PXI-4110 User Manual

2025-09-23

Contents

PXI-4110 User Manual

The PXI-4110 User Manual provides detailed descriptions of the product functionality and the step by step processes for use.

Looking for Something Else?

For information not found in the User Manual for your product, such as specifications and API reference, browse ***Related Information***.

Related information:

- PXI-4110 Specifications
- PXI-4110 Calibration Procedure
- NI-DCPower Help
- NI-DCPower LabVIEW VI Reference
- NI-DCPower Properties
- 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

PXI-4110 Overview

The PXI-4110 is a triple-output, single-quadrant, programmable power supply in a single-slot, 3U PXI module. It is designed for engineers performing design validation and manufacturing test applications. Use the PXI-4110 for constant voltage (CV) applications or PXI-4110 constant current (CC) operation with programmable setpoint levels and limits. Voltage and current applications support measurement readback.

Device Capabilities

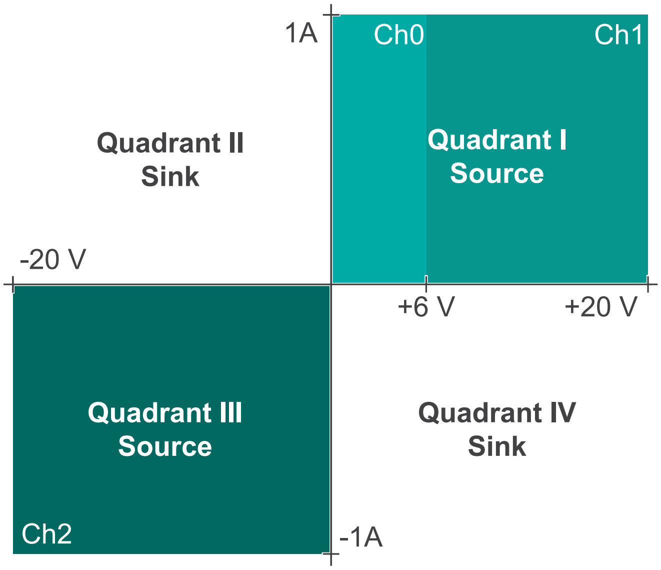
The PXI-4110 has the following channel capabilities.

- Channel 0: 0 V to 6 V, 1 A, 6 W power supply.
- Channel 1: 0 V to 20 V, 1 A, 20 W (with auxiliary supply) or 2 W (internally powered), bank-isolated[1] power supply.
- Channel 2: -20 V to 0 V, 1 A, 20 W (with auxiliary supply) or 2 W (internally powered), bank-isolated power supply.

> **Note** When internally powered, the combined outputs of Channels 1 and 2 must not exceed 3 W.

1. In bank isolation, or channel-to-bus isolation, several physical lines are built into groups called banks. The ground loop protection is high between banks because isolation barriers exist between channels in different banks. However, it is still possible for signals on channels within a bank to affect each other.

Figure 1. PXI-4110 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	1.0

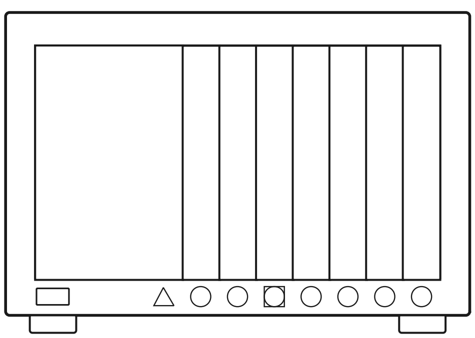
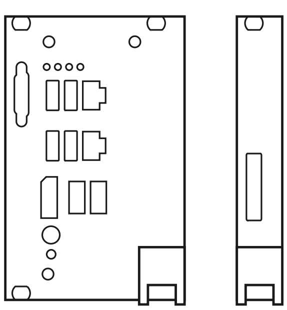
Components of a PXI-4110 System

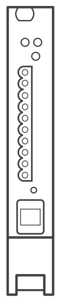
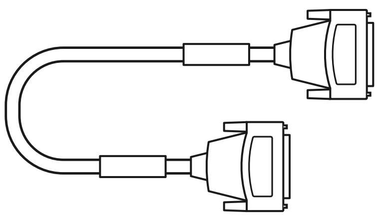
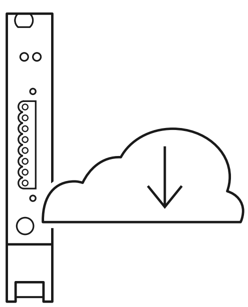
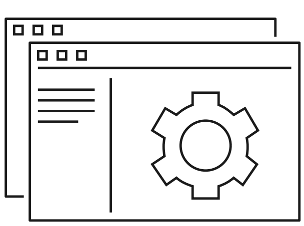
The PXI-4110 is designed for use in a system that includes other hardware components, drivers, and software.

Notice A system and the surrounding environment must meet the requirements defined in ***PXI-4110 Specifications***.

The following list defines the minimum required hardware and software for a system that includes a PXI-4110.

Table 2. System Components

Component	Description and Recommendations
PXI Chassis 	A PXI chassis houses the PXI-4110 and supplies power for PXI-4110 functions.
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 PXI-4110, 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 PXI-4110 and execute measurements using the PXI-4110. **Note** NI recommends always using the most current version of NI-DCPower with the PXI-4110. 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 • C/C++

Component	Description and Recommendations
	• .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
APS-4100, an optional auxiliary 12 V power source	The PXI-4110 is available in kits with an APS-4100 (779647-11) and without (779647-10). This part number is for a stand-alone APS-4110, which can be used as a replacement auxiliary supply or to enable higher power and current on the PXI-4110 modules that do not have an auxiliary supply.	779671-01
PXI slot blockers	—	199198-01
Screw Terminal Connector Kit for the PXI-4110 programmable power supply or PXI-4130 SMU	Ships with PXI-4110.	780557-01

Additional Cabling and Accessory Guidance

- If you choose to connect an optional auxiliary 12 V power source to the instrument to enable full instrument capability, you must purchase the kit for your instrument that includes the NI APS-4100 auxiliary power source (part number 779647-11), purchase the APS-4100 from NI (part number 779671-01), or use an auxiliary power source from a third-party vendor that meets the power supply requirements for the instrument. Refer to the ***PXI-4110 Specifications*** for these requirements.
- 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***.

PXI-4110 Theory of Operation

The PXI-4110 is a triple-output, programmable power supply that uses elements of switching and linear power supply designs.

Each output channel on the PXI-4110 has a preregulation switching stage and a linear regulation stage. To improve efficiency and to reduce heat dissipation on the power supply, the preregulation stage controls the voltage level across the control element in the linear regulation stage.

The voltage and current control loops work together through the linear regulation stage to regulate the output in constant voltage (CV) or constant current (CC) mode based on the configured setpoint level, limits, and load characteristics.

- 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, unless the current limit is reached.

Voltage and current measurements on each channel are measured with multiplexed SAR ADCs with a fixed measurement aperture. Measurements are performed on-demand and are not synchronized with each other.

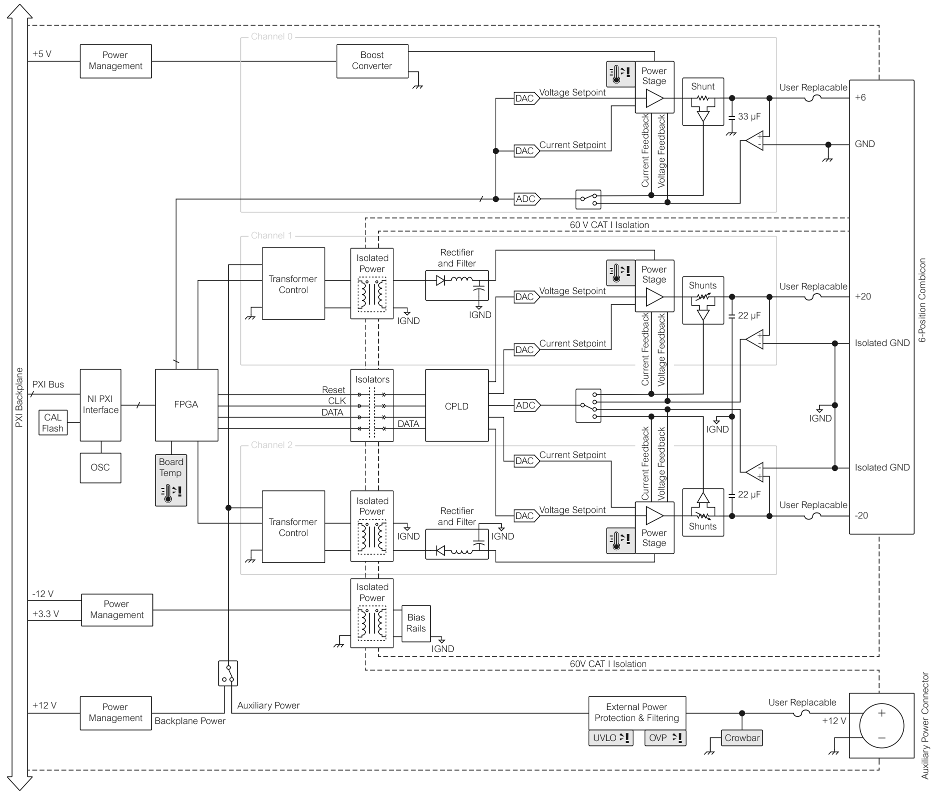
The bank-isolated outputs (channels 1 and 2) on the PXI-4110 can operate from the PXI chassis power (internal power) or from an auxiliary DC power supply. The non-isolated output (channel 0) always operates from the PXI chassis power (internal power).

- **Internal power**—Isolated output channels are restricted to lower output current limits, and total power on the isolated channels is limited to 3 W.
- **Auxiliary DC power**—Isolated output channels can increase the current to 1 A on each channel, delivering a total of 40 W maximum.

Block Diagram

The following diagram illustrates the design of the PXI-4110.

Figure 2. PXI-4110 Block Diagram

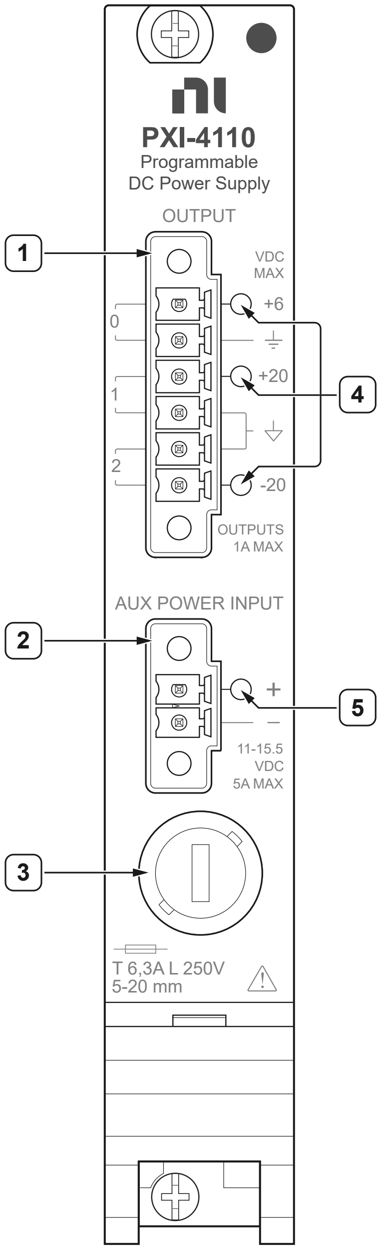


Legend

Error Monitor | Chassis / Non Isolated GND | Isolated GND | Reported Temperature Sensor

PXI-4110 Front Panel

Figure 3. PXI-4110 Front Panel



1. Output Connector
2. Auxiliary Power Input Connector
3. Auxiliary Power Input Fuse Holder
4. Output Channel LEDs
5. Auxiliary Power Input LED

PXI-4110 Pinout

The following figures show the terminals on the PXI-4110 output connector and auxiliary power input connector.

Output Connector

Figure 4. PXI-4110 Output Connector Pinout

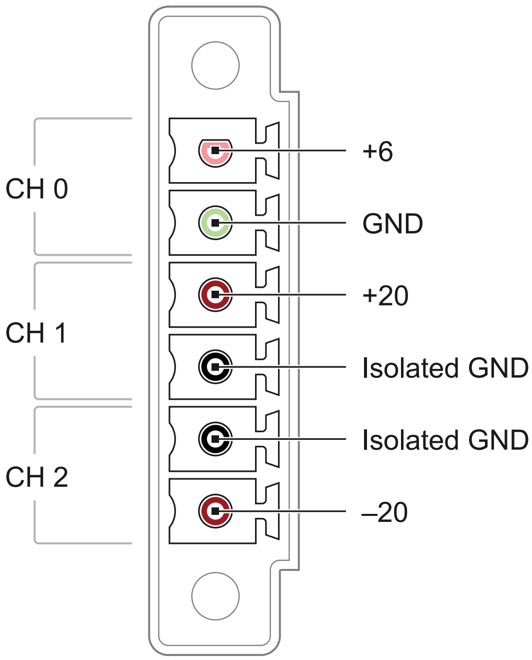


Table 4. Output Connector Signal Descriptions

Signal Name	Description
CH <0> +6 V	(0 V to +6 V) 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> GND	LO force terminal connected to channel power stage (generates and/or dissipates power) and internally tied to chassis ground. Positive polarity is defined as voltage measured on HI > LO.
CH <1> +20 V	(0 V to +20 V) HI force terminal connected to channel power stage (generates and/or dissipates power). Positive polarity is defined as voltage measured on HI

Signal Name	Description
	> LO.
CH <1..2> Isolated GND	LO force terminal connected to channel power stage (generates and/or dissipates power). Positive polarity is defined as voltage measured on HI > LO.
CH <2> -20 V	(0 V to -20 V) HI force terminal connected to channel power stage (generates and/or dissipates power). Positive polarity is defined as voltage measured on HI > LO.

Auxiliary Power Input Connector

Figure 5. PXI-4110 Auxiliary Power Input Connector Pinout

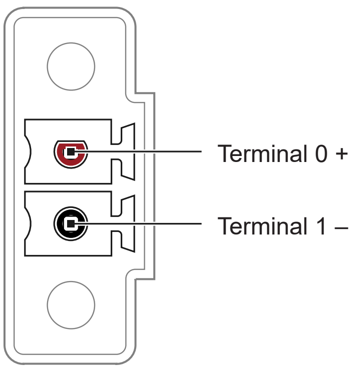


Table 5. Auxiliary Power Input Signal Descriptions

Signal Name	Description
Terminal 0 +	An optional terminal that, if provided with 11 V to 15.5 V and ≥60 W, increases the output current capability of channels 1 and 2 to 1 A.
Terminal 1 -	This terminal provides the return current path to the aux power supply; internally connected to chassis ground.

PXI-4110 LED Indicators

The PXI-4110 features Output Channel LEDs and an Auxiliary Power Input LED.

Output Channel LEDs

The Output Channel LEDs, located on the module front panel, indicates the output channel state.

The following table lists the Output Channel LED states.

Table 6. Output Channel LED Status Indicator

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 overtemperature condition

Auxiliary Power Input LED

The Auxiliary Power Input LED, located on the module front panel, indicates the state of the auxiliary power input.

The following table lists the Auxiliary Power Input LED states.

Table 7. Auxiliary Power Input LED Indicator Status

Status Indicator	Auxiliary Power Input State
(Off)	Auxiliary power input disconnected or out of range
Green	Auxiliary power input connected and within range

Note A green Auxiliary Power Input status indicator does not indicate that the auxiliary power is in use. To determine if the PXI-4110 is using auxiliary power, use the **niDCPower Source In Use** property or the NIDCPOWER_ATTR_POWER_SOURCE_IN_USE attribute.

PXI-4110 Installation and Configuration

Complete the following steps to install the PXI-4110 into a chassis and prepare it for use.

1. Unpacking the Kit
2. Installing the Software
3. Installing the PXI-4110 into a Chassis
4. Installing the Optional Auxiliary 12 V Power Source on the PXI-4110
5. Installing the Output Connector on the PXI-4110
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.

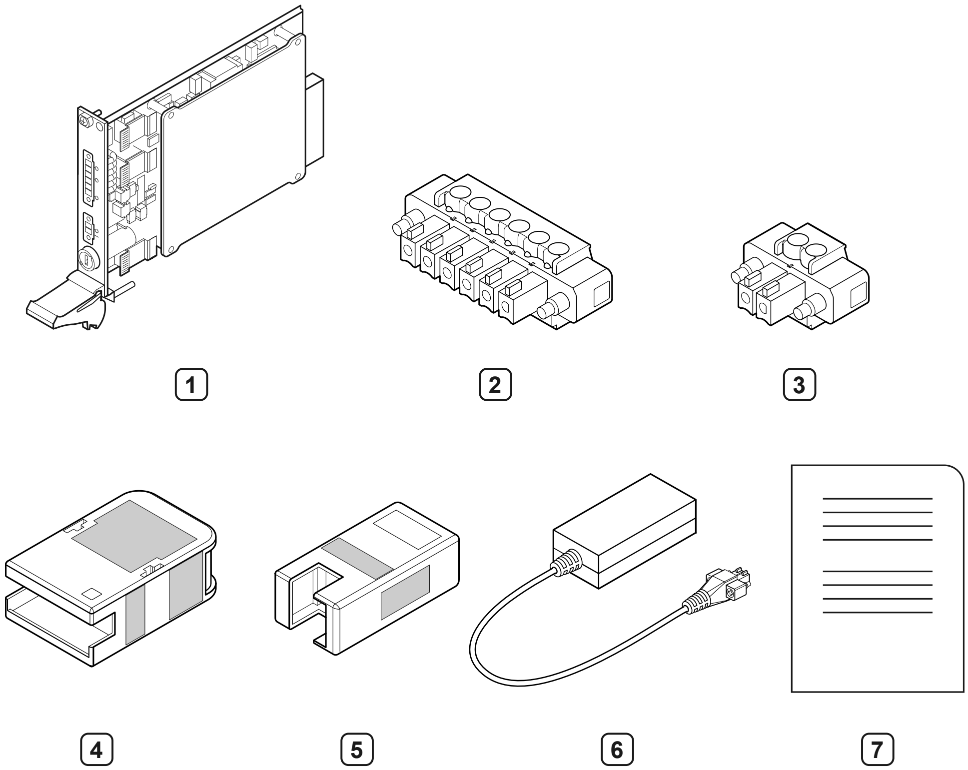
3. Unpack any other items and documentation from the kit.

> **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 PXI-4110 kit.

Figure 6. PXI-4110 Kit Contents



1. PXI-4110 Module
2. 6-position MINI-COMBICON connector
3. 2-position MINI-COMBICON connector
4. Backshell for 6-position MINI-COMBICON connector
5. Backshell for 2-position MINI-COMBICON connector
6. (Optional) Auxiliary 12 V power source
7. 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.

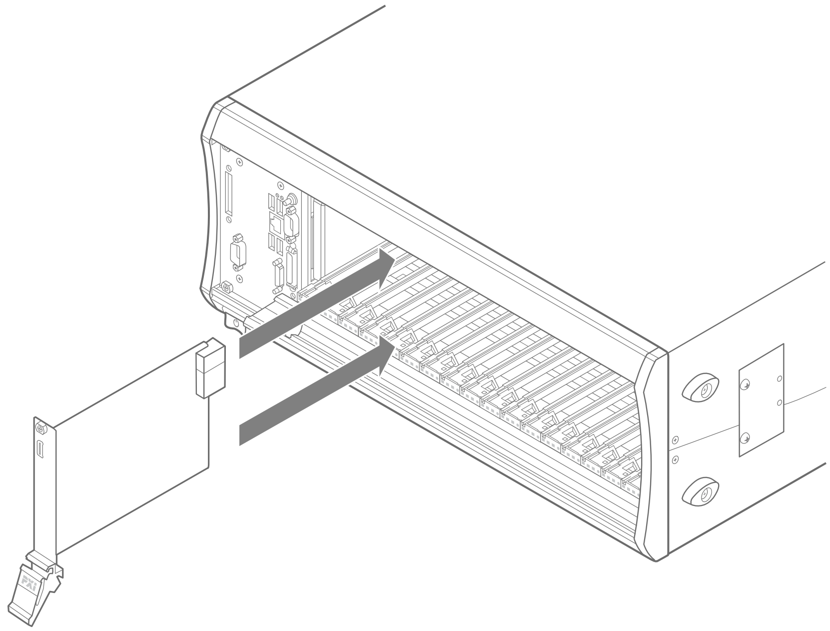
Installing the PXI-4110 into a Chassis

When operating without an auxiliary power source, channels 1 and 2 of the PXI-4110 are operational at a lower output current (≤100 mA) and a reduced total power (3 W max total).

> **Notice** To prevent damage to the PXI-4110 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 PXI-4110.
   The AC power cord grounds the chassis and protects it from electrical damage while you install the PXI-4110.
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. Remove the black plastic covers from all the captive screws on the module front panel.
5. Identify a supported slot in the chassis. You can place the PXI-4110 module in PXI peripheral slots ( )or PXI Express hybrid peripheral slots ( ).
6. Touch any metal part of the chassis to discharge static electricity.
7. Ensure that the ejector handle is in the unlatched (downward) position.
8. 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.

Figure 7. Module Installation



1. Chassis
2. Hardware module
3. Ejector handle in down (unlatched) position

9. Latch the module in place by pulling up on the ejector handle.
10. 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.

11. 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 Optional Auxiliary 12 V Power Source on the PXI-4110

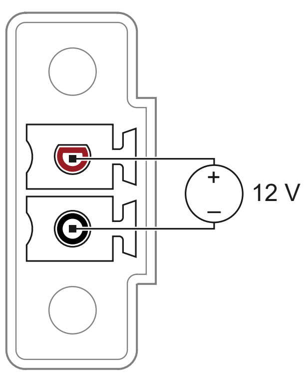
Installing an auxiliary 12 V power source is an optional step that allows you to gain full output power of the isolated channels on the PXI-4110. Compatible auxiliary 12 V power sources must be capable of providing 11 V to 15.5 V and ≥60 W to increase the output current capability of channels 1 and 2 to 1 A. Complete the following steps to install the auxiliary 12 V power source.

Note If available, the PXI-4110 automatically uses the optional auxiliary 12 V power source when the session is opened. To override this feature, use Power Source in the NI-DCPower API within supported sessions. Use the **niDCPower Power Source In Use** property or the **NIDCPOWER_ATTR_POWER_SOURCE_IN_USE** attribute to programmatically determine which power source is in use.

Note The auxiliary power source provided by NI uses sufficient wire gauge to maintain voltage requirements for the instrument. If you use a third-party auxiliary power source, you must use the appropriate wire gauge to ensure that it can provide the required current without dropping below the minimum voltage at the auxiliary power input connector. You must use a 11 V to 15.5 V, ≥60 W power source.

1. Connect the power source to the auxiliary power input connector on the PXI-4110 front panel.

   Figure 8. Installing an Optional Auxiliary 12 V Power Source

2. Tighten the screws to hold the auxiliary 12 V power source in place.
3. Connect the 2-position backshell to the device.[2]

2. This step is required if you are using a third-party auxiliary power supply. However, the APS-4110 has an overmolded connector. If you are using the APS-4110 as your auxiliary power source, you are not required to use the backshell or the 2-position connector included in the kit.

> **Note** Using the provided backshell for auxiliary power provides protection against accidental shorts to auxiliary power terminals and strain relief.

Resuming Operation After Auxiliary Power Loss

In case of auxiliary power loss during operation, the isolated output is disabled, and the power supply is shut down to prevent damage to the PXI-4110 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.
   - 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.

Changing or Removing Auxiliary Power

Complete the following steps to change or remove auxiliary power from the PXI-4110.

> **Tip** It is often more convenient to close the existing session and open a new session when managing auxiliary power state changes.

1. Disable the output channels.
2. Disconnect/connect the auxiliary power source.
3. Reset the power supply using the niDCPower Reset VI or the niDCPower_reset function.
4. Reconfigure the power supply.

Installing the Output Connector on the PXI-4110

Complete the following steps to install the 6-position MINI-COMBICON output connector and prepare signal connections.

1. Screw the signal wires into the screw terminals of the MINI-COMBICON.
2. Attach the 6-position backshell to the cable assembly.
3. Connect the 6-position assembled connector to the device.

> **Note** Using the provided backshell for the output connector provides protection against accidental shorts to output terminals and strain relief.

4. Screw in the flange to lock the connector to the PXI-4110.
5. Power on the chassis.

Connecting Multiple Channels in Series

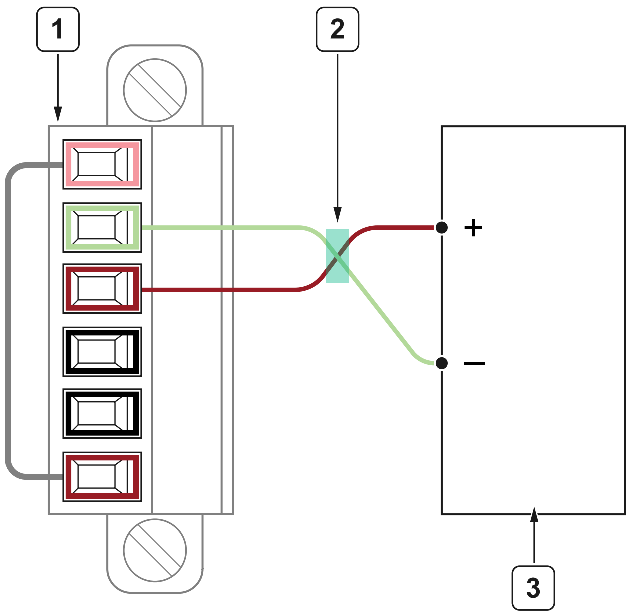
> **Caution** Do not exceed 60 V DC from any terminal to ground when cascading power supplies.

You can cascade multiple channels in series to generate greater output voltage because channels 1 and 2 on the PXI-4110 are bank-isolated outputs with a shared terminal, which is a series arrangement. The isolation rating of the channel 1 + 2 bank is 60 V, which allows it to be floated on top of the output of channel 0 for up to 46 V at 1 A as illustrated in the following figure.

> **Note** You must use the APS-4100 when operating channels 1 and 2 in series with channel 0 to ensure all channels have matching maximum current capabilities.

> **Caution** The PXI-4110 does not provide isolation when using CH 0.

Figure 9. Series Connection Diagram



1. PXI-4110 Output Connector
2. Twist lead
3. Load

Connecting Multiple Channels in Parallel

You can connect identical channels from multiple PXI-4110 modules in parallel to generate greater output current.

> **Caution** Do not exceed 60 V DC from any terminal to ground when cascading power supplies.

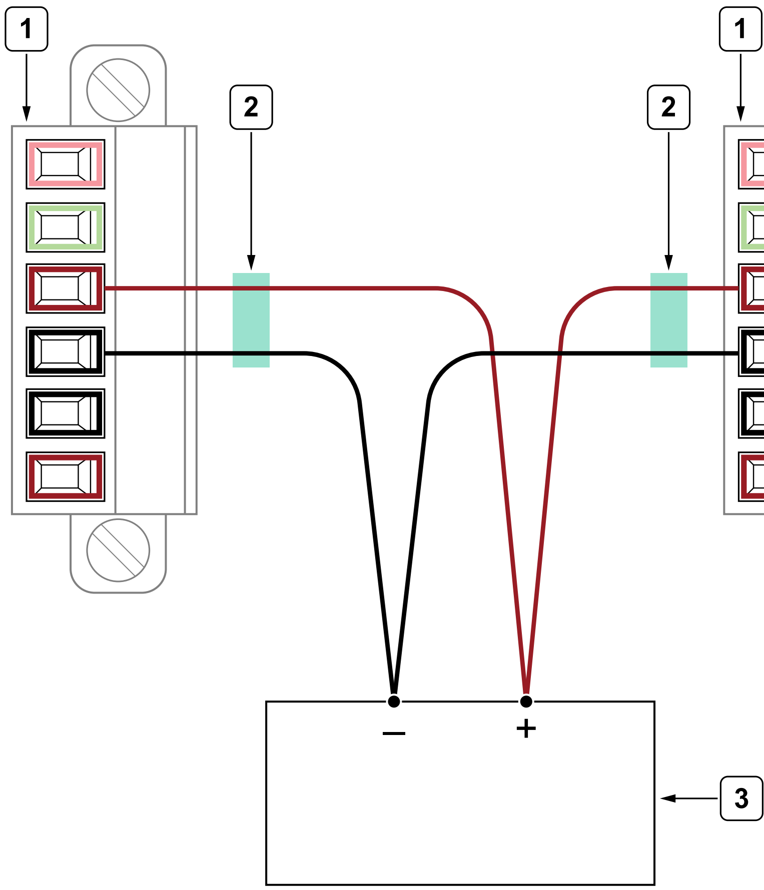
NI recommends limiting the number of output channels connected in parallel to two. The following figure shows connections for parallel operation of channel 1 using two PXI-4110 modules.

> **Note** You cannot cascade channels 1 and 2 in parallel to generate voltage at 2 A because the channels share a common ground path and do not operate in the same quadrant.

Note NI does not recommend operating channels 0 and 1 in parallel due to the chance of user error in programming the voltage limits of channel 1, which can exceed the ratings of channel 0.

Note You must use APS-4100 for total output current above 200 mA in this connected configuration.

Figure 10. Parallel Connection Diagram



1. PXI-4110 Output Connector
2. Twist lead
3. Load

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

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 PXI-4110.
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 PXI-4110 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 PXI-4110 appears in the Device Manager.
   a. Under an NI entry, confirm that a PXI-4110 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 PXI-4110 Fails the Self-Test?

1. Reset the PXI-4110 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 PXI-4110

Refer to the following topics for guidance about PXI-4110 signal connections.

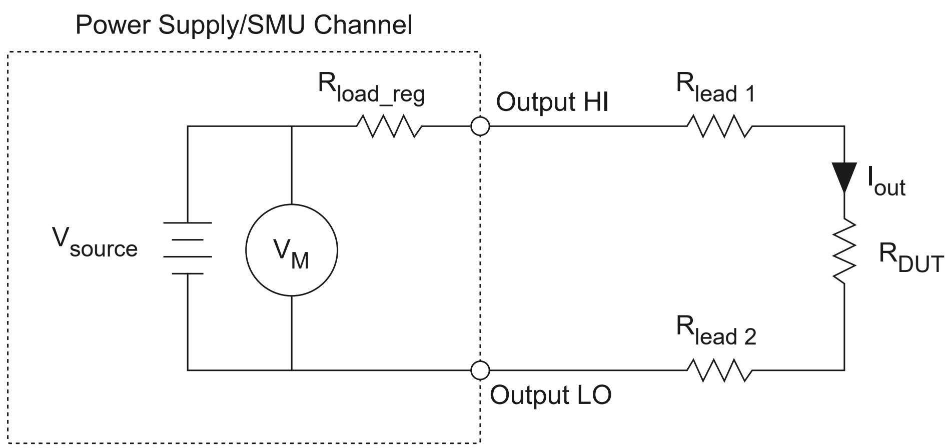
Use the Output HI and Output LO terminals for local sense measurements.

Note In the following sections, Output HI refers to the +6, +20 or -20 terminals, and Output LO refers to the GND or Isolated GND terminals.

Making Local Sense Measurements

Local sense measurements use a single set of leads for output and voltage measurement. The PXI-4110 only supports local sense measurements.

Figure 11. Connecting Signals for Local Sense Measurement



When the PXI-4110 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 or SMU to the load. This error can be calculated using the following equation:

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

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.

Minimizing Voltage Drop Loss when Cabling

Voltage drop loss is introduced by the cabling wires that connect the power supply or SMU to the load terminals.

The voltage drop due to current-resistance 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.

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 SMU 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 power supply or SMU were to short circuit.

Table 8. Wire Gauge and Noise

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)

AWG Rating	mΩ/m (mΩ/ft)
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 power supply or SMU to a constant load, be sure to account for voltage drop in your application. If necessary, adjust the output voltage of the device.

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:

$V = I \times R$

V = 1 A × (13.2 mΩ/m × 1 m)

V = 13.2 mV

As illustrated in the preceding example, a 1 m, 16 AWG wire carrying 1 A results in a voltage drop of 13.2 mV.

Source Mode

The PXI-4110 channels can generate voltage and current in ***Single Point*** source mode.

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

- DC voltage
- DC current

The Source Mode With Channels function defines the source mode the PXI-4110 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.

Sourcing Voltage and Current

The PXI-4110 can source voltage and 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 PXI-4110.
2. Configure the PXI-4110 for Sourcing
   Use the NI-DCPower driver with the PXI-4110 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 PXI-4110 for Measuring
   Once you configure channels and they are in the Running state, the PXI-4110 can take measurements.
4. Configure Events
   You can use events to coordinate the operation of multiple channels and instruments.
5. Initiate the PXI-4110 for Sourcing and Measuring
   Initiate the channels of the PXI-4110 to apply a configuration and start generating.
6. Acquire Measurements
   The source mode that you configured channels to use determines how the PXI-4110 acquires measurements.
7. Cease Generation
   NI-DCPower includes one option for stopping generation on PXI-4110 channels and returning the channels to a known state.
8. Close the Session
   Use the NI-DCPower driver to close a session with the PXI-4110.

Initialize a Session

Use the NI-DCPower driver to initialize a session with the PXI-4110.

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 PXI-4110 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.

Configure the PXI-4110 for Sourcing

Use the NI-DCPower driver with the PXI-4110 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	`voltage level` input to Configure Voltage Level function	`current limit` input to Configure Current Limit function
DC Current	Single Point	`current level` input to Configure Current Level function	`voltage limit` input to 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, among other aspects, you can specify output ranges.

Configure the PXI-4110 for Measuring

Once you configure channels and they are in the Running state, the PXI-4110 can take measurements.

Use the **niDCPower Measure** property or the **NIDCPOWER_ATTR_MEASURE_WHEN** attribute to configure how NI-DCPower takes measurements.

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 PXI-4110 takes a measurement and returns it.

Configure Events

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

NI-DCPower Named Event Types

You can route events on most NI-DCPower instruments. NI-DCPower includes specific events you can use 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.

  The amount of configurable delay you can add depends on your instrument.

> **Note** You must call the Source Complete event with the **Wait for Event With Channels** VI or the **niDCPower_WaitForEventWithChannels** function.

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 method for PXI-4110.

- **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

Initiate the PXI-4110 for Sourcing and Measuring

Initiate the channels of the PXI-4110 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 PXI-4110 acquires measurements.

Measuring and Querying

Use the following functions to acquire measurements in Single Point source mode:

1. Measure using one of the following options.
   - The niDCPower Measure Multiple VI or the niDCPwer_MeasureMultiple function
   - The niDCPower Measure VI or the niDCPower_Measure function
2. Call the niDCPower Query in Compliance VI or the niDCPower_QueryInCompliance function to query the output state.

Cease Generation

NI-DCPower includes one option for stopping generation on PXI-4110 channels and returning the channels to a known state.

Option	How To	Description
Disabling the	Set the Output Enabled	Generates 0 V on a channel. ±2% of the current limit range presently configured for the channel remains on the channel.

Option	How To	Description
output	property to `False`	
	Call the niDCPower Reset Device VI	Disables power generation, resets all properties included in a session to their default values, clears errors, commits the instrument properties, and leaves the instrument in the Uncommitted state.

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 PXI-4110.

When you disable the output of the PXI-4110, the instrument is configured to output a DC voltage at 0 V with current limits at ±2% of the presently configured current limit range in, unless otherwise noted, a low-impedance state.

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.

Close the Session

Use the NI-DCPower driver to close a session with the PXI-4110.

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 9. 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`
.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

PXI-4110 Operating Guidelines

Refer to the following sections for information about PXI-4110 features and guidelines for operating the PXI-4110.

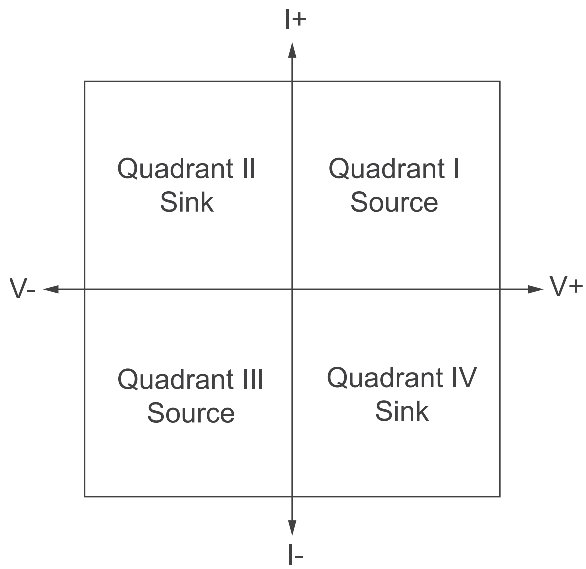
Sourcing and Sinking

The terms sourcing and sinking describe power flow into and out of a device, respectively. The PXI-4110 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 PXI-4110 operates in the Quadrant I (Ch0 and Ch1) or Quadrant III (Ch2) regions.



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 ***PXI-4110 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 PXI-4110.

Decreasing Virtual Output Capacitance

Virtual output capacitance can significantly limit output slew rate. For example, consider the PXI-4110 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 PXI-4110.

You can perform any of the following actions to decrease output inductance:

- Use shorter length cabling.
- Reduce the loop area between Output HI and Output LO.

Protection

The output channels and the auxiliary power input of the PXI-4110 are protected against overcurrent, overvoltage, inverse voltage, and overtemperature conditions.

Output Channel Protection

All output channels on the PXI-4110 are current-limited and fused. In the event of an overcurrent, overvoltage, or inverse voltage condition, an output channel fuse may blow to protect the PXI-4110 and the load. When its fuse is blown, an output channel can source only a few milliamperes of current regardless of the programmed current limit.

Caution Each output channel of the PXI-4110 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.

Overtemperature conditions exist when the enclosure or component temperatures exceed safe operating limits. In the event of an overtemperature condition, the thermal shutdown circuits on the PXI-4110 disable the output channel that indicated the failure condition. When disabled, you can only program a reset on an output channel after the failure condition is cleared.

Auxiliary Power Input Protection

The auxiliary power input of the PXI-4110 can accept voltages from 11 V to 15.5 V. Applying a voltage below 11 V or above 15.5 V disables the auxiliary power input.

Overvoltage conditions exist on the auxiliary power input when you apply >20 V to the input. In the event of an overvoltage condition, crowbar protection is enabled. Crowbar protection shunts the auxiliary power input to ground.

In the event of an overcurrent (>6.3 A) or an inverse voltage condition, the auxiliary power input fuse may blow to protect the PXI-4110 and the load. You can use the niDCPower Auxiliary Power Source Available property or the NIDCPOWER_ATTR_AUXILIARY_POWER_SOURCE_AVAILABLE attribute to troubleshoot the auxiliary power input fuse.

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 using local sense in constant voltage mode, 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.

- 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 or SMU remains stable when driving a capacitive load.

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:

$(\Delta V/\Delta t) = (I/C)$

where ΔV is the change in the output voltage

Δt is the change in time

I is the current limit

C is the total capacitance across the load

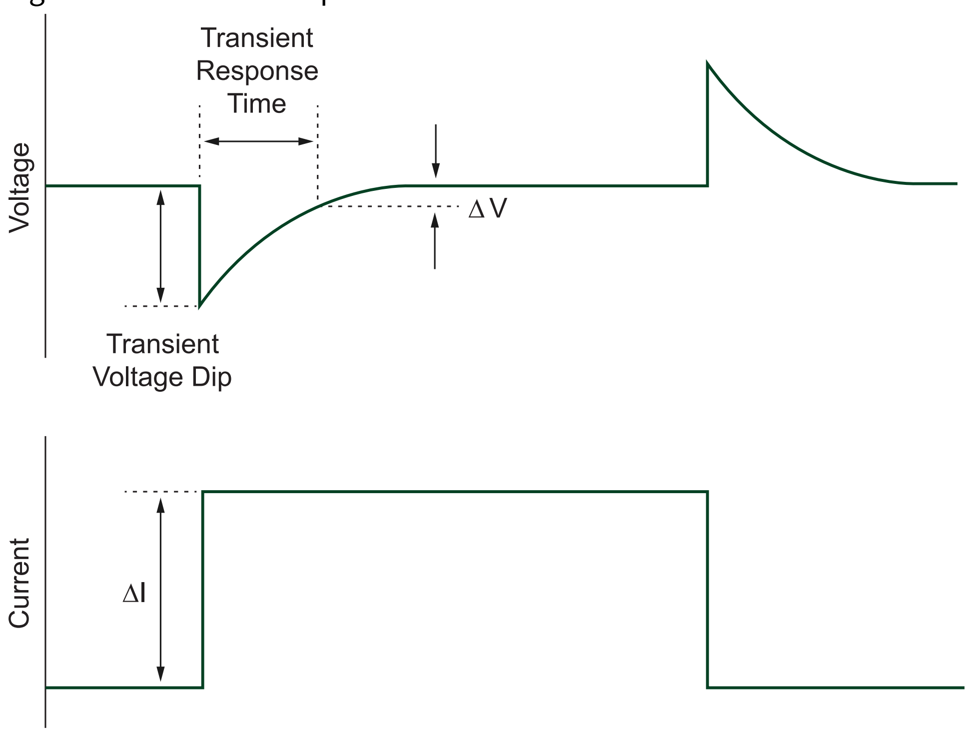
Series resistance and lead inductance from cabling can affect the stability of the device. In some situations, you may need to increase the capacitive load or locally bypass the circuit or system being powered to stabilize the power supply or SMU.

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 12. 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 or SMU limits the output current.

Occasionally, a peak current may come close to exceed the current limit and cause the power supply or SMU to temporarily move into constant current mode or unregulated mode.

To remain within the power supply or SMU 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 or SMU.

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 or SMU.

> **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 ***PXI-4110 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

NI power supplies and SMUs use one or more ranges for voltage and current output, as well as one or more ranges for voltage and current measurement.

Use the highest resolution (smallest) range possible for a particular application to get maximum output and measurement accuracy. Refer to the ***PXI-4110 Specifications*** for more information about what ranges are available for a particular channel on your device.

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.

Changing Ranges

You can use the following VIs and functions to configure output ranges for your device.

Table 10. Supported Configurable Output Ranges for Each Device Channel

Range	VI	Function
Voltage level range	niDCPower Configure Voltage Level Range	`niDCPower_ConfigureVoltageLevelRange`
Voltage limit range	niDCPower Configure Voltage Limit Range	`niDCPower_ConfigureVoltageLimitRange`
Current level range	niDCPower Configure Current Level Range	`niDCPower_ConfigureCurrentLevelRange`
Current limit range	niDCPower Configure Current Limit Range	`niDCPower_ConfigureCurrentLimitRange`

When you configure an output range, if you request a range that differs from the ranges described in the ***PXI-4110 Specifications***, NI-DCPower selects the highest resolution (smallest) range available that accommodates the requested range. For example, if you request 100 mA current range on a device with only 20 mA and 200 mA current limit ranges, NI-DCPower selects the 200 mA range.

To change the range, the configured range must be able to accommodate the configured output value. For example, if the current limit range is 1 A and the current limit is 50 mA, changing the current limit range to 20 mA is not allowed because 50 mA is not possible in the new range.

> **Note** Changing current ranges implies a change in the shunts used to measure current. Under loaded conditions, particularly in constant current mode, this will result in glitches at the output. To reduce the risk of damage to the DUT, the range change is designed so that the current may be less than programmed but not more.

Level and limit changes occur simultaneously when a range change is not required. The changes occur when the channel configuration is applied upon entering the Running state. However, changes do not occur simultaneously if there is a voltage or current range change involved.

When changing ranges in the Running state, be aware of the order of the output range and output value changes because the configuration change takes effect immediately in this state. To avoid ordering issues, NI recommends that you configure the output range and output value in the Uncommitted state and then transition to the Running state. Alternatively, you can enable source autoranging for the range you want to change.

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.

Notice If the current range is changed while the PXI-4110 is in constant current mode, a spike in the output current could occur for a maximum of 3 ms. This will not occur if the PXI-4110 is in constant voltage mode.

Source Autoranging

When you enable source autorange by setting **Source » Output Function**, NI-DCPower automatically changes the output range based on the configured output setpoint. NI-DCPower automatically changes to the highest resolution (smallest) range that can accommodate the configured output value. You can selectively enable source voltage level/limit and current limit/level autorange on a channel.

Note While source autorange selects the best range based on the setpoint, it does not change the range until you program a new setpoint.

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 Isolated GND 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 +6, +20, or -20 terminal and its corresponding return terminal (GND or Isolated GND), 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 or SMU. 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 or SMU:

- Connect the probe directly to the terminals of the power supply or SMU. 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 60 Hz to enable rejection of power line noise.

You can reject AC noise by adjusting the number of samples in a measurement so that the aperture time of the measurement is a multiple of the AC noise period. You can configure the number of samples to average to reject AC noise.

Rejecting AC Noise in DC Measurements with Measurement Averaging

The PXI-4110 allows you to adjust the number of samples averaged in each measurement to influence the aperture time of your measurements, which allows you to reject specific AC noise frequencies. You can set the number of samples to average programmatically using the **niDCPower Samples To Average** property or the **NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE** attribute.

The number of samples you choose to average in a measurement implicitly controls the aperture time based on the following relationship:

Aperture Time = ***Samples To Average*** / ***Maximum Sample Rate***

where

- ***Samples To Average*** is the number of samples, as determined by Samples To Average, that compose each measurement; the default value and valid range of samples to average depend on your instrument
- ***Maximum Sample Rate*** is the maximum sample rate of the instrument as documented in the specifications for your instrument

The overall hardware measurement rate of the instrument is the reciprocal of the aperture time.

Complete the following steps to reject AC noise frequencies by manipulating the aperture time of your measurements with measurement averaging.

1. Based on the frequency f (Hz) you need to reject and the maximum sample rate of your instrument as indicated in the specifications, calculate the number of samples you need to average to reject the frequency.

   Samples To Average = ***Maximum Sample Rate*** / f

2. Set Samples To Average to the value you calculated.

   > **Tip** To improve noise reduction while keeping frequency rejection, you can use integer multiples of ***Samples To Average***, as long as that multiple is a supported value of Samples To Average for your instrument and the longer aperture time that results is appropriate for your application.

   > **Note** If you set the Samples To Average property in the Running state, the output channel measurements may move out of synchronization.
   >
   > If this occurs, set Reset Average Before Measurement to `True` before calling Measure Multiple in your program. You can set Reset Average Before Measurement to `False` after Measure Multiple runs.

Determining Measurement Rate

Although the measurement speed of the PXI-4110 is 3 kS/s for all voltage and current measurements, the measurement rate of the PXI-4110 can vary depending on the setting of the **niDCPower Samples To Average** property or the **NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE** attribute.

The default value of the **niDCPower Samples To Average** property and the **NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE** attribute is 10. As expressed in the following equation, the PXI-4110 returns 300 measurements per second using the default value:

$$\frac{3000 \text{ samples}}{\text{second}} \times \frac{1 \text{ measurement}}{10 \text{ samples}} = \frac{300 \text{ measurements}}{\text{second}}$$

If no measurement averaging is used (Samples To Average = 1), the PXI-4110 returns 3,000 measurements per second.

While measuring without averaging yields the fastest measurement rate, noise from the environment (for example, the 50 Hz or 60 Hz noise introduced by cabling) increases measurement uncertainty.

Adjust the **niDCPower Samples To Average** property or the **NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE** attribute as necessary to optimize the noise performance and measurement rate for your application.

> **Note** Measurement rate refers only to the hardware measurement rate and does not include software latency.

Rejecting Noise

If you know the noise frequency, you can reject it from the signal. To determine the number of measurements necessary to reject noise from a signal, divide the measurement speed of the PXI-4110 by a full wavelength cycle of noise.

Table 11. Number of Samples to Average Based on Frequencies Rejected

Number of Samples to Average	Frequencies Rejected for 3 kHz Sample Rate
1	3 kHz
50	60 Hz
60	50 Hz
300	50 Hz and 60 Hz

For frequencies not listed in this table, use the following formula:

$\boldsymbol{N} = 3000/\boldsymbol{F_r}$

where ***N*** is the number of samples to average

F_r is the frequency rejected

> **Note** To improve noise reduction while keeping frequency rejection, set the number of samples to average to ***N***, ***2N***, ***3N***, and so on. The maximum allowed samples to average is 511.

> **Tip** Set the **niDCPower Samples To Average** property or the **NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE** attribute to 300, an integer multiple of both 60 kHz and 50 kHz, to actively reject both noise frequencies.

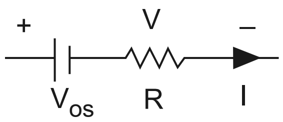
Resistance Measurements

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, I_1 and I_2, create voltage drops of V_1 and V_2, respectively. Thus, the following two equations can be derived:

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

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

$R = (V_2 - V_1) / (I_2 - I_1)$

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

All of the input and output connections on the PXI-4110 front panel have user-replaceable fuses.

If you suspect a blown output channel fuse, remember that an output channel with a blown fuse can source only a few milliamperes of current, regardless of the programmed current limit.

Refer to the table below for fuse ratings and manufacturer information.

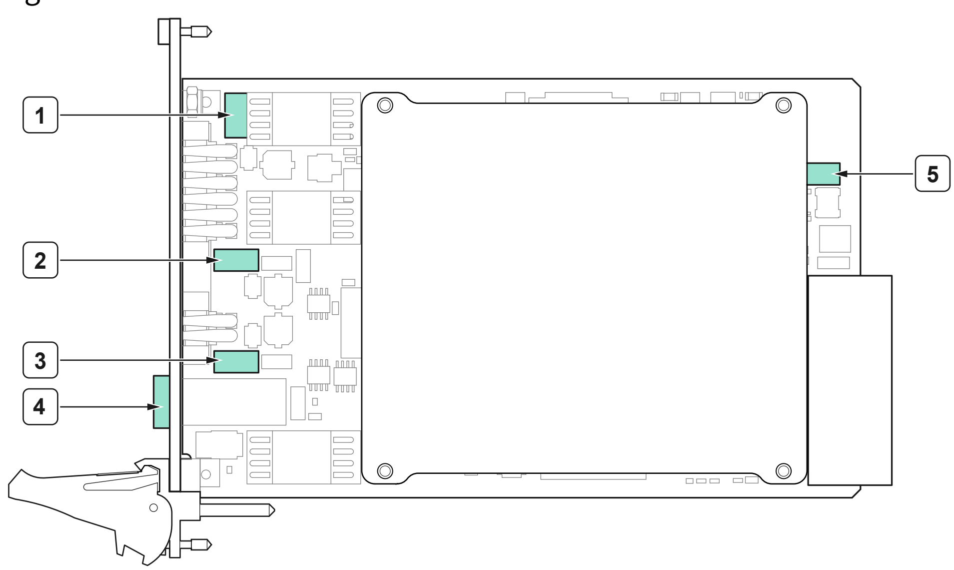
Table 12. Fuse Ratings

Input/Output	Fuse Rating	Description	Recommended Manufacturer Part Number
Channels 0, 1, 2	F 1.5 A 125 V	User-replaceable chip fuse	Littelfuse 045301.5
Auxiliary power input	T 6.3 A L 250 V	User-replaceable 5 × 20 mm glass fuse	Littelfuse 21806.3

Tip Although blown output channel and auxiliary power input fuses are not software detectable, you can use the niDCPower Auxiliary Power Source Available property or the NIDCPOWER_ATTR_AUXILIARY_POWER_SOURCE_AVAILABLE attribute to troubleshoot the auxiliary power input fuse.

Identify the fuse you want to replace using the following figure.

Figure 13. Fuses on the PXI-4110



1. Output Channel Fuse (Channel 0)
2. Output Channel Fuse (Channel 2)
3. Output Channel Fuse (Channel 1)
4. Auxiliary Input Fuse
5. Spare Output Channel Fuse

To replace a fuse on the PXI-4110, complete the following steps:

1. Power down the chassis.
2. Disconnect all output and auxiliary power connections.
3. Remove the PXI-4110 from the chassis.
4. Remove the fuse.

Fuse	Process
Output channel fuse	a. Using small pliers, gently pull the fuse to release it from the fuse holder.
Auxiliary input power fuse	a. Using a flathead screwdriver, turn the fuse holder cap counter-clockwise to release it from the PXI-4110 front panel. b. Gently pull the auxiliary power input fuse to release it from the fuse holder cap.

5. Install the replacement fuse.

Fuse	Process
Output channel fuse	a. Using small pliers, gently place the replacement fuse into the fuse holder.
Auxiliary input power fuse	Use the auxiliary input fuse holder to service the auxiliary fuse on the PXI-4110. a. Slide the replacement fuse into the fuse holder cap. b. Screw the cap clockwise to replace it on the PXI-4110 front panel.

Note You can use the spare fuse included on the PXI-4110 to replace an output channel fuse.

Sourcing and Measuring Terminology

Refer to the following terms when learning more about the features and usage of the PXI-4110:

- **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 ***PXI-4110 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

PXI-4110 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 ***PXI-4110 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 ***PXI-4110 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 PXI-4110 System

NI recommends the following to clean and maintain your instrument's 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 the hardware with a soft, nonmetallic brush. Make sure that the hardware is completely dry and free from contaminants before returning it to service.

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