase of a National Instruments NI 5102 instrument. The NI 5102 family consists of five different devices tailored to your choice of bus: the PCI, the PXI, the ISA, the PCMCIA, and the universal serial bus (USB). Your 5102 instrument has the following features:

- Two 8-bit resolution analog input channels
- Real-time sampling rate of 20 MS/s to 1 kS/s; 1 GS/s random interleaved sampling (RIS)
- 15 MHz analog input bandwidth
- Analog trigger channel with software-selectable level, slope, and hysteresis
- Two digital triggers
- Software-selectable AC/DC coupling
- 663,000-sample onboard memory
- Real-Time System Integration (RTSI) triggers (PCI, PXI, and ISA form factors only)

All 5102 instruments follow industry-standard Plug and Play specifications on all platforms and offer seamless integration with compliant systems. If your application requires more than two channels for data acquisition, you can synchronize multiple devices on all platforms using RTSI bus triggers, on devices that use the RTSI bus, or the PFI digital triggers on the I/O connector. The NI 5102 (PXI) uses the PXI trigger bus for multiboard synchronization. Unless otherwise noted, any discussion of the RTSI trigger bus is also applicable to the PXI trigger bus for the NI 5102 (PXI) in this manual.

To improve timing resolution for repetitive signals, you can use random interleaf sampling (RIS) on your NI 5102. This method of sampling allows you to view pretrigger data and achieve an effective sampling rate as high as 1 GS/s, 50 times the real-time sampling rate on the device.

Detailed specifications of the NI 5102 instruments are in Appendix A, *Specifications*.

Using PXI with CompactPCI

♦ NI 5102 (PXI) Only

Using PXI-compatible products with standard CompactPCI products is an important feature provided by the *PXI Specification*, revision 1.0. If you use a PXI-compatible plug-in device in a standard CompactPCI chassis, you will be unable to use PXI-specific functions, but you can still use the basic plug-in device functions. For example, the PXI trigger bus on your NI 5102 (PXI) instrument 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 NI 5102 (PXI) instrument will work in any standard CompactPCI chassis adhering to the *PICMG CompactPCI 2.0 R2.1* document.

PXI-specific features, RTSI bus trigger, RTSI Clock, and Serial Communication, are implemented on the J2 connector of the CompactPCI bus. Table 1-1 lists the J2 pins used by your NI 5102 (PXI) instrument, which is compatible with any CompactPCI chassis with a sub-bus that does not drive these lines. Even if the sub-bus is capable of driving these lines, the NI 5102 (PXI) is still compatible as long as those pins on the sub-bus are disabled by default and are never enabled. Damage can result if these lines are driven by the sub-bus.

Table 1-1. NI 5102 (PXI) J2 Pin Assignment

NI 5102 (PXI) Signal	PXI Pin Name	PXI J2 Pin Number
RTSI Trigger <0..5>	PXI Trigger <0..5>	B16, A16, A17, A18, B18, C18
RTSI Trigger 6	PXI Star	D17
RTSI Clock	PXI Trigger (7)	E16
Serial Communication	LBR (6, 7, 8, 9, 10, 11, 12)	EI5, A3, C3, D3, E3, A2, B2

What You Need to Get Started

To set up and use your NI 5102, you will need the following:

- ❑ One of the following NI 5102 instruments:
  - NI 5102 (PCI)
  - NI 5102 (PXI)
  - NI 5102 (ISA)
  - NI 5102 (PCMCIA)
  - NI 5102 (USB)
- ❑ *NI 5102 User Manual*
- ❑ *NI-DAQ for PC Compatibles*, version 5.0 or later
- ❑ NI 5102 Instrument Driver
- ❑ One of the following software packages and documentation:
  - VirtualBench-Scope
  - VirtualBench-DSA
  - LabVIEW
  - LabWindows/CVI
  - ComponentWorks
  - Measure

- ❑ Cables and accessories:

  NI 5102 (PCI, PXI, ISA, PCMCIA, USB)

  – Two SP200B 10X-1X selectable oscilloscope probes

  – SMB100 cable and screwdriver for probe compensation

  NI 5102 (PXI)

  – AUX to BNC cable

  NI 5102 (PCMCIA)

  – PSH32-C5 I/O cable assembly

  NI 5102 (USB)

  – NI 5102 (USB) power supply

- ❑ Vinyl pouch for storing cables and accessories for the NI 5102 (PCMCIA) only

- ❑ Your computer

Unpacking

♦ NI 5102 (PCI, PXI, ISA)

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 via 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 the connectors.

♦ NI 5102 (PCMCIA)

Your PC card is shipped in an antistatic vinyl case; when you are not using the card, you should store it in this case. Because the card is enclosed in a fully shielded case, no additional electrostatic precautions are necessary. However, for your own safety and to protect the card, never attempt to touch the pins of the connectors.

- ♦ NI 5102 (USB)

  Your NI 5102 (USB) is shipped in a fully shielded case, and no electrostatic precautions are necessary. However, for your own safety and to protect your NI 5102 (USB) device, *never* attempt to touch the connector pins.

Software Programming Choices

There are several options to choose from when programming your National Instruments NI 5102. If you are using the NI 5102 as a stand-alone general-purpose oscilloscope, you can use VirtualBench to make measurements interactively without writing a single line of code.

If you want to integrate the NI 5102 in your test and measurement application, you can program the device using LabVIEW, LabWindows/CVI, C/C++, ComponentWorks for Visual Basic, or Measure for MS Excel. Figure 1-1 illustrates this relationship. If you are using your instruments programatically you have two programming choices–the NI-Scope Instrument Driver or the NI-DAQ API.

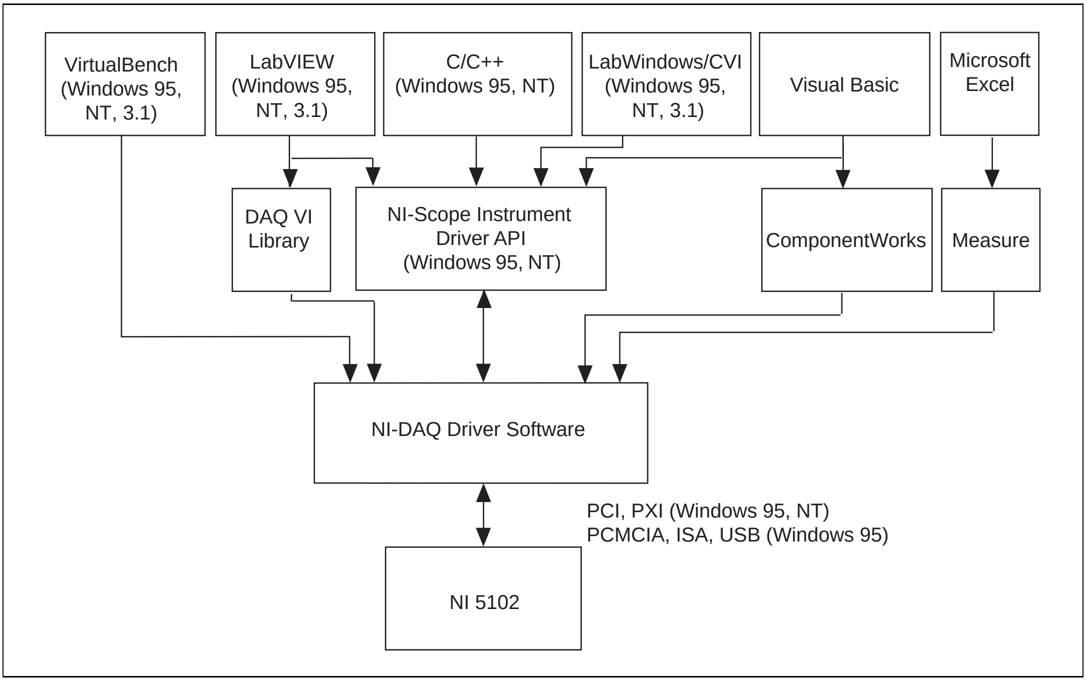

Figure 1-1. The Relationship Between the Programming Environment, NI-DAQ, and Your Hardware

NI 5102 Instrument Driver

The NI 5102 Instrument Driver provides flexibility and programmability in a standard instrument driver format. This is the preferred choice for programming your instrument.

The instrument driver API is designed after a classical, full-featured oscilloscope instrument driver. The instrument driver lets you avoid making low-level software calls. As shown in Figure 1-1, the NI 5102 Instrument Driver works with LabVIEW, LabWindows/CVI, or conventional programming languages, such as C and Visual Basic.

NI-DAQ API

The NI-DAQ API allows you to program your NI 5102 in LabVIEW using calls that are supported on other National Instruments DAQ devices. The DAQ VI Library offers a collection of VIs that you can use to program your NI 5102 to function as a digitizer.

NI-DAQ Driver Software

You need to have the NI-DAQ driver software installed regardless of the software you choose for programming your NI 5102.

The NI-DAQ driver software contains all of the device-specific code that is required to program the NI 5102. It also encapsulates the mechanism of communicating to the hardware over different buses such as USB, ISA, PCI, PXI, or PCMCIA.

National Instruments Application Software

VirtualBench is a suite of VIs that allows you to use your DAQ products just as you use stand-alone instruments, but you benefit from the processing, display, and storage capabilities of PCs. VirtualBench instruments load and save waveform data to disk in the same forms used in popular spreadsheet programs and word processors. A report generation capability complements the raw data storage by adding timestamps, measurements, user name, and comments.

The complete VirtualBench suite contains VirtualBench-AODC, VirtualBench-Arb, VirtualBench-Board Calibrator, VirtualBench-DIO, VirtualBench-DMM, VirtualBench-DSA, VirtualBench-Function Generator, VirtualBench-Logger, and VirtualBench-Scope. Your NI 5102 can be used with VirtualBench-Scope and VirtualBench-DSA.

VirtualBench-Scope and VirtualBench-DSA are turn-key applications you can use to make measurements as you would with a standard oscilloscope or a DSA instrument.

LabVIEW and LabWindows/CVI are innovative program development software packages for data acquisition and control applications. LabVIEW uses graphical programming, whereas LabWindows/CVI enhances traditional programming languages. Both packages include extensive libraries for data acquisition, instrument control, data analysis, and graphical data presentation.

LabVIEW features interactive graphics, a state-of-the-art user interface, and a powerful graphical programming language. You can program the NI 5102 in LabVIEW through an instrument driver application programming interface (API) for quick application development, or use the LabVIEW Data Acquisition VI Library, a series of VIs for using LabVIEW with National Instruments DAQ hardware, for increased flexibility and control.

LabWindows/CVI features interactive graphics, a state-of-the-art user interface, and uses the ANSI standard C programming language. The LabWindows/CVI Data Acquisition Library, a series of functions for using LabWindows/CVI with National Instruments DAQ hardware, is included with the NI-DAQ software kit.

Note ***NI 5102 instruments can use only the easy I/O interface under data acquisition in LabWindows/CVI. The easy I/O interface provides limited functionality in CVI. To use the NI 5102 to its full capabilities, you should use the instrument driver as shown in Figure 1-1.***

Using LabVIEW or LabWindows/CVI software will greatly reduce the development time for your data acquisition and control application.

ComponentWorks contains tools for data acquisition and instrument control built on NI-DAQ driver software. ComponentWorks provides a higher-level programming interface for building virtual instruments with Visual Basic, Visual C++, Borland Delphi, and Microsoft Internet Explorer. With ComponentWorks, you can use all of the configuration tools, resource management utilities, and interactive control utilities included with NI-DAQ.

Measure is a data acquisition and instrument control add-in for Microsoft Excel. With Measure, you can acquire data directly from plug-in DAQ boards, GPIB instruments, or serial (RS-232) devices. Measure has easy-to-use dialogs for configuring your measurements. Your data is placed directly into Excel worksheet cells, from which you can perform your analysis and report generation operations using the full power and flexibility of Excel.

Optional Equipment

National Instruments offers a variety of products to use with your NI 5102, including probes, cables, and other accessories, as follows:

- Probes with accessories for high-voltage applications
- Cables for master/slave timing and triggering
- Cables for external triggering
- RTSI bus cables for NI 5102 (PCI, ISA)
- AUX Interface Cables for NI 5102 (PXI) only

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

2

Installation and Configuration

This chapter describes how to install and configure your NI 5102.

Software Installation

You should install your software before you install your NI 5102. Refer to the appropriate release notes indicated below for specific instructions on the software installation sequence.

If you are using VirtualBench, LabVIEW, LabWindows/CVI, or ComponentWorks, refer to the release notes for your software. After you have installed your software, refer to the NI-DAQ release notes and follow the instructions given there for your operating system and your software.

To install NI-DAQ, refer to your NI-DAQ release notes. Find the installation section for your operating system and follow the instructions given there.

Hardware Installation

☞ **Note** ***You should install your driver software before installing your hardware. Refer to the*** *Where to Start with Your NI 5102* ***document for software installation information.***

If you have an older version of NI-DAQ already in your system, that software may not work with your device. Install NI-DAQ from the CD shipped with your NI 5102.

♦ NI 5102 (PCI, ISA)

You can install the NI 5102 (PCI) in any PCI slot and the NI 5102 (ISA) in any ISA slot in your computer. However, for best noise performance, leave as much room as possible between the NI 5102 and other hardware. Before installing your 5102 instrument, consult your PC user manual or technical reference manual for specific instructions and warnings. Follow these general instructions to install your NI 5102:

1. Write down the NI 5102 serial number on the *NI 5102 Hardware and Software Configuration Form* in Appendix B, *Customer Communication*. You may need this serial number for future reference if you need to contact technical support.
2. Turn off your computer.
3. Remove the top cover or access port to the I/O channel.
4. Remove the expansion slot cover on the back panel of the computer.
5. For the NI 5102 (PCI), insert the card into a PCI slot. For the NI 5102 (ISA), insert the card into a 16-bit ISA slot. It may be a tight fit, but do not force the device into place.
6. Screw the mounting bracket of the NI 5102 to the back panel rail of the computer.
7. Check the installation.
8. Replace the cover.
9. Turn on your computer.

The NI 5102 (PCI or ISA) is now installed.

♦ NI 5102 (PXI)

You can install the NI 5102 (PXI) in any available slot in your PXI or CompactPCI chassis.

Note ***The NI 5102 (PXI) has connections to several reserved lines on the CompactPCI J2 connector. Before installing a NI 5102 (PXI) in a CompactPCI system that uses J2 connector lines for purposes other than PXI, see*** *Using PXI with CompactPCI* ***in Chapter 1,*** *Introduction****, of this manual.***

1. Turn off and unplug your PXI or CompactPCI chassis.
2. Choose an unused PXI or CompactPCI peripheral slot. For maximum performance, install the NI 5102 (PXI) in a slot that supports bus arbitration, or bus-master cards. The NI 5102 (PXI) contains onboard bus-master DMA logic that can operate only in such a slot. If you choose a slot that does not support bus masters, you will have to disable the onboard DMA controller using your software. PXI-compliant chassis must have bus arbitration for all slots.
3. Remove the filler panel for the peripheral slot you have chosen.
4. Touch a metal part on your chassis to discharge any static electricity that might be on your clothes or body.

5. Insert the NI 5102 (PXI) in the selected 5 V slot. Use the injector/ejector handle to fully inject the device into place.
6. Screw the front panel of the NI 5102 (PXI) to the front panel mounting rails of the PXI or CompactPCI chassis.
7. Visually verify the installation.
8. Plug in and turn on the PXI or CompactPCI chassis.

The NI 5102 (PXI) is now installed.

- NI 5102 (PCMCIA)

You can install the NI 5102 (PCMCIA) in any available Type II PCMCIA slot in your computer. For Windows 3.*x*, you must have Card and Socket Services 2.1 or later installed in your computer. If you have Windows 95, your operating system automatically configures the card for your computer and assigns the base address.

Before installing your NI 5102 (PCMCIA), please consult your PC user manual or technical reference manual for specific instructions and warnings. Use the following general instructions to install your NI 5102 (PCMCIA):

1. Turn off your computer. If your computer supports hot insertion, you may insert or remove the NI 5102 (PCMCIA) at any time, whether the computer is powered on or off.
2. Remove the PCMCIA slot cover on your computer.
3. Insert the 68-pin I/O connector of the NI 5102 (PCMCIA) into the PCMCIA slot. The card is keyed so that you can insert it only one way.
4. Attach the PSH32-C5 I/O cable, shown in Figure 4-4, *NI 5102 (PCMCIA) I/O Connectors*, to the PC Card to provide BNC connectivity. The cable connector latches into the NI 5102 (PCMCIA). The other end of the cable assembly is a panel to which you can connect standard probes and cables. When plugging and unplugging the cable, always grasp the cable by the connector. Never pull directly on the cable to unplug it from the NI 5102 (PCMCIA).

The NI 5102 (PCMCIA) is now installed.

- NI 5102 (USB)

You can attach your NI 5102 (USB) in any available high-power or low power USB port. The following are general installation instructions, but consult your PC user manual or technical reference manual for specific instructions and warnings.

Note ***If you are using the BP-1 battery pack, follow the installation instructions in your BP-1 installation guide and disregard steps 1 and 3 in this manual.***

1. Verify that the AC voltage input on the external power supply matches the voltage supplied in your area (110 V or 60 Hz/220 V or 50 Hz).
2. Verify that the external power supply voltage matches the power supply required by the NI 5102 (USB). You can find the supply voltage information on the external supply and also on the rear panel of the NI 5102 (USB).
3. Connect one end of the external supply to the electrical outlet. Connect the other end to the rear panel jack. Notice that the jack has a locking plug. You may need this lock if the connection between the external supply and the NI 5102 (USB) is not secure.
4. Plug the upstream end of the USB cable into any available upstream socket, and plug the downstream end of the USB cable into the NI 5102 (USB), as shown in Figure 2-1.
5. Flip the rocker switch to turn the power on for the NI 5102 (USB). The PC should immediately detect the NI 5102 (USB). When the PC recognizes the NI 5102 (USB), the LED on the front panel will blink or be lit.
6. If the LED remains lit after the NI 5102 (USB) is powered up and connected to the host, it is functioning properly. If the LED is blinking or off, there may be a problem. Refer to Table 2-1 for the LED pattern descriptions. When the LED blinks, it turns on and off for one second each for as many times as necessary, then waits three seconds before repeating the cycle.

The NI 5102 (USB) is now installed.

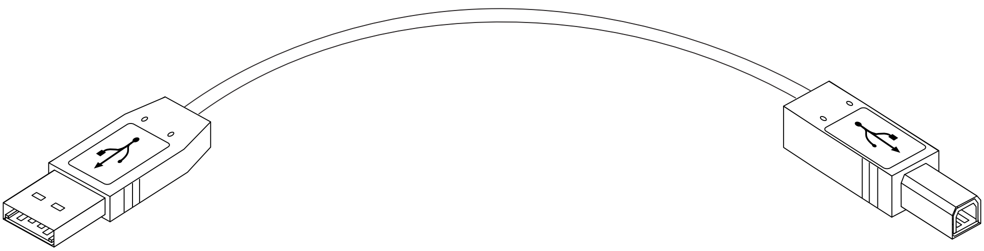

Figure 2-1. NI 5102 (USB) Upstream and Downstream Connectors

Table 2-1. NI 5102 (USB) LED Patterns

LED	NI 5102 (USB) State	Description
On	Configured State	Your NI 5102 (USB) is configured.
Off	Off or in the low-power, suspend mode	Your NI 5102 (USB) is turned off or in the low-power, suspend mode.
2 Blinks	Addressed state	This pattern is displayed if the host computer detects your NI 5102 (USB) but cannot configure it because NI-DAQ is not installed properly or because there are no system resources available. If the NI 5102 (USB) remains in this state, check your software installation.
4 Blinks	General error state	If this pattern is displayed, contact National Instruments.

Hardware Configuration

The NI 5102 is a fully software-configurable, Plug and Play device. Hardware configuration information and resource requirements are stored in nonvolatile memory. The Plug and Play services query the device, read the information, and arbitrate resource allocation for items such as base address, interrupt level, and DMA channel. After assigning these resources, the operating system enables the device for operation.

Power Considerations

♦ NI 5102 (USB) Only

The NI 5102 (USB) remains powered when the rocker switch is set to on, regardless of whether the host computer is on or off, on whether the USB cable is attached or not.

If power consumption is a concern, the recommended way to turn off the NI 5102 (USB) is with the rocker switch located on the rear panel. This switch turns the device on and off by disconnecting both the external power supply and the USB supply.

3

Digitizer Basics

This chapter explains the basic information you need to understand about making measurements with digitizers, including important terminology and how to use your probe.

Understanding Digitizers

To understand how digitizers work, you should be familiar with the Nyquist theorem and how it affects analog bandwidth and sample rate. You should also understand vertical sensitivity, analog-to-digital converter (ADC) resolution, record length, and triggering options.

Nyquist Theorem

The Nyquist theorem states that a signal must be sampled at least twice as fast as the bandwidth of the signal to accurately reconstruct the waveform; otherwise, the high-frequency content will *alias* at a frequency inside the spectrum of interest (passband). An alias is a false lower frequency component that appears in sampled data acquired at too low a sampling rate. Figure 3-1 shows a 5 MHz sine wave digitized by a 6 MS/s ADC. The dotted line indicates the aliased signal recorded by the ADC at that sample rate.

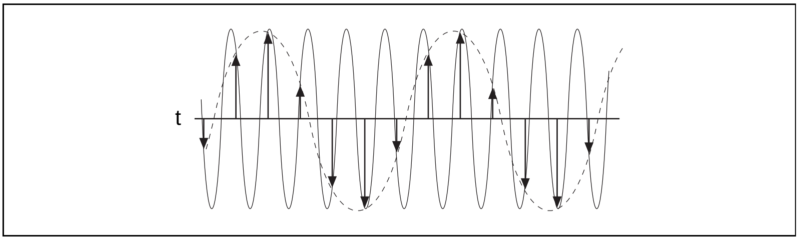

Figure 3-1. Aliased Sine Wave When Waveform is Under Sampled

The 5 MHz frequency aliases back in the passband, falsely appearing as if it were a 1 MHz sine wave. To prevent aliasing in the passband, a lowpass filter limits the frequency content of the input signal above the Nyquist rate.

Analog Bandwidth

Analog bandwidth describes the frequency range (in hertz) in which a signal can be digitized accurately. This limitation is determined by the inherent frequency response of the input path—from the tip of the probe to the input of the ADC—which causes loss of amplitude and phase information. *Analog bandwidth* is the frequency at which the measured amplitude is 3 dB below the actual amplitude of the signal. This amplitude loss occurs at very low frequencies if the signal is AC coupled and at very high frequencies regardless of coupling. When the signal is DC coupled, the bandwidth of the amplifier will extend all the way to the DC voltage. Figure 3-2 illustrates the effect of analog bandwidth on a high-frequency signal. The result is a loss of high-frequency components and amplitude in the original signal as the signal passes through the instrument.

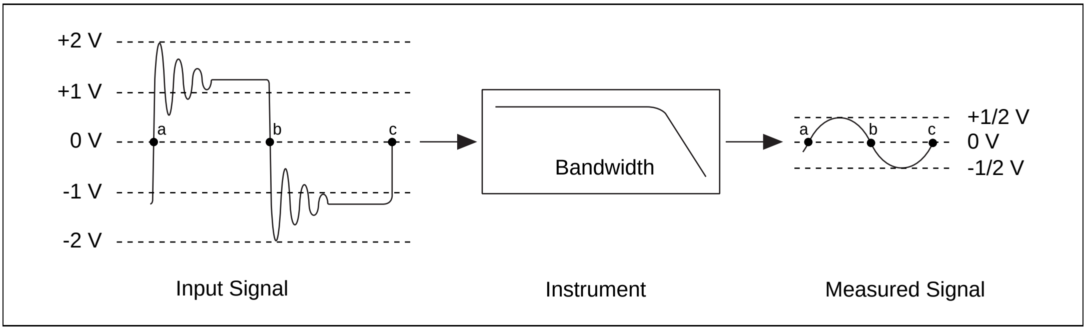

Figure 3-2. Analog Bandwidth

Sample Rate

Sample rate is the rate at which a signal is sampled and digitized by an ADC. According to the Nyquist theorem, a higher sample rate produces accurate measurement of higher frequency signals if the analog bandwidth is wide enough to let the signal to pass through without attenuation. A higher sample rate also captures more waveform details.

Figure 3-3 illustrates a 1 MHz sine wave sampled by a 2 MS/s ADC and a 20 MS/s ADC. The faster ADC digitizes 20 points per cycle of the input signal compared with 2 points per cycle with the slower ADC. In this example, the higher sample rate more accurately captures the waveform shape as well as frequency.

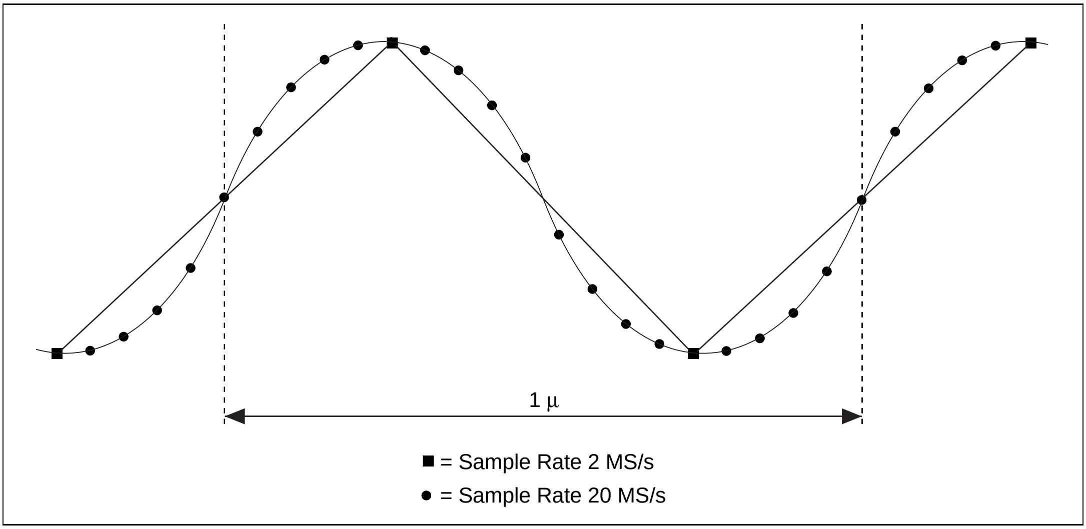

Figure 3-3. 1 MHz Sine Wave Sample

Vertical Sensitivity

Vertical sensitivity describes the smallest input voltage change the digitizer can capture. This limitation is because one distinct digital voltage encompasses a range of analog voltages. Therefore, it is possible that a minute change in voltage at the input is not noticeable at the output of the ADC. This parameter depends on the input range, gain of the input amplifier, and ADC resolution. It is specified in volts per least significant bit (LSB). Figure 3-4 shows the transfer function of a 3-bit ADC with a vertical range of 5 V having a vertical sensitivity of 5/8 V/LSB.

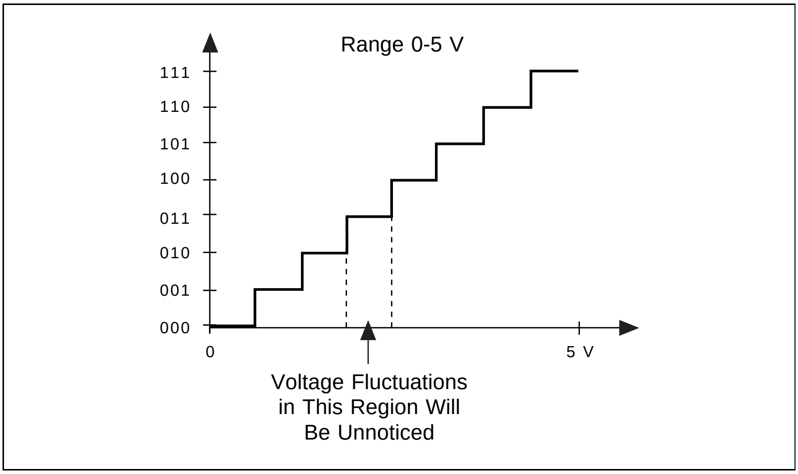

Figure 3-4. Transfer Function of a 3-Bit ADC

ADC Resolution

ADC resolution limits the accuracy of a measurement. The higher the resolution (number of bits), the more accurate the measurement. An 8-bit ADC divides the vertical range of the input amplifier into 256 discrete levels. With a vertical range of 10 V, the 8-bit ADC cannot resolve voltage differences smaller than 39 mV. In comparison, a 12-bit ADC with 4,096 discrete levels can resolve voltage differences as small as 2.4 mV.

Record Length

Record length refers to the amount of memory dedicated to storing digitized samples for postprocessing or display. In a digitizer, record length limits the maximum duration of a single-shot acquisition. For example, with a 1,000-sample buffer and a sample rate of 20 MHz, the duration of acquisition is 50 µs (the number of points multiplied by the acquisition time/point or 1,000 × 50 ns). With a 100,000-sample buffer and a sample rate of 20 MHz, the duration of acquisition is 5 ms (100,000 × 50 ns). The NI 5102 has a buffer size of 663,000 samples. When performing a single-channel acquisition, you can use the entire available memory to capture data for a duration of 33.1 ms at 20 MS/s.

The NI 5102 (PCI, PXI) can transfer data to host memory while acquiring data, thus expanding their single-shot record length to 16 million samples on each channel.

Triggering Options

One of the biggest challenges of making a measurement is to successfully trigger the signal acquisition at the point of interest. Since most high-speed digitizers actually record the signal for a fraction of the total time, they can easily miss a signal anomaly if the trigger point is set incorrectly. The NI 5102 is equipped with sophisticated triggering options, such as 256 trigger thresholds, programmable hysteresis, trigger hold-off, and bilevel triggering on input channels as well as on a dedicated trigger channel. The NI 5102 also has two digital triggers that give you more flexibility in triggering by allowing you to connect a TTL/CMOS digital signal to trigger the acquisition. See Chapter 4, *Hardware Overview*, for more information on triggering.

Making Accurate Measurements

For accurate measurements, you should use the right settings when acquiring data with your NI 5102. Knowing the characteristics of the signal in consideration helps you to choose the correct settings. Such characteristics include:

- Peak-to-peak value—This parameter, in units of volts, reflects the maximum change in signal voltage. If V is the signal voltage at any given time, then $V_{pk\text{-}to\text{-}pk} = V_{max} – V_{min}$. The peak-to-peak value affects the vertical sensitivity or gain of the input amplifier. If you do not know the peak-to-peak value, start with the smallest gain (maximum input range) and increase it until the waveform is digitized using the maximum dynamic range without clipping the signal. Refer to Appendix A, *Specifications*, for the maximum input voltage for your NI 5102 instrument. Figure 3-5 shows that a gain of 5 is the best setting to digitize a 300 mV, 1 MHz sine wave without clipping the signal.

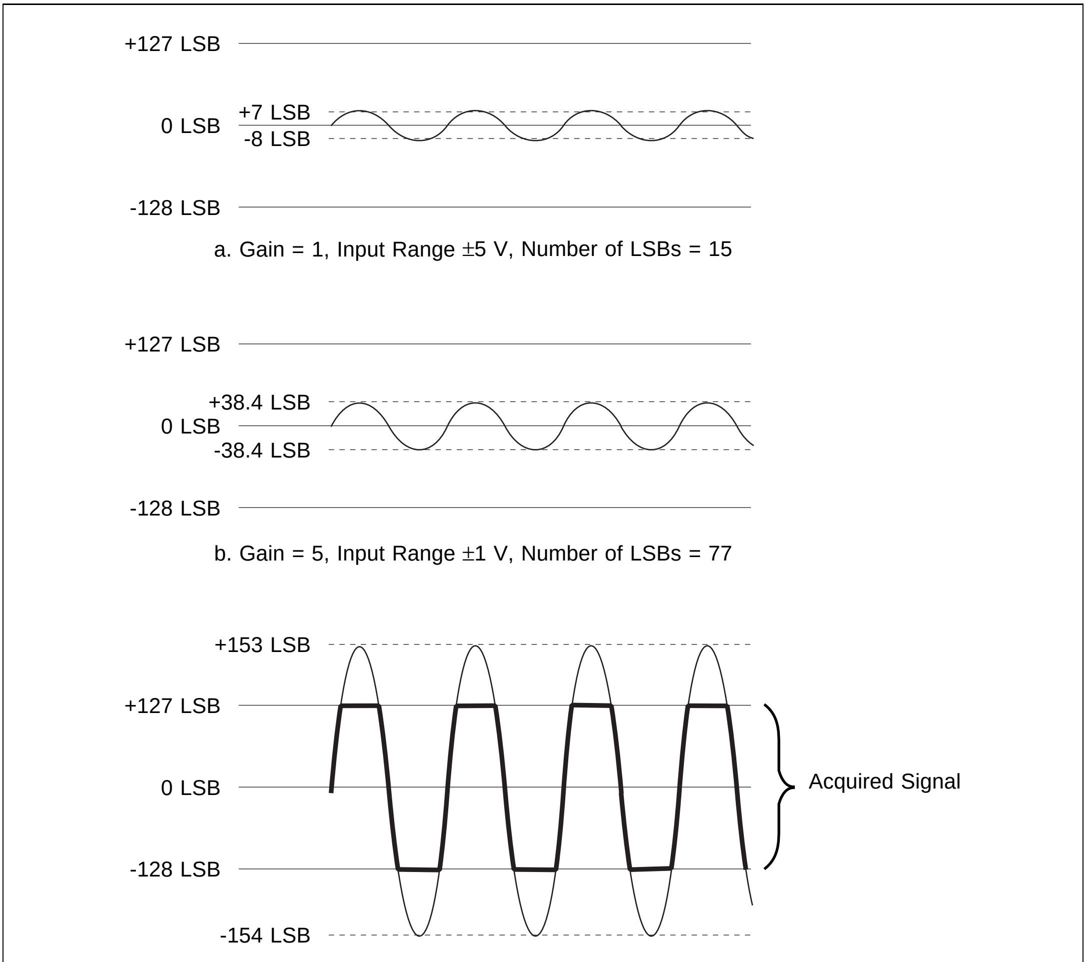

Figure 3-5. Dynamic Range of an 8-Bit ADC with Three Different Gain Settings

- Source impedance—Most digitizers and digital storage oscilloscopes (DSOs) have a 1 MΩ input resistance in the passband with an X1 probe and a 10 MΩ input resistance with an X10 probe. If the source impedance is large, the signal will be attenuated at the amplifier input and the measurement will be inaccurate. If the source impedance is unknown but suspected to be high, change the attenuation ratio on your probe and acquire data. If the X10 measurement results in amplitude gain, your measurement may be inaccurate. To correct this, try reducing the source impedance by buffering. See *Understanding the*

Probe and Its Effects on Your Waveform later in this chapter for more information.

In addition to the input resistance, all digitizers, DSOs, and probes present some input capacitance in parallel with the resistance. This capacitance can interfere with your measurement in much the same way as the resistance does. You can reduce this capacitance by using an attenuating probe (X10, X100, or X1000) or an active probe. See Appendix A, *Specifications*, or your probe specifications for accurate input capacitance numbers.

- Input frequency—If your sample rate is less than twice the highest frequency component at the input, the frequency components above half your sample rate will alias in the passband at lower frequencies, indistinguishable from other frequencies in the passband. If the signal's highest frequency is unknown, you should start with the digitizer's maximum sample rate to prevent aliasing and reduce the digitizer's sample rate until the display shows either enough cycles of the waveform or the information you need.
- General signal shape—Some signals are easy to capture by ordinary triggering methods. A few iterations on the trigger level finally render a steady display. This method works for sinusoidal, triangular, square, and saw tooth waves. Some of the more elusive waveforms, such as irregular pulse trains, runt pulses, and transients, may be more difficult to capture. Figure 3-6 shows an example of a difficult pulse-train trigger.

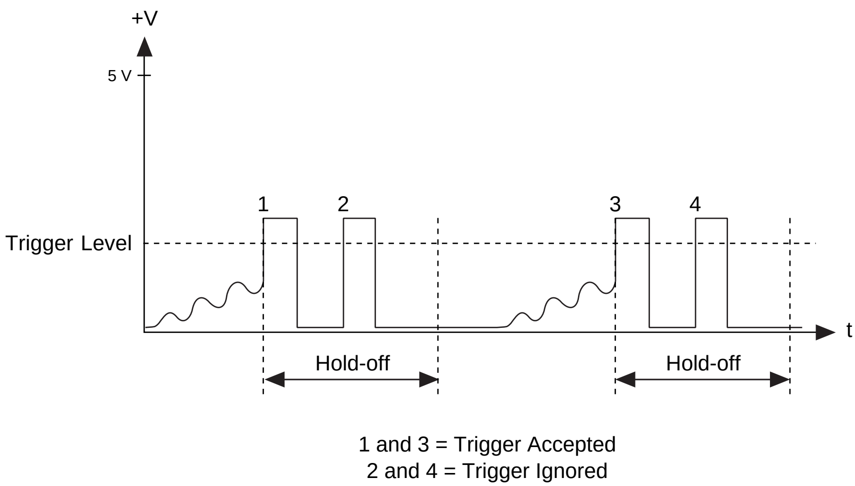

Figure 3-6. Difficult Pulse Train Signal

Ideally, the trigger event should occur at condition one, but sometimes the instrument may trigger on condition two because the signal crosses the trigger level. You can solve this problem without using complicated signal processing techniques by using *trigger hold-off*, which lets you specify a time from the trigger event to ignore additional triggers that fall within that time. With an appropriate hold-off value, the waveform in Figure 3-6 can be properly captured by discarding conditions two and four.

- Input coupling—You can configure the input channels on your NI 5102 to be DC coupled or AC coupled. DC coupling allows the DC and low-frequency components of a signal to pass through without attenuation. In contrast, AC coupling removes DC offsets and attenuates the low-frequency components of a signal. This feature can be exploited to zoom in on AC signals with large DC offsets, such as switching noise on a 12 V power supply. Refer to Appendix A, *Specifications*, for the input limits that must be observed regardless of coupling.

Understanding the Probe and Its Effects on Your Waveform

Signals travel from the tip of the probe to the input amplifier and are then digitized by the ADC. This signal path makes the probe an important electrical system component that can severely affect the accuracy of the measurement. A probe can potentially influence measured amplitude and phase, and the signal can pick up additional noise on its way to the input stage. Several types of probes are available including passive, active, and current probes.

Passive Probe

The passive probe is the most widely used general-purpose oscilloscope probe. Passive probes are specified by bandwidth (or rise time), attenuation ratio, compensation range, and mechanical design aspects. Probes with attenuation, X10, X100, or X1000, have a tunable capacitor that can reduce capacitive effects at the input. The ability to cancel or minimize effective capacitance improves the probe’s bandwidth and rise time. Figure 3-7 shows a typical X10 probe model. You should adjust the tunable capacitor, C_p, to obtain a flat frequency response. C_p is the probe capacitance, R_p is the probe resistance, C_{in} is the input capacitance, R_{in} is the input resistance.

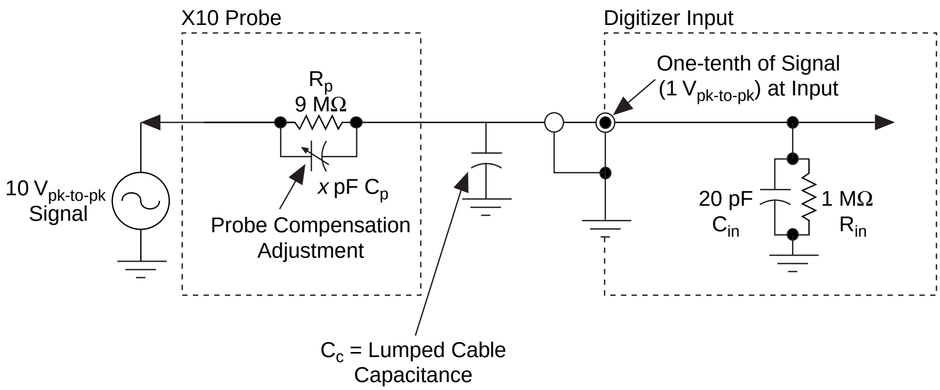

Figure 3-7. Typical X10 Probe

Analytically, obtaining a flat frequency response means:

$$R_{in}/(R_{in} + R_p) = C_p/(C_p + C_{in} + C_c)$$

It can be shown that:

$$R_{in}(C_{in} + C_c) = C_pR_p$$

or the time constant of the probe equals the time constant of the digitizer input.

How to Compensate Your Probe

Adjusting the tunable probe capacitor to get a flat frequency response is called *probe compensation*. On the NI 5102, you can select a 0–5 V, 1 kHz pulse train as reference to output on PFI1 or PFI2. Refer to Figure 3-8 as you follow these instructions to compensate your probe:

1. Connect the BNC end of the probe to an input channel, either CH0 or CH1 and select x10 attenuation on the body of the probe tip.
2. Attach the BNC adapter (probe accessory) to the tip of the probe.
3. Connect the SMB100 probe-compensation cable to one of the PFI lines. On the NI 5102 (PXI) this line is PFI1.
4. Attach the probe with the BNC adapter to the BNC female end of the SMB100 cable.
5. Enable the probe compensation signal on the PFI line you selected in step 3. See your application software documentation for more information how to perform this step.

6. Digitize data on the input channel, amplifying the signal until the signal starts to clip. Then go back one step so it does not clip anymore. This step ensures that you use the main dynamic range of the ADC.
7. Adjust the tunable capacitor to make the waveform look as square as possible.
8. For the most accurate measurements, compensate probes for each channel (CH0 and CH1) and use them on that channel only. Recompensate when using the same probe on a different channel.

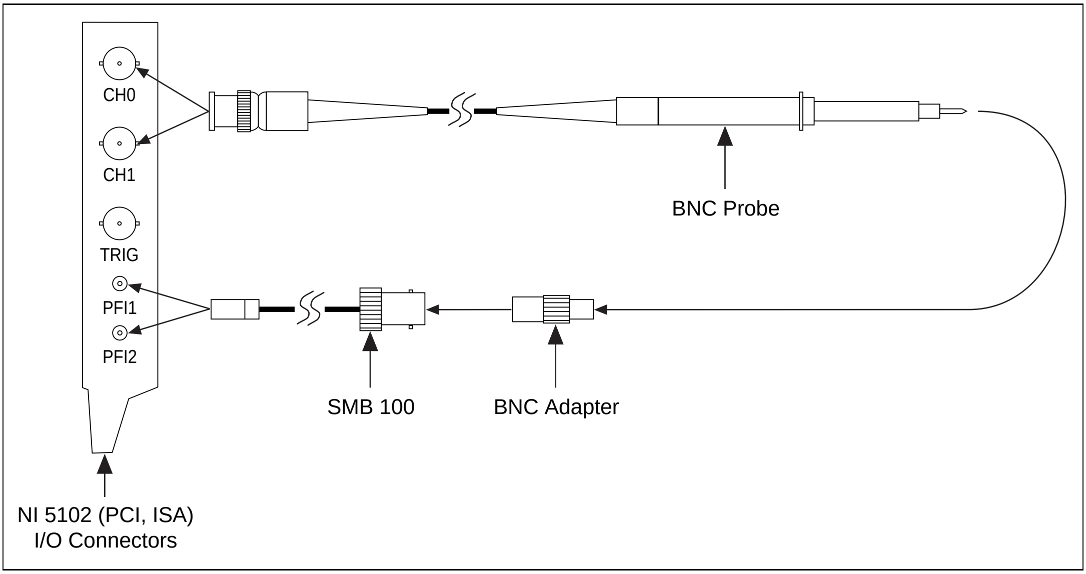

Figure 3-8. Connecting the Probe Compensation Cabling

As shown in Figure 3-9, an undercompensated probe attenuates higher frequency signals, whereas an overcompensated probe amplifies higher frequencies. Calibrate your probe frequently to ensure accurate measurements from your NI 5102.

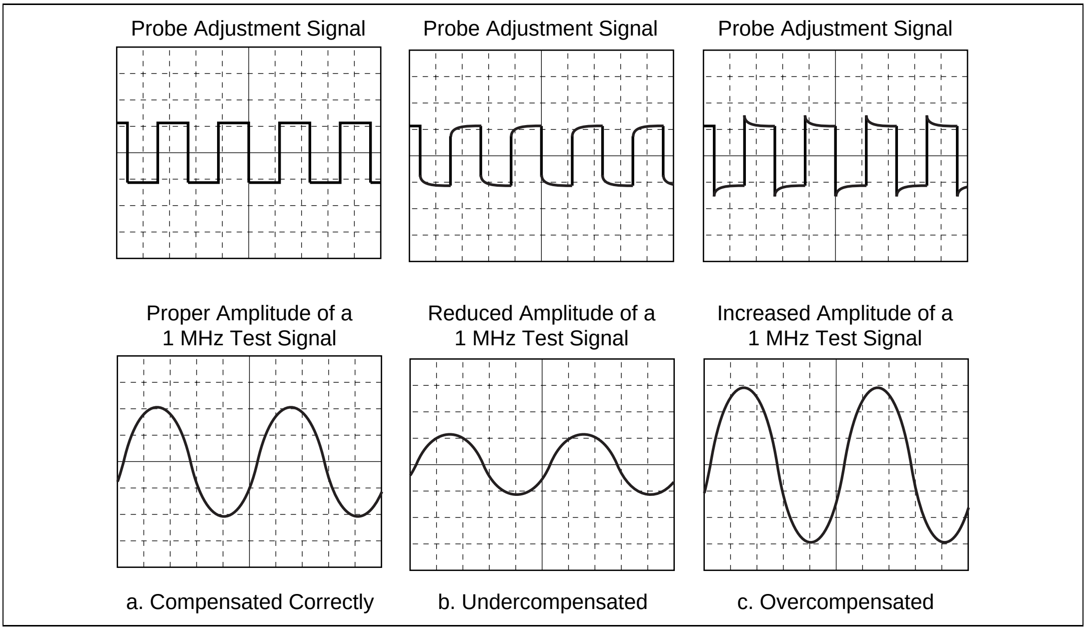

Figure 3-9. Probe Compensation Comparison

Active and Current Probes

You can also use active probes and current probes with digitizers and DSOs.

Active probes such as differential and field-effect transistor (FET) probes contain active circuitry in the probe itself to reject noise and amplify the signal. FET probes are useful for low-voltage measurements at high frequencies and differential probes are noted for their high CMRR and nongrounded reference.

Instead of using a series resistance in the loop to measure current, current probes magnetically measure AC and/or DC current flowing in a conductor. This lack of series resistance causes very little interference in the circuit being tested.

4

Hardware Overview

This chapter includes an overview of the NI 5102, explains the operation of each functional unit making up your NI 5102, and describes the signal connections.

Figure 4-1 shows a block diagram of the NI 5102 (PCI, PXI, ISA).

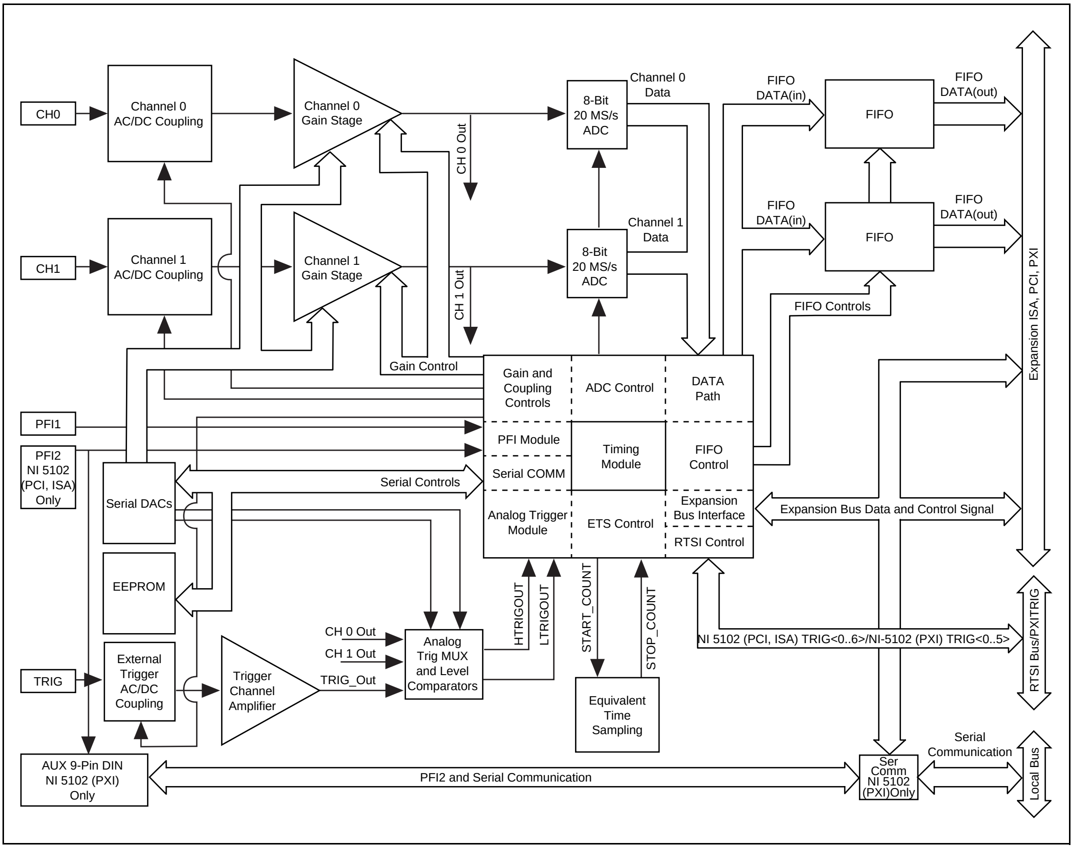

Figure 4-1. NI 5102 (PCI, PXI, ISA) Block Diagram

Figure 4-2 shows a block diagram of the NI 5102 (PCMCIA, USB).

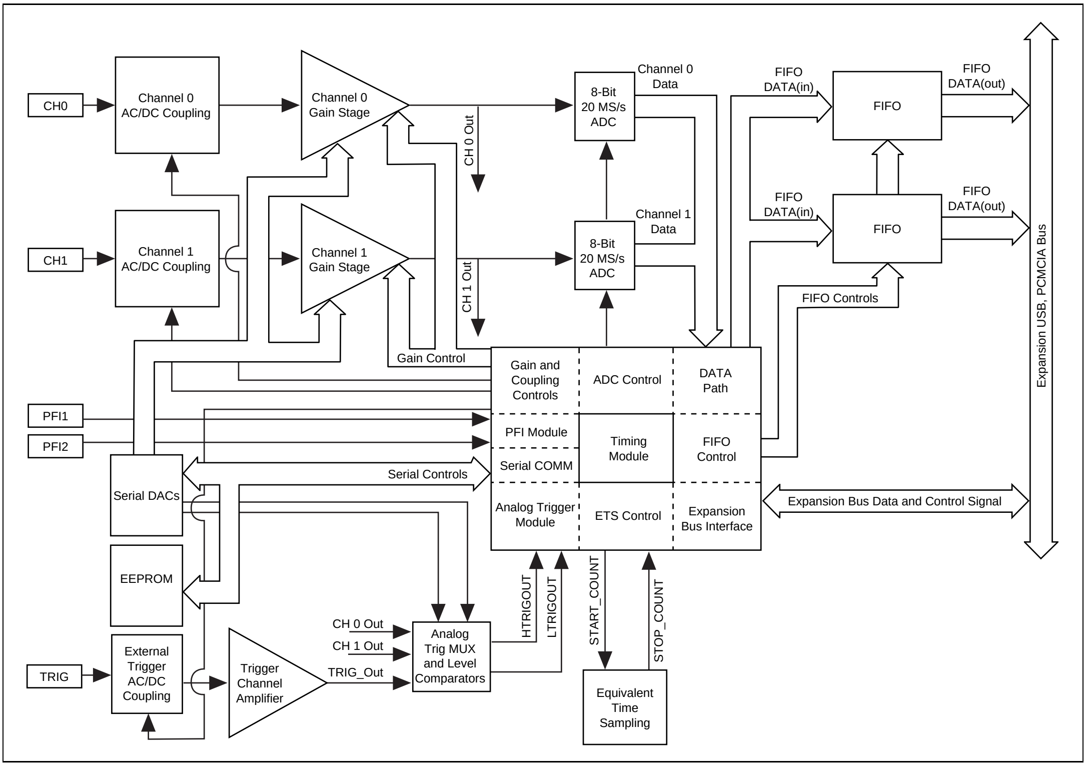

Figure 4-2. NI 5102 (PCMCIA, USB) Block Diagram

I/O Connector

- NI 5102 (PCI, ISA, PCMCIA, USB

These NI 5102 instruments have two standard BNC female connectors for CH0 and CH1 analog input connections, one standard BNC female connector for the TRIG channel, and two standard SMB female connectors for the multipurpose digital timing and triggering signals, PFI1 and PFI2.

The NI 5102 (PCI, ISA) give you direct BNC connectivity on the bracket, as shown in Figure 4-3.

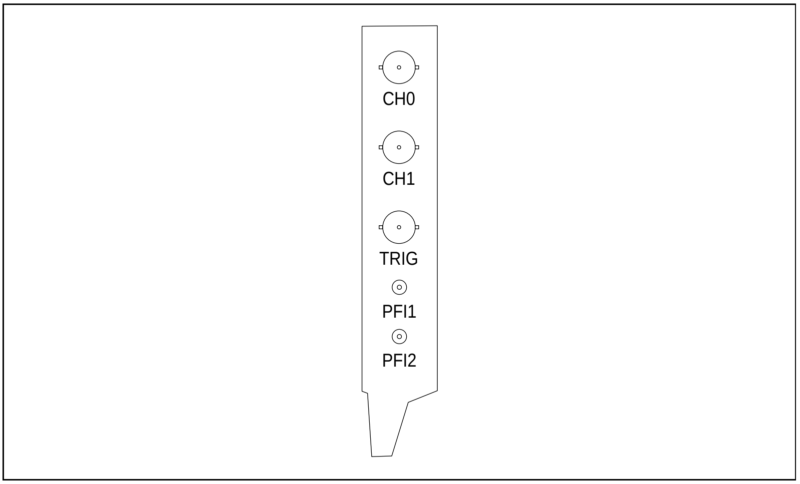

Figure 4-3. NI 5102 (PCI, ISA) I/O Connectors

Use the cable assembly provided for these connections on the NI 5102 (PCMCIA), as shown in Figure 4-4.

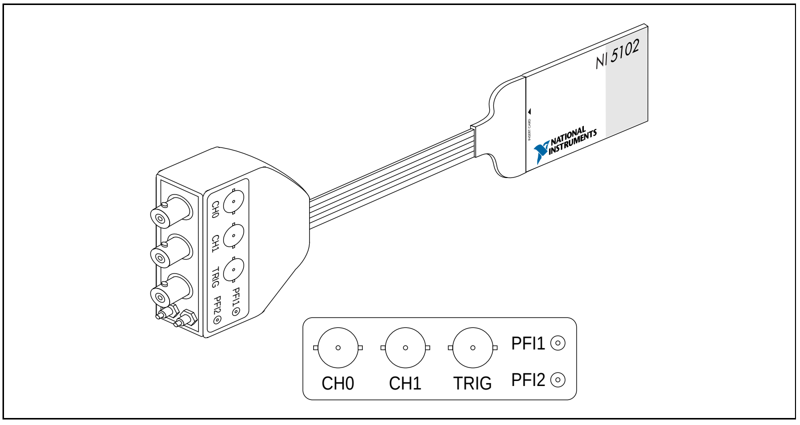

Figure 4-4. NI 5102 (PCMCIA) I/O Connectors

The NI 5102 (USB) gives you direct BNC connectivity, as shown in Figure 4-5.

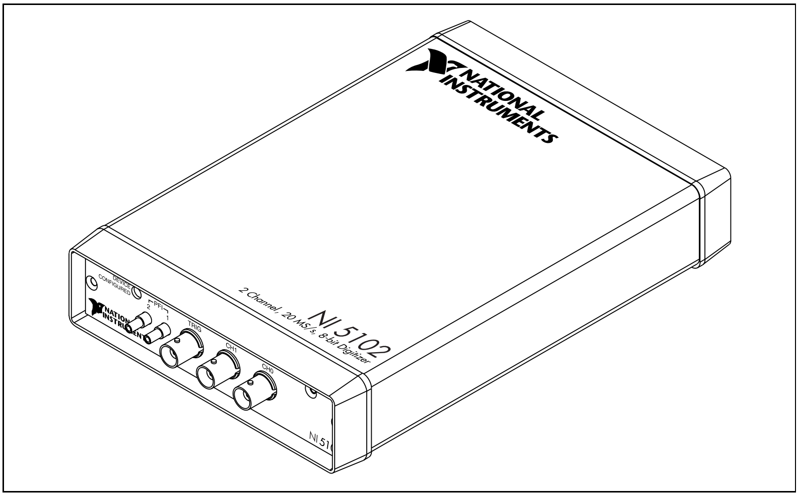

Figure 4-5. NI 5102 (USB) I/O Connectors

♦ NI 5102 (PXI)

The NI 5102 (PXI) has two standard BNC female connectors for CH0 and CH1 analog input connections, one standard BNC female connector for the TRIG channel, one standard SMB female connector for a multipurpose digital timing and triggering signal, PFI1, and a 9-pin mini-DIN connector, AUX, for serial communication or PFI2. The NI 5102 (PXI) gives you direct BNC connectivity on the bracket, as shown in Figure 4-6.

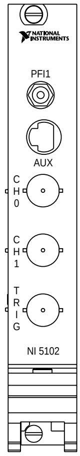

Figure 4-6. NI 5102 (PXI) I/O Connectors

Signal Connections

You can use CH0 and CH1 to digitize data as well as to trigger an acquisition. Use the TRIG channel for an external analog trigger only; data on the TRIG channel cannot be digitized. PFI1 and PFI2 are digital signals that you can use for timing-critical applications. When used as inputs, PFI lines can trigger an acquisition and/or allow an external scan clock connection. When used as outputs, PFI lines can output Start Trigger, Stop Trigger, Scan Clock, and End of Acquisition signals as well as Analog Trigger Circuit Output, frequency output, and TTL low and high voltage information. Signal names and descriptions vary depending on the acquisition mode you are using. See the *Acquisition Modes* section later in this chapter for more information on timing and triggering.

Table 4-1. I/O Connector Signal Descriptions

Signal	Description
CH0, CH1	Digitizes data and triggers acquisitions
TRIG	Used for external analog triggering
PFI1, PFI2	Software-configurable digital triggers, external scan clock, or digital outputs
AUX for NI 5102 (PXI) only	Serial communication or PFI2 (with optional cable)

Serial Communications Port (AUX)

- NI 5102 (PXI)

  The serial communication port, AUX, provides +5V and GND for applications that may require up to 100 mA of current operation and PF12 for triggering.

  PFI2 has the same functionality as described above, but it is overloaded on TRIG0 (SCANCLK) on the mini-DIN connector and is accessible only through the optional 9-pin mini-DIN to BNC female cable adapter.

Analog Input

The two analog input channels are referenced to common ground in bipolar mode. These settings are fixed; therefore, neither the reference nor the polarity of input channels can be changed. You cannot use CH0 or CH1 to make differential measurements or measure floating signals, unless you subtract the digital waveforms in software. For accurate measurements, make sure the signal being measured is referenced to the same ground as your NI 5102 by attaching the probe's ground clip to the signal ground. Table 4-2 shows the input ranges available on CH0 and CH1.

Table 4-2. CH0 and CH1 Input Ranges

Gain	Input range			
	X1 Probe	**X10 Probe**	**X100 Probe**	**X1000 Probe**
1	±5 V (default setting)	±50 V	±500 V	±5000 V
5	±1 V	±10 V	±100 V	±1000 V
20	±0.25 V	±2.5 V	±25 V	±250 V
100	±50 mV	±0.5 V	±5 V	±50 V

Note ***The X10, X100, and X1000 designations are used to indicate a signal attenuation rather than amplification. For example, with a X100 probe and a gain of 1, if you measure a 400 V signal, the NI 5102 will receive 4 V (400 V/100 = 4 V) at its input connector.***

The TRIG channel has a fixed input range of ±5 V. All NI 5102 instruments power up with a default gain of 1, thereby allowing the largest input range available. TRIG channel range values are the same as the gain of 1 values in Table 4-2.

The CH0, CH1, and TRIG channels have a software-programmable coupling selection between AC and DC. Use AC coupling when your AC signal contains a large DC component. Without AC coupling, it is difficult to view details of the AC component with a large DC offset and a small AC component, such as switching noise on a DC supply. If you enable AC coupling, you remove the large DC offset for the input amplifier and amplify only the AC component. This technique makes effective use of dynamic range to digitize the signal of interest.

The *low-frequency corner* in an AC-coupled circuit is the frequency below which signals are attenuated by at least 3 dB. The low-frequency corner is 11 Hz with an X1 probe, 1.1 Hz with an X10 probe, 0.11 Hz with anX100 probe, and 4 Hz with an X1000 probe.

When changing coupling on the NI 5102 instruments, the input stage takes a finite time to settle, as shown in Table 4-3.

Table 4-3. AC/DC Coupling Change Settling Rates

Action	Time Constant
Switching from AC to DC settling time	0.5 ms
Switching from DC to AC X1 probe time constant X10 probe time constant X100 probe time constant X1000 probe time constant	 15 ms 150 ms 1.5 s 40 ms

Caution ***When switching coupling from DC to AC, returned data is accurate about 20 time constants after switching to AC. This delay is based on switching to AC and, at the same time, switching from a gain of 1 to a gain of 100. The NI-DAQ driver software does not provide the delay to account for settling time; therefore, acquisitions immediately following a coupling change may yield incorrect data.***

ADC Pipeline Delay

The ADC on the NI 5102 is a pipelined flash converter with a maximum conversion rate of 20 MS/s. The pipelined architecture imposes a 2.5 Scan Clock cycle delay to convert analog voltage into a digital value, as shown in Figure 4-7.

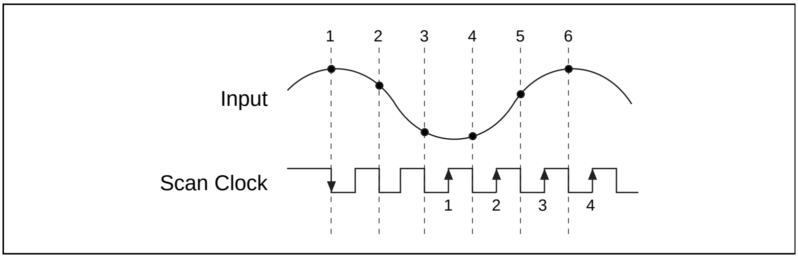

Figure 4-7. Scan Clock Delay

In reference to the Scan Clock signal, the digital value corresponding to the first conversion (the first falling edge of the Scan Clock signal) outputs synchronously with the third rising edge of the Scan Clock signal.

Using a pipelined architecture also introduces a lower limit on the scan rate. For the NI 5102, the accuracy starts to degrade below about 1 kS/s.

The NI 5102 automatically adjusts for pipelined delay when you use the internal scan clock. If you use an external scan clock, you must provide a free-running clock to ensure reliable operation. You must also follow timing specifications on the external scan clock as described in Appendix A, *Specifications*.

Acquisition Modes

The NI 5102 supports two acquisition modes—posttrigger acquisition and pretrigger acquisition.

Posttrigger Acquisition

In posttrigger acquisition mode, the hardware acquires a number of scans after the Start Trigger occurs. When the trigger occurs, the input signal is digitized and the desired number of scans are stored in onboard memory. Table 4-4 shows the minimum and maximum number of samples the 5102 instrument can acquire.

Table 4-4. Possible Number of Samples for Posttriggered Scans

Number of Channels	NI 5102 (PCI, PXI)		NI 5102 (ISA, PCMCIA, USB)	
	Min	Max	Min	Max
One	1	16,777,088*	1	663,000
Two	1	16,777,088*	1	331,500
* Dependent on available memory				

Note ***If Scan Clock is externally supplied, you must supply a free-running clock for proper operation.***

On the NI 5102 (ISA, PCMCIA, USB), data transfer takes place after an acquisition ends, limiting the scan count to the size of the onboard memory.

On the NI 5102 (PCI, PXI), data can be moved very quickly from the card to host memory while an acquisition is in progress. The NI 5102 (PCI, PXI) take advantage of the National Instruments MITE on the application-specific integrated circuit (ASIC) to master the PCI bus and transfer data acquired on both channels to PC memory in real time without losing data. This technology lets you acquire more data than 663,000 samples, the size of the onboard memory. This property of the PCI bus extends the maximum scan count to 16 million scans.

Figure 4-8 shows the timing signals involved in a posttrigger acquisition. In this example, the hardware is programmed to acquire 10 posttriggered scans.

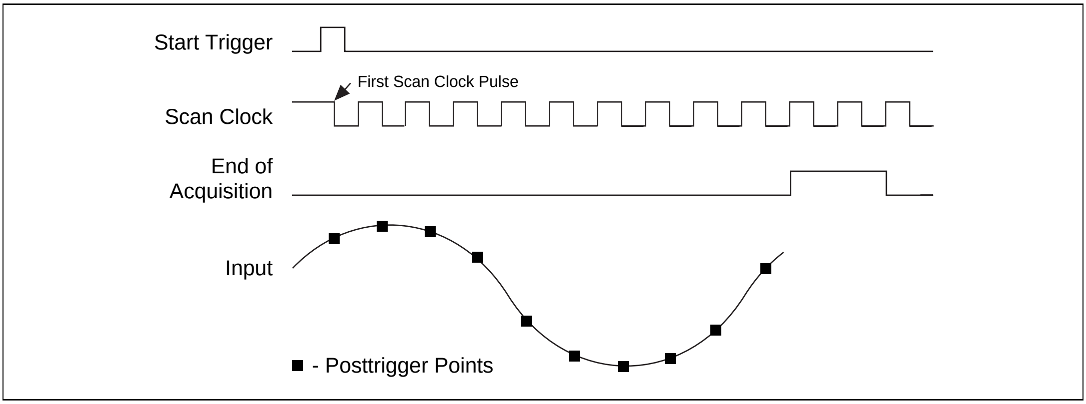

Figure 4-8. Posttrigger Acquisition

Table 4-5 describes the posttrigger acquisition signals.

Table 4-5. Posttrigger Acquisition Signals

Signal	Description
Start Trigger	Triggers the acquisition. It can be generated through software, or CH0, CH1, TRIG, PFI1, and PFI2, or any of the seven RTSI bus trigger lines. RTSI bus trigger lines are available only on the NI 5102 (PCI, PXI, ISA).
Scan Clock	Causes the ADC to convert the input signal into digital data. This signal is also used in the memory controller to write the data into onboard memory. This signal can be generated internally, with a 24-bit counter clocked with a 20 MHz signal to generate pulses from 20 MHz to 1.19 Hz. The 24-bit counter provides a wide choice of valid frequencies for the Scan Clock signal. In addition, Scan Clock can also be selected from CH0, CH1, TRIG, PFI1, and PFI2, or any of the seven RTSI bus trigger lines. RTSI bus trigger lines are available only on the NI 5102 (PCI, PXI, ISA).
End of Acquisition	Indicates end of acquisition to the control logic in the hardware. It is generated from a counter that keeps track of the number of points remaining in the acquisition. It can be exported from the device on the PFI lines.

Pretrigger Acquisition

In pretrigger acquisition mode, the device acquires a certain number of scans, called the pretrigger scan count, *before* the trigger occurs. After satisfying the pretrigger scan count requirement, hardware keeps acquiring data and stores it in a circular buffer implemented in onboard memory. The size of the circular buffer equals the pretrigger scan count. When the trigger occurs, hardware acquires and stores the posttrigger scans and the acquisition terminates. Table 4-6 shows the minimum and maximum number of samples available on the NI 5102 in pretriggered mode.

Table 4-6. Possible Number of Samples for Pretriggered Mode

Number of Channels	NI 5102 (PCI, PXI)		NI 5102 (ISA, PCMCIA, USB	
	Min	Max	Min	Max
One Pretriggered scans Posttriggered scans	 1 1	 663,000 16,777,216*	 1 1	 663,000 – A 663,000 – B
Two Pretriggered scans Posttriggered scans	 1 1	 331,500 16,777,216*	 1 1	 331,500 – A 331,500 – B

* Dependent on available memory
A — The number of posttriggered scans
B — The number of pretriggered scans

Note ***If Scan Clock is externally supplied, a free-running clock must be used for proper operation.***

Figure 4-9 shows the relevant timing signals for a typical pretriggered acquisition. The illustration represents five pretrigger and five posttrigger scans, and above-high-level analog triggering is used. See the *Analog Trigger Circuit* section later in this chapter for more information on analog trigger types.

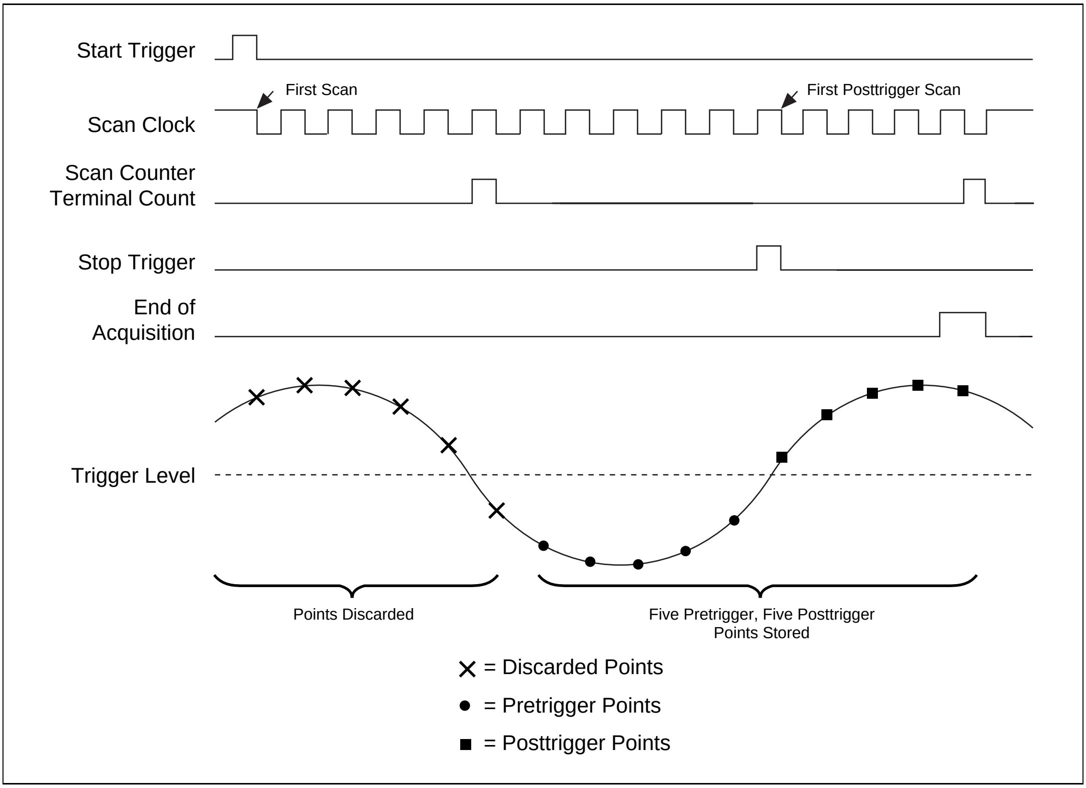

Figure 4-9. Pretrigger Acquisition

Table 4-7 describes the pretrigger acquisition signals.

Table 4-7. Pretrigger Acquisition Signals

Signal	Description
Start Trigger	Starts data acquisition. In pretrigger mode, the Start Trigger signal enables the storage of pretrigger data. Start Trigger can only be generated through software in pretrigger mode.
Scan Clock	Causes the ADC to convert the input signal into digital data. This signal is also used in the memory controller to write the data into onboard memory. This signal can be generated internally, with a 24-bit down counter clocked with a 20 MHz signal to generate pulses from 20 MHz to 1.19 Hz. The 24-bit counter provides a wide choice of valid frequencies for the Scan Clock signal. In addition, Scan Clock can also be selected from CH0, CH1, TRIG, PFI1, and PFI2, or any of the seven RTSI bus trigger lines. RTSI bus trigger lines are available only on the NI 5102 (PCI, PXI, ISA).
Scan Counter Terminal Count	Is an internally generated signal that pulses once to indicate that the pretrigger sample count requirement is met. Between the time when this signal pulses and the Stop Trigger occurs, hardware overwrites the oldest points in memory with the most recent points in a circular fashion. All STOP triggers occurring before Scan Counter Terminal Count are ignored by the device.
Stop Trigger	Terminates the acquisition sequence after acquiring the posttrigger sample count. This trigger can be generated through software, or CH0, CH1, TRIG, PFI1, and PFI2, or any of the seven RTSI bus trigger lines. RTSI bus trigger lines are available only on the NI 5102 (PCI, PXI, ISA).
End of Acquisition	Indicates end of acquisition to the control logic in the hardware. It is generated from a counter that keeps track of points remaining to acquire. It can be exported from the device on the PFI lines.

Trigger Sources

The Scan Clock, Start Trigger, and Stop Trigger signals can be generated through software or supplied externally as digital triggers or as analog triggers on one of the input channels or the TRIG channel. Figure 4-10 shows the different trigger sources. In addition, Scan Clock is available from a source (counter) internal to the NI 5102.

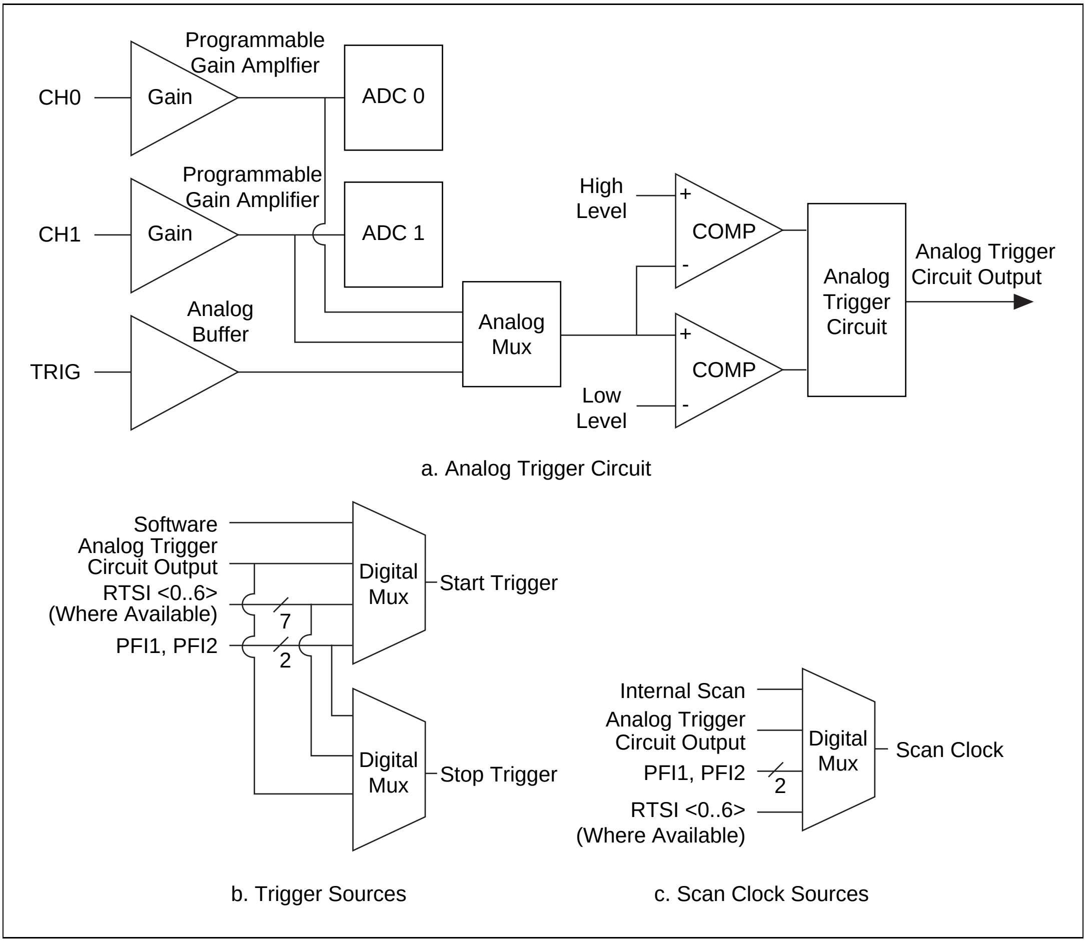

Figure 4-10. Scan Clock, Start Trigger, and Stop Trigger Signal Sources

Analog Trigger Circuit

The NI 5102 contains a sophisticated analog trigger circuit that accepts Boolean outputs from level comparators and makes intelligent decisions about the trigger. Five analog triggering modes are available, as shown in Figures 4-11 through 4-15. You can set **lowValue** and **highValue** independently in software.

In below-low-level analog triggering mode, the trigger is generated when the signal value is less than **lowValue**. **HighValue** is unused.

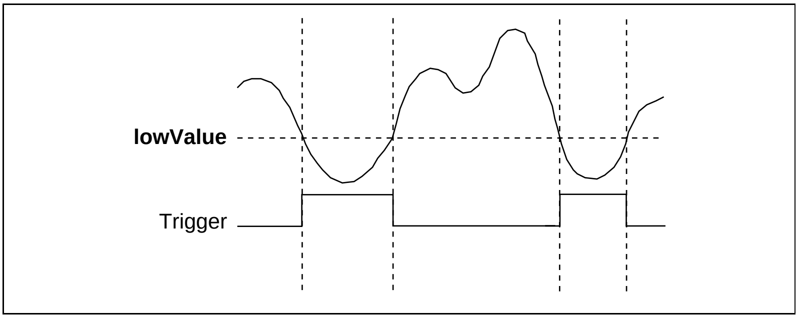

Figure 4-11. Below-Low-Level Analog Triggering Mode

In above-high-level analog triggering mode, the trigger is generated when the signal value is greater than **highValue**. **LowValue** is unused.

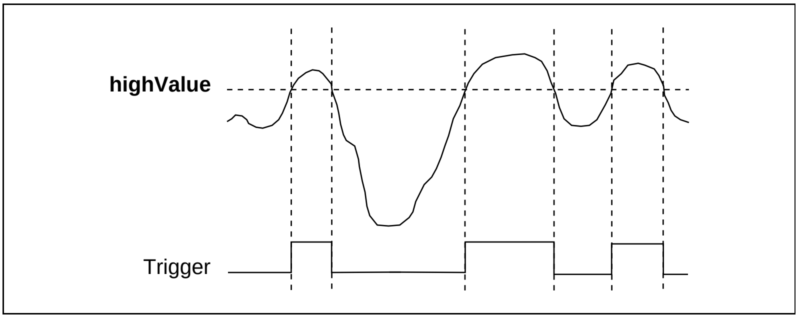

Figure 4-12. Above-High-Level Analog Triggering Mode

In inside-region analog triggering mode, the trigger is generated when the signal value is between the **lowValue** and the **highValue**.

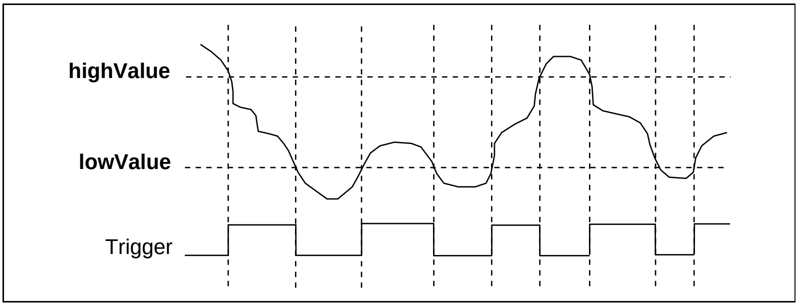

Figure 4-13. Inside-Region Analog Triggering Mode

In high-hysteresis analog triggering mode, the trigger is generated when the signal value is greater than **highValue**, with hysteresis specified by **lowValue**.

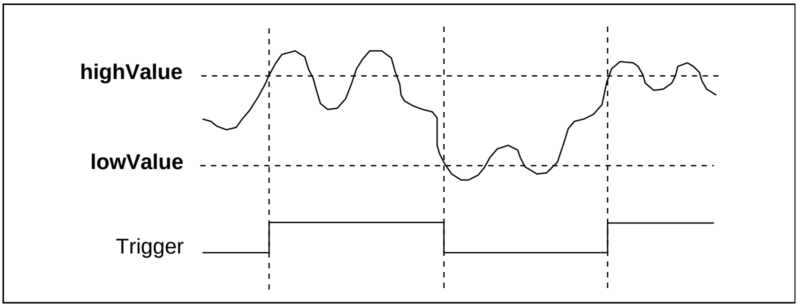

Figure 4-14. High-Hysteresis Analog Triggering Mode

In low-hysteresis analog triggering mode, the trigger is generated when the signal value is less than **lowValue**, with hysteresis specified by **highValue**.

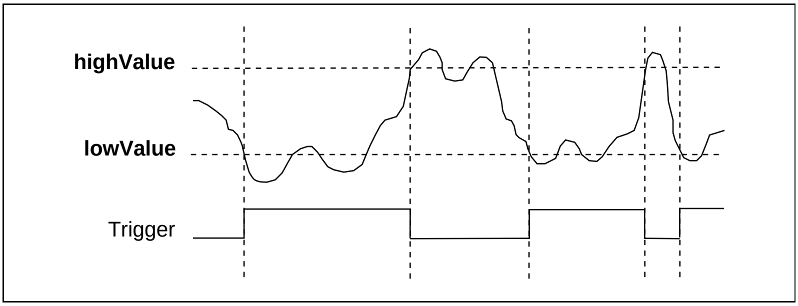

Figure 4-15. Low-Hysteresis Analog Triggering Mode

Trigger Hold-off

Trigger hold-off is provided in hardware using a 24-bit down counter clocked by a 2.5 MHz internal timebase. With this configuration, you can select a hardware hold-off value of 800 ns to 6.71 s in increments of 400 ns.

When acquisition is in progress, the counter is loaded with a digital value that corresponds to the desired hold-off time. The End of Acquisition signal triggers the counter to start counting down. Before the counter reaches its terminal count (TC), all triggers are rejected in hardware. At TC, the hold-off counter reloads the hold-off value and waits for the End of Acquisition to repeat the process. Figure 4-16 shows a timing diagram of signals when hold-off is enabled.

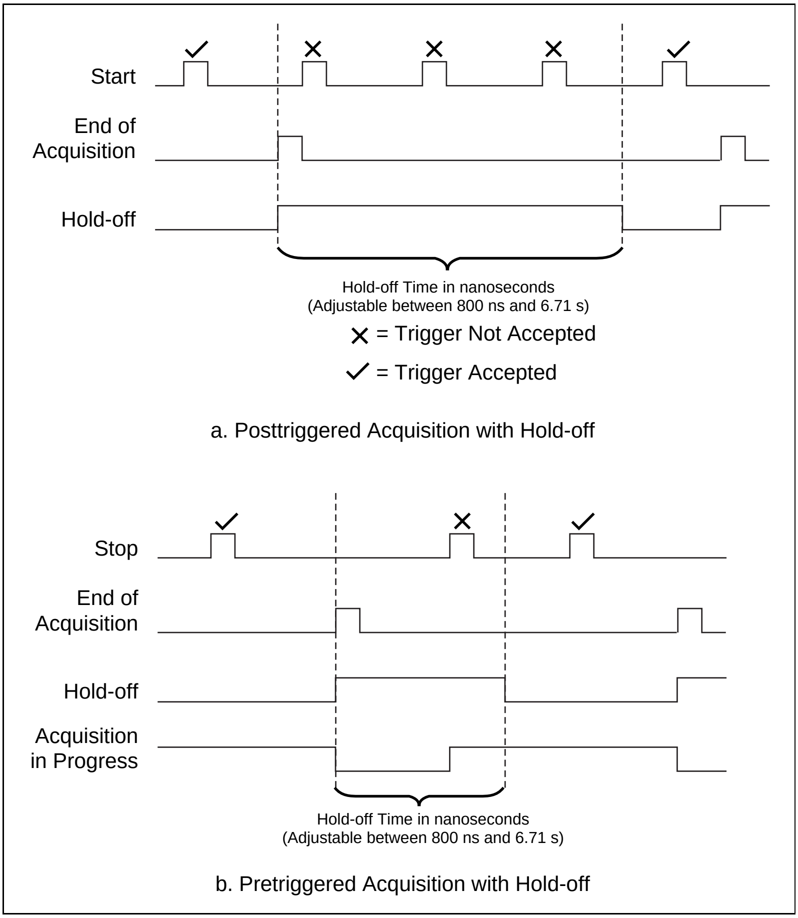

Figure 4-16. Pretrigger and Posttrigger Acquisitions with Hold-off

Note ***When you use trigger hold-off, you cannot calibrate your probe or generate an asynchronous frequency at the same time. The counter that is used to implement trigger hold-off also generates the probe calibration signal and the asynchronous pulse train.***

Random Interleaved Sampling

Random Interleaved Sampling (RIS) is a form of Equivalent Time Sampling (ETS) that allows acquisition of pretriggered data. ETS refers to any method used to sample signals in such a way that the apparent sampling rate is higher than the real sampling rate. ETS is accomplished by sampling different points along the waveform for each occurrence of the trigger, and then reconstructing the waveform from the data acquired over many cycles.

In RIS, the arrival of the waveform trigger point occurs at some time randomly distributed between two sampling instants. The time from the trigger to the next sampling instant is measured, and this measurement allows the waveform to be reconstructed. Figure 4-17 shows three occurrences of a waveform. In Frame 1, the dotted points are sampled, and the trigger occurs time t_1 before the next sample. In Frame 2, the square points are sampled, and the trigger occurs time t_2 before the next sample. In Frame 3, the triangular points are sampled, and the trigger occurs time t_3 before the next sample. With knowledge of the three times, t_1, t_2, and t_3, you can reconstruct the waveform as if it had been sampled at a higher rate, as shown at the bottom of the figure.

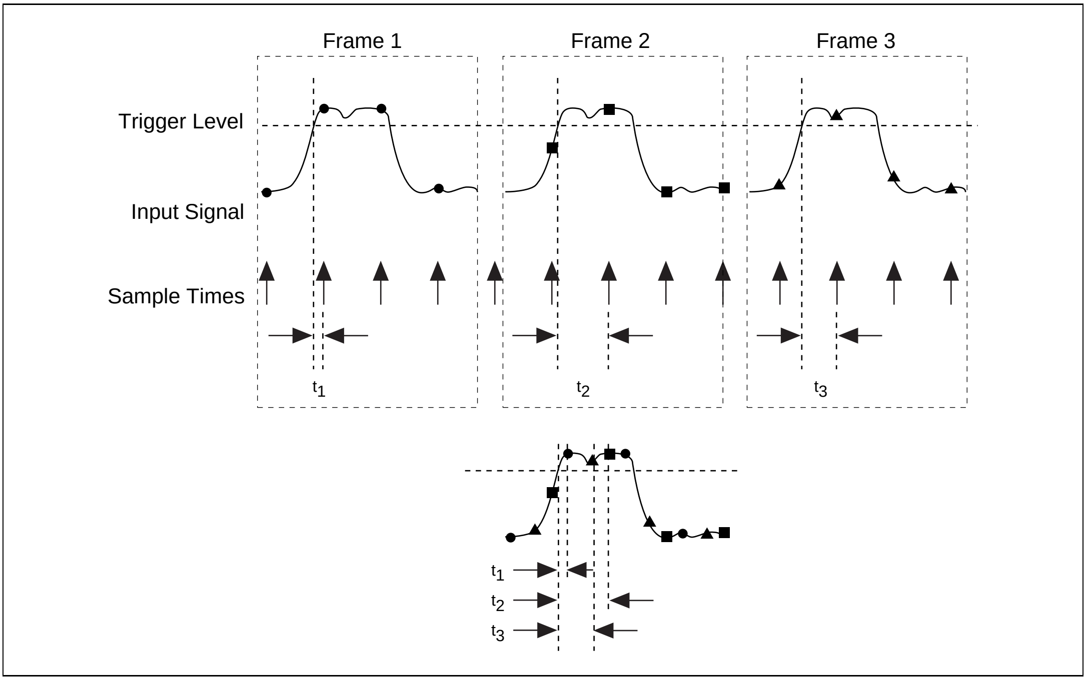

Figure 4-17. Waveform Reconstruction with RIS

The time measurement is made with a time-to-digital converter (TDC). The resolution of the TDC is the number of physical bins to which the TDC can quantize the trigger arrival time. This resolution should be several times higher than the maximum desired interpolation factor, which is the maximum number of logical bins to which you want the trigger arrival time quantized. The higher resolution ensures that when the TDC output is requantized to the desired interpolation factor, all output values have a roughly equal probability of occurrence; that is, all logical bins will contain approximately the same number of physical bins.

For example, consider the maximum interpolation factor to be 5. If the TDC could output values from 0 to 15, then each logical bin will contain three physical bins, as shown in Figure 4-18.

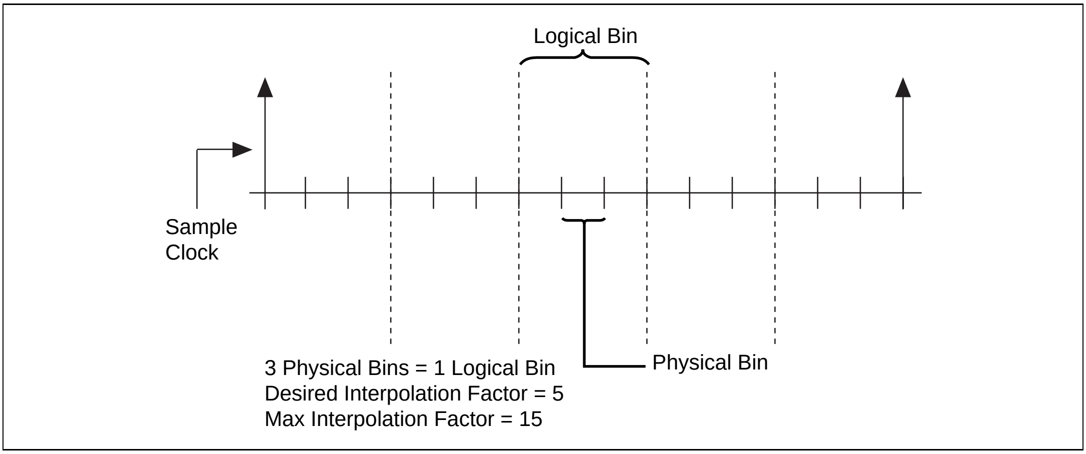

Figure 4-18. Relationship between Interpolation Factor, Logical Bins, and Physical Bins

The maximum interpolation factor on the NI 5102 is 50, resulting in a maximum ETS rate of 1 GS/s. At this rate, the ratio of logical bins to physical bins is approximately 1:9.

To reconstruct the waveform with RIS, you need to know the RIS OFFSET, which is the minimum value that the TDC can return, and the range of values, RIS GAIN, which is the maximum TDC value minus the minimum TDC value.

RIS OFFSET and RIS GAIN may vary slightly from board to board. Both these parameters are computed individually for each board at the factory and the values are stored in the onboard EEPROM.

Use RIS GAIN to determine the number of physical bins per logical bin for the desired interpolation factor. You could use RIS OFFSET to start the waveform reconstruction at the origin, but this parameter may drift over time and temperature, which could result in an inaccurate waveform.

Note ***ETS and RIS work only with repetitive signals.***

Calibration

Calibration is the process of minimizing measurement errors by making small circuit adjustments. On the NI 5102, NI-DAQ automatically makes these adjustments by retrieving precalculated values from the onboard EEPROM and writing them to calibration DACs (CalDACs).

All NI 5102 instruments are factory calibrated to the levels indicated in Appendix A, *Specifications*. Factory calibration involves nulling input offset, output offset, and gain errors on CH0 and CH1 and measuring RIS offset and RIS gain of the TDC, all at room temperature (25° C). These constants are stored in a write-protected area in the EEPROM. To recalibrate your NI 5102, contact National Instruments.

RTSI Bus Trigger and Clock Lines

♦ NI 5102 (PCI and ISA)

The RTSI bus (not available on the NI 5102 (PCMCIA or USB) allows National Instruments boards to synchronize timing and triggering on multiple devices. The RTSI bus has seven bidirectional trigger lines and one bidirectional clock signal.

You can program any of the seven trigger lines as inputs to provide Start Trigger, Stop Trigger, and Scan Clock signals sourced from a master board. Similarly, you can program a master board to output its internal Start Trigger, Stop Trigger, Scan Clock, and Analog Trigger Circuit Output signals on any of the trigger lines, as shown in Figure 4-19.

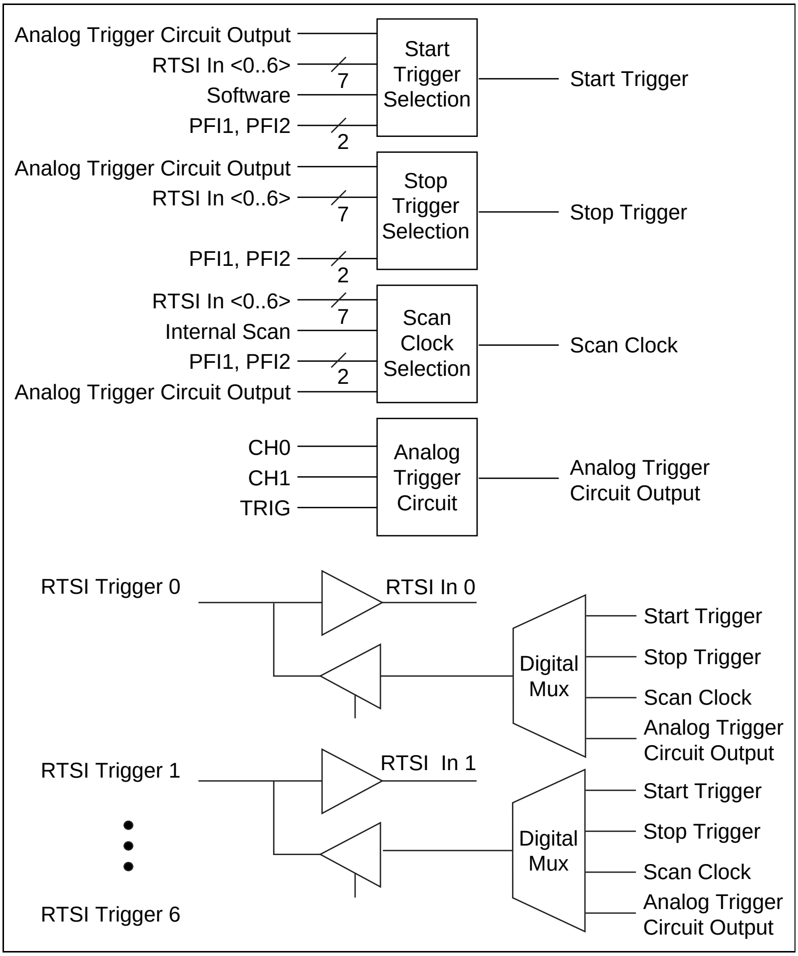

Figure 4-19. RTSI Bus Trigger Lines

The RTSI bus clock line is a special clock line on the RTSI bus that can carry only the timebase of the master board to the slave board. For the smallest jitter between measurements on different boards, you should configure the slave devices to use the RTSI bus clock from the master device.

- ♦ NI 5102 (PXI)

The NI 5102 (PXI) uses the PXI Trigger <0..5> to carry RTSI Trigger <0..5> and uses PXI Trigger 7 to carry the RTSI clock signal to all other PXI slots in the system. The RTSI Trigger 6 signal is reserved for use with PXI Star Trigger.

PFI Lines

All NI 5102 instruments have two multipurpose programmable function digital input/output lines, PFI1 and PFI2, that you can use for external timing and triggering or outputting various signals. You can individually select the direction of these lines to be input or output.

PFI Lines as Inputs

PFI1 or PFI2 can be selected as inputs for the Start Trigger, Stop Trigger, and Scan Clock signals. On the NI 5102 (PXI), PFI2 is accessible through the optional 9-pin mini-DIN to BNC female cable adapter. Unless your application requires the PFI2 signal to be passed through to the PXI back plane on TRIG0 (SCANCLK), disable the Backplane Scan Clock via your application software (reset state is disabled).

PFI Lines as Outputs

On the NI 5102 (PXI), PFI2 is accessible through the optional 9-pin mini-DIN to BNC female cable adapter. PFI1 or PFI2 can be selected to output the following digital signals:

- Start Trigger—This signal is synchronized to the 20 MHz timebase. When the Start condition is satisfied, either through a software, analog, or digital trigger, Start Trigger will transition high for 100 ns (two clock periods of the 20 MHz timebase) and transition back to its idle state.
- Stop Trigger—This signal is synchronized to the 20 MHz timebase. When the Stop condition is satisfied, either through an analog or digital trigger, Stop Trigger will transition high for 100 ns (two clock periods of the 20 MHz timebase) and transition back to its idle state.
- Scan Clock—This signal is also the clock to the ADC that represents the rate at which the input is sampled. The default state of this signal is high.
- End of Acquisition—This signal is generated internally to indicate to internal state machines that acquisition has ended. End of Acquisition, synchronous to Scan Clock, pulses high for two Scan Clock periods at the end of acquisition. This signal may be useful to trigger external circuits for timing critical applications.
- Analog Trigger Circuit Output—This signal is the digital output of the Analog Trigger Circuit on the NI 5102. The frequency and duty cycle of this signal depends on the trigger channel, the lowValue and

highValue trigger levels, polarity, and triggering mode. For more information, see the *Analog Trigger Circuit* section earlier in this chapter.

- Frequency Output—This signal is a digital pulse train with programmable frequency. The most common application of frequency output for the NI 5102 is to provide a signal for compensating the probe. You can select two timebases to generate this frequency as follows:

  7.16 MHz (asynchronous to 20 MHz internal timebase)

  1.25 MHz (synchronous to 20 MHz internal timebase)

  The NI 5102 uses a 16-bit counter to programmatically select frequency at the output. The pulse train frequency as a function of the counter value can be expressed as:

  Frequency = timebase/divide_ratio

  where

  divide_ratio = 3 .. 65,535

  Alternatively, to compute divide_ratio for a particular frequency, the relationship is:

  divide_ratio = timebase/frequency

  For example, to generate a 1 kHz pulse train, common for probe compensation, select the following parameters:

  timebase = 1.25 MHz

  divide_ratio = 1,250

- Low—This is the TTL low voltage referenced to the ground potential of the computer. This is a signal at logic level low. Do not use this as GND for your circuit.
- High—This is the TTL high voltage referenced to the ground potential of the computer. This is a signal at logic level high. Do not use this as VCC for your circuit.

Caution ***Refer to the output drive specification of PFI lines in Appendix A, Specifications. Failure to observe these limits may severely damage your NI 5102.***

Master/Slave Operation

You can use two or more NI 5102 instruments in one system to increase the number of channels for your application by synchronizing devices over the RTSI bus or PFI lines.

Use the RTSI bus for synchronizing two or more NI 5102 (PCI, PXI, ISA) instruments. For the NI 5102 (PCMCIA, USB), you must use the PFI lines.

Restrictions

To ensure proper master/slave operation on your 5102 instrument, you must observe the following restrictions:

- You must use all channels for acquisition. For example, if you want to use three channels at a time, you cannot use two channels on the master and one channel on the slave, you must use four channels for data acquisition and discard data on the fourth channel.
- The desired pretrigger number of scans and total number of scans must be a multiple of four. This is a hardware limitation.
- There is a maximum of one sample clock timing jitter between master and slave cards.

Connecting Devices

♦ NI 5102 (PCI, PXI, ISA)

You can synchronize NI 5102 (PCI, PXI, ISA) instruments over the RTSI bus. You can configure a system where a NI 5102 (PCI or ISA) can be the master device controlling a mix of NI 5102 (PCI, ISA) slave devices. The NI 5102 (PXI) can control only other NI 5102 (PXI) instruments. The NI 5102 (PXI) has the RTSI connectivity on the bus connector; the optional RTSI bus cable is not needed. However, you need a RTSI bus cable to synchronize two or more NI 5102 (PCI or ISA) instruments over the RTSI bus as follows:

1. If you are using multiple NI 5102 (PXI) instruments, skip this step. If you are using the NI 5102 (PCI or the ISA), connect the master device with the slave device over the RTSI connector. The cable and connector are keyed so there is only one way to insert the cable in the connector.
2. Ensure that no other card in the system is configured to output its internal timebase on the RTSI bus clock line. The safest approach is to restart your system, if possible.

3. Program the master device to output its internal timebase on the RTSI bus clock line.
4. Program the master device to output its Scan Clock and Stop Trigger on unused RTSI bus trigger lines.
5. Program the slave device to use RTSI bus clock as its main timebase.
6. Program the slave device to use external Scan Clock and external Stop Trigger on RTSI bus trigger lines selected in step 4.
7. Refer to the *Determining Pretriggered and Posttriggered Scan Counts* section later in this chapter for information on how to configure the number of pretrigger and posttriggered scans for the master and the slave devices.
8. Arm the slave device for acquisition before arming the master device.

- NI 5102 (PCMCIA, USB)

You need two SMB200 cables (optional) and two NI 5102 (PCMCIA) or NI 5102 (USB) instruments with cable assemblies to create a four-channel digitizer as follows:

1. Connect PFI1 of the master device to PFI1 of the slave device with the SMB200 cable.
2. Connect PFI2 of the master device to PFI2 of the slave device with the SMB200 cable.
3. Configure PFI1 of the master device to output Scan Clock and PFI2 of the master device to output Stop Trigger.
4. Configure the slave device to use external scans on PFI1, external Stop Trigger on PFI2, and software Start Trigger.
5. Refer to the *Determining Pretriggered and Posttriggered Scan Counts* section later in this chapter for information on how to configure the number of pretrigger and posttriggered scans for the master and the slave devices.
6. Arm the slave device for acquisition before arming the master device.

You cannot use the PFI1 and PFI2 lines on master and slave devices for any other purpose when synchronizing two cards.

Determining Pretriggered and Posttriggered Scan Counts

To determine the pretriggered and posttriggered scan counts, let A denote the desired pretriggered scans, and B denote the desired total number of scans. Use Table 4-8 to determine how you should program the master and the slave devices.

Table 4-8. Master/Slave Programming

Sample Rate	Master Board		Slave Board	
	Pretrigger Scans	Total Number of Scans	Pretrigger Scans	Total Number of Scans
20 MHz	A + 1	B + 4	A + 6	B
10 MHz	A + 1	B + 4	A + 3	B
6.667 MHz	A + 1	B + 4	A + 1	B
5 MHz or lower	A + 1	B + 4	A	B

This algorithm results in an extra pretriggered point on all boards and three additional posttriggered points on the master board. If this is an undesirable effect, you could discard points in the application.

For example, when programming a master-slave system for 500 pretriggered and 1,000 total number of scans at 20 MHz, refer to Table 4-8 to find that the boards should be programmed as follows:

- Master board—pretrigger scans = 500 + 1 = 501;
  total number of scans = 1,000 + 4 = 1004
- Slave board(s)—pretrigger scans = 500 + 6 = 506;
  total number of scans = 1,000

When programming a master-slave system for 500 pretrigger and 1,000 total number of scans at 100 kHz, you should program the boards as follows:

- Master board—pretrigger scans = 500 + 1 = 501;
  total number of scans = 1,000 + 4 = 1,004
- Slave board(s)— pretrigger scans = 500;
  total number of scans = 1,000

A

Specifications

This appendix lists the specifications of the NI 5102. These specifications are typical at 25° C unless otherwise stated. The operating temperature range is 0° to 50° C.

Input Characteristics

Number of input channels .... 2 single-ended, simultaneously sampled

Input impedance .... 1 MΩ ±1% in parallel with 25 pF ±10 pF
(Impedance increases with attenuating probes)
CH0, CH1, TRIG

ADC resolution .... 8 bits, 1 in 256

Maximum sample rate

- Internal .... 20 MS/s each channel in realtime mode
- External sample clock .... 20 MS/s
  - Minimum high or low time ...... 24 ns
- RIS mode .... 1 GS/s

Minimum sample rate .... 1 kS/s (internal/external)

Maximum input range .... ±5000 V, DC + peak AC<5Mhz (with a X1000 probe)
±500 V, DC + peak AC<15Mhz (with a X100 probe)
±50 V, DC + peak AC<15Mhz (with a X10 probe)
±5 V, DC + peak AC<15Mhz (with a X1 probe)

Input signal ranges (CH0, CH1) (without probe attenuation)	±5 V at gain of 1 ±1 V at gain of 5 ±0.25 V at gain of 20 ±50 mV at gain of 100
Input coupling	AC or DC, software-selectable
Overvoltage protection	±42 V (DC + peak AC<10Khz without external attenuation) CH0, CH1, TRIG only
Onboard FIFO memory depth	663,000 samples
Max waveform buffer	Up to 16 million samples on each channel on NI 5102 (PCI, PXI) with bus mastering, depends on available host memory 663,000 samples on NI 5102 (ISA, PCMCIA)
Data transfers	Programmed I/O supported on all boards; direct-to-memory burst transfers with PCI bus mastering on NI 5102 (PCI, PXI) only

Transfer Characteristics

Relative accuracy	±1 LSB typ, ±1.8 LSB max
Differential nonlinearity	±0.3 LSB typ, ±0.5 LSB max
No missing codes	8 bits guaranteed
Offset error after calibration	±1.5 LSB max
Gain error after calibration	±1% max
DC accuracy	±2.5% of full scale at all gains

Dynamic Characteristics

Bandwidth

- Small signal (–3 dB) .... 15 MHz typ
- Large signal (2% THD) .... 10 MHz typ
- AC coupling low frequency cut-off............................. 11 Hz (1.1 Hz with X10 probe)

Settling for full-scale step to ±1% full-scale range .... 50 ns typ

System noise .... 0.5 LSB rms typ

Crosstalk.. –60 dB

S/H Characteristics

Interchannel skew .... 1 ns

Aperture jitter... 1 ns rms

Stability

Recommended warmup time .... 15 minutes

Offset temperature coefficient .... (1 mV/° C)/gain + 30 µV/° C

Gain temperature coefficient.................. 50 ppm/° C

Timebase accuracy................................. 100 ppm over operating temperature range

Triggers

Analog Trigger

Source... CH0, CH1, TRIG

Level... 256 levels between ±Full-scale for CH0 and CH1; ±5 V for TRIG; software-selectable

Slope... Positive or negative, Software-selectable

Resolution .... 8 bits, 1 in 256

Hysteresis .... Software-programmable, up to full-scale

Bandwidth .... 15 MHz

Trigger hold-off .... 800 ns to 6.71 seconds

Digital Triggers (PFI1 and PFI2)

Compatibility .... TTL/CMOS

Response .... Rising or falling edge; software-selectable

Pulse width .... 10 ns min

DC characteristics over operating range

Symbol	Parameter	Conditions	Min	Max
V_{IH}	Input HIGH voltage	—	2.0 V	V_{cc}+ 0.5 V
V_{IL}	Input LOW voltage	—	–0.5	0.8 V
V_{OH}	Output HIGH voltage	I_{OH} = –4 mA I_{OH} = –16 mA I_{OH} = –10 µA	3.7 V 2.4 V VCC-0.1 V	—
V_{OL}	Output LOW voltage	I_{OL} = 16 mA I_{OL} = 10 µA	—	0.45 V 0.1 V
C_{in}	Input capacitance (nominal)	—	—	10 pF
I_{OS}	Output short circuit current[1]	V_O = GND V_O = Vcc	–15 mA 40 mA	–120 mA 210 mA

[1] Only one output at a time; duration should not exceed 30 s.

RTSI (NI 5102 for PCI, PXI, ISA Only)

Trigger lines .... 7 I/O (6 I/O on the PXI-5102)

Clock lines 1

Power Consumption

NI 5102 (PCI) 5 V DC (±5%)................ 500 mA typ

NI 5102 (PXI) 5 V DC (±5%)................ 550 mA typ

NI 5102 (ISA) 5 V DC (±5%)................ 300 mA typ

NI 5102 (PCMCIA) 5 V DC (±5%)....... 260 mA typ, active
60 mA standby

NI 5102 (USB)
External power supply .... 4 W max

Physical

PCMCIA card type................................ Type II

Dimensions
NI 5102 (PCI) .... 10.67 by 17.45 cm
(4.2 by 6.87 in.)
NI 5102 (PXI) .... 10.00 by 17.00 cm
(3.94 by 6.69 in.)
NI 5102 (ISA) .... 10.67 by 17.45 cm
(4.2 by 6.87 in.)
NI 5102 (USB)................................ 14.6 by 21.3 by 3.8 cm
(5.8 by 8.4 by 1.5 in.)

Environment

Operating temperature............................ 0° to 55° C

Storage temperature .... –55° to 150° C

Relative humidity.................................. 5% to 90% noncondensing

B

Customer Communication

For your convenience, this appendix contains forms to help you gather the information necessary to help us solve your technical problems and a form you can use to comment on the product documentation. When you contact us, we need the information on the Technical Support Form and the configuration form, if your manual contains one, about your system configuration to answer your questions as quickly as possible.

National Instruments has technical assistance through electronic, fax, and telephone systems to quickly provide the information you need. Our electronic services include a bulletin board service, an FTP site, a fax-on-demand system, and e-mail support. If you have a hardware or software problem, first try the electronic support systems. If the information available on these systems does not answer your questions, we offer fax and telephone support through our technical support centers, which are staffed by applications engineers.

Electronic Services

Bulletin Board Support

National Instruments has BBS and FTP sites dedicated for 24-hour support with a collection of files and documents to answer most common customer questions. From these sites, you can also download the latest instrument drivers, updates, and example programs. For recorded instructions on how to use the bulletin board and FTP services and for BBS automated information, call 512 795 6990. You can access these services at:

United States: 512 794 5422
Up to 14,400 baud, 8 data bits, 1 stop bit, no parity

United Kingdom: 01635 551422
Up to 9,600 baud, 8 data bits, 1 stop bit, no parity

France: 01 48 65 15 59
Up to 9,600 baud, 8 data bits, 1 stop bit, no parity

FTP Support

To access our FTP site, log on to our Internet host, `ftp.natinst.com`, as `anonymous` and use your Internet address, such as `joesmith@anywhere.com`, as your password. The support files and documents are located in the `/support` directories.

Fax-on-Demand Support

Fax-on-Demand is a 24-hour information retrieval system containing a library of documents on a wide range of technical information. You can access Fax-on-Demand from a touch-tone telephone at 512 418 1111.

E-Mail Support (Currently USA Only)

You can submit technical support questions to the applications engineering team through e-mail at the Internet address listed below. Remember to include your name, address, and phone number so we can contact you with solutions and suggestions.

`support@natinst.com`

Telephone and Fax Support

National Instruments has branch offices all over the world. Use the list below to find the technical support number for your country. If there is no National Instruments office in your country, contact the source from which you purchased your software to obtain support.

Country	Telephone	Fax
Australia	03 9879 5166	03 9879 6277
Austria	0662 45 79 90 0	0662 45 79 90 19
Belgium	02 757 00 20	02 757 03 11
Brazil	011 288 3336	011 288 8528
Canada (Ontario)	905 785 0085	905 785 0086
Canada (Québec)	514 694 8521	514 694 4399
Denmark	45 76 26 00	45 76 26 02
Finland	09 725 725 11	09 725 725 55
France	01 48 14 24 24	01 48 14 24 14
Germany	089 741 31 30	089 714 60 35
Hong Kong	2645 3186	2686 8505
Israel	03 6120092	03 6120095
Italy	02 413091	02 41309215
Japan	03 5472 2970	03 5472 2977
Korea	02 596 7456	02 596 7455
Mexico	5 520 2635	5 520 3282
Netherlands	0348 433466	0348 430673
Norway	32 84 84 00	32 84 86 00
Singapore	2265886	2265887
Spain	91 640 0085	91 640 0533
Sweden	08 730 49 70	08 730 43 70
Switzerland	056 200 51 51	056 200 51 55
Taiwan	02 377 1200	02 737 4644
United Kingdom	01635 523545	01635 523154
United States	512 795 8248	512 794 5678

Technical Support Form

Photocopy this form and update it each time you make changes to your software or hardware, and use the completed copy of this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

If you are using any National Instruments hardware or software products related to this problem, include the configuration forms from their user manuals. Include additional pages if necessary.

Name ____

Company ____

Address ____

____

Fax (___) _________________Phone (___) ________________________________

Computer brand_____________ Model ___________________Processor____________________

Operating system (include version number) ____________________________________

Clock speed ______MHz RAM _____MB Display adapter __________________________

Mouse ___yes ___no Other adapters installed_______________________________

Hard disk capacity _____MB Brand____

Instruments used ____

____

National Instruments hardware product model _____________ Revision ____________________

Configuration ____

National Instruments software product ___________________ Version ____________________

Configuration ____

The problem is: ____

____

____

____

____

List any error messages: ____

____

____

The following steps reproduce the problem: _______________________________

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NI 5102 Hardware and Software Configuration Form

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DAQ hardware ____________________

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Interrupt level of hardware ____________________

DMA channels of hardware ____________________

Base I/O address of hardware ____________________

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Other boards in system ____________________

Base I/O address of other boards ____________________

DMA channels of other boards ____________________

Interrupt level of other boards ____________________

Other Products

Computer make and model ____________________

Microprocessor ____________________

Clock frequency or speed ____________________

Type of video board installed ____________________

Operating system version ____________________

Operating system mode ____________________

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Programming language version ____________________

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Base I/O address of other boards ____________________

DMA channels of other boards ____________________

Interrupt level of other boards ____________________

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Glossary

Prefix	Meaning	Value
p-	pico-	10^{-12}
n-	nano-	10^{-9}
μ-	micro-	10^{-6}
m-	milli-	10^{-3}
k-	kilo-	10^{3}
M-	mega-	10^{6}
G-	giga-	10^{9}

Numbers/Symbols

°	degree
–	negative of, or minus
Ω	ohm
/	per
%	percent
+	positive of, or plus
±	plus or minus
+5V	+5 Volts signal

A

A	amperes
AC	alternating current
AC coupled	allowing the transmission of AC signals while blocking DC signals

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
alias	a false lower frequency component that appears in sampled data acquired at too low a sampling rate
amplification	a type of signal conditioning that improves accuracy in the resulting digitized signal and reduces noise
amplitude flatness	a measure of how close to constant the gain of a circuit remains over a range of frequencies
analog bandwidth	the frequency at which the measured amplitude is 3 dB below the actual amplitude of the signal. This amplitude loss occurs at very low frequencies if the signal is AC coupled and at very high frequencies, regardless of coupling
Analog Trigger Circuit Output	digital output of the analog trigger circuit
ANSI	American National Standards Institute
ASIC	Application-Specific Integrated Circuit—a proprietary semiconductor component designed and manufactured to perform a set of specific functions for a specific customer
attenuate	to decrease the amplitude of a signal
attenuation ratio	the factor by which a signal's amplitude is decreased

B

b	bit—one binary digit, either 0 or 1
B	byte—eight related bits of data, an eight-bit binary number. Also used to denote the amount of memory required to store one byte of data

bandwidth	the range of frequencies present in a signal, or the range of frequencies to which a measuring device can respond
bipolar	a signal range that includes both positive and negative values (for example, –5 V to +5 V)
BNC	a type of coaxial signal connector
buffer	temporary storage for acquired or generated data
burst-mode	a high-speed data transfer in which the address of the data is sent followed by back-to-back data words while a physical signal is asserted
bus	the group of conductors that interconnect individual circuitry in a computer. Typically, a bus is the expansion vehicle to which I/O or other devices are connected. Examples of PC buses are the PCI bus, AT bus, NuBus, Micro Channel, and EISA 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
cache	high-speed processor memory that buffers commonly used instructions or data to increase processing throughput
CalDAC	calibration DAC
calibration	the process of minimizing measurement errors by making small circuit adjustments
cascading	process of extending the counting range of a counter chip by connecting to the next higher counter
C_c	lumped cable capacitance
CH0	channel number zero
CH1	channel number one

channel	pin or wire lead to which you apply or from which you read the analog or digital signal. Analog signals can be single-ended or differential. For digital signals, you group channels to form ports. Ports usually consist of either four or eight digital channels
C_{in}	input capacitance
circuit trigger	a condition for starting or stopping clocks
clock	hardware component that controls timing for reading from or writing to groups
CMOS	complementary metal-oxide semiconductor
CMRR	common-mode rejection ratio—a measure of an instrument’s ability to reject interference from a common-mode signal, usually expressed in decibels (dB)
code width	the smallest detectable change in an input voltage of a DAQ device
cold-junction compensation	a method of compensating for inaccuracies in thermocouple circuits
common-mode range	the input range over which a circuit can handle a common-mode signal
common-mode signal	the mathematical average voltage, relative to the computer’s ground, of the signals from a differential input
common-mode voltage	any voltage present at the instrumentation amplifier inputs with respect to amplifier ground
compensation range	the range of a parameter for which compensating adjustment can be made
conditional retrieval	a method of triggering in which you simulate an analog trigger using software. Also called software triggering
conversion device	device that transforms a signal from one form to another. For example, analog-to-digital converters (ADCs) for analog input, digital-to-analog converters (DACs) for analog output, digital input or output ports, and counter/timers are conversion devices
conversion time	the time required, in an analog input or output system, from the moment a channel is interrogated (such as with a read instruction) to the moment that accurate data is available

counter/timer	a circuit that counts external pulses or clock pulses (timing)
coupling	the manner in which a signal is connected from one location to another
C_p	probe capacitance
CPU	central processing unit
crosstalk	an unwanted signal on one channel due to an input on a different channel
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
current sinking	the ability of a DAQ device to dissipate current for analog or digital output signals
current sourcing	the ability of a DAQ device to supply current for analog or digital output signals

D

D/A	digital-to-analog
D*/A	digital-to-analog, active low
DAC	digital-to-analog converter—an electronic device, often an integrated circuit, that converts a digital number into a corresponding analog voltage or current
daisy-chain	a method of propagating signals along a bus, in which the devices are prioritized on the basis of their position on the bus
DAQ	data acquisition—(1) collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures and inputting them to a computer for processing; (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=20log10 V1/V2, for signals in volts
DC	direct current

DC coupled	allowing the transmission of both AC and DC signals
default setting	a default parameter value recorded in the driver. In many cases, the default input of a control is a certain value (often 0) that means *use the current default setting*. For example, the default input for a parameter may be *do not change current setting*, and the default setting may be *no AMUX-64T boards*. If you do change the value of such a parameter, the new value becomes the new setting. You can set default settings for some parameters in the configuration utility or manually using switches located on the device
device	a plug-in DAQ device, card, or pad that can contain multiple channels and conversion devices. Plug-in boards, PCMCIA cards, and devices such as the DAQPad-1200, which connects to your computer parallel port, are all examples of DAQ devices. SCXI modules are distinct from devices, with the exception of the SCXI-1200, which is a hybrid
DIFF	differential mode
differential input	an analog input consisting of two terminals, both of which are isolated from computer ground, whose difference is measured
differential measurement system	a way you can configure your device to read signals, in which you do not need to connect either input to a fixed reference, such as the earth or a building ground
digital port	*See* port
digital trigger	a TTL level signal having two discrete levels—a high and a low level
DIN	Deutsche Industrie Norme
DIO	digital input/output
DIP	dual inline package
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

DOS	disk operating system
down counter	performing frequency division on an internal signal
DRAM	dynamic RAM
drivers	software that controls a specific hardware device such as a DAQ device or a GPIB interface board
DSO	digital storage oscilloscope
dual-access memory	memory that can be sequentially accessed by more than one controller or processor but not simultaneously accessed. Also known as shared memory.
dynamic range	the ratio of the largest signal level a circuit can handle to the smallest signal level it can handle (usually taken to be the noise level), normally expressed in decibels

E

EEPROM	electrically erasable programmable read-only memory—ROM that can be erased with an electrical signal and reprogrammed
EISA	extended industry standard architecture
electrostatically coupled	propagating a signal by means of a varying electric field
EMC	electromechanical compliance
encoder	a device that converts linear or rotary displacement into digital or pulse signals. The most popular type of encoder is the optical encoder, which uses a rotating disk with alternating opaque areas, a light source, and a photodetector
End of Acquisition	end of acquisition signal
EPROM	erasable programmable read-only memory—ROM that can be erased (usually by ultraviolet light exposure) and reprogrammed
ETS	equivalent time sampling

expansion ROM	an onboard EEPROM that may contain device-specific initialization and system boot functionality
external trigger	a voltage pulse from an external source that triggers an event such as A/D conversion

F

false triggering	triggering that occurs at an unintended time
FET	field-effect transistor
fetch-and-deposit	a data transfer in which the data bytes are transferred from the source to the controller, and then from the controller to the target
FIFO	first-in first-out memory buffer—the first data stored is the first data sent to the acceptor. FIFOs are often used on DAQ devices to temporarily store incoming or outgoing data until that data can be retrieved or output. For example, an analog input FIFO stores the results of A/D conversions until the data can be retrieved into system memory, a process that requires the servicing of interrupts and often the programming of the DMA controller. This process can take several milliseconds in some cases. During this time, data accumulates in the FIFO for future retrieval. With a larger FIFO, longer latencies can be tolerated. In the case of analog output, a FIFO permits faster update rates, because the waveform data can be stored on the FIFO ahead of time. This again reduces the effect of latencies associated with getting the data from system memory to the DAQ device
filtering	a type of signal conditioning that allows you to filter unwanted signals from the signal you are trying to measure
flash ADC	an ADC whose output code is determined in a single step by a bank of comparators and encoding logic
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
ft	feet

G

gain	the factor by which a signal is amplified, sometimes expressed in decibels
gain accuracy	a measure of deviation of the gain of an amplifier from the ideal gain
GND	ground signal
grounded measurement system	*See* RSE

H

h	hour
half-flash ADC	an ADC that determines its output code by digitally combining the results of two sequentially performed, lower-resolution flash conversions
half-power bandwidth	the frequency range over which a circuit maintains a level of at least –3 dB with respect to the maximum level
hardware	the physical components of a computer system, such as the circuit boards, plug-in boards, chassis, enclosures, peripherals, cables, and so on
hex	hexadecimal
Hz	hertz—the number of scans read or updates written per second

I

IBM	International Business Machines
IC	integrated circuit
ID	identification
IEEE	Institute of Electrical and Electronics Engineers
in.	inches
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
instrument driver	a set of high-level software functions that controls a specific GPIB, VXI, or RS-232 programmable instrument or a specific plug-in DAQ device. Instrument drivers are available in several forms, ranging from a function callable language to a virtual instrument (VI) in LabVIEW
interrupt	a computer signal indicating that the CPU should suspend its current task to service a designated activity
interrupt level	the relative priority at which a device can interrupt
interval scanning	scanning method where there is a longer interval between scans than there is between individual channels comprising a scan
INTR*	interrupt request signal, active low
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
I_{OS}	output short circuit current
IRQ	interrupt request
ISA	industry standard architecture
isolation	a type of signal conditioning in which you isolate the transducer signals from the computer for safety purposes. This protects you and your computer from large voltage spikes and makes sure the measurements from the DAQ device are not affected by differences in ground potentials
isolation voltage	the voltage that an isolated circuit can normally withstand, usually specified from input to input and/or from any input to the amplifier output, or to the computer bus

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
kbytes/s	a unit for data transfer that means 1,000 or 10^3 bytes/s
kS	1,000 samples
Kword	1,024 words of memory

L

LabVIEW	laboratory virtual instrument engineering workbench
latched digital I/O	a type of digital acquisition/generation where a device or module accepts or transfers data after a digital pulse has been received. Also called handshaked digital I/O
LED	light-emitting diode
low-frequency corner	in an AC-coupled circuit, the frequency below which signals are attenuated by at least 3 dB
LSB	least significant bit

M

m	meters
M	(1) Mega, the standard metric prefix for 1 million or 10^6, when used with units of measure such as volts and hertz; (2) mega, the prefix for 1,048,576, or 2^{20}, when used with B to quantify data or computer memory
MB	megabytes of memory
Mbytes/s	a unit for data transfer that means 1 million or 10^6 bytes/s
memory buffer	*See* buffer

MFLOPS	million floating-point operations per second—the unit for expressing the computational power of a processor
MIPS	million instructions per second—the unit for expressing the speed of processor machine code instructions
MISO	Master-In-Slave-Out signal
MITE	MXI Interfaces to Everything—a custom ASIC designed by National Instruments that implements the PCI bus interface. The MITE supports bus mastering for high speed data transfers over the PCI bus
MOSI	Master-Out-Slave-In signal
MS	million samples
MSB	most significant bit
MTBF	mean time between failure
mux	multiplexer—a switching device with multiple inputs that sequentially connects each of its inputs to its output, typically at high speeds, in order to measure several signals with a single analog input channel

N

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

NRSE — nonreferenced single-ended mode—all measurements are made with respect to a common (NRSE) measurement system reference, but the voltage at this reference can vary with respect to the measurement system ground

Nyquist Sampling Theorem — a law of sampling theory stating that if a continuous bandwidth-limited signal contains no frequency components higher than half the frequency at which it is sampled, then the original signal can be recovered without distortion

O

onboard channels — channels provided by the plug-in DAQ device

onboard RAM — optional RAM usually installed into SIMM slots

operating system — base-level software that controls a computer, runs programs, interacts with users, and communicates with installed hardware or peripheral devices

P

passband — the range of frequencies that a device can properly propagate or measure

PC Card — a credit-card-sized expansion card that fits in a PCMCIA slot; often referred to as a PCMCIA card

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 workstations; it offers a theoretical maximum transfer rate of 132 Mbytes/s

PCMCIA — an expansion bus architecture that has found widespread acceptance as a *de facto* standard in notebook-size computers. It originated as a specification for add-on memory cards written by the Personal Computer Memory Card International Association

peak to peak — a measure of signal amplitude; the difference between the highest and lowest excursions of the signal

pF — picofarads

PFI — programmable function input

PGIA	programmable gain instrumentation amplifier
pipeline	a high-performance processor structure in which the completion of an instruction is broken into its elements so that several elements can be processed simultaneously from different instructions
Plug and Play devices	devices that do not require DIP switches or jumpers to configure resources on the devices—also called switchless devices
Plug and Play ISA	a specification prepared by Microsoft, Intel, and other PC-related companies that will result in PCs with plug-in boards that can be fully configured in software, without jumpers or switches on the boards
port	(1) a communications connection on a computer or a remote controller (2) a digital port, consisting of four or eight lines of digital input and/or output
postriggering	the technique used on a DAQ device to acquire a programmed number of samples after trigger conditions are met
potentiometer	an electrical device the resistance of which can be manually adjusted; used for manual adjustment of electrical circuits and as a transducer for linear or rotary position
ppm	parts per million
pretriggering	the technique used on a DAQ device to keep a continuous buffer filled with data, so that when the trigger conditions are met, the sample includes the data leading up to the trigger condition
probe compensation	adjusting the tunable probe capacitor to get a flat frequency response
protocol	the exact sequence of bits, characters, and control codes used to transfer data between computers and peripherals through a communications channel, such as the GPIB bus
pts	points
pulse trains	multiple pulses
pulsed output	a form of counter signal generation by which a pulse is outputted when a counter reaches a certain value
PXI	PCI eXtensions for Instrumentation—an open specification that builds off the CompactPCI specification by adding instrumentation-specific features

R

RAM	random-access memory
real time	a property of an event or system in which data is processed as it is acquired instead of being accumulated and processed at a later time
record length	the amount of memory dedicated to storing digitized samples for postscripting or display. In a digitizer, this limits the maximum duration of a single-shot acquisition
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
referenced single-ended measurement system	all measurements are made with respect to a common reference measurement system or a ground. Also called a grounded measurement system
relative accuracy	a measure in LSB of the accuracy of an ADC. It includes all nonlinearity and quantization errors. It does not include offset and gain errors of the circuitry feeding the ADC
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 percent of full scale.
R_{in}	input resistance
RIS	random-interleaved sampling
RIS GAIN	the range of values that TDC can return; the maximum TDC value minus the minimum TDC value
RIS OFFSET	the minimum value that the TDC can return
rise time	the difference in time between the 10% and 90% points of a system’s step response
rms	root mean square—a measure of signal amplitude; the square root of the average value of the square of the instantaneous signal amplitude
ROM	read-only memory

R_p	probe resistance
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 boards, for precise synchronization of functions

S

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
sample rate	the rate at which a signal is sampled and digitized by an ADC
scan	one or more analog or digital input samples. Typically, the number of input samples in a scan is equal to the number of channels in the input group. For example, one pulse from the scan clock produces one scan which acquires one new sample from every analog input channel in the group
scan clock	the clock controlling the time interval between scans. On boards with interval scanning support (for example, the AT-MIO-16F-5), this clock gates the channel clock on and off. On boards with simultaneous sampling (for example, the EISA-A2000), this clock clocks the track-and-hold circuitry
SCANCLK	scan clock signal
scan rate	the number of scans per second. For example, a scan rate of 10 Hz means sampling each channel 10 times per second
SC_TC	scan counter terminal count signal
SCXI	Signal Conditioning eXtensions for Instrumentation—the National Instruments product line for conditioning low-level signals within an external chassis near sensors so only high-level signals are sent to DAQ devices in the noisy PC environment

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 device that has an extremely stable onboard reference and calibrates its own A/D and D/A circuits without manual adjustments by the user
settling time	the amount of time required for a voltage to reach its final value within specified limits
S/H	sample-and-hold—a circuit that acquires and stores an analog voltage on a capacitor for a short period of time
shared memory	*See* dual-access memory
signal divider	performing frequency division on an external signal
SIMM	single in-line memory module
Slot0Sel	slot 0 select signal
SMB	a type of miniature coaxial signal connector
SNR	signal-to-noise ratio—the ratio of the overall rms signal level to the rms noise level, expressed in decibels
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 impedance	a parameter of signal sources that reflects current-driving ability of voltage sources (lower is better) and the voltage-driving ability of current sources (higher is better)
SPICLK	Serial Peripheral Interface Clock signal
S/s	samples per second—used to express the rate at which a DAQ device samples an analog signal
Start Trigger	start trigger signal
STC	system timing controller

switchless device	devices that do not require dip switches or jumpers to configure resources on the devices—also called Plug and Play devices
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
system noise	a measure of the amount of noise seen by an analog circuit or an ADC when the analog inputs are grounded
system RAM	RAM installed on a personal computer and used by the operating system, as contrasted with onboard RAM

T

TC	terminal count—the highest value of a counter
TDC	time-to-digital converter
T/H	track-and-hold—a circuit that tracks an analog voltage and holds the value on command
time constant	a measure of a system’s response time
transfer rate	the rate, measured in bytes/s, at which data is moved from source to destination after software initialization and set up operations; the maximum rate at which the hardware can operate
TRIG	a trigger channel
trigger	any event that causes or starts some form of data capture
trigger hold-off	a signal processing technique that lets you specify a time from the trigger event to ignore additional triggers that fall within that time
TTL	transistor-transistor logic

U

unipolar	a signal range that is always positive (for example, 0 to +10 V)
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 that 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_{DC}	volts direct current
VDMAD	virtual DMA driver
vertical sensitivity	describes the smallest input voltage change the digitizer can capture
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_{IH}	volts, input high
V_{IL}	volts, input low
V_{in}	volts in
V_O	volts, output
V_{OH}	volts, output high
V_{OL}	volts, output low
$V_{pk\text{-}to\text{-}pk}$	the maximum signal voltage minus the minimum signal voltage. This reflects the maximum change in signal voltage and affects the vertical sensitivity or gain of the input amplifier
V_{ref}	reference voltage

W

W	watts
waveform	multiple voltage readings taken at a specific sampling rate
word	the standard number of bits that a processor or memory manipulates at one time. Microprocessors typically use 8, 16, or 32-bit words
working voltage	the highest voltage that should be applied to a product in normal use, normally well under the breakdown voltage for safety margin

Z

zero-overhead looping	the ability of a high-performance processor to repeat instructions without requiring time to branch to the beginning of the instructions
zero-wait-state memory	memory fast enough that the processor does not have to wait during any reads and writes to the memory

Index

D

E

F

H

I

L

M

N

O

P

R

S

T

U

V