# Computer-Based Instruments

## NI 5911 User Manual

**High-Speed Digitizer with FLEX ADC™**

NATIONAL INSTRUMENTS™

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**Worldwide Technical Support and Product Information**

`ni.com`

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For further support information, see the *Technical Support Resources* appendix. To comment on the documentation, send e-mail to `techpubs@ni.com`.

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# Compliance

## FCC/Canada Radio Frequency Interference Compliance*

### Determining FCC Class

The Federal Communications Commission (FCC) has rules to protect wireless communications from interference. The FCC places digital electronics into two classes. These classes are known as Class A (for use in industrial-commercial locations only) or Class B (for use in residential or commercial locations). Depending on where it is operated, this product could be subject to restrictions in the FCC rules. (In Canada, the Department of Communications (DOC), of Industry Canada, regulates wireless interference in much the same way.)

Digital electronics emit weak signals during normal operation that can affect radio, television, or other wireless products. By examining the product you purchased, you can determine the FCC Class and therefore which of the two FCC/DOC Warnings apply in the following sections. (Some products may not be labeled at all for FCC; if so, the reader should then assume these are Class A devices.)

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

FCC Class B products display either a FCC ID code, starting with the letters **EXN**, or the FCC Class B compliance mark that appears as shown here on the right.

Trade Name Model Number
FC Tested to Comply with FCC Standards
FOR HOME OR OFFICE USE

Consult the FCC web site `http://www.fcc.gov` for more information.

### FCC/DOC Warnings

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

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

### Class A

#### Federal Communications Commission

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

#### Canadian Department of Communications

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

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

### Class B

#### Federal Communications Commission

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

### Canadian Department of Communications

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

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

## Compliance to EU Directives

Readers in the European Union (EU) must refer to the Manufacturer's Declaration of Conformity (DoC) for information** pertaining to the CE Mark compliance scheme. The Manufacturer includes a DoC for most every hardware product except for those bought for OEMs, if also available from an original manufacturer that also markets in the EU, or where compliance is not required as for electrically benign apparatus or cables.

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

* Certain exemptions may apply in the USA, see FCC Rules §15.103 **Exempted devices**, and §15.105(c). Also available in sections of CFR 47.

** The CE Mark Declaration of Conformity will contain important supplementary information and instructions for the user or installer.

# Conventions

The following conventions are used in this manual:

» — 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.

**bold** — Bold text denotes items that you must select or click on in the software, such as menu items and dialog box options. Bold text also denotes parameter names.

*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. Text in this font is also used for proper names of functions or variables.

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# 1 Taking Measurements with the NI 5911

Thank you for buying a National Instruments (NI) 5911 digitizer, featuring the FLEX ADC. This chapter provides information on installing, connecting signals to, and acquiring data from your NI 5911.

## Installing the NI 5911

There are two main steps involved in installation:

1. Install the NI-SCOPE driver software. You use this driver to write programs to control your NI 5911 in different application development environments (ADEs). Installing NI-SCOPE also allows you to interactively control your NI 5911 with the Scope Soft Front Panel.
2. Install your NI 5911. For step-by-step instructions for installing NI-SCOPE and the NI 5911, see *Where to Start with Your NI Digitizer.*

For multiple-board considerations, see the *Operating Environment* section in Appendix A, *Specifications,* of this manual.

## Connecting Signals

Figure 1-1 shows the front panel for the NI 5911. The front panel contains three connectors—a BNC connector, an SMB connector, and a 9-pin mini circular DIN connector (see Figure 1-2).

The BNC connector is for attaching the analog input signal you wish to measure. The BNC connector is analog input channel 0. To minimize noise, do not allow the shell of the BNC cable to touch or lie near the metal of the computer chassis. The SMB connector is for external triggers and for generating a probe compensation signal. The SMB connector is PFI1. The DIN connector gives you access to an additional external trigger line. The DIN connector can be used to access PFI2.

**Note** The +5 V signal is fused at 1.1 A. However, NI recommends limiting the current from this pin to 30 mA. The fuse is self-resetting.

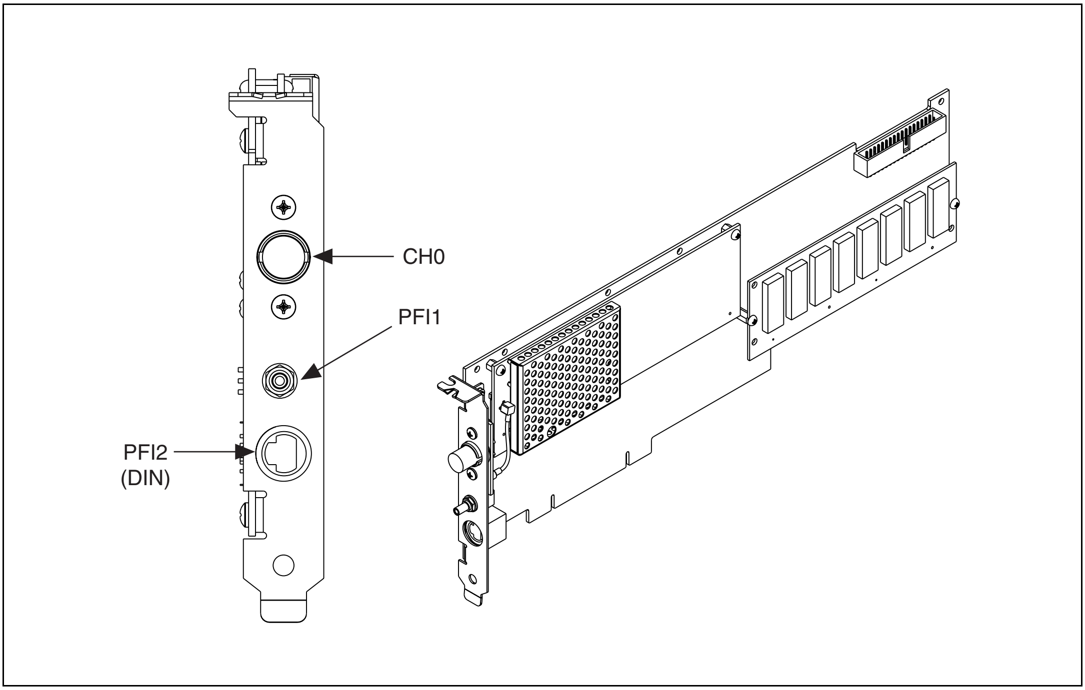
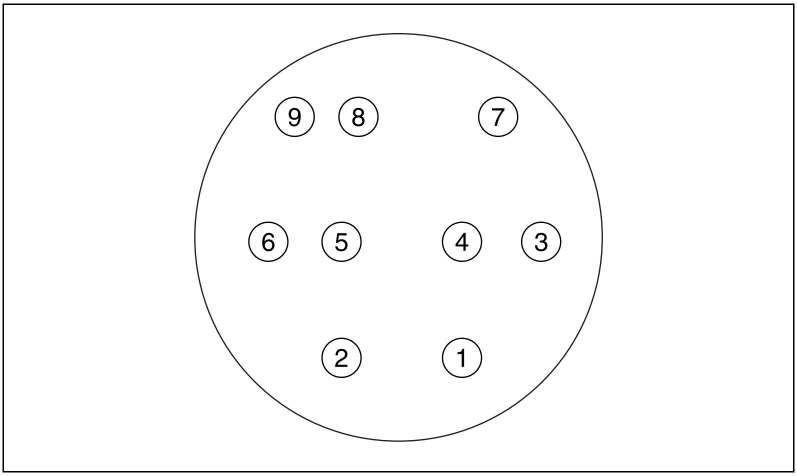



**Figure 1-1.** NI 5911 Connectors




| | | | | | |
|---|---|---|---|---|---|
| 1 | +5 Volts (Fused) | 4 | Reserved | 7 | Reserved |
| 2 | GND | 5 | Reserved | 8 | Reserved |
| 3 | Reserved | 6 | PFI 2 | 9 | Reserved |

**Figure 1-2.** 9-Pin Mini Circular DIN Connector

# Acquiring Data with Your NI 5911

You can acquire data either programmatically—by writing an application for your NI 5911—or interactively with the Scope Soft Front Panel.

## Programmatically Controlling Your NI 5911

To help you get started programming your NI 5911, NI-SCOPE comes with examples that you can use or modify.

You can find examples for these different ADEs:

- LabVIEW—Go to `Program Files\National Instruments\LabVIEW\Examples\Instr\niScopeExamples\`
- LabWindows/CVI, C, and Visual Basic with Windows 98/95—Go to `vxipnp\win95\Niscope\Examples\c\`
- LabWindows/CVI, C, and Visual Basic with Windows 2000/NT—Go to `vxipnp\winnt\Niscope\Examples\`

For information about using NI-SCOPE to programmatically control your digitizer, refer to your *NI-SCOPE Software User Manual*. Other resources include the *NI-SCOPE Instrument Driver Quick Reference Guide*. It contains abbreviated information on the most commonly used functions and LabVIEW VIs. For more detailed function reference help, see the *NI-SCOPE Function Reference Help* file, located at **Start»Programs» National Instruments»NI-SCOPE**. For more detailed VI help, use LabVIEW context-sensitive help (**Help»Show Context Help**) or the *NI-SCOPE VI Reference Help*, located at **Start»Programs»National Instruments»NI-SCOPE.**

## Interactively Controlling Your NI 5911 with the Scope Soft Front Panel

The Scope Soft Front Panel allows you to interactively control your NI 5911 as you would a desktop oscilloscope. To launch the Scope Soft Front Panel select **Start»Programs»National Instruments»NI-SCOPE» NI-SCOPE Soft Front Panel**. Refer to the *Scope Soft Front Panel Help* file for instructions on configuring the Scope Soft Front Panel for your specific application.

**Note** Press F1 with the Scope Soft Front Panel running to access the *Scope Soft Front Panel Help*.

# 2

# Hardware Overview

This chapter includes an overview of the NI 5911, explains the operation of each functional unit making up your NI 5911, and describes the signal connections. Figure 2-1 shows a block diagram of the NI 5911.

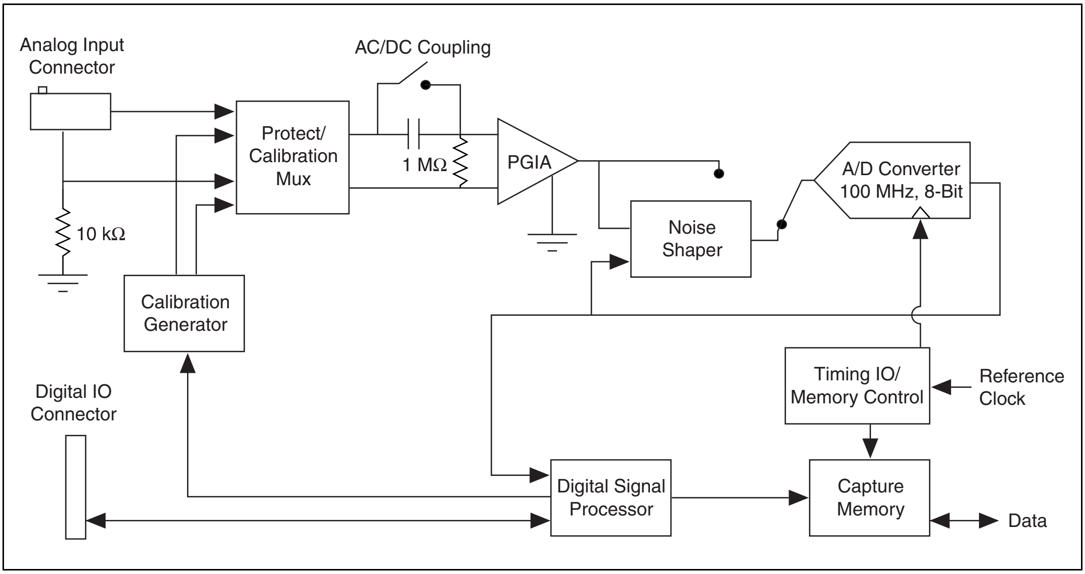



**Figure 2-1.** NI 5911 Block Diagram

## Differential Programmable Gain Input Amplifier (PGIA)

The analog input of the NI 5911 is equipped with a differential programmable gain input amplifier. The PGIA accurately interfaces to and scales the signal presented to the analog-to-digital converter (ADC) regardless of source impedance, source amplitude, DC biasing, or common-mode noise voltages.

## Differential Input

When measuring high dynamic range signals, ground noise is often a problem. The PGIA of the NI 5911 allows you to make noise-free signal measurements. The PGIA differential amplifier efficiently rejects any noise present on the ground signal. Internal to the PGIA, the signal presented at the negative input is subtracted from the signal presented at the positive input. As shown in Figure 2-2, this subtraction removes ground noise from the signal. The inner conductor of the BNC is V+; the outer shell is V−.

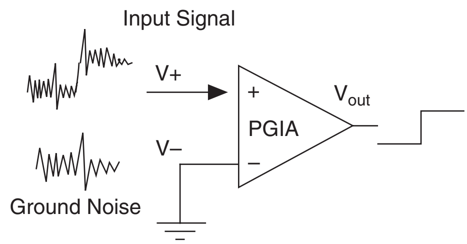



**Figure 2-2.** Noise-Free Measurements of Signal

## Grounding Considerations

The path for the positive signal has been optimized for speed and linearity. You should always apply signals to the positive input and ground to the negative input. Reversing the inputs will result in higher distortion and lower bandwidth.

The negative input of the amplifier is grounded to PC ground through a 10 kΩ resistor. The PGIA is therefore referenced to ground, so it is not necessary to make any external ground connections. If the device you connect to the NI 5911 is already connected to ground, ground-loop noise voltages may be induced into your system. Notice that in most of these situations, the 10 kΩ resistance to PC ground is normally much higher than the cable impedances you use. As a result, most of the noise voltage occurs at the negative input of the PGIA where it is rejected, rather than in the positive input, where it would be amplified.

## Input Ranges

To optimize the ADC resolution, you can select different gains for the PGIA. In this way, you can scale your input signal to match the full input range of the converter. The NI 5911 PGIA offers seven different input ranges, from ±0.1 V to ±10 V, as shown in Table 2-1.

**Table 2-1.** Input Ranges for the NI 5911

| Range | Input Protection Threshold |
|---|---|
| ±10 V | ±10 V |
| ±5 V | ±5 V |
| ±2 V | ±5 V |
| ±1 V | ±5 V |
| ±0.5 V | ±5 V |
| ±0.2 V | ±5 V |
| ±0.1 V | ±5 V |

**Note** If you try to acquire a signal below the set input range the sensitive front-end components of the NI 5911 may become unstable and begin returning invalid data. To return the digitizer to a stable configuration, switch to the maximum input range setting and acquire an AC-coupled or 0 V signal.

## Input Impedance

The input impedance of the NI 5911 PGIA is 1 MΩ between the positive and negative input, ±2% depending on input capacitance. The output impedance of the device connected to the NI 5911 and the input impedance of the NI 5911 form an impedance divider, which attenuates the input signal according to the following formula:

$$V_m = \frac{V_s R_{in}}{R_s + R_{in}}$$

where $V_m$ is the measured voltage, $V_s$ is the source voltage, $R_s$ is the external source impedance, and $R_{in}$ is the input impedance.

If the device you are measuring has a very large output impedance, your measurements will be affected by this impedance divider. For example, if the device has 1 MΩ output impedance, your measured signal will be one-half the actual signal value.

### Input Bias

The inputs of the PGIA typically draw an input bias current of 1 nA at 25 °C. Attaching a device with a very high source impedance can cause an offset voltage to be added to the signal you measure, according to the formula $R_s \times 1\ nA$, where $R_s$ is the external source impedance. For example, if the device you have attached to the NI 5911 has an output impedance of 10 kΩ, typically the offset voltage is 10 µV (10 kΩ ×1 nA).

## Input Protection

The NI 5911 features input-protection circuits that protect both the positive and negative analog input from damage from AC and DC signals up to ±42 V.

If the voltage at one of these inputs exceeds a threshold voltage, $V_{tr}$, the input clamps to $V_{tr}$ and a resistance of 100 kΩ is inserted in the path to minimize input currents to a nonharmful level.

The protection voltage, $V_{tr}$, is input range dependent, as shown in Table 2-1.

## AC Coupling

When you need to measure a small AC signal on top of a large DC component, you can use AC coupling. AC coupling rejects any DC component in your signal before it enters into the PGIA. Activating AC coupling inserts a capacitor in series with the input impedance. Input coupling can be selected via software. See the *Digitizer Basics* appendix in your *NI-SCOPE Software User Manual* for more information on input coupling.

# Oscilloscope and Flexible Resolution Modes

In oscilloscope mode, the NI 5911 works as a conventional desktop oscilloscope, acquiring data at 100 MS/s with a vertical resolution of 8 bits. This mode is useful for displaying waveforms and for deriving waveform parameters such as slew rate, rise time, and settling time.

Flexible resolution differs from oscilloscope mode in two ways: it has higher resolution (sampling rate dependent), and the signal bandwidth is limited to provide antialiasing protection. This mode is useful for spectral analysis, distortion analysis, and other measurements for which high resolution is crucial.

## Oscilloscope Mode

The ADC converts at a constant rate of 100 MS/s, but you can choose to store only a fraction of these samples into memory at a lower rate. This allows you to store waveforms using fewer data points and decreases the burden of storing, analyzing, and displaying the waveforms. If you need faster sampling rates, you can use Random Interleaved Sampling (RIS) to effectively increase the sampling rate to 1 GS/s for repetitive waveforms.

In oscilloscope mode, all signals up to 100 MHz are passed to the ADC. You need to ensure that your signal is band-limited to prevent aliasing. Aliasing and other sampling terms are described more thoroughly in your *NI-SCOPE Software User Manual*.

## Sampling Methods—Real-Time and RIS

There are two sampling methods available in oscilloscope mode, *real-time* and *random interleaved sampling* (RIS). Using real-time sampling, you can acquire data at a rate of $100/n$ MS/s, where $n$ is a number from 1 to $2^{32}$. RIS sampling can be used on repetitive signals to effectively extend the sampling rate above 100 MS/s. In RIS mode, you can sample at rates of 100 MS/s $\times n$, where $n$ is a number from 2 to 10.

## Flexible Resolution Mode

Table 2-2 shows the relationship between the available sampling rates, resolution, and the corresponding bandwidth for flexible resolution mode.

**Table 2-2.** Available Sampling Rates and Corresponding Bandwidth in Flexible Resolution Mode

| Sampling Rate | Resolution | Bandwidth |
|---|---|---|
| 12.5 MS/s | 11 Bits | 3.75 MHz |
| 5 MS/s | 14 Bits | 2 MHz |
| 2.5 MS/s | 15.5 Bits | 1 MHz |
| 1 MS/s | 17.5 Bits | 400 kHz |
| 500 kS/s | 18 Bits | 200 kHz |
| 200 kS/s | 18.5 Bits | 80 kHz |
| 100 kS/s | 19 Bits | 40 kHz |
| 50 kS/s | 19.5 Bits | 20 kHz |
| 20 kS/s | 20.5 Bits | 8 kHz |
| 10 kS/s | 21 Bits | 4 kHz |

Like any other type of converter that uses noise shaping to enhance resolution, the frequency response of the converter is only flat to its maximum useful bandwidth. The NI 5911 has a bandwidth of 4 MHz. Beyond this frequency, there is a span where the converter acts resonant and where a signal is amplified before being converted. These signals are attenuated in the subsequent digital filter to prevent aliasing. However, if the applied signal contains major signal components in this frequency range, such as harmonics or noise, the converter may overload and signal data will be invalid. In this case, you will receive an overload warning. You must then either select a higher input range or attenuate the signal.

## How Flexible Resolution Works

The ADC can be sourced through a noise shaping circuit that moves quantization noise on the output of the ADC from lower frequencies to higher frequencies. A digital lowpass filter applied to the data removes all but a fraction of the original shaped quantization noise. The signal is then resampled to a lower sampling frequency and a higher resolution. Flexible resolution provides antialiasing protection due to the digital lowpass filter.

# Calibration

The NI 5911 can be calibrated for very high accuracy and resolution due to an advanced calibration scheme. There are two different types of calibration: internal, or self, calibration and external calibration. A third option, internal restore, restores factory settings and should be used only in the event of a self-calibration failure.

*Internal calibration* is performed via a software command that compensates for drifts caused by environmental temperature changes. You can internally calibrate your NI 5911 without any external equipment connected. *External calibration* recalibrates the device when the specified calibration interval has expired. See Appendix A, *Specifications*, for the calibration interval. External calibration requires you to connect an external precision voltage reference to the device.

## Internally Calibrating the NI 5911

Internally calibrate your NI 5911 with a software function or a LabVIEW VI. See Chapter 3, *Common Functions and Examples*, of your *NI-SCOPE Software User Manual* for step-by-step instructions for calibrating your digitizer.

## When Internal Calibration Is Needed

To provide the maximum accuracy independent of temperature changes, the NI 5911 contains a heater that stabilizes the temperature of the most sensitive circuitries on the board. However, the heater can accommodate for temperature changes over a fixed range of ±5 °C. When temperatures exceed this range, the heater no longer is able to stabilize the temperature, and signal data becomes inaccurate. When the temperature range has been exceeded, you receive a warning, and you need to perform an internal calibration.

## What Internal Calibration Does

Internal calibration performs the following operations:

- The heater is set to regulate over a range of temperatures centered at the current environmental temperature. The circuit components require a certain amount of time to stabilize at the new temperature. This temperature stabilization accounts for the majority of the calibration time.
- Gain and offset are calibrated for each individual input range.

- The linearity of the ADC is calibrated using an internal sinewave generator as reference.
- The time-to-digital converter used for RIS measurements is calibrated.

**Caution** Do *not* apply high-amplitude or high-frequency signals to the NI 5911 during internal calibration. For optimal calibration performance, disconnect the input signal from the NI 5911.

### Why Errors Occur During Acquisition

The NI 5911 uses a heater circuit to maintain constant temperature on the critical circuitry used in flexible resolution mode. If this circuit is unable to maintain the temperature within specification, an error is generated. This error indicates that the temperature of the ADC is out of range and should be recalibrated by performing an internal calibration. During acquisition in flexible resolution mode, an error will be generated if the input to the ADC goes out of range for the converter. The fact that this condition has occurred may not be obvious from inspecting the data due to the digital filtering that takes place on the acquired data. Therefore, an error occurs to let you know that the data includes some samples that were out of the range of the converter and may be inaccurate.

## External Calibration

External calibration calibrates the internal reference on the NI 5911. The NI 5911 is already calibrated when it is shipped from the factory. Periodically, the NI 5911 will need external calibration to remain within the specified accuracy. For more information on calibration, contact NI, or visit `ni.com/calibration`. For actual intervals and accuracy, refer to Appendix A, *Specifications*.

# Triggering and Arming

There are several triggering methods for the NI 5911. The trigger can be an analog level that is compared to the input or any of several digital inputs. You can also call a software function to trigger the board. Figure 2-3 shows the different trigger sources. When you use a digital signal, that signal must be at a high TTL level for at least 40 ns before any triggers will be accepted.

**Note** The NI 5911 does *not* support delayed triggering.

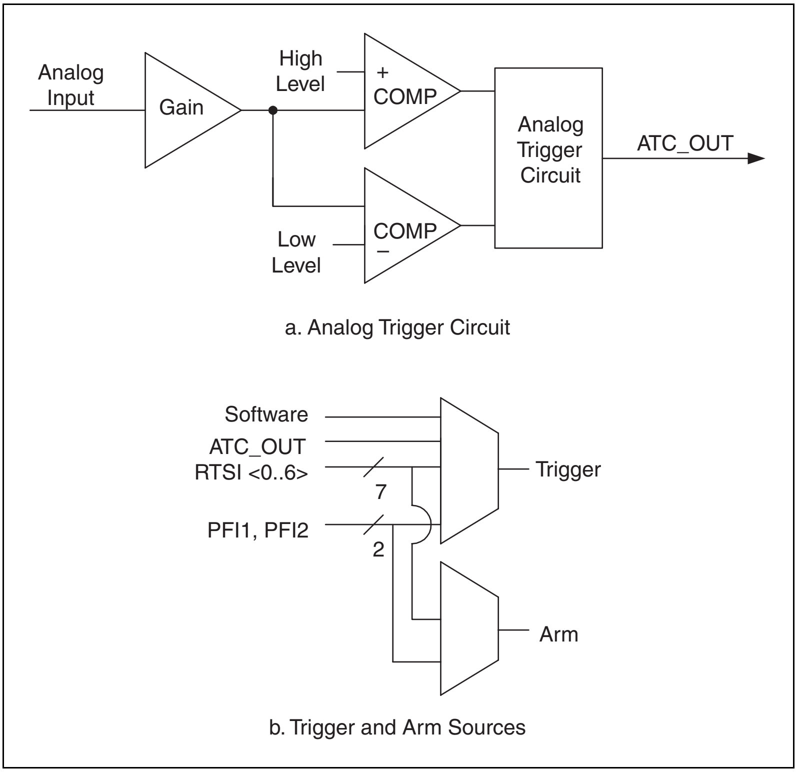



**Figure 2-3.** Trigger Sources

## Analog Trigger Circuit

The analog trigger on the NI 5911 operates by comparing the current analog input to an onboard threshold voltage. This threshold voltage is the trigger value, and can be set within the current input range in 170 steps. This means that for a ±10 V input range, the trigger can be set in increments of 20 V/170 = 118 mV. There may also be a hysteresis value associated with the trigger that can be set in the same size increments. The hysteresis value creates a trigger window the signal must pass through before the trigger is accepted. You can generate triggers on a rising or falling edge condition. For a more complete discussion of triggering, see Chapter 3, *Common Functions and Examples*, of your *NI-SCOPE Software User Manual*.

## Trigger Hold-Off

Trigger hold-off is the minimum length of time (in seconds) from an accepted trigger to the start of the next record. In other words, when a trigger is accepted, the trigger counter is loaded with the desired hold-off time. After completing its current record, the digitizer records no data and accepts no triggers until the hold-off counter runs out. When the counter runs out, the next record begins and a trigger may be accepted. Setting a hold-off time shorter than posttrigger acquisition time has no effect, as triggers are always rejected during an acquisition.

**Note** Time to acquire posttrigger samples is (*posttrigger samples*)/(*sample rate* (*megahertz*)).

Trigger hold-off is provided in hardware using a 32-bit counter clocked by a 25 MHz internal timebase. With this configuration, you can select a hardware hold-off value of 40 ns to 171.8 s in increments of 40 ns. For more information regarding trigger hold-off, see the *Common Trigger Parameters* section in Chapter 3, *Common Functions and Examples*, of your *NI-SCOPE Software User Manual*.

# Memory

The NI 5911 allocates at least 4 kB of onboard memory for every acquisition. Samples are stored in this buffer before transfer to the host computer. Thus the minimum size for a buffer in the onboard memory is approximately 4,000 8-bit oscilloscope mode samples or 1,000 32-bit flexible resolution mode samples. Software allows you to specify buffers of less than these minimum sizes. However, the minimum number of points are still acquired into onboard memory, but only the specified number of points are transferred into the memory of the host computer.

The total number of samples that can be stored depends on the size of the acquisition memory module installed on the NI 5911 and the size of each acquired sample.

## Triggering and Memory Usage

During the acquisition, samples are stored in a circular buffer that is continually rewritten until a trigger is received. After the trigger is received, the NI 5911 continues to acquire posttrigger samples if you have specified a posttrigger sample count. The acquired samples are placed into onboard memory. The number of posttrigger or pretrigger samples is only limited by the amount of onboard memory.

# Multiple-Record Acquisitions

After the trigger has been received and the posttrigger samples have been stored, the NI 5911 can be configured to begin another acquisition that is stored in another onboard memory record. This is a multiple-record acquisition. To perform multiple-record acquisitions, configure the NI 5911 to the number of records you want to acquire before starting the acquisition. The NI 5911 acquires an additional record each time a trigger is accepted until all the requested records are stored in memory. You may acquire up to 1024 records if your NI 5911 is equipped with 4 MB of onboard memory, or 4096 records with 16 MB. Software intervention after the initial setup is not required.

Multiple-record acquisitions can quickly acquire numerous triggered waveforms because they allow hardware rearming of the digitizer before the data is fetched. Therefore the *dead time*, or the time when the digitizer is not ready for a trigger, is extremely small.

For more information on multiple-record acquisitions and dead time, see the *Making a Multiple-Record Acquisition* section in Chapter 5, *Tasks and Examples*, of your *NI-SCOPE Software User Manual.*

# RTSI Bus and Clock PFI

The RTSI bus allows NI digitizers to synchronize timing and triggering on multiple devices. The RTSI bus has seven bidirectional trigger lines and one bidirectional clock signal.

You can program any of the seven trigger lines to provide or accept a synchronous trigger signal. You can also use any of the RTSI trigger lines to provide a synchronization pulse from a master device if you are synchronizing multiple NI 5911s.

You can use the RTSI bus clock line to provide or accept a 10 MHz reference clock to synchronize multiple NI 5911 devices.

## PFI Lines

The NI 5911 has two digital lines that can accept a trigger, accept or generate a reference clock, or output a 1 kHz square wave. The function of each PFI line is independent. However, only one trigger source can be accepted during acquisition.

### PFI Lines as Inputs

You can select PFI1 or PFI2 as inputs for a trigger or a reference clock. Please see the *Synchronization* section below for more information about the use of reference clocks in the NI 5911.

### PFI Lines as Outputs

You can select PFI1 or PFI2 to output several digital signals.

Reference Clock is a 10 MHz clock that is synchronous to the 100 MHz sample clock on the NI 5911. You can use the reference clock to synchronize to another NI 5911 configured as a slave device or to other equipment that can accept a 10 MHz reference.

Frequency Output is a 1 kHz digital pulse train signal with a 50% duty cycle. The most common application of Frequency Output for the NI 5911 is to provide a signal for compensating a passive probe.

## Synchronization

The NI 5911 uses a digital phase locked loop to synchronize the 100 MHz sample clock to a 10 MHz reference. This reference frequency can be supplied by an internal crystal oscillator or through an external frequency input through the RTSI bus clock line or a PFI input.

The NI 5911 may also output its 10 MHz reference on the RTSI bus clock line or a PFI line so that other NI 5911s or other equipment can be synchronized to the same reference.

While the reference clock input is sufficient to synchronize the 100 MHz sample clocks, it is also necessary to synchronize clock dividers on each NI 5911 so that internal clock divisors are synchronized on each different device. These lower frequencies are important because they are used to determine trigger times and sample position.

To synchronize the NI 5911 clock dividers, you must connect the digitizers with an NI RTSI bus cable. One of the RTSI bus triggers must be designated as a synchronization line. This line will be an output from the master device and an input on the slave device. To synchronize the digitizers, a single pulse is sent from the master NI 5911 to the slaves. This pulse supplies the slave devices with a reference time to clear their clock dividers. Hardware arming cannot be used during an acquisition using multiple devices. For more information about synchronization, refer to your *NI-SCOPE Software User Manual*.

# A

# Specifications

This appendix lists the specifications of the NI 5911. These specifications are typical at 25 °C unless otherwise stated.

## Acquisition System

Bandwidth ............................................. 100 MHz maximum, see Table 2-2, *Available Sampling Rates and Corresponding Bandwidth in Flexible Resolution Mode*

Number of channels ............................... 1

Number of flexible resolution ADC....... 1

Max sample rate .................................... 1 GS/s repetitive, 100 MS/s single shot

Resolution

| Sample Rate | Mode | Effective Resolution |
|---|---|---|
| 100/*n** MS/s | Oscilloscope | 8 Bits |
| 12.5 MS/s | Flexible Resolution | 11 Bits |
| 5 MS/s | Flexible Resolution | 14 Bits |
| 2.5 MS/s | Flexible Resolution | 15.5 Bits |
| 1 MS/s | Flexible Resolution | 17.5 Bits |
| 500 kS/s | Flexible Resolution | 18 Bits |
| 200 kS/s | Flexible Resolution | 18.5 Bits |
| 100 kS/s | Flexible Resolution | 19 Bits |
| 50 kS/s | Flexible Resolution | 19.5 Bits |

| Sample Rate | Mode | Effective Resolution |
|---|---|---|
| 20 kS/s | Flexible Resolution | 20.5 Bits |
| 10 kS/s | Flexible Resolution | 21 Bits |
| * $1<n<2^{32}$ in oscilloscope mode | | |

Sample onboard memory........................4 MB or 16 MB

Memory sample depth

| Sampling Frequency | Mode | Sample Depth (4 MB) | Sample Depth (16 MB) |
|---|---|---|---|
| 100/*n** MS/s | Oscilloscope | 4 MS | 16 MS |
| 12.5 MS/s | Flexible Resolution | 1 MS | 4 MS |
| 5 MS/s | Flexible Resolution | 1 MS | 4 MS |
| 2.5 MS/s | Flexible Resolution | 1 MS | 4 MS |
| 1 MS/s | Flexible Resolution | 1 MS | 4 MS |
| 500 kS/s | Flexible Resolution | 1 MS | 4 MS |
| 200 kS/s | Flexible Resolution | 1 MS | 4 MS |
| 100 kS/s | Flexible Resolution | 1 MS | 4 MS |
| 50 kS/s | Flexible Resolution | 1 MS | 4 MS |
| 20 kS/s | Flexible Resolution | 1 MS | 4 MS |
| 10 kS/s | Flexible Resolution | 1 MS | 4 MS |
| * $1<n<2^{32}$ in oscilloscope mode | | | |

Vertical sensitivity (input ranges)

| Input Range | Noise Referred to Input |
|---|---|
| ±10 V | 174 dBfs/$\sqrt{\text{Hz}}$ |
| ±5 V | 168 dBfs/$\sqrt{\text{Hz}}$ |
| ±2 V | 160 dBfs/$\sqrt{\text{Hz}}$ |
| ±1 V | 154 dBfs/$\sqrt{\text{Hz}}$ |

| Input Range | Noise Referred to Input |
|---|---|
| ±0.5 V | 148 dBfs/ $\sqrt{\text{Hz}}$ |
| ±0.2 V | 140 dBfs/ $\sqrt{\text{Hz}}$ |
| ±0.1 V | 134 dBfs/ $\sqrt{\text{Hz}}$ |

# Acquisition Characteristics

## Accuracy

DC gain accuracy .................................. ±0.05% signal ±0.0001% fs for all input ranges at 1 MS/s in flexible resolution mode

DC offset accuracy ................................ ±0.1 mV ±0.01% fs for all input ranges at 1 MS/s in flexible resolution mode

Input coupling ....................................... DC and AC, software selectable

AC coupling cut-off frequency (–3 dB) .................................................. 2.3 Hz ±13%

Input impedance .................................... 1 MΩ ±2%

Max measurable input voltage ............... ±10 V (DC + peak AC)

Input protection ..................................... ±42 VDC (DC + peak AC)

Input bias current .................................. ±1 nA, typical at 25 °C

## Common-Mode Characteristics

Impedance to chassis ground ................. 10 kΩ

Common-mode rejection ratio ............... CMRR > –70 dB, ($F_{in}$ < 1 kHz)

## Filtering

| Sampling Frequency | Filter Mode | Bandwidth | Ripple | Alias Attenuation |
|---|---|---|---|---|
| 100/*n** MS/s | Oscilloscope | 100 MHz | ±3 dB | N/A |
| 12.5 MS/s | Flexible Resolution | 3.75 MHz | ±0.2 dB | –60 dB |
| 5 MS/s | Flexible Resolution | 2 MHz | ±0.1 dB | –70 dB |
| 2.5 MS/s | Flexible Resolution | 1 MHz | ±0.05 dB | –80 dB |
| 1 MS/s | Flexible Resolution | 400 kHz | ±0.005 dB | –80 dB |
| 500 kS/s | Flexible Resolution | 200 kHz | ±0.005 dB | –80 dB |
| 200 kS/s | Flexible Resolution | 80 kHz | ±0.005 dB | –80 dB |
| 100 kS/s | Flexible Resolution | 40 kHz | ±0.005 dB | –80 dB |
| 50 kS/s | Flexible Resolution | 20 kHz | ±0.005 dB | –80 dB |
| 20 kS/s | Flexible Resolution | 8 kHz | ±0.005 dB | –80 dB |
| 10 kS/s | Flexible Resolution | 4 kHz | ±0.005 dB | –80 dB |

* $1<n<2^{32}$ in oscilloscope mode

## Dynamic Range

Noise (excluding input-referred noise)

| Sampling Frequency | Bandwidth | Noise Density | Total Noise |
|---|---|---|---|
| 100/*n** MS/s | 100 MHz | –120 dBfs/$\sqrt{\text{Hz}}$ | –43 dBfs |
| 12.5 MS/s | 3.75 MHz | –135 dBfs/$\sqrt{\text{Hz}}$ | –64 dBfs |
| 5 MS/s | 2 MHz | –150 dBfs/$\sqrt{\text{Hz}}$ | –83 dBfs |
| 2.5 MS/s | 1 MHz | –155 dBfs/$\sqrt{\text{Hz}}$ | –91 dBfs |

| Sampling Frequency | Bandwidth | Noise Density | Total Noise |
|---|---|---|---|
| 1 MS/s | 400 kHz | –160 dBfs/ $\sqrt{Hz}$ | –104 dBfs |
| 500 kS/s | 200 kHz | –160 dBfs/ $\sqrt{Hz}$ | –107 dBfs |
| 200 kS/s | 80 kHz | –160 dBfs/ $\sqrt{Hz}$ | –111 dBfs |
| 100 kS/s | 40 kHz | –160 dBfs/ $\sqrt{Hz}$ | –114 dBfs |
| 50 kS/s | 20 kHz | –160 dBfs/ $\sqrt{Hz}$ | –117 dBfs |
| 20 kS/s | 8 kHz | –160 dBfs/ $\sqrt{Hz}$ | –121 dBfs |
| 10 kS/s | 4 kHz | –160 dBfs/ $\sqrt{Hz}$ | –124 dBfs |
| * $1<n<2^{32}$ in oscilloscope mode | | | |

## Distortion

| Sampling Frequency | SFDR for input 0 dBfs | SFDR for input –20 dBfs | SFDR for input –60 dBfs (typical) |
|---|---|---|---|
| 100 MS/s | 50 dB | 50 dB | N/A |
| 12.5 MS/s | 65 dB | 85 dB | 125 dB |
| 5 MS/s | 70 dB | 90 dB | 130 dB |
| 2.5 MS/s | 75 dB | 95 dB | 135 dB |
| 1 MS/s | 85 dB | 105 dB | 145 dB |
| 500 kS/s | 90 dB | 110 dB | 150 dB |
| 200 kS/s | 100 dB | 110 dB | 160 dB |
| 100 kS/s | 100 dB | 110 dB | 160 dB |
| 50 kS/s | 100 dB | 110 dB | 160 dB |
| 20 kS/s | 100 dB | 110 dB | 160 dB |
| 10 kS/s | 100 dB | 110 dB | 160 dB |

## Timebase System

Reference clock...................................... 10 MHz

Clock accuracy (as master) .................... 10 MHz ±50 ppm

| | |
|---|---|
| Clock input tolerance (as slave) | 10 MHz ±100 ppm |
| Clock jitter | <75 pSrms, independent of reference clock source |
| Clock compatibility | TTL for both input and output |
| Interpolator resolution (repetitive only) | 1 ns |
| Sampling clock frequencies | |
| Oscilloscope mode | 100 MHz/*n*, where $1<n<2^{32}$ |
| Flexible resolution mode | 100 MHz/*n*, where *n* = 8; 20; 50; 100; 200; 500; 1,000; 2,000; 5,000; 10,000 |
| Reference clock sources | PFI lines, RTSI clock, or onboard |
| Phase difference between multiple instruments | <5 ns, at any input frequency <100 MHz, from input connector to input connector |

## Triggering Systems

| | |
|---|---|
| Modes | Above threshold, below threshold, between thresholds, outside thresholds |
| Source | CH0, RTSI<0..6>, PFI 1,2 |
| Slope | Rising/falling |
| Hysteresis | Full-scale voltage/*n*, where *n* is between 1 and 170; full-scale voltage on TRIG is fixed to ±5 V (without external attenuation) |
| Coupling | AC/DC on CH0, TRIG |
| Pretrigger depth | 1 to 16 million samples |
| Posttrigger depth | 1 to 16 million samples |
| Holdoff time | 5 µs – 171.85 s in increments of 40 ns |

Sensitivity .............................................. 170 steps in full-scale voltage range

TRIG input range .................................. ±5 V (without external attenuation)

TRIG input impedance .......................... 1 MΩ ± 1% in parallel with 30 pF ± 15 pF

TRIG input protection ........................... ±42 V [(DC + peak AC) < 10 kHz, without external attenuation]

## Acquisition Modes

RIS ........................................................ 1 GS/s down to 200 MS/s effective sample rate, repetitive signals only. Data is interleaved in software.

RIS accuracy .......................................... <0.5 ns

Single-shot ............................................ 100 MS/s down to 10 kS/s sample rate for transient and repetitive signals

## Power Requirements

+5 VDC ................................................ 4 A

+12 VDC ............................................... 100 mA

–12 VDC ............................................... 100 mA

## Physical

Dimensions ............................................ 33.8 by 9.9 cm (13.3 by 3.9 in)

I/O connectors

- Analog input CH0 ........................... BNC female
- Digital triggers ................................ SMB female, 9-pin mini DIN

## Operating Environment

**Note** Multiple NI 5911s in the same computer may raise operating temperatures beyond specification and give rise to imprecise data. NI strongly recommends leaving an empty PCI slot between multiple NI 5911s or adding a fan.

Ambient temperature ..............................5 to 40 °C

Relative humidity ..................................10% to 90%, noncondensing

## Storage Environment

Ambient temperature ..............................–20 to 65 °C

## EMC Compliance

CE2001, FCC

## Calibration

Internal...................................................Internal calibration is done upon software command. The calibration involves gain, offset and linearity correction for all input ranges and input modes.

Interval.............................................1 week, or any time temperature changes beyond ±5 °C. Hardware detects temperature variations beyond calibration limits, which can also be queried by software.

External..................................................Internal reference requires recalibration

Interval.............................................1 year

Warm-up time........................................1 minute

B

# Technical Support Resources

## Web Support

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

## NI Developer Zone

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

## Customer Education

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

## System Integration

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

# Worldwide Support

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

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

# Glossary

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

## Symbols

| | |
|---|---|
| % | percent |
| + | positive of, or plus |
| – | negative of, or minus |
| / | per |
| ° | degree |
| ± | plus or minus |
| Ω | ohm |

## A

| | |
|---|---|
| A | amperes |
| A/D | analog to digital |
| AC | alternating current |

| | |
|---|---|
| AC coupled | the passing of a signal through a filter network that removes the DC component of the signal |
| ADC | analog-to-digital converter—an electronic device, often an integrated circuit, that converts an analog voltage to a digital number |
| ADC resolution | the resolution of the ADC, which is measured in bits. An ADC with16 bits has a higher resolution, and thus a higher degree of accuracy, than a 12-bit ADC. |
| alias | a false lower frequency component that appears in sampled data acquired at too low a sampling rate |
| amplification | a type of signal conditioning that improves accuracy in the resulting digitized signal and reduces noise |
| amplitude flatness | a measure of how close to constant the gain of a circuit remains over a range of frequencies |
| attenuate | to reduce in magnitude |

# B

| | |
|---|---|
| b | bit—one binary digit, either 0 or 1 |
| B | byte—eight related bits of data, an eight-bit binary number. Also used to denote the amount of memory required to store one byte of data. |
| bandwidth | the range of frequencies present in a signal, or the range of frequencies to which a measuring device can respond |
| buffer | temporary storage for acquired or generated data (software) |
| bus | the group of conductors that interconnect individual circuitry in a computer. Typically, a bus is the expansion vehicle to which I/O or other devices are connected. Examples of PC buses are the PCI and ISA bus. |

# C

| | |
|---|---|
| C | Celsius |
| channel | pin or wire lead to which you apply or from which you read the analog or digital signal |

| | |
|---|---|
| clock | hardware component that controls timing for reading from or writing to groups |
| CMRR | common-mode rejection ratio—a measure of an instrument's ability to reject interference from a common-mode signal, usually expressed in decibels (dB) |
| counter/timer | a circuit that counts external pulses or clock pulses (timing) |
| coupling | the manner in which a signal is connected from one location to another |

## D

| | |
|---|---|
| dB | decibel—the unit for expressing a logarithmic measure of the ratio of two signal levels: dB=20log10 V1/V2, for signals in volts |
| DC | direct current |
| default setting | a default parameter value recorded in the driver. In many cases, the default input of a control is a certain value (often 0) that means *use the current default setting*. |
| device | a plug-in data acquisition board, card, or pad. The NI 5911 is an example of a device. |
| differential input | an analog input consisting of two terminals, both of which are isolated from computer ground, whose difference is measured |
| double insulated | a device that contains the necessary insulating structures to provide electric shock protection without the requirement of a safety ground connection |
| drivers | software that controls a specific hardware instrument |

## E

| | |
|---|---|
| EEPROM | electrically erasable programmable read-only memory—ROM that can be erased with an electrical signal and reprogrammed |
| equivalent time sampling | any method used to sample signals in such a way that the apparent sampling rate is higher than the real sampling rate |
| event | the condition or state of an analog or digital signal |

## F

| | |
|---|---|
| filtering | a type of signal conditioning that allows you to filter unwanted signals from the signal you are trying to measure |
| fs | full-scale—total voltage in the input range. A ±10 V input range is 20 V fs |

## G

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

## H

| | |
|---|---|
| hardware | the physical components of a computer system, such as the circuit boards, plug-in boards, chassis, enclosures, peripherals, cables, and so on |
| harmonics | multiples of the fundamental frequency of a signal |
| Hz | hertz—per second, as in cycles per second or samples per second |

## I

| | |
|---|---|
| I/O | input/output—the transfer of data to/from a computer system involving communications channels, operator interface devices, and/or data acquisition and control interfaces |
| in. | inches |
| inductance | the relationship of induced voltage to current |
| input bias current | the current that flows into the inputs of a circuit |
| input impedance | the measured resistance and capacitance between the input terminals of a circuit |
| instrument driver | a set of high-level software functions that controls a specific plug-in DAQ board. Instrument drivers are available in several forms, ranging from a function callable language to a virtual instrument (VI) in LabVIEW. |
| interrupt | a computer signal indicating that the CPU should suspend its current task to service a designated activity |

| | |
|---|---|
| interrupt level | the relative priority at which a device can interrupt |
| ISA | industry standard architecture |

## 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 graphical programming ADE developed by National Instruments |
| LSB | least significant bit |

## M

| | |
|---|---|
| m | meters |
| MB | megabytes of memory |
| memory buffer | *see* buffer |
| MS | million samples |
| MSB | most significant bit |

## N

| | |
|---|---|
| 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. |
| Nyquist frequency | a frequency that is one-half the sampling rate. *See also* Nyquist Sampling Theorem. |
| Nyquist Sampling Theorem | the theorem states that if a continuous bandwidth-limited analog signal contains no frequency components higher than half the frequency at which it is sampled, then the original signal can be recovered without distortion. |

## O

| | |
|---|---|
| Ohm's Law | (R=V/I)—the relationship of voltage to current in a resistance |
| overrange | a segment of the input range of an instrument outside of the normal measuring range. Measurements can still be made, usually with a degradation in specifications. |
| oversampling | sampling at a rate greater than the Nyquist frequency |

## P

| | |
|---|---|
| passband | the frequency range that a filter passes without attenuation |
| PCI | Peripheral Component Interconnect—a high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA; it is achieving widespread acceptance as a standard for PCs and workstations and offers a theoretical maximum transfer rate of 132 Mbytes/s |
| peak value | the absolute maximum or minimum amplitude of a signal (AC + DC) |
| posttriggering | the technique to acquire a programmed number of samples after trigger conditions are met |

| | |
|---|---|
| pretriggering | the technique used on a device to keep a buffer filled with data, so that when the trigger conditions are met, the sample includes the data leading up to the trigger condition |
| PXI | PCI eXtensions for Instrumentation. PXI is an open specification that builds off the CompactPCI specification by adding instrumentation-specific features. |

## R

| | |
|---|---|
| R | resistor |
| RAM | random-access memory |
| real-time sampling | sampling that occurs immediately |
| random interleaved sampling | method of increasing the sample rate by repetitively sampling a repeated waveform |
| resolution | the smallest signal increment that can be detected by a measurement system. Resolution can be expressed in bits or in digits. The number of bits in a system is roughly equal to 3.3 times the number of digits. |
| rms | root mean square—a measure of signal amplitude; the square root of the average value of the square of the instantaneous signal amplitude |
| ROM | read-only memory |
| RTSI bus | real-time system integration bus—the National Instruments timing bus that connects devices directly, by means of connectors on top of the boards, for precise synchronization of functions |

## S

| | |
|---|---|
| s | seconds |
| S | samples |
| S/s | samples per second—used to express the rate at which an instrument samples an analog signal. 100 MS/s would equal 100 million samples each second. |

| | |
|---|---|
| sense | in four-wire resistance the sense measures the voltage across the resistor being excited by the excitation current |
| settling time | the amount of time required for a voltage to reach its final value within specified limits |
| source impedance | a parameter of signal sources that reflects current-driving ability of voltage sources (lower is better) and the voltage-driving ability of current sources (higher is better) |
| system noise | a measure of the amount of noise seen by an analog circuit or an ADC when the analog inputs are grounded |

## T

| | |
|---|---|
| temperature coefficient | the percentage that a measurement will vary according to temperature. *See also* thermal drift |
| thermal drift | measurements that change as the temperature varies |
| thermal EMFs | thermal electromotive forces—voltages generated at the junctions of dissimilar metals that are functions of temperature. Also called thermoelectric potentials. |
| thermoelectric potentials | *see* thermal EMFs |
| transfer rate | the rate, measured in bytes/s, at which data is moved from source to destination after software initialization and set up operations; the maximum rate at which the hardware can operate |
| trigger | any event that causes or starts some form of data capture |

## U

| | |
|---|---|
| undersampling | sampling at a rate lower than the Nyquist frequency—can cause aliasing |
| update rate | the number of output updates per second |

## V

| | |
|---|---|
| V | volts |
| VAC | volts alternating current |
| VDC | volts direct current |
| $V_{error}$ | voltage error |
| 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 |
| $V_{rms}$ | volts, root mean square value |

## W

| | |
|---|---|
| waveform shape | the shape the magnitude of a signal creates over time |
| working voltage | the highest voltage that should be applied to a product in normal use, normally well under the breakdown voltage for safety margin |

# Index

## G



## H



## I



## M



## N

## O



## P



## R



## S



## T



## V



## W