

# PXI

## NI PXI-4220 User Manual

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# Conventions

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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.



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. When this icon is marked on the product, refer to the *Read Me First: Safety and Radio-Frequency Interference* document, shipped with the product, for precautions to take.



When symbol is marked on a product it denotes a warning advising you to take precautions to avoid electrical shock.



When symbol is marked on a product it denotes a component that may be hot. Touching this component may result in bodily injury.

**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.

*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.

*monospace italic*

Italic text in this font denotes text that is a placeholder for a word or value that you must supply.

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# About the NI PXI-4220

This chapter provides an introduction to the NI PXI-4220 device and its installation.

The NI PXI-4220 is part of the SC Series of data acquisition (DAQ) devices with integrated signal conditioning. The SC Series reduces measurement setup and configuration complexity by integrating signal conditioning and DAQ on the same product.

The NI PXI-4220 is a full-featured dynamic strain device with programmable bridge-sensor signal conditioning, programmable filter, and programmable gain settings per channel ensuring maximum accuracy for bridge sensors. The NI PXI-4220 features the National Instruments (NI) programmable gain amplifier (PGA), an instrumentation-class amplifier that guarantees fast settling times at all gain settings. The NI PXI-4220 also uses the NI-DAQmx DAQ Assistant, specifically the **Strain Gage Calibration** wizard, to easily perform offset null compensation and shunt calibration.

The NI PXI-4220 is a two-channel module for interfacing to Wheatstone bridge configurations. The NI PXI-4220 has the following features:

- Two differential analog input (AI) channels
- 16-bit resolution
- 333 kS/s single-channel sampling rate
- 66 kS/s per channel when simultaneously sampling
- Direct connectivity through two male D-Subminiature (D-SUB) connectors
- Instrumentation amplifier per channel
- Simultaneous sample-and-hold (SS/H) capability using track-and-hold (T/H) circuitry
- Synchronization with other DAQ devices through the PXI trigger bus
- 4-pole software programmable Butterworth filters with software selectable filter settings of bypass (no filtering), 10 Hz, 100 Hz, 1 kHz, and 10 kHz per channel
- Programmable voltage excitation with remote sense per channel
- Programmatic offset null compensation per channel

- Programmatic shunt calibration per channel
- Programmatic bridge completion per channel
- Programmable Function Input (PFI) pin for external timing, triggering, and calibration.

You can configure most settings on a per-channel basis through software. The NI PXI-4220 is configured using Measurement & Automation Explorer (MAX) or through function calls to NI-DAQmx.

## What You Need to Get Started

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To set up and use the NI PXI-4220, you need the following:

- Hardware
  - NI PXI-4220 device
  - PXI chassis
  - Sensors as required by your application
- Software
  - NI-DAQ 7.0 or later
  - One of the following:
    - LabVIEW
    - Measurement Studio
    - LabWindows™/CVI™
    - Refer to **National Instruments»NI-DAQ»NI-DAQ Read Me** for supported text-based compilers
- Documentation
  - *NI PXI-4220 User Manual*
  - *DAQ Quick Start Guide*
  - *Read Me First: Safety and Radio-Frequency Interference*
  - PXI chassis user manual
  - Documentation for your software
- Tools
  - 1/8 in. flathead screwdriver

You can download NI documents from [ni.com/manuals](http://ni.com/manuals).

# National Instruments Documentation

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The *NI PXI-4220 User Manual* is one piece of the documentation set for your DAQ system. You could have any of several types of manuals, depending on the hardware and software in your system. Use the manuals you have as follows:

- *DAQ Quick Start Guide*—This document describes how to install NI-DAQ devices and NI-DAQ. Install NI-DAQmx before you install the PXI module.
- PXI chassis manual—Read this manual for maintenance information on the chassis and for installation instructions.
- Software documentation—You may have both application software and NI-DAQmx software documentation. NI application software includes LabVIEW, Measurement Studio, and LabWindows/CVI. After you set up the hardware system, use either your application software documentation or the NI-DAQmx documentation to help you write your application. If you have a large, complex system, it is worthwhile to look through the software documentation before you configure the hardware.

## Installing the Application Software, NI-DAQ, and the DAQ Device

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Refer to the *DAQ Quick Start Guide*, packaged with the NI-DAQ software, for instructions for installing your application software, NI-DAQ driver software, and the DAQ device to which you will connect the NI PXI-4220.

NI-DAQ 7.0 or later is required to configure and program the NI PXI-4220 device. If you do not have NI-DAQ 7.0 or later, you can either contact an NI sales representative to request it on a CD or download the it from [ni.com](http://ni.com).

# Installing the NI PXI-4220

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**Note** Refer to the *Read Me First: Radio-Frequency Interference* document before removing equipment covers or connecting or disconnecting any signal wires.

Refer to the *DAQ Quick Start Guide* to unpack, install, and configure the NI PXI-4220 in a PXI chassis.

## LED Pattern Descriptions

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The following LEDs on the NI PXI-4220 front panel confirm the system is functioning properly:

- The *ACCESS* LED is normally green and blinks yellow for a minimum of 100 ms during the NI PXI-4220 configuration.
- The *ACTIVE* LED is normally green and blinks yellow for a minimum of 100 ms during data acquisition.

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# Connecting Signals

This chapter describes how to connect Wheatstone bridge sensors to the NI PXI-4220 in quarter-, half-, and full-bridge configurations, and for remote sensing.

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## Connecting Bridge Sensor Signals to the NI PXI-4220

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This section discusses how to connect the signals of supported strain-gauge configuration types as well as full-bridge sensors such as load, force, torque, and pressure sensors. It also discusses connecting leads for remote sensing. Refer to Chapter 4, *Theory of Operation*, for a discussion of strain-gauge concepts.



**Caution** Refer to the *Read Me First: Safety and Radio-Frequency Interference* document before removing equipment covers or connecting/disconnecting any signal wires.

Figure 2-1 shows the NI PXI-4220 front label, including the location of the D-SUB connectors and PFI0/CAL SMB connector.

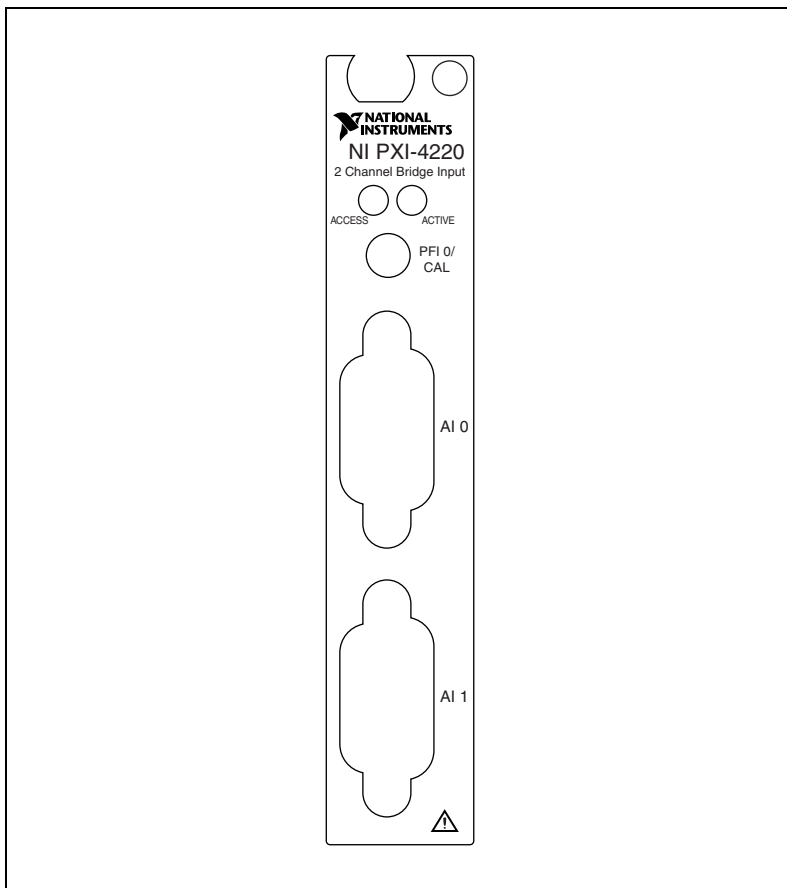


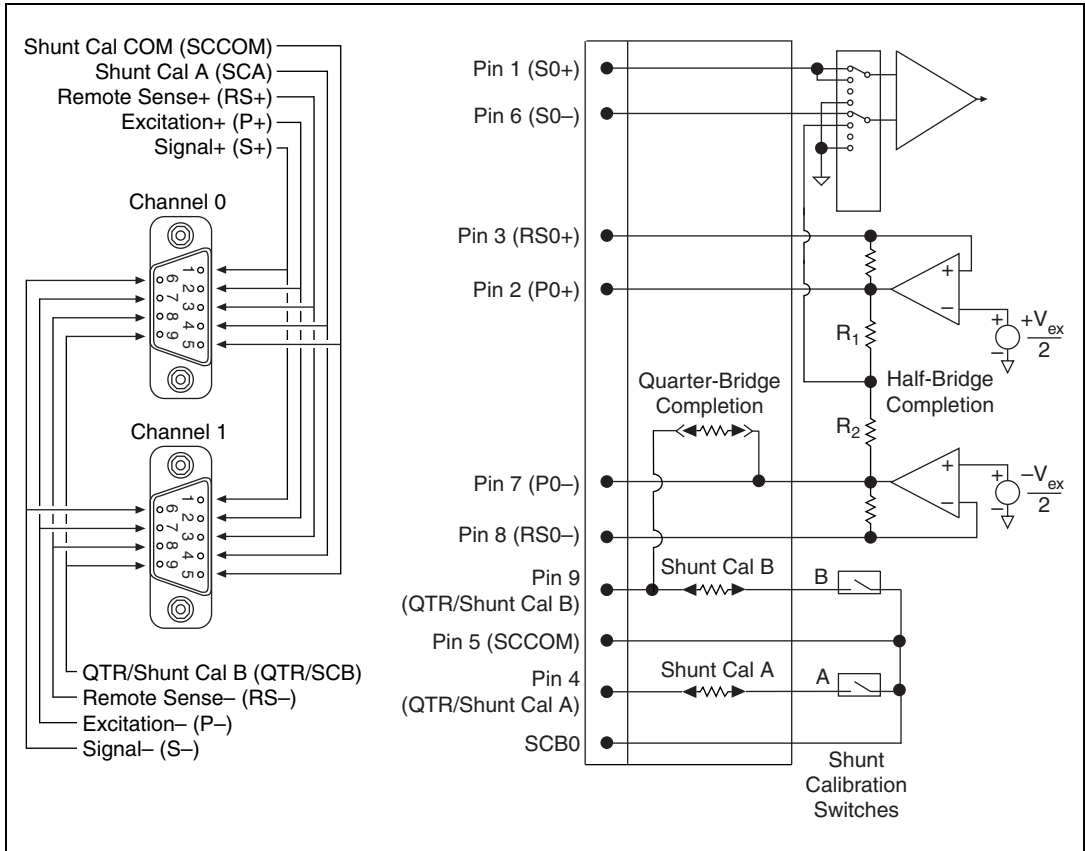
Figure 2-1. NI PXI-4220 Front Label

Construct a signal lead with an SMB connection to connect a timing or triggering signal to the PFI0/CAL SMB connector.



**Caution** The PFI0/CAL SMB connector is for low-voltage timing and calibration signals *only*. Voltages greater than  $\pm 10$  V can damage the device.

Figure 2-2 shows the pin signal assignments for each of the NI PXI-4220 D-SUB connectors. Refer to Figure 2-2 when constructing D-SUB connection leads to ensure the signal wires are routed correctly. In the electrical connection diagram, each signal connection node is labeled with a pin number to indicate which pin carries the signal.



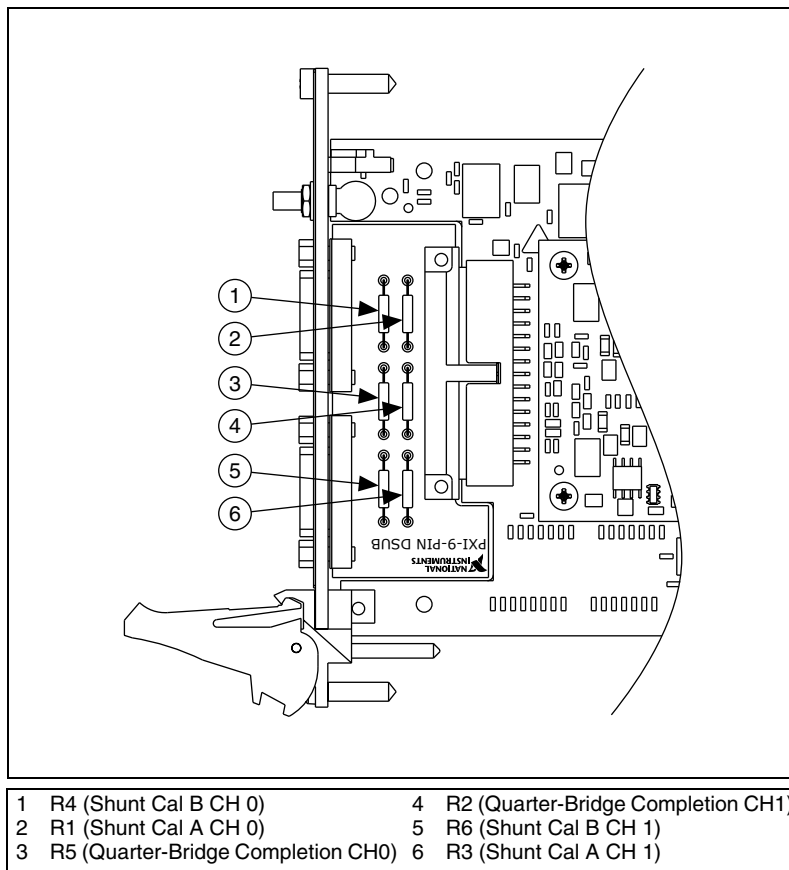
**Figure 2-2.** PXI-4220 Front Connector and General Circuit Diagram



**Note** Refer to Figure 2-3 for quarter-bridge and shunt cal completion resistor locations.



Figure 2-3 shows the location of the socketed NI PXI-4220 resistors.



**Figure 2-3.** Socketed Resistor Locations

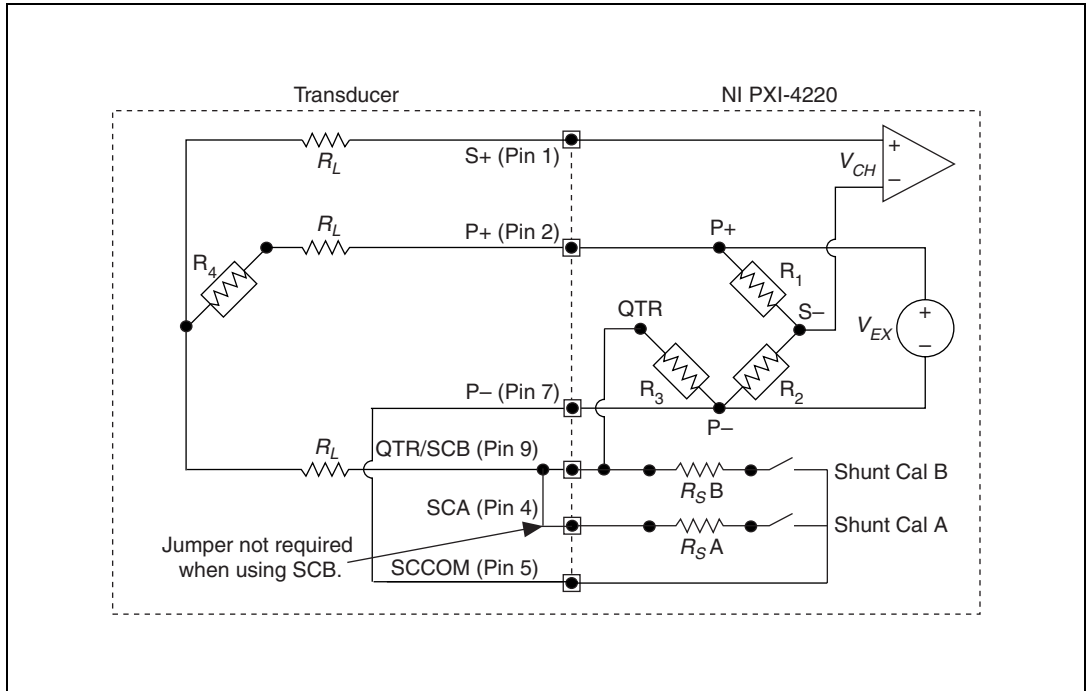
## Quarter-Bridge Type I

This section provides information about connecting the quarter-bridge strain-gauge configuration type I.

Figure 2-4 shows the quarter-bridge type I circuit wiring diagram. Refer to the *Quarter-Bridge Type I* section of Chapter 4, *Theory of Operation*, for more information.



**Note** If you have a two-wire strain-gauge element, connect the active element leads to S+ (pin 1) and P+ (pin 2) and short S+ (pin 1) to QTR/SCB (pin 9) and SCA (pin 4).



**Figure 2-4.** Quarter-Bridge I Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  and  $R_2$  are half-bridge completion resistors.
- $R_3$  is the quarter-bridge completion resistor (dummy resistor).
- $R_4$  is the active element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the measured voltage.
- $R_{S A}$  is shunt calibration resistor A.
- $R_{S B}$  is shunt calibration resistor B.

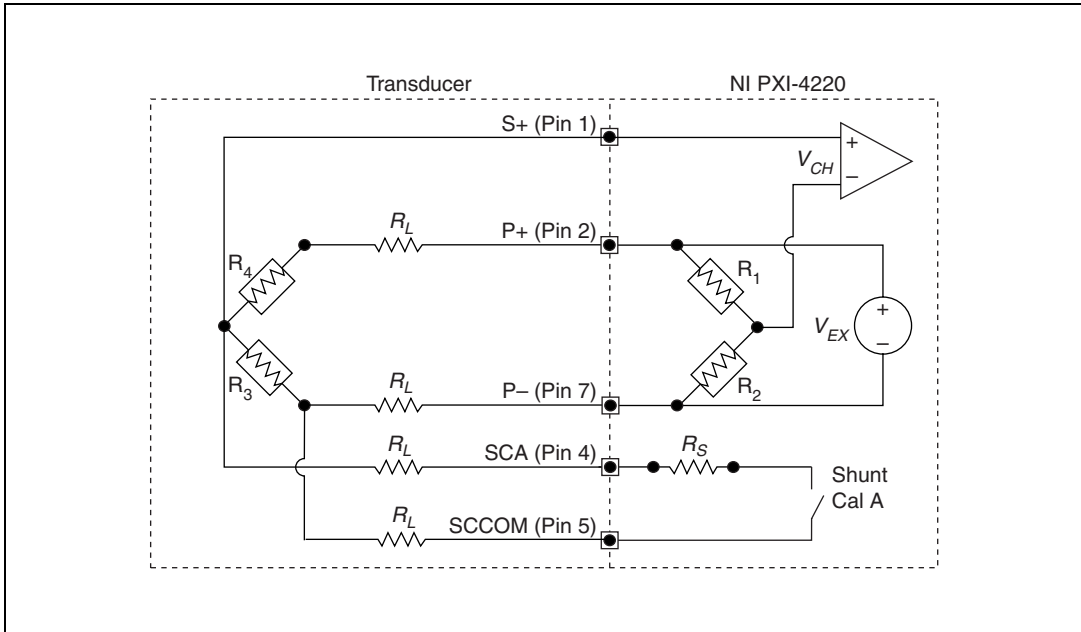
This configuration uses the Shunt Cal A switch for shunt calibration.



**Note** The value of the quarter-bridge completion resistor (dummy resistor) must equal the nominal resistance of the strain gauge. NI recommends using a 0.1% precision resistor. If a less precise resistor is used, offset null compensation calibration is not as accurate. Refer to the [Offset Null Compensation](#) section of Chapter 4, *Theory of Operation*, for more information.

## Quarter-Bridge Type II

This section provides information about connecting the quarter-bridge strain-gauge configuration type II. Figure 2-5 shows the quarter-bridge type II circuit wiring diagram. Refer to the *Quarter-Bridge Type II* section of Chapter 4, *Theory of Operation*, for more information.



**Figure 2-5.** Quarter-Bridge II Circuit Diagram

The following symbols apply to the circuit diagram and equations:

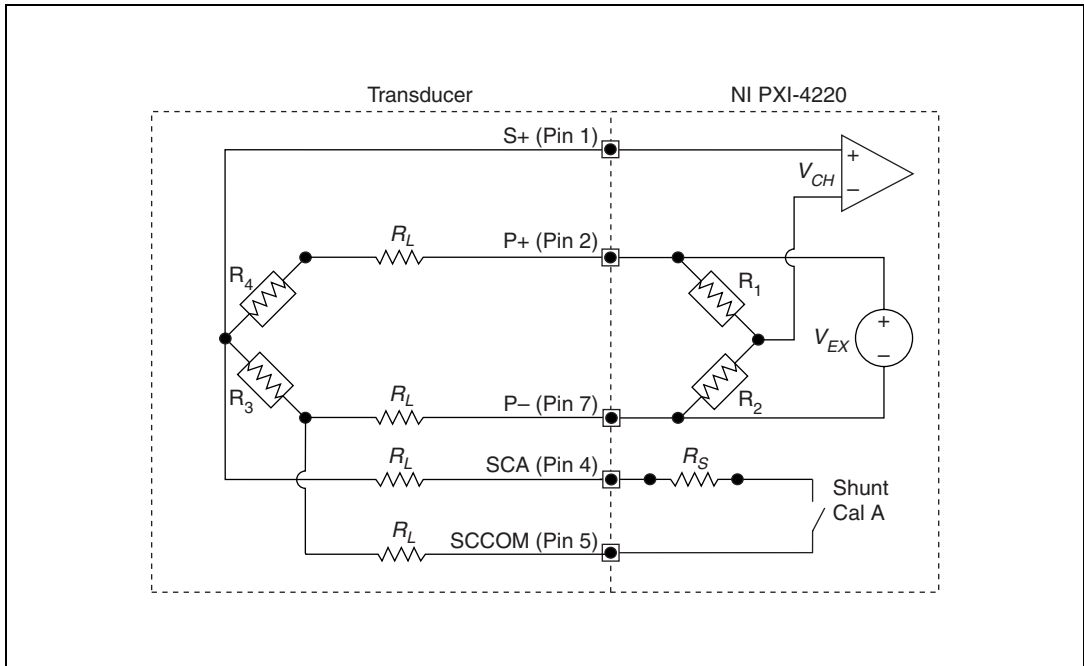
- $R_1$  and  $R_2$  are half-bridge completion resistors.
- $R_3$  is the quarter-bridge temperature-sensing element (dummy gauge).
- $R_4$  is the active element measuring tensile strain (+ $\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the voltage measured.
- $R_S$  is shunt calibration resistor A.



**Note** The quarter-bridge type II is often confused with the more commonly used half-bridge type I. For more information, refer to the *Quarter-Bridge Type II* and *Half-Bridge Type I* sections of Chapter 4, *Theory of Operation*.

## Half-Bridge Type I

This section provides information about connecting the half-bridge strain-gauge configuration type I. Figure 2-6 shows the half-bridge type I circuit wiring diagram. Refer to the *Half-Bridge Type I* section of Chapter 4, *Theory of Operation*, for more information.



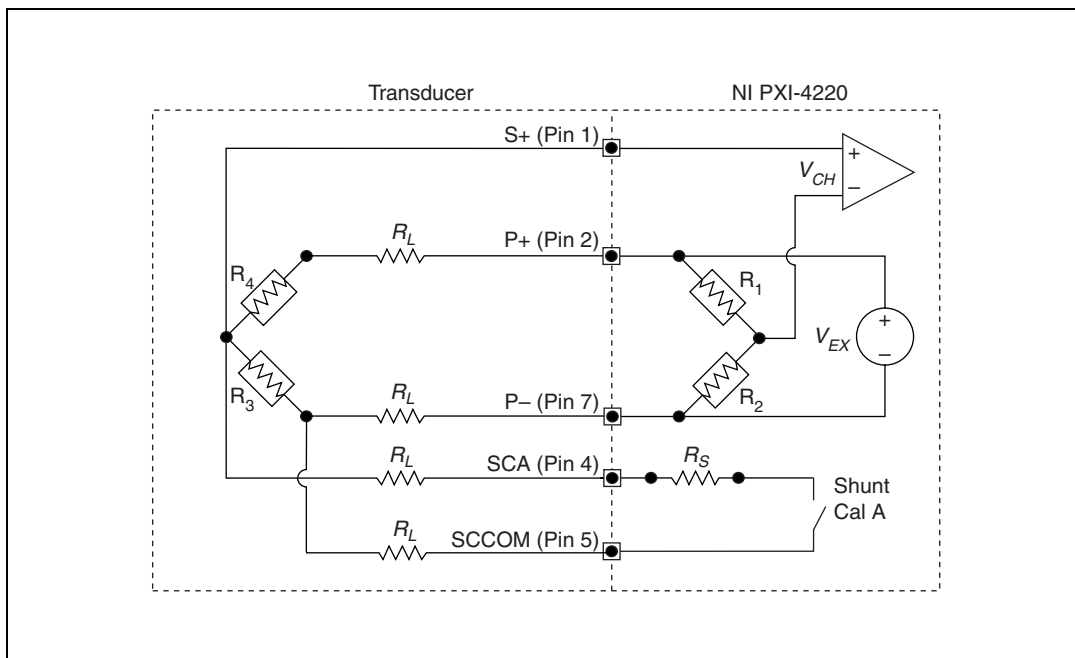
**Figure 2-6.** Half-Bridge Type I Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  and  $R_2$  are half-bridge completion resistors.
- $R_3$  is an active element measuring compression from Poisson effect ( $-v\epsilon$ ).
- $R_4$  is an active element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the voltage measured.
- $R_S$  is shunt calibration resistor A.

## Half-Bridge Type II

This section provides information about connecting the half-bridge strain-gauge configuration type II. Figure 2-7 shows the half-bridge type II circuit wiring diagram. Refer to the *Half-Bridge Type II* section of Chapter 4, *Theory of Operation*, for more information.



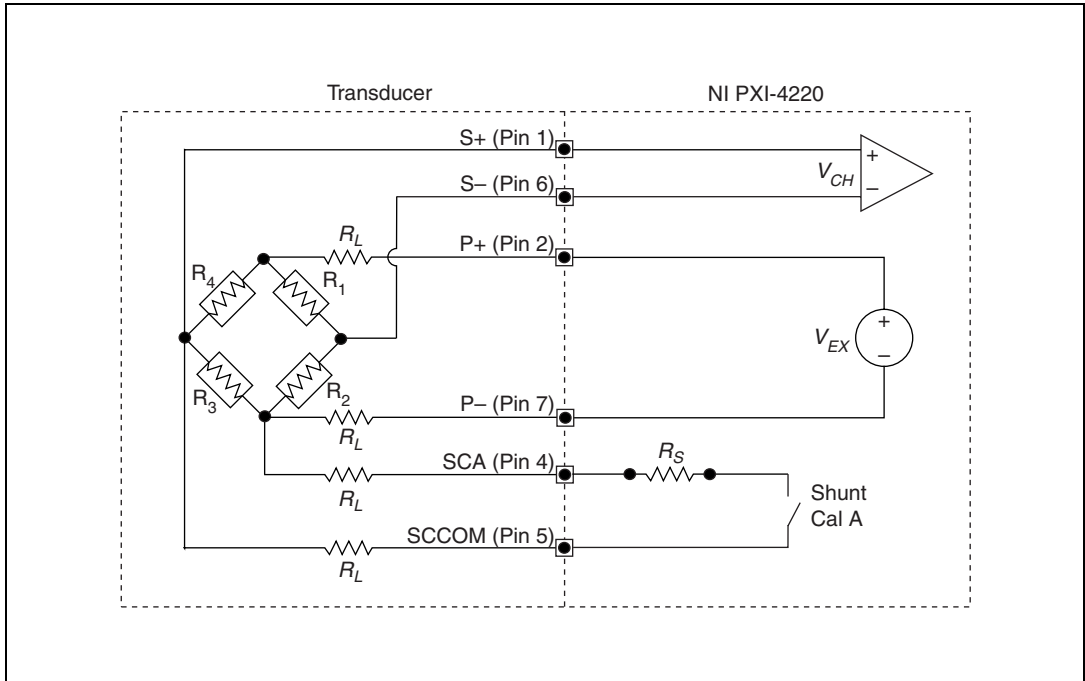
**Figure 2-7.** Half-Bridge Type II Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  and  $R_2$  are half-bridge completion resistors.
- $R_3$  is an active element measuring compressive strain ( $-\epsilon$ ).
- $R_4$  is an active element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the voltage measured.
- $R_S$  is shunt calibration resistor A.

## Full-Bridge Type I

This section provides information about connecting the full-bridge strain-gauge configuration type I. Figure 2-8 shows the full-bridge type I circuit wiring diagram. Refer to the *Full-Bridge Type I* section of Chapter 4, *Theory of Operation*, for more information.



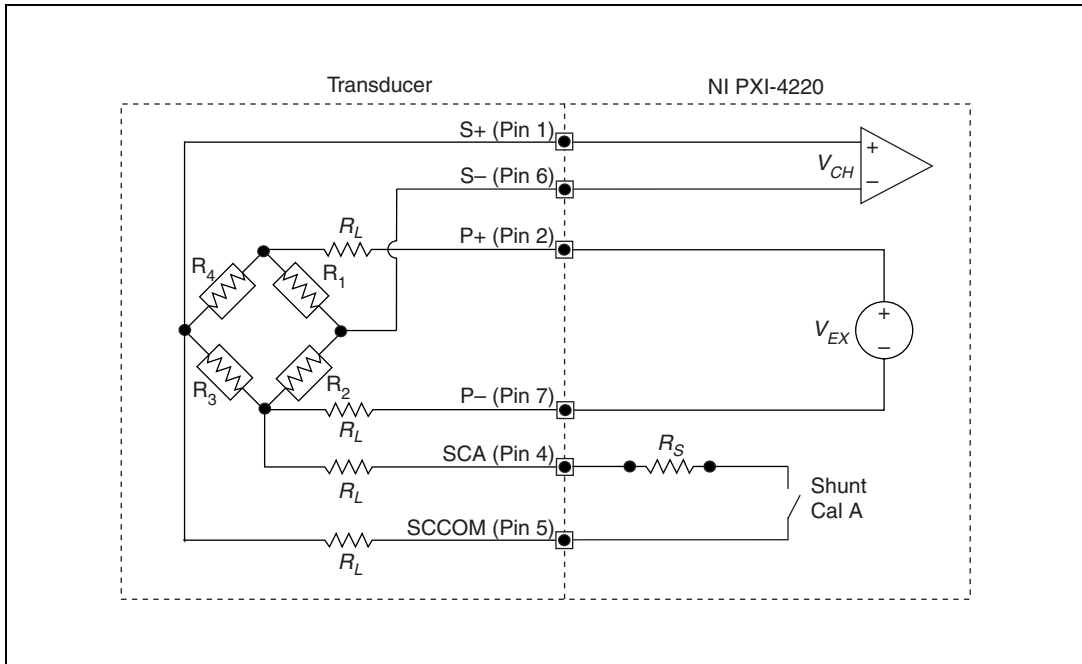
**Figure 2-8.** Full-Bridge Type I Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  is an active element measuring compressive strain ( $-\epsilon$ ).
- $R_2$  is an active element measuring tensile strain ( $+\epsilon$ ).
- $R_3$  is an active element measuring compressive strain ( $-\epsilon$ ).
- $R_4$  is an active element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the measured voltage.
- $R_S$  is shunt calibration resistor A.

## Full-Bridge Type II

This section provides information about connecting the full-bridge strain-gauge configuration type II. Figure 2-9 shows the full-bridge type II circuit wiring diagram. Refer to the *Full-Bridge Type II* section of Chapter 4, *Theory of Operation*, for more information.



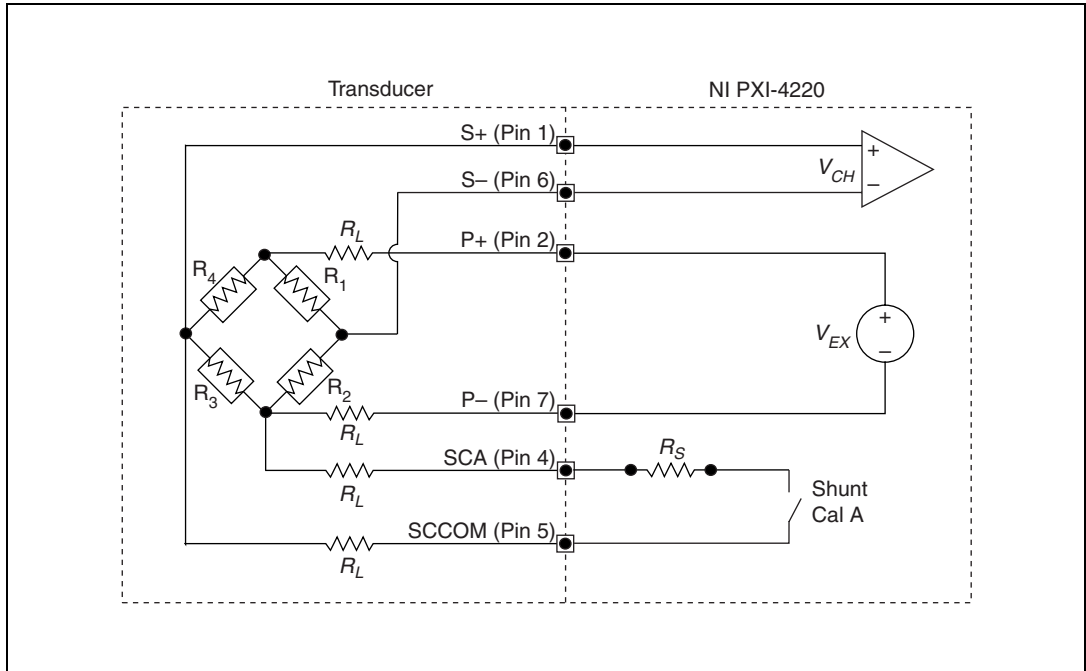
**Figure 2-9.** Full-Bridge Type II Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  is an active element measuring compressive Poisson effect ( $-\nu\epsilon$ ).
- $R_2$  is an active element measuring tensile Poisson effect ( $+\nu\epsilon$ ).
- $R_3$  is an active element measuring compressive strain ( $-\epsilon$ ).
- $R_4$  is an active element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the measured voltage.
- $R_S$  is shunt calibration resistor A.

## Full-Bridge Type III

This section provides information about connecting the full-bridge strain-gauge configuration type I. The full-bridge type III only measures axial strain. Figure 2-10 shows the full-bridge type III circuit wiring diagram. Refer to the *Full-Bridge Type III* section of Chapter 4, *Theory of Operation*, for more information.



**Figure 2-10.** Full-Bridge Type III Circuit Diagram

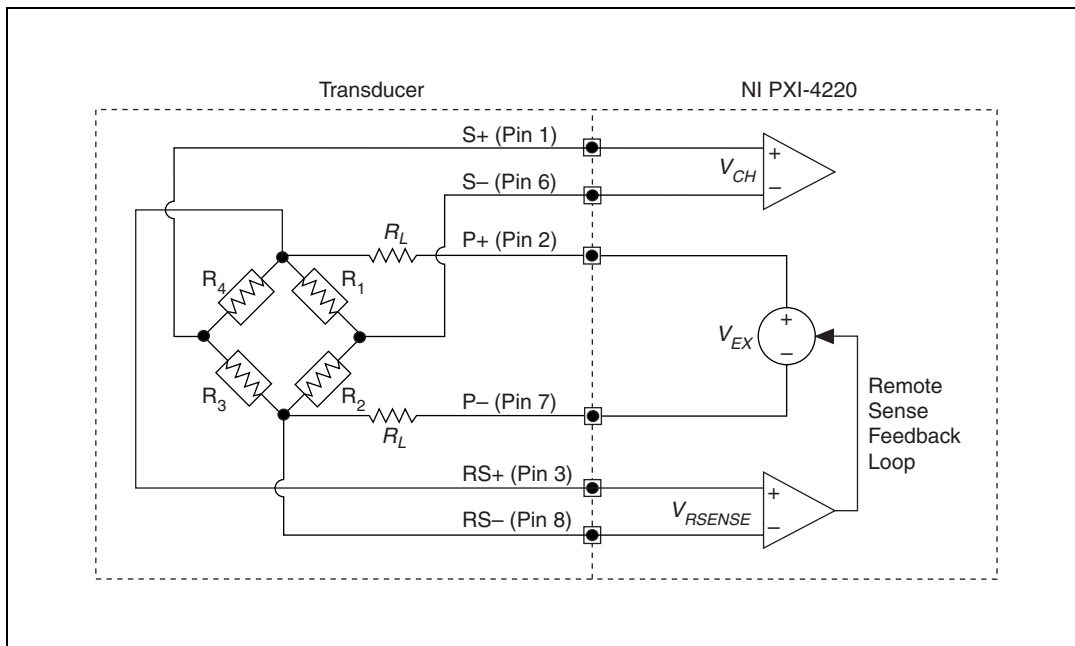
The following symbols apply to the circuit diagram and equations:

- $R_1$  is an active element measuring compressive Poisson effect ( $-v\epsilon$ ).
- $R_2$  is an active element measuring tensile strain ( $+\epsilon$ ).
- $R_3$  is an active element measuring compressive Poisson effect ( $-v\epsilon$ ).
- $R_4$  is an active element measuring the tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the measured voltage.
- $R_S$  is shunt calibration resistor A.



## Remote Sense

For remote sensing, wire the NI PXI-4220 for remote sense as shown in Figure 2-11. Refer to the *Remote Sense* section of Chapter 4, *Theory of Operation*, for more information about remote sensing. Using remote sense with the NI PXI-4220 is recommended to properly regulate the excitation voltage,  $V_{EX}$ , being applied to the sensor.



**Figure 2-11.** Remote Sense Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$ ,  $R_2$ ,  $R_3$ , and  $R_4$  are the transducer bridge elements.
- $V_{CH}$  is the measured voltage.
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{RSENSE}$  is the measured bridge excitation.



**Note** Remote sense is illustrated using a full-bridge circuit diagram for simplicity, but in general, the  $V_{RSENSE}$  terminals should be connected to your transducer at the points that supply  $V_{EX}$ . For example, connect RSX+ (pin 3) to PX+ (pin 2), and RSX- (pin 8) to PX- (pin 7) at the sensor.

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# Configuring and Testing

This chapter provides details on configuring the NI PXI-4220 in MAX. In MAX you can use device test panels to verify device functionality and signal connection. MAX also allows you to easily create, configure, and test **NI-DAQmx Tasks** and **NI-DAQmx Global Channels** to control and configure the NI PXI-4220.

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## Verifying and Self-Testing Using Device Test Panels

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Once you have successfully installed the NI PXI-4220, verified the installation, and connected the signals, use the NI PXI-4220 device test panels to verify the device is measuring signals properly.

The test panels allow you to measure the signal connected to the NI PXI-4220 directly as well as configure some of the properties of your measurement. To open the NI PXI-4220 device test panels when in MAX, complete the following steps:

1. Display the list of devices and interfaces by clicking the + next to the **Devices and Interfaces** icon.
2. Display the list of NI-DAQmx devices by clicking the + next to **NI-DAQmx Devices** icon.
3. Click **PXI-4220**.
4. Click the **Test Panels** button in the device toolbar.
5. Configure the settings shown on the screen and click **Start** to take a measurement.

To measure scaled voltages, further configure channel properties, and configure timing settings, use an **NI-DAQmx Task** or **NI-DAQmx Global Channel**.

# NI PXI-4220 Software-Configurable Settings

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This section describes how to set the bridge configuration, voltage excitation level, filter bandwidth, and gain/input signal range, as well as how to use configuration utilities in MAX to programmatically perform offset null compensation and shunt calibration. It also describes how to perform configuration of these settings for the NI PXI-4220 in NI-DAQmx. For more information about the relationship between the settings and the measurements and how to configure settings in your application, refer to Chapter 5, *Developing Your Application*.

## Common Software-Configurable Settings

This section describes the most frequently used software-configurable settings for the NI PXI-4220.

### Bridge Configuration and Completion

Bridge configuration is a software-configurable setting that allows you to connect quarter-, half-, or full-bridge sensors configurations. Refer to Chapter 4, *Theory of Operation*, for more information.

### Excitation Level

Excitation level is a software-configurable setting that allows you to set the voltage excitation level on Pins 2 and 7. You can choose voltage excitation settings between 0 and 10 V. To prevent the module from overheating, refer to Table 3-1 for appropriate excitation levels for common sensor resistances.

$$\begin{aligned} & \text{(maximum excitation voltage)} = \\ & \text{(resistance connected between the excitation terminals)} \times (29.0 \text{ mA}) \end{aligned}$$

Table 3-1 shows the maximum allowable excitation voltages for standard bridge configurations and resistances. For other bridge resistances, the maximum allowable excitation voltage is:

$$V_{EX, \text{ max}} = (\text{bridge resistance})(29.0 \text{ mA})$$

Refer to Chapter 4, *Theory of Operation*, for more information about excitation.

**Table 3-1.** Excitation Voltage for Configuration and Gauge Resistances

Configuration/ Sensor	Resistance	Excitation Voltage Range
Quarter- or Half-Bridge	120 $\Omega$	0 to 6.950 V
	350 $\Omega$	0 to 10 V
	1000 $\Omega$	0 to 10 V
Full-Bridge or Full-Bridge Sensor	120 $\Omega$	0 to 3.475 V
	350 $\Omega$	0 to 10 V
	1000 $\Omega$	0 to 10 V

## Filter

Lowpass Filter Cutoff Frequency is a software-configurable setting that allows you to select a lowpass filter cutoff frequency. You can choose 10 Hz, 100 Hz, 1 kHz, 10 kHz, or disable the filter. With the filter disabled, the module has a bandwidth of 20 kHz. Refer to Chapter 4, *Theory of Operation*, for more information.

## Gain/Input Range

Gain/input range refers to the signal conditioning gain and digitizer input range, software-configurable settings that allow you to choose the appropriate amplification to fully utilize the range of the NI PXI-4220 DAQ circuitry. In most applications, NI-DAQ sets the gain for you determined by the input range. Refer to Chapter 4, *Theory of Operation*, for more information. Otherwise, you should determine the appropriate gain using the input signal voltage range and the full-scale limits of the NI PXI-4220 signal conditioning output signal.

## Offset Null Compensation Potentiometers

Coarse and fine offset null compensation potentiometers are software-configurable settings that allow you to remove unwanted offset voltage. In most cases, you do not explicitly set the potentiometers, but instead allow driver software to automatically adjust them for you. However, if you want to explicitly set the potentiometers, you can write an application program that adjusts the settings. Refer to Chapter 4, *Theory of Operation*, for more information.

## Shunt Calibration Switches

Shunt calibration switches A and B are software-configurable settings that allow you to engage or disengage the shunt calibration resistors in order to perform gain calibration. In most cases, you do not explicitly control the shunt calibration switches, but instead allow driver software to automatically adjust them for you during the automated shunt calibration procedure. However, if you want to explicitly control the calibration switches, you can write an application program that controls the shunt calibration switches. Refer to Chapter 4, *Theory of Operation*, for more information.



**Note** Null calibration is done for you automatically if you perform shunt calibration using the NI-DAQmx driver. Refer to Chapter 4, *Theory of Operation*, for more information about how to perform shunt calibration using the driver.

## Simultaneous Sample and Hold

When it is critical to measure two or more signals at the same instant in time, simultaneous sample and hold (SS/H) is required. Typical applications that might require SS/H include vibration measurements and phase difference measurements. You can disable this setting through your application if you require scan rates beyond the maximum allowable with SS/H engaged. NI recommends leaving SS/H engaged. Disabling SS/H introduces a small offset voltage. You can compensate for this offset by performing offset null calibration. Refer to Chapter 5, *Developing Your Application*, for more information about how to enable and disable SS/H.



**Note** You cannot change the simultaneous sampling mode in MAX. You must use an ADE such as LabVIEW to configure the setting. Refer to your ADE help file for more information.

## Configurable Settings in MAX

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**Note** If you are not using an NI ADE, or if you are using an NI ADE prior to version 7.0 or an unlicensed copy of an NI ADE, additional dialog boxes from the NI License Manager appear allowing you to create a task or global channel in unlicensed mode. These messages continue to appear until you install version 7.0 or later of an NI ADE.

You can use MAX to configure your bridge-based sensor measurement. This section describes where you can access each software-configurable setting available in MAX.

## NI-DAQmx

In NI-DAQmx, you can configure software settings such as bridge configuration, voltage excitation level, filter bandwidth, gain/input range, and calibration settings in the following two ways:

- **NI-DAQmx Task** or **Global Channel** in MAX
- Functions in your application



**Note** Some software-configurable settings can only be set through your application. This section only discusses settings available in MAX. Refer to Chapter 5, *Developing Your Application*, for information about using functions in your application.

The following sections describe settings you can change in MAX and where they are located. Strain and custom voltage with excitation are the most commonly used **NI-DAQmx Task** or **NI-DAQmx Global Channel** types with the NI PXI-4220. Use the **Custom Voltage with Excitation NI-DAQmx Task** or **Global Channel** when measuring load, force, torque, pressure or other bridge-based sensors. You can configure the following settings using MAX or your application.

- **Bridge Configuration**—set through the settings tab of your **NI-DAQmx Task** or **NI-DAQmx Global Channel** and functions in your application. The default bridge configuration for NI-DAQmx is full bridge.
- **Voltage Excitation**— set either through **NI-DAQmx Task** or **NI-DAQmx Global Channel**. You also can set the voltage excitation level through your application. In NI-DAQmx you can choose from contiguous voltages between 0 and 10 V. The default voltage excitation in NI-DAQmx is 0 V.
- **Lowpass Filter Cutoff Frequency**—set using the **Device** tab through either the **NI-DAQmx Task** or **NI-DAQmx Global Channel**. You also can set it through your application. The default filter cutoff frequency in NI-DAQmx is 10 kHz.
- **Input Range**—set the input range through **NI-DAQmx Task** or **NI-DAQmx Global Channel**. When you set the minimum and maximum range of the **NI-DAQmx Task** or **NI-DAQmx Global Channel**, the driver selects the best gain for the measurement. You also can set it through your application.
- **Calibration Settings**—set offset null compensation potentiometer settings and control shunt calibration switches only through **Strain NI-DAQmx Task** or **Strain NI-DAQmx Global Channel** or through your application. The **Custom Voltage with Excitation NI-DAQmx Task** or **NI-DAQmx Global Channel** cannot adjust calibration

settings in MAX at this time. In these cases, adjust calibration settings in your application. The default configuration settings set the potentiometers at their midpoint, 62 for the coarse potentiometer and 2,047 for the fine potentiometer. The default state of the shunt calibration switches is open. This leaves the shunt calibration resistor disconnected from the circuit.



**Note** For more information about how to further configure the NI PXI-4220, or how to use LabVIEW to configure the device and take measurements, refer to Chapter 5, *Developing Your Application*.

## Creating a Strain Global Channel or Task

To create a new NI-DAQmx strain global task or channel, complete the following steps:

1. Double-click the **Measurement & Automation Explorer** icon on the desktop.
2. Right-click **Data Neighborhood** and select **Create New**.
3. Select **NI-DAQmx Task** or **NI-DAQmx Global Channel** and click **Next**.
4. Select **Analog Input**, and then select **Strain**.
5. If you are creating a task, keep the **Create New Local Channels** selected and select the channels to add to the task. You can select blocks of channels by pressing the <Shift> key while making the selections or individual channels by pressing the <Ctrl> key while making the selections. If you are creating a global channel, you can select only one channel. Click **Next**.
6. Name the task or channel, and then click **Finish**.
7. In the box labeled **Channel List**, select the channel(s) you want to configure. You can select blocks of channels by pressing the <Shift> key while making the selections or individual channels by pressing the <Ctrl> key while making the selections.
8. Enter the specific values for your application in the **Settings** tab. Context help information for each setting is provided on the right side of the screen.
9. Click the **Device** tab and select the auto-zero mode and lowpass filter cutoff frequency.



**Note** For most NI PXI-4220 applications, you should set the autozero mode to **None**. Autozero is not useful for relative transducers such as strain gauges. Autozero performs a software compensation for offset voltage from the signal conditioning and DAQ circuitry, not the transducer, and is therefore not as accurate as hardware offset null compensation.

10. Ensure that you have selected the strain channel(s) you wish to calibrate in the **Channel List** box, and then click **Calibration** to perform offset null compensation and shunt calibration on the strain channel(s).
11. On the screen that opens, you can choose to enable offset null compensation and/or shunt calibration, and enter the shunt calibration resistor information. Click **Next**.
12. The **Measure and Calibrate** screen displays information specific to the strain channel(s). Click **Measure** to acquire a signal from the strain channel(s) and **Reset Data** to reset the values to default. Click **Calibrate** to calibrate the strain channel(s). When you have completed calibrating the strain channel(s), click **Finish**.



**Note** For offset null compensation and shunt calibration of quarter-bridge configuration types, the value of the quarter-bridge completion resistor must equal the nominal resistance of the strain gauge.

13. If you are creating a task and want to set timing or triggering controls, enter the values in the **Task Timing** and **Task Triggering** tabs.

## Creating a Custom Voltage with Excitation Global Channel or Task

Use the **Custom Voltage with Excitation NI-DAQmx Task** or **Global Channel** when measuring load, force, torque, pressure, or other bridge-based sensors. To create an **NI-DAQmx Custom Voltage with Excitation Task** or **NI-DAQmx Global Channel**, complete the following steps:

1. Double-click the **Measurement & Automation Explorer** icon on the desktop.
2. Right-click **Data Neighborhood** and select **Create New**.
3. Select **NI-DAQmx Global Channel** or **NI-DAQmx Task** and click **Next**.
4. Select **Analog Input**, and then select **Custom Voltage with Excitation**.



5. If you are creating a channel, you can select only one channel. If you are creating a task, keep the **Create New Local Channels** selected and select the channels to add to the task. You can select blocks of channels by pressing the <Shift> key while making the selections or individual channels by pressing the <Ctrl> key while making the selections. Click **Next**.
6. Select the name of the task or channel, and then click **Finish**.
7. In the box labeled **Channel List**, select the channel(s) you want to configure. You can select blocks of channels by pressing the <Shift> key while making the selections or individual channels by pressing the <Ctrl> key while making the selections.
8. Enter the specific values for your application in the **Settings** tab. Context help information for each setting is provided on the right side of the screen.
9. Click the **Device** tab and select the auto-zero mode and lowpass filter cutoff frequency.
10. If you are applying custom scaling, select **Create New** from the **Custom Scaling** drop-down and follow the wizard instructions.
11. If you are creating a task and want to set timing or triggering controls, enter the values in the **Task Timing** and **Task Triggering** tabs.

## Verifying the Signal

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This section describes how to take measurements using test panels in order to verify signal connection, system configuration, and device installation.

### Verifying the Signal in NI-DAQmx Using a Task or Global Channel

You can verify the signals on the NI PXI-4220 using NI-DAQmx by completing the following steps:

1. Click the + next to **Data Neighborhood**.
2. Click the + next to **NI-DAQmx Tasks**.
3. Click the task.
4. In the **Channel List**, select + to add channels to the strain task or – to delete channels.
5. In the window that opens, click the + next to the module.
6. Select the channel(s) you want to verify. You can select a block of channels using the <Shift> key or multiple channels using the <Ctrl> key. Click **OK**.

7. Enter the appropriate information on the **Settings** tab.
8. Click the **Device** tab.
9. Enter the appropriate information on the **Device** tab.
10. Click the **Test** button
11. Click the **Start** button.
12. After you have completed verifying the channels, click the **Stop** button.

You have now verified the NI PXI-4220 configuration and signal connection.



**Note** For more information about how to further configure the NI PXI-4220, or how to use LabVIEW to configure the module and take measurements, refer to Chapter 5, *Developing Your Application*.

# Theory of Operation

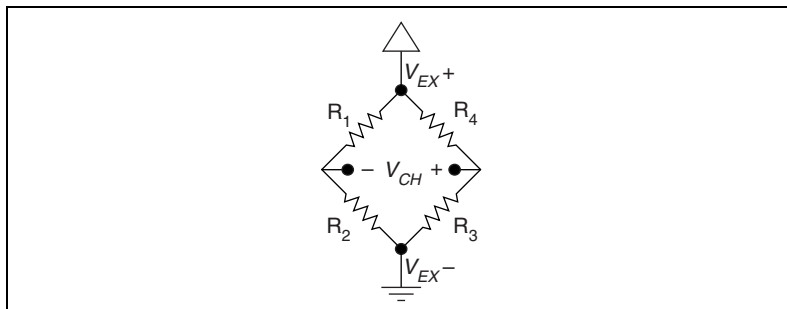
This chapter discusses strain-gauge concepts, the theory of operational measurement concepts, and timing and control concepts.

## Strain Gauge Theory

This section discusses how to arrange, connect, and scale signals from bridge-based sensors, especially strain gauges.

### Wheatstone Bridges

All strain-gauge configurations are based on the concept of a Wheatstone bridge. A Wheatstone bridge is a network of four resistive legs. One or more of these legs are active sensing elements. Figure 4-1 shows a Wheatstone bridge circuit diagram.



**Figure 4-1.** Basic Wheatstone Bridge Circuit Diagram

The Wheatstone bridge is the electrical equivalent of two parallel voltage divider circuits.  $R_1$  and  $R_2$  compose one voltage divider circuit, and  $R_4$  and  $R_3$  compose the second voltage divider circuit. The output of a Wheatstone bridge is measured between the middle nodes of the two voltage dividers.

A physical phenomenon, such as a change in strain or temperature applied to a specimen, changes the resistance of the sensing elements in the Wheatstone bridge. The Wheatstone bridge configuration is used to measure the small variations in resistance that the sensing elements produce corresponding to physical changes in the specimen.

## Strain Gauges

Strain-gauge configurations are arranged as Wheatstone bridges. The gauge is the collection of all of the active elements of the Wheatstone bridge. There are three types of strain-gauge configurations: quarter-, half-, and full-bridge. The number of active element legs in the Wheatstone bridge determines the kind of bridge configuration. Refer to Table 4-1 to see how many active elements are in each configuration.

**Table 4-1.** Strain-Gauge Configurations

Configuration	Number of Active Elements
Quarter-bridge	1
Half-bridge	2
Full-bridge	4

Each of these configurations is subdivided into multiple configuration types. The orientation of the active elements and the kind of strain measured determines the configuration type. NI supports seven configuration types in software. However, with custom software scaling, you can use all Wheatstone bridge configuration types with any NI hardware product that supports the gauge configuration type.

The supported strain gauge configuration types measure axial strain, bending strain, or both. While you can use some similar configuration types to measure torsional strain, NI software scaling does not support these configuration types. It is possible to use NI products to measure torsional strain, but to properly scale these configuration types you must create a custom scale in MAX or perform scaling in your software application.

This document discusses all of the mechanical, electrical, and scaling considerations of each strain-gauge configuration type supported by NI.

## Acronyms, Formulas, and Variable Definitions

In the figures and equations in this document, the acronyms, formulas, and variables are defined as:

$\epsilon$  is the measured strain (+ $\epsilon$  is tensile strain and  $-\epsilon$  is compressive strain).

$\epsilon_S$  is the simulated strain.

$GF$  is the gauge factor, which should be specified by the gauge manufacturer.

$R_g$  is the nominal gauge resistance, which should be specified by the gauge manufacturer.

$R_L$  is the lead resistance. If lead lengths are long,  $R_L$  can significantly impact measurement accuracy.

$R_S$  is the shunt calibration resistor value.

$U$  is the ratio of expected signal voltage to excitation voltage with the shunt calibration circuit engaged. Parameter  $U$  appears in the equations for simulated strain and is defined by the following equation:

$$U = \frac{-R_g}{4R_S + 2R_g}$$

$\nu$  is the Poisson's ratio, defined as the negative ratio of transverse strain to axial strain (longitudinal) strain. Poisson's ratio is a material property of the specimen you are measuring.

$V_{CH}$  is the measured signal's voltage.

$V_{EX}$  is the excitation voltage.

$V_r$  is the voltage ratio that is used in the voltage to strain conversion equations and is defined by the following equation:

$$V_r = \left( \frac{V_{CH}(\text{strained}) - V_{CH}(\text{unstrained})}{V_{EX}} \right)$$

## Software Scaling and Equations

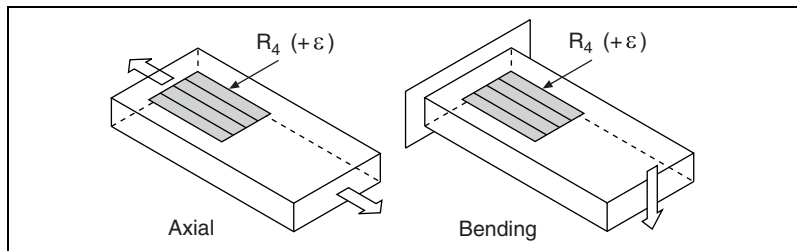
Once you have acquired the voltage signal  $V_{CH}$ , you can scale this voltage to the appropriate strain units in software. This is done automatically for you in MAX using a strain task or strain channel. You also can scale the voltages manually in your application using the voltage to strain conversion equations provided in this document for each configuration type.

Finally, there are voltage to strain conversion functions included in LabVIEW and NI-DAQmx. In LabVIEW, the conversion function, `Convert Strain Gauge Reading.vi`, is in the **Functions»All Functions»NI Measurements»Data Acquisition»Signal Conditioning** subpalette.

The names given the strain-gauge types in the following sections directly correspond to bridge selections in MAX and the LabVIEW Convert Strain Gauge Reading VI.

## Quarter-Bridge Type I

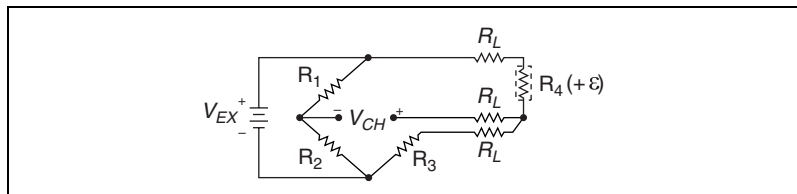
This section provides information about the quarter-bridge strain-gauge configuration type I. The quarter-bridge type I measures either axial or bending strain. Figure 4-2 shows how to position a strain-gauge resistor in an axial and bending configurations. Figure 4-3 shows the quarter-bridge type I circuit wiring diagram.



**Figure 4-2.** Quarter-Bridge Type I Measuring Axial and Bending Strain

A quarter-bridge type I has the following characteristics:

- A single active strain-gauge element is mounted in the principle direction of axial or bending strain.
- A passive quarter-bridge completion resistor (dummy resistor) is required in addition to half-bridge completion.
- Temperature variation in specimen decreases the accuracy of the measurements.
- Sensitivity at  $1000 \mu\epsilon$  is  $\sim 0.5 \text{ mV}_{\text{out}} / V_{\text{EX}}$  input.



**Figure 4-3.** Quarter-Bridge Type I Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  and  $R_2$  are half-bridge completion resistors.
- $R_3$  is the quarter-bridge completion resistor (dummy resistor).

- $R_4$  is the active strain-gauge element measuring tensile strain (+ $\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the measured voltage.

To convert voltage readings to strain units, use the following equation:

$$\text{strain } (\epsilon) = \frac{-4V_r}{GF(1 + 2V_r)} \times \left(1 + \frac{R_L}{R_g}\right)$$

where

- $R_g$  is the nominal gauge resistance of the sensor.
- $R_L$  is the lead resistance.
- $GF$  is the gauge factor.

To simulate the effect on strain of applying a shunt resistor across R3, use the following equation:

$$\epsilon_s = \frac{-4U}{GF(1 + 4U)}$$

The value of the quarter-bridge completion resistor (dummy resistor) must equal the nominal resistance of the strain gauge. NI recommends using a 0.1% precision resistor. If a less precise resistor is used, offset null compensation calibration is not as accurate.

To minimize temperature drift errors, the strain gauge should have a self-temperature-compensation (STC) number that corresponds to the thermal expansion coefficient of the material under test. STC gauges have a temperature sensitivity that counteracts the thermal expansion coefficient of the test specimen. The STC number approximately equals the thermally induced change in strain with change in temperature and is expressed in units of microstrain per degree Fahrenheit. For example, if the test specimen is aluminum, use a gauge with an STC number of 13.0. If the test specimen is steel, use a gauge with an STC number of 6.0.

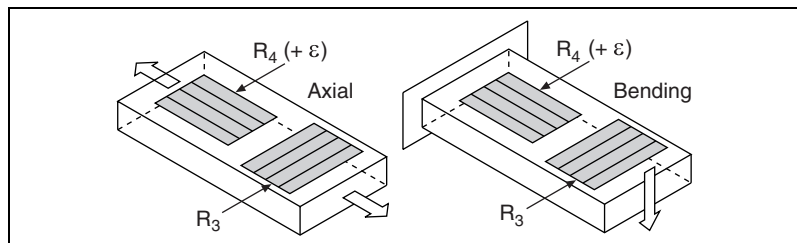
To minimize temperature drift errors in the wiring, use the three-wire connection shown in Figure 2-4, *Quarter-Bridge 1 Circuit Diagram*. The wires connected to pins P+ (pin 2) and QTR/SCB (pin 9) carry the same current and are on opposite sides of the same element of the bridge. Therefore, any temperature-related changes in voltage drop across  $R_L$  caused by temperature variation of the leads cancel out, leaving  $V_{CH}$

unchanged. The voltage drop across the lead resistance on a quarter-bridge type I configuration is uncompensated in hardware. It is important to accurately determine the gauge lead resistance and enter it in MAX or in the application software equation so the software can compensate for the voltage drop.

You can neglect lead resistance ( $R_L$ ) of the wiring if shunt calibration is performed or if lead length is very short ( $\sim <10$  ft), depending on the wire gauge. For example, 10 ft of 24-AWG copper wire has a lead resistance of  $0.25 \Omega$ .

## Quarter-Bridge Type II

This section provides information about the quarter-bridge strain-gauge configuration type II. The quarter-bridge type II measures either axial or bending strain. Figure 4-4 shows how to position a strain-gauge resistor in an axial and bending configurations. Figure 4-5 shows the quarter-bridge type II circuit wiring diagram.



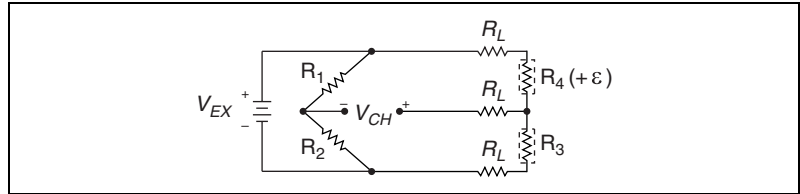
**Figure 4-4.** Quarter-Bridge Type II Measuring Axial and Bending Strain

A quarter-bridge type II has the following characteristics:

- One active strain-gauge element and one passive, temperature-sensing quarter-bridge element (dummy gauge). The active element is mounted in the direction of axial or bending strain. The dummy gauge is mounted in close thermal contact with the strain specimen, but not bonded to the specimen, and is usually mounted transverse (perpendicular) to the principle axis of strain.
- Often confused with the half-bridge type I configuration. There is a key difference between the quarter-bridge type II and half-bridge type I configurations. In the half-bridge type I configuration, the  $R_3$  element is active and bonded to the strain specimen to measure the effect of Poisson's ratio. In the quarter-bridge type II configuration, the  $R_3$  element is not necessarily bonded to the surface, but is in close thermal contact with the specimen or with another piece of the same material at the same temperature.



- Completion resistors provide half-bridge completion.
- Compensates for specimen temperature variation.
- Sensitivity at 1000  $\mu\epsilon$  is  $\sim 0.5 \text{ mV}_{\text{out}}/V_{\text{EX}}$  input.



**Figure 4-5.** Quarter-Bridge Type II Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  and  $R_2$  are half-bridge completion resistors.
- $R_3$  is the quarter-bridge temperature-sensing element (dummy gauge).
- $R_4$  is the active strain-gauge element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the voltage measured.

To convert voltage readings to strain units, use the following equation:

$$\text{strain } (\epsilon) = \frac{-4V_r}{GF(1 + 2V_r)} \times \left(1 + \frac{R_L}{R_g}\right)$$

where

- $R_g$  is the nominal gauge resistance.
- $R_L$  is the lead resistance.
- $GF$  is the gauge factor.

To simulate the effect on strain of applying a shunt resistor across  $R_3$ , use the following equation:

$$\epsilon_s = \frac{-4U}{GF(1 + 4U)}$$

The dummy gauge element must always be unstrained and mounted to the same type of material as the active gauge, but not strained. The dummy gauge temperature must closely track the temperature of the active gauge.

The nominal value of  $R_3$  is equal to  $R_g$ .

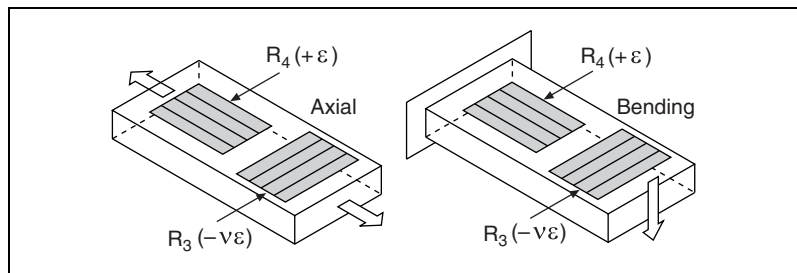
Gauges need not have an STC number corresponding to the material type of the test specimen.

As shown in Figure 2-5, *Quarter-Bridge II Circuit Diagram*, for greatest calibration accuracy, use separate wires between the bridge and the shunt calibration pins SCA (pin 4) and SCCOM (pin 5). Do not directly short SCA (pin 4) or SCCOM (pin 5) inside your connector unless the strain-gauge leads are short and have minimal lead resistance.

You can neglect lead resistance ( $R_L$ ) of the wiring if shunt calibration is performed or if lead length is very short ( $\sim <10$  ft), depending on the wire gauge. For example, 10 ft of 24-AWG copper wire has a lead resistance of  $0.25 \Omega$ .

## Half-Bridge Type I

This section provides information about the half-bridge strain-gauge configuration type I. The half-bridge type I measures either axial or bending strain. Figure 4-6 shows how to position strain-gauge resistors in an axial and bending configurations. Figure 4-7 shows the half-bridge type I circuit wiring diagram.

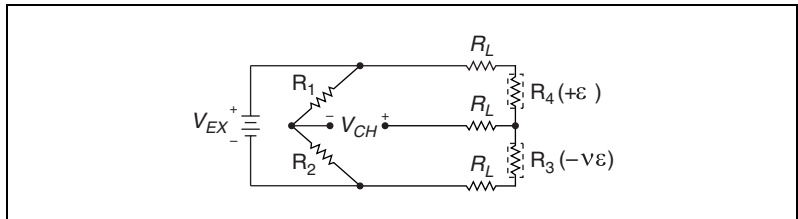


**Figure 4-6.** Half-Bridge Type I Measuring Axial and Bending Strain

A half-bridge type I has the following characteristics:

- Two active strain-gauge elements. One is mounted in the direction of axial strain, and the other acts as a Poisson gauge and is mounted transverse (perpendicular) to the principal axis of strain.
- Completion resistors provide half-bridge completion.
- Sensitive to both axial and bending strain.
- Compensates for specimen temperature variation.

- Compensates for the aggregate effect on the principle strain measurement due to the Poisson's ratio of the specimen material.
- Sensitivity at 1000  $\mu\epsilon$  is  $\sim 0.65 \text{ mV}_{\text{out}}/\text{V}_{\text{EX}}$  input.



**Figure 4-7.** Half-Bridge Type I Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  and  $R_2$  are half-bridge completion resistors.
- $R_3$  is the active strain-gauge element measuring compression from Poisson effect ( $-v\epsilon$ ).
- $R_4$  is the active strain-gauge element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the voltage measured.

To convert voltage readings to strain units, use the following equation:

$$\text{strain } (\epsilon) = \frac{-4V_r}{GF[(1 + \nu) - 2V_r(\nu - 1)]} \times \left(1 + \frac{R_L}{R_g}\right)$$

where

- $R_g$  is the nominal gauge resistance.
- $R_L$  is the lead resistance.
- $\nu$  is the Poisson's ratio.
- $GF$  is the gauge factor.

To simulate the effect on strain of applying a shunt resistor across  $R_3$ , use the following equation:

$$\epsilon_s = \frac{-4U}{GF[(1 + \nu) - 2U(\nu - 1)]}$$



**Notes** In half-bridge type I,  $R_4$  is mounted along the principal axis of the stress field and  $R_3$  is mounted transverse to the axis of the stress field. Use this configuration in applications where no stress exists along the axis of the transverse strain gauge.

The nominal values of  $R_3$  and  $R_4$  equal  $R_g$ .

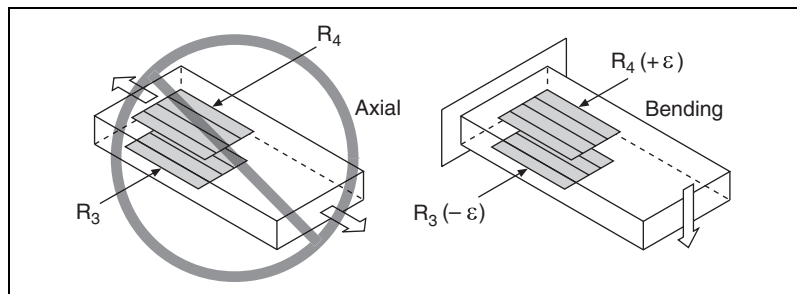
Gauges need not have an STC number corresponding to the material type of the test specimen.

As shown in Figure 2-6, *Half-Bridge Type I Circuit Diagram*, for greatest calibration accuracy, use separate wires between the bridge and the shunt calibration pins SCA (pin 4) and SCCOM (pin 5). Do not directly short SCA (pin 4) or SCCOM (pin 5) inside your connector unless the strain-gauge leads are short and have minimal lead resistance.

You can neglect lead resistance ( $R_L$ ) of the wiring if shunt calibration is performed or if lead length is very short ( $\sim <10$  ft), depending on the wire gauge. For example 10 ft of 24-AWG copper wire has a lead resistance of  $0.25 \Omega$ .

## Half-Bridge Type II

This section provides information about the half-bridge strain-gauge configuration type II. The half-bridge type II measures bending strain only. Figure 4-8 shows how to position strain-gauge resistors in a bending configuration. Figure 4-9 shows the half-bridge type II circuit wiring diagram.

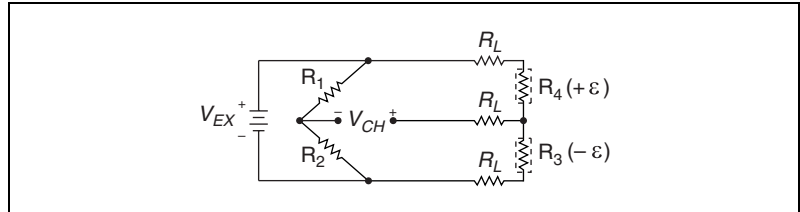


**Figure 4-8.** Half-Bridge Type II Rejecting Axial and Measuring Bending Strain

A half-bridge type II configuration has the following characteristics:

- Two active strain-gauge elements. One is mounted in the direction of bending strain on one side of the strain specimen (top), and the other is mounted in the direction of bending strain on the opposite side (bottom).
- Completion resistors provide half bridge completion.

- Sensitive to bending strain.
- Rejects axial strain.
- Compensates for specimen temperature variation.
- Sensitivity at 1000  $\mu\epsilon$  is  $\sim 1 \text{ mV}_{\text{out}}/V_{\text{EX}}$  input.



**Figure 4-9.** Half-Bridge Type II Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  and  $R_2$  are half-bridge completion resistors.
- $R_3$  is the active strain-gauge element measuring compressive strain ( $-\epsilon$ ).
- $R_4$  is the active strain-gauge element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the voltage measured.

To convert voltage readings to strain units, use the following equation:

$$\text{strain } (\epsilon) = \frac{-2V_r}{GF} \times \left(1 + \frac{R_L}{R_g}\right)$$

where

- $R_g$  is the nominal gauge resistance.
- $R_L$  is the lead resistance.
- $GF$  is the gauge factor.

To simulate the effect on strain of applying a shunt resistor across  $R_3$ , use the following equation:

$$\epsilon_s = \frac{-2U}{GF}$$



**Notes** Half-bridge type II requires one strain gauge to undergo tensile strain while the other strain gauge undergoes compressive strain of the same magnitude. This configuration is often used to measure bending strain where the strain gauges are mounted on opposite sides of a beam.

The nominal values of  $R_3$  and  $R_4$  equal  $R_g$ .

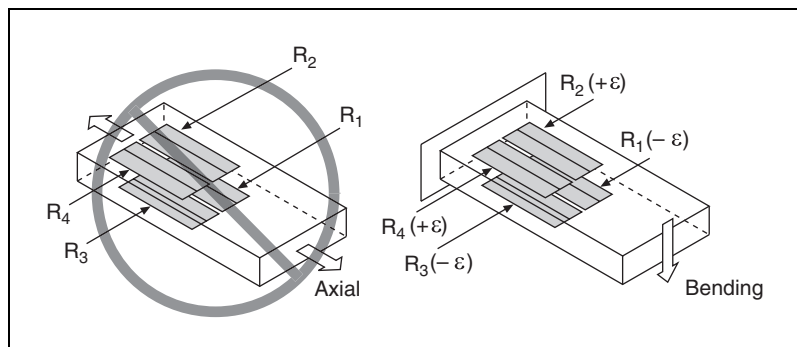
Gauges need not have an STC number corresponding to the material type of the test specimen.

As shown in Figure 2-7, *Half-Bridge Type II Circuit Diagram*, for greatest calibration accuracy, use separate wires between the bridge and the shunt calibration pins SCA (pin 4) and SCCOM (pin 5). Do not directly short SCA (pin 4) or SCCOM (pin 5) inside your connector unless the strain-gauge leads are short and have minimal lead resistance.

You can neglect lead resistance ( $R_L$ ) of the wiring if shunt calibration is performed or if lead length is very short ( $\sim <10$  ft), depending on the wire gauge. For example, 10 ft of 24-AWG copper wire has a lead resistance of  $0.25 \Omega$ .

## Full-Bridge Type I

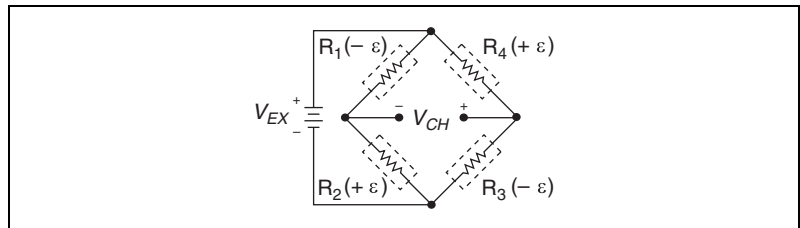
This section provides information about the full-bridge strain-gauge configuration type I. The full-bridge type I measures bending strain only. Figure 4-10 shows how to position strain-gauge resistors in a bending configuration. Figure 4-11 shows the full-bridge type I circuit wiring diagram.



**Figure 4-10.** Full-Bridge Type I Rejecting Axial and Measuring Bending Strain

A full-bridge type I configuration has the following characteristics:

- Four active strain-gauge elements. Two are mounted in the direction of bending strain on one side of the strain specimen (top), and the other two are mounted in the direction of bending strain on the opposite side (bottom).
- Highly sensitive to bending strain.
- Rejects axial strain.
- Compensates for specimen temperature variation.
- Compensates for lead resistance.
- Sensitivity at  $1000 \mu\epsilon$  is  $\sim 2.0 \text{ mV}_{\text{out}}/V_{EX}$  input.



**Figure 4-11.** Full-Bridge Type I Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  is an active strain-gauge element measuring compressive strain ( $-\epsilon$ ).
- $R_2$  is an active strain-gauge element measuring tensile strain ( $+\epsilon$ ).
- $R_3$  is an active strain-gauge element measuring compressive strain ( $-\epsilon$ ).
- $R_4$  is an active strain-gauge element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the measured voltage.

To convert voltage readings to strain units, use the following equation:

$$\text{strain } (\varepsilon) = \frac{-V_r}{GF}$$

where

- $GF$  is the gauge factor.

To simulate the effect on strain of applying a shunt resistor across  $R_3$ , use the following equation:

$$\varepsilon_s = \frac{-U}{GF}$$



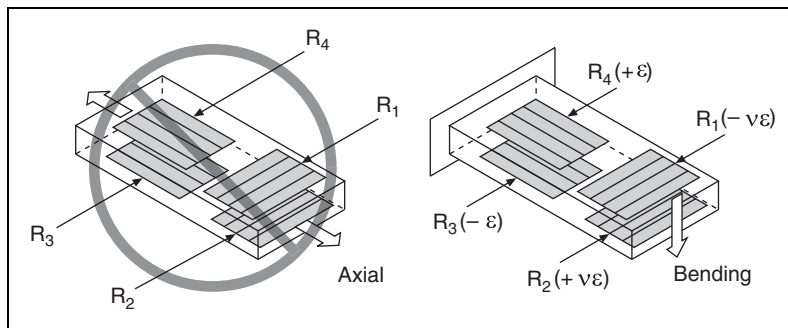
**Notes** The nominal values of  $R_1$ ,  $R_2$ ,  $R_3$ , and  $R_4$  equal  $R_g$ .

Gauges need not have an STC number corresponding to the material type of the test specimen.

As shown in Figure 2-8, *Full-Bridge Type I Circuit Diagram*, for greatest calibration accuracy, use separate wires between the bridge and the shunt calibration pins SCA (pin 4) and SCCOM (pin 5). Do not directly short SCA (pin 4) or SCCOM (pin 5) inside your connector unless the strain-gauge leads are short and have minimal lead resistance.

## Full-Bridge Type II

This section provides information about the full-bridge type II strain-gauge configuration. The full-bridge type II only measures bending strain. Figure 4-12 shows how to position strain-gauge resistors in a bending configuration. Figure 4-13 shows the full-bridge type II circuit wiring diagram.

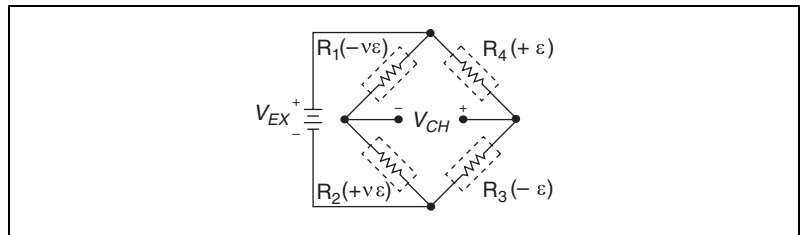


**Figure 4-12.** Full-Bridge Type II Rejecting Axial and Measuring Bending Strain



A full-bridge type II configuration has the following characteristics:

- Four active strain-gauge elements. Two are mounted in the direction of bending strain with one on one side of the strain specimen (top), and the other on the opposite side (bottom). The other two act together as a Poisson gauge and are mounted transverse (perpendicular) to the principal axis of strain with one on one side of the strain specimen (top), the other on the opposite side (bottom).
- Rejects axial strain.
- Compensates for specimen temperature variation.
- Compensates for the aggregate effect on the principle strain measurement due to the Poisson's ratio of the specimen material.
- Compensates for lead resistance.
- Sensitivity at  $1000 \mu\epsilon$  is  $\sim 1.3 \text{ mV}_{\text{out}} / V_{\text{EX}}$  input.



**Figure 4-13.** Full-Bridge Type II Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  is an active strain-gauge element measuring compressive Poisson effect ( $-v\epsilon$ ).
- $R_2$  is an active strain-gauge element measuring tensile Poisson effect ( $+v\epsilon$ ).
- $R_3$  is an active strain-gauge element measuring compressive strain ( $-\epsilon$ ).
- $R_4$  is an active strain-gauge element measuring tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the measured voltage.

To convert voltage readings to strain units, use the following equation:

$$\text{strain } (\epsilon) = \frac{-2V_r}{GF(1 + \nu)}$$

where

- $GF$  is the gauge factor.
- $\nu$  is the Poisson's ratio.

To simulate the effect on strain of applying a shunt resistor across  $R_3$ , use the following equation:

$$\epsilon_s = \frac{-2U}{GF(1 + \nu)}$$



**Notes** Full-bridge type II is sometimes used for strain measurement of bending beams.  $R_3$  and  $R_4$  are positioned along the beam axis and on opposite sides of the beam, and  $R_1$  and  $R_2$  are positioned transverse to the beam axis and on opposite sides of the beam.

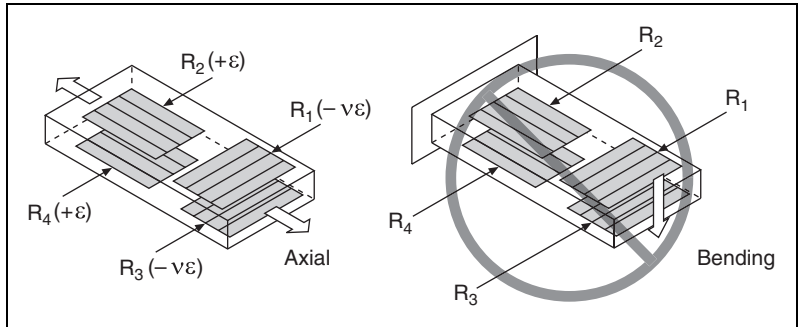
The nominal values of  $R_1$ ,  $R_2$ ,  $R_3$ , and  $R_4$  equal  $R_g$ .

Gauges need not have an STC number corresponding to the material type of the test specimen.

As shown in Figure 2-9, *Full-Bridge Type II Circuit Diagram*, for greatest calibration accuracy, use separate wires between the bridge and the shunt calibration pins SCA (pin 4) and SCCOM (pin 5). Do not directly short SCA (pin 4) or SCCOM (pin 5) inside your connector unless the strain-gauge leads are short and have minimal lead resistance.

## Full-Bridge Type III

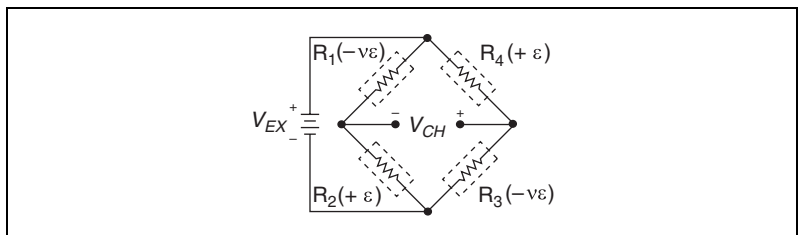
This section provides information about the full-bridge strain-gauge configuration type III. The full-bridge type III only measures axial strain. Figure 4-14 shows how to position strain-gauge resistors in an axial configuration. Figure 4-15 shows the full-bridge type III circuit wiring diagram.



**Figure 4-14.** Full-Bridge Type III Measuring Axial and Rejecting Bending Strain

A full-bridge type III configuration has the following characteristics:

- Four active strain-gauge elements. Two are mounted in the direction of axial strain with one on one side of the strain specimen (top), and the other on the opposite side (bottom). The other two act together as a Poisson gauge and are mounted transverse (perpendicular) to the principal axis of strain with one on one side of the strain specimen (top), the other on the opposite side (bottom).
- Compensates for specimen temperature variation.
- Rejects bending strain.
- Compensates for the aggregate effect on the principle strain measurement due to the Poisson's ratio of the specimen material.
- Compensates for lead resistance.
- Sensitivity at  $1000 \mu\epsilon$  is  $\sim 1.3 \text{ mV}_{\text{out}}/V_{\text{EX}} \text{ input}$



**Figure 4-15.** Full-Bridge Type III Circuit Diagram

The following symbols apply to the circuit diagram and equations:

- $R_1$  is an active strain-gauge element measuring compressive Poisson effect ( $-v\epsilon$ ).
- $R_2$  is an active strain-gauge element measuring tensile strain ( $+\epsilon$ ).

- $R_3$  is an active strain-gauge element measuring compressive Poisson effect ( $-\nu\epsilon$ ).
- $R_4$  is an active strain-gauge element measuring the tensile strain ( $+\epsilon$ ).
- $V_{EX}$  is the excitation voltage.
- $R_L$  is the lead resistance.
- $V_{CH}$  is the measured voltage.

To convert voltage readings to strain units, use the following equation:

$$\text{strain } (\epsilon) = \frac{-2V_r}{GF[(\nu + 1) - \nu_r(\nu - 1)]}$$

where

- $GF$  is the gauge factor.
- $\nu$  is the Poisson's ratio.

To simulate the effect on strain of applying a shunt resistor across  $R_3$ , use the following equation:

$$\epsilon_s = \frac{-4U}{GF[(\nu + 1) - U(\nu - 1)]}$$



**Notes** Full-bridge type III is sometimes used for axial strain measurement.  $R_2$  and  $R_4$  are positioned along the beam axis and on opposite sides of the beam, and  $R_1$  and  $R_3$  are positioned transverse to the beam axis and on opposite sides of the beam.

The nominal values of  $R_1$ ,  $R_2$ ,  $R_3$ , and  $R_4$  equal  $R_g$ .

Gauges need not have an STC number corresponding to the material type of the test specimen.

As shown in Figure 2-10, *Full-Bridge Type III Circuit Diagram*, for greatest calibration accuracy, use separate wires between the bridge and the shunt calibration pins SCA (pin 4) and SCCOM (pin 5). Do not directly short SCA (pin 4) or SCCOM (pin 5) inside your connector unless the strain-gauge leads are short and have minimal lead resistance.

## NI PXI-4220 Theory of Operation

This section provides information about the circuit features of the module. Refer to the block diagram in Figure 4-16, while reading this section.

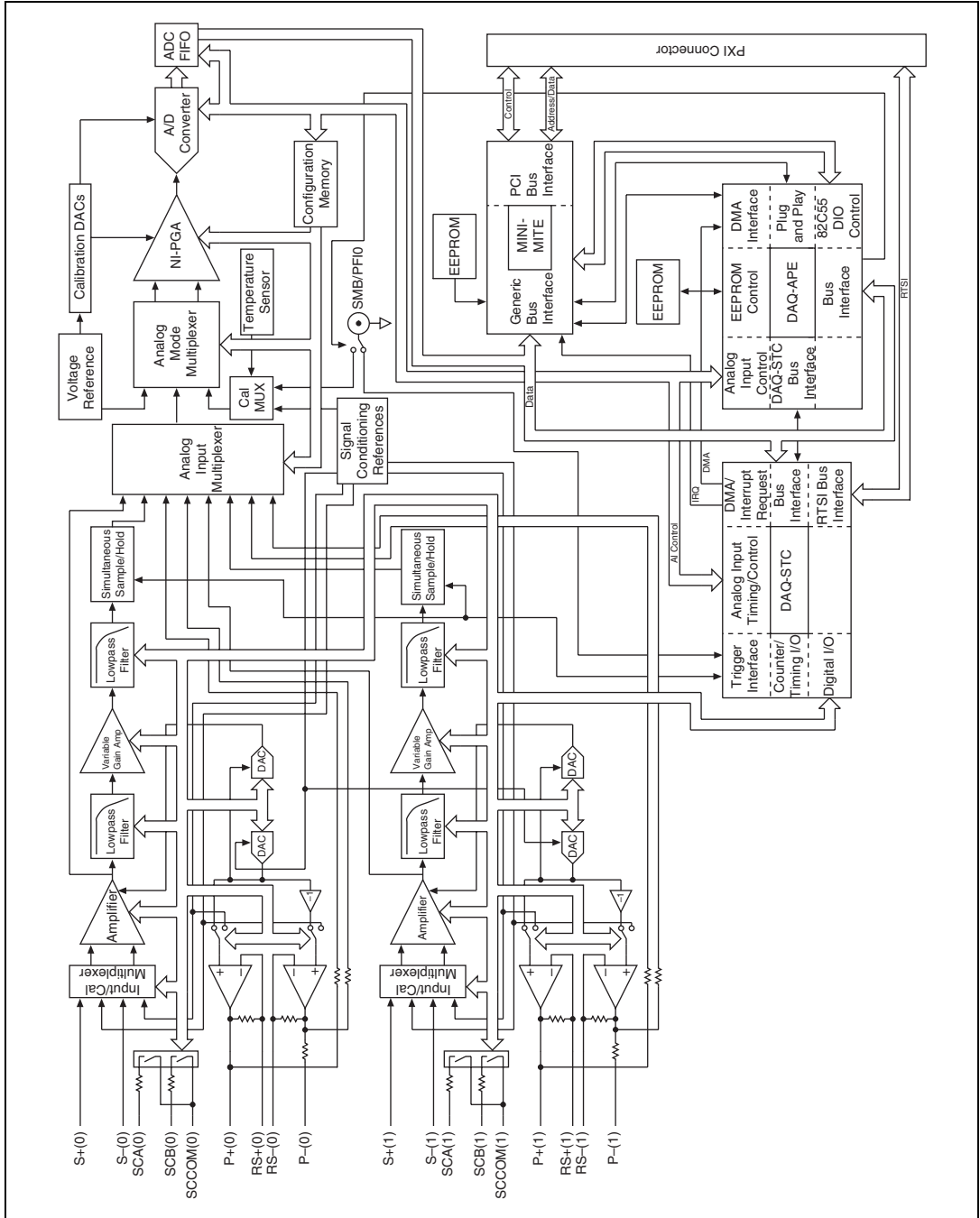


Figure 4-16. Block Diagram of the NI PXI-4220

The instrumentation amplifier stage presents a very high input impedance to external signals and passes only the differential signal. The offset null compensation circuitry adjusts the signal voltage by a specified offset after an offset null compensation calibration is performed.

The signal from the instrumentation amplifier stage passes through a lowpass filter stage, a variable gain stage, another lowpass filter stage, and finally a simultaneous sample-and-hold stage before reaching the multiplexing and analog-to-digital conversion stage.

The NI PXI-4220 includes a 4-pole Butterworth filter per channel with four software-selectable cutoff frequencies to reduce signal noise and improve accuracy. You can programmatically configure the filter bandwidths on a per channel basis for cutoff frequencies of 10 Hz, 100 Hz, 1 kHz, 10 kHz, or disable the filter. The variable gain stage allows you to set the gain at many discrete settings between 1 and 50. These settings, along with the 1 or 20 gain setting of the instrumentation amplifier, permit the NI PXI-4220 to have 49 gain settings between 1 and 1,000.

By default the NI PXI-4220 T/H circuitry is enabled to allow SS/H, which allows you to acquire synchronized measurements from both channels. You cannot enable or disable SS/H on a per channel basis. Disabling SS/H results in higher maximum sample rates. Disabling SS/H introduces a small offset voltage. You can compensate for this offset by performing offset null calibration.

The NI PXI-4220 uses a multiplexed architecture that enables the measurement of multiple channels using a single analog-to-digital converter (ADC). With SS/H disabled, the multiplexing architecture of the NI PXI-4220 results in measurements between channels that are separated in time. The time delay between channels is determined by the sample rate at which you acquire measurements. For most low-frequency measurement applications, this time delay or phase delay is not significant.

Excitation circuitry and the shunt calibration switches are two circuitry stages that are not directly in the signal path. The excitation stage is a stable output with a controlled feedback loop called remote sense. The remote sense signal is connected to the analog multiplexer. You can scan the remote sense lines independently in your application.

The shunt calibration switches are controlled by the digital interface and control circuitry. You must connect the shunt calibration pins to the bridge for shunt calibration to function correctly. When the switch is closed, a socketed shunt calibration resistor in the NI PXI-4220 connects across a leg of a Wheatstone bridge.

For more detailed information about the operation of any of these circuitry stages, refer to the *Bridge Configuration and Completion*, *Excitation*, *Gain/Input Range*, *Filter*, *Offset Null Compensation*, *Shunt Calibration*, and *Simultaneous Sample and Hold* sections.

## Bridge Configuration and Completion

You can configure the NI PXI-4220 for use with Wheatstone bridge sensors that require bridge completion. Bridge completion is necessary for quarter- or half-bridge sensors. You can set the NI PXI-4220 for quarter-, half-, or full-bridge configuration to match the configuration completion requirements of each sensor. When quarter- or half-bridge configuration is selected, SX<sup>-</sup> (pin 6) (where X is a particular channel) is disconnected from the front signal connector and internally connected to a half-bridge completion network. When quarter-bridge configuration type I is selected, a socketed quarter-bridge completion resistor is internally connected between PX<sup>-</sup> (pin 7) and QTR/SCBX (pin 9). You then field wire the quarter-bridge sensor between SX<sup>+</sup> (pin 1) and PX<sup>+</sup> (pin 2) with a third lead connected to QTR/SCBX (pin 9) as shown in Figure 2-4, *Quarter-Bridge I Circuit Diagram*. Make sure that the value of the precision quarter-bridge completion resistor exactly matches the nominal gauge resistance of the strain gauge. The quarter-bridge completion resistor is socketed for easy replacement. The quarter-bridge completion resistor for AI 0 is located on the NI PXI-4220 at reference designator **R5**, and the completion resistor for AI 1 is located at **R2**.



**Note** The NI PXI-4220 ships with a 350  $\Omega$  quarter-bridge completion resistor installed.

Refer to the *Configurable Settings in MAX* section of Chapter 3, *Configuring and Testing*, for more information about programmatically setting bridge completion in MAX. For more information about programmatically setting bridge completion in NI-DAQmx, refer to the *Developing Your Application in NI-DAQmx* section of Chapter 5, *Developing Your Application*.

## Excitation

The NI PXI-4220 provides DC excitation voltage for a Wheatstone bridge sensor. For half- and full-bridge applications, the excitation voltage is available at pins PX<sup>+</sup> (pin 2) and PX<sup>-</sup> (pin 7). For quarter-bridge applications, PX<sup>-</sup> (pin 7) is not used; instead, wire to SX<sup>+</sup> (pin 1) and PX<sup>+</sup> (pin 2) and short SX<sup>+</sup> (pin 1) to pin QTR/SCBX (pin 9). Pin QTR/SCBX (pin 9) internally connects to PX<sup>-</sup> (pin 7).

The output buffers have negative feedback connections at pins RSX+ (pin 3) and RSX– (pin 8). You should run separate wires from the bridge to these pins so that the amplifiers obtain feedback directly from the bridge, thereby forcing bridge voltage to equal the desired setting.

Pin PX+ (pin 2) is always positive with respect to chassis ground, and pin PX– (pin 7) is always negative with respect to chassis ground. The inverting amplifier –X1 forces the voltage at pin PX– (pin 7) to equal the negative of the voltage at pin PX+ (pin 2). For example, if you set the module output for +5 V, pin PX+ (pin 2) is at +2.5 V with respect to ground, and pin PX– (pin 7) is at –2.5 V with respect to chassis ground. The excitation setting originates from an internal digital-to-analog converter (DAC). You can set the excitation voltage between 0 V and 10 V. You can power a 350  $\Omega$  full-bridge at 10 V without exceeding the maximum power rating of the excitation source. The excitation outputs are protected with surge suppressors that prevent either of the excitation output pins from exceeding 6 V with respect to chassis ground.



**Note** Chassis ground is at the same potential as earth ground when the PXI chassis is plugged into a standard 3-prong AC outlet. If pin PX– (pin 7) is connected to earth ground, the excitation source does not function properly.

Refer to the [Configurable Settings in MAX](#) section of Chapter 3, [Configuring and Testing](#), for more information about programmatically setting excitation level in MAX. For more information about programmatically setting excitation level in NI-DAQmx, refer to the [Developing Your Application in NI-DAQmx](#) section of Chapter 5, [Developing Your Application](#).

## Remote Sense

The excitation output buffers have negative feedback connections at the remote-sense pins, RSX+ (pin 3) and RSX– (pin 8). You should run separate wires from the bridge to these pins so that the amplifiers obtain feedback directly from the bridge, forcing the excitation voltage applied to the bridge to equal the voltage at pins RSX+ (pin 3) and RSX– (pin 8). This removes unwanted DC offset in the excitation and compensates for changes in lead resistance caused by temperature variation in the lead wires.



**Note** NI recommends connecting the remote sense pins directly to the sensor to obtain optimum excitation voltage regulation and measurement accuracy.



The NI PXI-4220 excitation output circuits set the output voltage by monitoring the remote sense pins. Hence, the NI PXI-4220 corrects for a voltage ( $I \times R$ ) drop in the excitation leads between the module and the bridge, even if lead resistance changes with temperature.

You can scan the remote sense pins. The output multiplexer has input connections to the RSX+ (pin 3) and RSX- (pin 8) signals. You can scan these signals for monitoring and scaling purposes, even if the remote sense pins are not connected. Take the difference of these signals to determine the real excitation voltage.

Wire the NI PXI-4220 for remote sense as shown in Figure 2-11, [Remote Sense Circuit Diagram](#). There are no configuration settings you need to change in the software.



**Note** If you use remote sense, set  $R_L$  to zero in the MAX configuration of the channel and in your application equations for measured strain ( $\epsilon$ ).

If you leave the remote sense pin unconnected, internal 1 k $\Omega$  resistors provide feedback to the buffers from pins PX+ (pin 2) and PX- (pin 7). Therefore, you need not install a jumper wire between RSX+ (pin 3) and PX+ (pin 2), or RSX- (pin 8) and PX- (pin 7) when you do not have remote sense leads available from the sensor. NI recommends performing a shunt calibration to compensate for the voltage drop across lead resistance and other forms of gain error.

If you are not connecting remote sense and are not performing shunt calibration, you must scale the measurements in your application to compensate for the excitation voltage drop across the lead resistance. Use the following gain adjustment factor:

$$\text{Gain Adjust Factor} = 1 + \frac{2R_L}{R_g}$$

This gain adjust factor is used in your application to compensate for the voltage drop across the leads as follows:

$$V_{CH} \times \text{Gain Adjusting Factor}$$

## Gain/Input Range

In normal NI PXI-4220 operation you do not need to set the gain. NI-DAQmx automatically sets the appropriate gain based on the range of your task or global channel, or the input limits set in LabVIEW.

The NI PXI-4220 has multiple gain stages to provide optimal overall signal gains appropriate for fully utilizing the range of the NI PXI-4220 DAQ circuitry. The first gain stage (the instrumentation amplifier stage) provides gains of either 1 or 20. The second gain stage provides many discrete settings between 1 and 50. Together, these two gain stages combine for 49 overall gain settings between 1 and 1,000. This allows the driver to select a gain setting for your input range that fully utilizes the input range of the ADC. The third stage, the NI programmable gain instrumentation amplifier (NI PGIA) stage provides four input ranges of  $\pm 10$  V,  $\pm 5$  V,  $\pm 0.5$  V, and  $\pm 0.05$  V for the ADC.

For overall module gain settings equal to or greater than 20, the gain of the first stage is set to 20 so that the noise and offset drift of later stages is small in comparison to this stage. The instrumentation amplifier stage uses operational amplifiers with very low temperature drift and noise characteristics. If overall module gain is less than 20, the first stage is set to 1 and the appropriate second stage gain is applied.

For common strain-gauge configurations where the gauge factor is 2.0, the maximum input signal (in microvolts) is:

$$\text{quarter bridge} = (\text{max strain}) \times (\text{excitation voltage}) \times (0.5 \mu\text{V/V}/\mu\epsilon)$$

$$\text{half bridge} = (\text{max strain}) \times (\text{excitation voltage}) \times (1.0 \mu\text{V/V}/\mu\epsilon)$$

$$\text{full bridge} = (\text{max strain}) \times (\text{excitation voltage}) \times (2.0 \mu\text{V/V}/\mu\epsilon)$$

After you determine the input signal voltage, you can use the following equation to determine the appropriate gain:

$$\text{gain} \leq (\text{NI PXI-4220 output voltage range (10 V)}) \div (\text{maximum input signal voltage})$$

If you are using a bridge-based sensor, use the manufacturer-specified sensitivity (usually expressed in the units of millivolts per volt) to determine the maximum input signal. The maximum input signal is:

$$(\text{max input signal voltage}) = \frac{(\text{sensor sensitivity}) \times (\text{excitation voltage}) \times (\text{maximum input})}{(\text{sensor full-scale input})}$$

For example, if you have a 0–500 psi pressure sensor with 3.0 mV/V sensitivity, an excitation voltage of 10 V, and a maximum pressure of 200 psi, the maximum signal is:

$$12 \text{ mV} = \frac{(3.0 \text{ mV/V}) \times (10 \text{ V}) \times (200 \text{ psi})}{(500 \text{ psi})}$$

For example, because the NI PXI-4220 DAQ circuitry has a maximum analog input range of  $\pm 10$  V and you have set the maximum input to the NI PXI-4220 to be +12 mV, set the gain to the setting closest to

$$833 = \frac{10 \text{ V}}{12 \text{ mV}}$$

but *less* than 833. A larger gain setting saturates the NI PXI-4220 DAQ circuitry for a 12 mV signal. In this example, the closest gain that is less than 833 for the NI PXI-4220 is 750.

Refer to the [Configurable Settings in MAX](#) section of Chapter 3, [Configuring and Testing](#), for more information about programmatically setting gain using range settings in MAX. For more information about programmatically setting gain using range settings in NI-DAQmx, refer to the [Developing Your Application in NI-DAQmx](#) section of Chapter 5, [Developing Your Application](#).

## Filter

The NI PXI-4220 provides two filtering stages with an overall response of a four-pole Butterworth filter. You can control the cutoff frequency of the filter through software. You can choose 10 Hz, 100 Hz, 1 kHz, 10 kHz, or filter bypass to disable the filter. For additional flexibility in cutoff frequency settings and for greater upper-band suppression in the stop-band, NI recommends combining the hardware filtering provided by the NI PXI-4220 with digital filtering. NI recommends using the Advanced Analysis functions of LabVIEW for digital filtering, for example the Filter Express VI available at **Functions»Analysis**. The Advanced Analysis functions are only available in LabVIEW Full or Professional versions.

Refer to the [Configurable Settings in MAX](#) section of Chapter 3, [Configuring and Testing](#), for more information about programmatically setting the cutoff frequency of the filter in MAX. For more information about programmatically setting the cutoff frequency of the filter in NI-DAQmx, refer to the [Developing Your Application in NI-DAQmx](#) section of Chapter 5, [Developing Your Application](#).

## Offset Null Compensation

The NI PXI-4220 provides offset null compensation to adjust signal voltages to proper levels when the strain gauge or bridge sensor is at rest (unstrained). For most sensors offset null compensation is used to remove an initial voltage offset from the Wheatstone bridge. Many strain gauge signal conditioning devices use a manually adjusted multiturn screw potentiometer for offset null compensation. In the NI PXI-4220, offset null compensation is performed electronically using software-controlled electronic potentiometers.

Two offset null compensation potentiometers are used, one for coarse adjustments and the other for fine adjustments. The sum of the two potentiometer signals is added to the analog input path to adjust the signal voltage to remove the offset, which nulls the strain-gauge channel. The voltage input to the potentiometers is a voltage proportional to the excitation voltage setting. Therefore, if the excitation voltage changes by a small amount due to changes such as temperature and sensor loading, the correction signal produced by the potentiometers changes by the same amount and the offset null compensation is maintained.

The offset null compensation potentiometers are controlled digitally using control codes. The control codes of the potentiometers are set in software using integer values. The coarse potentiometer ranges from 0 to 127 and the fine potentiometer from 0 to 4,095. The span of correction (the voltage nulling range) for each potentiometer depends on the channel gain setting. Table 4-2 summarizes the nulling range and scale of the control codes.

**Table 4-2.** Control Codes for Coarse and Fine Null Potentiometers

Offset Null Compensation Potentiometer	Range (Integer Values)	Mid-Scale	Module Channel Gain Settings	Approximate Correction Span at Analog Input
Coarse	0 to 127	62	$\geq 20$	$V_{EX}/10$
			$< 20$	$2 \times V_{EX}$
Fine	0 to 4095	2047	$\geq 20$	$V_{EX}/364$
			$< 20$	$V_{EX}/18$

In most cases, you do not explicitly set the offset null compensation potentiometers, but instead allow the NI-DAQmx driver software to automatically adjust them for you. This can be done in MAX.

Refer to the [Configurable Settings in MAX](#) section of Chapter 3, [Configuring and Testing](#), for more information about programmatically performing offset null compensation in MAX. For more information about programmatically performing offset null compensation in NI-DAQmx, refer to the [Developing Your Application in NI-DAQmx](#) section of Chapter 5, [Developing Your Application](#).

## Shunt Calibration

Shunt calibration is a process used to obtain a gain adjust factor, which is used to correct for system gain error and discrepancies between nominal gauge factor and actual gauge factor of the strain gauge.

The gain adjust factor is derived using theoretical (simulated) signal levels that should result from engaging a shunt resistor across one leg of a bridge sensor, and the measured signal levels with the shunt resistor actually engaged.

Use the following formula to calculate the gain adjust factor:

$$\text{Gain Adjust Factor} = \frac{\text{simulated signal level}}{\text{measured signal level with shunt resistor engaged}}$$

The gain adjust factor is then multiplied by each future measurement to obtain highly accurate measurements that are adjusted for any gain errors or discrepancies in the nominal gauge factor. Refer to the [Configurable Settings in MAX](#) section of Chapter 3, [Configuring and Testing](#), for more information about performing shunt calibration automatically in global channels using NI-DAQmx in MAX. For more information about programmatically performing shunt calibration in NI-DAQmx, refer to the [Developing Your Application in NI-DAQmx](#) section of Chapter 5, [Developing Your Application](#).

The NI PXI-4220 has two independent shunt calibration circuits available for each channel at pins SCA (pin 4), QTR/SCB (pin 9), and SCCOM (pin 5) on the D-SUB connectors. Each shunt calibration circuit consists of a resistor in series with a switch. The NI PXI-4220 shunt calibration switch is a long-life solid-state switch. The electronic switch is galvanically isolated from ground; therefore, you can connect shunt calibration resistor A to any external bridge element.

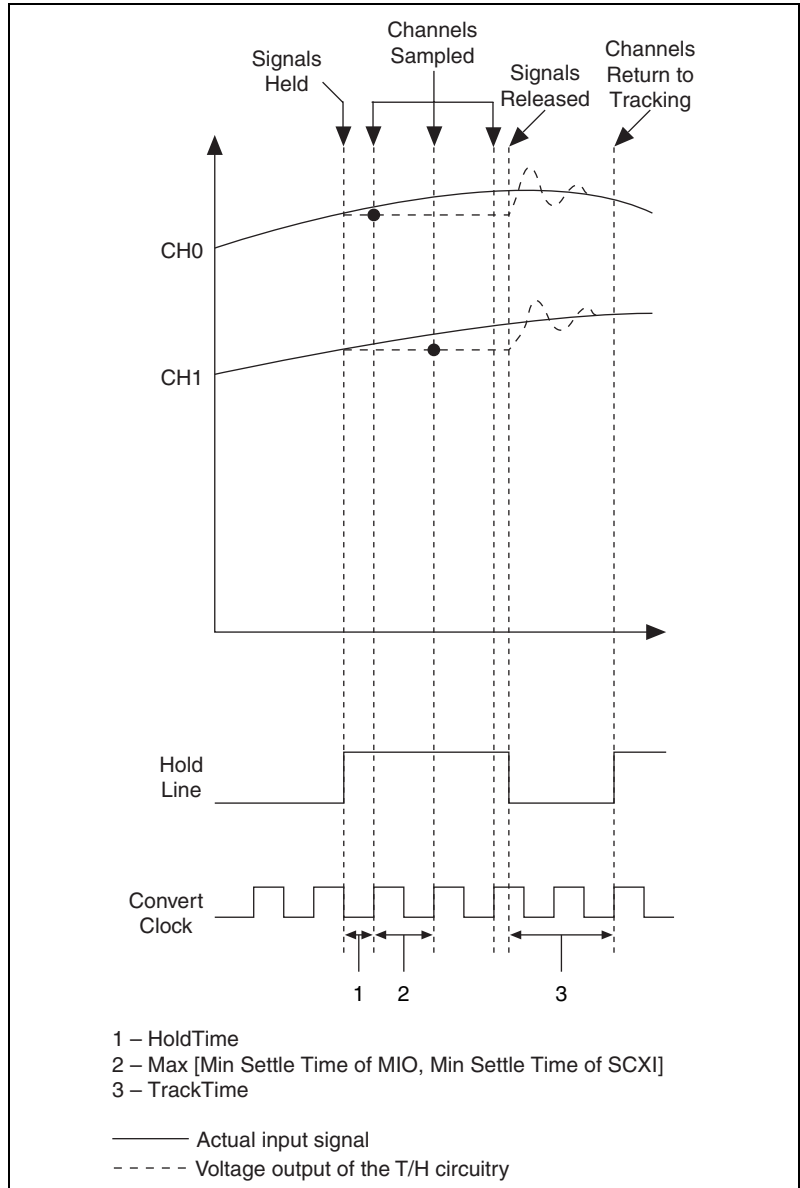
Shunt calibration resistor B cannot be enabled in software using NI-DAQmx 7.0. If you enable shunt calibration resistor B in your application, remember that shunt calibration resistor A and shunt calibration resistor B have a common lead, SCCOM. With this common lead shunt calibration resistor A and shunt calibration resistor B can only perform shunt calibration across the same element or two adjacent elements.



**Note** Perform an offset null compensation just before you perform a shunt calibration. Performing a shunt calibration before an offset null compensation causes improper gain adjustment because you incorrectly compensate for the offset signal voltage.

## Simultaneous Sample and Hold

SS/H signal conditioning allows multiplexing DAQ devices to return synchronized samples of all channels with negligible skew time between channels. SS/H signal conditioning is performed on the NI PXI-4220 with T/H circuitry. The outputs of the T/H amplifiers follow their inputs, also called *tracking* the inputs, until they receive a hold signal from the DAQ circuitry. Both channels on the NI PXI-4220 hold their signal at the same time. Multiple NI PXI-4220 devices can be synchronized, allowing you to simultaneously sample channels on multiple modules. The DAQ circuitry then digitizes the signal of each channel, giving you simultaneous sampling between channels since no time elapsed between the holding of each signal. All signals are then released and the T/H circuitry output returns to tracking the input signal. For accurate measurements, refer to Table 4-3 to determine the maximum sample rate when using the NI PXI-4220 with SS/H enabled. Figure 4-17 shows an example of a signal during a SS/H sampling.



**Figure 4-17.** Signal During Simultaneous Sample and Hold Sampling

It is possible to enable and disable SS/H programmatically in NI-DAQmx, although NI recommends that you leave SS/H enabled for most applications. By default, the NI PXI-4220 has SS/H enabled. You should only disable SS/H if your application does not require simultaneous

sampling and requires higher acquisition rates than are possible with SS/H enabled. Refer to the [Configuring Channel Properties](#) section of Chapter 5, [Developing Your Application](#), for more information about programmatically enabling and disabling SS/H in LabVIEW.

## Maximum Acquisition Rate

Table 4-3 shows the maximum acquisition rates for the NI PXI-4220 when scanning one or two channels, and with SS/H enabled or disabled.

**Table 4-3.** Maximum Sampling Rates

Number of Channels	SS/H Enabled	SS/H Disabled
1	100.0 kS/s	333 kS/s
2	66 kS/s/ch	100.0 kS/s/ch

## Measurement Considerations

This section provides more information on the type of signal connection made to the NI PXI-4220 and important factors that can affect your measurement.

### Differential Signals

Both of the analog inputs of the NI PXI-4220 are differential. In general, a differential measurement system is preferable because it rejects not only common-mode voltages and ground loop-induced errors, but also the noise picked up in the environment to a certain degree.

### Common-Mode Rejection Ratio

The ability of a measurement device to reject voltages that are common to both input pins is referred to as the common-mode rejection ratio (CMRR), and is usually stated in decibels at a given frequency or over a given frequency band of interest. Common-mode signals can arise from a variety of sources and can be induced through conductive or radiated means. One of the most common sources of common-mode interference is due to 50 or 60 Hz powerline noise.

The minimum NI PXI-4220 CMRR is 85 dB at gains  $\geq 20$ . This results in 0.006% of the CMV introduced as error on the measured signal.



## Effective CMR

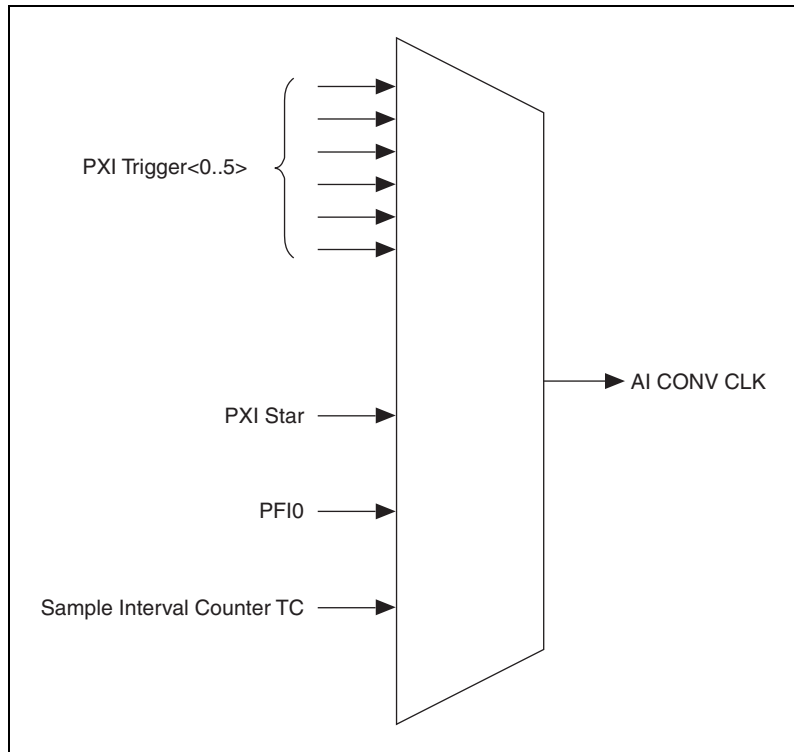
When the frequency of a common-mode signal is known and outside of the measurement frequency band of interest, you can use an analog or digital filter, or both, to further reduce the residual error left from the finite CMRR of the instrument. The combined CMR of the instrument and the filter attenuation results in an effective CMR. When expressed in decibels, the effective CMR is equal to the sum of the CMRR and the attenuation due to the filter at a specified frequency.

## Timing and Control Functional Overview

The NI PXI-4220 is similar to the NI E Series DAQ device architecture in many ways. This architecture uses the NI data acquisition system timing controller (DAQ-STC) for time-related functions. The DAQ-STC consists of two timing groups that control AI and general-purpose counter/timer functions. These groups include a total of seven 24-bit and three 16-bit counters and a maximum timing resolution of 50 ns. The DAQ-STC makes possible applications such as internal hardware timing or multiple-point acquisitions, equivalent time sampling, and seamless changing of the sampling rate.

The NI PXI-4220 uses the PXI trigger bus to easily synchronize several measurement functions between multiple NI PXI-4220 devices to a common trigger or timing event. The PXI trigger bus is connected through the rear signal connector to the PXI chassis backplane. The DAQ-STC provides a flexible interface for connecting timing signals to other devices or external circuitry. The NI PXI-4220 can also use the PXI trigger bus to interconnect timing signals between PXI devices and the programmable function input (PFI) pin on the front SMB connector to connect the device to external circuitry. These connections are designed to enable the device to both control and be controlled by other devices and circuits.

The DAQ-STC has internal timing signals you can control by an external source. These timing signals can also be controlled by signals internally generated by the DAQ-STC, and these selections are software configurable. Figure 4-18 shows an example of the signal routing multiplexer controlling the AI CONV CLK signal.



**Figure 4-18.** AI CONV CLK Signal Routing

Figure 4-18 shows that AI CONV CLK can be generated from a number of sources, such as the external signals PFI0 and PXI\_Trig<0..5>, and the internal signals sample interval (SI2) counter TC.

## Programmable Function Inputs

PFI0 is connected to the front SMB connector of the NI PXI-4220. Software can select PFI0 as the external source for a given timing signal. Any timing signal can use the PFI0 pin as an input, and multiple timing signals can simultaneously use the same PFI. This flexible routing scheme reduces the need to change physical connections to the I/O connector for different applications. The front SMB connector also uses the programmable functionality of PFI0 to route precision voltage sources into the NI PXI-4220 for external device calibration. You can enable PFI0 to output only the AI START TRIG signal.

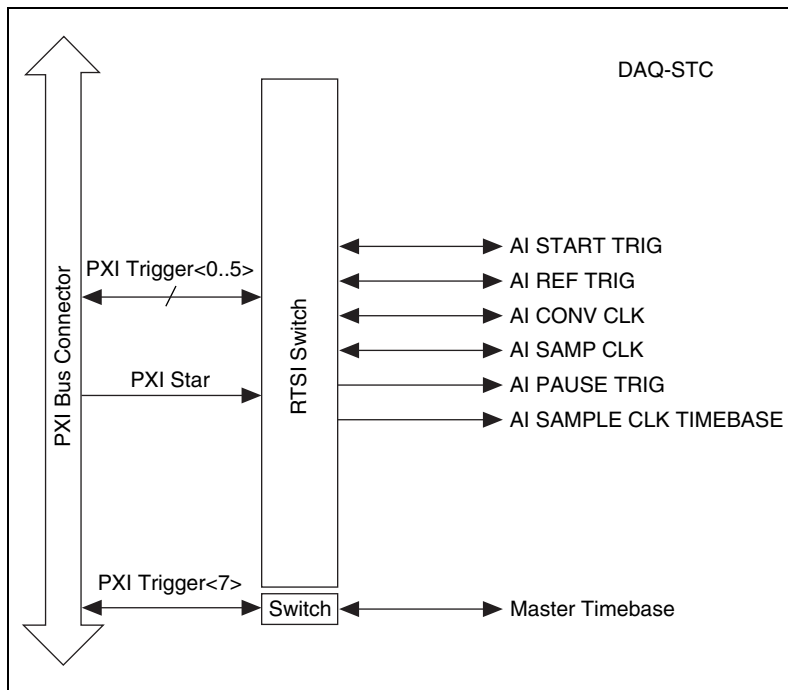
## Device and PXI Clocks

Many functions performed by the NI PXI-4220 require a frequency timebase to generate the necessary timing signals for controlling A/D conversions, digital-to-analog converter (DAC) updates, or general-purpose signals at the I/O connector.

The NI PXI-4220 can use either its internal 20 MHz master timebase or an external timebase received over the PXI trigger bus on the PXI clock line. The external timebase is software configurable. If you configure the device to use the internal timebase, you can program the device to share its internal timebase over the PXI trigger bus to another device programmed to receive this timebase signal. This clock source, whether local or from the PXI trigger bus, is used directly by the device as the primary frequency source. The default configuration uses the internal timebase without sharing the clock over the PXI trigger bus timebase signal. The NI PXI-4220 can use the PXI\_Trig<7> line to synchronize `Master Timebase` with other devices.

For the NI PXI-4220, PXI\_Trig<0..5> or PXI\_Star connects through the NI PXI-4220 backplane. The PXI star trigger line allows the NI PXI-4220 to receive triggers from any star trigger controller plugged into slot 2 of the chassis. The NI PXI-4220 cannot drive the PXI star trigger line. For more information on the star trigger, refer to the *PXI Hardware Specification Revision 2.1* and *PXI Software Specification Revision 2.1*.

Figure 4-19 shows this signal connection scheme.



**Figure 4-19.** NI PXI-4220 PXI Trigger Bus Signal Connection

Table 4-4 provides more information about each of the timing signals available on the PXI trigger bus. For more detailed timing signal information, refer to Appendix B, *Timing Signal Information*.

**Table 4-4.** PXI Trigger Bus Timing Signals

<b>Signal</b>	<b>Direction</b>	<b>Description</b>	<b>Availability on PF10 SMB</b>	<b>Availability on PXI Trigger Bus</b>
AI START TRIG	Input	This is the source for the analog input digital start trigger, the trigger that begins an acquisition.	Input	Input
	Output	This sends out the actual analog input start trigger.	Output	Output
AI REF TRIG	Input	This is the trigger that creates the reference point between the pretrigger samples and the posttrigger samples.	Input	Input
	Output		Output	
AI SAMP CLK	Input	This clock controls the time interval between samples. Each time the sample clock produces a pulse, one sample per channel is acquired.	Input	Input
	Output		Output	
AI CONV CLK	Input	This clock directly causes analog-to-digital conversions.	Input	Input
	Output		Output	
AI PAUSE TRIG	Input	This signal can pause and resume acquisition.	Input	Input
AI SAMPLE CLK TIMEBASE	Input	This timebase provides the master clock from which the sample clocks are derived.	Input	Input

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# Developing Your Application

This chapter describes basic programming information about the NI PXI-4220 and how to develop your application in LabVIEW.

## Developing Your Application in NI-DAQmx

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**Note** If you are not using an NI ADE, or if you are using an NI ADE prior to version 7.0 or an unlicensed copy of an NI ADE, additional dialog boxes from the NI License Manager appear allowing you to create a task or global channel using the DAQ Assistant in unlicensed mode. These messages continue to appear until you install version 7.0 or later of an NI ADE in order to take full advantage of the NI DAQ Assistant.

This section describes how to configure and use NI-DAQmx to control the NI PXI-4220 in LabVIEW. LabVIEW provides greater flexibility and access to more settings than MAX, but you can use LabVIEW in conjunction with MAX to quickly create a customized application.

### Typical Program Flow

Figure 5-1 shows a typical program flow chart about creating a task, configuring channels, taking a measurement, analyzing the data, presenting the data, stopping the measurement, and clearing the task. The [Creating a Task Using DAQ Assistant or Programmatically](#) section, [Adjusting Timing and Triggering](#) section, [Configuring Channel Properties](#) section, [Perform Offset Null Compensation](#) section, [Perform Shunt Calibration](#) section, [Acquiring, Analyzing, and Presenting](#) section, and [Completing the Application](#) section further describes some of the steps shown in Figure 5-1.

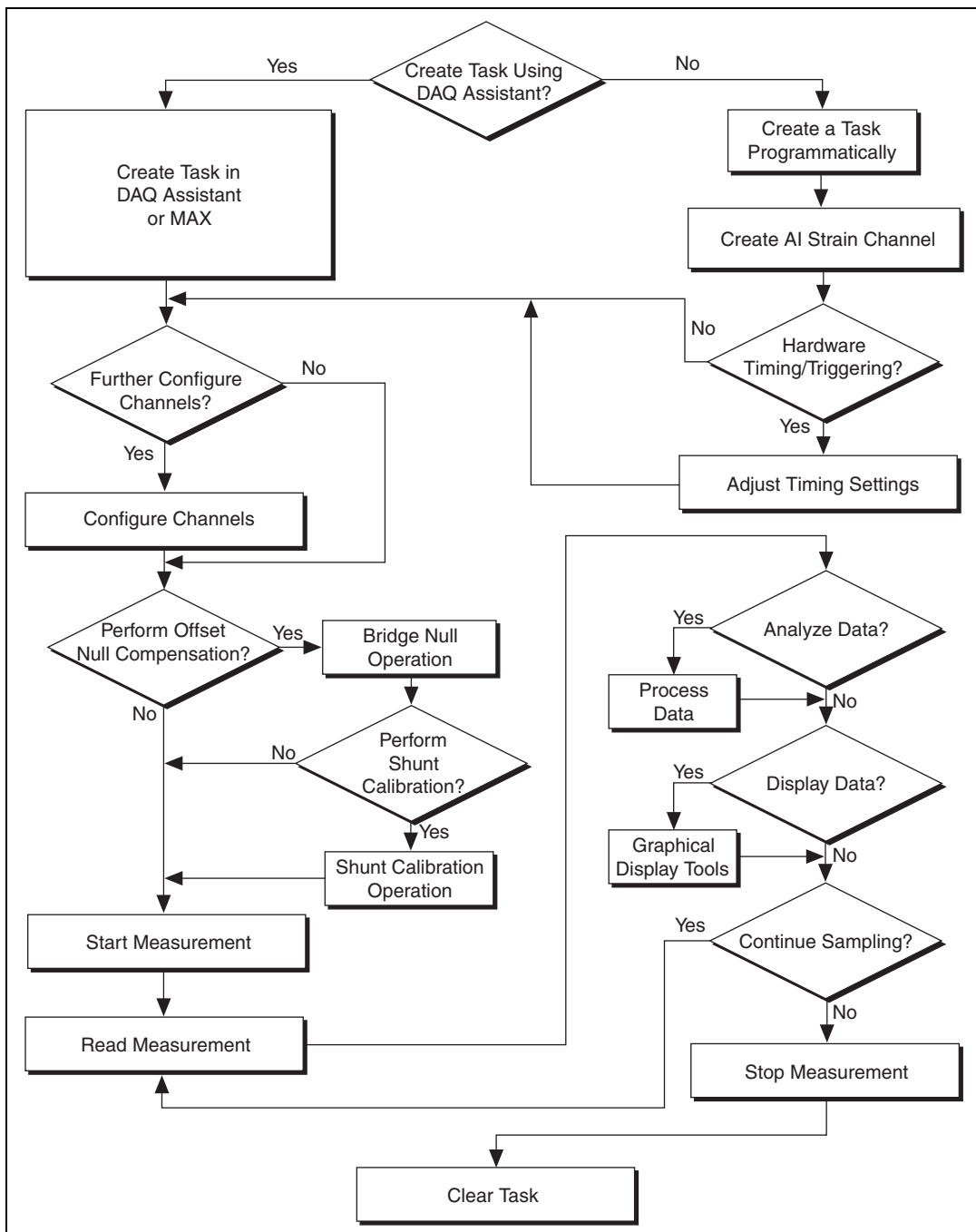


Figure 5-1. Typical Program Flowchart

## General Discussion of Typical Flow Chart

The following sections briefly discuss some considerations for a few of the steps in Figure 5-1. These sections are meant to give you an overview of some of the options and features available when programming with NI-DAQmx.

### Creating a Task Using DAQ Assistant or Programmatically

When creating an application, you must first decide whether to create the appropriate task using the DAQ Assistant or programmatically in the ADE.

Developing your application using NI-DAQmx gives you the ability to configure most settings such as measurement type, selection of channels, bridge configuration, excitation voltage, signal input limits, task timing, and task triggering using the DAQ Assistant tool. You can access the DAQ Assistant either through MAX or through your NI ADE. Choosing to use the DAQ Assistant can simplify the development of your application. NI recommends creating tasks using the DAQ Assistant for ease of use, when using a sensor that requires complex scaling, or when many properties differ between channels in the same task.

If you are using an ADE other than an NI ADE, or if you want to explicitly create and configure a task for a certain type of acquisition, you can programmatically create the task from your ADE using function or VI calls. If you create a task using the DAQ Assistant, you can still further configure the individual properties of the task programmatically using function calls or property nodes in your ADE. NI recommends creating a task programmatically if you need explicit control of programmatically adjustable properties of the DAQ system. Programmatically creating tasks is also recommended if you are synchronizing multiple devices using master and slave tasks. Refer to the [Synchronizing the NI PXI-4220](#) section for more information about synchronizing multiple NI PXI-4220 devices.

Programmatically adjusting properties for a task created in the DAQ Assistant overrides the original, or default, settings only for that session. The changes are not saved to the task configuration. The next time you load the task, the task uses the settings originally configured in the DAQ Assistant.



## Adjusting Timing and Triggering

There are several timing properties that you can configure either through the DAQ Assistant or programmatically by using function calls or property nodes in your application. If you create a task in the DAQ Assistant, you still can modify the timing properties of the task programmatically in your application.

When programmatically adjusting timing settings, you can set the task to acquire continuously, acquire a buffer of samples, or acquire one point at a time. For continuous acquisition, you must use a While Loop around the acquisition components even if you configured the task for continuous acquisition using MAX or the DAQ Assistant. For continuous and buffered acquisitions, you can set the acquisition rate and the number of samples to read in the DAQ Assistant or programmatically in your application. By default, the clock settings are automatically set by an internal clock based on the requested sample rate. You also can select advanced features such as clock settings that specify an external clock source, internal routing of the clock source, or select the active edge of the clock signal.

## Configuring Channel Properties

All of the different ADEs used to configure the NI PXI-4220 access an underlying set of NI-DAQmx properties. Table 5-1 lists of the properties that configure the NI PXI-4220. You can use this list to determine what kind of properties you need to set to configure the device for your application. For a complete list of NI-DAQmx properties, refer to your ADE Help.



**Note** Some properties cannot be adjusted while a task is running. For these properties, you must stop the task, make the adjustment, and restart the application. Table 5-1 assumes all properties are configured before the task is started.

**Table 5-1.** NI-DAQmx Properties

Property	Short Name	Description
<b>Analog Input» General Properties» Advanced»Range»High</b>	AI . Rng . High	Specifies the upper limit of the input range.
<b>Analog Input» General Properties» Advanced»Range»Low</b>	AI . Rng . Low	Specifies the lower limit of the input range.

Table 5-1. NI-DAQmx Properties (Continued)

Property	Short Name	Description
<b>Analog Input» General Properties»Filter» Analog Lowpass»Enable</b>	AI.Lowpass.Enable	Enables the lowpass filter of the channel.
<b>Analog Input» General Properties»Filter» Analog Lowpass» Cutoff Frequency</b>	AI.Lowpass.CutoffFreq	Specifies in hertz the frequency corresponding to the –3 dB cutoff of the filter. You can specify 10, 100, 1,000, or 10,000.
<b>Analog Input» General Properties» Signal Conditioning» Bridge»Configuration</b>	AI.Bridge.Cfg	Specifies whether the sensor is a type of Wheatstone bridge.
<b>Analog Input» General Properties» Signal Conditioning» Bridge»Shunt Cal» Shunt Cal Enable</b>	AI.Bridge.ShuntCal.Enable	Specifies whether to place the shunt calibration resistor across one arm of the bridge.
<b>Analog Input» General Properties» Signal Conditioning» Excitation»Value</b>	AI.Excit.Val	Specifies the amount of excitation in volts.
<b>Analog Input» Strain»Strain Gage» Configuration</b>	AI.StrainGage.Cfg	Specifies the strain-gauge configuration type.
<b>Analog Input» General Properties» Signal Conditioning» Bridge»Nominal Resistance</b>	AI.Bridge.NomResistance	Specifies in ohms the resistance of the bridge in an unloaded condition.
<b>Analog Input»Strain» Strain Gage»Gage Factor</b>	AI.StrainGage.GageFactor	Specifies the sensitivity of the strain gauge.
<b>Analog Input»Strain» Strain Gage»Poisson Ration</b>	AI.StrainGage.PoissonRatio	Specifies the ratio of lateral strain to axial strain in the specimen material.

**Table 5-1.** NI-DAQmx Properties (Continued)

Property	Short Name	Description
<b>Analog Input» General Properties» Signal Conditioning» Bridge»Initial Bridge Voltage</b>	AI.Bridge.InitialVoltage	Specifies in volts the output voltage of the bridge in the unloaded condition.
<b>Analog Input» General Properties» Signal Conditioning» Bridge»Balance»Coarse Potentiometer Property</b>	AI.Bridge.Balance.CoarsePot	Specifies by how much to compensate for offset in the signal. This value can be between 0 and 127.
<b>Analog Input» General Properties» Signal Conditioning» Bridge»Balance» Fine Potentiometer Property</b>	AI.Bridge.Balance.FinePot	Specifies by how much to compensate for offset in the signal. This value can be between 0 and 4,095.
<b>Analog Input» General Properties» Signal Conditioning» Excitation»Source</b>	AI.Excit.Src	Specifies the source of excitation.
<b>Analog Input» General Properties» Advanced» Sample and Hold Enable</b>	AI.SampAndHold.Enable	Specifies whether to enable the sample and hold circuitry of the device.



**Note** This is *not* a complete list of NI-DAQmx properties and does not include every property you may need to configure your application. It is a representative sample of important properties to configure for strain and Wheatstone bridge measurements. For a complete list of NI-DAQmx properties and more information about NI-DAQmx properties, refer to your ADE Help.

## Perform Offset Null Compensation

The NI PXI-4220 provides offset null compensation circuitry to adjust signal voltages to proper levels when the strain gauge or bridge sensor is at rest (unstrained). For most sensors, offset null compensation is used to remove an initial voltage offset from the Wheatstone bridge. If you are measuring strain, you can use a strain task or global channel to perform offset null compensation. The offset null compensation is performed during

the configuration of the global channel(s). Refer to the *Creating a Strain Global Channel or Task* section of Chapter 3, *Configuring and Testing*, for information about offset null compensation when in MAX. If you are not measuring strain, or would like to adjust the offset to an arbitrary voltage, you can manually adjust the coarse and fine potentiometer settings using properties.

For more information about offset null compensation, refer to the *Offset Null Compensation* section of Chapter 4, *Theory of Operation*.

## Perform Shunt Calibration

Shunt calibration is a process used to obtain a gain adjust factor, which is used to correct for system gain error and discrepancies between nominal gauge factor and actual gauge factor of the strain gauge. If you are measuring strain, you can use a strain task or global channel to perform shunt calibration. The shunt calibration is performed during the configuration of the global channel(s). Refer to the *Creating a Strain Global Channel or Task* section of Chapter 3, *Configuring and Testing*, for information about shunt calibration when in MAX.

To manually perform shunt calibration, refer to the *Shunt Calibration* section of Chapter 4, *Theory of Operation*.

## Acquiring, Analyzing, and Presenting

After configuring the task and channels, you can start your acquisition, read measurements, analyze the data returned, and display it according to the needs of your application. Typical methods of analysis include digital filtering, averaging data, performing harmonic analysis, applying a custom scale, or adjusting measurements mathematically.

Some custom scaling applications require the actual excitation voltage applied to the bridge instead of the nominal excitation voltage output by the NI PXI-4220. You can scan the remote sense pins RSX+ (pin 3) and RSX- (pin 8) with the DAQmx physical channels `DevX/_pPosX` and `DevX/_pNegX` to find the actual excitation voltage. Take the difference of the two physical channels to determine the actual excitation applied to the bridge, and use this value in your scaling equation.



**Note** If RSX+ and RSX- are not wired to the bridge where PX+ and PX- connect, then `_pPosX` and `_pNegX` only measure the internal excitation. Measuring this voltage does not correct for the voltage drop in the excitation leads.

NI provides powerful analysis toolsets for each NI ADE to help you perform advanced analysis on the data without requiring you to have a programming background. After you acquire the data and perform any required analysis, it is useful to display the data in a graphical form or log it to a file. NI ADEs provide easy to use tools for graphical display, such as charts, graphs, slide controls, and gauge indicators. NI ADEs have tools that allow you to easily save the data to files such as spreadsheets for easy viewing, ASCII files for universality, or binary files for smaller file sizes.

## Completing the Application

After you have completed the measurement, analysis, and presentation of the data, it is important to stop and clear the task. This releases any memory used by the task and frees up the DAQ hardware for use in another task.

## Developing an Application Using LabVIEW

This section describes in more detail the steps shown in the typical program flowchart in Figure 5-1, such as how to create a task in LabVIEW and how to configure the channels of the NI PXI-4220. If you need more information or for further instructions, select **Help»VI, Function, & How-To Help** from the LabVIEW menu bar.



**Note** Except where otherwise stated, the VIs in Table 5-2 are located on the **Functions»All Functions»NI Measurements»DAQmx - Data Acquisition** subpalette and accompanying subpalettes in LabVIEW.

**Table 5-2.** Programming a Task in LabVIEW

Flowchart Step	VI or Program Step
Create Task in DAQ Assistant	Create a DAQmx Task Name Constant located on the <b>Controls»All Controls»I/O»DAQmx Name Controls</b> subpalette, right-click it, and select <b>New Task (DAQ Assistant)</b> .
Create a Task Programmatically (optional)	DAQmx Create Task.vi—This VI is optional if you created and configured your task using the DAQ Assistant. However, if you use it in LabVIEW any changes you make to the task will not be saved to a task in MAX.

**Table 5-2.** Programming a Task in LabVIEW (Continued)

Flowchart Step	VI or Program Step
Create AI Strain Channel (optional)	DAQmx Create Virtual Channel.vi (AI Voltage by default, to change to a strain gauge channel click <b>AI Voltage</b> and select <b>Analog Input»Strain»Strain Gage.</b> )—This VI is optional if you created and configured your task and channels using the DAQ Assistant. Any channels created with this VI are not saved in the task in the DAQ Assistant, they are only available for the present session.
Adjust Timing Settings (optional)	DAQmx Timing.vi (Sample Clock by default)—This VI is optional if you created and configured your task using the DAQ Assistant. Any timing settings modified with this VI are not saved in the task in the DAQ Assistant, they are only available for the present session.
Configure Channels (optional)	DAQmx Channel Property Node—Refer to the <a href="#">Using a DAQmx Channel Property Node in LabVIEW</a> section for more information. This step is optional if you created and fully configured the channels in your task using the DAQ Assistant. Any channel modifications made with a channel property node are not saved in the task in the DAQ Assistant, they are only available for the present session.
Perform Offset Null Compensation	Use the DAQmx Perform Bridge Offset Nulling Calibration VI found at <b>Functions»All Functions»NI Measurements»DAQmx - Data Acquisition»DAQmx Advanced»DAQmx Calibration</b> . You can also perform offset null compensation when you create and configure your channels using the DAQ Assistant. Refer to the <a href="#">Creating a Strain Global Channel or Task</a> section of Chapter 3, <a href="#">Configuring and Testing</a> , for information about offset null compensation in MAX.
Perform Shunt Calibration	You can perform shunt calibration when you create and configure your channels using the DAQ Assistant. Refer to the <a href="#">Creating a Strain Global Channel or Task</a> section of Chapter 3, <a href="#">Configuring and Testing</a> , for information about shunt calibration in MAX.
Start Measurement	DAQmx Start Task.vi
Read Measurement	DAQmx Read.vi

**Table 5-2.** Programming a Task in LabVIEW (Continued)

Flowchart Step	VI or Program Step
Analyze Data	Some examples of data analysis include filtering, scaling, harmonic analysis, or level checking. Some data analysis tools are located on the <b>Functions»Signal Analysis</b> subpalette and on the <b>Functions»All Functions»Analyze</b> subpalette.
Display Data	You can use graphical tools such as charts, gauges, and graphs to display your data. Some display tools are located on the <b>Controls»Numeric Indicators</b> subpalette and <b>Controls»All Controls»Graph</b> subpalette.
Continue Sampling	For continuous sampling, use a While Loop. If you are using hardware timing, you also need to set the <code>DAQmx Timing.vi</code> sample mode to Continuous Samples. To do this, right-click the terminal of the <code>DAQmx Timing.vi</code> labeled <b>sample mode</b> and select <b>Create»Constant</b> . Click the box that opens and select <b>Continuous Samples</b> .
Stop Measurement	<code>DAQmx Stop Task.vi</code> (This VI is optional; clearing the task automatically stops the task.)
Clear Task	<code>DAQmx Clear Task.vi</code>

## Using a DAQmx Channel Property Node in LabVIEW



**Note** With the NI PXI-4220 you must use property nodes to disable SS/H.

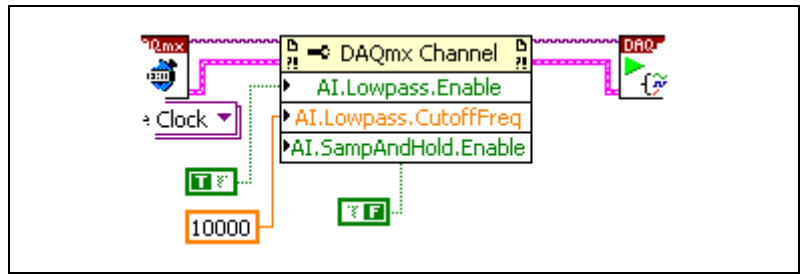
You can use property nodes in LabVIEW to manually configure your channels. To create a LabVIEW property node, complete the following steps:

1. Launch LabVIEW.
2. You can create the property node in a new VI or in an existing VI.
3. Open the block diagram view.
4. From the **All Functions** toolbox select **All Functions»NI Measurements»DAQmx - Data Acquisition**, and select `DAQmx Channel Property Node`.
5. There is a box labeled **Active Channels**, which allows you to specify exactly what channel(s) you want to configure. If you want to configure several channels with different properties, separate the lists of properties with another **Active Channels** box and assign the appropriate channel to each list of properties.



**Note** If you do not use Active Channels, the properties are set on all of the channels in the task.

6. Right-click **ActiveChans** and select **Add Element**. Left-click the new **ActiveChans** box. Navigate through the menus and select the property you want to define.
7. You must change the property to read or write to either get the property or write a new value. Right-click the property, go to **Change To**, and select **Write**, **Read**, or **Default Value**.
8. After you have added the property to the property node, right-click the terminal to change the attributes of the property, add a control, constant, or indicator.



**Figure 5-2.** LabVIEW Channel Property Node with Filtering Enabled at 10 kHz and SS/H Disabled

9. To add another property to the property node, right-click an existing property and left-click **Add Element**. To change the new property left-click it and select the property you wish to define.



**Note** Refer to the *LabVIEW Help* for information about property nodes and specific NI-DAQmx properties.



## Synchronization and Triggering

If you have multiple NI PXI-4220 devices, you can synchronize them to acquire samples at the same time and at the same rate. With SS/H enabled, and each device synchronized, you can use multiple NI PXI-4220 devices to acquire and analyze complex signals.



**Note** The phase difference is lower between channels on the same device with SS/H than between channels on different devices.

For multiple NI PXI-4220 devices to start an acquisition simultaneously, they must all reference a common start trigger. To prevent drift over the course of the acquisition, they must share a common timebase or sample clock.

The NI PXI-4220 that generates the start trigger and the timebase for all of the synchronized devices is called the master. The master NI PXI-4220 exports the shared timing signals through the PXI bus to the slave devices.

Each NI PXI-4220 contains a DAQ-STC chip and is capable of generating a hardware sample clock based on its timebase clock and start trigger. When using a shared timebase and start trigger, each slave NI PXI-4220 still generates a hardware sample clock, but it generates the clock using the timebase and start trigger of the master NI PXI-4220. This causes the slave device to acquire samples at the same time as the master.

The preferred method of synchronization is to use a shared timebase, but it is also possible to synchronize multiple NI PXI-4220 devices by sharing the sample clock between them. This manual only discusses the shared timebase method.

### Synchronizing the NI PXI-4220

Figure 5-3 shows a typical program flow chart for synchronizing the sample clocks and start triggers of two devices, taking a measurement, and clearing the data.

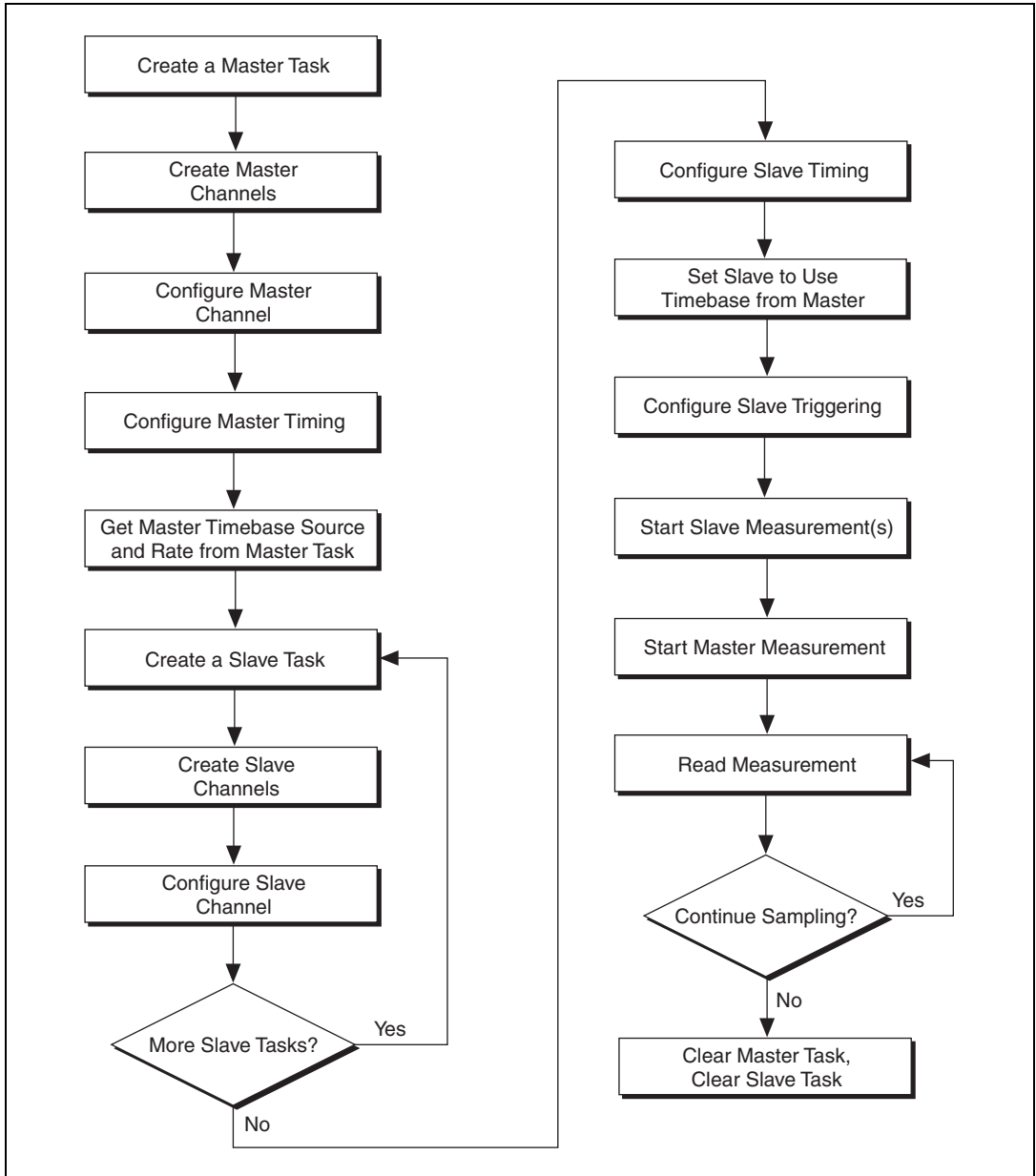


Figure 5-3. General Synchronizing Flowchart

## Synchronizing the NI PXI-4220 Using LabVIEW

This section describes in more detail the steps shown in the general synchronizing flowchart in Figure 5-3. For more information about synchronizing the NI PXI-4220 using LabVIEW or for further instructions, select **Help»VI, Function, & How-To Help** from the LabVIEW menu bar.



**Note** Except where otherwise stated, the VIs in Table 5-3 are located on the **Functions»All Functions»NI Measurements»DAQmx - Data Acquisition** subpalette and accompanying subpalettes in LabVIEW.

**Table 5-3.** Synchronizing the NI PXI-4220 Using LabVIEW

Flowchart Step	VI or Program Step
Create a Master Task	DAQmx Create Task.vi—This VI is optional if you created and configured your task using the DAQ Assistant. However, if you use it in LabVIEW, any changes you make to the task are not saved to a task in MAX.
Create Master Channels	DAQmx Create Virtual Channel.vi (AI Voltage by default—To change to a strain gauge channel, click <b>AI Voltage</b> and select <b>Analog Input»Strain»Strain Gage</b> .)
Configure Master Channels	Use a DAQmx Channel Property Node—Refer to the <a href="#">Using a DAQmx Channel Property Node in LabVIEW</a> section for more information.
Configure Master Timing	DAQmx Timing.vi (Sample Clock by default)
Get Master Timebase Source and Rate from Master Task	Use a DAQmx Timing Property Node to get MasterTimebase.Src and MasterTimebase.Rate.
Create a Slave Task	DAQmx Create Task.vi—This VI is optional if you created and configured your task using the DAQ Assistant. However, if you use it in LabVIEW, any changes you make to the task are not saved to a task in MAX.
Create Slave Channels	DAQmx Create Virtual Channel.vi (AI Voltage by default—To change to a strain gauge channel, click <b>AI Voltage</b> and select <b>Analog Input»Strain»Strain Gage</b> .)
Configure Slave Channels	DAQmx Channel Property Node—Refer to the <a href="#">Using a DAQmx Channel Property Node in LabVIEW</a> section for more information.
Configure Slave Timing	DAQmx Timing.vi (Sample Clock by default)

**Table 5-3.** Synchronizing the NI PXI-4220 Using LabVIEW (Continued)

Flowchart Step	VI or Program Step
Set Slave to Use Timebase from Master	Use a DAQmx Timing Property Node to set <code>MasterTimebase.Src</code> and <code>MasterTimebase.Rate</code> to the values retrieved from the master task in the <i>Get Master Timebase Source and Rate from Master Task</i> step.
Configure Slave Triggering	DAQmx Trigger.vi (Start Digital Edge)—Use <code>/MasterDevice/ai/StartTrigger</code> as the source, substituting the master device identifier for <code>MasterDevice</code> .
Start Slave Measurement(s)	DAQmx Start Task.vi
Start Master Measurement	DAQmx Start Task.vi
Read Measurement	DAQmx Read.vi
Continue Sampling	For continuous sampling, use a While Loop. You also need to have set the sample mode to <b>Continuous Samples</b> in the <i>Configure Master Timing</i> and <i>Configure Slave Timing</i> steps. To set the sample mode, right-click the terminal of the DAQmx Timing.vi labeled <b>sample mode</b> and select <b>Create»Constant</b> . Click the box that opens and select <b>Continuous Samples</b> .
Clear Master Task	DAQmx Clear Task.vi
Clear Slave Task	DAQmx Clear Task.vi

## Other Application Documentation and Material

The following locations provide more information that you may find useful when setting up or connecting signal sources or programming your application.

- LabVIEW Example Programs, available by selecting **Open»Examples** from the opening screen. Most of the examples applicable to the NI PXI-4220 are located in **Hardware Input and Output»DAQmx»Analog Measurements** and **Hardware Input and Output»DAQmx»Synchronization»Multi-Device**.



**Note** The example program `Acq Strain Samples (with Calibration).vi`, located in **Hardware Input and Output»DAQmx»Analog Measurements»Strain**, allows you to programmatically perform shunt calibration in LabVIEW.

- *PXI-4220 Supported Properties* in the LabVIEW VI, Function, & How-To Help.
- Application Note 025: *Field Wiring and Noise Considerations for Analog Signals* available at [ni.com](http://ni.com). Go to [ni.com/info](http://ni.com/info) and enter the info code `rdfwn3`.

## Calibrating the NI PXI-4220

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There are two types of calibration used to improve the accuracy of the NI PXI-4220. Device calibration ensures the accuracy of the NI PXI-4220. System calibration removes the offset and gain errors, two sources of potential measurement errors.

### Calibrating the NI PXI-4220

The NI PXI-4220 is shipped with a calibration certificate and is calibrated at the factory to the specifications described in Appendix A, *Specifications*. Calibration constants are stored on the NI PXI-4220.

### Internal Calibration Procedure

The NI PXI-4220 incorporates internal calibration paths that allow routing channel inputs to ground or to an onboard high-precision reference voltage. NI driver software disconnects the channel inputs from the front signal connector and reconnects the inputs to ground or to an onboard reference when performing an internal two-point calibration. The driver software determines the correct adjustment factors for offset and gain error and stores them as calibration constants. The driver software automatically uses these adjustment factors to correctly scale each measurement. You need not change any input connections for an internal calibration.

To obtain the highest level of accuracy, you should periodically perform an internal calibration. You can self-calibrate the NI PXI-4220 within MAX.

To perform a self-calibration, complete the following steps:

1. Double-click the **Measurement & Automation Explorer** icon on the desktop.
2. Display the list of devices and interfaces by clicking the **+** next to the **Devices and Interfaces** icon.
3. Display the list of NI-DAQmx devices by clicking the **+** next to **NI-DAQmx Devices** icon.
4. Right-click the NI PXI-4220 and select **Self-Calibrate**.

5. A dialog box opens indicating that the NI PXI-4220 is self-calibrating.
6. When the dialog box closes, the NI PXI-4220 is successfully self-calibrated.



**Note** To maintain the accuracy specifications in Appendix A, *Specifications*, NI recommends performing an internal calibration at an ambient temperature within  $\pm 1$  °C of the acquisition temperature.

## External Device Calibration

NI recommends you perform an external calibration once a year. At the time of publication, there is currently no external calibration procedure document available for the NI PXI-4220. Return the NI PXI-4220 to NI for external calibration. NI provides a certificate of calibration with the calibrated NI PXI-4220. For information about how to contact NI, refer to the *Signal Conditioning Technical Support Information* document.

## Calibrating the System

You should perform offset null compensation or shunt calibration on transducers in your system to improve accuracy. This is considered system, or end-to-end, calibration.

### Offset Null Compensation

Performing an offset null compensation removes offset in the measurement system. Factors such as imperfections in the strain gauge, electrical offset in the measurement system, signal leads with significant lead resistance, as well as other system variables can create offset. Refer to the *Offset Null Compensation* section of Chapter 4, *Theory of Operation*, for information about how to perform offset null compensation.

### Shunt Calibration

Performing shunt calibration removes gain or amplitude errors in the measurement system. Factors such as non-ideal gauges, incorrect strain gauge factor, temperature fluctuations, as well as other system variables can create these errors. Refer to the *Shunt Calibration* section of Chapter 4, *Theory of Operation*, for information about how to perform shunt calibration.

## Specifications

This appendix lists the specifications for the NI PXI-4220 device. These specifications are typical at 25 °C unless otherwise noted. All specifications are with SS/H enabled unless otherwise noted.

### Analog Input

Number of input channels ..... 2

Voltage gain settings ..... X1 to X1000 with the following gain settings: 1; 1.15; 1.3; 1.5; 1.8; 2; 2.2; 2.4; 2.7; 3.1; 3.6; 4.2; 5.6; 6.5; 7.5; 8.7; 10; 11.5; 13; 15; 18; 20; 22; 24; 27; 31; 36; 42; 56; 65; 75; 87; 100; 115; 130; 150; 180; 200; 220; 240; 270; 310; 360; 420; 560; 650; 750; 870; 1,000.

Resolution ..... 16 bits, 1 in 65,536

**Table A-1.** Maximum Sampling Rates

Number of Channels	SS/H Enabled	SS/H Disabled
1	100.0 kS/s	333 kS/s
2	66 kS/s/ch	100.0 kS/s/ch

Input coupling ..... DC

Bandwidth ..... 20 kHz, filter bypassed

## NI PXI-4220 Accuracy Information

Nominal Range	Gain	Absolute Accuracy						Absolute Accuracy at Full Scale
		% of Reading 1 Year	Maximum Offset ( $\mu\text{V}$ )	Noise + Quantization ( $\mu\text{V}$ )		Temperature Drift		
				Single Pt.	Averaged	Gain Drift ( $\%/^{\circ}\text{C}$ )	Offset Drift ( $\mu/^{\circ}\text{C}$ )	
$\pm 10.0\text{ V}$	1	0.1	3000	5000	500	0.0300	25.00	$\pm 13.5\text{ mV}$
$\pm 5.0\text{ V}$	2	0.1	1500	2500	250	0.0300	25.00	$\pm 6.8\text{ mV}$
$\pm 1.8\text{ V}$	4.2	0.1	500	1000	100	0.0300	25.00	$\pm 2.4\text{ mV}$
$\pm 1.0\text{ V}$	10	0.1	300	500	50	0.0300	25.00	$\pm 1.4\text{ mV}$
$\pm 500.0\text{ mV}$	20	0.1	150	250	25	0.0300	5.00	$\pm 675\text{ }\mu\text{V}$
$\pm 180.0\text{ mV}$	42	0.1	75	100	10	0.0300	5.00	$\pm 265\text{ }\mu\text{V}$
$\pm 100.0\text{ mV}$	100	0.1	50	50	5.0	0.0300	5.00	$\pm 155\text{ }\mu\text{V}$
$\pm 50.0\text{ mV}$	200	0.1	50	25	2.5	0.0300	5.00	$\pm 103\text{ }\mu\text{V}$
$\pm 18.0\text{ mV}$	420	0.1	50	10	1.0	0.0300	5.00	$\pm 69\text{ }\mu\text{V}$
$\pm 10.0\text{ mV}$	1000	0.1	50	10	1.0	0.0300	5.00	$\pm 61\text{ }\mu\text{V}$

Accuracies are valid for measurements following an internal self-calibration and using the 10 kHz filter setting. Averaged numbers assume an average of 100 single-channel readings.

Measurement accuracies are listed for operational temperatures within  $\pm 1\text{ }^{\circ}\text{C}$  of internal calibration temperature and  $\pm 10\text{ }^{\circ}\text{C}$  of external or factory calibration temperature.

The absolute accuracy at full scale calculations use the maximum range input voltage (for example, 10 V on the  $\pm 10\text{ V}$  range) at one year accuracy, assuming averaged data.

## Overvoltage Protection

D-SUB connectors

Powered on ..... $\pm 35\text{ V}$

Powered off ..... $\pm 25\text{ V}$

SMB connector

Powered on and off..... $\pm 15\text{ V}$



## T/H Characteristics

Acquisition time .....	7 $\mu$ s typ
Hold mode settling time .....	3 $\mu$ s typ
Droop rate .....	30 mV/s typ, 100 mV/s max
Interchannel skew .....	200 ns typ
Intermodule skew .....	250 ns typ

## Transfer Characteristics

Offset error .....	150 $\mu$ V ( $G \leq 20$ ) 3 mV ( $G < 20$ )
Gain error .....	$\pm 0.1\%$
Non-linearity .....	Better than 0.02% of FSR
DNL .....	$\pm 0.5$ LSB typ $\pm 1$ LSB max
No missing codes .....	16 bits, guaranteed

## Calibration

Recommended warm-up time .....	15 minutes
External calibration interval .....	1 year
Onboard calibration reference	
Level .....	5.000 V $\pm 1$ mV (actual value stored in EEPROM)
Temperature coefficient .....	$\pm 5$ ppm/ $^{\circ}$ C
Long-term stability .....	15 ppm/ $\sqrt{1,000}$ h
Pre-calibration errors <sup>1</sup>	
Pre-calibration gain error .....	$\pm 18,900$ ppm max
Signal conditioning component only .....	$\pm 1\%$ max

<sup>1</sup> The pre-calibration errors apply only for users doing register-level programming. NI-DAQmx users do not see the pre-calibration errors.

## Amplifier Characteristics

Input impedance (DC) .....	>1 G
Input bias current .....	$\pm 20$ nA max
Input offset current .....	$\pm 20$ nA max
CMRR (DC to 60 Hz)	
Gain $\geq 20$ .....	>85 dB
Gain <20 .....	>60 dB
Crosstalk at 1 kHz, gain = 200 .....	$\geq 95$ dB

## Dynamic Characteristics

Minimum scan interval	
$\pm 0.0015\%$ relative accuracy (16-bit) .....	5 $\mu$ s
Wideband noise, gain = 200, 10 kHz filter .....	40 $\mu$ V <sub>pp</sub>
Noise RTI, gain = 200, 0.1 to 10 Hz .....	1.5 $\mu$ V <sub>pp</sub>
Spot noise RTI, gain = 200, 1000 Hz .....	16nV $\sqrt{\text{Hz}}$

## Filter Characteristics

Lowpass filter type .....	4-pole Butterworth (24 dB/octave rolloff)
Lowpass filter settings .....	10 Hz, 100 Hz, 1 kHz, 10 kHz, or bypass
Bandwidth, filter bypassed .....	-3 db at 20 kHz
NMR, 10 Hz filter .....	-62 dB at 60Hz typ

## Stability

Recommended warm-up time .....	15 min
Gain drift (with self-calibration at temperature) .....	$\pm 40$ ppm/ $^{\circ}$ C max
Gain drift (without self-calibration) .....	$\pm 45$ ppm/ $^{\circ}$ C max

## Offset drift (with self-calibration at temperature)

Gain  $\geq 20$  .....  $\pm 2 \mu\text{V}/^\circ\text{C}$  typ,  $\pm 5 \mu\text{V}/^\circ\text{C}$  maxGain  $< 20$  .....  $\pm 15 \mu\text{V}/^\circ\text{C}$  typ,  $\pm 25 \mu\text{V}/^\circ\text{C}$  max

## Offset drift (without self-calibration at temperature)

Gain  $\geq 20$  .....  $\pm 18 \mu\text{V}/^\circ\text{C}$  typ,  $\pm 23 \mu\text{V}/^\circ\text{C}$  maxGain  $< 20$  .....  $\pm 350 \mu\text{V}/^\circ\text{C}$  typ,  
 $\pm 375 \mu\text{V}/^\circ\text{C}$  max

## Null Compensation

Range .....  $\pm 4\%$  of excitation voltage,  
20,000 counts of resolution  
( $\pm 80,000$  microstrain null  
compensation range,  
4 microstrain resolution for  
quarter-bridge,  $\text{GF} = 2.0$ ).

## Excitation

Type ..... Constant voltage

Settings ..... 0.0 to 10.0 V  
in 1,024 equally spaced  
incrementsError .....  $\pm 20 \text{ mV} \pm 0.3\%$  of nominal setting  
 $\pm 0.1\%$  of value read from remote  
sense

Maximum operating current ..... 29 mA, all ranges

Short-circuit protection ..... Yes

Regulation, no load to 120  $\Omega$  loadWith remote sense .....  $\pm 0.003\%$ Without remote sense .....  $\pm 0.30\%$ Temperature drift .....  $\pm 0.005\%/^\circ\text{C}$ ,  $\pm 30 \mu\text{V}/^\circ\text{C}$  maxNoise, DC to 10 kHz .....  $200 \mu\text{V}_{\text{pp}}$

Remote sense .....	Error less than $\pm 0.02\%$ per $\Omega$ of lead resistance, both leads
Protection .....	Surge arrestors in parallel with excitation terminals, shunt to ground

## Bridge Completion<sup>1</sup>

Half-bridge.....	Two precision resistors, 5 k $\Omega$ each
Quarter-bridge .....	350 $\Omega$ resistor socketed on PXI-4220 (120 $\Omega$ resistor included in kit)

## Shunt Calibration<sup>2</sup>

Type .....	Two independent points
Resistor .....	100 k $\Omega$ resistors socketed on PXI-4220
Switch resistance .....	32 $\Omega$ typical, 50 $\Omega$ max
Switch off leakage .....	<1 nA
Switch break-down voltage .....	$\pm 60$ V

## Digital, Timing, Power

### Digital Triggers

Number of triggers .....	2
Purpose .....	Start and stop trigger, gate, clock
Source .....	PFI0/TRIG1 (front SMB connector), PXI_Trig<0..5>, PXI_Star (PXI trigger bus)

<sup>1</sup> Half-bridge completion is performed inside the module and configured under software control. The quarter-bridge completion resistor is located near the front of the PXI-4220 and is socketed. Resistors shipped with the PXI-4220 are 350  $\Omega$  (installed) and 120  $\Omega$  (in bag with kit) RN-55 style (standard 1/4 W size). The tolerance is  $\pm 0.1\%$  and the temperature coefficient is 10 ppm/ $^{\circ}$ C max.

<sup>2</sup> Shunt calibration resistors are located near the front of the PXI-4220 and are socketed. Resistors shipped with the PXI-4220 are 100 k $\Omega$  RN-55 style (standard 1/4 W size). The tolerance is  $\pm 0.1\%$  and the temperature coefficient is 10 ppm/ $^{\circ}$ C max.

Slope .....	Positive or negative; software selectable
Compatibility .....	5 V/TTL
Response .....	Rising or falling edge
Pulse width.....	10 ns min
Impedance.....	10 k $\Omega$
Coupling.....	DC
<b>PXI Trigger Bus</b>	
Trigger lines.....	6
Star trigger .....	1
FIFO buffer size .....	512 samples
Data transfers .....	DMA, interrupts, programmed I/O
DMA modes.....	Scatter-gather (single transfer, demand transfer)
Configuration memory size.....	512 words
Bus interface .....	Master, slave
Power requirements.....	1 A at $\pm 5$ VDC ( $\pm 5\%$ )

## Physical

<b>Dimensions</b>	
(not including connectors) .....	16.0 $\times$ 10.0 $\times$ 2.0 cm (6.3 $\times$ 3.9 $\times$ 0.79 in.)
Analog input signal connector .....	9-pin D-SUB

## Maximum Working Voltage

(Signal + common-mode) .....	Either the SX+ (pin 1) or SX- (pin 6) input should remain within $\pm 10$ V of ground. Both inputs should remain within $\pm 10$ V of each other. Maximum working voltage refers to the signal voltage plus the common mode voltage.
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## Environment

Operating temperature .....	0 to 55 °C
Storage temperature .....	-20 to 70 °C
Humidity .....	10 to 90% RH, noncondensing
Maximum altitude.....	2,000 m
Pollution Degree (indoor use only).....	2

## Safety

The PXI-4220 is designed to 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 61010-1
- CAN/CSA-C22.2 No 61010-1



**Note** For UL and other safety certifications, refer to the product label, or visit [ni.com/certification](http://ni.com/certification), search by model number or product line, and click the appropriate link in the Certification column.

## 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, operate this device with shielded cabling.

## CE Compliance

The PXI-4220 meets 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, visit [ni.com/certification](http://ni.com/certification), search by model number or product line, and click the appropriate link in the Certification column.

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# Timing Signal Information

This appendix contains more information on the timing signals discussed in Chapter 4, *Theory of Operation*.

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## Connecting Timing Signals

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**Caution** Exceeding the maximum input voltage ratings listed in Appendix A, *Specifications*, can damage the device and the computer. NI is *not* liable for any damage resulting from such signal connections.

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## Programmable Function Input Connections

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You can externally control seven internal timing signals from PFI0 and the PXI trigger bus pins. The source for each of these signals is software configurable from PFI0, PXI\_Trig<0..5>, or PXI\_Star when you want external control. This flexible routing scheme reduces the need to change the physical wiring to the device I/O connector for applications requiring alternative wiring.

As an input, each PFI signal can be individually configured for edge or level detection and polarity selection. You can use the polarity selection for any timing signal, but the edge or level detection depends on the particular timing signal being controlled. The detection requirements for each timing signal are listed in the corresponding sections.

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

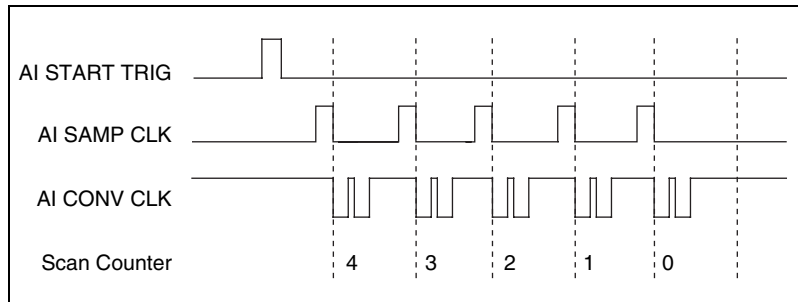
In level-detection mode, there are no pulse width requirements imposed by the PFIs themselves. Limits can be imposed by the particular timing signal being controlled. These requirements are listed in the sections describing the particular signals.



# DAQ Timing Connections

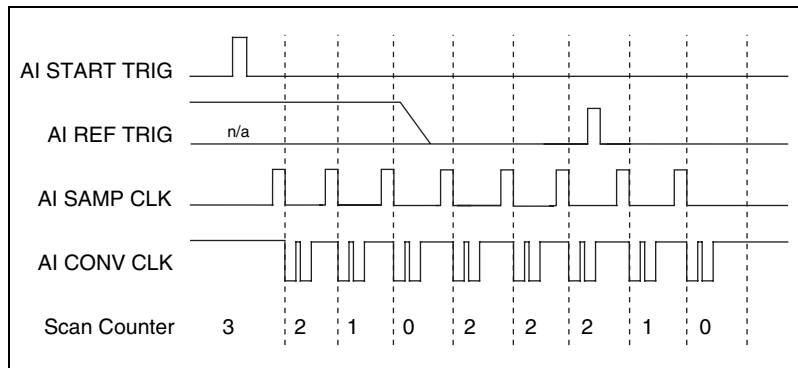
The timing signals are AI START TRIG, AI REF TRIG, AI SAMP CLK, AI CONV CLK, AI PAUSE TRIG, AI SAMPLE CLK TIMEBASE, and AI HOLD COMPLETE.

Posttriggered DAQ allows you to view data that is acquired after a trigger event is received. Figure B-1 shows a typical posttriggered sequence.



**Figure B-1.** Typical Posttriggered Sequence

Pretriggered DAQ allows you to view data that is acquired before the trigger of interest in addition to data acquired after the trigger. Figure B-2 shows a typical pretriggered sequence.



**Figure B-2.** Typical Pretriggered Sequence

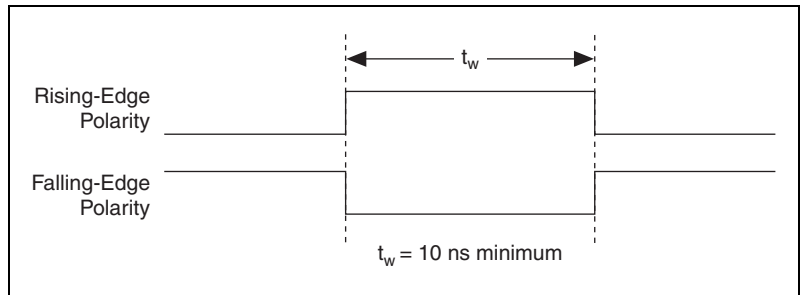
## AI START TRIG Signal

The AI START TRIG signal can be input or output through PFI0 or PXI\_Trig<0..5>. It can only be input through PXI\_Star.

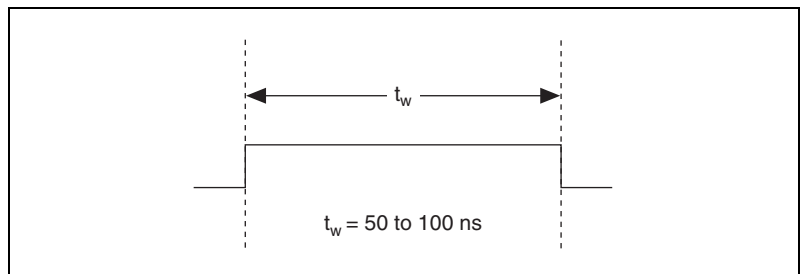
As an input, AI START TRIG is configured in the edge-detection mode. You can select PFI0 as the source for AI START TRIG and configure the polarity selection for either rising or falling edge. The selected edge of AI START TRIG starts the sequence for both posttriggered and pretriggered acquisitions. Refer to Figures B-1 and B-2 for the relationship of AI START TRIG to the sequence.

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

Figures B-3 and B-4 show the input and output timing requirements for AI START TRIG.



**Figure B-3.** AI START TRIG Input Signal Timing



**Figure B-4.** AI START TRIG Output Signal Timing

The device also uses AI START TRIG to initiate pretriggered operations. In pretriggered applications, AI START TRIG is generated by a software trigger unless a PFI pin is selected as the source of AI START TRIG. Refer to the *AI REF TRIG Signal* section for a complete description of the use of AI START TRIG and AI REF TRIG in a pretriggered operation.

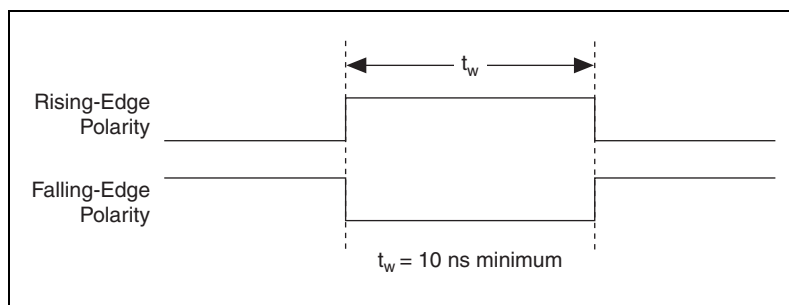
## AI REF TRIG Signal

The AI REF TRIG signal can be input through PFI0, PXI\_Trig<0..5>, or PXI\_Star. Refer to Figure B-2 for the relationship of AI REF TRIG to the sequence.

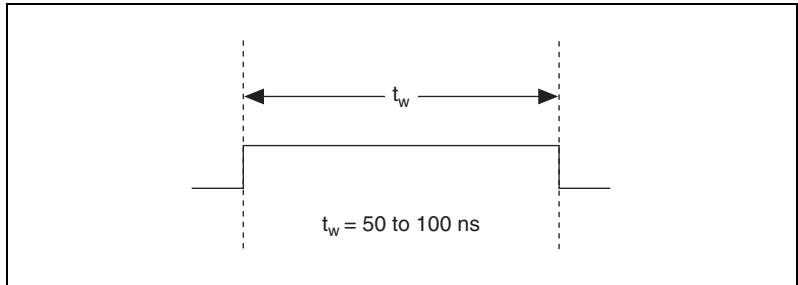
As an input, AI REF TRIG is configured in edge-detection mode. You can configure the polarity selection for either rising or falling edge. The selected edge of AI REF TRIG initiates the posttriggered phase of a pretriggered sequence. In pretriggered mode, the AI START TRIG signal initiates the acquisition.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

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

Figures B-5 and B-6 show the input and output timing requirements for AI REF TRIG.



**Figure B-5.** AI REF TRIG Input Signal Timing



**Figure B-6.** AI REF TRIG Output Signal Timing

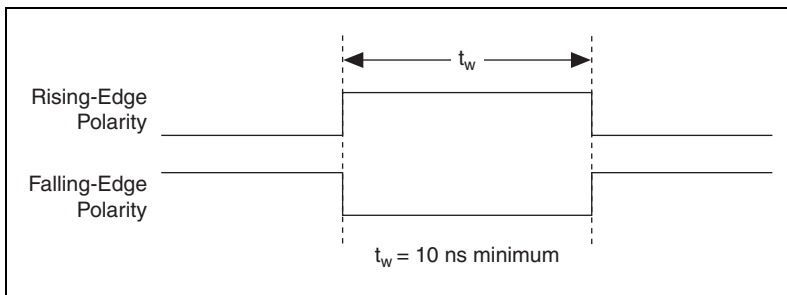
## AI SAMP CLK Signal

The AI SAMP CLK signal can be externally input from PFI0, PXI\_Trig<0..5>, or PXI\_Star. It can be output on any PXI trigger bus line. Refer to Figures B-1 and B-2 for the relationship of AI SAMP CLK to the sequence.

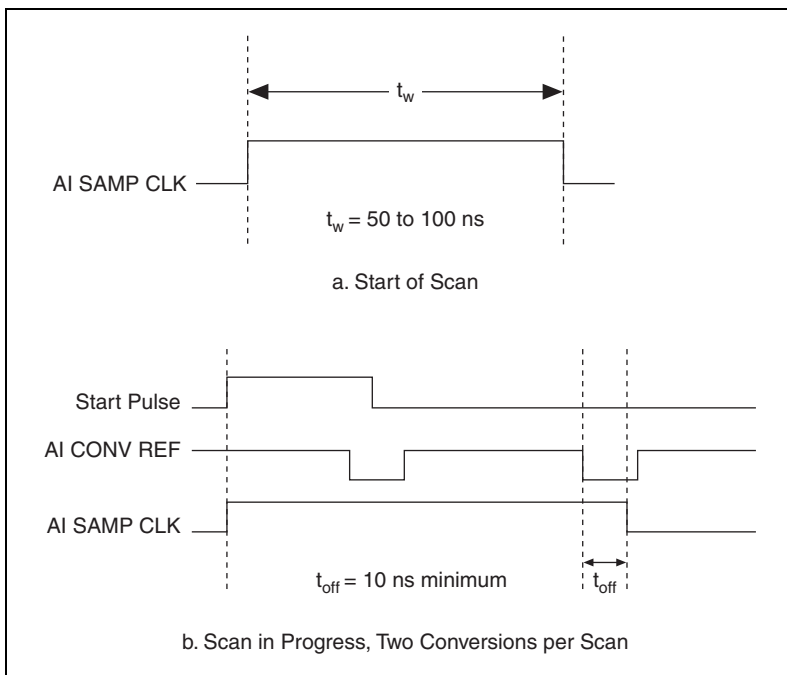
As an input, AI SAMP CLK is configured in edge-detection mode. You can configure the polarity selection for either rising or falling edge. The selected edge of AI SAMP CLK initiates a scan. The SI2 counter starts if you select an internally triggered AI CONV CLK.

As an output, AI SAMP CLK reflects the actual start pulse that initiates a scan, even if the starts are externally triggered by another PFI, PXI\_Trig<0..5>, or PXI\_Star. You have two output options. The first option is an active high pulse with a pulse width of 50 to 100 ns, which indicates the start of the scan. The second option is an active high pulse that terminates at the start of the last conversion in the scan, which indicates a scan in progress. AI SAMP CLK is deasserted,  $t_{\text{off}}$ , after the last conversion in the scan is initiated. This output is set to high-impedance at startup.

Figures B-7 and B-8 show the input and output timing requirements for AI SAMP CLK.



**Figure B-7.** AI SAMP CLK Input Signal Timing



**Figure B-8.** AI SAMP CLK Output Signal Timing

The AI CONV CLK pulses are masked off until the device generates AI SAMP CLK. If you use internally generated conversions, the first AI CONV CLK appears when the onboard SI2 counter reaches zero. If you select an external AI CONV CLK, the first external pulse after AI SAMP CLK generates a conversion. Separate the AI SAMP CLK pulses by at least one scan period.

A counter on the device internally generates AI SAMP CLK unless you select some external source. The AI START TRIG signal starts this counter, and the application software or the sample counter stops it.

Scans generated by either an internal or external AI SAMP CLK are inhibited unless they occur within a sequence. Scans occurring within a sequence can be gated by either the hardware AI PAUSE TRIG signal or the software command register gate.

## AI CONV CLK Signal

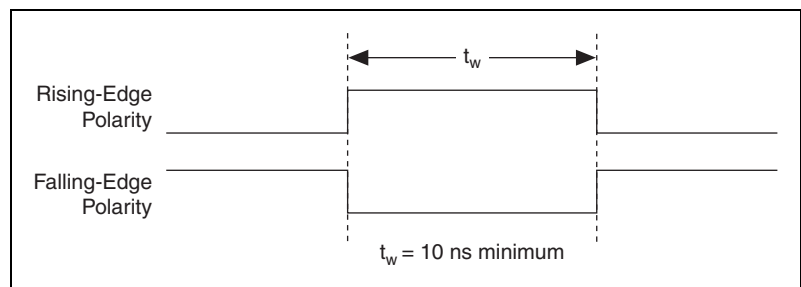
PFI0, PXI\_Trig<0..5>, or PXI\_Star can externally input the AI CONV CLK signal, which is also available as an output on PXI\_Trig<0..5>.

Refer to Figures B-1 and B-2 for the relationship of AI CONV CLK to the sequence.

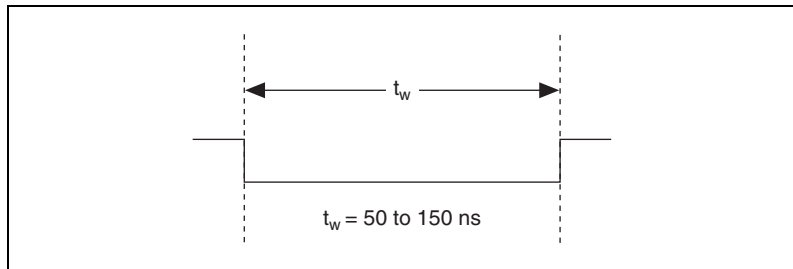
As an input, AI CONV CLK is configured in edge-detection mode. You can configure the polarity selection for either rising or falling edge. The selected edge of AI CONV CLK initiates an A/D conversion.

As an output, AI CONV CLK reflects the actual convert pulse that connects to the ADC, even if the conversions are externally generated by another PFI. The output is an active low pulse with a pulse width of 50 to 100 ns. This output is set to high-impedance at startup.

Figures B-9 and B-10 show the input and output timing requirements for AI CONV CLK.



**Figure B-9.** AI CONV CLK Input Signal Timing



**Figure B-10.** AI CONV CLK Output Signal Timing

The ADC switches to hold mode within 60 ns of the selected edge. This hold-mode delay time is a function of temperature and does not vary from one conversion to the next. Separate the AI CONV CLK pulses by at least one conversion period.

The NI PXI-4220 sample interval counter generates AI CONV CLK unless you select an external source. The AI SAMP CLK signal starts the counter, which counts down and reloads itself until the scan finishes. The counter then reloads itself in preparation for the next AI SAMP CLK pulse.

A/D conversions generated by an internal or external AI CONV CLK signal are inhibited unless they occur within a sequence. Scans occurring within a sequence can be gated by either the hardware AI PAUSE TRIG signal or the software command register gate.

## AI PAUSE TRIG Signal

PFI0, PXI\_Trig<0..5>, or PXI\_Star can externally input the AI PAUSE TRIG signal, which is not available as an output on the I/O connector. AI PAUSE TRIG can mask off scans in a sequence. You can configure the pin you select as the source for AI PAUSE TRIG in level-detection mode. You can configure the polarity selection for the pin as either active high or active low.

In level-detection mode, the AI SAMP CLK signal is masked off and no scans can occur.

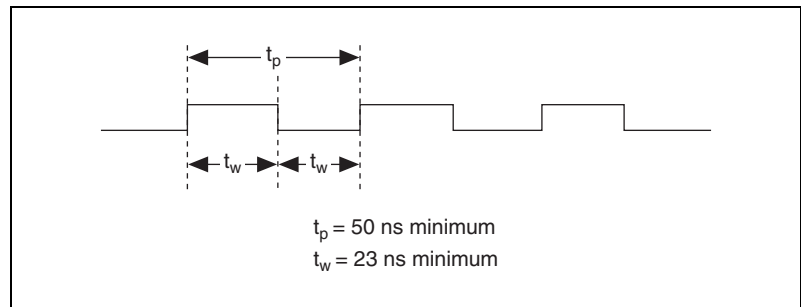
AI PAUSE TRIG can neither stop a scan in progress nor continue a previously gated-off scan. In other words, after a scan has started, AI PAUSE TRIG does not gate off conversions until the beginning of the next scan. Conversely, if conversions are gated off, AI PAUSE TRIG does not gate them back on until the beginning of the next scan.

## AI SAMPLE CLK TIMEBASE Signal

PFI0, PXI\_Trig<0..5>, or PXI\_Star can externally input the AI SAMPLE CLK TIMEBASE signal, which is not available as an output on the I/O connector. The onboard scan interval (SI) counter uses AI SAMPLE CLK TIMEBASE as a clock to time the generation of the AI SAMP CLK signal. Configure the pin you select as the source for AI SAMPLE CLK TIMEBASE in level-detection mode. Configure the polarity selection for the pin for either active high or active low.

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

Either the 20 MHz or 100 kHz internal timebase generates AI SAMPLE CLK TIMEBASE unless you select an external source. Figure B-11 shows the timing requirements for AI SAMPLE CLK TIMEBASE.



**Figure B-11.** AI SAMPLE CLK TIMEBASE Signal Timing

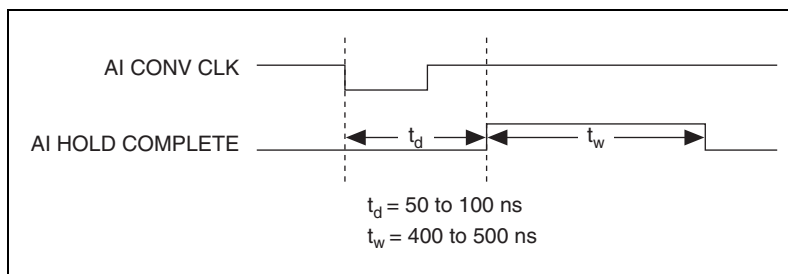


## AI HOLD COMPLETE Signal

AI HOLD COMPLETE is an output-only signal that generates a pulse with the leading edge occurring approximately 50 to 100 ns after an A/D conversion begins. The polarity of this output is software configurable, but the polarity is typically configured so that a low-to-high leading edge can clock external analog input multiplexers indicating when the input signal has been sampled and can be removed. This signal has a 400 to 500 ns pulse width and is software enabled. Figure B-12 shows the timing for AI HOLD COMPLETE.



**Note** The polarity of AI HOLD COMPLETE is not software selectable when programmed using NI-DAQmx. It is a positive polarity pulse.



**Figure B-12.** AI HOLD COMPLETE Signal Timing



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# Removing the NI PXI-4220

This section provides details about removing an NI PXI-4220 device from MAX and from a PXI chassis.



**Note** You must physically remove the NI PXI-4220 from the chassis before you can remove it from MAX.

## Removing the NI PXI-4220 from a PXI Chassis

---

Consult the PXI chassis documentation for additional instructions and cautions. To remove the NI PXI-4220 device from a PXI chassis, complete the following steps while referring to Figure C-1:

1. Power off the PXI chassis. Do *not* remove the NI PXI-4220 device from a chassis that is powered on.
2. Rotate the mounting screws that secure the NI PXI-4220 to the chassis counter-clockwise until they are loose, but do not completely remove the screws.
3. Remove the NI PXI-4220 by pushing down steadily on the injector/ejector handle until the device disengages from the chassis.
4. Slide the device completely out.

The next time you restart the computer the NI PXI-4220 will have a red circle with a white **X** inside it next to the device in MAX.

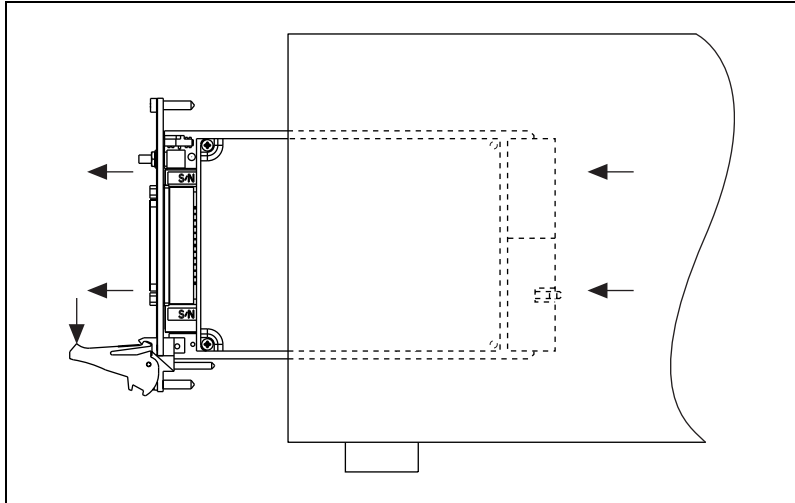


Figure C-1. Injector/Ejector Handle Position Before Device Removal

## Removing the NI PXI-4220 from MAX

To remove an NI PXI-4220 device from MAX, complete the following steps after launching MAX:

1. Expand **Devices and Interfaces** to display the list of installed devices and interfaces. The NI PXI-4220 should have a red circle with a white **X** inside it next to the device to indicate it has been physically removed from the chassis.
2. Right-click the NI PXI-4220 and click **Delete**.
3. You are presented with a confirmation window. Click **Yes** to continue deleting the device or **No** to cancel this action.

The NI PXI-4220 is now removed from the list of installed devices in MAX.

---

# Common Questions

This appendix lists common questions related to the use of the NI PXI-4220.

## **Which version of NI-DAQ works with the NI PXI-4220 and how do I get the most current version of NI-DAQ?**

You must have NI-DAQ 7.0 or later and use NI-DAQmx. Visit [ni.com](http://ni.com), select **Download Software»Drivers and Updates»Search Drivers and Updates**, and enter the keyword NI-DAQ to find the latest version of NI-DAQ for your operating system.

## **When no signal is connected to the NI PXI-4220, what sort of behavior should I expect?**

While the NI PXI-4220 may react differently due to system and condition variables, in most cases, when no signal is connected to the NI PXI-4220 the instrumentation amplifiers float, and the signal will likely drift to the positive or negative voltage rail.

## **How do I control the gain, excitation voltage, filter setting, bridge configuration, potentiometer settings, and shunt calibration switches from LabVIEW?**

The gain of each NI PXI-4220 channel is automatically set based on the channel limits used in setting up the acquisition. Although excitation voltage, filter setting, and bridge configuration are usually set using MAX, you also can control or change these settings programmatically using a **DAQmx Channel Property Node** in LabVIEW.

## **Are there any special considerations for an NI PXI-4220 channel *not* connected to a Wheatstone bridge?**

If you are attempting to make a voltage with no bridge signal conditioning, you should set the excitation voltage to zero and the bridge configuration to full bridge. This is because the NI PXI-4220 input offset correction constants are obtained with the excitation set to 0 V. With the excitation voltage other than zero, error voltages from the auto-nulling circuits can

increase offset error beyond the limits given in the specifications. You cannot perform offset null compensation when the excitation is set to 0 V.

**How do I program the NI PXI-4220?**

Refer to Chapter 5, *Developing Your Application*, for application programming information or your ADE help file. There is no register-level programming manual available for the NI PXI-4220.

**If I am powering my bridge-based transducers with an external voltage source, what voltage setting should I set on the NI PXI-4220?**

Even with an external voltage source for the transducers, internal excitation voltage is still used by the offset null compensation circuitry inside the NI PXI-4220. Set the internal excitation voltage equal to the external excitation voltage to ensure the accuracy of offset null compensation.

**How do I perform an external calibration of the NI PXI-4220?**

As of the NI PXI-4220 release, an external calibration document is not available. To see if an NI PXI-4220 external calibration document is currently available, click **Manual Calibration Procedures** at [ni.com/calibration](http://ni.com/calibration).

# Glossary

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

## Symbols

%	percent
+	positive of, or plus
-	negative of, or minus
/	per
°	degree
$\Omega$	ohm

## A

A	amperes
A/D	analog-to-digital
AC	alternating current
ADC	analog-to-digital converter—an electronic device, often an integrated circuit, that converts an analog voltage to a digital number

ADE	application development environment
AI	analog input
AI CONV CLK	convert signal
AI HOLD COMPLETE	scan clock signal
AI PAUSE TRIG	analog input gate signal
AI SAMP CLK	start scan signal
AIGND	analog input ground signal
AISENSE	analog input sense 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 to +5 V)
breakdown voltage	the voltage high enough to cause breakdown of optical isolation, semiconductors, or dielectric materials. <i>See also</i> working voltage.
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.
bus master	a type of a plug-in device or controller with the ability to read and write devices on the computer bus

## C

C	Celsius
CalDAC	calibration DAC

CH	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.
channel clock	the clock controlling the time interval between individual channel sampling within a scan. Devices with SS/H do not have this clock.
channel rate	reciprocal of the interchannel delay
CMR	common-mode rejection
CMRR	common-mode rejection ratio—the ability of an instrument to reject interference from a common-mode signal, usually expressed in decibels (dB)
common-mode signal	any voltage present at the instrumentation amplifier inputs with respect to amplifier ground
counter/timer	a circuit that counts external pulses or clock pulses (timing)
CTR	counter
<b>D</b>	
D/A	digital-to-analog
DAC	digital-to-analog converter—an electronic device, often an integrated circuit, that converts a digital number into a corresponding analog voltage or current
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
DAQ Assistant	a configuration utility with which you define and configure your DAQ operation
DAQ-STC	data acquisition system timing controller chip



dB	decibel—the unit for expressing a logarithmic measure of the ratio of two signal levels: $db = 20 \cdot \log_{10}(V1/V2)$ , for signals in volts
DC	direct current
DGND	digital ground signal
DIFF	differential mode
differential input	an analog input consisting of two terminals, both of which are isolated from computer ground, whose difference is measured
DIO	digital input/output
dithering	the addition of Gaussian noise to an analog input signal
DMA	direct memory access—a method by which data can be transferred to/from computer memory from/to a device or memory on the bus while the processor does something else. DMA is the fastest method of transferring data to/from computer memory.
DNL	differential nonlinearity—a measure in least significant bit of the worst-case deviation of code widths from their ideal value of 1 LSB
driver	software that controls a specific hardware device such as a DAQ device
<b>E</b>	
EEPROM	electrically erasable programmable read-only memory—ROM that can be erased with an electrical signal and reprogrammed
EMC	electromagnetic compatibility
EMI	electromagnetic interference—defines unwanted electromagnetic radiation from a device, which could interfere with desired signals in test or communication equipment
ESD	electrostatic discharge

**F**

FIFO first-in first-out memory buffer

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

ft feet

**G**

g grams

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

gain accuracy a measure of deviation of the gain of an amplifier from the ideal gain

grounded measurement system *See* referenced single-ended configuration.

**H**

h hour

Hz hertz—the number of scans read or updates written per second

**I**

I/O input/output—the transfer of data to/from a computer system involving communications channels, operator interface devices, and/or DAQ and control interfaces

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 bias current the current that flows into the inputs of a circuit

input impedance the resistance and capacitance between the input terminals of a circuit

input offset current	the difference in the input bias currents of the two inputs of an instrumentation amplifier
instrumentation amplifier	a circuit whose output voltage with respect to ground is proportional to the difference between the voltages at its two high impedance inputs
interchannel delay	amount of time that passes between sampling consecutive channels. The interchannel delay must be short enough to allow sampling of all the channels in the channel list, within the scan interval. The greater the interchannel delay, the more time the PGA is allowed to settle before the next channel is sampled. The interchannel delay is regulated by AI CONV CLK.

## 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—a program development application based on the programming language G and used commonly for test and measurement purposes
LED	light-emitting diode
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

MAX	Measurement & Automation Explorer—NI software for configuring devices and channels.
maximum working voltage	the highest voltage with respect to ground that should be applied to an input terminal during normal use, normally well under the breakdown voltage for safety margin. Includes both the signal and common-mode voltages.

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.
MSB	most significant bit
mux	multiplexer—a switching device with multiple inputs that sequentially connects each of its inputs to its output, typically at high speeds, in order to measure several signals with a single analog input channel
MXI	Multisystem eXtension Interface
<b>N</b>	
NI	National Instruments
NI-DAQ	NI driver software for DAQ hardware
NI-DAQmx	the latest NI-DAQ driver with new VIs, functions, and development tools for controlling measurement devices
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.
normal mode voltage	voltage that occurs in the case of interference between two conductors of a circuit
NRSE	nonreferenced single-ended mode—all measurements are made with respect to a common (NRSE) measurement system reference, but the voltage at this reference can vary with respect to the measurement system ground
<b>0</b>	
OUT	output pin—a counter output pin where the counter can generate various TTL pulse waveforms

## P

PCI	peripheral component interconnect
PFI	programmable function input
PGA	programmable gain amplifier
port	(1) a communications connection on a computer or a remote controller; (2) a digital port, consisting of four or eight lines of digital input and/or output
ppm	parts per million
PXI	PCI eXtensions for Instrumentation—an open specification that builds on the CompactPCI specification by adding instrumentation-specific features
PXI trigger bus	the timing bus that connects PXI DAQ devices directly, by means of connectors built into the backplane of the PXI chassis, for precise synchronization of functions. This bus is functionally equivalent to the RTSI bus for PCI DAQ devices.

## R

referenced single-ended configuration	RSE—all measurements are made with respect to a common reference measurement system or ground; also called a grounded measurement system
relative accuracy	a measure in LSB of the accuracy of an ADC. It includes all nonlinearity and quantization errors. It does not include offset and gain errors of the circuitry feeding the ADC.
resolution	the smallest signal increment that can be detected by a measurement system. Resolution can be expressed in bits, in proportions, or in percent of full scale. For example, a system has 16-bit resolution, one part in 65,536 resolution, and 0.0015% 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	<i>See</i> referenced single-ended configuration.
RTSI bus	real-time system integration bus—the NI timing bus that connects DAQ devices directly, for precise synchronization of functions
<b>S</b>	
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 SS/H, this counter counts the output of the scan clock and hence the number of scans.
scan	one or more analog or digital input samples. Typically, the number of input samples in a scan is equal to the number of channels in the input group. For example, one pulse from the scan clock produces one scan which acquires one new sample from every analog input channel in the group.
scan clock	the clock controlling the time interval between scans
scan interval	controls how often a scan is initialized. The scan interval is regulated by AI SAMP CLK.
scan rate	reciprocal of the scan interval
self-calibrating	a property of a DAQ device that has an extremely stable onboard reference and calibrates its own A/D and D/A circuits without manual adjustments by the user
settling time	the amount of time required for a voltage to reach its final value within specified limits
signal conditioning	the manipulation of signals to prepare them for digitizing
software trigger	a programmed event that triggers an event such as DAQ
SS/H	simultaneous sample-and-hold
STC	system timing controller

## 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
TRIG	trigger signal
trigger	any event that causes or starts some form of data capture
TTL	transistor-transistor logic—a digital circuit composed of bipolar transistors wired in a certain manner

## V

V	volts
$V_{CC}$	positive supply voltage
VDC	volts direct current
VI	virtual instrument—(1) a combination of hardware and/or software elements, typically used with a PC, that has the functionality of a classic stand-alone instrument; (2) a LabVIEW software module (VI), which consists of a front panel user interface and a block diagram program
$V_{IN}$	volts in
$V_m$	measured voltage
$V_{rms}$	volts, root mean square

## W

waveform	multiple voltage readings taken at a specific sampling rate
WFTRIG	waveform generation trigger signal

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