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Computer-Based Instruments

NI 4350/4351 User Manual

High-Precision Temperature and Voltage Meters

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About This Manual

This manual describes the electrical and mechanical aspects of the NI 4350/4351 family of instruments and contains information concerning its operation and programming.

Organization of This Manual

The *NI 4350/4351 User Manual* is organized as follows:

- Chapter 1, *Introduction*, describes the NI 4350/4351 family of high-precision temperature and voltage meters, lists what you need to get started, explains how to unpack your instrument, and describes the optional software and optional equipment.
- Chapter 2, *Installation and Configuration*, describes how to install and configure your NI 435*x* instrument.
- Chapter 3, *NI 435x Operation*, describes how to use your NI 435*x* instrument and includes operation tips on taking measurements with temperature sensors such as thermocouples, RTDs, and thermistors, as well as measuring voltage and resistances.
- Appendix A, *Specifications*, lists the specifications of the NI 4350 and NI 4351.
- Appendix B, *Signal Connections*, explains the signal correlation between your NI 435*x* 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.

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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 NI 435*x* 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.
`monospace`	Text in this font is used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames and extensions, and for statements and comments taken from programs.
NI 4350 (ISA)	Refers only to the NI 4350 for ISA bus computers. You may have software that refers to this instrument as the PC-4350.
NI 4350 (PCMCIA)	Refers only to the NI 4350 for computers with a Type II PCMCIA slot. You may have software that refers to this instrument as the DAQCard-4350.
NI 4350 (USB)	Refers only to the NI 4350 for computers that are USB compatible. You may have software that refers to this instrument as the DAQPad-4350.
NI 4350/4351	Refers to all instruments in the National Instruments 4350 and 4351 families.
NI 4351 (PCI)	Refers only to the NI 4351 for PCI bus computers.

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NI 4351 (PXI)	Refers only to the NI 4351 for PXI bus computers.
NI 435*x*	Refers to all instruments in the National Instruments 4350 and 4351 families.

National Instruments Documentation

The *NI 4350/4351 User Manual* is one piece of the documentation set for your computer-based instrument 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 computer-based instrument 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 application software, NI435X instrument driver software, and NI-DAQ software documentation. National Instruments application software includes LabVIEW, LabWindows/CVI, 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.

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Introduction

Chapter 1

This chapter describes the NI 4350/4351 family of high-precision temperature and voltage meters, lists what you need to get started, explains how to unpack your instrument, and describes the optional software and optional equipment.

About the NI 435*x* Instruments

Thank you for buying a National Instruments 435*x* instrument. The NI 435*x* family consists of five instruments for the bus of your choice: PCMCIA, ISA, Universal Serial Bus (USB), PXI, and PCI.

The NI 435*x* instruments feature accurate thermocouple and DC voltage measurements. You can also take temperature measurements with resistance temperature detectors (RTDs), thermistors, ohm measurements using the built-in precision current sources, and current measurements using external shunt resistors. You can use the NI 435*x* instrument with a personal computer to make the same measurements you would with standard bench-top instruments such as data loggers and DMMs.

The NI 435*x* instruments contain a 24-bit sigma-delta 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 on the NI 4350 (PCMCIA, ISA, USB) and NI 4351 (PXI, PCI) and up to 15 kΩ with the additional built-in 1 mA precision current source on the NI 4351 (PXI, PCI). In addition, the NI 435*x* instruments have programmable TTL-compatible digital

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I/O (DIO) for monitoring TTL-level inputs, interfacing with external devices, and generating alarms.

The NI 435*x* instrument is Plug and Play compatible. The instrument is fully software-calibrated. Because the NI 435*x* instrument works with a variety of operating systems, you can develop applications that scale across several platforms.

A system based on an NI 435*x* instrument offers flexibility, performance, and size, making it ideal for service, repair, and manufacturing and for use in industrial and laboratory environments. The NI 435*x* instrument, used with your computer, is a versatile, cost-effective platform for high-resolution measurements.

Detailed specifications for the NI 435*x* instruments are in Appendix A, *Specifications*.

Using PXI with CompactPCI

Using PXI-compatible products with standard CompactPCI products is an important feature provided by the *PXI Specification*, Revision 1.0. If you use a PXI-compatible plug-in instrument in a standard CompactPCI chassis, you will be unable to use PXI-specific functions, but you can still use the basic plug-in instrument functions. For example, the RTSI bus on certain PXI instruments are available in a PXI chassis, but not in a CompactPCI chassis. However, the NI 4351 (PXI) does not offer any PXI-specific functions, and therefore all of its functions are available on the CompactPCI bus.

What You Need to Get Started

To set up and use your NI 435*x* instrument, you will need the following:

- ❑ One of the following NI 435*x* instruments:
  - NI 4350 (PCMCIA)
  - NI 4350 (ISA)
  - NI 4350 (USB)
  - NI 4351 (PXI)
  - NI 4351 (PCI)

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- ❑ NI-DAQ 6.5 for PC compatibles or higher
- ❑ NI435X instrument driver
- ❑ One of the following software packages and documentation:
  - VirtualBench 2.1.1a or higher
  - LabVIEW 4.0 or higher
  - LabWindows/CVI 4.0 or higher
  - BridgeVIEW 1.0 or higher
  - Third-party compiler
- ❑ Optional cables and accessories
- ❑ Your computer

Unpacking

- NI 4350 (PCMCIA)

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

- NI 4350 (ISA), NI 4351 (PXI, PCI)

  Your NI 4350 (ISA) or NI 4351 (PXI, PCI) 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.

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- *Never* touch the exposed pins of the connector.
- Also, do not touch the printed circuit board or any components on board. This may affect performance of the instrument.

⚠ **Caution:** ***The NI 435x (ISA, PXI, PCI) is ESD/contamination sensitive. Handle the board using the edges or metal bracket.***

♦ NI 4350 (USB)

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

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 NI435*X* 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

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included with the NI-DAQ software kit. The LabWindows/CVI Data Acquisition library is functionally equivalent to the NI-DAQ software.

NI 435*x* instruments are supported by the Easy I/O for DAQ library in LabWindows/CVI. Use of the NI435X instrument driver is 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 format that can be used with popular spreadsheet programs and word processors. A report generation capability complements the raw data storage by adding timestamps, measurements, user name, and comments.

Your NI 435*x* works with VirtualBench-Logger and VirtualBench-DIO. 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, 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.

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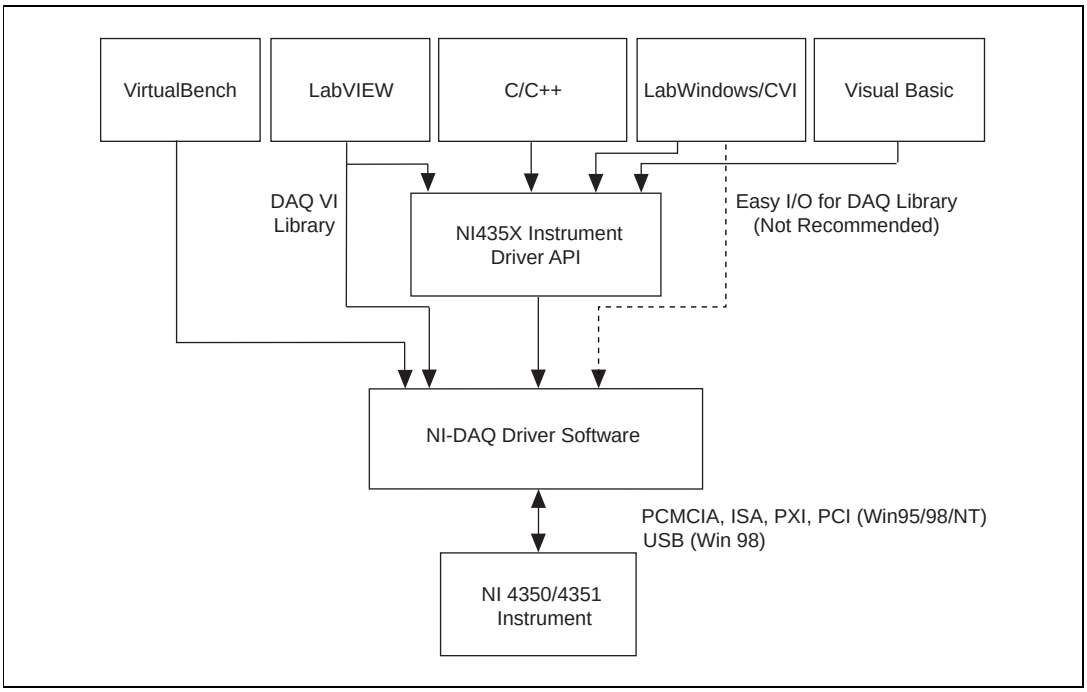


Figure 1-1. The Relationship between the Programming Environment, NI435X Instrument Drivers, NI-DAQ and Your Hardware

Optional Equipment

National Instruments offers a variety of products to use with your NI 435*x*, including cables, connector blocks, terminal blocks and other accessories, as follows:

- Cables and adapters with thermocouple miniconnectors
- 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 web site or call the office nearest you.

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Installation and Configuration

Chapter 2

This chapter describes how to install and configure your NI 435*x* instrument.

Software Installation

Install your software before you install your NI 435*x* instrument. Refer to the appropriate release notes for specific instructions on the software installation sequence.

If you are using LabVIEW, LabWindows/CVI, or VirtualBench, refer to the release notes for your software. After you have installed your software, refer to the NI-DAQ release notes and follow the instructions given there for your operating system and your software.

If you are using programming languages such as Visual Basic, C, or C++ with NI-DAQ, follow the NI-DAQ instructions for installing third party compilers.

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

Hardware Installation

- NI 4350 (PCMCIA)

  You can install your NI 4350 (PCMCIA) in any available Type II PCMCIA slot in your computer. Windows 95 or higher includes the Plug and Play services your operating system will use. Windows NT 4.0 or higher includes the drivers needed to use PCMCIA cards.

  The operating system configures the NI 4350 (PCMCIA) and automatically assigns the base address and the interrupt level. Before installing your NI 4350 (PCMCIA), consult your computer user manual or technical reference manual for specific instructions and warnings.

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Use the following general instructions to install your NI 4350 (PCMCIA):

1. Write down your NI 4350 (PCMCIA) serial number on the *NI 4350/4351 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 NI 4350 (PCMCIA) 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 NI 4350 (PCMCIA) into the PCMCIA slot until the connector is firmly seated. Notice that the NI 4350 (PCMCIA) connectors are keyed so that you can insert it in only one way.
5. Run Measurement & Automation Explorer to make sure that the NI 4350 (PCMCIA) is configured.
6. Configure your accessory using Measurement & Automation Explorer.

Your NI 4350 (PCMCIA) is now installed.

- NI 4350 (ISA)

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

1. Write down your NI 4350 (ISA) serial number on the *NI 4350/4351 Hardware and Software Configuration Form* in Appendix C.
2. Turn off and unplug your computer.

Warning: ***To protect both yourself and the computer from electrical hazards, the computer should remain off until you finish installing the NI 4350 (ISA).***

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.

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Caution: ***The NI 4350 (ISA) is ESD/contamination sensitive. Handle the board using the metal bracket or edges.***

5. Insert the NI 4350 (ISA) 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 NI 4350 (ISA) to the back panel rail of the computer.
7. Replace the cover.
8. Plug in and turn on your computer.
9. Run Measurement & Automation Explorer to make sure that your NI 4350 (ISA) is configured.
10. Configure your accessory using Measurement & Automation Explorer.

Your NI 4350 (ISA) is now installed.

- NI 4350 (USB)

You can connect your NI 4350 (USB) to any available USB connector, which supports high-power, bus-powered peripheral devices. The following are general installation instructions, but consult your PC user manual or technical reference manual for specific instructions and warnings:

1. Connect the USB cable from the computer port or from any other hub to the port on the NI 4350 (USB).
2. Your computer should detect the NI 4350 (USB) immediately. When the computer recognizes the NI 4350 (USB), the LED on the front panel blinks or lights up, depending on the status of your device.

   If the LED comes on after the NI 4350 (USB) is connected to the host, it is functioning properly. If the LED remains off or blinks, refer to Table 2-1.

   The LED blinks on and off for one second each for as many times as necessary, then waits three seconds before repeating the cycle.

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Table 2-1. LED Patterns for the NI 4350 (USB) States

LED	NI 4350 (USB) State	Description
On	Configured state	Your NI 4350 (USB) is configured.
Off	Off or in the low-power, suspend mode	Your NI 4350 (USB) is turned off or in the low-power, suspend mode.
1 blink	Attached state	Your NI 4350 (USB) is recognized but not configured.
2 blinks	Addressed state	This pattern is displayed if the host computer detects your NI 4350 (USB) but cannot configure it because NI-DAQ is not properly installed or there are no system resources available. Check your software installation.
3 blinks	Power supply failure	This pattern is displayed if the internal power supply shuts down. Refer to the *Power Considerations for the NI 4350 (USB)* section for more information.
4 blinks	General error state	If this pattern is displayed, contact National Instruments.

3. Run Measurement & Automation Explorer to make sure that your NI 4350 (USB) is configured.
4. Configure your accessory using Measurement & Automation Explorer.

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- NI 4351 (PXI)

  You can install your NI 4351 (PXI) in any available 5 V peripheral slot in your PXI or CompactPCI chassis.

Note: ***The NI 4351 (PXI) does not have any connections to reserved lines on the CompactPCI J2 connector. Therefore, you can use the NI 4351 (PXI) in a CompactPCI system that uses J2 connector lines for purposes other than PXI.***

1. Turn off and unplug your PXI or CompactPCI chassis.

Warning: ***To protect both yourself and the computer from electrical hazards, the computer should remain off until you finish installing the NI 4351 (PXI).***

2. Choose an unused PXI or CompactPCI 5 V peripheral slot.
3. Remove the filler panel for the peripheral slot you have chosen.
4. Touch a metal part on your chassis to discharge any static electricity that might be on your clothes or body.

Caution: ***The NI 4351 (PXI) is ESD/contamination sensitive. Handle the board using the metal bracket or edges.***

5. Insert the NI 4351 (PXI) in the selected 5 V slot. Use the injector/ejector handle to fully inject the device into place.
6. Screw the front panel of the NI 4351 (PXI) to the front panel mounting rails of the PXI or CompactPCI chassis.
7. Visually verify the installation.
8. Plug in and turn on the PXI or CompactPCI chassis.
9. Run Measurement & Automation Explorer to make sure that your NI 4351 (PXI) is configured.
10. Configure your accessory using Measurement & Automation Explorer.

Your NI 4351 (PXI) is now installed.

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- NI 4351 (PCI)

  You can install your NI 4351 (PCI) in any available PCI expansion slot in your computer. However, to achieve the best noise performance, you should leave as much room as possible between the NI 4351 (PCI) and other boards and hardware. The following are general instructions, but consult your computer user manual or technical reference manual for specific instructions and warnings.

  1. Plug in but do not turn on your computer before installing the NI 4351 (PCI) device. The power cord grounds the computer and protects it from electrical damage while you are installing the module.

Warning: ***To protect both yourself and the computer from electrical hazards, the computer should remain off until you finish installing the NI 4351 (PCI).***

2. Remove the top cover or access port to the PCI bus.
3. Select any available PCI expansion slot.
4. Locate the metal bracket that covers the cut-out in the back panel of the chassis for the slot you have selected. Remove and save the bracket-retaining screw and the bracket cover.
5. Touch the metal part of the power supply case inside the computer to discharge any static electricity that might be on your clothes or body.

Caution: ***The NI 4351 (PCI) is ESD/contamination sensitive. Handle the board using the metal bracket or edges.***

6. Line up the NI 4351 (PCI) with the 68-pin connector near the cut-out on the back panel. Slowly push down on the top of the NI 4351 (PCI) until its card-edge connector is resting on the expansion slot receptacle. Using slow, evenly distributed pressure, press the NI 4351 (PCI) straight down until it seats in the expansion slot.
7. Reinstall the bracket-retaining screw to secure the NI 4351 (PCI) to the back panel rail.
8. Check the installation.
9. Replace the computer cover and turn on the computer.

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10. Run Measurement & Automation Explorer to make sure that your NI 4351 (PCI) is configured.
11. Configure your accessory using Measurement & Automation Explorer.

Your NI 4351 (PCI) is now installed.

Configuration

Your NI 435*x* is a completely software-configurable, Plug and Play instrument. The Plug and Play services query the instrument and allocate the required resources. Then the operating system enables the instrument for operation.

Power Considerations for the NI 4350 (USB)

The NI 4350 (USB) is designed to remain powered only when the USB cable connects it to the host PC and the PC is powered.

The NI 4350 (USB) is designed to run in a standalone mode, drawing power only from the USB cable. There are circumstances when the NI 4350 (USB) may require more power than the USB power supply can safely deliver, so if the NI 4350 (USB) tries to draw more than the allowed current from the USB power supply, internal protection circuitry will turn off most of the circuitry in the NI 4350 (USB) to protect the USB supply. This over-current condition makes the LED blink in the power supply overload pattern described in Table 2-1.

☞ **Note:** ***When the NI 4350 (USB) turns off, any data acquisition in progress will be aborted and the data will be lost.***

The host computer has the ability to go into a power-saving *suspend* mode and, during this time, the NI 4350 (USB) can go either into a low-power mode also or remain in a fully powered, static state. This low-power mode is important if you are using a laptop or if power consumption is a concern.

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In the powered, static state of the NI 4350 (USB), all digital outputs will be static at a fixed voltage.

☞ **Note:** ***Refer to the NI-DAQ function,*** `Set_DAQ_Device_Info`***, in the NI-DAQ documentation or to the Set DAQ Device Information.vi in the LabVIEW documentation to change the settings that determine the behavior of the NI 4350 (USB) during the suspend state. The default setting is to remain fully powered.***

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Chapter 3

NI 435*x* Operation

This chapter describes how to use your NI 435*x* instrument and includes operation tips on taking measurements with temperature sensors such as thermocouples, RTDs, and thermistors, as well as measuring voltages and resistances.

Warming up Your NI 435*x* Instrument

To minimize the effects of thermal drift and to ensure the specified accuracy, allow the NI 435*x* 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 NI 435*x* instrument warms up for about 30 minutes.

Choosing a Measurement Mode

Each analog input channel can be configured in two possible measurement modes—the *volts* mode or the *4-wire ohms* mode. Use the *volts* mode for thermocouple and voltage measurements and the *4-wire ohms* mode for RTD, thermistor, and resistance measurements using the built-in current source to provide excitation for your resistive sensors. In the *4-wire ohms* mode, the software will return the resistance value by dividing the voltage measured by the value of the current source stored onboard.

☞ **Note:** ***VirtualBench, the NI435X instrument driver, and the Measurement & Automation Explorer channel wizard select the measurement mode automatically, depending on the sensor type you specify.***

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Choosing a Range

The volts mode has six bipolar input ranges: ±625 mV, ±1.25 V, ±2.5 V, ±3.75 V, ±7.5 V, and ±15 V.

The *4-wire ohms* mode has six corresponding input ranges when used with the built-in 25 µA current source: 25, 50, 100, 150, 300, and 600 kΩ, and 625 Ω, 1.2 kΩ, 3.75 kΩ, 7.5 kΩ, and 15 kΩ with the built-in 1 mA current source on the NI 4351 (PXI, PCI). Choose the smallest range for the best measurement results.

☞ **Note:** ***With VirtualBench, the NI435X instrument driver, or the Measurement & Automation Explorer channel wizard, you can specify the range based on your sensor type in engineering units appropriate to the sensor. This sensor range is used to automatically set the actual hardware range.***

Choosing a Reading Rate

The *reading rate* is the rate at which your NI 435*x* takes a new measurement. This rate has a direct relationship with the digital filter built into the ADC used in the NI 435*x*.

The digital filter has the characteristics shown in Figure 3-1. You can set the frequency of the first notch of this filter to 10, 50, or 60 Hz. Setting the notch filter at one of these frequencies rejects any noise at that frequency as well as at all its multiples.

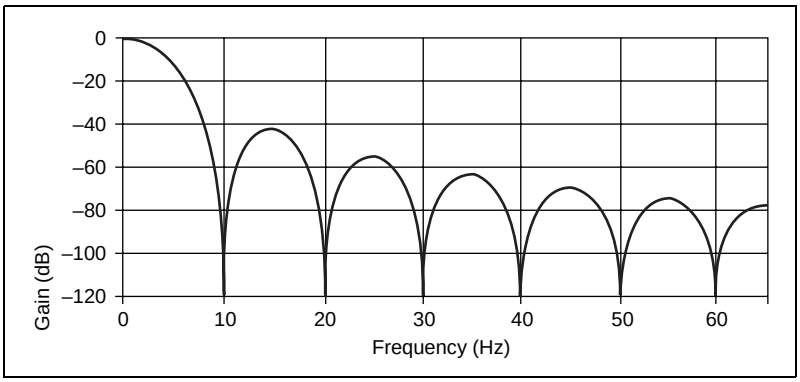


Figure 3-1. Digital Filter Characteristics for 10 Hz Setting

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In single-channel measurements, the reading rate is the same as the notch filter frequency—10, 50, or 60 readings/s. In multiple-channel measurements, the reading rates adjust to allow the analog and digital filters to settle to the specified accuracy.

☞ **Note:** ***To determine the reading rate per channel when scanning multiple channels, divide the multiple-channel measurement reading rate in Table 3-1 by the number of channels in the scan.***

In certain applications, such as resistance measurements above 25 kΩ or voltage measurements with more than 25 kΩ of source resistance, you should measure the same channel for up to 1 s, then switch to another channel to achieve the specified accuracy.

To optimize measurement accuracy and minimize the noise level, choose the 10 Hz notch filter setting.

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

Table 3-1. Filtering and Sample Rates

LabVIEW	NI435*X* Instrument Driver VirtualBench-Logger		Equivalent Filter Setting		Harmonics of Noise Frequencies Rejected (Hz)	Single-Channel Measurement Reading Rate (readings/s)	Multiple-Channel Measurement Reading Rate (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	1.4‡
50	50	fast	1 8	50 400	50 and 400	50	8.8	2.1‡
60	60	fast	1	60	60	60	9.7	2.1‡

*Number of power-line cycles used for filtering
†Power line frequency
‡For resistance ranges of 50 kΩ and higher

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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 devices, 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 NI 435*x* 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 the outputs of plug-in devices with nonisolated outputs, voltage across RTDs, thermistors, or resistors you may be measuring using the built-in current sources of the NI 435*x*.

Using Programmable Ground-Referencing

Your NI 435*x* 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.

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Table 3-2. Using Programmable Ground-Referencing

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

☞ **Note:** ***The default setting for programmable ground referencing is** on **in volts measurement mode and** off **in 4-wire ohms mode.***

Using Programmable Open-Thermocouple Detection

The NI 435*x* 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.

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

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

☞ **Note:** ***The default setting for programmable open-thermocouple detection in volts and 4-wire ohms measurement modes is*** *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 NI 435*x* instrument accessory creates the *reference junction* or *cold junction*, shown in Figure 3-2. 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*.

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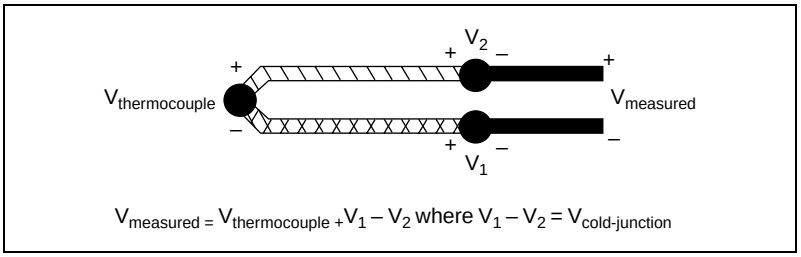


Figure 3-2. Effect of the Cold Junction

With the NI 435*x* instruments, you can perform cold-junction compensation in software. To do this, you can use the thermistor temperature sensor on the NI 435*x* accessory to measure the ambient temperature at the cold junction and compute the appropriate compensation for the unwanted thermoelectric voltages using software.

You have several options for performing cold-junction compensation, as shown below.

- If you are using the NI435X instrument driver, LabVIEW, LabWindows/CVI, VirtualBench, or the Measurement & Automation Explorer channel wizard, your software will automatically perform cold-junction compensation on all channels configured as thermocouple channels.
- If you are using LabVIEW and are not using the instrument driver or the Measurement & Automation Explorer channel wizard, your software includes examples 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. These examples are located in the DAQ analog input example library and have *NI 435x* in their title.
- If you are not using either of the previous software options, follow the steps below to perform cold-junction compensation:
  1. Measure the resistance of the thermistor cold-junction sensor, $R_{\text{thermistor cold-junction}}$, and compute the cold-junction temperature, $T_{\text{cold-junction}}$, using the thermistor resistance-temperature conversion formula.
  2. From this temperature of the cold-junction, $T_{\text{cold-junction}}$, compute the equivalent thermocouple voltage, $V_{\text{cold-junction}}$, for this junction using a standard thermocouple conversion formula.

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3. Measure the voltage, $V_{measured}$, and add the cold-junction voltage, $V_{cold\text{-}junction}$, computed in step 2.
4. Convert the resulting voltage to temperature using a standard thermocouple conversion formula.

Connecting Your Thermocouple

The NI 435*x* accessories—the PSH32-TC6 and the CB-27T for the NI 4350 (PCMCIA), and the TC-2190 and the TBX-68T for the NI 435*x* (ISA, USB, PXI, PCI)—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 NI 435*x* instrument analog inputs are protected against damage from voltages within ±42 VDC in all ranges when powered up and ±17 VDC when the NI 435*x* 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 NI 435x instrument is powered up and ±17 VDC when the NI 435x instrument is powered down.***

Input Ranges

Choose the ±625 mV range in volts mode when you are measuring thermocouples. You can measure both the thermocouples and the thermistor cold-junction sensor on the NI 435*x* accessory in the same scan by choosing the 25 kΩ range for measuring the thermistor. These ranges offer 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.

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Auto-Zero

Auto-zero is a method that instruments use to remove any 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 NI 435*x* instrument may have. This is especially useful when your NI 435*x* instrument is operating at an ambient temperature other than that of calibration (23 °C typical).

☞ **Note:** ***When using the VirtualBench-Logger along with NI 435x 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 NI 435*x* instrument.

When you use the PSH32-TC6, CB-27T, TC-2190, and TBX-68T accessories, always switch on ground-referencing on CH1. Doing this ground-references the auto-zero channel.

On all the NI 435*x* instrument accessories used with thermocouples, analog channel CH0 is dedicated to the thermistor cold-junction sensor. The built-in current source return terminal IEX– or IEX0– 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. Current source terminal IEX1– is also tied to –2.5 V through a resistor.

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☞ **Note:** ***When using VirtualBench-Logger, the Measurement & Automation Explorer channel wizard, or the NI435X Instrument Driver, the ground-referencing switch on the cold-junction sensor channel and auto-zero channel is set appropriately, automatically.***

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:

error voltage = resistance of the thermocouple • 125 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 of the wire (use 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 NI 435*x* 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 NI 435*x* instrument may exhibit additional errors. To minimize these errors, keep the thermocouples and the NI 435*x* 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. Choose the notch filter frequency of 10 Hz for 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.

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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 NI 435*x* instrument, and its accessories.

Measuring DC Voltage

Connecting Your DC Voltage Signal

The NI 435*x* accessories—the CB-27T and CB-27 for the NI 4350 (PCMCIA), and the TBX-68T and TBX-68 for the NI 435*x* (ISA, USB, PXI, PCI)—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 NI 435*x* analog inputs are protected against damage from voltages within ±42 VDC in all ranges when powered up and ±17 VDC when the NI 435*x* 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 NI 435x instrument is powered up and ±17 VDC when the NI 435x instrument is powered down.***

Input Ranges

Your NI 435*x* 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 NI 435*x* 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.

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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 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 NI 435*x* instrument may have. This is especially useful when the NI 435*x* instrument is operating at an ambient temperature other than that of calibration (23 °C typical).

☞ **Note:** ***When using the VirtualBench-Logger along with NI 435x 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 NI 435*x* instrument.

When you use the CB-27T and TBX-68T accessories, always switch on ground-referencing on CH1. Doing this ground-references the auto-zero channel.

☞ **Note:** ***When using the VirtualBench-Logger, or NI435X Instrument Driver, or the Measurement & Automation Explorer channel wizard, along with the NI 435x accessories— PSH32-TC6, CB-27T, TC-2190, or TBX-68T— the ground-referencing switch on the auto-zero channel is set appropriately, automatically.***

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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. If either of these is greater than 25 kΩ, you should measure the same channel for up to 1 s, then switch to another channel to achieve the specified accuracy.

AC Noise Effects

Your NI 435*x* 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 NI 435*x* instrument may exhibit additional errors. To minimize these errors, keep the signal source and the NI 435*x* 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 notch filter frequency of 10 Hz 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 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 NI 435*x* instrument accessory. Avoid using dissimilar metal wires in connections. Also, minimize temperature gradients in the space enclosing the signal source, the NI 435*x* instrument, and its accessories.

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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 NI 435*x*, 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*.When using the NI435X instrument driver, set the measurement mode to *Resistance*. These modes will return the measurements in units of resistance (ohms) 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 device 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 devices. 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.

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Relationship of Resistance and Temperature in RTDs

Compared to other temperature devices, 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:

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

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 3-3 shows a typical resistance-temperature curve for a 100 Ω platinum RTD.

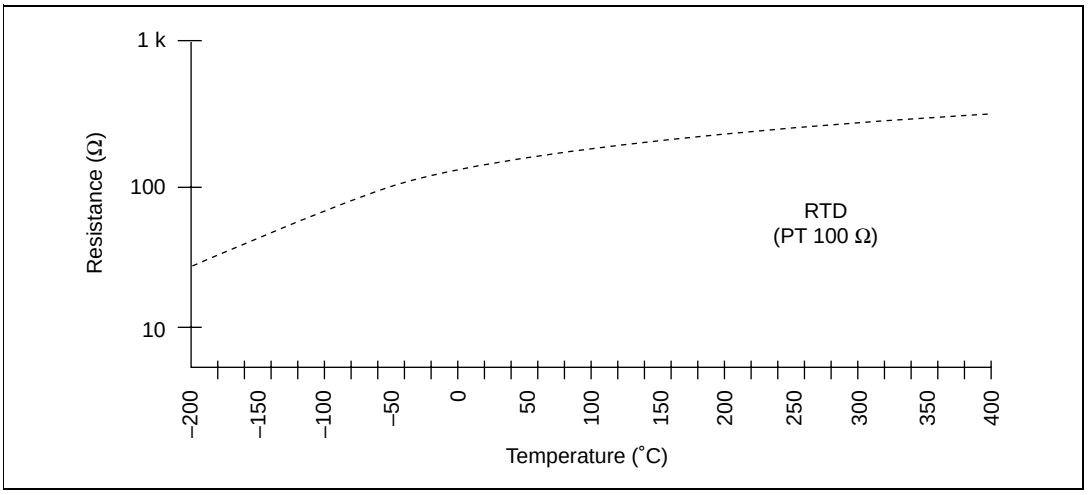


Figure 3-3. Resistance-Temperature Curve for a 100 Ω Platinum RTD

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:

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

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where R_{RTD} is the resistance of the RTD at temperature T_{RTD}, 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_{RTD} 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:

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

Most platinum RTD curves follow one of three standardized curves: the DIN 43760 standard (α = 0.00385), the U.S. Industrial or American standard (α = 0.003911), or the International Temperature Scale (ITS-90) that is used with wire-wound RTDs (α = 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*
IEC751	0.00385055	$3.9083 \bullet 10^{-3}$	$-5.775 \bullet 10^{-7}$	$-4.183 \bullet 10^{-1}$
DIN 43 760	0.003850	$3.9080 \bullet 10^{-3}$	$-5.8019 \bullet 10^{-7}$	$-4.2735 \bullet 10^{-12}$
American	0.003911	$3.9692 \bullet 10^{-3}$	$-5.8495 \bullet 10^{-7}$	$-4.2325 \bullet 10^{-12}$
ITS-90	0.003925	$3.9848 \bullet 10^{-3}$	$-5.870 \bullet 10^{-7}$	$-4.0000 \bullet 10^{-12}$
* For temperatures below 0 °C only; C = 0.0 for temperatures above 0 °C.				

☞ **Note:** ***Software packages, such as VirtualBench, NI435X instrument driver, Measurement & Automation Explorer channel wizard, LabVIEW, and LabWindows/CVI 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 device, you must pass current through the device and measure the resulting voltage. However, any resistance in the lead wires that connect your measurement system to the RTD will

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add errors to your readings. For example, consider a two-wire RTD element connected to the NI 435*x* instrument accessory that also supplies a constant current source IEX to excite the RTD. As shown in Figure 3-4, the voltage drop across the lead resistance R_L, adds to the measured voltage.

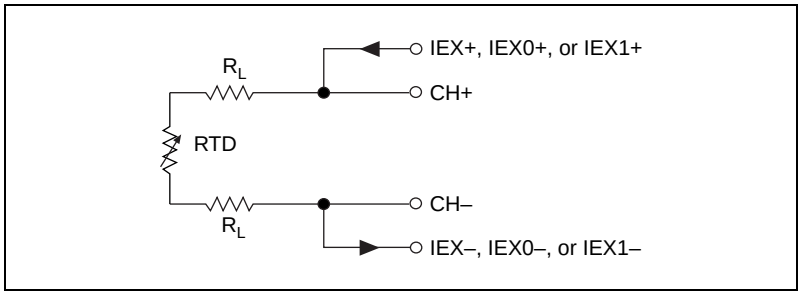


Figure 3-4. Two-Wire RTD Measurement

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 3-5 illustrates this configuration.

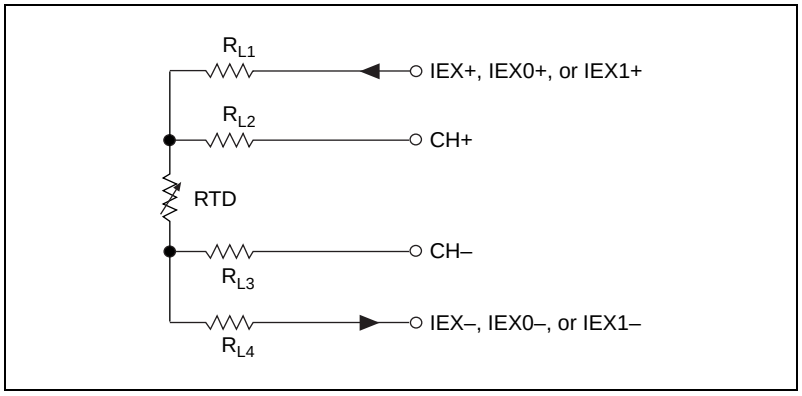


Figure 3-5. Four-Wire RTD Measurement

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

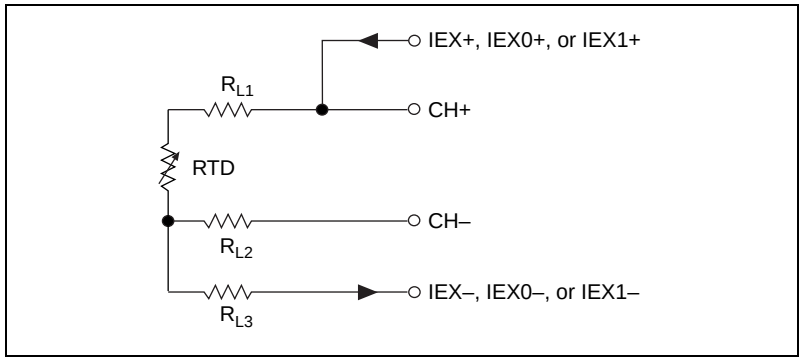


Figure 3-6. Three-Wire RTD Measurement

Another variation of the three-wire RTD configuration is shown in Figure 3-7. In this configuration, the effects of the lead wire resistance cancel out, as long as all three wires have the same lead resistance.

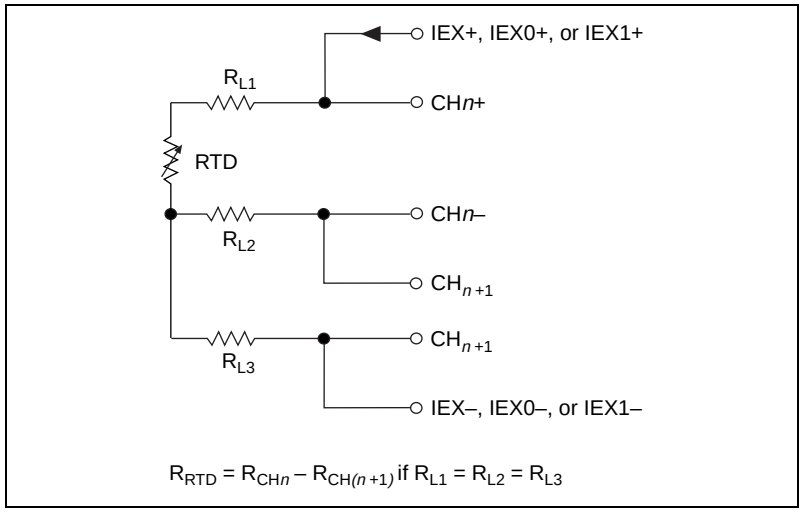


Figure 3-7. Three-Wire RTD Measurement and Lead Wire Resistance Compensation

See Figure 3-10 for an example of how you can use different transducers connected to analog channels in the same measurement setup.

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☞ **Note:** ***For best results, use the 1 mA current source when using the NI 4351 and the 25 µA source when using the NI 4350 with RTDs with resistances below 1 kΩ. See the*** `readme.doc` ***for software issues regarding the 1 mA source.***

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 device 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 devices 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 3-8 shows the resistance-temperature curve for a 5,000 Ω thermistor. The curve of a 100 Ω RTD is also shown for comparison.

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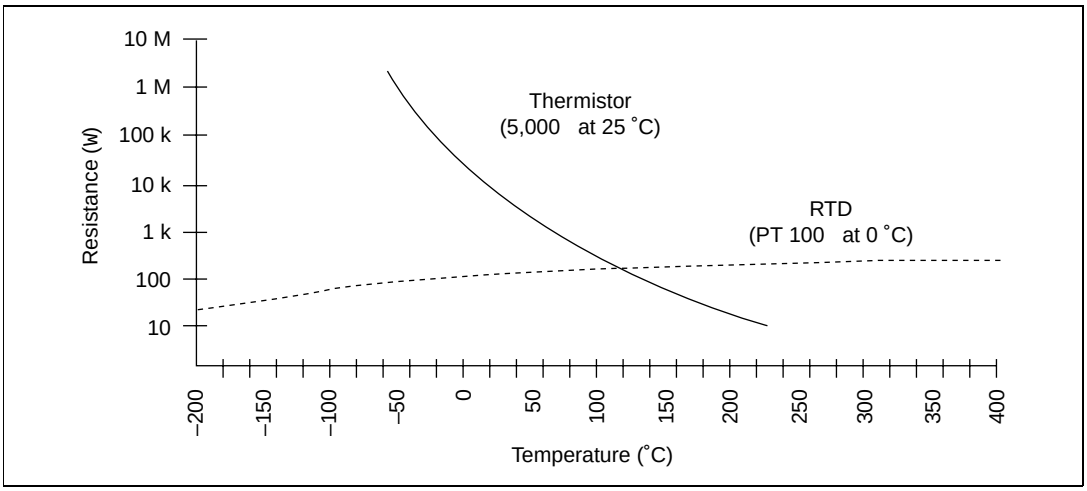


Figure 3-8. Resistance-Temperature Curve of a Thermistor

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

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

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

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provided by the thermistor manufacturer, or calculated from the resistance-versus-temperature curve.

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

Connecting Your Thermistor

Because the thermistor is a resistive device, you must pass a current through the thermistor to produce a voltage that can be measured by the NI 435*x* instrument. The high resistance and high sensitivity of the thermistor simplify the necessary measurement circuitry and signal conditioning. Special three-wire, or four-wire connections are not necessary. As shown in Figure 3-9, the measured voltage Vt will be equal to (Rt • I_{ex}).

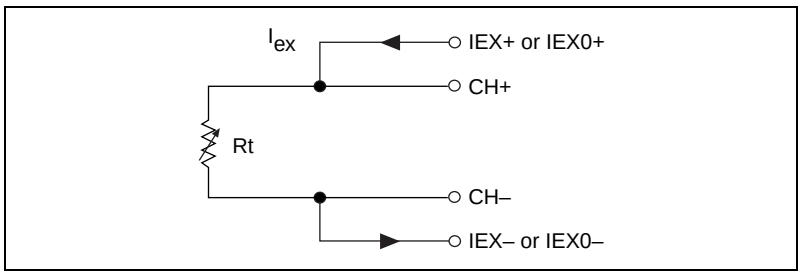


Figure 3-9. Thermistor Measurement

See Figure 3-10 for an example of how you can use different transducers connected to analog channels in the same measurement setup.

☞ **Note:** ***Use the 25 µA current source for thermistors above 1 kΩ.***

Connecting Your Resistor

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

The NI 435*x* accessories—the CB-27T and CB-27 for the NI 4350 (PCMCIA), and the TBX-68T and TBX-68 for the NI 435*x* (ISA, USB, PXI, PCI)—are designed to be used with RTDs, thermistors, and resistors. Consult your accessory installation guide for instructions on

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how to connect your resistors. Figures 3-10 and 3-11 show examples of how to use different transducers connected to analog channels in the same measurement setup.

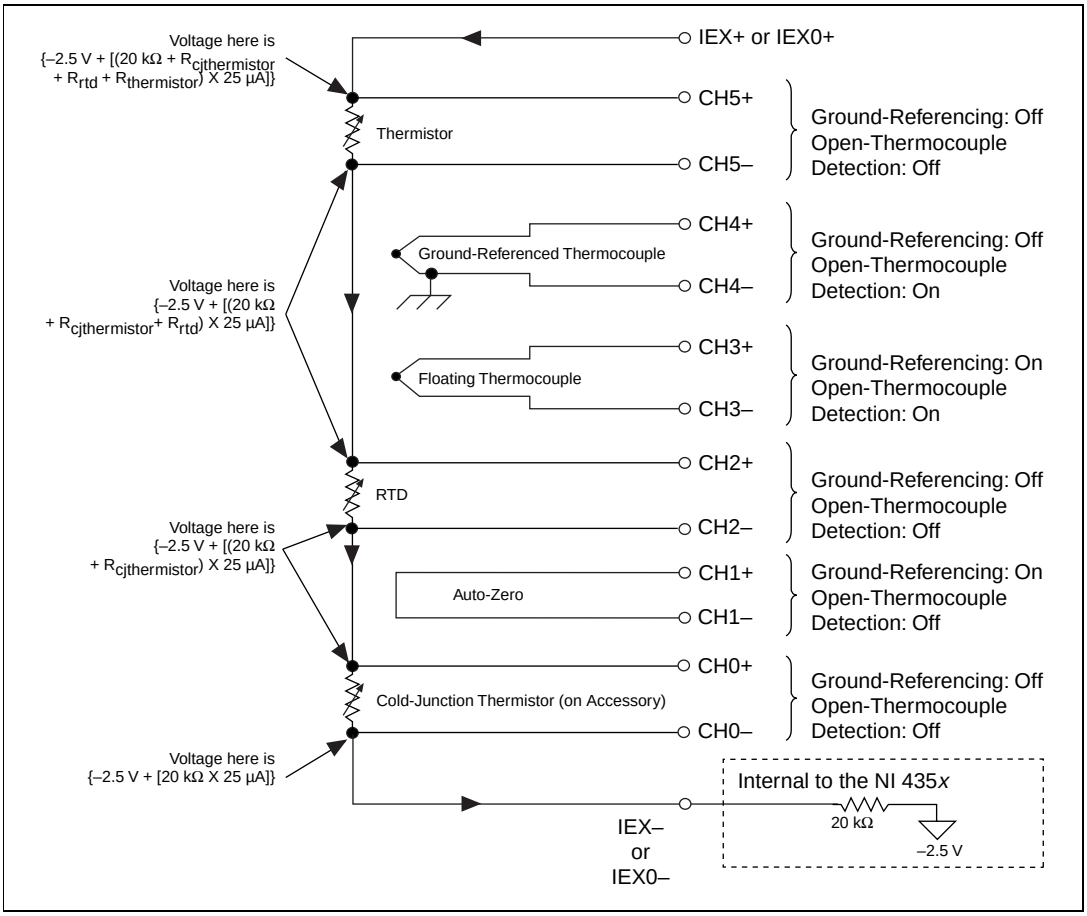


Figure 3-10. Multiple Transducer Connections to Analog Channels in One Measurement Setup, Channels 0–5

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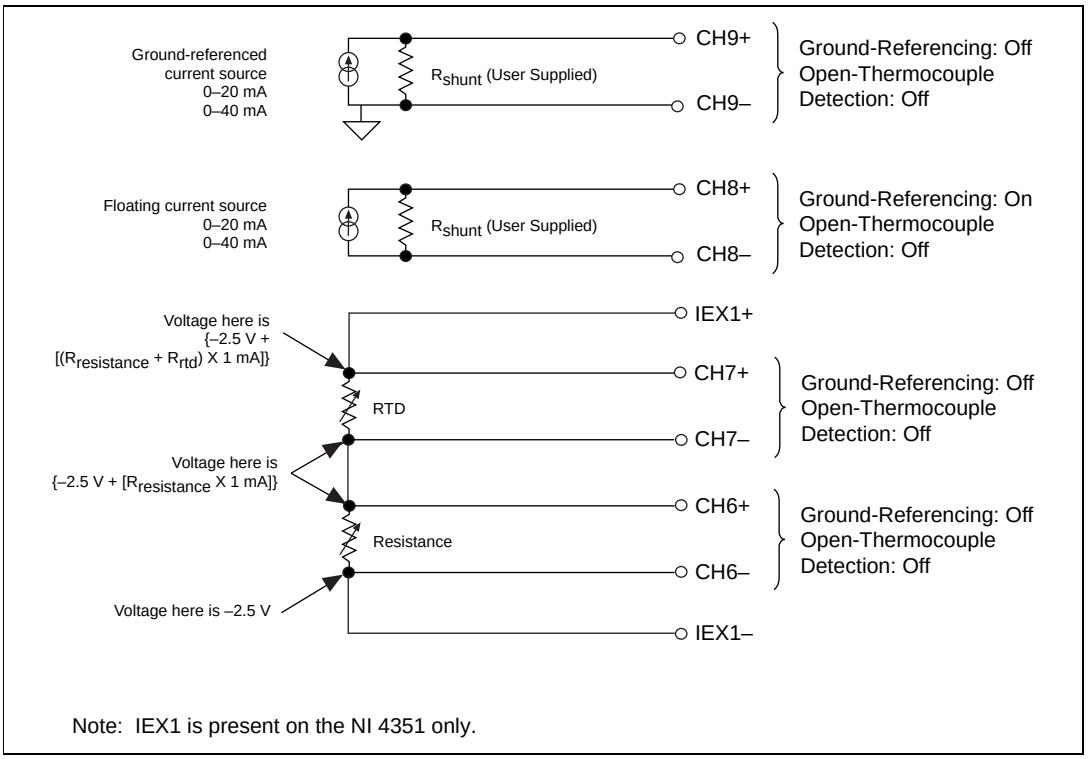


Figure 3-11. Multiple Transducer Connections to Analog Channels in One Measurement Setup, Channels 6–9

The NI 435*x* 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 NI 435x instrument is powered up and ±17 VDC when the NI 435x instrument is powered down.***

Input Ranges

The NI 435*x* has six ranges for resistance measurements. These ranges are 25, 50, 100, 150, 300, and 600 kΩ with the 25 µA current source. 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. The NI 4351 (PXI, PCI)

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has six additional ranges of 625 Ω, 1.25 kΩ, 2.5 kΩ, 3.75 kΩ, 7.5 kΩ, and 15 kΩ with the 1 mA current source.

To determine the most suitable input range for your application, estimate the voltage developed across the resistor by following the procedure outlined in Figures 3-10 and 3-11. Also estimate the common-mode voltage at the inputs and verify that the range you select can handle that common mode voltage. Also estimate the common-mode voltage at the inputs and verify that the range you select can handle that common-mode voltage. Choose the lowest range in the *4-wire ohms* mode when you are measuring RTDs and thermistors, for best results.

The NI 435*x* instrument can measure resistances to its specified accuracy as long as the voltage across the resistors is within the selected input range specified above. 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.

For resistance higher than 25 kΩ, a settling time of over 1 s may be required when changing channels, to achieve the specified accuracy.

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 any 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 NI 435*x* instrument may have. This is especially useful when your NI 435*x* instrument is operating at an ambient temperature other than that of calibration (23 °C typical). Use the

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four-wire mode in LabVIEW while reading the offset for resistance measurements.

☞ **Note:** ***When using VirtualBench-Logger along with NI 435x 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 terminals, IEX–, IEX0–, and IEX1–, are tied to –2.5 V through internal circuits. 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 Figures 3-10 and 3-11 for examples 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 Table 3-5.

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Table 3-5. Guidelines for Resistance Measurement

Resistance Being Measured (Ω)	Measurement Technique
R ≤ 1 kΩ	Four-wire
1 kΩ < R ≤ 10 kΩ	Four-wire or three-wire
R > 10 kΩ	Four-wire, three-wire, or two-wire

Self-Heating

The current source on the NI 435*x* 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 devices), power dissipated is equal to I^2R, which heats the resistive devices. 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:

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

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

RTDs are relatively 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

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higher in still air than in moving water. The self-heating in RTDs due to the built-in 25 µA is negligible. When using 1 mA excitation current, a 100 Ω RTD would dissipate:

$$I^2R = (1\ mA)^2 \bullet 100\ \Omega = 0.1\ mW$$

If this RTD has a dissipation constant of 5 mW/°C, the RTD will self-heat by 0.02 °C.

AC Noise Effects

The NI 435*x* instruments reject AC noise as specified in NMR in Appendix A, *Specifications*. However, if the amplitudes of the AC noise are large compared to the DC signal, or if the peak value (AC + DC) of the measured signal is outside the input range, the NI 435*x* instrument may exhibit additional errors. To minimize these errors, keep the signal source and the NI 435*x* 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 notch filter frequency of 10 Hz 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 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 NI 435*x* instrument accessory. Avoid using dissimilar metal wires in connections. Also, keep out temperature gradients in the space enclosing the signal source, the NI 435*x* instrument and its accessories.

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Using the Current Source

The NI 435*x* features a precision current source, which supplies 25 µA and provides excitation to a total maximum resistance of 600 kΩ. The NI 4351 has an additional precision current source, which supplies 1 mA and provides excitation to a total maximum resistance of 15 kΩ.

These resistances 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.

☞ **Note:** ***See the*** `readme.doc` ***file for software issues regarding the 1 mA current source.***

Using Digital Inputs and Outputs

The NI 435*x* features TTL-compatible digital lines. These lines can be individually configured either as inputs or as outputs. At power-up, these digital lines are configured as high-impedance inputs with a weak pull-up.

You can use the DIO lines as an interface to control processes, control events such as turning on and off heaters, relays, 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.

You can use the digital input lines to trigger analog acquisitions. To do this with the LabVIEW or NI435*X* instrument driver, set up the analog acquisition configuration, then poll the digital input line for your trigger condition and, upon getting the trigger, start the analog acquisition.

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Connecting Your Digital Input and Output

All NI 435*x* accessories are designed to be used for DIO. Refer to your accessory installation guide for instructions on how to connect your DIO lines. Figure 3-12 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.

For the NI 435*x* (ISA, USB, PXI, PCI), you can use the TBX-68T (revision C or later) to connect to digital signal conditioning accessories with optocouplers, solid-state relays, and electromechanical relays, such as the SC-2061, SC-2062, SC-2063, SSR Series, and the ER Series.

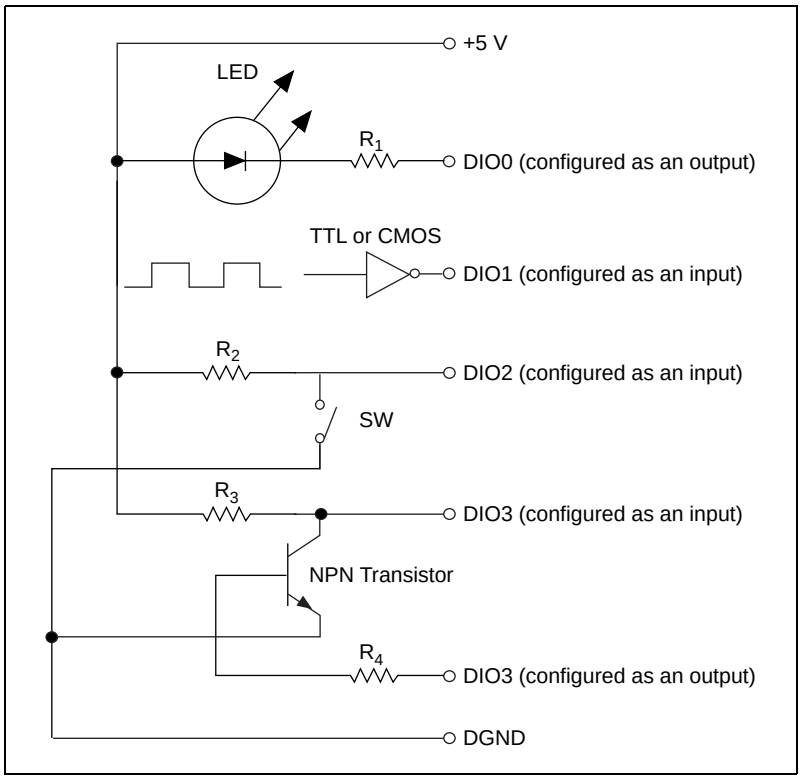


Figure 3-12. Examples of DIO Applications

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The DIO lines of the NI 435*x* 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.***

Note: ***If the number of digital input lines is not adequate for your application, you can use the analog input channels to measure the voltage of the digital signal you want to measure. Then you can determine the logic level based on the thresholds of the logic family of the digital signal you are monitoring. Table 3-6 shows the thresholds of CMOS and TTL logic families using analog inputs as digital inputs.***

Table 3-6. Logic Family Thresholds

Logic Family	Low	High
CMOS	< 0.8 V	> 2.0 V
TTL	< 0.8 V	> 2.0 V
Note: Check your logic family data sheets for any variations.		

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Specifications

Appendix A

This appendix lists the specifications of the NI 4350 and NI 4351. These specifications are for 15 to 35 °C ambient temperature range for one year unless otherwise specified. All specifications are relative to calibration standards and require a 30 minute warm-up period. Specifications do not include transducer error. Temperature coefficient is applicable for 0 to 15 °C and 35 to 55 °C. For thermocouples, add the accessory error in °C only if the accessory (TC-2190, PSH32-TC6, CB-27T, TBX-68T) is in the 0 to 15 °C and 35 to 55 °C temperature range.

Accuracy Specifications

Thermocouple Accuracy[1]

Thermocouple Type	°C	Error (°C) 15–35 °C, 1 Year			0–15 °C, 35–55 °C	
		Filter Setting			Temperature Coefficient °C/°C[†]	Accessory Error °C[*]
		10 Hz	50 Hz	60 Hz		
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		

[1] Thermocouple measurement specifications include cold-junction compensation error (with sensor between 15 and 35 °C), isothermal accuracy and system noise. The specifications assume that the 0.625 V range is used and that ground-referencing and open-thermocouple detection are enabled for a floating thermocouple. Specifications improve with ground-referencing enabled and open-thermocouple detection disabled for a floating thermocouple. The specifications also assume that the cold-junction sensor is between 15 and 35 °C.

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Thermocouple Type	°C	Error (°C) 15–35 °C, 1 Year			0–15 °C, 35–55 °C	
		Filter Setting			Temperature Coefficient °C/°C†	Accessory Error °C*
		10 Hz	50 Hz	60 Hz		
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		
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 NI 435*x* is outside 15–35 °C temperature range
* Add when thermocouple accessory is outside 15–35 °C temperature range

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RTD Accuracy (with IEX or IEX0)[2]

RTD	°C	Error (°C) 15–35 °C, 1 Year			0–15 °C, 35–55 °C
		Filter Setting			Temperature Coefficient °C/°C
		10 Hz	50 Hz	60 Hz	
Pt 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	

RTD Accuracy (with IEX1)[3]

RTD	°C	Error (°C) 15–35 °C, 1 Year			0–15 °C, 35–55 °C
		Filter Setting			Temperature Coefficient °C/°C
		10 Hz	50 Hz	60 Hz	
Pt 100 Ω	–200	0.05	0.06	0.07	0.01
	0	0.12	0.13	0.14	
	100	0.16	0.17	0.18	
	300	0.23	0.24	0.26	
	600	0.36	0.37	0.39	

[2] RTD specifications assume that the 25 kΩ (25 µA current source) range is used and worst case common-mode voltage for this range is present. Specifications improve if actual common-mode voltage is less than worst case. Specifications improve for a 1,000 Ω RTD.

[3] RTD specifications assume that the 625 Ω range (1 mA current source) is used and worst case common-mode voltage for this range is present. Specifications improve if actual common-mode voltage is less than worst case.

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Thermistor Accuracy (with IEX or IEX0)[4]

Thermistor	°C	Accuracy (°C) 15–35 °C, 1 Year, Filter Setting: 10 Hz, 50 Hz, 60 Hz	Temperature Coefficient 0–15 °C, 35–55 °C
		°C	°C/°C
5,000 Ω	0–50	0.03	0.001

DC Voltage Accuracy[5]

Range	% of Reading 15–35 °C			Add µV (with Auto-zero) 15–35 °C			Add µV (without Auto-zero) 15–35 °C			Temperature Coefficient 0–15 °C, 35–55 °C	
				Filter Setting			Filter Setting				
Volts °C	24 Hr	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

[4] Thermistor accuracy is valid for all filter settings. Specifications assume that the 25 kΩ range is used and worst case common-mode voltage for this range is present. Specifications improve is actual common-mode voltage is less than worst case.

[5] Voltage specifications do not include errors resulting from common-mode voltages. Calculate additional error because of common-mode voltages as: common-mode voltage/$10^{(\text{CMR specification in db}/20)}$.

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Resistance Accuracy (with IEX or IEX0)[6]

Range	% of Reading 15–35 °C			Add Ω (with Auto-zero) 15–35 °C			Add Ω (without Auto-zero) 15–35 °C			Temperature Coefficient 0–15 °C, 35–55 °C
				Filter Setting			Filter Setting			
Ω	24 Hr	90 Day	1 Year	10 Hz	50 Hz	60 Hz	10 Hz	50 Hz	60 Hz	%Reading/°C
600000	0.0435	0.0464	0.0494	20.11	23.64	24.63	24.17	26.67	27.37	0.0013
300000	0.0441	0.0470	0.0500	19.82	21.80	23.22	23.97	25.37	26.37	0.0013
150000	0.0453	0.0482	0.0512	19.54	20.16	20.67	23.77	24.21	24.57	0.0013
100000	0.0355	0.0384	0.0414	0.51	1.00	1.28	1.26	1.60	1.80	0.0013
50000	0.0361	0.0390	0.0420	0.45	0.80	1.02	1.21	1.46	1.62	0.0013
25000	0.0373	0.0402	0.0432	0.41	0.54	0.74	1.18	1.28	1.42	0.0013

Resistance Accuracy (with IEX1)[7]

Range	% of Reading 15–35 °C			Add Ω (with Auto-zero) 15–35 °C			Add Ω (without Auto-zero) 15–35 °C			Temperature Coefficient 0–15 °C, 35–55 °C
				Filter Setting			Filter Setting			
Ω	24 Hr	90 Day	1 Year	10 Hz	50 Hz	60 Hz	10 Hz	50 Hz	60 Hz	%Reading/°C
15000	0.0320	0.0349	0.0379	1.53	1.62	1.64	1.63	1.69	1.71	0.0013
7500	0.0326	0.0355	0.0385	1.52	1.57	1.61	1.63	1.66	1.69	0.0013
3750	0.0338	0.0367	0.0397	1.51	1.53	1.54	1.62	1.63	1.64	0.0013
2500	0.0240	0.0269	0.0299	0.03	0.04	0.05	0.05	0.06	0.06	0.0013
1250	0.0246	0.0275	0.0305	0.03	0.04	0.04	0.05	0.05	0.06	0.0013
625	0.0258	0.0287	0.0317	0.02	0.02	0.02	0.04	0.04	0.04	0.0013

[6] Resistance specifications assume worst case common-mode voltage for the given range. Specifications improve if actual common-mode voltage is less than worst case. Measurement accuracy is affected by source impedance. Resistances > 25 kΩ may require 1 s setting time.

[7] Resistance specifications assume worst case common-mode voltage for the given range. Specifications improve if actual common-mode voltage is less than worst case. Measurement accuracy is affected by source impedance.

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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 NI 4350 at 38 °C and accessory (cold-junction sensor) at 23 °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 NI 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 1 V 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 1 V 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%/°C + 1 µV/°C}+ $(0.5V/10^{100/20})$]

Analog Input

Input Characteristics

Number of channels

PCMCIA ..... 8 differential or 6 thermocouple

ISA, USB, PXI, PCI ..... 16 differential or
14 thermocouple

Digits 5 1/2

Type of ADC..... Sigma-delta

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

Calibration cycle.....One year

Reading rates

Mode	Reading Rate (readings/s)		Power-Line Noise Rejection
Single channel	10		10
	50		50
	60		60
Multiple channel acquisition	2.8	1.4*	10
	8.8	2.1*	50
	9.7	2.1*	60
* Resistance ranges ≥ 50 kΩ			

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

(CH<0..8/15>, IEX±, IEX0±, IEX1±) .....±42 V powered on, ±17 V powered off

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

Warm-up time.....30 minutes

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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, 400 Hz)

- Range ≥ 2.5 V..... 80 dB
- Range < 2.5 V ..... 100 dB

NMR (50 Hz, 60 Hz, 400 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

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Excitation

Number of channels 2

Parameter	IEX or IEX0	IEX1
Level	25 µA	1 mA
Maximum Load Resistance	600 kΩ	15 kΩ
Temperature Coefficient	±15 ppm/°C	±15 ppm/°C

Digital I/O and Alarm Outputs

Number of lines

PCMCIA 4

ISA, USB, PXI, PCI 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} = 5 V)	—	–10 µA
Input high current (V_{in} = 5 V)	—	10 µA)
Output low voltage (I_{out} = 8 mA)	—	0.4 V
Output high voltage (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)

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Power Requirement

PCMCIA ..... 130 mA at +5 V

ISA..... 160 mA at +5 V

USB ..... High power, USB powered peripheral (500 mA)

PXI..... 480 mA at +5 V

PCI..... 480 mA at +5 V

Power available at I/O connector..... +4.6 V to +5.2 V, 1 A (ISA, PXI, PCI)
+4.6 V to +5.2 V, 50 mA (USB)

Physical

Dimensions

- PCMCIA ..... Type II PC Card
- ISA ..... ISA (half size)
- USB..... 14.6 by 21.3 by 3.8 cm (5.8 by 8.4 by 1.5 in.)
- PXI .....16 by 10 cm (6.3 by 3.9 in.)
- PCI ..... PCI (half size)

I/O connector

- PCMCIA ..... 32-pin female, shielded and latched
- ISA, USB, PXI, PCI ..... 68-pin male, shielded and latched

Environment

Operating temperature..... 0 to 55 °C

Storage temperature ..... –20 to 70 °C

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Signal Connections

Appendix
B

This section explains the signal correlation between your NI 435*x* and the accessories you might use with it.

- The NI 4350 (PCMCIA) 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 NI 4350 (PCMCIA).

Table B-1. Using the NI 4350 (PCMCIA) with the CB-27

NI 4350 (PCMCIA) 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

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Table B-1. Using the NI 4350 (PCMCIA) with the CB-27 (Continued)

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

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- Table B-2 shows how the screw terminals on the TBX-68 connector block and the SH6868 and R6868 cables correspond to the signal names on the NI 435*x* (ISA, USB, PXI, PCI).

Table B-2. Using the NI 435*x* (ISA, USB, PXI, PCI) with the TBX-68

NI 435*x* (ISA, USB, PXI, PCI) Signal Name	TBX-68 Screw Terminal
CH0+	68
CH0 –	34
CH1+	33
CH1–	66
CH2+	65
CH2–	31
CH3+	30
CH3–	63
CH4+	62
CH4–	29
CH5+	28
CH5–	61
CH6+	60
CH6–	26
CH7+	25
CH7–	58
CH8+	57
CH8–	23
CH9+	22

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Table B-2. Using the NI 435*x* (ISA, USB, PXI, PCI) with the TBX-68 (Continued)

NI 435*x* (ISA, USB, PXI, PCI) Signal Name	TBX-68 Screw Terminal
CH9–	55
CH10+	54
CH10–	21
CH11+	19
CH11–	53
CH12+	52
CH12–	18
CH13+	17
CH13–	50
CH14+	49
CH14–	15
CH15+	13
CH15–	46
IEX+, IEX0+ (NI 4351)	12
IEX–, IEX0– (NI 4351)	45
IEX1+ (NI 4351 only)	44[1]
IEX1– (NI 4351 only)	10[1]
DIO0	7
DIO1	6
DIO2	5
DIO3	4

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Table B-2. Using the NI 435*x* (ISA, USB, PXI, PCI) with the TBX-68 (Continued)

NI 435*x* (ISA, USB, PXI, PCI) Signal Name	TBX-68 Screw Terminal
DIO4	37
DIO5	3
DIO6	2
DIO7	1
+5V	8[2]
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

[1] Screw terminals 10 and 44 are AGND on the NI 4350 only and will not be labeled AGND on Revision C or higher of the TBX-68T.

[2] The current available may be limited to less than 50 mA (typical) when using the NI 4350 (USB).

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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.

National Instruments has technical assistance through electronic, fax, and telephone systems to quickly provide the information you need. Our electronic services include a web site, an FTP site, a fax-on-demand system, and e-mail support. If you have a hardware or software problem, first try the electronic support systems. If the information available on these systems does not answer your questions, we offer fax and telephone support through our technical support centers, which are staffed by applications engineers.

Electronic Services

FTP Support

To access our FTP site, log on to our Internet host, `ftp.natinst.com`, as `anonymous` and use your Internet address, such as `joesmith@anywhere.com`, as your password. The support files and documents are located in the `/support` directories.

Fax-on-Demand Support

Fax-on-Demand is a 24-hour information retrieval system containing a library of documents on a wide range of technical information. You can access Fax-on-Demand from a touch-tone telephone at 512 418 1111.

E-Mail Support (Currently USA Only)

You can submit technical support questions to the applications engineering team through e-mail at the Internet address listed below. Remember to include your name, address, and phone number so we can contact you with solutions and suggestions.

`support@natinst.com`

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Telephone and Fax Support

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Country	Telephone	Fax
Australia	03 9879 5166	03 9879 6277
Austria	0662 45 79 90 0	0662 45 79 90 19
Belgium	02 757 00 20	02 757 03 11
Brazil	011 288 3336	011 288 8528
Canada (Ontario)	905 785 0085	905 785 0086
Canada (Québec)	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 6120092	03 6120095
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
Taiwan	02 377 1200	02 737 4644
United Kingdom	01635 523545	01635 523154
United States	512 795 8248	512 794 5678

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Technical Support Form

Photocopy this form and update it each time you make changes to your software or hardware, and use the completed copy of 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.

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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NI 4350/4351 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 _____

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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Documentation Comment Form

National Instruments encourages you to comment on the documentation supplied with our products. This information helps us provide quality products to meet your needs.

Title: *NI 4350/4351 User Manual*

Edition Date: December 1998

Part Number: 321566C-01

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

_____

_____

_____

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If you find errors in the manual, please record the page numbers and describe the errors.

_____

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Thank you for your help.

Name _____

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Glossary

Prefix	Meanings	Value
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
±	plus or minus
/	per
°	degree
Ω	ohm
+5V	+5 V output signal

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A

A	ampere—unit of current
AC	alternating current
AC coupled	allowing the transmission of AC signals while blocking DC signals
ADC	analog-to-digital converter—an electronic device, often an integrated circuit, that converts an analog voltage to a digital format
AGND	analog ground signal
ANSI	American National Standards Institute
AT bus	*See* bus.
attenuation	decreasing the amplitude of a signal
auto-zeroing	the process of removing an offset error from a measurement
AWG	American Wire Gauge

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
bipolar	a signal range that includes both positive and negative values (for example, –5 V to +5 V)
buffer	temporary storage for acquired data
bus	the group of signals 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.

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C

C	Celsius
channel	pin or wire to which you apply or from which you read the analog or digital signal. For digital signals, you group channels to form ports. Ports usually consist or either four or eight digital channels.
CH*x*	channel signal
clock	hardware component that controls timing for reading from or writing to groups
CMOS	complimentary metal oxide semiconductor
CMR	common-mode rejection
CompactPCI	refers to the core specification defined by the PCI Industrial Computer Manufacturer's Group (PICMG)
coupling	the manner in which a signal is connected from one location to another
CPU	central processing unit

D

DAQ	data acquisition—(1) collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures and inputting them to a computer for processing; (2) collecting and measuring the same kinds of electrical signals with A/D and/or DIO boards plugged into a computer, and possibly generating control signals with D/A and/or DIO boards in the same computer
dB	decibel—the unit for expressing a logarithmic measure of the ratio of two signal levels: dB=20 x $\log_{10}(V_1/V_2)$ for signals in volts
DC	direct current
DC coupled	allowing the transmission of both AC and DC signals
device	a plug-in data acquisition board, card, or instrument that can contain multiple channels and conversion devices. Plug-in boards, PCMCIA cards, and instruments such as the NI 4350 (USB), which connects to your computer USB port, are all examples of DAQ devices.

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DGND	digital ground signal
DIO	digital input and output
drivers	software that controls a specific hardware instrument
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 decibels

E

EEPROM	electrically erasable programmable read-only memory—ROM that can be erased with an electrical signal and reprogrammed
EMF	electromotive force
event	the condition or state of an analog or digital signal

F

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

G

gain	factor by which a signal is amplified, sometimes expressed in decibels
GND	ground

H

hardware	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

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I

IC	integrated circuit
IEX*x*	voltage excitation signal
in.	inches
interrupt	a computer signal indicating that the CPU should suspend its current task to service a designated activity
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 bus
ITS	International Temperature Scale

K

K	(1) kelvin—a unit of temperature
kbytes/s	a unit for data transfer that means 1,000 or 10^3 bytes/s
kS	1,000 samples

L

LabVIEW	laboratory virtual instrument engineering workbench
latch	digital device that stores the digital data based on a control signal
LED	light-emitting diode

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M

m	meter—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 2^{20} or 1,048,576 bytes/s

N

NI-DAQ	National Instruments driver software for DAQ hardware, including computer-based instruments
NIST	National Institute of Standards and Technology
NMR	normal mode rejection
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.
NPN	type of bipolar transistor
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

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P

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 and 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
PLC	power line cycles
PLF	power line frequency
Plug and Play devices	devices 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
port	(1) a communications connection on a computer or remote controller; (2) a digital port, consisting of four or eight lines of digital input and/or output
PTC	positive temperature coefficient
PXI	PCI eXtensions for Instrumentation—an open specification that builds on the CompactPCI specification by adding instrumentation-specific features

R

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.

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rms	root mean square—the square root of the average value of the square of the instantaneous signal amplitudes; a measure of signal amplitude
RSVD*x*	reserved
RTD	resistance temperature detector. A metallic probe that measures temperature based upon its resistance.

S

s	second—a unit of time
S	sample
S/s	samples per second—used to express the rate at which a NI 435*x* samples an analog signal
sigma-delta	technology used for analog to digital conversion
sinter	to cause to become a coherent mass by heating without melting
system noise	a measure of the amount of noise seen by an analog circuit or an ADC when the analog inputs are grounded

T

TTL	transistor-transistor logic
thermocouple	kind of temperature sensor
thermistor	kind of temperature sensor

U

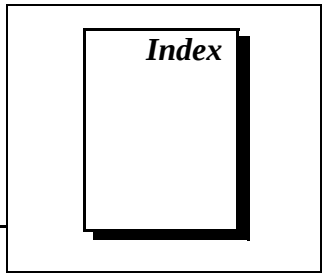
update	One or more analog or digital output samples. Typically the number of output samples in an update is equal to the number of channels in the output group.
update rate	the rate at which the measurement data is updated
USB	Universal Serial Bus

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V

V	volt—an electric unit
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

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