Computer-Based Instruments

NI 5911 User Manual

Digital Oscilloscope for PCI

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Worldwide Technical Support and Product Information

ni.com

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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.
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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Taking Measurements with the NI 5911

Thank you for buying a National Instruments 5911 digital oscilloscope with flexible resolution. 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). NI-SCOPE also allows you to interactively control your NI 5911 with VirtualBench-Scope.
2. Install your NI 5911. For step-by-step instructions for installing NI-SCOPE and the NI 5911, see the *Where to Start with Your National Instruments Oscilloscope/Digitizer.*

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.

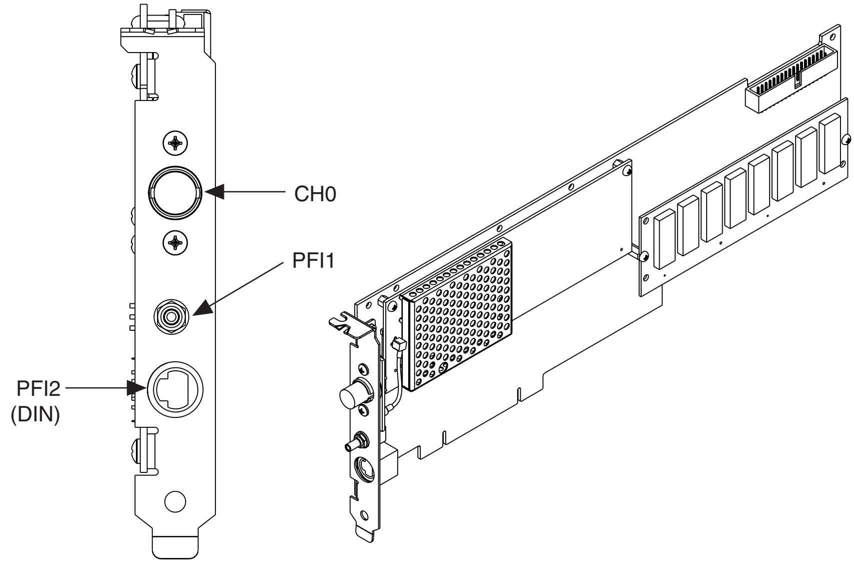
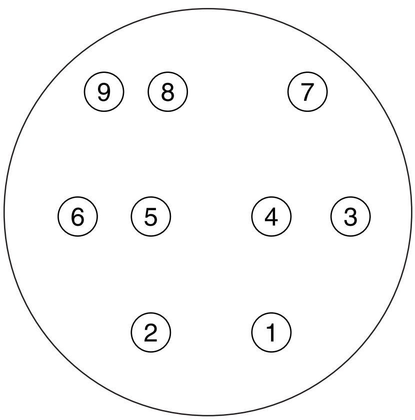


Figure 1-1. NI 5911 Connectors



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

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

Acquiring Data with Your NI 5911

You can acquire data either programmatically—by writing an application for your NI 5911—or interactively with the VirtualBench-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 LabVIEW examples by going to `Program Files\National Instruments\LabVIEW\Examples\Instr\niScopeExamples.llb`. Examples for CVI, C, and Visual Basic programmers using Windows 98/95 are located in `vxipnp\win95\Niscope\Examples`, and examples for CVI, C, and Visual Basic programmers using Windows 2000/NT are available at `vxipnp\winnt\Niscope\Examples`.

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 SCOPE**. For more detailed VI help, use LabVIEW context-sensitive help (**Help»Show Context Help**).

Interactively Controlling Your NI 5911 with VirtualBench-Scope

The VirtualBench-Scope soft front panel allows you to interactively control your NI 5911 as you would a desktop oscilloscope.

The following sections explain how to make connections to your NI 5911 and take simple measurements using the VirtualBench-Scope soft front panel, as shown in Figure 1-4. To launch the soft front panel, select **Start»Programs»National Instruments SCOPE»VirtualBench-Scope**.

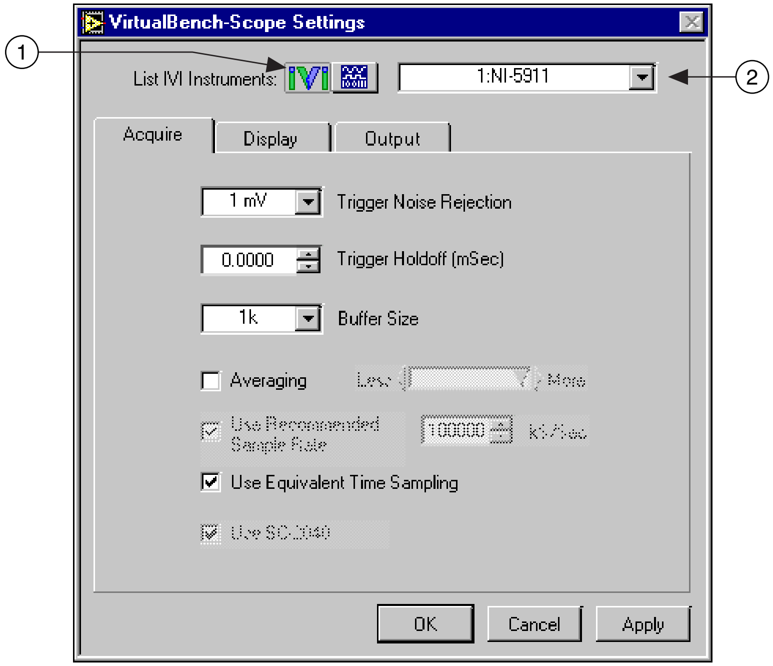
Using the VirtualBench-Scope Soft Front Panel

The following sections describe how to perform simple analog input measurements using the VirtualBench-Scope soft front panel.

Acquiring Data

When you launch VirtualBench-Scope, it operates in continuous run mode. To start acquiring signals with VirtualBench-Scope, complete the following steps:

1. Connect a signal to Channel 0 of your NI 5911.
2. Configure VirtualBench-Scope.
   a. From the **Edit** menu on the front panel, select **General Settings**.
   b. Select **NI 5911** from the instrument list as shown in Figure 1-3. If the NI 5911 is not in the device list, make sure you have properly configured the device using Measurement & Automation Explorer (MAX). For more information on how to configure your NI 5911 in MAX, refer to the *Where to Start with Your Oscilloscope/Digitizer* document that shipped with your NI 5911.
   c. Click **OK** to use these settings.



1 Device Type Selector	2 Device List

Figure 1-3. Acquire Tab of VirtualBench-Scope Settings Dialog Box

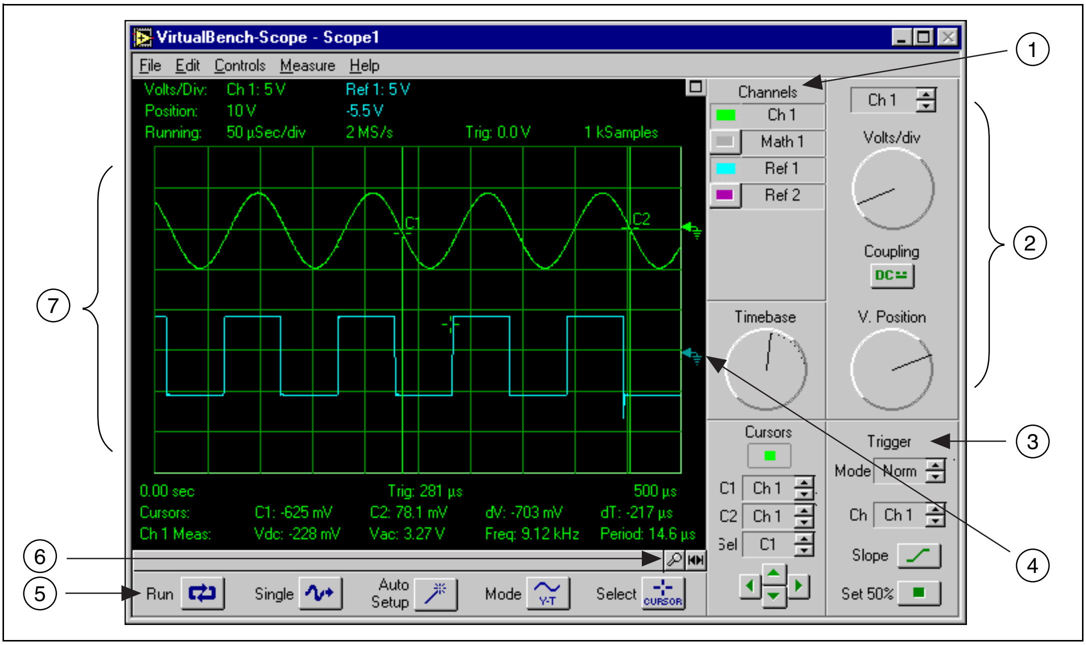
Note When you launch VirtualBench-Scope, it automatically uses the settings of your previous VirtualBench-Scope session.

3. Enable the **Ch 0** button in the channel selector area. Disable all other channels. Disabled channels have a gray frame around them.
4. Click **Auto Setup** on the main control bar.
5. Click **Run** to start the acquisition.

Note Refer to the *VirtualBench-Scope Online Help* for additional help configuring VirtualBench-Scope for your specific application.

Soft Front Panel Features

The following figure shows the VirtualBench-Scope soft front panel.



1	Channels Selector	4	Vertical Slider	6	Zoom Controls
2	Channel Settings Group	5	Main Control Bar	7	Graphics Display
3	Trigger Settings Group				

Figure 1-4. VirtualBench-Scope Soft Front Panel

The VirtualBench-Scope soft front panel has the following features:

- **Channels** selector—picks a channel or math functions that display waveforms.
- Channel settings group:
  - Channel settings selector selects the channel whose settings will be modified.
  - **Coupling** toggles between DC and AC coupling.
  - **Volts/div** adjusts the vertical resolution of the channel you select.
  - **V. Position** controls the displayed voltage offset.
- **Timebase** controls the length of the time period that is displayed. Turn the knob clockwise to reduce the time period. Each horizontal division represents one time period.
- **Vertical Slider** adjusts the voltage offset for each channel. Use this slider to adjust multiple waveforms.
- **Trigger** settings group controls the conditions required for signal acquisition. For example, you can command VirtualBench-Scope to wait for a digital trigger or command it to acquire data without triggering (in free-run mode).
- Main control bar buttons:
  - **Run** acquires data continuously. Deselecting this button places the VirtualBench-Scope in idle mode.
  - **Single** instructs VirtualBench-Scope to perform a single-sweep acquisition.
  - **Auto Setup** configures the scope for the best timebase, volts per division, and trigger setting for each channel currently selected with the channel selector.
  - **Mode** sets the mode of the scope to either volts versus time or X versus Y mode.
  - **Select Cursor** activates two cursors on the waveform display.
- The zoom controls adjust the view of your display data. Click the magnifying glass icon to zoom in on the displayed data. Click the arrows to the right of the magnifying glass to zoom out to full scale.

Note Refer to the *VirtualBench-Scope Online Help* for additional help on the front panel items.

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.

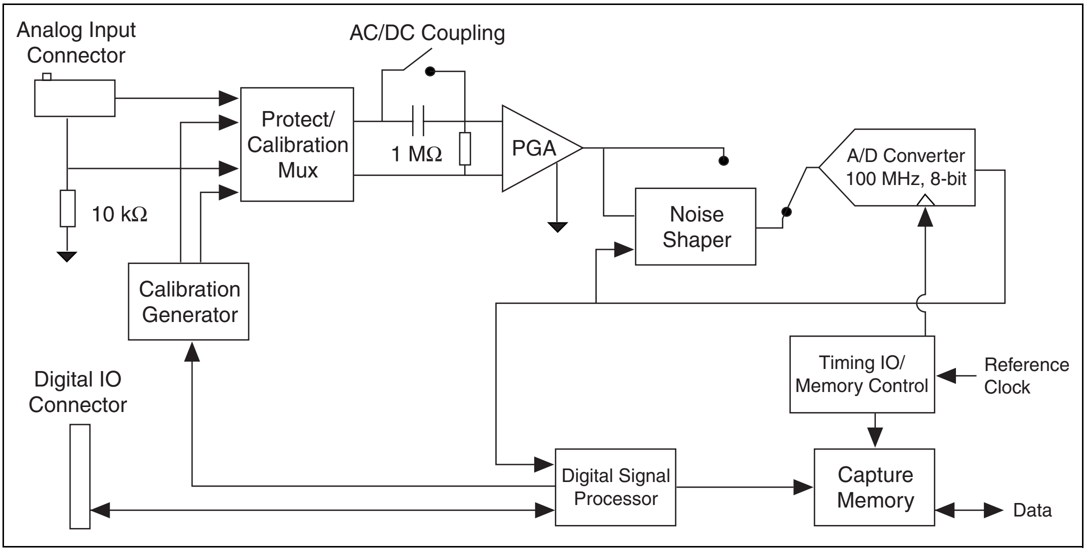


Figure 2-1. NI 5911 Block Diagram

Differential Programmable Gain Input Amplifier (PGIA)

The NI 5911 has a differential programmable gain input amplifier (PGIA) at the analog input. The purpose of the PGIA is to accurately interface to and scale 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 NI 5911 PGIA is a differential amplifier. The PGIA differential amplifier efficiently rejects any noise which may be 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–.

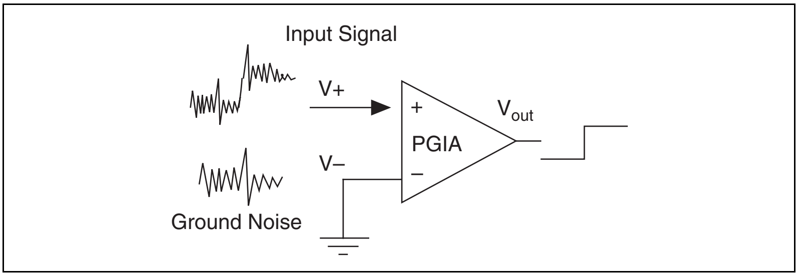


Figure 2-2. Noise-Free Measurements of Signal

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

Input Impedance

The input impedance of the NI 5911 PGIA is 1 MΩ between the positive and negative input. 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, 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 Appendix B, *Digitizer Basics*, 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 Appendix B, *Digitizer Basics*.

Sampling Methods—Real Time and RIS

There are two sampling methods available in oscilloscope mode, *Real Time* and RIS. Using real time sampling, you can acquire data at a rate of 100 MS/*n* where *n* is a number from 1 to 4.3 million. 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 * *n,* where *n* is a number from 2 to 10. The available sampling rates, resolutions, and bandwidth for flexible resolution mode are shown in Table 2-2.

Flexible Resolution Mode

Table 2-2 shows the relationship between the available sampling rates 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	12 bits	4 MHz
5 MS/s	14 bits	2 MHz
2.5 MS/s	16 bits	800 kHz
1 MS/s	18 bits	400 kHz
500 kS/s	18 bits	200 kHz
200 kS/s	19 bits	80 kHz
100 kS/s	19 bits	40 kHz
50 kS/s	20 bits	20 kHz

Table 2-2. Available Sampling Rates and Corresponding Bandwidth in Flexible Resolution Mode (Continued)

Sampling Rate	Resolution	Bandwidth
20 kS/s	20 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 a warning signaling overload. You then need to 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. *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. Read more about the function, `niScope_CalSelfCalibrate`, in your *NI-SCOPE Function Reference Help* file. LabVIEW users, see the context sensitive help (**Help»Show Context Help**) for `niscope Cal Self Calibrate.vi`.

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:

1. 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.
2. Gain and offset are calibrated for each individual input range.
3. The linearity of the ADC is calibrated using an internal sinewave generator as reference.
4. The time-to-digital converter used for RIS measurements is calibrated.

Note 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 has circuitry to detect error conditions that may affect the acquired data. 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 by inspecting the acquired 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 National Instruments, 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.

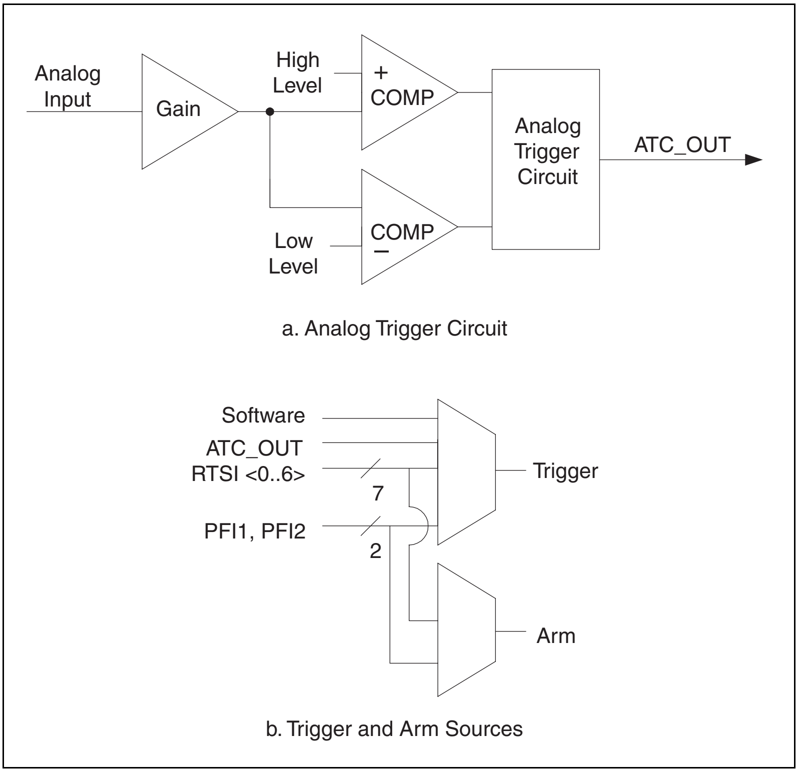


Figure 2-3. Trigger Sources

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, the trigger value, 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 as illustrated in the following figures. The four different modes of operation for the analog trigger are shown in Figures 2-4 to 2-7.

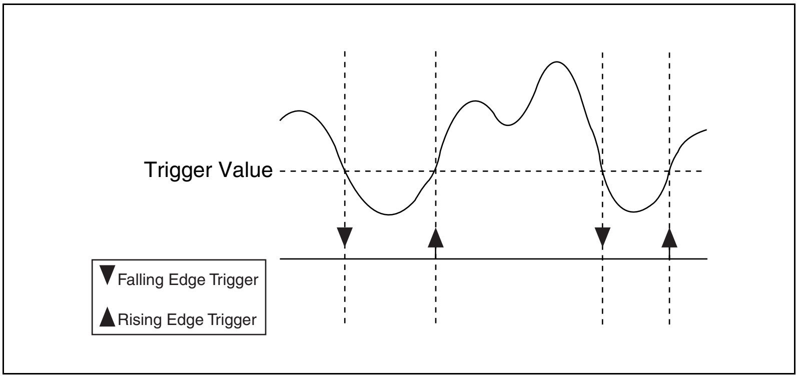


Figure 2-4. Below-Level Analog Triggering Mode

In below-level analog triggering mode, the trigger is generated when the signal value is less than the trigger value.

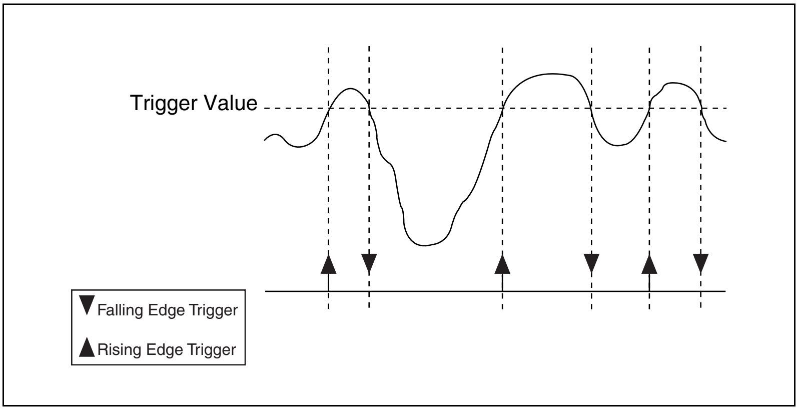


Figure 2-5. Above-Level Analog Triggering Mode

In above-level analog triggering mode, the trigger is generated when the signal value is greater than trigger value.

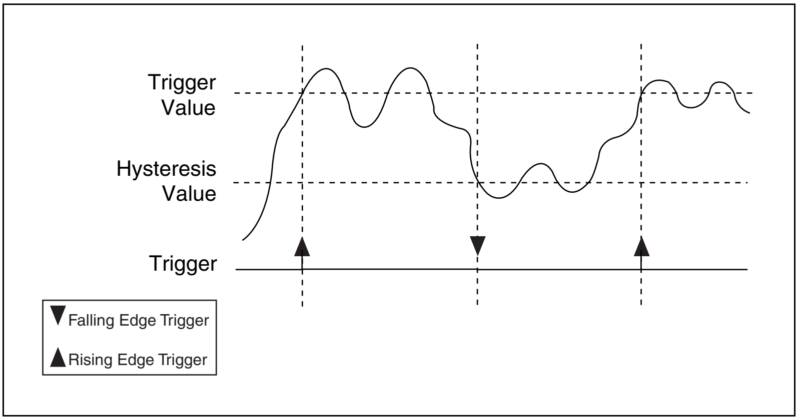


Figure 2-6. High-Hysteresis Analog Triggering Mode

In high-hysteresis analog triggering mode, the trigger is generated when a signal crosses above the hysteresis value and then crosses above the trigger value. The signal must cross back below the hysteresis value before another trigger is generated.

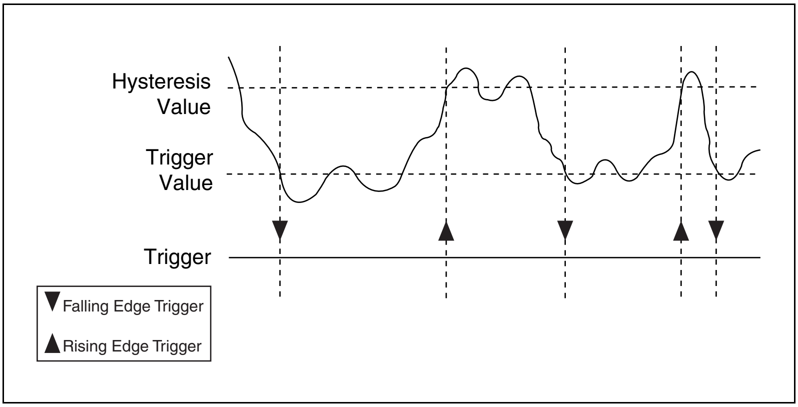


Figure 2-7. Low-Hysteresis Analog Triggering Mode

In low-hysteresis analog triggering mode, the trigger is generated when the signal crosses below the hysteresis value and then crosses the trigger value. The signal must cross back above the hysteresis value before another trigger is generated.

Trigger Hold-Off

The trigger hold-off is a length of time that the NI 5911 waits after a trigger is accepted before it accepts another trigger. In other words, when a trigger is received during acquisition, the trigger counter is loaded with the desired hold-off time. Hardware then rejects all triggers until the counter has expired or the current acquisition completes, whichever is longer.

Note The time the acquisition takes to complete from the time a trigger occurs is (*posttrigger samples*)/(*sample rate* (*megahertz*)). If this time is larger than the trigger hold-off time, the trigger hold-off has no effect because triggers are always rejected during acquisition.

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. Figure 2-8 shows a timing diagram of signals when hold-off is enabled and the hold-off time is longer than posttriggered acquisition.

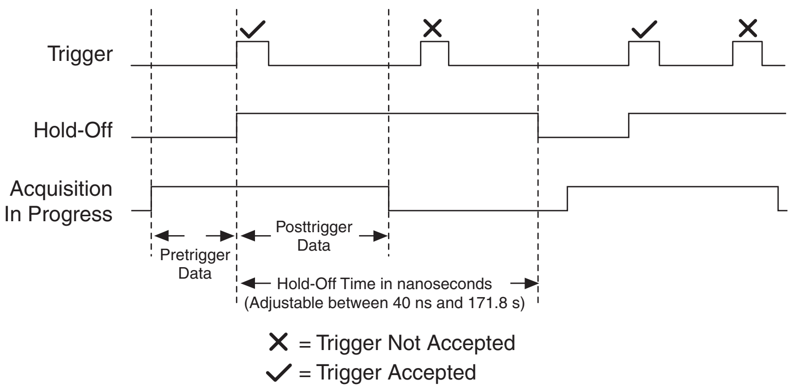


Figure 2-8. Timing with Hold-Off Enabled

Memory

The NI 5911 stores samples in onboard memory before transferring the samples to the host computer. The minimum size for a buffer in the onboard memory is approximately 4,000 8-bit oscilloscope mode samples or 1,000 32-bit decimation 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 retrieved into the host computer's memory.

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 memory record on the board. 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. This process does not require software intervention after the initial setup has been completed.

Between each record, there is a *dead time* of approximately 5 µs during which the trigger is not accepted. During this time, the memory controller is setting up for the next record. There may also be additional dead time while the minimum number of pretrigger samples are being acquired. Figure 2-9 shows a timing diagram of a multiple record acquisition.

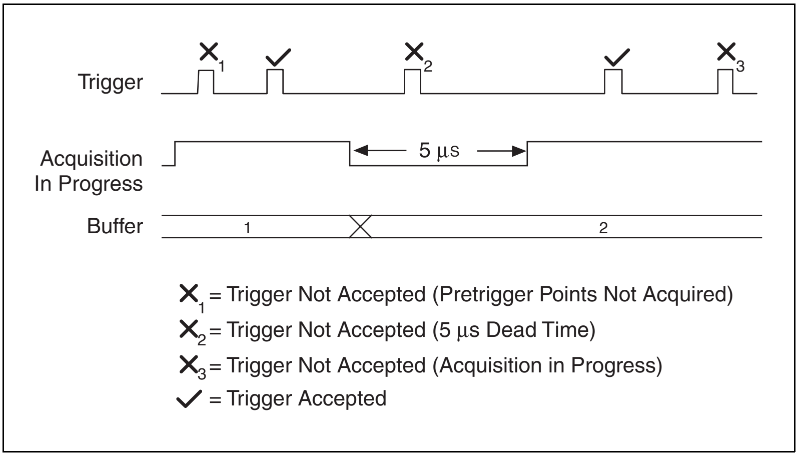


Figure 2-9. Multiple Buffer Acquisition

RTSI Bus Trigger and Clock Lines

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

You can program any of the seven trigger lines 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 board if you are synchronizing multiple NI 5911 boards.

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

PFI Lines

The NI 5911 has two digital lines that can accept a trigger, accept or generate a reference clock, or output a square wave of programmable frequency. 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 section, *Synchronization*, 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 a crystal oscillator on the board 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 5911 boards 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 also synchronized on the different boards. 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 boards with a National Instruments 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 board and an input on the slave boards. To synchronize the boards, a single pulse is sent from the master to the slaves, which gives them a reference time to clear the clock dividers on the boards. Hardware arming cannot be used during a multiple board acquisition.

A

Specifications

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

Acquisition System

Bandwidth .... 100 MHz maximum, at all input ranges

Number of channels .... 1 for PCI, 2 for VXI

Number of flexible resolution ADC....... 1 for PCI, 2 for VXI

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

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

Memory sample depth

Sampling Frequency	**Mode**	**Sample Depth (4 MB)**	**Sample Depth (16 MB)**
100 MHz/*n**	Oscilloscope	4 MS	16 MS
12.5 MHz	Flexible Resolution	1 MS	4 MS
5 MHz	Flexible Resolution	1 MS	4 MS
2.5 MHz	Flexible Resolution	1 MS	4 MS
1 MHz	Flexible Resolution	1 MS	4 MS
500 kHz	Flexible Resolution	1 MS	4 MS
200 kHz	Flexible Resolution	1 MS	4 MS
100 kHz	Flexible Resolution	1 MS	4 MS
50 kHz	Flexible Resolution	1 MS	4 MS

Sampling Frequency	Mode	Sample Depth (4 MB)	Sample Depth (16 MB)
20 kHz	Flexible Resolution	1 MS	4 MS
10 kHz	Flexible Resolution	1 MS	4 MS
* $1<n<2^{32}$ in oscilloscope mode			

Memory record sizes ....2,000 samples, to maximum sample depth determined by sample frequency

Vertical sensitivity (input ranges)

Input Range	Noise Referred to Input
±10 V	174 dBfs/ $\sqrt{Hz}$
±5 V	168 dBfs/ $\sqrt{Hz}$
±2 V	160 dBfs/ $\sqrt{Hz}$
±1 V	154 dBfs/ $\sqrt{Hz}$
±0.5 V	148 dBfs/ $\sqrt{Hz}$
±0.2 V	140 dBfs/ $\sqrt{Hz}$
±0.1 V	134 dBfs/ $\sqrt{Hz}$

Acquisition Characteristics

Accuracy

Amplitude accuracy...............................±0.05% signal ±0.0001% fs (5 to 40 °C) for all input ranges at 1 kHz (excluding ripple from digital filters)

DC offset...0.1 mV + 0.01% fs (5 to 40 °C) for all input ranges

Input coupling..DC and AC, software selectable

AC coupling cut-off frequency
(–3 dB)...15 Hz ±2%

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 MHz/*n*	Oscilloscope	100 MHz	±3 dB	N/A
12.5 MHz	Flexible Resolution	3.75 MHz	±0.2 dB	–60 dB
5 MHz	Flexible Resolution	2 MHz	±0.1 dB	–70 dB
2.5 MHz	Flexible Resolution	1 MHz	±0.05 dB	–80 dB
1 MHz	Flexible Resolution	400 kHz	±0.005 dB	–80 dB
500 kHz	Flexible Resolution	200 kHz	±0.005 dB	–80 dB
200 kHz	Flexible Resolution	80 kHz	±0.005 dB	–80 dB
100 kHz	Flexible Resolution	40 kHz	±0.005 dB	–80 dB
50 kHz	Flexible Resolution	20 kHz	±0.005 dB	–80 dB
20 kHz	Flexible Resolution	8 kHz	±0.005 dB	–80 dB
10 kHz	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 MHz/n	100 MHz	–120 dBfs/$\sqrt{\text{Hz}}$	–43 dBfs
12.5 MHz	3.75 MHz	–135 dBfs/$\sqrt{\text{Hz}}$	–64 dBfs
5 MHz	2 MHz	–150 dBfs/$\sqrt{\text{Hz}}$	–83 dBfs
2.5 MHz	1 MHz	–155 dBfs/$\sqrt{\text{Hz}}$	–91 dBfs
1 MHz	400 kHz	–160 dBfs/$\sqrt{\text{Hz}}$	–104 dBfs
500 kHz	200 kHz	–160 dBfs/$\sqrt{\text{Hz}}$	–107 dBfs
200 kHz	80 kHz	–160 dBfs/$\sqrt{\text{Hz}}$	–111 dBfs
100 kHz	40 kHz	–160 dBfs/$\sqrt{\text{Hz}}$	–114 dBfs
50 kHz	20 kHz	–160 dBfs/$\sqrt{\text{Hz}}$	–117 dBfs
20 kHz	8 kHz	–160 dBfs/$\sqrt{\text{Hz}}$	–121 dBfs
10 kHz	4 kHz	–160 dBfs/$\sqrt{\text{Hz}}$	–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 MHz/n	50 dB	50 dB	N/A
12.5 MHz	65 dB	85 dB	125 dB
5 MHz	70 dB	90 dB	130 dB
2 MHz	75 dB	95 dB	135 dB
1 MHz	85 dB	105 dB	145 dB
500 kHz	90 dB	110 dB	150 dB
200 kHz	100 dB	110 dB	160 dB
100 kHz	100 dB	110 dB	160 dB
50 kHz	100 dB	110 dB	160 dB

Sampling Frequency	SFDR for input 0 dBfs	SFDR for input –20 dBfs	SFDR for input –60 dBfs (typical)
20 kHz	100 dB	110 dB	160 dB
10 kHz	100 dB	110 dB	160 dB

Timebase System

Number of timebases .... 2, RTSI clock configured as a 10 MHz clock output (Master), or RTSI clock configured as a 10 MHz reference clock input (Slave).

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, 1000, 2000, 5000, 10000

Synchronization .... Via RTSI trigger lines

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 by time	40 ns – 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

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

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

Storage Environment

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

EMC Compliance

CE97, 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

Digitizer Basics

This appendix explains basic information you need to understand about making measurements with digitizers, including important terminology.

Understanding Digitizers

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

Nyquist Theorem

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

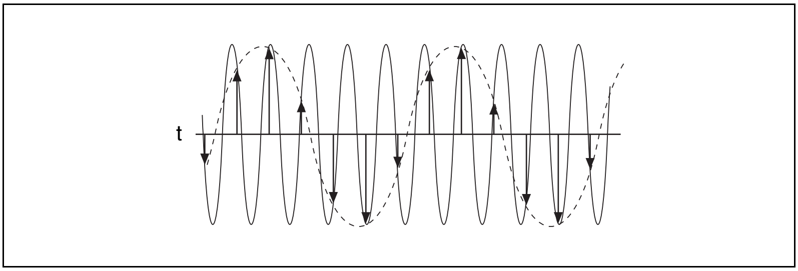


Figure B-1. Sine Wave Demonstrating the Nyquist Frequency

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

Analog Bandwidth

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

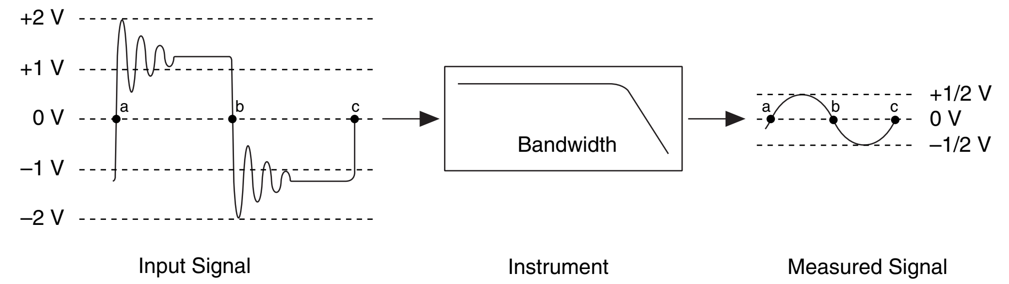


Figure B-2. Analog Bandwidth

Sample Rate

Sample rate is the rate at which a signal is sampled and digitized by an ADC. According to the Nyquist theorem, a higher sample rate produces accurate measurement of higher frequency signals if the analog bandwidth is wide enough to let the signal to pass through without attenuation. A higher sample rate also captures more waveform details. Figure B-3 illustrates a 1 MHz sine wave sampled by a 2 MS/s ADC and a 20 MS/s ADC. The faster ADC digitizes 20 points per cycle of the input signal compared with 2 points per cycle with the slower ADC. In this example, the higher sample rate more accurately captures the waveform shape as well as frequency.

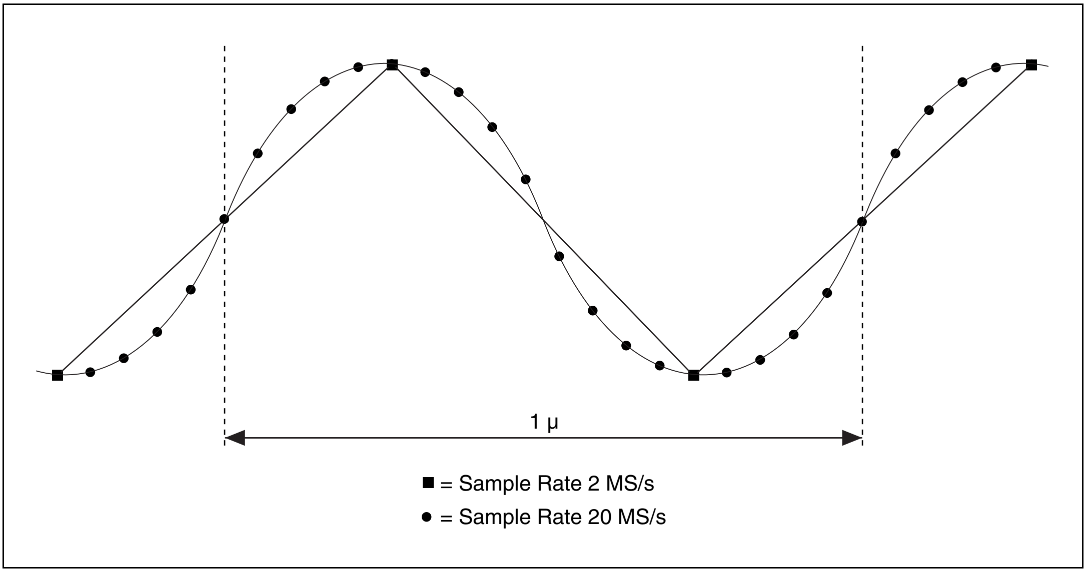


Figure B-3. 1 MHz Sine Wave Sample

Vertical Sensitivity

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

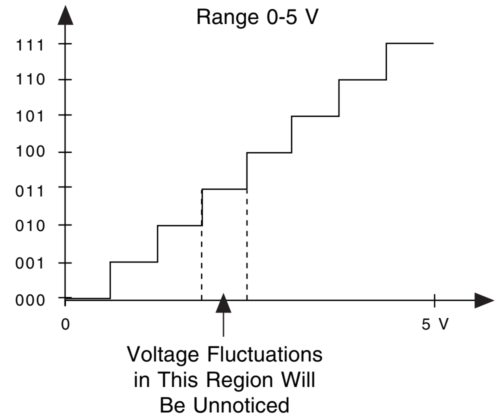


Figure B-4. Transfer Function of a 3-Bit ADC

ADC Resolution

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

Record Length

Record length refers to the amount of memory dedicated to storing digitized samples for postprocessing or display. In a digitizer, record length limits the maximum duration of a single-shot acquisition. For example, with a 1,000-sample buffer and a sample rate of 20 MHz, the duration of acquisition is 50 µs (the number of points multiplied by the acquisition time/point or 1,000 × 50 ns). With a 100,000-sample buffer and a sample rate of 20 MHz, the duration of acquisition is 5 ms (100,000 × 50 ns).

Triggering Options

One of the biggest challenges of making a measurement is to successfully trigger the signal acquisition at the point of interest. Since most high-speed digitizers actually record the signal for a fraction of the total time, they can easily miss a signal anomaly if the trigger point is set incorrectly. The NI 5911 is equipped with sophisticated triggering options, such as trigger thresholds, programmable hysteresis values, and trigger hold-off. The NI 5911 also has two digital triggers that give you more flexibility in triggering by allowing you to connect a TTL/CMOS digital signal to trigger the acquisition.

Random Interleaved Sampling

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

In RIS, the arrival of the waveform trigger point occurs at some time randomly distributed between two sampling instants. The time from the trigger to the next sampling instant is measured, and this measurement allows the waveform to be reconstructed. Figure B-5 shows three occurrences of a waveform. In Frame 1, the dotted points are sampled, and the trigger occurs time t_1 before the next sample. In Frame 2, the square points are sampled, and the trigger occurs time t_2 before the next sample. In Frame 3, the triangular points are sampled, and the trigger occurs time t_3 before the next sample. With knowledge of the three times, t_1, t_2, and t_3, you can reconstruct the waveform as if it had been sampled at a higher rate, as shown at the bottom of the figure.

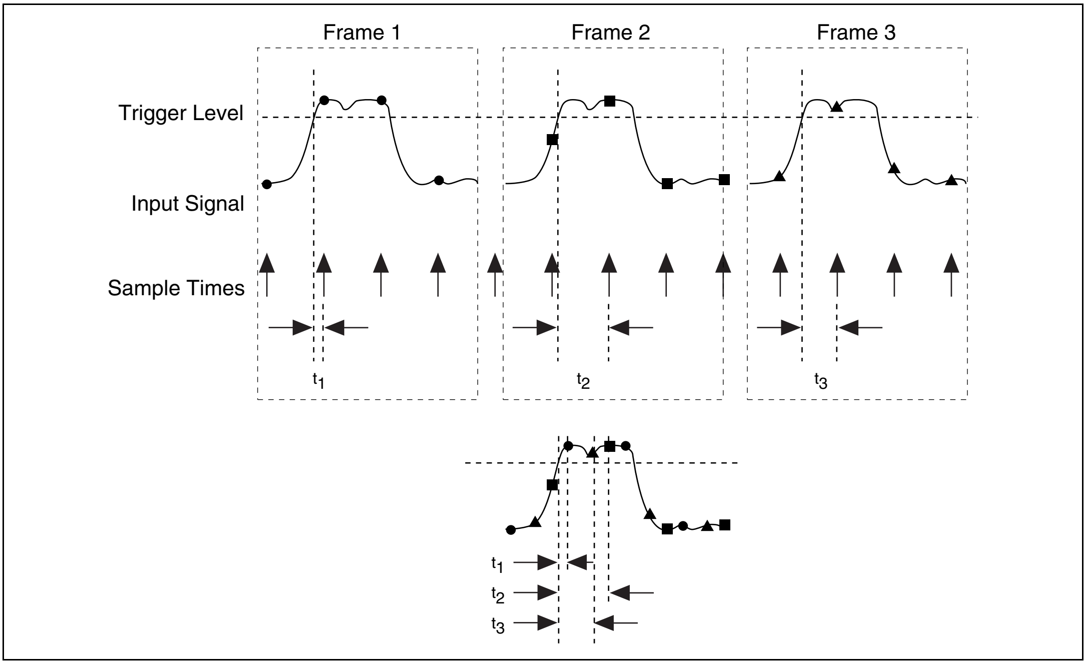


Figure B-5. Waveform Reconstruction with RIS

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

For example, consider the maximum interpolation factor to be 5. If the TDC could output values from 0 to 15, then each logical bin will contain three physical bins, as shown in Figure B-6.

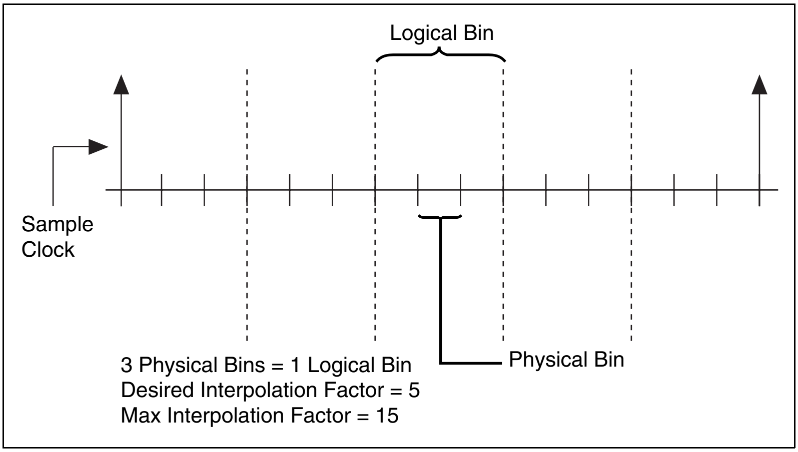


Figure B-6. Relationship between Interpolation Factor, Logical Bins, and Physical Bins

Making Accurate Measurements

For accurate measurements, you should use the right settings when acquiring data with your NI 5911. Knowing the characteristics of the signal in consideration helps you to choose the correct settings. Such characteristics include:

- Peak-to-peak value—This parameter, in units of volts, reflects the maximum change in signal voltage. If V is the signal voltage at any given time, then $V_{pk\text{-}to\text{-}pk} = V_{max} - V_{min}$. The peak-to-peak value affects the vertical sensitivity or gain of the input amplifier. If you do not know the peak-to-peak value, start with the smallest gain (maximum input range) and increase it until the waveform is digitized using the maximum dynamic range without clipping the signal. Refer to Appendix A, *Specifications*, for the maximum input voltage for your NI 5911 device. Figure B-7 shows that a gain of 5 is the best setting to digitize a 300 mV, 1 MHz sine wave without clipping the signal.

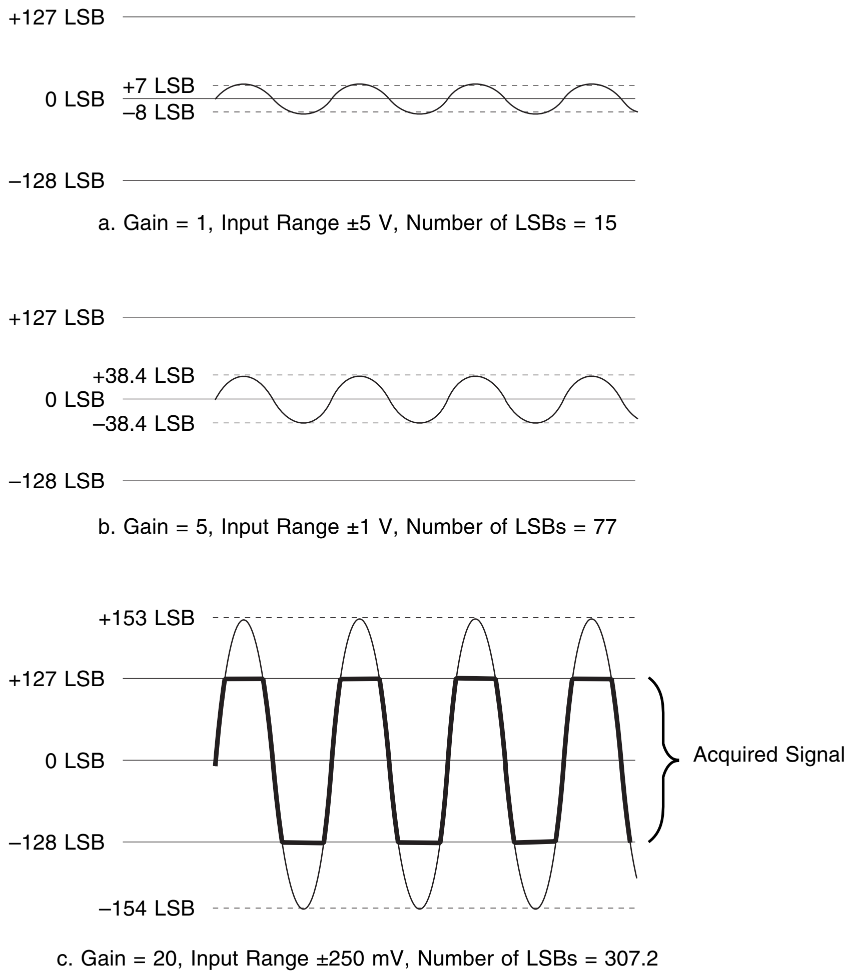


Figure B-7. Dynamic Range of an 8-Bit ADC with Three Different Gain Settings

- Source impedance—Most digitizers and digital storage oscilloscopes (DSOs) have a 1 MΩ input resistance in the passband. If the source impedance is large, the signal will be attenuated at the amplifier input and the measurement will be inaccurate. If the source impedance is unknown but suspected to be high, change the attenuation ratio on your probe and acquire data. In addition to the input resistance, all digitizers, DSOs, and probes present some input capacitance in parallel with the resistance. This capacitance can interfere with your measurement in much the same way as the resistance does.
- Input frequency—If your sample rate is less than twice the highest frequency component at the input, the frequency components above half your sample rate will alias in the passband at lower frequencies, indistinguishable from other frequencies in the passband. If the signal's highest frequency is unknown, you should start with the digitizer's maximum sample rate to prevent aliasing and reduce the digitizer's sample rate until the display shows either enough cycles of the waveform or the information you need.
- General signal shape—Some signals are easy to capture by ordinary triggering methods. A few iterations on the trigger level finally render a steady display. This method works for sinusoidal, triangular, square, and saw tooth waves. Some of the more elusive waveforms, such as irregular pulse trains, runt pulses, and transients, may be more difficult to capture. Figure B-8 shows an example of a difficult pulse-train trigger.

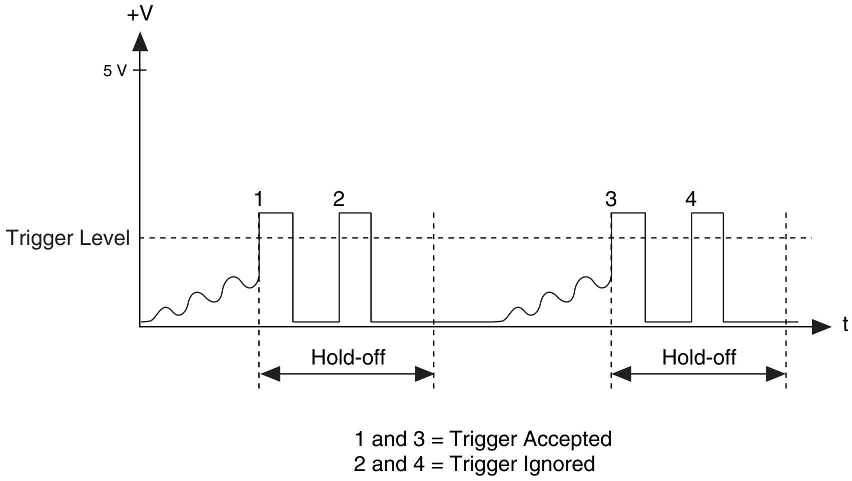


Figure B-8. Difficult Pulse Train Signal

Ideally, the trigger event should occur at condition one, but sometimes the instrument may trigger on condition two because the signal crosses the trigger level. You can solve this problem without using complicated signal processing techniques by using *trigger hold-off*, which lets you specify a time from the trigger event to ignore additional triggers that fall within that time. With an appropriate hold-off value, the waveform in Figure B-8 can be properly captured by discarding conditions two and four.

- Input coupling—You can configure the input channels on your NI 5911 to be DC coupled or AC coupled. DC coupling allows DC and low-frequency components of a signal to pass through without attenuation. In contrast, AC coupling removes DC offsets and attenuates low frequency components of a signal. This feature can be exploited to zoom in on AC signals with large DC offsets, such as switching noise on a 12 V power supply. Refer to Appendix A, *Specifications*, for input limits that must be observed regardless of coupling.

C

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

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* 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* 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

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