

# **SCXI-1141**

## **User Manual**

*Eight-Channel Elliptic Lowpass Filter Signal Conditioning Module*

**October 1994 Edition**

**Part Number 320748A-01**

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# About This Manual

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This manual describes the electrical and mechanical aspects of the SCXI-1141 and contains information concerning its installation and operation.

The SCXI-1141 is one of the National Instruments Signal Conditioning eXtensions for Instrumentation (SCXI) Series modules. The SCXI-1141 has eight independently configurable channels of differential amplification and filtering.

## Organization of This Manual

The *SCXI-1141 User Manual* is organized as follows:

- Chapter 1, *Introduction*, describes the SCXI-1141; lists the contents of your SCXI-1141 kit; describes the optional software, optional equipment, and custom cables; and explains how to unpack the SCXI-1141.
- Chapter 2, *Configuration and Installation*, describes the SCXI-1141 jumper configurations, installation of the SCXI-1141 into the SCXI chassis, and cable wiring.
- Chapter 3, *Signal Connections*, describes input and output signal connections to the SCXI-1141 module via the SCXI-1141 front and rear signal connectors and includes specifications and connection instructions for the signals given on the SCXI-1141 connectors.
- Chapter 4, *Theory of Operation*, contains an overview of the SCXI-1141 module and explains the operation of each functional unit of the SCXI-1141.
- Chapter 5, *Calibration*, discusses the SCXI-1141 calibration procedures.
- Appendix A, *Specifications*, lists the specifications for the SCXI-1141.
- Appendix B, *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 in this manual, including abbreviations, acronyms, metric prefixes, mnemonics, and symbols.
- The *Index* contains an alphabetical list of key terms and topics in this manual, including the page where you can find each one.



## Conventions Used in This Manual

The following conventions are used in this manual:

<b><i>bold italic</i></b>	Bold italic text denotes a note, caution, or warning.
<i>italic</i>	Italic text denotes emphasis, a cross reference, or an introduction to a key concept.
Lab board	Lab board refers to the National Instruments Lab-LC, Lab-NB, Lab-PC, and Lab-PC+ boards unless otherwise noted.
MC	MC refers to the Micro Channel series computers.
MIO board	MIO board refers to the National Instruments AT-MIO-16, AT-MIO-16D, AT-MIO-16F-5, AT-MIO-16X, AT-MIO-64F-5, MC-MIO-16, NB-MIO-16, and NB-MIO-16X multichannel I/O DAQ boards unless otherwise noted.
MIO-type board	MIO-type board refers to National Instruments DAQ boards that have at least analog and digital inputs and outputs. These boards include the MIO boards, the Lab boards, and the PC-LPM-16 board unless otherwise noted.
monospace	Text in this font denotes text or characters that are to be literally input from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, variables, filenames, and extensions, and for statements and comments taken from program code.
NB	NB refers to the NuBus series computers.
PC	PC refers to the IBM PC/XT, the IBM PC AT, and compatible computers.
SCXIbus	SCXIbus refers to the backplane in the chassis. A signal on the backplane is referred to as the SCXIbus <signal name> line (or signal). The SCXIbus descriptor may be omitted when the meaning is clear. Descriptions of all SCXIbus signals are in your SCXI chassis manual.
Slot 0	Slot 0 refers to the power supply and control circuitry in the SCXI chassis.

Abbreviations, acronyms, metric prefixes, mnemonics, symbols, and terms are listed in the *Glossary*.

## National Instruments Documentation

The *SCXI-1141 User Manual* is one piece of the documentation set for your SCXI 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:

- *Getting Started with SCXI*—This is the first manual you should read. It gives an overview of the SCXI system and contains the most commonly needed information for the modules, chassis, and software.
- Your SCXI user manuals—Read these manuals next for detailed information about signal connections and module configuration. They also explain in greater detail how the module works and contain application hints.
- Your DAQ hardware user manuals—These manuals have detailed information about the DAQ hardware that plugs into or is connected to your computer. Use these manuals for hardware installation and configuration instructions, specification information about your DAQ hardware, and application hints.
- Software manuals—Examples of software manuals you may have are the LabVIEW and LabWindows® manual sets and the NI-DAQ manuals. After you set up your hardware system, use either the application software (LabVIEW or LabWindows) manuals or the NI-DAQ manuals to help you write your application. If you have a large and complicated system, it is worthwhile to look through the software manuals before you configure your hardware.
- Accessory installation guides or manuals—If you are using accessory products, these are the terminal block and cable assembly installation guides or accessory board user manuals. They explain how to physically connect the relevant pieces of the system. Consult these guides when you are making your connections.

## Related Documentation

The following National Instruments manual contains detailed information for the register-level programmer:

- *SCXI-1141 Register-Level Programmer Manual*

This manual is available from National Instruments by request. If you are using NI-DAQ, LabVIEW, or LabWindows, you should not need the register-level programmer manual. Using NI-DAQ, LabVIEW, or LabWindows is quicker than and as flexible as using the low-level programming described in the register-level programmer manual. Refer to *Software Programming Choices* in Chapter 1, *Introduction*, of this manual to learn about your programming options.

## **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 B, *Customer Communication*, at the end of this manual.

# Chapter 1

## Introduction

---

This chapter describes the SCXI-1141; lists the contents of your SCXI-1141 kit; describes the optional software, optional equipment, and custom cables; and explains how to unpack the SCXI-1141.

### About the SCXI-1141

The SCXI-1141 has eight lowpass elliptic filters with differential input amplifiers.

You can use the SCXI-1141 for antialiasing applications as well as for general-purpose amplification and filtering of signals. The SCXI-1141 works with the National Instruments MIO and Lab PC+ boards, and the SCXI-1200 data acquisition and control module. The Lab-PC board, PC-LPM-16, and the DAQCard-700 work with the SCXI-1141 but cannot scan the module; these boards can only perform single-channel reads. You can control several SCXI-1141s in a chassis with one DAQ board and in combination with other SCXI module types. Each SCXI-1141 module can multiplex its channels into a single channel of the DAQ board, although separate outputs are also available. You can multiplex the output of several SCXI-1141s into a single channel, thus greatly increasing the number of analog input signals that the DAQ board can digitize.

The SCXI-1304 shielded terminal block has screw terminals for easy signal attachment to the SCXI-1141 and is the terminal block recommended for use with this module.

### What You Need to Get Started

To set up and use your SCXI-1141, you will need the following:

- SCXI-1141 module
- SCXI-1141 User Manual*

If your kit is missing any of the components, contact National Instruments.

Detailed SCXI-1141 specifications are in Appendix A, *Specifications*.

### Software Programming Choices

Your SCXI hardware kit does not include software. There are four options to choose from when programming your National Instruments DAQ and SCXI hardware. You can use LabVIEW, LabWindows, NI-DAQ, or register-level programming software. The SCXI-1141 works with LabVIEW for Windows, LabVIEW for Macintosh, LabWindows, LabWindows/CVI, NI-DAQ for PC compatibles, and NI-DAQ for Macintosh.

## LabVIEW and LabWindows Application Software

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

LabVIEW currently runs on three different platforms—AT/MC/EISA computers running Microsoft Windows, the Macintosh platform, and the Sun SPARCstation platform. 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 boards, is included with LabVIEW. The LabVIEW Data Acquisition VI Libraries are functionally equivalent to the NI-DAQ software, except that the SCXI functions are not included in the LabVIEW software for Sun.

LabWindows has two versions—LabWindows for DOS is for use on PCs running DOS, and LabWindows/CVI is for use on PCs running Windows and Sun SPARCstations. LabWindows/CVI features interactive graphics, a state-of-the-art user interface, and uses the ANSI standard C programming language. The LabWindows Data Acquisition Library, a series of functions for using LabWindows with National Instruments boards, is included with LabWindows for DOS and LabWindows/CVI. The LabWindows Data Acquisition libraries are functionally equivalent to the NI-DAQ software, except that the SCXI functions are not included in the LabVIEW software for Sun.

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

## NI-DAQ Driver Software

The NI-DAQ driver software is included at no charge with all National Instruments DAQ boards. NI-DAQ has an extensive library of functions that you can call from your application programming environment. These functions include routines for analog input (A/D conversion), buffered data acquisition (high-speed A/D conversion), analog output (D/A conversion), waveform generation, digital I/O, counter/timer operations, SCXI, RTSI, self-calibration, messaging, and acquiring data to extended memory.

NI-DAQ also internally addresses many of the complex issues between the computer and the plug-in board such as programming the PC interrupt and DMA controllers. NI-DAQ maintains a consistent software interface among its different versions so that you can change platforms with minimal modifications to your code. Figure 1-1 illustrates the relationship between NI-DAQ and LabVIEW and LabWindows. You can see that the DAQ parts of LabVIEW and LabWindows are functionally equivalent to the NI-DAQ software.

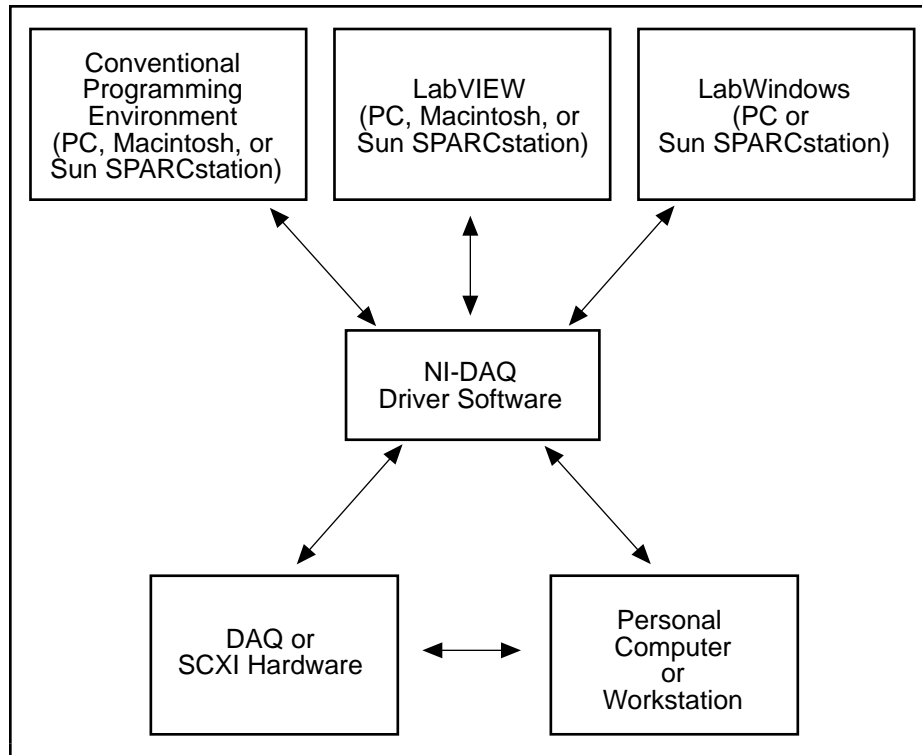


Figure 1-1. The Relationship between the Programming Environment, NI-DAQ, and Your Hardware

The National Instruments PC, AT, MC, EISA, DAQCard, and DAQPad series DAQ hardware is packaged with NI-DAQ software for PC compatibles. NI-DAQ software for PC compatibles comes with language interfaces for Professional BASIC, Turbo Pascal, Turbo C, Turbo C++, Borland C++, and Microsoft C for DOS; and Visual Basic, Turbo Pascal, Microsoft C with SDK, and Borland C++ for Windows. NI-DAQ software for PC compatibles is on high-density 5.25 in. and 3.5 in. diskettes. You can use your SCXI-1141, together with other PC, AT, MC, EISA, DAQCard, and SCXI hardware, with NI-DAQ software for PC compatibles.

The National Instruments NB Series DAQ boards are packaged with NI-DAQ software for Macintosh. NI-DAQ software for Macintosh comes with language interfaces for MPW C, THINK C, Pascal, and Microsoft QuickBASIC. Any language that uses Device Manager Toolbox calls can access NI-DAQ software for Macintosh. You can use your SCXI-1141, together with other NB Series DAQ boards and SCXI hardware, with NI-DAQ software for Macintosh.

The National Instruments SB Series DAQ boards are packaged with NI-DAQ software for Sun, which comes with a language interface for ANSI C.

## Register-Level Programming

The final option for programming any National Instruments DAQ hardware is to write register-level software. Writing register-level programming software can be very time consuming and inefficient, and is not recommended for most users. The *only* users who should consider writing register-level software should meet at least one of the following criteria:

- National Instruments does not support your operating system or programming language.
- You are an experienced register-level programmer who is more comfortable writing your own register-level software.

Always consider using NI-DAQ, LabVIEW, or LabWindows to program your National Instruments DAQ hardware. Using the NI-DAQ, LabVIEW, or LabWindows software is easier than, and as flexible as, register-level programming and can save you weeks of development time.

The *SCXI-1141 User Manual* and your software manuals contain complete instructions for programming your SCXI-1141 module with NI-DAQ, LabVIEW, or LabWindows. If you are using NI-DAQ, LabVIEW, or LabWindows to control your hardware, you should not need the register-level programmer manual.

The *SCXI-1141 Register-Level Programmer Manual* contains low-level programming details, such as register maps, bit descriptions, and register programming hints, that you will need only for register-level programming. If you want to obtain the register-level programmer manual, please fill out the *Register-Level Programmer Manual Request Form* in Appendix B, *Customer Communication*, at the end of this manual and send it to National Instruments.

## Optional Equipment

Contact National Instruments to order any of the following optional equipment:

- SCXI-1310 96-pin connector and shell
- SCXI-1304 AC/DC coupling terminal block
- SCXI-1340 cable assembly
- SCXI-1341 Lab-NB/Lab-PC/Lab-PC+ cable assembly
- SCXI-1342 PC-LPM-16 cable assembly
- SCXI-1343 rear screw terminal adapter
- SCXI-1344 Lab-LC cable assembly
- SCXI-1345 shielded cable assembly with a 1, 2, 5, or 10 m cable
- SCXI-1347 shielded cable assembly with a 1, 2, 5, or 10 m cable
- SCXI-1349 shielded cable assembly with a 1, 2, 5, or 10 m cable

- SCXI-1350 multichassis adapter
- SCXI-1351 one-slot cable extender
- Standard 0.5 or 1.0 m ribbon cable
- NB5 0.5 or 1.0 m cable
- NB6 0.5 or 1.0 m cable

Refer to Chapter 3, *Signal Connections*, the accessory installation guides, and the *National Instruments Catalog* for additional information on cabling, connectors, and adapters.

## Custom Cables

The SCXI-1141 rear signal connector is a 50-pin male ribbon-cable header. The manufacturer part number for the header National Instruments uses is as follows:

- AMP Inc. (part number 1-103310-0)

The mating connector for the SCXI-1141 rear signal connector is a 50-position polarized ribbon-socket connector with strain relief. National Instruments uses a polarized or keyed connector to prevent inadvertent upside-down connection to the SCXI-1141. Recommended manufacturer part numbers for this mating connector are as follows:

- Electronic Products Division/3M (part number 3425-7650)
- T&B/Ansley Corporation (part number 609-5041CE)

Standard 50-conductor 28 AWG stranded ribbon cables that work with these connectors are as follows:

- Electronic Products Division/3M (part number 3365/50)
- T&B/Ansley Corporation (part number 171-50)

The SCXI-1141 front connector is a 96-pin DIN C male connector. Some manufacturer part numbers for the connector National Instruments uses are as follows:

- Harting Electronik, Inc. (part number 09-03-396-6921)
- Panduit Corporation (part number 100-096-033)

The mating connector for the SCXI-1141 front connector is a 96-pin reversed DIN C female connector. The manufacturer part number for the mating connector National Instruments uses is as follows:

- AMP Inc. (part number 535020-1; right-angle pins)
- Panduit Corporation (part number 100-096-434; straight-solder eyelet pins)



## Unpacking

Your SCXI-1141 module is shipped in an antistatic package to prevent electrostatic damage to the module. Electrostatic discharge can damage several components on the module. To avoid such damage in handling the module, take the following precautions:

- Ground yourself via a grounding strap or by holding a grounded chassis, such as an SCXI chassis.
- Touch the antistatic package to a metal part of your SCXI chassis before removing the module from the package.
- Remove the module from the package and inspect the module for loose components or any other sign of damage. Notify National Instruments if the module appears damaged in any way. *Do not* install a damaged module into your SCXI chassis.
- *Never* touch the exposed pins of connectors.

# Chapter 2

## Configuration and Installation

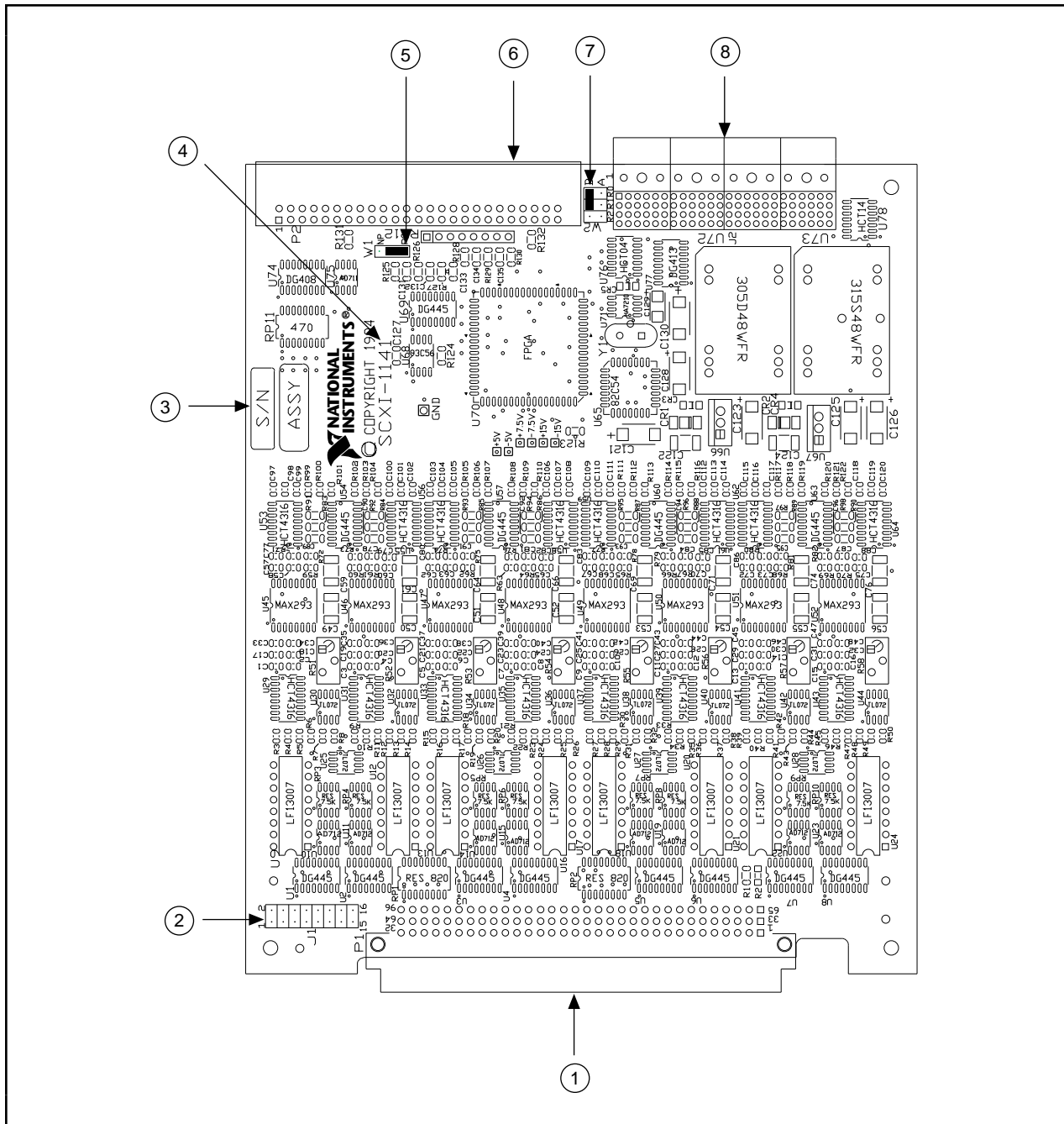
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This chapter describes the SCXI-1141 jumper configurations, installation of the SCXI-1141 into the SCXI chassis, and cable wiring.

### Module Configuration

The SCXI-1141 has two jumpers as shown in Figure 2-1. Jumper W1 is set at the factory for a single-chassis system, and jumper W2 is set at the factory for a differential input DAQ board.

**Note:** *The factory settings for the SCXI-1141 jumper configuration need no adjustment in most applications. The jumpers may need to be changed only when using a multichassis system, when using a DAQ board in single-ended mode, or to change the default grounding and shielding configuration.*



**Legend:**

1 -	Front Signal Connector
2 -	J1
3 -	Serial Number and Assembly Number
4 -	Product Name
1 -	W1
2 -	Rear Signal Connector
3 -	W2
4 -	SCXIBus Connector

Figure 2-1. SCXI-1141 Parts Locator Diagram

Tables 2-1 and 2-2 list the description and configuration of the configurable jumpers.

Table 2-1. Module Configuration of Your Chassis System

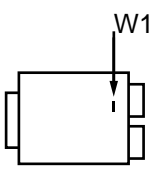

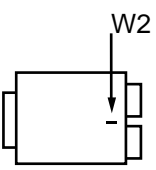
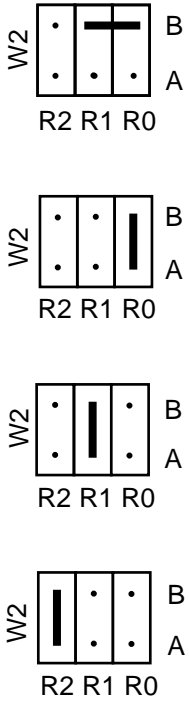
Jumper	Description	Configuration
	<p>Position P (pullup)—Use this setting for a single-chassis system or for the first chassis in a multichassis system. (Factory setting)</p> <p>Position NP (no pullup)—Use this setting for additional chassis in a multichassis system.</p>	<p>W1</p> 

Table 2-2. Module Grounding and Shielding Configuration

Jumper	Description	Configuration
	<p>Factory setting in parking position. Use this setting with DAQ boards in differential mode.</p> <p>Connects the analog reference to AOGND (pins 1 and 2 of the rear signal connector).</p> <p>Connects the SCXIBus guard to the analog reference.</p> <p>Enables the Pseudodifferential Reference mode (pin 19 of the rear signal connector is connected to the analog reference).</p>	<p>W2</p> 

**Note:** *The shaded area indicates the position of the jumper.*

Tables 2-1 and 2-2 list the description and configuration of the user-configurable jumpers. To change the configuration of the module, refer to Figures 2-1 and 2-2 as you perform the following steps:

1. Remove the grounding screw of the top cover.
2. Snap out the top cover of the shield by placing a screwdriver in the groove at the bottom of the module and pushing down.
3. Remove the jumpers you want to change and replace them on the appropriate pins.
4. Record the new jumper settings on the *SCXI-1141 Hardware Configuration Form* in Appendix B, *Customer Communication*.
5. Snap the top cover back in place.
6. Replace the grounding screw to ensure proper shielding.

You must use software to further configure the module. Refer to your software manual or to the *SCXI-1141 Register-Level Programmer Manual* if you are a register-level programmer.

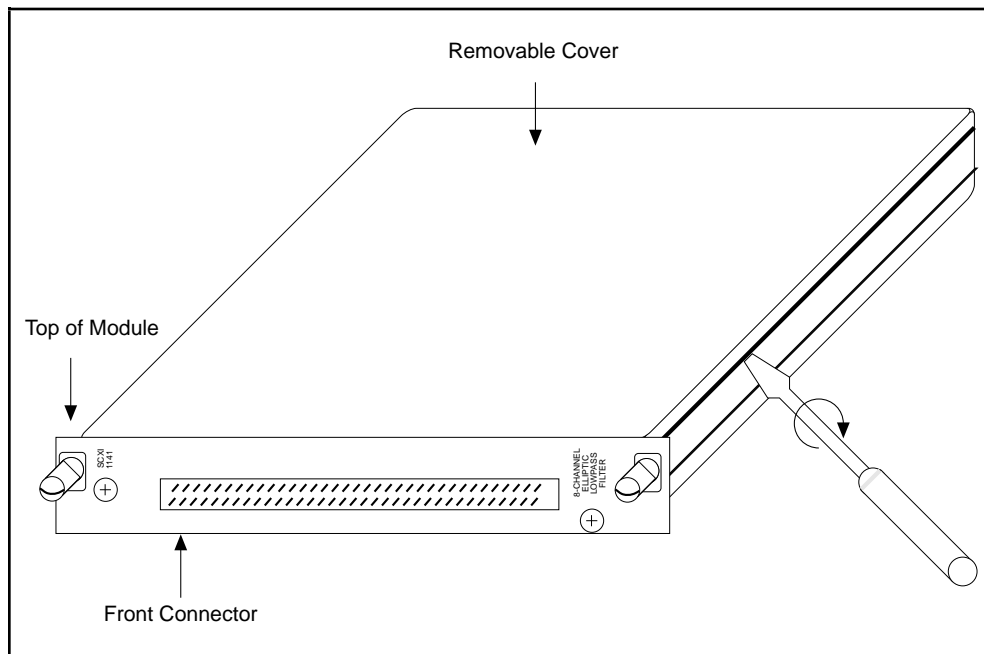


Figure 2-1. Removing the SCXI Module Cover

## Supplementary Jumper Configuration Information

Jumper W1, when set to position P, connects a 2.2 k $\Omega$  pullup resistor to the SERDATOUT line. An open-collector driver drives the SERDATOUT line. An open-collector driver actively drives low or goes to a high-impedance state, relying on a pullup resistor to make the signal line go high. If too many pullup resistors are attached to the SERDATOUT line, the drivers cannot drive the line low. To prevent this, set jumper W1 to position P on only one of the SCXI-1141s that are cabled to the DAQ board in a multiple chassis system. It does not matter which of the SCXI-1141s that are cabled to the DAQ board has the pullup connected.

## Hardware Installation

You can install the SCXI-1141 in any available SCXI chassis slot. After you have made any necessary changes to the jumper configuration and have verified the configuration and power availability, you are ready to install the SCXI-1141. The following are general installation instructions; consult the user manual or technical reference manual of your SCXI chassis for specific instructions and warnings.

1. Turn off the computer that contains the DAQ board or disconnect the DAQ board from your SCXI chassis.
2. Turn off the SCXI chassis. Do not insert the SCXI-1141 into a chassis that is turned on.
3. Insert the SCXI-1141 into the module guides. Gently guide the module into the back of the slot until the connectors make good contact. If you have already installed a cable assembly in the rear of the chassis, you must firmly engage the module and cable assembly; however, do not *force* the module into place.
4. Screw the front mounting panel of the SCXI-1141 to the top and bottom threaded strips of your SCXI chassis.
5. If you are connecting this module to an MIO-16 board, attach the connector at the metal end of the SCXI-1340 cable assembly to the rear signal connector on the SCXI-1141 module. Screw the rear panel to the rear threaded strip. Attach the loose end of the cable to the DAQ board.

**Notes:** *Cable your DAQ board to only one module in each chassis.*

*For installation procedures with other SCXI accessories and DAQ boards, consult your cable installation guide.*

6. Check the installation.
7. Turn on the SCXI chassis.
8. Turn on the computer or reconnect the DAQ board to your chassis.

The SCXI-1141 module is installed. You are now ready to install and configure your software.

## Software Installation

If you are using NI-DAQ, refer to your NI-DAQ manual. The software installation and configuration instructions are in Chapter 1, *Introduction to NI-DAQ*. Find the installation and system configuration section for your operating system and follow the instructions given there.

If you are using LabVIEW, the software installation instructions are in your LabVIEW release notes. After you have installed LabVIEW, refer to the *Configuring LabVIEW* section of Chapter 1 in your LabVIEW user manual for software configuration instructions.

If you are using LabWindows, the software installation instructions are in Part 1, *Introduction to LabWindows*, of the *Getting Started with LabWindows* manual. After you have installed LabWindows, refer to Chapter 1, *Configuring LabWindows*, of the *LabWindows User Manual* for software configuration instructions.

If you are a register-level programmer, refer to the *SCXI-1141 Register-Level Programmer Manual*.

# Chapter 3

## Signal Connections

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This chapter describes input and output signal connections to the SCXI-1141 module via the SCXI-1141 front and rear signal connectors and includes specifications and connection instructions for the signals on the SCXI-1141 connectors.

**Warning:** *Connections that exceed any of the maximum ratings of input or output signals on the SCXI-1141 can damage the SCXI-1141 module, the SCXIbus, any connected DAQ board, and the computer in which the DAQ board is installed. Maximum input ratings for each signal are given in this chapter under the discussion of that signal. National Instruments is NOT liable for any damages resulting from such signal connections.*

### Front Connector

Figure 3-1 shows the pin assignments for the SCXI-1141 front connector.



Pin Number	Signal Name	Column			Signal Name
		A	B	C	
32	IN0+	○	○	○	IN0-
31		○	○	○	
30	IN1+	○	○	○	IN1-
29		○	○	○	
28	AGND	○	○	○	AGND
27		○	○	○	
26	IN2+	○	○	○	IN2-
25		○	○	○	
24	IN3+	○	○	○	IN3-
23		○	○	○	
22	AGND	○	○	○	AGND
21		○	○	○	
20	IN4+	○	○	○	IN4-
19		○	○	○	
18	IN5+	○	○	○	IN5-
17		○	○	○	
16	AGND	○	○	○	AGND
15		○	○	○	
14	IN6+	○	○	○	IN6-
13		○	○	○	
12	IN7+	○	○	○	IN7-
11		○	○	○	
10		○	○	○	
9		○	○	○	
8	DGND	○	○	○	DGND
7		○	○	○	
6	RSVD	○	○	○	DGND
5		○	○	○	
4	RSVD	○	○	○	EXTCLK
3		○	○	○	
2	DGND	○	○	○	OUTCLK
1		○	○	○	

Figure 3-1. SCXI-1141 Front Connector

## Front Connector Signal Connection Descriptions

Pins	Signal Names	Description
A32, A30, A26, A24, A20, A18, A14, A12	IN+<0..7+>	Positive Input Channels—These pins connect to the noninverting inputs of the instrumentation amplifier of each channel.
C32, C30, C26, C24, C20, C18, C14, C12	IN-<0..7->	Negative Input Channels—These pins connect to the inverting inputs of the instrumentation amplifier of each channel.
A28, A22, A16, C28, C22, C16	AGND	Analog Ground—These pins connect to the module analog ground
A8, A2, C8, C6	DGND	Digital Ground—These pins connect to the module digital ground.
A6, A4	RSVD	Reserved—Do not connect any signals to these pins.
C4	EXTCLK	External Clock—This signal may be used to set the filter cutoff frequencies.
C2	OUTCLK	Output Clock—This signal has a frequency that is proportional to the cutoff frequency. You can use this signal in tracking filter applications.

### Analog Input Channels

The SCXI-1141 instrumentation amplifiers can reject any voltage within their common-mode input range caused by ground potential differences between the signal source and the module. In addition, the amplifiers can reject common-mode noise pickup in the leads connecting the signal sources to the SCXI-1141. However, you should take care to minimize noise pickup. The common-mode rejection of the instrumentation amplifiers decreases significantly at high frequencies. The amplifiers do not reject normal-mode noise.

The maximum differential input voltage range of the SCXI-1141 instrumentation amplifiers is a function of the gain of the amplifiers,  $G$ , and is equal to  $5 \text{ V}/G$ . The common-mode input range of the SCXI-1141, however, is *not* a function of gain—the differential input amplifier will reject common-mode signals as long as the signal at both inputs is within  $\pm 5 \text{ V}$  of the module analog ground. The inputs are protected against maximum input voltages of up to  $\pm 15 \text{ V}$  powered off and  $\pm 30 \text{ V}$  powered on.

**Warning:** *Exceeding the differential or common-mode input ranges distorts input signals. Exceeding the maximum common-mode input voltage rating can damage the SCXI-1141, the SCXIbus, and the DAQ board. National Instruments is NOT liable for any damages resulting from such signal connections.*

All eight channels have fully differential inputs, so the signals to be measured should be ground referenced. If they are not, connect a 100 k $\Omega$  resistor from the negative input to ground to provide a DC path for the input bias currents. If this is not done, the bias currents of the instrumentation amplifiers of the nonreferenced channels will charge up stray capacitances, resulting in uncontrollable drift and possible saturation.

**Note:** *The recommended SCXI-1304 terminal block has all necessary circuitry for AC or DC coupling and for floating or ground-referenced signals. The SCXI-1304 Installation Guide has instructions for signal connection. The following figures provide supplemental information on connecting signals to the SCXI-1141.*

Figure 3-2 illustrates how to connect a ground-referenced signal.

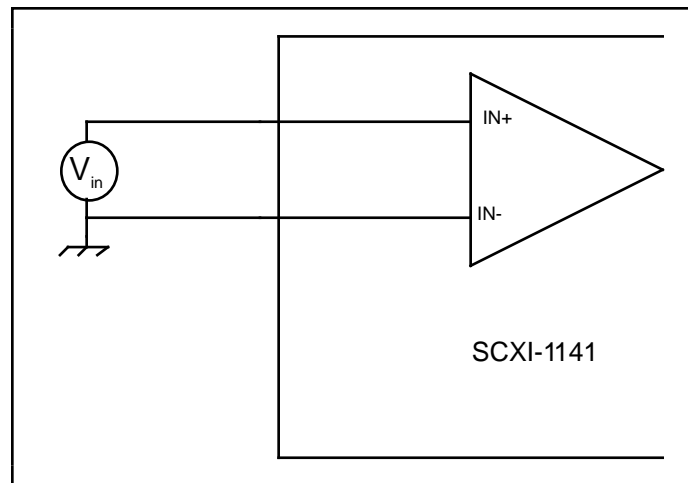


Figure 3-2. Ground-Referenced Signal Connection

Figure 3-3 illustrates how to connect a floating signal.

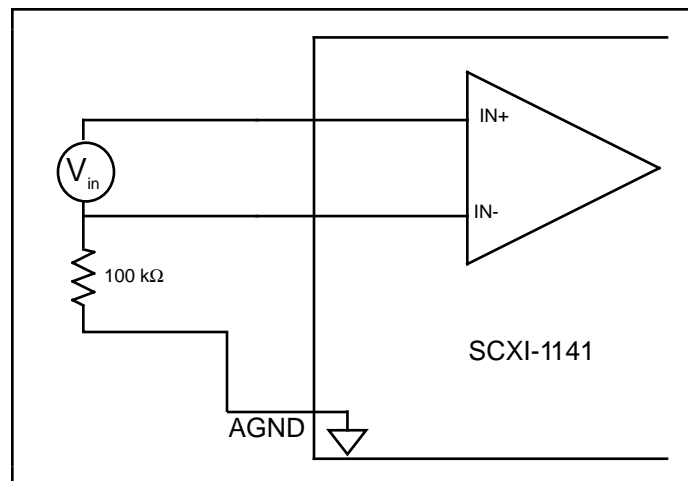


Figure 3-3. Floating Signal Connection

For AC-coupled signals, connect an external resistor from the AC-coupled input channel to ground. This provides the DC path for the positive input bias current. Typical resistor values range from 100 k $\Omega$  to 10 M $\Omega$ . This solution, although necessary, lowers the input impedance of the channel and introduces an additional DC offset voltage proportional to the product of the input bias current and the resistor value used. The inputs of the SCXI-1141 have a typical bias current of about  $\pm 200$  pA. Using a 1 M $\Omega$  resistor results in  $\pm 500$   $\mu$ V of offset, which is insignificant in most applications. However, if larger valued bias resistors are used, significant input offset may result. Lower valued bias resistors increase loading of the source, possibly resulting in gain error.

Figures 3-4 through 3-6 illustrate how to connect AC-coupled signals.

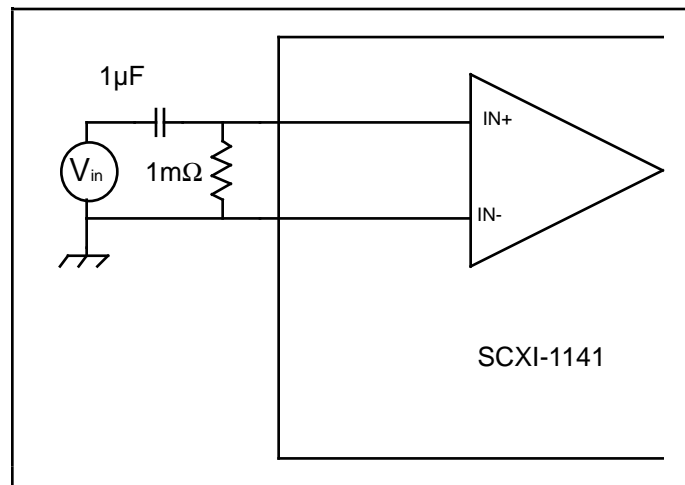


Figure 3-4. Ground-Referenced AC-Coupled Signal Connection

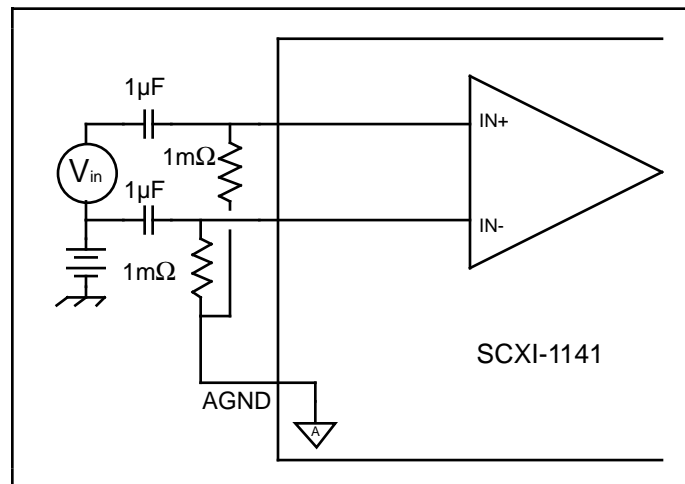


Figure 3-5. Ground-Offset AC-Coupled Signal Connection

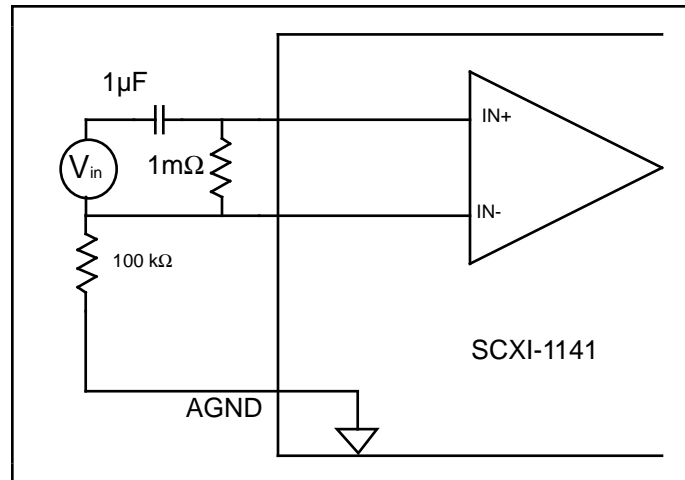


Figure 3-6. Floating AC-Coupled Signal Connection

### Digital Input and Output

You can use the EXTCLK input pin on the front connector to control the filters cutoff frequency for special purposes. The clock should be a TTL-logic-level or CMOS-logic-level square wave, with a frequency of less than 10 MHz and at least 100 times the desired cutoff frequency. The absolute maximum input voltage for the EXTCLK pin is -0.5 to 5.5 V with respect to DGND.

The OUTCLK pin on the front connector is a CMOS-logic-level output clock, which you can configure to have a frequency that is proportional to the cutoff frequency of the filters.

See Chapter 4, *Theory of Operation*, for more details on using these two signals.

### Rear Signal Connector

**Note:** *If you will be using the SCXI-1141 with a National Instruments DAQ board and cable assembly, you do not need to read the remainder of this chapter. If you will also be using the SCXI-1180 feedthrough panel, the SCXI-1343 rear screw terminal adapter, or the SCXI-1351 one-slot cable extender with the SCXI-1141, you should read this section.*

Figure 3-7 shows the pin assignments for the SCXI-1141 rear signal connector.

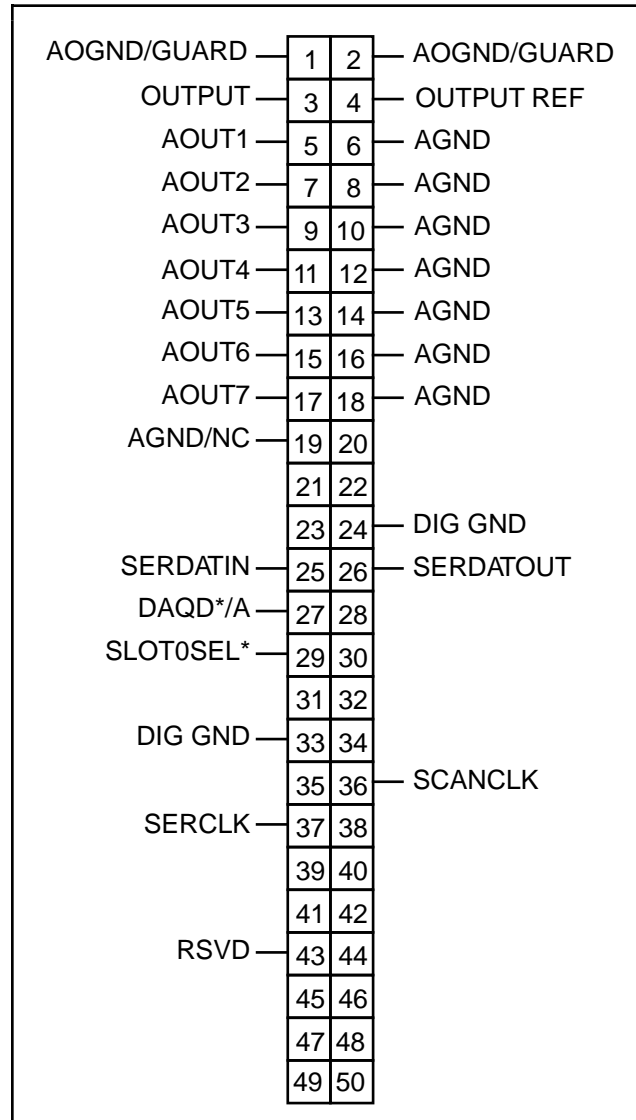


Figure 3-7. SCXI-1141 Rear Signal Connector

## Rear Signal Connection Descriptions

Pin	Signal Name	Description
1, 2	AOGND/GUARD	Analog Output Ground—These pins are connected to the module analog ground when jumper W2 is in position AB-R0. These pins are connected to the SCXIBus guard when W2 is in position R0R1-A.
3	OUTPUT	Output—This is the main module analog output. In Scan mode, the outputs of all eight channels appear here in sequence. Outputs from other modules can also appear here through the analog bus. In Nonscanning mode, this is the output of channel 0.
5, 7, 9, 11, 13, 15, 17	AOUT<1..7>	Analog Outputs—These pins are the outputs of channels 1 through 7, independent of whether or not scanning is enabled.
19	OUTPUT REF/NC	Analog Ground/No Connect—This pin is connected to the output reference when jumper W2 is in position AB-R2. Otherwise, this pin is unconnected.
25	SERDATIN	Serial Data In—This signal taps into the SCXIBus MOSI line to send serial input data to a module or Slot 0.
27	DAQD*/A	DAQ Board Data/Address Line—This signal taps into the SCXIBus D*/A line to indicate to the module whether the incoming serial stream is data or address information.
29	SLOT0SEL*	Slot 0 Select—This signal taps into the SCXIBus INTR* line to indicate whether the information on MOSI is being sent to a module or Slot 0.
24, 33	DIGGND	Digital Ground—These pins supply the reference for DAQ digital signals and are tied to the module digital ground.
37	SERCLK	Serial Clock—This signal taps into the SCXIBus SPICLK line to clock the data on the MOSI and MISO lines.
43	RSVD	Reserved.
4	OUTPUT REF	Output Reference—This pin connects to the module analog ground unless an output from another module is selected through the analog bus, in which case the pins connect to the analog ground for the selected module.
6, 8, 10, 12, 14, 16, 18	AGND	Analog Ground—These pins connect to the module analog ground. They are used as the reference points for AOUT1 through AOUT7.
26	SERDATOUT	Serial Data Out—This signal taps into the SCXIBus MISO line to accept serial output data from a module.
36	SCANCLK	Scan Clock—The signal at this pin indicates to the SCXI-1141 that a sample has been taken by the DAQ board and causes the SCXI-1141 to change channels.

All other pins are not connected.

The signals on the rear signal connector can be classified as analog output signals, digital I/O signals, or timing I/O signals. Signal connection guidelines for each of these groups are given in the following section.

### Analog Output Signal Connections

Pins 3 through 19 of the rear signal connector are analog output signal pins. Pin 3 is the main output, and pin 4 is its reference signal. All eight channels are multiplexed onto this output under hardware control in scan mode. In nonscanning mode, the output simply becomes the output of one selected channel. Channel 0 is the power-up and reset default. When scanning multiple modules, you can also connect this output to the SCXIBus analog bus and the analog bus will drive this output.

Pins 5, 7, 9, 11, 13, 15, and 17 are direct outputs from channels 1 through 7, respectively. Thus, if you program pin 3 to monitor the channel 0 output, all eight channels are available simultaneously at the connector. Pins 6, 8, 10, 12, 14, 16, and 18 are the reference signals for outputs 1 through 7.

If possible, you should use differential connections to measure the outputs. If your DAQ board uses single-ended inputs, connect the ground (or the negative input, for NRSE mode) of the DAQ board to pin 19 and set jumper W2 to position AB-R2 so that pin 19 connects to the analog output reference.

**Warning:** *The SCXI-1141 analog outputs are not overvoltage protected, although they are short-circuit protected. Applying external voltage to these outputs may result in damage to the SCXI-1141. National Instruments is NOT liable for any damages resulting from such signal connections.*

### Digital I/O Signal Connections

Pins 24 through 27, 29, 33, 36, 37 and 43 constitute the digital I/O lines of the rear signal connector. These pins are in one of three categories—digital input signals, digital output signals, and timing signals. Pins 24 and 33 are the digital ground reference for all the DAQ board digital signals and are tied to the module digital ground.

The digital input signals are pins 25, 27, 29, and 37. The DAQ board uses these pins to configure the SCXI module when the module is under DAQ board control. Each digital line emulates the SCXIBus communication signals as follows:

- Pin 25 is SERDATIN and is equivalent to the SCXIBus MOSI serial data input line.
- Pin 27 is DAQD\*/A and is equivalent to the SCXIBus D\*/A line. Pin 27 indicates to the module whether the incoming serial stream on SERDATIN is data (DAQD\*/A = 0) or address (DAQD\*/A = 1) information.



- Pin 29 is SLOTOSEL\* and is equivalent to the SCXIBus INTR\* line. Pin 29 indicates whether the data on the SERDATIN line is being sent to Slot 0 (SLOTOSEL\* = 0) or to a module (SLOTOSEL\* = 1).
- Pin 37 is SERCLK and is equivalent to the SCXIBus SPICLK line and is used to clock the serial data on the SERDATIN line into the module registers.

The digital output signal are pins 26 and 28:

- Pin 26 is SERDATOUT and is equivalent to the SCXIBus MISO serial data output line.

The digital I/O signals of the SCXI-1141 match the digital I/O lines of the MIO-16. When used with an SCXI-1341 or an SCXI-1342 cable assembly, the SCXI-1141 signals match the digital lines of the Lab-NB/ Lab-PC/Lab-LC boards and the PC-LPM-16 board, respectively. Table 3-1 lists the equivalencies. For more information, consult your cable installation guide.

Table 3-1. SCXIBus to SCXI-1141 Rear Signal Connector to DAQ Board  
Pin Equivalencies

SCXIBus Line	SCXI-1141 Rear Signal Connector	MIO-16	Lab-NB Lab-PC Lab-PC+ Lab-LC	PC-LPM-16
MOSI	SERDATIN	ADIO0	PB4	DOUT4
D*/A	DAQD*/A	ADIO1	PB5	DOUT5
INTR*	SLOTOSEL*	ADIO2	PB6	DOUT6
SPICLK	SERCLK	EXTSTROBE*	PB7	DOUT7
MISO	SERDATOUT	BDIO0	PC1	DIN6

The digital timing signals are pins 36 and 43:

- Pin 36 is SCANCLK, and you use it as a clock for the SCXI-1141 multiplexer counter. The DAQ board should pulse this signal at the end of each conversion if the module is in multiplexed mode.
- Pin 43 is a reserved digital input.

The following specifications and ratings apply to the digital I/O and timing lines.

- Absolute maximum voltage
  - Input rating -0.5 to 5.5 V with respect to DIGGND
- Digital input specifications (referenced to DIGGND):
  - $V_{IH}$  input logic high voltage 2 V min

- $V_{IL}$  input logic low voltage      0.8 V max
- $I_I$  input current leakage             $\pm 1 \mu\text{A}$  max
- Digital output specifications (referenced to DIGGND)
  - $V_{OH}$  output logic high voltage    3.7 min at 4 mA
  - $V_{OL}$  output logic low voltage    0.4 max at 4 mA

# Chapter 4

## Theory of Operation

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This chapter contains an overview of the SCXI-1141 module and explains the operation of each functional unit of the SCXI-1141.

### Functional Overview

The SCXI-1141 has eight software-controlled input channels that amplify and filter signals. Each channel has an output range of  $\pm 5$  V and has an input amplifier with gains of 1, 2, 5, 10, 20, 50, and 100. Each amplifier gain can be independently set. The analog inputs are overvoltage protected. The filters are lowpass, sharp rolloff, 8th-order elliptic filters that can have a cutoff frequency from 10 Hz to 25 kHz. All eight filters have the same cutoff frequency.

The SCXI-1141 has an internal counter for automatic scanning. You can operate multiple SCXI-1141 modules under SCXIbus control or directly from a DAQ board. The outputs of all eight channels are available at the rear connector. You can also multiplex the SCXI-1141 outputs onto a single channel and send outputs from other SCXI modules from the SCXIbus onto this channel.

The major components of the SCXI-1141 are as follows:

- Digital control and calibration circuitry
- Input amplifiers
- Lowpass filters

The usage and theory of operation of each of these components is explained in the remainder of this chapter.

### Power-Up State

When the SCXI-1141 is powered up or reset through software or the SCXI chassis reset button, the following states are defined:

- The gain of each amplifier is set to 1.
- Channel 0 is selected as the OUTPUT signal.
- All filters are placed in bypass mode.
- The external clock input is disabled.

The cutoff frequency of the filters and the output clock frequency are not defined at power-up.

The block diagram in Figure 4-1 illustrates the key functional components of the SCXI-1141.

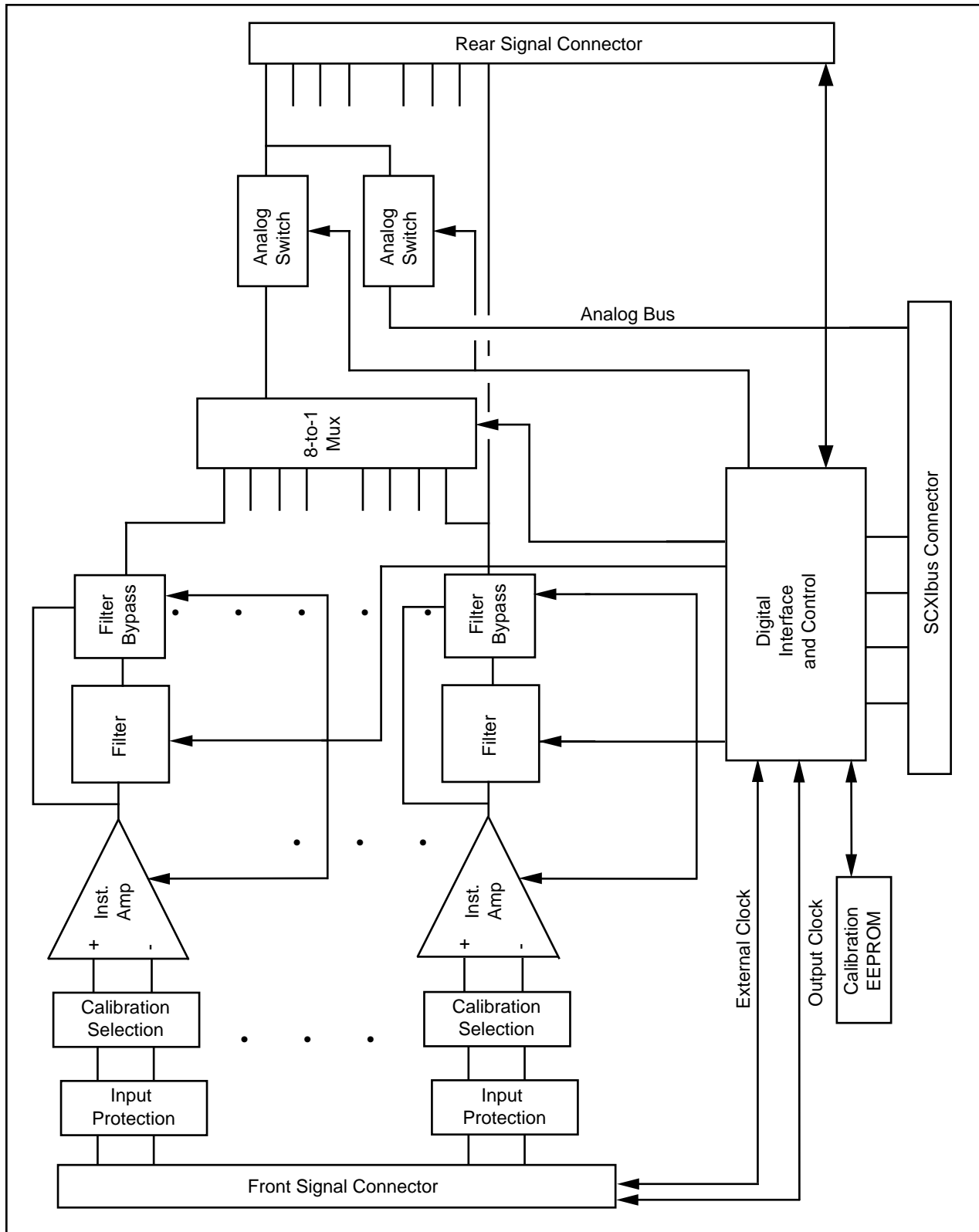


Figure 4-1. SCXI-1141 Block Diagram

## Digital Control Circuitry

The digital control circuitry contains a Module ID register, a configuration register for the module, a gain register, two frequency dividers, and an EEPROM for storing gain calibration constants.

The Module ID register contains the module ID 20 hex, a code unique to the SCXI-1141. You can read this module ID over the SCXIbus to determine the type of module that is in a particular slot.

Use the configuration register to select channels and configure the SCXI-1141 for scanning, calibration, and control options.

The gain register sets the gain of each amplifier.

The frequency dividers control the filter cutoff frequency and the output clock frequency.

The EEPROM stores the calibration constants that are to be written to the gain adjustment registers for each gain, for all eight channels. Information in the EEPROM is retained when the module is turned off. The SCXI-1141 has calibration constants already stored in the EEPROM. You can modify these constants for your own set of operating conditions. One set of constants is reserved and cannot be modified except at the factory, which ensures that you do not accidentally erase the default calibration constants. For more information on the EEPROM and calibration, see Chapter 5, *Calibration*.

Complete details on the digital control circuitry are in the *SCXI-1141 Register-Level Programmer Manual*.

## Input Amplifiers

The input amplifiers are fully differential amplifiers with input protection and calibration circuitry. The inputs are protected against input voltages up to  $\pm 15$  V powered off and  $\pm 30$  V powered on. The amplifiers provide gain to the differential signal between the inputs while rejecting common-mode noise voltages. The available gains are 1, 2, 5, 10, 20, 50, and 100. The output range of the amplifiers is  $\pm 5$  V. Select the gain to prevent the output signals from reaching  $\pm 5$  V, or distortion will occur.

In general, to provide optimum measurement resolution and noise rejection, you can select as high a gain as will not cause the output to exceed this limit. However, THD increases at higher output levels, especially at higher input frequencies. If THD is of significant concern in a given application, a lower gain (one or two steps lower) may be more appropriate.

## Gain and Offset Correction

The input amplifiers have intrinsic errors in their gains and in the DC offsets. To compensate for the gain errors, calibration constants are stored in the EEPROM for each gain and for each channel. These constants contain the adjustment factors used to correct for the gain errors. If you are using National Instruments software, these constants are read automatically from the EEPROM and the appropriate correction factor is applied when the data is scaled to a voltage.

If you are writing your own software, see the *SCXI-1141 Register-Level Programmer Manual* for information on how to read the EEPROM and interpret the calibration constants. Gain errors are determined and calibration constants loaded into the EEPROM at the factory. However, gain errors drift with temperature changes. You may add an additional set or subset of calibration constants to the EEPROM to optimize performance under a specific set of conditions. Details of this procedure are given in Chapter 5, *Calibration*.

To account for offset errors, you can configure the module to send a 0 V differential signal through the amplifiers. The signal at the output will be the DC offset error and should be read and subtracted from all subsequent readings. When reading this offset error, the filter should either be in bypass mode or allowed to settle for several seconds. Several readings should be taken and averaged to minimize noise errors. This procedure is called an autozeroing cycle. Because the offset voltage changes with each gain, you should perform a new autozeroing cycle each time the gain is changed. Offset errors also drift with changes in temperature, so it is recommended that the offset correction be updated periodically. Measurements made during the warm-up period of the module and chassis (about 20 min) are most susceptible to drifting offset errors.

## Lowpass Filters

The SCXI-1141 filters are eighth-order, elliptic lowpass filters. These filters are a hybrid of a switched capacitor and a continuous time architecture, thus providing good frequency control while avoiding the sampling errors found in conventional switched capacitor designs. To better acquaint you with these filters, this section describes what the filters do and presents examples of how to use them on the SCXI-1141.

### Filter Theory

Filters are generally grouped into one of five classifications—*lowpass*, *highpass*, *bandpass*, *bandstop*, and *all-pass*. These classifications refer to the frequency range (the *passband*) of signals that the filter is intended to pass from the input to the output without attenuation. Because the SCXI-1141 uses a lowpass filter, this discussion is limited to lowpass filters.

An ideal lowpass filter does not attenuate any signal components in the passband, which is defined as all frequencies below the *cutoff* frequency. An ideal lowpass filter completely attenuates all signal components in the *stopband*, which includes all frequencies above the cutoff frequency. The ideal lowpass filter also has a phase shift that is linear with respect to frequency. This linear phase property means that signal components of all frequencies are delayed by a constant time, independent of frequency, thereby preserving the overall shape of the signal.

In practice, real filters subject input signals to mathematical *transfer functions* that approximate the characteristics of an ideal filter. Figure 4-2 compares the attenuation of transfer functions of a real filter and an ideal filter.

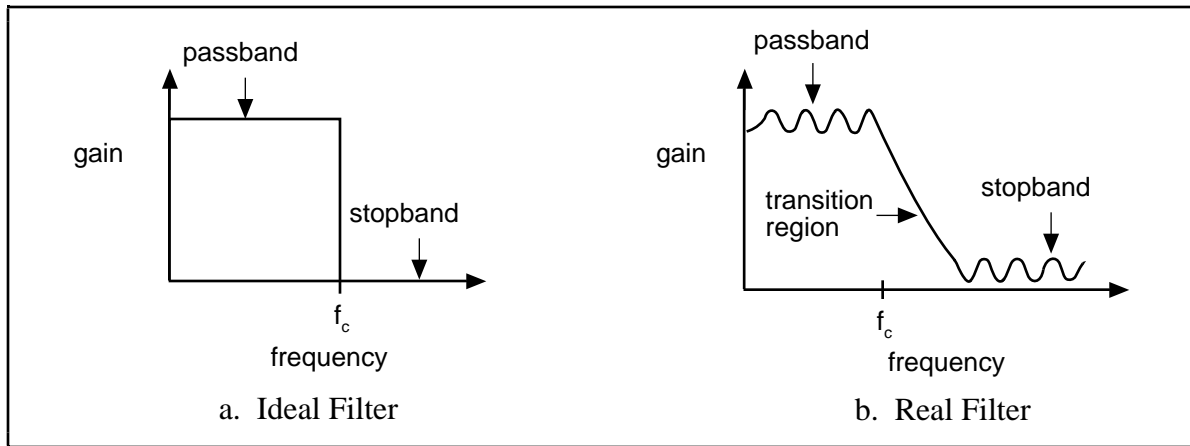


Figure 4-2. Real Lowpass Filter Transfer Function Characteristics

As Figure 4-2b shows, a real filter has *ripple* (an uneven variation in attenuation versus frequency) in the passband, a transition region between the passband and the stopband, and a stopband with finite attenuation and ripple.

In addition, real filters have some nonlinearity in their phase response. This causes signals at higher frequencies to be delayed by longer times than signals at lower frequencies, resulting in an overall shape distortion of the signal. This can be observed when a square wave or step input is sent through the filter; an ideal filter simply smooths the edges of the input, whereas a real filter causes some ringing in the signal as the higher frequency components of the signal are delayed. Figure 4-3 shows examples of these responses to a step input.

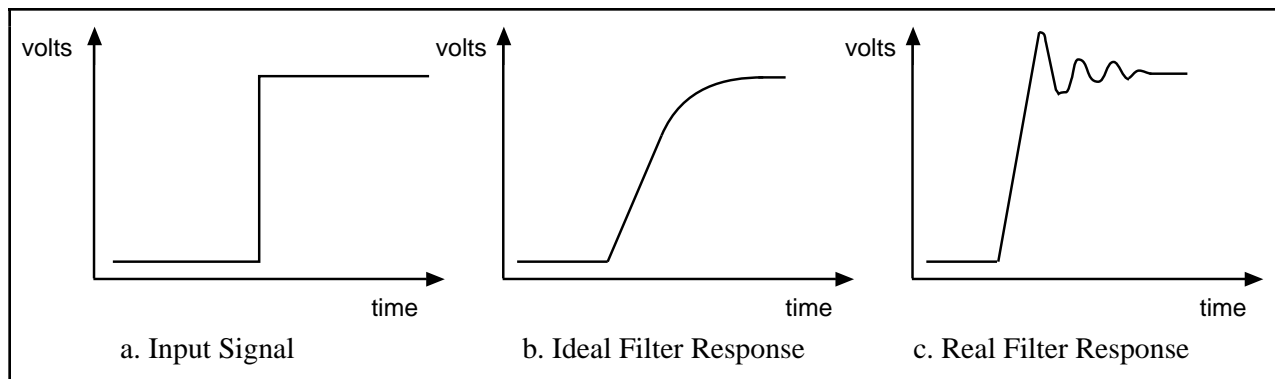


Figure 4-3. Real and Ideal Filter Responses to a Step Input

## Performance of the SCXI-1141 Filters

The filters used in the SCXI-1141 are *elliptic filters*, and are characterized by a very sharp transition region, high attenuation in the stopband, and good flatness in the passband. These characteristics make the elliptic filter an ideal choice for applications in which signals very near the cutoff frequency must be removed. Typically, the SCXI-1141 attenuates signals above 1.5 times the cutoff frequency by 80 dB. The drawback of using elliptic filters is their nonlinear phase response.

### Magnitude Response

The typical magnitude response of the SCXI-1141 filters is shown in Figure 4-4. Figure 4-4a shows the full transfer function while Figure 4-4b shows the ripple in the passband response. Both graphs are plotted with the frequency axis normalized to the cutoff frequency, where the cutoff frequency has the value of 1. As the figure shows, the SCXI-1141 provides 80 dB attenuation above 1.5 times the cutoff frequency, and less than 0.2 dB of peak-to-peak ripple in the passband.

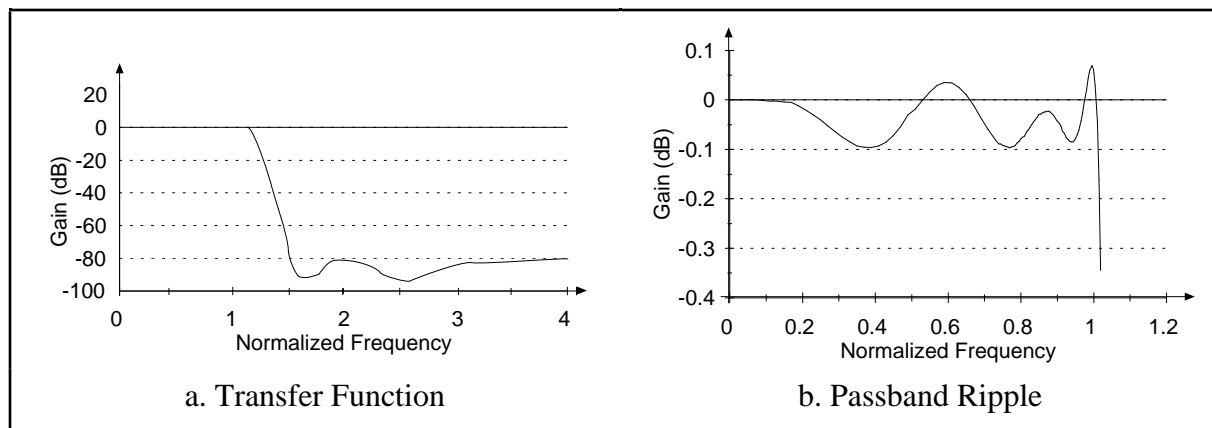


Figure 4-4. Typical Magnitude Response of the SCXI-1141 Filters

### Phase Response

Figure 4-5 demonstrates the phase response characteristics of the SCXI-1141 filters. Figure 4-5a shows the phase shift as a function of frequency (normalized so that the cutoff frequency = 1). In an ideal filter, this would be a linear relationship. Figure 4-5b shows the deviation of the actual phase response from an ideal (linear) response. Generally, phase response is described in terms of the differential nonlinearity, or group delay. Group delay is defined as the negative derivative of the phase shift with respect to the frequency  $\omega$  and in the ideal filter is a constant. The group delay of the SCXI-1141 filters is shown in Figure 4-5c.

The most common effect of phase nonlinearity is ringing in response a step input. Figure 4-5d shows the SCXI-1141 response to a step input. As the figure shows, the peak voltage of the



output is greater than the peak voltage of the input. When you choose a gain setting to keep the output signal within the  $\pm 5V$  output range, you must consider the added effects of ringing if steps inputs are expected.

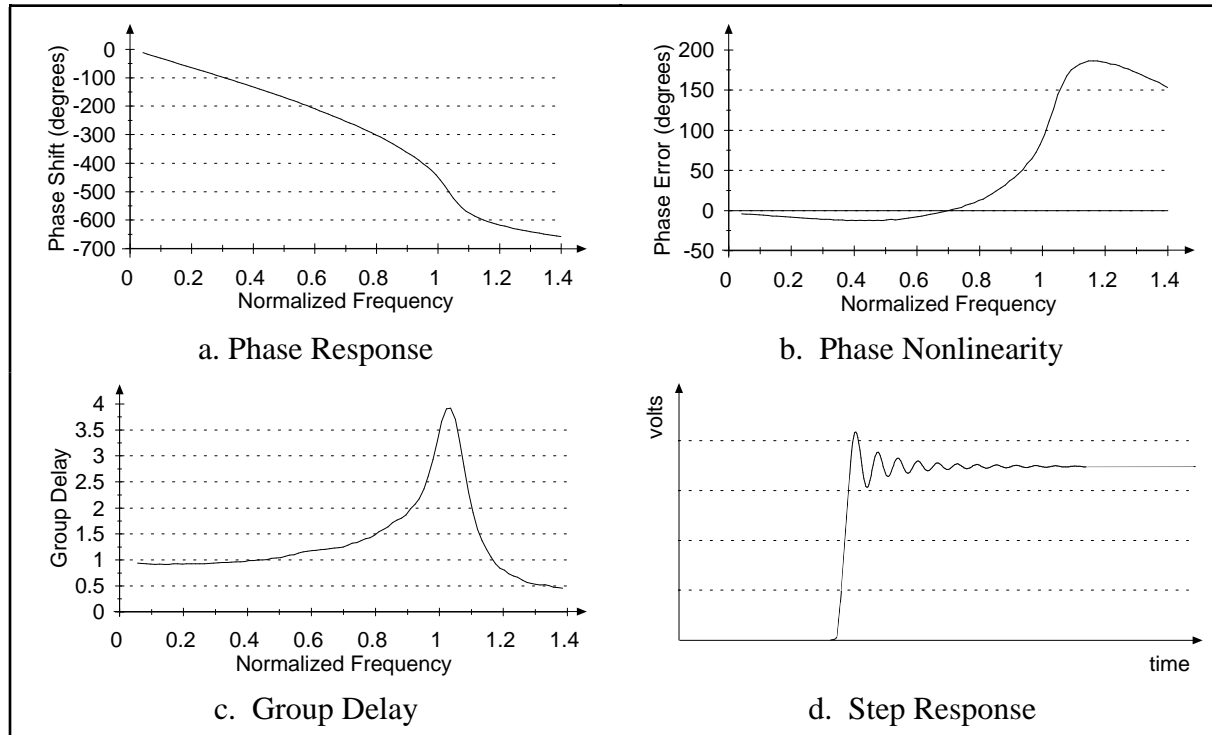


Figure 4-5. Phase Response Characteristics of the SCXI-1141 Filters

## Setting the Cutoff Frequency

The cutoff frequencies of the filters in the SCXI-1141 are set internally by dividing a base frequency of 100 kHz by an integer. You can determine the allowable cutoff frequencies for the SCXI-1141 as follows:

$$f_c = \frac{100}{n} \text{ kHz}$$

where  $n$  is an integer  $\geq 4$  and  $f_c \geq 10$  Hz; in other words,  $f_c = \{25, 20, 16.7, 14.3, 12.5, \dots\}$  kHz.

If you are using National Instruments software, the software automatically chooses a divisor,  $n$ , that best matches the cutoff frequency you specify and returns the actual cutoff frequency chosen.

The correct cutoff frequency depends on your application. If phase nonlinearity, ringing, or passband ripple are a concern in your application, you may need to set the cutoff frequency several times higher than the signal frequency range of interest. At frequencies much lower than the cutoff frequency, passband ripple and phase nonlinearity are much less noticeable. If you use the filter to prevent aliasing, you must set the cutoff frequency no higher than one-third of the frequency at which that channel is being sampled.

## Using the SCXI-1141 as an Antialiasing Filter

Aliasing, a phenomenon of sampled data systems, causes high-frequency signal components to take on the identity of a low-frequency signal. Figure 4-6 shows an example of aliasing.

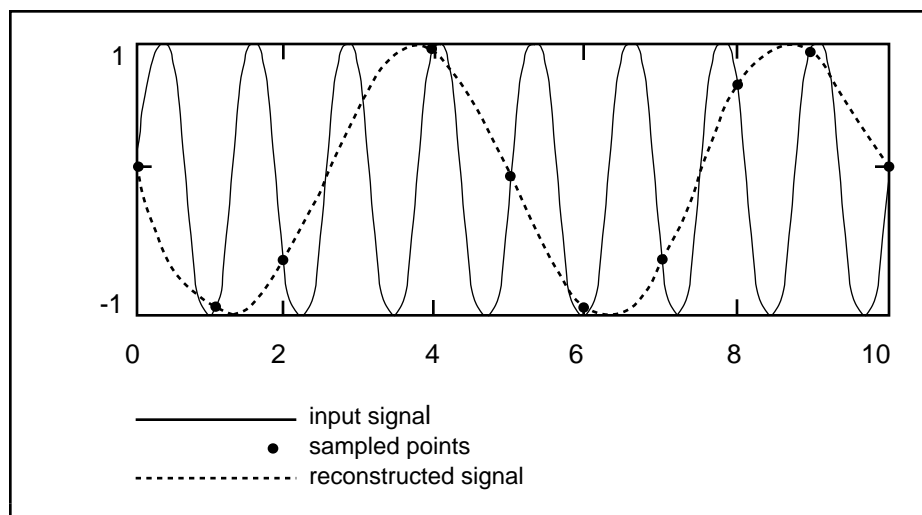


Figure 4-6. Aliasing of an Input Signal with a Frequency 0.8 Times the Sample Rate

The solid line depicts a high-frequency signal being sampled at the indicated points. However, when these points are connected to reconstruct the waveform, as shown by the dotted line, the signal appears to have a lower frequency. Any signal with a frequency greater than one-half of its sample rate will be aliased and incorrectly analyzed as having a frequency below one-half of the sample rate. This limiting frequency of one-half the sample rate is known as the *Nyquist frequency*.

To prevent aliasing, you must remove all of the signal components with frequencies greater than the Nyquist frequency from an input signal *before* it is sampled. When the data has been sampled and aliasing has occurred, it is impossible to accurately reconstruct the original signal. The SCXI-1141 removes these high-frequency signals before they reach a DAQ board and cause aliasing. Because the SCXI-1141 stopband begins at 1.5 times the cutoff frequency, the Nyquist frequency should be at least 1.5 times the cutoff frequency. Thus, the rate at which the DAQ board samples a channel should be at least 3 times the filter cutoff frequency.

For example, if a DAQ board is scanning all eight channels of the SCXI-1141 at a rate of 120,000 channels/s, the sample rate for each of the eight channels is:

$$\frac{120,000}{8} = 15,000 \text{ samples/s,}$$

and the cutoff frequency for the filters should be set no higher than:

$$\frac{15,000}{3} = 5,000 \text{ Hz.}$$

## Using the External Clock Input

You can set the cutoff frequencies of filters in the SCXI-1141 by using the external clock input in applications that require external control of the cutoff frequency or that require finer resolution than the module provides internally. The cutoff frequency for each filter using the external clock as a base is  $f_{\text{ext}}/(100*n)$ , where  $f_{\text{ext}}$  is the frequency of the external clock and  $n$  is an integer you select,  $2 \leq n \leq 2^{16}$ . When the frequency of the external clock changes, the cutoff frequency changes proportionally.

An external clock can control the SCXI-1141 filters because they use a *switched capacitor* architecture, which uses analog sampling. However, this technique is also susceptible to aliasing in much the same way as the digital sampling of a DAQ board (with a Nyquist frequency of one-half the external clock frequency). Analog sampling also creates high-frequency images of the signal because the output waveform has a staircase shape.

Unlike many filters available from other manufacturers using this switched capacitor architecture, the SCXI-1141 prevents these errors by using sets of prefilters and postfilters that do not sample the signal. A different set of prefilters and postfilters is used for each of 12 ranges of input frequencies. The prefilters reduce signals that may alias into a lower frequency by at least 40 dB, while the postfilters reconstruct the output waveform, reducing high-frequency images to at least -80 dB.

National Instruments software automatically chooses the correct set of prefilters and postfilters when you specify a cutoff frequency. However, when the external clock input is used to set the cutoff frequency of a filter, you must still supply an approximate cutoff frequency so that the software can determine the appropriate set of prefilters and postfilters.

Table 4-1 gives the ranges of cutoff frequencies that the prefilters and postfilters use.

Table 4-1. Cutoff Frequency Ranges for the SCXI-1141 Prefilters and Postfilters

Range	Cutoff Frequencies
A	10–25 kHz
B	4.3–10 kHz
C	1.9–4.4 kHz
D	1.5–3.4 kHz
E	700 kHz–1.8 Hz
F	300–700 Hz
G	130–300 Hz
H	100–225 Hz
I	49–110 Hz
J	21–49 Hz
K	15–21 Hz
L	10–15 Hz

For best results, the cutoff frequency of a particular filter should remain within this range. If the cutoff frequency were to go above this range, the prefilters and postfilters would interfere with signals in the passband, causing additional attenuation near the cutoff frequency. If the cutoff frequency were to go below this range, the level of protection from aliasing within the filter and from imaging in the output would decrease.

### Using the Output Clock

An output clock is available to control your external setup or signals. The output clock may be configured as a digital clock with a frequency that is proportional to the cutoff frequency of the filters. This clock is controlled by one of the frequency dividers. When an integer  $2 < m < 2^{16}$  is written to this divider, the output clock has a frequency equal to  $10 \text{ MHz}/m$  when the internal frequency base is used, and  $f_{\text{ext}}/m$  when the external clock is selected as the frequency base. Thus, when you set the filter cutoff frequency using the integer  $n$  described earlier, the frequency of the output clock is equal to the cutoff frequency of the filters times the ratio  $(100 \cdot n)/m$ .

This signal is a 0 to +5 V CMOS clock with a 50/50% duty cycle when  $m$  is even, and a duty cycle of  $\frac{m-1}{2 \times m} / \frac{m+1}{2 \times m}$  when  $m$  is odd.

### DC-Correction Circuitry and Overload Recovery

The SCXI-1141 incorporates circuitry that corrects for the DC gain and offset errors of the filters, leaving only the errors of the amplifiers. However, this correction takes approximately 15 s to completely respond to changes in these errors due to overload conditions (caused by driving the output signal outside of the  $\pm 5 \text{ V}$  range) and upon power-up (no data should be taken during the first 15 s). Overload conditions result whenever the input signal exceeds  $\pm 5 \text{ V/gain}$ . You must use a gain setting that prevents the maximum input signal from exceeding this limit, or the DC-correction circuitry will take 15 s to recover from overloads.

## Filter Bypass Mode

You can bypass the filter of any channel through software control, thus making the unfiltered signal available at the output. The input amplifiers are not bypassed.

Filter bypass mode can be a useful means of examining the effects that the filter has on your input. Using this mode, you can examine an input signal without the added effects of passband ripple and phase nonlinearities.

At power up and at reset, all the channels of the SCXI-1141 default to the filter bypass mode. You must turn the filter bypass mode off before you can use any of the filters.

## Analog Outputs

The connector signals AOUT<1..7> and AGND are the outputs of channels 1 through 7, respectively. You can configure the OUTPUT and OUTPUT REF signals as any channel (0 through 7) of the SCXI-1141 or as the output of a channel passed along the SCXIbus from any other module in the chassis. Thus, the SCXI-1141 can present its outputs in both parallel and multiplexed modes.

### Parallel Mode

When the OUTPUT signal is configured to be the output of channel 0, the rear signal connector simultaneously carries each of the outputs of the SCXI-1141 on different pins, and the module is in parallel mode. In this mode, you can use an SCXI-1180 feedthrough panel to make each of the outputs available at the front of the chassis. A DAQ board cabled to an SCXI-1141 in parallel mode reads a separate output signal from the module on each of its analog inputs. You cannot multiplex the parallel outputs of a module onto the SCXIbus; only a DAQ board directly cabled to the module has access to the outputs.

### Multiplexed Mode (Recommended)

In multiplexed mode, the output signals for channels 1 through 7 are sent to the rear signal connector but are usually ignored. All reads from the module are from the OUTPUT signal of the rear signal connector, which can be configured as the output of any channel of the SCXI-1141 or as the output of any other module in multiplexed mode that is sending its output onto the SCXIbus. You can also configure the SCXI-1141 to send any one of its outputs to the SCXIbus. Thus, in multiplexed mode only, one module in a chassis needs to be connected to a DAQ board; you can pass signals from the other modules to the DAQ board via the SCXIbus.

Multiplexed mode is also useful for performing scanning operations with the SCXI-1141. The MIO boards, Lab-PC+, and the SCXI-1200 all support scanning. The SCXI chassis is programmed with a module scan list that dynamically controls which module sends its output to the SCXIbus during a scan. You can specify this list to scan the modules in any order, with an arbitrary number of channels for each module entry in the list. However, the channels on the SCXI-1141 must be scanned in a consecutive, ascending order (after channel 7 is scanned the module wraps back to channel 0 and continues). You can program the SCXI-1141 to start scans with any channel.

# Chapter 5

## Calibration

---

This chapter discusses the SCXI-1141 calibration procedures.

### Overview

The onboard calibration hardware that calibrates the SCXI-1141 consists of an EEPROM to store the gain calibration constants, autozero circuitry on the amplifier inputs, and a potentiometer to adjust the AC gain of the filter. When autozeroing is selected, the input signals are disconnected from the amplifier inputs and the amplifier inputs are connected to ground.

Autozeroing is a method for nulling out offset error sources that compromise the quality of measurements. Autozeroing determines each output of the SCXI-1141 at a given gain of an amplifier. It is recommended that you perform autozeroing at the start of an experiment for each gain to be used. Doing this helps eliminate error due to drift in the amplifier internal circuitry and increases the accuracy of the measurement. Notice that the autozero path is different from the analog input path; therefore, even after autozeroing, a residual input offset still exists and has a value of less than 6  $\mu\text{V}$ . The offsets of the filters are internally compensated for; generally only the offsets of the amplifiers need to be autozeroed. The filters should be in bypass mode during an autozero cycle of the amplifiers only to avoid long settling times. If you are autozeroing the offsets of both the amplifiers and the filters, the filters must not be in bypass mode and the filters should be given 15 s to completely settle to the autozero voltage.

The DC gain errors of the filters (below 0.1 Hz) are also internally compensated for. The AC gain of each filter is adjusted with a trimming potentiometer with an adjustment range of  $\pm 0.15$  dB. The gain errors of the amplifiers are the same for DC and AC signals. When you are using National Instruments software, calibration constants representing these errors for each gain of each amplifier are stored in the onboard EEPROM for future use and for automatic calibration. If you are not using National Instruments software, refer to the *SCXI-1141 Register-Level Programmer Manual* for a more detailed description of the EEPROM.

The AC gain of the filters is calibrated at the factory, and the calibration constants for the amplifiers are already loaded into the EEPROM. If you are using National Instruments software such as NI-DAQ, LabVIEW, or LabWindows and are using the factory-determined calibration constants, you do not need to read the following section.

You need to read the following section only if you intend to determine new calibration constants or recalibrate the AC gain of the filters.

# Calibration Procedure

## Calibration Equipment Requirements

According to standard practice, the equipment you use to calibrate the SCXI-1141 should be 10 times as accurate as the SCXI-1141. Practically speaking, calibration equipment with four times the accuracy of the item under calibration is generally considered acceptable. To calibrate the SCXI-1141, you need the following equipment:

- A voltage source capable of providing a DC voltage of  $4.9 \text{ V}/G_s$  and less than 500 Hz sine wave, where  $G_s$  is the gain of the amplifier to be calibrated
- A voltmeter with the following specifications:
  - Accuracy  $\pm 0.002\%$  standard  
 $\pm 0.005\%$  sufficient
  - Range -5 to +5 V
  - Resolution 8.5 digits

To make sure that the measuring instrument, referred to as the digital multimeter (DMM), does not introduce an additional offset, you can determine the offset errors of the DMM by shorting its leads together and reading the measured value. This value, the DMM offset, must be subtracted from all subsequent measurements.

## Amplifier Gain Calibration

To determine the gain calibration factors of an SCXI-1141 amplifier at a given gain,  $G_s$ , perform the following steps for a two-point calibration.

1. Set the SCXI-1141 channel to the desired gain and configure the filter for bypass mode.
2. Depending on how you want to calibrate your module, you can perform one of the following procedures.
  - Autozeroing selects one of the calibration points to be at 0 V input. You must provide the other calibration point at positive or negative full scale:
    - a. Enable autozeroing.
    - b. Measure the SCXI-1141 output with the DMM and store the measured value for future use.
    - c. Disable autozeroing.
    - d. Apply  $4.9 \text{ V}/G_s$  or  $-4.9 \text{ V}/G_s$  to the amplifier input.
    - e. Go to step 3.

- To select positive and negative full scale to be the two calibration points, apply  $-4.9 \text{ V}/G_s$  and  $4.9 \text{ V}/G_s$ .
  - a. Apply  $-4.9 \text{ V}/G_s$  to the amplifier input.
  - b. Measure the input voltage with the DMM and store the measured value.
  - c. Measure the SCXI-1141 output with the DMM and store the measured value.
  - d. Apply  $4.9 \text{ V}/G_s$  at the amplifier input.
  - e. Go to step 3.

**Note:** *If you are using a calibrator that supplies accurate voltages, you can skip steps b and c directly above and step 3 below.*

3. Measure the input voltage with the DMM and store the measured value.
4. Measure the SCXI-1141 output with the DMM and store the measured value.
5. You now have two pairs of voltages. Each pair consists of an input voltage and an output voltage. For the autozeroing option, the pairs are {0 V input, offset output} and { $4.9 \text{ V}/G_s$  input, 4.9 V output} or { $-4.9 \text{ V}/G_s$  input,  $-4.9 \text{ V}$  output}. For the positive or negative full-scale calibration point options, the pairs are { $-4.9 \text{ V}/G_s$  input,  $-4.9 \text{ V}$  output} and { $4.9 \text{ V}/G_s$  input, 4.9 V output}.
6. Convert the output voltage from volts to your DAQ board binary unit. You must take into consideration the polarity of your DAQ board, its resolution (12 bits or 16 bits), and gain. For example, if you are using an AT-MIO-16F-5 in bipolar mode and are using a gain of  $G_{MIO} = 0.5$ , your output voltages for the autozeroing option will be represented in binary units as given by the following formula:

$$\text{Binary} = \text{Voltage} \cdot \frac{2^{12}}{10} \cdot G_{MIO}$$

Refer to your DAQ board user manual to determine the appropriate formula for you to use.

7. You now have a new set of pairs referred to as voltage binary pairs {voltage input1, binary output1} and {voltage input 2, binary output 2}. Pass these pairs to the `SCXI_Cal_Constants` function or VI as described in your software user manual.

**Note:** *When you are using the autozeroing option with 0 V and  $4.9 \text{ V}/G_s$ , this sets your gain error to 0% at 0 V and at positive full-scale voltage. However, because of nonlinearity, the error at the negative full-scale voltage will be two times the nonlinearity error. This is also true for the positive full-scale voltage if you use the negative full-scale voltage and 0 V as your two calibration points.*

*When you are making a measurement and using National Instruments software, the driver automatically performs the software correction using the `Cal_Constants` in the EEPROM.*



### Filter AC Gain Calibration

The AC gain of the filter is independent of the gain of the amplifier, so this procedure may be done with any amplifier gain. Ideally, the amplifier gain ( $G_s$ ) and the amplitude of the sine wave ( $V_s$ ) should be set so that  $V_s = 3.4 \text{ V}_{\text{rms}}/G_s$ .  $V_s$  may be set to a lower amplitude, but not a larger one. To prevent errors due to ripple in the passband, the frequency of the sine wave should be lower than 1/50 times the cutoff frequency. Ideally, you should set the filters to a cutoff frequency of 25 kHz and use a sine wave of less than 500 Hz.

To calibrate AC gain of a filter, perform the following steps.

1. Set the SCXI-1141 amplifier gain and the sine wave source amplitude to appropriate levels.
2. Set the SCXI-1141 filters to the filter bypass mode.
3. Apply the sine wave to the channel inputs.
4. Measure the amplitude of the sine wave at the output of the module and record this value.
5. Set the SCXI-1141 filters to a cutoff frequency of 25 kHz and disable the filter bypass mode.
6. Measure the amplitude of the sine wave at the output and adjust the potentiometer until the amplitude is at the same level as it was with the filter in bypass mode.
7. Repeat these steps for the other channels.

# Appendix A

## Specifications

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This appendix lists the specifications for the SCXI-1141. These specifications are typical at 25° C and 50% humidity unless otherwise stated. The operating temperature range is 0° to 50° C.

### Amplifier Characteristics

Number of channels .....	8 differential
Output signal range .....	± 5 V
Channel gains (software selectable) .....	1, 2, 5, 10, 20, 50, 100
Max working voltage .....	± 5 V (signal + common mode)
Overvoltage protection .....	± 15 V powered off, ± 30 V powered on
Input coupling .....	DC (AC available with SCXI-1304 terminal block)
Input impedance .....	10 GΩ in parallel with 40 pF
Input bias current .....	300 pA
Input offset current .....	150 pA
Common-mode rejection ratio .....	60 dB (G = 1)
DC gain error .....	± 0.6% before calibration, ±0.02% after calibration <sup>1</sup>
DC input offset .....	0.6 mV (can be autozeroed)

### Filter Characteristics

Filter type .....	8th order elliptic
Filter architecture .....	Switched capacitor with prefilters and postfilters
Rolloff rate .....	135 dB/octave
Cutoff frequency ( $f_c$ ) range.....	10 Hz to 25 kHz
Cutoff choices (software selectable) .....	Divided from 100 kHz or external clock (for example, 25 kHz, 20 kHz, 16.7 kHz, 14.3 kHz, or from external)
Passband ripple.....	0.2 dB DC to $f_c$
Stopband attenuation .....	80 dB at $1.5 \cdot f_c$
Prefilter aliasing rejection .....	>80 dB below $99 \cdot f_c$ , > 40 dB above $99 \cdot f_c$
Sampled image + clock feedthrough.....	<-75 dB

### System Noise

THD, 1 kHz .....	-70 dB
0–25 kHz .....	-60 dB
Input noise .....	$30 \text{ nV} \cdot \sqrt{f_c}$
Output noise .....	$230 \text{ } \mu\text{V}_{\text{rms}}$

---

<sup>1</sup> The SCXI-1141 is factory calibrated so that  $V_{\text{in}(-)} = 0 \text{ V}$ , and  $V_{\text{in}(+)} = \pm\text{fullscale}$ .

## Stability

Gain temperature coefficient .....	20 ppm/°C
Input offset drift .....	10 $\mu$ V/°C
Output offset drift .....	0.1 mV/°C

## Physical

Dimensions .....	1.2 by 6.8 by 8.0 in. (3.0 by 17.3 by 24.4 cm)
I/O connectors .....	50-pin male ribbon-cable rear connector 96-pin DIN C male front connector (screw terminal adapters available)

## Environment

Operating temperature .....	0° to 50° C
Storage temperature .....	-55° to 150° C
Relative humidity .....	5% to 90% noncondensing

# Appendix B

## Customer Communication

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For your convenience, this appendix contains forms to help you gather the information necessary to help us solve technical problems you might have as well as a form you can use to comment on the product documentation. Filling out a copy of the *Technical Support Form* before contacting National Instruments helps us help you better and faster.

National Instruments provides comprehensive technical assistance around the world. In the U.S. and Canada, applications engineers are available Monday through Friday from 8:00 a.m. to 6:00 p.m. (central time). In other countries, contact the nearest branch office. You may fax questions to us at any time.

### Corporate Headquarters

(512) 795-8248

Technical support fax: (800) 328-2203  
(512) 794-5678

<b>Branch Offices</b>	<b>Phone Number</b>	<b>Fax Number</b>
Australia	(03) 879 9422	(03) 879 9179
Austria	(0662) 435986	(0662) 437010-19
Belgium	02/757.00.20	02/757.03.11
Denmark	45 76 26 00	45 76 71 11
Finland	(90) 527 2321	(90) 502 2930
France	(1) 48 14 24 00	(1) 48 14 24 14
Germany	089/741 31 30	089/714 60 35
Italy	02/48301892	02/48301915
Japan	(03) 3788-1921	(03) 3788-1923
Mexico	95 800 010 0793	95 800 010 0793
Netherlands	03480-33466	03480-30673
Norway	32-848400	32-848600
Singapore	2265886	2265887
Spain	(91) 640 0085	(91) 640 0533
Sweden	08-730 49 70	08-730 43 70
Switzerland	056/20 51 51	056/20 51 55
Taiwan	02 377 1200	02 737 4644
U.K.	0635 523545	0635 523154

# Technical Support Form

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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 \_\_\_\_\_

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 will reproduce the problem \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

# SCXI-1141 Hardware 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.

- SCXI-1141 Revision \_\_\_\_\_
- Chassis Slot \_\_\_\_\_
- Chassis Type \_\_\_\_\_

Jumper Settings	Your Setting	Factory Setting
W1		
W2		

**Note:** Mark your jumper positions on the jumper diagram in the left column.

- Other Modules and Chassis in System \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
- DAQ Boards Installed \_\_\_\_\_  
 \_\_\_\_\_

# Register-Level Programmer Manual Request Form

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National Instruments offers a register-level programmer manual at no charge to customers who are not using National Instruments software.

Title: **SCXI-1141 Register-Level Programmer Manual**

Part Number: **340708A-01**

Please indicate your reasons for obtaining the register-level programmer manual. Check all that apply.

- National Instruments does not support your operating system or programming language.
- You are an experienced register-level programmer who is more comfortable writing your own register-level software.
- Other. Please explain.

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Thank you for your help.

Name \_\_\_\_\_

Title \_\_\_\_\_

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(Street Address, Not P.O. Box) \_\_\_\_\_

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National Instruments Corporation  
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Austin, TX 78730-5039

Fax to: Data Entry Department  
National Instruments Corporation  
(512) 794-8411

# Documentation Comment Form

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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: **SCXI-1141 User Manual**

Edition Date: **October 1994**

Part Number: **320748A-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 \_\_\_\_\_

Title \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

\_\_\_\_\_

Phone ( \_\_\_\_\_ ) \_\_\_\_\_

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Austin, TX 78730-5039

Fax to: Technical Publications  
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MS 53-02  
(512) 794-5678



# Glossary

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

°	degrees
>	greater than
≥	greater than or equal to
<	less than
-	negative of, or minus
$\Omega$	ohms
%	percent
±	plus or minus
+	positive of, or plus
A	amperes
AC	alternating current
AGND	Analog Ground signal
AGND/NC	Analog Ground/No Connect signal
ANSI	American National Standards Institute
AOGND/GUARD	Analog Output Ground
AOUT	Analog Output signal
Arms	amperes, root mean square
AWG	American Wire Gauge
C	Celsius
CMOS	complementary metal-oxide semiconductor
CMRR	common-mode rejection ratio
D/A	digital-to-analog
DAQ	data acquisition
DAQD*/A	Data Acquisition Board Data/Address Line signal
dB	decibels
DC	direct current
DIGGND	Digital Ground signal
DIN	Deutsche Industrie Norme
DMA	direct memory access
DMM	digital multimeter
EEPROM	electrically erased programmable read-only memory
EXTCLK	External Clock signal
$f_c$	cutoff frequency

## Glossary

F <sub>ext</sub>	external frequency
G <sub>s</sub>	gain
hex	hexadecimal
Hz	hertz
in	inch
IN+	positive input channel signal
IN-	negative input channel signal
I/O	input/output
INTR*	Interrupt signal
max	maximum
MB	megabytes
min	minutes/minimum
MIO	multifunction I/O
MISO	Master-In-Slave-Out signal
MOSI	Master-Out-Slave-In signal
NP	no pullup
NRSE	nonreferenced single-ended
OUTCLK	Output Clock signal
OUTPUT	Output signal
OUTPUT REF	Output Reference signal
P	pullup
ppm	parts per million
rms	root mean square
RSVD	Reserved signal/bit
RTSI	Real-Time System Integration
s	seconds
SCXI	Signal Conditioning eXtensions for Instrumentation (bus)
SCANCLK	Scan Clock Signal
SERCLK	Serial Clock signal
SERDATIN	Serial Data In signal
SERDATOUT	Serial Data Out signal
SLOT0SEL	Slot 0 Select signal
SPICLK	Serial Peripheral Interface Clock signal
THD	total harmonic distortion
V	volts
VI	Virtual Instrument
V <sub>rms</sub>	volts, root mean square

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