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PXIe-4112 User Manual

2024-02-05

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Welcome to the PXIe-4112 User Manual

The PXIe-4112 User Manual provides detailed descriptions of product functionality and step-by-step processes for use.

Looking for something else?

For information not found in the User Manual for your product, like specifications or API reference, browse Related Information.

Related information:

- PXIe-4112 Specifications
- PXIe-4112 Calibration Procedure
- NI-DCPower Help
- NI-DCPower Properties
- NI-DCPower LabVIEW VI Reference
- NI-DCPower C Function Reference
- NI-DCPower .NET API Overview
- NI-DCPower Python Reference
- NI-DCPower and LabVIEW Compatibility
- Software and Driver Downloads
- Release Notes
- License Setup and Activation
- Dimensional Drawings
- Product Certifications
- Letter of Volatility
- Discussion Forums
- NI Learning Center

PXIe-4112 Overview

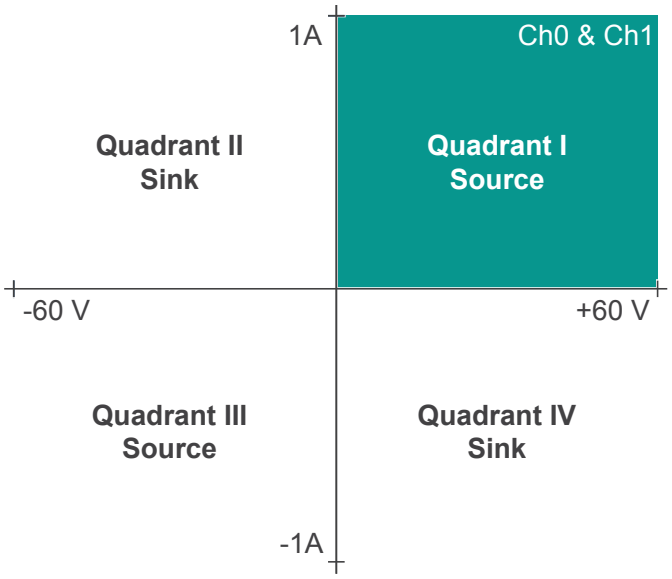
The PXIe-4112 is a programmable precision DC power supply featuring two 60 W single quadrant channels in a single PXI express slot. The PXIe-4112 can simultaneously measure both voltage and current while supplying power. Use the PXIe-4112 for any automated test application that requires a power source with readback capabilities.

Device Capabilities

The PXIe-4112 is a two-channel, single quadrant programmable DC power supply that has the following features and capabilities.

- Two isolated 60 W power supply channels (channels are isolated from each other and from chassis ground)
- Output disconnect relays
- 4-wire remote sense
- 5 kS/s maximum sampling rate

Figure 1. PXIe-4112 Quadrant Diagram



Driver Support

NI recommends that you use the newest version of the driver for your module.

Table 1. Earliest Driver Version Support

Driver Name	Earliest Version Support
NI-DCPower	1.8

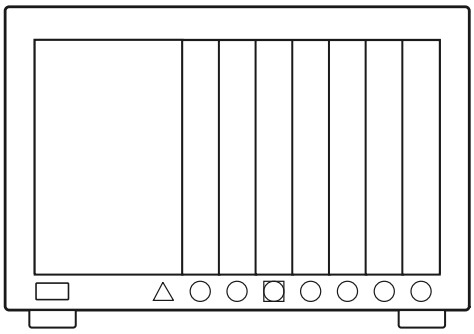
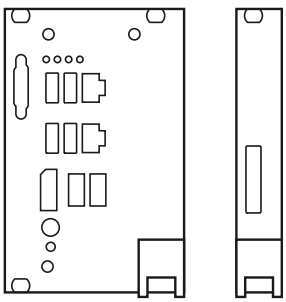
Components of a PXIe-4112 System

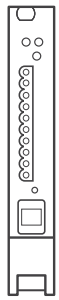
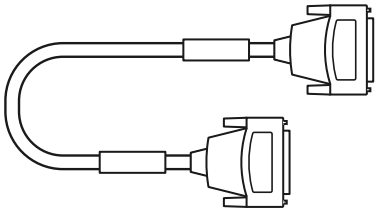
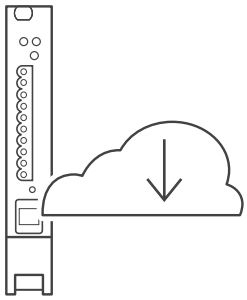
The PXIe-4112 is designed for use in a system that includes other hardware components, drivers, and software.

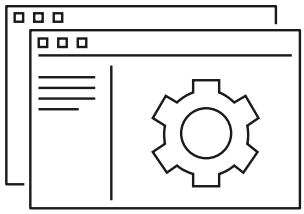
Notice A system and the surrounding environment must meet the requirements defined in **PXIe-4112 Specifications**.

The following list defines the minimum required hardware and software for a system that includes a PXIe-4112.

Table 2. System Components

Component	Description and Recommendations
PXI Chassis 	A PXI chassis houses the PXIe-4112 and supplies power for PXIe-4112 functions. **Note** The chassis fan must be set to highest setting.
PXI Controller or PXI Remote Control Module 	You can install a PXI controller or a PXI remote control (MXI) module depending on your system requirements. These components, installed in the same PXI chassis as the PXIe-4112, interface with the instrument using NI device drivers.
Programmable Power Supply	Your programmable power supply instrument.

Component	Description and Recommendations
	
Cables and Accessories 	Cables and accessories allow connectivity to/from your instrument for measurements. Refer to **Cables and Accessories** for recommended cables and accessories and guidance.
NI-DCPower Driver 	Instrument driver software that provides functions to interact with the PXIe-4112 and execute measurements using the PXIe-4112. **Note** NI recommends to always use the most current version of NI-DCPower with the PXIe-4112. You can find the NI-DCPower driver requirements in the **NI-DCPower Readme**.
NI Applications	NI-DCPower offers driver support for the following applications: ▪ InstrumentStudio ▪ LabVIEW ▪ LabWindows/CVI

Component	Description and Recommendations
	▪ C/C++ ▪ .NET ▪ Python

Cables and Accessories

NI recommends using the following cables and accessories with your module:

Table 3. Cables and Accessories

Accessory Description	Notes	Part Number
Screw Terminal Connector Kit for PXIe-4112/3 Power Supplies	Ships with the PXIe-4112	782887-01
Auxiliary Power Supply Module for NI PXIe-4112/13	Ships with the PXIe-4112	782888-01
PXI slot blockers	—	199198-01

Additional Cabling and Accessory Guidance

NI recommends that you install PXI slot blockers (p/n 199198-01) to fill empty instrument slots in a PXI chassis. For more information about installing slot blockers and filler panels, go to ni.com/r/pxiblocker.

Programming Options

You can generate signals interactively using InstrumentStudio or you can use the NI-DCPower instrument driver to program your device in the supported ADE of your choice.

- **InstrumentStudio**—When you install NI-DCPower on a 64-bit system, you can monitor, control, and record measurements from supported devices

using InstrumentStudio. InstrumentStudio is a software-based soft front panel application that allows you to perform interactive measurements on several different device types in a single program.
InstrumentStudio is automatically installed when you install the NI-DCPower driver on a 64-bit system. You can access InstrumentStudio in any of the following ways:

- From the Windows start menu, select **National Instruments** » **[Driver] Soft Front Panel**. This launches InstrumentStudio and runs a soft front panel populated with NI-DCPower devices.
- From the Windows start menu, select **National Instruments** » **InstrumentStudio**. This launches InstrumentStudio and runs a soft front panel populated with devices detected on your system.
- From Measurement & Automation Explorer (MAX), select a device and then click **Test Panels...**. This launches InstrumentStudio and runs a soft front panel for the device you selected.

- **NI-DCPower Instrument Driver** —The NI-DCPower API configures and operates the module hardware and performs basic acquisition and measurement functions.
  - LabVIEW—Available on the LabVIEW Functions palette at **Measurement I/O** » **NI-DCPower**. Examples are available from the **Start** menu in the **National Instruments** folder.
  - LabVIEW NXG—Available from the diagram at **Hardware Interfaces** » **Electronic Test** » **NI-DCPower**. Examples are available from the **Learning** tab in the **Examples** » **Hardware Input and Output** folder.
  - LabWindows/CVI—Available at **Program Files** » **IVI Foundation** » **IVI** » **Drivers** » **NI-DCPower**. LabWindows/CVI examples are available from the **Start** menu in the **National Instruments** folder.
  - C/C++—Available at **Program Files** » **IVI Foundation** » **IVI**. Refer to the **Creating an Application with NI-DCPower in Microsoft Visual C and C++** topic of the **NI DC Power Supplies and SMUs Help** to manually add all

required include and library files to your project. NI-DCPower does not ship with installed C/C++ examples.

- Python—For more information about installing and using Python, refer to the **NI-DCPower Python Documentation**.

PXIe-4112 Theory of Operation

Each output channel on the PXIe-4112 contains a switching stage that is responsible for power isolation and regulation.

The PXIe-4112 can operate in either constant voltage mode or constant current mode.

- In constant voltage mode, the device acts as a precision voltage source. Regardless of the load, the voltage across the output terminals is held constant at the programmed value up to the programmed current limit.
- In constant current mode, the device acts as a precision current source. Regardless of the output voltage, the current through the load is held constant at the programmed value up to the programmed voltage limit.

The PXIe-4112 is primarily designed for constant voltage mode operation and has a bulk output capacitor in the output filter. When switching from constant voltage mode to constant current mode, this capacitance is pre-charged and must be discharged through the load before constant current regulation is achieved.

The channels of the PXIe-4112 can only operate with an auxiliary DC power supply connected, which supplies 48 V. The isolated output channels can output 1 A at up to 60 V on each channel, delivering a total of 60 W maximum per channel (120 W total).

A measurement circuit on the PXIe-4112 can simultaneously read the voltage and current values using two SAR analog-to-digital converters. Voltage is measured differentially between the Sense + and Sense - terminals (remote sense). Remote sense is used to compensate for voltage drop that results from resistance in cables, connectors, and switches. The PXIe-4112 always utilizes the remote sense terminals for voltage measurement and feedback. Local sense can be achieved by installing the included sense jumpers at the output connector. Current is measured using shunt resistors in series with the - terminal.

The PXIe-4112 includes flexible source and measurement units that enable multiple programming modes and timing options:

- Single Point Source Mode for software timed source/measurement operation.
- Sequence Source mode for basic hardware timed operation, where the user specifies a set of setpoint steps and source delays between each step while other parameters are held constant.

Note The PXIe-4112 does not support sequence step delta time or advanced sequences.

Protection

There are several protection mechanisms built into the PXIe-4112 that guard against common faults. Protection mechanisms that trigger a shutdown will disable the channel output and open the output disconnect relays.

- **Open Sense Lead Protection**—In the event the Sense terminals are left disconnected during operation, the 1 kΩ open-sense protection resistors provide a voltage feedback path to prevent the output voltage from saturating to a large voltage level.
- **Reversed Sense Lead Protection**—In the event the Sense terminals are connected in reverse, the module shuts down when the output has reached a level of ~7 V.
- **Over-Current Protection (OCP)**—The switching power stage employs peak cycle-by-cycle current protection which limits maximum current independently from the current control loop. This protection is continuous and does not trigger an error directly.
- **Auxiliary Power Voltage Protection**—The auxiliary power input port shuts down the module when the voltage on the port is outside the functional range. Protection against reversed voltage on the aux power input port is provided by a clamp diode that limits the voltage until the aux power fuse is opened.

- **Auxiliary Power Current Protection**—The auxiliary power input port is protected by an electronic circuit breaker along with a fuse. Triggering either mechanism shuts down the module.
- **Over-Temperature Protection (OTP)**—Temperature is monitored at multiple locations on the board and triggers a shutdown when limits are reached.

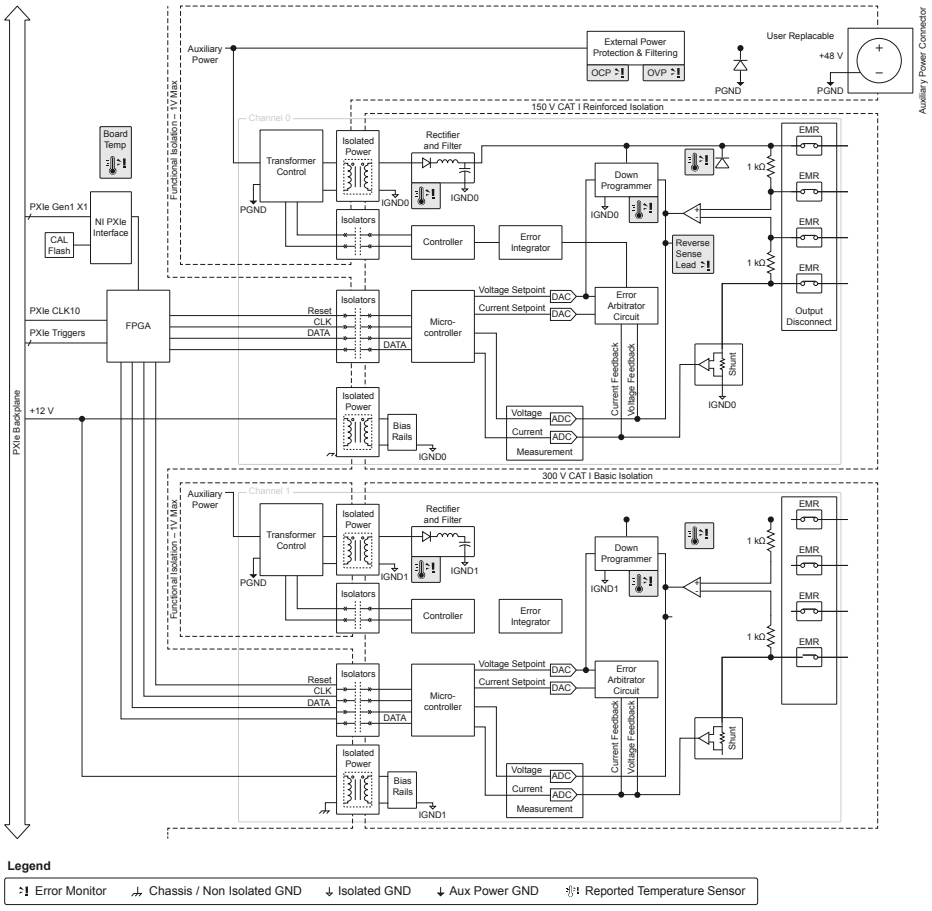
Isolation

The output terminals of the PXIe-4112 are electrically isolated from chassis ground through a 150 V DC, Category I isolation barrier. This allows any power supply terminal to float ±150 V DC with respect to chassis ground. Each channel is also electrically isolated from each other, allowing terminals of one channel to float as high as +150 V DC relative to chassis ground while the other channel can float as low as -150 V DC.

Block Diagram

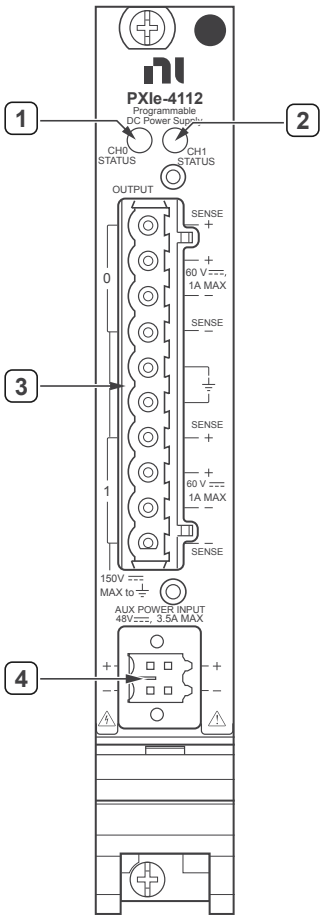
The following diagram illustrates the design of the PXIe-4112.

Figure 2. PXIe-4112 Block Diagram



PXIe-4112 Front Panel

Figure 3. PXIe-4112 Front Panel



1. Channel 0 Status LED
2. Channel 1 Status LED
3. Output Connector
4. Auxiliary Power Input Connector

PXIe-4112 Pinout

The following figures show the terminals on the PXIe-4112 output connector and auxiliary power input connector.

Output Connector

Figure 4. PXIe-4112 Output Connector Pinout

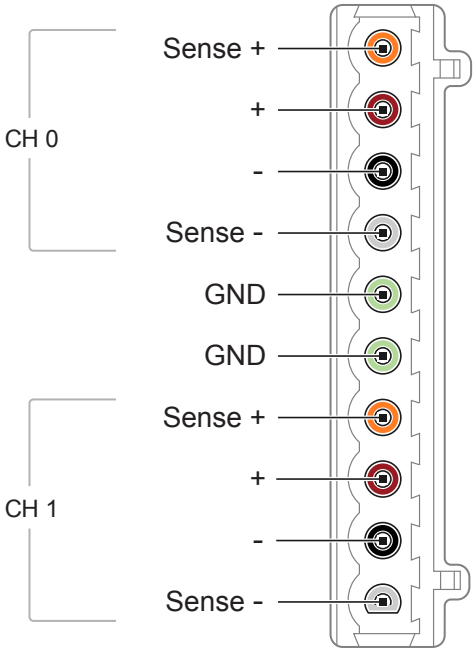


Table 4. Signal Descriptions

Signal	Description
CH <0..1> +	HI force terminal connected to channel power stage (generates and/or dissipates power). Positive polarity is defined as voltage measured on HI > LO.
CH <0..1> -	LO force terminal connected to channel power stage (generates and/or dissipates power). Positive polarity is defined as voltage measured on HI > LO.

Signal	Description
CH <0..1> Sense +	Voltage remote sense input terminals. Used to compensate for **I*R** voltage drops in cable leads, connectors, and switches.
CH <0..1> Sense -	
GND	Tied to chassis ground through module front panel. Use for connections to cable shields or grounding the LO force terminal.

Auxiliary Power Input Connector

Figure 5. PXIe-4112 Auxiliary Power Input Connector

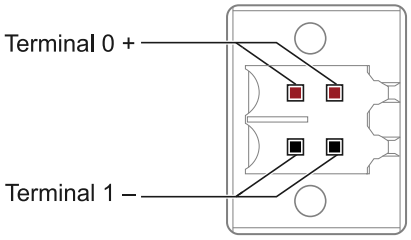


Table 5. Signal Descriptions

Signal	Description
Terminal 0 +	Positive Auxiliary Power Input
Terminal 1 -	Negative Auxiliary Power Input

PXIe-4112 LED Indicators

The PXIe-4112 features a Channel 0 Status LED and a Channel 1 Status LED.

Channel Status LEDs

The channel status LEDs, located on the front panel, provide feedback about device operation.

The following table lists the channel status LEDs states.

Table 6. Channel Output Indicator Status

Status Indicator	Channel Output State
(Off)	Disabled
Green	Enabled (Constant Voltage Mode)
Amber	Enabled (Constant Current Mode)
Red	Disabled because of error, such as an over-temperature condition

PXIe-4112 Installation and Configuration

Complete the following steps to install the PXIe-4112 into a chassis and prepare it for use:

1. Unpacking the Kit
2. Installing the Software
3. Installing the PXIe-4112 into a Chassis
4. Installing the Auxiliary 48 V Power Source on the PXIe-4112
5. Installing the Output Connector Assembly on the PXIe-4112
6. Verifying the Installation in MAX

Unpacking the Kit

Notice To prevent electrostatic discharge (ESD) from damaging the device, ground yourself using a grounding strap or by holding a grounded object, such as your computer chassis.

1. Touch the antistatic package to a metal part of the computer chassis.
2. Remove the device from the package and inspect the device for loose components or any other sign of damage.

   Notice Never touch the exposed pins of connectors.

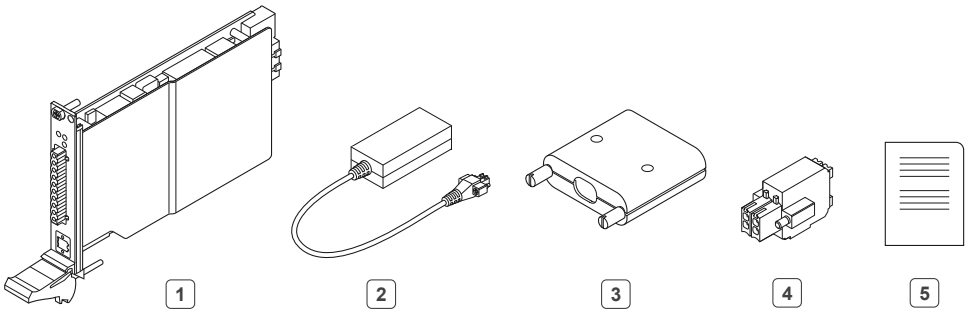
   Note Do not install a device if it appears damaged in any way.
3. Unpack any other items and documentation from the kit.

Note Store the device in the antistatic package when the device is not in use.

Kit Contents

Refer to the following figure to identify the contents of the PXIe-4112 kit.

Figure 6. PXIe-4112 Kit Contents



1. PXIe-4112 Module
2. Auxiliary 48 V Power Source
3. Output Connector Assembly
4. Additional Auxiliary Power Connector
5. Documentation

Installing the Software

You must be an Administrator to install NI software on your computer.

1. Install an ADE, such as LabVIEW or LabWindows™/CVI™.
2. Download the driver software installer from ni.com/downloads.
   NI Package Manager downloads with the driver software to handle the installation. Refer to the NI Package Manager Manual for more information about installing, removing, and upgrading NI software using NI Package Manager.
3. Follow the instructions in the installation prompts.

   Note Windows users may see access and security messages during installation. Accept the prompts to complete the installation.

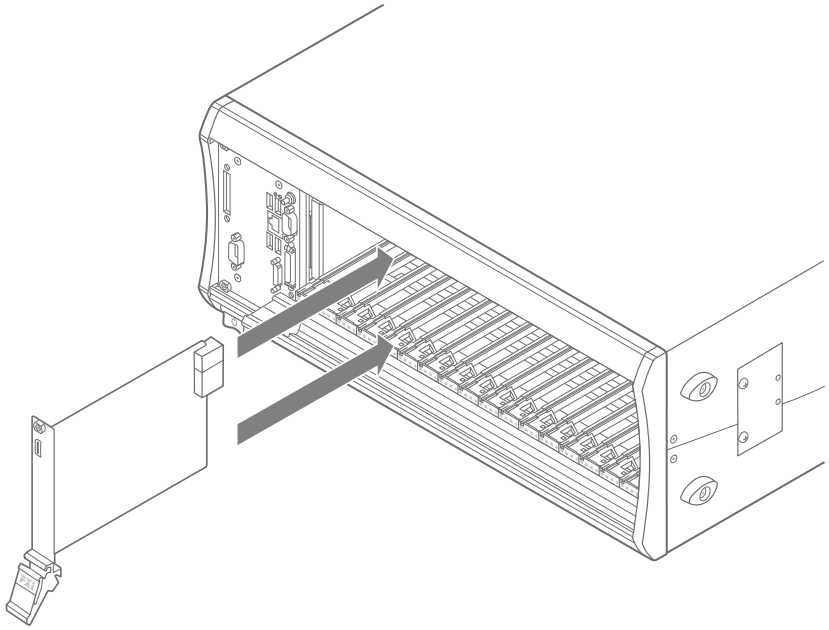
4. When the installer completes, select **Restart** in the dialog box that prompts you to restart, shut down, or restart later.

Installing the PXIe-4112 into a Chassis

Notice To prevent damage to the PXIe-4112 caused by ESD or contamination, handle the module using the edges or the metal bracket.

1. Ensure the AC power source is connected to the chassis before installing the module.
   The AC power cord grounds the chassis and protects it from electrical damage while you install the module.
2. Power off the chassis.
3. Inspect the slot pins on the chassis backplane for any bends or damage prior to installation. Do not install a module if the backplane is damaged.
4. Position the chassis so that inlet and outlet vents are not obstructed.
   For more information about optimal chassis positioning, refer to the chassis documentation.
5. Remove the black plastic covers from all the captive screws on the module front panel.
6. Identify a supported slot in the chassis. The PXIe-4112 module can be placed in PXI Express hybrid peripheral slots (), PXI Express system timing slots (), or PXI Express peripheral slots ().
7. Touch any metal part of the chassis to discharge static electricity.
8. Ensure that the ejector handle is in the downward (unlatched) position.

Figure 7. Module Installation



9. Place the module edges into the module guides at the top and bottom of the chassis. Slide the module into the slot until it is fully inserted.
10. Latch the module in place by pulling up on the ejector handle.
11. Secure the module front panel to the chassis using the front-panel mounting screws.

> **Note** Tightening the top and bottom mounting screws increases mechanical stability and also electrically connects the front panel to the chassis, which can improve the signal quality and electromagnetic performance.

12. Cover all empty slots using either filler panels (standard or EMC) or slot blockers with filler panels, depending on your application.

> **Note** For more information about installing slot blockers and filler panels, go to ni.com/r/pxiblocker.

Installing the Auxiliary 48 V Power Source on the PXIe-4112

Complete the following steps to install the auxiliary 48 V power source on the module PXIe-4112 and prepare it for use.

1. Connect the power source to the auxiliary power input connector on the PXIe-4112 front panel.

   Figure 8. Connecting the Required 48 V Power Source

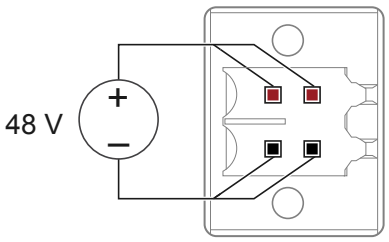
   

   Table 7. Signal Descriptions

Signal	Description
Terminal 0 +	Positive Auxiliary Power Input
Terminal 1 -	Negative Auxiliary Power Input

2. Tighten the screws to hold the auxiliary 48 V power source in place.

Note An auxiliary 48 V power source is required to operate the PXIe-4112. NI recommends using a power source that is greater than 3.5 A. The auxiliary power source provided by NI uses sufficient wire gauge to maintain voltage requirements for the device. If you use a third-party auxiliary power source, you must use the appropriate wire gauge to ensure that it can provide the required device current without dropping below the minimum voltage at the auxiliary power input connector

Resuming Operation After Auxiliary Power Loss

In case of auxiliary power loss during operation, the isolated outputs (both channels) are disabled, and the power supply is shut down to prevent damage to the PXIe-4112 and the load. If auxiliary power loss occurs, complete the following steps to resume operation:

1. Troubleshoot the failure.

- Verify that all connections, including the front panel connections to the output channels and auxiliary power supply, are secure.
- Verify that the output channels are enabled. If necessary, use the niDCPower Configure Output Enabled VI or the niDCPower_ConfigureOutputEnabled function to enable the output channels. Also verify that the Source:Output Connected property is set to TRUE or the NIDCPOWER_ATTR_OUTPUT_CONNECTED function is set to VI_TRUE.
- Inspect the auxiliary input fuse and verify that it is in working condition. If necessary, replace any blown fuses.

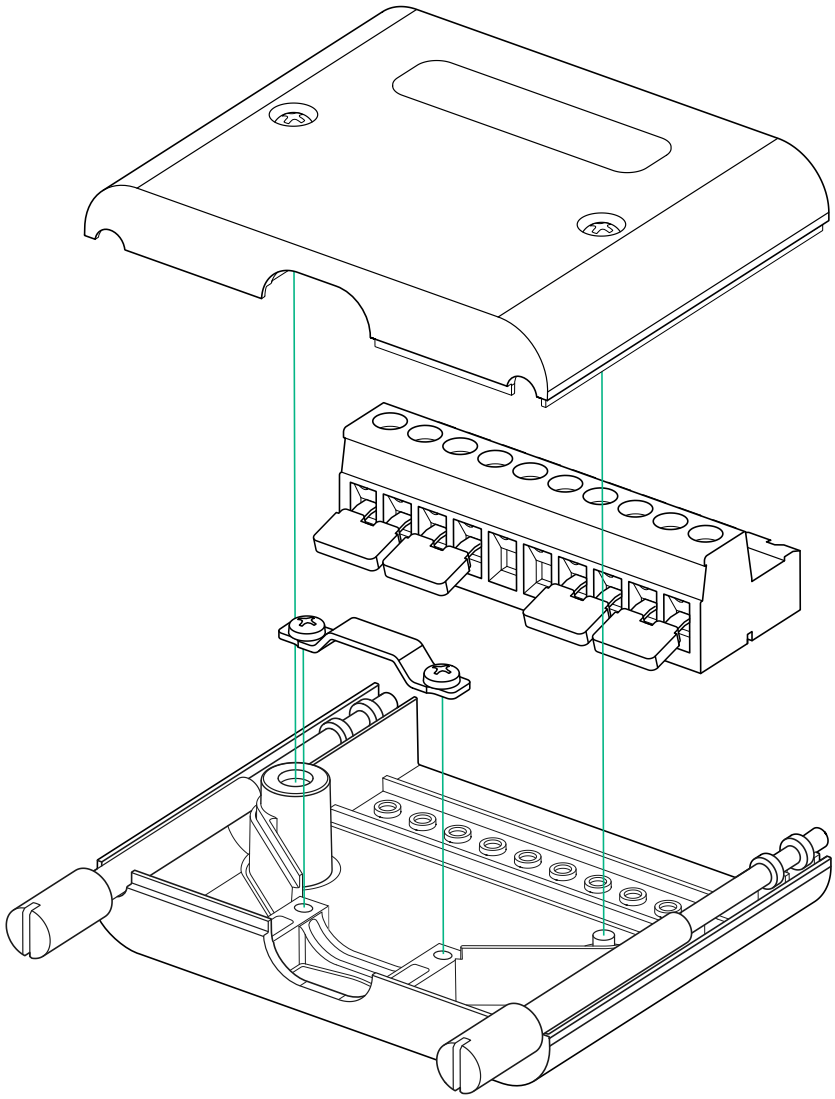
2. Restore auxiliary power.
3. Reset the power supply using the niDCPower Reset VI or the niDCPower_reset function.
4. Reconfigure the power supply.

Installing the Output Connector Assembly on the PXIe-4112

Complete the following steps to install the output connector assembly with a module and prepare signal connections.

1. Disconnect and open the output connector assembly using the following steps:
    a. Loosen the thumbscrews at the top and bottom of the output connector assembly.
    b. Disconnect the output connector assembly from the PXIe-4112.
    c. Remove the screws from the output connector assembly.
    d. Open the backshell of the output connector assembly to expose the output connector plug.

Figure 9. Disassembled Output Connector Assembly



Note The control loop of the PXIe-4112 always includes the sense leads. As a result, the sense leads must always be connected to maintain proper output regulation, so you must ensure that the sense leads do not accidentally become disconnected while the output is enabled. Internal protection resistors on the PXIe-4112 minimize the impact of open sense leads by providing a fallback sense path from the output terminals. When the sense terminals are disconnected and this fallback path is active, the output terminal voltage is approximately 2% higher than the programmed value, and

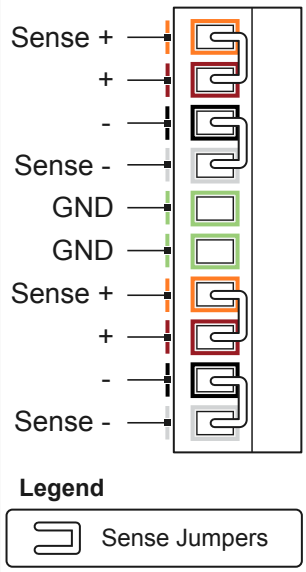
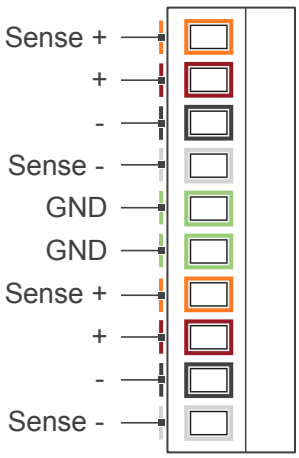
the accuracy of the measured voltage is degraded by the same amount.

2. Verify that the sense jumpers are in the correct position for your configuration.

Note While you can manually wire the hardware for local sense, the NI-DCPower API supports only remote sense for this device. Thus, NI-DCPower cannot detect whether a local or remote sense hardware configuration is in use. Ensure you select the appropriate hardware configuration for your application.

- For local sense configuration, use the provided sense jumpers to connect the Sense + and Sense - terminals to the respective + and - terminals on the output connector plug.
- For remote sense configuration, remove all sense jumpers from the output connector plug. The Sense + and Sense - terminals must be connected remotely to their respective + and - terminals at the DUT.

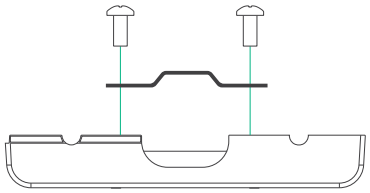
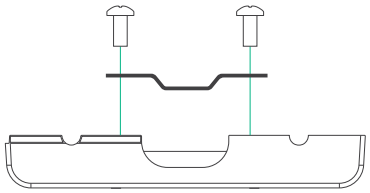
Table 8. Jumper Configuration

Local Sense Jumper Configuration	Remote Sense Jumper Configuration
Figure 10. Output Connector Plug Local Sense Configuration 	**Figure 11.** Output Connector Plug Remote Sense Configuration 

Note Connect sense terminals to their respective output terminals on the output connector plug to manually wire the hardware for local sense measurements.

3. Verify that the terminals are wired correctly for your configuration.
   - For local sense configuration, connect the + and - terminals on the output connector plug to the DUT.
   - For remote sense configuration, connect the +, -, Sense +, and Sense - terminals on the output connector plug to the DUT. Sense + and Sense - terminals must be connected remotely to their respective Output + and Output - terminals at the DUT.
4. Close the output connector assembly and reconnect it to the PXIe-4112 using the following steps:
   a. If using remote sense, secure the wires with the strain relief and secure the strain relief with screws.

Table 9. Output Connector Assembly Strain Relief

Strain Relief Position	When to Use	Diagram
Strain Relief Up	Use if you are connecting wires with a large total cross-sectional area	
Strain Relief Down	Use if you are connecting wires with a small total cross-sectional area	

   b. Close the backshell of the output connector assembly and secure it with screws.
   c. Connect the output connector assembly to the PXIe-4112.

d. Tighten the thumbscrews at the top and bottom of the output connector assembly.

5. Plug in and power on the chassis.
6. (External Controller Only) If you are using an external controller instead of an embedded controller, power on the controller.

Combining Multiple Outputs for Local Sense Measurements

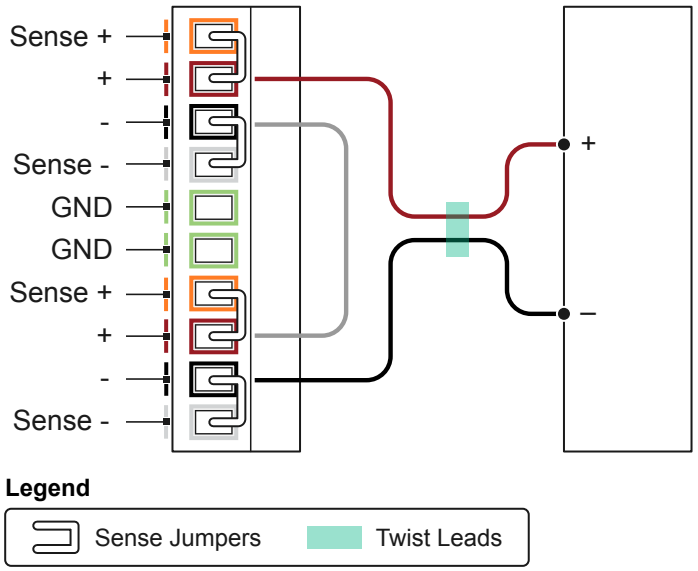
Cascading Multiple Channels in Series

Caution Do not exceed 150 V DC from any terminal to ground when cascading power supplies.

Because both channels on the PXIe-4112 are isolated outputs, you can cascade multiple channels in series to generate greater output voltage. For safety reasons, all the terminals must be less than 150 V DC from ground. Any terminal on the isolated channels can be connected to ground. When you cascade channels in series, a single PXIe-4112 can generate up to 120 V at 1 A using both channels, as illustrated in the following figure.

Caution Operating the PXIe-4112 with both channels in series has the ability to generate hazardous voltages up to 120 V DC. Shock hazards exist when voltage levels are greater than 30 V RMS, 42.4 V peak, or 60 V DC. Use extreme caution when a shock hazard is present. Always ensure the test system is de-energized before connecting or disconnecting the backshell assembly or cables from the PXIe-4112.

Figure 12. Series Connections for Local Sense Measurements

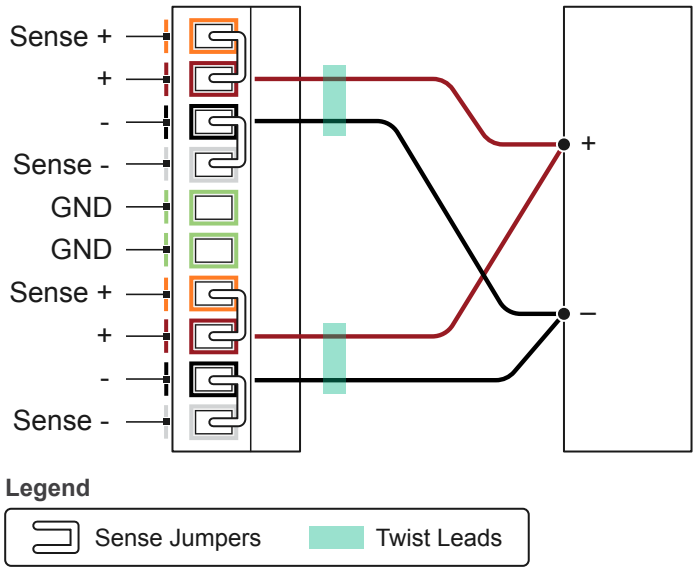


Connecting Multiple Channels in Parallel

Similarly, you can use the PXIe-4112 to connect multiple channels in parallel to generate greater output current. NI has tested and supports connecting no more than two output channels in parallel. Connect channels 0 and 1 in parallel to generate up to 2 A at 60 V, as shown in the following figure.

Note When connecting multiple channels in parallel, verify that all connected channels are set to output the same voltage level or voltage limit.

Figure 13. Parallel Connections for Local Sense Measurements



Combining Multiple Outputs for Remote Sense Measurements

Cascading Multiple Channels in Series

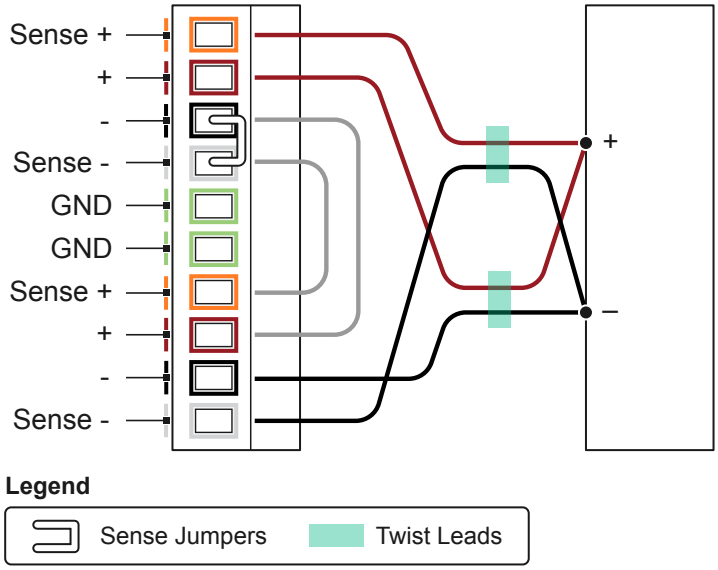
Caution Do not exceed 150 V DC from any terminal to ground when cascading power supplies.

Because both channels on the PXIe-4112 are isolated outputs, you can cascade multiple channels in series to generate greater output voltage. For safety reasons, all the terminals must be less than 150 V DC from ground. Any terminal on the isolated channels can be connected to ground. When you cascade channels in series, a single PXIe-4112 can generate up to 120 V at 1 A using both channels, as illustrated in the following figure.

Caution Operating the PXIe-4112 with both channels in series has the ability to generate hazardous voltages up to 120 V DC. Shock hazards exist when voltage levels are greater than 30 V RMS, 42.4 V peak, or 60 V DC. Use extreme caution when a shock hazard is present. Always ensure the test

system is de-energized before connecting or disconnecting the backshell assembly or cables from the PXIe-4112.

Figure 14. Series Connections for Remote Sense Measurements

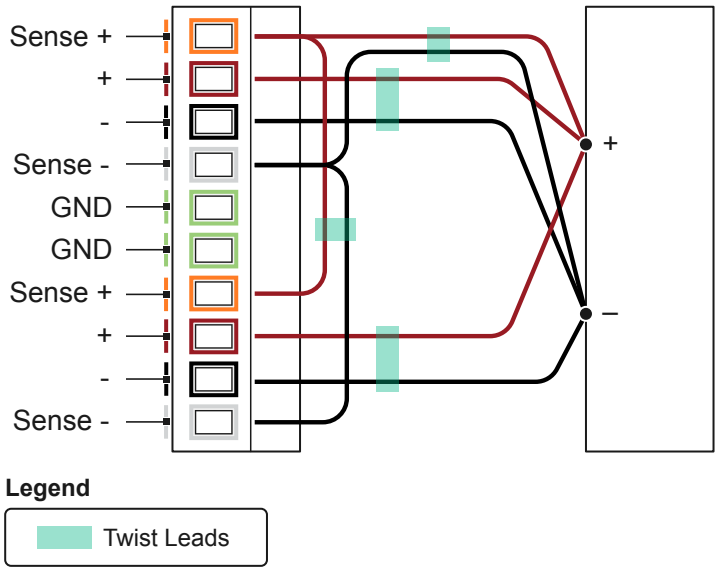


Connecting Multiple Channels in Parallel

Similarly, you can use the PXIe-4112 to connect multiple channels in parallel to generate greater output current. NI has tested and supports connecting no more than two output channels in parallel. Connect channels 0 and 1 in parallel to generate up to 2 A at 60 V, as shown in the following figure.

Note When connecting multiple channels in parallel, verify that all connected channels are set to output the same voltage level or voltage limit.

Figure 15. Parallel Connections for Remote Sense Measurements



Verifying the Installation in MAX

Use Measurement & Automation Explorer (MAX) to configure your NI hardware. MAX informs other programs about which NI hardware products are in the system and how they are configured. MAX is automatically installed with NI-DCPower .

1. Launch MAX.
2. In the configuration tree, expand **Devices and Interfaces** to see the list of installed NI hardware.
   Installed modules appear under the name of their associated chassis.
3. Expand your **Chassis** tree item.
   MAX lists all modules installed in the chassis. Your default names may vary.

   Note If you do not see your module listed, press <F5> to refresh the list of installed modules. If the module is still not listed, power off the system, ensure the module is correctly installed, and restart.

4. Record the identifier MAX assigns to the hardware. Use this identifier when programming the PXIe-4112.
5. Self-test the hardware by selecting the item in the configuration tree and clicking **Self-Test** in the MAX toolbar.

MAX self-test performs a basic verification of hardware resources.

What Should I Do if the PXIe-4112 Does Not Appear in MAX?

1. In the MAX configuration tree, expand **Devices and Interfaces**.
2. Expand the **Chassis** tree to see the list of installed hardware, and press <F5> to refresh the list.
3. If the module is still not listed, power off the system, ensure that all hardware is correctly installed, and restart the system.
4. Navigate to the Device Manager by right-clicking the Start button, and selecting **Device Manager**.
5. Verify the PXIe-4112 appears in the Device Manager.
    a. Under an NI entry, confirm that a PXIe-4112 entry appears.

    > **Note** If you are using a PC with a device for PXI remote control system, under **System Devices**, also confirm that no error conditions appear for the **PCI-to-PCI Bridge**.

    b. If error conditions appear, reinstall the NI-DCPower driver.

What Should I Do if the PXIe-4112 Fails the Self-Test?

1. Reset the PXIe-4112 through MAX, and then perform the self-test again.
2. Restart the system, and then perform the self-test again.
3. Power off the chassis.
4. Reinstall the failed module in a different slot.
5. Power on the chassis.
6. Perform the self-test again.

Connecting Signals to the PXIe-4112

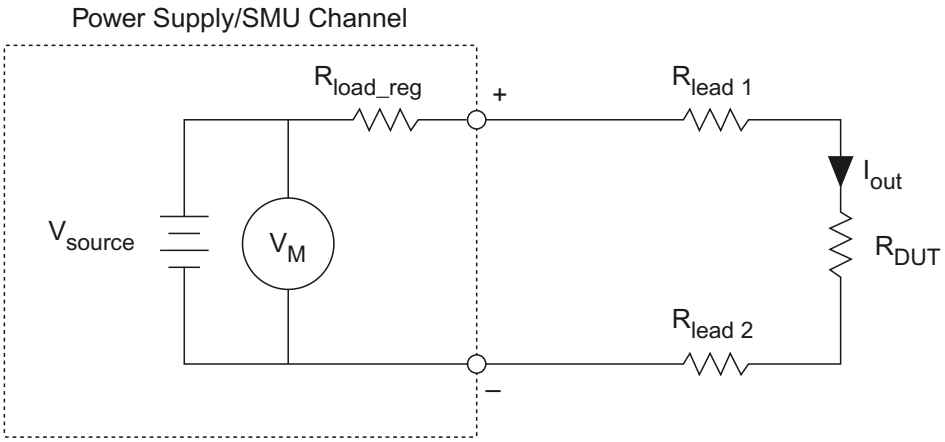
Refer to the following topics for guidance about PXIe-4112 signal connections.

- Use the + and - terminals for local sense measurements.
- Use the +, -, Sense +, and Sense - terminals for remote sense measurements.

Making Local Sense Measurements

Local sense measurements use a single set of leads for output and voltage measurement.

Figure 16. Connecting Signals for Local Sense Measurement



When the PXIe-4112 is operating in Constant Voltage mode, local sense forces the requested voltage at the output terminals of the module. The actual voltage at the DUT terminals is lower than the requested output because of the output lead resistance error.

The error in the DUT voltage measurement is due to the output current, the output resistance of the source (specified as voltage load regulation), and the resistance of the leads used to connect the power supply to the load. This error can be calculated using the following equation:

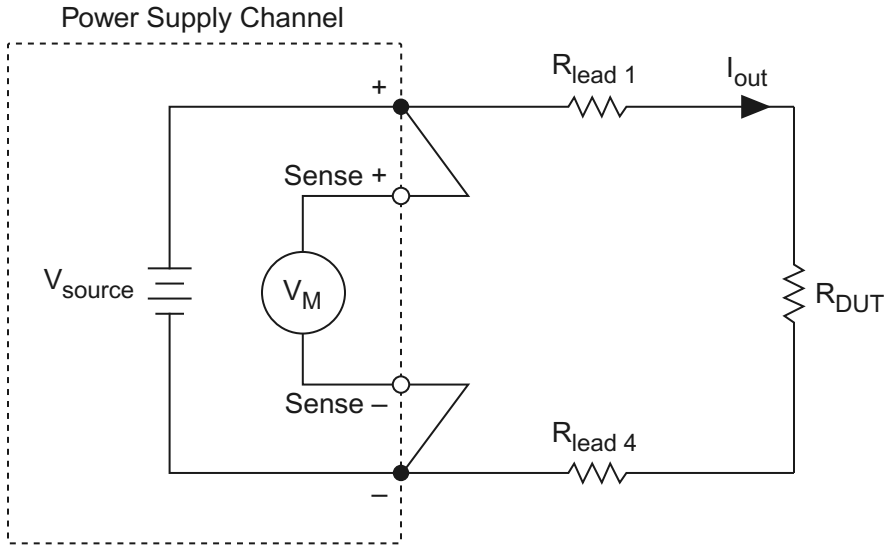
Local Sense Error (Volts) = $\mathbf{I_{out}}(\mathbf{R_{lead1}} + \mathbf{R_{lead2}} + \mathbf{R_{out.source}})$

The output resistance of the source typically includes the effective resistance of protection circuitry in series with the sourcing path, and is usually negligible in comparison to external resistance. However, for high-current applications, you may notice the resistance of the protection circuitry. Use remote sense measurements for high-current applications.

Using a Local Sense Hardware Configuration with a Remote Sense Channel Configuration

If the source has remote sense capabilities and a 2-wire configuration needs to be maintained, you can remove the effect of any protection circuitry in series with the sourcing path by configuring the channel for remote sense and connecting the sense terminals externally to their respective output terminals, as illustrated in the following figure.

Figure 17. Connecting Local Sense Hardware with a Remote Sense Channel Configuration



Note The PXIe-4112 can be used with this local sense hardware configuration but support only remote sense in the NI-DCPower API. Refer to the Installing the Output Connector Assembly topic for more information.

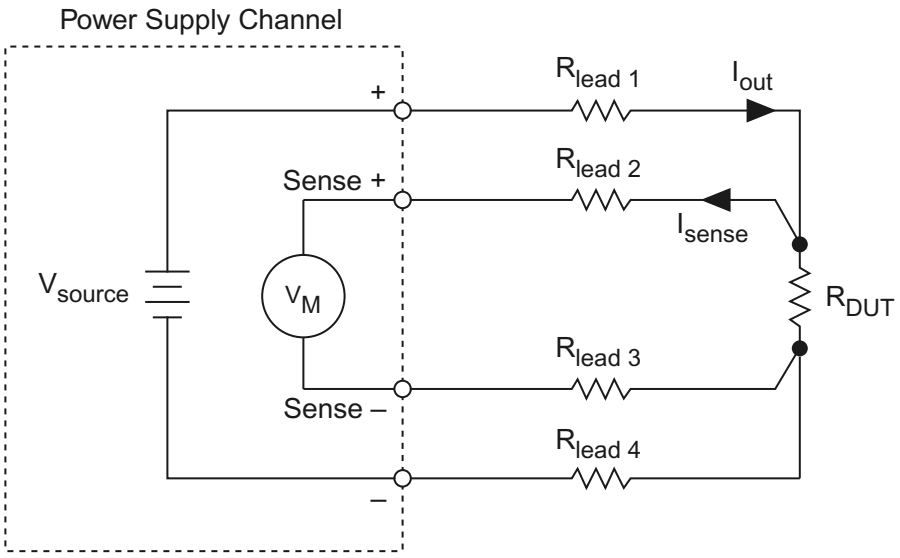
Note The control loop of the PXIe-4112 always includes the sense leads. As a result, the sense leads must always be connected to maintain proper output regulation, so you must ensure that the sense leads do not accidentally become disconnected while the output is enabled. Internal protection resistors on the PXIe-4112 minimize the impact of open sense leads by providing a fallback sense path from the output terminals. When

the sense terminals are disconnected and this fallback path is active, the output terminal voltage is approximately 2% higher than the programmed value, and the accuracy of the measured voltage is degraded by the same amount.

Making Remote Sense Measurements

Remote source measurements, sometimes referred to as 4-wire sense, require 4-wire connections to the DUT (and 4-wire switches if a switching system is used to expand the channel count). In a remote sense configuration, one set of leads carries the output current, while another set of leads measures voltage directly at the DUT terminals.

Figure 18. Connecting for a Remote Sense Measurement



Tip Using remote sense enables more accurate voltage output and measurements when the output lead voltage drop is significant.

Although the current flowing in the output leads can be several amps or more, depending on the instrument, a very small amount of current flows through the sense leads. This results in a much smaller voltage drop error for measurements versus the local sense error. When using remote sense in the DC Voltage output function, the output voltage is forced at the end of the sense leads instead of the output terminals. When using remote sense in the DC Current output function, the voltage limit is measured at the end of the sense leads instead of at the output

terminals. Using remote sense results in a voltage at the DUT terminals that is more accurate than what can be achieved using local sense. Ideally, the sense leads should be connected as close to the DUT terminals as possible.
When using remote sense, remember that the magnitude of the voltage drop across the higher current output leads is usually limited to one or two volts per lead, depending on the power supply. When attempting to force a voltage using the DC Voltage output function, dropping more voltage across the output leads than the specified maximum in remote sense mode may result in a voltage at the load that is less than the requested level.

> **Notice** When attempting to force a current using the DC Current output function while using either local or remote sense, excessive line drop may force the power supply into Constant Voltage mode before the requested current level can be reached.

Configuring a channel for remote sense operation without connecting the sense leads to the DUT can result in measurements that do not meet the published specifications. If a channel is configured for remote sense and the remote sense leads are left open, the channel may source a voltage higher than the voltage level or voltage limit.
Refer to the **PXIe-4112 Specifications** for more information about remote sense support and the maximum output lead voltage drop allowed.
The PXIe-4112 features internal open-sense protection through a 1 kΩ resistor between the force (+/-) and sense (Sense +/-) lines. This protection provides a secondary measurement path to maintain the instrument output in regulation if remote sense becomes disconnected.

Minimizing Voltage Drop Loss when Cabling

Voltage drop loss is introduced by the cabling wires that connect the module (SMU, power supply, or electronic load) to the DUT.
The voltage drop due to I*R loss is determined by the resistance of the cabling wire (a property of the wire gauge and length) and the amount of current flowing through the wire. Modules with remote sense capabilities can compensate for voltage drop by measuring the voltage across the load terminals with a second set of leads that do not carry a significant current.
To minimize voltage drop caused by cabling:

- Keep each wire pair as short as possible
- Use the thickest wire gauge appropriate for your application. NI recommends 18 AWG or lower.

To reduce noise picked up by the cables that connect the module to a load, twist each wire pair. Refer to the following table to determine the wire gauge appropriate for your application.

Caution Use wire that is thick enough to avoid overheating if the output current from the module or DUT were to short circuit.

Table 10. Typical Wire Gauge Resistance

AWG Rating	mΩ/m (mΩ/ft)
10	3.3 (1.0)
12	5.2 (1.6)
14	8.3 (2.5)
16	13.2 (4.0)
18	21.0 (6.4)
20	33.5 (10.2)
22	52.8 (16.1)
24	84.3 (25.7)
26	133.9 (40.8)
28	212.9 (64.9)

Calculating Voltage Drop

When cabling a module to the DUT, be sure to account for voltage drop in your application. Remote voltage sense is the recommended method to compensate for the effects of force lead voltage drop. A negative simulated output resistance can be applied on modules that support the programmable output resistance feature. On modules that do not support these features programming a higher voltage level/limit may be a viable mechanism for compensating for lead voltage drop in some use cases.

Use the amount of current flowing through the cabling wires and the resistance of the wires to calculate the total voltage drop for each load, as shown in the following example:

Operating within the recommended current rating, determine the maximum voltage drop across a 1 m, 16 AWG wire carrying 1 A:

$V = \mathbf{I} \times \mathbf{R}$

$V = 1\ A \times (13.2\ m\Omega/m \times 1\ m)$

$V = 13.2\ mV$

Source Modes

The PXIe-4112 channels can generate voltage and current in **Single Point** or **Sequence** source mode.

Within Single Point and Sequence source mode, you can output the following:

- DC voltage
- DC current

The Source Mode With Channels function defines the source mode the PXIe-4112 channels are operating in.

Single Point Source Mode

In **Single Point** source mode, the source unit applies a single source configuration when it enters the Running state.

You can then update the source configuration **dynamically** (when a channel is in the Running state) by modifying those properties that support dynamic reconfiguration.

Sequence Source Mode

In **Sequence** source mode, the source unit steps through a predetermined set of source configurations.

Sequence source mode on the PXIe-4112 only supports simple sequence, which allows you to define a series of voltage or current levels and source delays for a channel using the Set Sequence function.

A channel can step through a sequence without any interaction between the host system and NI-DCPower. Because the host system is not involved in executing the changes between steps of the sequence, the changes between steps in a sequence are deterministic.

Simple Sequences

You can use simple sequencing in Sequence source mode.

Create by setting the source mode to Sequence and using the Set Sequence function.

Control the initial state by manually configuring the channel(s) before calling the Set Sequence function



Note You cannot import and export sequences in simple sequencing.

Refer to the NI-DCPower examples in your application development environment to see how you can program with simple sequences.

Sourcing Voltage and Current

The PXIe-4112 can perform operations to source and measure voltage and current. In order to perform these operations, use the NI-DCPower driver to configure software settings and execute operations.

Refer to the following table for an overview of common source and measure operations as well as the software setting combinations that enable the PXIe-4112 to perform each operation.

Table 11. Software Settings for PXIe-4112 Source and Measure Operations

PXIe-4112 Operation	Software Settings	
	Output Function	Source Mode
Source voltage	DC Voltage	Single Point or Sequence
Measure current or voltage		
Source current	DC Current	
Measure voltage or current		

Complete the following general steps to source current or voltage.

1. Initialize a Session
   Use the NI-DCPower driver to initialize a session with the PXIe-4112.
2. Configure the PXIe-4112 for Sourcing
   Use the NI-DCPower driver with the PXIe-4112 to control the output the instrument generates. Depending on the output function and source mode, you can configure the appropriate output levels and limits.
3. Configure the PXIe-4112 for Measuring
   Several parameters can be configured to control how the PXIe-4112 performs measurements once it is in the running state.
4. Configure Triggers and Events
   You can use triggers and events to coordinate the operation of multiple channels and instruments.

5. Initiate the PXIe-4112 for Sourcing and Measuring
   Initiate the channels of the PXIe-4112 to apply a configuration and start generating.
6. Acquire Measurements
   The source mode that you configured channels to use determines how the PXIe-4112 acquires measurements.
7. Cease Generation
   NI-DCPower includes different options for stopping generation on PXIe-4112 channels and returning the channels to a known state.
8. Close the Session
   Use the NI-DCPower driver to close a session with the PXIe-4112.

Initialize a Session

Use the NI-DCPower driver to initialize a session with the PXIe-4112.

Use the niDCPower Initialize With Independent Channels VI or the niDCPower_InitializeWithIndependentChannels function to initialize a session.

For any application you write, you must open a session to establish communication with the PXIe-4112 or specified channel(s) by initializing.

Initializing returns an instrument handle with the session configured to a known state. Initialization can take a significant amount of time compared to other NI-DCPower VIs and functions, so you should not include it in a loop when repeatedly acquiring data. Ideally, your program should call Initialize With Independent Channels one time. If the reset parameter is set to TRUE, device channels are reset to the default state, which may include resetting relays.

Configure the PXIe-4112 for Sourcing

Use the NI-DCPower driver with the PXIe-4112 to control the output the instrument generates. Depending on the output function and source mode, you can configure the appropriate output levels and limits.

Complete the following steps to define an output type, choose a source mode, and set the output levels and limits relevant to those selections.

1. Use the Configure Output Function function to set the output type you want to generate: DC Voltage or DC Current.

- Select an output type:

Option	Description
DC Voltage	A channel attempts to generate the desired output voltage level, as long as the output current is below the current limit.
DC Current	A channel attempts to generate the desired output current level, as long as the output voltage is below the voltage limit.

2. Configure the source mode with the Configure Source Mode With Channels function.
   The source mode controls how the channel generates output levels.
3. Depending on your output function and source mode, set the relevant levels and limits with the following functions and/or properties.

   - DC output functions:

Output Function	Source Mode	Level Control	Limit Control
DC Voltage	Single Point	Use Configure Voltage Level function	Use Configure Current Limit function
	Sequence (Simple sequences only)	Use Set Sequence function to specify voltage level values.	Use Configure Current Limit function
DC Current	Single Point	Use Configure Current Level function	Use Configure Voltage Limit function
	Sequence (Simple sequences only)	Use Set Sequence function to specify current level values.	Use Configure Voltage Limit function

4. Further define the parameters of the channel output.
   The NI-DCPower API includes numerous functions and properties to exert finer control over the output. For example, on some modules, you can specify

output ranges, set asymmetric compliance limits with respect to zero, or take advantage of triggering.

Configure the PXIe-4112 for Measuring

Several parameters can be configured to control how the PXIe-4112 performs measurements once it is in the running state.

Use the **niDCPower Measure** property or the **NIDCPOWER_ATTR_MEASURE_WHEN** attribute to configure when measurements are started.

The following table lists the settings for the **niDCPower Measure** property or the **NIDCPOWER_ATTR_MEASURE_WHEN** attribute.

Measure When	Details
On Demand	Acquire measurements on demand using the niDCPower Measure VI and the niDCPower_Measure function to measure either the voltage or the current on a single channel. Or use the niDCPower Measure Multiple VI and the niDCPower_MeasureMultiple function to measure both the voltage and the current on multiple channels. When you call these VIs and functions, the PXIe-4112 takes a measurement and returns it.
Automatically after Source Complete	The PXIe-4112 acquires a measurement after every source operation and stores it in a buffer on the device. You can use the niDCPower Fetch Multiple VI and the niDCPower_FetchMultiple function to retrieve measurements from the buffer.
On Measure Trigger	The PXIe-4112 acquires a measurement when it receives a Measure trigger and stores it in a buffer on the device. You can use the niDCPower Fetch Multiple VI and the niDCPower_FetchMultiple function to retrieve measurements from the buffer.

Configure Triggers and Events

You can use triggers and events to coordinate the operation of multiple channels and instruments.

Triggers

A **trigger** is an input signal received by an instrument or instrument channel that causes the instrument or channel to perform an action. Triggers are routed to **input terminals** to coordinate actions.

An **input terminal** is a physical trigger line, such as a PXI trigger line, or an output terminal on another instrument or channel, where an instrument or channel awaits a digital edge trigger signal.

For purposes of programming instruments with NI APIs, triggers comprise two parts:

- The action, represented with the name of the trigger, that you want the instrument or channel to take.
- The signal condition you want to serve as the stimulus for that action (for example, a rising or falling digital edge on a signal, or a software-generated edge you configure).

Triggers can be internal (software-generated) or external. You can export external triggers and use them with events to synchronize hardware operation with external circuitry or other instruments.

Most NI-DCPower instruments accept external triggers routed between the instruments using PXI trigger lines. Events assigned to a PXI trigger line can coordinate actions across channels and across instruments.

Events

An **event** is a signal generated by an instrument or instrument channel that indicates a specific operation was completed or a specific state was reached. Events can be routed to **output terminals** to coordinate the action of multiple channels or multiple instruments.

For purposes of programming instruments with NI APIs, you can control three aspects of the pulse that represents each discrete event type:

- Polarity
- Width

- Destination

Event output terminals enable you to route an event signal pulse to external devices. You can modify the polarity and duration of the pulse that is generated when an event occurs to be compatible with trigger inputs of external devices.

You typically configure events for a specific hardware condition and then export those events for use in the test program or export them to a PXI trigger line to cause an action in another instrument configured to wait for a trigger on the same PXI trigger line.

NI-DCPower Named Trigger Types

Named trigger types in NI-DCPower define the action you want an instrument or instrument channel to take upon detecting a specific signal condition.
The following named triggers are available for NI-DCPower instruments:

- **Start**—In Sequence source mode, a channel waits for a **Start** trigger upon entering the Running state; receiving the Start trigger causes a channel to begin source and measure operations.
  A channel does not perform any source or measure operations until it receives this trigger.
  This trigger is not used in Single Point source mode.
- **Source**—Receiving a **Source** trigger causes a channel to modify the source configuration.
  This trigger is available only when sourcing DC voltage or DC current.
- **Measure**—Receiving a **Measure** trigger, if Measure When is set to On Measure Trigger, causes a channel to take a measurement.
  A channel ignores this trigger if a measurement is already in progress or if Measure When is set to a different value.
- **Sequence Advance**—In Sequence source mode, a channel waits for the **Sequence Advance** trigger once an iteration of a sequence completes; receiving a Sequence Advance trigger causes the channel to begin the next iteration of the sequence.
  Sequence Loop Count must be set to a value greater than one for a sequence to iterate, and thus for this trigger to occur.
  This trigger is not used in Single Point source mode.

Trigger Signal Conditions

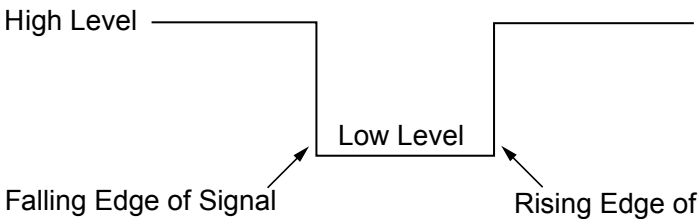
NI-DCPower includes three possible signal conditions that can serve as the stimulus for an action an instrument or channel can take: digital edge, software edge, and none (disabled).

Digital Edge

A channel performs an operation corresponding to a trigger when the channel detects a rising edge or a falling edge on a physical trigger line. Digital edge triggering is ideal for synchronizing channels.

You can configure each named trigger in NI-DCPower to operate based on a digital edge.

Figure 19. Digital Edge Trigger



The channels may be on the same or different physical instruments. If they are on different physical instruments, NI-DCPower routes the signal over the PXI backplane trigger lines.

To configure a digital edge trigger, you must specify the input terminal that should be connected to the trigger. The input terminal can be a physical trigger line or an output terminal from another instrument or channel. If you specify an output terminal from another instrument, NI-DCPower automatically finds a route (if one is available) from that terminal to the input terminal via a physical PXI backplane trigger line.

Software Edge

When configured for software edge triggering, channels wait to receive a trigger signal sent when you call Send Software Edge Trigger.

You can configure each named trigger in NI-DCPower to operate based on a software edge trigger.

None (Disabled)

When a trigger is configured as "none" (disabled), channels do not wait for any specific signal condition to occur before performing the action that corresponds to that trigger.

For example, if the Source trigger type is set to "none," a channel does not need to receive a Source trigger to begin a source operation.

NI-DCPower Named Event Types

You can route events on most NI-DCPower instruments. NI-DCPower includes specific events you can use in tandem with triggers to coordinate actions across channels of an instrument and across instruments.

- **Source Complete**—Generated by a channel when a sourcing operation, plus any configured source delay, is completed.
  In Single Point source mode, this event is generated whenever the source configuration is modified plus the associated source delay.
  In Sequence source mode, this event is generated after each step of the sequence plus the associated source delay for the step.
  The amount of configurable delay you can add depends on your instrument.
- **Sequence Iteration Complete**—Generated in Sequence source mode once all steps in a single iteration of a sequence are completed.
  One event is generated per iteration of the sequence. For example, if the sequence is configured to loop ten times on a channel, the channel generates ten events.
- **Sequence Engine Done**—Generated in Sequence source mode once all iterations of a sequence are completed.
- **Measure Complete**—Generated when a measurement, plus any configured measure delay, is completed.
  The amount of configurable measure delay you can add depends on your instrument.

NI-DCPower Event Signal Configurations

Each event type in NI-DCPower has its own set of three properties that you can use to configure the polarity, width, and destination of the event pulse signal.

- **Pulse polarity**—Whether the generated event pulse is a rising edge (positive pulse) or a falling edge (negative pulse)
- **Pulse width**—The duration of the event pulse
- **Output terminal**—The physical trigger line or input terminal on another instrument or channel to which the event is routed

Valid Pulse Widths for Events on the PXI Platform

PXI instruments have an allowable range of pulse widths you can configure for events.
You set the pulse width in terms of the duration, in seconds, the pulse should last. Pulse width applies only to events that are connected to external physical trigger lines, such as the PXI trigger lines. The PXIe instrument event pulse width range is [250 ns, 1.6 µs].
This range is defined by the **PXI Express Specification**.

NI-DCPower Synchronization Methods

Synchronization allows you to coordinate the action of multiple NI instruments. There are multiple approaches to synchronizing NI instruments; the accuracy (trigger delay and jitter) of the synchronization depends on the approach you take and the system and instruments in use.
NI-DCPower supports the following synchronization methods.

- **Software-Based Synchronization**—Sends a software command from a host computer to an instrument. Not deterministic on general-purpose operating systems such as Windows.
  Accuracy: tens of milliseconds
- **Time-Based Synchronization**—Uses a time-based protocol such as GPS, 1588, or IRIG-B to coordinate events. Can be used over large distances (>10 m).
  Remote chassis that include a PXI synchronization module can be programmed to generate triggers on the backplane at a specific time.
  Accuracy: <100 ns + NI-DCPower instrument trigger delay and jitter
- **Signal-Based Synchronization**—Uses trigger signals to coordinate operations.
  Comprises the following:

- PXI Trigger Routing—Sends a trigger signal, which corresponds to an event, from one instrument to another through the routes available in a PXI chassis (for PXIe/PXI instruments). The closer the signal paths between instruments are in length, the better the synchronization accuracy. Accuracy: tens of nanoseconds + NI-DCPower instrument trigger delay and jitter
- External Triggering—Sends a signal external to a PXI chassis or, for other instrument form factors, to an instrument through I/O lines. The closer the signal paths between instruments are in length, the better the synchronization accuracy. Time locking improves determinism.



Note Most NI-DCPower instruments cannot receive external digital triggers via their front panels. However, for NI-DCPower instruments that support triggering, you can send an external trigger to the instrument through another instrument installed in your chassis that does accept external triggers. You can route these trigger signals through the trigger lines on the chassis backplane.

Refer to the **PXIe-4112 Specifications** for the trigger delay and jitter of your instrument.

Multichannel Synchronization and Signal Routing in NI-DCPower

You can synchronize multiple channels with NI-DCPower by routing signals—events and triggers—from one channel to another, including channels that span multiple physical instruments.
You can export (**route**) the trigger and event signals to one of the physical PXI backplane trigger lines using Export Signal With Channels.



Tip You can use Wait For Event With Channels to make a channel wait to take an action until a specific event is generated.

Instead of explicitly exporting signals to physical trigger lines, NI-DCPower can automatically create routes for you. To have NI-DCPower automatically create routes, set the digital edge input terminal of one channel to be the event from another channel.

Example: Synchronizing Measure and Source Operations

To make PXI1Slot3/0 wait for the measurement of PXI1Slot3/1 to complete before PXI1Slot3/0 changes the source configuration, route the Measure Complete event of PXI1Slot3/1 to the Source trigger of PXI1Slot3/0.
To do this, configure the Source trigger of PXI1Slot3/0 to anticipate a digital edge and set the input terminal to /PXI1Slot3/Engine1/MeasureCompleteEvent.

Initiate the PXIe-4112 for Sourcing and Measuring

Initiate the channels of the PXIe-4112 to apply a configuration and start generating.

Use the niDCPower Initiate With Channels VI or the niDCPower_InitiateWithChannels function to apply the configuration and start generating voltage or current.

Acquire Measurements

The source mode that you configured channels to use determines how the PXIe-4112 acquires measurements.

Measuring and Querying

The following functions are only supported in Single Point source mode. These functions acquire the measurements and compliance state from the instrument at the time of the function call.

1. Measure with the niDCPower Measure Multiple VI or the niDCPower_MeasureMultiple function.
2. Call the niDCPower Query in Compliance VI or the niDCPower_QueryInCompliance function to query the output state.

These functions acquire the measurements and compliance state from the instrument at the time of the function call.

Fetching

The PXIe-4112 automatically acquires measurements when you configure the following VIs or functions:

- niDCPower Create Advanced Sequence With Channels VI or the niDCPower_CreateAdvancedSequenceWithChannels function

- niDCPower Set Sequence VI or the niDCPower_SetSequence function
- niDCPower Configure Output Function VI set to Pulse Voltage or Pulse Current or the niDCPower_ConfigureOutputFunction function set to NIDCPOWER_VAL_PULSE_CURRENT or NIDCPOWER_VAL_PULSE_VOLTAGE

These measurements are automatically acquired by coercing the niDCPower Measure When property to Automatically After Source Complete or the NIDCPOWER_ATTR_MEASURE_WHEN attribute to NIDCPOWER_VAL_AUTOMATICALLY_AFTER_SOURCE_COMPLETE. To fetch these measurements, call the niDCPower Fetch Multiple VI or the niDCPower_FetchMultiple function. NI-DCPower returns the measurement values in an array. The compliance state corresponding to each measurement is returned in a separate array at the same time.

Note If you want the measure unit to operate independently of the source unit in this context, set the niDCPower Measure When property or the NIDCPOWER_ATTR_MEASURE_WHEN attribute to a value other than Automatically After Source Complete or NIDCPOWER_VAL_AUTOMATICALLY_AFTER_SOURCE_COMPLETE.

In Single Point source mode, the PXIe-4112 also automatically acquires measurements if the Measure When property is set to anything other than On Demand.

Cease Generation

NI-DCPower includes different options for stopping generation on PXIe-4112 channels and returning the channels to a known state.

Option	How To	Description
Disabling the output	Set the Output Enabled property to False	Generates 0 V on a channel by disabling the switching power stage and leaving the down programmer active.
Disconnecting the output	Set the Output Connected property to False	Opens physical switches on the channel that disconnect the force and sense terminals from

Option	How To	Description
		the internal circuitry of the module.

Note To avoid excessive relay wear, do not set Output Connected to True with a non-zero voltage connected to the output.

Disabling the Output

The output of a channel is enabled by default when the channel enters the Running state. However, you can programmatically enable and disable the output channel(s) of the PXIe-4112.
When you disable the output of the PXIe-4112, the channel generates 0 V by disabling the switching power stage and leaving the down programmer active.
When you enable a previously disabled channel, levels and limits are applied to the channel depending on the output function as follows:

- **Voltage output functions**—The programmed voltage level and current limit are applied to the channel(s)
- **Current output functions**—The programmed current level and voltage limit are applied to the channel(s)

You can use the Configure Output Enabled function to toggle the output of an instrument.

Tip To ensure the output is disabled on the hardware, after using the Configure Output Enabled function or Output Enabled property, use the Wait For Event With Channels function. This function waits for the Source Complete event before calling the Abort With Channels function to transition the session out of the Running state.

Disconnecting the Output

You can open software-controlled switches in order to completely disconnect the +, -, and Sense terminals from the output connector of a channel.

For example, you might disconnect the output if a battery is connected to an output terminal in order to prevent the battery from discharging.

> **Notice** Only disconnect the output when it is necessary for your application. Excessive connecting and disconnecting of the output can cause premature wear on the relay.

- **Programming the output relay directly**—Use the Output Connected property to control the state of the output relay.
- **Output disconnected indirectly**—The output relay is disconnected when you call the Reset Device function or the Disable function.
- **Power-up behavior**—The instrument powers up with the output disconnected.
- **Output connected by default in certain states**—The output is automatically connected when a channel enters the running state following a device reset or system reboot, unless the default value of the Output Connected property is overridden.

Close the Session

Use the NI-DCPower driver to close a session with the PXIe-4112.

Use the niDCPower Close VI or the niDCPower_close function to close a session.

Closing a session is essential for freeing resources, including deallocating memory, destroying threads, and freeing operating system resources. You should close every session that you initialize, even if an error occurs during the program. When debugging your application, it is common to abort execution before you close. While aborting the execution should not cause problems, NI does not recommend doing so.

When you close a session, the channels continue to operate in their last configured state. If you close a session while the output channels are enabled and actively sourcing or sinking power, the channels continue to source or sink power until they are disabled or reset.

Example Programs

NI-DCPower includes several example applications that demonstrate the functionality of your device and can serve as interactive tools, programming models, and building blocks for your own applications.

NI Example Finder

The NI Example Finder is a utility that organizes examples into categories and allows you to browse and search installed examples. For example, search for "DCPower" to locate all NI-DCPower examples. You can see descriptions and compatible hardware models for each example or see all the examples compatible with one particular hardware model.

To locate examples using the NI Example Finder within LabVIEW or LabWindows/CVI, select **Help** » **Find Examples** and navigate to **Hardware Input and Output** » **Modular Instruments** » **NI-DCPower**.

Installed Example Locations

The installation location for NI-DCPower example programs differs by programming language and development environment. Refer to the following table for information about example program installation locations.

Table 12. Installed NI-DCPower Example Locations

Option	Installed Example Location
LabVIEW	<LabVIEW>\examples\instr\nidcpower, where <LabVIEW> is the directory for the specific LabVIEW version that is installed.
LabWindows/CVI	Users\Public\Documents\National Instruments\CVI\samples\niDCPower

Option		Installed Example Location
.NET	4.0	Users\Public\Documents\National Instruments\NI-DCPower\Examples\DotNET 4.0
	4.5	Users\Public\Documents\National Instruments\NI-DCPower\Examples\DotNET 4.5

Common Example Programs

The following NI-DCPower example programs demonstrate common SMU and power supply functions and operations.

- **NI-DCPower Source DC Voltage**—Demonstrates how to force an output voltage.
- **NI-DCPower Source DC Current**—Demonstrates how to force an output current.
- **NI-DCPower Hardware Timed Voltage Sweep**—Demonstrates how to sweep the voltage on a single channel and display the results in a graph.
- **NI-DCPower Measure Record**—Demonstrates how to take multiple measurements in succession.
- **NI-DCPower Measure Step Response**—Demonstrates how to measure the output while it is changing.



Note PXI-4110 and PXI-4130 do not support the following NI-DCPower example programs:

- NI-DCPower Hardware Timed Voltage Sweep
- NI-DCPower Measure Record
- NI-DCPower Measure Step Response

PXIe-4112 Operating Guidelines

Refer to the following sections for information about PXIe-4112 features and guidelines for operating the PXIe-4112.

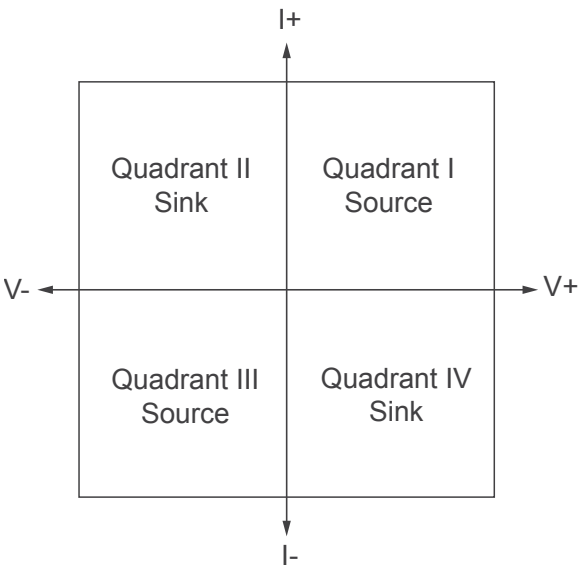
Sourcing and Sinking

The terms sourcing and sinking describe power flow into and out of a device, respectively. The PXIe-4112 is capable of only sourcing power and not sinking power.

Devices that are sourcing power are delivering power into a load, while devices that are sinking power behave like a load, absorbing power that is being driven into them and providing a return path for current.

A battery is one example of a device that is capable of both sourcing and sinking power. During the charging process, the battery acts as a power sink by drawing current from the charging circuit. After it has been removed from the charger and installed into an electronic device, the battery begins to act as a source that delivers power to a load.

The following quadrant diagram graphically represents whether a particular channel is sourcing or sinking power. Quadrants consist of the various combinations of positive and negative currents and voltages. Quadrants I and III represent sourcing power, while Quadrants II and IV represent sinking power. The PXIe-4112 operates only in the Quadrant I region.



For example, when you have a positive voltage and current flowing out of the positive terminal (that is, a positive current), the output operation falls within Quadrant I and is sourcing power. When you have a positive voltage and a current flowing into the positive terminal (that is, a negative current), the output operation falls within Quadrant IV, and is sinking power.

A single-quadrant channel on a power supply can operate only in one quadrant. For example, while the PXI-4110 has multiple channels capable of sourcing power in either Quadrant I or Quadrant III, individually, each channel on the PXI-4110 can operate only within one quadrant (channels 0 and 1 operate only within Quadrant I, and channel 2 operates only within Quadrant III). Thus, all channels on the PXI-4110 are single-quadrant supplies.

Devices that are capable of sourcing power in both Quadrant I and III are sometimes referred to as bipolar because they can generate both positive and negative voltages and currents. Bipolar output channels may or may not have current sinking capabilities (Quadrants II and IV).

An output channel on a four-quadrant power supply or SMU can both source and sink power with a positive or negative voltage and current. For example, a PXI-413x SMU is capable of both sourcing power in Quadrant I or Quadrant III and sinking power in Quadrant II or Quadrant IV. Thus, PXI-413x SMUs are bipolar, four-quadrant devices.

Refer to the **PXIe-4112 Specifications** for more information about the sourcing capability of your device, as well as detailed power limits.

Output Impedance

NI power supplies and SMUs include output amplifiers that drive their outputs through series resistors. The resistors enable the measurement and control of output current. The value of the resistor is larger for low-current ranges and smaller for high-current ranges.

Depending on whether the device is in constant voltage mode or in constant current mode, feedback can make the output behave like a true voltage or current source at DC. At higher frequencies, there is no feedback, and the output behaves like a voltage source in series with the selected output resistor.

In constant current mode, the controller forces the output current, as determined by the voltage across the sense resistor, to match the setpoint, regardless of the actual output voltage. The slew rate of the instrument to a new setpoint will be limited by output capacitance in constant current mode.

In constant voltage mode, the controller forces the output voltage to match the setpoint, even when there is a voltage drop across the resistor. The slew rate of the instrument to a new setpoint will be limited by output inductance in constant voltage mode.

Output Capacitance

- **Virtual Capacitance**—Represents a capacitance synthesized by the action of a control loop on a resistor rather than from an actual capacitor. A true current source has an output impedance of infinity. Because of the finite bandwidth of the control loop, the output behaves like a true current source only at DC. At higher frequencies, the output impedance approaches the value of the series resistance. The output behaves like a current source in parallel with a capacitor. The value of the virtual capacitance increases as the output current decreases in percent of full-scale range.
- **Real Capacitance**—Capacitance added by components and interconnections in the device. Generally, this real capacitance is smaller than the virtual capacitance caused by the operation of the control loop, especially in high current ranges. However, some devices include large values of real output capacitance to improve performance for certain use cases.

Output Inductance

- **Virtual Inductance**—Represents an inductance synthesized by the action of a control loop on a resistor rather than from an actual inductor. A true voltage source has an output impedance of zero. Because of the finite bandwidth of the control loop, the output behaves like a true voltage source only at DC. At higher frequencies, the output impedance approaches the value of the series resistance. In general, the output behaves like a voltage source in series with a parallel combination of the series resistance and an inductor.
- **Real Inductance**—Inductance added by components and interconnections in the device. Generally, this real inductance is smaller than the virtual inductance caused by the operation of the control loop, especially in low current ranges.

Decreasing Output Capacitance

Output capacitance has an effect on the output slew rate. You can decrease output capacitance and increase the speed of the PXIe-4112.

Decreasing Virtual Output Capacitance

Virtual output capacitance can significantly limit output slew rate. For example, consider the PXIe-4112 stepping from 1 V to 2 V in the 1 A range with a 20 mA compliance limit. Even in the absence of a load, the 20 mA compliance current charging the virtual capacitance limits the output slew rate. You can adjust the settings of NI-DCPower to decrease the effect of virtual output capacitance.

You can decrease output capacitance by increasing the compliance limit. In that case, the real output capacitance does not decrease, but the current available to charge it increases. Increasing the compliance limit to full-scale value of the current range in the preceding example effectively removes the output-current-related slew rate limit.

Decreasing Real Output Capacitance

Real output capacitance can limit slew rate. To decrease output capacitance, you can use shorter length cabling to reduce the actual capacitance of the load.

When slew rate is limited by the current available to charge a real output capacitance, changing ranges or GBW settings has no effect. Changing ranges or GBW settings affects only the virtual output capacitance.

Using NI-DCPower to Decrease the Impact of Output Capacitance

You can increase the compliance limit in NI-DCPower to decrease the impact of output capacitance. The real output capacitance does not decrease, but the current available to charge it increases. Increasing the compliance limit to 100 mA in the preceding example effectively removes the output-current-related slew rate limit.

Note The current ADC does not measure the current that charges the virtual output capacitance. Therefore, when the output slew rate is limited by the available charging current, that current may not be measured by the current measurement circuitry.

Decreasing Output Inductance

Cable inductance has an effect on the output current slew rate. You can decrease cabling inductance and increase the speed of the PXIe-4112.
You can perform any of the following actions to decrease output inductance:

- Use shorter length cabling.
- Reduce the loop area between the + and - terminals.

Protection

The output channels and the auxiliary power input of the PXIe-4112 are protected against overcurrent, overvoltage, inverse voltage, and over-temperature conditions.

Output Channel Protection

All output channels on the PXIe-4112 are overcurrent-protected. In the event of an overcurrent condition, the channel enters current compliance mode. The channel has cycle-by-cycle current limiting and additional over-current protection on the external power input that protects the channel in the event of a current compliance mode failure. In the event that an inverse voltage is applied to the channel, a reverse

protection diode prevents damage to the channel. A thermal overload circuit protects this diode by engaging the output disconnect feature in the event of an inverse voltage with large current capability.

> **Caution** Each output channel of the PXIe-4112 can withstand the application of an external voltage up to 10 V beyond the rated output level. Applying an external voltage greater than 10 V beyond the rated output level can damage the output channel.

In the event of an over-temperature condition (that is, the enclosure or component temperatures exceed safe operating limits), the thermal shutdown circuits on the PXIe-4112 disable the output channel that indicated the failure condition, disable all other channels, disable external power, and disconnect the outputs. When disabled, an output channel can only be reset programmatically after the failure condition is cleared.

Auxiliary Input Protection

The auxiliary power input of the PXIe-4112 can accept voltages up to 52.8 V. Applying a voltage above 52.8 V disables the auxiliary power input.

This device is overvoltage protected >52.8 V. Refer to the **PXIe-4112 Specifications** for more information about overvoltage protection for this device.

In the event of an overcurrent (>6.3 A) or an inverse voltage condition, the auxiliary power input fuse may blow to protect the PXIe-4112 and the load.

Overload Protection (OLP)

The PXIe-4112 is protected against overcurrent (OCP) conditions and overvoltage (OVP) conditions.

> **Note** Refer to NI-DCPower Overload Protection Error (OLP) Codes for more information about these NI-DCPower errors.

Overcurrent Protection (OCP)

Overcurrent Protection (OCP) engages protection circuitry when the maximum specified current has been surpassed. This feature disables the output of the affected channel and disconnects the channel circuitry from the output connector pins. By internally disconnecting the output, it protects both the PXIe-4112 and the device under test (DUT).

To clear an OCP condition, first identify and fix the cause of the error and then reset the channel or device in MAX or use the niDCPower Reset Device VI or the niDCPower_ResetDevice function.

Do not apply voltages at the output that exceed the ratings of the PXIe-4112. Refer to the **PXIe-4112 Specifications** for information about voltage ratings.

Overvoltage Protection (OVP)

Overvoltage Protection (OVP) is a feature that prevents excessive voltage from being applied to a device under test (DUT) connected to a power supply. When voltage output exceeds a certain limit, the device output shuts down and NI-DCPower generates an error.

To clear an OVP error condition, first identify and fix the cause of the error and then use the niDCPower Reset VI or the niDCPower_Reset function.

Load Regulation

Load regulation is a measure of the ability of an output channel to remain constant given changes in the load.
Depending on the control mode enabled on the output channel, the load regulation specification can be expressed in one of two ways:

- In constant voltage mode, variations in output current result in changes in the output voltage. This variation is expressed as a percentage of output voltage range per amp of current change, or as a change in voltage per amp of current change, and is synonymous with a series resistance.
  - When Sense - is connected to -, and Sense + is connected to + at the terminal block, the load regulation specification defines how close the output series resistance is to 0 Ω—the series resistance of an ideal voltage

source. Many supplies have protection circuitry at the output that slightly increases the output series resistance.

- The PXIe-4112 requires the niDCPower Sense property or NIDCPOWER_ATTR_SENSE attribute to be configured for Remote, even while maintaining a 2-wire configuration. Configure the channel for remote sense and connect the sense terminals externally to their respective output terminals (connect Sense - to the - terminal, and Sense + to the + terminal).

- In constant current mode, variations in load voltage result in changes to the output current. This variation is typically expressed as a percentage of output current range per volt of output change, and is synonymous with a resistance in parallel with the output channel terminals. In constant current mode, the load regulation specification defines how close the output shunt resistance is to infinity—the parallel resistance of an ideal current source. In fact, when load regulation is specified in constant current mode, parallel resistance is expressed as 1/**load regulation**.

Inductive Loads

In constant voltage mode, most inductive loads remain stable. However, when operating in constant current mode in higher current ranges, increasing output capacitance may help improve stability.

Capacitive Loads

Generally, a power supply remains stable when driving a capacitive load. Occasionally, certain capacitive loads can cause ringing in the transient response of the instrument. The instrument may temporarily move into constant current mode or unregulated mode when the output voltage is reprogrammed while capacitive loads are present.

The slew rate is the maximum rate of change of the output voltage as a function of time. When driving a capacitor, the slew rate is limited to the output current limit divided by the total load capacitance, as expressed in the following equation:

$(\Delta \mathbf{V}/\Delta \mathbf{t}) = (\mathbf{I}/\mathbf{C})$

where $\Delta \mathbf{V}$ is the change in the output voltage

$\Delta \mathbf{t}$ is the change in time

I is the current limit

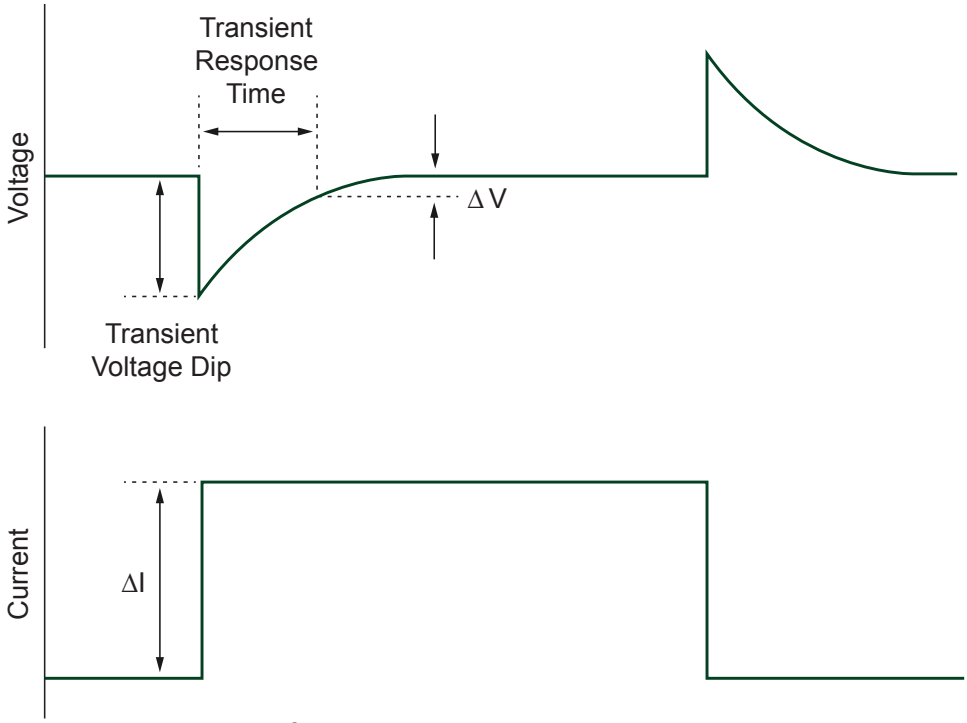
C is the total capacitance across the load

Series resistance and lead inductance from cabling can affect the stability of the device. In some situations, you may need to increase the capacitive load or locally bypass the circuit or system being powered to stabilize the power supply.

Transient Response

In reference to power supplies and SMUs, transient response describes how a supply responds to a sudden change in load.
Changes in load current, such as a current pulse, can cause large voltage transients. The transient response specifies how long it takes before the transients recover. The following figure shows how the transient behavior is typically specified. The transient response time specifies how quickly the supply can recover to within a certain voltage (Δ**V**) when a specific change in load (Δ**I**) occurs. Some power supplies also specify a maximum transient voltage dip under the same load conditions.

Figure 20. Transient Response



There is a trade-off between transient response and the stability of the supply under a wide variety of loads. To achieve the fastest transient response, an instrument should have a high gain-bandwidth (GBW) product, but the higher GBW is, the more likely it is that the instrument will become unstable with certain loads. Thus, most

instruments compromise performance to achieve stability under most conditions. Other instruments allow a degree of customization to enable optimization of performance under different circumstances.

Pulse Loads

Load current can vary between a minimum and a maximum value in some applications. In the case of a varying load, or pulse load, the constant current circuit of the power supply limits the output current.
Occasionally, a peak current may come close to exceeding the current limit and cause the power supply to temporarily move into constant current mode or unregulated mode.
To remain within the power supply output specifications with pulsed loads, use niDCPower Configure Current Limit to configure the current limit to a value greater than the expected peak current of the load.
In extreme situations, you may be able to parallel-connect multiple power supply channels to provide higher peak currents.

Reverse Current Loads

Occasionally, an active load may pass a reverse current to the power supply.
To avoid reverse current loads, use a bleed-off load to preload the output of the device. Ideally, a bleed-off load should draw the same amount of current from the device that an active load may pass to the power supply.

Caution Power supplies not designed for four-quadrant operation may become damaged if reverse currents are applied to their output terminals. Reverse currents can cause the device to move into an unregulated mode and can damage the instrument. Refer to the **PXIe-4112 Specifications** for more information about channel capabilities.

Note The sum of the bleed-off load current and the current supplied to the load must be less than the maximum current of the instrument.

Ranges

The PXIe-4112 uses one fixed range for voltage output and measurement, as well as one fixed range for current output and measurement.

Note The measurement range is implicitly selected based on the configured output range. Thus, you cannot change the measurement range independently of the output range. The selected measurement range is large enough to measure any voltage or current within the configured output range.

Ranges are typically described as the maximum possible value from zero that the range can output or measure (not including the overrange). For example, in the 20 mA current level range, the current level can be configured up to 20 mA.

- When niDCPower Configure Output Function is set to DC Voltage, the voltage level range and current limit range are in use.
- When niDCPower Configure Output Function is set to DC Current, the current level range and voltage limit range are in use.

Overranging

If niDCPower Overranging Enabled is set to TRUE, the valid values for the programmed output (voltage level, voltage limit, current level, and current limit) may be extended beyond their normal operating range on channels that support this feature.

Enabling overranging for a particular channel extends voltage and current output capabilities from 100% to 105% for the output range. Overranging is applicable to output ranges only and does not apply to measurement ranges. Measurements in any given range may be made up to 105% of the range by default without enabling overranging.

Noise

Noise is unwanted signals present on the output channels that can affect devices connected to the output channels.

Noise can be characterized as normal-mode noise or common-mode noise. Regardless of its characterization, noise is meaningful only when it is specified with an associated bandwidth.

- **Common-mode noise**—Noise present between the Output common - terminal and the chassis or earth ground. In this sense, the equivalent circuit is a current noise source connected across these two terminals. When you connect an impedance between the output common/ground and chassis or earth ground, a noise current can flow in the impedance, resulting in an unexpected offset or other undesirable error.
- **Normal-mode noise**—Noise present between the + terminal and the common - terminal, appearing either in series (constant voltage mode) or parallel (constant current mode) with the output of the device. Normal-mode noise can be expressed as voltage noise or current noise, depending on the control mode of the output channel.
  AC-to-DC rectification causes ripple, a type of periodic normal-mode noise.

Verifying Output Noise Specifications

Exercise care when verifying the noise specifications of an output device, such as a power supply. When verifying the specified wideband noise of a device, the effects of ground loops, unnecessarily long probe ground leads, and electrically noisy environments can combine and skew your measurements.

Observe the following recommendations when verifying the output noise specifications of a power supply:

- Connect the probe directly to the terminals of the power supply. Do not use long leads, loose wires, or unshielded cables.
- Limit the probe ground lead to 2.54 cm (1 in.) at most. Connect this lead directly to the output common/ground terminal of the appropriate channel.
- Set the bandwidth of the measurement device to the bandwidth of interest.
- Exercise caution when making measurements in a modern laboratory environment—with computers, electronic ballasts, switching power supplies, and so on—to avoid measuring the environment noise instead of the device noise.

AC and DC Noise Rejection

You can manipulate the aperture time of measurements made with SMUs and power supplies to reject specific AC noise frequencies in DC voltage and current measurements.

Each measurement that an NI-DCPower instrument returns is an average of one or more higher-speed samples. All instruments return a multiple of 50 Hz and/or 60 Hz to enable rejection of power line noise.

You can reject AC noise by adjusting the measurement aperture time to be a multiple of the AC noise period.

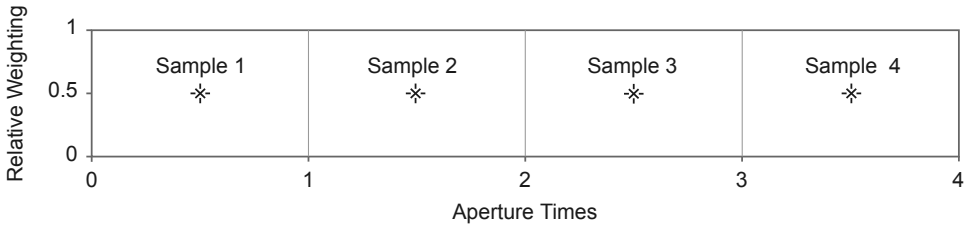
You can reject the frequency of noise by adjusting the aperture time to be a multiple of an AC noise frequency with **Period** = 1/**f**.

Normal DC Measurement Noise Rejection

The PXIe-4112 only supports normal DC measurement noise rejection. With normal noise rejection, the instrument assigns equal weight to each sample. This setting mimics the behavior of most traditional power supplies and SMUs.

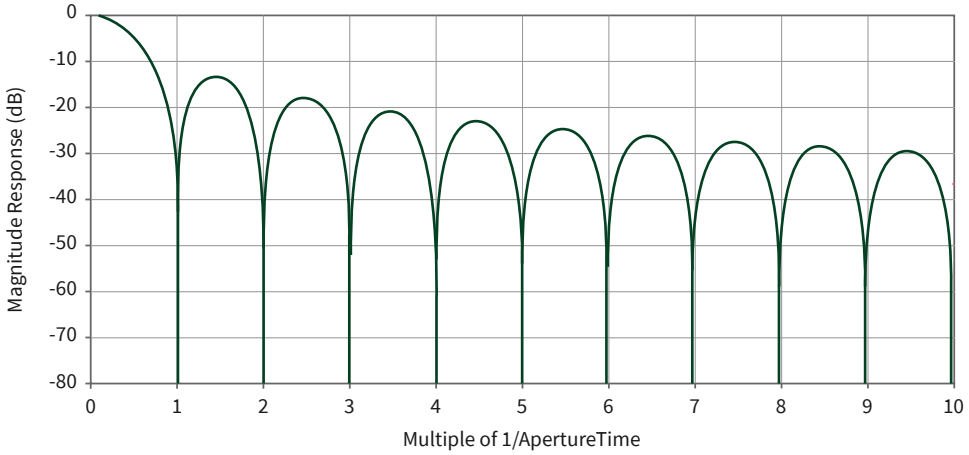
The following figure shows normal weighting, with aperture times on the x-axis and relative weighting on the y-axis.

Figure 21. Normal Noise Rejection



The following figure shows the resulting noise rejection as a function of frequency, with multiples of 1 / **Aperture Time** on the x-axis and magnitude response, in dB, on the y-axis.

Figure 22. Normal Noise Rejection by Frequency



The best frequency rejection is available only near integer multiples of 1 / **Aperture Time**. You can achieve the fastest possible readings along with good power-line noise rejection by setting the aperture to one power-line cycle (PLC) and noise rejection to Normal.

Rejecting AC Noise in DC Measurements with Aperture Time

Directly adjusting the aperture time of your measurements allows you to reject specific AC noise frequencies in your DC measurements with NI-DCPower.

Complete the following steps to reject AC noise frequencies by adjusting the aperture time of your measurements.

1. Based on the aperture time unit you intend to use, calculate the aperture time required to reject the frequency f (Hz) you need to reject.
   - Aperture time units: **Aperture Time** = 1 / f seconds
   - Aperture time units: power line cycles (PLC)

Power Line Frequency	Target Aperture Time (PLC)
60 Hz	**Aperture Time** = 60 Hz / f
50 Hz	**Aperture Time** = 50 Hz / f

Note Each NI-DCPower instrument supports discrete aperture times: an instrument-specific minimum value and integer multiples of that value. When you set an unsupported aperture time,

> NI-DCPower coerces the value to the nearest longer supported value for your instrument.

2. Configure the aperture time you calculated.
    a. Set the aperture time and the appropriate units with Configure Aperture Time.
    b. If using power line cycle units, provide the frequency of the AC power line for your system to Configure Power Line Frequency.

Power Measurements

Each channel of the PXIe-4112 has two synchronized ADCs that measure voltage and current. You can use NI-DCPower to measure power flowing to or from the PXIe-4112.
You can use the following VIs and functions to measure both current and voltage for both channels of the PXIe-4112.

- niDCPower Measure Multiple VI or niDCPower_MeasureMultiple function
- niDCPower Fetch Multiple VI or niDCPower_FetchMultiple function

Power can be computed as the product of the voltage and the current. If the power measurement is positive, the PXIe-4112 is sourcing power. If the power measurement is negative, the PXIe-4112 is sinking power.

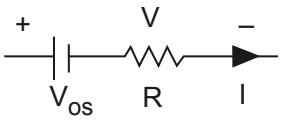
Resistance Measurements

NI power supplies and SMUs can make resistance measurements because they can both generate and measure test voltages and currents. Because they can operate as precision current sources at high current levels, these devices are well suited to measure low resistance values.

To measure a resistance with an NI power supply or SMU, select a test current that creates a voltage drop within module capabilities. After the channel output is enabled and settled, use the niDCPower Measure Multiple VI or the niDCPower_MeasureMultiple function to measure the actual current being delivered to the resistor as well as the measured voltage across the resistor. To determine the accuracy of a resistance measurement, the accuracy specifications of both current and voltage measurements for the power supply or SMU should be taken into account. For channels with remote sense capabilities, enabling this feature results in a more accurate voltage measurement at the resistor terminals.

Compensation for Offset Voltages

When measuring low-value resistances, thermal voltages may introduce significant offsets into the resistance measurement path. If an offset voltage exists in series with the resistance to be measured, as in the following figure, taking a second measurement at a different current output setpoint allows the offset to be accounted for in the resistance calculation.



The two test currents, $\mathbf{I_1}$ and $\mathbf{I_2}$, create voltage drops of $\mathbf{V_1}$ and $\mathbf{V_2}$, respectively. Thus, the following two equations can be derived:

- $\mathbf{V_1 = I_1R + V_{OS}}$
- $\mathbf{V_2 = I_2R + V_{OS}}$

Rearranging these two equations allows you to calculate the unknown resistance, **R**, without measuring $\mathbf{V_{OS}}$. Assuming the currents $\mathbf{I_1}$ and $\mathbf{I_2}$ are different, the following equation can be derived:

$\mathbf{R} = (\mathbf{V_2} - \mathbf{V_1}) / (\mathbf{I_2} - \mathbf{I_1})$

For the best signal-to-noise performance, test currents of opposite polarity should be used (for example, +100 mA and -100 mA). If currents of opposite polarity are not feasible, the next best solution is to use test currents that are as far apart as possible. For example, if your first current is 1 A, you could choose a second test current of 10 mA.

Replacing a Fuse

The auxiliary power input connection on the PXIe-4112 front panel has a user-replaceable fuse. The fuse rating and manufacturer information is as follows:

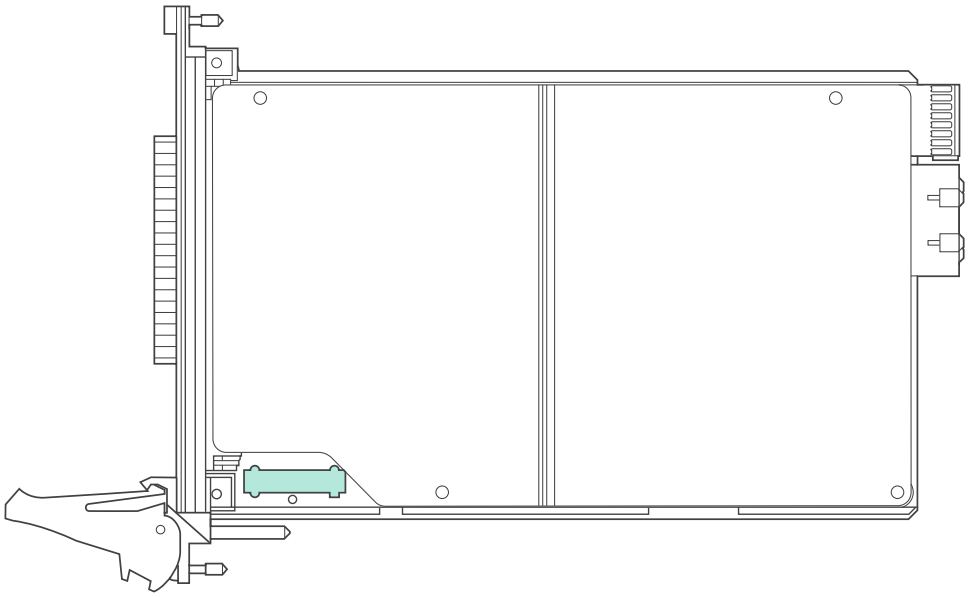
- **Input/Output**—Auxiliary power input
- **Fuse Rating**—T 6.3 A L 250 V
- **Description**—User-replacable 5 x 20 mm glass fuse

- **Recommended Manufacturer Part Number**—Littelfuse 021606.3MXP

To replace a fuse on the PXIe-4112, complete the following steps:

1. Power down the chassis.
2. Disconnect all output and auxiliary power connections.
3. Remove the PXIe-4112 from the chassis.
4. Locate the fuse to replace using the following figure.

   Figure 23. Location of Auxiliary Input Fuse



5. Use a small flathead screwdriver to gently pry the auxiliary power input fuse from the fuse holder.
6. Insert the replacement fuse into the fuse holder and ensure that the fuse snaps into place.

Measurement Configuration and Timing

The PXIe-4112 can acquire measurements automatically after a sourcing operation or when triggered. The PXIe-4112 uses a successive approximation (SAR) ADC for sampling voltage and current.

The state sequence of the device measurement circuitry differs depending on the measure record length that you use. The measure record length indicates how many

measurements to acquire after the measure trigger and before the measure complete event.

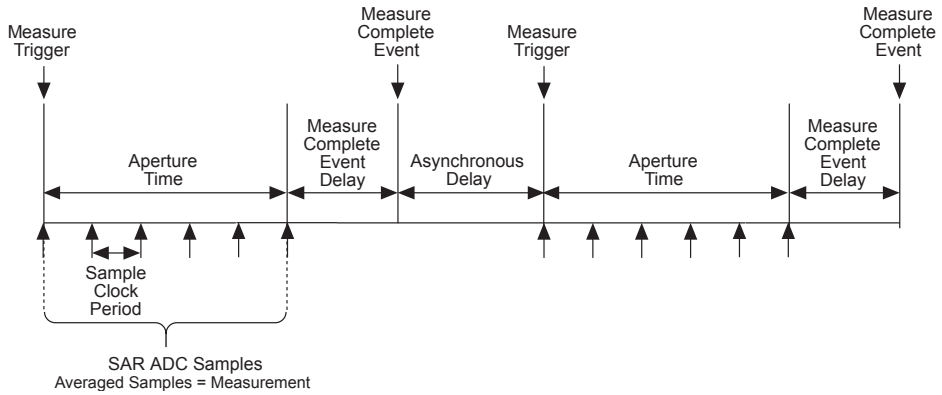
Multiple Asynchronous Measurement Timing

If you make multiple measurements that are each timed with asynchronous measurement start triggers, the measure record length is one and the PXIe-4112 measurement circuitry operates in one of the three active states:

- **Aperture time**—During the aperture time, the PXIe-4112 samples the input signal and converts the signal two or more times at a fixed sample clock interval for the programmed aperture time of the device. The PXIe-4112 then averages these samples to generate the returned measurement.
- **Measure complete event delay**—During the measure complete event delay, the measurement circuitry of the device waits for a length of time that you specify before generating the measure complete event. The default value is zero.
- **Asynchronous delay**—During the asynchronous delay, the measurement circuitry of the device is idle until a trigger initiates the next measurement.

The following figure illustrates the sequence of these states for two sample measurements.

Figure 24. Multiple Asynchronous Measurement Timing



In this example, two measurements are made, so the measure trigger and measure complete event occur twice, once for each measurement. The aperture time is five divided by the sample clock rate, meaning that for each measurement, a total of six

samples are averaged. The sample clock period is fixed for the device at a value of 1/5.25 kHz.

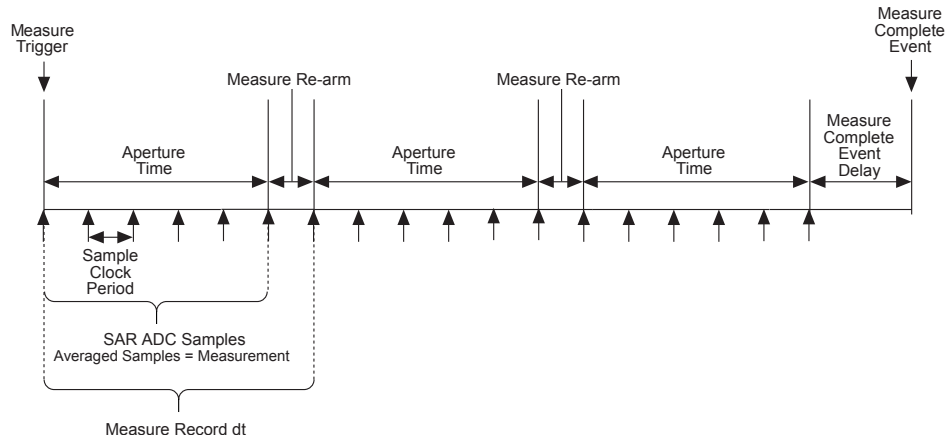
Measure Record Timing

If you make a sequence of hardware-timed measurements in response to a single measurement start trigger, you can configure the measure record length to greater than one and the PXIe-4112 measurement circuitry operates in one of the three active states:

- **Aperture time**—During the aperture time, the PXIe-4112 samples the input signal two or more times and converts the signal at a fixed sample clock interval for the programmed aperture time of the device. The PXIe-4112 then averages these samples to generate the returned measurement.
- **Measure re-arm**—During the measure re-arm time, which has a duration of one sample clock period, the measurement circuitry of the device waits before acquiring samples for the next measurement.
- **Measure complete event delay**—During the measure complete event delay, the measurement circuitry of the device waits for a length of time that you specify before generating the measure complete event. The default value is zero.

The following figure illustrates the sequence of these states for a measurement record length of three.

Figure 25. Measure Record Timing



In this example, the aperture time is five divided by the sample clock rate, meaning that for each measurement, a total of six samples are averaged. The sample clock period is fixed for the device at a value of 1/5.25 kHz. The measure record dt is the aperture time and the measure re-arm time added together.

Aperture Time

The PXIe-4112 supports aperture times based on the power line frequency of the device. The PXIe-4112 acquires samples at a fixed rate of 1/5250 s, a single period of a 5.25 kHz clock.
When setting an aperture time to acquire a measurement, the PXIe-4112 executes as follows:

1. Acquires the number of samples that occur during the aperture time.
2. Averages the samples.
3. Returns one measurement that represents the average reading over the specified aperture time.

As a result, the aperture time must be a multiple of 1/5250 s. If you specify an aperture time that is not a multiple of 1/5250 s, NI-DCPower coerces the value to the next highest valid aperture time.
Use the niDCPower Configure Aperture Time VI or the niDCPower_ConfigureApertureTime function to set the aperture time of the device. Use the niDCPower Configure Power Line Frequency VI or the niDCPower_ConfigurePowerLineFrequency function to set the power line frequency for a specified channel of the device. Use the niDCPower Configure Aperture Time VI or the niDCPower_ConfigureApertureTime function to set the aperture time of the device. Use the niDCPower Configure Power Line Frequency VI or the niDCPower_ConfigurePowerLineFrequency function to set the power line frequency for a specified channel of the device.

Rejecting Power Line Noise

You can reject power line noise from the signal by adjusting the aperture time:

1. Set the power line frequency (50 Hz or 60 Hz).
2. Set the aperture units to power line cycles (PLCs).

3. Set the aperture time to integer multiples of 1.

Sourcing and Measuring Terminology

Refer to the following terms when learning more about the features and usage of the PXIe-4112:

- **Aperture Time**—The period during which an ADC reads the voltage or current on a power supply or SMU. Aperture time can be specified in seconds (s) or power line cycles (PLCs). Measurement resolution, measurement speed, and frequency rejection are all functions of aperture time.

  Tip Select longer aperture times to improve measurement resolution; select shorter aperture times to increase the measurement speed.

- **Compliance**—For power supplies and SMUs, a channel is operating in compliance when it cannot reach the requested output level because the programmed limit has been reached.
- **Line Regulation**—A measure of the ability of the power supply or SMU to maintain the output level given changes in the input line voltage. Line regulation is expressed as percent of change in the output level relative to the change in the input line voltage.
  For NI DC power supplies and SMUs, the line regulation specification only applies to devices with an auxiliary power input.
- **Load Regulation**—A measure of the ability of an output channel to remain constant given changes in the load. Load regulation expression depends on the control mode enabled on the output channel.
- **Resolution**—The smallest change in the voltage or current measurement that can be detected by hardware. It is usually specified in absolute units, like µV or nA.
  - Measurement resolution is typically limited by the ADC used for the measurement, but may also be limited by other factors, such as noise.
  - Output resolution is typically limited by the finite number of steps that are available in the device DAC circuit, but may also be limited by other factors, such as noise.

Refer to the **PXIe-4112 Specifications** for measurement resolution and output resolution information.

- **Sensitivity**—Sensitivity is the smallest unit of a given parameter that can be meaningfully detected with an instrument under specified conditions. This unit is generally equal to the measurement resolution in the smallest range of a power supply or SMU.
- **Settling Time**—Settling time specifies the time required for an output channel to stabilize to within a specified percentage of its final value. This value is typically included in the device specifications.

Calibration

PXIe-4112 only supports external calibration.

External Calibration

Every power supply or SMU performs within its specifications over some finite temperature range and time period. If the temperature changes or time exceed those specified, and your application requires tight specifications, external calibration is required.

Calibration and Temperature Variation

When a system is composed of multiple integrated instruments, the system is subject to temperature rise caused by inherent compromises in air circulation and other factors. Self-heating from surrounding equipment, uncontrolled manufacturing floor environment, and dirty fan filters are among these factors.

Refer to the **PXIe-4112 Specifications** for the following information for your instrument:

- Recommended operating temperature range
- Calibration interval

Refer to Best Practices for Building and Maintaining PXI Systems for the definition of ambient temperature.

If the ambient temperature is outside of the specified range, you may need to know the measurement accuracy to account for temperature variation. One way to calculate the specified accuracy outside of the temperature range is to

externally calibrate the system at the desired temperature. External calibration, though inconvenient, should allow the device to attain its full rated accuracy at the calibration temperature. You can learn more about external calibration at ni.com/calibration.

Another way to calculate the specified accuracy outside of the temperature range is to add the temperature coefficient accuracy for each additional degree outside the calibration range.

The following equation represents the temperature coefficient (tempco).

Tempco = **X**% of accuracy specification/°C

For example, consider an instrument outputting 5 V with voltage accuracy specified at 0.05% of output + 100 µV in the range 18 °C to 28 °C, and tempco specified as 10% of accuracy specification per °C. If the last external calibration was performed at 23 °C, the following equation represents the 1-year accuracy of the instrument in the 18 °C to 28 °C range:

0.05% of 5 V + 100 µV = 2.6 mV

If the ambient temperature changes to 38 °C, the device is operating 10 degrees outside the specified range, the accuracy is calculated as follows:

±(2.6 mV + ((10% of 2.6 mV)/°C) * 10 °C) = ±5.2 mV

The total error is twice the specified error (5.2 mV in the example above, versus 2.6 mV if temperature effect is ignored) due to the 38 °C ambient temperature. If the additional error term due to temperature drift is unacceptable, some devices support self-calibration at the desired measurement temperature to improve accuracy.

Refer to the **PXIe-4112 Calibration Procedure** for the external calibration procedure for your instrument.

Accuracy

A measurement or output level on a power supply can differ from the actual or requested value.

Accuracy represents the uncertainty of a given measurement or output level and can be defined in terms of the deviation from an ideal transfer function, as follows:

y = **mx** + **b**

where **m** is the ideal gain of the system

x is the input to the system

b is the offset of the system

Applying this example to a power supply signal measurement, **y** is the reading obtained from the device with **x** as the input, and b is an offset error that you may be able to null before the measurement is performed. If **m** is 1 and **b** is 0, the output measurement is equal to the input. If **m** is 1.0001, the error from the ideal is 0.01%.

Parts per million (ppm) is another common unit used to represent accuracy. The following table shows ppm to percent conversions.

ppm	Percent
1	0.0001
10	0.001
100	0.01
1,000	0.1
10,000	1

Most high-resolution, high-accuracy power supplies describe accuracy as a combination of an offset error and a gain error. These two error terms are added to determine the total accuracy specification for a given measurement. NI power supplies typically specify offset errors with absolute units (for example, mV or µA), while gain errors are specified as a percentage of the reading or the requested value.

Determining Accuracy

The following example illustrates how to calculate the accuracy of a 1 mA current measurement in the 2 mA range of an instrument with an accuracy specification of 0.03% + 0.4 µA:

Accuracy = (0.0003 × 1 mA) + 0.4 µA = 0.7 µA

Therefore, the reading of 1 mA should be within ±0.7 µA of the actual current.

Note Temperature can have a significant impact on the accuracy of a power supply and is a common problem for precision measurements. The temperature coefficient, or tempco, expresses the error caused by

temperature. Errors are calculated as ±(**% of reading** + **offset range**)/°C and are added to the accuracy specification when operating outside the power supply rated accuracy temperature range.

Cleaning the PXIe-4112

NI recommends the following to clean and maintain your power supply system:

- Clean the fan filters on the chassis regularly to prevent fan blockage and to ensure efficient air circulation. Cleaning frequency depends on the amount of use and the operating environment. For specific information about cleaning procedures and other recommended maintenance, refer to the chassis user documentation.
- Clean devices and terminal blocks by brushing off light dust with a soft, nonmetallic brush. Remove other contaminants with a soft, lint-free, dampened cloth. Do not use detergent or chemical solvents. The unit must be completely dry and free from contaminants before returning to service.

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