

# Computer-Based Instruments

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## NI 4050 User Manual

Digital Multimeter Card for PCMCIA



March 2000 Edition  
Part Number 321427C-01

## **Worldwide Technical Support and Product Information**

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# Compliance

## FCC/Canada Radio Frequency Interference Compliance\*

### Determining FCC Class

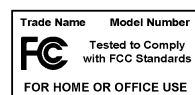
The Federal Communications Commission (FCC) has rules to protect wireless communications from interference. The FCC places digital electronics into two classes. These classes are known as Class A (for use in industrial-commercial locations only) or Class B (for use in residential or commercial locations).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

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

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

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

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



### FCC/DOC Warnings

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

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

### Class A

#### Federal Communications Commission

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

#### Canadian Department of Communications

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

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

### Class B

#### Federal Communications Commission

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

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.

- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

## **Canadian Department of Communications**

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

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

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

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

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

# Conventions

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The following conventions are used in this manual:

» The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.



This icon denotes a note, which alerts you to important information.



This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash.

**bold**

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

*italic*

Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text that is a placeholder for a word or value that you must supply.

monospace

Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. 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 4050

Thank you for buying a National Instruments 4050 digital multimeter card. A system based on the NI 4050 offers the flexibility, performance, and size that makes it ideal for service, repair, and manufacturing as well as for use in industrial and laboratory environments. The NI 4050, used in conjunction with your computer, is a versatile, cost-effective platform for high-resolution measurements.

For the most current versions of manuals and example programs, visit [www.ni.com/instruments](http://www.ni.com/instruments) for free downloads.

Detailed specifications for the NI 4050 are in Appendix A, *Specifications*.



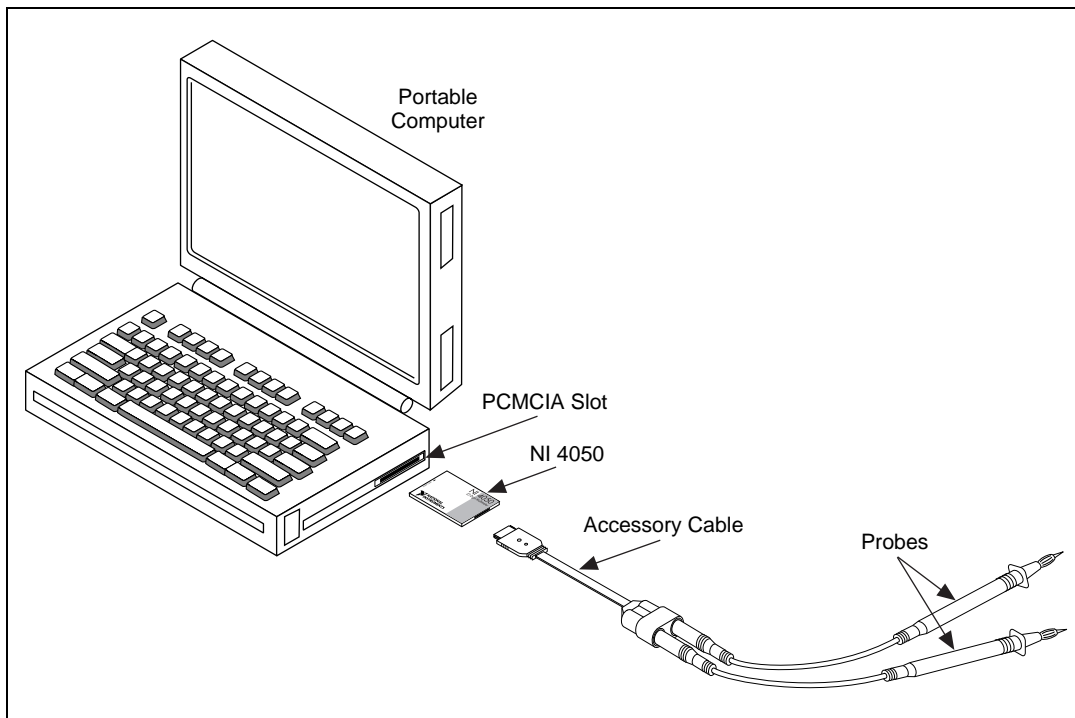
**Note** Before using any measurement equipment, it is important that you thoroughly understand the safety instructions for that product. The beginning of Chapter 2, *NI 4050 Operation*, covers the safety guidelines for your NI 4050.

## Cable and Probes

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The NI 4050 instrument kit contains the NI 4050 accessory cable that connects the NI 4050 to a pair of test probes with shrouded banana plugs, which are also included in the kit. Both the NI 4050 accessory cable and the test probes meet international safety requirements including UL 3111 and IEC 1010-1 for the full ranges of applications supported by the NI 4050. Before using any probes or accessories not supplied by National Instruments, ensure that they meet applicable safety requirements for the signal levels you may encounter.

To use the NI 4050 accessory cable and probes with the NI 4050, first connect the cable to the card as shown in Figure 1-1. The accessory cable connector is polarized so that it cannot be plugged in incorrectly.



**Figure 1-1.** Installing the NI 4050 and Cables

The test probes connect to the NI 4050 accessory cable via shrouded banana jacks. The shrouds around the banana jacks prevent you from contacting potentially hazardous voltages connected to the test probes. You can also connect the cable to standard, unshrouded banana jack probes or accessories; however, use unshrouded probes or accessories only when the voltages are less than  $30 V_{\text{rms}}$  or  $42 V_{\text{pk-to-pk}}$ .



**Caution** To prevent possible safety hazards, the maximum voltage between either of the inputs and the ground of the computer should never exceed  $\pm 250 \text{ VDC}$  or  $250 V_{\text{rms}}$ .

# Introduction to the VirtualBench-DMM Soft Front Panel

The following sections explain how to make connections to your NI 4050 and take simple measurements using the VirtualBench-DMM, as shown in Figure 1-2. To launch the soft front panel, select **Start»Programs»National Instruments DMM»Soft Front Panel**.

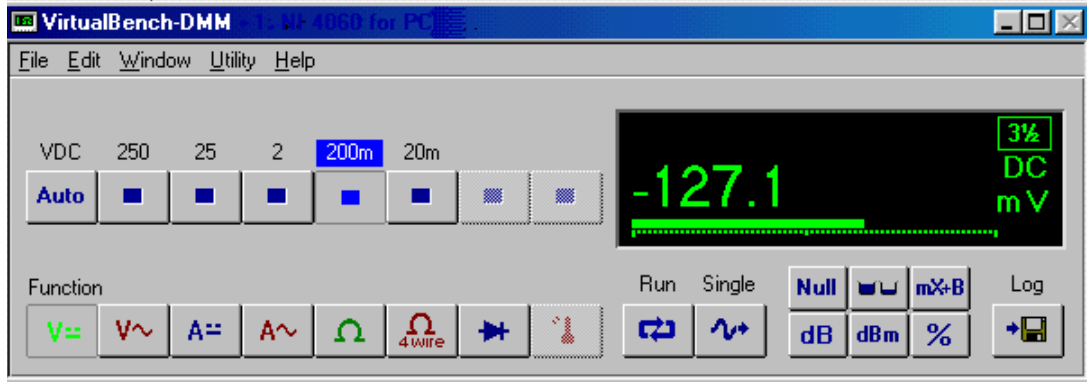
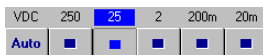


Figure 1-2. NI-DMM Soft Front Panel

The following text describes the options available on the soft front panel. Refer to **Help»Online Reference** located on the soft front panel for information on front panel menus.



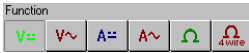
The range selector determines the range of measurements VirtualBench-DMM makes. The range differs for each measurement mode. If the measurement exceeds the range, +OVER or –OVER appears in the measurement display. **Auto** selects the range that best matches the input signal.



The value indicator displays the value measured by your NI 4060 (The value shown is an example only.).



The unit indicator displays the measurement units of the value you are measuring. The units are expressed as VAC, VDC, mVAC, mVDC,  $\Omega$ , k $\Omega$ , M $\Omega$ , mA, AC, or mA DC. The indicator also displays the digits of resolution. By clicking on the indicator, you can change the DMM's resolution.



The **Function** selector allows you select a measurement mode. Select **Edit>Settings** and click on the tabs for **Current and Resistance** or **Temperature** to control the data type acquired by VirtualBench-DMM.



DC volts measures the DC component of a voltage signal.



AC volts measures the AC component of a voltage signal.



DC current measures the DC component of a current source.



AC current measures the AC component of a current source.



2-wire measures resistance using the 2-wire method.



4-wire measures resistance using the 4-wire method.



Diode measures the voltage drop across a diode. The maximum voltage VirtualBench-DMM measures is 2 V.



Temperature measures temperature.



The run button starts and stops continuous DMM measurements.



The single button performs a single measurement.



The math buttons allow you to manipulate readings mathematically.



**Null** starts relative mode. VirtualBench-DMM makes all subsequent measurements relative to the measurement it makes when you click on Null.



**Max/Min** displays the maximum and minimum values that occur after you start Relative mode.



**mX+B** enables the  $mX+B$  calculation on all readings.



**dB** compresses a large range of measurements into a much smaller range by expressing DC or AC voltage in decibels.



**dBm** shows decibels above or below a 1 mW reference.



% selects the percentage calculation. VirtualBench-DMM expresses the displayed reading as a percent deviation from the reference value entered in the Math Settings. Refer to **Help»Online Reference, Math Settings** topic for more information about dB, dBm, mX+B, and percentage calculations.



The log button enables data logging. To configure the datalog file and log interval, select **Edit»Settings**. Refer to **Help»Online Reference, Logging Measurements to Disk** topic for more details.

Digits of Precision—A pop-up ring control in the DMM front panel display allows you to set measurement accuracy to 3 1/2, 4 1/2, or 5 1/2. A larger value gives greater precision but slower measurement performance. Refer to Figure 1-3.

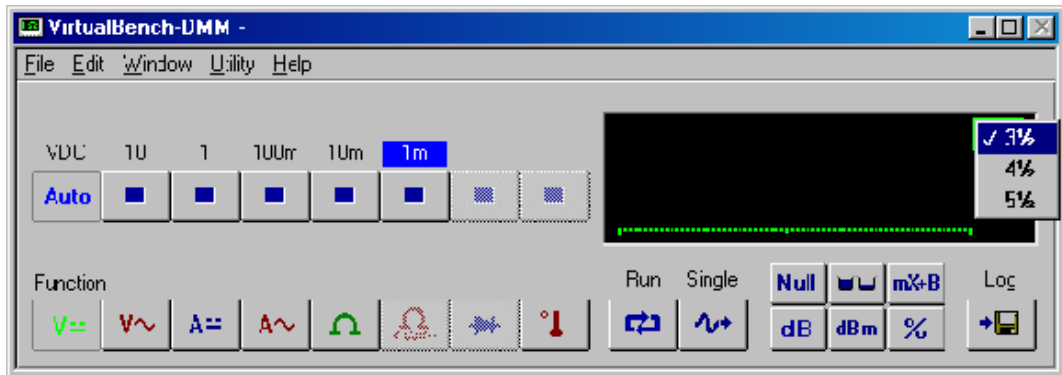


Figure 1-3. Digits of Precision

## Use the Soft Front Panel

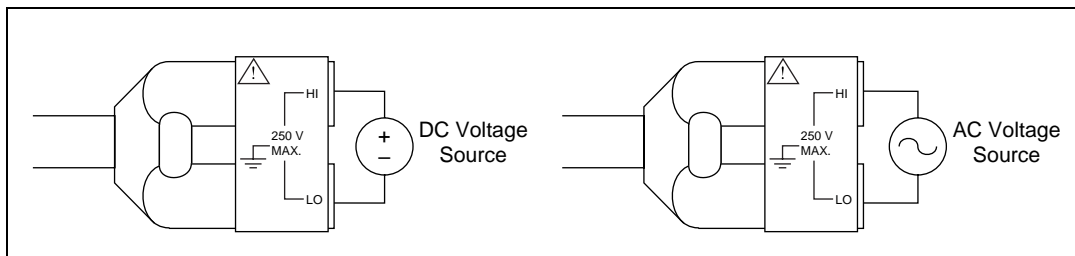
The following sections describe procedures for measuring DC and AC voltage, resistance, diode, and temperature, using the soft front panel.

### Measure DC and AC Voltage

Use the following procedure to measure DC and AC voltage using the soft front panel:

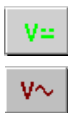
1. Connect the test probes to voltage signals as shown in Figure 1-4. For DC voltages, the HI (red) terminal is the positive terminal, and the LO (black) terminal is negative. For AC voltages, positive and negative terms are irrelevant.

The NI 4050 is protected against damage from voltages within  $\pm 250$  VDC or  $250 V_{\text{rms}}$  in all ranges. You should never apply voltages above these levels to the inputs.



**Figure 1-4.** Connecting Probes for Voltage Measurement

2. Select the mode you will measure:



- DC Volts
- AC Volts



3. Select the range for your measurement or autoranging:

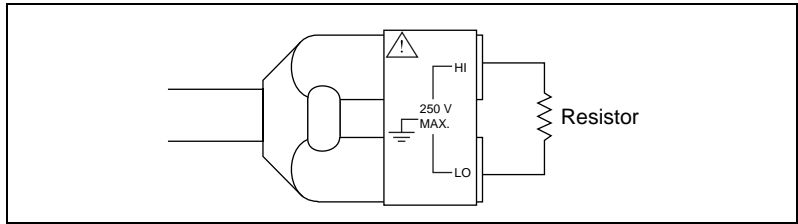
- DC Volts— $\pm 20$  mV,  $\pm 200$  mV,  $\pm 2$  V,  $\pm 25$  V, and  $\pm 250$  V
- AC Volts— $20$  mV<sub>rms</sub>,  $200$  mV<sub>rms</sub>,  $2$  V<sub>rms</sub>,  $25$  V<sub>rms</sub>, and  $250$  V<sub>rms</sub>

The value indicator displays the voltage measured.

## Measure 2-Wire Resistance

Use the following procedure to measure 2-wire resistance using the soft front panel:

1. Connect the test probes to a resistor as shown in Figure 1-5. To accurately measure the value of a resistor, make sure the resistor is not connected to any other circuits. Erroneous or misleading readings may result if the resistor you are measuring is connected to external circuits that supply voltages or currents or to external circuits that change the effective resistance of that resistor.



**Figure 1-5.** Connections for Resistance Measurement



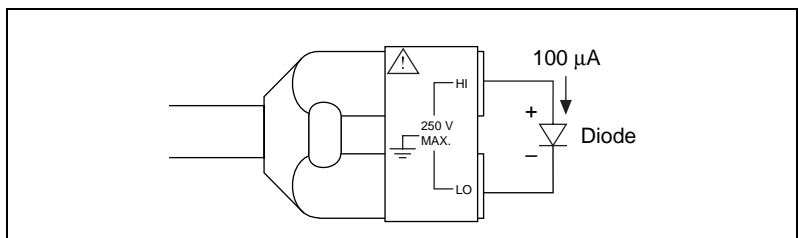
2. Select 2-wire resistance mode.
3. Select the range for your measurement—200  $\Omega$ , 2 k $\Omega$ , 20 k $\Omega$ , 200 k $\Omega$ , 2 M $\Omega$ , 200 M $\Omega$ , or autorange.

The value indicator indicates the resistance measured. See the [2-Wire Resistance Measurements](#) section of Chapter 2, *NI 4050 Operation*, for more information on 2-wire resistance measurements.

## Measuring the Voltage Drop Across a Diode

The NI 4050 can excite a device under test and read the resulting voltage drop. Diode mode is useful for testing diodes. Use the following procedure to measure the forward drop across a diode. Voltage up to 2 V can be measured in this mode.

1. Connect the test probes to a diode as shown in Figure 1-6. To accurately measure the forward voltage of a diode, make sure that the diode is not connected to any other circuits. The NI 4050 biases the diode with a current of 100  $\mu\text{A}$  and measures the resulting voltage drop. Diode measurements are made with a fixed range of 2.0 V.



**Figure 1-6.** Connecting Signals for Diode Test



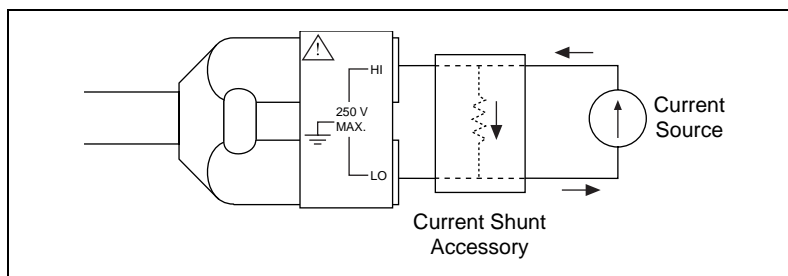
2. Select diode mode.
3. Select the range for your measurement. Only the 2 V range is available for diode measurement.



The value indicator will indicate the voltage drop measured. If the display indicates 2.200 VDC, the diode is either reverse biased or defective. See the [Diode Measurements](#) section of Chapter 2, *NI 4050 Operation*, for more information on diode measurements.

## Measure Current

You can use the NI 4050 to measure current with an optional National Instruments CSM series current shunt module. These accessories are connected between the NI 4050 cable and the test probes as shown in Figure 1-7.



**Figure 1-7.** Connections for Current Measurement

Current shunt accessories contain a precision resistor that converts the current through the shunt into a voltage that the NI 4050 can measure in voltage mode. While the soft front panel cannot measure current directly with the NI 4050, you can calculate the value of the current flowing through the shunt by dividing the voltage measured by the value of the precision resistor.



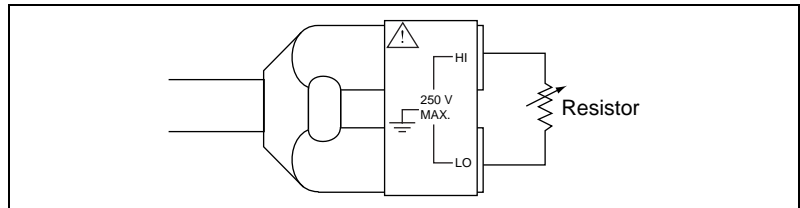
## Measure Temperature

You can measure temperature using common temperature transducers such as resistive temperature devices (RTD) and thermistors. You can measure transducers in the 2-wire resistance mode, as shown in Figure 1-8.

Although the soft front panel does not support temperature measurements, you can convert and scale the transducer value to temperature programmatically through software.



**Note** The NI 4050 for PCMCIA does not support 4-wire resistance measurements. To avoid measurement errors due to resistance offset, before doing resistance measurements, measure the resistance to your loads.



**Figure 1-8.** Connecting Signals for RTDs and Thermistors

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# NI 4050 Operation

This chapter contains safety instructions, measurement fundamentals and concerns, and scanning information.

## Safety Instructions

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**Cautions** To avoid personal injury or damage to electronic equipment, observe the following:

Do *not* operate this instrument in an explosive atmosphere or where there may be flammable gases or fumes.

Equipment described in this document must be used in an Installation Category II environment per IEC 664. This category requires local level supply mains-connected installation.

The NI 4050 must be used in a UL-listed laptop or personal computer.

To prevent safety hazards, the maximum voltage between either of the inputs and the ground of the computer should never exceed  $\pm 250$  VDC or  $250 V_{\text{rms}}$ .

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

Do *not* operate this instrument in a manner that contradicts the information specified in this document. Misuse of this instrument could result in a shock hazard.

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

Connections that exceed any of the maximum signal ratings on the NI 4050 can create a shock or fire hazard or can damage any or all of the devices connected to the NI 4050. National Instruments is *not* liable for any damages or injuries resulting from incorrect signal connections.

Clean the instrument and accessories by brushing off light dust with a soft, nonmetallic brush. Remove other contaminants with a stiff nonmetallic brush. The unit must be completely dry and free from contaminants before returning to service.

# Measurement Fundamentals

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## Warm Up

The required warm-up time for the NI 4050 is 30 minutes. This warm-up time is important because measurements made with the NI 4050 multimeter can change with temperature. This change is called a thermal drift and affects your accuracy. To minimize the effects of thermal drift and ensure the specified accuracies, take all measurements after the NI 4050 has had a chance to fully warm up. Depending on your environment, the NI 4050 can operate significantly above ambient temperature. Therefore, measurements made immediately after powering up the system can differ significantly from measurements made after the system has fully warmed up. The NI 4050 temperature specifications are listed in the *Accuracy* sections in Appendix A, *Specifications*.

## Selecting the Resolution

The resolution on the NI 4050 multimeter is programmable. You can select from three different resolutions: 5 1/2 digits, 4 1/2 digits, or 3 1/2 digits. These settings allow you to trade off speed for resolution. The 5 1/2 digit setting has the highest resolution and slowest reading rate, while the 3 1/2 digit setting gives you the least resolution and fastest reading rate. Measurement mode and range affect the reading rate by requiring different conversion times to obtain a given resolution for the different modes and ranges.

## Grounding

When measuring ground-referenced signals, connect the ground-referenced side of your signal to the IN HI + terminal for best performance.

# Voltage Measurements

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## DC Voltage

Your NI 4050 multimeter uses a high-resolution delta sigma, A/D converter (ADC) to sample signals and convert them into a digital form. The ADC is preceded by a series of gain and attenuation circuitry that allow both small and large signals to be measured using the same converter. The NI 4050 uses a digital filter, which heavily rejects powerline frequencies (50–60 Hz) and their harmonics, as well as high-frequency noise.

## Input Ranges

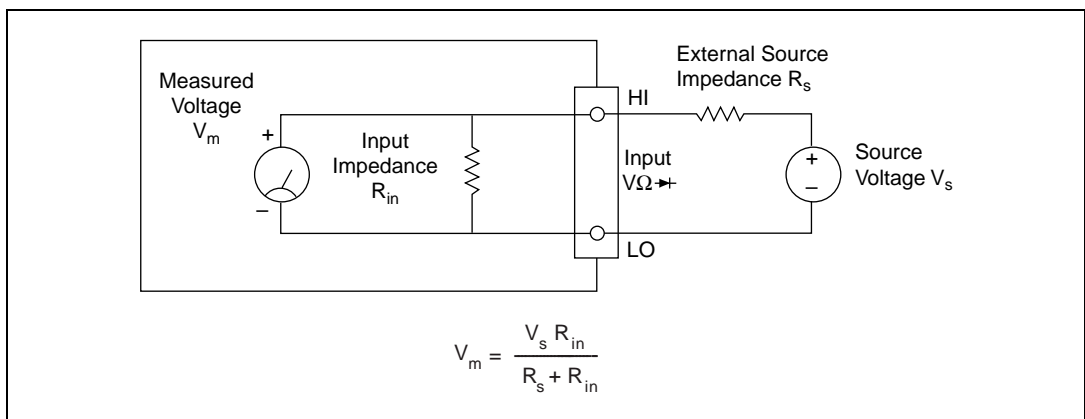
The NI 4050 has five input ranges available for measuring DC voltages. These ranges are  $\pm 20$  mV,  $\pm 200$  mV,  $\pm 2.0$  V,  $\pm 25$  V, and  $\pm 250$  V. Each range has a 10% overrange, except for the 250 V range. The 250 V and 25 V input ranges have a 1 M $\Omega$  input impedance; the 2 V, 200 mV, and 20 mV ranges have an input impedance greater than 1 G $\Omega$ . Take these values into consideration when measuring high-impedance sources. When the NI 4050 is powered off, the 250 V and 25 V input range have a 1 M $\Omega$  input impedance and the 2 V, 200 mV, and 20 mV ranges have an input impedance of 100 k $\Omega$ .

If you are taking measurements that require a high degree of accuracy, you should consider problems associated with input impedance, noise effects, and thermal electromotive forces (thermal EMFs). These effects are discussed in the [Measurement Considerations](#) section.

## Measurement Considerations

### Input Impedance

Figure 2-1 illustrates the input impedance of an NI 4050 and its effect on the measurement of a circuit under test. If you know the source impedance of the circuit being tested, you can correct for the attenuation caused by the NI 4050 in software. Since  $R_{in}$  is large, at least 1 M $\Omega$ , it will require a large source impedance,  $R_s$ , to cause a large change in the measured voltage,  $V_m$ .



**Figure 2-1.** Effect of Input Impedance on Signal Measurements

## Thermal EMF

Thermal EMFs, or thermoelectric potentials, are voltages generated at the junctions of dissimilar metals and are functions of temperature. Thermal EMFs in a circuit under test can cause higher than expected offsets that change with temperature.

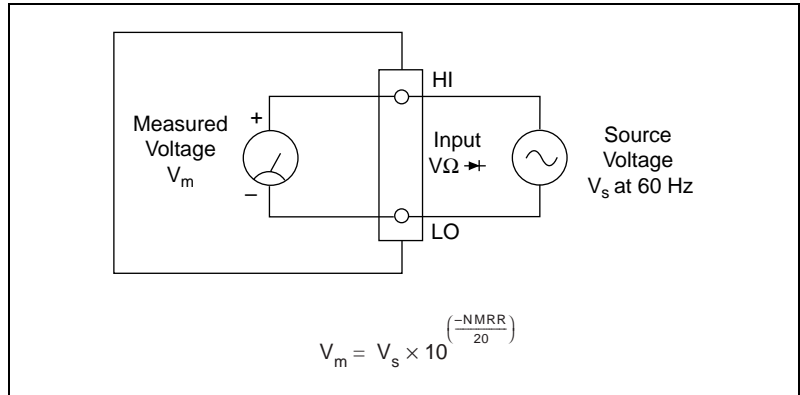
## Noise Rejection

The NI 4050 filters out AC voltages in the DC voltage measurement ranges. However, if the amplitudes of the AC voltages are large compared to the DC voltages, or if the peak value (AC + DC) of the measured voltage is outside the overrange limits, the NI 4050 may exhibit additional errors. To minimize these errors, keep the NI 4050 away from strong AC magnetic sources and minimize the area of the loop formed by the test leads. Choosing the 5 1/2 digit resolution will also help minimize noise from AC sources. If the peak value of the measured voltage is likely to exceed the selected input range, select the next highest input range.

## Normal Mode Rejection

Normal mode rejection (NMR) is the ability of the NI 4050 to reject a normally (differentially) applied signal. The ability is quantified in the normal mode rejection ratio (NMRR) specification, which indicates the capability of the NI 4050 to reject 50 or 60 Hz and is valid only at the specified frequency and useful only when taking DC measurements. The NMRR is specified at the powerline frequency because this is typically where most measurement noise occurs.

Figure 2-2 shows a 60 Hz signal connected differentially to the NI 4050 in DC Volts mode.  $V_m$  is the voltage that will be measured after the signal is rejected. NMR is very useful when trying to measure DC voltages in the presence of large powerline interference.

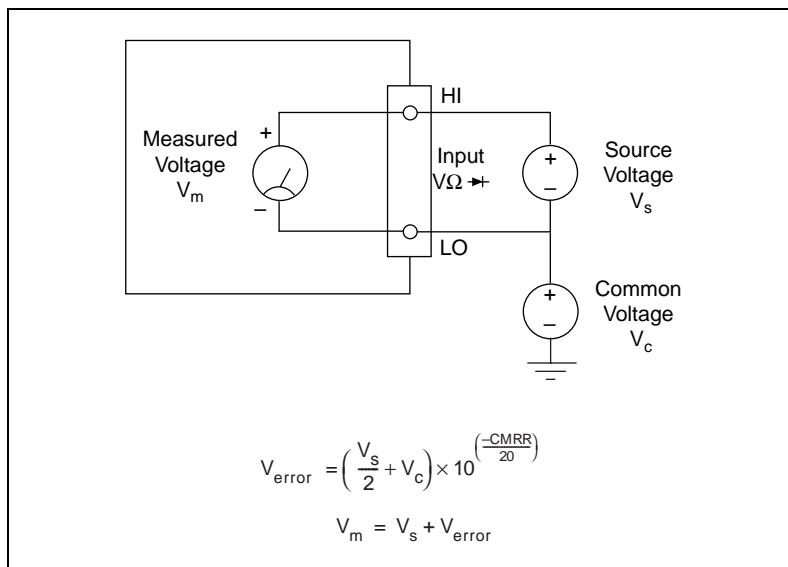


**Figure 2-2.** Normal Mode Measurement Effects

If you are measuring signals in the presence of large normal mode voltages, consult Appendix A, *Specifications*, to calculate the additional error to your system. Use the equation in Figure 2-2 to calculate the voltage error due to normal mode voltage.

### Common Mode Rejection

Common mode rejection (CMR) is the ability of the NI 4050 to reject signals that are common to both input terminals. The ability is quantified in the common mode rejection ratio (CMRR) specification. Theoretically, the floating measurement circuitry of the NI 4050 should have an infinite CMRR. Parasitic resistances and capacitances to earth ground limit the CMR of the NI 4050. This effect is most noticeable when measuring small signals in the presence of a large common mode voltage, as shown in Figure 2-3.



**Figure 2-3.** Common Mode Measurement Effects

Using the equation in Figure 2-3, you can calculate the voltage error due to the common mode voltage. If you are measuring signals in the presence of large common mode voltages, consult Appendix A, *Specifications*, to calculate the additional error to your system.

### Effective Common Mode Rejection

Effective common mode rejection is the sum of the CMRR and the NMRR at a given frequency. It is the effective rejection on a given noise signal that is applied to both input leads as it gets rejected first by the CMR capability of the instrument then again by its NMR capability. This specification is most useful at the powerline frequency where most of the noise resides and is only valid for DC measurements.

## AC Voltage

In the AC voltage ranges, the NI 4050 measures the AC-coupled RMS value of a signal. The RMS value of a signal is a fundamental measurement of the magnitude of an AC signal. The RMS value of an AC signal can be defined mathematically as the square root of the average of the square of the signal.

In practical terms, the RMS value of an AC signal is the DC value required to produce an equivalent amount of heat in the same resistive load. The NI 4050 first AC-couples the measured signal to remove any DC

components and then measures the RMS value of the AC component. This method lets you measure a small AC signal in the presence of a large DC offset.

## Input Ranges

The NI 4050 has five input ranges available for measuring AC voltages. These ranges are 20 mV<sub>rms</sub>, 200 mV<sub>rms</sub>, 2.0 V<sub>rms</sub>, 25 V<sub>rms</sub>, and 250 V<sub>rms</sub>. The impedance in each of these ranges is a 0.068  $\mu$ F capacitor followed by 1 M $\Omega$ . When the NI 4050 is powered off, the 250 V, 25 V, and 2 V input ranges have a 0.068  $\mu$ F capacitor, followed by a 1 M $\Omega$  input impedance. The 200 mV and 20 mV ranges have a 0.068  $\mu$ F capacitor, followed by an approximate 100 k $\Omega$  input impedance.

The NI 4050 can measure AC voltages to its specified accuracy as long as the voltage is at least 10% and no more than 100% of the selected input range. The DC component in any of these ranges can be as high as 250 VDC. Each range, except for the 250 V range, has a 10% overrange.

The AC voltage measurement accuracy depends on many factors, including the signal amplitude, frequency, and waveform shape.

## Measurement Considerations

### AC Offset Voltage

The AC measurements of the NI 4050 are specified over the range of 10% to 100% of the full-scale input range. Below 10% of the input range, errors due to the AC voltage offset become significant. This offset, unlike DC voltage offsets, cannot simply be subtracted from the readings or zeroed out because the offset gets converted in the RMS conversion. To minimize the errors due to the AC offset voltage, choose an input range that keeps the measured voltage between 10% and 100% of full scale.

### Frequency Response

The accuracy of the NI 4050's AC voltage measurements is a function of the input signal frequency. Your NI 4050 is calibrated at the factory using a 1 kHz sine wave. Your frequency-dependent error will be minimal around this frequency. The error will then increase as you approach the upper and lower bandwidth limits. This additional error is added to the accuracy errors in computing the absolute error.



These additional errors are shown in Appendix A, *Specifications*. While the NI 4050 is characterized and specified over the 20 Hz to 25 kHz frequency range, measurements outside of this range can still be made with decreased accuracy.

## Resistance Measurements

### 2-Wire Resistance Measurements

The NI 4050 measures 2-wire resistance by passing a current through the device under test and reading the resulting voltage drop through the same connections, as illustrated in Figure 2-4. The resistance value is then computed using Ohm's Law ( $R=V/I$ ). To accurately measure the value of a resistor, make sure the resistor is not connected to any other circuits. Erroneous or misleading readings can result if the resistor you are measuring is connected to external circuits that supply voltages or currents, or to external circuits that change the effective resistance of that resistor.

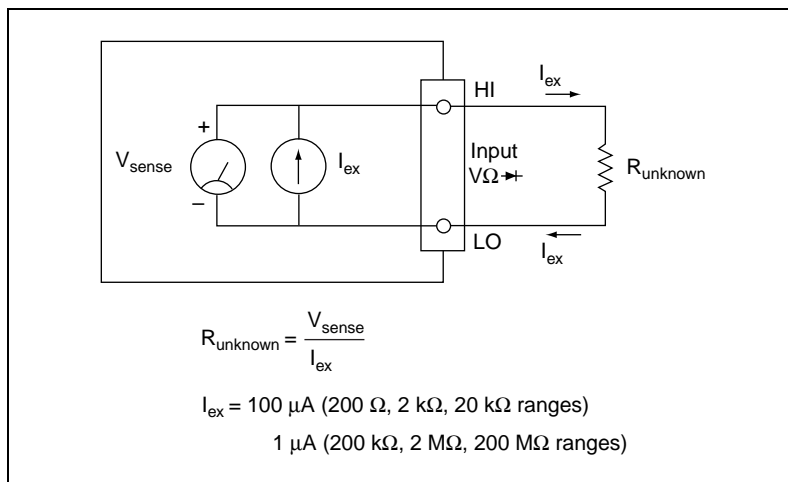


Figure 2-4. Circuit for 2-Wire Resistance Measurements

### Input Ranges

The NI 4050 has five basic input ranges for 2-wire resistance as well as an extended range. The basic ranges are 200  $\Omega$ , 2.0 k $\Omega$ , 20 k $\Omega$ , 200 k $\Omega$ , and 2 M $\Omega$ . With the extended range, measurements up to at least 200 M $\Omega$  are possible.

In the extended ohms range, the NI 4050 adds a  $1\text{ M}\Omega$  resistor in parallel with the test resistor, and then calculates the value of the resistor being tested. The test current for the  $200\ \Omega$ ,  $2.0\ \text{k}\Omega$ , and  $20\ \text{k}\Omega$  ranges is  $100\ \mu\text{A}$ . The test current for the  $200\ \text{k}\Omega$ ,  $2\ \text{M}\Omega$ , and  $200\ \text{M}\Omega$  ranges is  $1\ \mu\text{A}$ .

## Continuity Measurements

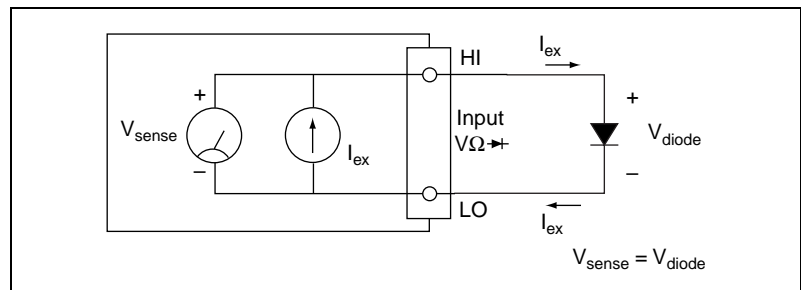
Many traditional multimeters can take continuity measurements, which test for the presence or absence of continuity between the two test probes. These measurements are simply resistance measurements, where the resistance between the two probes is measured and compared to a set value. You can perform continuity measurements on a circuit by setting the NI 4050 to the  $200\ \Omega$  range and comparing the measured value to some low resistance value, typically  $10\ \Omega$ . If the measured value is less than  $10\ \Omega$ , there is continuity between the test probes.

## Diode Measurements

To properly measure the forward voltage of a diode, make sure that the diode is not connected to any other circuits. The NI 4050 biases the diode with a current of  $100\ \mu\text{A}$  and measures the resulting voltage drop, as illustrated in Figure 2-5. Diode measurements are made with a fixed range of  $2.0\ \text{V}$ .



**Note** Different multimeters use different currents to excite the diode. This may result in different readings for the same diode.



**Figure 2-5.** Circuit for Diode Measurements



# Specifications

This appendix lists the specifications of the NI 4050. These specifications are guaranteed between 15 and 35 °C unless otherwise specified.

## DC Voltage

Accuracy (% of reading ± μV)

Range	24 Hour (25 °C ± 1 °C)	90 Day (25 °C ± 10 °C)	1 Year (25° C ± 10 °C)	Temperature Coefficient (% of Reading/ °C ± μV/ °C)
250.000 V	0.0032% ± 4.9 mV	0.021% ± 49 mV	0.024% ± 49 mV	0.0017% ± 4800 μV
25.0000 V	0.0032% ± 4.9 mV	0.021% ± 49 mV	0.024% ± 49 mV	0.0017% ± 4800 μV
2.00000 V	0.0029% ± 37 μV	0.014% ± 260 μV	0.017% ± 260 μV	0.0009% ± 25 μV
200.000 mV	0.0029% ± 27 μV	0.014% ± 250 μV	0.017% ± 250 μV	0.0009% ± 25 μV
20.0000 mV	0.0029% ± 27 μV	0.014% ± 250 μV	0.017% ± 250 μV	0.0009% ± 25 μV

Accuracy numbers are for 5 1/2 digits and include the effects of full-scale and zero-scale errors, temperature variation, linearity, and noise.

## Noise Rejection

NMRR (10 Hz reading rate, 50/60 Hz powerline frequency ±1%)..... 80 dB

DC ECMRR ..... 140 dB (with a 1 kΩ imbalance in LO lead)

AC ECMR (RDC to 60 Hz) ..... 150 dB (with a 1 kΩ imbalance in LO lead)

## Input Characteristics

Input bias current ..... 1 nA max

Input resistance ..... > 1 GΩ (2 V, 200 mV, 20 mV ranges);  
1 MΩ (250 V, 25 V)

## DC Current

Accuracy (% of reading  $\pm \mu\text{A}$ )

DC current measurements require the use of the CSM current shunt modules.

Range	24 Hour (25 °C $\pm$ 1 °C)	90 Day (25 °C $\pm$ 10 °C)	1 Year (25 °C $\pm$ 10 °C)	Temperature Coefficient (% of Reading/ $^{\circ}\text{C} \pm \mu\text{A}/^{\circ}\text{C}$ )
200.000 mA*	0.1% $\pm$ 27 $\mu\text{A}$	0.14% $\pm$ 250 $\mu\text{A}$	0.15% $\pm$ 250 $\mu\text{A}$	0.0035% $\pm$ 25 $\mu\text{A}$
20.0000 mA*	0.1% $\pm$ 27 $\mu\text{A}$	0.14% $\pm$ 250 $\mu\text{A}$	0.15% $\pm$ 250 $\mu\text{A}$	0.0035% $\pm$ 25 $\mu\text{A}$
10.0000 A**	0.02% $\pm$ 4 mA	0.035% $\pm$ 26 mA	0.035% $\pm$ 26 mA	0.007% $\pm$ 2.5 mA

Accuracy numbers are for 5 1/2 digits and include the effects of full-scale and zero-scale errors, temperature variation, linearity, and noise.

\* Requires 200 mA shunt, CSM-200mA.

\*\* Requires 10 A shunt, CSM-10A.

## Input Characteristics

200 mA shunt

Input protection .....Fuse F1 500 mA/250 V fast fusing

Shunt resistor .....1  $\Omega$

Burden voltage.....< 400 mV at 200 mA

10 A shunt

Input protection .....Fuse F1 12.5 A/250 V fast fusing

Shunt resistor .....10 m $\Omega$

Burden voltage.....< 300 mV at 10 A

## AC Voltage

Accuracy (% of reading  $\pm$  mV)

Range	24 Hour (25 °C $\pm$ 1 °C)	90 Day (25 °C $\pm$ 10 °C)	1 Year (25 °C $\pm$ 10 °C)	Temperature Coefficient (% of Reading/ $^{\circ}$ C $\pm$ mV/ $^{\circ}$ C)
250.000 V	0.6% $\pm$ 500 mV	0.62% $\pm$ 680 mV	0.62% $\pm$ 680 mV	0.007% $\pm$ 20 mV
25.0000 V	0.3% $\pm$ 30 mV	0.32% $\pm$ 210 mV	0.32% $\pm$ 210 mV	0.007% $\pm$ 20 mV
2.00000 V	0.4% $\pm$ 3 mV	0.42% $\pm$ 21 mV	0.42% $\pm$ 21 mV	0.019% $\pm$ 2 mV
200.000 mV	0.3% $\pm$ 0.22 mV	0.32% $\pm$ 1.20 mV	0.32% $\pm$ 1.20 mV	0.007% $\pm$ 0.110 mV
20.0000 mV	0.4% $\pm$ 100 $\mu$ V	0.42% $\pm$ 170 $\mu$ V	0.42% $\pm$ 170 $\mu$ V	0.019% $\pm$ 12 $\mu$ V

Accuracy numbers are for 5 1/2 digits and include the effects of full-scale and zero-scale errors, temperature variation, linearity, and noise, applies for sine waves  $\geq$  10% of input range. Accuracy may be affected by source impedance, cable capacitances dielectric absorption, or slew rate.

## Noise Rejection

AC CMRR (DC to 60 Hz)..... > 80 dB (with a 1 k $\Omega$  imbalance in LO lead)

## Input Characteristics

Input resistance ..... 1 M $\Omega$  all ranges

Bandwidth ..... 20 Hz–25 kHz

## Additional AC Errors

Frequency-dependent errors

Input Frequency	Additional Error (% of Reading)
20–50 Hz	2.5%
50–100 Hz	1%
100 Hz–5 kHz	0%
5–10 kHz	1%
10–25 kHz	2.5%

## AC Current

Accuracy (% of reading  $\pm$  mA)

AC current measurements require the use of the CSM current shunt module.

Range	24 Hour (25 °C $\pm$ 1 °C)	90 Day (25 °C $\pm$ 10 °C)	1 Year (25 °C $\pm$ 10 °C)	Temperature Coefficient (% of Reading/°C $\pm$ mA/°C)
200.000 mA*	0.45% $\pm$ 0.22 mA	0.47% $\pm$ 1.2 mA	0.47% $\pm$ 1.2 mA	0.007% $\pm$ 0.110 mA
20.0000 mA*	0.35% $\pm$ 110 $\mu$ A	0.37% $\pm$ 170 $\mu$ A	0.37% $\pm$ 170 $\mu$ A	0.019% $\pm$ 0.120 mA
10.0000 A**	0.3% $\pm$ 22 mA	0.32% $\pm$ 120 mA	0.32% $\pm$ 120 mA	0.026% $\pm$ 11 mA

Accuracy numbers are for 5 1/2 digits and include the effects of full-scale and zero-scale errors, temperature variation, linearity, and noise.

\* Requires 200 mA shunt, CSM-200mA.

\*\* Requires 10 A shunt, CSM-10A.

## Input Characteristics

200 mA shunt

Input protection .....Fuse F1 500 mA/250 V fast fusing

Shunt resistor .....1  $\Omega$

Burden voltage.....< 400 mV at 200 mA

10 A shunt

Input protection .....Fuse F1 12.5 A/250 V fast fusing

Shunt resistor .....10 m $\Omega$

Burden voltage.....< 300 mV at 10 A

## Resistance

Accuracy (% of reading  $\pm \Omega$ )

Range	24 Hour (25 °C $\pm$ 1 °C)	90 Day (25 °C $\pm$ 10 °C)	1 Year (25 °C $\pm$ 10 °C)	Temperature Coefficient (% of Reading/ $^{\circ}$ C $\pm$ $\Omega$ / $^{\circ}$ C)
Extended Ohm ( $>$ 2 M $\Omega$ )	0.1% $\pm$ 6 k $\Omega$	0.1% $\pm$ 60 k $\Omega$	0.1% $\pm$ 60 k $\Omega$	0.0072% $\pm$ 6 k $\Omega$
2.00000 M $\Omega$	0.012% $\pm$ 55 $\Omega$	0.077% $\pm$ 370 $\Omega$	0.080% $\pm$ 20 $\Omega$	0.0072% $\pm$ 35 $\Omega$
200.000 k $\Omega$	0.012% $\pm$ 37 $\Omega$	0.077% $\pm$ 350 $\Omega$	0.080% $\pm$ 2 $\Omega$	0.0072% $\pm$ 35 $\Omega$
20.0000 k $\Omega$	0.006% $\pm$ 0.5 $\Omega$	0.024% $\pm$ 4 $\Omega$	0.027% $\pm$ 4 $\Omega$	0.0020% $\pm$ 0.40 $\Omega$
2.00000 k $\Omega$	0.006% $\pm$ 0.4 $\Omega$	0.024% $\pm$ 4 $\Omega$	0.027% $\pm$ 4 $\Omega$	0.0020% $\pm$ 0.40 $\Omega$
200.000 $\Omega$	0.006% $\pm$ 0.4 $\Omega$	0.024% $\pm$ 4 $\Omega$	0.027% $\pm$ 4 $\Omega$	0.0020% $\pm$ 0.40 $\Omega$

Accuracy numbers are for 5 1/2 digits and include the effects of full-scale and zero-scale errors, temperature variation, linearity, and noise.

Measurement mode ..... 2-wire Ohms

Test current ..... 100  $\mu$ A for 200  $\Omega$ , 2 k $\Omega$ ,  
20 k $\Omega$  ranges  
1  $\mu$ A for 2 M $\Omega$ , 200 k $\Omega$  ranges  
1  $\mu$ A and 1 M $\Omega$  in parallel for  
extended Ohms mode

## Diode Testing

Accuracy (% of reading  $\pm \mu$ V)

Range	24 Hour (25 °C $\pm$ 1 °C)	90 Day (25 °C $\pm$ 10 °C)	1 Year (25 °C $\pm$ 10 °C)	Temperature Coefficient (% of Reading/ $^{\circ}$ C $\pm$ $\mu$ V/ $^{\circ}$ C)
2 V	0.006% $\pm$ 60 $\mu$ V	0.024% $\pm$ 400 $\mu$ V	0.027% $\pm$ 400 $\mu$ V	0.002% $\pm$ 40 $\mu$ V

Accuracy numbers are for 5 1/2 digits and include the effects of full-scale and zero-scale errors, temperature variation, linearity, and noise.

Test current ..... 100  $\mu$ A

## General Specifications

Settling time .....	Affected by source impedance and input signal changes
Warm-up time .....	30 minutes for measurements accurate within specifications
Bus type .....	PCMCIA, slave
Altitude .....	Up to 2,000 m; at higher altitudes the installation category must be derated
Working voltage .....	250 V maximum between either input terminal and earth ground
Power requirement .....	+5 VDC, 45 mA in operational mode
Safety .....	Designed in accordance with IEC 1010-1 and UL 3111 for electrical measuring and testing equipment, Installation Category II, Pollution Degree 2, Double Insulated, Indoor use, UL 3111 listed

## Physical

Dimensions .....	Type II PC Card
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## Environment

Operating temperature .....	0 to 55 °C
Storage temperature .....	-20 to 70 °C
Relative humidity .....	10% to 90% noncondensing



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# 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

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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](http://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, New Zealand 09 914 0488, Norway 32 27 73 00, Poland 0 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 2528 7227, United Kingdom 01635 523545

# Glossary

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

## Numbers/Symbols

%	percent
+	positive of, or plus
-	negative of, or minus
/	per
°	degree
±	plus or minus
$\Omega$	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 with 16 bits has a higher resolution, and thus a higher degree of accuracy, than a 12-bit ADC.
ADE	Application Development Environment
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
aperture time	the period of time over which a measurement is averaged; also called the number of powerline cycles
attenuate	to reduce in magnitude
autozero	technique of internally shorting the internal circuit while disconnecting the measurement to compensate for temperature effects

## **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.
burden voltage	the voltage drop across the input section of the current mode

## **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)

CompactPCI	refers to the core specification defined by the PCI Industrial Computer Manufacturer's Group (PICMG)
conversion device	device that transforms a signal from one form to another. For example, analog-to-digital converters (ADCs) for analog input, digital-to-analog converters (DACs) for analog output, digital input or output ports, and counter/timers are conversion devices.
conversion time	the time required, in an analog input or output system, from the moment a channel is interrogated (such as with a read instruction) to the moment that accurate data is available
coupling	the manner in which a signal is connected from one location to another
CPU	central processing unit
crest factor	the ratio of the peak value of the signal to the RMS value of the signal
CSM	current shunt module

## D

DAQ	data acquisition—(1) collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures and inputting them to a computer for processing; (2) collecting and measuring the same kinds of electrical signals with A/D and/or DIO boards plugged into a computer, and possibly generating control signals with D/A and/or DIO boards in the same computer
dB	decibel—the unit for expressing a logarithmic measure of the ratio of two signal levels: $dB=20\log_{10} V_1/V_2$ , for signals in volts
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 <i>use the current default setting</i> .
device	a plug-in data acquisition board, card, or pad that can contain multiple channels and conversion devices. Plug-in boards, PCMCIA cards, devices such as the DAQPad-1200, which connects to your computer parallel port, are all examples of DAQ devices.

dielectric absorption	a parasitic phenomenon related to capacitors that can cause unexpectedly long settling times in circuits using capacitors with poor dielectric absorption specifications
differential input	an analog input consisting of two terminals, both of which are isolated from computer ground, whose difference is measured
DMM	digital multimeter
DNL	differential nonlinearity—a measure in LSB of the worst-case deviation of code widths from their ideal value of 1 LSB
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

ECMR	Effective Common Mode Rejection—a measure of an instrument's ability to reject interference from a common-mode signal. This includes both the effects of normal mode rejection and common mode rejection.
EEPROM	electrically erasable programmable read-only memory—ROM that can be erased with an electrical signal and reprogrammed
EXT TRIG IN	external trigger input signal

## F

F	farads
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
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**H**

harmonics	multiples of the fundamental frequency of a signal
half-power bandwidth	the frequency range over which a circuit maintains a level of at least $-3$ dB with respect to the maximum level
hardware	the physical components of a computer system, such as the circuit boards, plug-in boards, chassis, enclosures, peripherals, cables, and so on
Hz	hertz—per second, as in cycles per second or samples per second

**I**

$I_{\text{ex}}$	excitation current
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
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
Installation Category (Overvoltage Category)	classification system for expected transients on electrical supply installations
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
isolation	a type of signal conditioning in which you isolate the transducer signals from the computer for safety purposes. This protects you and your computer from large voltage spikes and makes sure the measurements from the DAQ device are not affected by differences in ground potentials.
isolation voltage	the voltage that an isolated circuit can normally withstand, usually specified from input to input and/or from any input to the amplifier output, or to the computer bus

## M

m	meters
MB	megabytes of memory

## N

NI-DAQ	National Instruments driver software for DAQ hardware.
NMRR	normal mode rejection ratio—a measure of an instrument's ability to reject a signal applied directly to the differential inputs of the instrument
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

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

range error an error in accuracy that is determined by the input range that is selected. The range error is independent of the value of the signal being measured.

reading error an error in accuracy that is determined by the input range, as well as the value being measured

reading rate the rate at which a new measurement is taken. In addition to the measurement speed, the selection of the reading rate affects the filtering, and thus the noise level, of measurements.

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

$R_{\text{sense}}$  the sense resistor. The voltage across this resistor is measured and converted to a current.

## 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. <i>See also</i> thermal drift
thermal drift	measurements that change as the temperature varies
thermoelectric potentials	<i>See</i> thermal EMFs
thermal EMFs	thermal electromotive forces—voltages generated at the junctions of dissimilar metals that are functions of temperature. Also called thermoelectric potentials.
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

## U

UL	Underwriters Laboratory
----	-------------------------

**V**

V	volts
VAC	volts alternating current
VDC	volts direct current
$V_{\text{error}}$	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
VMC	voltmeter complete signal
$V_{\text{rms}}$	volts, root mean square value
$V_{\text{sense}}$	the voltage that is created across the device under test when excited by a current

**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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