Computer-Based Instruments

NI 4060 User Manual

Digital Multimeter for PCI and PXI/CompactPCI

NATIONAL INSTRUMENTS™

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Compliance

FCC/Canada Radio Frequency Interference Compliance*

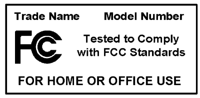
Determining FCC Class

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.

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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

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»Substitute Fonts** directs you to pull down the **File** menu, select the **Page Setup** item, select **Options**, and finally select the **Substitute Fonts** options from the last dialog box.
	This icon to the left of bold italicized text denotes a note, which alerts you to important information.
	This icon to the left of bold italicized text denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash.
	This icon to the left of bold italicized text denotes a warning, which advises you of precautions to take to avoid being electrically shocked.
bold	Bold text denotes the names of menus, menu items, parameters, dialog boxes, dialog box buttons or options, icons, windows, Windows 95 tabs, or LEDs.
bold italic	Bold italic text denotes a note, caution, or warning.
italic	Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text from which you supply the appropriate word or value, as in Windows 3.*x*.
NI 4060	Refers to either of the devices in the NI 4060 family—NI 4060 for PCI or NI 4060 for PXI.

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1

Taking Measurements with the NI 4060

Thank you for buying a National Instruments 4060 digital multimeter. A system based on the NI 4060 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 4060, 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` for free downloads.

Detailed specifications for the NI 4060 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 4060 Operation*, covers the safety guidelines for your NI 4060.

Connecting Signals

Figure 1-1 shows the front panels for the NI 4060 device. These front panels contain five connectors—four banana jacks and one 9-pin mini circular DIN connector.

The four banana jack connectors are high-voltage, safety signal connectors. The 9-pin mini circular DIN connector labeled AUX I/O is a digital signal connector, which carries TTL-level triggering signals for use with external scanning equipment. Scanning is discussed in Chapter 2, *NI 4060 Operation*.

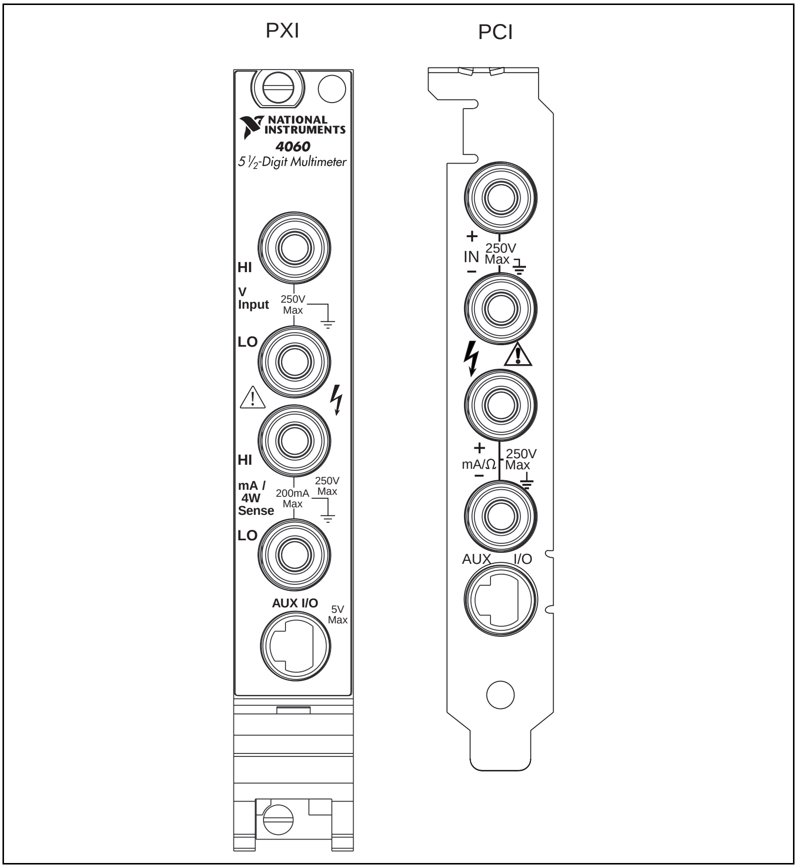


Figure 1-1. Connectors on the NI 4060 Family of Products

Cable and Probes

The NI 4060 kit contains a pair of test probes with safety banana plugs. These probes meet international safety requirements, including UL 3111 and IEC 1010-1, for the full range of applications supported by the NI 4060. 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 4060, connect the test probes to the NI 4060 via safety 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_{rms} and 42 V_{pk}, or 60 VDC.

Caution To prevent possible safety hazards, the maximum voltage between either of the inputs and the ground of the computer should never exceed ±300 VDC or 300 V_{rms}. The maximum current that can be measured between the current inputs is ±200 mA DC or 200 mA_{rms}.

Introduction to the VirtualBench-DMM Soft Front Panel

The following sections explain how to make connections to your NI 4060 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**.

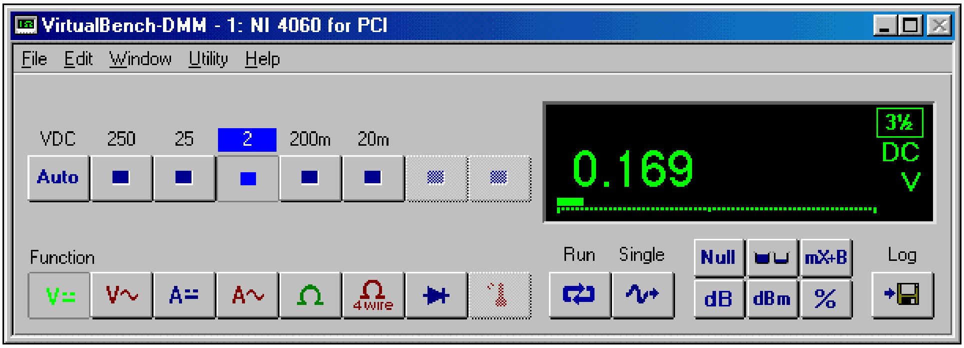
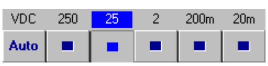


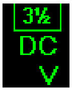
Figure 1-2. NI-DMM Soft Front Panel

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

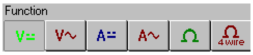


The range selector determines the range of measurements VirtualBench-DMM makes. The range differs for each measurement mode. If the measurement exceeds the range, +OVER or –OVER appears in the measurement display. **Auto** selects the range that best matches the input signal.

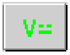
The value indicator displays the value measured by your NI 4060 (The value shown is an example only.).



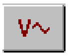
The unit indicator displays the measurement units of the value you are measuring. The units are expressed as VAC, VDC, mVAC, mVDC, Ω, kΩ, MΩ, mA, AC, or mA DC. The indicator also displays the digits of resolution, and by clicking on the indicator, you can select the resolution.



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.

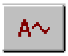


DC volts measures the DC component of a voltage signal.

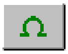


AC volts measures the AC component of a voltage signal.

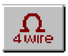
DC current measures the DC component of a current source.



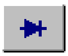
AC current measures the AC component of a current source.



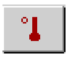
2-wire measures resistance using the 2-wire method.



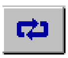
4-wire measures resistance using the 4-wire method.



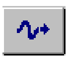
Diode measures the voltage drop across a diode. The maximum voltage VirtualBench-DMM measures is 2 V.



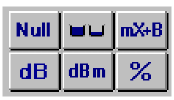
Temperature measures temperature.



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.

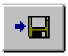
Max/Min displays the maximum and minimum values that occur after you start Relative mode.

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.

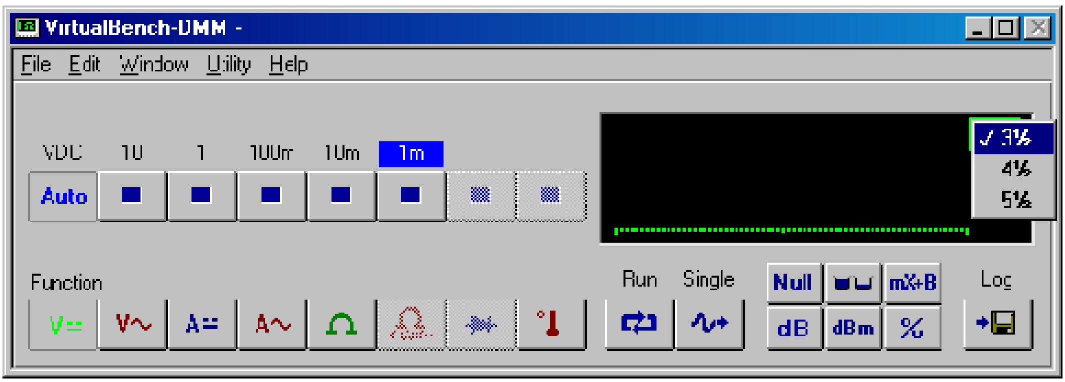


Figure 1-3. Digits of Precision

Use the Soft Front Panel

The following sections describe procedures for measuring DC and AC voltage; 2-wire and 4-wire resistance; DC and AC current; diode; and temperature using the soft front panel. Figures 1-4 through 1-9 depict the NI 4060 for PXI; the same connections apply for all NI 4060 devices.

Measure DC and AC Voltage

This section gives the procedures for measuring DC and AC voltage using the soft front panel.

1. Connect your signal to the top terminal pair, as shown in Figure 1-4. For DC voltages, the HI (red) input terminal is positive and the LO (black) input terminal is negative. For AC voltages, positive and negative terms are irrelevant.

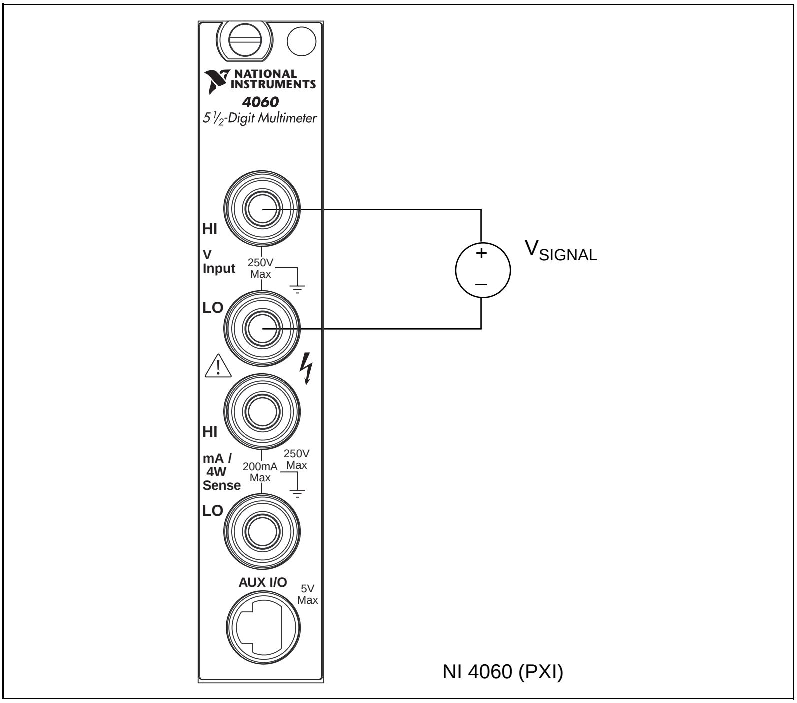
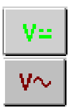
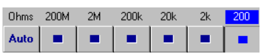


Figure 1-4. Connecting Signals for Voltage Measurements



2. Select the mode you will measure:
   - DC Volts
   - AC Volts



3. Select the range for your measurement or autoranging:
   - DC Volts—± 20 mV, ± 200 mV, ± 2 V, ± 25 V, and ± 250 V
   - AC Volts—20 mV_{rms}, 200 mV_{rms}, 2 V_{rms}, 25 V_{rms}, and 250 V_{rms}

The value indicator displays the voltage measured.

Measure 2-Wire Resistance

This section gives the procedure for measuring 2-wire resistance using the soft front panel:

1. Connect the signal to the top terminal pair, as shown in Figure 1-5.

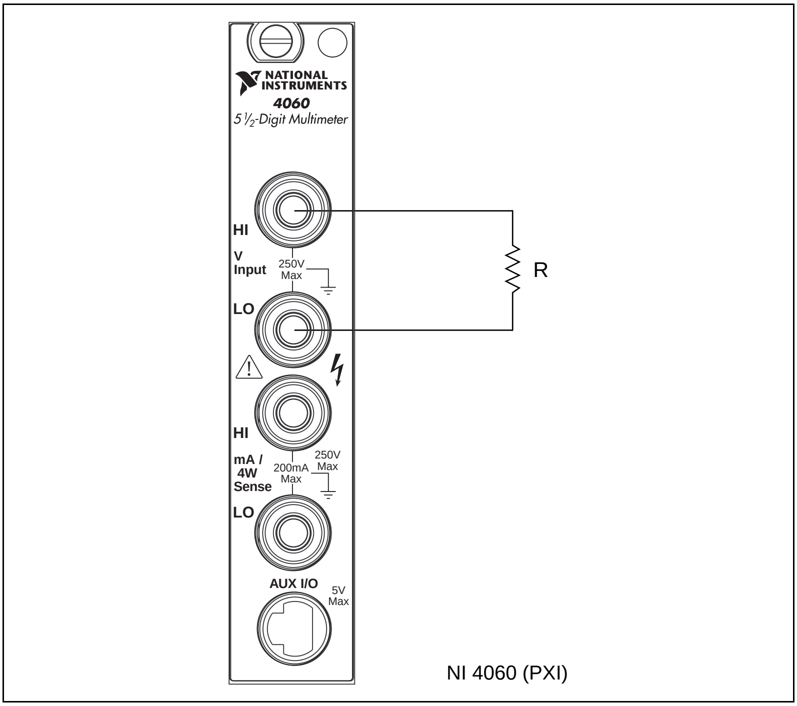
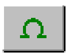
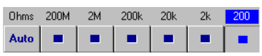


Figure 1-5. Connecting Signals for 2-Wire Resistance



2. Select 2-wire resistance mode.



3. Select the range for your measurement—200 Ω, 2 kΩ, 20 kΩ, 200 kΩ, 2 MΩ, 200 MΩ, or autorange.

The value indicator indicates the resistance measured. See the *2-Wire Resistance Measurements* section of Chapter 2, *NI 4060 Operation*, for more information on 2-wire resistance measurements.

Measure 4-Wire Resistance

4-wire resistance measurements use both pairs of terminals. This configuration allows you to measure low resistances accurately by eliminating the effects of lead resistance. This section gives the procedures for measuring 4-wire resistance using the soft front panel.

1. Connect the top signal pair to the top pair of banana jack connectors.
2. Connect the bottom signal pair to the bottom pair of banana jack connectors.

   These connections are shown in Figure 1-6.

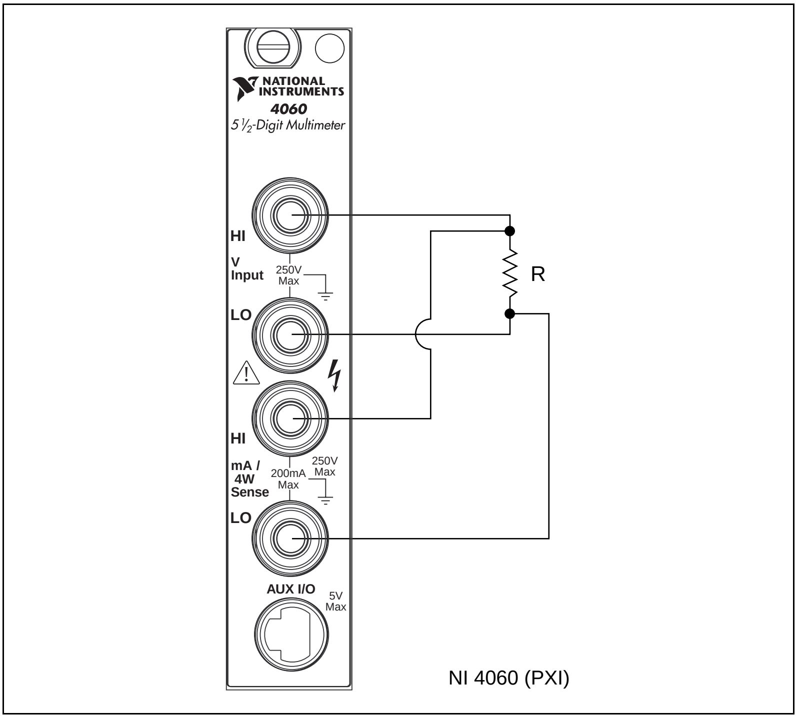
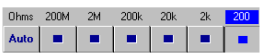


Figure 1-6. Connecting Signals for 4-Wire Resistance

3. Select 4-wire resistance mode.



4. Select the range for your measurement—200 Ω, 2 kΩ, 20 kΩ, 200 kΩ, 2 M, or autorange.

The value indicator indicates the resistance measured. See the *4-Wire Resistance Measurements* section of Chapter 2, *NI 4060 Operation*, for more information on 4-wire resistance measurements.

Measure DC and AC Current

This section gives the procedures for measuring DC and AC current using the soft front panel.

1. Connect the signal to the bottom terminal pair, as shown in Figure 1-7. The HI (red) input terminal is positive, and the LO (black) input terminal is negative.

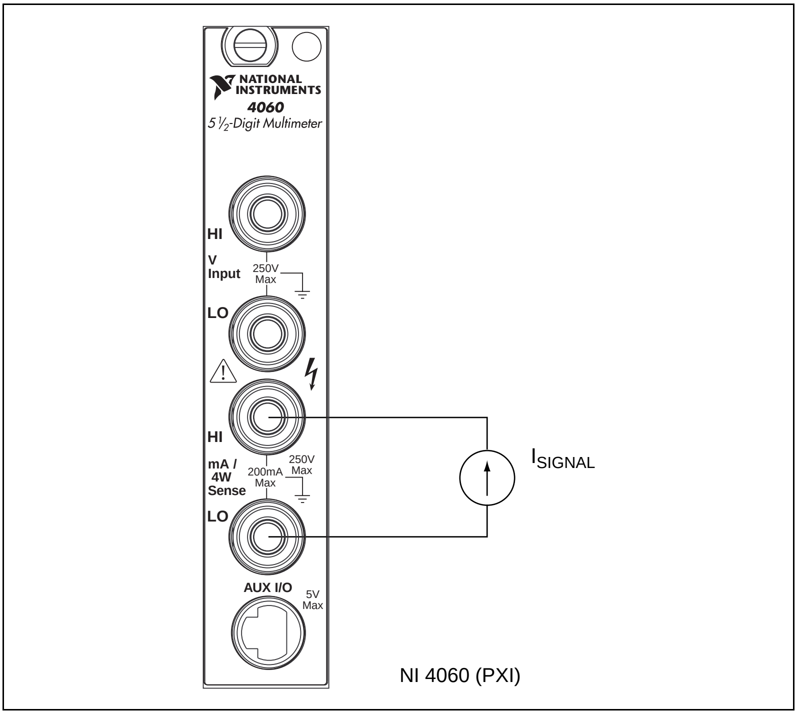
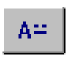
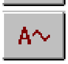


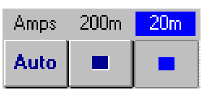
Figure 1-7. Connecting Signals for Current Measurement

2. Select the mode you will measure:





   - Amps DC
   - Amps AC



3. Select the range for your measurement or autoranging. The NI 4060 has two input ranges available for measuring DC current: ± 20 mA and ± 200 mA. The NI 4060 also has two input ranges available for measuring AC current: 20 mA_{rms} and 200 mA_{rms}.

For 10 A range (with external shunt, CSM-10A), the DMM must operate in voltage mode to be able to read the voltage drop across the shunt.

The value indicator indicates the current measured.

Measure the Voltage Drop Across a Diode

The NI 4060 can excite a device under test and read the resulting voltage drop. Diode mode is useful for testing diodes. Voltage up to 2 V can be measured in this mode.

1. Connect the signal to the top terminal pair, as shown in Figure 1-8.

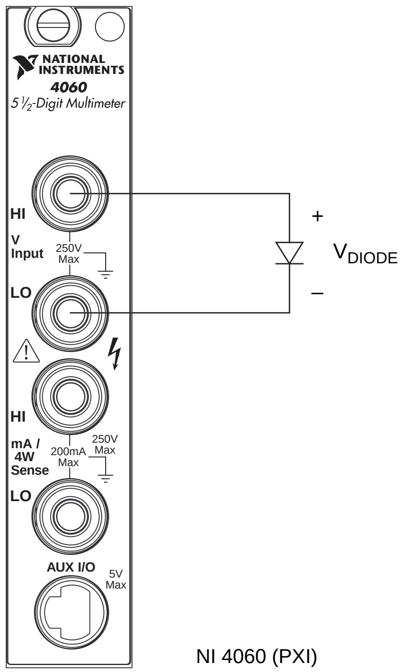


Figure 1-8. Connecting Signals for Diode Test

2. Select diode mode.

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

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 4060 Operation*, for more information on diode measurements.

Measure Temperature

You can measure temperature using common temperature transducers such as resistive temperature devices (RTD) and thermistors. You can measure resistive transducers in the 2-wire resistance mode, as shown in Figure 1-9.

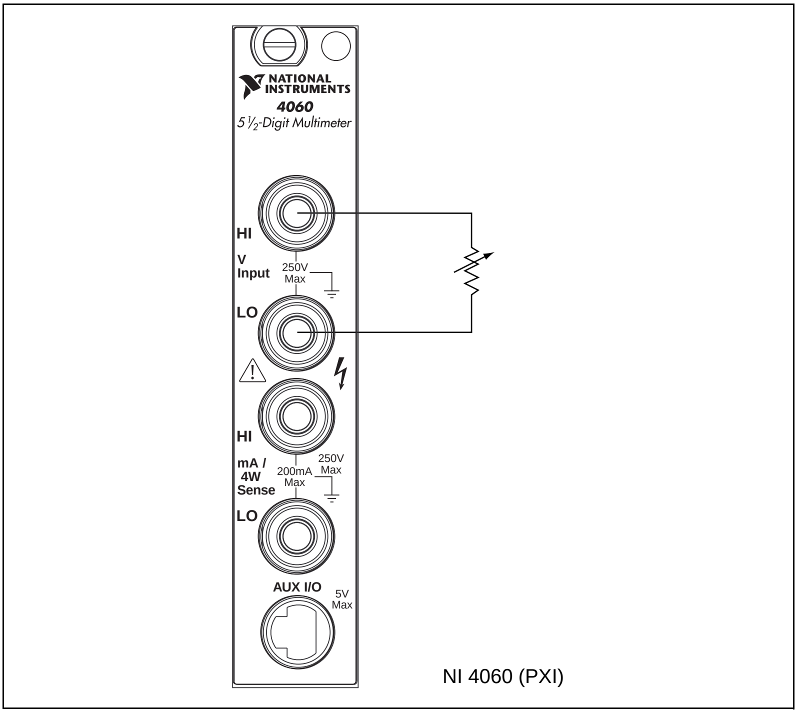


Figure 1-9. Connecting Signals for RTDs and Thermistors.

Although the soft front panel does not support automatic conversion to temperature, you can include this mathematical operation in the program you will write in your Application Development Environment (ADE), such as LabVIEW or LabWindows/CVI, convert and scale the transducers' value to temperature programmatically through software.

You can also measure the devices in 4-wire resistance mode to eliminate the effects of lead resistance, as shown in Figure 1-6.

2

NI 4060 Operation

This chapter contains safety instructions; measurement fundamentals and considerations; and scanning information.

Safety Instructions

⚠ **Caution** To avoid personal injury or damage to electronic equipment, observe the following cautions:

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.

To prevent safety hazards, the maximum voltage between either of the inputs and the ground of the computer should *never* exceed ±300 VDC or 300 V_{rms}.

The NI 4060 must be used in a NRTL-listed chassis or personal computer.

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 4060 can create a shock or fire hazard or can damage any or all of the devices connected to the NI 4060. 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

Warm Up

The required warm-up time for the NI 4060 is 30 minutes. This warm-up time is important because measurements made with the NI 4060 multimeter can change with temperature. This change is called a thermal drift and is influenced by temperature coefficients. To minimize the effects of thermal drift and ensure the specified accuracies, take all measurements after the NI 4060 has had a chance to fully warm up. Depending on your environment, the NI 4060 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 4060 temperature coefficient specifications are listed in the *Accuracy* sections in Appendix A, *Specifications*.

Selecting the Resolution

The resolution on the NI 4060 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.

Autozeroing

Autozeroing is a technique that removes the effect of temperature drift on the measurement accuracy. Autozeroing disconnects the external signals from the circuit, internally shorts the input of the NI 4060, and takes a measurement. Ideally, this value should be zero, but real components can cause an offset from zero to occur. By measuring the value with the input leads internally shorted, autozeroing automatically eliminates this error. Autozeroing is not supported in AC voltage, AC current, and diode modes. Autozeroing reduces the reading rate of your measurements by approximately 50%.

Grounding

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

Voltage Measurements

DC Voltage

Your NI 4060 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 4060 uses a digital filter, which heavily rejects powerline frequencies (50–60 Hz) and their harmonics, as well as high frequency noise.

Input Ranges

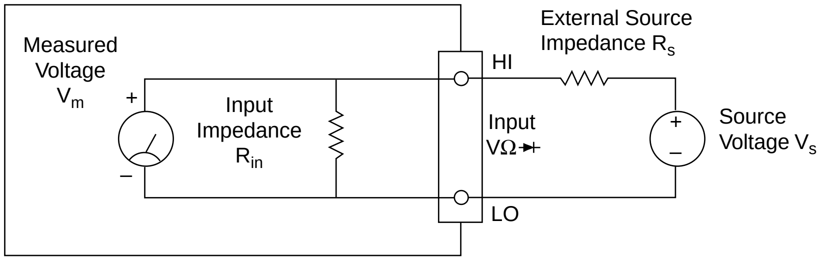
The NI 4060 has five input ranges available for measuring DC voltages. These ranges are ±20 mV, ±200 mV, ±2.0 V, ±25V, and ±250 V. Each range has a 10% overrange. The 250 V range can overrange to 300 V. The 250 V and 25 V input ranges have a 1 MΩ input impedance; the 2 V, 200 mV, and 20 mV ranges have an input impedance greater than 1 GΩ. Take these values into consideration when measuring high-impedance sources. When the NI 4060 is powered off, the 250 V and 25 V input range have a 1 MΩ input impedance and the 2 V, 200 mV, and 20 mV ranges have an input impedance of 100 kΩ.

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 4060 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 4060 in software. Since R_{in} is large, at least 1 MΩ, it will require a large source impedance, R_s, to cause a large change in the measured voltage, V_m.



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

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.

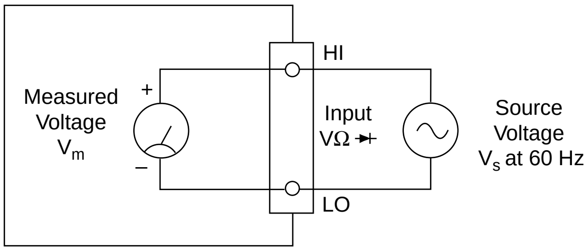
Noise Rejection

The NI 4060 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 4060 may exhibit additional errors. To minimize these errors, keep the NI 4060 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 NI 4060's ability 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 4060 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 4060 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.



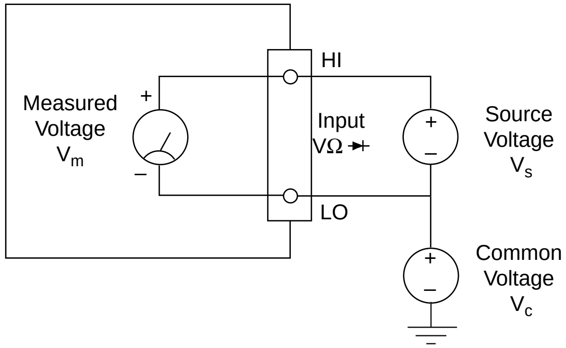
$$V_m = V_s \times 10^{\left(\frac{-NMRR}{20}\right)}$$

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 NI 4060's ability 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 4060 should have an infinite CMRR. Parasitic resistances and capacitances to earth ground limit the CMR of the NI 4060. This effect is most noticeable when measuring small signals in the presence of a large common mode voltage, as shown in Figure 2-3.



$$V_{error} = \left(\frac{V_s}{2} + V_c\right) \times 10^{\left(\frac{-CMRR}{20}\right)}$$

$$V_m = V_s + V_{error}$$

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 4060 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 4060 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 4060 has five input ranges available for measuring AC voltages. These ranges are 20 mV_{rms}, 200 mV_{rms}, 2.0 V_{rms}, 25 V_{rms}, and 250 V_{rms}. The impedance in each of these ranges is a 0.068 µF capacitor followed by 1 MΩ. When the NI 4060 is powered off, the 250 V, 25 V, and 2 V input ranges have a 0.068 µF capacitor, followed by a 1 MΩ input impedance. The 200 mV and 20 mV ranges have a 0.068 µF capacitor, followed by an approximate 100 kΩ input impedance.

The NI 4060 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 has a 10% overrange. The 250 VAC range can overrange up to 300 V.

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 4060 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 try to choose an input range that keeps the measured voltage between 10% and 100% of full scale.

Frequency Response

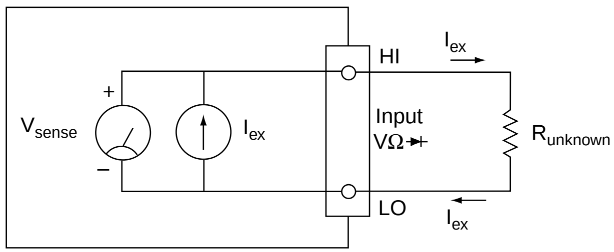
The accuracy of the NI 4060's AC voltage measurements is a function of the input signal frequency. Your NI 4060 is calibrated at the factory using a 60 Hz sine wave. Your frequency-dependent error will be minimal around this frequency. The error will then increase as you approach the upper and lower 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 4060 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 4060 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.



$$R_{unknown} = \frac{V_{sense}}{I_{ex}}$$

I_{ex} = 100 μA (200 Ω, 2 kΩ, 20 kΩ ranges)

1 μA (200 kΩ, 2 MΩ, 200 MΩ ranges)

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

Input Ranges

The NI 4060 has five basic input ranges for 2-wire resistance as well as an extended range. The basic ranges are 200 Ω, 2.0 kΩ, 20 kΩ, 200 kΩ, and 2 MΩ. With the extended range, measurements up to at least 200 MΩ are possible.

In the extended ohms range, the NI 4060 adds a 1 MΩ resistor in parallel with the test resistor, and then calculates the value of the resistor being tested. The test current for the 200 Ω, 2.0 kΩ, and 20 kΩ ranges is 100 µA. The test current for the 200 kΩ, 2 MΩ, and 200 MΩ ranges is 1 µA.

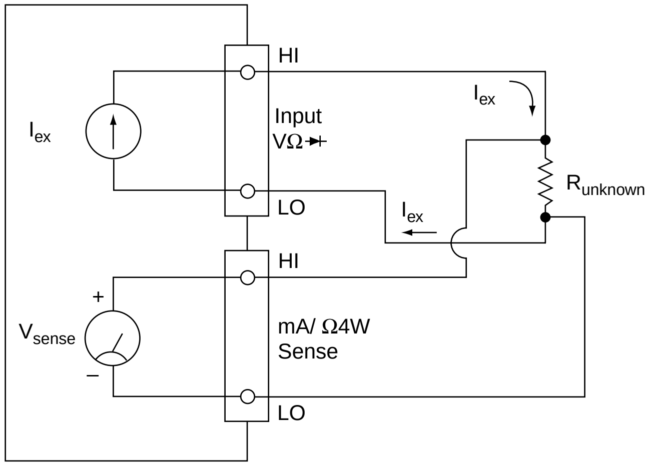
Continuity Measurements

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 4060 to the 200 Ω range and comparing the measured value to some low resistance value, typically 10 Ω. If the measured value is less than 10 Ω, there is continuity between the test probes.

4-Wire Resistance Measurements

4-wire resistance measurements work using a similar principle as 2-wire resistance measurements. However, the 4-wire method is more accurate when measuring small resistances (< 100 Ω).

4-wire resistance measurements separate the current excitation leads from the voltage sense leads. This method allows the test currents to flow through the device under test while allowing a separate path for the voltage drop to be sensed as illustrated in Figure 2-5. The only drawback is that the 2-wire ohms method doubles the number of connections for a resistance measurement.



$$R_{unknown} = \frac{V_{sense}}{I_{ex}}$$

I_{ex} = 100 µA (200 Ω, 2 kΩ, 20 kΩ ranges)
1 µA (200 kΩ, 2 MΩ ranges)

Figure 2-5. Circuit for 4-Wire Measurements

Figure 2-5 illustrates the different paths for the excitation current and the sense voltage. The sense leads should be connected as close as possible to the device to be measured. Any extra lead length between the actual device to be measured and the sense leads will add error to the measurement.

Input Ranges

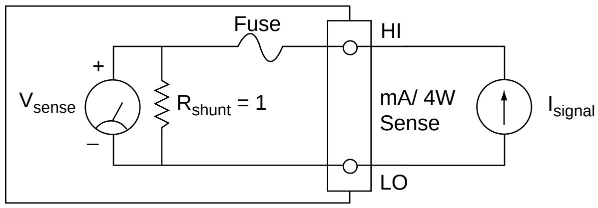
The NI 4060 has five input ranges for 4-wire resistance: 200 Ω, 2.0 kΩ, 20 kΩ, 200 kΩ, and 2 MΩ. Extended ohms range is not supported in the 4-wire configuration.

Current Measurements

DC Current

The NI 4060 uses the same input circuitry to measure current as it does DC voltage, with the exception that it switches in a 1 Ω current shunt in parallel with the input. Figure 2-6 illustrates how DC current measurements are made.

The current shunt is protected by a 500 mA/250 V fast-acting fuse. Refer to Appendix B, *Fuse Replacement*, for instructions on replacing this fuse.



$$I_{signal} = \frac{V_{sense}}{R_{shunt}}$$

$$R_{shunt} = 1\ \Omega$$

Figure 2-6. Circuit for Current Measurements

Input Ranges

The NI 4060 has two input ranges for DC current: ± 200 mA and ± 20 mA. Overranging allows you to measure an additional 10% of your current range. You can measure larger currents using an optional external shunt accessory such as the CSM-10A current shunt, available from National Instruments, or a third-party shunt. With the CSM-10A current shunt, you can measure currents up to 10 A.

To take measurements using an external shunt, set the voltmeter to DC voltage. Using the value of the resistor, the resulting voltage measured can be scaled and converted to current in software.

AC Current

The NI 4060 uses the same input circuitry to measure AC current as it does AC voltage, with the exception that it switches in the same 1 Ω current shunt used in the DC current mode in parallel with the input. The current shunt is protected by a 500 mA/250 V fast-acting fuse. Refer to Appendix B, *Fuse Replacement*, for instructions on replacing this fuse.

Input Ranges

The NI 4060 has two input ranges for AC current: 200 mA_{rms} and 20 mA_{rms}. Overranging allows you to measure an additional 10% of your current range.

You can measure larger currents using an optional external shunt accessory such as the CSM-10A current shunt available from National Instruments, or a third-party shunt. You can take measurements using an external shunt by setting the voltmeter to AC voltage. Using the value of the resistor, you can scale and convert the resulting voltage measured to current in software.

Measurement Considerations

Burden Voltage

To measure current, the current must pass through a resistance. While the shunt resistance is where the actual current is being sensed, the current will experience other voltage drops such as the lead resistance and the fuse resistance. These voltage drops add up to the burden voltage, as shown in Figure 2-7.

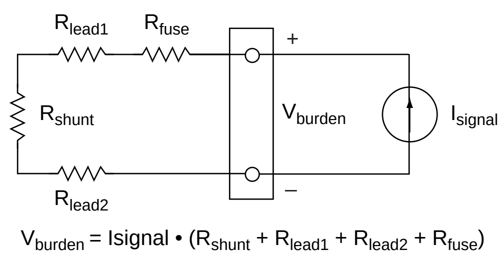


Figure 2-7. Effect of Burden Voltage on Current Measurements

Resistor Heating

Larger current measurements can heat the current shunt resistor and cause it to drift. This should not present a problem because the maximum current range is relatively small compared with the shunt power rating and because the current shunt has an excellent temperature coefficient of resistance. However, you should consider this when measuring larger currents over a long period of time.

Errors in AC Current Measurements

The additional errors that apply for AC voltage also apply for AC current. Resistor heating and burden apply in the same manner as they apply in DC current measurements mentioned above. Burden voltage can actually be increased due to the inductance in the measurement path.

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 4060 biases the diode with a current of 100 µA and measures the resulting voltage drop, as illustrated in Figure 2-8. Diode measurements are made with a fixed range of 2.0 V.

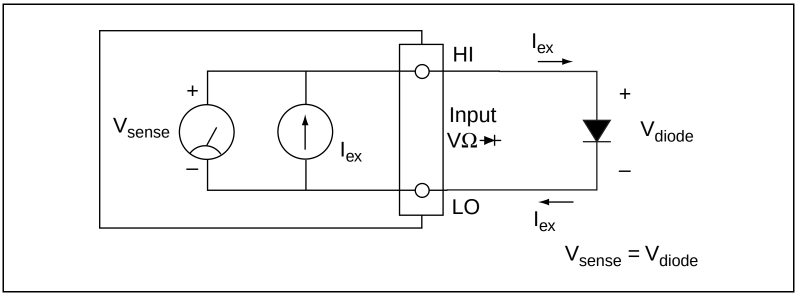


Figure 2-8. Circuit for Diode Measurements

Scanning

You can use the NI 4060 with National Instruments multiplexers as well as third-party multiplexers that use traditional voltmeter signaling.

Traditional voltmeter signaling is a handshake protocol. In this protocol, the voltmeter starts a measurement when a trigger pulse occurs on its EXT TRIG IN line, and emits a digital pulse on the voltmeter complete (VMC) line when it finishes taking a measurement.

AUX I/O Connector and Optional Trigger Cables

This 9-pin mini DIN connector is on the front panel of your NI 4060.

Warning This connection is not isolated. It is *not* referenced to your measurement circuit. It is referenced to the ground of your computer. The digital signals on this connector should not operate beyond -0.5 to 5.5 V of your computer ground. The trigger signals are TTL-compatible.

Using the optional triggering cable available for purchase for the NI 4060, you can break out the trigger signals to two female BNC connectors, as shown in Figure 2-9.

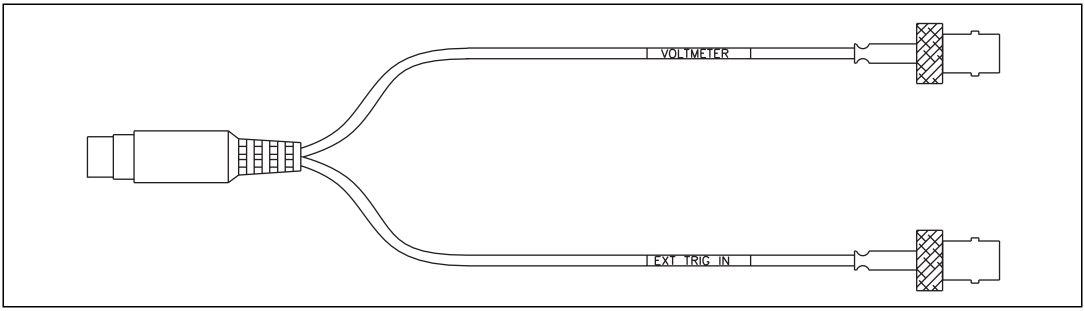


Figure 2-9. Auxiliary Trigger Cable (SH9MD-2BNC)

Scanning Communication Methods

The NI 4060 controls scanning through two methods: handshaking and synchronous.

Handshaking Mode

In handshaking mode, the voltmeter emits a digital pulse on the VMC line when it finishes taking a measurement on one channel of the multiplexer. This pulse causes the multiplexer to advance to the next channel. When the analog circuitry of the multiplexer has settled, the multiplexer emits a digital pulse on the EXT TRIG IN line. When the NI 4060 receives this pulse, it takes another measurement. Figure 2-10 illustrates the hardware configuration for scanning using this method.

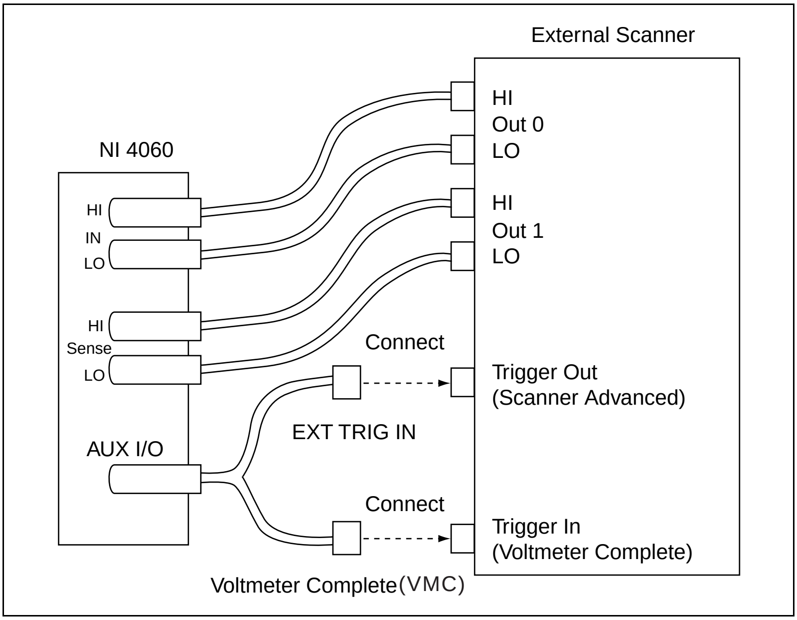


Figure 2-10. Hardware Connections to an External Multiplexer in Handshaking Mode

Figure 2-11 depicts the VMC waveform that is generated by the NI 4060 and shows the specifications for the EXT TRIG IN waveform. The measurement time is not a physical signal; it illustrates how the measurement can be delayed from the trigger.

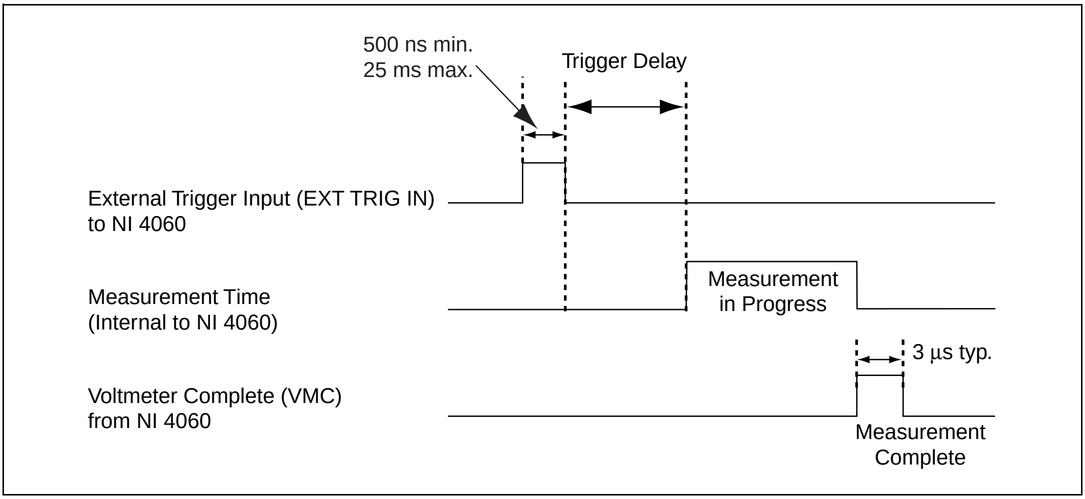


Figure 2-11. Handshaking Mode Trigger Timing

The polarities shown in Figure 2-11 are for illustration only and are programmable via the instrument driver. The trigger delay time is also user-configurable via the instrument driver. Its defaults are set to allow the NI 4060 to settle to the new input value after the external multiplexer changes channels.

Synchronous Mode

In synchronous mode, the voltmeter emits a digital pulse on the VMC line when it finishes taking a measurement. This pulse causes the multiplexer to advance to the next channel. After a programmable delay has occurred, the voltmeter takes another measurement without requiring an external trigger. This delay allows the external multiplexer and NI 4060 to settle to the new channel. This method allows you to use multiplexers that do not have the capability to trigger the NI 4060. Figure 2-12 illustrates the hardware configuration for scanning using this method.

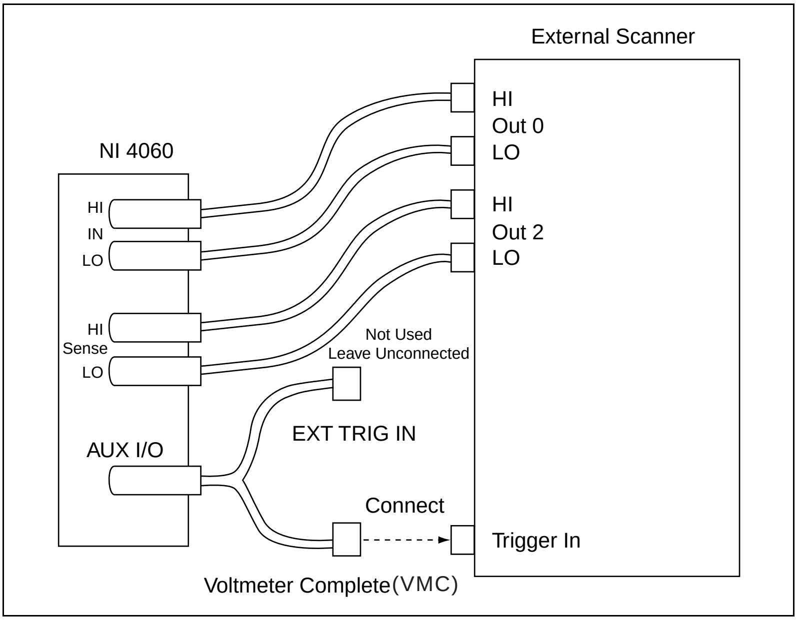


Figure 2-12. Hardware Connections to an External Multiplexer in Synchronous Mode

Figure 2-13 depicts the VMC waveform that is generated by the NI 4060. The measurement time is not a physical signal; it illustrates how the measurement can be delayed from the trigger. The polarities on the timing diagram are for illustration only; they are programmable via the instrument driver. The trigger delay time is also user-configurable via the instrument driver. Its defaults are set to allow the NI 4060 to settle to the new input value after the external multiplexer changes channels, because there is no way for the NI 4060 to know when the external multiplexer has settled. You can use the trigger delay to add additional delay to compensate for the multiplexer setting time.

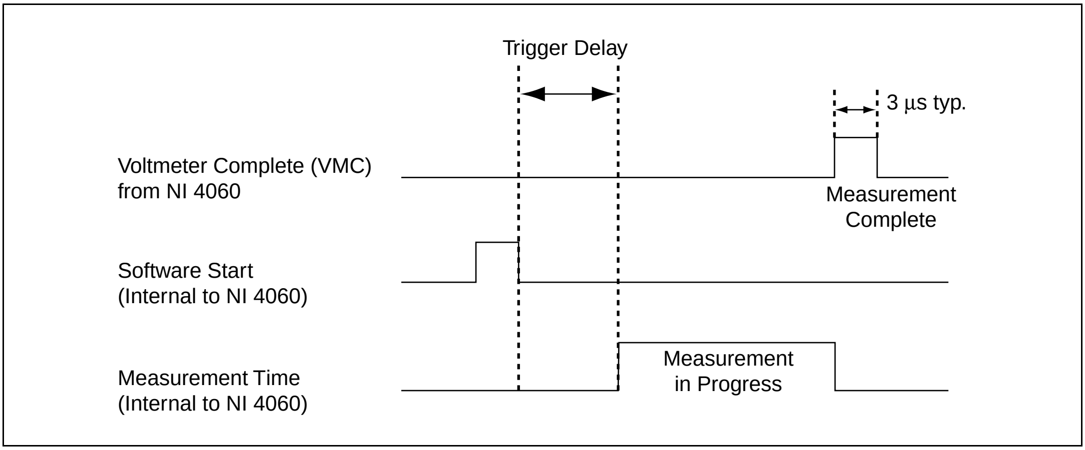


Figure 2-13. Synchronous Mode Trigger Timing

Measurement Considerations

Settling Time

Settling time is the time required for a measurement system to stabilize after an input change before that input can be measured accurately. Take care when trying to measure rapidly changing inputs. The NI 4060 settling time is dictated by the measurement range, cable properties, source impedance, and change in input level. The cable used should be short, have low dielectric absorption, and minimal capacitance—Teflon cable is recommended. Your source should have a low output impedance. Settling time becomes especially important in scanning systems. The scanner or multiplexer requires an additional settling time before the measurement can be taken. The NI 4060 software allows for a programmable delay between channels so that both the multimeter and the multiplexer can settle.

Mode and Range Changes

When you change the DMM mode or range, an additional default delay time is inserted before the first measurement. This delay time varies with the digit of resolution, range, and mode selected.

Relay Life

When you use the NI 4060 with an external multiplexer, take care in designing the signal groupings. The internal mode and range changes occur through electromechanical relays. As with any electromechanical device, the relays are subject to wear. A good practice is to group signals according to mode to limit the number of mode changes the NI 4060 must cycle through, thus extending the component's life.

A

Specifications

This appendix lists the specifications of the NI 4060. 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% ± 1.25 mV	0.021% ± 1.25 mV	0.024% ± 1.25 mV	0.0017% ± 480 µV
25.0000 V	0.0032% ± 1 mV	0.021% ± 1 mV	0.024% ± 1 mV	0.0017% ± 480 µV
2.00000 V	0.0029% ± 10 µV	0.014% ± 10 µV	0.017% ± 10 µV	0.0009% ± 5 µV
200.000 mV	0.0029% ± 6 µV	0.014% ± 6 µV	0.017% ± 6 µV	0.0009% ± 1 µV
20.0000 mV	0.0029% ± 6 µV	0.014% ± 6 µV	0.017% ± 6 µV	0.0009% ± 1 µV
Accuracy numbers are for 5 1/2 digits with autozero on and include the effects of full-scale and zero-scale errors, temperature variation, linearity, and noise. *The NI 4060 can overrange to 300 V.				

Noise Rejection

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

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

AC ECMR (RDC to 50/60 Hz)
(with a 1 kΩ imbalance in HI lead)........ 150 dB

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 ± µA)

Range	24 Hour (25 °C ± 1 °C)	90 Day (25 °C ± 10 °C)	1 Year (25 °C ± 10 °C)	Temperature Coefficient (% of reading/ °C ± µA/ °C)
20.0000 mA	0.015% ± 10 µA	0.039% ± 10 µA	0.042% ± 10 µA	0.0035% ± 1 µA
200.000 mA	0.015% ± 10 µA	0.039% ± 10 µA	0.042% ± 10 µA	0.0035% ± 1 µA
10.000 A*	0.11% ± 1 mA	0.035% ± 2 mA	0.0035% ± 2 mA	0.007% ± 0.1 mA
Accuracy numbers are for 5 1/2 digits with autozero on and include the effects of full-scale and zero-scale errors, temperature variation, linerarity, and noise. *Requires 10 A shunt, CSM-10A.				

Input Characteristics

Maximum input ....200 mA/250 V

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

Shunt resistor ....1 Ω

Burden voltage..< 400 mV at 200 mA DC

AC Voltage

Accuracy

(% of reading ± mV)

Range	24 Hour (25 °C ± 1 °C)	90 Day (25 °C ± 10 °C)	1 Year (25 °C ± 10 °C)	Temperature Coefficient (% of reading/ °C ± mV/ °C)
250.000 V*	0.6% ± 250 mV	0.62% ± 680 mV	0.62% ± 680 mV	0.007% ± 20 mV
25.0000 V	0.16% ± 30 mV	0.18% ± 210 mV	0.18% ± 210 mV	0.007% ± 20 mV
2.00000 V	0.28% ± 3 mV	0.30% ± 21 mV	0.30% ± 21 mV	0.019% ± 2 mV
200.000 mV	0.16% ± 0.22 mV	0.18% ± 1.20 mV	0.18% ± 1.20 mV	0.007% ± 0.110 mV
20.0000 mV	0.28% ± 100 µV	0.30% ± 170 µV	0.30% ± 170 µV	0.019% ± 12 µV

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

*The NI 4060 can overrange to 300 V.

Noise Rejection

AC CMRR at 50/60 Hz
(with a 1 kΩ imbalance in HI lead)........ > 80 dB

Input Characteristics

Input resistance .... 1 MΩ

Bandwidth .... 20 Hz–25 kHz

Additional AC Errors

Frequency-dependent errors

Input Frequency	Additional Error (% of Full-Scale)
20–50 Hz	2.5%
50–100 Hz	0%
100 Hz–20 kHz	1%
20–25 kHz	2.5%

AC Current

Accuracy

(% of reading ± mA)

Range	24 Hour (25 °C ± 1 °C)	90 Day (25 °C ± 10 °C)	1 Year (25 °C ± 10 °C)	Temperature Coefficient (% of reading/ °C ± mA/ °C)
200.000 mA	0.18% ± 0.22 mA	0.20% ± 1.2 mA	0.20% ± 1.2 mA	0.009% ± 0.110 mA
20.0000 mA	0.30% ± 100 µA	0.32% ± 170 µA	0.32% ± 170 µA	0.022% ± 12 µA
10.000 A*	0.3% ± 22 mA	0.32% ± 120 mA	0.32% ±120 mA	0.026% ±11 mA
Accuracy numbers are for 5 1/2 digits and include the effects of full-scale and zero-scale errors, temperature variation, linerarity, and noise. *Requires 10 A shunt, CSM-10A.				

Input Characteristics

Maximum input ....200 mA/250 V

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

Shunt resistor ....1 Ω

Burden voltage..< 400 mV at 200 mA AC

Resistance

Accuracy

(% of reading ± Ω)

Range	24 Hour (25 °C ± 1 °C)	90 Day (25 °C ± 10 °C)	1 Year (25 °C ± 10 °C)	Temperature Coefficient (% of reading/ °C ± Ω/ °C)
Extended Ohm (> 2 MΩ)	0.1% ± 6 kΩ	0.1% ± 60 kΩ	0.1% ± 60 kΩ	0.0072% ± 6 kΩ
2.00000 MΩ*	0.012% ± 9 Ω	0.077% ± 27 Ω	0.080% ± 27 Ω	0.0072% ± 2 Ω
200.000 kΩ	0.012% ± 5 Ω	0.077% ± 22 Ω	0.080% ± 22 Ω	0.0072% ± 2 Ω
20.0000 kΩ	0.006% ± 0.09 Ω	0.024% ± 0.3 Ω	0.027% ± 0.3 Ω	0.0020% ± 0.02 Ω
2.00000 kΩ	0.006% ± 0.05 Ω	0.024% ± 0.2 Ω	0.027% ± 0.2 Ω	0.0020% ± 0.02 Ω
200.000 Ω	0.006% ± 0.05 Ω	0.024% ± 0.2 Ω	0.027% ± 0.2 Ω	0.0020% ± 0.02 Ω

Accuracy numbers are for the 4-wire resistance mode 5 1/2 digits with autozero on and include the effects of full-scale and zero-scale errors, temperature variation, linearity, and noise.
*With autozero on or while scanning, and when large resistance with capacitive loads is measured, additional delay time is required.

Measurement modes

Ohms .... 2-wire Ohms or 4-wire Ohms

Extended ohms .... 2-wire mode only

Maximum lead resistance....................... 10 Ω (200 Ω range),
1 kΩ (all other ranges)

Test current .... 100 µA for 200 Ω, 2 kΩ,
20 kΩ ranges
1 µA for 2 MΩ, 200 kΩ ranges
1 µA and 1 MΩ in parallel for
extended Ohms mode

Additional error for 2-wire resistance .... 0.6 Ω

Diode Testing

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)
2 V	0.006% ± 7 µV	0.024% ± 22 µV	0.027% ± 22 µV	0.0020% ± 2 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.				

Test current ....100 µA

General Specifications

Settling time...Affected by source impedance and input signal changes

Warm-up time..30 minutes for measurements accurate within specifications

Bus type

PCI...Slave

PXI...Slave

CompactPCI ....Slave

Altitude ....Up to 2,000 m; at higher altitudes the installation category must be derated

Working voltage ....300 V maximum between either input terminal and earth ground

Power requirement.................................+5 VDC, 250 mA in operational mode

Safety ....Designed in accordance with IEC 61010-1 and UL 3111-1 for electrical and testing equipment; Installation Category II, Pollution Degree 2, Reinforced Insulation, Indoor Use Only

Physical

Dimensions

PCI .... 10.8 by 17.5 cm (4.25 by 6.9 in.)

PXI .... 10 by 16 cm (3.9 by 6.33 in.)

Environment

Operating temperature............................ 0 to 55 °C

Storage temperature .... –20 to 70 °C

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

B

Fuse Replacement

This appendix explains how to replace the fuse in your NI 4060. Replace the fuse with one of the fuse types listed in the chart below.

Caution For continued protection against fire, replace only with fuses of the same type and rating. See the following chart for fuse types.

Fuse Rating	Fuse Type	Manufacturer	Part Number
500 mA/250 V	Fast acting	Schurter	FSF 034.1513
500 mA/250 V	Fast acting	LittelFuse	217.500

NI 4060 for PCI

1. Remove all signal connections from your NI 4060. Power down your computer and remove the board.
2. Turn to the back of the board and remove the four screws, as shown in Figure B-1. These screws hold the top and bottom insulators onto the board.

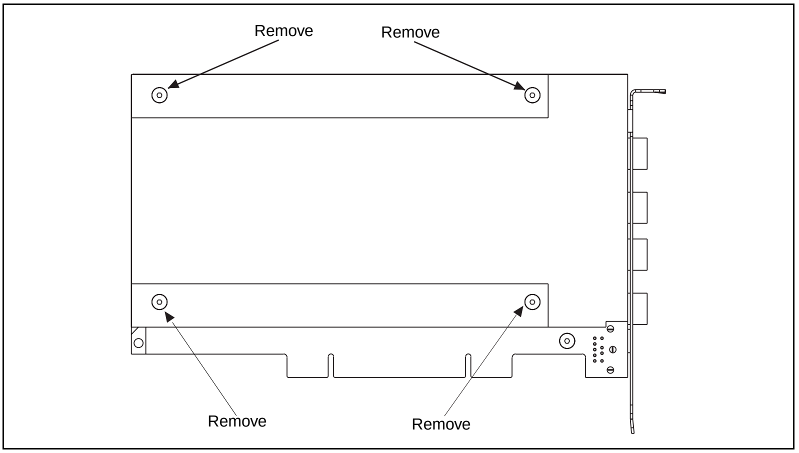


Figure B-1. Insulator Screw Location on NI 4060 (PCI)

3. Remove the bottom and top insulators.
4. Turn to the front of the board and locate the 5 by 20 mm glass fuse, as shown in Figure B-2. Visually verify that the fuse is blown and remove it.

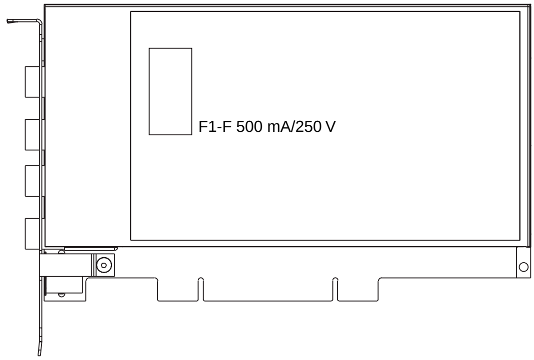


Figure B-2. Fuseholder Location on NI 4060 (PCI)

5. Press the new fuse into the silver holding fixture until you hear a snap.
6. Reattach the top and bottom covers in the same order as you removed them.

Caution Do not operate the NI 4060 without both insulators replaced and fastened.

NI 4060 for PXI

1. Remove all signal connections from your NI 4060. Power down your computer and remove the board.
2. Hold the board as shown in Figure B-3 and locate the fuse holder.

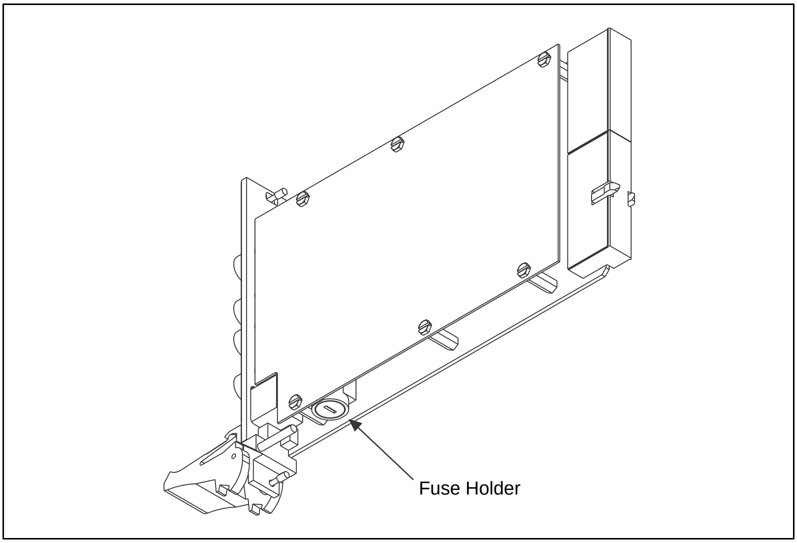


Figure B-3. Fuseholder Location on NI 4060 (PXI)

3. Insert a screwdriver into the slot on the fuse holder.
4. Turn counterclockwise.
5. Pull out the holder and remove the blown fuse.
6. Insert the 5 by 20 mm glass fuse into the holder and slide the holder in.
7. Turn the fuse holder clockwise until it snaps shut.

C

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

National Instruments has offices located around the globe. Many branch offices maintain a Web site to provide information on local services. You can access these Web sites from `www.ni.com/worldwide`

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

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.
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=20log10 V1/V2, for signals in volts
DC	direct current
default setting	a default parameter value recorded in the driver. In many cases, the default input of a control is a certain value (often 0) that means *use the current default setting*.
device	a plug-in data acquisition board, card, or pad 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
DLL	dynamic-link library
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

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_{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_{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. *See also* thermal drift.
thermal drift	measurements that change as the temperature varies
thermoelectric potentials	*See* 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_{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_{rms}	volts, root mean square value
V_{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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