# SCXI™

# SCXI-1141/1142/1143 User Manual

## Eight-Channel Lowpass Filter Modules

National Instruments™

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# About This Manual

This manual describes the electrical and mechanical aspects of the SCXI-1141/1142/1143 modules and contains information concerning its installation and operation.

The SCXI-1141/1142/1143 modules are National Instruments Signal Conditioning eXtensions for Instrumentation (SCXI) Series modules. The SCXI-1141/1142/1143 modules have eight configurable channels of differential amplification and filtering.

## Conventions

The following conventions appear 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, DBIO<3..0>. |
|  | 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. |
|  | This icon denotes a warning, which advises you of precautions to take to avoid being electrically shocked. |
| *italic* | Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font 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, and code excerpts. |
| SCXI-1141/1142/1143 | SCXI-1141/1142/1143 refers to the SCXI-1141 module, the SCXI-1142 module, and the SCXI-1143 module. |

# How to Use the Manual Set

The *SCXI-1141/1142/1143 User Manual* is one piece of the documentation set for your SCXI system. You could have any of several types of manuals, depending on the hardware and software in your system. Use the manuals you have as follows:

- *Getting Started with SCXI*—This is the first manual you should read. It gives an overview of the SCXI system and contains the most commonly needed information for the modules, chassis, and software.
- Your SCXI user manuals—Read these manuals next for detailed information about signal connections and module configuration. They also explain in greater detail how the module works and contain application hints.
- Your DAQ hardware user manuals—These manuals have detailed information about the DAQ hardware that plugs into or is connected to your computer. Use these manuals for hardware installation and configuration instructions, specification information about your DAQ hardware, and application hints.
- Software manuals—Examples of software manuals you may have are the LabVIEW and LabWindows/CVI 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, look through the software manuals before you configure your hardware.
- Accessory installation guides or manuals—Consult these guides when you are installing terminal blocks, cable assemblies, or other SCXI accessories.

# 1 Introduction

This chapter describes the SCXI-1141/1142/1143 modules, and lists the contents of your SCXI-1141/1142/1143 kit.

## About the SCXI-1141/1142/1143 Modules

The SCXI-1141/1142/1143 modules have eight lowpass elliptic, Bessel, and Butterworth filters with differential input amplifiers respectively.

You can use the SCXI-1141/1142/1143 modules for antialiasing applications as well as for general-purpose signal amplification and filtering. The SCXI-1141/1142/1143 modules work with National Instruments E Series MIO DAQ devices, and the SCXI-1200 data acquisition and control module. You can control several SCXI-1141/1142/1143 modules in a chassis with one DAQ device and in combination with other SCXI modules. Each SCXI-1141/1142/1143 module can multiplex its channels into a single channel of the DAQ device, although separate outputs are also available. You can multiplex the output of several SCXI-1141/1142/1143 modules into a single channel, thus greatly increasing the number of analog input signals that the DAQ device can digitize.

The SCXI-1304 shielded terminal block has screw terminals for easily connecting signals to the SCXI-1141/1142/1143 modules and is the terminal block recommended for use with this module.

Detailed SCXI-1141/1142/1143 module specifications are in Appendix A, *Specifications*.

# What You Need to Get Started

To set up and use your SCXI-1141/1142/1143 modules, you will need the following:

- ❑ SCXI-1141/1142/1143 module
- ❑ *SCXI-1141/1142/1143 User Manual*
- ❑ NI-DAQ
  - Version 6.5.1 or later for the SCXI-1141 module
  - Version 6.6 or later for the SCXI-1142 and SCXI-1143 modules
- ❑ Recommended: SCXI-1304 or SCXI-1305 terminal block

If your shipment is missing any of the above items, contact National Instruments.

# 2

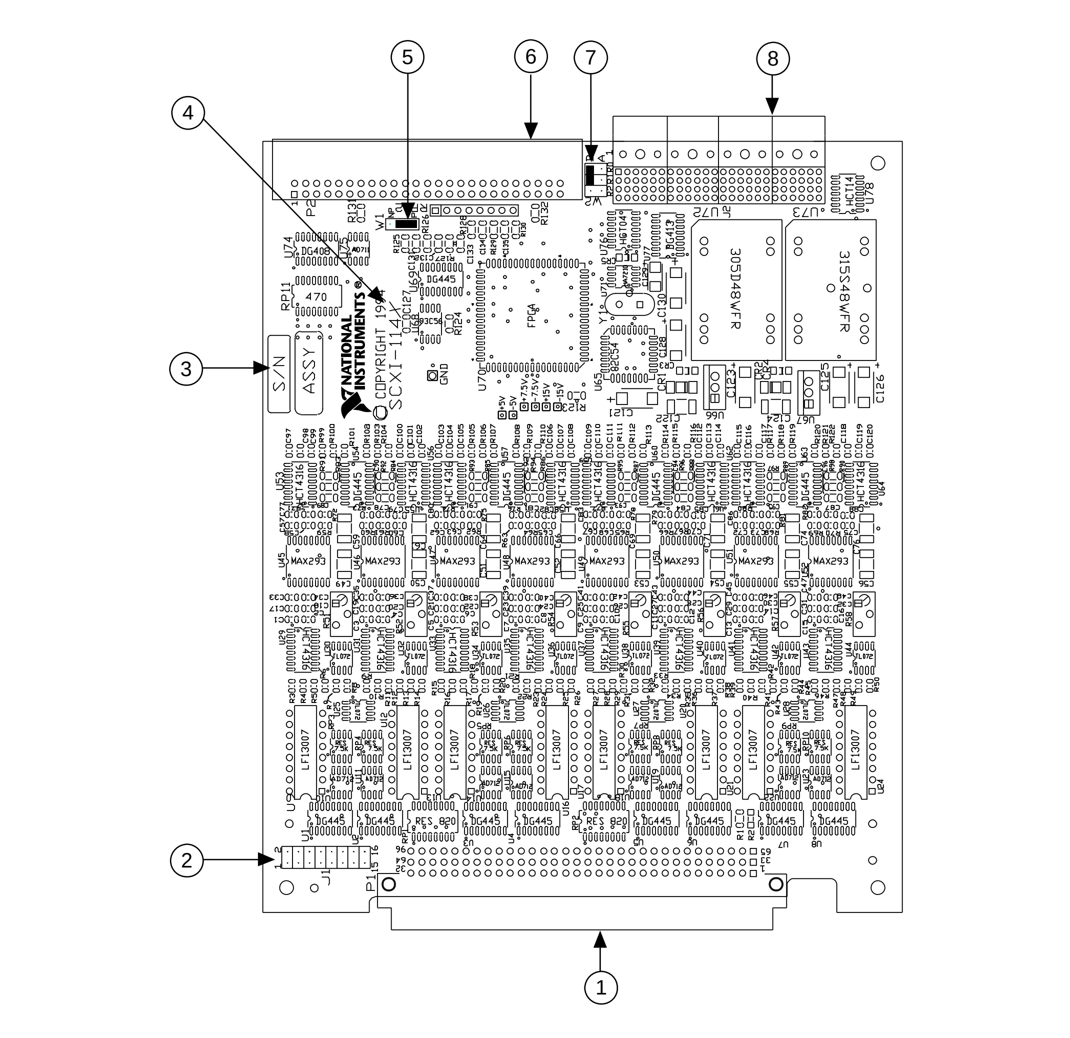
# Configuration and Installation

This chapter describes the SCXI-1141/1142/1143 modules, jumper configurations, installation of the SCXI-1141/1142/1143 modules into an SCXI chassis, and signal connections.

## Module Configuration

The SCXI-1141/1142/1143 modules have two jumpers as shown in Figure 2-1. Jumper W1 is set at the factory for a single-chassis system, and jumper W2 is set at the factory for a differential input DAQ device.

**Note** The factory settings for the SCXI-1141/1142/1143 module jumpers need no adjustment in most applications. The jumpers may need to be changed only when using a multichassis system, when using a DAQ device in single-ended mode, or to change the default grounding and shielding configuration.




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Front Signal Connector | 3 | Serial and Assembly Number | 5 | Jumper W1 | 7 | Jumper W2 |
| 2 | Jumper J1 | 4 | Product Name | 6 | Rear Signal Connector | 8 | SCXIbus Connector |

**Figure 2-1.** SCXI-1141/1142/1143 Modules Parts Locator Diagram

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

**Table 2-1.** Module Configuration for Single or Multichassis Systems

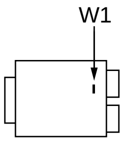
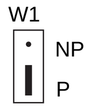
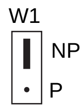
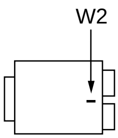
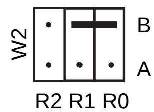
| Jumper | Description | Configuration |
|---|---|---|
|   | Position P (pull up)—Use this setting for a single-chassis system or for the first chassis in a multichassis system. (Factory setting) |   |
| | Position NP (no pull up)—Use this setting for additional chassis in a multichassis system. |   |
| Notes: You can ignore the jumper position if the module in the chassis is not connected directly to the DAQ device.<br>The darkened rectangle indicates the position of the jumper. | | |

**Table 2-2.** Module Grounding and Shielding Configuration

| Jumper | Description | Configuration |
|---|---|---|
|   | Use this setting with DAQ devices in differential mode. |   |
| Note: The darkened rectangle indicates the position of the jumper. | | |

To change the configuration of the module, refer to Figures 2-1 and 2-2 as you perform the following steps:

1. Remove the grounding screw from the rear of the module.
2. Snap out the removable cover by placing a screwdriver in the groove at the bottom of the module and prying downward.
3. Remove the jumpers you want to change and replace them on the appropriate pins.
4. Snap the removable cover back in place.
5. Refasten the grounding screw to ensure proper shielding.

You must use NI-DAQ 6.5.1 or later with the SCXI-1141 module. You must use NI-DAQ 6.6 or later with the SCXI-1142/1143 modules. Use Measurement & Automation Explorer to further configure your module.

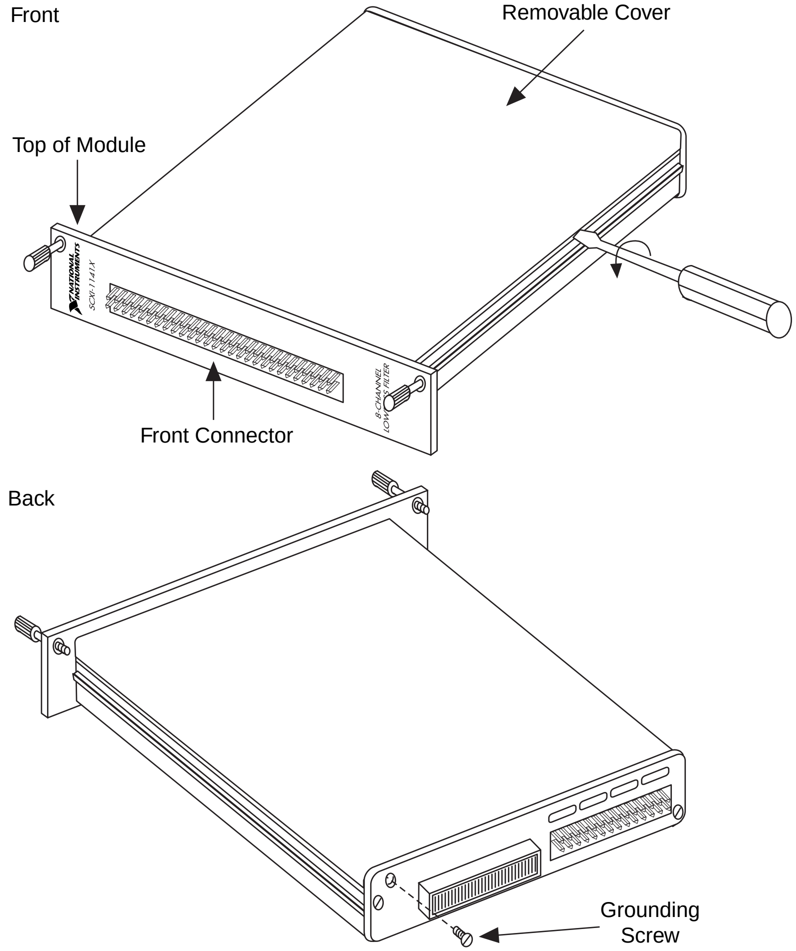



**Figure 2-2.** Removing the SCXI Module Cover

# Supplementary Jumper Configuration Information

The SERDATOUT line on the rear 50-pin connector of the module is used to transmit digital data from the SCXI chassis to the DAQ device. Jumper W1, when set to position P, connects a 2.2 kΩ pullup resistor to the SERDATOUT line as shown in Figure 2-3. An open-collector driver drives the SERDATOUT line. An open-collector output either actively drives low or goes to a high-impedance state, relying on a pullup resistor to make the signal line go high. If too many pullup resistors are attached to the SERDATOUT line, the drivers cannot drive the line low. To prevent this, set jumper W1 to position P on only one of the SCXI-1141/1142/1143 modules that are connected directly to the DAQ device in a multiple chassis system. It does not matter which of the SCXI-1141/1142/1143 modules that are connected directly to the DAQ device has the pullup resistor connected.

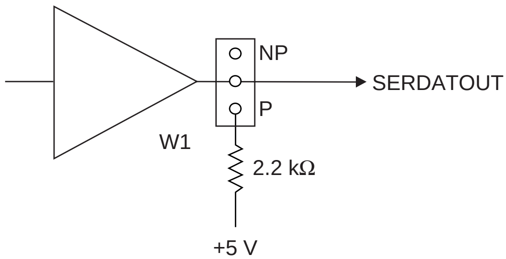



**Figure 2-3.** Jumper W1 Diagram

# Installing the SCXI-1141/1142/1143 Modules

The following section describes how to install your SCXI-1141/1142/1143 modules for use with SCXI chassis and National Instruments DAQ devices.

## Unpacking

Your SCXI-1141/1142/1143 module is shipped in an antistatic package to prevent electrostatic damage to the module. Electrostatic discharge can damage several components on the module. To avoid damaging the module, take the following precautions:

- Ground yourself using a grounding strap or by touching a grounded object, such as an SCXI chassis that is plugged into a power outlet.
- Before removing the module from the package, touch the antistatic package to a metal part of an SCXI chassis that is plugged into a power outlet.
- Remove the module from the package and inspect the module for loose components or any other sign of damage. Notify National Instruments if the module appears damaged in any way. *Do not* install a damaged module in an SCXI chassis.
- *Never* touch the exposed pins of connectors.

## Installing the SCXI-1141/1142/1143 Module in an SCXI Chassis

You need the following items to complete the installation:

- SCXI-1141/1142/1143 modules
- SCXI chassis or PXI combination chassis
- 1/4 in. flathead screwdriver

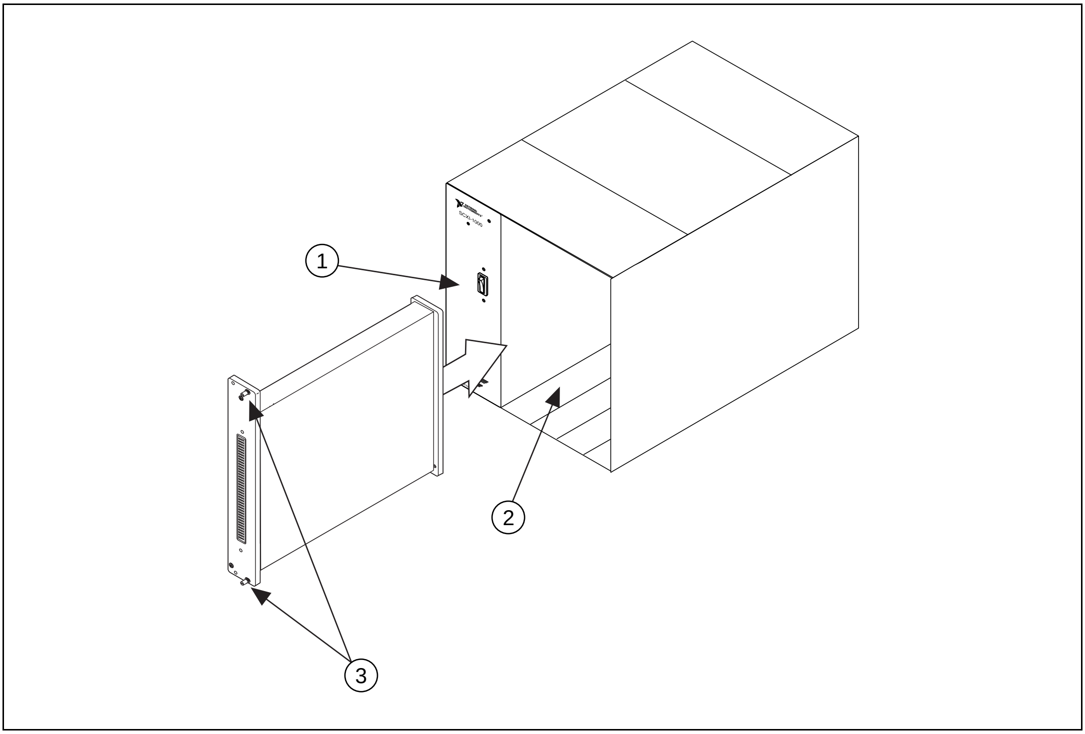
To install your SCXI-1141/1142/1143 module in an SCXI chassis, follow these steps while referring to Figure 2-4:

1. Turn off the computer that contains the DAQ device or disconnect it from the SCXI chassis.
2. Turn off the SCXI chassis.

**Caution** Do *not* insert the SCXI-1141/1142/1143 module into a chassis that is turned on.

3. Insert the SCXI-1141/1142/1143 module into an open slot in the SCXI chassis. Gently guide the module into the slot guides and push it to the back of the slot until the front face of the module is flush with the front of the chassis.

4. Insert any other SCXI modules into the remaining slots in the same manner as described in step 3.
5. Secure all the SCXI modules to the SCXI chassis using both thumbscrews.




| | | | | | |
|---|---|---|---|---|---|
| 1 | SCXI-Chassis Power Switch | 2 | SCXI-Chassis Slots | 3 | SCXI-Module Thumbscrews |

**Figure 2-4.** Installing the SCXI-1141/1142/1143 Module

To complete your SCXI-1141/1142/1143 module installation, follow one of the procedures in the appropriate section that follows.

## Connecting the SCXI-1141/1142/1143 Modules to a DAQ Device for Multiplexed Scanning in an SCXI Chassis

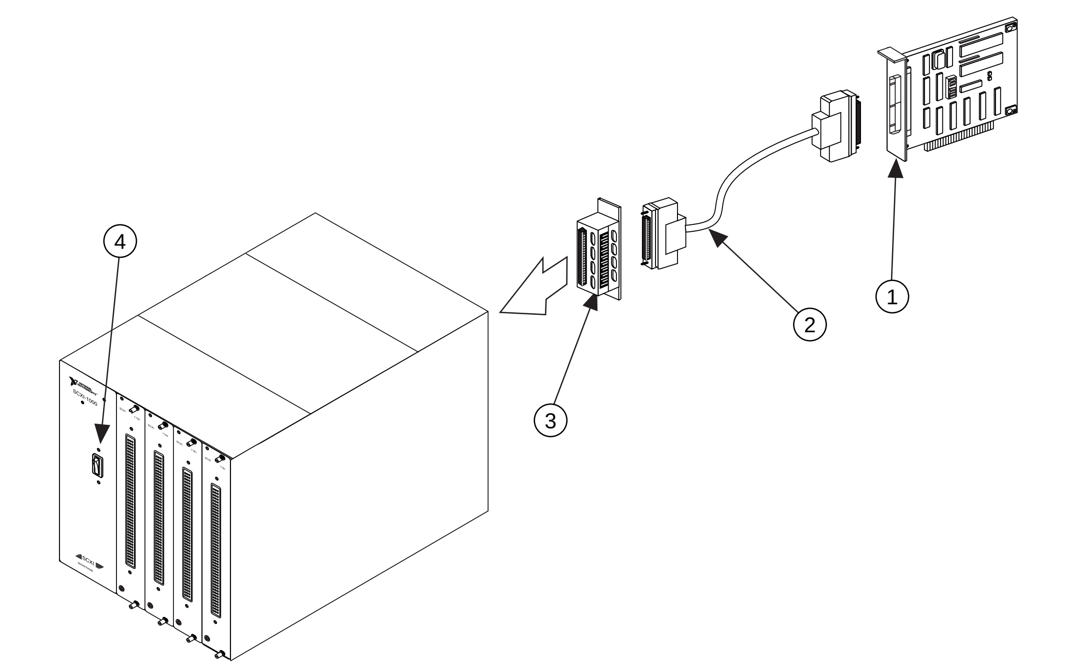
Use this configuration to multiplex all eight input channels and the CJC channel of the SCXI-1141/1142/1143 modules into a single channel of your DAQ device. You need the following items for this installation:

- SCXI chassis with the SCXI modules installed
- SCXI cable assembly, which consists of a cable adapter and a cable
- National Instruments DAQ device installed in your computer
- 1/4 in. flathead screwdriver

Consult your SCXI chassis documentation, other SCXI module documentation, and DAQ device documentation for additional instructions and warnings. Your SCXI-1141/1142/1143 modules and any other SCXI modules should already be installed in the chassis according to their installation instructions.

You can connect the DAQ device to most modules in the chassis that are configured for multiplexed operation. However, if you use an SCXI-1140, it must be the cabled module. To connect these modules to the DAQ device for multiplexed operation, follow these steps while referring to Figure 2-5:

1. Turn off the SCXI chassis and the computer containing the DAQ device.
2. Insert the cable adapter into the back of the SCXI chassis aligned with the module that is to be connected to the DAQ device. See the installation guide for your cable assembly for more information.
3. Connect the cable to the back of the cable adapter ensuring that the cable fits securely.
4. Connect the other end of the cable to the DAQ device that you use to control the SCXI system.
5. Check the cable installation, making sure the connectors are securely fastened at both ends.
6. Turn on the SCXI chassis.
7. Turn on the computer.
8. If you have already installed the appropriate software, you are ready to configure the SCXI-1141/1142/1143 modules for multiplexed mode operation. See *Configuration and Self-Test* later in this chapter for information on configuring and testing the installation.




| | | |
|---|---|---|
| 1 DAQ Device | 3 Cable Adapter | 4 SCXI Chassis Power Switch |
| 2 Cable | | |

**Figure 2-5.** Connecting the SCXI Modules for Multiplexed Operation

## Connecting the SCXI-1141/1142/1143 Modules to a DAQ Device for Multiplexed Scanning in a PXI Combination Chassis

Use this configuration to multiplex all eight channels and the CJC channel of your SCXI-1141/1142/1143 modules into a single channel of your DAQ device in a combination PXI chassis. You need the following items for this installation:

- PXI combination chassis with the SCXI modules installed
- National Instruments PXI DAQ device installed in the right-most slot

Consult your PXI chassis documentation, other SCXI module documentation, and DAQ device documentation for additional instructions and warnings. You should have already installed your SCXI-1141/1142/1143 modules and any other SCXI modules in the chassis according to their installation instructions. To connect the

SCXI-1141/1142/1143 modules with a DAQ device in a PXI combination chassis for multiplexed scanning, follow these steps:

1. No cables are required for this connection if the National Instruments PXI DAQ device is installed in the right-most slot. This device can be configured to control the SCXI system. If the DAQ device for controlling the SCXI system is not installed in the right-most slot of the PXI combination chassis, configure the system as described earlier in *Connecting the SCXI-1141/1142/1143 Modules to a DAQ Device for Multiplexed Scanning in an SCXI Chassis*.
2. Turn on the SCXI chassis.

If you have already installed the appropriate software, you are ready to configure the SCXI-1141/1142/1143 modules for multiplexed scanning. See *Configuration and Self-Test* later in this chapter for information on configuring and testing the installation.

## Connecting the SCXI-1141/1142/1143 Modules to a DAQ Device for Parallel Scanning

Use this configuration to route all eight channels of your SCXI-1141/1142/1143 modules in parallel to eight input channels of the DAQ device with which it is connected. In this mode, you cannot directly access the CJC channel. You can use this mode if you require a higher scanning rate than your SCXI system allows. You need the following items to complete this installation:

- SCXI chassis or PXI combination chassis with the SCXI-1141/1142/1143 module(s) installed
- For each SCXI-1141/1142/1143 module operating in parallel mode, you need one each of the following:
  - National Instruments DAQ device
  - SCXI cable assembly, which consists of a cable adapter and a cable
- 1/4 in. flathead screwdriver

Consult the documentation for your SCXI/PXI chassis and accessories for additional instructions and warnings. All modules should already be installed according to their installation instructions. To set up the SCXI-1141/1142/1143 module for access by a DAQ device in parallel mode, follow these steps while referring to Figure 2-5:

1. Turn off the SCXI chassis and the computer containing the DAQ device.
2. Insert the cable adapter into the back of the SCXI-1141/1142/1143 module that is to be accessed in parallel mode by the DAQ device, as described in the appropriate installation guide for your cable assembly.
3. Connect the cable to the back of the cable adapter and ensure that the cable fits securely.
4. Connect the other end of the cable to the National Instruments DAQ device that you want to use to access the SCXI-1141/1142/1143 module in parallel mode.
5. Connect additional SCXI-1141/1142/1143 modules intended for parallel mode operation by repeating steps 2 through 4.
6. Check the installation, making sure the connectors are securely fastened at both ends.
7. Turn on the SCXI chassis.
8. Turn on the computer.
9. If you have already installed the appropriate software, you are ready to configure the SCXI-1141/1142/1143 modules you configured for parallel mode operation. See *Configuration and Self-Test* later in this chapter.

You are now ready to configure and test the SCXI-1141/1142/1143 modules using Measurement & Automation Explorer.

# Configuration and Self-Test

Use the National Instruments Measurement & Automation Explorer to configure and test your SCXI-1141/1142/1143 modules. If you need help during the configuration process, open the Measurement & Automation Help file by selecting **Help Topics** from the **Help** menu. Follow these steps to configure your SCXI system:

1. Double-click the **Measurement & Automation Explorer** icon on your desktop.

If you have added new modules to an existing chassis, go to step 4. If you inserted modules into an empty chassis, go to step 2.

2. Add a new chassis by right-clicking on **Devices and Interfaces** and selecting **Insert** from the pop-up menu. Select the appropriate chassis from the list box and click **OK**.
3. Configure the chassis by selecting a **Chassis ID**. This is an integer value you choose to uniquely identify the chassis for programming and scanning.
   a. Select the **Chassis Address**. This is needed to address the chassis in a multichassis SCXI system.
      - Unless you are using multiple chassis with the same DAQ device, select a Chassis Address of zero, which is the factory default setting for all SCXI chassis.
      - If you are using multiple chassis, refer to your SCXI chassis user manual for further information.
      - For remote SCXI chassis, you also need to select the **Baud Rate** and **COM Port**.

   b. After completing the chassis configuration, click **Next.**
4. You now have the choice of automatically detecting which modules are installed in the chassis or manually adding them:
   - If you have just added the chassis to **Devices and Interfaces** and are using an E Series MIO DAQ device, you can automatically detect the modules.
   - If the chassis is already listed in **Devices and Interfaces**, you must add new modules manually.

Go to the appropriate section that follows to continue the software configuration of your chassis.

## Auto-Detecting Modules

If you select auto-detect, you must have your chassis connected to your DAQ device, except in the case of a remote chassis. For remote chassis, connect to the computer using a serial-port cable.

To auto-detect your SCXI module(s), follow these steps:

1. Make sure the chassis power is turned on.
2. Perform the steps in the *Configuration and Self-Test* section if you have not already done so.
3. Select **Yes** under **Auto-Detect modules?** and click **Next**. If your chassis is a remote SCXI chassis, go to step 6.
4. Select your communication path and click **Next**.
5. If modules were detected, select the module connected to your DAQ device as your communication path.
6. Click **Finish**.

Your Measurement & Automation Explorer software should now recognize your SCXI chassis and SCXI module(s). If the software did not recognize your module(s), check your cable connections and retry auto-detecting or try installing the modules manually before taking troubleshooting measures. If the software recognized any module as an SCXI custom module, you may be using the wrong version of NI-DAQ.

## Manually Adding Modules

If you did not auto-detect your SCXI modules, you must add each of your modules separately. If you are still in the **Chassis Configuration** window, select **No** under **Auto-Detect modules?** and click **Finish**. Use the following steps to manually add modules.

1. Display the list of installed devices and interfaces by clicking the **+** next to the **Devices and Interfaces** icon.
2. The chassis you selected is displayed in the list. Display the list of modules in the chassis by clicking the **+** next to the chassis description.
3. Right-click on the appropriate installation slot and select **Insert**.
4. Select the module installed in that slot and click **Next**. If the appropriate module name does not appear on the list, you may be using the incorrect version of NI-DAQ.

5. Configure your module.
   a. Complete one of the following steps depending on whether your SCXI module is connected to a DAQ device.
      - If the selected module is connected to a DAQ device, select that device by using the **Connected to** control.
      - If you want this DAQ device to control the chassis, confirm that there is a check in the checkbox labeled **This device will control the chassis.**
      - If it is not connected to a National Instruments device, select **None**.
   b. Select the appropriate scanning mode for your SCXI-1141/1142/1143 module by using the **Operating Mode** control. If parallel mode is selected, the checkbox labeled **This device will control the chassis** automatically becomes deselected. Click **Next.**
   c. Select the appropriate default gain and filter settings for each channel on the SCXI-1141/1142/1143 module. Click **Next**.
   d. Select the terminal block you are using with this module. If the terminal block you are using has configurable gain, click **Back** to modify the terminal block gain settings.
   e. When you have completed configuration, click **Finish**.

If you need to manually install more SCXI-1141/1142/1143 modules in your chassis, repeat steps 3 through 5 to configure each module.

Your SCXI chassis and SCXI module(s) should now be configured properly. If you need to make changes in your module configuration, see the *Configuring the SCXI-1141/1142/1143 Modules* section. If your configuration is complete, test the system as described in *Self-Test Verification* section to ensure that your SCXI system is communicating properly with the DAQ device.

## Configuring the SCXI-1141/1142/1143 Modules

Use Measurement & Automation Explorer to configure your SCXI-1141/1142/1143 modules after auto-detection or to alter your original configuration selections. Perform the following steps to configure your SCXI-1141/1142/1143 modules:

1. Double-click the **Measurement & Automation Explorer** icon on your desktop.
2. Display the list of installed devices and interfaces by clicking the **+** next to the **Devices and Interfaces** icon.
3. Locate the SCXI chassis in the list. Display the list of modules in the chassis by clicking the **+** next to the chassis description.
4. Right-click on the SCXI-1141/1142/1143 module you want to configure and select **Properties**. Click on the **General** tab.
   a. Complete one of the following steps depending on whether your SCXI module is connected to a DAQ device.
      - If the module you are configuring is connected to a DAQ device, select the cabled device by using the **Connected to** control.
      - If you want this DAQ device to control the chassis, confirm that there is a check in the checkbox labeled **This device will control the chassis.**
      - If the module you are configuring is not connected to a DAQ device, select **None**.

   b. Select the appropriate mode for your SCXI-1141/1142/1143 module by using the **Operating Mode** control. If parallel mode is selected, the checkbox labeled **This device will control the chassis** is deselected automatically.
5. Click on the **Channel** tab. Select the appropriate gain and filter settings for each channel on the SCXI-1141/1142/1143 module.
6. Click on the **Accessory** tab. Select the terminal block you are using for this module.
7. When all of your configuration selections are completed, click **OK**.

Your SCXI chassis and SCXI module(s) should now be configured properly. You should now test the system in the section that follows to ensure that your SCXI system is communicating properly with the DAQ device.

## Self-Test Verification

To test the successful configuration of your system, follow the steps that follow after opening Measurement & Automation Explorer:

1. Verify that the chassis power is on and that the chassis is correctly connected to a DAQ device.
2. Display the list of installed devices and interfaces by clicking the **+** next to the **Devices and Interfaces** icon.
3. From the list that appears, locate the chassis you want to test. Right-click on the chassis and click **Test**.
4. If the communication test is successful, a message **The chassis has been verified** appears. Click **OK**.

Your SCXI system should now operate properly with your application development environment (ADE) software. If the test did not complete successfully, see the *Troubleshooting Self-Test Verification* section for troubleshooting steps.

## Troubleshooting Self-Test Verification

If the configuration software does not verify your chassis configuration, perform the following steps to successfully complete your system configuration:

- If you get the warning message, **Unable to test chassis at this time**, you have not designated at least one module as connected to a DAQ device. Return to the *Configuring the SCXI-1141/1142/1143 Modules* section of this document and change the configuration of the cabled module in your system from **Connected to: None** to **Connected to: Device *x***.
- If you get the warning message **Failed to find** followed by the module codes and the message **Unable to communicate with chassis**, take the following troubleshooting actions:
    a. Make sure that the SCXI chassis is powered on.
    b. Make sure the cable to the SCXI system is properly connected to a DAQ device.
    c. Inspect the DAQ device connector and SCXI cable adapter for any bent pins.
    d. Make sure you are using the correct National Instruments cable.
    e. Test your DAQ device to verify it is working properly. See your DAQ device user manual for more information.

- If you get the warning message **Failed to find** followed by module codes and then the message **Instead found: module with ID 0X*xx***, return to *Configuring the SCXI-1141/1142/1143 Modules* and make sure the correct module is in the specified slot. Delete the incorrect module as described in *Removing the SCXI-1141/1142/1143 Module from Measurement & Automation Explorer* and then add the correct module as described in *Manually Adding Modules*.
- If you get the warning message **Failed to find** followed by a module code and then the message **Slot *x* is empty**, check to see if the configured module is installed in the specified slot. If not, install the module by referring to the *Installing the SCXI-1141/1142/1143 Module in an SCXI Chassis* section. If the module is installed in the correct slot, turn off the chassis, remove the module as specified in *Removing the SCXI-1141/1142/1143 Modules from an SCXI Chassis*, and verify that no connector pins are bent on the rear signal connector. Reinstall the module as shown in the *Installing the SCXI-1141/1142/1143 Module in an SCXI Chassis* section, ensuring that the module is properly aligned in the slot.
- After checking the preceding items, return to the *Self-Test Verification* section and retest your SCXI system.

# Removing the SCXI-1141/1142/1143 Modules

This section describes how to remove the SCXI-1141/1142/1143 modules from an SCXI chassis and from Measurement & Automation Explorer.

## Removing the SCXI-1141/1142/1143 Modules from an SCXI Chassis

Only a qualified person who has read and understands all the safety information in this manual should remove an SCXI module. You need the following items to complete this task:

- SCXI chassis or PXI combination chassis with the SCXI-1141/1142/1143 module(s) installed
- 1/4 in. flathead screwdriver

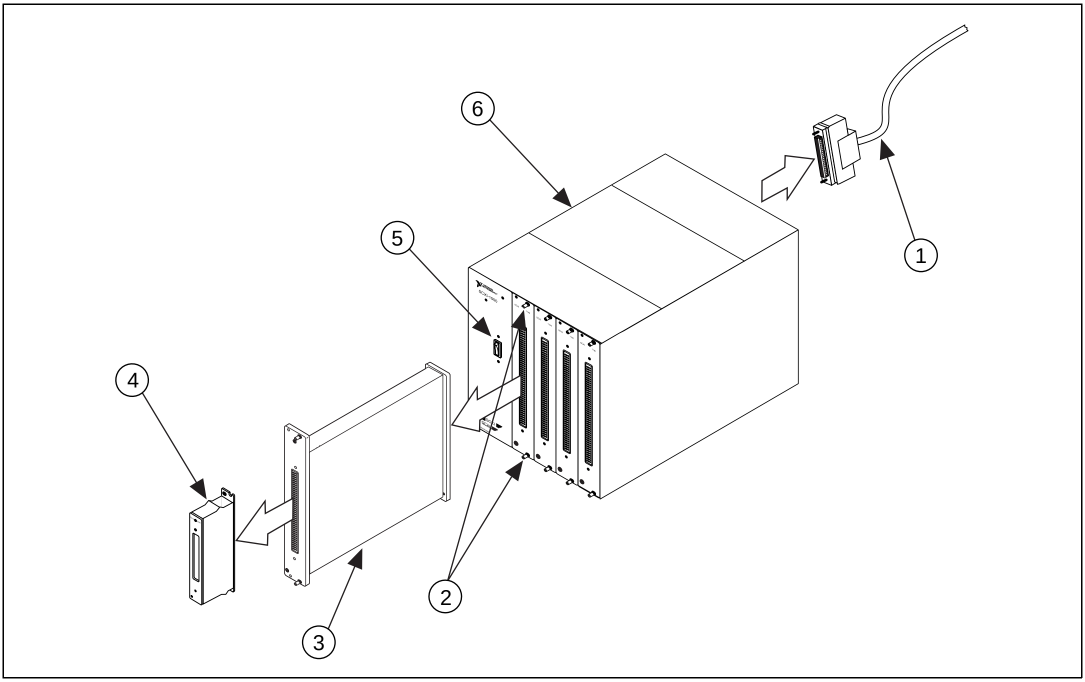
Consult the documentation for your SCXI/PXI chassis and accessories for additional instructions and warnings. To remove the SCXI-1141/1142/1143 module from an SCXI chassis, perform the following steps while referring to Figure 2-6:

1. Disconnect the cable running from the SCXI module to the DAQ device.
2. Remove all signals from terminal blocks connected to the SCXI-1141/1142/1143 module.

**Caution** Read the safety information in the terminal block installation guide before adding or removing any signals from the SCXI module or terminal blocks.

3. Remove any terminal blocks that connect to the SCXI-1141/1142/1143 module.
4. Turn off the SCXI chassis power. Do not remove the SCXI-1141/1142/1143 module from a chassis that is turned on.
5. Rotate the thumbscrews securing the SCXI-1141/1142/1143 module to the chassis counter-clockwise until they are loose, but do not completely remove them.

6. Remove the SCXI-1141/1142/1143 module by pulling steadily on both thumbscrews until the module slides completely out.




| | | | | | |
|---|---|---|---|---|---|
| 1 | Cable | 3 | SCXI-1141/1142/1143 Module | 5 | SCXI Chassis Power Switch |
| 2 | SCXI Module Thumbscrews | 4 | Terminal Block | 6 | SCXI Chassis |

**Figure 2-6.** Removing the SCXI-1141/1142/1143 Module

## Removing the SCXI-1141/1142/1143 Module from Measurement & Automation Explorer

To remove a module from Measurement & Automation Explorer, open Measurement Explorer and perform the following steps:

1. Display the list of installed devices and interfaces by clicking the **+** next to the **Devices and Interfaces** icon.
2. Locate the SCXI chassis in the list. Display the list of modules in the chassis by clicking the **+** next to the **Chassis** icon.
3. Right-click on the module or chassis you want to delete and click **Delete**.
4. You will be presented with a confirmation window. Click **Yes** to continue deleting the module or chassis or **No** to cancel this action.

**Note** Deleting the SCXI chassis deletes all modules in the chassis. All configuration information for these modules is also lost.

Your SCXI chassis and/or SCXI module(s) should now be removed from the list of installed devices in Measurement & Automation Explorer.

# 3

# Signal Connections

This chapter describes input and output signal connections to the SCXI-1141/1142/1143 modules through their front and rear signal connectors.

**Warning** Connections that exceed any of the maximum ratings of input or output signals on the SCXI-1141/1142/1143 modules can damage the SCXI-1141/1142/1143 modules, the SCXIbus, any connected DAQ device, and the computer with which the DAQ device is used. National Instruments is not liable for any damage resulting from such signal connections.

## Front Connector

Figure 3-1 shows the pin assignments for the SCXI-1141/1142/1143 modules front connector. Pins without signal labels are not connected.

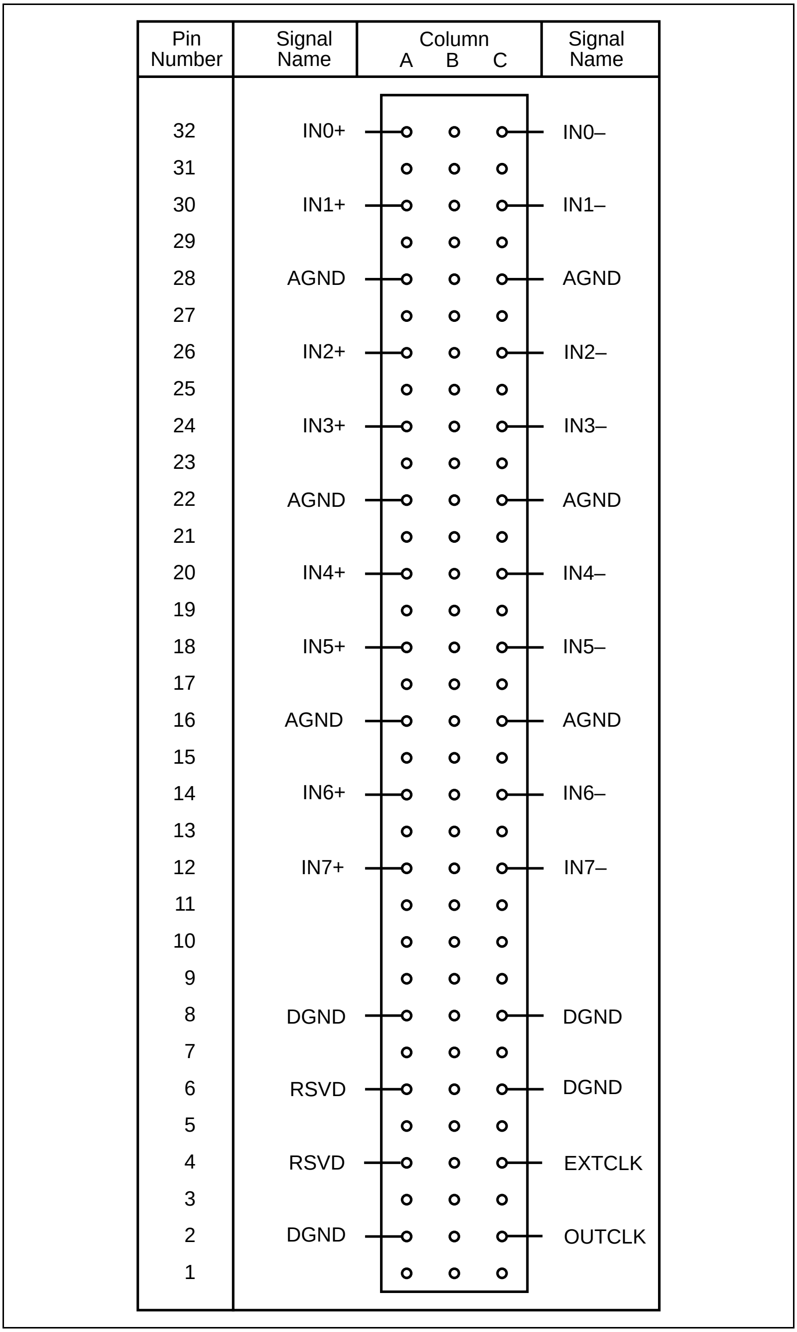



**Figure 3-1.** SCXI-1141/1142/1143 Modules Front Connector

## Front Connector Signal Descriptions

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

## Analog Input Channels

The SCXI-1141/1142/1143 modules instrumentation amplifiers can reject any voltage within their common-mode input range caused by ground-potential differences between the signal source and the module. In addition, the amplifiers can reject common-mode noise pickup in the leads connecting the signal sources to the SCXI-1141/1142/1143 modules. However, you should take care to minimize noise pickup. The common-mode rejection of the instrumentation amplifiers decreases significantly at high frequencies. The amplifiers do not reject normal-mode noise.

The maximum differential input voltage range of the SCXI-1141/1142/1143 modules instrumentation amplifiers is a function of the gain of the amplifiers, G, and is equal to 5 V/G. The common-mode input range of the SCXI-1141/1142/1143 modules, however, is not a function of gain—the differential input amplifier will reject common-mode signals as long as the signal at both inputs is within ±5 V of the module analog ground. The inputs are protected against maximum input voltages of up to ±15 V powered off and ±30 V powered on.

**Warning** Exceeding the differential or common-mode input voltage limits will distort input signals. Exceeding the maximum common-mode input voltage rating can damage the SCXI-1141/1142/1143 modules, the SCXIbus, and the DAQ device. National Instruments is *not* liable for any damage resulting from such signal connections.

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

**Note** The recommended SCXI-1304 or SCXI-1305 terminal block has all necessary circuitry for AC or DC coupling and for floating or ground-referenced signals. The *SCXI-1304 AC/DC Coupling Terminal Block Installation Guide* and *SCXI-1305 AC/DC Coupling BNC Terminal Block Installation Guide* have instructions for signal connection. Figures 3-2 through 3-6 provide supplemental information on connecting signals to the SCXI-1141/1142/1143 modules.

Figure 3-2 illustrates how to connect a ground-referenced signal source to an SCXI-1141/1142/1143 modules channel.

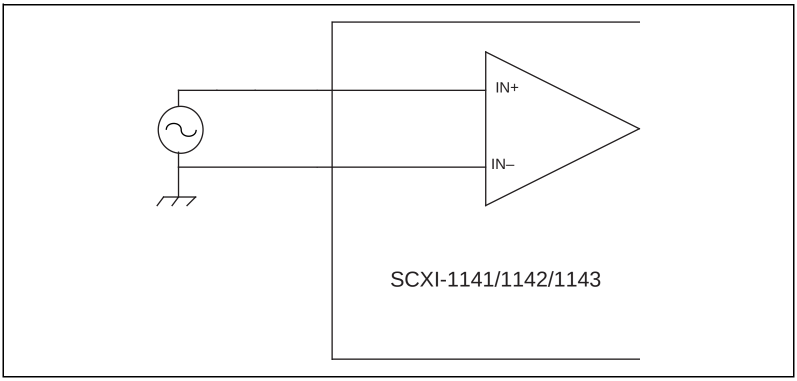



**Figure 3-2.** Ground-Referenced Signal Connection

Figure 3-3 illustrates how to connect a non-referenced (floating) signal source to an SCXI channel.

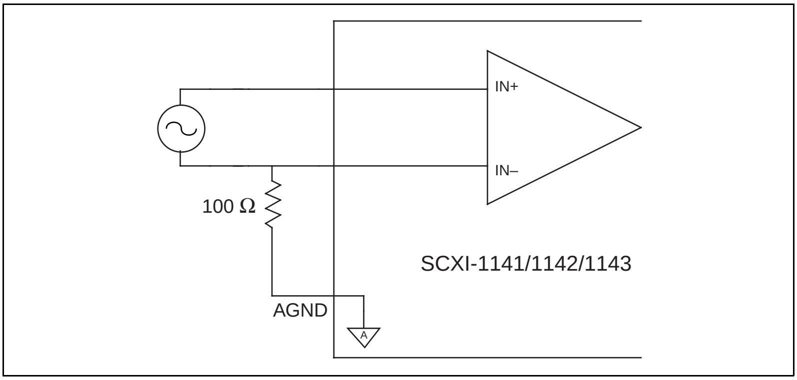



**Figure 3-3.** Floating Signal Connection

For AC-coupled signals, connect an external resistor from the AC-coupled input channel to ground. This provides a DC path for the amplifier input bias current. Typical resistor values range from 100 kΩ to 10 MΩ. This solution, although necessary, lowers the input impedance of the channel and introduces an additional DC offset voltage proportional to the product of the input bias current and the resistor value used. The inputs of the SCXI-1141/1142/1143 modules have a typical bias current of about ±200 pA. Using a 1 MΩ resistor results in ±500 µV of offset, which is insignificant in most applications. However, if larger-valued bias resistors are used, significant input offset may result. Lower-valued bias resistors increase loading of the source, which can result in gain error.

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

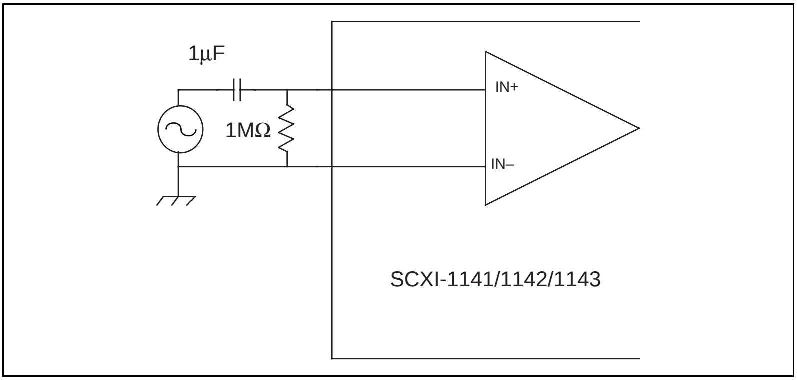



**Figure 3-4.** Ground-Referenced AC-Coupled Signal Connection

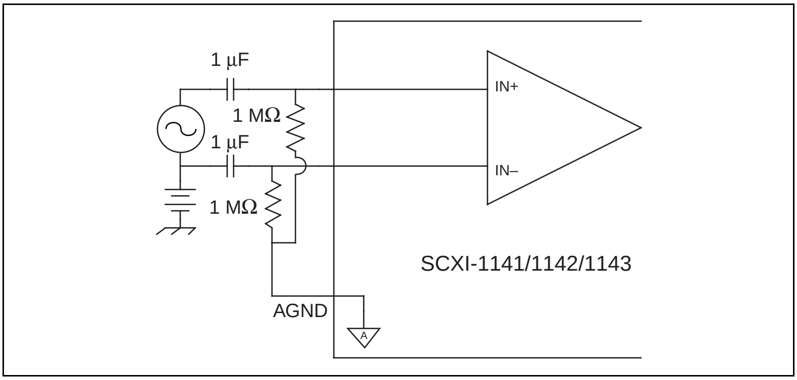



**Figure 3-5.** Ground-Offset AC-Coupled Signal Connection

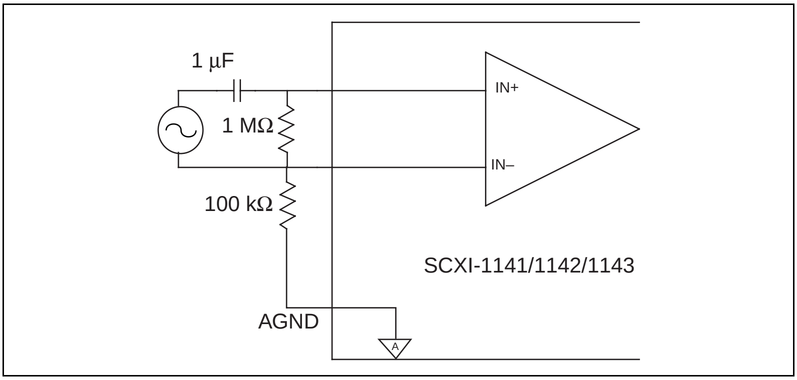



**Figure 3-6.** Floating AC-Coupled Signal Connection

# Digital Input and Output

You can use the EXTCLK input pin on the front connector of the SCXI-1141/1142/1143 modules to control filter cutoff frequency for special purposes. The clock should be a TTL-logic-level or CMOS-logic-level square wave, with a frequency of less than 10 MHz and at least 100 times the desired cutoff frequency. The absolute maximum input voltage for the EXTCLK pin is 5.5 V with respect to DGND; the minimum input voltage is –0.5 V.

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

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

# Rear Signal Connector

**Note** If you will be using the SCXI-1141/1142/1143 modules with a National Instruments DAQ device and SCXI cable assembly, you do not need to read the remainder of this chapter. If you will also be using the SCXI-1180 feedthrough panel, the SCXI-1343 rear screw-terminal adapter, or the SCXI-1351 one-slot cable extender with the SCXI-1141/1142/1143 modules, you should read this section.

Figure 3-7 shows the pin assignments for the SCXI-1141/1142/1143 modules rear signal connector. Pins without signal labels are not connected.

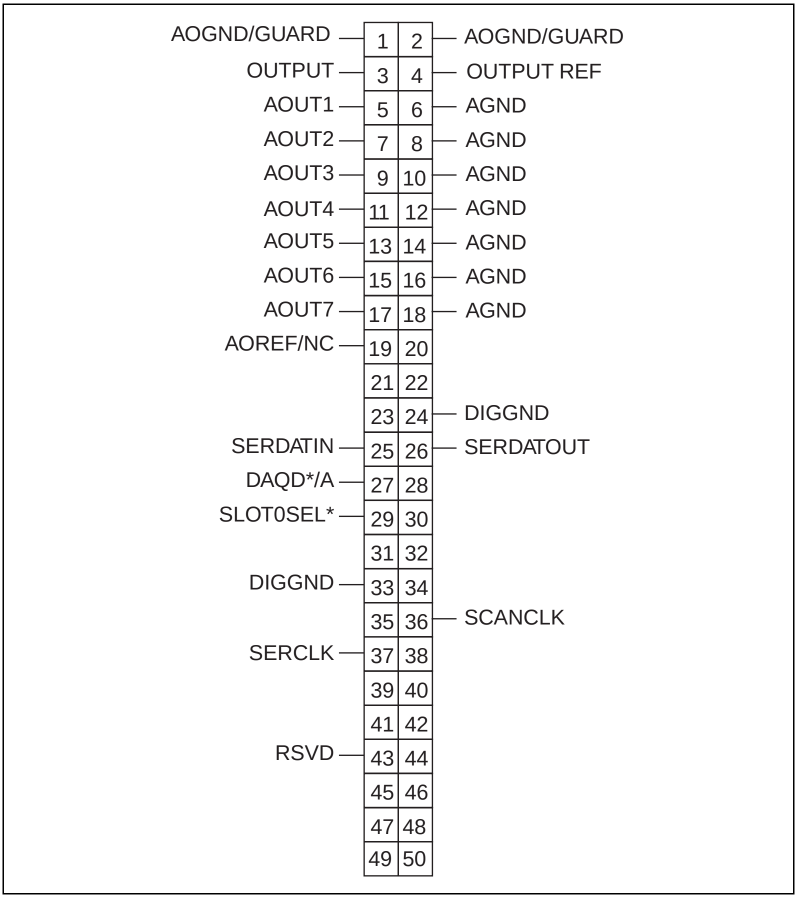



**Figure 3-7.** SCXI-1141/1142/1143 Modules Rear Signal Connector

## Rear Signal Connection Descriptions

| Pin | Signal Name | Description |
|---|---|---|
| 1, 2 | AOGND/GUARD | Analog Output Ground—These pins are connected to the module analog ground when jumper W2 is in position AB-R0. These pins are connected to the SCXIbus guard when W2 is in position R0R1-A. |
| 3 | OUTPUT | Output—This is the main module analog output. In multiplexed mode, the outputs of all eight channels appear here in sequence. Outputs from other modules can also appear here through the analog bus. In parallel mode, this is the output of channel 0. |
| 5, 7, 9, 11, 13, 15, 17 | AOUT<1..7> | Analog Outputs—These pins are the outputs of channels 1 through 7, regardless of the scanning mode. |
| 19 | AOREF/NC | Analog Output Reference/No Connect—This pin is connected to the output reference when jumper W2 is in position AB-R2. Otherwise, this pin is unconnected. |
| 25 | SERDATIN | Serial Data In—This signal taps into the SCXIbus MOSI line to send serial input data to a module or Slot 0. |
| 27 | DAQD*/A | Board Data/Address Line—This signal taps into the SCXIbus D*/A line to indicate to the module whether the incoming serial stream is data or address information. |
| 29 | SLOT0SEL* | Slot 0 Select—This signal taps into the SCXIbus INTR* line to indicate whether the information on MOSI is being sent to a module or Slot 0. |
| 24, 33 | DIGGND | Digital Ground—These pins supply the reference for DAQ digital signals and are tied to the module digital ground. |
| 37 | SERCLK | Serial Clock—This signal taps into the SCXIbus SPICLK line to clock the data on the MOSI and MISO lines. |
| 43 | RSVD | Reserved. |
| 4 | OUTPUT REF | Output Reference—This pin connects to the module analog ground unless an output from another module is selected through the analog bus, in which case the pins connect to the analog ground for the selected module. |

| Pin | Signal Name | Description |
|---|---|---|
| 6, 8, 10, 12, 14, 16, 18 | AGND | Analog Ground—These pins connect to the module analog ground. They are used as the reference points for AOUT1 through AOUT7. |
| 26 | SERDATOUT | Serial Data Out—This signal taps into the SCXIbus MISO line to accept serial output data from a module. |
| 36 | SCANCLK | Scan Clock—The signal at this pin indicates to the SCXI-1141/1142/1143 modules that a sample has been taken by the DAQ device and causes the SCXI-1141/1142/1143 modules to change channels. |
| All other pins are not connected.<br>* means the signal is asserted low. | | |

The signals on the rear signal connector can be classified as analog output signals, digital I/O, or timing I/O signals.

## Analog Output Signal Connections

Pins 3 through 19 of the rear signal connector are analog output signal pins. Pin 3 is the main output, and pin 4 is its reference signal. All eight channels are multiplexed onto this output when the module is software-configured for multiplexed scanning mode. In parallel scanning mode, the output of pin 3 simply becomes the output of one selected channel. Channel 0 is the power-up and reset default. When scanning multiple modules, you can also connect this output to the SCXIbus analog bus and the analog bus will drive this output.

Pins 5, 7, 9, 11, 13, 15, and 17 are direct outputs from channels 1 through 7, respectively. In parallel mode, all eight channels are available simultaneously at the rear connector. Pins 6, 8, 10, 12, 14, 16, and 18 are the reference signals for outputs 1 through 7.

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

**Warning** The SCXI-1141/1142/1143 modules analog outputs are not overvoltage protected, although they are short-circuit protected. Applying external voltage to these outputs may result in damage to the SCXI-1141/1142/1143 modules. National Instruments is *not* liable for any damage resulting from such signal connections.

## Digital I/O Signal Connections

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

The digital input signals are pins 25, 27, 29, and 37. Each digital line emulates the SCXIbus communication signals as follows:

- Pin 25 is SERDATIN and is equivalent to the SCXIbus MOSI serial data input line.
- Pin 27 is DAQD*/A and is equivalent to the SCXIbus D*/A line. Pin 27 indicates to the module whether the incoming serial stream on SERDATIN is data (DAQD*/A = 0) or address (DAQD*/A = 1) information.
- Pin 29 is SLOT0SEL* and is equivalent to the SCXIbus INTR* line. Pin 29 indicates whether the data on the SERDATIN line is being sent to Slot 0 (SLOT0SEL* = 0) or to a module (SLOT0SEL* = 1).
- Pin 37 is SERCLK and is equivalent to the SCXIbus SPICLK line. Pin 37 is used to clock the serial data on the SERDATIN line into the module registers.

The digital output signal is pin 26. Pin 26 is SERDATOUT and is equivalent to the SCXIbus MISO serial data output line.

The digital I/O signals of the SCXI-1141/1142/1143 modules correspond to the digital I/O lines of an E Series MIO DAQ device. Table 3-1 lists the equivalencies.

**Table 3-1.** SCXIbus to SCXI-1141/1142/1143 Modules Rear Signal Connector to DAQ Device Pin Equivalencies

| SCXIbus Line | SCXI-1141/1142/1143 Rear Signal Connector | E Series MIO DAQ Device |
|---|---|---|
| MOSI | SERDATIN | DIO0 |
| D*/A | DAQD*/A | DIO1 |
| INTR* | SLOT0SEL* | DIO2 |
| SPICLK | SERCLK | EXTSTROBE* |
| MISO | SERDATOUT | DIO4 |
| * means the signal is asserted low | | |

The digital timing signals are pins 36 and 43:

- Pin 36 is SCANCLK, the signal used as a clock for the SCXI-1141/1142/1143 modules multiplexer counter. The DAQ device will pulse this signal at the end of each conversion if the module is in multiplexed mode.
- Pin 43 is a reserved digital input.

# 4

# Theory of Operation

This chapter contains an overview of the SCXI-1141/1142/1143 modules and explains the operation of each functional unit of the SCXI-1141/1142/1143 modules.

## Functional Overview

The SCXI-1141/1142/1143 modules have eight software-controlled input channels that amplify and filter signals. Each channel has an output range of ±5 V and has an input amplifier with gains of 1, 2, 5, 10, 20, 50, and 100. Each amplifier gain can be independently set. The analog inputs are overvoltage protected. The SCXI-1141/1142/1143 modules filters are lowpass, sharp rolloff, 8th-order elliptic, Bessel, and Butterworth filters that can have a cutoff frequency from 10 Hz to 25 kHz. All eight filters have the same cutoff frequency. The outputs of all eight channels are available at the rear connector.

The major components of the SCXI-1141/1142/1143 modules are as follows:

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

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

### Power-Up State

When the SCXI-1141/1142/1143 module is powered up or reset through software or the SCXI chassis reset button, the following states are defined:

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

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

The block diagram in Figure 4-1 illustrates the key functional components of the SCXI-1141/1142/1143 modules.

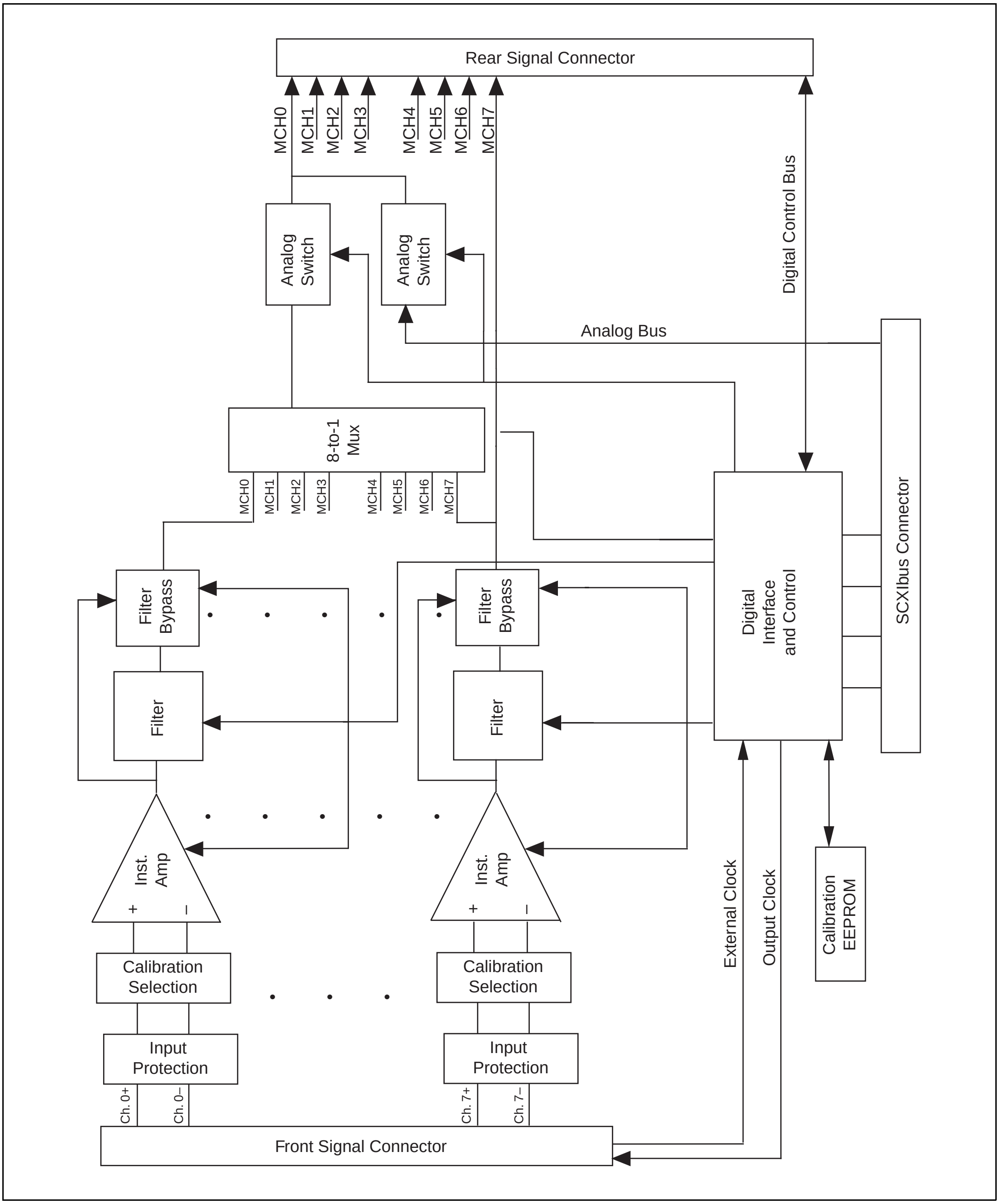



**Figure 4-1.** SCXI-1141/1142/1143 Modules Block Diagram

# Digital Control Circuitry

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

The Module ID register contains 20 (hex) for the SCXI-1141module, 35 (hex) for the SCXI-1142 module, and 34 (hex) for the SCXI-1143 module. You can read this module ID over the SCXIbus to determine the type of module that is in a particular slot.

Use the configuration register to select channels and configure the SCXI-1141/1142/1143 modules for scanning, calibration, and control options.

The gain register sets the gain of each amplifier.

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

The EEPROM stores the calibration constants for each gain for all eight channels. Information in the EEPROM is retained when the module is turned off. The SCXI-1141/1142/1143 modules have calibration constants already stored in the EEPROM. You can modify these constants for your own set of operating conditions. One set of constants is reserved and cannot be modified except at the factory, which ensures that you do not accidentally erase the default calibration constants. For more information on the EEPROM and calibration, see Chapter 5, *Calibration*.

# Input Amplifiers

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

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

## Gain and Offset Correction

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

Gain errors are determined and calibration constants are loaded into the EEPROM at the factory. However, gain errors drift with temperature changes. You may add an additional set or subset of calibration constants to the EEPROM to optimize performance under a specific set of conditions. Details of this procedure are given in Chapter 5, *Calibration*.

To account for offset errors, you can configure the module to send a 0 V differential signal through the amplifiers. The signal at the output will represent the DC offset error and should be read and subtracted from all subsequent readings. When reading this offset error, the filter should either be in bypass mode or allowed to settle for several seconds. Several readings should be averaged to minimize noise errors. This procedure is called *calibration*.

Because the offset voltage changes with each gain, you should perform a new calibration each time the gain is changed. Offset errors also drift with changes in temperature, so you should update the offset correction periodically. Measurements made during the warm-up period of the module (approximately 20 minutes) and chassis are most susceptible to drifting offset errors.

# Lowpass Filters

The SCXI-1141/1142/1143 modules filters are eighth-order elliptic, Bessel, and Butterworth lowpass filters. These filters are a hybrid of a switched-capacitor and a continuous-time architecture, thus providing good frequency control while avoiding the sampling errors found in conventional switched-capacitor designs. To better acquaint you with these filters, this section describes what the filters do and presents examples of how to use them on the SCXI-1141/1142/1143 modules.

## Filter Theory

Filters are generally grouped into one of five classifications—*lowpass, highpass, bandpass, bandstop,* and *all-pass*. These classifications refer to the frequency range (the *passband*) of signals that the filter is intended to pass from the input to the output without attenuation. Because the SCXI-1141/1142/1143 modules use a lowpass filter, this discussion is limited to lowpass filters.

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

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

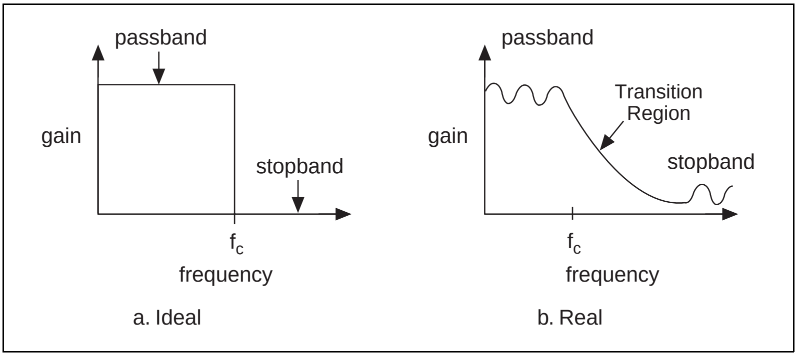



**Figure 4-2.** Ideal and Real Lowpass Filter Transfer Function Characteristics

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

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

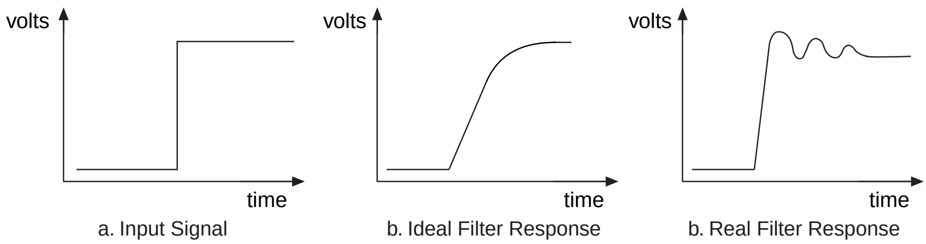



**Figure 4-3.** Real and Ideal Filter Responses to a Step Input Signal

# Performance of the SCXI-1141/1142/1143 Modules Filters

The SCXI-1141/1142/1143 modules are elliptic, Bessel, and Butterworth filters, respectively. Each filter design optimizes a particular set of characteristics. Therefore, selecting the appropriate module depends on your application.

## Magnitude Response

The typical magnitude response of the SCXI-1141/1142/1143 modules filters is shown in Figures 4-4 and 4-5. Figure 4-4 shows the full transfer function while Figure 4-5 shows the ripple in the passband. Both graphs are plotted with the frequency axis normalized to the cutoff frequency value of 1.

As Figure 4-4 shows, the SCXI-1141/1142/1143 modules provide 80 dB attenuation above 1.5 times the cutoff frequency for the SCXI-1141 module, six times for the SCXI-1142 module, and 3.2 times for the SCXI-1143 module. The SCXI-1141, which incorporates an elliptic filter, is designed to provide maximum attenuation immediately above the cutoff frequency. Therefore, it is the ideal choice for applications in which you must remove signals very near the cutoff frequency.

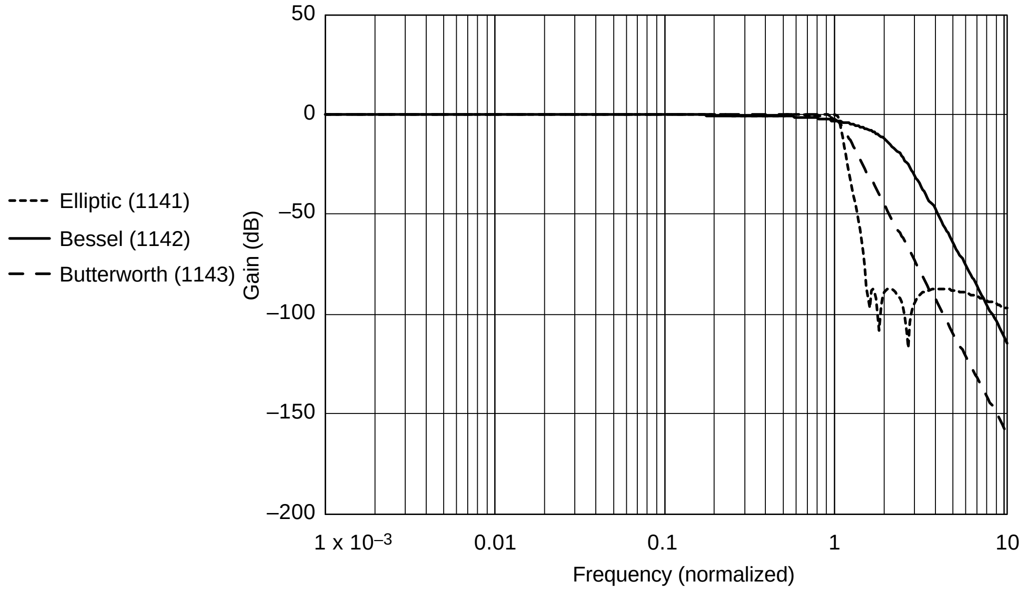



**Figure 4-4.** Typical Magnitude Response of the SCXI-1141/1142/1143 Modules Filters

Figure 4-5 compares the magnitude response of the SCXI-1141/1142/1143 modules within the passband. The passband magnitude response begins to drop off immediately for the SCXI-1142 module. The SCXI-1141 performs much better than the SCXI-1142 in the passband, but it still exhibits about 0.1 dB of ripple in magnitude in the passband. The SCXI-1143 module Butterworth filter is designed for maximum flatness in the passband and is nearly perfectly flat in most of the passband. For this reason the SCXI-1143 module filter is the ideal choice for applications where flatness in the passband is critical.

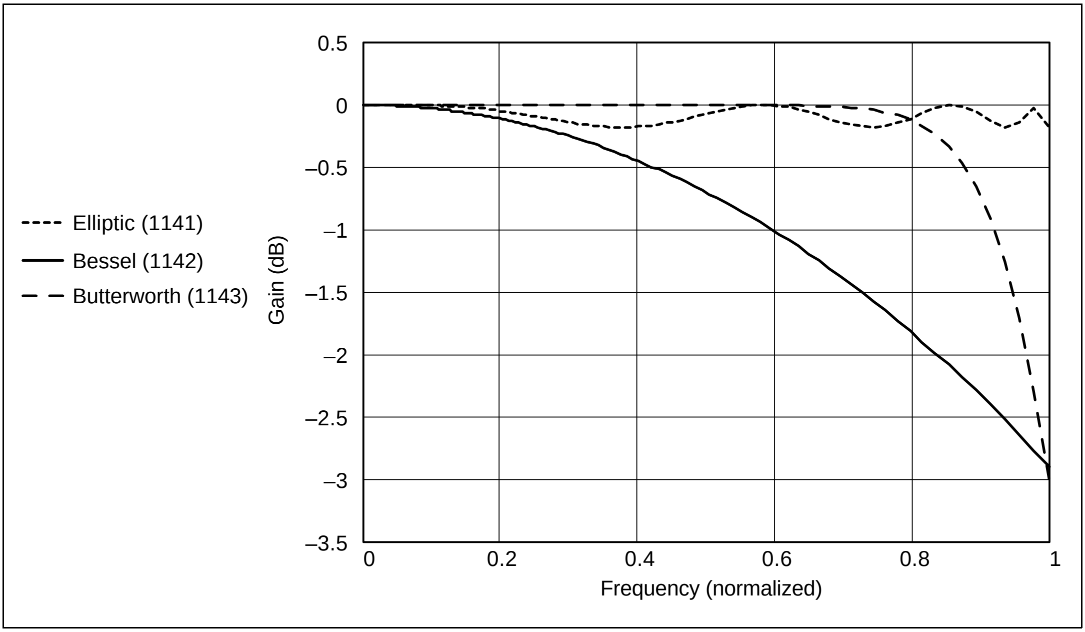



**Figure 4-5.** Typical Passband Responses of the SCXI-1141/1142/1143 Modules

## Phase Response

Figures 4-6 through 4-9 illustrate the phase response characteristics of the SCXI-1141/1142/1143 modules filters. Figure 4-6 shows the phase shift as a function of frequency (normalized so that the cutoff frequency = 1). In an ideal filter, this would be a linear relationship. Figure 4-7 shows the deviation of the actual phase response from an ideal (linear) response. Generally, phase response is described in terms of the differential nonlinearity, or group delay. Group delay is defined as the negative derivative of the phase shift with respect to the frequency. In the ideal filter, group delay is a constant. The group delay of the SCXI-1141/1142/1143 modules filters is shown in Figure 4-8.

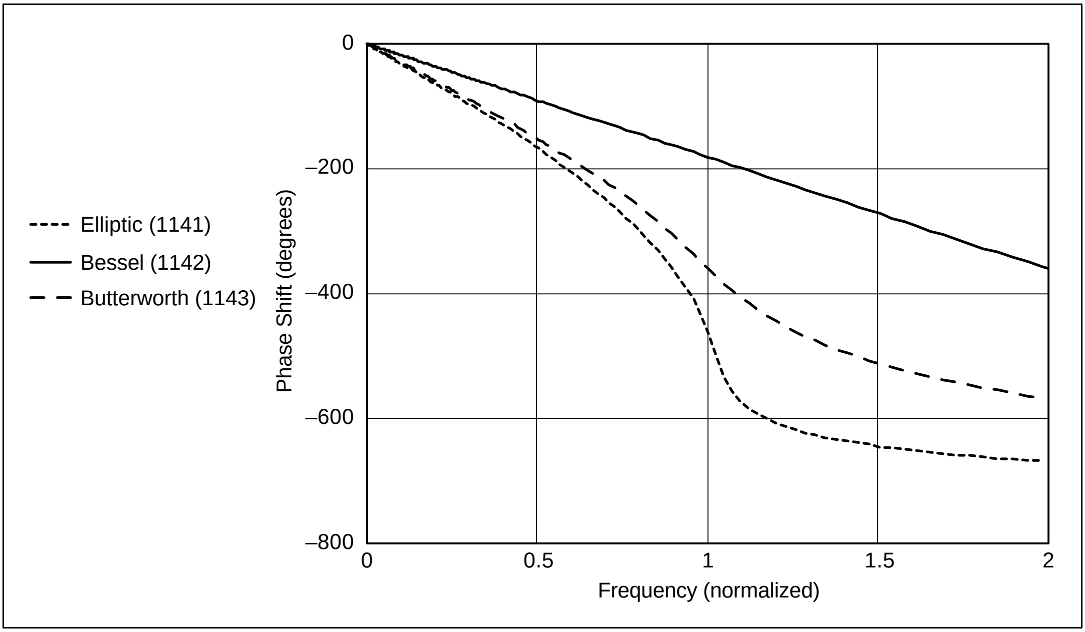



**Figure 4-6.** Phase Response Characteristics of the SCXI-1141/1142/1143 Modules Filters

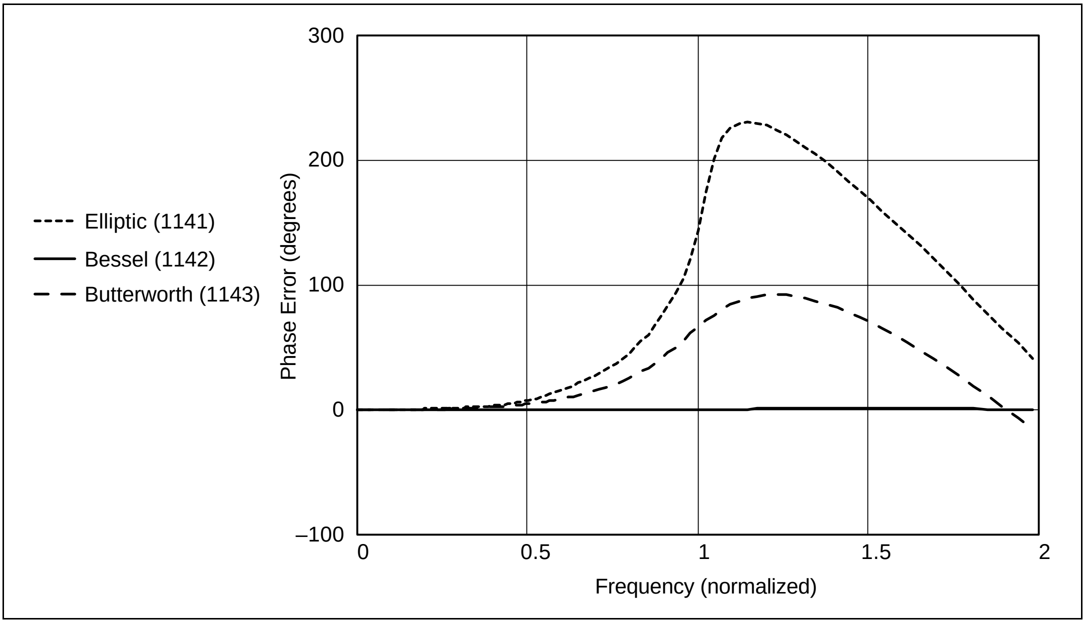



**Figure 4-7.** Phase Error of the SCXI-1141/1142/1143 Modules

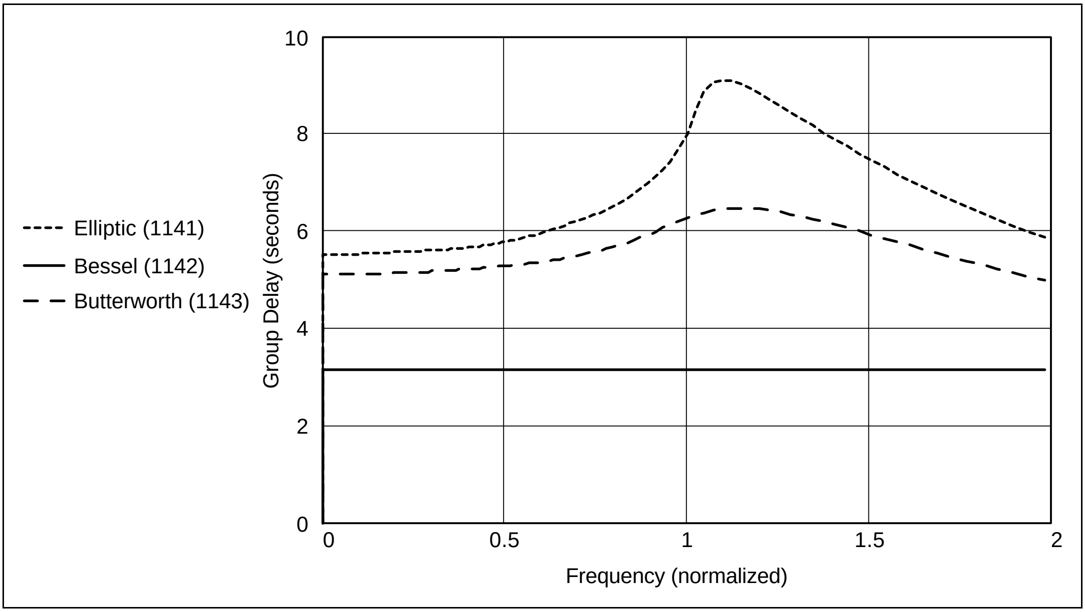



**Figure 4-8.** Group Delay of the SCXI-1141/1142/1143 Modules

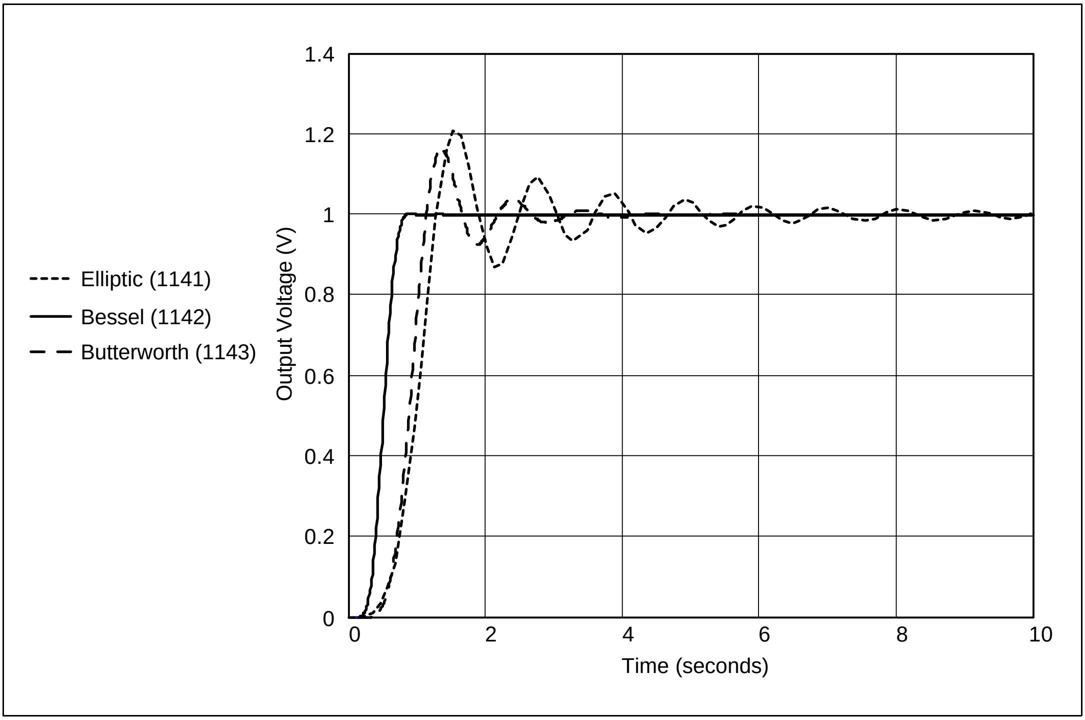



**Figure 4-9.** Unit Step Response of the SCXI-1141/1142/1143 Modules

Figures 4-7 and 4-8 show the advantages of the SCXI-1142 Bessel filter. The Bessel filter is designed for constant group delay at the expense of passband gain and stopband rolloff. As a result, the SCXI-1142 Bessel filter is the best choice when the phase information of a signal is important or a signal must maintain a constant delay regardless of its frequency components.

The most common effect of phase nonlinearity is ringing in response to a step input. As Figure 4-9 shows, the SCXI-1141 elliptic filter exhibits the most overshoot and ringing while the SCXI-1142 Bessel filter has no overshoot or ringing. The SCXI-1143 module Butterworth filter has a step response that is a compromise between the SCXI-1141 module and SCXI-1142 module. The SCXI-1143 module filter has an overshoot, but it has less ringing than the SCXI-1141. You should consider the step response if the intended application is sensitive to overshoot or ringing. Additionally, use care when selecting gain settings to assure that the input signal plus any overshoot voltage result in an output signal within the ±5 V range of the SCXI-1141/1142/1143 modules.

## Setting the Cutoff Frequency

The cutoff frequencies of the filters in the SCXI-1141/1142/1143 modules are set internally by dividing a base frequency of 100 kHz by an integer. You can determine the allowable cutoff frequencies for the SCXI-1141/1142/1143 modules as follows:

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

where $n$ is an integer $\geq 4$ and $f_c \geq 10$ Hz. In other words, $f_c = \{25, 20, 16.7, 14.3, 12.5, ..., 0.01\}$ kHz.

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

The correct cutoff frequency depends on your application. If phase nonlinearity, ringing, passband ripple, or aliasing are a concern in your application, you may need to set the cutoff frequency several times higher than the signal frequency range of interest. At frequencies much lower than the cutoff frequency, passband ripple and phase nonlinearity are much less noticeable. If you use the filter to prevent aliasing, you must set the cutoff frequency no higher than one-third of the frequency at which that channel is being sampled for the SCXI-1141 module, one-twelfth the frequency for the SCXI-1142 module, or one-sixth the frequency for the SCXI-1143 module.

## Using the SCXI-1141/1142/1143 Modules as an Antialiasing Filter

Aliasing, a phenomenon of sampled data acquisition systems, causes high-frequency signal components to take on the identity of a low-frequency signal. Figure 4-10 shows an example of aliasing.

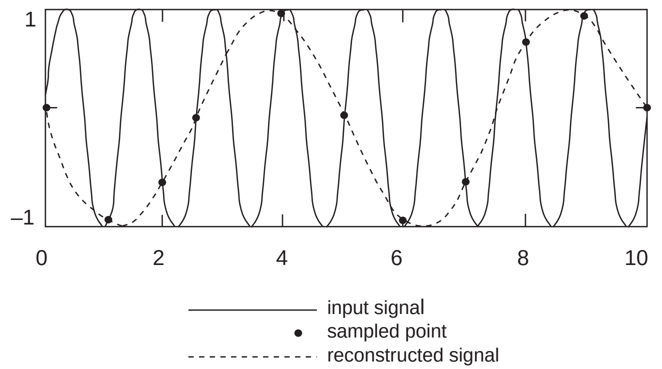



**Figure 4-10.** Aliasing of an Input Signal with a Frequency 0.8 Times the Sample Rate

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

To prevent aliasing, you must remove all of the signal components with frequencies greater than the Nyquist frequency from an input signal *before* it is sampled. After an unfiltered signal has been sampled and aliasing has occurred, it is impossible to accurately reconstruct the original signal. The SCXI-1141/1142/1143 modules remove these high-frequency signals before they reach a DAQ device and cause aliasing.

Because the SCXI-1141 module stopband begins at 1.5 times the cutoff frequency, the Nyquist frequency should be at least 1.5 times the cutoff frequency. Thus, the rate at which the DAQ device samples a channel should be at least three times the filter cutoff frequency.

The stopband for the SCXI-1142 module begins at six times the cutoff frequency, so you should sample it at a rate of 12 times the cutoff frequency.

The stopband for the SCXI-1143 module begins at 3.2 times the cutoff frequency, so you should sample it at a rate of 6.4 times the cutoff frequency.

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

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

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

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

Using this stopband, the filter attenuates the input signal by 80 dB or more. This is enough attenuation to prevent aliasing on DAQ systems with 12 bits of precision or less. On systems with more than 12 bits of precision or systems with extremely high amounts of out-of-passband noise, higher sampling rates or lower cutoff frequencies are necessary to prevent aliasing.

You can operate the filter cutoff frequency closer to the sampling rate with the consequence of having some aliasing. If you can tolerate aliasing in the transition band, you can reduce the sampling rate to 2.6 times the cutoff frequency for the SCXI-1141 module, five times the cutoff frequency for the SCXI-1142 module, and 3.5 times the cutoff frequency for the SCXI-1143 module.

## Using the External Clock Input

You can set the cutoff frequencies of filters in the SCXI-1141/1142/1143 modules by using the external clock input in applications that require external control of the cutoff frequency or that require finer resolution than the module provides internally. The cutoff frequency for each filter using the external clock as a base is $f_{ext}/(100 \times n)$, where $f_{ext}$ is the frequency of the external clock and $n$ is an integer you select such that, $2 \leq n \leq 2^{16}$. When the frequency of the external clock changes, the cutoff frequency changes proportionally.

An external clock can control the SCXI-1141/1142/1143 modules filters because they use a switched-capacitor architecture, which uses analog sampling. However, this technique is also susceptible to aliasing in much the same way as the digital sampling of a DAQ device (with a Nyquist frequency of one-half the external clock frequency). Analog sampling also creates high-frequency images of the signal because the output waveform has a staircase shape.

Unlike filters available from other manufacturers using this switched-capacitor architecture, the SCXI-1141/1142/1143 modules prevent these errors by using sets of prefilters and postfilters that do not sample the signal. A different set of prefilters and postfilters is used for each of 12 ranges of input frequencies. The prefilters reduce signals that may alias into a lower frequency by at least 40 dB, while the postfilters reconstruct the output waveform, reducing high-frequency images to at least –80 dB.

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

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

**Table 4-1.** Cutoff Frequency Ranges for the SCXI-1141/1142/1143 Modules Prefilters and Postfilters

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

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

# Using the Output Clock

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

When $m$ is even, this signal is a 0 to +5 V CMOS clock with a 50% duty cycle. When $m$ is odd, the duty cycle is as follows:

$$\frac{m-1}{m+1}$$

# DC-Correction Circuitry and Overload Recovery

The SCXI-1141/1142/1143 modules incorporate circuitry that corrects for the DC gain and offset errors of the filters, leaving only the errors of the amplifiers. However, this correction circuitry takes approximately 15 s to completely respond to changes in these errors due to overload conditions (caused by driving the output signal outside of the ±5 V range) and upon power-up (no data should be taken during the first 15 s). Overload conditions result whenever the input signal exceeds ±5 V/gain. You must use a gain setting that prevents the maximum input signal from exceeding this limit, or the DC-correction circuitry will take 15 s to recover from overloads.

## Filter Bypass Mode

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

You can use the filter bypass to examine the effect that the filter has on the input signal. Using this mode, you can examine an input signal without the added effects of passband ripple and phase nonlinearities.

At power-up and at reset, all the channels of the SCXI-1141/1142/1143 modules default to the filter bypass mode.

# Analog Outputs

The connector signals AOUT<1..7> and AGND are the outputs of channels 1 through 7, respectively. You can configure the OUTPUT and OUTPUT REF signals as any channel (0 through 7) of the SCXI-1141/1142/1143 modules or as the output of a channel passed along the SCXIbus from any other module in the chassis. Thus, the SCXI-1141/1142/1143 modules can present its outputs in both parallel and multiplexed modes.

## Multiplexed Mode (Recommended)

In multiplexed mode, the output signals for channels 1 through 7 are sent to the rear signal connector but are usually ignored. All samples from the module are from the OUTPUT signal of the rear signal connector, which can be configured as the output of any channel of the SCXI-1141/1142/1143 modules or as the output of any other module in multiplexed mode that is sending its output onto the SCXIbus. You can also configure the SCXI-1141/1142/1143 modules to send any one of its outputs to the SCXIbus. Thus, in multiplexed mode only, one module in a chassis needs to be connected to a DAQ device. You can pass signals from the other modules to the DAQ device through the SCXIbus.

Multiplexed mode is also useful for performing scanning operations with the SCXI-1141/1142/1143 modules. E Series MIO devices and the SCXI-1200 support scanning. The SCXI chassis is programmed with a module scan list that dynamically controls which module sends its output to the SCXIbus during a scan. You can specify this list to scan the modules in any order, with an arbitrary number of channels for each module entry in the list. However, the channels on the SCXI-1141/1142/1143 modules must be scanned in a consecutive, ascending order. After channel 7 is scanned, the module wraps back to channel 0 and continues. You can program the SCXI-1141/1142/1143 modules to start scans with any channel.

## Parallel Mode

When the OUTPUT signal is configured to be the output of channel 0, the rear signal connector simultaneously carries each of the outputs of the SCXI-1141/1142/1143 modules channels on different pins, and the module is in parallel mode. In this mode, you can use an SCXI-1180 feedthrough panel to make each of the outputs available at the front of the chassis.
A DAQ device cabled to an SCXI-1141/1142/1143 modules in parallel mode reads a separate output signal from the module on each of its analog inputs. You cannot multiplex the parallel outputs of a module onto the SCXIbus. Only a DAQ device directly cabled to the module has access to the outputs.

# 5 Calibration

The onboard calibration hardware that calibrates the SCXI-1141/1142/1143 modules consist of an EEPROM to store the gain calibration constants, calibration circuitry on the amplifier inputs, and a potentiometer to adjust the AC gain of the filter.

Calibration is a method for nulling out offset error sources that reduce measurement accuracy. When calibration is performed, the input signals are disconnected from the amplifier inputs and the amplifier inputs are connected to ground. Calibration determines each output of the SCXI-1141/1142/1143 modules at a given gain of an amplifier. You should calibrate at the start of an application for each gain to be used. Doing this helps eliminate error due to drift in the amplifier internal circuitry and increases the accuracy of the measurement.

The calibration path is different from the analog input path. Therefore, even after calibrating, a residual input offset still exists and has a value of less than 6 µV. The offsets of the filters are internally compensated for; generally only the offsets of the amplifiers need to be calibrated. The filters should be in bypass mode during calibration to avoid long settling times. If you are calibrating the offsets of both the amplifiers and the filters, the filters must not be in bypass mode and the filters should be given 15 s to completely settle to the calibration voltage.

The DC gain errors of the filters (below 0.1 Hz) are also internally compensated for. The AC gain of each filter is adjusted with a trimming potentiometer with an adjustment range of ±0.15 dB. The gain errors of the amplifiers are the same for DC and AC signals. Calibration constants representing these errors for each gain of each amplifier are stored in the onboard EEPROM for future use and for automatic calibration.

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

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

# Calibration Procedure

National Instruments calibrates every SCXI-1141/1142/1143 module at the factory. You should calibrate the modules annually or more frequently if the modules are operated in a harsh environment.

## Calibration Equipment Requirements

According to standard practice, the equipment you use to calibrate the SCXI-1141/1142/1143 modules should be 10 times as accurate as the SCXI-1141/1142/1143 modules. Practically speaking, calibration equipment with four times the accuracy of the item under calibration is generally considered acceptable. To calibrate the SCXI-1141/1142/1143 modules, you need the following equipment:

- A voltage source capable of providing a DC voltage of 4.9 V/*G*, and less than 500 Hz sine wave, where *G* is the gain of the amplifier to be calibrated.
- A voltmeter with the following specifications:
  - Accuracy ± 0.002% standard<br>± 0.005% sufficient
  - Range –5 to +5 V
  - Resolution 8.5 digits
- SCXI-1304 or SCXI-1305 terminal block or equivalent.
- NB1 cable and CB-50 or CB-50LP terminal block (or equivalent).

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

## Amplifier Gain Calibration

To determine the gain calibration factors of an SCXI-1141/1142/1143 modules amplifier at a given gain $G_s$, perform the following steps for a two-point calibration:

1. Set the SCXI-1141/1142/1143 modules channel to the desired gain and configure the filter for bypass mode.
2. Depending on how you want to calibrate your module, perform one of the following procedures:
   - Select one of the calibration points to be at 0 V input. You must provide the other calibration point at positive or negative full scale:
     a. Enable calibration.
     b. Measure the SCXI-1141/1142/1143 module output with the DMM and store the measured value for future use.
     c. Disable calibration.
     d. Apply 4.9 V/$G_s$ or –4.9 V/$G_s$ to the amplifier input.
     e. Go to step 3.
   - Select positive and negative full scale to be the two calibration points, apply –4.9 V/$G_s$ and 4.9 V/$G_s$.
     a. Apply –4.9 V/$G_s$ to the amplifier input.

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

     b. Measure the input voltage with the DMM and store the measured value.
     c. Measure the SCXI-1141/1142/1143 module output with the DMM and store the measured value.
     d. Apply 4.9 V/$G_s$ at the amplifier input.
     e. Go to step 3.
3. Measure the input voltage for each calibration point with the DMM and store the measured values.
4. Measure the SCXI-1141/1142/1143 module output for each calibration point with the DMM and store the measured values.

5. You now have two pairs of voltages. Each pair consists of an input voltage and an output voltage. For the calibration option, the pairs are {0 V input, offset output} and {4.9 V/$G_s$ input, 4.9 V output} or {–4.9 V/$G_s$ input, –4.9 V output}. For the positive or negative full-scale calibration point options, the pairs are {–4.9 V/$G_s$ input, –4.9 V output} and {4.9 V/$G_s$ input, 4.9 V output}.
6. Convert the output voltage from volts to your DAQ device binary unit. You must take into consideration the polarity of your DAQ device, its resolution (12 bits or 16 bits), and gain. For example, if you are using an AT-MIO-16E-1 in bipolar mode and are using a gain of $G_{MIO}$ = 0.5, your output voltages for the calibration option will be represented in binary units as given by the following formula:

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

   Refer to your DAQ device user manual to determine the appropriate formula for you to use.
7. You now have a new set of pairs referred to as voltage binary pairs {voltage input1, binary output1} and {voltage input 2, binary output 2}. Pass these pairs to the `SCXI_Cal_Constants` function in NI-DAQ or an equivalent VI as described in your software user manual.

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

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

## Filter AC Gain Calibration

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

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

1. Set the SCXI-1141/1142/1143 module amplifier gain and the sine wave source amplitude to appropriate levels.
2. Set the SCXI-1141/1142/1143 module filters to the filter bypass mode.
3. Apply the sine wave to the channel inputs.
4. Measure the amplitude of the sine wave at the output of the module and record this value.
5. Set the SCXI-1141/1142/1143 module filters to a cutoff frequency of 25 kHz and disable the filter bypass mode.
6. Measure the amplitude of the sine wave at the output and adjust the potentiometer until the amplitude is at the same level as it was with the filter in bypass mode.
7. Repeat these steps for the other channels.

# Appendix A

# Specifications

This appendix lists the specifications for the SCXI-1141/1142/1143 modules. These specifications are typical at 25 °C and 50% humidity unless otherwise stated. The operating temperature range is 0 to 50 °C.

## Amplifier Characteristics

Number of channels .............................. 8 differential

Output signal range ................................ ± 5 V

Channel gains (software-selectable) ...... 1, 2, 5, 10, 20, 50, 100

Maximum working voltage.................... ± 5 V (signal + common mode)

Input overvoltage protection

- Powered on ..................................... ± 30 V
- Powered off..................................... ± 15 V

Input coupling ........................................ DC (AC available with SCXI-1304 or SCXI-1305 terminal block)

Input impedance

- Powered on ..................................... 10 GΩ in parallel with 40 pF
- Powered off..................................... 2.4 kΩ

Input bias current ................................... 300 pA

Input offset current................................. 150 pA

Common-mode rejection ratio ............... 60 dB (G = 1)

DC gain error ........................................±0.6% before calibration, ±0.02% after calibration[1]

DC input offset ......................................0.6 mV (can be calibrated)

# Filter Characteristics

Filter type

- SCXI-1141 module..........................8th-order elliptic
- SCXI-1142 module..........................8th-order Bessel
- SCXI-1143 module..........................8th-order Butterworth

Filter architecture...................................Switched capacitor with prefilters and postfilters

Rolloff rate.............................................135 dB/octave

Cutoff frequency ($f_c$) range.....................10 Hz to 25 kHz

Cutoff choices (software-selectable) ......Divided from 100 kHz or external clock (for example, 25 kHz, 20 kHz, 16.7 kHz, 14.3 kHz, or from external)

Passband ripple
(SCXI-1141 module only)......................0.2 dB, DC to $f_c$

Phase matching
(SCXI-1142 only)...................................3° max error at $f_c$

Stopband attenuation

- SCXI-1141module...........................80 dB at 1.5 • $f_c$
- SCXI-1142 module..........................80 dB at 6 • $f_c$
- SCXI-1143 module..........................80 dB at 3.2 • $f_c$

Prefilter aliasing rejection.......................> 80 dB below 99 • $f_c$, > 40 dB above 99 • $f_c$

Sampled image + clock feedthrough ......<–75 dB

[1] SCXI-1141/1142/1143 modules factory calibration conditions: $V_{in}(–) = 0$ V, $V_{in}(+) = \pm$ fullscale.

## System Noise

THD

- 1 kHz .............................................. –70 dB
- 0–25 kHz ......................................... –60 dB

Input noise ............................................ 30 nV • $\sqrt{f_c}$

Output noise .......................................... 230 µ$V_{rms}$

## Stability

Gain temperature coefficient .................. 20 ppm/°C

Input offset drift .................................... 10 µV/°C

Output offset drift .................................. 0.1 mV/°C

## Digital Input/Output

EXTCLK pin input voltage
with respect to DIGGND ....................... 5.5 V max
–0.5 V min

Absolute maximum voltage input rating
with respect to DIGGND ....................... –0.5 to 5.5 V

Digital input referenced to DIGGND

- VIH, input logic high voltage ......... 2 V min
- VIL, input logic low voltage ........... 0.8 V max

Digital output referenced to DIGGND

- VOH, output logic high voltage ...... 3.7 V min at 4 mA
- VOL, output logic low voltage ....... 0.4 V max at 4 mA

## Physical

Dimensions ............................................ 1.2 by 6.8 by 8.0 in.
(3.0 by 17.3 by 24.4 cm)

I/O connectors

- Rear connector ................................ 50-pin male ribbon-cable
- Front connector ............................... 96-pin DIN C male
(screw terminal adapters available)

# Environment

Operating temperature ............................0 to 50 °C

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

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

# B

# Technical Support Resources

This appendix describes the comprehensive resources available to you in the Technical Support section of the National Instruments Web site and provides technical support telephone numbers for you to use if you have trouble connecting to our Web site or if you do not have internet access.

## NI Web Support

To provide you with immediate answers and solutions 24 hours a day, 365 days a year, National Instruments maintains extensive online technical support resources. They are available to you at no cost, are updated daily, and can be found in the Technical Support section of our Web site at `www.natinst.com/support`.

### Online Problem-Solving and Diagnostic Resources

- **KnowledgeBase**—A searchable database containing thousands of frequently asked questions (FAQs) and their corresponding answers or solutions, including special sections devoted to our newest products. The database is updated daily in response to new customer experiences and feedback.
- **Troubleshooting Wizards**—Step-by-step guides lead you through common problems and answer questions about our entire product line. Wizards include screen shots that illustrate the steps being described and provide detailed information ranging from simple getting started instructions to advanced topics.
- **Product Manuals**—A comprehensive, searchable library of the latest editions of National Instruments hardware and software product manuals.
- **Hardware Reference Database**—A searchable database containing brief hardware descriptions, mechanical drawings, and helpful images of jumper settings and connector pinouts.
- **Application Notes**—A library with more than 100 short papers addressing specific topics such as creating and calling DLLs, developing your own instrument driver software, and porting applications between platforms and operating systems.

## Software-Related Resources

- **Instrument Driver Network**—A library with hundreds of instrument drivers for control of standalone instruments via GPIB, VXI, or serial interfaces. You also can submit a request for a particular instrument driver if it does not already appear in the library.
- **Example Programs Database**—A database with numerous, non-shipping example programs for National Instruments programming environments. You can use them to complement the example programs that are already included with National Instruments products.
- **Software Library**—A library with updates and patches to application software, links to the latest versions of driver software for National Instruments hardware products, and utility routines.

# Worldwide Support

National Instruments has offices located around the globe. Many branch offices maintain a Web site to provide information on local services. You can access these Web sites from `www.natinst.com/worldwide`.

If you have trouble connecting to our Web site, please contact your local National Instruments office or the source from which you purchased your National Instruments product(s) to obtain support.

For telephone support in the United States, dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

Australia 03 9879 5166, Austria 0662 45 79 90 0, Belgium 02 757 00 20, Brazil 011 284 5011, Canada (Calgary) 403 274 9391, Canada (Ontario) 905 785 0085, Canada (Québec) 514 694 8521, China 0755 3904939, Denmark 45 76 26 00, Finland 09 725 725 11, France 01 48 14 24 24, Germany 089 741 31 30, Greece 30 1 42 96 427 Hong Kong 2645 3186, India 91805275406, Israel 03 6120092, Italy 02 413091, Japan 03 5472 2970, Korea 02 596 7456, Mexico (D.F.) 5 280 7625, Mexico (Monterrey) 8 357 7695, Netherlands 0348 433466, Norway 32 27 73 00, Singapore 2265886, Spain (Barcelona) 93 582 0251, Spain (Madrid) 91 640 0085, Sweden 08 587 895 00, Switzerland 056 200 51 51, Taiwan 02 2377 1200, United Kingdom 01635 523545

# 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- | $10^{6}$ |
| G- | giga- | $10^{9}$ |

## Numbers/Symbols

| | |
|---|---|
| ° | degrees |
| > | greater than |
| ≥ | greater than or equal to |
| < | less than |
| ≤ | less than or equal to |
| – | negative of, or minus |
| Ω | ohms |
| % | percent |
| ± | plus or minus |
| + | positive of, or plus |

## A

| | |
|---|---|
| A | amperes |
| AC | alternating current |
| ADE | application development environment |
| AGND | analog ground signal |
| AGND/NC | analog ground/no connect signal |
| aliasing | the consequence of sampling that causes signals with frequencies higher than half the sampling frequency to appear as lower frequency components |
| ANSI | American National Standards Institute |
| AOGND/GUARD | analog output ground |
| AOUT | analog output signal |
| AWG | American Wire Gauge |

## B

| | |
|---|---|
| bias current | the small input current flowing into or out of the input terminals of an amplifier |
| BNC | a type of coaxial signal connector |

## C

| | |
|---|---|
| C | Celsius |
| CJC | cold-junction compensation |
| CMOS | complementary metal-oxide semiconductor |
| CMRR | common-mode rejection ratio |
| common-mode noise | noise that appears on both inputs of a differential amplifier |
| cutoff frequency | the frequency that defines the upper end of the passband of a lowpass filter |

## D

| | |
|---|---|
| D/A | digital-to-analog |
| DAQ | data acquisition |
| DAQD*/A | data acquisition board data/address line signal |
| dB | decibels |
| DC | direct current |
| DIGGND | digital ground signal |
| DIN | Deutsche Industrie Norme (German Industrial Standard) |
| DMM | digital multimeter |

## E

| | |
|---|---|
| EEPROM | electrically erasable programmable read-only memory |
| EXTCLK | external clock signal |

## F

| | |
|---|---|
| $f_c$ | cutoff frequency |
| $F_{ext}$ | external frequency |

## G

| | |
|---|---|
| G | gain |
| gain error | the difference between the actual and intended gain of a system |

## H

| | |
|---|---|
| hex | hexadecimal (base 16) |
| Hz | hertz |

# I

| | |
|---|---|
| in | inch |
| IN+ | positive input channel signal |
| IN– | negative input channel signal |
| I/O | input/output |
| INTR* | interrupt signal |

# L

| | |
|---|---|
| lowpass filter | a filter that passes signals below a cutoff frequency while blocking signals above that frequency |

# M

| | |
|---|---|
| max | maximum |
| MB | megabytes |
| min | minutes/minimum |
| MIO | multifunction I/O |
| MISO | Master-In-Slave-Out signal |
| MOSI | Master-Out-Slave-In signal |
| multiplex | to route one of many input signals to a single output |

# N

| | |
|---|---|
| normal-mode noise | noise that appears in only one input of a differential amplifier |
| NP | no pull-up |

| | |
|---|---|
| NRSE | nonreferenced single-ended |
| Nyquist frequency | the frequency that a sampling system can faithfully reproduce, which is half the sampling frequency |

## O

| | |
|---|---|
| offset error | the output of a system with a zero volt input |
| OUTCLK | output clock signal |
| OUTPUT | output signal |
| OUTPUT REF | output reference signal |

## P

| | |
|---|---|
| P | pull-up |
| passband | the range of input frequencies that are passed to the filter output without attenuation |
| ppm | parts per million |

## R

| | |
|---|---|
| rms | root mean square |
| rolloff | the ratio that a system attenuates signals in the stopband with respect to the passband, usually defined in decibels per octave |
| RSVD | reserved signal/bit |
| RTSI | Real-Time System Integration |

## S

| | |
|---|---|
| s | seconds |
| S/s | samples per second—used to express the rate at which a DAQ device samples an analog signal |

| | |
|---|---|
| sample | an instantaneous measurement of a signal, normally using an analog-to-digital convertor in a DAQ device |
| sample rate | the number of samples a system takes over a given time period, usually expressed in samples per second |
| scan | a collection of samples, usually with each sample coming from a different input channel |
| scan rate | the number of scans a system takes during a given time period, usually expressed in scans per second |
| SCXI | Signal Conditioning eXtensions for Instrumentation |
| SCXIbus | located in the rear of an SCXI chassis, the SCXIbus is the backplane that connects modules in the same chassis to each other |
| SCANCLK | scan clock signal |
| SERCLK | serial clock signal |
| SERDATIN | serial data in signal |
| SERDATOUT | serial data out signal |
| SLOT0SEL | slot 0 select signal |
| SPICLK | serial peripheral interface clock signal |
| stopband | the portion of a frequency spectrum blocked by a filter |

## T

| | |
|---|---|
| THD | total harmonic distortion |
| TTL | transistor-transistor logic |

## V

| | |
|---|---|
| V | volts |
| VI | virtual instrument (a LabVIEW program) |
| $V_{rms}$ | volts, root mean square |

## W

working voltage — the highest voltage that should be applied to a product during normal use, normally well under the breakdown voltage for safety margin

# Index

## D



## E



## F

## N



## O



## P



## R

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## U



## W