Computer-Based Instruments

NI 5112 User Manual

Digital Oscilloscope for PCI and PXI

NATIONAL INSTRUMENTS™

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Conventions

The following conventions are used in this manual:

<>	Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, DBIO<3..0>.
»	The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.
✎	This icon denotes a note, which alerts you to important information.
⚠	This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash.
⚡	This icon denotes a warning, which advises you of precautions to take to avoid being electrically shocked.
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. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames and extensions, and code excerpts.

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Taking Measurements with the NI 5112

Thank you for buying a National Instruments 5112 digital oscilloscope. The NI 5112 offers a complete solution for performing high-speed signal acquisition and analysis in a compact, affordable board. The NI 5112 provides the features of a standalone oscilloscope mated with the versatility of a data acquisition board.

The NI 5112 features include:

- Two 100 MHz analog input channels
- Two 8-bit 100 MS/s ADCs
- 16 MB on-board sample memory per channel
- ±50 V of DC offset
- Software-selectable AC/DC coupling
- Complete self-calibration support via software

Detailed specifications for the NI 5112 are in Appendix A, *Specifications.*

Connecting Signals

Figure 1-1 shows the front panel for the NI 5112, which contains five connectors—three BNC connectors, an SMB connector, and a 9-pin miniature circular DIN connector.

Two of the BNC connectors, CH0 and CH1, are for attaching the analog input signals you wish to measure. The third BNC connector, ATRIG, is for the analog trigger channel. The SMB connector, PFI1, is for external digital triggers and for generating a probe compensation signal. The DIN connector, AUX, gives you access to an additional external digital trigger line, PFI2.

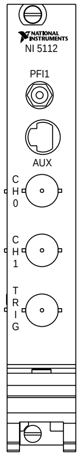


Figure 1-1. NI 5112 Connectors

Introduction to the VirtualBench-Scope Soft Front Panel

Use the VirtualBench-Scope soft front panel to interactively control your NI 5112 as you would a desktop oscilloscope.

The following sections explain how to make connections to your NI 5112 and take simple measurements using the VirtualBench-Scope soft front panel, as shown in Figure 1-3 later in this chapter. To launch the soft front panel, select **Start»Programs» National Instruments SCOPE» VirtualBench-Scope**.

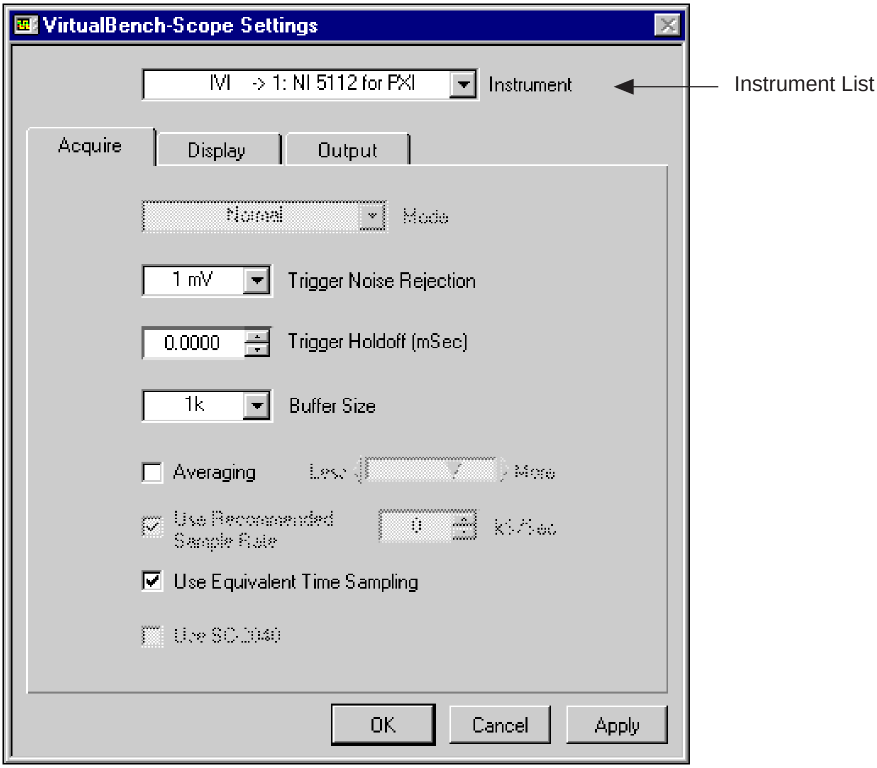
Using the VirtualBench-Scope Soft Front Panel

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 and/or Channel 1 of your NI 5112.
2. Configure VirtualBench-Scope.
    a. From the **Edit** menu on the front panel, select **General Settings**.
    b. Select **NI 5112** from the instrument list as shown in Figure 1-2. If NI 5112 is not in the device list, make sure you have properly configured the device using Measurement & Automation Explorer. For more information on how to configure your NI 5112 in Measurement & Automation Explorer, refer to the *Where to Start with Your NI 5112 Oscilloscope* documentation that shipped with your NI 5112.
    c. Click **OK** to use these settings.



Instrument: NI -> 1: NI 5112 for PXI

Mode: Normal

Trigger Noise Rejection: 1 mV

Trigger Holdoff (mSec): 0.0000

Buffer Size: 1k

☐ Averaging   Less … More

☑ Use Recommended Sample Rate   0 kS/Sec

☑ Use Equivalent Time Sampling

☐ Use SC-2040

Figure 1-2. Acquire Tab of VirtualBench-Scope Settings Dialog Box

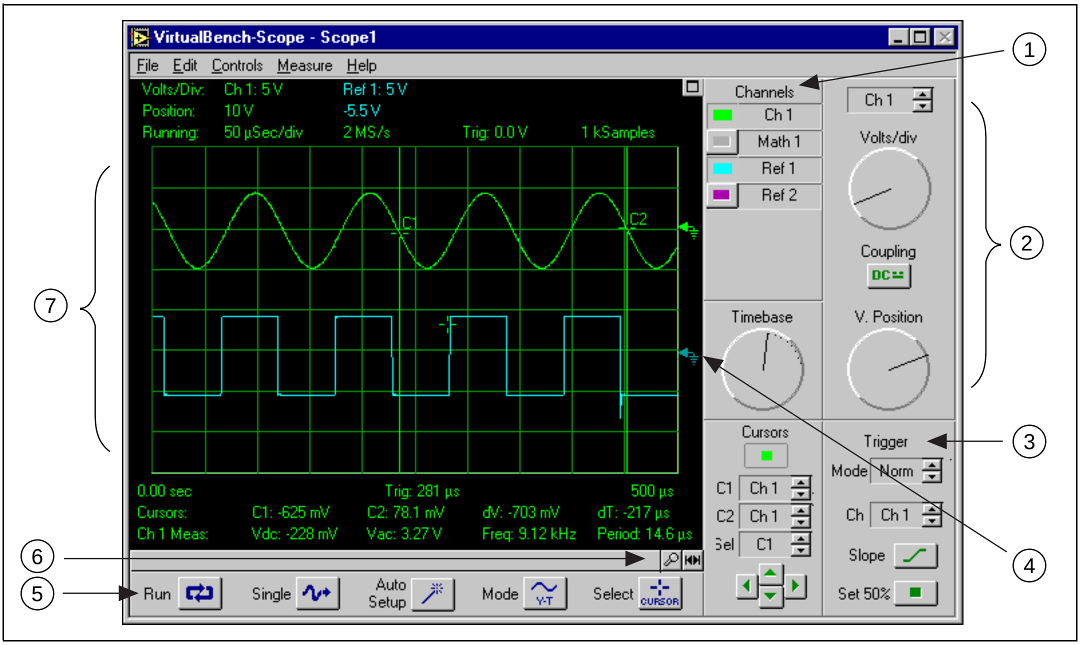
Note When you launch VirtualBench-Scope, it automatically uses the settings of your previous VirtualBench-Scope session.

3. Enable the **Ch 0** and/or **Ch 1** 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

Figure 1-3 shows the VirtualBench-Scope soft front panel.



Volts/Div: Ch 1: 5 V Ref 1: 5 V
Position: 10 V -5.5 V
Running: 50 µSec/div 2 MS/s Trig: 0.0 V 1 kSamples

0.00 sec Trig: 281 µs 500 µs
Cursors: C1: -625 mV C2: 78.1 mV dV: -703 mV dT: -217 µs
Ch 1 Meas: Vdc: -228 mV Vac: 3.27 V Freq: 9.12 kHz Period: 14.6 µs

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

Figure 1-3. VirtualBench-Scope Soft Front Panel

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

- Channel selector picks channels 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 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.
- 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.
- **Cursors** activates two cursors on the waveform display.

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

Safety Information

The following paragraphs contain important safety information concerning hazardous voltages and hazardous operating conditions. Please adhere to these safety instructions while configuring or connecting signals to the NI 5112.

Warnings *Shock Hazard*—This unit should only be installed by qualified personnel aware of the dangers involved. Disconnect all power before installing or removing the device. If signal wires are connected to the device, dangerous voltages may exist even when the equipment is turned off. Before you remove the device, disconnect the AC power line or any high-voltage sources, $\geq 30\ V_{rms}$ and $42.4\ V_{peak}$, or 60 VDC, that may be connected to the device.

Do not operate the device in an explosive atmosphere or where there may be flammable gases or fumes.

To ensure adequate grounding, the device must be properly installed in the chassis. National Instruments is *not* liable for any damages or injuries resulting from inadequate safety earth ground connections.

Warnings You *must* insulate all of your signal connections to the *highest* voltage with which the NI 5112 may come in contact.

Equipment described in this document must be used in an Installation Category II or lower environment per IEC-61010-1 and UL-3111-1.

Do not operate damaged equipment. The safety-protection features built into this device can be impaired if the device becomes damaged in any way. If it is damaged, turn the device off and do not use it until service-trained personnel can check its safety. If necessary, return the device to National Instruments for service and repair to ensure that its safety is not compromised.

Clean the device and accessories by brushing off light dust with a soft non-metallic brush. Remove other contaminants with a stiff non-metallic brush. The unit must be completely dry and free from contaminants before returning it to service.

The device must be used in a UL-listed chassis.

Do not substitute parts or modify equipment. Because of the danger posed by introducing additional hazards, do not install unauthorized parts or modify the device. Return the device to National Instruments for service and repair to ensure that its safety features are not compromised.

Connections, including power signals to ground and vice versa, that exceed any of the maximum signal ratings on the NI 5112 can damage any or all of the devices in the same chassis. National Instruments is *not liable for any damages or injuries* resulting from incorrect signal connections.

Use only National Instruments oscilloscope probes or probes bearing the CE mark.

2

Hardware Overview

This chapter includes an overview of the NI 5112, explains the operation of each functional unit making up your NI 5112, and describes the signal connections. Figure 2-1 shows a block diagram of the NI 5112.

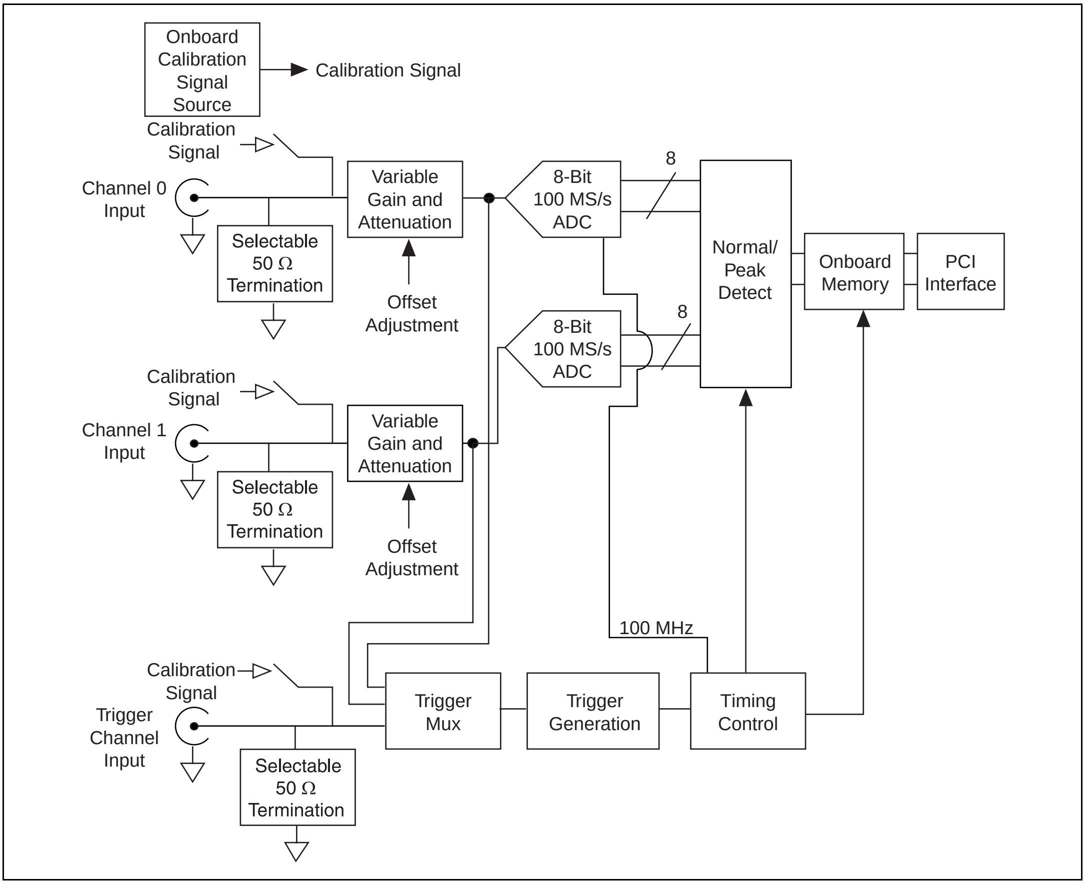


Figure 2-1. NI 5112 Block Diagram

Measurement Fundamentals

The NI 5112 has a programmable gain amplifier (PGA) at the analog input. The purpose of the PGA is to accurately interface to and scale the signal presented at the connector to the analog-to-digital converter (ADC) regardless of source impedance, source amplitude, or DC biasing.

Input Ranges

To optimize the ADC resolution, you can select different gains for the PGA. In this way, you can scale your input signal to match the full input range of the converter. The NI 5112 PGA offers a variable input range, from ±0.025 V inputs to ±25 V inputs. The input range is adjustable in 10% steps across the entire input range.

Input Impedance

The input impedance of the NI 5112 is software selectable between 1 MΩ and 50 Ω. The output impedance of the device connected to the NI 5112 and the input impedance of the NI 5112 form an impedance divider, which attenuates the input signal according to the following formula:

$$V_m = V_s \times \left(\frac{R_{in}}{R_{in} + R_s} \right)$$

where V_m is the measured voltage, V_s is the source voltage, R_s is the output impedance of the external device, 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, and you have selected the 1 MΩ input impedance of the NI 5112, your measured signal will be half the actual signal value.

When performing measurements on systems that are expected to be terminated with a 50 Ω load, you can select the 50 Ω input impedance of the NI 5112. With 50 Ω input impedance selected, the input voltage is limited to ±5 V. If the input exceeds 5 V, an overload-protection relay may open, and the board will revert to 1 MΩ impedance.

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 PGA. Activating AC coupling inserts a capacitor in series with the input. You can select input coupling via software. See Appendix B, *Digitizer Basics*, for more information on input coupling.

DC Offset

While AC coupling can center the waveform about its average DC value, DC offset can position the waveform about an arbitrary DC value. DC offset can apply up to 50 V of offset to the NI 5112 input stage. This ability allows you to examine small changes in the input signal without using all of your dynamic range to view the entire signal. Figure 2-2 shows how DC offset can improve resolution.

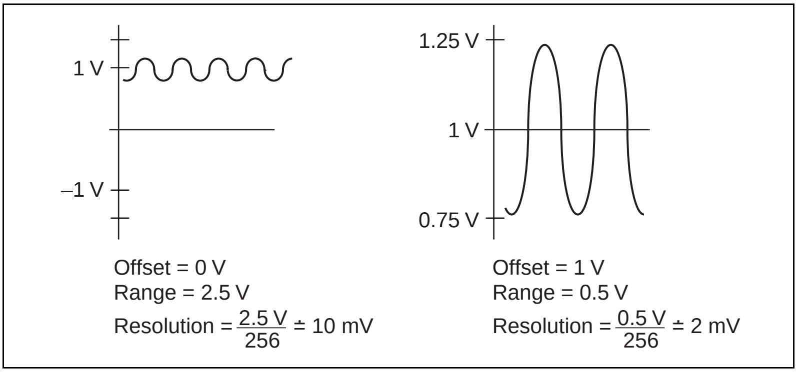


Figure 2-2. DC Offset

Table 2-1 lists the maximum DC offset for a given input voltage range.

Table 2-1. Maximum DC Offset

Vertical Range	Maximum Selectable Offset
50 mV–500 mV	±500 mV
500 mV–5 V	±5 V
5 V–50 V	±50 V

20 MHz Bandwidth Limit

The NI 5112 has a selectable 20 MHz bandwidth limit on the analog input channels. This limit enables a lowpass filter that can remove unwanted noise above 20 MHz from your measurement.

External Trigger

The NI 5112 external trigger is a front panel BNC input that allows you to connect an analog signal as a trigger without connecting the trigger to one of the input channels. This external trigger allows you to use the input channels and external trigger concurrently. The input range for the external trigger input is ±10 V. You can select either AC or DC coupling.

Acquisition System

The NI 5112 acquisition system controls the way samples are acquired and stored. Two sampling methods are available: *real-time sampling* and *random interleaved sampling* (RIS). Using real-time sampling, you can acquire data at a rate of 100 MS/*n*, where *n* is a number from 1 to 100e+6. RIS 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 25.

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 5112 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 limited only by the amount of onboard memory.

Acquisition Modes

Regardless of the user requested sample rate, the NI 5112 ADC is always running at 100 MS/s. The NI 5112 can acquire data in one of two modes: normal and peak-detect modes. Figure 2-3 shows these modes. In normal mode, the NI 5112 stores a stream of 8-bit samples into the onboard memory at the requested sample rate. If you request a rate less than 100 MS/s, the timing engine of the NI 5112 only stores 1 sample in a group of *n* samples, effectively reducing the sample rate to 100 MS/*n*.

The NI 5112 can operate in peak-detect mode when sampling at rates less than 25 MS/s. In peak-detect mode, the NI 5112 stores two samples in a group of *n* samples, the maximum and minimum. Peak-detect mode is useful for detecting high-frequency noise and anomalies on a signal sampled at a slower rate.

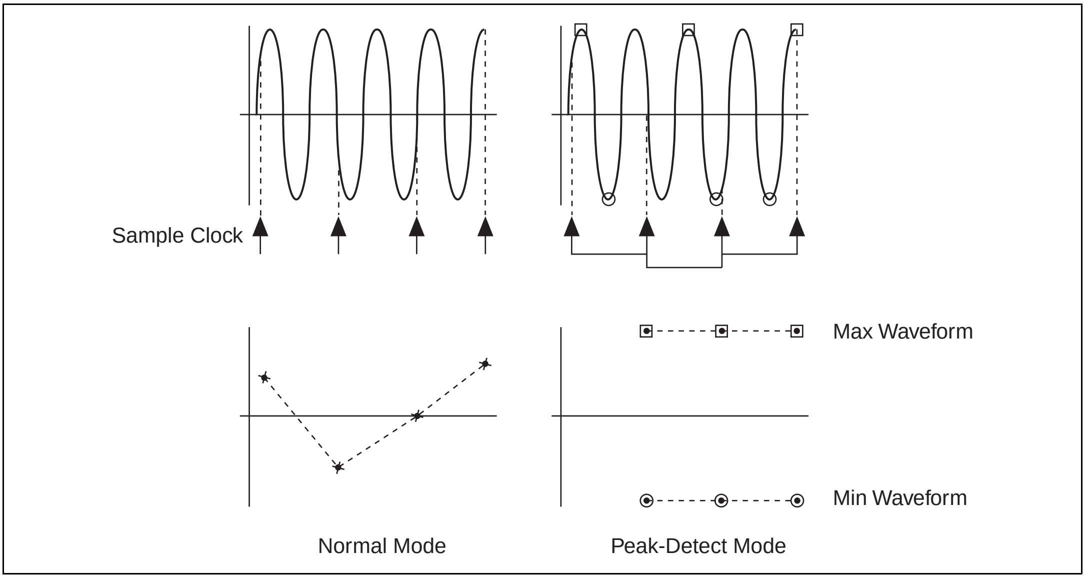


Figure 2-3. Normal Mode and Peak-Detect Mode

Calibration

The NI 5112 can calibrate numerous board parameters due to an advanced calibration scheme. There are two different calibration schemes depending on the type of calibration to be performed. *Internal calibration*, the more common of the two schemes, is performed via a software command that compensates for drifts caused by environmental temperature changes. Internal calibration can be executed without any external equipment connected. *External calibration*, which is performed much less frequently, is used to recalibrate the board when the specified calibration interval has expired. External calibration requires you to connect an external precision instrument to the board.

Internal Calibration

To provide the maximum accuracy independent of temperature changes, the NI 5112 needs to be recalibrated if the environmental conditions change in your PC beyond the specified calibration temperature range. Since the environmental conditions inside of your system are most likely different from the conditions the board was calibrated under at the factory, you should recalibrate your board after installing it in your system.

By executing a software command, you can internally calibrate the NI 5112 without connecting any external equipment. Internal calibration uses a precision-traceable onboard reference for the calibration.

Internal calibration performs the following operations:

- Gain and offset are calibrated for each individual input range.
- AC flatness is calibrated over the entire bandwidth to be within specified tolerances.
- Analog trigger levels are calibrated.
- The time-to-digital converter used for RIS measurements is calibrated.

You can perform internal calibration in several ways. You can use the VirtualBench-Scope front panel for calibration by selecting **Calibrate** from the **Utility** menu. The software examples also include a calibration example that you can use to calibrate the board.

To find examples in LabVIEW, go to **instr.LIB»Niscope»niScope.LLB**. For CVI, go to **VXIPNP»Win 95» niscope»Examples**.

External Calibration

External calibration adjusts the internal reference on the NI 5112. Although the NI 5112 is factory calibrated, it needs periodic external calibration to verify that it is still within the specified accuracy. For more information on calibration, contact National Instruments or visit the National Instruments Web site at `www.ni.com`

Triggering and Arming

There are several triggering methods for the NI 5112. 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 2-4 shows the different trigger sources. The digital triggers are TTL-level signals with a minimum pulse-width requirement of 10 ns.

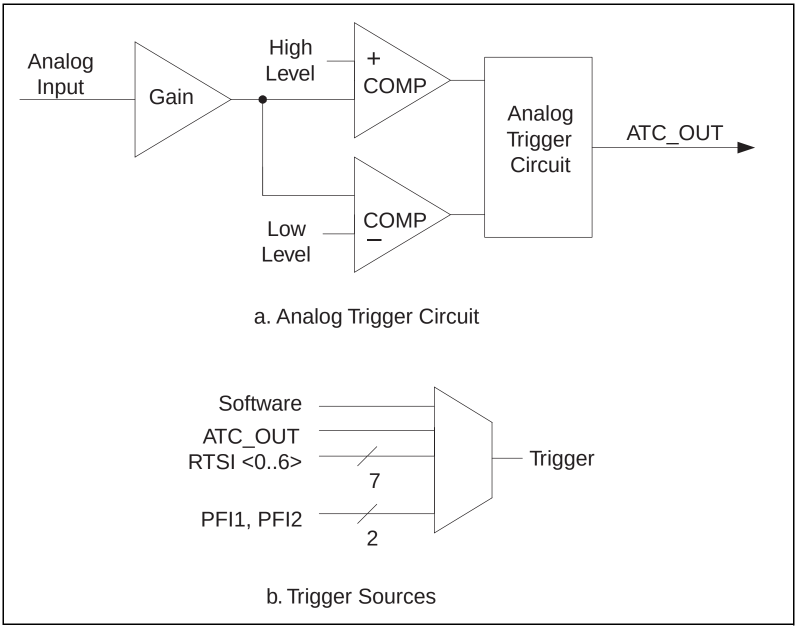


Figure 2-4. Trigger Sources

Analog Trigger Circuit

The analog trigger on the NI 5112 operates by comparing the current analog input to an onboard threshold voltage. This threshold voltage, **triggerValue**, can be set to any voltage within the current input range. A **hysteresisValue** associated with the trigger is used to create a trigger window the signal must pass through before the trigger is accepted. Triggers can be generated on a rising-edge or falling-edge condition as illustrated in the following two figures.

High-Hysteresis Analog Triggering Mode

In high-hysteresis analog triggering mode, the trigger is generated when the signal value is greater than **triggerValue**, with the hysteresis specified by **hysteresisValue**. The signal must cross back below the voltage equal to **triggerValue** minus **hysteresisValue** before another trigger is generated.

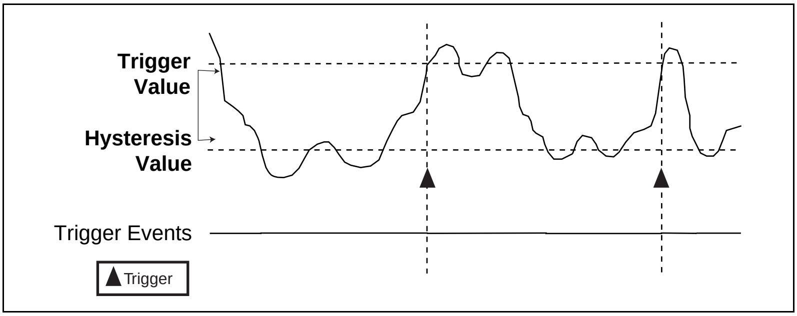


Figure 2-5. High-Hysteresis Analog Triggering Mode

Low-Hysteresis Analog Triggering Mode

In low-hysteresis analog triggering mode, the trigger is generated when the signal value is less than **triggerValue**, with the hysteresis specified by **hysteresisValue**. The signal must cross back above the voltage equal to **triggerValue** plus **hysteresisValue** before another trigger is generated.

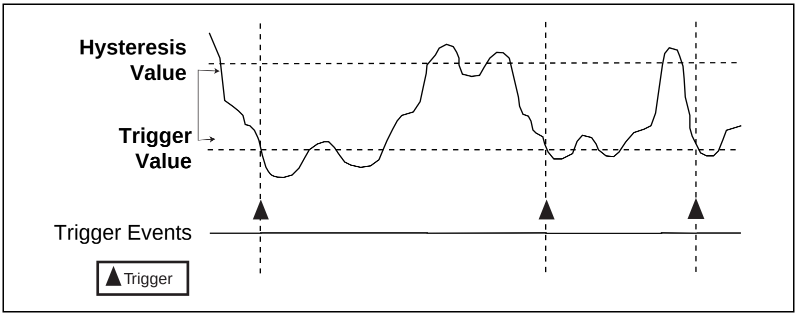


Figure 2-6. Low-Hysteresis Analog Triggering Mode

Rising-Edge Analog Trigger

Rising-edge analog trigger mode is the same as high-hysteresis analog trigger mode, except that the hysteresis value used is automatically set to 2.5% of the range of the chosen trigger source.

Falling-Edge Analog Trigger

Falling-edge analog trigger mode is the same as low-hysteresis analog trigger mode, except that the hysteresis value used is automatically set to 2.5% of the range of the chosen trigger source.

Trigger Hold-Off

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 500 ns to 171.8 s in increments of 40 ns.

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. The time the acquisition takes to complete from the time a trigger occurs is determined by the following equation:

$$acquisition\ completion\ time = \frac{posttrigger\ samples}{sample\ rate(MS/s)}$$

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. Figure 2-7 shows a timing diagram of signals when hold-off is enabled and the hold-off time is longer than posttriggered acquisition.

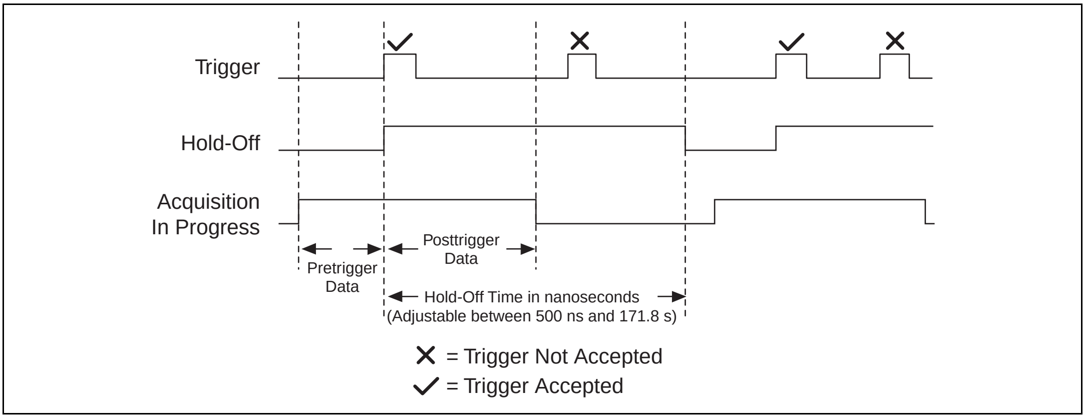


Figure 2-7. Timing with Hold-Off Enabled

Memory

Samples are acquired into onboard memory on the NI 5112 before being transferred to the host computer. The minimum size for a buffer is approximately 256 8-bit samples, although you can specify smaller buffers in software. When specifying a smaller buffer size, 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.

Multiple-Record Acquisitions

After the trigger has been received and the posttrigger samples have been stored, you can configure the NI 5112 to begin another acquisition that is stored in another memory record on the board. This process is a *multiple-record acquisition.* To perform multiple-record acquisitions, configure the NI 5112 to the number of records to be acquired before starting the acquisition. The NI 5112 acquires an additional record each time a trigger is accepted until all the requested records have been stored in memory. After the initial setup, this process does not require software intervention.

Between each record, there is a *dead time* of approximately 500 ns during which the trigger is not accepted. During this time, the memory controller sets up for the next record. There may also be additional dead time while the minimum number of pretrigger samples are being acquired. You cannot retrieve data from a multiple-record acquisition until all the records have been acquired. To increase the dead time between records, use the trigger hold-off feature. Figure 2-8 shows a timing diagram of a multiple-record acquisition.

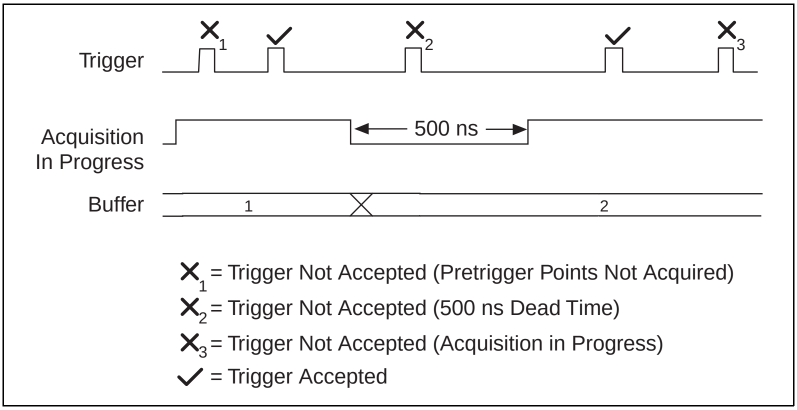


Figure 2-8. Multiple-Record Acquisition

PXI Trigger Bus, RTSI Bus, and Clock Lines

The PXI Trigger bus and RTSI bus allow National Instruments boards to synchronize timing and triggering on multiple devices. The NI 5112 for PXI uses the PXI backplane trigger bus to route triggers and a clock between multiple boards. The NI 5112 for PCI uses the RTSI bus to accomplish this routing.

The PXI backplane has seven bidirectional trigger lines, 13 matched-length star trigger lines, and a 10 MHz clock. The RTSI bus has seven bidirectional trigger lines and one bidirectional clock signal.

You can program any of the trigger lines to provide or accept a synchronous trigger signal. You can also use any of the trigger lines to provide a synchronization pulse from a master board if you are synchronizing multiple NI 5112 boards.

You can use the RTSI bus clock line to provide or accept a 10 MHz reference clock to synchronize multiple NI 5112 boards. In PXI, the reference clock for the boards is supplied from the PXI backplane, ensuring that all of the boards are synchronously clocked.

PFI Lines

The NI 5112 has two front-panel 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 an input for a trigger or a reference clock. Please see the Synchronization section for more information about the use of reference clocks in the NI 5112.

PFI Lines as Outputs

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

Reference Clock is a 10 MHz TTL-level clock signal that is synchronous to the 100 MHz sample clock on the NI 5112. You can use the reference clock to synchronize to another NI 5112 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 5112 is to provide a signal for compensating a passive probe.

Trigger Output is a TTL signal that pulses to a high level for at least 40 ns after the board triggers. This trigger is synchronized to a 25 MHz clock on the board.

Synchronization

The NI 5112 uses a phase-lock 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 5112 can also output its 10 MHz reference on the RTSI bus clock line or a PFI line so that other NI 5112 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 5112 board 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 5112 for PCI clock dividers, you must connect the boards with a National Instruments RTSI bus cable and designate one of the RTSI bus triggers 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.

To synchronize the NI 5112 for PXI, a PXI backpane trigger must be designated as a synchronization line. The behavior of this line is identical to the behavior of the RTSI line as described above.

You can synchronize the NI 5112 for PXI to 10 MHz output from another board or the backplane 10 MHz reference.

A

Specifications

This appendix lists the specifications of the NI-5112. These specifications are typical at 25 °C unless otherwise specified.

Acquisition System

Resolution	8 bits
Bandwidth (-3 dB)	100 MHz minimum 20 MHz typical with bandwidth limit enabled
Number of channels	2 simultaneously sampled, single ended
Maximum sample rate	2.5 GS/s repetitive, 100 MS/s single-shot
Onboard sample memory	16 MB per channel
Calibrated vertical ranges	±25 mV to ±25 V in 10% steps
Calibrated offset ranges	±500 mV for vertical ranges smaller than 500 mV, ±5 V for vertical ranges between 500 mV and 5 V, ±50 V for vertical ranges greater than 5 V
DC accuracy	±2.5 % of range setting ±0.5 % of offset setting
Input coupling	DC or AC, software selectable
AC coupling cutoff freq. (–3 dB)	11 Hz with 1x probe 1.1 Hz with 10x probe
Input impedance	1 MΩ || 30 pF or 50 Ω software selectable

Input protection	±42 V (DC + peak AC)

Calibration

Internal	Internal calibration is done on software command. The calibration involves gain, offset, frequency response, and timing adjustment for all input ranges.
Interval	24 hours, or any time temperature changes beyond ±2 °C from temperature at which last internal calibration was performed
External	Internal reference requires external recalibration.
Interval	5 years

Timebase System

Number of timebases	3 PXI clock input on NI 5112 for PXI, RTSI clock, and 10 MHz onboard reference
Clock accuracy (as master)	50 ppm
Clock input tolerance (as slave)	1% minimum
Clock input levels	TTL
Interpolator resolution	100 ps
Sampling clock frequency	100 MHz fixed, data can be decimated by *n* where 1<*n*<2^32
Synchronization between boards	Via PXI backplane 10 MHz reference clock or to digital trigger input (NI 5112 for PXI); via RTSI clock line or to digital trigger input (NI 5112 for PCI)

Triggering System

Modes	Edge, hysteresis, analog, digital
Source	Ch0, Ch1, TRIG, PFI<1..2>, RTSI <0..6>, PXI-Star
Slope	Rising/falling
Hysteresis	Fully programmable
Coupling	DC or AC on CH0, CH1, TRIG
Pretrigger depth	Up to 16 MB
Posttrigger depth	Up to 16 MB
Holdoff time	500 ns –171.85 s
Trigger sensitivity	>1000 steps in full-scale voltage range
DC accuracy	±2.5% of range setting ±0.5% of offset setting
Bandwidth	100 MHz
TRIG input range	±10 V
TRIG input impedance	1 MΩ || 30 pF or 50 Ω, software selectable
TRIG input protection	±42 V DC + peak AC

Acquisition Methods

Random interleaved sampling (RIS)	2.5 GS/s to 200 MS/s effective sample rate for repetitive signals only
Real-time sampling	100 MS/s to 1 S/s sample rate for transient and repetitive signals

Power Requirements

+3.3 VDC	0.5 A
+5 VDC	1.5 A
+12 VDC	80 mA
-12 VDC	120 mA

Physical

Dimensions	10 × 16 cm (4.2 × 6.87 in.)

I/O Connectors

Analog inputs CH0, CH1	BNC female
Analog trigger TRIG	BNC female
Digital trigger PFI1	SMB male
Digital trigger PFI2.	9-pin DIN

Operating Environment

Ambient temperature	0 to 55 °C
Storage temperature	–20 to 70 °C
Relative humidity	10 to 90% noncondensing

Storage Environment

Ambient temperature	–20 to 70 °C
Relative humidity	5 to 95% noncondensing

Safety

Designed in accordance with IEC-61010-1, UL 3111-1, and CAN/CSA C22.2 no. 1010.1 for electrical measuring and test equipment

Approved for altitudes up to 2000 m

Installation Category II

Pollution Degree 2

Indoor use only

Certifications and Compliances

CE Mark Compliance

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.

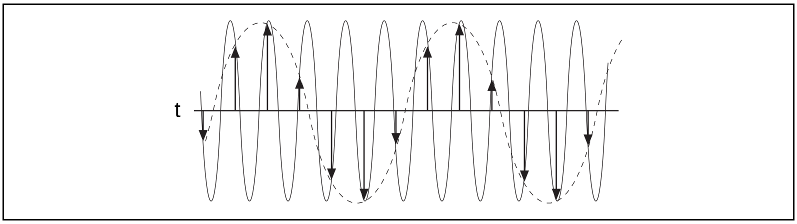


Figure B-1. Sine Wave Demonstrating the Nyquist Frequency

The 5 MHz frequency aliases back in the passband, falsely appearing as 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.

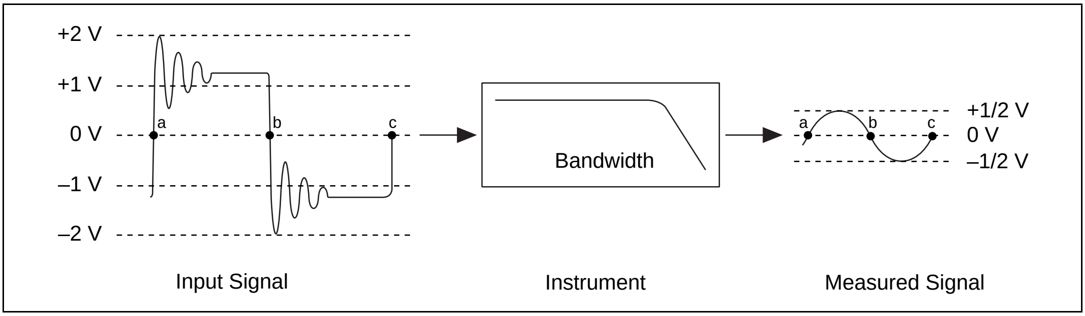


Figure B-2. Analog Bandwidth

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.

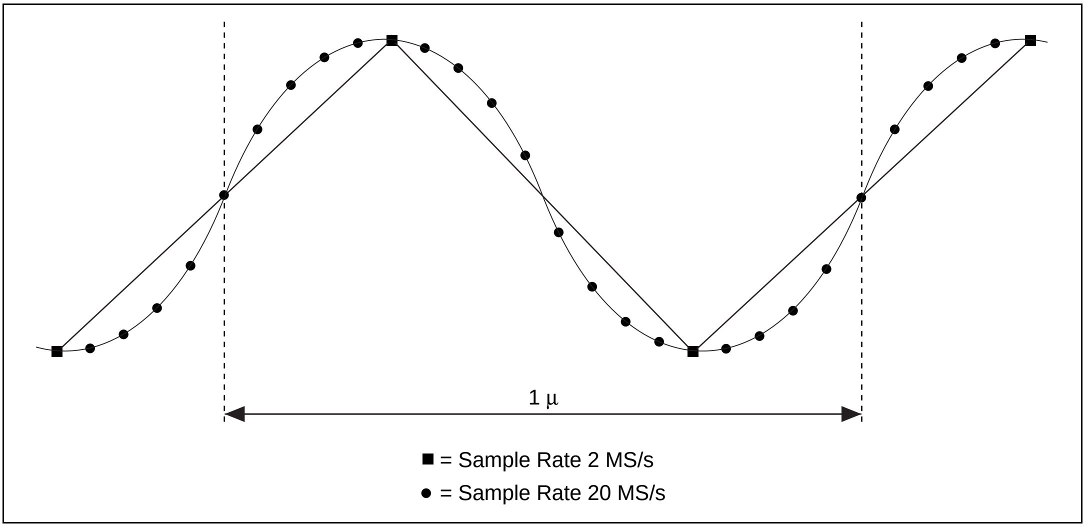


Figure B-3. 1 MHz Sine Wave Sample

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, a minute change in voltage at the input might not be 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.

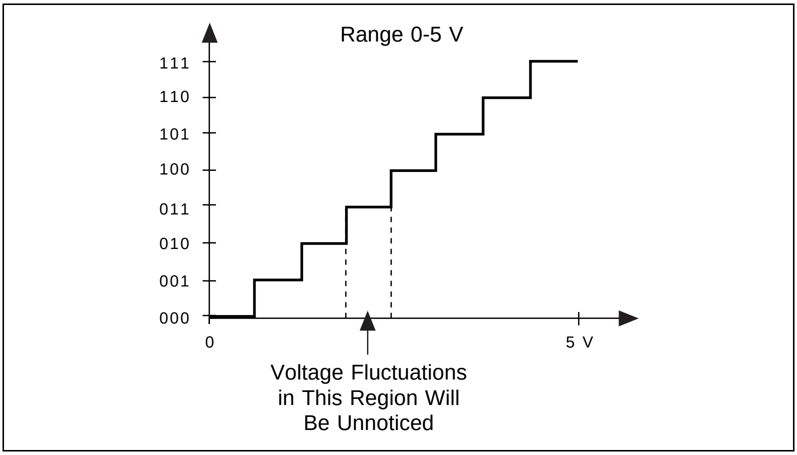


Figure B-4. Transfer Function of a 3-Bit ADC

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 x 50 ns). With a 100,000-sample buffer and a sample rate of 20 MHz, the duration of acquisition is 5 ms (100,000 x 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 5112 is equipped with sophisticated triggering options such as trigger thresholds, programmable hysteresis values, and trigger hold-off. The NI 5112 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.

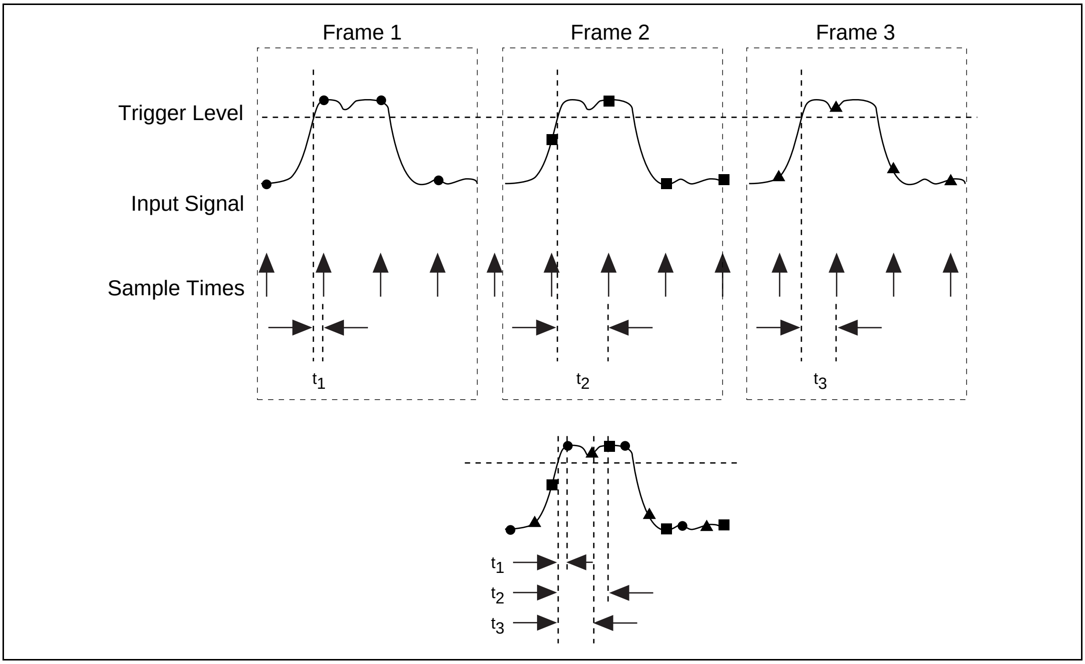


Figure B-5. Waveform Reconstruction with RIS

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.

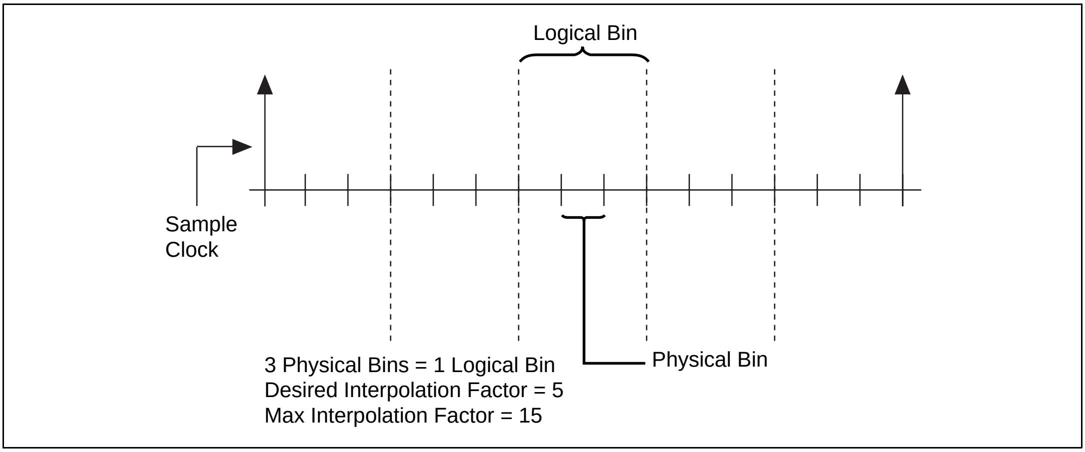


Figure B-6. Relationship between Interpolation Factor, Logical Bins, and Physical Bins

The maximum interpolation factor on the NI 5112 is 25, resulting in a maximum ETS rate of 2.5 GS/s. At this rate, the ratio of logical bins to physical bins is approximately 1:40.

Making Accurate Measurements

For accurate measurements, you should use the right settings when acquiring data with your NI 5112. 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 5112 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.

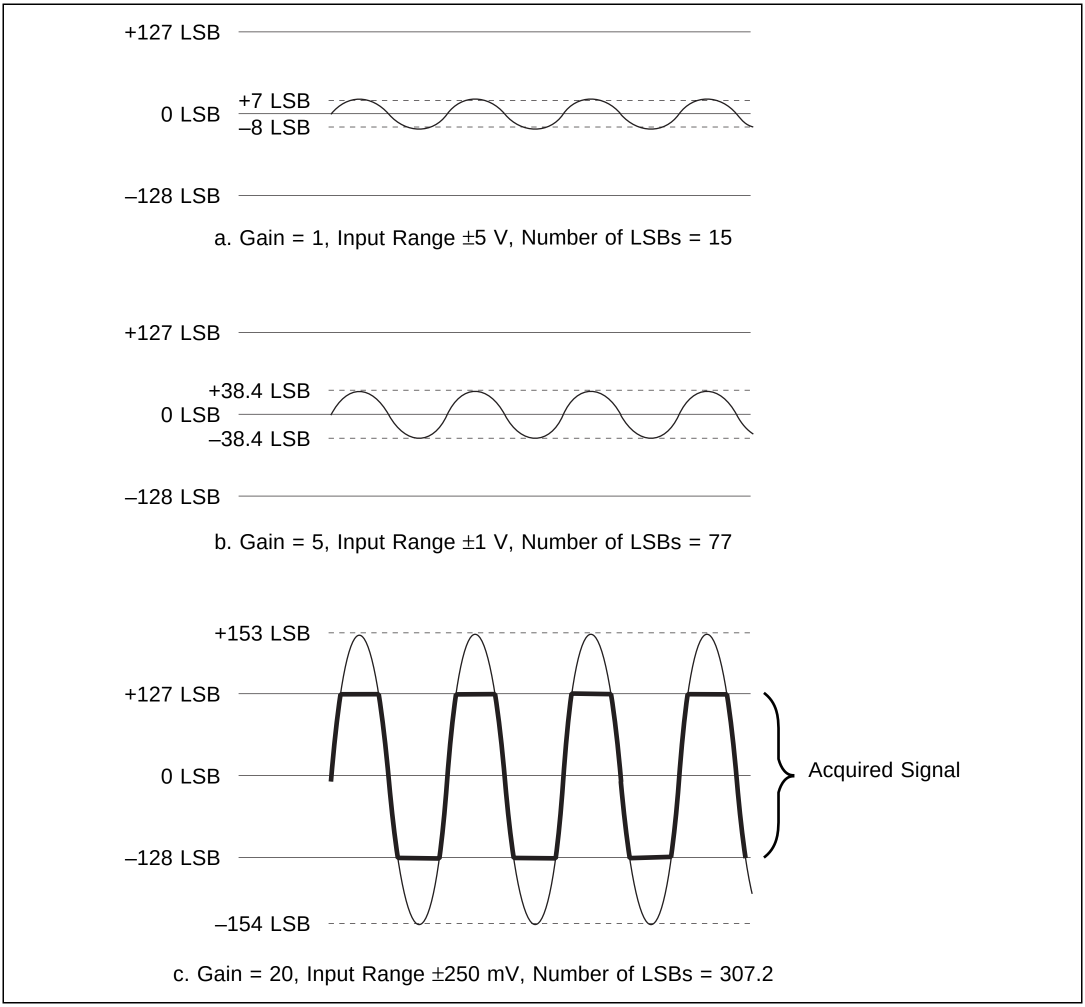


Figure B-7. Dynamic Range of an 8-Bit ADC with Three Different Gain Settings

- 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.

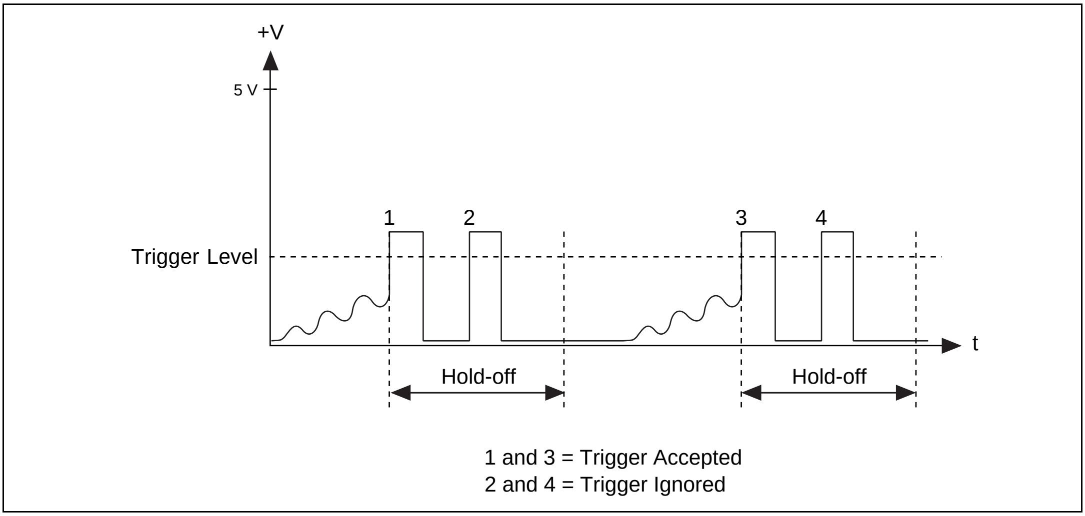


Figure B-8. Difficult Pulse Train Signal

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 5112 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.

Technical Support Resources

This appendix describes the comprehensive resources available to you in the Technical Support section of the National Instruments Web site and provides technical support telephone numbers for you to use if you have trouble connecting to our Web site or if you do not have internet access.

NI Web Support

To provide you with immediate answers and solutions 24 hours a day, 365 days a year, National Instruments maintains extensive online technical support resources. They are available to you at no cost, are updated daily, and can be found in the Technical Support section of our Web site at `www.ni.com/support`

Online Problem-Solving and Diagnostic Resources

- **KnowledgeBase**—A searchable database containing thousands of frequently asked questions (FAQs) and their corresponding answers or solutions, including special sections devoted to our newest products. The database is updated daily in response to new customer experiences and feedback.
- **Troubleshooting Wizards**—Step-by-step guides lead you through common problems and answer questions about our entire product line. Wizards include screen shots that illustrate the steps being described and provide detailed information ranging from simple getting started instructions to advanced topics.
- **Product Manuals**—A comprehensive, searchable library of the latest editions of National Instruments hardware and software product manuals.
- **Hardware Reference Database**—A searchable database containing brief hardware descriptions, mechanical drawings, and helpful images of jumper settings and connector pinouts.
- **Application Notes**—A library with more than 100 short papers addressing specific topics such as creating and calling DLLs, developing your own instrument driver software, and porting applications between platforms and operating systems.

Software-Related Resources

- **Instrument Driver Network**—A library with hundreds of instrument drivers for control of standalone instruments via GPIB, VXI, or serial interfaces. You also can submit a request for a particular instrument driver if it does not already appear in the library.
- **Example Programs Database**—A database with numerous, non-shipping example programs for National Instruments programming environments. You can use them to complement the example programs that are already included with National Instruments products.
- **Software Library**—A library with updates and patches to application software, links to the latest versions of driver software for National Instruments hardware products, and utility routines.

Worldwide Support

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If you have trouble connecting to our Web site, please contact your local National Instruments office or the source from which you purchased your National Instruments product(s) to obtain support.

For telephone support in the United States, dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

Australia 03 9879 5166, Austria 0662 45 79 90 0, Belgium 02 757 00 20, Brazil 011 284 5011, Canada (Calgary) 403 274 9391, Canada (Ontario) 905 785 0085, Canada (Québec) 514 694 8521, China 0755 3904939, Denmark 45 76 26 00, Finland 09 725 725 11, France 01 48 14 24 24, Germany 089 741 31 30, Greece 30 1 42 96 427, Hong Kong 2645 3186, India 91805275406, Israel 03 6120092, Italy 02 413091, Japan 03 5472 2970, Korea 02 596 7456, Mexico (D.F.) 5 280 7625, Mexico (Monterrey) 8 357 7695, Netherlands 0348 433466, Norway 32 27 73 00, Poland 48 22 528 94 06, Portugal 351 1 726 9011, Singapore 2265886, Spain 91 640 0085, Sweden 08 587 895 00, Switzerland 056 200 51 51, Taiwan 02 2377 1200, United Kingdom 01635 523545

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}

Numbers/Symbols

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

A

A	amperes
AC	alternating current
AC coupled	the passing of a signal through a filter network that removes the DC component of the signal

A/D	analog-to-digital
ADC	analog-to-digital converter—an electronic device, often an integrated circuit, that converts an analog voltage to a digital number
ADC resolution	the resolution of the ADC, which is measured in bits. An ADC with16 bits has a higher resolution, and thus a higher degree of accuracy, than a 12-bit ADC.
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.
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
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)
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*.
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

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

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
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
ISA	industry standard architecture

M

m	meters
MB	megabytes of memory

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.

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.

P

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
PFI	Programmable Function Input
peak value	the absolute maximum or minimum amplitude of a signal (AC + DC)
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 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

S

s	seconds
S	samples
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
S/s	samples per second—used to express the rate at which an instrument samples an analog signal
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

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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