DAQ

SCB-68 User Manual for Advanced Functions

68-Pin Shielded Desktop Connector Block

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Worldwide Technical Support and Product Information

ni.com

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The following conventions are used in this manual:

<> — Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, AO <3..0>.

» — The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.

This icon denotes a note, which alerts you to important information.

This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash.

bold — Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names.

italic — Italic text denotes variables, emphasis, a cross-reference, or an introduction to a key concept. Italic text also denotes text that is a placeholder for a word or value that you must supply.

`monospace` — Text in this font denotes text or characters that you should enter 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, operations, variables, filenames, and extensions.

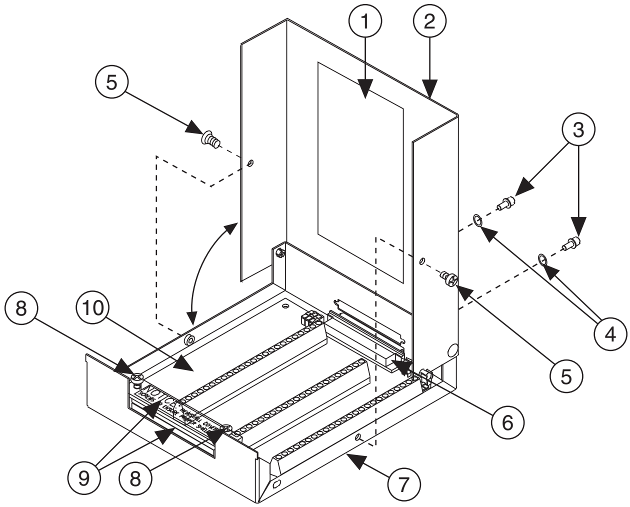
Platform — Text in this font denotes a specific platform and indicates that the text following it applies only to that platform.

Contents

1

Introduction

The SCB-68 is a shielded I/O connector block with 68 screw terminals for easy signal connection to a National Instruments 68-pin or 100-pin DAQ device. The SCB-68 features a general breadboard area for custom circuitry and sockets for interchanging electrical components. These sockets or component pads allow filtering, 4 to 20 mA current input measurement, open thermocouple detection, and voltage attenuation. The open component pads allow you to easily add signal conditioning to the analog input (AI), analog output (AO), and PFI 0 signals of a 68-pin or 100-pin DAQ device.



1	Quick Reference Label	5	Shielding Screws	8	Strain-Relief Screws
2	Top Cover	6	68-Pin I/O Connector	9	Strain-Relief Hardware
3	68-Pin Connector Screws	7	Base	10	SCB-68 Board Assembly
4	Lock Washers				

Figure 1-1. SCB-68 Parts Locator Diagram

This document contains information about advanced functions of the SCB-68. Refer to the following chapters for detailed information:

- Chapter 2, *Temperature Sensor and Thermocouple*, features information about using the temperature sensor, taking thermocouple measurements, open thermocouple detection, and thermocouple input filtering.
- Chapter 3, *Soldering and Desoldering Components on the SCB-68*
- Chapter 4, *Adding Components for Special Functions*, features information about installing bias resistors, filtering, current input measurement, attenuating voltage, and adding power filters.
- Appendix A, *Specifications*

Related Documentation

For more information about using the SCB-68 with your DAQ device, refer to the following resources:

- Documentation for your DAQ device at `ni.com/manuals`
- *Measurement & Automation Explorer Help*
- *DAQ Getting Started Guide*
- NI KnowledgeBase at `ni.com/kb`
- NI Developer Zone at `ni.com/zone`
- *SCB-68 User Guide*, included in your SCB-68 kit and also available at `ni.com/manuals`, provides information about SCB-68 installation, the temperature sensor and signal conditioning switch configuration, analog input measurement connection, and accessory fuse and power.

2

Temperature Sensor and Thermocouple

This chapter covers the following temperature sensor and thermocouple-related topics:

- *Using the Temperature Sensor*
- *Taking Thermocouple Measurements*
- *Temperature Sensor Output and Accuracy*
- *Thermocouple Sources of Error*
- *Open Thermocouple Detection*
- *Thermocouple Input Filtering*

Using the Temperature Sensor

To accommodate thermocouples with DAQ devices, the SCB-68 has a temperature sensor for cold-junction compensation (CJC), shown in Figure 3-1, *SCB-68 Printed Circuit Board Diagram*. To power the temperature sensor, set switches S1, S2, and S3 for single-ended or differential mode as described in the *Using the SCB-68 with MIO DAQ Devices* section of the *SCB-68 User Guide*. This configuration also powers the signal conditioning area and circuitry. Refer to Figure 4-1, *Analog Input and Cold-Junction Compensation Circuitry*, for a diagram of the CJC circuitry on the SCB-68.

Taking Thermocouple Measurements

You can measure thermocouples in differential or single-ended configuration:

- Differential configuration has better noise immunity. Use bias resistors when the DAQ device is in differential input mode, as described in the *Installing Bias Resistors* section of Chapter 4, *Adding Components for Special Functions*.

- Single-ended configuration has twice as many inputs. For single-ended configuration, set your DAQ device for referenced single-ended (RSE) input mode.

The maximum voltage level thermocouples generate is typically only a few millivolts. You should use a DAQ device with high gain for best resolution. For more information about thermocouple measurements, refer to the NI Developer Zone tutorial, *Taking Thermocouple Temperature Measurements*. To access this document, go to `ni.com/info` and enter the info code `rdtttm`.

The DAQ device must have a ground reference because thermocouples are floating signal sources. For more information about floating signal sources, refer to the *Connecting Analog Input Signals* section of Chapter 4, *Adding Components for Special Functions*. For more information about field wiring, refer to the NI Developer Zone document, *Field Wiring and Noise Considerations for Analog Signals*. To access this document, go to `ni.com/info` and enter the info code `rdfwn3`.

CJC with the SCB-68 is accurate only if the temperature sensor reading is close to the actual temperature of the screw terminals. Therefore, when reading thermocouples, keep the SCB-68 away from drafts or other temperature gradients, such as those caused by heaters, radiators, fans, and warm equipment.

Temperature Sensor Output and Accuracy

The SCB-68 temperature sensor outputs 10 mV/°C and has an accuracy of ±1 °C.

You also can determine the temperature using the following formulas:

$$T_C = 100 \times V_t$$

$$T_K = T_C + 273.15$$

$$T_F = \left[\frac{9}{5} \times T_C\right] + 32$$

where V_t is the temperature sensor output voltage;

and T_C, T_K, and T_F are the temperature readings in degrees Celsius, Kelvin, and Fahrenheit, respectively.

Thermocouple Sources of Error

When taking thermocouple measurements with the SCB-68, the possible sources of error are as follows:

- **Compensation error**—Can arise from two sources—inaccuracy of the temperature sensor and temperature differences between the temperature sensor and the screw terminals. The temperature sensor on the SCB-68 is specified to be accurate to ±1 °C. You can minimize temperature differences between the temperature sensor and the screw terminals by keeping the SCB-68 away from drafts, heaters, and warm equipment.
- **Linearization error**—A consequence of the polynomials being approximations of the true thermocouple output. The linearization error depends upon the degree of polynomial used.
- **Measurement error**—The result of inaccuracies in the DAQ device. These inaccuracies include gain, offset, and noise. Accuracy can be calculated from the DAQ device specifications. For best results, you must use a well-calibrated DAQ device. NI recommends that you run self-calibration on your DAQ device frequently to reduce error.
- **Thermocouple wire error**—The result of inconsistencies in the thermocouple manufacturing process. These inconsistencies, or nonhomogeneities, are the result of defects or impurities in the thermocouple wire. The errors vary depending on the thermocouple type and the gauge of wire used, but an error of ±2 °C is typical. For more information about thermocouple wire errors and more specific data, consult the thermocouple manufacturer.
- **Noise error**—Error due to inherent system noise. Use the average of a large number of samples to obtain the most accurate reading. Noisy environments require averaging more samples for greater accuracy.

$$\frac{\textit{white noise}}{\sqrt{\textit{number of samples}}} = \textit{resulting noise}$$

  For best results, use the average of at least 100 readings to reduce the effects of noise; typical absolute accuracies should then be about ±2 °C.

Open Thermocouple Detection

You can build open thermocouple detection circuitry by connecting a high-value resistor between the positive input and +5 V. A resistor of a few MΩ or more is sufficient, but a high-value resistor allows you to detect an open or defective thermocouple.

Note Refer to Chapter 3, *Soldering and Desoldering Components on the SCB-68*, for more information about adding components and for soldering and desoldering instructions.

- **Differential analog input open thermocouple detection**—Use position A to connect a high-value resistor between the positive input and +5 V. Leave the 0 Ω resistors at positions F and G in place for each channel used. Refer to Table 4-1, *Analog Input Channels Component Locations*, for component positions for all analog input channels.

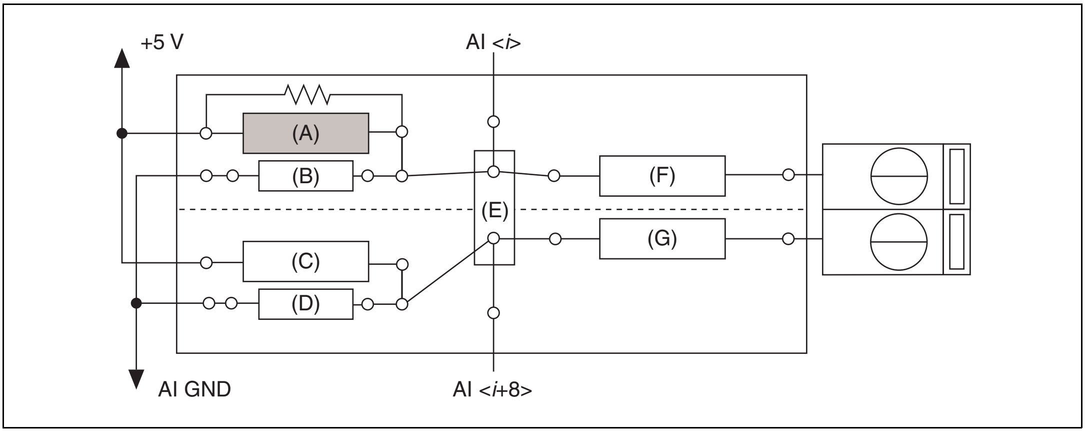


Figure 2-1. Differential Analog Input Open Thermocouple Detection

- **Single-ended analog input open thermocouple detection**—Use position A for one channel and C for the next channel when you connect a high-value resistor between the positive input and +5 V. Leave the 0 Ω resistors at positions F and G in place for each channel used. Refer to Table 4-1, *Analog Input Channels Component Locations*, for component positions for all analog input channels.

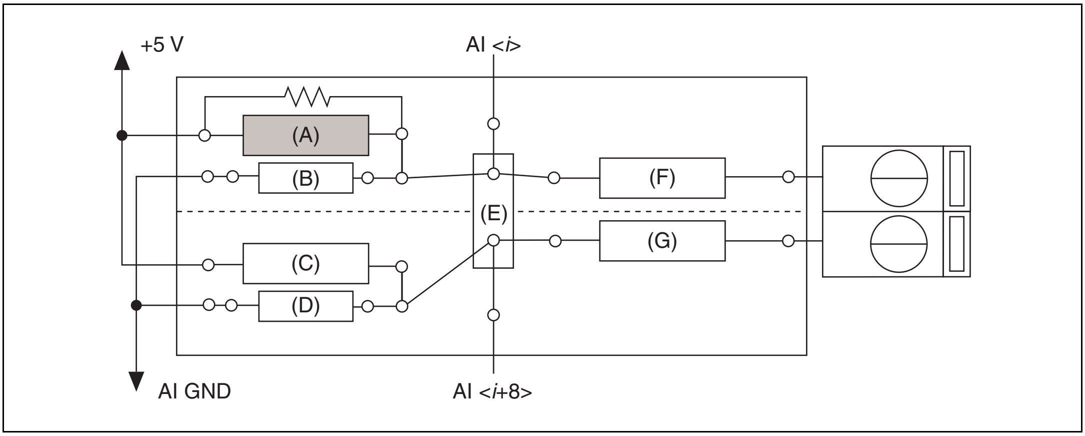


Figure 2-2. Single-Ended Analog Input Open Thermocouple Detection on AI <*i*>

If the thermocouple opens, the voltage measured across the input terminals rises to +5 V, a value much larger than any legitimate thermocouple voltage. You can create a bias current return path by using a 100 kΩ resistor between the negative input and AI GND.

Thermocouple Input Filtering

To reduce noise, you can connect a simple one-pole RC lowpass filter to the analog inputs of the SCB-68. Refer to the *Lowpass Filtering* section of Chapter 4, *Adding Components for Special Functions*, for more information.

3

Soldering and Desoldering Components on the SCB-68

Some applications require you to make modifications to the SCB-68, usually in the form of adding components to the printed circuit device.

Note Some versions of the SCB-68 have 0 Ω resistors hardwired in the factory-default positions. In such cases, to move these resistors to and from the factory-default positions, you must solder and desolder on the SCB-68 circuit card assembly.

Soldering Equipment

To solder components on the SCB-68, you need the following:

- ❑ Phillips #1 and #2 screwdrivers
- ❑ 0.125 in. flathead screwdriver
- ❑ Soldering iron and solder
- ❑ Long nose pliers
- ❑ Components specific to your application

Removing the SCB-68 Board from the Base

Refer to Figure 1-1, *SCB-68 Parts Locator Diagram*, while completing the following steps to remove the SCB-68 from the base.

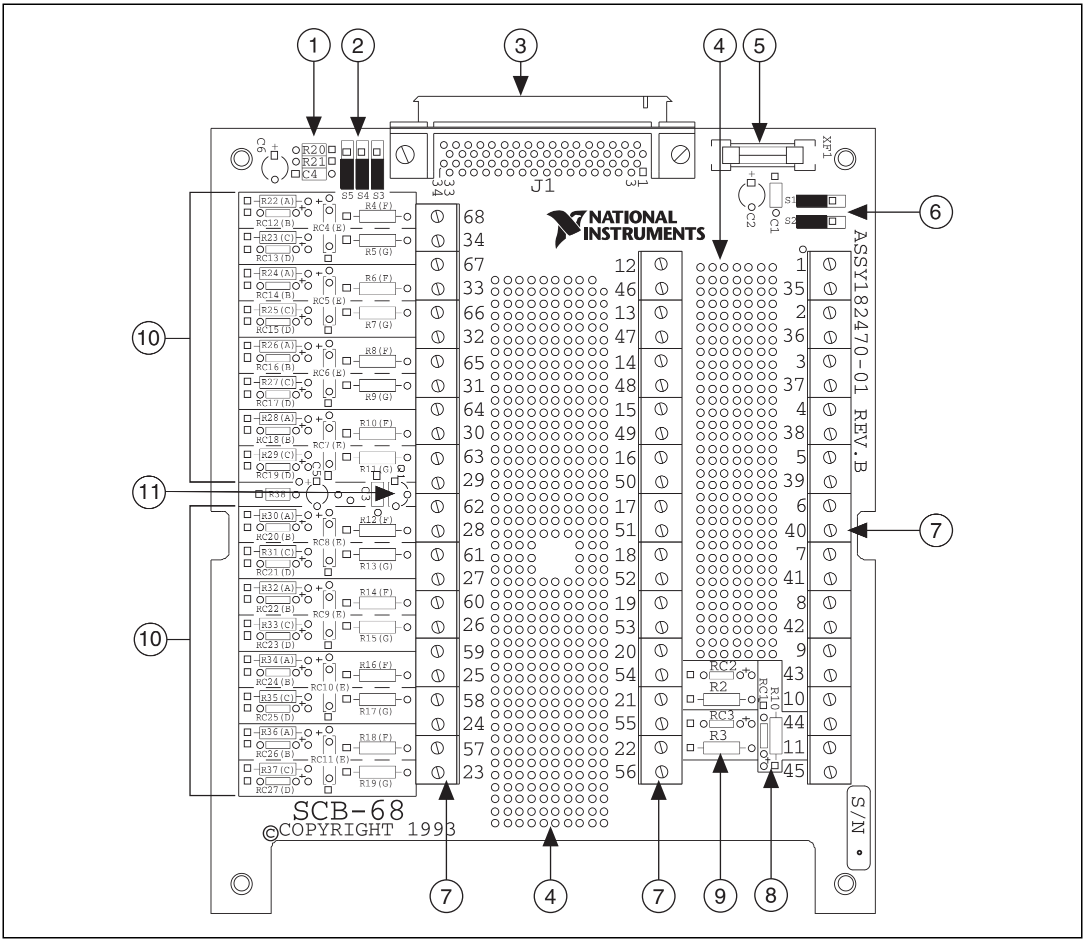
1. Disconnect the 68-pin cable from the SCB-68, if connected.
2. Remove the shielding screws on either side of the top cover with a Phillips #1 screwdriver, then open the box.
3. Loosen the strain-relief screws with a Phillips #2 screwdriver.
4. Remove the signal wires from screw terminals with a flathead screwdriver.
5. Remove the device-mount screws with a Phillips #1 screwdriver.

6. Remove the 68-pin connector screws with a flathead screwdriver.
7. Tilt the SCB-68 up and pull it out.

To reinstall the SCB-68, reverse the order of the steps.

Soldering and Desoldering Guidelines

As you solder and desolder components on the SCB-68, refer to Figure 3-1.



1	+5 V Power Pads R20 and R21	5	Fuse	9	Analog Output Pads
2	Switches S3, S4, and S5	6	Switches S1 and S2	10	Analog Input Pads
3	68-Pin I/O Connector	7	Screw Terminals	11	Temperature Sensor
4	Breadboard Area	8	PFI 0 Pads		

Figure 3-1. SCB-68 Printed Circuit Board Diagram

Note If the kit is missing any of the components in Figure 3-1, contact NI.

The SCB-68 ships with 0 Ω resistors in the F and G positions. You must remove the resistors to use the positions. Use a low-wattage soldering iron (20 to 30 W) when soldering to the SCB-68.

To desolder on the SCB-68, vacuum-type tools work best. Be careful to avoid damaging the component pads when desoldering. Use only rosin-core electronic-grade solder because acid-core solder damages the printed-circuit device and components.

4

Adding Components for Special Functions

This chapter describes how to condition signals by adding components to the open component locations of the SCB-68.

This chapter describes the following signal conditioning applications:

- *Installing Bias Resistors* (analog input)
- *Filtering* (analog input, analog output, and digital input)
- *Current Input Measurement* (analog input)
- *Attenuating Voltage* (analog input, analog output, and digital input)
- *Adding Power Filters*

Caution Add components at your own risk. NI is *not* liable for any damage resulting from improperly added components.

In addition to the applications described in this chapter, you can build many other types of signal conditioning using the component pads and the general-purpose breadboard area of the SCB-68. Refer to Chapter 3, *Soldering and Desoldering Components on the SCB-68*, for more information about adding components and for soldering and desoldering instructions.

After building one of the applications described in this chapter or your custom circuitry, refer to the *Getting Started with the SCB-68* section of the *SCB-68 User Guide* for instructions about how to configure the SCB-68 in Measurement & Automation Explorer (MAX). You can create virtual channels in MAX to create a custom scale or map your voltage ranges to the type of transducer that you use.

Channel Pad Configurations

When you use the SCB-68 with a 68-pin or 100-pin MIO DAQ device, you can use the component pads on the SCB-68 to condition 16 AI channels, two AO channels, and PFI 0.

Conditioning Analog Input Channels

Figure 4-1 shows the analog input and CJC circuitry on the SCB-68.

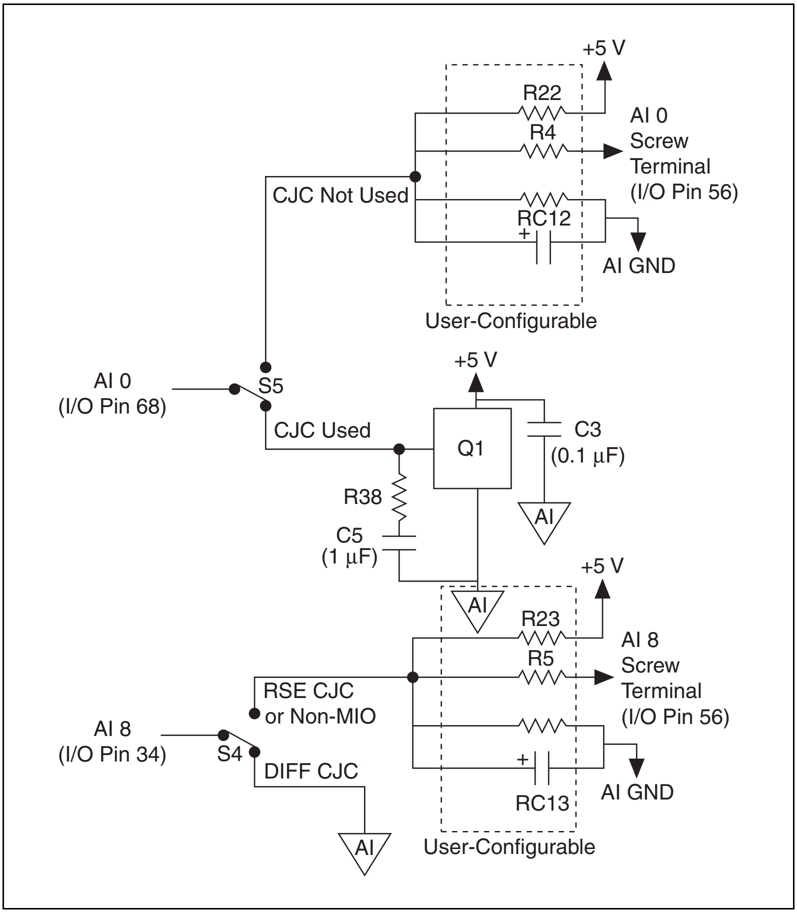


Figure 4-1. Analog Input and Cold-Junction Compensation Circuitry

Figure 4-2 illustrates the AI channel configuration. You can use AI <*i*> and AI <*i*+8> as either a differential channel pair or as two single-ended channels.

To use the SCB-68 with ground-referenced single-ended inputs, do *not* use the open positions that connect the input to AI GND, positions B and D, for grounded sources as shown in Figure 4-2. Build any signal conditioning circuitry requiring a ground reference in the custom breadboard area using AI SENSE as the ground reference instead of building the circuitry in the open component positions.

Note Some versions of the SCB-68 have 0 Ω resistors hardwired in the factory-default positions. In such cases, to move these resistors to and from the factory-default positions, you must solder and desolder on the SCB-68 circuit card assembly. When soldering, refer to Chapter 3, *Soldering and Desoldering Components on the SCB-68*.

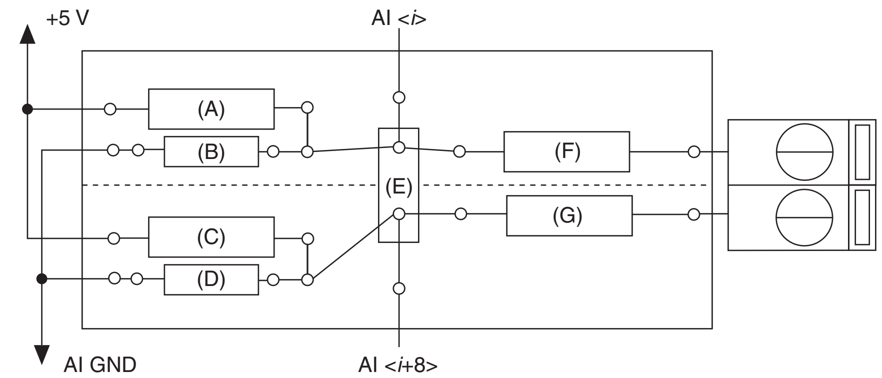


Figure 4-2. Analog Input Channel Pad Configuration for AI <*i*> and AI <*i*+8>

Table 4-1 correlates the component labels of the SCB-68 to component locations A through G for differential channels 0 through 7.

Table 4-1. Analog Input Channels Component Locations

Channel								
Single-Ended	**Differential**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
AI 0, AI 8	AI 0	R22	RC12	R23	RC13	RC4	R4	R5
AI 1, AI 9	AI 1	R24	RC14	R25	RC15	RC5	R6	R7
AI 2, AI 10	AI 2	R26	RC16	R27	RC17	RC6	R8	R9
AI 3, AI 11	AI 3	R28	RC18	R29	RC19	RC7	R10	R11
AI 4, AI 12	AI 4	R30	RC20	R31	RC21	RC8	R12	R13
AI 5, AI 13	AI 5	R32	RC22	R33	RC23	RC9	R14	R15
AI 6, AI 14	AI 6	R34	RC24	R35	RC25	RC10	R16	R17
AI 7, AI 15	AI 7	R36	RC26	R37	RC27	RC11	R18	R19

R denotes a socket for one component.
RC denotes sockets for two components to be connected in parallel.

Conditioning Analog Output Channels

Figure 4-3 shows the circuitry for both analog output channels on the SCB-68.

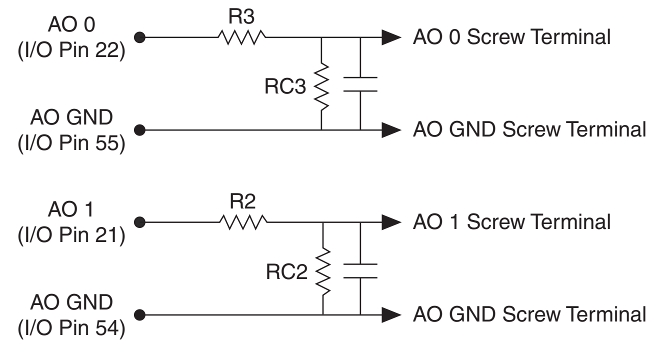


Figure 4-3. Analog Output Circuitry

Figure 4-4 illustrates the generic AO channel pad configuration.

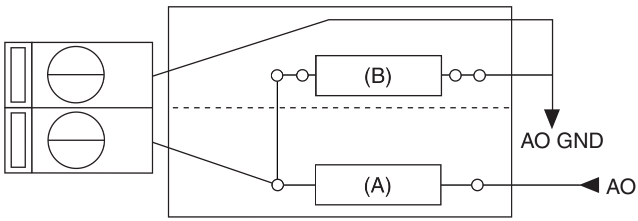


Figure 4-4. Analog Output Channel Pad Configuration

Table 4-2 correlates the component labels of the SCB-68 to component locations A and B for analog output channels 0 and 1.

Table 4-2. Analog Output Channels Component Locations

Channel	A	B
AO 0	R3	RC3
AO 1	R2	RC2
R denotes a socket for one component. RC denotes sockets for two components to be connected in parallel.		

Conditioning PFI 0

Figure 4-5 shows the shows the digital input channel configuration for PFI 0 on the SCB-68.

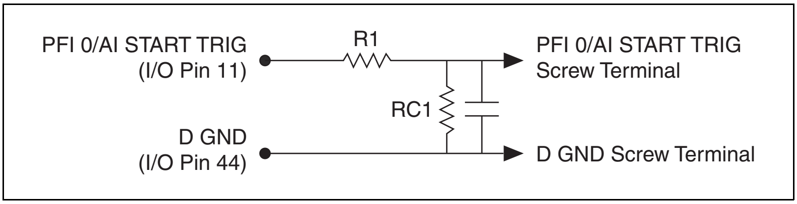


Figure 4-5. Digital Trigger Circuitry

Figure 4-6 illustrates the digital input channel configuration for PFI 0.

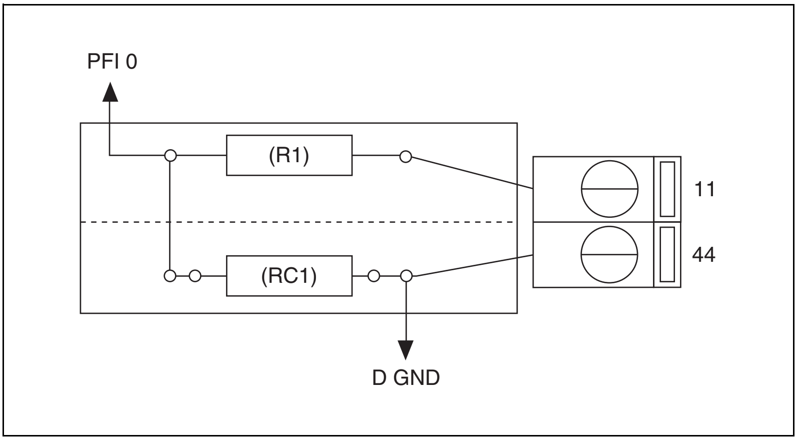
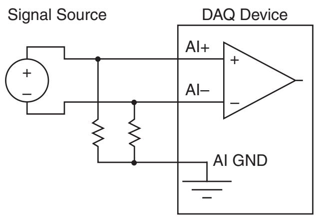
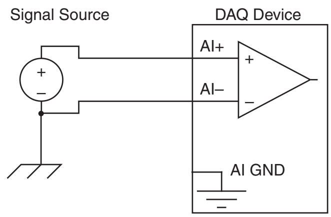
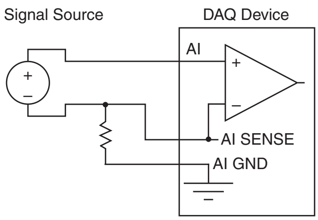
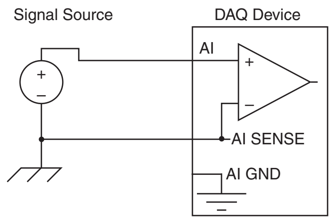
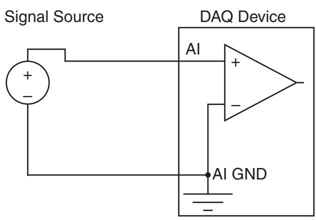
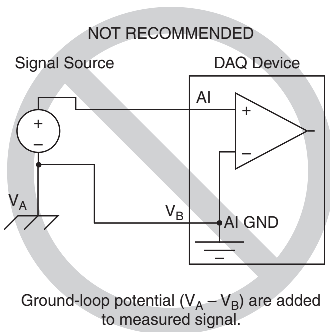


Figure 4-6. Digital Input Channel Pad Configuration

Connecting Analog Input Signals

Table 4-3 summarizes the recommended input configuration for both types of signal sources.

Table 4-3. Analog Input Configuration

AI Ground-Reference Setting*	Floating Signal Sources (Not Connected to Building Ground) Examples: • Ungrounded thermocouples • Signal conditioning with isolated outputs • Battery devices	Ground-Referenced Signal Sources* Example: • Plug-in instruments with non-isolated outputs
Differential (DIFF)		
Non-Referenced Single-Ended (NRSE)		
Referenced Single-Ended (RSE)		

* Refer to the documentation for your DAQ device for descriptions of the RSE, NRSE, and DIFF modes, analog input signal sources, and software considerations.

Connecting Floating Signal Sources

What Are Floating Signal Sources?

A floating signal source is not connected to the building ground system, but has an isolated ground-reference point. Some examples of floating signal sources are outputs of transformers, thermocouples, battery-powered devices, optical isolators, and isolation amplifiers. An instrument or device that has an isolated output is a floating signal source.

When to Use Differential Connections with Floating Signal Sources

Use differential input connections for any channel that meets any of the following conditions:

- The input signal is low-level (less than 1 V).
- The leads connecting the signal to the device are greater than 3 m (10 ft).
- The input signal requires a separate ground-reference point or return signal.
- The signal leads travel through noisy environments.
- Two analog input channels, AI+ and AI–, are available for the signal.

Differential signal connections reduce noise pickup and increase common-mode noise rejection. Differential signal connections also allow input signals to float within the common-mode limits of the NI-PGIA.

Refer to the *Using Differential Connections for Floating Signal Sources* section for more information about differential connections.

When to Use Non-Referenced Single-Ended (NRSE) Connections with Floating Signal Sources

Only use NRSE input connections if the input signal meets the following conditions:

- The input signal is high-level (greater than 1 V).
- The leads connecting the signal to the device are less than 3 m (10 ft).

Differential input connections are recommended for greater signal integrity for any input signal that does not meet the preceding conditions.

In the single-ended modes, more electrostatic and magnetic noise couples into the signal connections than in differential configurations. The coupling is the result of differences in the signal path. Magnetic coupling is proportional to the area between the two signal conductors. Electrical coupling is a function of how much the electric field differs between the two conductors.

With this type of connection, the NI-PGIA rejects both the common-mode noise in the signal and the ground potential difference between the signal source and the device ground.

Refer to the documentation for your DAQ device for more information about NRSE connections.

When to Use Referenced Single-Ended (RSE) Connections with Floating Signal Sources

Only use RSE input connections if the input signal meets the following conditions:

- The input signal can share a common reference point, AI GND, with other signals that use RSE.
- The input signal is high-level (greater than 1 V).
- The leads connecting the signal to the device are less than 3 m (10 ft).

Differential input connections are recommended for greater signal integrity for any input signal that does not meet the preceding conditions.

In the single-ended modes, more electrostatic and magnetic noise couples into the signal connections than in differential configurations. The coupling is the result of differences in the signal path. Magnetic coupling is proportional to the area between the two signal conductors. Electrical coupling is a function of how much the electric field differs between the two conductors.

With this type of connection, the NI-PGIA rejects both the common-mode noise in the signal and the ground potential difference between the signal source and the device ground.

Refer to the documentation for your DAQ device for more information about RSE connections.

Using Differential Connections for Floating Signal Sources

It is important to connect the negative lead of a floating source to AI GND (either directly or through a bias resistor). Otherwise, the source can float out of the maximum working voltage range of the NI-PGIA and the DAQ device returns erroneous data.

The easiest way to reference the source to AI GND is to connect the positive side of the signal to AI+ and connect the negative side of the signal to AI GND as well as to AI– without using resistors. This connection works well for DC-coupled sources with low source impedance (<100 Ω).

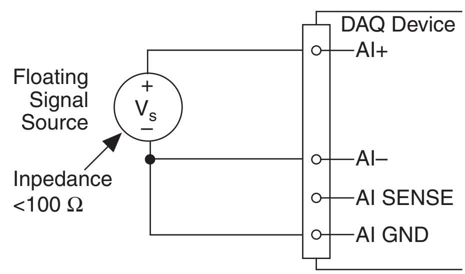


Figure 4-7. Differential Connections for Floating Signal Sources without Bias Resistors

However, for larger source impedances, this connection leaves the differential signal path significantly off balance. Noise that couples electrostatically onto the positive line does not couple onto the negative line because it is connected to ground. This noise appears as a differential mode signal instead of a common-mode signal, and thus appears in your data. In this case, instead of directly connecting the negative line to AI GND, connect the negative line to AI GND through a resistor that is about 100 times the equivalent source impedance. The resistor puts the signal path nearly in balance, so that about the same amount of noise couples onto both connections, yielding better rejection of electrostatically coupled noise. This configuration does not load down the source (other than the very high input impedance of the NI-PGIA).

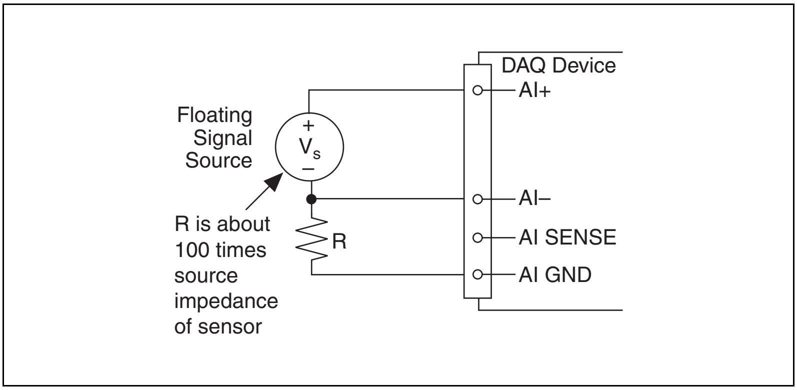


Figure 4-8. Differential Connections for Floating Signal Sources with Single Bias Resistor

You can fully balance the signal path by connecting another resistor of the same value between the positive input and AI GND, as shown in Figure 4-9. This fully balanced configuration offers slightly better noise rejection, but has the disadvantage of loading the source down with the series combination (sum) of the two resistors. If, for example, the source impedance is 2 kΩ and each of the two resistors is 100 kΩ, the resistors load down the source with 200 kΩ and produce a –1% gain error.

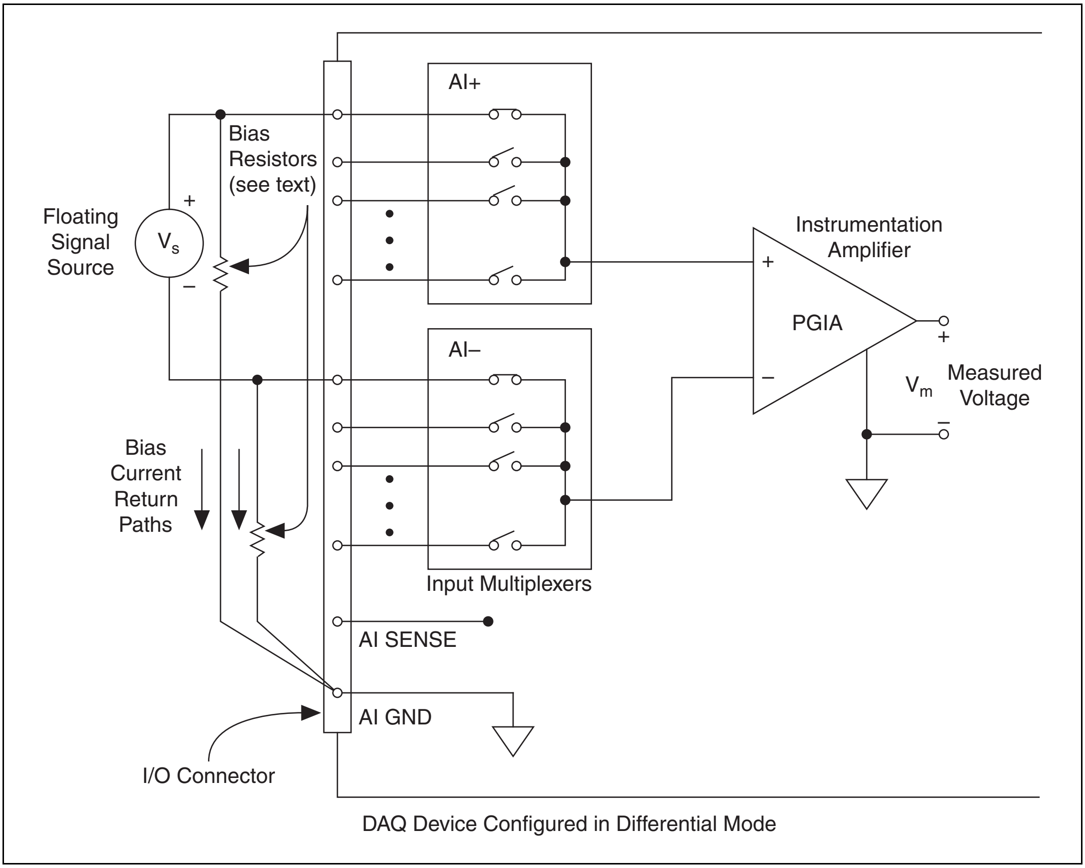


Figure 4-9. Differential Connections for Floating Signal Sources with Balanced Bias Resistors

Both inputs of the NI-PGIA require a DC path to ground in order for the NI-PGIA to work. If the source is AC coupled (capacitively coupled), the NI-PGIA needs a resistor between the positive input and AI GND. If the source has low-impedance, choose a resistor that is large enough not to significantly load the source, but small enough not to produce significant input offset voltage as a result of input bias current (typically 100 kΩ to 1 MΩ). In this case, connect the negative input directly to AI GND. If the source has high output impedance, balance the signal path as previously described using the same value resistor on both the positive and negative inputs; be aware that there is some gain error from loading down the source, as shown in Figure 4-10.

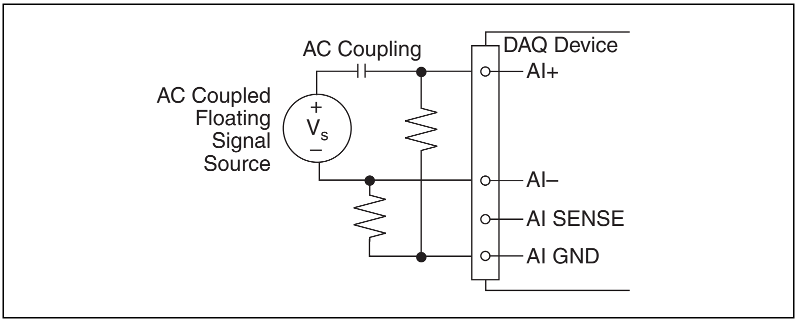


Figure 4-10. Differential Connections for AC Coupled Floating Sources with Balanced Bias Resistors

Refer to the *Installing Bias Resistors* section for information about installing bias resistors on the SCB-68.

Installing Bias Resistors

To install a single bias resistor on the negative line (AI–) of a differential pair, put the resistor in position D on the SCB-68, as shown in Figure 4-11.

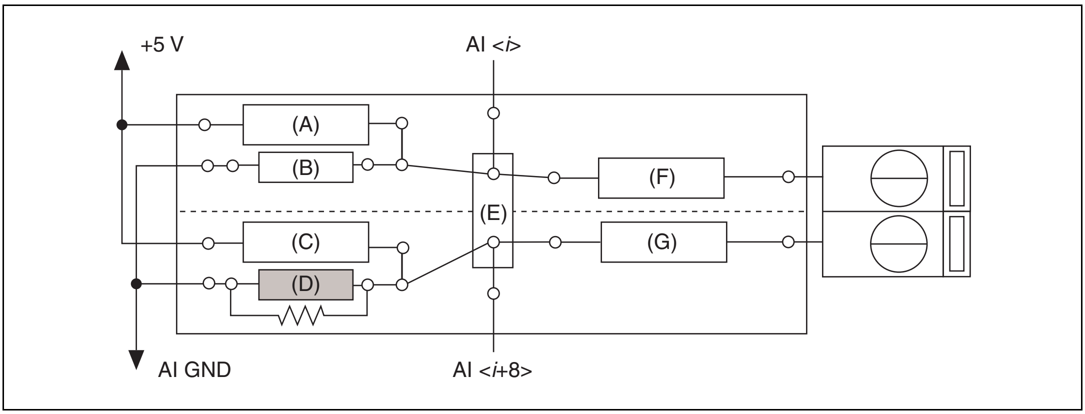


Figure 4-11. AI Differential Configuration with Single Bias Resistor

To install balanced bias resistors, put resistors in positions B and D on the SCB-68, as shown in Figure 4-12.

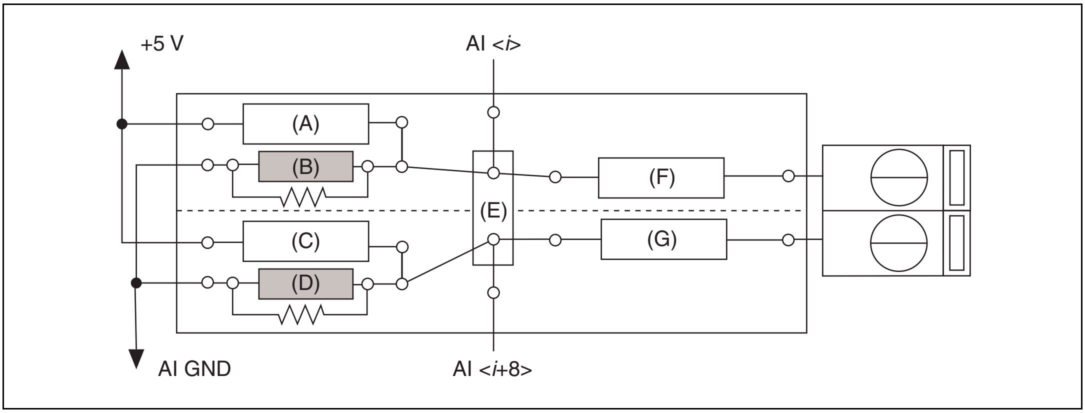


Figure 4-12. AI Differential Configuration with Balanced Bias Resistors

Filtering

This section discusses lowpass and highpass filtering on the SCB-68.

Lowpass Filtering

This section discusses the following topics regarding lowpass filtering on the SCB-68:

- *One-Pole Lowpass RC Filter*
- *Selecting Components for Lowpass Filtering*
- *Adding Components for Lowpass Filtering*
- *Lowpass Filtering Applications*

Lowpass filters highly or completely attenuate signals with frequencies above the cut-off frequency, or high-frequency stopband signals. Lowpass filters do not attenuate signals with frequencies below the cut-off frequency, or low-frequency passband signals. Ideally, lowpass filters have a phase shift that is linear with respect to frequency. This linear phase shift delays signal components of all frequencies by a constant time, independent of frequency, thereby preserving the overall shape of the signal.

In practice, lowpass filters subject input signals to a mathematical transfer function that approximates the characteristics of an ideal filter. By analyzing the Bode Plot, or the plot that represents the transfer function, you can determine the filter characteristics.

Figures 4-13 and 4-14 show the Bode Plots for the ideal filter and the real filter, respectively, and indicate the attenuation of each transfer function.

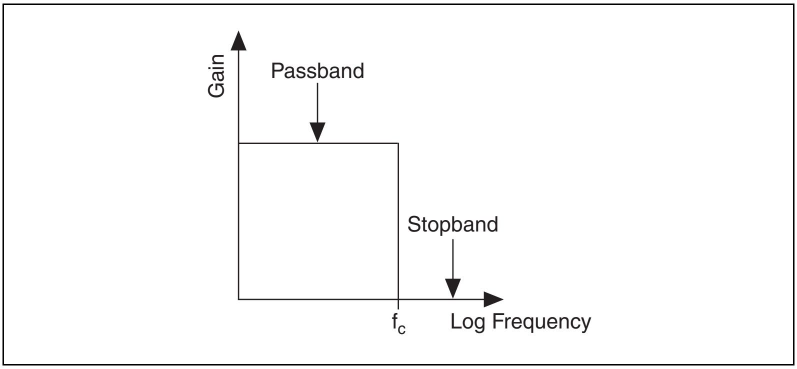


Figure 4-13. Transfer Function Attenuation for an Ideal Filter

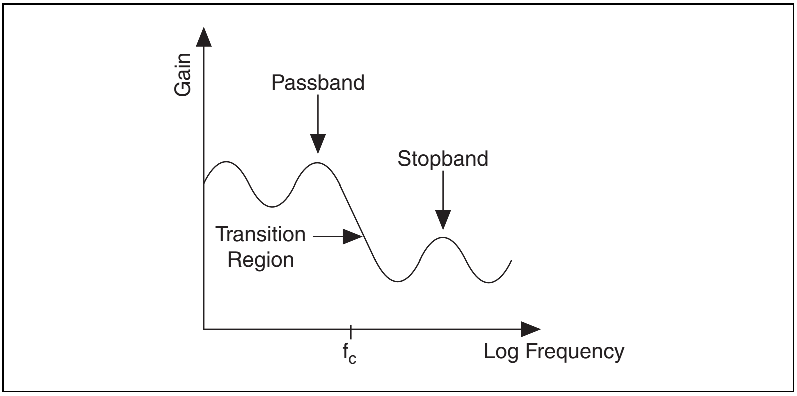


Figure 4-14. Transfer Function Attenuation for a Real Filter

The cut-off frequency, f_c, is defined as the frequency beyond which the gain drops 3 dB. Figure 4-13 shows how an ideal filter causes the gain to drop to zero for all frequencies greater than f_c. Thus, f_c does not pass through the filter to its output. Instead of having a gain of absolute zero for frequencies greater than f_c, the real filter has a transition region between the passband and the stopband, a ripple in the passband, and a stopband with a finite attenuation gain.

Real filters have some nonlinearity in their phase response, causing signals at higher frequencies to be delayed longer than signals at lower frequencies and resulting in an overall shape distortion of the signal. For example, when the square wave, shown in Figure 4-15, enters a filter, an ideal filter 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.

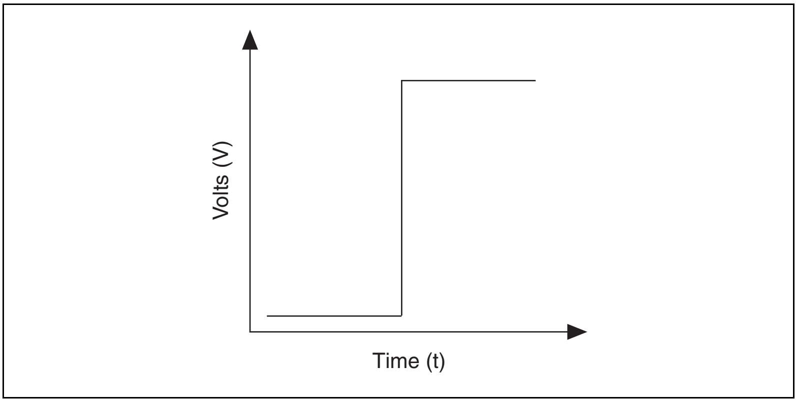


Figure 4-15. Square Wave Input Signal

Figures 4-16 and 4-17 show the difference in response to a square wave between an ideal and a real filter, respectively.

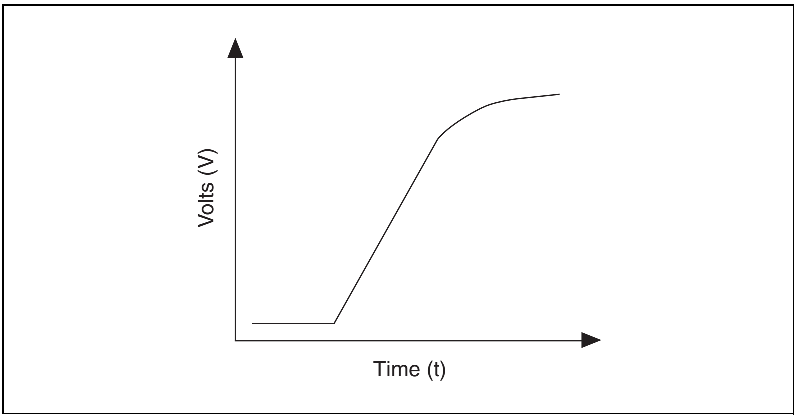


Figure 4-16. Response of an Ideal Filter to a Square Wave Input Signal

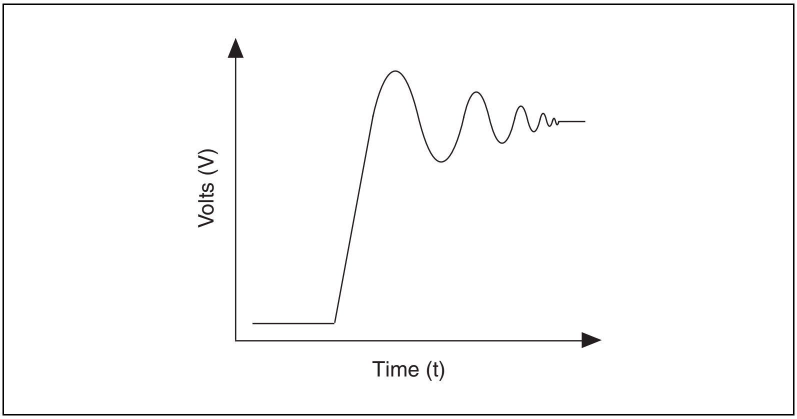


Figure 4-17. Response of a Real Filter to a Square Wave Input Signal

One-Pole Lowpass RC Filter

Figure 4-18 shows the transfer function of a simple series circuit consisting of a resistor (*R*) and capacitor (*C*) when the voltage across *R* is assumed to be the output voltage (V_m).

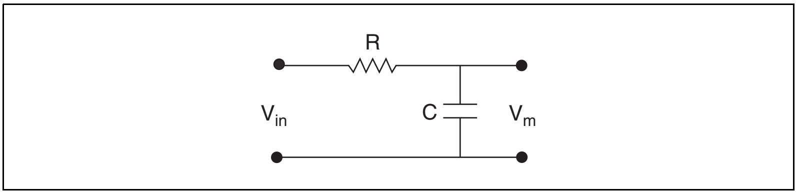


Figure 4-18. Simple RC Lowpass Filter

The transfer function is a mathematical representation of a one-pole lowpass filter, with a time constant of:

$$\frac{1}{2\pi RC}$$

Use Equation 4-1 to design a lowpass filter for a simple resistor and capacitor circuit, where the values of the resistor and capacitor alone determine f_c:

$$T(s) = \frac{G}{1 + (2\pi RC)s} \tag{4-1}$$

where *G* is the DC gain and *s* represents the frequency domain.

Selecting Components for Lowpass Filtering

To determine the value of the components in the circuit, fix *R* (10 kΩ is reasonable) and isolate *C* from Equation 4-1 as follows:

$$C = \frac{1}{2\pi R f_C} \tag{4-2}$$

The cut-off frequency in Equation 4-2 is f_c.

For best results, choose a resistor that has the following characteristics:

- Low wattage of approximately 0.125 W
- Precision of at least 5%
- Temperature stability
- Tolerance of 5%
- AXL package (suggested)
- Carbon or metal film (suggested)

Choose a capacitor that has the following suggested characteristics:

- AXL or RDL package
- Tolerance of 20%
- Maximum voltage of at least 25 V

Adding Components for Lowpass Filtering

Using the circuit shown in Figure 4-18, you can use a two-component circuit to build a simple RC filter with analog input, analog output, or digital input.

Lowpass Filters on Analog Input Signals

You can build a lowpass filter for the following analog input modes:

- **Differential analog input lowpass filter**—To build a differential lowpass filter, refer to Figure 4-19. Add the resistor to position F and the capacitor to position E. Refer to Table 4-1 for component positions for all analog input channels.

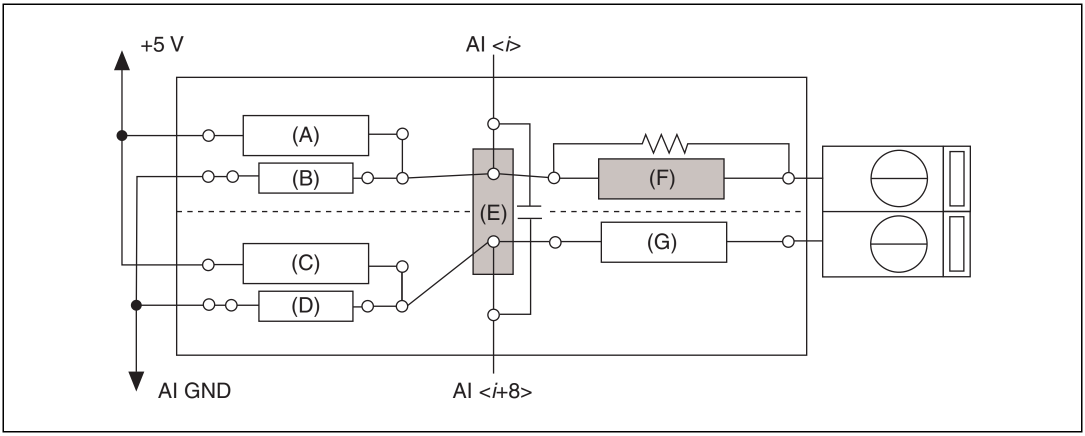


Figure 4-19. SCB-68 Circuit Diagram for Differential Analog Input Lowpass Filter

- **Single-ended analog input lowpass filter**—To build a single-ended lowpass filter, refer to Figure 4-20. Add the resistor to position F or G, depending on the AI channel you are using. Add the capacitor to position B or D, depending on the AI channel you are using. Refer to Table 4-1 for component positions for all analog input channels.

Note Filtering increases the settling time of the instrumentation amplifier to the time constant of the filter used. Adding RC filters to scanning channels greatly reduces the practical scanning rate, since the instrumentation amplifier settling time can be increased to $10T$ or longer, where $T = (R)(C)$.

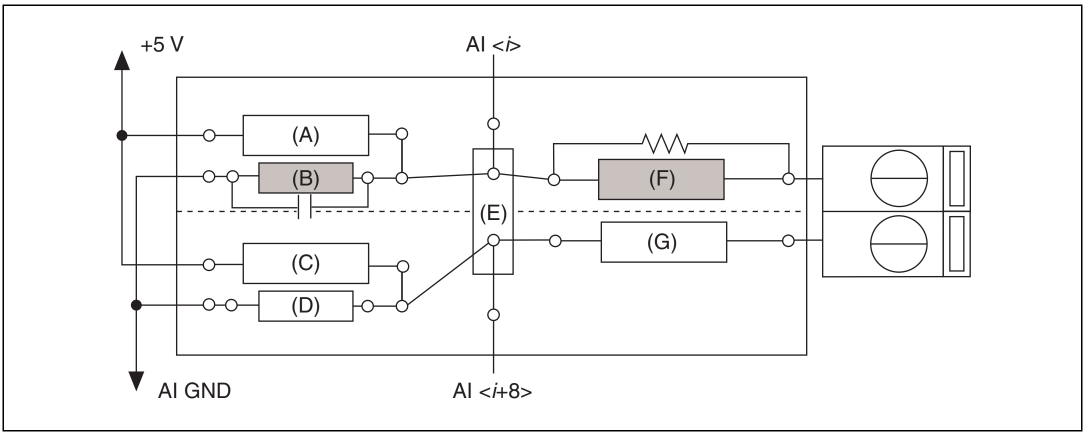


Figure 4-20. SCB-68 Circuit Diagram for Single-Ended Analog Input Lowpass Filter on AI <*i*>

Lowpass Smoothing Filters on Analog Output Signals

To build a lowpass filter for analog output, put a resistor in position A and a capacitor in position B, as shown in Figure 4-21. Refer to Table 4-2 for component positions for both analog output channels.

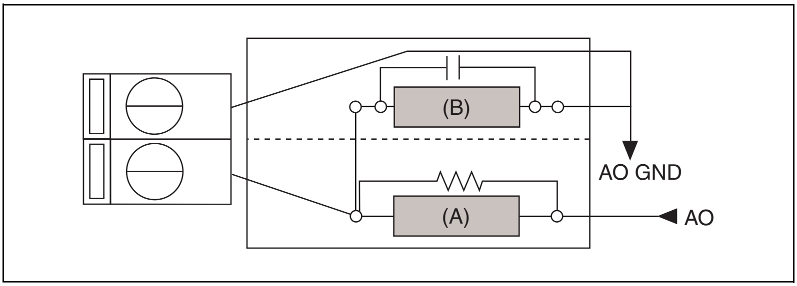


Figure 4-21. SCB-68 Circuit Diagram for Analog Output Lowpass Filter

Lowpass Digital Filters on Digital Trigger Input Signals

For PFI 0, add the resistor to position R1 and the capacitor to position RC1. Refer to Figure 4-22 for the digital input channel pad configuration.

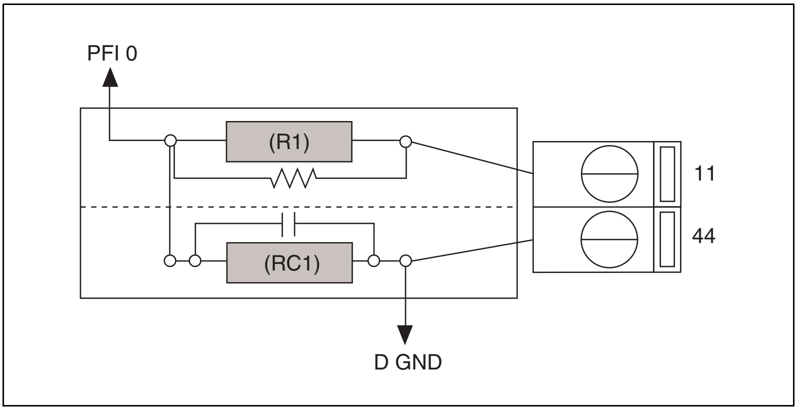


Figure 4-22. SCB-68 Circuit Diagram for Digital Trigger Input Lowpass Filter

Lowpass Filtering Applications

The following sections list applications where lowpass filtering can be useful.

Analog Input Lowpass Filtering Applications

The following applications benefit from lowpass filtering:

- **Noise filtering**—You can use a lowpass filter to highly attenuate the noise frequency on a measured signal. For example, power lines commonly add a noise frequency of 60 Hz. Adding a filter with f_c<60 Hz at the input of the measurement system causes the noise frequency to fall into the stopband.

  Referring to Equation 4-2, fix the resistor value at 10 kΩ to calculate the capacitor value and choose a commercial capacitor value that satisfies the following relationship:

$$C > \frac{1}{2\pi(10,000)(60)} \tag{4-3}$$

- **Antialiasing filtering**—Aliasing causes high-frequency signal components to appear as a low-frequency signal, as Figure 4-23 shows.

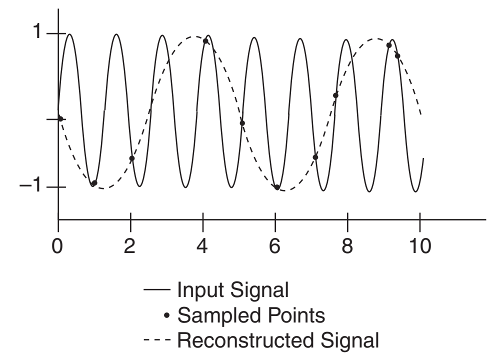


Figure 4-23. Aliasing of a High-Frequency Signal

The solid line depicts a high-frequency signal being sampled at the indicated points. 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 is aliased and incorrectly analyzed as having a frequency below one-half the sample rate. This limiting frequency of one-half the sample rate is called the Nyquist frequency.

To prevent aliasing, remove all signal components with frequencies greater than the Nyquist frequency from input signals before those signals are sampled. Once a data sample is aliased, it is impossible to accurately reconstruct the original signal.

To design a lowpass filter that attenuates signal components with a frequency higher than half of the Nyquist frequency, substitute the half Nyquist value for the f_c value in Equation 4-3.

Note (NI PCI/PXI-6115/6120/6289 Devices Only) NI PCI/PXI-6115/6120 and NI PCI/PXI-6289 devices provide filters and may not need antialiasing filters implemented at the SCB-68 terminal block. Refer to your device documentation for more information.

Analog Output Lowpass Filtering Applications

The following applications benefit from lowpass filtering:

- **Protection for external circuitry**—Lowpass filters can smooth stairstep-like curves on AO signals. If the curves are not smoothed, the AO signals can be a hazard for some external circuitry connected to it. Figure 4-24 shows the output of a lowpass filter when a stairstep-like signal is the input.

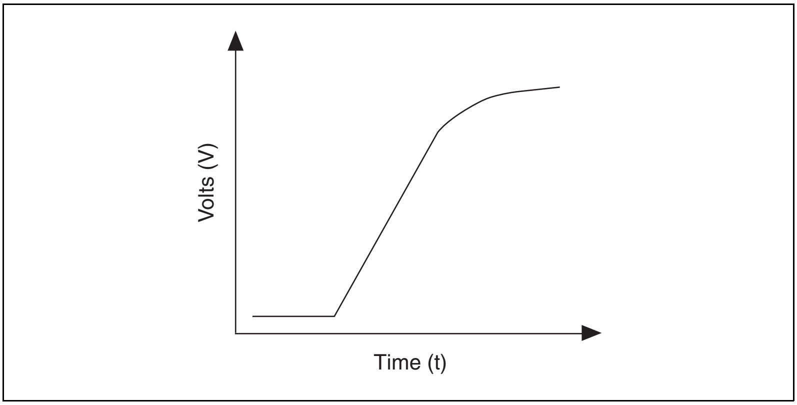


Figure 4-24. Lowpass Filtering of AO Signals

- **Deglitching analog output signals**—Lowpass filters can be used to decrease glitches from an analog output signal. When you use a DAC to generate a waveform, you may observe glitches on the output signal. These glitches are normal; when a DAC switches from one voltage to another, it produces glitches due to released charges. The largest glitches occur when the most significant bit of the DAC code changes. You can build a lowpass deglitching filter to remove some of these glitches, depending on the frequency and nature of the output signal. To select a cutoff frequency for the deglitching filter, refer to your DAQ device documentation for the maximum glitch duration.

PFI 0 Lowpass Filtering Applications

Lowpass filters can function as debouncing filters to smooth noise on digital trigger input signals, thus enabling the trigger-detection circuitry of the DAQ device to understand the signal as a valid digital trigger.

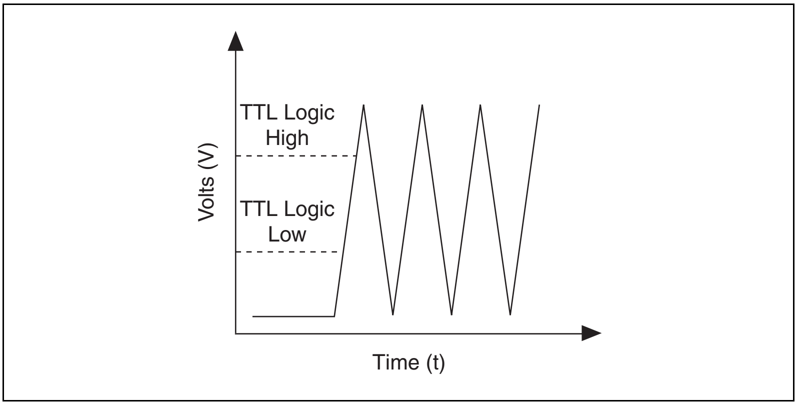


Figure 4-25. Digital Trigger Input Signal with a High-Frequency Component

Apply a lowpass filter to the signal to remove the high-frequency component for a cleaner digital signal, as Figure 4-26 shows.

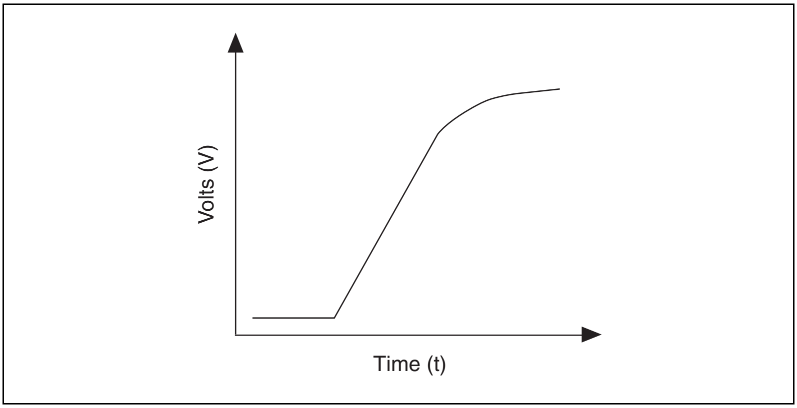


Figure 4-26. Lowpass Filtering of Digital Trigger Input Signals

Note Due to the filter order, the digital trigger input signal is delayed for a specific amount of time depending on the filter you use before the DAQ device senses the signal at the trigger input.

Highpass Filtering

This section discusses the following topics regarding highpass filtering on the SCB-68:

- *One-Pole Highpass RC Filter*
- *Selecting Components for Highpass Filtering*
- *Adding Components for Highpass Filtering*
- *Highpass Filtering Applications*

Highpass filters highly or completely attenuate signals with frequencies below the cut-off frequency, or low-frequency stopband signals. Highpass filters do not attenuate signals with frequencies above the cut-off frequency, or high-frequency passband signals.

The cut-off frequency, f_c, is defined as the frequency below which the gain drops 3 dB. Figure 4-27 shows how an ideal filter causes the gain to drop to zero for all frequencies less than f_c. Thus, f_c does not pass through the filter to its output.

In practice, highpass filters subject input signals to a mathematical transfer function that approximates the characteristics of an ideal filter. By analyzing the Bode Plot, or the plot that represents the transfer function, you can determine the filter characteristics.

Figures 4-27 and 4-28 show the Bode Plots for the ideal filter and the real filter, respectively, and indicate the attenuation of each transfer function.

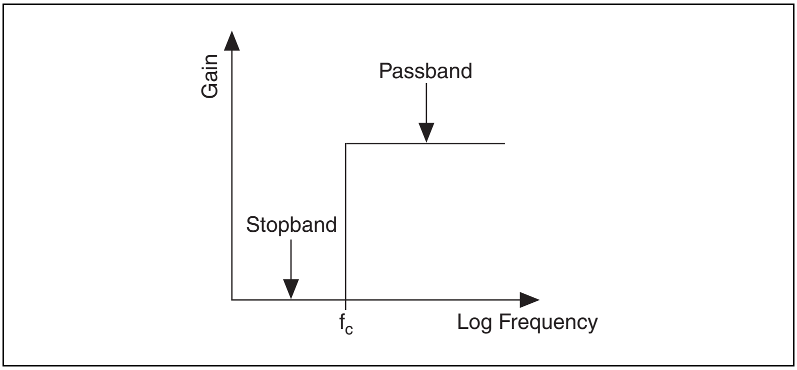


Figure 4-27. Transfer Function Attenuation for an Ideal Filter

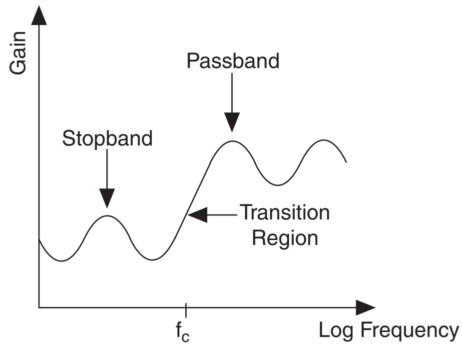


Figure 4-28. Transfer Function Attenuation for a Real Filter

Instead of having a gain of absolute zero for frequencies less than f_c, the real filter has a transition region between the passband and the stopband, a ripple in the passband, and a stopband with a finite attenuation gain.

One-Pole Highpass RC Filter

Figure 4-29 shows the transfer function of a simple series circuit consisting of a resistor (*R*) and capacitor (*C*) when the voltage across *R* is assumed to be the output voltage (V_m).

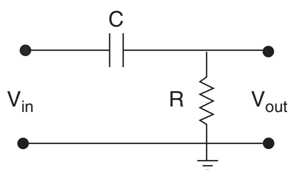


Figure 4-29. Simple RC Highpass Circuit

The transfer function is a mathematical representation of a one-pole highpass filter, with a time constant of:

$$\frac{1}{2\pi RC}$$

Use Equation 4-4 to design a lowpass filter for a simple resistor and capacitor circuit, where the values of the resistor and capacitor alone determine f_c:

$$T(s) = \frac{G}{1 + (2\pi RC)s} \tag{4-4}$$

where G is the DC gain and s represents the frequency domain.

Selecting Components for Highpass Filtering

To determine the value of the components in the circuit, fix R (10 kΩ is reasonable) and isolate C from Equation 4-4 as follows:

$$C = \frac{1}{2\pi R f_C} \tag{4-5}$$

The cutoff frequency in Equation 4-5 is f_c.

For best results, choose a resistor that has the following characteristics:

- Low wattage of approximately 0.125 W
- Precision of at least 5%
- Temperature stability
- Tolerance of 5%
- AXL package (suggested)
- Carbon or metal film (suggested)

Choose a capacitor that has the following suggested characteristics:

- AXL or RDL package
- Tolerance of 20%
- Maximum voltage of at least 25 V

Adding Components for Highpass Filtering

Using the circuit shown in Figure 4-29, you can use a two-component circuit to build a simple RC filter with an analog input.

- **Differential analog input highpass filter**—To build a differential lowpass filter, add the resistor to position E and the capacitor to position F, as shown in Figure 4-30. Refer to Table 4-1 for component positions for all analog input channels.

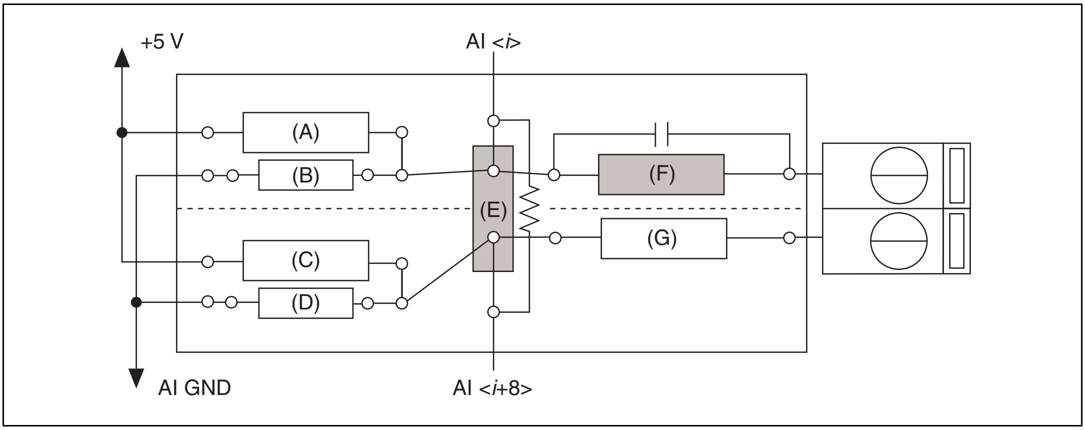


Figure 4-30. SCB-68 Circuit Diagram for Differential Analog Input Highpass Filter

- **Single-ended analog input highpass filter**—To build a single-ended lowpass filter, refer to Figure 4-31. Add the resistor to position B or D, depending on the AI channel you are using. Add the capacitor to position F or G, depending on the AI channel you are using. Refer to Table 4-1 for component positions for all analog input channels.

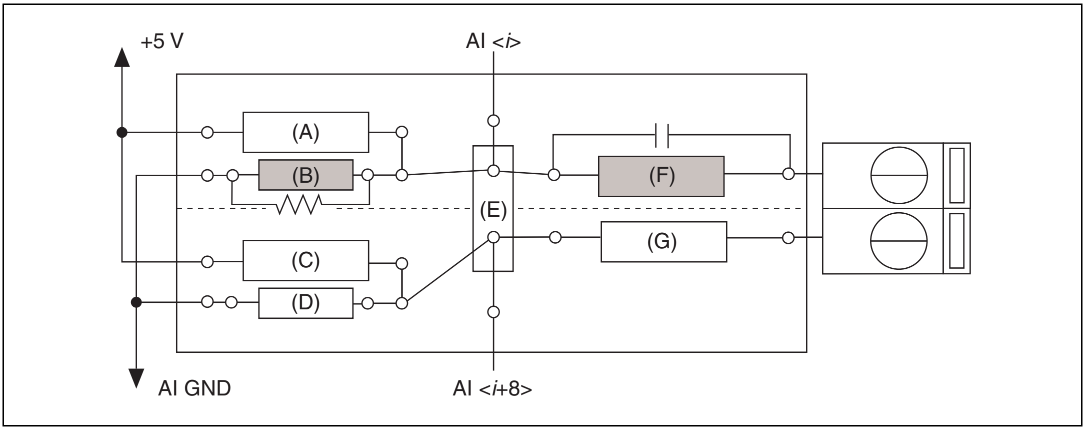


Figure 4-31. SCB-68 Circuit Diagram for Single-Ended Analog Input Highpass Filter on AI <*i*>

Highpass Filtering Applications

One of the most common applications for highpass filters for analog inputs is to use the filter to do AC coupling. AC coupling can be achieved by creating a highpass filter with a very low cutoff frequency. This filter allows most dynamic signals through, while it blocks any DC offsets in the signal. This can be used to increase the resolution with which you can measure a dynamic signal that is riding on top of an offset, as shown in Figure 4-32.

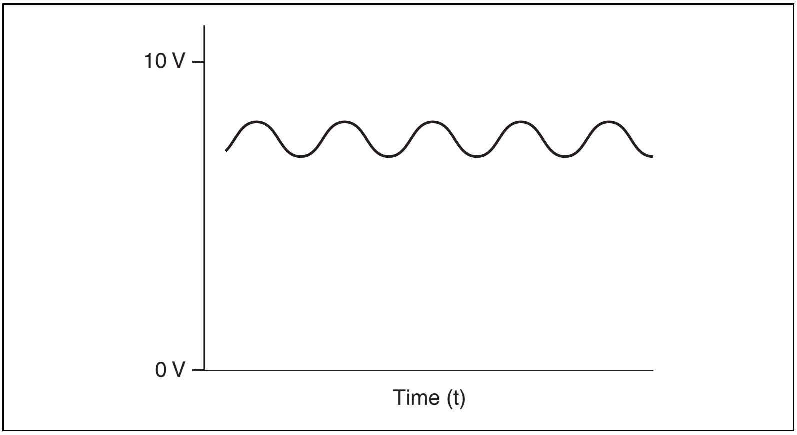


Figure 4-32. Signal before Passing through Filter

Without the AC coupling you would use the ±10 V range or the 0–10 V range. After passing through the filter, the dynamic portion of the signal is retained and centered around 0, as shown in Figure 4-33.

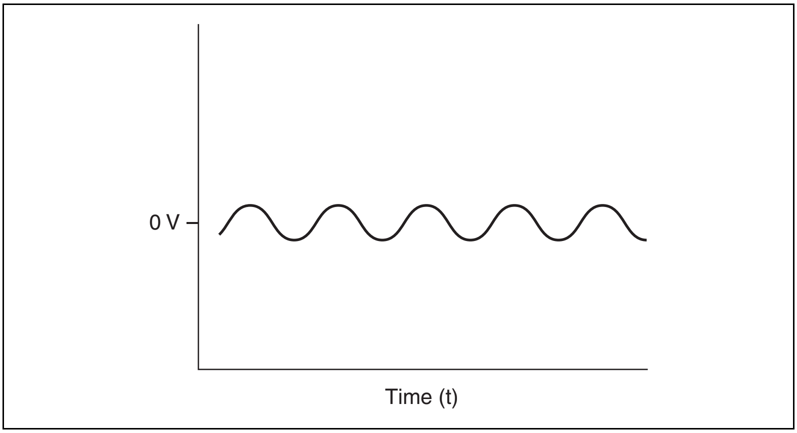


Figure 4-33. Signal after Passing through Filter

You can now reduce your range to ±1 V to increase the resolution of the measurement.

Current Input Measurement

Some DAQ devices cannot directly measure current. This section describes how to add components for measuring current up to 20 mA.

The conversion from current to voltage is based on Ohm's Law, summarized by the following equation:

$$V = I \times R$$

where V is voltage, I is current, and R is resistance.

By putting a resistor with a known value in series with the current and measuring the voltage produced across the resistor as shown in Figure 4-34, you can calculate the current flowing through the circuit.

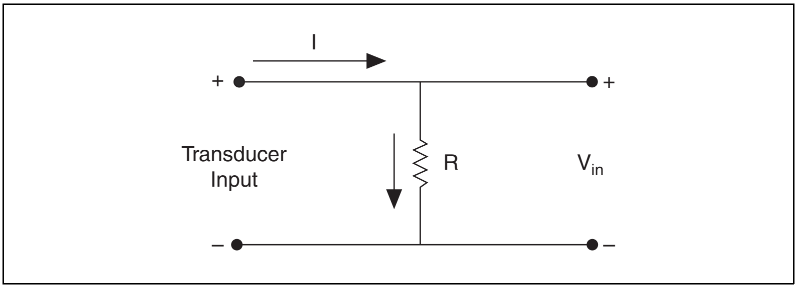


Figure 4-34. Current-to-Voltage Electrical Circuit

The application software must linearly convert voltage back to current. The following equation demonstrates this conversion, where the resistor is the denominator and V_{in} is the input voltage into the DAQ device:

$$I = \frac{V_{in}}{R}$$

Selecting a Resistor for Current Input Measurement

For best results when measuring current, choose a resistor that has the following characteristics:

- Low wattage of approximately 0.125 W
- Precision of at least 5%
- Temperature stability
- Tolerance of 5%
- 232 Ω (suggested)
- AXL package (suggested)
- Carbon or metal film (suggested)

If you use the resistor described above, you can convert a 20 mA current to 4.64 V by setting the device range to either (–5 to +5 V) or (0 to 5 V).

Adding Components for Current Input Measurement

Caution Do *not* exceed ±10 V at the analog inputs. NI is *not* liable for any device damage or personal injury resulting from improper connections.

You can build a one-resistor circuit for measuring current at the single-ended or differential inputs of the SCB-68:

- **Differential analog inputs**—To build a one-resistor circuit that measures current at the differential inputs of the SCB-68, add the resistor to position E for each differential channel pair that is used. Leave the 0 Ω resistors in place for positions F and G. Refer to Table 4-1 for component positions for all analog input channels. Calculate the current according to the following equation:

$$I = \frac{V_m}{R_E}$$

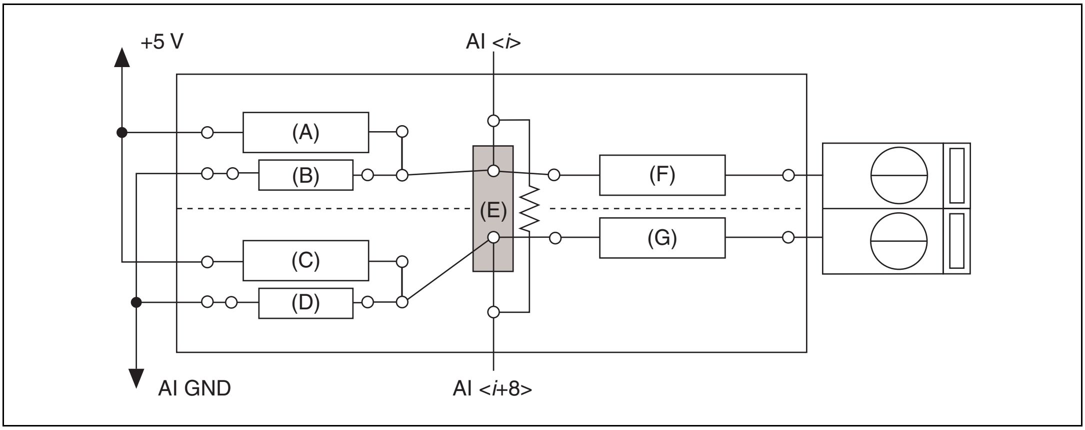


Figure 4-35. Measuring Current with Differential Analog Inputs

- **Single-ended analog inputs**—To build a one-resistor circuit that measures current at the single-ended analog inputs of the SCB-68, add the resistor to position B or D, depending on the channel being used. Leave the 0 Ω resistors in place for channel positions F and G, respectively. Refer to Table 4-1 for component positions for all analog input channels. Calculate the current according to the following equation,

$$I = \frac{V_m}{R_{B \text{ or } D}}$$

where $R_{B \text{ or } D}$ is the resistance of the resistor in position B or D.

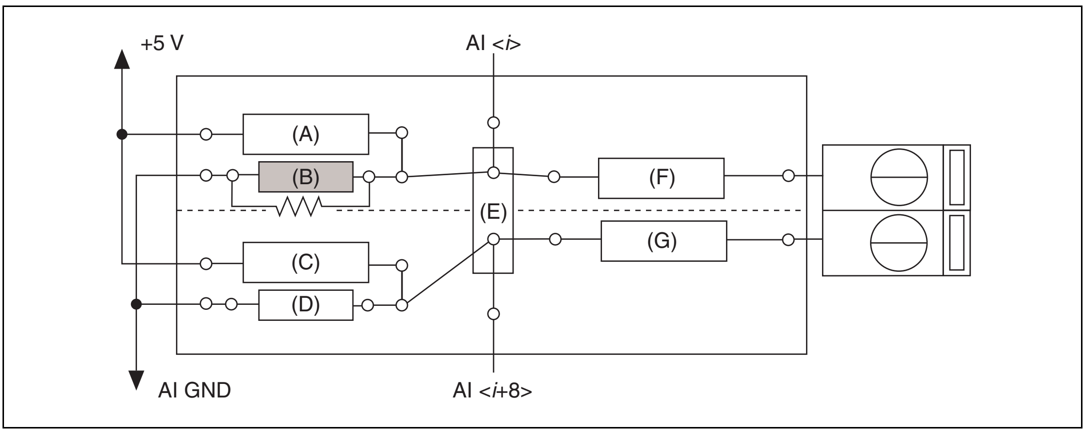


Figure 4-36. Measuring Current with Single-Ended Analog Input (AI <i>)

Attenuating Voltage

Transducers can generate more than 10 VDC per channel, but DAQ devices cannot read more than 10 VDC per input channel. Therefore, you must attenuate output signals from the transducer to fit within the DAQ device specifications. Figure 4-37 shows how to use a voltage divider to attenuate the output signal of the transducer.

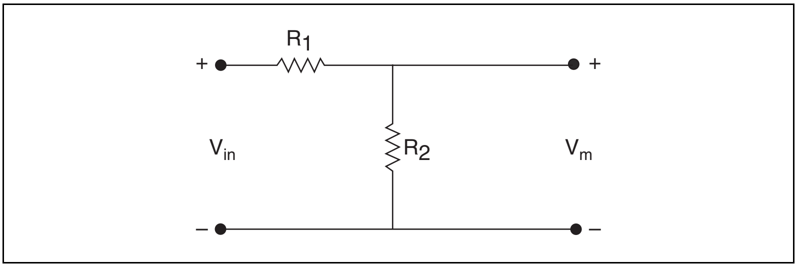


Figure 4-37. Attenuating Voltage with a Voltage Divider

The voltage divider splits the input voltage (V_{in}) between two resistors (R_1 and R_2), causing the voltage on each resistor to be noticeably lower than V_{in}. Use Equation 4-6 to determine the V_m that the DAQ device measures:

$$V_m = V_{in}\left(\frac{R_2}{R_1 + R_2}\right) \tag{4-6}$$

Use Equation 4-7 to determine the overall gain of a voltage divider circuit:

$$G = \frac{V_m}{V_{in}} = \frac{R_2}{R_1 + R_2} \tag{4-7}$$

The accuracy of Equation 4-7 depends on the tolerances of the resistors that you use.

Caution The SCB-68 is *not* designed for any input voltages ≥42 V, even if a user-installed voltage divider reduces the voltage to within the input range of the DAQ device. Input voltages ≥42 V can damage the SCB-68, any devices connected to it, and the host computer. Overvoltage can also cause an electric shock hazard for the operator.

Selecting Components for Attenuating Voltage

To set up the resistors, complete the following steps.

1. Select the value for R_2 (10 kΩ is recommended).
2. Use Equation 4-6 to calculate the value for R_1.

   Base the R_1 calculation on the following values:

   - Maximum V_{in} you expect from the transducer
   - Maximum voltage (<10 VDC) that you want to input to the DAQ device

Accuracy Considerations for Attenuating Voltage

For best results when attenuating voltage, choose a resistor that has the following characteristics:

- Low wattage of approximately 0.125 W
- Precision of at least 5%
- Temperature stable
- Tolerance of 5%
- AXL package (suggested)
- Carbon or metal film (suggested)

Verify that R_1 and R_2 drift together with respect to temperature; otherwise, the system may consistently read incorrect values.

Adding Components for Attenuating Voltage

You can build a circuit for attenuating voltages at the analog inputs, analog outputs, and digital inputs of the SCB-68.

Attenuating Voltage on Analog Input Signals

You can build a two- or three-resistor circuit for attenuating voltages at the single-ended analog inputs and differential analog inputs of the SCB-68:

- **Differential analog input attenuators**—To build a three-resistor circuit for attenuating voltages at the differential analog inputs of the SCB-68, refer to Figure 4-38. Refer to Table 4-1 for component positions for all analog input channels.

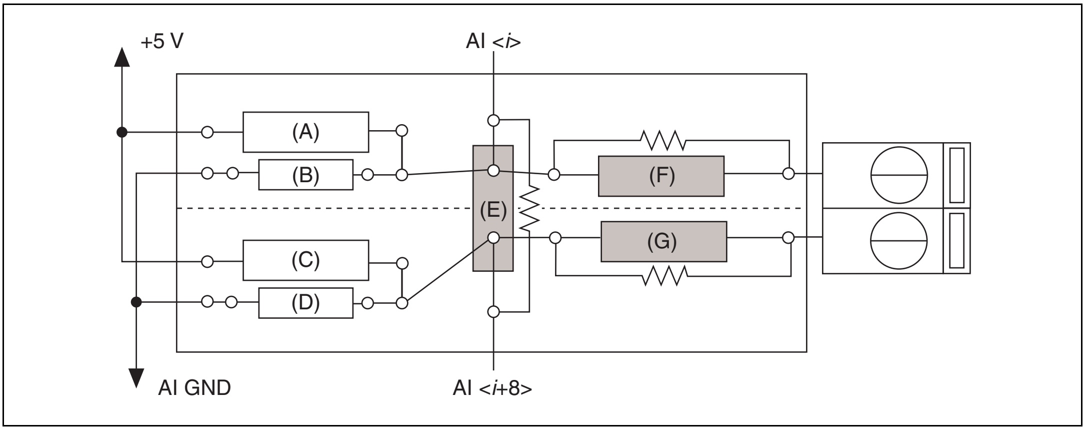


Figure 4-38. SCB-68 Circuit Diagram for Differential Analog Input Attenuation

Install resistors in positions E, F, and G of the chosen differential channel pair. Use the following equation to determine the gain of the circuit:

$$G = \frac{R_E}{(R_E + R_F + R_G)}$$

- **Single-ended analog input attenuators**—To build a two-resistor circuit for attenuating voltages at the single-ended analog inputs of the SCB-68, refer to Figure 4-39. Refer to Table 4-1 for component positions for all analog input channels.

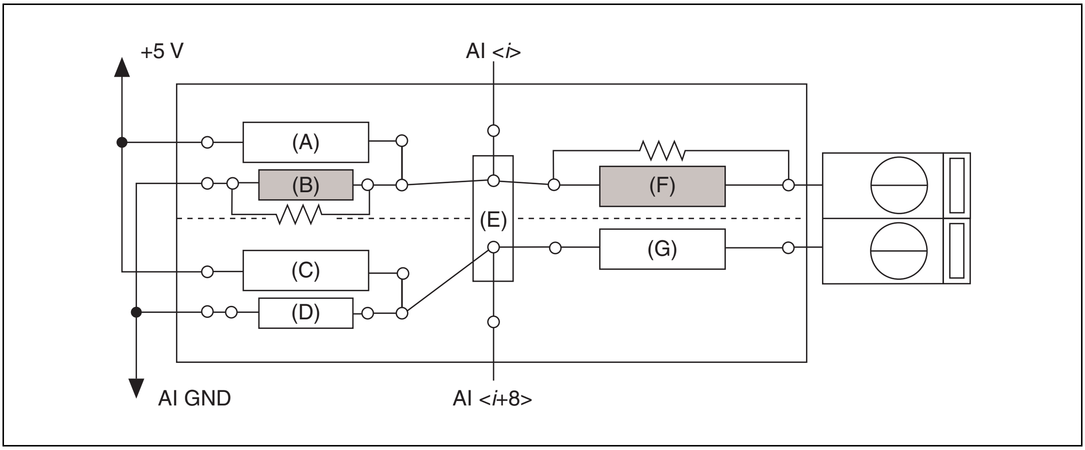


Figure 4-39. SCB-68 Circuit Diagram for Single-Ended Analog Input Attenuation on AI <*i*>

Install resistors in positions B and F, or positions D and G, depending on the channel you are using on the SCB-68. Use the following equation to calculate the gain of the circuit:

$$G = \frac{R_{B \text{ or} D}}{(R_{B \text{ or} D} + R_{F \text{ or} G})}$$

where $R_{B \text{ or } D}$ is the resistance of the resistor in position B or D, and $R_{F \text{ or } G}$ is the resistance of the resistor in position F or G.

Attenuating Voltage on Analog Output Signals

To build a two-resistor circuit for attenuating voltages at the AO 0 and AO 1 pins on the SCB-68, refer to the pad positions in Figure 4-40. Refer to Table 4-2 for component positions for both analog output channels.

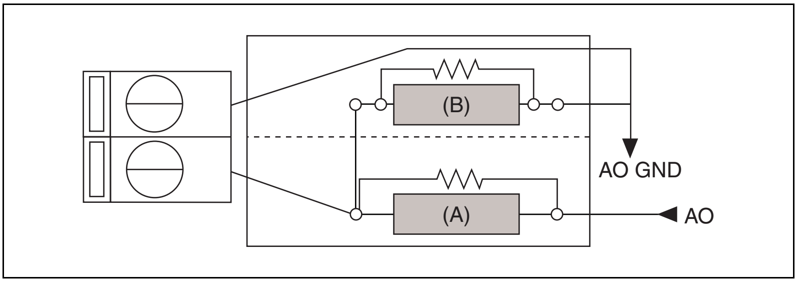


Figure 4-40. SCB-68 Circuit Diagram for Analog Output Attenuation

Install resistors in positions A and B and determine the gain according to Equation 4-8:

$$G = \frac{R_B}{(R_B + R_A)} \qquad (4\text{-}8)$$

Attenuating Voltage on Digital Inputs

To build a two-resistor circuit for attenuating voltages at the PFI 0 pin on the SCB-68, refer to the pad positions in Figure 4-41.

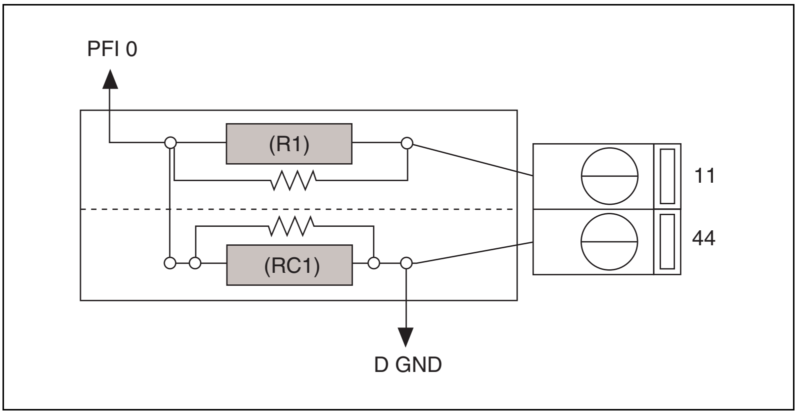


Figure 4-41. SCB-68 Circuit Diagram for Digital Input Attenuation

Use positions R1 and RC1 for PFI 0, and determine the gain according to Equation 4-9:

$$G = \frac{RC1}{(RC1 + R1)} \tag{4-9}$$

Voltage Dividers

You can build voltage dividers for the analog inputs, analog outputs, and digital inputs of the SCB-68.

Voltage Dividers for Analog Input

When calculating the values for R_1 and R_2, consider the input impedance value from the point of view of V_{in}, as shown in Figure 4-42.

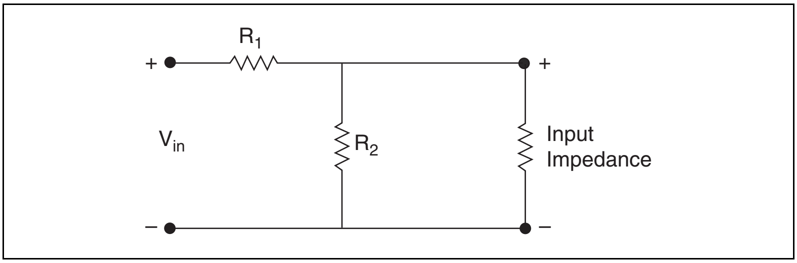


Figure 4-42. Input Impedance Electrical Circuit

The following equation shows the relationship among all of the resistor values:

$$Z_{in} = R_1 + \frac{(R_2 \times Input\ Impedance)}{(R_2 + Input\ Impedance)}$$

Z_{in} is the new input impedance. Refer to the device specifications for the input impedance of your device.

Voltage Dividers for Analog Output

When you use the circuit shown in Figure 4-37 for analog output, the output impedance changes. Thus, you must choose the values for R_1 and R_2 so that the final output impedance value is as low as possible. Refer to the device specifications for the output impedance for your device. Figure 4-43 shows the electrical circuit you use to calculate the output impedance.

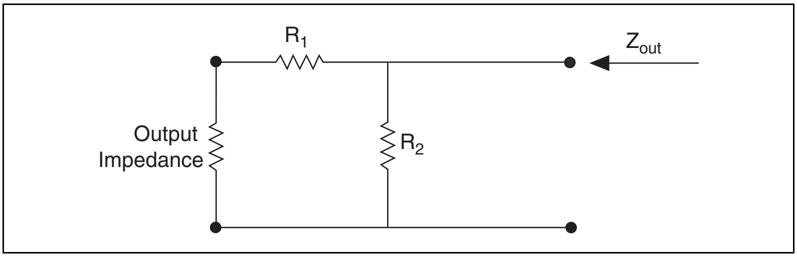


Figure 4-43. Electrical Circuit for Determining Output Impedance

The following equation shows the relationship between R_1, R_2, and Z_{out}, where Z_{out} is the old output impedance and Z_{out2} is the new output impedance:

$$Z_{out2} = \frac{(Z_{out} + R_1) \times R_2}{Z_{out} + R_1 + R_2}$$

Voltage Dividers for Digital Inputs

If you use the V_{in} voltage of Figure 4-37 to feed TTL signals, you must calculate V_{in} so that the voltage drop on R_2 does not exceed 5 V.

Caution A voltage drop exceeding 5 V on R_2 can damage the internal circuitry of the DAQ device. NI is *not* liable for any device damage resulting from improper use of the SCB-68 and the DAQ device.

Adding Power Filters

Refer to the *SCB-68 User Guide* for information about the +5 V power lines and SCB-68 fuse replacement.

A 470 Ω series resistor (R21) is part of the power filter for the +5 V power on the SCB-68. Due to the nature of the filter design, as the filtered +5 V is loaded, the voltage supplied to the SCB-68 circuitry and screw terminal 8 decreases. Pad R20, shown in Figure 3-1, *SCB-68 Printed Circuit Board Diagram*, is in parallel with R21. You can install a resistor, if needed, to decrease the overall resistance used in the filter and reduce the loading effect. However, completely shorting R20 bypasses the filter while capacitively coupling D GND to AI GND and AO GND and is not recommended.

Caution NI is *not* liable for any device damage resulting from improper use of the SCB-68 and the DAQ device.

Figure 4-44 shows the power supply circuitry on the SCB-68.

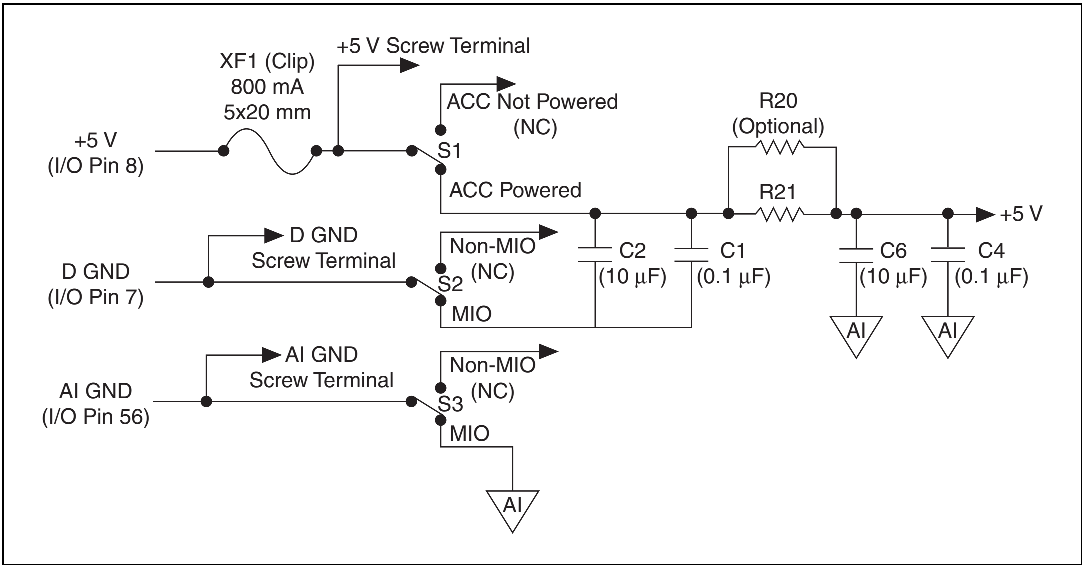


Figure 4-44. +5 V Power Supply

A Specifications

This appendix lists the SCB-68 specifications. These specifications are typical at 25 °C unless otherwise noted.

General

Number of screw terminals .... 68, all I/O signals are available at screw terminals

Temperature sensor

- Accuracy .... ±1.0 °C over a 0 to 110 °C range
- Output .... 10 mV/°C

Caution Do *not* connect hazardous voltages (≥42 V_{pk}/60 VDC) to the SCB-68.

Power Requirement

Power consumption (at +5 VDC, ±5%)

- Typical .... 1 mA with no signal conditioning installed
- Maximum.. 800 mA from host computer

Note The power specifications pertain to the power supply of the host computer when using internal power or to the external supply connected at the +5 V screw terminal when using external power. The maximum power consumption of the SCB-68 is a function of the signal conditioning components installed and any circuits constructed on the general-purpose breadboard area. If the SCB-68 is powered from the host computer, the maximum +5 V current draw, which is limited by the fuse, is 800 mA.

Fuse

Manufacturer ....Littelfuse part number 235.800 (or equivalent)

Ampere rating ....800 mA

Size ....5 · 20 mm

Voltage rating ....250 V

Nominal resistance ....0.195 Ω

Physical

Dimensions (including feet) ....18.1 × 15.2 × 4.5 cm (7.1 × 6.0 × 1.8 in.)

Weight ....828 g (1 lb 13 oz)

I/O connector ....One 68-pin male SCSI connector

Screw terminals 68

- Wire gauge......................................14–30 AWG
- Torque..0.5–0.6 N · m (4.43–5.31 lb · in.)

Resistor sockets ....0.032 to 0.038 in. (in diameter)

Maximum Working Voltage

Maximum working voltage refers to the signal voltage plus the common-mode voltage.

Channel-to-earth ....30 V_{rms}/42 V_{pk}/60 VDC

Channel-to-channel................................30 V_{rms}/42 V_{pk}/60 VDC

Environmental

The SCB-68 is intended for indoor use only.

Operating temperature ....0 to 70 °C

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

Relative humidity ....5 to 90% RH, noncondensing

Pollution Degree (indoor use only)........ 2

Maximum altitude................................. 2,000 meters

Safety

This product meets the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326 (IEC 61326): Class A emissions; Basic immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- AS/NZS CISPR 11: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note For the standards applied to assess the EMC of this product, refer to the *Online Product Certification* section.

Note For EMC compliance, operate this product according to the documentation.

CE Compliance CE

This product meets the essential requirements of applicable European Directives as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

Environmental Management

National Instruments is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial not only to the environment but also to NI customers.

For additional environmental information, refer to the *NI and the Environment* Web page at `ni.com/environment`. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of their life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers and National Instruments WEEE initiatives, visit `ni.com/environment/weee.htm`.

电子信息产品污染控制管理办法 （中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 `ni.com/environment/rohs_china`。(For information about China RoHS compliance, go to `ni.com/environment/rohs_china`.)

B

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- **System Integration**—If you have time constraints, limited in-house technical resources, or other project challenges, National Instruments Alliance Partner members can help. To learn more, call your local NI office or visit `ni.com/alliance`.

- **Declaration of Conformity (DoC)**—A DoC is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electromagnetic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting `ni.com/certification`.

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