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SC-2040
User Manual

Eight-Channel Simultaneous Sample-and-Hold Accessory

September 1994 Edition

Part Number 371191A-01

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About This Manual

This manual describes the electrical and mechanical aspects of the SC-2040 and contains information concerning its configuration and operation. The SC-2040 is an eight-channel simultaneously sampling differential amplifier for the National Instruments MIO-16E Series DAQ boards. The SC-2040 samples all eight channels at the same time, preserving interchannel phase relationships for the MIO-16E.

Organization of This Manual

The *SC-2040 User Manual* is organized as follows:

- Chapter 1, *Introduction*, describes the SC-2040, lists what you need to get started with your SC-2040, describes the optional software and optional equipment, and explains how to unpack your SC-2040.
- Chapter 2, *Configuration and Installation*, describes the configuration and installation of your SC-2040. The topics discussed are switch and jumper configuration, connection of the SC-2040 to the MIO-16E, and the power-on sequence for your SC-2040 configuration.
- Chapter 3, *Signal Connections*, describes the signal connections to the SC-2040 board, and cable wiring.
- Chapter 4, *Theory of Operation*, contains a functional overview of the SC-2040 board and explains the operation of each functional unit making up the SC-2040.
- Chapter 5, *Calibration Procedures*, discusses the calibration procedures for the SC-2040 board.
- Appendix A, *Specifications*, lists the specifications for the SC-2040.
- 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 used in this manual, including abbreviations, acronyms, metric prefixes, mnemonics, and symbols.
- The *Index* contains an alphabetical list of key terms and topics used 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:

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.
MIO-16E	MIO-16E refers to the National Instruments E-Series of MIO-16 DAQ boards unless otherwise noted.
`monospace`	Lowercase 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.

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

The National Instruments Documentation Set

The *SC-2040 User Manual* is one piece of the documentation set for your system. You could have any of several types of manuals, depending on the hardware and software in your system. Use the manuals you have as follows:

- Your DAQ hardware 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 might 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 manuals–If you are using accessory products, read 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 together. Consult these guides when you are making your connections.

Related Documentation

The following document contains information that you may find helpful as you read this manual:

- Your DAQ hardware user manual

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 SC-2040, lists what you need to get started with your SC-2040, describes the optional software and optional equipment, and explains how to unpack your SC-2040.

About the SC-2040

The SC-2040 is an eight-channel simultaneously sampling differential amplifier for the National Instruments MIO-16E Series DAQ boards. Each channel provides DIP-switch-selectable gain followed by a track-and-hold amplifier. The track-and-hold amplifiers sample all the inputs at the same time, which is useful for preserving interchannel phase relationships. The MIO-16E can trigger the track-and-hold amplifiers, or you can supply an external trigger source.

Note: ***When a board is referred to without an AT prefix (that is, MIO-16E), the reference applies to the AT versions of that board.***

The SC-2040 is a circuitboard assembly that is placed on a workbench or mounted in a 19-in. rack. You can configure the SC-2040 to draw power from the MIO-16E board or from an external +5 V supply. A red LED indicates when the board is powered on. Input signal leads are attached at screw terminals.

What You Need to Get Started

To set up and use your SC-2040, you will need the following components:

- SC-2040 board
- *SC-2040 User Manual*
- 1.0, 2.0, 5.0, or 10.0 m SH6868 or R6868 cable

Detailed specifications of the SC-2040 are in Appendix A, *Specifications*.

Software Programming Choices

Your SC-2040 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 SC-2040 works with LabVIEW for Windows, LabVIEW for Macintosh, LabWindows for DOS, LabWindows/CVI for Windows, NI-DAQ software for PC compatibles, and NI-DAQ software 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 DAQ hardware, 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 for 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 DAQ hardware, is included with the NI-DAQ software kit. The LabWindows Data Acquisition libraries are functionally equivalent to the NI-DAQ software, except that the SCXI functions are not included in the LabWindows/CVI 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 hardware. NI-DAQ is not packaged with SCXI or accessory products. 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 DAQ hardware such as programming interrupts 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 data acquisition parts of LabVIEW and LabWindows are functionally equivalent to the NI-DAQ software.

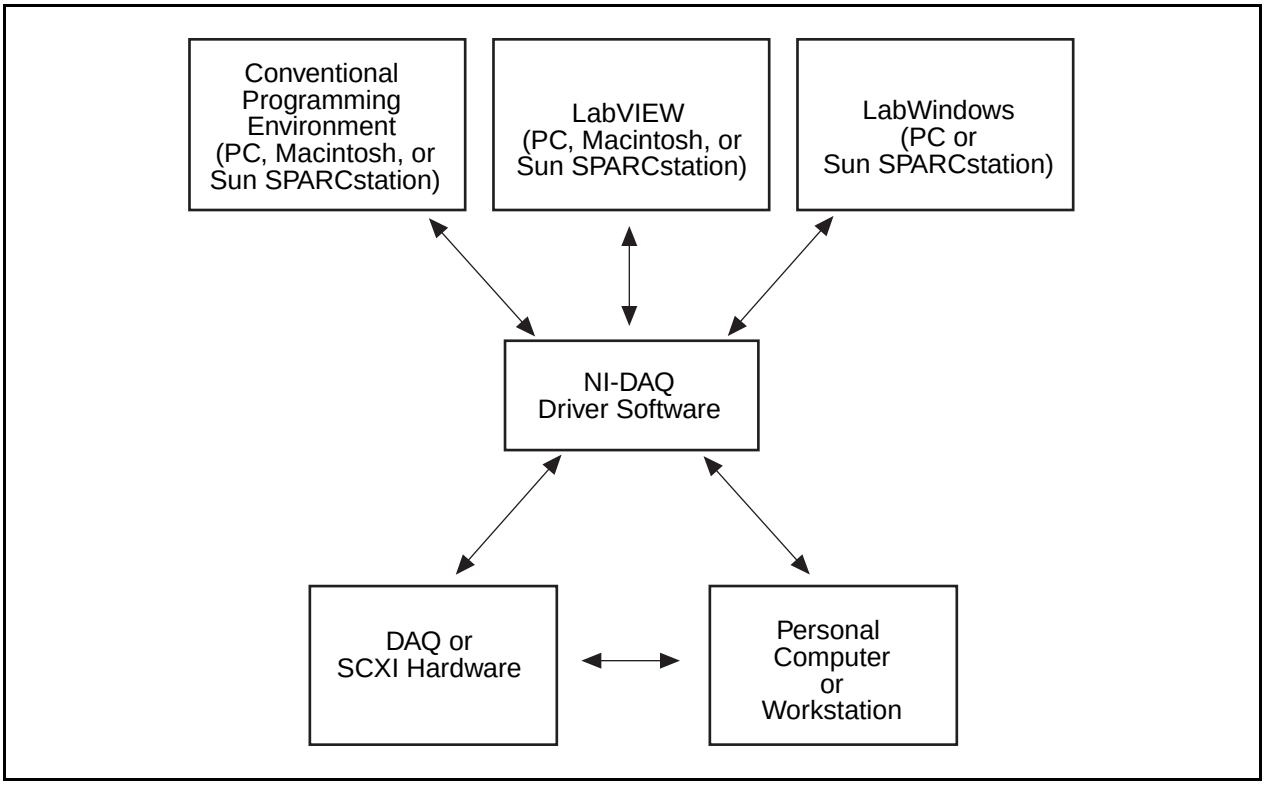


Figure 1-1. The Relationship between the Programming Environment, NI-DAQ, and Your Hardware

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. You can use your AT-MIO-16, together with other PC, AT, MC, EISA, DAQCard, and DAQPad Series DAQ 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 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

There are no register-level programming concerns for the SC-2040. When using the SC-2040, only the MIO-16E Series board needs to be programmed. Refer to your MIO-16E board manual for further information on register-level programming.

Optional Equipment

Contact National Instruments to order the following optional equipment:

- CB-50 I/O connector (50-screw terminals) with 0.5 or 1.0 m cable
- Single or double height rack-mount kit with acrylic plastic cover
- Single or double height rack-mount kit with metal wraparound cover

Unpacking

Your SC-2040 board is shipped in an antistatic package to prevent electrostatic damage to the board. Electrostatic discharge can damage several components on the board. To avoid such damage in handling the board, take the following precautions:

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

Chapter 2
Configuration and Installation

This chapter describes the configuration and installation of your SC-2040. The topics discussed are switch and jumper configuration, connection of the SC-2040 to the MIO-16E, and the power-on sequence for your SC-2040 configuration.

Board Configuration

The SC-2040 has 10 jumpers, eight DIP switches, and one slide switch that you use to configure the board. These switches and jumpers are shown in Figure 2-1.

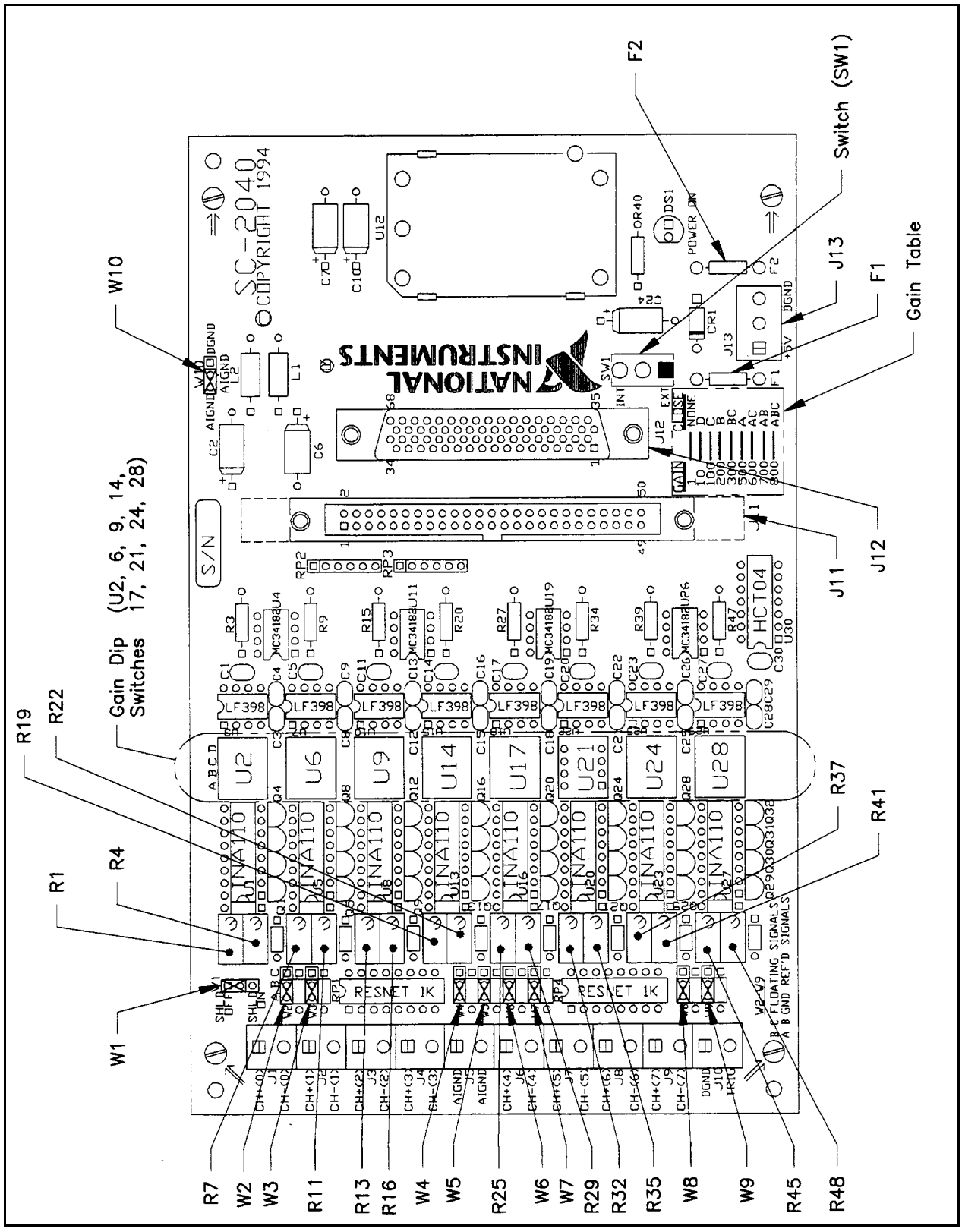


Figure 2-1. SC-2040 Parts Locator Diagram

The SC-2040 has one switch that controls whether the board is powered from an external supply or from the MIO-16E board. Furthermore, two jumpers control how the board is shielded and grounded. Additionally, there are eight sets of switches and jumpers that configure the gain settings and input modes of the eight SC-2040 channels.

Table 2-1. Power Supply Selection

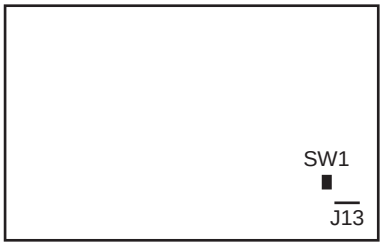
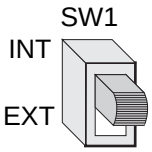
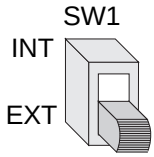
Switch	Description	Configuration
	INT position—Use this setting to configure the SC-2040 to draw power through the MIO-16E board. (factory setting)	 A. Internal Power
	EXT position—Use this setting to draw +5 V power from an external supply connected to connector J13.	 B. External Power

Table 2-2. Shield Selection

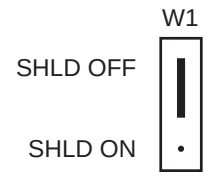
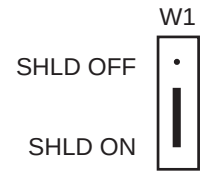
Jumper	Description	Configuration
W1 —	SHLD OFF position—Place the jumper in this position to keep the SC-2040 analog ground isolated from the metal standoffs in the corners of the board (factory setting).	
	SHLD ON position—Place the jumper in this position to connect the SC-2040 analog ground to the metal standoffs or to a rack-mount kit, which may provide shielding for the SC-2040.	

Table 2-3. DAQ Board Ground Isolation Selection

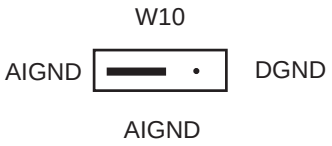
Jumper	Description	Configuration
W10 —	AIGND-AIGND position—Use this setting if you are using a MIO-16E DAQ board. Place the jumper in this position to keep the SC-2040 digital ground and analog grounds isolated (factory setting).	
	AIGND-DGND position—Place the jumper in this position to connect the SC-2040 analog ground to digital ground.	

Table 2-4. Channel Gain Selection

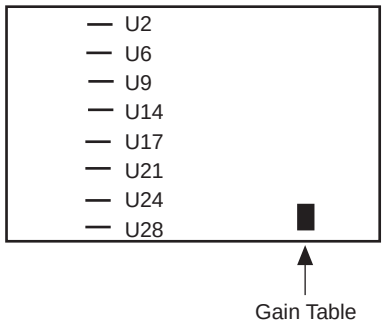
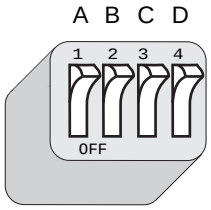
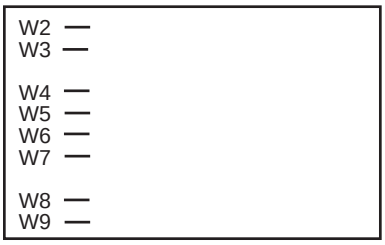
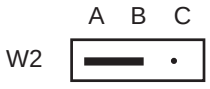
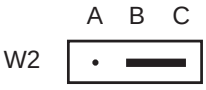
Switch	Description	Configuration
	Unity gain position—For unity gain (gain = 1), open all the switches by pushing down the OFF end of the switches. (factory setting) Other gains—Refer to *Supplementary Configuration Information*, later in the chapter, and the gain table on the board itself.	 The unity gain position has the number side up.

Table 2-5. Channel Input Mode

Switch	Description	Configuration
	A-B position—Use this setting for connecting ground-referenced signals to the SC-2040 (factory setting). B-C position—Use this setting for connecting floating (non-ground referenced) sources. A 100 kΩ resistor is connected from the negative channel input to the SC-2040 analog ground.	  The W3–W9 jumper positions are the same as on W2.

Supplementary Configuration Information

Power Supply Selection

Set switch SW1 to the INT position to connect the SC-2040 power converter to the +5 V lines on the MIO-16E board. Set switch SW1 to the EXT position to draw power from an external +5 V power supply connected to J13.

The MIO-16E is fused to provide 5 W of power (at +5 V and 1 A). The SC-2040 consumes nearly all of this available power. Therefore, if you have other DAQ accessories that you would like to power from the MIO, you should switch the SC-2040 to external power and provide an external +5 V power source. In external power mode, the SC-2040 is fuse limited to 1 A at +5 V.

Shield Selection

If you are using a rack-mount kit, shield the SC-2040 from unwanted noise by connecting the analog ground on the board to the metal chassis of the rack using jumper W1. When you set W1 to the SHLD ON position, the jumper connects the analog ground to the metal standoffs used to mount the board in a rack. In the SHLD OFF position, the SC-2040 analog ground is isolated from the metal standoffs.

DAQ Board Ground Isolation Selection

You can use jumper W10 to connect the SC-2040 digital and analog grounds. If you are using a MIO-16E board, you must isolate the grounds by leaving the jumper in its default position.

Gain Selection

The gain selection switches can select gains of 1, 10, 100, 200, 300, 500, 600, 700, and 800 for each channel, as shown in Table 2-6.

Table 2-6. Gain Switches for Each Channel

Channel	Close Switches
0	U2
1	U6
2	U9
3	U14
4	U17
5	U21
6	U24
7	U28

To close a switch, push down the number side. Closing switch A selects a gain of 500. Closing switch B selects a gain of 200. Closing switch C selects a gain of 100. Closing switch D selects a gain of 10. Opening all the switches selects a gain of 1. You can select other gains by closing more than one switch, as shown in Table 2-7.

Table 2-7. Switch Settings for Gain Selection

Desired Gain	Close Switches
1	None
10	D
100	C
200	B
300	B and C
500	A
600	A and C
700	A and B
800	A, B, and C

Input Mode Selection

Jumpers W2 through W9 select the input mode for each channel on the SC-2040. Position A-B leaves the negative input of the instrumentation amplifier connected only to the front connector. This is the factory-default setting. Position B-C connects the negative input of the instrumentation amplifier to the board analog ground through a 100 kΩ resistor. This setting is useful for keeping floating, or nonground-referenced, sources from saturating the instrumentation amplifier. Table 2-8 shows the input mode jumper and channel selections.

Table 2-8. Input Mode Selection Jumpers

Channel	Use Jumper
0	W2
1	W3
2	W4
3	W5
4	W6
5	W7
6	W8
7	W9

Installation

Note: ***You must turn off power to the PC, and to the SC-2040 board if the board is externally powered, before installing the board or making any connections to it.***

To install the SC-2040, connect the 68-pin ribbon from the MIO-16E I/O connector to connector J12 on the SC-2040. The SC-2040 can be mounted in a rack-mount chassis using the mounting holes (indicated with an arrow on the board) in the four corners of the SC-2040 board.

The SC-2040 is installed. You are now ready to install and configure your software.

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 of 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.

Power-on Sequence

If the SC-2040 is powered by an external power source, you must turn on power to the SC-2040 *before* turning on the computer. Similarly, you must turn off power to the SC-2040 *after* turning off the computer. The red LED labeled DS1 indicates when power is applied to the board.

Chapter 3
Signal Connections

This chapter describes the signal connections to the SC-2040 board, and cable wiring.

I/O Connector Pin Description

Warning: ***Connections that exceed any of the maximum ratings of input or output signals on the MIO-16 can result in damage to the MIO-16 board and to the personal computer. This includes connecting any power signals to ground and vice versa. National Instruments is not liable for any damages resulting from any such signal connections.***

Corresponding signals on connectors J11 and J12 are connected together through the SC-2040. Connector J12 carries the signals to and from the MIO-16E board. Use connector J11 to access these signals. You can use this connector to monitor these signals, using a National Instruments CB-50, for example, or you can use this connector to connect to other DAQ accessories. Figure 3-1 shows these connectors.

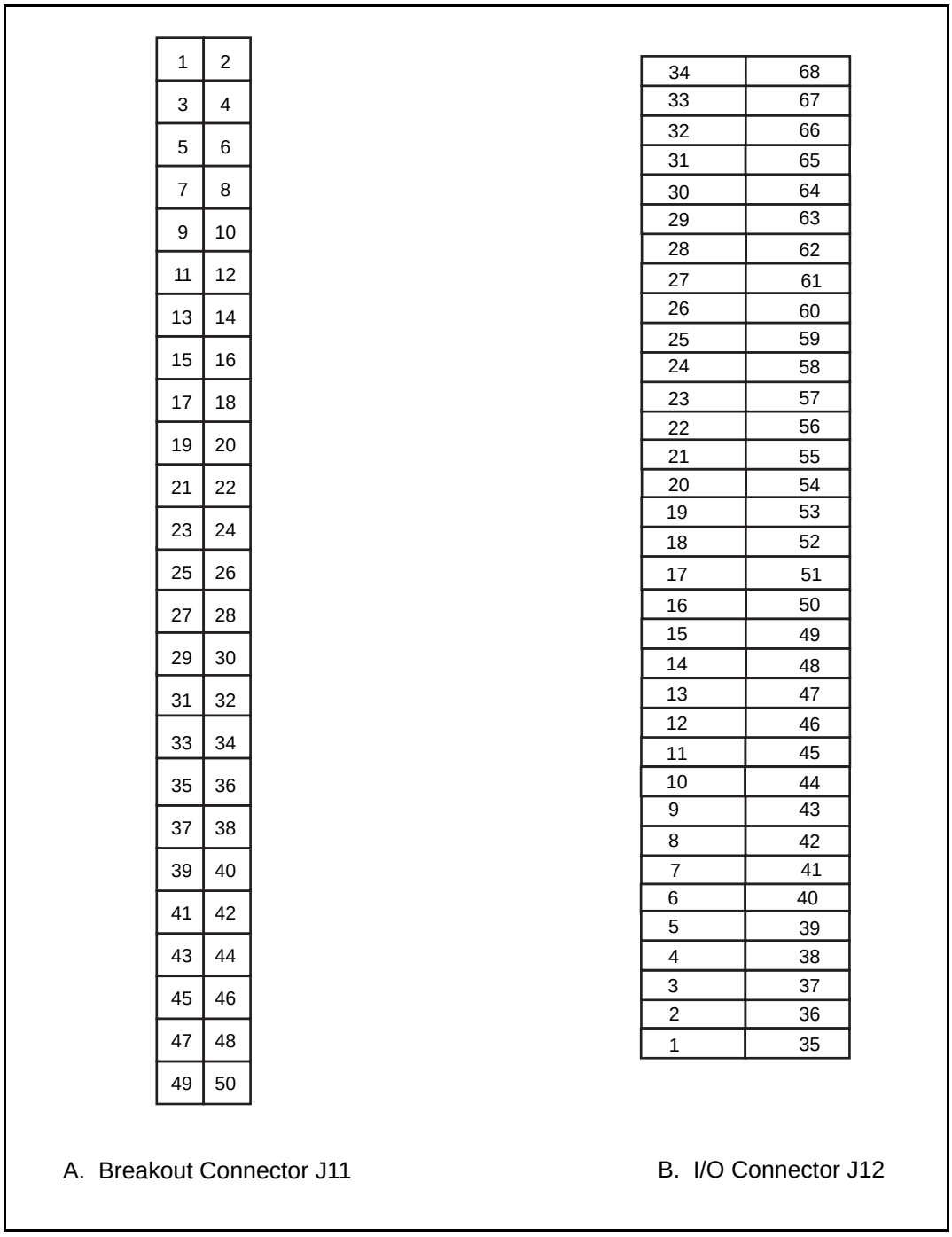


Figure 3-1. SC-2040 I/O Connectors J11 and J12

Table 3-1 lists the pin assignments for the breakout connector J11 and the I/O connector J12 on the SC-2040 and the corresponding and MIO-16E Series signal names.

Table 3-1. Pin Assignments for Connectors J11 and J12

Breakout Connector J11 Pin Numbers	SC-2040 Signal Names[1]	MIO-16E Series Signal Names	I/O Connector J12 Pin Numbers
1, 2	AIGND	AIGND	24, 27, 29, 32, 56, 59, 64, 67
3	ACH0	ACH0	68
4	AIGND	ACH8	34
5	ACH1	ACH1	33
6	AIGND	ACH9	66
7	ACH2	ACH2	65
8	AIGND	ACH10	31
9	ACH3	ACH3	30
10	AIGND	ACH11	63
11	ACH4	ACH4	28
12	AIGND	ACH12	61
13	ACH5	ACH5	60
14	AIGND	ACH13	26
15	ACH6	ACH6	25
16	AIGND	ACH14	58
17	ACH7	ACH7	57
18	AIGND	ACH15	23
19	NC	AISENSE	62
20	NC	DAC0OUT	22
21	NC	DAC1OUT	21
22	NC	EXTREF	20
23	NC	AOGND	54, 55
24, 33	DGND	DGND	4, 7, 9, 12, 13, 15, 18, 35, 36, 39, 44, 50, 53
25	NC	DIO0	52
26	NC	DIO4	19
27	NC	DIO1	17
28	NC	DIO5	51
29	NC	DIO2	49
30	NC	DIO6	16
31	NC	DIO3	47
32	NC	DIO7	48
34, 35	+5V	+5V	8, 14
36	NC	SCANCLK	46
37	NC	EXTSTROBE*	45
38	NC	PFI0/TRIG1	11
39	NC	PFI1/TRIG2	10
40	TRIG	PFI2/CONVERT*	43
41	NC	PFI3/GPCTR1_SOURCE	42
42	NC	PFI4/GPCTR1_GATE	41
43	NC	GPCTR1_OUT	40
44	NC	PFI5/UPDATE*	6
45	NC	PFI6/WFTRIG	5
46	TRACK*/HOLD	PFI7/STARTSCAN	38
47	NC	PFI8/GPCTR0_SOURCE	37
48	NC	PFI9/GPCTR0_GATE	3
49	NC	GPCTR0_OUT	2
50	NC	FREQ_OUT	1

[1] All signals labeled NC are unused by the SC-2040.

Signal Connection Description

Table 3-2. Input Connectors Signal Summary

Connector	Signal Name	Description
J5	AIGND	Analog Input Ground—These inputs provide a bias current return point for AC-coupled signals.
J1, J2, J3, J4, J6, J7, J8, J9	CH+<0..7>	Positive Inputs—These inputs are the positive signal inputs for channels 0 through 7.
J1, J2, J3, J4, J6, J7, J8, J9	CH-<0..7>	Negative Inputs—These inputs are the negative signal inputs for channels 0 through 7.
J10, J13	DGND	Digital Ground—These inputs provide the reference for all digital signals and the reference for the +5 V power source.
J10	TRIG	Trigger—This input, which is connected directly to the PFI2 pin on connectors J11 and J12, is a trigger input for the MIO-16E. A low-to-high transition on TRIG alerts the MIO-16E to place the SC-2040 into hold mode and start acquiring data.
J13	+5 V	+5 VDC Source—When external power is selected, this input provides DC power for the SC-2040 from an external +5 V. The SC-2040 fuses the input to 1 A of the +5 V supply.

Table 3-3. Output Connectors (J11 and J12) Signal Summary

J11 Pin (50-pin)	J12 Pin (68-pin)	Signal Name	Description
1, 2, 4, 6, 8, 10, 12, 14, 16, 18	23, 24, 26, 27, 29, 31, 32, 34, 56, 58, 59, 61, 63, 64, 66, 67	AIGND	Analog Input Ground—These pins establish the reference point for the SC-2040 outputs (ACH<0..7>). They are also connected directly to the AIGND input connector J5 for use with AC-coupled signals.
3, 5, 7, 9, 11, 13, 15, 17	68, 33, 65, 30, 28, 60, 25, 57	ACH<0..7>	Analog Channels 0 through 7—These pins carry the outputs of the SC-2040 eight channels to the DAQ board. They are referenced to AIGND.
24, 33	4, 7, 9, 12, 13, 15, 18, 35, 36, 39, 44, 50, 53	DGND	Digital Ground—These pins are the reference for the +5 V power source and for the digital signals used by the SC-2040: TRIG (PFI2) and TRACK*/HOLD (PFI7/STARTSCAN).
34, 35	8, 14	+5 V	+5 VDC Source—When internal power is selected, these pins provide DC power for the SC-2040 from the MIO-16E board. The MIO-16E pins are fused to 1 A of +5 V supply.
40	43	TRIG (PFI2)	Trigger—This pin, which is connected directly to the TRIG input on screw terminal connector J10, is a trigger input to the MIO-16E PFI2 line. A low-to-high transition on PFI2 alerts the MIO-16E to place the SC-2040 into hold mode and start acquiring data.

(continues)

Table 3-3. Output Connectors (J11 and J12) Signal Summary (Continued)

J11 Pin (50-pin)	**J12 Pin (68-pin)**	**Signal Name**	**Description**
46	38	TRACK*/HOLD (PFI7/STARTSCAN)	Track-or-hold—This pin, used as an output from the MIO-16E, controls whether the SC-2040 is in hold mode or track mode. A high level output from the DAQ board places the SC-2040 into hold mode, while a low level returns the SC-2040 into track mode. *With an MIO-16E attached, pin 46 on J11 should be used for monitoring purposes only.*
others	others	compatibility	The remaining pins provide 50 pin compatibility with the 68 pin MIO-16E. They can be monitored from connector J11. Refer to Figure 3-1 for pin locations and to Chapter 3, *Signal Connections*, in your MIO-16E manual for pin descriptions.

The signals from the SC-2040 screw terminal connectors are connected to the MIO-16E via J12 as shown in Figure 3-2. Observe that the PFI7/STARTSCAN signal returns from the MIO-16E as a level-sensitive track-and-hold signal to the SC-2040. Notice also that AISENSE is disconnected.

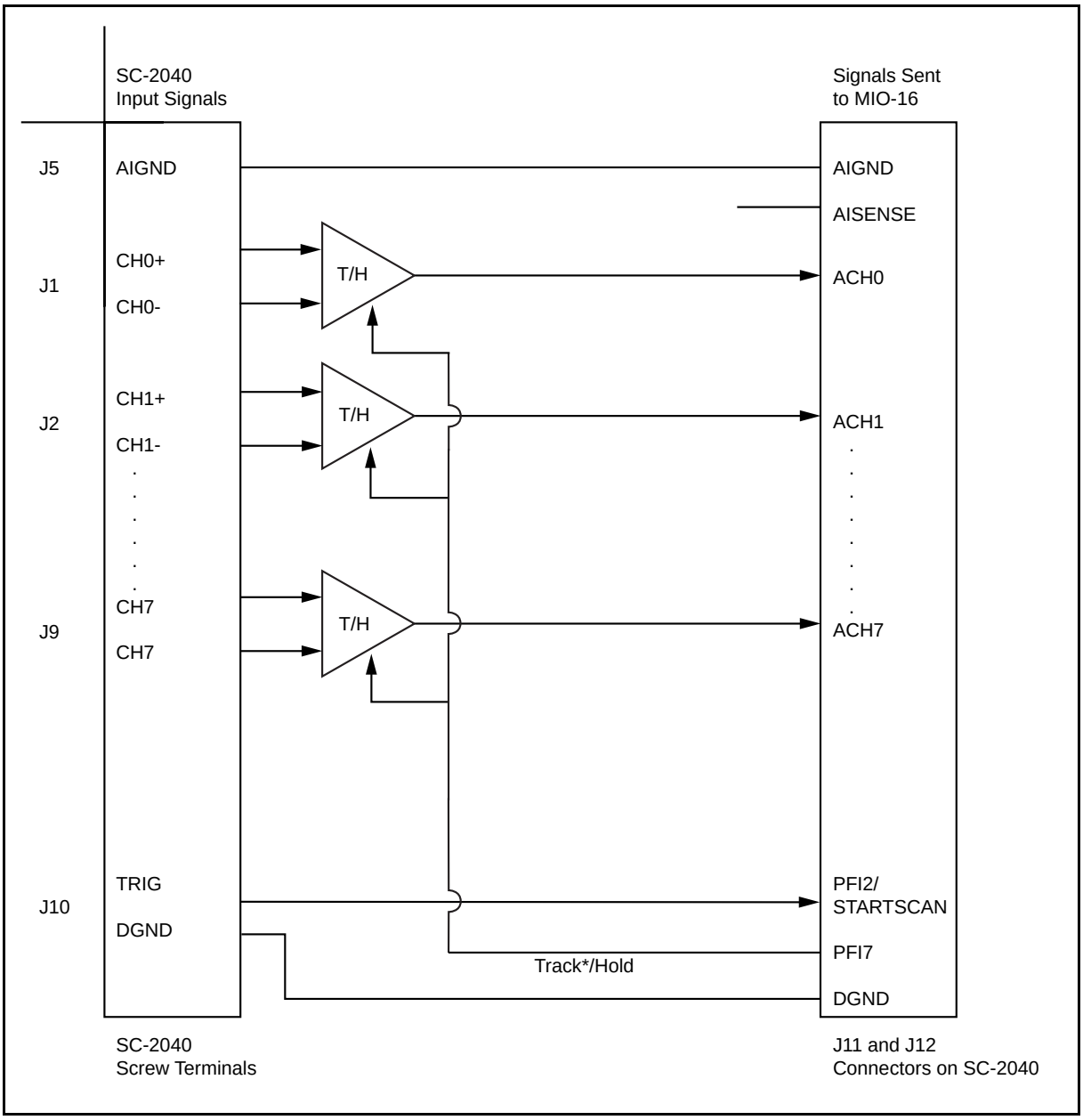


Figure 3-2. SC-2040 Signal Routing

Analog Signal Inputs

Connect the differential signals to be measured to the screw terminal connectors J1 through J4 and J5 through J9.

DC-Coupled Inputs

Note: ***If all your inputs are DC-coupled, leave connector J5 disconnected.***

All eight channels have fully differential inputs, so the signals you are measuring should be ground referenced. If they are not, set jumpers W2 through W9 of the nonreferenced channels to position B-C to create a DC path for the input bias currents. If you do not do this, the bias currents of the instrumentation amplifiers of the nonreferenced channels produce stray capacitances, resulting in uncontrollable drift and possible saturation.

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

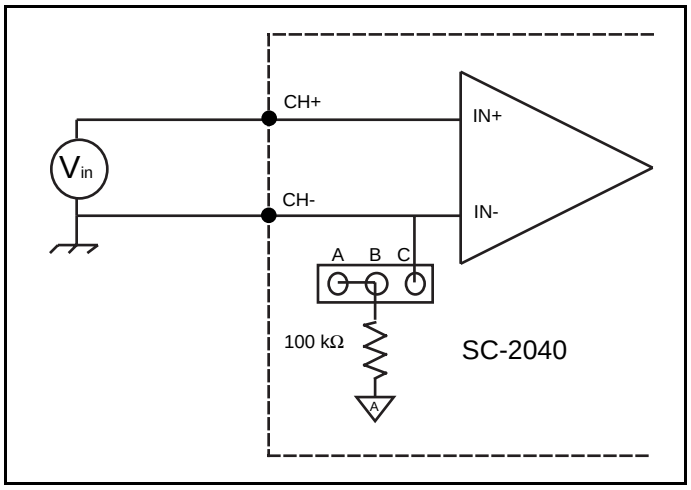


Figure 3-3. Ground-Referenced Signal Connection

Figure 3-4 illustrates how to connect a floating signal.

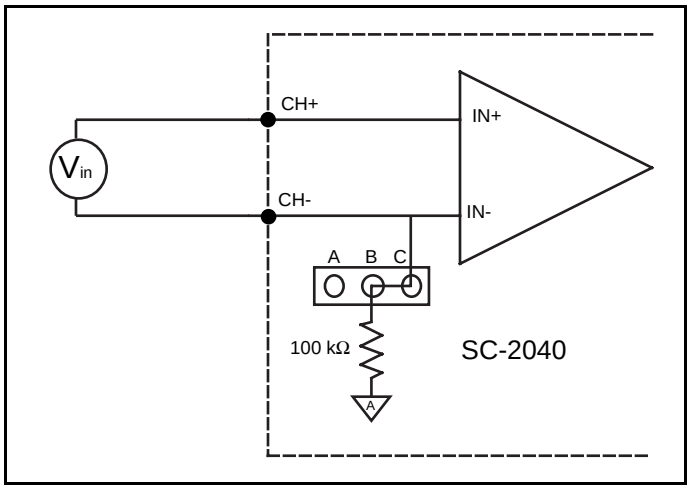


Figure 3-4. Floating Signal Connection

AC-Coupled Signals

Note: ***For AC-coupled signals, you must reference the analog ground of your instrumentation to the DAQ board. The SC-2040 connector J5 provides the analog reference, connecting directly to the MIO-16E board as shown in Figure 3-2.***

For AC-coupled signals, set jumpers W2 through W9 to position B-C with an external resistor from the positive input channel connected to its negative ground. Doing this creates the DC path for the positive input bias current. Typical resistor values range from 100 kΩ to 10 MΩ. This solution, although necessary in this case, lowers the input impedance of the channel and introduces an additional offset voltage proportional to the product of the input bias current and the resistor value used. The inputs of the SC-2040 have a typical bias current of about ±100 pA. When you use a 1 MΩ resistor, the result is ±100 µV of offset, which is insignificant in most applications. However, if you use larger valued bias resistors, significant input offset may result. Lower valued bias resistors will increase loading of the source, possibly resulting in gain error.

Figures 3-5 through 3-7 illustrate how to connect AC-coupled signals.

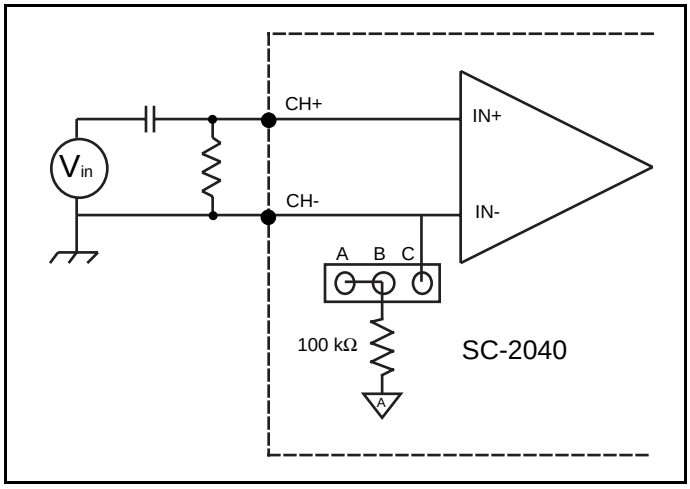


Figure 3-5. Ground-Referenced AC-Coupled Signal Connection

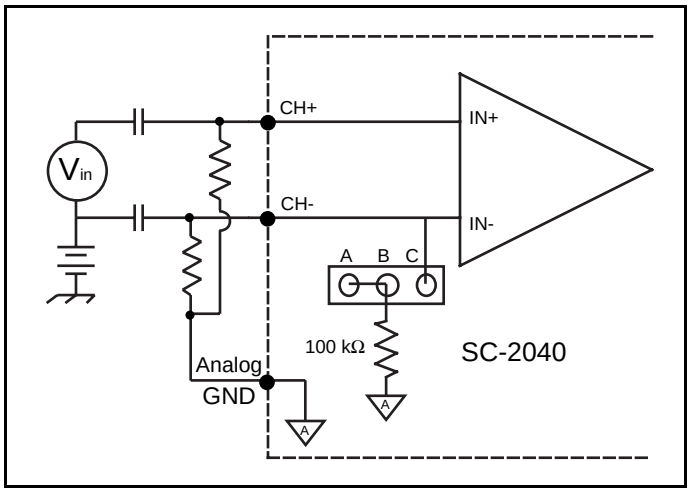


Figure 3-6. Ground-Offset AC-Coupled Signal Connection

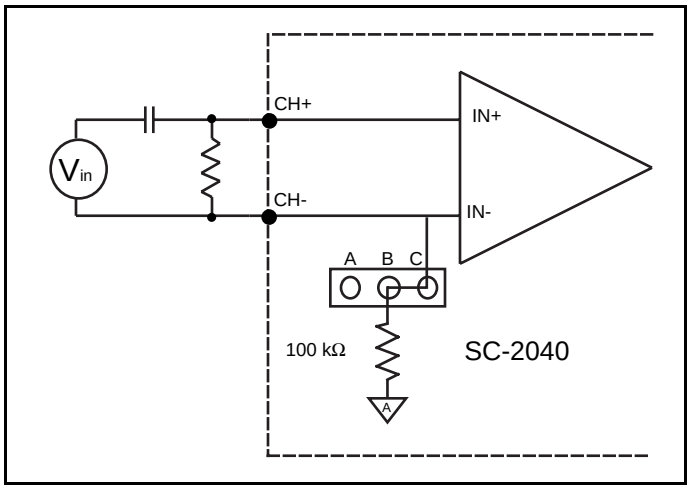


Figure 3-7. Floating AC-Coupled Signal Connection

Analog Input Ranges

Warning: ***Exceeding the differential and common-mode input ranges results in distorted input signals. Exceeding the maximum input voltage rating can result in damage to the SC-2040 board, and the DAQ board. National Instruments is NOT liable for any damages resulting from such signal connections.***

The SC-2040 instrumentation amplifiers can reject any voltage within their common-mode input range caused by ground-potential differences between the signal source and the board. In addition, the amplifiers can reject common-mode noise pickup in the leads connecting the signal sources to the SC-2040 board. However, you should be careful 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 common-mode input range of the SC-2040 instrumentation amplifiers is defined as the magnitude of the greatest common-mode signal that can be rejected. Thus the common-mode input range for the SC-2040 depends on the gain and size of the differential input signal:

$(V_{diff} = V^{+}_{in} - V^{-}_{in})$.

The exact formula for the permissible common-mode input range is as follows:

$$V_{cm\text{-}allowed} = \pm (12\ V - \frac{G\,|V_{diff}|}{2}).$$

Thus, with a differential voltage of 10 V and a gain of $G = 1$, the maximum possible common-mode voltage would be ±7 V. The same range would apply for a differential input of 100 mV and a gain of 100. The range increases to ±12 V for zero differential input voltage. The actual common-mode voltage available at the input is measured with respect to the SC-2040 ground, and can be calculated by the following formula:

$$V_{cm\text{-}actual} = \frac{\left(V^{+}_{in} - V^{-}_{in}\right)}{2}.$$

where V^{+}_{in} is the signal at the positive input (IN0+ through IN7+), and V^{-}_{in} is the signal at the corresponding negative input (IN0- through IN7-). Both V^{+}_{in} and V^{-}_{in} are measured with respect to the SC-2040 chassis ground.

Digital Signal Inputs

If you are using an external trigger, connect the trigger source and the digital reference to screw connector J9. This signal should be in the range 0 to +5 V, with switching occurring around 1.5 V.

Note: ***All digital signals on the SC-2040 are referenced to the +5 V power supply. If the MIO-16E supplies power, it provides this reference. If an external supply provides power, it provides this reference through connector J13.***

A rising edge on the trigger will place the SC-2040 into hold mode, and the SC-2040 will return to track mode when the MIO-16E indicates that the data acquisition is complete.

Although the TRIG signal is a digital signal, it is still susceptible to noise, particularly at its transitions. This noise can cause the SC-2040 to enter hold mode on the wrong edge. Two possible sources of noise are interference and reflection. The best way to reduce noise corruption is to minimize the distance that the signal must travel. Furthermore, you can minimize interference by properly shielding the incoming trigger signal. You can minimize reflection by ensuring that the impedance of the source of the trigger signal matches the impedance of the cable used to transmit the signal; inserting a small resistor (about 50 Ω) in series with the signal source will minimize reflection.

Monitoring Signal Outputs

You can use connector J11 to monitor the signals being sent to and from the MIO-16E board. Figure 4-3 shows a sampled analog signal as the SC-2040 channel output.

You can also monitor the state of the SC-2040 through line PFI7/STARTSCAN. A high level on PFI7/STARTSCAN indicates the SC-2040 is in hold mode, while a low level indicates that the SC-2040 is in track mode.

Other Connection Considerations

Refer to the sections titled *Analog Input Signal Connections* and *Cabling and Field Wiring* in Chapter 3 of your MIO-16E board user manual for additional signal connection information.

Chapter 4
Theory of Operation

This chapter contains a functional overview of the SC-2040 board and explains the operation of each functional unit making up the SC-2040.

Functional Overview

The SC-2040 consists of eight channels, each one comprising an instrumentation amplifier with DIP switch-programmable gains of 1, 10, 100, 200, 300, 500, 600, 700, or 800, and a track-and-hold amplifier. The analog inputs are overvoltage protected. The DAQ board or a user-supplied external trigger switches the SC-2040 between hold mode and track mode as desired. All eight channels are simultaneously placed in hold mode.

The block diagram in Figure 4-1 illustrates the key functional components of the SC-2040.

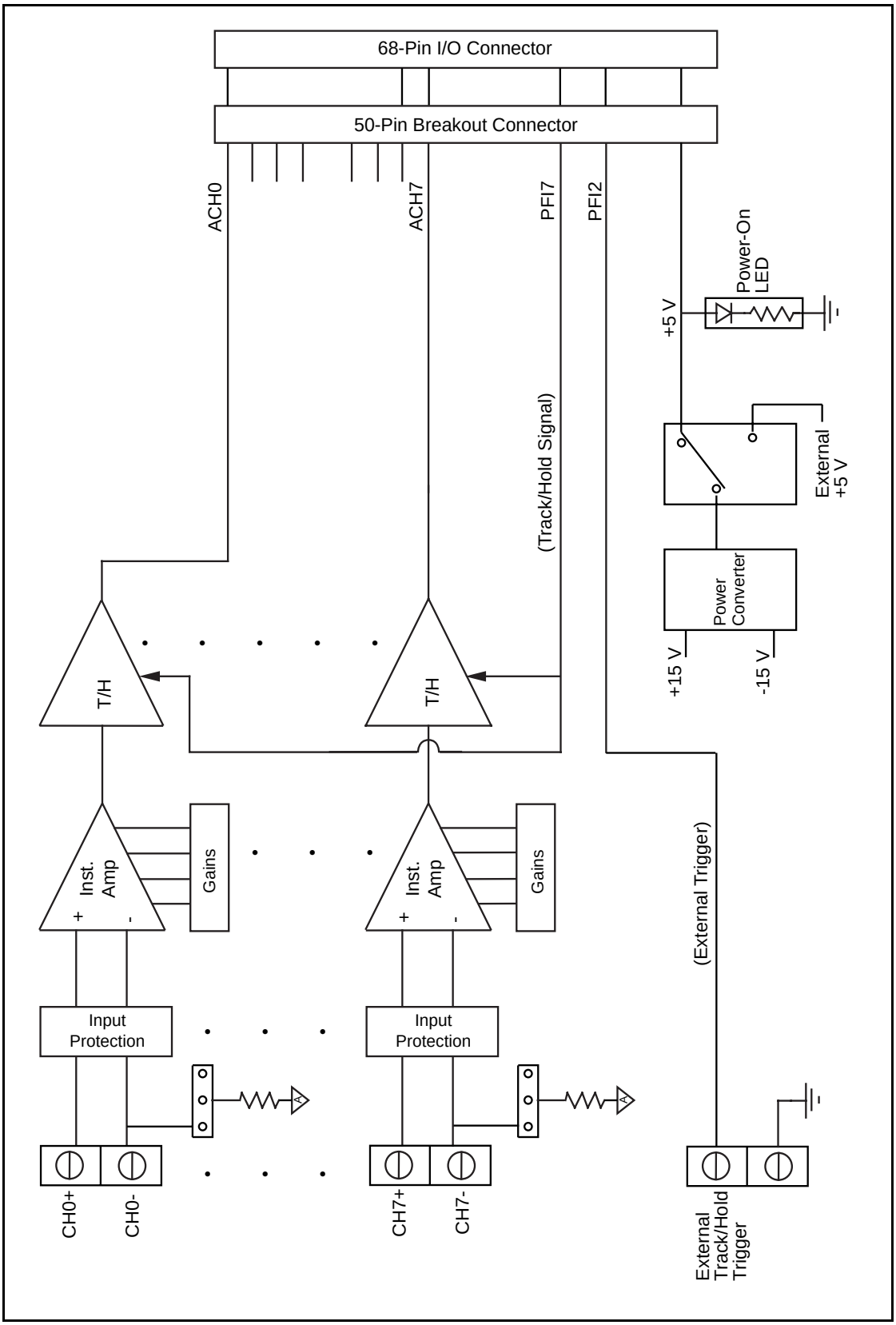


Figure 4-1. SC-2040 Block Diagram

Analog Circuitry

The analog input circuitry consists of eight channels with DIP-switch-programmable instrumentation amplifiers followed by buffered track-and-hold amplifiers. In addition, you can include the voltage-regulation circuitry and input protection in the analog section. Each block is described in the following paragraphs.

Input Protection

The first block an incoming analog signal encounters is the input protection. Each input terminal is protected against input voltages up to ±15 V powered off and ±30 V powered on. The input protection consists of a 1 kΩ resistor in series with each input line followed by low-leakage diodes to the supply rails (±15 V).

Amplification

Next in the signal path are the instrumentation amplifiers, which fulfill two purposes on the SC-2040 board. First, the instrumentation amplifiers convert differential input signals into single-ended signals referred to the SC-2040 analog ground for input common-mode signal rejection. With this conversion, the SC-2040 can extract the analog input signals from common-mode noise voltages before the DAQ board samples and converts the signals. Second, the instrumentation amplifiers amplify input signals, resulting in an increase in measurement resolution and accuracy. Furthermore, the amplifiers exhibit low bias currents and good bandwidth, even at high gains.

You can select gains for each channel independently with separate DIP switches. Gains are 1, 10, 100, 200, and 500, although gains of 300, 600, 700, and 800 are available with reduced accuracy. See Appendix A, *Specifications,* for details on the performance of the instrumentation amplifiers.

Track-and-Hold (T/H) Circuitry

The track-and-hold amplifiers operate as simple buffers when in track mode, but freeze their outputs when placed into hold mode. Because all of the track-and-hold amplifiers in each SC-2040 board enter hold mode at the same time, they implement simultaneous sampling of all channels. Simultaneous sampling is useful for preserving phase relationships between channels.

The track-and-hold amplifiers are subject to various imperfections, which are listed in Appendix A, *Specifications*. The most relevant of these performance specifications are the track-mode acquisition time and the hold-mode settling time, as these parameters affect how the DAQ board acquires the data, most noticeably through the sampling rate.

The hold-mode settling time refers to how long it takes the T/H amplifiers to settle a stable value. Thus, the hold-mode settling time affects how long the DAQ board must wait *before* attempting to acquire data. The track-mode acquisition time refers to how long it takes the T/H amplifiers to

find the inputs again after having been in hold mode. Therefore, this delay indicates how long the SC-2040 must remain in track mode before it is ready to re-enter hold mode. Returning the SC-2040 to hold mode before the track-mode acquisition delay has elapsed will cause the SC-2040 to "hold" erroneously. Figure 4-2 illustrates these timing concerns. Typical hold mode settling times and track acquisition times for 12-bit and 16-bit accuracies are given in Appendix A, *Specifications*.

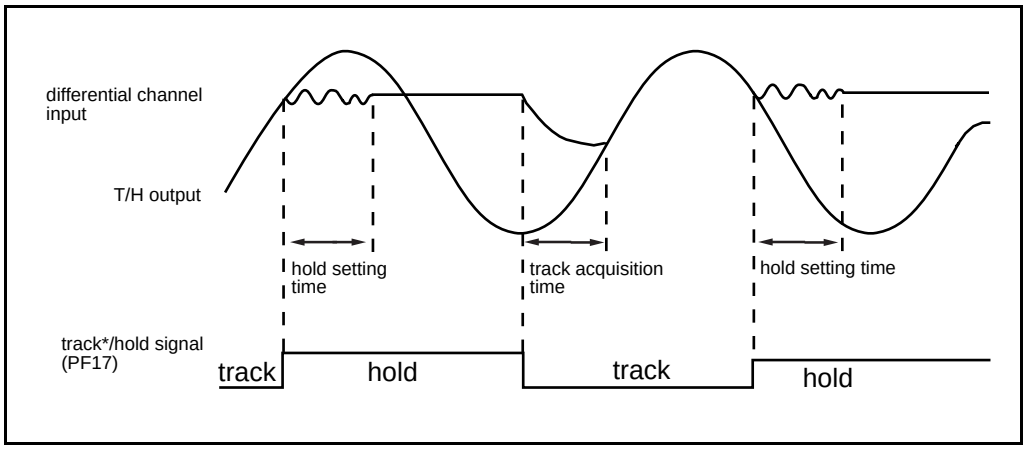


Figure 4-2. T/H Amplifier Hold Settling Time and Track Acquisition Time

Triggering from the DAQ Board

This section applies to you only if you are triggering the SC-2040 from the MIO-16E board.

Note: ***No signal should be connected to connector J10 for MIO-16E triggering.***

You can place the SC-2040 into hold mode on command using the MIO-16E DAQ board. You must either program the MIO-16E board for this purpose or use the NI-DAQ software included with your MIO board. After placing the SC-2040 into hold mode, the MIO-16E board performs data acquisition and conversion. Once this process is complete, the MIO-16E board releases the SC-2040 into track mode.

The MIO-16E board uses line PFI7/STARTSCAN to indicate to the SC-2040 whether it should track the input signals or hold them at a constant level. A logic zero (low level) on PFI7/STARTSCAN indicates track mode, while a logic one (high level) indicates hold mode, as indicated in Figure 4-3.

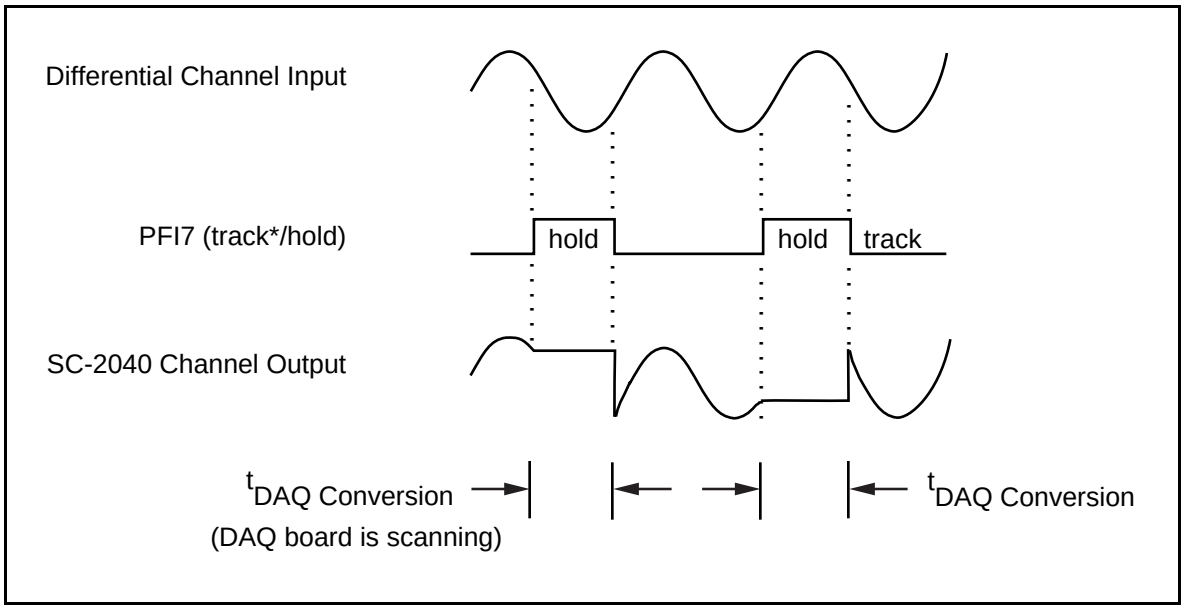


Figure 4-3. MIO-16E Controlled Triggering

External Triggering

This section applies to you only if you are triggering the board from an external signal connected to J10.

You can connect an external trigger to place the SC-2040 into hold mode on command. A rising edge on the external trigger signal places the SC-2040 into hold mode and alerts the MIO-16E board to start scanning the SC-2040 outputs. After the MIO-16E board has acquired data from all of the channels, it returns the SC-2040 to track mode. The external trigger signal is a digital input and must conform to digital logic levels.

Because the SC-2040 track-and-hold circuitry must re-acquire the input signals at the conclusion of each hold mode operation, the external trigger source should not return the SC-2040 to hold mode until after the SC-2040 has had time to re-acquire the signals. The acquisition times for the SC-2040 at various accuracies are given in Appendix A, *Specifications*.

The external trigger is connected directly to signal PFI2 on the DAQ board. A rising edge alerts the DAQ board to place the SC-2040 into hold mode. The DAQ board then begins scanning the channels. After the scanning process is complete, the board returns the SC-2040 to track mode using PFI7/STARTSCAN. Notice that additional rising edges from the external trigger are ignored while the MIO-16E is scanning. Figure 4-4 illustrates the external triggering process.

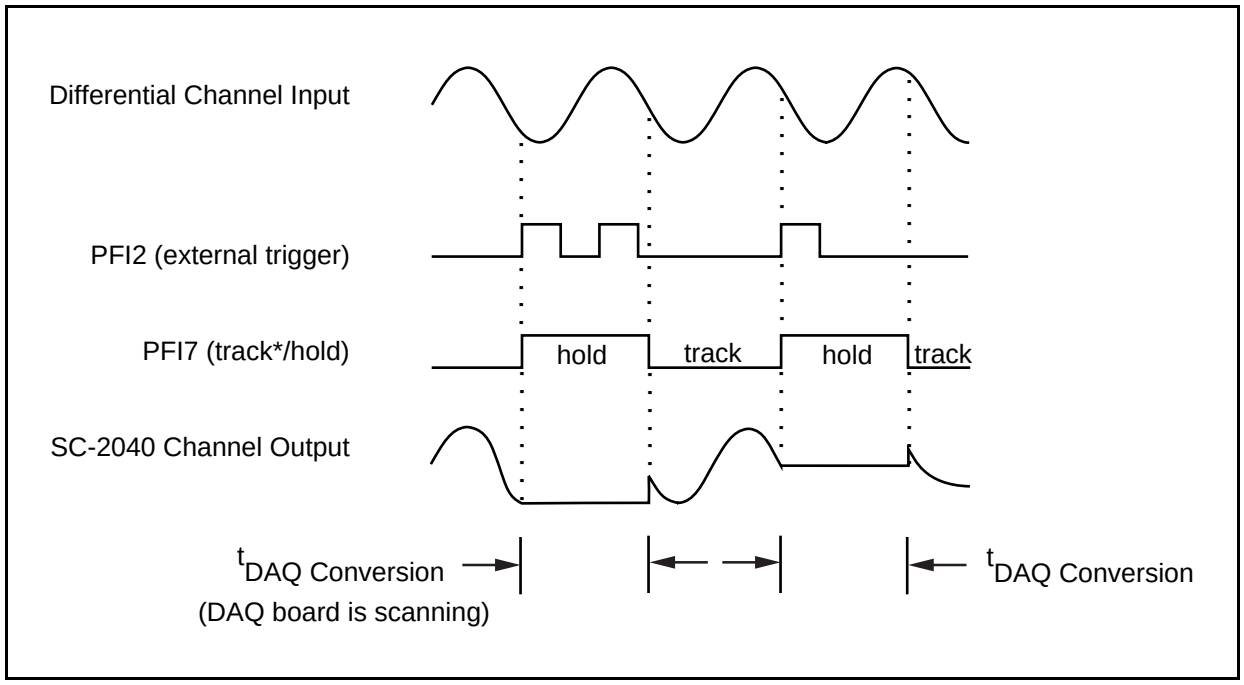


Figure 4-4. External Triggering

Output Connection

The output of every channel is connected to the 68-pin rear signal connector and the 50-pin supplemental I/O connector. The 68-pin connector carries signals to and from the DAQ board, and also provides +5 V power if selected by the power switch. The corresponding pins of the 50-pin connector are tied to those of the 68-pin connector so that you can monitor these signals on the 50-pin connector. The pin connections of these connectors are given in Chapter 3, *Signal Connections.*

Power Supply

The SC-2040 contains an onboard power switch to either power the SC-2040 from the MIO-16E board or to draw power from an external +5 V supply. From the +5 V power, an onboard DC-to-DC converter generates a ±15 V source, which is used to power the analog circuitry. A red LED indicates that the board is receiving power.

Chapter 5
Calibration Procedures

This chapter discusses the calibration procedures for the SC-2040 board.

Note: ***In many applications, the SC-2040 factory-hardware calibration is sufficient to meet accuracy requirements, and no further calibration, either hardware or software, is needed.***

Although hardware calibration is discussed in greater detail than software calibration, software calibration is the preferred choice for the following reasons:

- The calibration adjustments on the SC-2040 are inaccessible under most normal operating circumstances.
- With software calibration, the board is calibrated in the exact environment in which it will be operating. Software calibration compensates for system-introduced, in addition to board-introduced, errors. You can perform software calibration fairly frequently, which helps reduce drift effects.

Because board-introduced errors are minimal with the SC-2040, the use of software rather than hardware calibration does not significantly reduce dynamic range. The main drawback of software calibration is reduced throughput due to the increased processing time.

Software Calibration

Software calibration is very simple. Depending on your accuracy requirements, you may want to perform only offset adjustment; offset and gain adjustments; or offset, gain, and linearity adjustments.

Offset Adjustment

Offset adjustment requires you to apply an input signal of zero to the channel to be calibrated. *Zero input* can mean shorting the board inputs to zero, or it can mean applying zero excitation to the transducer being used. In the former case, you can remove only board and DAQ board offset; in the latter case, transducer offset is removed as well. In either case, measurements are taken with the zero input signal. Average these measurements to reduce uncertainty. This average represents the offset. Next, subtract the offset from all subsequent measurements. Notice that offset changes with gain; thus, during calibration, set the channel to the gain at which the subsequent measurements will be taken.

Gain Adjustment

Gain adjustment requires you to apply two different input signals. One of the two points is typically zero, because zero is easy to generate with a high degree of accuracy. The other should be near full scale, either a DC-voltage from a precision calibrator or a voltage generated by applying a known excitation to the transducer being used. Of course, you should generate both signals—zero and full scale—from the same source.

Take measurements on both signals and compute separate averages. Then combine the averages with the known input signals to generate linear correction factors for all subsequent measurements. Specifically, if the input *X* yields measurement *x*, and the input *Y* yields measurement *y*, then you should process measurement *z* as shown in the following equation to yield the corrected measurement *Z*:

$$Z = X + \frac{(Y - X)(z - x)}{(y - x)}.$$

Linearity Adjustment

The SC-2040 seldom needs linearity adjustment because its linearity is quite good, especially at low gains. Linearity error is often caused by the nonlinearity of the DAQ board you use. If necessary, the method described previously for correcting gain and offset error may be extended to include linearity by taking more points along the transfer function and processing the subsequently acquired data according to a polynomial fit of the calibration points.

Alternatively, and preferably for DAQ boards with no more than 12 bits of resolution, you can determine the nonlinearity of the system on a code-by-code basis, and you can subtract the error of each code from any measurement that returns that value. This method has the advantage of correcting differential as well as integral linearity errors. However, this method may be time-consuming. If time permits, you may determine the nonlinearity of your system on a code-by-code basis with even higher resolution DAQ boards. Describing methods of measuring system nonlinearity is beyond the scope of this manual. If linearity correction becomes necessary, refer to your DAQ board user manual.

Hardware Calibration

There are two potentiometers (pots) to adjust for each channel. These are set at the factory and should not need to be readjusted for most applications. The pots adjust input offset voltage and output offset voltage for each of the eight channels. Gain error and linearity are not adjustable. For detailed specifications of offset, gain, and linearity error, see Appendix A, *Specifications*.

Input offset is any error voltage that appears to be added to the input signal; that is, its effect is multiplied by the gain of the instrumentation amplifier. Output offset is any error voltage that appears to be added to the output signal; that is, its effect is independent of the gain of the instrumentation amplifier. At a fixed gain, these errors are indistinguishable; thus, it is necessary to switch between gains to properly calibrate the SC-2040.

Your accuracy needs determine how carefully the offsets need to be calibrated. A typical requirement might be for total offset referred to output to be less than half of an LSB of the DAQ board being used. For example, a 12-bit, 20 V system has a resolution of $20\ V/2^{12} = 4.88$ mV. Calibration to under 2 mV would thus be sufficient for most applications. The SC-2040 is factory calibrated to have total offset referred to output of less than 2 mV at low gains.

Table 5-1 shows which pots to adjust for each type of offset for each channel and which DIP switch selects the gain for each channel. Refer to the parts locator diagram in Chapter 2, *Configuration and Installation*, to determine the location of each component.

Table 5-1. Calibration Component Identification

Channel	Output Offset Adjust	Input Offset Adjust	Gain DIP Switch
0	R1	R4	U2
1	R7	R11	U6
2	R13	R16	U9
3	R18	R22	U14
4	R25	R29	U17
5	R32	R35	U21
6	R37	R41	U24
7	R45	R48	U28

A complicating factor in the calibration of the board is that the output offset is not the same in track mode as in hold mode. This difference is because of a phenomenon known as *hold step*, in which a small amount of charge is transferred to the track-and-hold amplifier hold capacitor during the transition from track mode to hold mode. This charge transfer slightly changes the voltage at the output of the track-and-hold amplifier.

The magnitude of the *hold step* on the SC-2040 is approximately 5 mV, enough to make it necessary to calibrate output offset in hold mode rather than track mode. You may calibrate input offset without switching the board to hold mode.

To calibrate the SC-2040 board, the following steps are required:

1. If you are using a rack-mount kit, remove the cover to expose the DIO switches and jumpers. Connect the board so that the pots and DIP switches are readily accessible.

2. Short each input of the board to ground.

   At low gains, more alternatives exist to serve as a short circuit, but at a gain of 500, 1 mV referred to the output is only 2 μV referred to the input. Thermoelectric effects make it difficult to keep a short circuit from generating such voltages. The best solution is to use short lengths of heavy copper wire, and to keep the short away from heat sources.

3. Program the DAQ board to take data in the differential input mode.

   The SC-2040 should switch between track mode and hold mode, with the DAQ board sampling occurring while the board is in hold mode.

4. Set the DAQ board to a high gain and measure its offset by shorting its input.

   You must subtract this measured offset from all subsequent board measurements to ensure accuracy.

   For the offset of the DAQ board not to affect the calibration, you must subtract the offset from all board offset measurements. Thus, you must first measure the offset to an accuracy better than that to which the board is to be calibrated. Furthermore, setting the DAQ board to a high gain (100, for example) makes it possible to resolve offset changes that would be indiscernible at lower gains. Because the DAQ board offset will not be independent of gain, you should set the gain first, and then measure the offset. To measure the offset, disconnect the board from the DAQ board, short circuit the board inputs to ground, and take some data. The measured value is the offset. For a reliable value, use software to average a few hundred readings. After you have measured and recorded the offset, remove the short circuits and reconnect the board.

5. Measure the output of the first channel with its gain set to one and adjust its output offset pot until the output is close to zero.

   At this gain, most of the board offset is due to output offset. The input offset adjustment has minimal effect. Set the DAQ board to read the channel. Acquire the data, averaging as in step 4. Adjust the output offset pot until the difference between the measured offset and the DAQ board offset is close to zero. There is no need to adjust it perfectly because the input offset adjustment in the next step might make a slight change in the measured gain-of-one offset.

6. Measure the output of the same channel with its gain set to 500 and adjust its input offset pot until the output is close to zero.

   At this gain, the input offset adjustment has the dominant effect. Acquire the data and average as before. Adjust the input offset pot until the difference between the measured offset and the DAQ board offset is close to zero. Again, it is not necessary to adjust the input offset perfectly because there will be a slight interdependence between the two offsets.

7. Repeat step 5, adjusting the offset as carefully as desired. Then repeat step 6, adjusting the offset as carefully as desired. Switch back to a gain of one to ensure that the low-gain offset is still calibrated. If necessary, repeat steps 5 and 6 until the offset is calibrated at both gains.

8. Repeat steps 5 through 7 for the additional channels you want to calibrate. There is no calibration interdependence among the channels.

9. Replace the rack-mount chassis cover, if used.

Appendix A
Specifications

This appendix lists the specifications for the SC-2040. These are typical at 25° C unless otherwise stated. The operating temperature range is 0° to 50° C.

Analog Input

Input Characteristics

Number of channels: 8 differential

Input signal ranges

Board Gain (Hardware Selectable)	Board Range Max Output Range ±10 V
1	±10 V
10	±1 V
100	±100 mV
200	±50 mV
300	±33.3 mV
500	±20 mV
600	±16.67 mV
700	±14.29 mV
800	±12.5 mV

Input coupling: DC

Max working voltage (signal + common mode): Average of 2 inputs should remain within ±7 V of ground

Overvoltage protection: ±30 V powered on, ±15 V powered off

Inputs protected: ACH<0..7>

Transfer Characteristics

Offset error

Pregain error after calibration: ±100 µV max

Postgain error after calibration: ±2 mV max

Gain error and nonlinearity

Gain (DIP-switch-selectable)	Max Gain Error	Max Gain Tempco	Max Nonlinearity
1	±0.05%	±25 ppm/°C	±0.01%
10	±0.1%	±25 ppm/°C	±0.01%
100	±0.2%	±45 ppm/°C	±0.02%
200	±0.4%	±60 ppm/°C	±0.02%
300	-0.3%, ±0.6%	±80 ppm/°C	±0.03%
500	±1.0%	±100 ppm/°C	±0.04%
600	-0.2%, ±1.5%	±120 ppm/°C	±0.05%
700	-0.1%, ±2.0%	±150 ppm/°C	±0.06%
800	-0.3%, ±3.0%	±200 ppm/°C	±0.07%

Amplifier Characteristics

Input impedance
Normal powered on 100 GΩ in parallel with 20 pF
Input bias current ±100 pA, ±10 mA max
Input offset current ±10 pA

CMRR

Gain	dB (min and typ)
Gain = 1	70 dB min, 90 dB typ
Gain = 10	87 dB min, 104 dB typ
Gain ≥ 100	100 dB min, 110 dB typ

Output range ±10 V

Dynamic Characteristics

Bandwidth

Gain	-3 dB Bandwidth
1	2 MHz
10	800 kHz
100	500 kHz
200	300 kHz
300	180 kHz
500	120 kHz
600	100 kHz
700	80 kHz
800	70 kHz

System noise

Gain	Filter
1	175 µVrms
10	50 µVrms
100	45 µVrms
200	40 µVrms
300	35 µVrms
500	33 µVrms
600	30 µVrms
700	29 µVrms
800	27 µVrms

Noise spectral density
Input noise (gain = 1) 12 nV/√Hz
Output noise 85 nV/√Hz
Slew rate 8 V/µs

S/H Characteristics

Measurement	0.012%	0.003%	0.0015%	0.00076%
Track mode acquisition time	7 µs	10 µs	50 µs	1 ms
Hold mode settling time	1 µs	1 µs	1 µs	2 µs
Hold step	-5 mV	—	—	—
Droop rate	±10 mV/s	—	—	—
Aperture time	250 ns	—	—	—
Interchannel skew	±50 ns	—	—	—

Stability

Recommended warm-up time 15 min
Offset temperature coefficient ±(10 + 150/gain) µV/°C

Gain temperature coefficient

Gain (DIP-switch-selectable)	Max Gain Tempco
1	±25 ppm/°C
10	±25 ppm/°C
100	±45 ppm/°C
200	±60 ppm/°C
300	±80 ppm/°C
500	±100 ppm/°C
600	±120 ppm/°C
700	±150 ppm/°C
800	±200 ppm/°C

Power Requirement

+5 VDC (±10 %) 800 mA
Total power dissipation 4 W

Physical

Dimensions 1.8 by 7.9 by 4.9 in. (4.6 by 20.1 by 12.4 cm)
I/O connectors
Input 20-screw terminals
Output 50-pin male ribbon-cable rear connector
68-pin male ribbon-cable rear connector

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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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 _____

_____

_____

_____

SC-2040 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.

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Glossary

Prefix	Meaning	Value
p-	pico-	10^{-12}
n-	nano-	10^{-9}
µ-	micro-	10^{-6}
m-	milli-	10^{-3}
k-	kilo-	10^{3}
M-	mega-	10^{6}

°	degrees
Ω	ohms
A	amperes
ACH#	DAQ board analog input channel number
A/D	analog-to-digital
Arms	amperes, root mean square
AWG	American Wire Gauge
C	Celsius
CH#+	module positive input channel number
CH#-	module negative input channel number
CMOS	complementary metallic oxide semiconductor
cps	counts per second
D/A	digital-to-analog
DAQ	data acquisition
dB	decibels
DC	direct current
DIN	Deutsche Industrie Norme
DIP	dual inline package
FIFO	first-in-first-out
hex	hexadecimal
Hz	hertz
in.	inches
I_I	input current leakage
I_{in}	input current
I/O	input/output
I_{out}	output current
LED	light-emitting diode
LSB	least significant bit
m	meters
MB	megabytes
MSB	most significant bit
ppm	parts per million

RAM	random-access memory
rms	root mean square
s	seconds
SPI	serial peripheral interface
tempco	temperature coefficient
T/H	track-and-hold
UL	Underwriters Laboratory
V	volts
VI	virtual instrument
V_{IH}	volts input high
V_{IL}	volts input low
V_{in}	volts in
V_{OH}	volts output high
V_{OL}	volts output low
V_{out}	volts out
VAC	volts alternating current
VDC	volts direct current
Vrms	volts, root mean square

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