DAQ

NI 447*X* User Manual

Dynamic Signal Acquisition Devices for PCI and PXI/CompactPCI

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FCC/Canada Radio Frequency Interference Compliance

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Depending on where it is operated, this Class A product could be subject to restrictions in the FCC rules. (In Canada, the Department of Communications (DOC), of Industry Canada, regulates wireless interference in much the same way.) Digital electronics emit weak signals during normal operation that can affect radio, television, or other wireless products.

All Class A products display a simple warning statement of one paragraph in length regarding interference and undesired operation. The FCC rules have restrictions regarding the locations where FCC Class A products can be operated.

Consult the FCC Web site at `www.fcc.gov` for more information.

FCC/DOC Warnings

This equipment generates and uses radio frequency energy and, if not installed and used in strict accordance with the instructions in this manual and the CE marking Declaration of Conformity*, may cause interference to radio and television reception. Classification requirements are the same for the Federal Communications Commission (FCC) and the Canadian Department of Communications (DOC).

Changes or modifications not expressly approved by NI could void the user's authority to operate the equipment under the FCC Rules.

Class A

Federal Communications Commission

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user is required to correct the interference at their own expense.

Canadian Department of Communications

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de la classe A respecte toutes les exigences du Règlement sur le matériel brouilleur du Canada.

Compliance to EU Directives

Readers in the European Union (EU) must refer to the manufacturer's Declaration of Conformity (DoC) for information* pertaining to the CE marking compliance scheme. The manufacturer includes a DoC for most hardware products except for those bought from OEMs. In addition, DoCs are usually not provided if compliance is not required, for example electrically benign apparatus or cables.

To obtain the DoC for this product, click **Declaration of Conformity** at `ni.com/hardref.nsf/`. This Web site lists the DoCs by product family. Select the appropriate product family, followed by your product, and a link to the DoC appears in Adobe Acrobat format. Click the Acrobat icon to download or read the DoC.

* The CE marking Declaration of Conformity contains important supplementary information and instructions for the user or installer.

Conventions

The following conventions are used in this manual:

<>	Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, DIO<3..0>.
»	The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.
♦	The ♦ symbol indicates that the following text applies only to a specific product, a specific operating system, or a specific software version.
	This icon denotes a note, which alerts you to important information.
	This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash.
bold	Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names and hardware labels.
CompactPCI	A Eurocard configuration of the PCI bus for industrial applications.
IEPE	Integral Electronics Piezoelectric, also known as integrated circuit piezoelectric.
italic	Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text that is a placeholder for a word or value that you must supply.
`monospace`	Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames and extensions, and code excerpts.
NI 447*X*	NI 447*X* refers to the NI PCI-4472, NI PCI-4474, NI PXI-4472, and NI PXI-4472B unless otherwise noted.

NI PCI/PXI-4472	NI PCI/PXI-4472 refers to the NI PCI-4472, NI PXI-4472, and NI PXI-4472B unless otherwise noted.
NI PXI-4472	NI PXI-4472 refers to the NI PXI-4472 and NI PXI-4472B unless otherwise noted.
PCI	A high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA, it is now accepted as a standard for PCs and workstations, and offers a theoretical maximum transfer rate of 132 Mbytes/s.
PXI	PXI stands for PCI eXtensions for Instrumentation. PXI is an open specification that builds off the CompactPCI specification by adding instrumentation-specific features.

Contents

Chapter 1
Getting Started with the NI 447*X*

Chapter 2
Using the NI 447*X*

Chapter 3
Device Overview and Theory of Operation

Chapter 4
Calibration

Appendix A
Specifications

Appendix B
Technical Support and Professional Services

Glossary

Index

1

Getting Started with the NI 447*X*

This chapter describes the NI 447*X* family of dynamic signal acquisition devices, which includes the NI PCI-4472, NI PCI-4474, NI PXI-4472, and NI PXI-4472B. It lists what you need to get started, explains how to unpack the device, and describes your programming choices.

About the NI 447*X*

The NI 447*X* devices are high-performance, high-accuracy analog input devices that are part of the National Instruments Dynamic Signal Acquisition/Analysis (DSA) product family. These devices are specifically designed for demanding dynamic signal acquisition applications.

The NI PCI/PXI-4472 (including the NI PXI-4472B) features eight analog input (AI) channels, and the NI PCI-4474 has four AI channels. The AI channels on all NI 447*X* devices are simultaneously sampled at a maximum rate of 102.4 kS/s with 24-bit resolution and multiple triggering modes, including external digital triggering. Each AI channel has an independent software-switchable 4 mA current source for integrated circuit piezoelectric, also known as *Integral Electronic Piezoelectric* (IEPE), accelerometers and microphone preamplifiers. The NI PXI-4472B differs from the other NI 447*X* devices in having a lower cutoff frequency for AC-coupled input channels. All references to the NI PXI-4472 in this manual also apply to the NI PXI-4472B unless otherwise noted. Refer to Appendix A, *Specifications*, for more details about the NI 447*X*.

The AI circuitry uses oversampling delta-sigma modulating A/D converters (ADCs). Delta-sigma converters are inherently linear, provide built-in brick-wall antialiasing filters, and have specifications that exceed other conventional technology for this application with regard to total harmonic distortion (THD), signal-to-noise ratio (SNR), and amplitude flatness. These features help you acquire signals with high accuracy and high fidelity without introducing noise or out-of-band aliases.

Applications for NI 447*X* devices include audio signal processing and analysis, acoustics and speech research, sonar, audio frequency test and measurement, vibration, structural dynamics, and modal analysis, or any application requiring high-fidelity signal acquisition.

What You Need to Get Started

To set up and use the NI 447*X* devices, you need the following items:

- ❑ One of the following devices:
  - – NI PCI-4472
  - – NI PCI-4474
  - – NI PXI-4472
  - – NI PXI-4472B
- ❑ *NI 447X User Manual*
- ❑ One of the following software packages and documentation:
  - – LabVIEW software for Windows
  - – Measurement Studio software for Windows
  - – A supported application development environment, such as Visual C++
- ❑ NI-DAQ driver software and documentation
- ❑ A PCI-bus computer, or a PXI or CompactPCI chassis and controller
- ❑ Female SMB connector cables

Related Documentation

The following documents contain information that you may find helpful:

- *DAQ Quick Start Guide*
- *Field Wiring and Noise Considerations for Analog Signals*, available in the NI Developer Zone at `ni.com/zone`
- *LabVIEW Help*
- *NI-DAQ Function Reference Help* for NI-DAQ version 6.9.*x* and earlier
- *PICMG 2.0 R3.0 CompactPCI* specification, available at `www.picmg.org`
- *PXI Specification Revision 2.0,* available at `www.pxisa.org`
- *Traditional NI-DAQ C Reference Help* for Traditional NI-DAQ version 7.0 and later

For free downloads of the latest documentation, drivers, and programming examples, visit `ni.com`.

Unpacking

The NI 447*X* ships in an antistatic package to prevent electrostatic damage (ESD) to the device. ESD can damage several components on the device.

Caution *Never* touch the exposed pins of connectors.

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

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

Remove the device from the package and inspect the device for loose components or any sign of damage. Notify NI if the device appears damaged in any way. Do *not* install a damaged device into the computer.

Store the NI 447*X* device in the antistatic envelope when not in use.

Software Programming Choices

When programming National Instruments data acquisition (DAQ) hardware, you can use an NI application development environment (ADE) or other ADEs. In either case, you use NI-DAQ.

NI-DAQ

NI-DAQ, which ships with the NI 447*X* device, has an extensive library of functions that you can call from the ADE. These functions allow you to use all the features of the NI 447*X*.

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

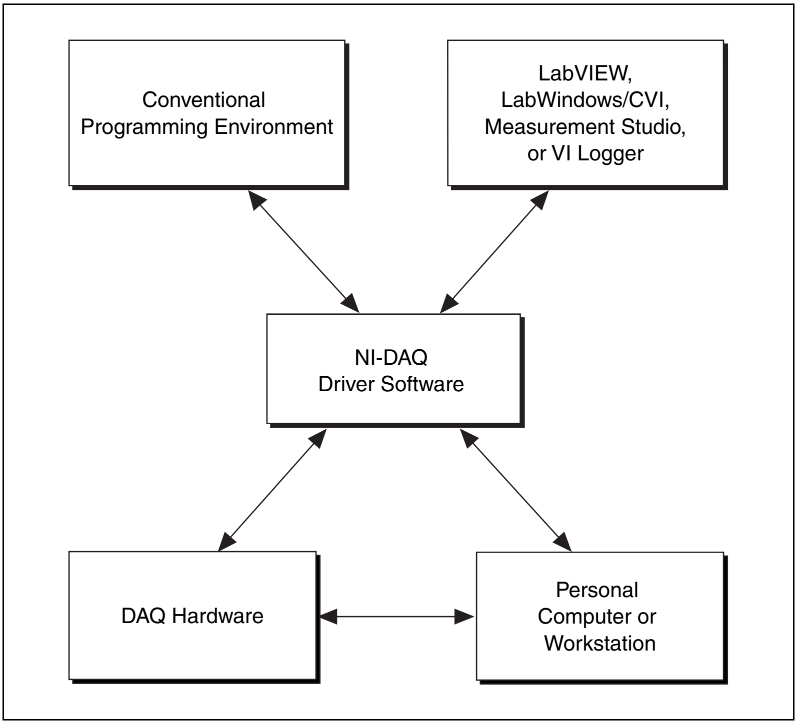

Figure 1-1. The Relationship among the Programming Environment, NI-DAQ, and the Hardware

To download a free copy of the most recent version of NI-DAQ, click **Download Software** at `ni.com`.

National Instruments ADE Software

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

LabWindows/CVI is a complete ANSI C ADE that features an interactive user interface, code generation tools, and the LabWindows/CVI Data Acquisition and Easy I/O libraries.

Measurement Studio, which includes tools for Visual C++ and tools for Visual Basic, is a development suite that allows you to design test and measurement applications. For Visual Basic developers, Measurement Studio features a set of ActiveX controls for using National Instruments

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

Using LabVIEW, LabWindows/CVI, or Measurement Studio greatly reduces the development time for your data acquisition and control application.

Using PXI with CompactPCI

- NI PXI-4472/4472B

Using PXI-compatible products with standard CompactPCI products is an important feature provided by the *PXI Specification Revision 2.0*. If you use a PXI-compatible plug-in device in a standard CompactPCI chassis, you are unable to use PXI-specific functions, but you can still use the basic plug-in device functions. For example, the RTSI bus on the NI PXI-4472 is available in a PXI chassis but not in a CompactPCI chassis.

Note The CompactPCI specification does not require the chassis to supply +3.3 V to the device, but the NI PXI-4472 requires +3.3 V power on the PCI bus in order to work. Refer to Appendix A, *Specifications*, for complete power requirements.

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. The NI PXI-4472 works in any standard CompactPCI chassis adhering to the *PICMG 2.0 R3.0 CompactPCI* specification.

Caution Damage to the equipment can occur if the lines shown in Table 1-1 are driven by a CompactPCI sub-bus.

PXI-specific features are implemented on the J2 connector of the CompactPCI bus. Table 1-1 lists the J2 pins used by the NI PXI-4472. The NI PXI-4472 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 PXI-4472 is still compatible as long as those pins on the sub-bus are disabled by default and not ever enabled. Damage may result if these lines are driven by the sub-bus.

Table 1-1. J2 Connector Pins Used by the NI PXI-4472

NI PXI-4472 Signal	PXI Pin Name	PXI J2 Pin Number
Master Clock Distribution	LBL<0..12>	C20, E20, A19, C19, D19, E19, D15, D2, E2, A1, C1, D1, E1
Sync Pulse	PXI Trigger 5	C18
Reserved	LBR<0..12>	A21, C21, D21, E21, A20, B20, E15, A3, C3, D3, E3, A2, B2
Master Clock Reception	PXI Star In	D17

In some circumstances, it is possible to drive some of these lines in the same chassis as the NI PXI-4472. For more information, search the NI Developer Zone at `ni.com/zone`.

Safety Information

The following section contains important safety information that you *must* follow when installing and using NI 447*X*.

Do *not* operate the NI 447*X* in a manner not specified in this document. Misuse of the NI 447*X* can result in a hazard. You can compromise the safety protection built into the NI 447*X* if the NI 447*X* is damaged in any way. If the NI 447*X* is damaged, return it to NI for repair.

Do *not* substitute parts or modify the NI 447*X* except as described in this document. Use the NI 447*X* only with the chassis, modules, accessories, and cables specified in the installation instructions. You *must* have all covers and filler panels installed during operation of the NI 447*X*.

Do *not* operate the NI 447*X* in an explosive atmosphere or where there may be flammable gases or fumes. If you must operate the NI 447*X* device in such an environment, it must be in a suitably rated enclosure.

If you need to clean the NI 447*X*, use a soft, nonmetallic brush. Make sure that the NI 447*X* is completely dry and free from contaminants before returning it to service.

Operate the NI 447*X* only at or below Pollution Degree 2. Pollution is foreign matter in a solid, liquid, or gaseous state that can reduce dielectric strength or surface resistivity. The following is a description of pollution degrees:

- Pollution Degree 1 means no pollution or only dry, nonconductive pollution occurs. The pollution has no influence.
- Pollution Degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Pollution Degree 3 means that conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation.

You *must* insulate signal connections for the maximum voltage for which the NI 447*X* is rated. Do *not* exceed the maximum ratings for the NI 447*X*. Do not install wiring while the NI 447*X* is live with electrical signals. Remove power from signal lines before connecting them to or disconnecting them from the NI 447*X*.

Operate the NI 447*X* at or below the *installation category*[1] marked on the hardware label. Measurement circuits are subjected to *working voltages*[2] and transient stresses (overvoltage) from the circuit to which they are connected during measurement or test. Installation categories establish standard impulse withstand voltage levels that commonly occur in electrical distribution systems. The following is a description of installation categories:

- Installation Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS[3] voltage. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.
- Installation Category II is for measurements performed on circuits directly connected to the electrical distribution system. This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (for example, 115 V for U.S. or 230 V for Europe). Examples of Installation Category II are measurements performed on household appliances, portable tools, and similar devices.

[1] Installation categories, also referred to as *measurement categories*, are defined in electrical safety standard IEC 61010-1.

[2] Working voltage is the highest rms value of an AC or DC voltage that can occur across any particular insulation.

[3] MAINS is defined as a hazardous live electrical supply system that powers equipment. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

- Installation Category III is for measurements performed in the building installation at the distribution level. This category refers to measurements on hard-wired equipment such as equipment in fixed installations, distribution boards, and circuit breakers. Other examples are wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and stationary motors with permanent connections to fixed installations.
- Installation Category IV is for measurements performed at the primary electrical supply installation (<1,000 V). Examples include electricity meters and measurements on primary overcurrent protection devices and on ripple control units.

2

Using the NI 447*X*

This chapter explains how to install, configure, and test the NI 447*X*. It also provides information you need to know to acquire signals with the NI 447*X*.

Installing the Software

Complete the following steps to install the software before installing the NI 447*X* device.

1. Install the ADE, such as LabVIEW or Measurement Studio, according to the instructions on the CD and the release notes.
2. Install the NI-DAQ driver software according to the instructions on the CD and the *DAQ Quick Start Guide* included with the device.

Note It is important to install the NI-DAQ before installing the NI 447*X* device to ensure that the device is properly detected.

Installing the Hardware

You can install the NI 447*X* device in any available slot in the PCI-bus computer or PXI/CompactPCI chassis. However, to achieve best noise performance, leave as much room as possible between the NI 447*X* device and other devices and hardware.

Note Follow the guidelines in the documentation for your computer or chassis for installing plug-in hardware.

The following are general installation instructions. Consult the computer or chassis user manual or technical reference manual for specific instructions and warnings about installing new devices.

Note It is important to install NI-DAQ before installing the NI 447*X* to ensure that the device is properly detected.

- NI PCI-4472 and NI PCI-4474
  1. Power off and unplug the computer.
  2. Remove the cover.
  3. Make sure there are no lighted LEDs on the motherboard. If any are lit, wait until they go out before continuing the installation.
  4. Remove the expansion slot cover on the back panel of the computer.
  5. Ground yourself using a grounding strap or by touching a grounded object. Follow the ESD protection precautions described in the *Unpacking* section of Chapter 1, *Getting Started with the NI 447X*.
  6. Insert the NI PCI-4472 or NI PCI-4474 into a PCI slot. Gently rock the device to ease it into place. It may be a tight fit, but do *not* force the device into place.
  7. Screw the mounting bracket of the NI PCI-4472 or NI PCI-4474 to the back panel rail of the computer.
  8. Visually verify the installation. Make sure the device is not touching other devices or components and is fully inserted into the slot.
  9. Replace the cover.
  10. Plug in and power on the computer.

Note For proper cooling, all covers and filler panels must be installed.

The NI PCI-4472 or NI PCI-4474 is now installed.

- NI PXI-4472
  1. Power off and unplug the PXI or CompactPCI chassis.

Note If you are installing more than one NI PXI-4472 device in a PXI or CompactPCI chassis and want to synchronize DAQ operations between the devices, one NI PXI-4472 must be installed in slot 2. Refer to the *Synchronizing Multiple Devices* section for more information.

  2. Choose an unused PXI or CompactPCI slot in the system.

Note For maximum performance when using a non-PXI chassis, install the NI PXI-4472 in a slot that supports bus arbitration or bus-master modules. The NI PXI-4472 contains onboard bus-master DMA logic that you can use only if the NI PXI-4472 is installed in such a slot. NI recommends installing the NI PXI-4472 in such a slot. If you choose a slot that does not support bus masters, you must disable the onboard DMA controller using software. A PXI-compliant chassis must have bus arbitration for all slots.

Caution The NI PXI-4472 has connections to several reserved lines on the CompactPCI J2 connector. Use of these lines by other devices in the CompactPCI system can damage the equipment. Before installing the NI PXI-4472 in a CompactPCI system that uses J2 connector lines for purposes other than PXI, refer to the *Using PXI with CompactPCI* section of Chapter 1, *Getting Started with the NI 447X*.

3. Make sure there are no lighted LEDs on the chassis. If any are lit, wait until they go out before continuing your installation.
4. Remove the filler panel for the slot you have chosen.
5. Ground yourself using a grounding strap or by touching a grounded object. Follow the ESD protection precautions described in the *Unpacking* section of Chapter 1, *Getting Started with the NI 447X*.
6. Insert the NI PXI-4472 into a 5 V PXI slot. Use the injector/ejector handle to fully insert the device into the chassis.
7. Screw the front panel of the NI PXI-4472 to the front panel-mounting rail of the system.

Note To ensure a good ground connection, securely fasten the front panel of the NI PXI-4472 to the chassis with the two screws attached for that purpose.

8. Visually verify the installation. Make sure the device is not touching other devices or components and is fully inserted into the slot.
9. Plug in and power on the computer.

The NI PXI-4472 is now installed.

Testing the Device

The NI 447*X* is completely software configurable. The system software automatically allocates all device resources, including base memory address and interrupt level. This device does not require DMA controller resources from the computer.

To check the configuration of the NI 447*X*, and to test its resource allocations to be sure they do not conflict with any others, refer to the *DAQ Quick Start Guide* included with the device.

You can modify data acquisition-related settings, such as input coupling, through NI application-level software, such as LabVIEW or Measurement Studio, or with NI-DAQ. Refer to device configuration instructions in the

NI-DAQ documents and in the *NI-DAQ Function Reference Help* (**Start»Programs»National Instruments»DAQ»NI-DAQ Help**) for more information.

Connecting Signals

The front panels of the NI PCI/PXI-4472 devices are shown in Figure 2-1, and the NI PCI-4474 front panel is shown in Figure 2-2. There are eight male SMB connectors on the front panel of the NI PCI/PXI-4472 and four male SMB connectors on the front panel of the NI PCI-4474 for connecting analog signals. Each NI 447*X* device also has one male SMB connector for connecting a digital trigger. The analog inputs are unbalanced differential channels with individually configurable AC/DC coupling and IEPE current conditioning. The digital input can accept TTL/CMOS-compatible signals.

Note To minimize noise and ensure more accurate measurements, do *not* allow the connector shells of your SMB cables, SMB-to-BNC adapters, or BNC cables to touch each other, the PCI-bus computer, or the PXI or CompactPCI chassis and controller.

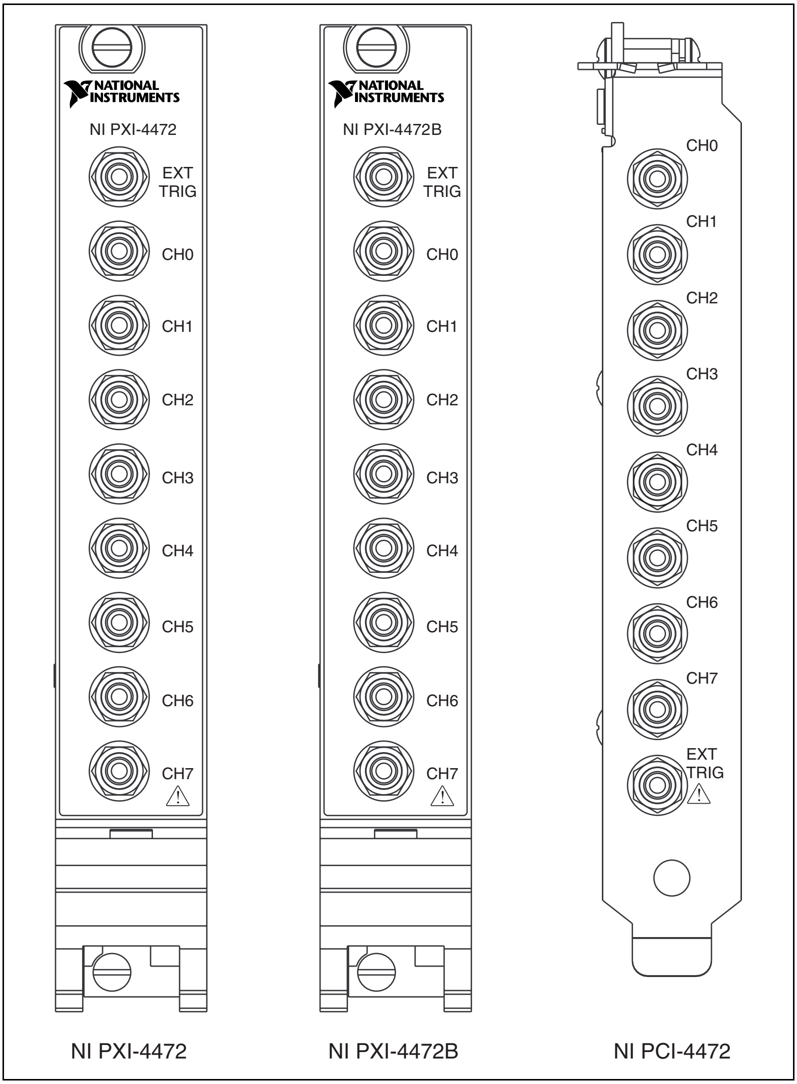

Figure 2-1. NI PCI/PXI-4472 Front Panels

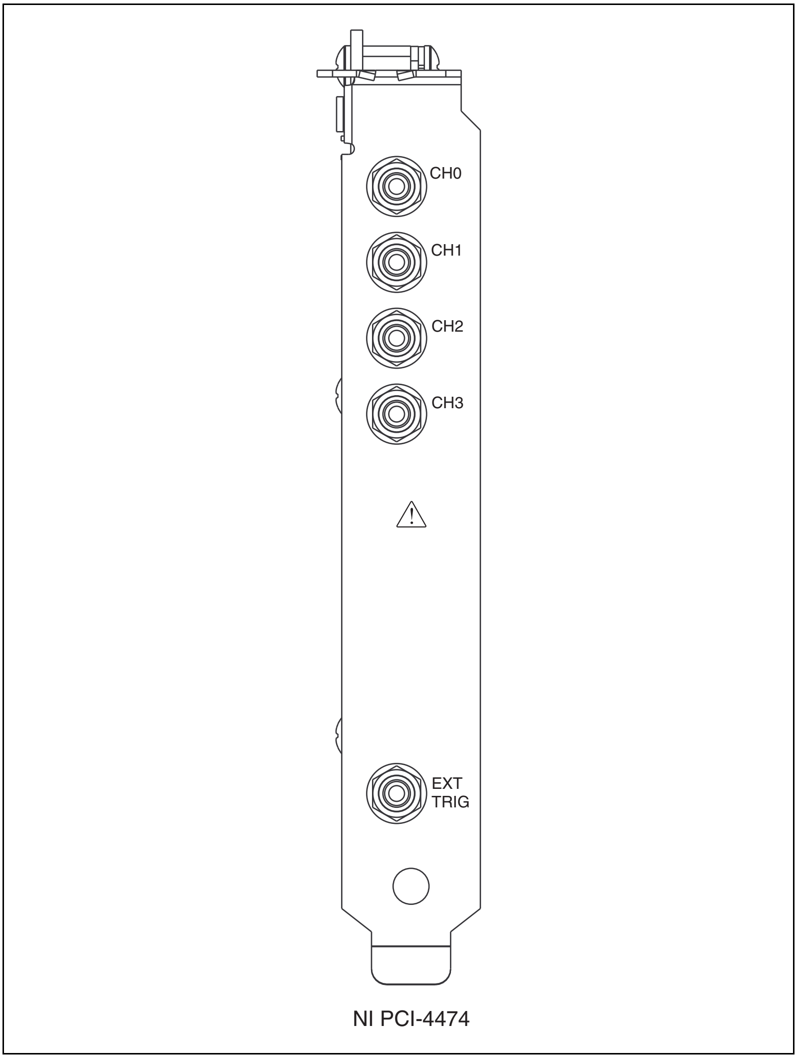

Figure 2-2. NI PCI-4474 Front Panel

Before configuring the AI channels and making signal connections, you must determine the following:

- Whether the input signal source is floating or grounded
- Whether the accelerometer or microphone you are using requires IEPE current stimulation

- Whether AC or DC coupling is best for your application

Note Use AC coupling when IEPE signal conditioning is enabled to remove any DC offset caused by the IEPE transducer. Using DC coupling with IEPE is appropriate only if the impedance of the sensor does not exceed 2.5 kΩ and you are acquiring very low frequency signals.

- The voltage range of the input signal

Signal Sources

The AI channels of the NI 447*X* have unbalanced differential inputs. Figure 2-3 shows the input configurations for floating and grounded signal sources.

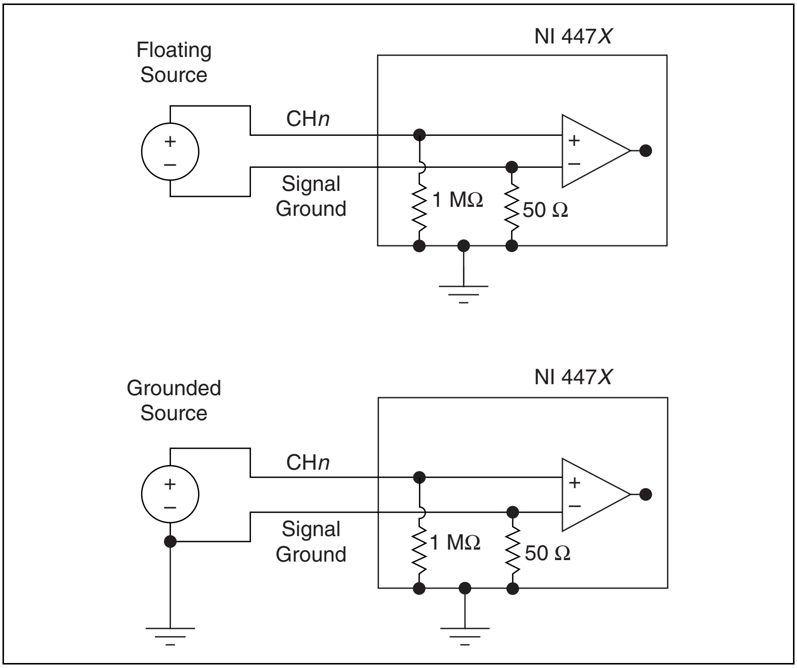

Figure 2-3. Input Configurations for the NI 447*X*

Caution Connecting a signal that varies more than ±2.5 V from the ground reference of the NI 447*X* to the ground (shield) of any AI channel can result in inaccurate measurements or damage to the device. NI is *not* responsible for damage caused by such connections.

Floating Signal Sources

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

It is important to tie the ground reference of a floating signal to the AI ground to establish a local reference for the signal. Otherwise, the measured input signal varies as the source floats out of the common-mode input range. With the NI 447*X*, you tie the signal ground to the AI ground simply by attaching the signal cable to any of the AI channel SMB connectors. Hence, all floating signals fed to the NI 447*X* are automatically ground referenced.

Note Attach the NI 447*X* to the chassis with screws to provide a reliable ground connection. If you are using an NI PCI-4472/4474, keep the small screw that held the PCI slot cover to the computer chassis. Reinsert this screw to securely attach the NI 447*X*. If you are using an NI PXI-4472, be sure to tighten the small screws at the top and bottom of the front face of the module.

Grounded Signal Sources

A ground-referenced signal source connects in some way to the building system ground and is, therefore, already connected to a common-ground point with respect to the NI 447*X*, assuming the PCI-bus computer or PXI or CompactPCI chassis and controller are plugged into the same power system. Non-isolated outputs of instruments and devices that plug into the building power system fall into this category.

The difference in ground potential, or common-mode voltage, between two instruments connected to the same building power system is typically between 1 and 100 mV, but the common-mode voltage can be much higher if power distribution circuits are not properly connected. This difference in ground potential induces currents in the ground system that can cause errors in your measurement. For low common-mode voltages, the 50 Ω resistor on the signal ground is usually sufficient to reduce this current to negligible levels, but results can vary depending on the system setup.

It is best to use the NI 447*X* to acquire data from floating signal sources, but you can measure signals from grounded sources if the ground reference of the source does not vary by more than ±2.5 V from the ground reference of the NI 447*X*.

Generating Onboard Current Excitation with IEPE Circuitry

If you attach an IEPE accelerometer or microphone preamplifier to an AI channel, you must enable the IEPE circuitry for that channel to generate the required excitation current. The IEPE circuitry of any input channel can be enabled or disabled independently of that of any other input channel.

When IEPE signal conditioning is enabled, large DC-offset voltages can occur on signal inputs due to the output bias voltage requirements of the IEPE transducer you are using. To remove this offset, you must enable AC coupling on the affected input channels of the NI 447*X*. Using DC coupling with IEPE is appropriate only if the impedance of the sensor does not exceed 2.5 kΩ and you are acquiring very low frequency signals.

In LabVIEW, use AI Parameter.vi to control the onboard excitation. You can control onboard excitation only for the channels that are configured for an acquisition in AI Config.vi. If you are programming in the NI-DAQ text application program interface (API), you should use the `AI_Change_Parameter` function with the **AI_CHANNEL_DSA_EXCITATION** parameter.

Input Coupling

You can configure each AI channel of the NI 447*X* to be AC- or DC-coupled. If you select DC coupling, any DC offset present in the source signal is passed to the A/D converter (ADC). The DC-coupled configuration is usually best if the signal source has only small amounts of offset voltage (less than ±100 mV) or if the DC content of the acquired signal is important.

If the source has a significant amount of unwanted offset (bias voltage), you should select AC coupling to take full advantage of the input signal range. Using AC coupling results in a drop in the low-frequency response of the analog input. The –3 dB cutoff frequency is approximately 3.4 Hz for the NI 447*X* (except the NI PXI-4472B). The –0.1 dB cutoff frequency is approximately 22.2 Hz.

♦ NI PXI-4472B

The –3 dB cutoff frequency is approximately 0.5 Hz for the NI PXI-4472B. The –0.1 dB cutoff frequency is approximately 3.2 Hz.

Input Polarity and Input Range

Caution Connections that exceed the rated input voltages can damage the computer and the connected equipment. Overvoltage protection is ±42.4 V on the positive signal line. The shield does *not* have overvoltage protection. Do *not* make a non-ground connection to the shield. Also, do *not* connect the shield to a ground that varies more than ±2.5 V from the ground of the NI 447*X*. NI is *not* liable for any damages resulting from such connections.

The NI 447*X* analog inputs are bipolar; that is, the input voltage range is centered on 0 V. The input voltage range is ±10 V with 2.38 μV resolution, and is always at a gain of 1.0 (0 dB). Due to the large dynamic range of the ADC used on the NI 447*X*, programmable gain is not required for most applications. Since the NI 447*X* does not have hardware to adjust the input gain, the component count in the input signal path is reduced, resulting in less noise and distortion. If the input signal has an amplitude greater than ±10 V, it is clipped and introduces large errors that can be easily identified in the frequency spectrum or by using the digital overload detection feature of the NI 447*X*.

All data read from the ADC are interpreted as two's complement format. In two's complement mode, digital data values read from the analog input channel are either positive or negative.

Digital Trigger

You can use the **EXT TRIG** SMB connector on the NI 447*X* for external digital triggering.

Using Test Panels to Acquire a Signal

To quickly test signal connections and the operation of the system, you can use the Test Panels to view a signal input to the NI 447*X*. To do so, complete the following steps:

1. Connect a known signal to an AI channel on the NI 447*X*.
2. Launch Measurement & Automation Explorer (MAX) from the desktop.
3. Open the **Devices and Interfaces** folder.
4. Right-click the icon for the NI 447*X* device you want to test and select **Test Panel** from the pop-up dialog.

5. Set the parameters as follows:
   - Channel—Select the input channel you are using.
   - Sample Rate (Hz)—Enter a sampling rate that is at least twice the highest frequency component of your input signal.
   - Data Mode—Select **Continuous**.
   - Y Scale Mode—Select **Auto Scale**.
6. Click **Start** to begin a continuous signal acquisition.

The Test Panel window displays a graph of the signal you input.

Field Wiring Considerations

Environmental noise can affect the accuracy of measurements made with the NI 447*X* if you do not take proper care when running signal wires between signal sources and the device. For more information, refer to the NI Developer Zone document, *Field Wiring and Noise Considerations for Analog Signals*, at `ni.com/zone`.

The following recommendations apply mainly to AI signal routing to the NI 447*X* although they also apply to signal routing in general.

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

- Route signals to the device carefully. Keep cabling away from noise sources. The most common noise source in a DAQ system is the video monitor. Separate the monitor from the analog signals as far as possible.
- Separate NI 447*X* signal lines from high-current or high-voltage lines. These lines can induce currents in or voltages on the NI 447*X* signal lines if they run in parallel paths at a close distance. To reduce the magnetic coupling between lines, separate them by a reasonable distance if they run in parallel, or run the lines at right angles to each other.
- Do *not* run signal lines through conduits that also contain power lines.
- Protect signal lines from magnetic fields caused by electric motors, welding equipment, breakers, or transformers by running them through dedicated metal conduits.

Selecting the Sample Clock Frequency

The eight AI channels of the NI PCI/PXI-4472 and the four AI channels of the NI PCI-4474 are simultaneously sampled at any software-programmable rate from 102.4 kS/s down to 1.0 kS/s in 190.7 µS/s increments for f_s > 51.2 kS/s or 95.37 µS/s increments for f_s ≤ 51.2 kS/s. The NI 447*X* uses direct digital synthesis (DDS) technology so that you can choose the correct sample rate for your application. All of the input channels acquire data at the same rate. One input channel *cannot* acquire data at a different rate from another input channel.

Notes If you do not specify a rate at a multiple of the increment, NI-DAQ automatically chooses the next higher step for you.

Unlike other converter technologies, delta-sigma converters must be run continuously and at a minimum clock rate to operate within specifications. Although the software allows you to use a lower sample rate, you must *always* use a sample rate of at least 1.0 kS/s to ensure the accuracy of the data acquisition.

Synchronizing Multiple Devices

This section provides basic instructions for synchronizing multiple NI 447*X* devices. For more information about how NI 447*X* devices are synchronized, refer to the *Synchronizing Multiple Devices* section of Chapter 3, *Device Overview and Theory of Operation*.

The NI 447*X* can send or receive the Direct Digital Synthesis (DDS) clock signal and the synchronization start signal to or from other NI 447*X* devices on the same bus to synchronize data acquisition. In a multi-device system, a master device drives the clock and synchronization signals to other slave, or receiving, devices.

Caution Do *not* use RTSI 5/TRIG 5 to drive any signals in the system if you are synchronizing multiple NI PXI-447*X* devices. The synchronization signal is driven on RTSI 5/TRIG 5, so driving other signals on RTSI 5/TRIG 5 could lead to double-driving the line, which might result in unpredictable behavior and might damage your system.

- NI PCI-4472 and NI PCI-4474

  In a PCI system, any NI PCI-4472 or NI PCI-4474 can be the master. The master broadcasts the ADC oversample clock to the other NI 447*X* devices using a reserved line in the RTSI cable.

  For specific LabVIEW programming instructions, refer to *Synchronizing Multiple PCI-DSA Devices* in the *LabVIEW Help*. In LabVIEW, click **Help** and select **VI, Function, & How-To Help** (or **LabVIEW Help** in LabVIEW 6.0) from the menu.

  For using NI-DAQ with other ADEs, refer to *Synchronizing Multiple PCI-DSA Devices: Select_Signal* in the *NI-DAQ Function Reference Help* (for NI-DAQ 6.9.*x*) or the *Traditional NI-DAQ C Reference Help* (for NI-DAQ 7.*x*). Select **Start»Programs»National Instruments»NI-DAQ** and the document title for the version of NI-DAQ you are using.

- NI PXI-4472

  To synchronize two or more NI PXI-4472 devices in a PXI/CompactPCI system, one of the NI PXI-4472 devices must be located in PXI Slot 2. This device is the master, and the PXI devices in other slots are slaves. The master broadcasts the ADC oversample clock to the other PXI devices on the PXI Star trigger lines and uses the RTSI 5/TRIG 5 line to drive the synchronization signal to the slave devices.

  For specific LabVIEW programming instructions, refer to *Synchronizing Multiple PXI-DSA Devices* in the *LabVIEW Help*. In LabVIEW, click **Help** and select **VI, Function, & How-To Help** (or **LabVIEW Help** in LabVIEW 6.0) from the menu.

  For using NI-DAQ with other ADEs, refer to *Synchronizing Multiple PXI-DSA Devices: Select_Signal* in the *NI-DAQ Function Reference Help* (for NI-DAQ 6.9.*x*) or the *Traditional NI-DAQ C Reference Help* (for NI-DAQ 7.*x*). Select **Start»Programs»National Instruments»NI-DAQ** and the document title for the version of NI-DAQ you are using.

Device Configuration Issues

When testing your NI 447*X*, it is important to remember that it is equipped with high performance antialiasing filters. Because of these filters, you cannot acquire a signal whose fundamental frequency exceeds one half the sampling rate. If you try to resolve such a signal, it is filtered as an alias and you see only a DC reading. This is the expected functionality for the NI 447*X*. If you suspect the filters are not passing your test signal, simply increase the sampling rate or decrease the analog signal frequency until the sampling rate is more than twice the analog frequency. For more information on the filters and aliasing, refer to the *Antialias Filtering* section of Chapter 3, *Device Overview and Theory of Operation*.

Note Unlike other converter technologies, delta-sigma converters must be run continuously and at a minimum clock rate to operate within specifications. Although the software lets you use a lower sample rate, you must *always* use a sample rate of at least 1.0 kS/s to ensure the accuracy of the data acquisition.

3

Device Overview and Theory of Operation

This chapter presents an overview of the hardware functions of the NI 447*X* and other useful information for understanding how the device works.

Functional Overview

Figure 3-1 shows a block diagram of the digital functions, and the analog function block diagram is shown in Figure 3-2.

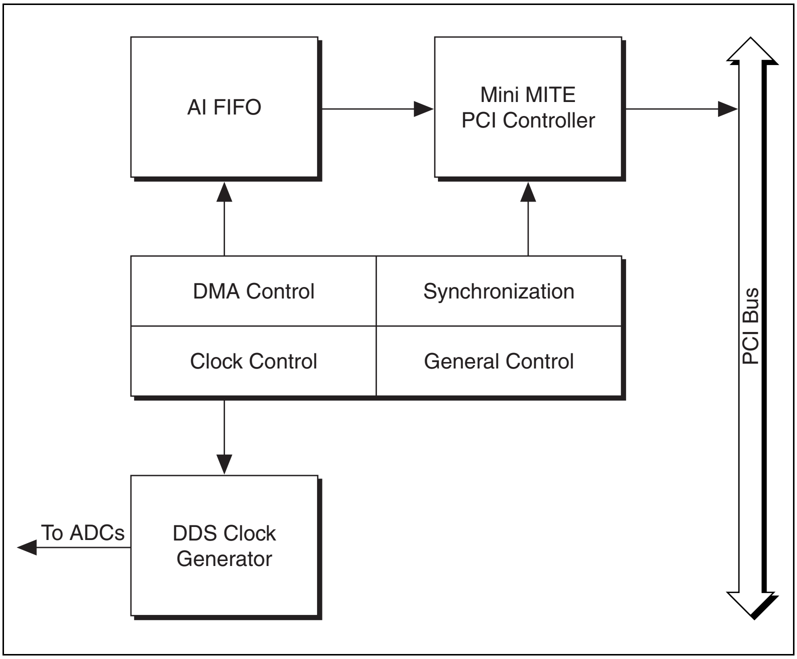

Figure 3-1. Digital Function Block Diagram

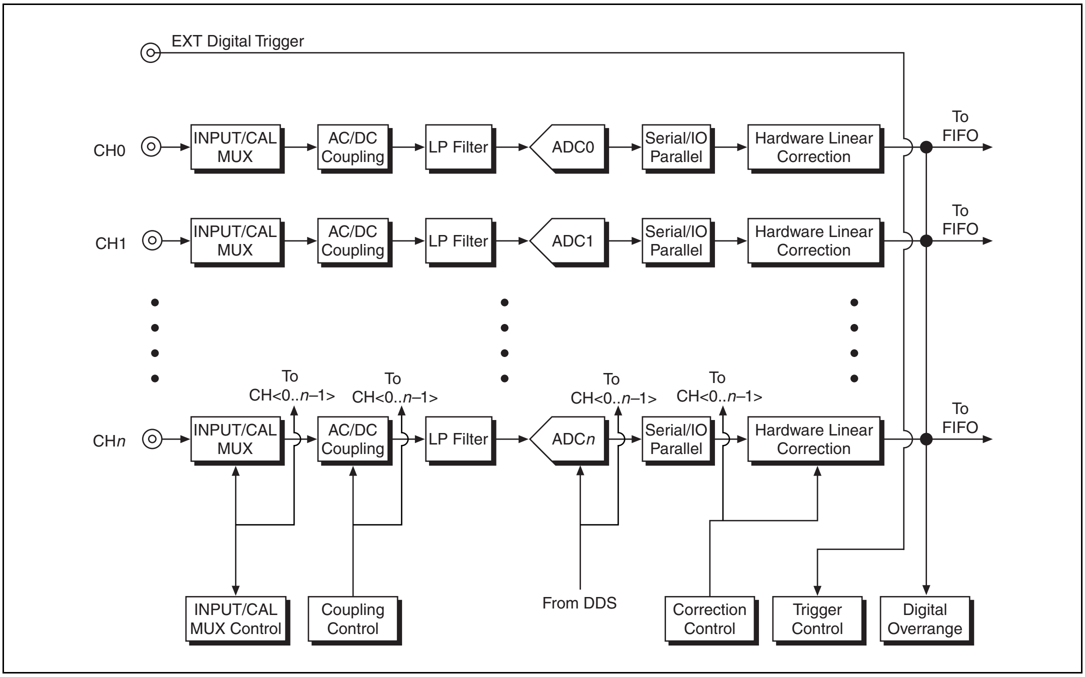

Figure 3-2. Analog Function Block Diagram

I/O Connectors

Caution Connections that exceed any of the maximum ratings for input signals on the NI 447*X* can damage the device, the computer, and the associated accessories. NI is *not* liable for any damage resulting from such signal connections.

The front panel of the NI PCI/PXI-4472 has nine SMB male connectors, and the front panel of the NI PCI-4474 has five SMB male connectors. These connectors are used for attaching analog and digital signals.

The **EXT TRIG** connector is the input for the PFI0/EXT_TRIG signal. Triggers cannot be output from the **EXT TRIG** connector. The EXT TRIG line is compatible with 5V TTL and CMOS voltage levels.

CH<0..*n*> are AI channels 0 through *n*. Input impedance on the positive (signal) wire of each input channel is 1 MΩ in parallel with 60 pF to ground. Input impedance on the negative (shield) wire is 50 Ω in parallel with 0.02 µF to ground. The signal line of each AI channel circuit is protected to ±42.4 V, whether power is on or off. The shield side of the

AI channels has no overvoltage protection. Do *not* apply a signal that varies by more than ±2.5 V from the ground of the NI 447*X*.

Analog Input Signal Connections

Figure 3-3 shows a diagram of one of the eight (NI PCI/PXI-4472) or four (NI PCI-4474) AI stages.

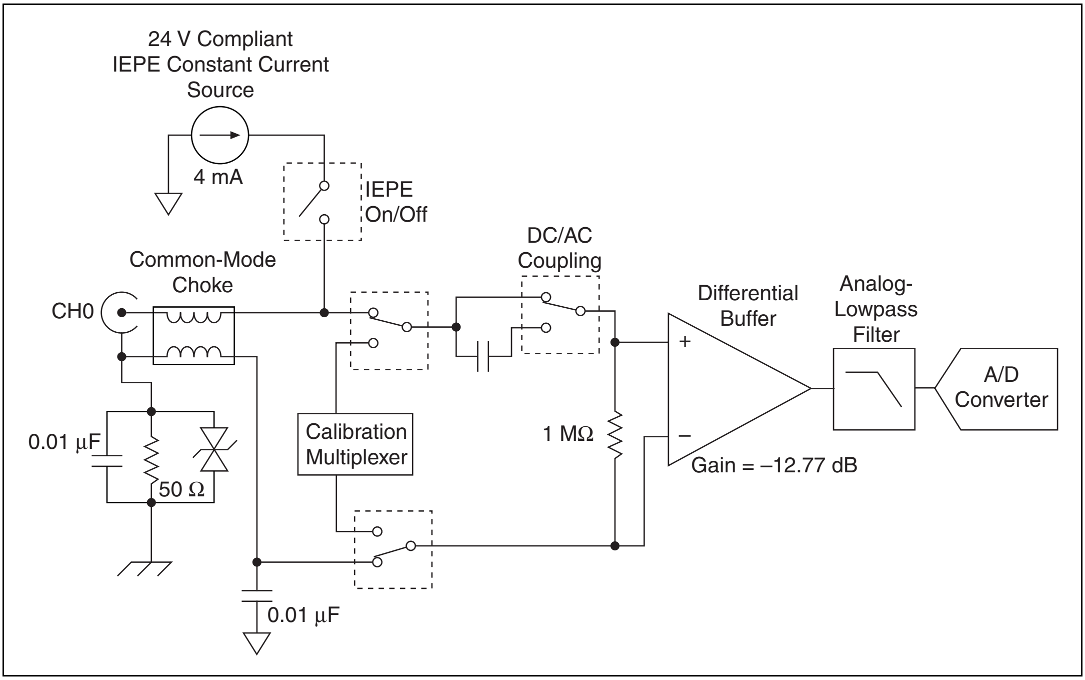

Figure 3-3. Analog Input Stage

The AI stage presents high-input impedance to the AI signals connected to the NI 447*X*. Signals are routed to the positive inputs of the AI stage, and their returns are routed to AIGND through a common-mode choke. The NI 447*X* ADCs measure these signals when they perform A/D conversions.

These input channels have 24-bit resolution and are simultaneously sampled at software-programmable rates from 102.4 kS/s down to 1.0 kS/s in 190.7 µS/s increments for f_s > 51.2 kS/s or 95.37 µS/s increments for $f_s \leq$ 51.2 kS/s. This flexibility in sample rates makes the device well-suited for a wide variety of applications, including audio, acoustics, and vibration analysis.

The unbalanced differential analog inputs have software-selectable AC/DC coupling.

Calibration

The NI 447*X* analog inputs have calibration adjustments. Onboard calibration circuits remove the offset and gain errors for each channel. For complete calibration instructions, refer to Chapter 4, *Calibration*.

Antialias Filtering

Any sampling system (such as an ADC) is limited in the bandwidth of the signals it can represent. Specifically, a sampling rate of f_s can only represent signals with a maximum frequency of $f_s/2$. This maximum frequency is known as the *Nyquist frequency*. The bandwidth from 0 Hz to the Nyquist frequency is the *Nyquist bandwidth*.

A digitizer may experience input signals containing frequency components above the Nyquist limit. It is important to understand how the digitizing system handles these out-of-band frequencies. The NI 447*X* products feature alias protection to eliminate these frequency components.

Many digitizers, including the successive approximation register (SAR) ADCs often used in DAQ products, do not have alias protection. Consider an ADC running at a sampling rate of 1,000 S/s. In this case, the Nyquist frequency is 500 Hz. Assume the analog input signal has a frequency of 400 Hz. In this case, the ADC will accurately report the frequency of this signal since it lies within the Nyquist bandwidth. Now assume the analog input frequency is increased to 600 Hz; it is now 100 Hz beyond the limit of the Nyquist bandwidth. The ADC is incapable of reproducing this frequency digitally. The digitized data does imply a well-defined frequency, but this frequency is inaccurate. The 600 Hz analog signal is represented incorrectly as a 400 Hz digital waveform! In general, the apparent frequency of a component will be the absolute value of the difference between the actual frequency of the input signal and the closest integer multiple of the sampling rate. If a 2,325 Hz sine wave were input to a SAR ADC running at 1,000 S/s, its apparent frequency will be:

$$2{,}325 - (2)(1{,}000) = 325 \text{ Hz}$$

If a 3,975 Hz sine wave is input, its digital frequency is represented as follows:

$$(4)(1{,}000) - 3{,}975 = 25 \text{ Hz}$$

This process by which the sampler modulates out-of-band components back down the Nyquist bandwidth is known as aliasing. The greatest danger of aliasing is that there is no straightforward way to know whether it has happened by looking at the ADC output. The 25 Hz observation described above will look just like a real 25 Hz signal in the digital domain, but it is clearly nowhere close the true analog frequency of 3,975 Hz. If an input signal contains several frequency components or harmonics, it is quite possible that some of these components will be represented correctly while others will be aliased.

Lowpass filtering to eliminate all components above the Nyquist frequency either before or during the digitization process can guarantee that the digitized data set is free of all aliases. The NI 447*X* employs both digital and analog low-pass filters to achieve this end.

The delta-sigma ADCs on the NI 447*X* include brick-wall digital filters whose cut-off frequency tracks the sampling rate. Thus, the filter topology automatically adjusts to follow the Nyquist frequency. The cutoff frequency of the digital filters is $0.4863f_s$. The rejection for frequency components above $0.5465f_s$ is greater than 110 dB. In the passband below $0.4535f_s$, the amplitude response of the filter is extremely flat. The digital filter has a negligible effect on frequency components that lie in the band of interest. Because the filter employs an FIR (Finite Impulse Response) architecture, its phase response is perfectly linear. Figures 3-4 and 3-5 show the frequency response of the NI 447*X* input circuitry.

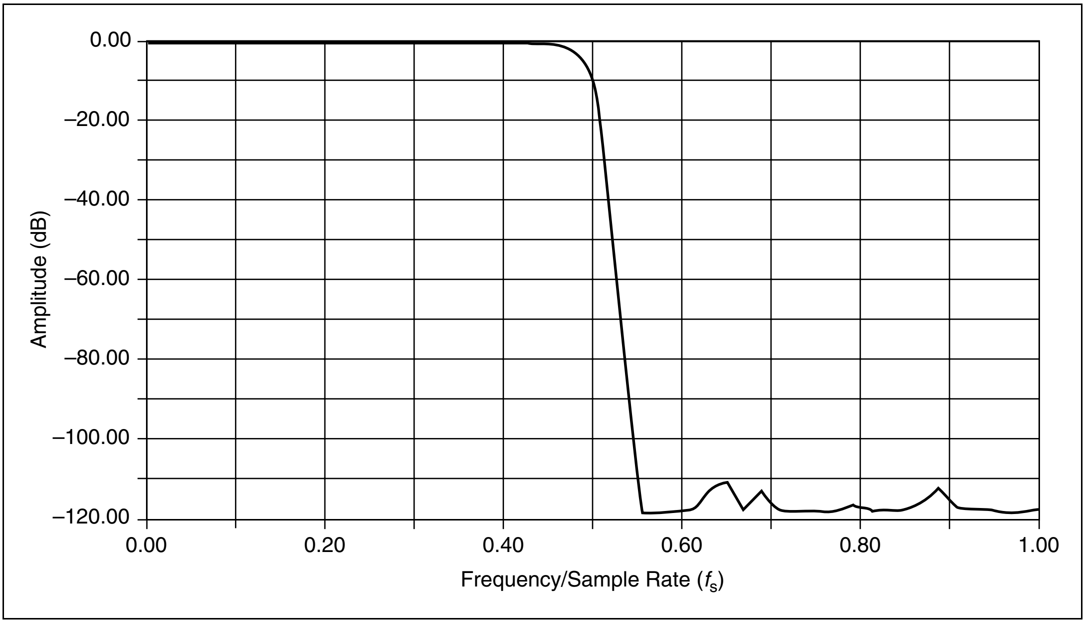

Figure 3-4. Input Frequency Response

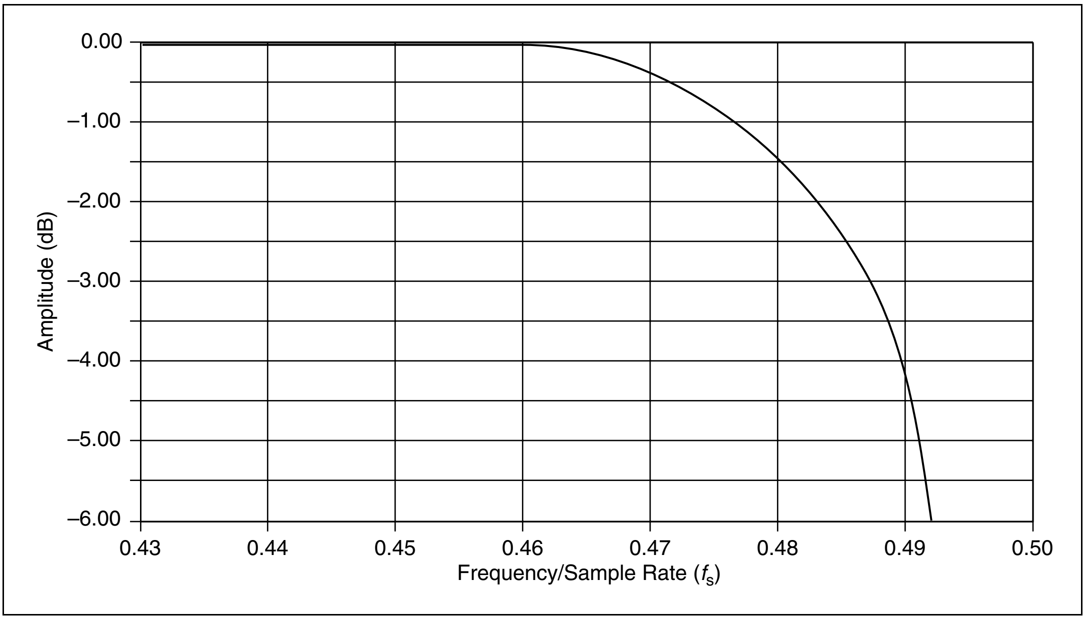

Figure 3-5. Input Frequency Response Near the Cutoff

Although the digital filter eliminates almost all out-of-band components, it is still susceptible to aliases from certain narrow frequency bands, specifically those bands that lie within plus or minus one Nyquist bandwidth of $64 \times f_s$ (for $f_s > 51.2$ kS/s) or $128 \times f_s$ (for $f_s < 51.2$ kS/s). For example, if $f_s = 10{,}000$ S/s, the digital filter could admit aliases from analog components between 1,275,000 Hz and 1,285,000 Hz.

In addition the digital filtering built in to the ADCs, the NI 447*X* devices also feature a fixed-frequency analog filter. The analog filter serves to remove high-frequency components in the analog signal path before they reach the ADC. This addresses the possibility of any high-frequency aliasing from the narrow bands not covered by the digital filter. Each input channel on the NI 447*X* is equipped with a two-pole lowpass Butterworth filter. The analog filter cutoff frequency is about 400 kHz. This filter has a gradual rolloff with very little attenuation for any frequencies within the 45 kHz input bandwidth of the NI 447*X*. The high cutoff frequency of the filter guarantees extremely flat amplitude response and minimal phase error for signals of interest. Frequency components that could pass the digital filter usually consist of high frequency noise. The analog lowpass filter removes these high-frequency components before they ever reach the ADC.

While the frequency response of the digital filter scales directly with the sample rate, the response of the analog filter is fixed. The analog filter response is optimized to produce good high-frequency alias rejection while maintaining a flat in-band frequency response. Because the analog filter is a two-pole system, its rolloff is not extremely sharp. It has excellent alias rejection at higher sampling rates, where only very high frequencies could pass through the digital filter. At lower sampling rates it does not filter potential aliases perfectly, but in most cases these residual aliases are noise rather than well-defined harmonics. Figure 3-6 shows the alias rejection near 64 or 128 times the sample rate (bands passed by the digital filter) versus sample rate. This graph accounts for the response of both the digital and analog filters. The rejection ratio is better than 110 dB for all aliases outside plus or minus one Nyquist bandwidth of multiples of 64 or 128 times f_s.

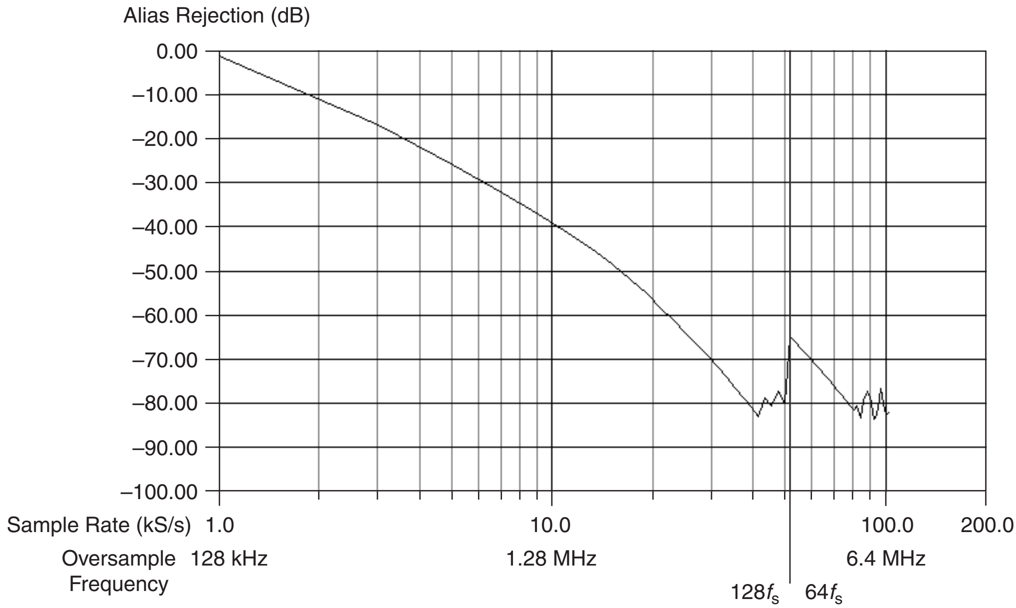

Figure 3-6. Alias Rejection at the Oversample Rate

No filter can prevent a type of aliasing caused by a *clipped* or *overranged* waveform, that is, one that exceeds the voltage range of the ADC. When clipping occurs, the ADC assumes the closest value in its digital range to the actual value of the signal, which is always either +8,388,607 ($2^{23} – 1$) or –8,388,608 ($–2^{23}$). Clipping always results in an abrupt change in the slope of the signal and causes the corrupted digital data to have high-frequency energy. This energy is spread throughout the frequency spectrum, and because the clipping happens *after* the antialiasing filters, the energy is aliased back into the baseband. The remedy for this problem is simple: do not allow the signal to exceed the nominal input range. Figure 3-7 shows the spectra of 10.5 V_{peak} and 10.0 V_{peak}, 3.0 kHz sine waves. The signal-to-THD-plus-noise (THD + N) ratio is 35 dB for the clipped waveform and 92 dB for the properly ranged waveform. Aliases of all the harmonics caused by clipping appear in Figure 3-7a.

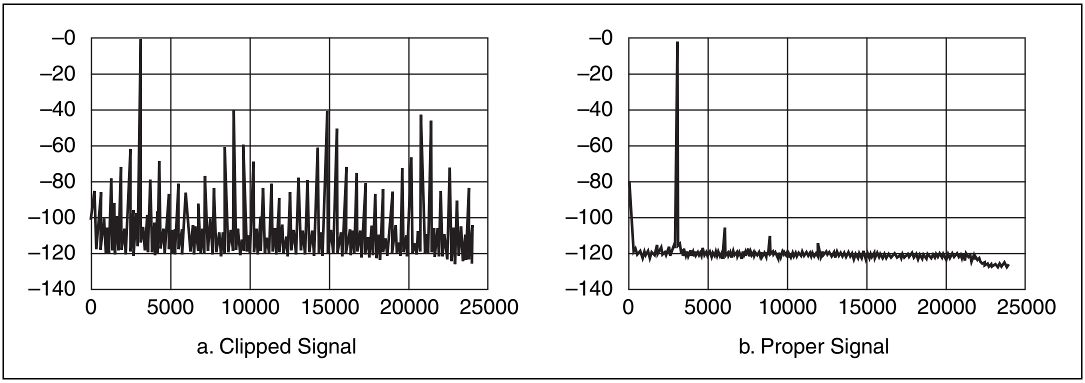

Figure 3-7. Comparison of a Clipped Signal to a Proper Signal

An overrange can occur on the analog signal as well as on the digitized signal. Furthermore, an analog overrange can occur independently from a digital overrange and vice versa. For example, a piezoelectric accelerometer might have a resonant frequency that, when stimulated, can produce an overrange in the analog signal, but because the delta-sigma technology of the ADC uses very sharp antialiasing filters, the overrange is not passed into the digitized signal. Conversely, a sharp transient on the analog input might not overrange, but the step response of those same delta-sigma antialiasing filters might cause the digitized data to be clipped.

The NI 447*X* includes digital overload detection circuitry. You can programatically poll the overload detection circuitry to monitor for an overload condition. If an overload is detected, the data acquired at that time may be corrupt.

The ADC

The NI 447*X* ADC uses a method of A/D conversion known as delta-sigma modulation. If the data rate is 51.2 kS/s, each ADC actually samples its input signal at 6.5536 MS/s (128 times the data rate) and produces 1-bit samples that are applied to the digital filter. This filter then expands the data to 24 bits, rejects signal components greater than 25.6 kHz (the Nyquist frequency), and digitally resamples the data at the more conventional rate of 51.2 kS/s.

The 1-bit, 6.5536 MS/s from the ADC carry all the information used to produce 24-bit samples at 51.2 kS/s. The delta-sigma ADC achieves this conversion from high speed to high resolution by adding a large amount of random noise to the signal so that the resulting quantization noise, although large, is restricted to frequencies above 25.6 kHz. This noise is not correlated with the input signal and is almost completely rejected by the digital filter.

The resulting output of the filter is a band-limited signal with a dynamic range of more than 100 dB. One of the advantages of a delta-sigma ADC is that it uses a 1-bit DAC as an internal reference. As a result, the delta-sigma ADC is free from the kind of differential nonlinearity (DNL) that is inherent in most high-resolution ADCs. This lack of DNL is especially beneficial when the ADC is converting low-level signals, in which noise and distortion are directly affected by converter DNL.

Noise

The NI 447*X* analog inputs typically have a dynamic range of more than 100 dB. The dynamic range of a circuit is the ratio of the magnitudes of the largest signal the circuit can carry to the residual noise in the absence of a signal.

Several factors can degrade the noise performance of the inputs. One of these factors is noise picked up from nearby electronic devices. The NI 447*X* works best when it is kept as far away as possible from other plug-in devices, power supplies, disk drives, and computer monitors. Cabling is also critical. Make sure to use well-shielded coaxial or balanced cables for all connections, and route the cables away from sources of interference such as computer monitors, switching power supplies, and fluorescent lights. Refer to the *Field Wiring Considerations* section of Chapter 2, *Using the NI 447X*, for more information.

One way to reduce the effects of noise on your measurements is to choose the sample rate carefully. Take advantage of the antialias filtering that removes signals beyond the band of interest. Computer monitor noise, for example, typically occurs at frequencies between 15 and 50 kHz. If the signal of interest is restricted to below 10 kHz, for example, the antialias filters reject the monitor noise outside the frequency band of interest, and a sampling rate of at least 21.6 kS/s guarantees that any signal components in the 10 kHz bandwidth of interest are acquired without aliasing and without being attenuated by the digital filter.

Triggering

In addition to supporting internal software triggering and external digital triggering to initiate an acquisition sequence, the NI 447*X* also supports analog-level triggering. You can configure the trigger circuit to monitor any one of the AI channels to generate the level trigger. Choosing an input channel as the level trigger channel does not influence the input channel capabilities. The level trigger circuit compares the full 24 bits of the programmed trigger level with the digitized 24-bit sample.

The trigger circuit generates an internal digital trigger based on the input signal and the user-defined trigger levels. For example, you can configure the AI section to start acquiring samples after the AI signal crosses a specific threshold. You also can route this internal trigger to the RTSI bus to synchronize the start of the acquisition operation by the NI 447*X* with the operation of other devices in your system.

The nature of delta-sigma converters means that the triggering circuits operate on the digital output of the converter. Since the trigger is generated at the output of the converter, triggers can occur only when a sample is actually generated. Placing the triggering circuits on the digital side of the converter does not affect most measurements unless an analog output is generated based on the input trigger. In this case, make sure you account for the inherent delays of the finite impulse response (FIR) filters internal to the delta-sigma converters. The delay through the input converter is 38.8 sample periods.

During repetitive sampling of a waveform, you might observe jitter because of the uncertainty of where a trigger level falls compared to the actual digitized data. Although this trigger jitter is never greater than one sample period, it can seem quite significant when the sample rate is only twice the bandwidth of interest. This jitter usually has no effect on the processing of the data, and you can decrease this jitter by sampling at a higher rate.

Five analog level triggering modes are available, as shown in Figures 3-8 through 3-12. You can set **lowValue** and **highValue** independently in the software.

In below-low-level triggering mode, shown in Figure 3-8, the trigger is generated when the signal value is less than **lowValue**. **highValue** is unused.

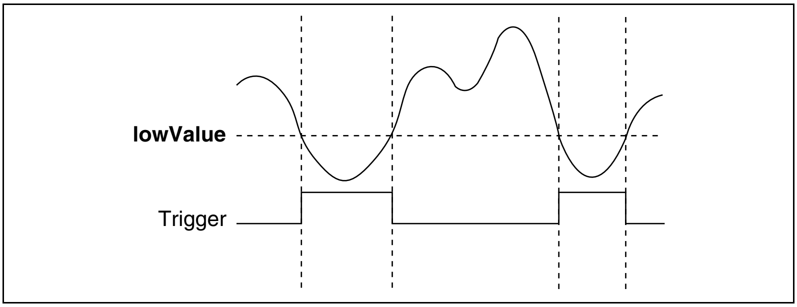

Figure 3-8. Below-Low-Level Triggering Mode

In above-high-level triggering mode, shown in Figure 3-9, the trigger is generated when the signal value is greater than **highValue**. **lowValue** is unused.

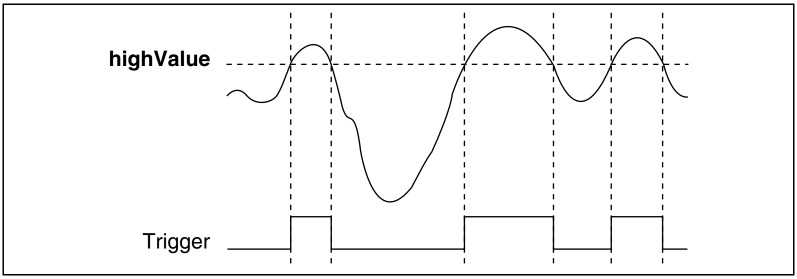

Figure 3-9. Above-High-Level Triggering Mode

In inside-region triggering mode, shown in Figure 3-10, the trigger is generated when the signal value is between **lowValue** and **highValue**.

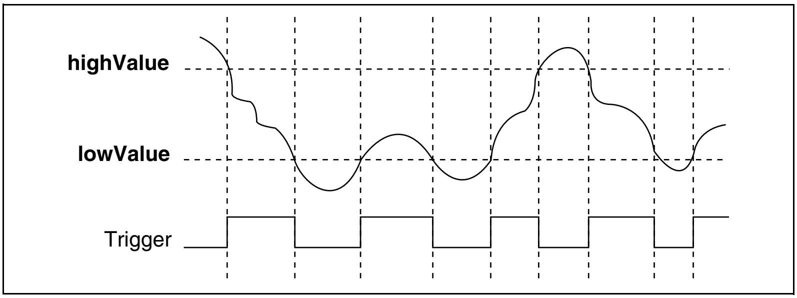

Figure 3-10. Inside-Region Triggering Mode

In high-hysteresis triggering mode, shown in Figure 3-11, the trigger is generated when the signal value is greater than **highValue**, with the hysteresis specified by **lowValue**.

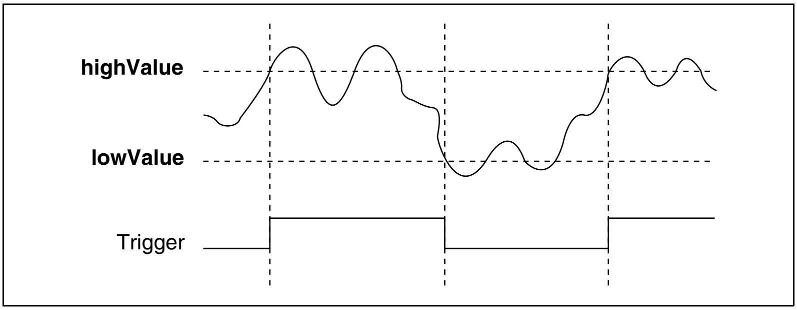

Figure 3-11. High-Hysteresis Triggering Mode

In low-hysteresis triggering mode, shown in Figure 3-12, the trigger is generated when the signal value is less than **lowValue**, with the hysteresis specified by **highValue**.

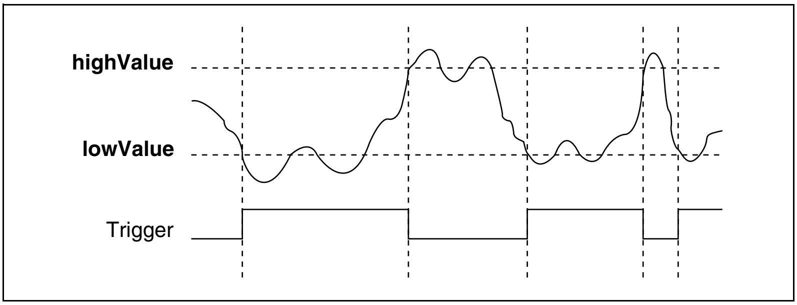

Figure 3-12. Low-Hysteresis Triggering Mode

You can use the **EXT TRIG** SMB connector on the NI 447*X* for dedicated external digital triggering.

Alternately, you can trigger the NI 447*X* from any other NI device that has the RTSI bus feature. You can programmatically route any RTSI/TRIG line to the NI 447*X* except RTSI 5/TRIG 5, which is reserved for internal use when synchronizing multiple NI 447*X* devices.

Note A PXI chassis with multiple PXI buses might not have RTSI connections across the bus boundaries.

Synchronizing Multiple Devices

This section provides low-level background information about the electrical signals needed to tightly synchronize NI 447*X* modules. This section describes three signals: the oversample clock, the SYNC pulse, and the acquisition start trigger.

Delta-Sigma ADCs and the Oversample Clock

The 24-bit ADCs employed on the NI 447*X* belong to a class of components called *delta-sigma* (or ΔΣ) ADCs. The advantages of delta-sigma components as compared to other digitizers include high dynamic range, excellent linearity, and digital filtering to remove aliased frequency components from the data.

Most ADCs, including the successive approximation ADCs used in many DAQ devices, are timed by a *sample clock*. This clock is simply a digital pulse train that drives the acquisition. In most cases, a rising edge on the sample clock signal starts a conversion. When an ADC is timed by a sample clock, the acquisition rate is exactly equal to the frequency of the sample clock. For example, a 10 kHz sample clock produces a 10 kS/s acquisition rate.

One distinguishing feature of delta-sigma converters, including those on the NI 447*X*, is that they use an *oversample clock* to drive the conversion. As the name implies, the physical frequency of the oversample clock signal is greater than the sample rate. When a single NI 447*X* acquires data, the high-frequency oversample clock is locally generated by a Direct Digital Synthesis (DDS) chip on the device. If two or more NI 447*X* modules are synchronized, they must share the oversample clock to ensure tight synchronization of the acquisition.

♦ NI PXI-4472

The NI PXI-4472 can use either its internal DDS timebase or a timebase received from another NI PXI-4472 over the PXI backplane. If you configure the NI PXI-4472 to use the internal timebase and place the NI PXI-4472 in Slot 2, you can program the device to drive its internal timebase over the PXI backplane to another NI PXI-4472 that you program to receive this timebase signal. The default configuration at startup is to use the internal timebase without driving the PXI backplane timebase signal. This timebase is software selectable.

- NI PCI-4472 and NI PCI-4474

  The NI PCI-4472 and NI PCI-4474 can use either its internal DDS timebase or a timebase received over the RTSI bus. If you configure the NI PCI-4472 or NI PCI-4474 to use the internal timebase, you can program the NI PCI-4472 or NI PCI-4474 to drive its internal timebase over the RTSI bus to another NI PCI-4472 or NI PCI-4474 that you program to receive this timebase signal. The default configuration at startup is to use the internal timebase without driving the RTSI bus timebase signal. This timebase is software selectable.

On the NI 447*X*, the ratio between the oversample (f_{os}) clock and the sample rate (f_s) can have one of two possible values, depending on the sample rate. Table 3-1 shows the possible values.

Table 3-1. Relationship between the Sample Rate and Oversample Clock

Sample Rate	Oversample Clock
$f_s \leq 51.2$ kS/s	$f_{os} = 256 \times f_s$
$f_s > 51.2$ kS/s	$f_{os} = 128 \times f_s$

The highest possible oversample frequency for the NI 447*X* occurs at either f_s = 51.2 kS/s or f_s = 102.4 kS/s. In both cases, the oversample rate is slightly faster than 13.1 MHz.

The ADCs on the NI 447*X* operate at half the oversample clock.

Most delta-sigma converters, including those on the NI 447*X*, require a very steady frequency for the oversample clock. The DDS chip on the NI 447*X* has good frequency characteristics and easily fulfills this need. However, arbitrarily changing frequencies, such as those from encoders, generally do not work well with delta-sigma ADCs. For this reason, the NI 447*X* and other National Instruments DSA products do not support external clocking from arbitrary signal sources.

The NI 447*X* SYNC Pulse

As discussed in the *Delta-Sigma ADCs and the Oversample Clock* section, the oversample clock is many times faster than the actual acquisition rate of the NI 447*X*. Using the concepts described in that section, you can share the oversample clock between two or more NI 447*X* modules. This sharing guarantees that both modules sample at the same frequency and that there will be no drift between their acquisitions. However, oversample-clock sharing does not guarantee that the samples on both modules are acquired at exactly the same time. Figure 3-13 illustrates the oversample pulse trains on two NI 447*X* devices sampling at 102.4 kS/s. In this example, there is a delay between acquisition samples of five oversample intervals, or about 350 ns. This delay may be any value up to a whole sample interval, which is about 10 µs at this acquisition rate.

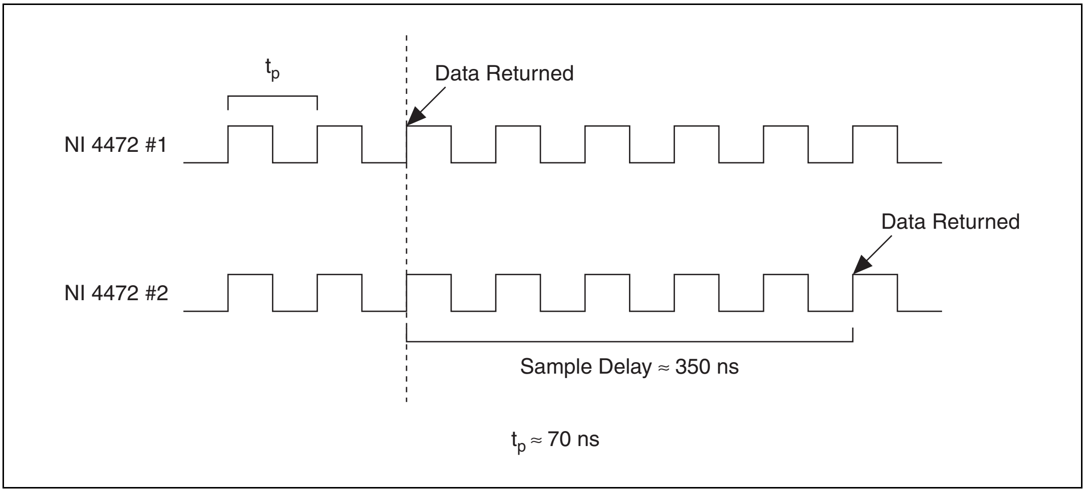

Figure 3-13. Sample Delay between NI 447*X* Modules After Receiving a Shared Oversample Clock

The solution to the clock-delay issue is to configure the master device to issue a SYNC pulse before the acquisition. The clock master sends a single active low, or inverted, pulse on the RTSI 5/TRIG 5 line, the dedicated line for the SYNC pulse. The ADCs in the clock master and clock slaves receive this pulse nearly simultaneously. The SYNC pulse forces all the ADCs to a reset state, emptying their digital filters and synchronizing their clock dividers. After exiting the reset state, all NI 447*X* modules run at the same frequency and have minimal phase difference between sample clocks. Figure 3-14 illustrates how this technique minimizes the sample delay.

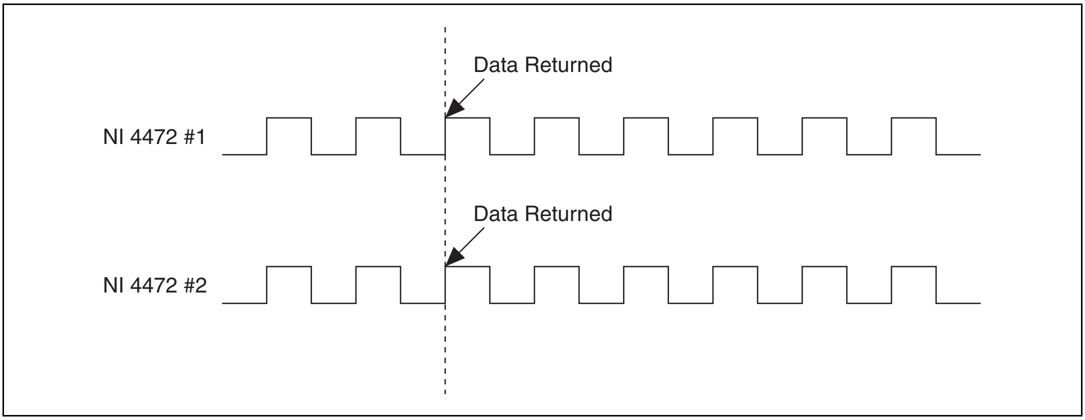

Figure 3-14. NI 447*X* Modules with Shared Oversample Clock Using the SYNC Pulse

The NI 4472 cannot acquire data while it is in the reset state that occurs immediately after it receives the SYNC pulse. During this period, the ADC returns only zeros. The length of the reset period t_{reset} (in samples) is a function of sample rate. Table 3-2 shows the possible lengths of the reset period.

Table 3-2. Reset Period as a Function of Sample Rate

Sample Rate	Reset Period (t_{reset})
$f_s \leq 51.2$ kS/s	$t_{reset} = 8{,}960$ samples
$f_s > 51.2$ kS/s	$t_{reset} = 17{,}920$ samples

Note The SYNC pulse is automatically handled by NI-DAQ through the RTSI 5/TRIG 5 line. Therefore, you do not need to make an explicit software call to generate or route the SYNC pulse.

The Acquisition Start Trigger

After sharing the oversampling clock and issuing the SYNC pulse, the ADCs on every NI 447*X* in the system run in lock-step. At this point, the only remaining task is to synchronize the beginning of the data acquisition on each NI 447*X*. You can choose RTSI <0..4>/TRIG <0..4> for the start trigger.

4 Calibration

This chapter discusses the calibration procedures for the NI 447*X*. The NI 447*X* comes with a calibration certificate. The certificate contains a unique tracking number linking the device to the NI corporate databases where the traceability information is stored.

Calibration refers to the process of minimizing measurement and output voltage errors by making small circuit adjustments. On the NI 447*X* devices, these adjustments are made to the digital data coming from the ADCs. NI-DAQ includes calibration functions for performing all of the steps in the calibration process. Some form of device calibration is required for all but the most forgiving applications. If you do not calibrate the device, the signals and measurements could have significant offset and gain errors. The four levels of calibration available are described in this chapter. The first level is the fastest, easiest, and least accurate, whereas the last level is the slowest, most complex, and most accurate.

Loading Calibration Constants

The NI 447*X* is factory calibrated at approximately 25 °C to the levels indicated in Appendix A, *Specifications*. Before shipment, the associated calibration constants—the values that were written to the calibration circuitry to achieve calibration in the factory—are stored in the onboard nonvolatile memory (EEPROM). Because the calibration circuits have no memory, they do not retain calibration information when the device is unpowered. Loading calibration constants refers to the process of loading the calibration circuits with the values stored in the EEPROM. NI-DAQ determines when this is necessary and does it automatically.

Self-Calibration

The NI 447*X* can measure and correct almost all of its calibration-related errors without any external signal connections. NI-DAQ provides a self-calibration method. Initiate self-calibration by calling the DSA Calibrate VI or the `Calibrate_DSA` function. This self-calibration process, which generally takes less than a minute, is the preferred method of assuring accuracy in your application. Initiate self-calibration to minimize the effects of any offset and gain drifts, particularly those due to temperature variations.

The NI 447*X* has an onboard calibration reference to ensure the accuracy of self-calibration. Its specifications are listed in Appendix A, *Specifications*. The reference voltage is measured at the factory or during an external calibration operation and stored in the EEPROM for subsequent self-calibrations.

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

External Calibration

The onboard calibration reference voltage is stable enough for most applications, but if you are using the device at an extreme temperature or if the onboard reference has not been measured for one year or more, you should externally calibrate the device.

External calibration refers to calibrating your device with a known external reference rather than relying on the onboard reference. The new calibration constants are stored in the onboard EEPROM, overwriting the factory calibration constants.

Externally calibrate the device by calling the DSA Calibrate VI or the `Calibrate_DSA` function. When you perform an external calibration, be sure to use a very accurate external DC reference. The reference should be several times more accurate than the device itself. For example, to calibrate the NI 447*X*, the external reference should have a DC accuracy better than ±115 ppm (±0.001 dB).

Note When you calibrate the NI 447*X*, make sure the inputs are DC-coupled and that IEPE power is turned off to avoid affecting the reference voltage reading.

Traceable Recalibration

Traceable recalibration is divided into three different areas—factory, on-site, and third party. Devices typically require this type of recalibration every year.

If you require factory recalibration, send the NI 447*X* back to NI. NI sends the device back to you with a new calibration certificate. Please check with NI for additional information such as cost and delivery times.

If your company has a metrology laboratory, you can recalibrate the NI 447*X* at your location (on-site). You also can send the NI 447*X* to a third party for recalibration. Please contact NI for approved third-party calibration service providers.

Calibration documentation and function libraries are available online at `ni.com/calibration`.

A

Specifications

This appendix lists the specifications of the NI 447*X*. These specifications are typical at 25 °C unless otherwise noted. The system must be allowed to warm up for 15 minutes to achieve the rated accuracy.

Note Be sure to keep the filler panels on all unused slots in your chassis or computer to maintain forced air cooling.

Analog Input

Channel Characteristics

Number of channels

- NI PCI/PXI-4472/4472B .... 8, simultaneously sampled
- NI PCI-4474 .... 4, simultaneously sampled

Input configuration .... Unbalanced differential

Resolution .... 24 bits, nominal

Type of ADC .... Delta-sigma

- Oversampling, for sample rate (f_s):
  - 1.0 kS/s ≤ f_s ≤ 51.2 kS/s .... 128 f_s
  - 51.2 kS/s < f_s ≤ 102.4 kS/s .... 64 f_s

Sample rates (f_s) .... 102.4 kS/s down to 1.0 kS/s in 190.7 µS/s increments for f_s > 51.2 kS/s or 95.37 µS/s increments for f_s ≤ 51.2 kS/s

Frequency accuracy .... ±25 ppm

Input signal range .... ±10 V_{peak}

FIFO buffer size .... 1,024 samples

Data transfers .... DMA

Transfer Characteristics

Offset (residual DC) ....±3 mV, max

Gain (amplitude accuracy).....................±0.1 dB, max, f_{in} = 1 kHz

Amplifier Characteristics

Input impedance (ground referenced)

Positive input..................................1 MΩ in parallel with 60 pF

Negative input (shield) ....50 Ω in parallel with 0.02 µF

Flatness (relative to 1 kHz)....................±0.1 dB, DC to 0.4535 f_s, max, DC-coupled

−3 dB bandwidth...................................0.4863 f_s

Input coupling..AC or DC, software-selectable

AC −3 dB cutoff frequency

NI 447*X* ....3.4 Hz (except NI PXI-4472B)

NI PXI-4472B ....0.5 Hz

Overvoltage protection

Positive input..................................±42.4 V

Negative input (shield) ....Not protected

Inputs protected

NI PCI/PXI-4472.....................CH<0..7>

NI PCI-4474 ....CH<0..3>

Common mode rejection ratio (CMRR)

f_{in} < 1 kHz ....>60 dB, min

Noise...Refer to Figures A-1 through A-3

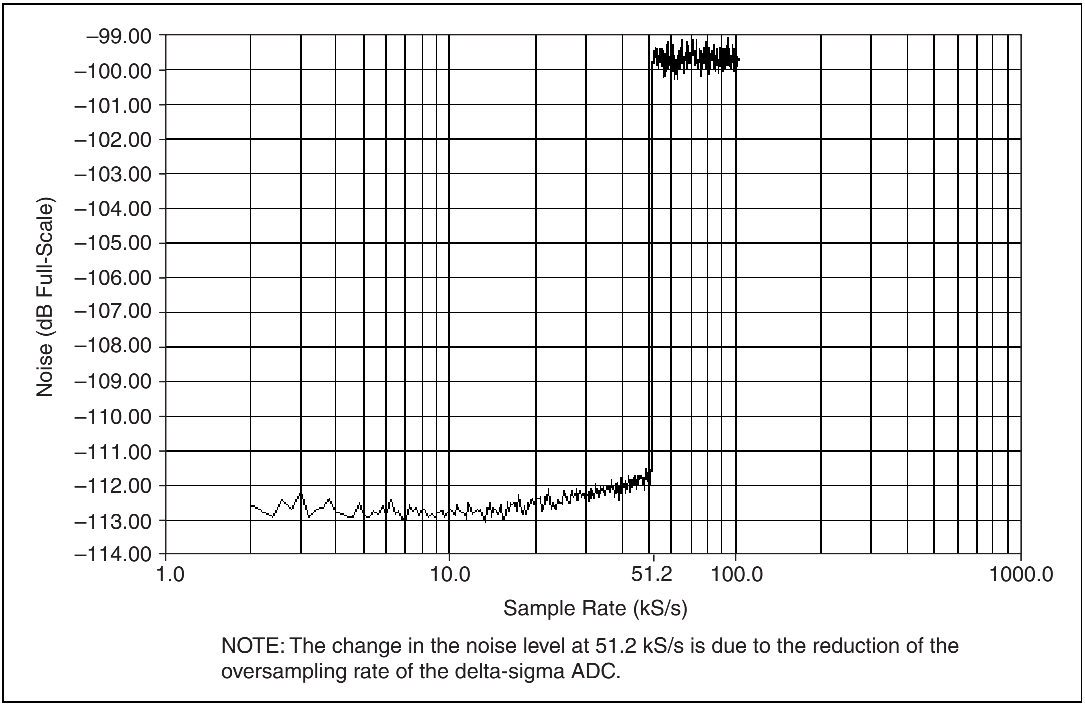

Figure A-1. Idle Channel Noise

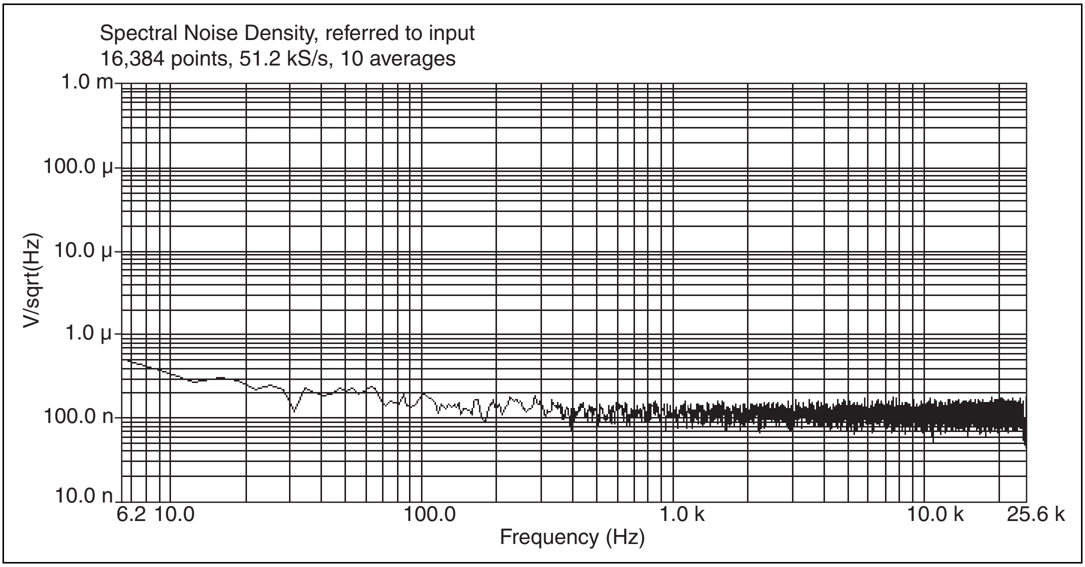

Figure A-2. Input Noise Spectral Density at 128-Times Oversampling

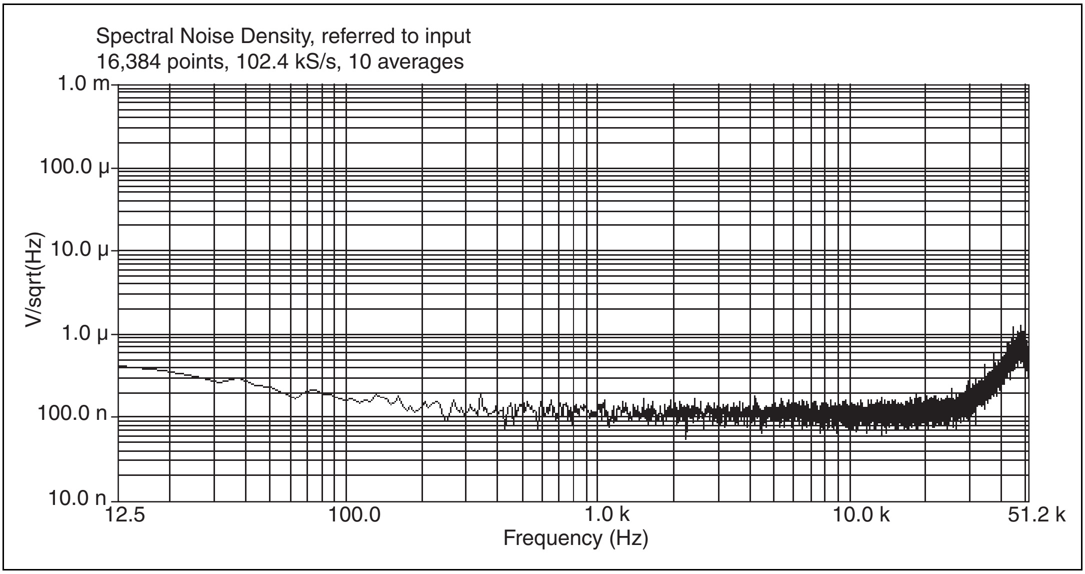

Figure A-3. Input Noise Spectral Density at 64-Times Oversampling

Dynamic Characteristics

Alias-free bandwidth (passband) ....DC (0 Hz) to 0.4535 f_s

Stop band ....0.5465 f_s

Alias rejection...110 dB

Delay through
ADC anti-aliasing filter ....38.8 sample periods

Spurious free dynamic range ....130 dB,
1.0 kS/s ≤ f_s ≤ 51.2 kS/s
118 dB,
51.2 kS/s < f_s ≤ 102.4 kS/s

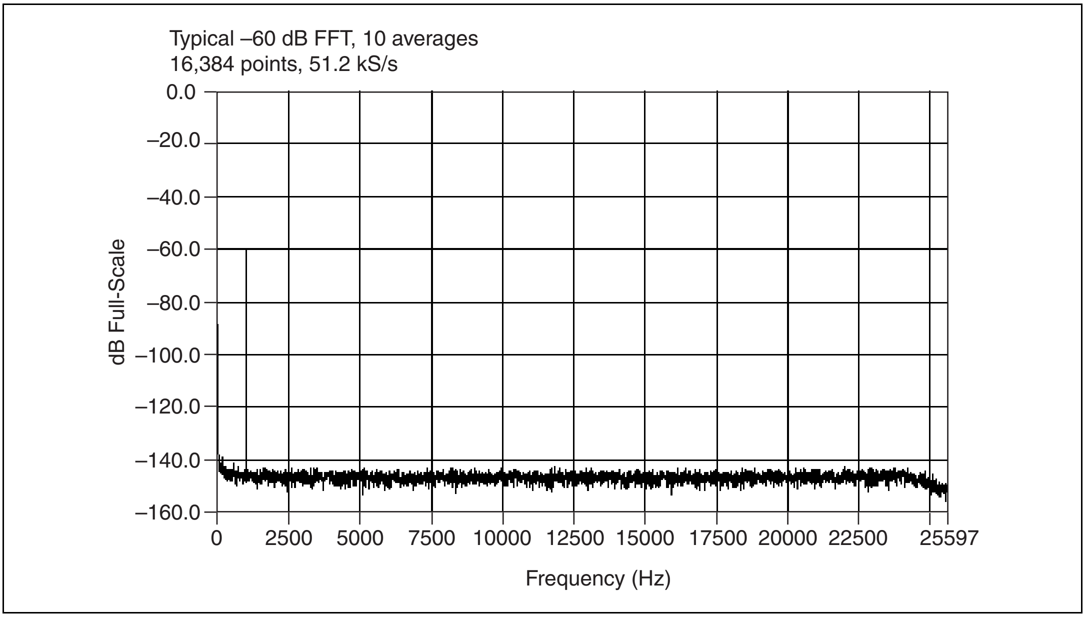

Figure A-4. Spurious-Free Dynamic Range at 51.2 kS/s

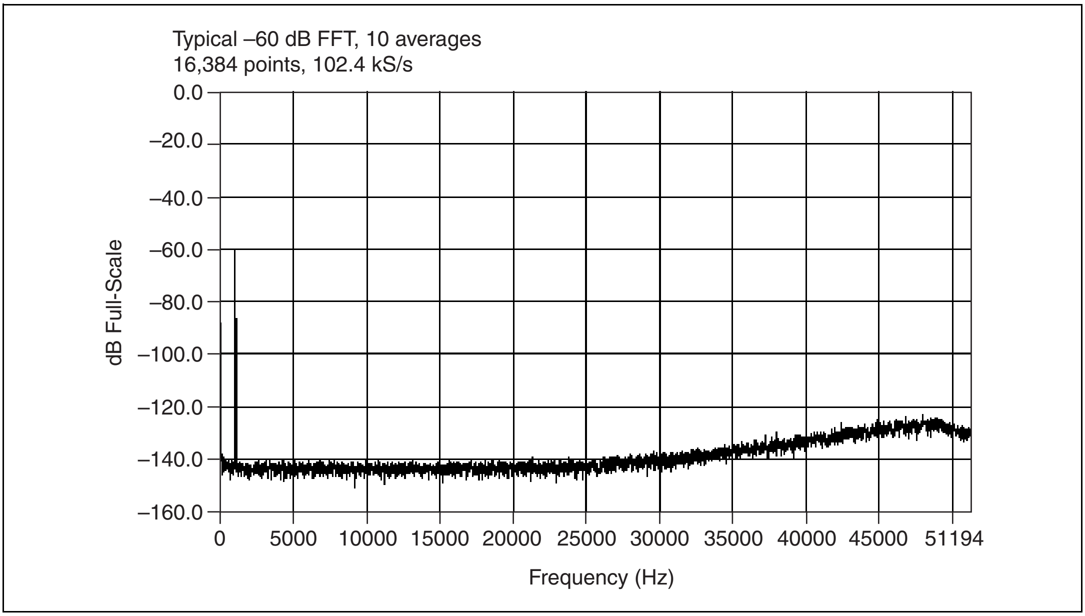

Figure A-5. Spurious-Free Dynamic Range at 102.4 kS/s

THD

0 dBFS input .... <–90 dB
–20 dBFS input .... <–100 dB
–60 dBFS input .... <–60 dB

IMD .... <–100 dB (CCIF 14 kHz + 15 kHz)

Crosstalk[1] (channel separation), f_{in} = 0 to 51.2 kHz
Between channels 0 and 1, 2 and 3, 4 and 5, or 6 and 7
Shorted input .... <–90 dB
1 kΩ load .... <–80 dB
Other channel combinations
Shorted input .... <–100 dB
1 kΩ load .... <–90 dB

Phase linearity .... <±0.5°

Interchannel phase mismatch .... <f_{in} (in kHz) × 0.018° + 0.082°

Interchannel gain mismatch .... ±0.1dB

Onboard Calibration Reference

DC level .... 5.000 V ±2.5 mV

Temperature coefficient .... ±5 ppm/°C max

Long-term stability .... ±20 ppm/ $\sqrt{1{,}000\ h}$

Signal Conditioning

Constant current source (software-enabled)
Current .... 4 mA, ±5%
Compliance .... 24 V
Output impedance .... >250 kΩ at 1 kHz
Current noise .... <500 pA/ $\sqrt{Hz}$

[1] Measured with full-scale (±10 V) input.

Triggers

Analog Trigger

Source	
NI PCI/PXI-4472	CH<0..7>
NI PCI-4474	CH<0..3>
Level	–10 to +10 V, full scale, programmable
Slope	Positive or negative (software selectable)
Resolution	24 bits, nominal
Hysteresis	Programmable

Digital Trigger

Compatibility	TTL/CMOS
Response	Rising or falling edge
Pulse width	10 ns, min

Bus Interface

Type	Master, slave

Power Requirements

+3.3 VDC	
NI PCI-4472, NI PCI-4474	0 mA
NI PXI-4472	400 mA, max
+5 VDC	
NI PCI-4472	2,600 mA, max
NI PCI-4474	2,000 mA, max
NI PXI-4472	2,200 mA, max
+12 VDC	120 mA, max
–12 VDC	120 mA, max

Physical

Dimensions (not including connectors)

NI PCI-4472/4474 ....17.5 by 10.7 cm (6.9 by 4.2 in.)

NI PXI-4472/4472B ....16.0 by 9.9 cm (6.3 by 3.9 in.) (1 3U CompactPCI slot)

Analog I/O connectors............................SMB male

Digital trigger connector.........................SMB male

Calibration

Internal..On software command; computes gain and offset corrections

Interval..Whenever temperature is different from temperature at last internal calibration by more than ±5 °C

External...Internal voltage reference read and stored in non-volatile memory

Interval..1 year

Warm-up time...15 minutes

Maximum Working Voltage

Maximum working voltage refers to the signal voltage plus the common-mode voltage.

Channel-to-earth ....42 V, Installation Category I

Channel-to-channel.................................42 V, Installation Category I

Environmental

Operating temperature ....0 to 50 °C

Storage temperature ....–20 to 70 °C

Humidity ....10 to 90% RH, noncondensing

Maximum altitude .... 2,000 meters

Pollution Degree (indoor use only) 2

Safety

The NI 447*X* devices meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 3111-1, UL 61010B-1
- CAN/CSA C22.2 No. 1010.1

Note For UL and other safety certifications, refer to the product label or to `ni.com`.

Electromagnetic Compatibility

Emissions .... EN 55011 Class A at 10 m
FCC Part 15A above 1 GHz

Immunity .... EN 61326:1997 + A2:2001,
Table 1

EMC/EMI.. CE, C-Tick, and FCC Part 15
(Class A) Compliant

Note For EMC compliance, you *must* operate this device with shielded cabling.

CE Compliance

The NI 447*X* devices meet the essential requirements of applicable European Directives, as amended for CE Marking, as follows:

Low-Voltage Directive (safety) 73/23/EEC

Electromagnetic Compatibility
Directive (EMC) 89/336/EEC

Note Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, click **Declarations of Conformity Information** at `ni.com/hardref.nsf/`. This Web site lists the DoCs by product family. Select the appropriate product family, followed by your product, and a link to the DoC appears in Adobe Acrobat format. Click the Acrobat icon to download or read the DoC.

B

Technical Support and Professional Services

Visit the following sections of the National Instruments Web site at `ni.com` for technical support and professional services:

- **Support**—Online technical support resources include the following:
  - **Self-Help Resources**—For immediate answers and solutions, visit our extensive library of technical support resources available in English, Japanese, and Spanish at `ni.com/support`. These resources are available for most products at no cost to registered users and include software drivers and updates, a KnowledgeBase, product manuals, step-by-step troubleshooting wizards, conformity documentation, example code, tutorials and application notes, instrument drivers, discussion forums, a measurement glossary, and so on.
  - **Assisted Support Options**—Contact NI engineers and other measurement and automation professionals by visiting `ni.com/support`. Our online system helps you define your question and connects you to the experts by phone, discussion forum, or email.
- **Training**—Visit `ni.com/custed` for self-paced tutorials, videos, and interactive CDs. You also can register for instructor-led, hands-on courses at locations around the world.
- **System Integration**—If you have time constraints, limited in-house technical resources, or other project challenges, NI Alliance Program members can help. To learn more, call your local NI office or visit `ni.com/alliance`.
- **Declaration of Conformity (DoC)**—A DoC is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electronic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting `ni.com/hardref.nsf`.

- **Calibration Certificate**—If your product supports calibration, you can obtain the calibration certificate for your product at `ni.com/calibration`.

If you searched `ni.com` and could not find the answers you need, contact your local office or NI corporate headquarters. Phone numbers for our worldwide offices are listed at the front of this manual. You also can visit the Worldwide Offices section of `ni.com/niglobal` to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

Glossary

Symbol	Prefix	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
Ω	ohm
%	percent
+	positive of, or plus
–	negative of, or minus
/	per

A

A	amperes
A/D	analog-to-digital
AC	alternating current
AC coupled	allowing the transmission of AC signals while blocking DC signals

ADC — analog-to-digital converter—an electronic device, often an integrated circuit, that converts an analog voltage to a digital number

ADC resolution — the size of the discrete steps in the ADCs input-to-output transfer function; therefore, the smallest voltage difference an ADC can discriminate with a single measurement

ADE — application development environment—an application designed to make it easier for you to develop software. Usually, ADEs have a graphical user interface and programming tools to help with development. Examples of ADEs are LabVIEW, LabWindows/CVI, Visual Basic, and Visual C++.

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

API — application program interface

asynchronous — (1) hardware—a property of an event that occurs at an arbitrary time, without synchronization to a reference clock; (2) software—a property of a function that begins an operation and returns prior to the completion or termination of the operation

attenuate — to decrease the amplitude of a signal

B

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)

buffer — temporary storage for acquired or generated data (software)

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 ISA and PCI bus.

C

C	Celsius
CCIF	*See* IMD.
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.
clip	clipping occurs when an input signal exceeds the input range of the amplifier
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
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
conditional retrieval	a method of triggering in which you simulate an analog trigger using software. Also called software triggering.
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
crosstalk	an unwanted signal on one channel due to an input on a different channel
current sourcing	the ability of a DAQ device to supply current for analog or digital output signals

D

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 devices plugged into a computer, and possibly generating control signals with D/A and/or DIO devices in the same computer
dB	decibel—the unit for expressing a logarithmic measure of the ratio of two signal levels: $dB = 20\log_{10} (V_1/V_2)$, for signals in volts
dBFS	absolute signal level compared to full scale
DC	direct current
DC coupled	allowing the transmission of both AC and DC signals
DDS clock	Direct Digital Synthesis clock—a type of clock source with an output frequency controlled by a digital input word
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 devices*. 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.
delta-sigma modulating ADC	a high-accuracy circuit that samples at a higher rate and lower resolution than is needed and (by means of feedback loops) pushes the quantization noise above the frequency range of interest. This out-of-band noise is typically removed by digital filters.
device	A plug-in DAQ board, card, or pad that can contain multiple channels and conversion devices. Plug-in boards and PCMCIA cards are all examples of DAQ devices. SCXI modules are distinct from devices.
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 trigger	a TTL level signal having two discrete levels—a high and a low level
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 LSBs of the worst-case deviation of code widths from their ideal value of 1 LSB
DoC	Declaration of Conformity
DOC	the Canadian Department of Communications
down counter	performing frequency division on an internal signal
drivers	software that controls a specific hardware device such as a DAQ device or a GPIB interface device
DSA	dynamic signal acquisition
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
ESD	electrostatic discharge
event	the condition or state of an analog or digital signal
external trigger	a voltage pulse from an external source that triggers an event such as A/D conversion

F

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 attenuate unwanted portions of the signal you are trying to measure

f_{in} — input signal frequency

FIR — finite impulse response—a non recursive digital filter with linear phase

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.

f_{os} — oversampling frequency or rate

f_{s} — sampling frequency or rate

G

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

grounded measurement system — *See* SE.

H

h	hour
hardware	the physical components of a computer system, such as the circuit boards, plug-in boards, chassis, enclosures, peripherals, and cables
hardware triggering	a form of triggering where you set the start time of an acquisition and gather data at a known position in time relative to a trigger signal
high-impedance	in logic circuits designed to have three possible states—0, 1, and hi-Z—the hi-Z (high impedance) state effectively removes the output from its circuit, and can be used to simplify bus communication by wire-ANDing tri-state inputs
Hz	hertz—cycles per second. Specifically refers to the repetition frequency of a waveform.

I

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
IEPE	Integral Electronics Piezoelectric, also known as integrated circuit piezoelectric—a type of transducer that operates using a constant current source as the conditioning medium and returns a signal in the form of voltage modulation on the same line as the current source
IMD	intermodulation distortion—the ratio, in dB, of the total rms signal level of harmonic sum and difference distortion products, to the overall rms signal level. The test signal is two sine waves added together according to the following standards: CCIF—A 14 kHz sine wave and a 15 kHz sine wave added in a 1:1 amplitude ratio.
in.	inches
INL	integral nonlinearity—a measure in LSB of the worst-case deviation from the ideal A/D or D/A transfer characteristic of the analog I/O circuitry
input impedance	the measured resistance and capacitance between the input terminals of a circuit and ground

interrupt — a computer signal indicating that the CPU should suspend its current task to service a designated activity

IRQ — interrupt request

K

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

kS — 1,000 samples

L

LabVIEW — laboratory virtual instrument engineering workbench

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

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

LSB — least significant bit

M

memory buffer — *See* buffer.

MITE — MXI Interface to Everything—a custom ASIC designed by NI that implements the PCI bus interface. The MITE supports bus-mastering for high-speed data transfers over the PCI bus.

MS — million samples

MSB — most significant bit

N

NC	normally closed, or not connected
NI-DAQ	NI 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.
Nyquist frequency	a frequency that is one-half the sampling rate. *See also* Nyquist Sampling Theorem.
Nyquist Sampling Theorem	the theorem states that if a continuous bandwidth-limited analog 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

offset-binary format	a method of digitally encoding sound that represents the range of amplitude values as an unsigned number, with the midpoint of the range representing silence. For example, an 8-bit sound stored in offset-binary format would contain sample values ranging from 0 to 255, with a value of 128 specifying silence (no amplitude). *See also* two's complement format.
operating system	base-level software that controls a computer, runs programs, interacts with users, and communicates with installed hardware or peripheral devices
oversampling	sampling at a rate greater than the Nyquist frequency

P

passband	the range of frequencies which a device can properly propagate or measure
PCI	Peripheral Component Interconnect—a high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA. It is achieving widespread acceptance as a standard for PCs and work-stations; it offers a theoretical maximum transfer rate of 132 Mbytes/s.
PFI	programmable function input
Plug and Play devices	devices that do not require DIP switches or jumpers to configure resources on the devices—also called switchless devices
port	a communications connection on a computer or a remote controller
posttriggering	the technique used on a DAQ device to acquire a programmed number of samples after trigger conditions are met
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

Q

quantization error	the inherent uncertainty in digitizing an analog value due to the finite resolution of the conversion process
quantizer	a device that maps a variable from a continuous distribution to a discrete distribution

R

relative accuracy	a measure in LSB of the linearity of an ADC. It includes all non-linearity 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% of full scale.
rise time	the difference in time between the 10% and 90% points of the step response of a system
rms	root mean square—the square root of the average value of the square of the instantaneous signal amplitude; a measure of signal amplitude
RSE	*See* SE.
RTSI bus	real-time system integration bus—the NI timing bus that connects DAQ devices directly, by means of connectors on top of the devices, for precise synchronization of functions

S

s	seconds
S	samples
S/s	samples per second—used to express the rate at which a DAQ device samples an analog signal
sample counter	the clock that counts the output of the channel clock, in other words, the number of samples taken. On devices with simultaneous sampling, this counter counts the output of the scan clock and hence the number of scans.
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 DSA device that has an extremely stable onboard reference and calibrates its own A/D and D/A circuits without manual adjustments by the user

sensor	a device that responds to a physical stimulus (heat, light, sound, pressure, motion, flow, and so on), and produces a corresponding electrical signal
Shannon Sampling Theorem	*See* Nyquist Sampling Theorem.
signal conditioning	the manipulation of signals to prepare them for digitizing
SMB	a type of coaxial 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.
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

T

THD	total harmonic distortion—the ratio of the total rms signal due to harmonic distortion to the overall rms signal, in decibel or a percentage
THD+N	signal-to-THD plus noise—the ratio in decibels of the overall rms signal to the rms signal of harmonic distortion plus noise introduced
transducer	*See* sensor.
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

t_p	the interval between pulses in a pulse train
t_{reset}	the length of the reset period
TRIG1 (EXT_TRIG)	trigger 1 signal
trigger	any event that causes or starts some form of data capture
tri-state	logic circuitry designed to have three possible outputs—0, 1, and hi-Z. The hi-Z (high impedance) state effectively pulls the output out of its circuit, and can be used to simplify bus communication by wire-ANDing tri-state inputs.
TTL	transistor-transistor logic
TTL-compatible	operating in a nominal range of 0 to 5 VDC, with a signal below 1 V a logic low, and a signal above 2.4 V a logic high
two's complement format	a system for digitally encoding sound that stores the amplitude values as a signed number, with silence represented by a sample with a value of 0. For example, with 8-bit sound samples, two's complement values would range from –128 to 127, with 0 meaning silence. *See also* offset-binary format.

U

unbalanced differential input	an analog input channel consisting of two terminals, with different input impedances, whose difference is measured. In the case of the NI 447*X*, one terminal is referenced to ground through a resistor. *See also* differential input.
undersampling	sampling at a rate lower than the Nyquist frequency—can cause aliasing

V

V	volts
V_{CC}	collector common voltage—power supply voltage
VDC	volts direct current

VI	virtual instrument—(1) a combination of hardware and/or software elements, typically used with a PC, that has the functionality of a classic stand-alone instrument; (2) a LabVIEW software module (VI), which consists of a front panel user interface and a block diagram program
V_{in}	volts in
V_{ref}	reference voltage

W

waveform	multiple voltage readings taken at a specific sampling rate

Index

R

S

T

U

W