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DAQMeter™ 4350 User Manual

Temperature and Voltage Measurement Instrument

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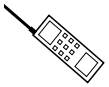
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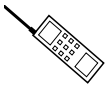
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About This Manual

This manual describes the electrical and mechanical aspects of the DAQMeter 4350 family of instruments and contains information concerning its operation and programming.

Organization of This Manual

The *DAQMeter 4350 User Manual* is organized as follows:

- Chapter 1, *Introduction*, describes the DAQMeter 4350 temperature and voltage measurement instruments, lists what you need to get started, describes the optional software and optional equipment, and explains how to unpack your DAQMeter 4350 instrument.
- Chapter 2, *Installation and Configuration*, describes how to install and configure your DAQMeter 4350 instrument.
- Chapter 3, *DAQMeter 4350 Operation*, describes how to use your DAQMeter 4350 instrument and includes operation tips on taking measurements with temperature sensors such as thermocouples, RTDs, and thermistors, as well as voltage and resistances.
- Appendix A, *Specifications*, lists the specifications of the DAQMeter 4350.
- Appendix B, *Signal Connections*, explains the signal correlation between your DAQMeter 4350 and the accessories you might use with it.
- Appendix C, *Customer Communication*, contains forms you can use to request help from National Instruments or to comment on our products.
- The *Glossary* contains an alphabetical list and description of terms used in this manual, including acronyms, abbreviations, definitions metric prefixes, mnemonics, and symbols.
- The *Index* alphabetically lists topics covered in this manual, including the page where you can find the topic.

Conventions Used in This Manual

The following conventions are used in this manual:

♦ The ♦ symbol indicates that the text following it applies only to a specific 4350 instrument.

☞ 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 box, 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 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*.

The *Glossary* lists abbreviations, acronyms, metric prefixes, mnemonics, symbols, and terms.

National Instruments Documentation

The *DAQMeter 4350 User Manual* is one piece of the documentation set for your DAQ system. You could have any of several types of manuals depending on the hardware and software in your system. Use the manuals you have as follows:

- Your DAQ hardware documentation—This documentation has detailed information about the DAQ hardware that plugs into or is connected to your computer. Use this documentation for hardware installation and configuration instructions, specification information about your DAQ hardware, and application hints.
- Software documentation—You may have both application software and NI-DAQ software documentation. National Instruments

application software includes ComponentWorks, LabVIEW, LabWindows®/CVI, Measure, and VirtualBench. After you set up your hardware system, use either your application software documentation or the NI-DAQ documentation to help you write your application. If you have a large, complicated system, it is worthwhile to look through the software documentation before you configure your hardware.

- Accessory installation guides or manuals—If you are using accessory products, read the terminal block, adapter, and cable assembly installation guides. They explain how to physically connect the relevant pieces of the system. Consult these guides when you are making your connections.

Customer Communication

National Instruments wants to receive your comments on our products and manuals. We are interested in the applications you develop with our products, and we want to help if you have problems with them. To make it easy for you to contact us, this manual contains comment and configuration forms for you to complete. These forms are in Appendix C, *Customer Communication*, at the end of this manual.

Chapter 1

Introduction

This chapter describes the DAQMeter 4350 temperature and voltage measurement instruments, lists what you need to get started, describes the optional software and optional equipment, and explains how to unpack your DAQMeter 4350 instrument.

About the DAQMeter 4350 Instruments

Thank you for buying a National Instruments DAQMeter 4350 instrument. The DAQMeter 4350 family consists of two instruments for the bus of your choice: the DAQCard-4350 for PCMCIA bus and the PC-4350 for the ISA bus.

The DAQMeter 4350 instruments feature accurate thermocouple and DC voltage measurements. You can also take temperature measurements with resistance temperature detectors (RTDs), thermistors, and ohm measurements using the built-in precision current source. You can use the DAQMeter 4350 instrument with a personal computer to make the same measurements you would with standard bench-top instruments such as data loggers and DMMs. The DAQMeter 4350 instruments contain a 24-bit analog-to-digital converter (ADC) with differential analog inputs. The low leakage construction, along with analog and digital filtering, provides excellent resolution, accuracy, and noise rejection. With software-programmable ground-referencing, you can reference your floating signal without compromising voltage measurements even if the floating signal is, in fact, ground-referenced. With software-programmable open-thermocouple detection, you can quickly detect a thermocouple that may have broken before or during measurement. You can measure up to a total resistance of 600 kΩ using the built-in 25 μA precision current source. In addition, the DAQMeter 4350 instruments have programmable TTL-compatible digital I/O (DIO) for monitoring TTL-level inputs, interfacing with external instruments, and generating alarms.

The DAQMeter 4350 instrument is Plug and Play compatible. The instrument is fully software-calibrated. Because the 4350 instrument works with a variety of operating systems, you can develop applications that scale across several platforms.

A system based on a DAQMeter 4350 instrument offers flexibility, performance, and size, making it ideal for service, repair, and manufacturing and for use in industrial and laboratory environments. The DAQMeter 4350 instrument, used with your computer, is a versatile, cost-effective platform for high-resolution measurements.

Detailed specifications for the DAQMeter 4350 instruments are in Appendix A, *Specifications*.

What You Need to Get Started

To set up and use your DAQMeter 4350 instrument, you will need the following items:

- ❑ One of the following DAQMeter 4350 instruments:
  - DAQCard-4350
  - PC-4350
- ❑ *DAQMeter 4350 User Manual*
- ❑ NI435X instrument driver
- ❑ One of the following software packages and documentation:
  - LabVIEW 4.0 or higher
  - LabWindows/CVI 4.0 or higher
  - VirtualBench 2.1 or higher
  - NI-DAQ 5.1 for PC compatibles or higher
  - BridgeVIEW
- ❑ Optional cables and accessories
- ❑ Phillips-head screwdriver
- ❑ Your computer

Software Programming Choices

There are several options to choose from to program and use your National Instruments DAQ instruments. You can use LabVIEW, LabWindows/CVI, VirtualBench, or the NI435X instrument driver.

National Instruments Application Software

LabVIEW and LabWindows/CVI are innovative program development software packages for data acquisition and control applications. LabVIEW uses graphical programming, whereas LabWindows/CVI enhances traditional programming languages. Both packages include extensive libraries for data acquisition, instrument control, data analysis, and graphical data presentation.

LabVIEW features interactive graphics, a state-of-the-art user interface and a powerful graphical programming language. The LabVIEW Data Acquisition VI Library, a series of VIs for using LabVIEW with National Instruments DAQ hardware, is included with LabVIEW. The LabVIEW Data Acquisition VI Library is functionally equivalent to the NI-DAQ software.

LabWindows/CVI features interactive graphics, a state-of-the-art user interface, and uses the ANSI standard C programming language. The LabWindows/CVI Data Acquisition Library, a series of functions for using LabWindows/CVI with National Instruments DAQ hardware, is included with the NI-DAQ software kit. The LabWindows/CVI Data Acquisition library is functionally equivalent to the NI-DAQ software.

DAQMeter 4350 instruments are supported by the Easy I/O for DAQ library in LabWindows/CVI. Use of the NI435X instrument driver is also recommended while using LabWindows/CVI.

Using LabVIEW or LabWindows/CVI software will greatly reduce the development time for your data acquisition and control application.

VirtualBench

VirtualBench is a suite of VIs that allows you to use your data acquisition products just as you use stand-alone instruments, but you benefit from the processing, display and storage capabilities of PCs. VirtualBench instruments load and save waveform data to disk in the same forms that can be used in popular spreadsheet programs and word processors. A report generation capability complements the raw data

storage by adding timestamps, measurements, user name and comments.

The complete VirtualBench suite contains VirtualBench-AODC, VirtualBench-Arb,VirtualBench-Cal, VirtualBench-DIO, VirtualBench-DMM, VirtualBench-DSA, VirtualBench-Function Generator, VirtualBench-Logger, and VirtualBench-Scope. Your DAQMeter 4350 works with VirtualBench-DIO and VirtualBench-Logger. VirtualBench-Logger is a turn-key application that allows you to make measurements as you would with a standard bench-type data logger. VirtualBench-DIO allows you to read from or write to the digital I/O lines.

NI435X Instrument Driver and NI-DAQ

The NI435X instrument driver provides flexibility and programmability in a standard instrument driver format.

The instrument driver application programming interface (API) is designed after a classical, full-featured data logger instrument driver. The NI435X instrument driver works with LabVIEW, LabWindows/CVI, or conventional programming languages such as C and Visual Basic.

Whether you are using the NI435X instrument driver, VirtualBench-Logger, LabVIEW, or LabWindows/CVI, your application uses the NI-DAQ driver software, as illustrated in Figure 1-1.

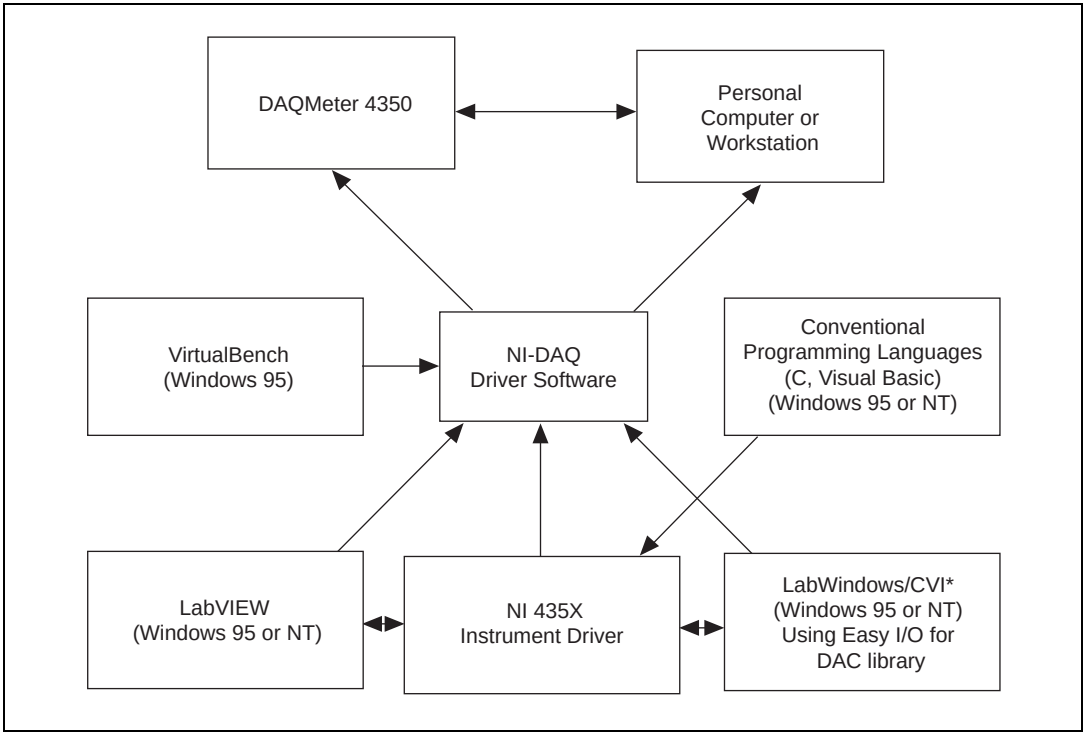


Figure 1-1. The Relationship between the Programming Environment, NI-DAQ, and Your Hardware

Optional Equipment

National Instruments offers a variety of products to use with your DAQMeter 4350, including cables, connector blocks, terminal blocks and other accessories, as follows:

- Cables and adapters with thermocouple mini-connectors
- Connector blocks including isothermal connector blocks
- Cables and cable accessories, shielded and ribbon

For more specific information about these products, refer to your National Instruments catalogue or call the office nearest you.

Unpacking

- DAQCard-4350

  Your DAQCard-4350 is shipped in an antistatic vinyl case; when you are not using your DAQCard-4350, store it in this case. Because your DAQCard-4350 is enclosed in a fully shielded case, no additional electrostatic precautions are necessary. However, for your own safety and to protect your DAQCard-4350, never attempt to touch the pins of the connectors.

- PC-4350

  Your PC-4350 is shipped in an antistatic vinyl package to prevent electrostatic damage to your instrument. Electrostatic discharge can damage several components on the instrument. To avoid such damage in handling the instrument, take the following precautions:

  - Ground yourself via a grounding strap or by holding a grounded object.
  - Touch the antistatic package to a metal part on your computer chassis before removing the instrument from the package.
  - Remove the instrument from the package and inspect the instrument for loose components or any other sign of damage. Notify National Instruments if the instrument appears damaged in any way. *Do not* install a damaged instrument in your computer.
  - *Never* touch the exposed pins of the connector.

Installation and Configuration

Chapter 2

This chapter describes how to install and configure your DAQMeter 4350 instrument.

Installation

☞ **Note:** ***You should install your NI-DAQ driver software before installing your hardware. Refer to the DAQMeter 4350 Read Me First document for software installation instructions.***

After you have installed your software, you are ready to install your hardware. Follow the appropriate instructions for your instrument.

- DAQCard-4350

You can install the DAQCard-4350 in any available Type II PCMCIA slot in your computer. Windows 95 and Windows NT 4.0 or higher include the Plug and Play services your operating system will use.

The operating system configures the DAQCard-4350 and automatically assigns the base address and the interrupt level. Before installing your DAQCard-4350, consult your computer user manual or technical reference manual for specific instructions and warnings. Use the following general instructions to install your DAQCard-4350:

1. Write down your DAQCard-4350 serial number on the *DAQMeter 4350 Hardware and Software Configuration Form* in Appendix C.
2. Turn off your computer. If your computer and operating system support hot insertion, you can insert or remove the DAQCard-4350 at any time, whether the computer is powered on or off.
3. Remove the PCMCIA slot cover on your computer.

4. Insert the 68-pin I/O connector of the DAQCard-4350 into the PCMCIA slot until the connector is firmly seated. Notice that the DAQCard-4350 connectors are keyed so that you can insert it in only one way.

Your DAQCard-4350 is now installed.

- PC-4350

You can install the PC-4350 in any available ISA, AT, or XT slot in your computer. However, for best noise performance, leave as much room as possible between the PC-4350 and other hardware. Before installing your PC-4350, consult your computer user manual or technical reference manual for specific instructions and warnings. Use the following general instructions to install your PC-4350:

1. Write down your PC-4350 serial number on the *DAQMeter 4350 Hardware and Software Configuration Form* in Appendix C.
2. Turn off and unplug your computer.
3. Remove the top cover or access port to the I/O channel.
4. Remove the expansion slot cover on the back panel of the computer.
5. Insert the PC-4350 in a 16-bit or 8-bit ISA slot. Although it may fit tightly, do not force the instrument into place.
6. Screw the mounting bracket of the PC-4350 to the back panel rail of the computer.
7. Replace the cover.
8. Plug in and turn on your computer.

Your PC-4350 is now installed.

Configuration

Your DAQMeter 4350 is a completely software-configurable, Plug and Play instrument. The Plug and Play services query the instrument and allocate resources such as base address and interrupt level. Then the operating system enables the instrument for operation.

Chapter 3

DAQMeter 4350 Operation

This chapter describes how to use your DAQMeter 4350 instrument and includes operation tips on taking measurements with temperature sensors such as thermocouples, RTDs, and thermistors, as well as voltages and resistances.

Warming-Up Your 4350 Instrument

To minimize the effects of thermal drift and to ensure the specified accuracy, allow the DAQMeter 4350 instrument to warm up for at least 10 minutes after power-up before taking measurements. To maximize the relative accuracy of measurements, take all measurements after your DAQMeter 4350 instrument warms up for about 30 minutes.

There are two acquisition modes available with the DAQMeter 4350 instrument. The following modes are selected automatically in software, depending on the number of channels you will measure:

- *Single-channel acquisition mode*—Take measurements for a single channel
- *Multiple-channel acquisition mode*—Take measurements for more than one channel

Choosing a Reading Rate

The *reading rate* is the rate at which your 4350 instrument takes a new measurement. If you are using LabVIEW, you can control the reading rate or measurement speed by setting the notch filter frequency. If you are using the NI435X instrument driver or VirtualBench, you can use the power line frequency along with either the *slow* or *fast* reading rate. In addition to affecting the measurement speed, the reading rate you use also affects the noise level of measurements.

In all measurement ranges, there are six possible reading rates available for use—10, 50, and 60 readings/s (readings/second) in single-channel measurement and 2.8, 8.8, and 9.7 readings/s in multiple-channel

measurement. The reading rate automatically sets the built-in filter to reject noise of 10, 50, or 60 Hz, and their multiples.

To optimize measurement accuracy and minimize the noise level, choose a reading rate of 10 readings/s in single-channel measurement and 2.8 readings/s in a multiple-channel measurement.

In practice, most of the noise encountered in measurements occurs at harmonics (multiples) of the local power line frequency (PLF). Table 3-1 shows what programming settings to use to reject harmonics of particular frequencies.

Table 3-1. Filtering and Sample Rates

LabVIEW	NI435X Instrument Driver VirtualBench Logger		Equivalent Filter Setting		Harmonics of Noise Frequencies Rejected (Hz)	Single-Channel Measurement (readings/s)	Multiple-Channel Measurement (readings/s)
Notch Filter Frequency Setting (Hz)	PLF† (Hz)	Reading Rate	PLC*	PLF† (Hz)			
10	50 or 60	slow	5 6 40	50 60 400	10, 50, 60, and 400	10	2.8
50	50	fast	1 8	50 400	50 and 400	50	8.8
60	60	fast	1	60	60	60	9.7

*number of power-line cycles used for filtering
†power line frequency

Knowing Your Signal Source

For accurate measurements, you must determine whether your signal source is floating or ground-referenced.

Floating Signal Source

A floating signal source is one that is not connected in any way to the building ground system but has an isolated ground-reference point. Examples of floating signal sources are thermocouples with

ungrounded junctions and outputs of transformers, batteries, battery-powered instruments, optical isolators, and isolation amplifiers.

Ground-Referenced Signal Source

A ground-referenced signal source is one that is connected in some way to the building system ground and is, therefore, already connected to a common ground point with respect to the DAQMeter 4350 instrument, assuming that the computer is plugged into the same power system. Examples of ground-referenced signal sources are thermocouples with grounded or exposed junctions connected to grounded test points and outputs of plug-in instruments with non-isolated outputs, voltage across RTDs, thermistors, or resistors you may be measuring using the built-in current source of the DAQMeter 4350.

Using Programmable Ground-Referencing

Your DAQMeter 4350 instrument has software-programmable ground-referencing on every channel, which you can use to ground-reference a floating signal source. This connects CH- to ground through a 10 MΩ resistor and provides a ground-reference for your floating signal source. Even if your signal source *is* ground-referenced, this resistance minimizes the effects of ground-loops, as long as the source impedance and the lead wire resistance is less than 100 Ω. Thus, you can take accurate measurements even if you are uncertain whether your signal source is floating or ground-referenced. Because you can set ground-referencing on a channel-by-channel basis, you can have ground-referenced signal sources connected to some channels and floating signal sources connected to other channels in the same measurement setup. Table 3-2 summarizes the settings to use for ground-referencing.

Table 3-2. Using Programmable Ground-Referencing

Signal Source	Programmable Ground-Referencing
Floating	On
Ground-referenced	Off

Using Programmable Open-Thermocouple Detection

The DAQMeter 4350 instruments have software-programmable, open-thermocouple detection on every channel, which you can use to detect an open or broken thermocouple. This feature connects CH+ to +2.5 V through a 10 MΩ resistor. This resistor acts as a pull-up resistor and, consequently, the voltage between CH+ and CH- rises rapidly above 100 mV if your thermocouple breaks open. All thermocouples functioning under normal conditions generate a voltage of less than 100 mV, even at very high temperatures, which makes this conclusion possible. You can detect this voltage level in software and conclude that your thermocouple is open.

To understand how setting open-thermocouple detection affects the accuracy of measurements, refer to the programmable open-thermocouple detection section later in this chapter. You can set open-thermocouple detection on a channel-by-channel basis. Table 3-3 summarizes the settings you should use for open-thermocouple detection.

Table 3-3. Using Programmable, Open-Thermocouple Detection

Signal Source	Programmable Open-Thermocouple Detection
Thermocouples	On or Off
Voltage signal sources other than thermocouples RTDs, thermistors, and resistors connected to the built-in *current source*	Off

Measuring Temperature with Thermocouples

The thermocouple is the most popular transducer for measuring temperature. Because the thermocouple is inexpensive, rugged, and can operate over a very wide range of temperatures, it is a versatile and useful sensor.

A thermocouple operates on the principle that the junction of two dissimilar metals generates a voltage that varies with temperature, or

thermal EMF. However, just measuring this voltage is not sufficient because connecting the thermocouple to the 4350 instrument accessory creates the *reference junction* or *cold-junction*, shown in Figure 3-1. These additional junctions act as thermocouples, themselves, and produce their own voltages. Thus, the final measured voltage, $V_{measured}$, includes both the thermocouple voltage, $V_{thermocouple}$, and the cold-junction voltage, $V_{cold\text{-}junction}$. The method of compensating for these unwanted cold-junction voltages is called *cold-junction compensation*.

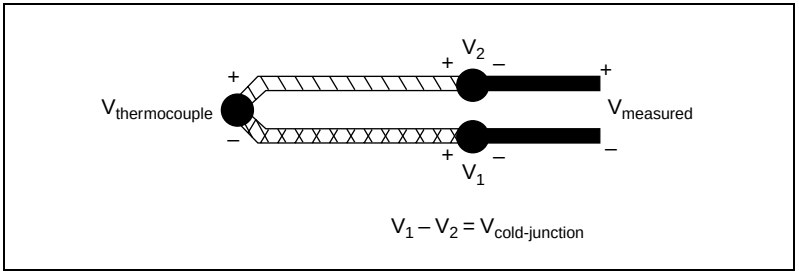


Figure 3-1. Effect of the Cold-Junction

With the 4350 instruments, you can perform cold-junction compensation in software. To do this, you can use the thermistor temperature sensor on the DAQMeter 4350 accessory to measure the ambient temperature at the cold-junction and compute the appropriate compensation for the unwanted thermoelectric voltages using software.

☞ **Note:** ***If you are using the 4350 instrument driver, VirtualBench, or the DAQ Channel Wizard, your software will automatically perform cold-junction compensation on all channels configured as thermocouple channels.***

☞ **Note:** ***If you are using LabVIEW, LabWindows/CVI, or NI-DAQ, your software includes routines that perform these temperature-to-voltage and voltage-to-temperature conversions for the cold-junction thermistor and various types of thermocouples based on the National Institute of Standards and Technology (NIST) standard reference tables.***

If you are not using any of these software applications, follow these steps to perform cold-junction compensation:

1. Measure the voltage of the thermistor cold-junction sensor, $V_{thermistor\ cold\text{-}junction}$, and compute the cold-junction temperature, $T_{cold\text{-}junction}$, using the thermistor voltage-temperature conversion formula.

2. From this temperature of the cold-junction, $T_{cold\text{-}junction}$, compute the equivalent thermocouple voltage, $V_{cold\text{-}junction}$, for this junction using a standard thermocouple conversion formula.
3. Measure the output voltage, $V_{measured}$, and add—not subtract—the cold-junction voltage, $V_{cold\text{-}junction}$, computed in step 1.
4. Convert the resulting voltage to temperature using a standard thermocouple conversion formula.

Connecting Your Thermocouple

The DAQMeter 4350 accessories—the PSH32-TC6 and the CB-27T for the DAQCard-4350, and the TC-2190 and the TBX-68T for the PC-4350—are designed to be used with thermocouples. Consult your accessory installation guide for instructions on how to connect your thermocouples. To make accurate measurements, make sure that the common-mode voltage of the thermocouple is within the input common mode limits of the selected input range.

The 4350 instrument analog inputs are protected against damage from voltages within ±42 VDC in all ranges when powered up and ±17 VDC when the 4350 instrument is powered down. You should never apply voltages above these levels to the inputs.



Caution: ***To prevent possible safety hazards, the maximum voltage between any of the analog inputs and the computer ground should never exceed ±42 VDC when the DAQMeter 4350 instrument is powered up and ±17 VDC when the 4350 instrument is powered down.***

Input Ranges

Your DAQMeter 4350 instrument has six input ranges available for measuring thermocouples. These ranges are ±625 mV, ±1.25 V, ±2.5 V, ±3.75 V, ±7.5 V, and ±15 V. It is recommended that you use the ±625 mV range when you are measuring thermocouples. You can measure both the thermocouples and the thermistor cold-junction sensor on the DAQMeter 4350 accessory in the same scan. This range offers the best resolution, noise rejection, and accuracy.

Optimizing Measurements

To make accurate thermocouple measurements, set the onboard programmable ground-referencing and open-thermocouple detection appropriately. Also consider problems associated with AC noise effects, thermal EMF, and other errors as discussed in the following sections.

Auto-Zero

Auto-zero is a method that instruments use to remove and offset errors in the measurement. Analog channel 1 (CH1) on the PSH32-TC6, CB-27T, TC-2190, and TBX-68T is dedicated for *auto-zero.* CH1+ is connected to CH1- on these accessories. You can measure the voltage offset on this auto-zero channel and subtract it from the voltage measurements on other channels. This way, you can compensate for any residual offset error the 4350 instrument may have. This is especially useful when your 4350 instrument is operating at an ambient temperature other than that of calibration (25° C typical).

☞ **Note:** ***When using the DAC Channel Wizard with LabVIEW and DAQMeter 4350 accessories—PSH32-TC6, CB-27T, TC-2190, or TBX-68T—auto-zeroing is implemented automatically.***

Programmable Ground-Referencing

If you determine that your thermocouple is ground-referenced, switch off ground-referencing on that channel.

If you determine that your thermocouple is floating, switch on ground-referencing on that channel. Otherwise, the thermocouple inputs may float out of the input common mode limits of the DAQMeter 4350 instrument.

When using the PSH32-TC6, CB-27T, TC-2190, and TBX-68T accessories, always switch on ground-referencing on CH1. With this, the auto-zero channel will be ground-referenced.

On all the 4350 instrument accessories used with thermocouples, analog channel CH0 is dedicated to the thermistor cold-junction sensor. The built-in current source return terminal IEX- is tied to –2.5 V through a resistor. This references any resistor excited by the current source to ground. Since this current source excites the cold-junction thermistor, CH0 is automatically ground-referenced. Therefore, when measuring the voltage across this thermistor, always switch off programmable

ground-referencing on CH0. Otherwise, the leakage current flowing into the thermistor may cause erroneous measurements in all the channels that use the current source.

Programmable Open-Thermocouple Detection

To detect open or broken thermocouples, switch on open-thermocouple detection on that channel. Then, if the thermocouple breaks, the voltage on that channel will rise rapidly above 100 mV, at which point you can conclude that the thermocouple is open.

Notice that when open-thermocouple detection is on and the floating thermocouple is not broken, a very small amount of current is injected into the thermocouple. It is approximately 125 nA when ground-referencing is also on. If the thermocouple is very long, this injected current can cause an error voltage to develop in the lead resistance of the thermocouple that is indistinguishable from the thermocouple voltage you are measuring. You can estimate this error voltage with the following formula:

$$\text{error voltage} = \text{resistance of the thermocouple} \times 125\ \text{nA}$$

For example, if you use a 100 ft. long, 24 AWG J-type thermocouple with a resistance of 0.878 Ω per double foot, the error voltage generated is approximately 11 μV, which corresponds to about 0.2° C. If this error is too large for your measurement, you can reduce the error by reducing the thermocouple resistance. Do this by reducing the length of the thermocouple or lowering the AWG wire (a wire of larger diameter). Alternatively, you can switch off the open-thermocouple detection to eliminate the current injected into the thermocouple.

AC Noise Effects

Your DAQMeter 4350 instrument rejects AC voltages as specified in NMR in Appendix A, *Specifications*. 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 input range, the DAQMeter 4350 instrument may exhibit additional errors. To minimize these errors, keep the thermocouples and the 4350 instrument and its accessory away from strong AC magnetic sources and minimize the area of the loop formed by the thermocouple wires connected to the accessory. Choosing the reading rate of 10 readings/s in single-channel measurement or 2.8 readings/s in multiple-channel measurement will provide you with the best AC noise rejection. If the peak value of the

measured voltage is likely to exceed the selected input range, select the next higher input range.

Thermal EMF

When using thermocouples, any thermal EMFs other than those at the hot-junction (where the thermocouple measures the test point temperature) and at the cold-junction on the accessory, will introduce error.

To minimize thermal EMFs, use wires of the same thermocouple type when extending the length of the thermocouple. Also, minimize temperature gradients in the space enclosing the thermocouple, the 4350 instrument, and its accessories.

Measuring DC Voltage

Connecting Your DC Voltage Signal

The DAQMeter 4350 accessories—the CB-27T and CB-27 for the DAQCard-4350, and the TBX-68T and TBX-68 for the PC-4350—are designed to be used with any DC voltage signal. Consult your accessory installation guide for instructions on how to connect your voltage signals.

The DAQMeter 4350 analog inputs are protected against damage from voltages within ±42 VDC in all ranges when powered up and ±17 VDC when the 4350 instrument is powered down. You should never apply voltages above these levels to the inputs.

⚠ **Caution:** ***To prevent possible safety hazards, the maximum voltage between any of the analog inputs and the computer ground should never exceed ±42 VDC when the DAQMeter 4350 instrument is powered up and ±17 VDC when the 4350 instrument is powered down.***

Input Ranges

Your DAQMeter 4350 instrument has six bipolar input ranges available for measuring DC voltage. These ranges are ±625 mV, ±1.25 V, ±2.5 V, ±3.75 V, ±7.5 V, and ±15 V. The 4350 instrument can measure DC voltage to the specified accuracy as long as the voltage is within the selected input range. To get the best resolution, noise rejection, and accuracy, choose the smallest possible range. Make sure that each

signal input to CH+ and CH– is within the input common mode limits of this input range. The input common mode limits are ±2.5 V and ±15 V for the lower three and higher three input ranges, respectively.

Optimizing Measurements

To make accurate voltage measurements, program the onboard ground-referencing and open-thermocouple detection appropriately. Also consider problems associated with AC noise effects, thermal electromotive forces (thermal EMFs), and other errors as discussed in the following sections.

Auto-Zero

Auto-zero is a method that instruments use to remove offset errors in the measurement. Analog channel 1 (CH1) on the CB-27T and TBX-68T is dedicated for *auto-zero.* CH1+ is connected to CH1– on these accessories. When using a CB-27 or TBX-68 accessory for RTDs, connect CH– to CH+ (any channel) to make that channel useful for auto-zero. You can measure the voltage offset on this auto-zero channel and subtract it from the voltage measurements on other channels. This way, you can compensate for any residual offset error the 4350 instrument may have. This is especially useful when the 4350 instrument is operating at an ambient temperature other than that of calibration (25° C typical).

☞ **Note:** ***When using the DAC Channel Wizard with LabVIEW and DAQMeter 4350 accessories—PSH32-TC6, CB-27T, TC-2190, or TBX-68T—auto-zeroing is implemented automatically.***

Programmable Ground-Referencing

If you determine that your signal source is ground-referenced, switch off ground-referencing on that channel.

If you determine that your signal source is floating, switch on ground-referencing on that channel. Otherwise, the inputs may float out of the input common mode limits of the DAQMeter 4350 instrument.

When using the CB-27T and TBX-68T accessories, always switch on ground-referencing on CH1. With this setting the auto-zero channel will be ground-referenced.

Programmable Open-Thermocouple Detection

When you measure voltage signals other than thermocouples, always switch off the onboard, open-thermocouple detection.

Source Impedance

For best results, maintain the source impedance and the lead wire resistance of your signal at less than 100 Ω.

AC Noise Effects

Your DAQMeter 4350 instrument rejects AC voltages as specified in NMR in Appendix A, *Specifications*. 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 input range, the DAQMeter 4350 instrument may exhibit additional errors. To minimize these errors, keep the signal source and the 4350 instrument and its accessories away from strong AC magnetic sources and minimize the area of the loop formed by the wires that connect the signal source with the accessories. Choosing the sample rate of 10 readings/s in single-channel measurement or 2.8 readings/s in multiple-channel measurement will provide you with the best AC noise rejection. If the peak value of the measured voltage is likely to exceed the selected input range, select the next higher input range.

Thermal EMF

Thermoelectric potentials or *thermal electromotive forces* (thermal EMFs) are voltages generated at the junctions of dissimilar metals and are functions of temperature. Thermal EMFs in the source generating the signal can introduce errors in measurements that change with variations in temperature.

To minimize thermal EMFs, use copper wires to connect the signal to the 4350 instrument accessory. Avoid using dissimilar metal wires in connections. Also, minimize temperature gradients in the space enclosing the signal source, the 4350 instrument, and its accessories.

Measuring Temperature with RTDs and Thermistors and Measuring Resistance

RTDs and thermistors are essentially resistors whose resistance varies with temperature. Therefore, measurement techniques for RTDs, thermistors, and resistors are quite similar. All techniques involve exciting the resistor with a current or a voltage source and measuring the resulting voltage or current, respectively, developed in the resistor. With the DAQMeter 4350, you can excite your resistor with the built-in precision current source and measure the resulting voltage. When using LabVIEW, set the measurements mode to *4-wire ohms*. This mode will return the measurements in units of resistance (Ω) by dividing the measured voltage with the calibrated value of the precision current source stored onboard. The following sections explain the various measurement techniques in detail.

Introduction to RTDs

An RTD is a temperature-sensing instrument whose resistance increases with temperature. An RTD consists of a wire coil or deposited film of pure metal. RTDs can be made of different metals and can have different resistances, but the most popular RTD is made of platinum and has a nominal resistance of 100 Ω at 0° C.

RTDs are known for their excellent accuracy over a wide temperature range. Some RTDs have accuracy as high as 0.01 Ω (0.026° C) at 0° C. RTDs are also extremely stable instruments. Common industrial RTDs drift less than 0.1° C/year and some models are stable to within 0.0025° C/year.

RTDs can be difficult to measure because they have relatively low resistance (100 Ω) that changes only slightly with temperature (less than 0.4 Ω/° C). To accurately measure these small changes in resistance, you may need to use special configurations that minimize errors from lead wire resistance.

The Relationship of Resistance and Temperature in RTDs

Compared to other temperature instruments, the output of an RTD is relatively linear with respect to temperature. The temperature coefficient, called *alpha* (α) differs between RTD curves. Although

various manufacturers may specify α differently, α is most commonly defined as the change in RTD resistance from 0° to 100° C, divided by the resistance at 0° C, divided by 100° C:

$$\alpha\ (\Omega/\Omega/^\circ\ C) = [(R_{100} - R_0)/R_0]/100^\circ\ C$$

where R_{100} is the resistance of the RTD at 100° C, and R_0 is the resistance of the RTD at 0° C.

For example, a 100 Ω platinum RTD with α = 0.00385 will measure 138.5 Ω at 100° C. Figure 3-2 shows a typical resistance-temperature curve for a 100 Ω platinum RTD.

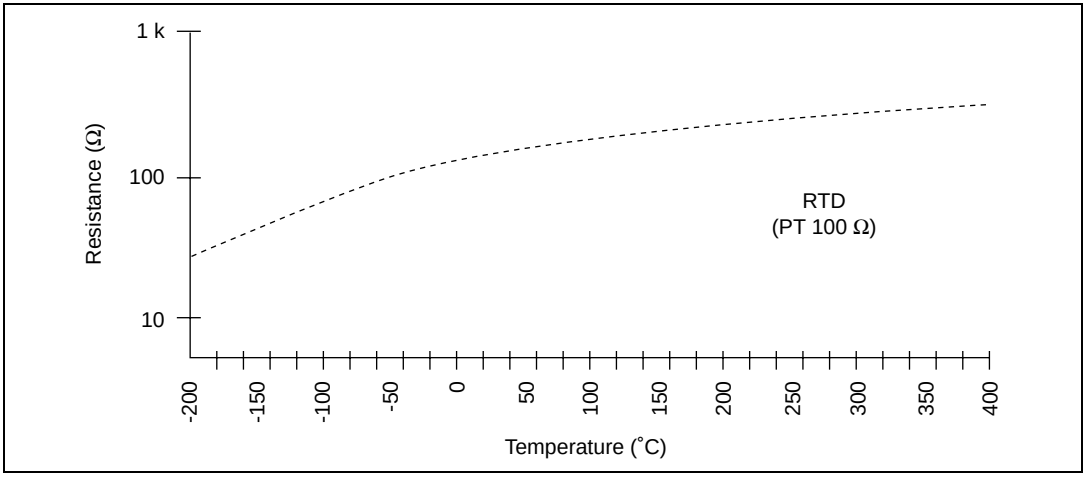


Figure 3-2. Resistance-Temperature Curve for a 100 Ω Platinum RTD

Although the resistance-temperature curve is relatively linear, converting measured resistance to temperature accurately requires curve fitting. The Callendar-Van Dusen equation is commonly used to approximate the RTD curve:

$$R_{RTD} = R_0 \times [1 + A \times t + B \times t^2 + C \times (t - 100)^3]$$

where R_{RTD} is the resistance of the RTD at temperature = t, R_0 is the resistance of the RTD in Ω at 0° C, A, B, and C are the Callendar-Van Dusen coefficients shown in Table 3-4, and t is the temperature in ° C. For temperatures above 0° C, coefficient C equals 0. Therefore, for temperatures above 0° C, this equation reduces to a quadratic:

$$t = \frac{2\left(\frac{R_{RTD}}{R_0} - 1\right)}{A + \sqrt{A^2 + 4BC\left(\frac{R_{RTD}}{R_0} - 1\right)}}$$

Most platinum RTD curves follow one of three standardized curves: the DIN 43760 standard ($\alpha = 0.00385$), the U.S. Industrial or American standard ($\alpha = 0.003911$), or the International Temperature Scale (ITS-90) that is used with wire-wound RTDs ($\alpha = 0.003925$). Table 3-4 lists the Callendar-Van Dusen coefficients for each of these three platinum RTD curves.

Table 3-4. Callendar-Van Dusen Coefficients Corresponding to Common RTDs

Standard	Temperature Coefficient α	A	B	C*
DIN 43 760	0.003850	3.9080×10^{-3}	-5.8019×10^{-7}	-4.2735×10^{-12}
American	0.003911	3.9692×10^{-3}	-5.8495×10^{-7}	-4.2325×10^{-12}
ITS-90	0.003925	3.9848×10^{-3}	-5.870×10^{-7}	-4.0000×10^{-12}
* For temperatures below 0° C only; C = 0.0 for temperatures above 0° C.				

☞ **Note:** ***Software packages, such as LabVIEW, LabWindows/CVI, VirtualBench, and NI-DAQ include routines that perform these conversions for different types of RTDs based on the various commonly used standards.***

Connecting Your RTD

Because the RTD is a resistive instrument, you must pass current through the instrument and measure the resulting voltage. However, any resistance in the lead wires that connect your measurement system to the RTD will add errors to your readings. For example, consider a two-wire RTD element connected to the 4350 instrument accessory that also supplies a constant current source IEX to excite the RTD. As shown in Figure 3-3, the voltage drop across the lead resistance R_L, adds to the measured voltage.

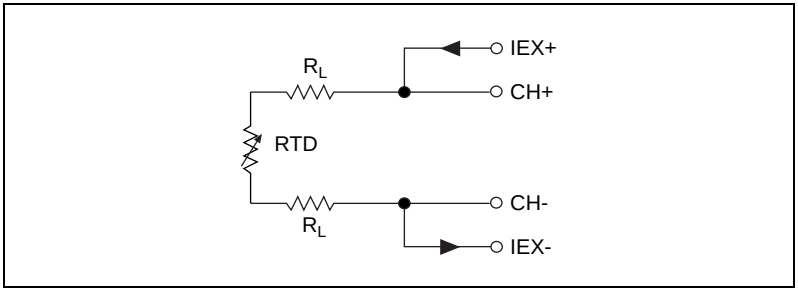


Figure 3-3. Two-Wire RTD Measurement

For example, a lead resistance R_L of 0.3 Ω in each wire adds a 0.6 Ω error to the resistance measurement. For a platinum RTD with $\alpha = 0.00385$, the resistance equals a 0.6 Ω/(0.385 Ω/° C = 1.6° C) error.

If you are using lead lengths greater than 10 ft., you may need to compensate for this lead resistance in order to increase accuracy. The preferred RTD measurement method is to use a four-wire RTD. One pair of wires carries the current through the RTD; the other pair senses the voltage across the RTD. Because only negligible current flows through the sensing wires, the lead resistance error of R_{L2} and R_{L3} is negligible. Figure 3-4 illustrates this configuration.

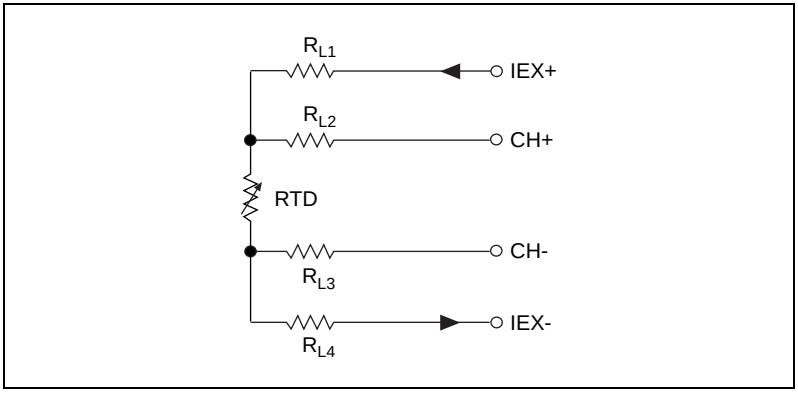


Figure 3-4. Four-Wire RTD Measurement

Alternatively, you can use a three-wire RTD instead. Figure 3-5 shows a the three-wire RTD in a Wheatstone configuration with a current source. Another variation of the three-wire RTD configuration is shown in Figure 3-6. In this configuration, the resistance R_{L1} of only one lead adds error to the measurement.

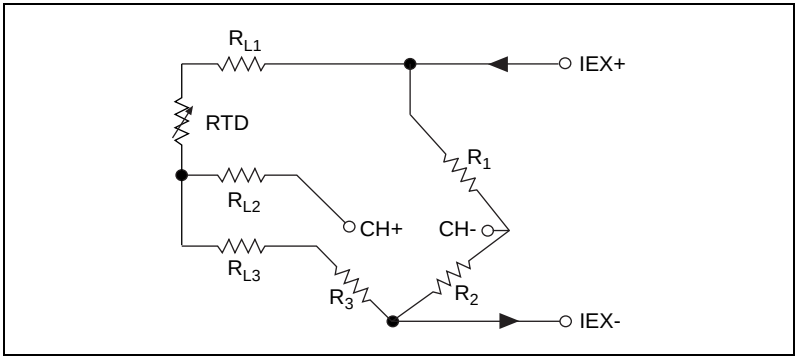


Figure 3-5. Three-Wire RTD Measurement with a Wheatstone Bridge and a Current Source

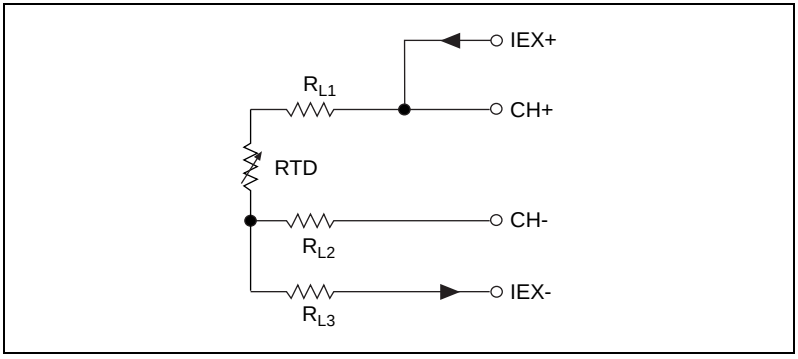


Figure 3-6. Three-Wire RTD Measurement

See Figure 3-9 for an example of how you can use different transducers to analog channels in the same measurement setup.

Introduction to Thermistors

A thermistor is a piece of semiconductor made from metal oxides, pressed into a small bead, disk, wafer, or other shape, sintered at high temperatures, and finally coated with epoxy or glass. The resulting instrument exhibits an electrical resistance that varies with temperature.

There are two types of thermistors—negative temperature coefficient (NTC) thermistors and positive temperature coefficient (PTC) thermistors. An NTC thermistor is one whose resistance decreases with increasing temperature. A PTC thermistor is one whose resistance increases with increasing temperature. NTC thermistors are much more commonly used than PTC thermistors, especially for temperature measurement applications.

A main advantage of thermistors for temperature measurement is their extremely high sensitivity. For example, a 2252 Ω thermistor has a sensitivity of –100 Ω/° C at room temperature. Higher resistance thermistors can exhibit temperature coefficients of –10 kΩ/° C or more. In comparison, a 100 Ω platinum RTD has a sensitivity of only 0.4 Ω/° C. The small size of the thermistor bead also yields a very fast response to temperature changes.

Another advantage of the thermistor is its relatively high resistance. Thermistors are available with base resistances (at 25° C) ranging from hundreds to millions of ohms. This high resistance diminishes the effect of inherent resistances in the lead wires, which can cause significant errors with low resistance instruments such as RTDs. For example, while RTD measurements typically require four-wire or three-wire connections to reduce errors caused by lead wire resistances, two-wire connections to thermistors are usually adequate.

The major trade-off for the high resistance and sensitivity of the thermistor is its highly nonlinear output and relatively limited operating range. Depending on the type of thermistors, upper ranges are typically limited to around 300° C. Figure 3-7 shows the resistance-temperature curve for a 5,000 Ω thermistor. The curve of a 100 Ω RTD is also shown for comparison.

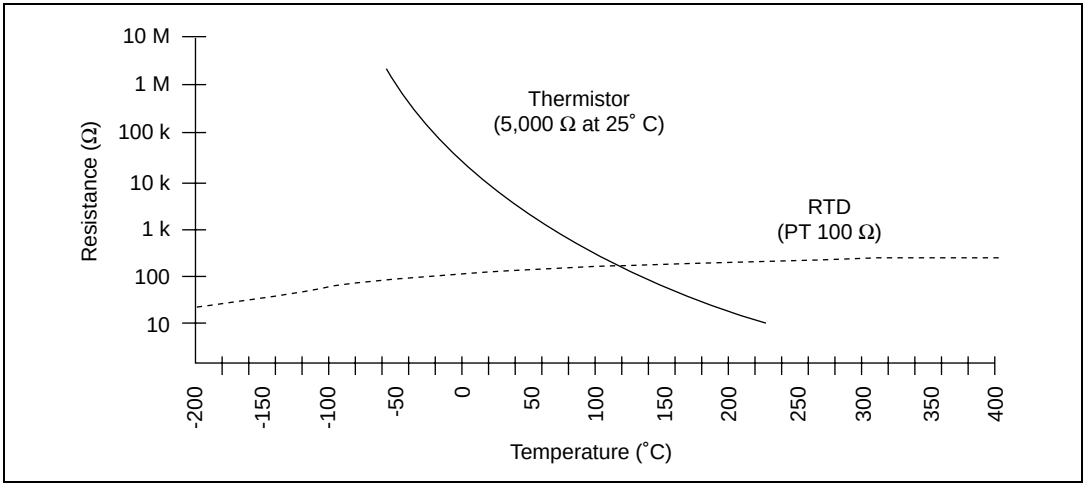


Figure 3-7. Resistance-Temperature Curve of a Thermistor

The thermistor has been used primarily for high-resolution measurements over limited temperature ranges. Continuous improvements in thermistor stability, accuracy, and the availability of interchangeable thermistors have prompted increased usage of thermistors in all types of industries.

Resistance-Temperature Characteristic of Thermistors

The resistance-temperature behavior of thermistors is highly dependent upon the manufacturing process. Therefore, thermistor manufacturers have not standardized thermistor curves to the extent that thermocouple or RTD curves have been standardized.

Typically, thermistor manufacturers supply the resistance-versus-temperature curves or tables for their particular instruments. The

thermistor curve, however, can be approximated relatively accurately with the Steinhart-Hart equation:

$$T(K) = \frac{1}{a + b \times lnRt + c \times (lnRt)^3}$$

Where T(K) is the temperature in kelvin, equal to T(° C) + 273.15, and Rt is the resistance of the thermistor. The coefficients a, b, and c can be provided by the thermistor manufacturer, or calculated from the resistance-versus-temperature curve.

Software packages such as LabVIEW, LabWindows/CVI, VirtualBench, and NI-DAQ include routines that perform these conversions for some types of thermistors. You can also modify these for your particular type of thermistor.

Connecting Your Thermistor

Because the thermistor is a resistive instrument, you must pass a current through the thermistor to produce a voltage that can be measured by the 4350 instrument. The high resistance and high sensitivity of the thermistor simplify the necessary measurement circuitry and signal conditioning. Special three-wire, four-wire, or Wheatstone bridge connections are not necessary. As shown in Figure 3-8, the measured voltage Vt will be equal to (Rt × IEX).

See Figure 3-9 for an example of how you can use different transducers connected to analog channels in the same measurement setup.

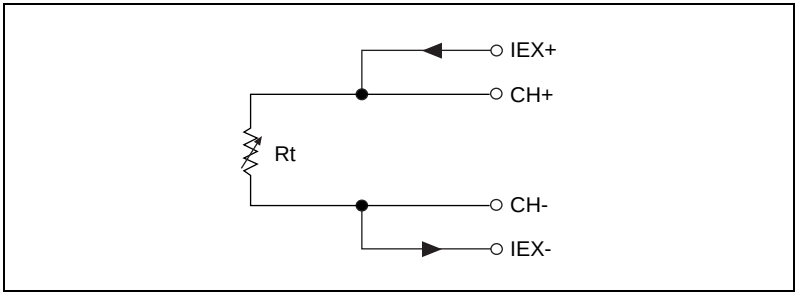


Figure 3-8. Thermistor Measurement

Connecting Your Resistor

You can use signal connection techniques, described in the sections, *Connecting Your RTD* and *Connecting Your Thermistor*, for any other resistor as well.

The DAQMeter 4350 accessories—the CB-27T and CB-27 for the DAQCard-4350, and the TBX-68T and TBX-68 for the PC-4350—are designed to be used with RTDs, thermistors, and resistors. Consult your accessory installation guide for instructions on how to connect your resistors. Figure 3-9 shows an example of how different transducers connected to analog channels can be used in the same measurement setup.

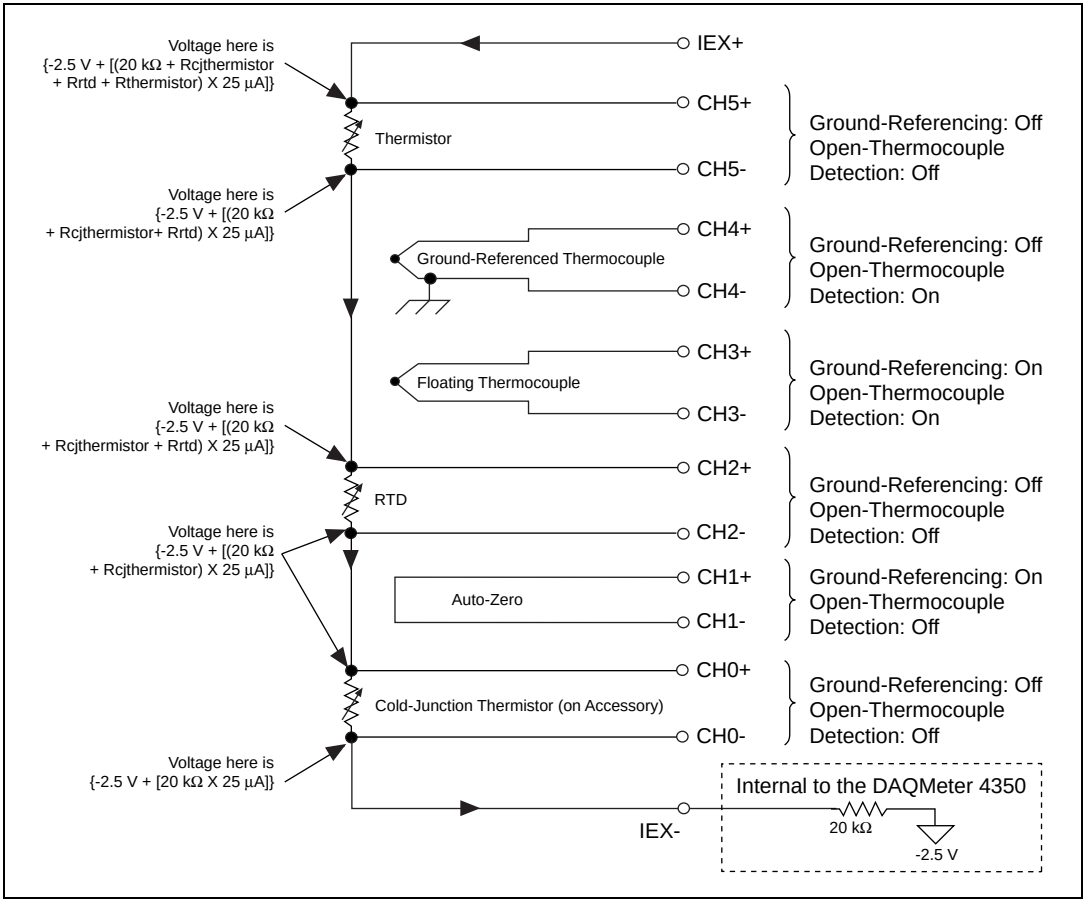


Figure 3-9. Multiple Transducer Connections to Analog Channels in One Measurement Setup

The 4350 instrument analog inputs are protected against damage from voltages within ±42 VDC in all ranges when powered up and ±17 VDC when powered down. Never apply voltages above these levels to the inputs.

Caution: ***To prevent possible safety hazards, the maximum voltage between any of the analog inputs and the computer ground should never exceed ±42 VDC when the 4350 instrument is powered up and ±17 VDC when the 4350 instrument is powered down.***

Input Ranges

The DAQMeter 4350 has six ranges for resistance measurements. These ranges are 25 kΩ, 50 kΩ, 100 kΩ, 150 kΩ, 300 kΩ, and 600 kΩ.These ranges correspond to the six input ranges available for measuring DC voltages developed across resistors. These ranges are ±625 mV, ±1.25 V, ±2.5 V, ±3.75 V, ±7.5 V, and ±15 V. To determine the most suitable input range for your application, estimate the voltage developed across the resistor by following the procedure outlined in Figure 3-9.

The DAQMeter 4350 instrument can measure DC voltages across resistors to its specified accuracy as long as the voltage is within the selected input range. To get the best resolution, noise rejection and accuracy, choose the smallest range in which your signals will be accommodated. Make sure that each signal input to CH+ and CH– is within the input common mode limits of this input range. The input common mode limits are ±2.5 V and ±15 V, for the lower three and higher three input ranges, respectively.

Optimizing Measurements

In addition to the potential problems discussed in the sections on connecting your RTDs and thermistors, also consider other problems associated with AC noise effects, thermal EMF, and other errors as discussed in the following sections.

Auto-Zero

Auto-zero is a method that instruments use to remove and offset errors in the measurement. Analog channel 1 (CH1) on the PSH32-TC6, CB-27T, TC-2190, and TBX-68T is dedicated for *auto-zero*. Ch1+ is connected to CH1– on these accessories. You can measure the voltage offset on this auto-zero channel and subtract it from the voltage measurements on other channels. This way, you can compensate for any residual offset error the 4350 instrument may have. This is especially useful when your 4350 instrument is operating at an ambient temperature other than that of calibration (25° C typical).

☞ **Note:** ***When using the DAC Channel Wizard with LabVIEW and DAQMeter 4350 accessories—PSH32-TC6, CB-27T, TC-2190, or TBX-68T—auto-zeroing is implemented automatically.***

Programmable Ground-Referencing

Always switch off ground-referencing on the channel connected to a resistor excited by the current source. The current source return terminal IEX– is tied to –2.5 V through a resistor. This causes any resistor excited by the current source to be ground-referenced. Otherwise, the leakage current flowing into the resistor can cause erroneous measurement for all channels that use the current source.

Programmable Open-Thermocouple Detection

Always switch off open-thermocouple detection on the channel connected to a resistor. Otherwise, the leakage current flowing into the resistor can cause erroneous measurement for all channels that use the current source.

Connecting to External Circuits

See Figure 3-9 for an example of how different transducers connect to analog channels in the same measurement setup. To measure the value of a resistor accurately, make sure the resistor is not electrically connected to any other circuits. Erroneous or misleading readings can result if the resistor you are measuring is electrically connected to external circuits that supply voltages or currents or is connected to external circuits that change the effective resistance of that resistor.

Two-Wire, Three-Wire, and Four-Wire Measurements

The discussion in *Connecting Your RTD* on whether to use two-wire, three-wire, or four-wire, earlier in this chapter, applies to any resistance measurement. Choose the appropriate measurement technique for your application as shown in Table3.5.

Table 3-5. Guidelines for Resistance Measurement

Resistance Being Measured (R Ω)	Measurement Technique
R ≤ 100 Ω	Four-wire
100 Ω < R ≤ 10 kΩ	Four-wire or three-wire
R > 10 kΩ	Four-wire, three-wire, or two-wire

Self-Heating

The value of the current source on the 4350 instrument is designed such that any error resulting from self-heating is negligible in most cases. This section explains how that occurs.

When current is passed through an RTD or a thermistor (both are resistive instruments), power dissipated is equal to I^2R, which heats the resistive instrument. This phenomena is called self-heating and is typically specified by manufacturers in the form of the dissipation constant, which is the power required to heat the thermistor by 1° C from ambient temperature and is usually has units of mW/° C. The dissipation constant depends significantly on how easily heat is transferred away from the thermistor, so the dissipation constant may be specified for different media—in still air, water, or oil bath.

Thermistors, with their small size and high resistance, are particularly prone to these self-heating errors. Typical dissipation constants range anywhere from less than 0.5 mW/° C for still air to 10 mW/° C or higher for a thermistor immersed in water. A 5,000 Ω thermistor powered by a 25 µA excitation current will dissipate

$I^2R = (25\ \mu A)^2 \times 5{,}000\ \Omega = 3.1\ \mu W.$

If this thermistor has a dissipation constant of 10 mW/° C, the thermistor will self-heat 0.003° C. Thus, the small value of the current source helps you prevent any appreciable error due to self-heating.

RTDs are inherently immune to this problem of self-heating because their resistance is relatively small—100 Ω at 0° C, for example. Here, also, the amount of self-heating depends significantly on the medium in which the RTD is immersed. An RTD can self-heat up to 100 times higher in still air than in moving water. The self-heating in RTDs due to the built-in 25 µA is negligible.

AC Noise Effects

The DAQMeter 4350 instruments reject AC voltages as specified in NMR in Appendix A, *Specifications*. 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 input range, the 4350 instrument may exhibit additional errors. To minimize these errors, keep the signal source and the 4350 instrument and its accessory away from strong AC magnetic sources and minimize the area of the loop

formed by the wires connecting the signal source with the accessory. Choosing the sample rates of 10 S/s in single-channel acquisition mode or 2.8 S/s in multiple-channel acquisition mode will provide you with the best AC noise rejection. If the peak value of the measured voltage is likely to exceed the selected input range, select the next higher input range.

Thermal EMF

Thermoelectric potentials or *thermal electromotive forces* (thermal EMFs) are voltages generated at the junctions of dissimilar metals and are functions of temperature. Thermal EMFs in the source generating the signal can introduce errors in measurements that change with variations in temperature.

To minimize thermal EMFs, use copper wires to connect the signal to the 4350 instrument accessory. Avoid using dissimilar metal wires in connections. Also, keep out temperature gradients in the space enclosing the signal source, the 4350 instrument and its accessories.

Using the Current Source

The DAQMeter 4350 features a precision current source, which supplies 25 μA and provides excitation to a total maximum resistance of 600 kΩ. This resistance can be in the form of RTDs, thermistors, or any other resistor. The calibrated value of the current source is stored on-board. Refer to the sections *Measuring Temperature with RTDs and Thermistors* and *Measuring Resistance* for details on how to use this current source.

Using Digital Inputs and Outputs

The DAQMeter 4350 features TTL-compatible digital lines. These lines can be individually configured either as an input or as an output. At power-up, these digital lines are configured as high-impedance inputs with a weak pull-up.

You can use the digital input and output (DIO) lines as an interface to control processes, control events such as turning on and off heaters, motors or lights, generate patterns for testing, and communicate with peripheral equipment. If the current and voltage specifications of the DIO lines are not appropriate for your requirements, you can use

external signal conditioning such as electromechanical relay, solid state relay, opto-coupler, and so on.

Connecting Your Digital Input and Output

All DAQMeter 4350 accessories are designed to be used for DIO. Refer to your accessory installation guide for instructions on how to connect your DIO lines. Figure 3-10 shows examples of how to connect DIO for various applications such as controlling an LED, monitoring a TTL-compatible or CMOS compatible signal, monitoring a low voltage switch, and monitoring a low voltage transistor.

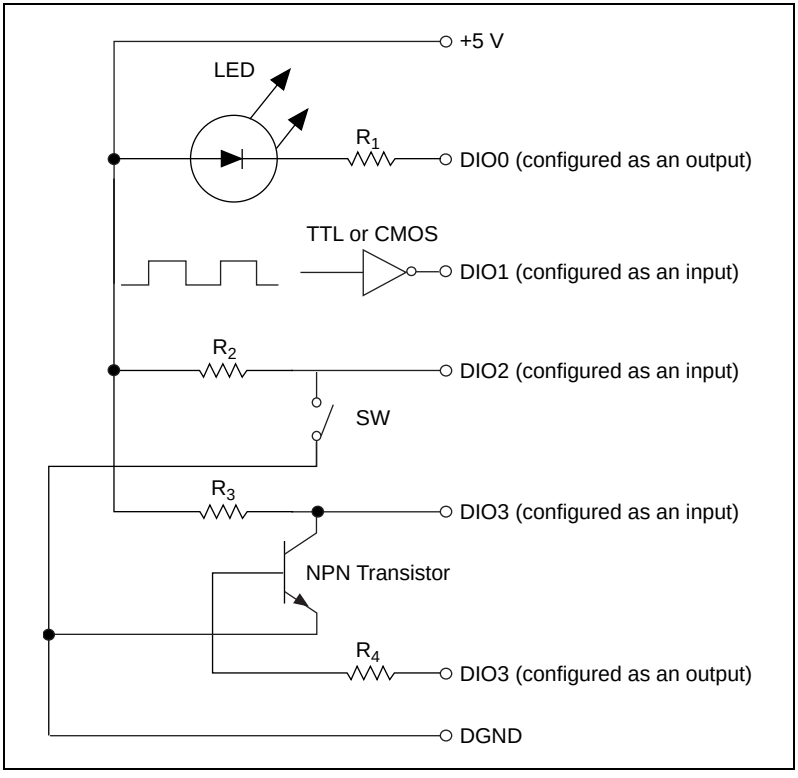


Figure 3-10. Examples of DIO Applications

The DIO lines of the 4350 instrument are protected against damage from voltages within –0.5 and +5.5 V with respect to digital ground (DGND). You should never apply voltages above these levels to these signals.

Caution: ***To prevent possible safety hazards, the voltage applied to the digital I/O lines should never be outside –0.5 V and +5.5 V, with respect to DGND.***

Specifications

Appendix A

This appendix lists the specifications of the DAQMeter 4350. These specifications are for 15° C–35° C ambient temperature range unless otherwise specified.

Accuracy Specifications

Thermocouple Accuracy[1, 2, 3, 4]

Thermocouple Type		Accuracy (° C) 15° C–35° C, 1 Year			0° C–15° C, 35° C–55° C	
		Filter Setting			Temperature Coefficient	Accessory Error
	° C	10 Hz	50 Hz	60 Hz	° C/° C[†]	° C[*]
J	*–100*	0.53	0.61	0.74	0.02	0.25
	0	0.42	0.49	0.59		
	760	0.42	0.47	0.55		
K	*–100*	0.60	0.72	0.89	0.03	0.27
	0	0.45	0.54	0.67		
	1000	0.60	0.69	0.81		
	1372	0.74	0.84	0.99		
N	*–100*	0.68	0.84	1.08	0.03	0.26
	0	0.54	0.67	0.86		
	400	0.42	0.51	0.65		
	1300	0.57	0.66	0.80		

Thermocouple Type		Accuracy (° C) 15° C–35° C, 1 Year			0° C–15° C, 35° C–55° C	
		Filter Setting			Temperature Coefficient	Accessory Error
	° C	10 Hz	50 Hz	60 Hz	° C/° C†	° C*
E	*–100*	0.55	0.62	0.74	0.02	0.28
	0	0.41	0.46	0.55		
	500	0.35	0.40	0.46		
	1000	0.46	0.50	0.57		
T	*–150*	0.81	0.96	1.17	0.03	0.36
	0	0.46	0.55	0.68		
	400	0.33	0.39	0.47		
R	*250*	0.82	1.16	1.65	0.06	0.12
	1000	0.72	0.99	1.37		
	1767	0.91	1.19	1.60		
S	*250*	0.91	1.28	1.83	0.07	0.13
	1000	0.77	1.05	1.47		
	1767	0.96	1.27	1.72		
B	*600*	1.08	1.64	2.47	0.11	0.00
	1000	0.76	1.14	1.69		
	1820	0.74	1.05	1.50		

† Add when thermocouple accessory and DAQMeter 4350 is outside 15° C–35 ° C temperature range
* Add when thermocouple accessory is outside 15° C–35° C temperature range

RTD Accuracy[3, 5, 6, 7]

RTD	° C	Accuracy (° C) 15° C–35° C, 1 Year			0° C–15° C, 35° C–55° C
		Filter Setting			Temperature Coefficient
		10 Hz	50 Hz	60 Hz	° C/° C
100 Ω	*–200*	1.00	1.33	1.81	0.01
	0	1.14	1.49	2.00	
	100	1.22	1.58	2.10	
	300	1.38	1.76	2.32	
	600	1.66	2.08	2.69	

Thermistor Accuracy[3, 5, 6]

Thermistor	° C	Accuracy (° C) 15° C–35° C, 1 Year, Filter Setting: 10 Hz, 50 Hz, 60 Hz	Temperature Coefficient 0° C–15° C, 35° C–55° C
		° C	° C/° C
5000 Ω	*0–50*	0.03	0.001

DC Voltage Accuracy[8]

Range	% of Reading 15° C–35° C			add μV (with Auto-zero) 15° C–35° C			add μV (without Auto-zero) 15° C–35° C			Temperature Coefficient 0° C–15° C, 35° C–55° C	
				Filter setting			Filter setting				
DC V	24Hr	90 Day	1 Year	10 Hz	50 Hz	60 Hz	10 Hz	50 Hz	60 Hz	%Reading/° C	μV/° C
15	0.0146	0.0175	0.0205	28	117	141	130	193	210	0.0009	5
7.5	0.0152	0.0181	0.0211	21	71	106	125	160	185	0.0009	5
3.75	0.0164	0.0193	0.0223	14	30	42	120	131	140	0.0010	5
2.5	0.0066	0.0095	0.0125	5	17	24	24	32	37	0.0004	1
1.25	0.0072	0.0101	0.0131	3	12	18	22	29	33	0.0004	1
0.625	0.0084	0.0113	0.0143	2	6	11	22	24	28	0.0005	1

Resistance Accuracy[6, 9]

Range	% of Reading 15° C–35° C			add Ω (with Auto-zero) 15° C–35° C			add Ω (without Auto-zero) 15° C–35° C			Temperature Coefficient 0° C–15° C, 35° C–55° C
				Filter setting			Filter setting			
Ω	24Hr	90 Day	1 Year	10 Hz	50 Hz	60 Hz	10 Hz	50 Hz	60 Hz	%Reading/° C
600000	0.0400	0.0429	0.0459	20.11	23.64	24.63	24.17	26.67	27.37	0.0013
300000	0.0406	0.0435	0.0465	19.82	21.80	23.22	23.97	25.37	26.37	0.0013
150000	0.0418	0.0447	0.0477	19.54	20.16	20.67	23.77	24.21	24.57	0.0013
100000	0.0320	0.0349	0.0379	0.51	1.00	1.28	1.26	1.60	1.80	0.0013
50000	0.0326	0.0355	0.0385	0.45	0.80	1.02	1.21	1.46	1.62	0.0013
25000	0.0338	0.0367	0.0397	0.41	0.54	0.74	1.18	1.28	1.42	0.0013

Accuracy Calculation Examples

The following are accuracy calculation examples:

- Measurement of 760° C using J type thermocouple at 28° C ambient temperature; filter setting of 10 Hz:

  accuracy is 0.42° C [directly from table]

- Measurement of 760° C using J type thermocouple with DAQMeter 4350 at 38° C and accessory (cold-junction sensor) at 2° C; filter setting of 10 Hz:

  accuracy is 0.48° C as a result of [0.42° C + (38° C – 35° C) * 0.02]

- Measurement of 760° C using J type thermocouple with DAQMeter 4350 and accessory (cold-junction sensor) at 38° C; filter setting of 10 Hz:

  accuracy is 0.73° C as a result of [0.42° C + (38° C – 35° C) * 0.02 + 0.25° C]

- Measurement of 1V using 1.25 V range, filter setting of 60 Hz at 28° C ambient temperature after 90 days of calibration with auto-zero; at 0 V common mode voltage:

  accuracy is 119 µV as a result of [1 V * 0.0101% +18 µV]

- Measurement of 1V using 1.25 V range, filter setting of 60 Hz at 38° C ambient temperature after 90 days of calibration with auto-zero; at 0.5 V common mode voltage:

  accuracy is 139 µV, as a result of: [1 V * 0.0101% +18 µV + (38° C – 35° C) * {1 V * 0.0004% + 1 µV}+ $(0.5/10^{100/20})$]

Analog Input

Input Characteristics

Number of channels

DAQCard-4350 .....8 differential or 6 thermocouple

PC-4350 .....16 differential or 14 thermocouple

Digits 5½

Type of ADC .....Sigma-delta

ADC resolution .....24 bits, no missing codes

Reading rates

Mode	Reading Rate (readings/s)	Power-Line Noise Rejection
Single channel	10	10
	50	50
	60	60
Multiple channel acquisition	2.8	10
	8.8	50
	9.7	60

Input coupling ..... DC

Maximum working voltage
(signal + common mode)

Range > 2.5 V ..... Each input should remain within ±15 V of ground

Range ≤ 2.5 V..... Each input should remain within ±2.5 V of ground

Over-voltage protection

(ACH<0..8/15>, IEX±)..... ±42 V powered on, ±17 V powered off

Data transfers ..... Interrupts, programmed I/O

Warm-up time ..... 30 minutes

Amplifier Characteristics

Input impedance

Normal powered on ..... >1 GΩ in parallel with 0.39 µF

Powered off ..... 10 kΩ

Overload..... 10 kΩ

Open-thermocouple detection .....10 MΩ between CH+ and +2.5 V (software selectable)

Ground-referencing.....10 MΩ between CH– and ground (software selectable)

Input bias current.....< 500 pA

CMR (DC, 50 Hz, 60 Hz)

Range > 2.5 V .....80 dB

Range ≤ 2.5 V .....100 dB

NMR (50 Hz, 60 Hz) .....> 100 dB

Dynamic Characteristics

Bandwidth .....20 Hz

Step response (full-scale step)

Accuracy	Time (s)
±0.1%	0.3
±0.01%	0.5
±0.0015%	2.4
±0.001%	3
±0.0004%	7

Excitation

Number of channels.....1

Level .....25 µA

Maximum load resistance .....600 kΩ

Temperature coefficient.....±15 ppm/° C

Digital I/O and Alarm Outputs

Number of lines

DAQCard-4350 4

PC-4350 8

Compatibility ..... TTL

DIO<0..3/7>

Level	Minimum	Maximum
Input low voltage	0.0 V	0.8 V
Input high voltage	2.0 V	5.0 V (V_{cc})
Input low current (V_{in} = 5V)	—	–10 μA
Input high current (V_{in} = 5V)	—	10 μA)
Output low current (I_{out} = 8mA)	—	0.4 V
Output high current (I_{out} = 8 mA)	3.8 V	—

Power-on state..... Tristate (weak pull up)

Data transfers ..... Programmed I/O

Bus Interface

Type..... Slave (Plug and Play)

Power Requirement

DAQCard-4350 ..... 130 mA at +5 V

PC-4350 ..... 160 mA at +5 V

Physical

Form factor

DAQCard-4350 ..... Type II PC Card (PCMCIA)

PC-4350 .....ISA (half size)

I/O connector

DAQCard-4350 .....32-pin female, shielded and latched

PC-4350 .....68-pin male, shielded and latched

Environment

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

Storage temperature .....–55° to 150° C

---

1 With ground-referencing on and open-thermocouple detection on for a floating thermocouple using 625 mV range

2 Accuracy is better for ground-referencing on and open-thermocouple detection off for a floating thermocouple

3 Add transducer error for total measurement accuracy

4 Accuracy includes cold-junction compensation, isothermal accuracy, noise, and using auto-zero

5 Specification assumes the highest common mode voltage possible for the 25 kΩ range

6 Accuracy is better if common mode voltage is less than the maximum allowed for that range

7 Accuracy using a 1000 Ω RTD is better than 100 Ω RTD

8 Add error resulting from CMR to the voltage specification: (common mode voltage)/$10^{(\text{CMR specification in dB})/20}$

9 Specification assumes the highest common mode voltage possible for that range

10 With following RTD: DIN43760, alpha = 0.00385, A = 3.90802, B = -5.80195e-7, C = -4.2735e-12

11 With 5000 Ω thermistor

Signal Connections

Appendix B

This section explains the signal correlation between your DAQMeter 4350 and the accessories you might use with it.

- The DAQCard-4350 kit includes a label that you should apply to your CB-27 accessory. This label provides the pin correlation between these two devices. The following table shows how the screw terminals on the CB-27 correspond to the signal names on the DAQCard-4350.

Table B-1. Using the DAQCard-4350 with a CB-27

DAQCard-4350 Signal Name	CB-27 Screw Terminal
CH0+	2
CH0–	3
CH1+	4
CH1–	5
CH2+	6
CH2–	7
CH3+	8
CH3–	9
CH4+	10
CH4–	11
CH5+	12
CH5–	13
CH6+	14

Table B-1. Using the DAQCard-4350 with a CB-27 (Continued)

DAQCard-4350 Signal Name	CB-27 Screw Terminal
CH6–	15
CH7+	16
CH7–	17
AGND	1
IEX+	20
IEX–	21
RSVD1	18
RSVD2	19
DIO0	23
DIO1	24
DIO2	25
DIO3	26
DGND	27
GND	22

- The PC-4350 accessories—TBX-68, SH6868, and R6868—have a one-to-one correlation to pins on the PC 4350.

Table B-2. Using the PC-4350 with the TBX-68

PC-4350 Signal Name	TBX-68 Screw Terminal
CH0+	68
CH0 –	34
CH1+	33
CH1–	66
CH2+	65
CH2–	31
CH3+	30
CH3–	63
CH4+	29
CH4–	62
CH5+	28
CH5–	61
CH6+	60
CH6–	26
CH7+	25
CH7–	58
CH8+	57
CH8–	23
CH9+	22

Table B-2. Using the PC-4350 with the TBX-68 (Continued)

PC-4350 Signal Name	TBX-68 Screw Terminal
CH9–	55
CH10+	21
CH10–	54
CH11+	53
CH11–	19
CH12+	52
CH12–	18
CH13+	17
CH13–	50
CH14+	49
CH14–	15
CH15+	13
CH15–	46
IEX+	12
IEX–	45
DIO0	7
DIO1	6
DIO2	5
DIO3	4
DIO4	37
DIO5	3

Table B-2. Using the PC-4350 with the TBX-68 (Continued)

PC-4350 Signal Name	TBX-68 Screw Terminal
DIO6	2
DIO7	1
+5V	8
DGND	35, 36, 38, 39, 40, 41, 42
AGND	9, 10, 11, 14, 16, 20, 24, 27, 32, 43, 44, 47, 48, 51, 56, 59, 64, 67

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Customer Communication

Appendix C

For your convenience, this appendix contains forms to help you gather the information necessary to help us solve your technical problems and a form you can use to comment on the product documentation. When you contact us, we need the information on the Technical Support Form and the configuration form, if your manual contains one, about your system configuration to answer your questions as quickly as possible.

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National Instruments has BBS and FTP sites dedicated for 24-hour support with a collection of files and documents to answer most common customer questions. From these sites, you can also download the latest instrument drivers, updates, and example programs. For recorded instructions on how to use the bulletin board and FTP services and for BBS automated information, call (512) 795-6990. You can access these services at:

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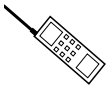
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Canada (Quebec)	514 694 8521	514 694 4399
Denmark	45 76 26 00	45 76 26 02
Finland	09 725 725 11	09 725 725 55
France	01 48 14 24 24	01 48 14 24 14
Germany	089 741 31 30	089 714 60 35
Hong Kong	2645 3186	2686 8505
Israel	03 5734815	03 5734816
Italy	02 413091	02 41309215
Japan	03 5472 2970	03 5472 2977
Korea	02 596 7456	02 596 7455
Mexico	5 520 2635	5 520 3282
Netherlands	0348 433466	0348 430673
Norway	32 84 84 00	32 84 86 00
Singapore	2265886	2265887
Spain	91 640 0085	91 640 0533
Sweden	08 730 49 70	08 730 43 70
Switzerland	056 200 51 51	056 200 51 55
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Technical Support Form

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If you are using any National Instruments hardware or software products related to this problem, include the configuration forms from their user manuals. Include additional pages if necessary.

Name _____

Company _____

Address _____

_____

Fax (___)_____ Phone (___) _____

Computer brand _____ Model _____ Processor_____

Operating system (include version number) _____

Clock speed _____MHz RAM _____MB Display adapter _____

Mouse ___yes ___no Other adapters installed _____

Hard disk capacity _____MB Brand _____

Instruments used _____

_____

National Instruments hardware product model _____ Revision _____

Configuration _____

National Instruments software product _____ Version _____

Configuration _____

The problem is: _____

_____

_____

_____

_____

List any error messages: _____

_____

_____

The following steps reproduce the problem:_____

_____

_____

_____ _____

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DAQMeter 4350 Hardware and Software Configuration Form

Record the settings and revisions of your hardware and software on the line to the right of each item. Complete a new copy of this form each time you revise your software or hardware configuration, and use this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

National Instruments Products

DAQ hardware _____

Interrupt level of hardware _____

DMA channels of hardware _____

Base I/O address of hardware _____

Programming choice _____

National Instruments software _____

Other boards in system _____

Base I/O address of other boards _____

DMA channels of other boards _____

Interrupt level of other boards _____

Other Products

Computer make and model _____

Microprocessor _____

Clock frequency or speed _____

Type of video board installed _____

Operating system version _____

Operating system mode _____

Programming language _____

Programming language version _____

Other boards in system _____

Base I/O address of other boards _____

DMA channels of other boards _____

Interrupt level of other boards _____

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Edition Date: August 1997

Part Number: 321566A-01

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Please comment on the completeness, clarity, and organization of the manual.

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Prefix	Meaning	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}

Numbers/Symbols

%	percent
+	positive of, or plus
–	negative of, or minus
±	plus or minus
/	per
°	degree
Ω	ohm
+5V	+5 V output signal

A

A	amperes
AC	alternating current
AGND	analog ground signal
AT bus	*See* bus.
attenuation	decreasing the amplitude of a signal
auto-zeroing	the process of removing an offset error from a measurement

B

b	bit—one binary digit, either 0 or 1
B	byte—eight related bits of data, an eight-bit binary number. Also used to denote the amount of memory required to store one byte of data.
bandwidth	the range of frequencies present in a signal, or the range of frequencies to which a measuring instrument can respond
buffer	temporary storage for acquired or generated 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 instruments are connected. Examples of PC buses are the AT bus (also known as the ISA bus) and the PCI bus.

C

C	Celsius
CH*x*	channel signal
clock	hardware component that controls timing for reading from or writing to groups

conversion instrument	instrument 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 instruments.
counter/timer	a circuit that counts external pulses or clock pulses (timing)
coupling	the manner in which a signal is connected from one location to another
CPU	central processing unit

D

D/A	digital-to-analog
DAC	digital-to-analog converter—an electronic instrument, often an integrated circuit, that converts a digital number into a corresponding analog voltage or current
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 x $\log_{10}$(V1/V2) for signals in volts
DC	direct current
DC coupled	allowing the transmission of both AC and DC signals
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*.
DGND	digital ground signal
DIO	digital input and output
drivers	software that controls a specific hardware instrument such as a DAQ board

dynamic range	the ratio of the largest signal level a circuit can handle to the smallest signal level it can handle (usually taken to be the noise level), normally expressed in dB

E

EEPROM	electrically erasable programmable read-only memory—ROM that can be erased with an electrical signal and reprogrammed
EMF	electromotive force

F

filters	digital or analog circuits that change the frequency characteristics of a waveform
ft	feet

G

GND	ground

H

h	hour
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—unit of frequency

I

IC	integrated circuit
IEEE	Institute of Electrical and Electronics Engineers
IEX	voltage excitation

in.	inches
instrument	a plug-in data acquisition board, card, or pad that can contain multiple channels and conversion instruments. Plug-in boards, PCMCIA cards, and instruments such as the DAQCard 4350, which connects to your PCMCIA bus, are all examples of DAQ instruments. SCXI modules are distinct from instruments, with the exception of the SCXI-1200, which is a hybrid.
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 instrument can interrupt
I/O	input/output—the transfer of data to/from a computer system involving communications channels, operator interface instruments, and/or data acquisition and control interfaces
ISA	industry standard architecture

K

k	kelvin—a unit of temperature
kbytes/s	a unit for data transfer that means 1,000 or 10^3 bytes/s

L

LabVIEW	laboratory virtual instrument engineering workbench
latch	digital instrument that stores the digital data based on a control signal

M

m	meters—a unit of length
M	(1) Mega, the standard metric prefix for 1 million or 10^6, when used with units of measure such as volts and hertz; (2) mega, the prefix for 1,048,576, or 2^{20}, when used with B to quantify data or computer memory
MB	megabytes of memory

Mbytes/s	a unit for data transfer that means 1 million or 10^6 bytes/s
MS	million samples

N

NI-DAQ	NI driver software for DAQ hardware
NIST	National Institute of Standards and Technology
noise	an undesirable signal—Electrical 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.
NTC	negative temperature coefficient

O

operating system	base-level software that controls a computer, runs programs, interacts with users, and communicates with installed hardware or peripheral instruments

P

passband	the range of frequencies which a instrument can properly propagate or measure
PC Card	a credit-card-sized expansion card that fits in a PCMCIA slot
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; it offers a theoretical maximum transfer rate of 132 Mbytes/s.
PCMCIA	an expansion bus architecture in notebook-size computers. It originated as a specification for add-on memory cards written by the Personal Computer Memory Card International Association.

peak to peak	a measure of signal amplitude; the difference between the highest and lowest excursions of the signal
Plug and Play instruments	instruments that do not require dip switches or jumpers to configure resources on the instruments—also called switchless instruments
Plug and Play ISA	a specification prepared by Microsoft, Intel, and other PC-related companies that will result in PCs with plug-in boards that can be fully configured in software, without jumpers or switches on the boards
PTC	positive temperature coefficient
pts	points

R

RAM	random-access memory
reading rate	the rate, in Hertz, at which each sample is updated
resolution	the smallest signal increment that can be detected by a measurement system. Resolution can be expressed in bits, in proportions, or in percent of full scale. For example, a system has 24-bit resolution, one part in 2^{24}=16777216 resolution, and 5.96 x 10^{-6}% of full scale.
rms	root mean square—the square root of the average value of the square of the instantaneous signal amplitude; a measure of signal amplitude
RSVD*x*	reserved
RTD	resistance temperature detector. A metallic probe that measures temperature based upon its coefficient of resistivity.

S

s	seconds
S	samples
sintered	to cause to become a coherent mass by heating without melting
S/s	samples per second—used to express the rate at which a DAQ board samples an analog signal

switchless instrument	instruments that do not require dip switches or jumpers to configure resources on the instruments—also called Plug and Play instruments
system noise	a measure of the amount of noise seen by an analog circuit or an ADC when the analog inputs are grounded

T

transfer rate	the rate, measured in bytes/s, at which data is moved from source to destination after software initialization and set up operations; the maximum rate at which the hardware can operate
trigger	any event that causes or starts some form of data capture
TTL	transistor-transistor logic

U

update rate	the rate at which the measurement data is updated

V

V	volts
VI	virtual instrument—(1) a combination of hardware and/or software elements, typically used with a PC, that has the functionality of a classic standalone instrument (2) a LabVIEW software module (VI), which consists of a front panel user interface and a block diagram program
VirtualBench	software suite of stand-alone virtual instruments that combine DAQ products, software, and PCs

W

waveform	multiple voltage readings taken at a specific sampling rate

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