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# PXle-4051

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2024-04-16



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# Welcome to the PXIe-4051 User Manual

The PXIe-4051 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-4051 Specifications](#)
- [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](#)
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- [NI Learning Center](#)

# PXIe-4051 Overview

The PXIe-4051 is a single-channel electronic load featuring enhanced capabilities including programmable compensation; it is designed for engineers building PXI systems that require voltage or current sinking and measurement.

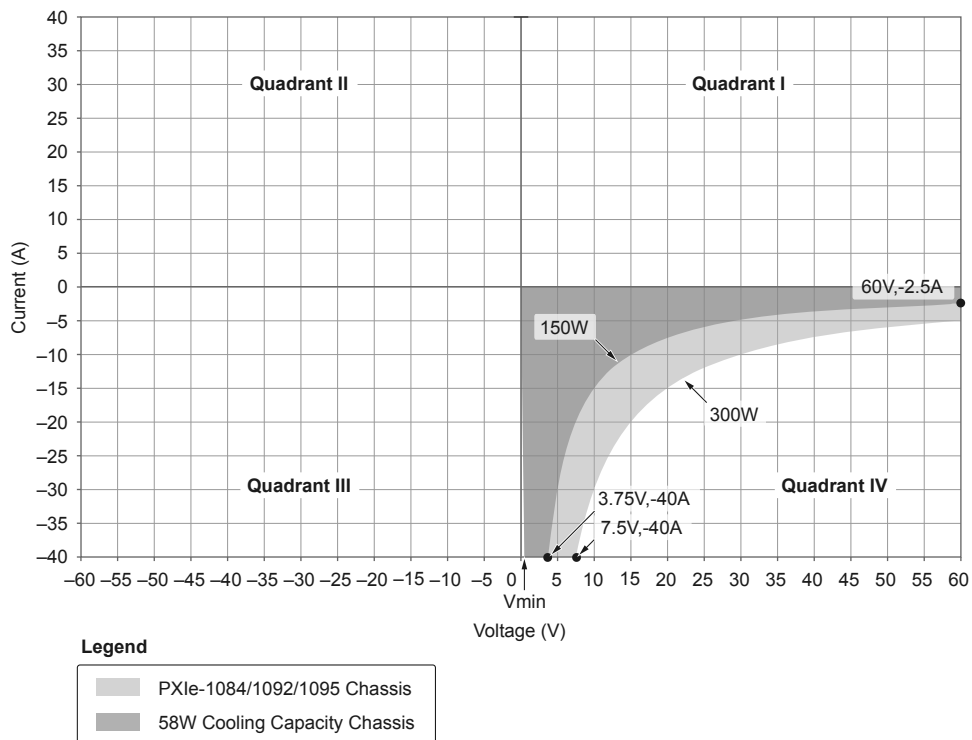
Use the PXIe-4051 in applications including manufacturing test, board-level test, and lab characterization with devices such as ICs, power management ICs (PMICs), power supply ICs and designs, and in anywhere a highly configurable programmable dynamic load is required.

## Device Capabilities

The PXIe-4051 is a high-precision electronic load that has the following features and capabilities.

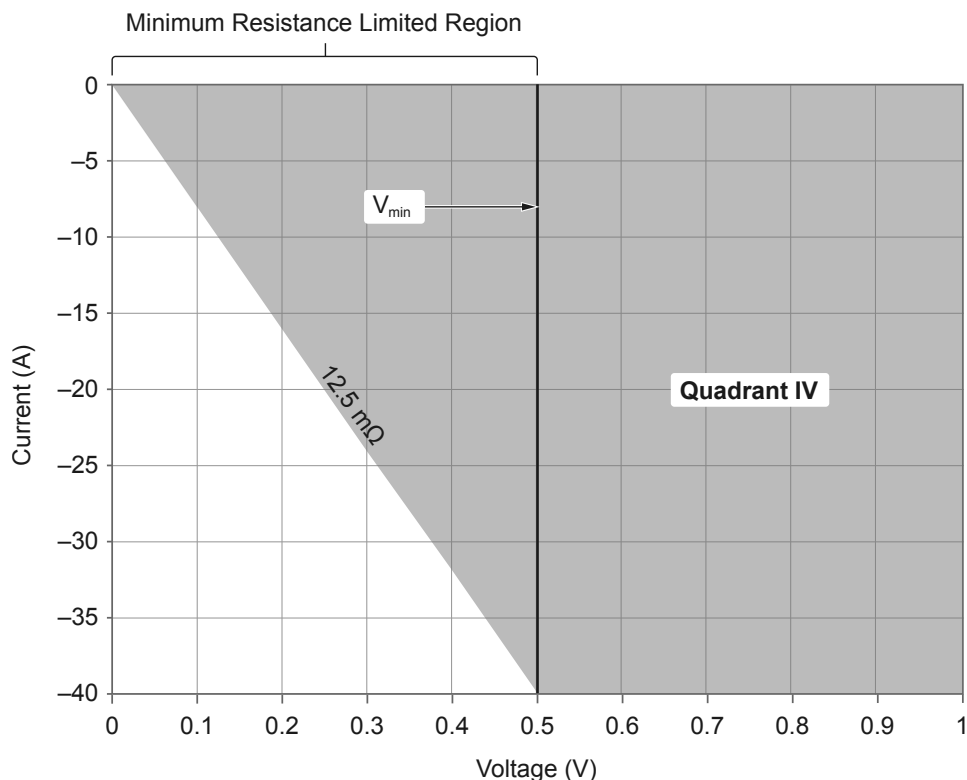
- 300 W Sink power
- Current Ranges: 4 A, 40 A
- Voltage Ranges: 6 V, 60 V
- Voltage remote sense
- Constant Current and Constant Voltage Modes
- Programmable current level slew rates
- Advanced sequences and steps
- 1.8 MSample/s maximum sampling rate and 100 kSample/s maximum update rate

Figure 1. PXIe-4051 Quadrant Diagram



**Note** For more information on operation at voltages below  $V_{min}$ , refer to the following figure.

**Figure 2.** Expanded View of Minimum Resistance Limited Region



**Note** The PXIe-4051 electronic load is a single quadrant instrument operating in quadrant IV (sink power). To match historical industry behavior of electronic loads, all other sections of the PXIe-4051 documentation and the NI-DCPower driver use a positive sign convention for current levels/limits and measurements. For code compatibility with SMU instruments, use the Instrument Mode property to determine the sign convention being used by NI-DCPower.

Model Variant	Chassis Type	Max DC Sinking Power
PXIe-4051	82 W Slot Cooling Capacity	300 W
	58 W Slot Cooling Capacity	150 W

## Driver Support

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



**Table 1.** Earliest Driver Version Support

Variant	Driver Name	Earliest Version Support
PXIe-4051	NI-DCPower	2023 Q4

# Components of a PXIe-4051 System

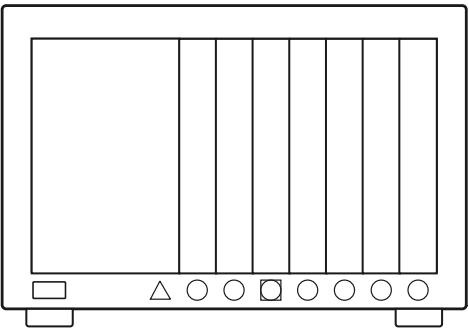

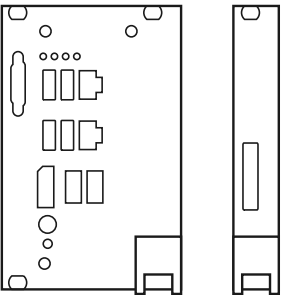
The PXIe-4051 is designed for use in a system that includes other hardware components, drivers, and software.

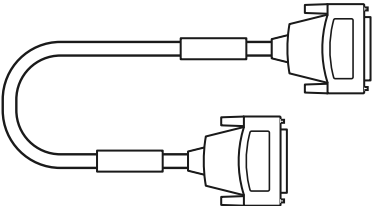
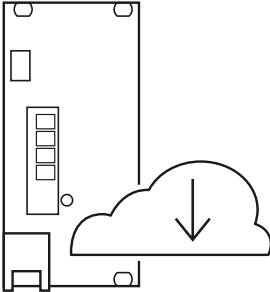

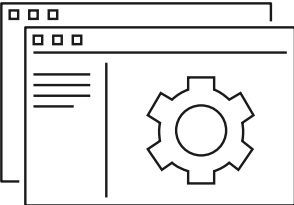


**Notice** A system and the surrounding environment must meet the requirements defined in **PXIe-4051 Specifications**.

The following list defines the minimum required hardware and software for a system that includes a PXIe-4051.

**Table 2.** System Components

Component	Description and Recommendations
<p>PXI Chassis</p> 	<p>A PXI chassis houses the PXIe-4051 and supplies power for PXIe-4051 functions.</p> <div data-bbox="813 978 1458 1178" style="border-left: 2px solid green; padding-left: 10px;">  <p><b>Note</b> NI recommends installing the PXIe-4051 in a chassis with slot cooling capacity <math>\geq 58</math> W for increased module capability.</p> </div>
<p>PXI Controller or PXI Remote Control Module</p> 	<p>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-4051, interface with the instrument using NI device drivers.</p>

Component	Description and Recommendations
<p data-bbox="168 266 472 296">Cables and Accessories</p> 	<p data-bbox="818 266 1435 415">Cables and accessories allow connectivity to/from your instrument for measurements. Refer to <b>Cables and Accessories</b> for recommended cables and accessories and guidance.</p>
<p data-bbox="168 554 415 583">NI-DCPower Driver</p> 	<p data-bbox="818 554 1398 663">Instrument driver software that provides functions to interact with the PXIe-4051 and execute measurements using the PXIe-4051.</p> <div data-bbox="818 688 1456 856" style="border-left: 2px solid green; padding-left: 10px;">  <p data-bbox="938 716 1419 825"><b>Note</b> NI recommends using the most current version of NI-DCPower with the PXIe-4051.</p> </div>
<p data-bbox="168 984 370 1014">NI Applications</p> 	<p data-bbox="818 984 1349 1058">NI-DCPower offers driver support for the following applications:</p> <ul data-bbox="894 1087 1162 1360" style="list-style-type: none"> <li>▪ InstrumentStudio</li> <li>▪ LabVIEW</li> <li>▪ LabWindows/CVI</li> <li>▪ C/C++</li> <li>▪ .NET</li> <li>▪ Python</li> </ul>

## Cables and Accessories

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

**Table 3.** Cables and Accessories

Accessory/Cable	Description	Part Number
Connector Kit for PXIe-415x and PXIe-405x	Output connector and backshell assembly, ships with the PXIe-4051	788197-01
PXI slot blockers	—	199198-01



**Note** For more information on supported cables and accessories for your instrument, refer to **NI SMU Cable and Accessory Compatibility**.

## Additional Cabling and Accessory Guidance

NI recommends installing PXI slot blockers (p/n 199198-01) to fill any empty instrument slots in a PXI chassis. For more information on installing slot blockers and filler panels, refer to [ni.com/r/pxiblocker](https://ni.com/r/pxiblocker).

### Related information:

- [NI SMU Cable and Accessory Compatibility](#)
- [Installing Slot Blockers and Filler Panels](#)

## 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 » 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 **Soft Front Panel**. 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.
    - 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-4051 Theory of Operation



**Note** In the following section, any references in the NI-DCPower API to a "source" actually refers to the sink functionality of the electronic load. Likewise, any references to an "output" instead refers to an input.

The PXIe-4051 combines a digital control loop architecture with precision electronics to implement voltage-controlled or current-controlled active shunt or load with built-in measurement of input voltage and current.

One significant advantage of the digital control loop architecture of the PXIe-4051 is the ability to make precise adjustments to the control loop through software to account for a variety of loading conditions.

The PXIe-4051 can operate in either Constant Voltage mode or Constant Current mode.

- In **Constant Voltage** mode, the device acts as a precision voltage shunt, and, regardless of the source, the voltage across the input 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 shunt, and, regardless of the input voltage, the current through the input is held constant at the programmed value.

A measurement circuit on the PXIe-4051 can simultaneously read the voltage and current values present at the input terminals (local sense) or sense terminals (remote sense). These measurements are performed by two integrating analog-to-digital converters which are synchronized at all times.

The PXIe-4051 features remote sense terminals. Remote sense is enabled to compensate for current-resistance loss drops in cables and switches.

The PXIe-4051 timing and triggering circuitry enables precise control of the sinking and measuring operations and synchronization with other devices.

The sequence engine of the PXIe-4051 enables precise control over the sinking functionality of the device and enables fast, deterministic timing. Additionally, you can utilize sequencing with the measurement functionality of a device to achieve specific measurement timing.

A sequence is a collection of setpoints that are executed one after another. A setpoint is a single input setting for the device. There are two methods for running a sequence:

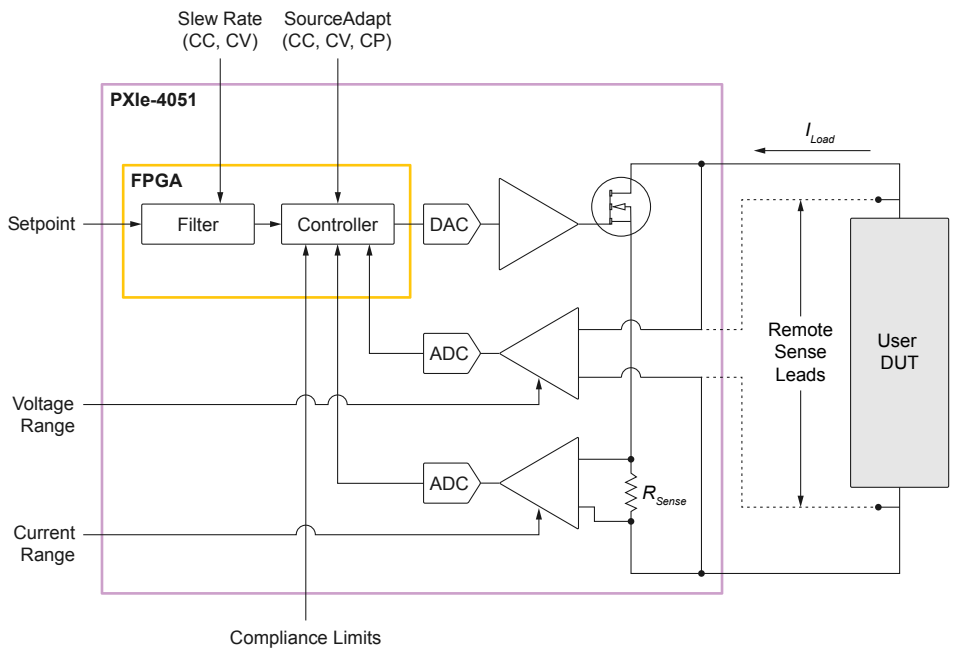
- Apply input values in succession: one setpoint followed by its corresponding Source Delay, immediately followed by the next setpoint.
- Use a trigger to configure the input to the next setpoint in the sequence at a precise time, followed by its corresponding Source Delay. When triggering a sequence, only one setpoint followed by its Source Delay is applied per received trigger.

Additional options allow for multiple executions of the sequence, synchronizing the engine at various points within its execution, and so on.

## Block Diagram

The following diagram illustrates the design of the PXIe-4051.

# PXIe-4051 Block Diagram





# PXIe-4051 Front Panel

Figure 3. PXIe-4051 Front Panel

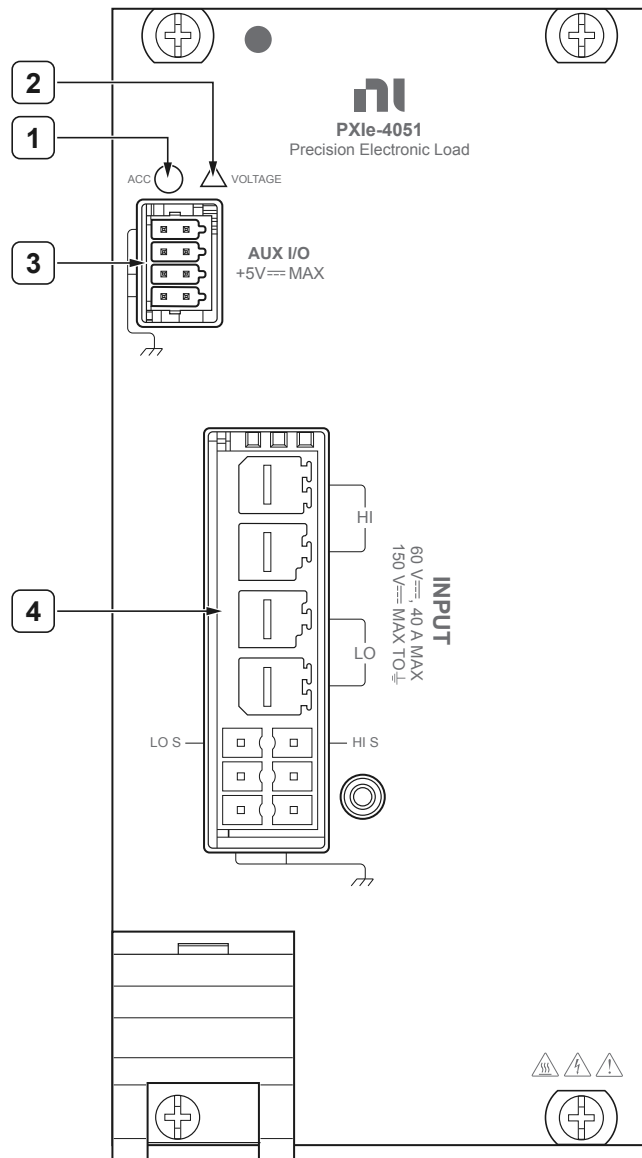


Table 4. Front Panel Descriptions

Front Panel Area	Description	
1	Access LED	Indicates module power and access status.

Front Panel Area		Description
2	Voltage LED	Indicates the module input channel state.
3	AUX I/O Connector	PFI I/O and fault connections.
4	Input I/O Connector	Primary input connection for input source and voltage sense.



**Note** For more information on LED indicators, refer to **PXIe-4051 LED Indicators**. For more information on pins, refer to the **PXIe-4051 Pinout**.

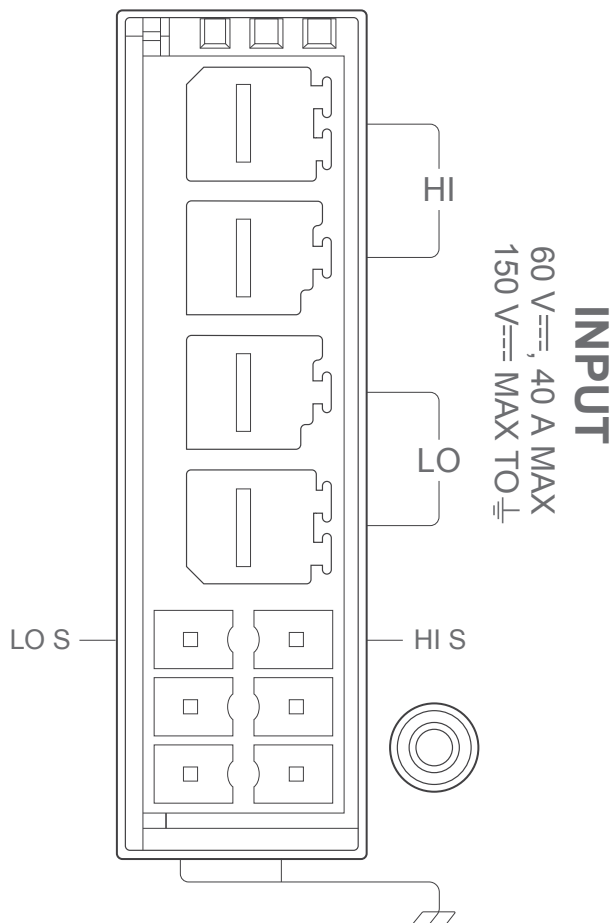
#### Related reference:

- [PXIe-4051 Pinout](#)
- [PXIe-4051 LED Indicators](#)

# PXIe-4051 Pinout


The following figures display the terminals on the PXIe-4051 connector.

## I/O Connections

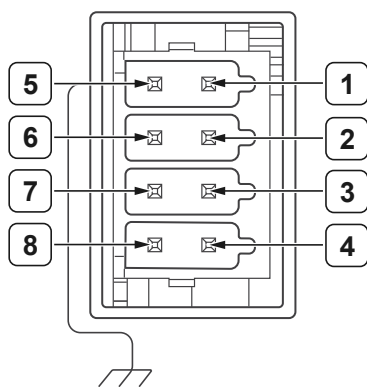


**Table 5.** Pin Descriptions

Pin	Description
HI	The input channel terminal capable of sinking DC potential.
LO	The input channel terminal referenced to circuit common.


Pin	Description
HI S	HI, remote voltage sense. Used to compensate for voltage measurement error due to cable voltage drops on the HI connection.
LO S	LO, remote voltage sense. Used to compensate for voltage measurement error due to cable voltage drops on the LO connection.
GND (  )	Connection to chassis (non-isolated) grounding. Used to update from a channel connection to a shield ground.

## AUX I/O Connectors



**Table 6.** Pin Descriptions

Pin		Descriptions
1	PFI 0	Programmable Function Interface for digital timing and triggering.
2	PFI 1	Device fault status output.
3	FAULT	Reserved.
4	RESERVED	



**Note** Before operating the electronic load, short this pin with a GND pin. For more information, refer to **Installing the Input**

Pin		Descriptions
		<b>and AUX I/O Connector on the PXIe-4051.</b>
5	GND	Ground reference for AUX I/O.
6	PFI 2	Programmable function interface for digital timing and triggering.
7	GND	Ground reference for AUX I/O.
8	GND	

### Related tasks:

- [Installing the Input and AUX I/O Connector on the PXIe-4051](#)

# PXIe-4051 LED Indicators

The PXIe-4051 features an Access LED and Voltage LED.

## Access LED

The Access LED, located on the module front panel, indicates module power and access.

The following table lists the Access LED states.

**Table 7.** Access LED Indicator Status

Status Indicator	Device State
(Off)	Not Powered
Green	Powered
Amber	Device is being accessed

## Why Is the Access LED Off When the Chassis Is On?

The LEDs may not light until the module has been configured in MAX. Before proceeding, verify that the PXIe-4051 appears in MAX.

If the Access LED fails to light after you power on the chassis, a problem may exist with the chassis power rails, a hardware module, or the LED.



**Notice** Apply external signals only while the PXIe-4051 is powered on. Applying external signals while the module is powered off may cause damage.

1. Disconnect any signals from the module front panel.
2. Power off the chassis.
3. Remove the module from the chassis and inspect it for damage.



**Notice** Do not reinstall a damaged module.

4. Install the module in a different, supported slot within the same PXI chassis.
5. Power on the chassis.



**Note** If you are using a PC with a device for PXI remote control system, power on the chassis before powering on the computer.

6. Verify that the module appears in MAX.
7. Reset the module in MAX and perform a self-test.


## Voltage LED

The Voltage LED, located on the module front panel, indicates the module input channel state.

The following table lists the Voltage LED states.

**Table 8.** Voltage LED Indicator Status

Status Indicator	Input Channel State
(Off)	The device input terminals are disconnected from the input circuitry through internal disconnect switches.
Green	The device input terminals are connected to the input circuitry and $< 42.4$ V DC is present.
Amber	The device input terminals are connected to the input circuitry and $\geq 42.4$ V DC is present.
Red	The device has a fault or is in error. The device will not operate until the error is cleared and/or the device is reset.



**Note** High voltage may be present on the input terminals from external sources.

Status Indicator	Input Channel State
	For more information on possible sources of the fault or error, refer to the driver software.



# PXIe-4051 Installation and Configuration

Complete the following steps to install the PXIe-4051 into a chassis and prepare it for use.

1. [Unpacking the Kit](#)
2. [Installing the Software](#)
3. [Installing the PXIe-4051 into a Chassis](#)
4. [Selecting an Output Accessory for Your Application](#)
5. [Verifying the Installation in MAX](#)
6. [Self-Calibrating the PXIe-4051 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.

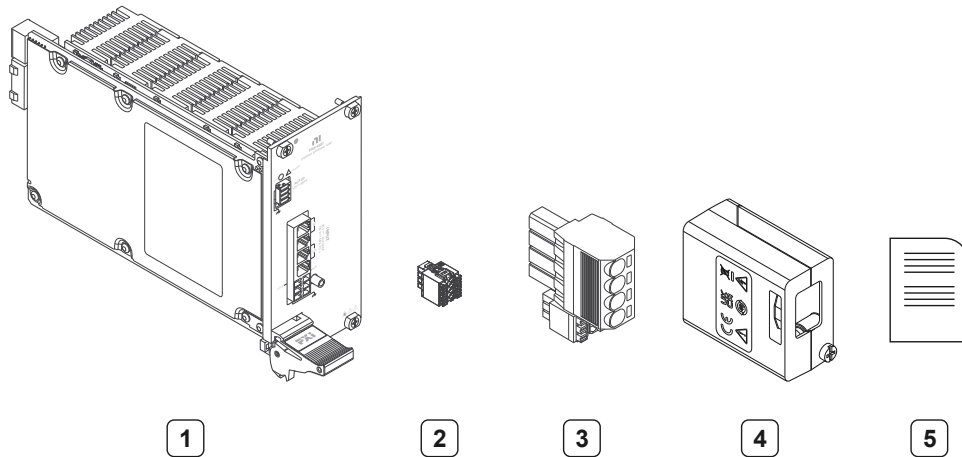
3. Unpack any other items and documentation from the kit.

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-4051 kit.

Figure 4. PXIe-4051 Kit Contents



1. PXIe-4051 Module
2. AUX I/O Connector
3. INPUT Connector
4. Backshell Assembly
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](http://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.

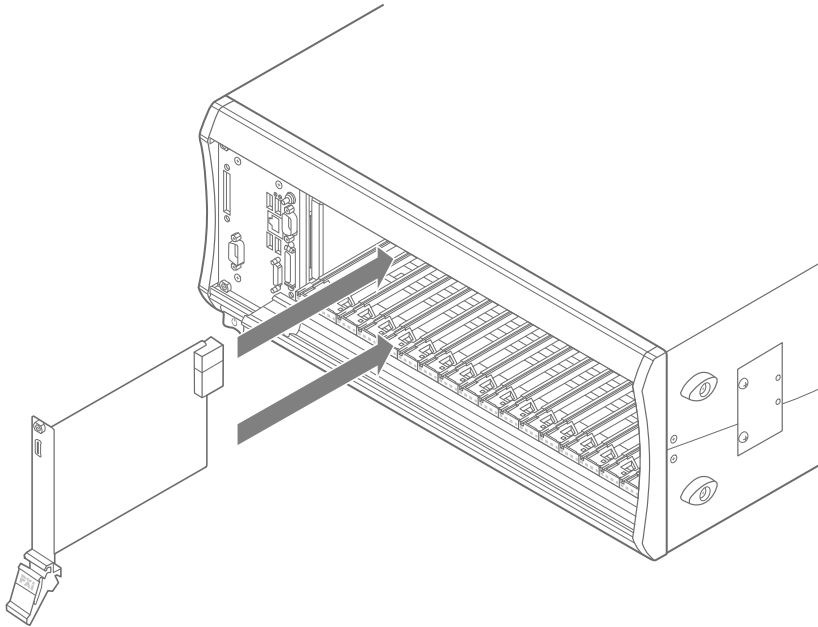
## Installing the PXIe-4051 into a Chassis



**Notice** To prevent damage to the PXIe-4051 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-4051 module can be placed in PXI Express hybrid peripheral slots (●<sup>H</sup>), 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 5. 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](https://ni.com/r/pxiblocker).

## Selecting an Output Accessory for Your Application

The PXIe-4051 offers two output accessories that can be attached to the front panel connector:

- **AUX I/O Connector**—This input connector ships with the PXIe-4051.
- **Input Connector**—This input connector ships with the PXIe-4051.

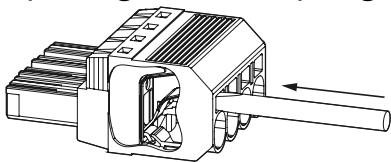
## Installing the Input Connector Assembly and Backshell Assembly onto the PXIe-4051

### PXIe-4051 Input Connector Preparation

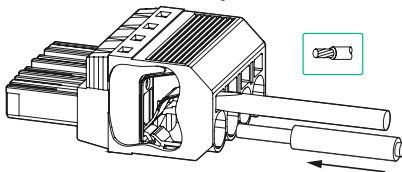


**Note** NI recommends a 0.6 x 3.5 screwdriver blade (blade standard DIN 5264).

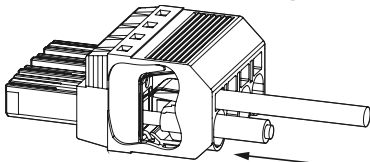
1. Open the clamping unit by pressing the screwdriver into the appropriate opening until the spring is completely opened.



2. Connect the conductor by plugging in the conductor into the clamping unit up to the end stop.

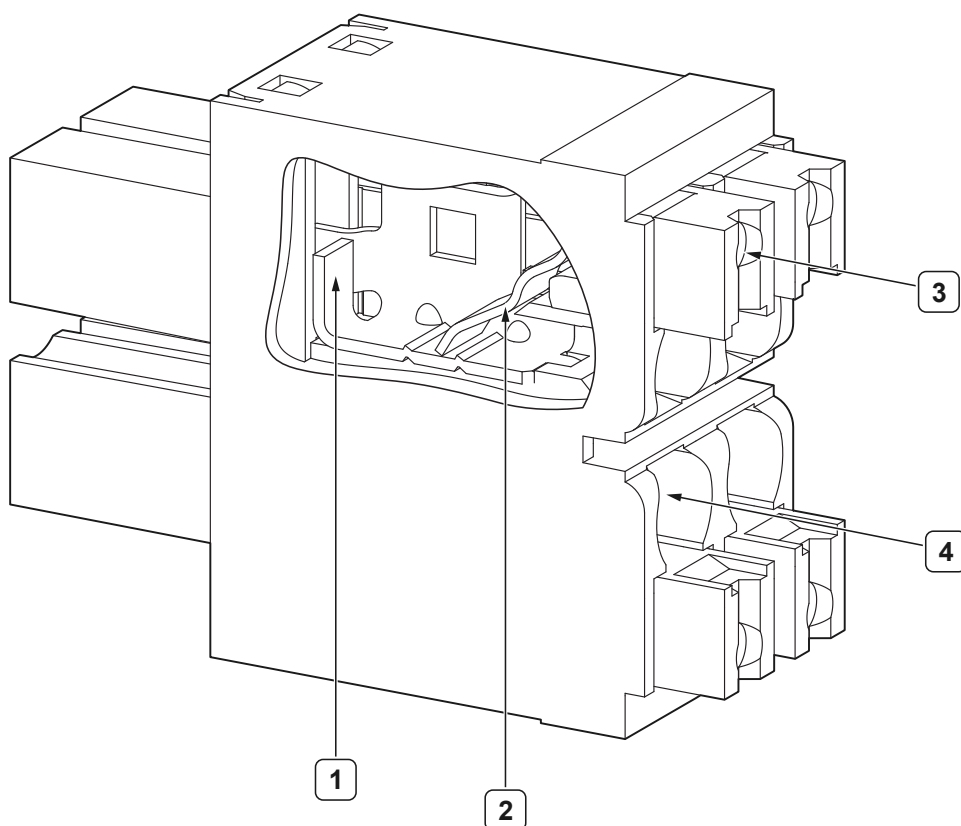


3. Close the clamping unit by removing the screwdriver from the opening.



4. Ensure the conductor is inserted up to the end stop by pulling gently on the conductors.

## HI Sense, LO Sense, and Shield GND Connections (Flexible/Stranded Conductors)

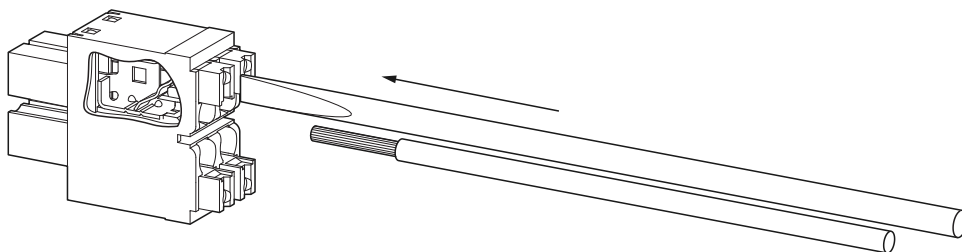


Part	Name
1	End stop
2	Spring clamp
3	Push-button (slider/pusher)
4	Conductor entry

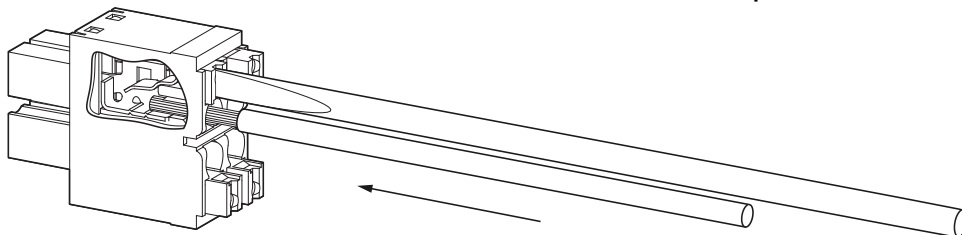


**Note** NI recommends a 0.4 x 2.5 screwdriver blade (blade standard DIN 5264).

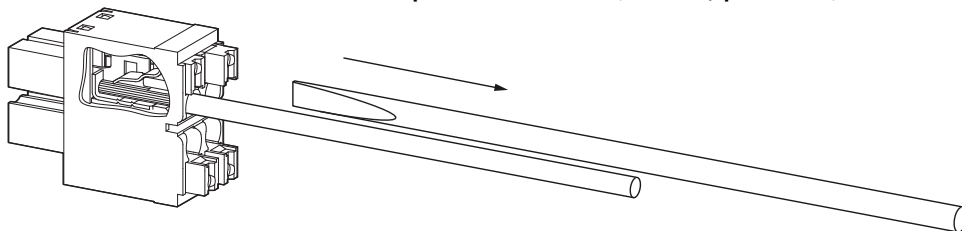
1. Open the contact point by pressing the push-button (slider/pusher).



2. Insert the stranded conductors without the crimped-on wire-end ferrules.



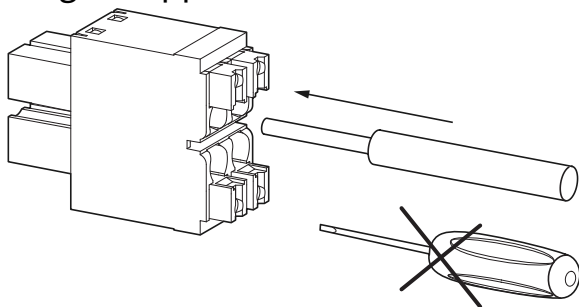
3. Remove the tool from the push-button (slider/pusher).



4. Verify that the conductor cannot be pulled out.

### HI Sense, LO Sense, and Shield GND Connections (Solid Conductors)

1. Plug a stripped solid conductor into the contact point up to the end stop.



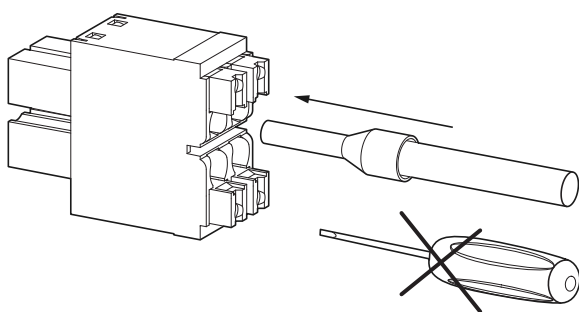
2. Verify that the conductor cannot be pulled out.

## HI Sense, LO Sense, and Shield GND Connections (Conductors with Wire-end Ferrules)

1. Plug a stranded conductor with a crimped-on wire-end ferrules, with or without plastic collars, into the contact point up to the end stop.



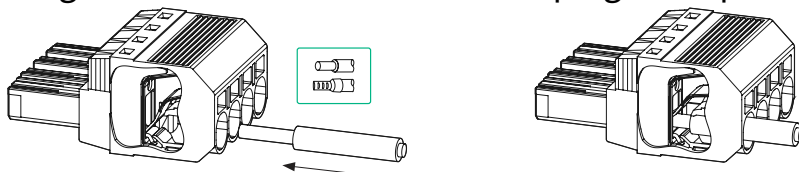
**Note** When plugging-in, an initial resistance (spring clamp) has to be overcome.



2. Verify that the conductor cannot be pulled out.

## HI and LO Connections (Solid Conductors / Conductors with Wire-end Ferrules)

1. Plug in the conductor into the clamping unit up to the end stop.



2. Ensure the conductor is inserted up to the end stop by pulling gently on the conductors.

## Backshell Assembly Preparation

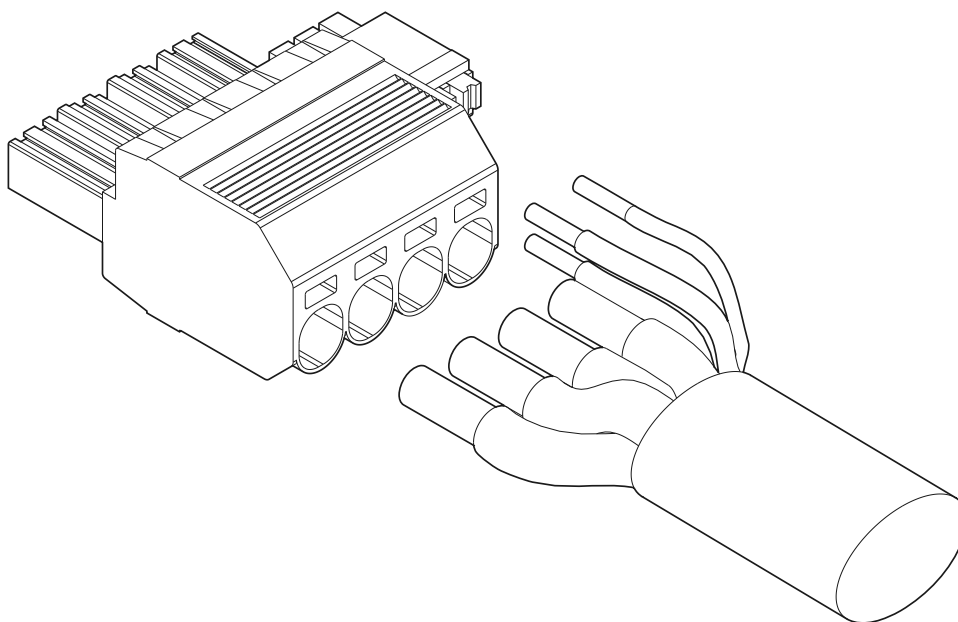
Prepare the output connector and cable to ensure proper grounding and install the input connector assembly onto the PXIe-4051.



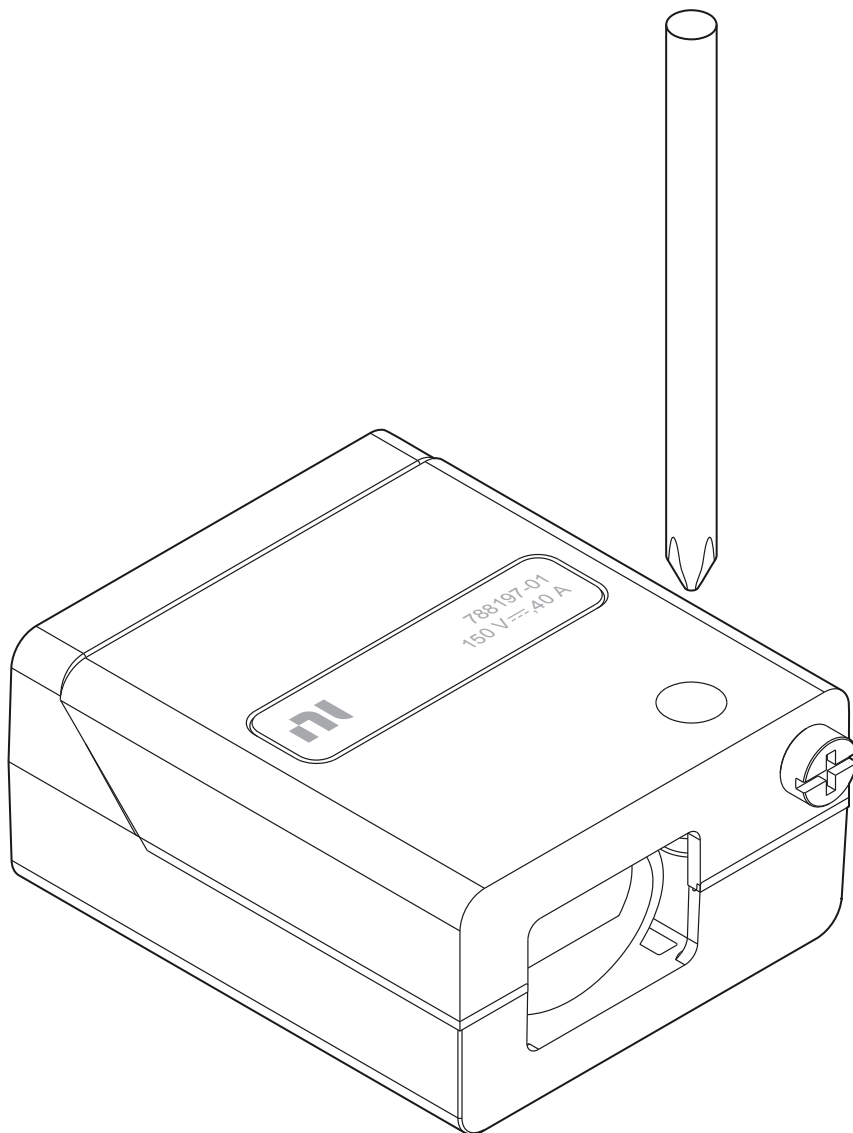
1. Insert a HI, LO, Hi Sense, LO Sense, and Drain Wire cable into the appropriate terminals.



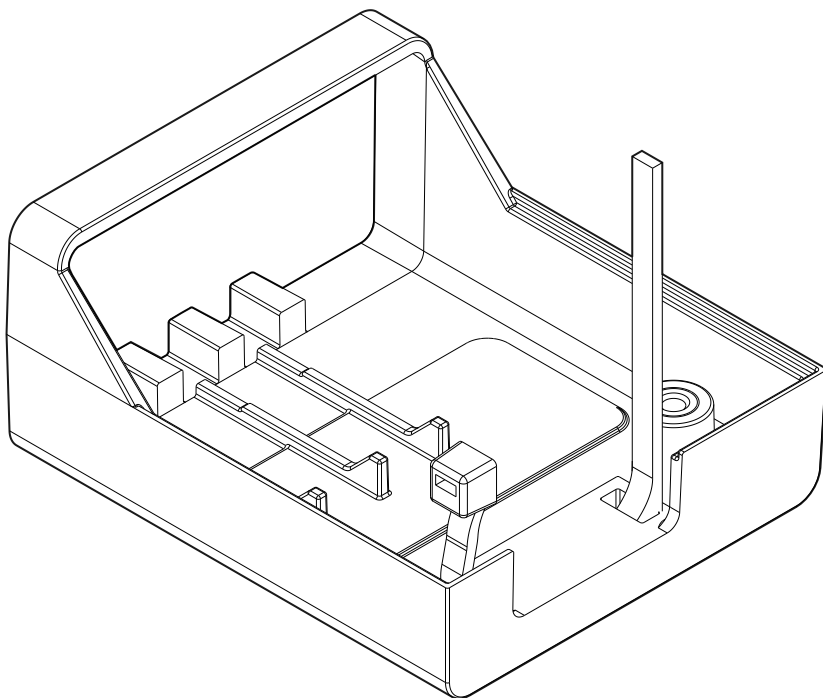
**Note** For more information on proper wiring, refer to the device user manual.



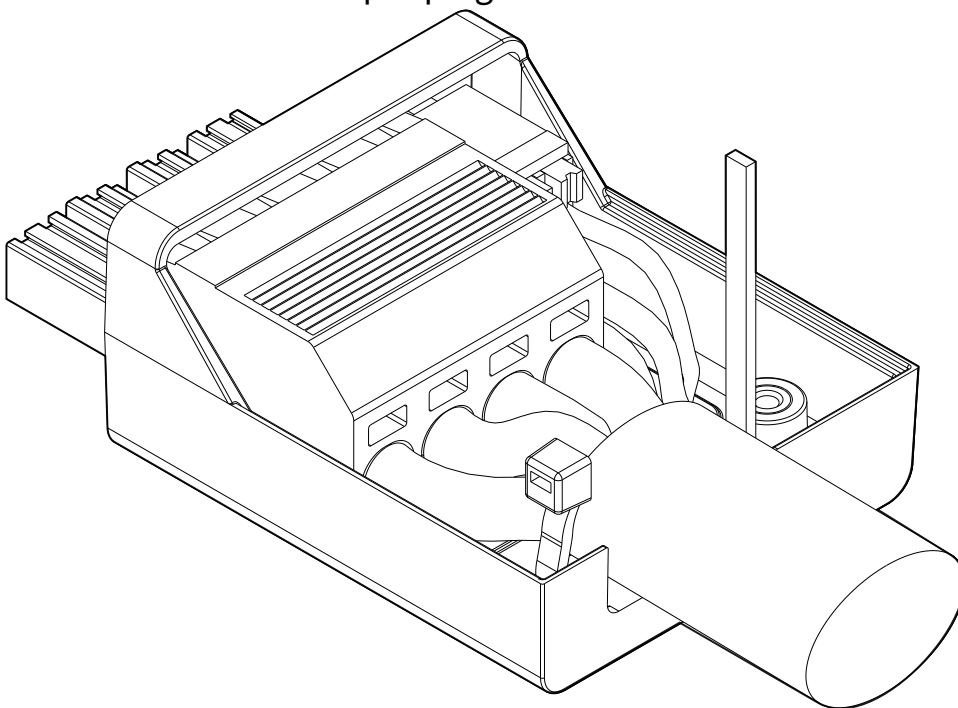
2. Open the backshell assembly by removing the cover screw.



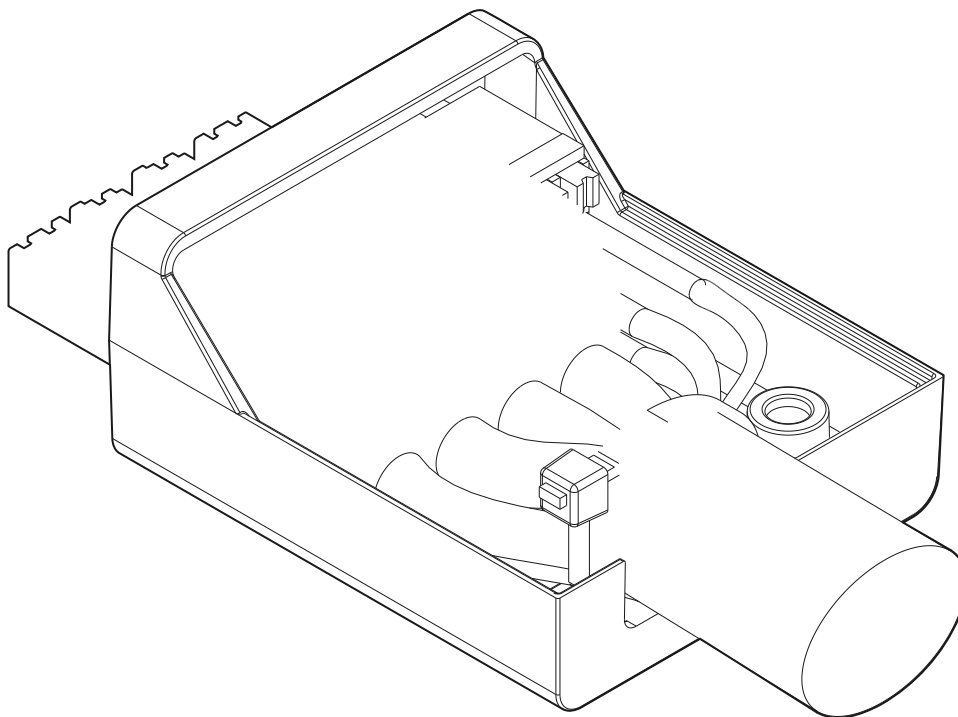
3. Remove the backshell top cover and insert a cable tie to the backshell bottom cover.



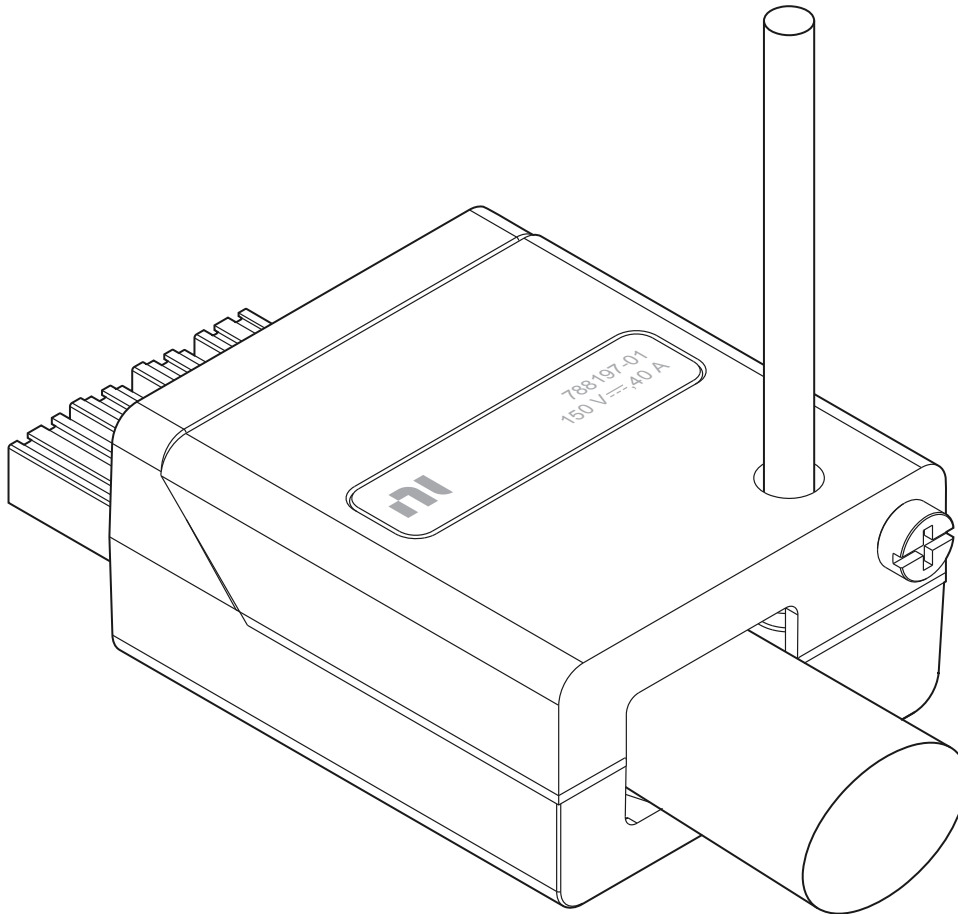
4. Place the assembled Input plug into the backshell.



5. Tighten the cable tie.



6. Reinstall the top cover and tighten the captive top-cover screws to a torque of  $0.3 \text{ N} \cdot \text{m}$  ( $2.7 \text{ lb.} \cdot \text{in.}$ ).



7. Insert the backshell assembly into the connector on the front panel.
8. Fasten the backshell to the device by tightening the jackscrew on the input connector assembly to a torque of  $0.3 \text{ N} \cdot \text{m}$  ( $2.7 \text{ lb} \cdot \text{in}.$ ).

## Installing the Input and AUX I/O Connector on the PXIe-4051

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

1. Ensure the AC power source is connected to the chassis.

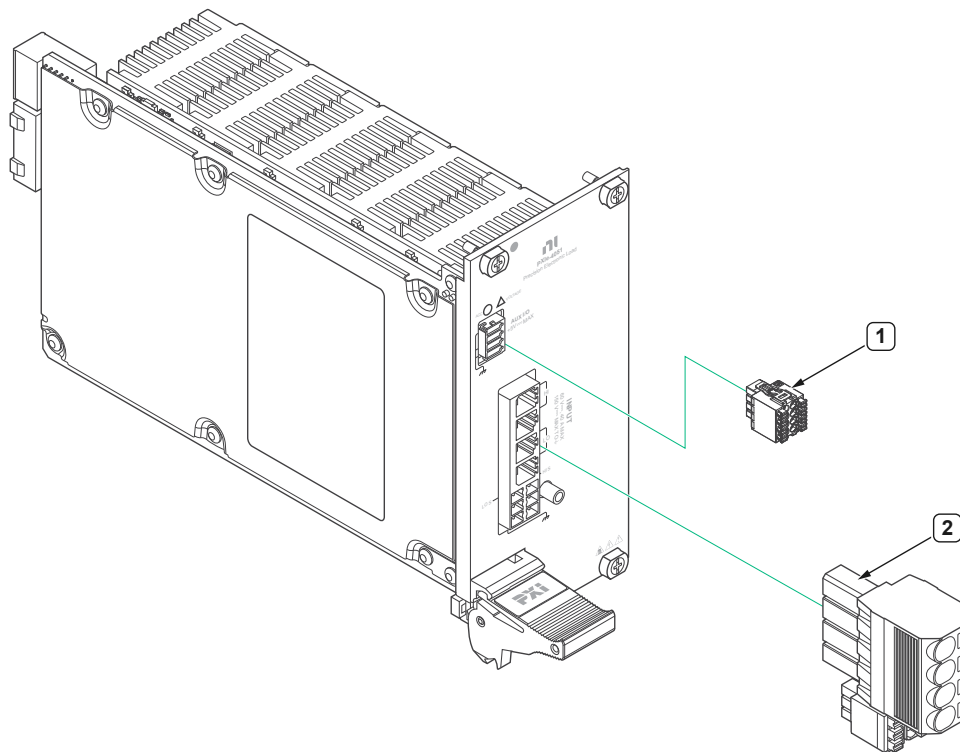


**Note** The AC power cord grounds the chassis and protects it from electrical damage.

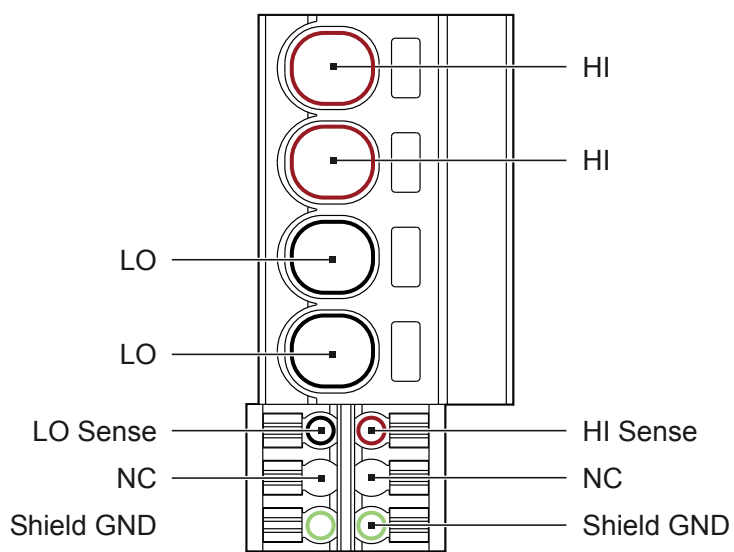
2. Power off the chassis.

3. Touch any metal part of the chassis to discharge static electricity.
4. Slide the accessory into the female COMBICON connector on the front panel of the module until it is fully inserted.

**Figure 6.** Input and AUX I/O Connector Installation with a PXIe-4051

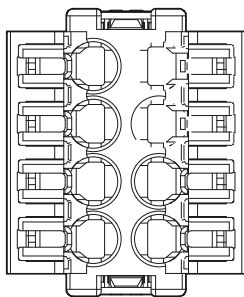


## Input Connector Front Panel




Signal Name	Description
HI	Primary channel input terminal capable of sinking a DC current (DC current in).
LO	Primary channel input terminal referenced to circuit common (DC current return).
HI Sense LO Sense	Use these terminals when remote sense is enabled to compensate for voltage drops due to resistance in cables and switches. HI Sense compensates for HI and LO Sense for LO.
Shield GND	Chassis grounding.

## AUX I/O Connector Front Panel



Signal Name	Description
GND	Ground reference for signals
PFI <0 , 1 , 2>	Programmable Function Interface for use with triggers or events.
FAULT	Device fault status output.
RESERVED	Reserved.



**Note** Before operating the electronic load, use the pre-installed jumper to short this pin to GND.

## 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.



**Note** The PXIe-4051 appears in MAX as NI PXIe-4051.

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-4051.
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-4051 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-4051 appears in the Device Manager.



- a. Under an NI entry, confirm that a PXIe-4051 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-4051 Fails the Self-Test?

1. Reset the PXIe-4051 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.

## Self-Calibrating the PXIe-4051 in MAX

Self-calibration adjusts the PXIe-4051 for variations in the module environment. The PXIe-4051 modules are externally calibrated at the factory. However, you should perform a complete self-calibration after you install the module.



**Note** The only supported values for the Self Calibration Persistence property and the NIDCPOWER\_ATTR\_SELF\_CALIBRATION\_PERSISTENCE attribute are **Write to EEPROM** and NIDCPOWER\_ATTR\_VAL\_WRITE\_TO\_EEPROM, respectively. This setting saves the calibration data to the onboard EEPROM, so the corrections survive power cycling and device resetting. Because EEPROM has a limited number of write cycles, NI recommends that you save your self-calibration data to EEPROM no more than once per day.

1. Install the PXIe-4051 and let it warm up for the recommended warm-up time listed in the **PXIe-4051 Specifications**.



**Note** Warm up begins when the PXI chassis has been powered on and the operating system has completely loaded.

2. Self-calibrate the PXIe-4051 by clicking the **Self-Calibrate** button in MAX or calling niDCPower Cal Self Calibrate VI (niDCPower\_CalSelfCalibrate).



**Note** Low energy transients can appear at the input terminals of your PXIe-4051 during certain situations, such as power-up, power-down, device driver loading, and self-calibration.

# Connecting Signals to the PXIe-4051

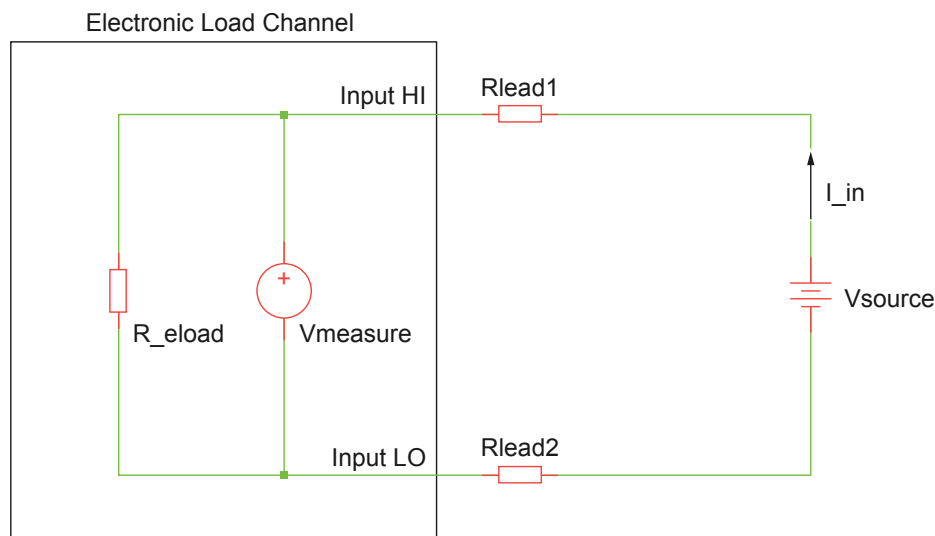
Refer to the following topics for guidance about PXIe-4051 signal connections.

- Use the Input HI and Input LO terminals for local sense measurements.
- Use the Input HI, Input LO, Sense HI, and Sense LO terminals for remote sense measurements.

## Making Local Voltage Sense Measurements

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

Figure 7. Connecting Signals for Local Sense Measurement



When the PXIe-4051 is operating in Constant Voltage mode, local sense forces the requested voltage at the input terminals of the module. The actual voltage at the DUT terminals is higher than the requested input voltage because of the input lead resistance error.

The error in the DUT voltage measurement is due to the input current, the output resistance of the  $V_{source}$ , and the resistance of the leads used to connect the electronic load to the source. This error can be calculated using the following equation:

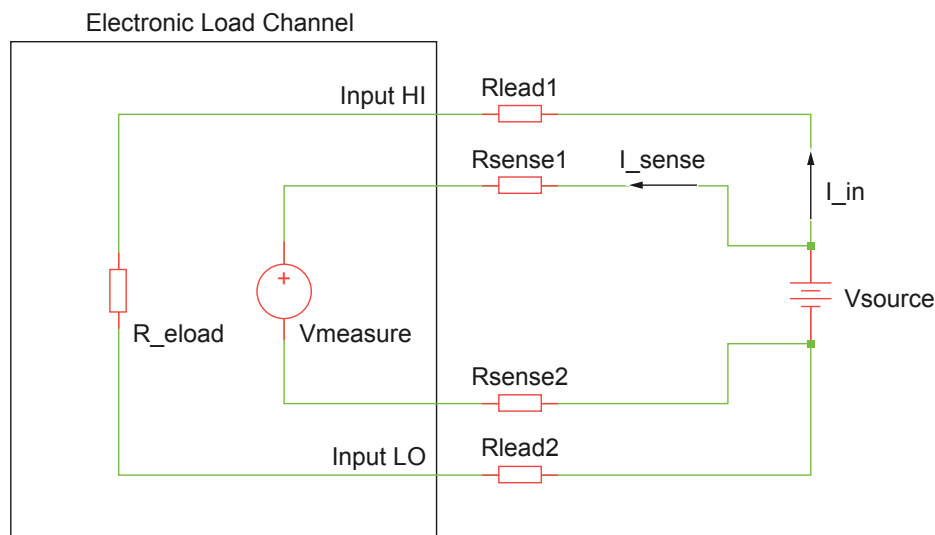
$$\text{Local Sense Error (Volts)} = I_{in}(R_{lead1} + R_{lead2} + R_{out}.V_{source})$$

Use remote sense measurements for high-current applications.

## 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 input current, while another set of leads measures voltage directly at the DUT terminals.

Figure 8. Connecting for a Remote Sense Measurement



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

Although the current flowing in the input 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 Constant Voltage function, the input voltage is forced at the end of the sense leads instead of the input terminals.
- When using remote sense in the Constant Current input function, the voltage is measured at the end of the sense leads instead of at the input terminals.

Using remote sense results in a voltage at the DUT terminals that is more accurate than what can be achieved using local sense. 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 input leads will cause the actual voltage at the input of the electronic load to be lower than that measured by the remote sense at the DUT. Especially when sinking high currents into the electronic load, you need to be careful that the voltage at the input terminal of the electronic load does not drop below the  $V_{\min}$  specifications which can result in loss of regulation.

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.

Refer to the **PXIe-4051 Specifications** for more information about remote sense support and the  $V_{\min}$  specifications.

The PXIe-4051 features internal open-sense protection through a 1 M $\Omega$  resistor between the force (Input HI/LO) and sense (Sense HI/LO) lines. This protection provides a secondary measurement path to maintain the instrument input 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 DUT to the electronic 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. Instruments 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 instrument 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 DUT were to short circuit.

**Table 9.** 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)
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 input voltage of the device or, if available, use remote sensing.

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:

$$V = I \times R$$

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

$$V = 13.2 \text{ mV}$$

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

## Minimizing Cable and Interconnect Inductance

To obtain the best performance while ensuring system stability, minimize the inductance in, and length of, the cables and interconnects between your source or DUT and the electronic load.



**Note** NI recommends tuning your system for stability at the highest intended current for the current test or operation.

If long cabling and high inductance are inherent to your setup, stabilize the system by altering the Transient Response property in the following ways:

- Select the gain-bandwidth setting as slow.
- Use the custom setting to reduce the bandwidth and compensate for long cables.

Compensating for long cabling means allowing lower bandwidth and dynamic performance for the electronic load in exchange for system stability, reduced ringing, and overshoot. The ability to customize system gain-bandwidth gives you the flexibility to determine the right balance of performance and stability for your system.

**Figure 9.** Ringing and overshoot effects due to long cabling or high inductance

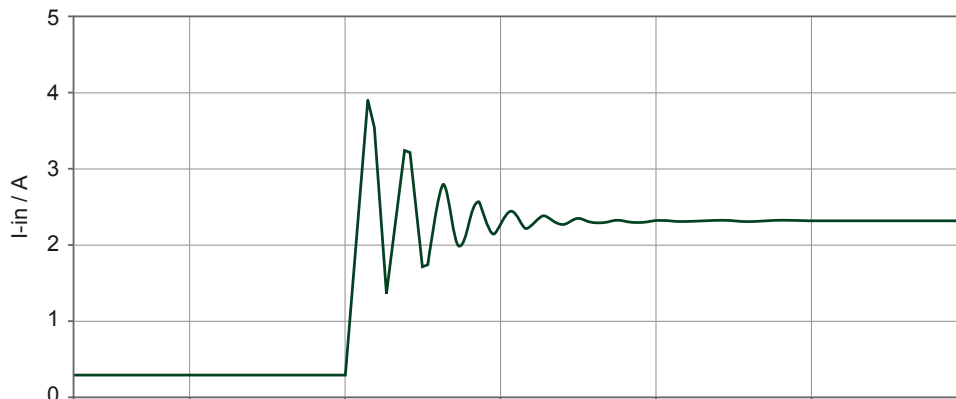
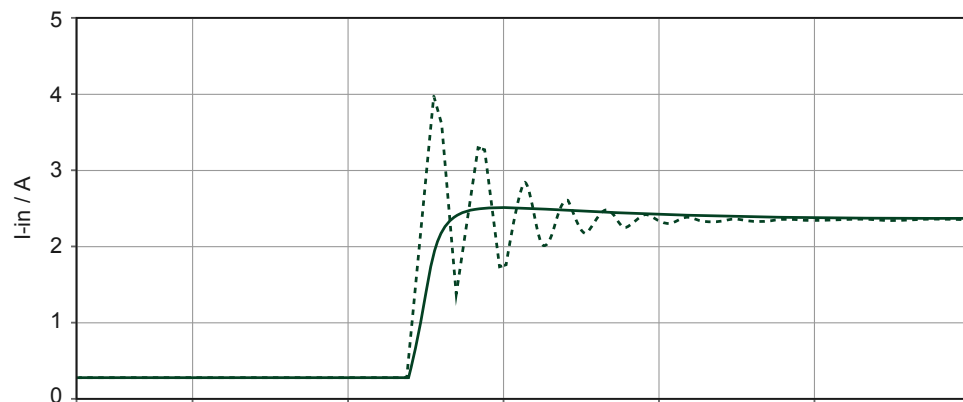


Figure 10. Ringing due to long cables compensated with gain-bandwidth adjustments





# Source Modes



**Note** In the following section, any references in the NI-DCPower API to a "source" actually refers to the sink functionality of the electronic load. Likewise, any references to an "output" instead refers to an input.

The PXIe-4051 channels can sink voltage and current in Single Point or Sequence Source mode.

Within Single Point and Sequence Source mode, you can input the following:

- DC Voltage
- DC Current

The niDCPower Configure Source Mode With Channels VI defines the Source Mode the PXIe-4051 channel is operating in.

## Single Point Source Mode

In **Single Point Source Mode**, the electronic load applies a single sink configuration when it enters the Running state.

You can then update the sink 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 electronic load steps through a predetermined set of sink configurations. Each sequence comprises a series of inputs for an NI-DCPower channel.

Sequence Source mode encompasses two types of sequences:

- **Simple sequence**—Allows you to define a series of voltage inputs or current inputs and Source Delays for a single channel.

- **Advanced sequence**—Allows you to define numerous properties per sequence step, in addition to basic voltage inputs or current inputs and Source Delays, for any number of channels.



**Note** You cannot program both simple sequences and advanced sequences within the same session.

A channel steps 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 versus Advanced Sequences

In Sequence Source Mode, you can use either simple sequencing or advanced sequencing. Each sequencing type has distinct capabilities and each is supported differently.

Task	Simple Sequencing	Advanced Sequencing
How to create	Set the Source Mode to Sequence and use the niDCPower Set Sequence VI	Set the Source Mode to Sequence; use the niDCPower Create Advanced Sequence With Channels VI, related advanced sequencing functions, and individual NI-DCPower properties
What you can configure	Voltage or current level per step of the sequence, along with Source Delay for each step	A wide variety of NI-DCPower properties per step of the sequence
Channels the sequence applies to	Any number of channels	Any number of channels
Controlling the initial state	Manually configure the channel(s) before calling the Set Sequence function	You can create a Commit step to configure channels to a known state before the sequence runs

Task	Simple Sequencing	Advanced Sequencing
Importing and exporting sequences	No capability	Can be transferred between sessions with the niDCPower Export Attribute Configuration and niDCPower Import Attribute Configuration VIs



**Note** You cannot program both simple sequences and advanced sequences within the same session.

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

## Sinking Examples

The following images are VI snippets that you can open as graphical code in LabVIEW. To add a VI snippet to your block diagram, save the image to your computer. Drag the saved image onto a LabVIEW Block Diagram Window. The depicted code will be added to your VI.



**Note** The PXIe-4051 does not support a programmable voltage limit. While using a voltage limit as an input to the NI-DCPower examples, you must set the limit to Inf.

Figure 11. NI-DCPower Sourcing/Sinking Current Example

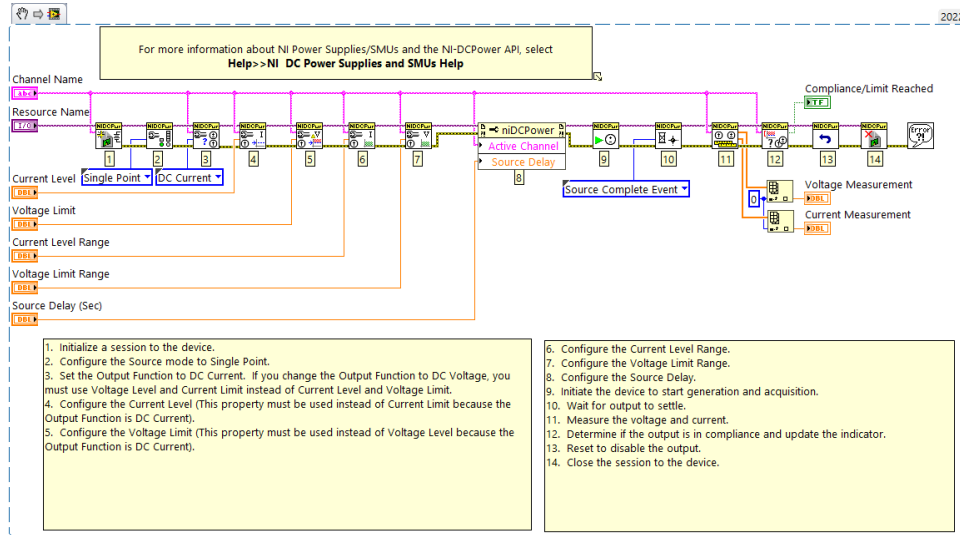
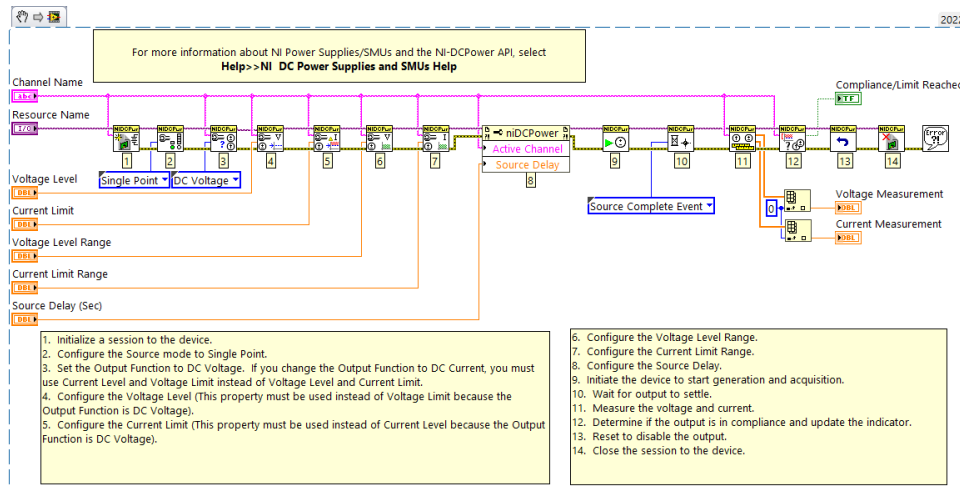


Figure 12. NI-DCPower Sourcing/Sinking Voltage Example



# Sinking Voltage and Current



**Note** In the following section, any references in the NI-DCPower API to a "source" actually refers to the sink functionality of the electronic load. Likewise, any references to an "output" instead refers to an input.

The PXIe-4051 can perform common electronic load operations to sink and measure voltage and current. In order to perform these operations, you must use the NI-DCPower driver to configure software settings and execute operations.

Refer to the following table for an overview of electronic load sink and measure operations as well as the software setting combinations that enable the PXIe-4051 to perform each operation.

**Table 10.** Software Settings for PXIe-4051 Sink and Measure Operations

PXIe-4051 Operation	NI-DCPower Settings	
	Output Function	Source Mode
Sink voltage	DC Voltage	Single Point or Sequence
Measure current or voltage		
Sink current	DC Current	
Measure voltage or current		

Complete the following general steps to sink current or voltage.

1. [Initialize a Session](#)  
Use the NI-DCPower driver to initialize a session with the PXIe-4051.
2. [Configure the PXIe-4051 for Sinking](#)  
Use the NI-DCPower driver with the PXIe-4051 to control the input the instrument sinks. Depending on the Output Function and Source Mode, you can configure the appropriate electronic load input levels and limits.
3. [Configure the PXIe-4051 for Measuring](#)  
Once you configure the channel and it is in the Running state, the PXIe-4051 can take measurements.

#### 4. [Configure Triggers and Events](#)

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

#### 5. [Initiate the PXIe-4051 for Sinking and Measuring](#)

Initiate the channels of the PXIe-4051 to apply a configuration and start sinking.

#### 6. [Acquire Measurements](#)

The Source Mode that you configured channels to use determines how the PXIe-4051 acquires measurements.

#### 7. [Cease Sinking](#)

NI-DCPower includes different options for stopping sinking on a PXIe-4051 channel and returning the channel to a known state.

#### 8. [Close the Session](#)

Use the NI-DCPower driver to close a session with the PXIe-4051.

## Initialize a Session

Use the NI-DCPower driver to initialize a session with the PXIe-4051.

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

For any application you write, you must open a session to establish communication with the PXIe-4051 or specified channel 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 `niDCPower Initialize With Independent Channels VI` one time. If the reset parameter is set to `TRUE`, device channel is reset to the default state.

## Configure the PXIe-4051 for Sinking

Use the NI-DCPower driver with the PXIe-4051 to control the input the instrument sinks. Depending on the Output Function and Source Mode, you can configure the appropriate electronic load input levels and limits.

Complete the following steps to define an Output Function, choose a Source Mode, and set the electronic load to the relevant input levels and limits.

1. Use the niDCPower Configure Output Function VI to set the Output function you want to sink: DC Voltage or DC Current.

- Select an Output function:

Option	Description
DC Voltage	A channel attempts to sink the desired input voltage level if the input current is below the current limit.
DC Current	A channel attempts to sink the desired output current level. The PXIe-4051 does not support a programmable voltage limit. In NI-DCPower, the Voltage Limit property is hardcoded by the driver to the value infinity for the PXIe-4051 and cannot be changed. However, the Voltage Limit Range property can still be used to configure a voltage range while using DC Current. Additionally, if the voltage applied to the input exceeds the normal operating margins, the PXIe-4051 will trip with an error and turn off the input. For more information on Overvoltage Protection, refer to <b>Overload Protection (OLP)</b> .

2. Configure the Source Mode with the niDCPower Configure Source Mode With Channels VI.

The Source Mode controls how the electronic load channel sinks input 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 niDCPower Configure Voltage Level VI	current limit input to niDCPower Configure Current Limit VI

Output Function	Source Mode		Level Control	Limit Control
	Sequence	Simple sequence	values input to niDCPower Set Sequence VI	current limit input to niDCPower Configure Current Limit VI
		Advanced sequence	Voltage Level property	Current Limit property
DC Current	Single Point		current level input to niDCPower Configure Current Level VI	N/A
	Sequence	Simple sequence	values input to niDCPower Set Sequence VI	N/A
		Advanced sequence	Current Level property	N/A

4. Further define the parameters of the channel input.

The NI-DCPower API includes numerous functions and properties to exert finer control over the input. For example, you can specify input ranges or take advantage of triggering.

**Related concepts:**

- [Overload Protection \(OLP\)](#)

## Configure the PXIe-4051 for Measuring

Once you configure the channel and it is in the Running state, the PXIe-4051 can take measurements.

Use the Measure When property or the NIDCPOWER\_ATTR\_MEASURE\_WHEN attribute to configure how NI-DCPower takes measurements.

The following table lists the settings for the Measure When property or the NIDCPOWER\_ATTR\_MEASURE\_WHEN attribute.



Measure When	Details
On Demand	Acquire measurements on demand using the niDCPower Measure VI or the niDCPower_Measure function to measure either the voltage or the current on a single channel. Or use the niDCPower Measure Multiple VI or the niDCPower_MeasureMultiple function to measure both the voltage and the current on multiple channels. When you call these VIs and functions, the PXIe-4051 takes a measurement and returns it.
Automatically after Source Complete	The PXIe-4051 acquires a measurement after every sink operation and stores it in a buffer on the device. You can use the niDCPower Fetch Multiple VI or the niDCPower_FetchMultiple function to retrieve measurements from the buffer.
On Measure Trigger	The PXIe-4051 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 or 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 sink and measure operations.  
A channel does not perform any sink 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 sink configuration.  
This trigger is available only when sinking DC voltage or DC current.
- **Measure**—Receiving a Measure trigger, if the Measure When property 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 the Measure When property 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.  
The Sequence Loop Count property must be set to a value greater than one for a sequence to iterate, and thus for this trigger to occur.

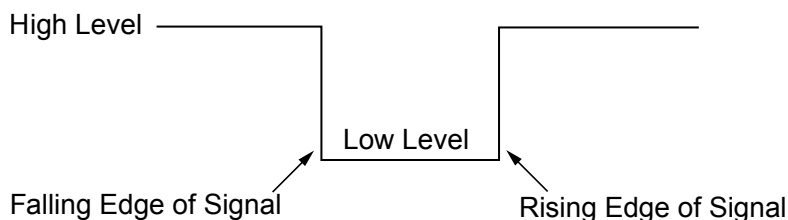
## Trigger Signal Conditions

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 13. 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 `niDCPower Send Software Edge Trigger With Channels VI`.

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 sink operation.

## 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 sinking operation, plus any configured Source Delay, is completed.  
In Single Point Source Mode, this event is generated whenever the sink 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  $\mu$ s].

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-4051 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 niDCPower Export Signal With Channels VI.



**Tip** You can use the niDCPower Wait For Event With Channels VI 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-4051 for Sinking and Measuring

Initiate the channels of the PXIe-4051 to apply a configuration and start sinking.

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-4051 acquires measurements.

## Measuring and Querying

Use the following functions to acquire measurements in Single Point Source Mode:

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 input state.

## Fetching

The PXIe-4051 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

These measurements are automatically acquired by coercing the 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.



**Note** If you want the measure unit to operate independently of the source unit in this context, set the 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.

## Cease Sinking

NI-DCPower includes different options for stopping sinking on a PXIe-4051 channel and returning the channel to a known state.



Option	How To	Description
Disabling the input	Set the Output Enabled property to FALSE	Sink 0 A on a channel. In DC Voltage Output Function, 2% of the current limit range presently configured for the channel remains on the channel.
Disconnecting the input	Set the Output Connected property to FALSE	Disconnects a switch on a channel that completely interrupts sinking on the channel.

## Disabling the Input

The input of a channel is enabled by default when the channel enters the Running state. However, you can programmatically enable and disable the input channel(s) of the PXIe-4051.

When you disable the input of the PXIe-4051, the instrument is configured with a setpoint that sinks at 0 A. Additionally in the DC Voltage Output Function, the current limit is configured to 2% of the presently configured current limit range. When you enable a previously disabled channel, levels and limits are applied to the channel depending on the Output Function as follows:

- **DC Voltage Output Function**—The programmed voltage level and current limit are applied to the channel(s)
- **DC Current Output Function**—The programmed current level is applied to the channel(s).



**Note** The PXIe-4051 does not support a programmable voltage limit. In NI-DCPower, the Voltage Limit property is hardcoded by the driver to the value infinity for the PXIe-4051 and cannot be changed.

You can use the Configure Output Enabled function to toggle the input of the PXIe-4051.



**Tip** To ensure the input is disabled on the hardware, after using the niDCPower Configure Output Enabled VI or Output Enabled property, use the niDCPower Wait For Event With Channels VI. This function can be used to wait for the Source Complete event before calling the Abort With Channels function to transition the session out of the Running state.

## Disconnecting the Input



**Note** In the following section, any references in the NI-DCPower API to a "source" actually refers to the sink functionality of the electronic load. Likewise, any references to an "output" instead refers to an input.

You can open an internal switch in order to completely disconnect the HI and LO and/or Sense terminals from the input connector of a channel.

Disconnecting the input always affects the HI and LO terminals. When remote sense is enabled, disconnecting the input also affects the HI Sense and LO Sense terminals.

- **Programming the output relay directly**—Use the Output Connected property to control the state of the internal switch.
- **Input connected indirectly**—The internal switch is connected when you call the niDCPower Reset Device VI or the niDCPower Disable VI.
- **Power-up behavior**—The instrument powers up with the input connected.
- **Input connected by default in certain states**—The input is automatically connected when a channel, depending on the instrument, enters a running state.

## Close the Session

Use the NI-DCPower driver to close a session with the PXIe-4051.

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 channel continues to operate in its last configured state. If you close a session while the input channel is enabled and actively sinking power, the channel continues to 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 11.** 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 functions and operations.

- **NI-DCPower Source DC Voltage**—Demonstrates how to force an output voltage on an SMU or an input voltage on an Electronic Load.
- **NI-DCPower Source DC Current**—Demonstrates how to force an output current on an SMU or an input current on an Electronic Load.
- **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 SMU output or the Electronic Load input while it is changing.



**Note** The PXIe-4051 does not support a programmable voltage limit. While using a voltage limit as an input to the NI-DCPower examples, you must set the limit to Inf.

# PXIe-4051 Operating Guidelines

Refer to the following sections for information about PXIe-4051 features and guidelines for operating the PXIe-4051.

## Overload Protection (OLP)

The PXIe-4051 is protected against overcurrent (OCP) conditions, overvoltage (OVP), and overpower (OVPWR) 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 input and turns off the internal FET to stop current from being sunked.

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

Do not apply voltages at the input that exceed the ratings of the PXIe-4051. For more information about voltage ratings, refer to the **PXIe-4051 Specifications**.

## Overvoltage Protection (OVP)

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

OVP is not available in electronic loads. However, if the user applies voltages that exceed the normal operating margins, PXIe-4051 will trip with an error and turn off the input. This action will not reduce the voltage that is applied to the input.



**Note** Do not exceed the specified voltage ratings on the inputs. For information about voltage ratings, refer to the **PXIe-4051 Specifications**.

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.

## Overpower Protection (OVPWR)

Overpower Protection (OVPWR) is a feature that prevents the electronic load from sinking excessive power. When the input power exceeds the device limits, the electronic load will attempt to limit the power by reducing the current flowing into it. Voltage or Current will no longer be regulated when OVPWR is activated.

If this fails to reduce the input power into the electronic load, it will proceed to trip, disables the input and turns off the internal FET. To clear an OVPWR trip condition, first identify and fix the cause of the error and then use the niDCPower Reset VI or the niDCPower\_Reset function.

### Related information:

- [PXIe-4051 Specifications](#)

## Fault

The fault output pin indicates when a device fault or error has occurred. When a fault occurs, this AUX I/O connector pin is driven low. By default, the fault output pin enables internal pull-up.



**Note** During a device reset, the fault output pin is temporarily driven low.

## Source Inductance

In Constant Voltage mode, the PXIe-4051 should remain stable with most source (or cable) inductance.



**Note** Operating in Constant Current mode, especially at high current level/source (or cable) inductance, can lead to instability. To achieve

stability with long cables, adjust the source adapt settings by reducing bandwidth and/or adding capacitance to the PXIe-4051 input.

## Source Capacitance

In Constant Current mode, PXIe-4051 remains stable with source capacitances.



**Note** In Constant Voltage mode, moving large source capacitances across a current source can lead to instability. To achieve stability, adjust the source adapt settings.

## Dynamic Sources

Source voltage or current can vary between a minimum and a maximum value in some applications. In Constant Current mode with a pulsing voltage source, the Constant Current circuit of the electronic load limits and regulates the input current. In Constant Voltage mode, occasionally, a peak current may come close to exceed the current limit and cause the PXIe-4051 to temporarily move into Constant Current mode or unregulated mode.

To remain within the power supply or SMU output specifications with pulsed loads, use the niDCPower Configure Current Limit VI 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 PXIe-4051 electronic loads to sink higher peak currents. Generally, parallel operation is only recommended in Constant Current mode.

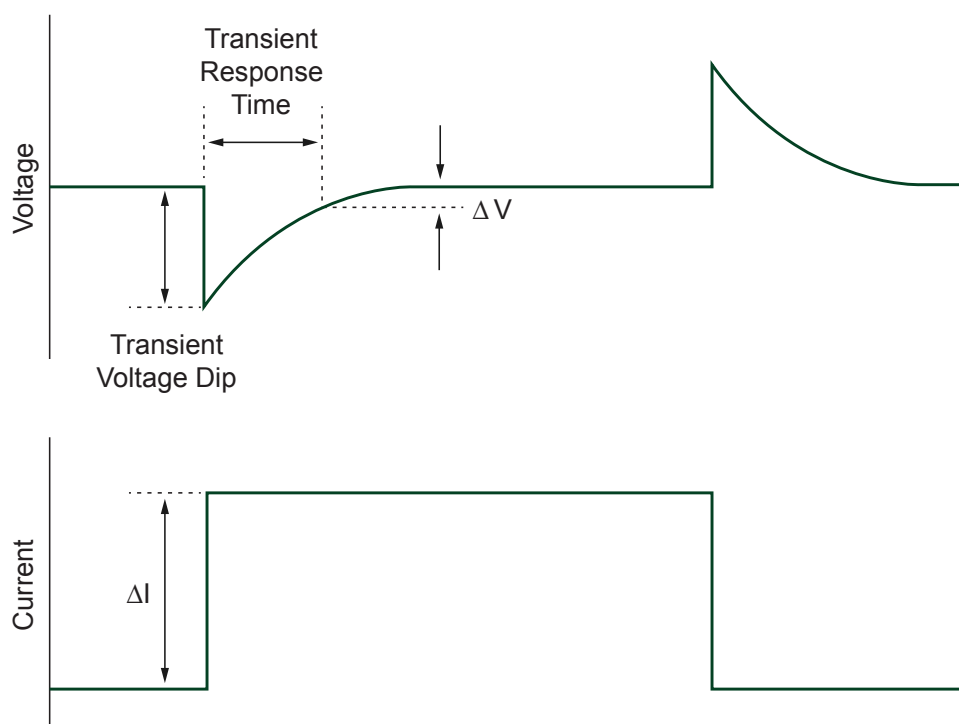
## Transient Response

Transient response describes how an electronic load responds to a sudden change in source voltage or current.

Changes in source 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 ( $\Delta V$ ) when a specific change in load ( $\Delta I$ ) occurs. Some power supplies also specify a maximum transient voltage dip under the same load conditions.



Figure 14. Transient Response



There is a trade-off between transient response and the stability of the system under a wide variety of sources connected to the electronic load. 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 sources. 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.

## Configuring Transient Response

Use the Transient Response property to set the transient response.

The following table lists the PXIe-4051 transient response settings available in NI-DCPower.

Table 12. Transient Response Settings

Transient Response	Description
Slow	Increases stability while decreasing the speed of the device. Select Slow if connecting a DUT causes the device to exhibit symptoms of

Transient Response	Description
	instability, such as unstable readings or excessive noise.
Normal (default)	Balances stability and the speed of the device. It is the default transient response setting and is appropriate for most situations.
Fast	Increases the speed of the device for improved transient response with benign loads. Select Fast if you need faster response and if doing so does not cause the instrument to exhibit symptoms of instability, such as unstable readings or excessive noise.
Custom	Allows freedom to adjust compensation for specific loads. Select Custom if you need to optimize the speed/stability tradeoff.

## Customizing Compensation

Set the Transient Response property to NIDCPOWER\_VAL\_CUSTOM to customize compensation on the device.

The following table lists the compensation parameter settings for the PXIe-4051. You can independently set the parameters for Constant Voltage mode and Constant Current mode. There are three compensation parameters for Constant Voltage mode and three compensation parameters for Constant Current mode, for a total of six writable and readable parameters.

**Table 13.** Compensation Parameters

Compensation Parameter	Mode	Details
Gain Bandwidth (GBW)	Both	Set the GBW of the instrument. Higher values give faster response but poorer stability. 10 Hz to 1 MHz
Compensation Frequency	Both	Set the geometric mean of the pole frequency and the zero frequency. It is the frequency of maximum phase shift caused by the pole-zero pair. 50 Hz to 1 MHz
Pole-Zero Ratio	Both	Set the ratio of the pole frequency to zero frequency. A

Compensation Parameter	Mode	Details
		lag compensator has a pole-zero ratio set to a value less than 1.0, and a lead compensator has a pole-zero ratio set to a value greater than 1.0. If the pole-zero ratio is set to exactly 1.0, the pole and zero cancel each other and have no effect. You can set the pole-zero ratio to any value between 0.0625 and 16.



**Tip** To begin customizing the transient response for your application, you can set Transient Response to **Slow**, **Normal**, or **Fast** and read the compensation parameters. This will provide you with a good starting point from which you can derive your custom settings.

## Slew Rates

In Constant Current mode, PXIe-4051 allows the user to independently program the rising and falling slew rates of a current step.

The **slew rate** is the rate at which a current increases to a set level. There are two independently programmable slew rates:

1. Rising slew rate
2. Falling slew rate



**Note** In Constant Current mode, the slew rate is defined as A/us.

To configure the rising or falling slew rate of the current level, set the Current Level Rising Slew Rate or Current Level Falling Slew Rate property.

Figure 15. Programmable Slew Rates in Constant Current Mode

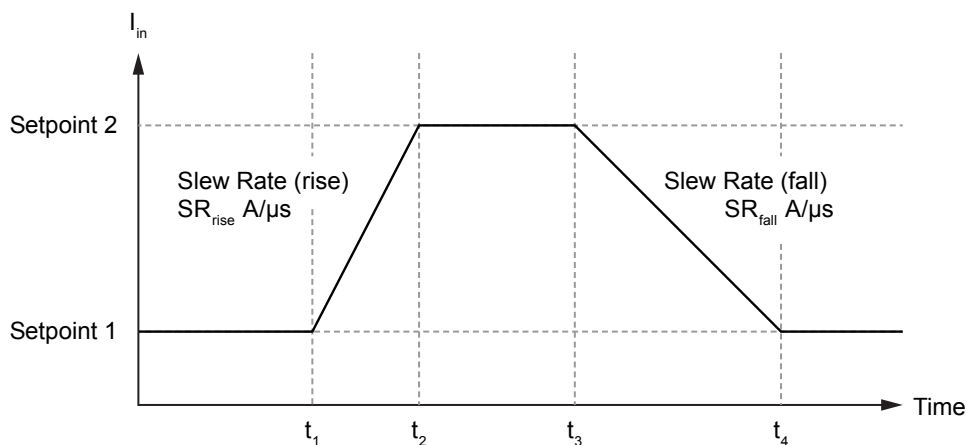


Table 14. Slew Rate Programmable Range

Mode	Programmable Range
CC	<ul style="list-style-type: none"> <li>■ 4 A Range <ul style="list-style-type: none"> <li>■ The Overranging Enabled property is set to FALSE: 1E-8 – 2.4 A/us</li> <li>■ The Overranging Enabled property is set to TRUE: 1E-8 – 2.52 A/us</li> </ul> </li> <li>■ 40 A Range <ul style="list-style-type: none"> <li>■ The Overranging Enabled property is set to FALSE: 1E-8 – 24 A/us</li> <li>■ The Overranging Enabled property is set to TRUE: 1E-8 – 25.2 A/us</li> </ul> </li> </ul>
CV	N/A



**Note** NI-DCPower will coerce the Slew Rate property to the highest supported value if you set the property to Infinity or any value higher than the maximum supported value. For more information on the default value, refer to **Properties Supported by the PXIe-4051**.

## Slew Rate and Transient Response (Gain Bandwidth)

Because the PXIe-4051 allows system bandwidth or speed programming, the achievable maximum slew rate is limited by the setup system bandwidth. You can make and optimize the system bandwidth using Transient Response adjustments through the SourceAdapt settings.

Due to physical limitations, you cannot slew faster than what the system bandwidth, including the PXIe-4051, wiring, and DUT, allows. Through the PXIe-4051, you can optimize your system bandwidth with a custom transient response and compensation. This allows you to achieve the maximum slew rate possible with your specific setup.

The slew rate control functionality allows you to define a desired slew rate for setpoint parameter in Constant Current mode. You can control the maximum slew rate (in A/us) between setpoints for both single point mode and sequence mode. Adjusting the maximum slew rate will not change the user-programmed step size but will provide a more deterministic control of the signal behavior between setpoints. The timing of receiving the Source Complete event and the Measure Complete event will not be impacted by the slew rate configuration.

The actual slew rate achieved between setpoint steps will not exceed the specified slew rate. The actual rate can become slower than what you have set if one of the following situations takes place:

- The transient response parameter takes precedence.
- The compliance parameter takes precedence.
- The maximum slew rates of the power stage are reached.

Slew rate control is implemented digitally through a linear interpolation filter between the user's sequence setpoints being applied and the setpoint in the digital loop.

Maximum realizable slew rates are limited by the programmed Gain Bandwidth (and compensations) in the transient response settings and by the limitations of the setup and system. However, you can use a programmable slew rate to obtain:

- Slower slew rates.
- Independent rising and falling slew rates.
- Unique slew rates for each step in a sequence

If the slew rates are programmed to be slower than the sequence step time, then you will not be able to achieve the steady state of programmed setpoint within the step timing that you desire.



**Note** Programmable Slew rates are available for Constant Current Mode only.

## Relationship between Transient Response, Rise Time, and Slew Rates Settings

Using slew rates with gain bandwidth (GBW) programming can give you the flexibility to optimize the performance of your setup within necessary physical limitations. This ensures that the electronic load can work in a wide variety of use cases.

To optimize your system:

1. Program the max slew rate into the system.
2. Setup the system and DUT with the shortest possible cabling.
3. Tune the system for the fastest possible rise time with minimal overshoots and ringing.
4. Estimate the Max GBW limited slew rate for the setup using the following equation.

$$80\% * \text{Current\_Step\_Amplitude} / \text{Rise\_Time}$$

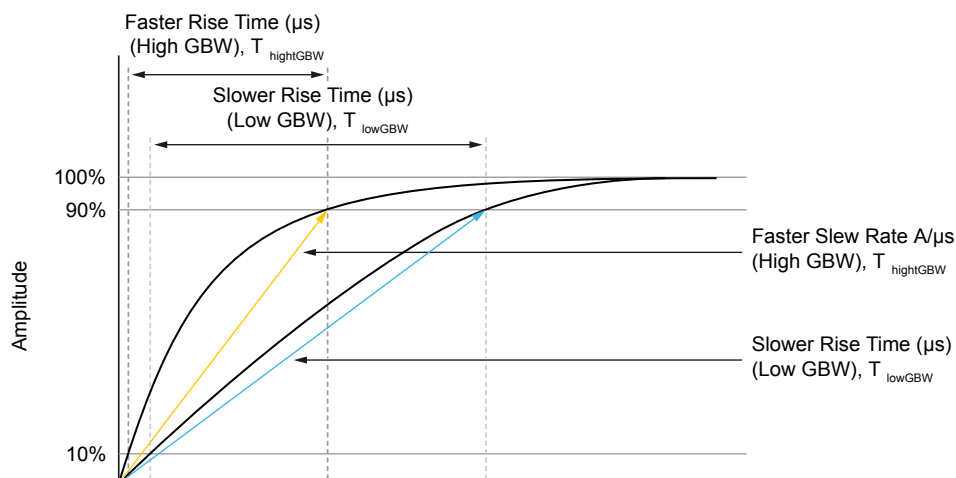


**Note** The maximum slew rate will change with the amplitude of the current step.

5. Program the desired slew rate, which can be equal to or slower than the max GBW limited slew rate.

Assuming that your system is stable when programmed with the maximum slew rate, setting a faster GBW (assuming system is still stable at the faster GBW) will result in a faster rise time and maximum slew rate. Even if you program a slew rate that is faster than the GBW limited slew rate, the system cannot physically achieve that faster rate.

**Figure 16.** Limitations on Slew Rates based on GBW

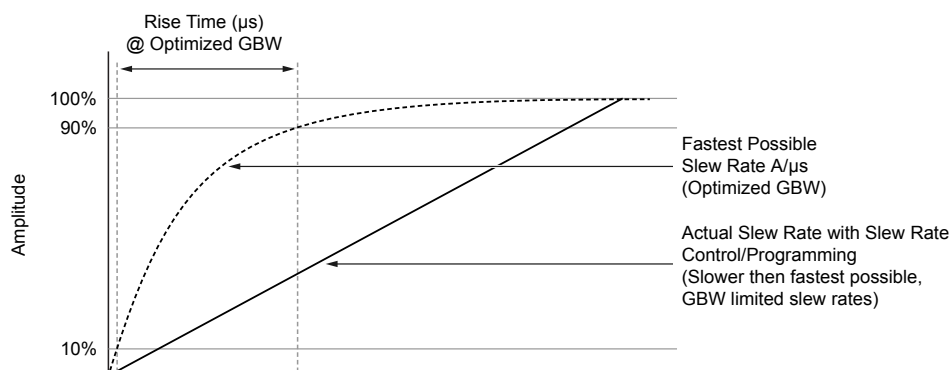


In order to increase the maximum attainable slew rates, you will need to increase the GBW. However, GBW cannot be increased indefinitely. It is limited by the stability of the system, including the electronic load, the cables, and any DUTs.

To reduce the slew rate, you can set a GBW lower than physically limited GBW. An issue with this method is that GBW actually determines rise time and not slew rates directly. Also, the amplitude of the step will determine the final slew rate numbers in A/us.

Effort is required to calculate the required slew rates from the GBW. Compensation settings or empirical experimentations will be necessary. Hence using the slew rate programming capability is recommended.

**Figure 17.** Optimizing the GBW



The slew rate programming capability will allow you to program a deterministic slew rate. As long as the programmed rate is slower than the fastest possible rate at the particular GBW settings, you will be able to obtain the exact slew rate that you desire.

When programming the slew rates, you can also have a different slew rate for the rising and falling of the step. In advanced sequences, it is possible to have unique and independent slew rates for each step in the sequence.

### $V_{load\_min}$ , Turn-on Behavior, and Conduction Voltage Settings

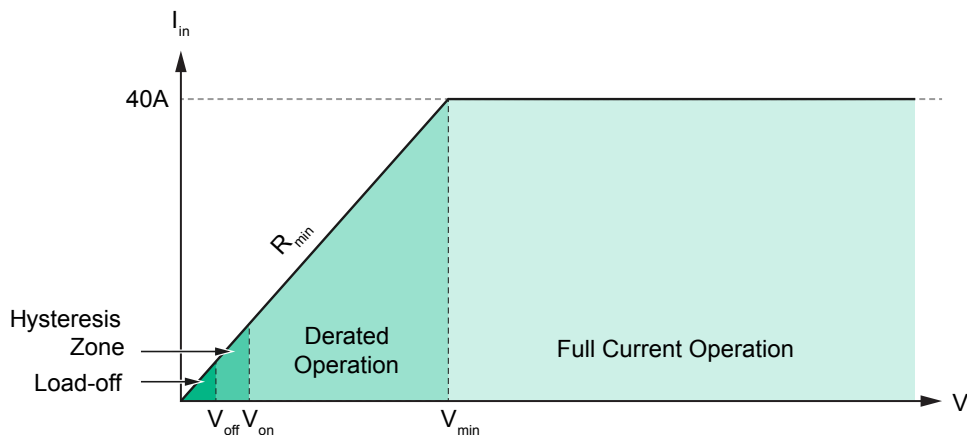
Depending on the voltage of the connected DUT or source, you can program specific automatic load on and off behaviors.

The following conditions are possible:

- Linear current derating below  $V_{load\_min}$ <sup>1</sup>
- User-programmable turn-on voltage,  $V_{on}$  with latching
- User-programmable turn-off voltage<sup>2</sup>,  $V_{off}$

The ability of the load to hit the desired current setpoint depends on the zone of operation.

Figure 18. Zones of Operation



**Note** When Conduction Voltage is disabled, the Hysteresis and Load-off zone are a part of the Derated Operation zone.

Zone	Description
Derated Operation	The current setpoint is limited by the minimum on resistance relationship.

<sup>1</sup> The minimum on resistance defines the relationship between input voltage and maximum possible load current when the input voltage is below  $V_{load\_min}$ .

<sup>2</sup> Turn-off voltage only has an effect when enabled and when latching is enabled.

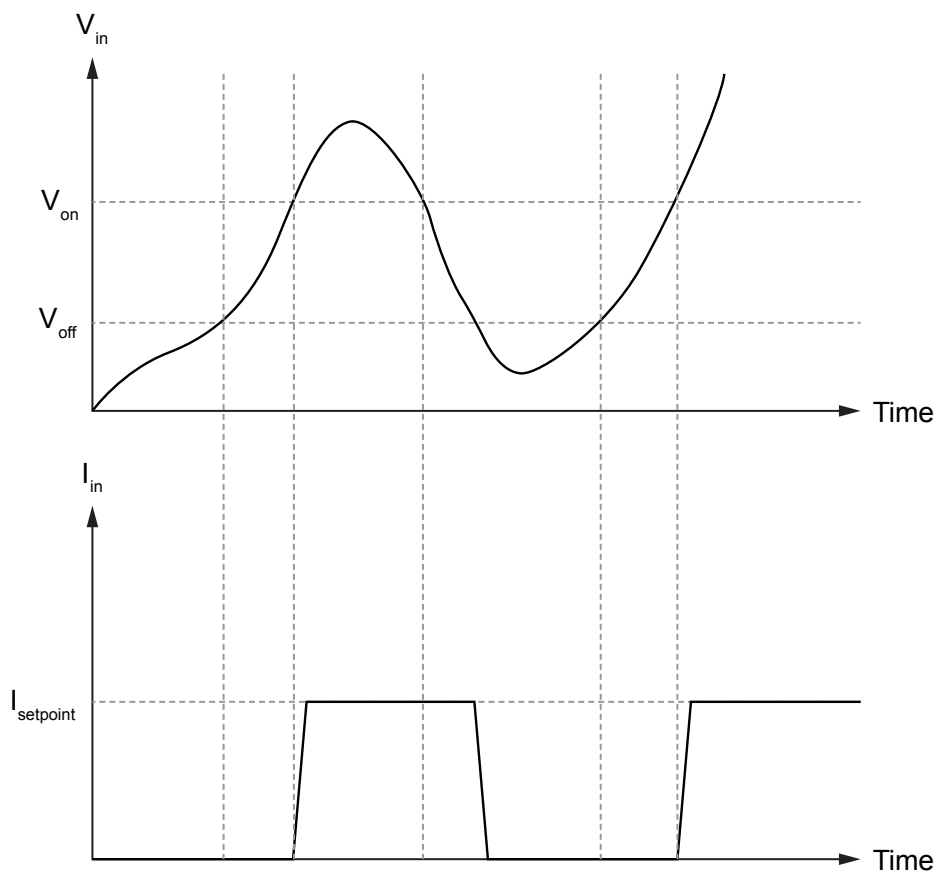


Zone	Description
Full Current Operation	The I-V relationships are limited by: <ul style="list-style-type: none"> <li>▪ Maximum current (40 A)</li> <li>▪ Maximum voltage (60 V)</li> <li>▪ Maximum power<sup>3</sup> (300W)</li> </ul>

When Conduction Voltage is enabled, the  $V_{on}$  and  $V_{off}$  settings will determine the Load turn on and off behaviors.

$V_{on}$ and $V_{off}$ Settings	Load Behavior
$V_{on} > V_{off}, V_{off} > 0$	Load will turn on when the input voltage rises above $V_{on}$ threshold and will turn off when it falls below $V_{off}$ .
$V_{on} > 0, V_{off} = 0$	Load will turn on when input voltage rises above $V_{on}$ and remains latched on.

<sup>3</sup> The maximum power of the load depends on the PXIe chassis. PXIe-4051 can be used in any 58 W or 82 W PXIe chassis. To achieve the full 300 W capacity, use a PXIe-1095, PXIe-1092, or PXIe-1084.

Figure 19.  $V_{on}$  and  $V_{off}$  Behaviors

In NI-DCPower, set the Conduction Voltage Mode property to enable Conduction Voltage on the device.

Conduction Voltage Mode	Description
Automatic	Conduction Voltage feature is enabled in Constant Current mode. Conduction Voltage feature is disabled in Constant Voltage mode.
Enabled	Conduction Voltage feature is enabled regardless of control mode.
Disabled	Conduction Voltage feature is disabled regardless of control mode.

If Conduction Voltage is enabled, set the Conduction Voltage On Threshold property to specify the turn-on voltage ( $V_{on}$ ) and set the Conduction Voltage Off Threshold property to specify the turn-off voltage ( $V_{off}$ ).

Conduction Voltage Threshold	Programmable Range	
Conduction Voltage On Threshold property	Constant Current mode	0 V – Configured Voltage Limit Range
	Constant Voltage mode	0 V – Configured Voltage Level
Conduction Voltage Off Threshold property	0 V – Configured Conduction Voltage On Threshold	



**Note** For more information on default Conduction Voltage property values, refer to **Properties Supported by the PXIe-4051**.

## Reverse Current Loads

The PXIe-4051 is not designed for reverse voltage or current operations. The electronic load will become damaged if reverse currents are applied to their input terminals.

Reverse currents can cause the device to move into an unregulated mode and can damage the instrument. For more information about channel capabilities, refer to the **PXIe-4051 Specifications**.

## Ranges



**Note** In the following section, any references in the NI-DCPower API to a "source" actually refers to the sink functionality of the electronic load. Likewise, any references to an "output" instead refers to an input.

Electronic loads use one or more ranges for voltage and current input, 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 input and measurement accuracy. Refer to the **PXIe-4051 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 input range. Thus, you cannot change the measurement range independently of the input range. The selected measurement range is

large enough to measure any voltage or current within the configured input range.

Ranges are typically described as the maximum possible value from zero that the range can input or measure (not including the overrange). For example, in the 4 A current level range, the current level can be configured up to 4 A.

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

## Changing Ranges

The following table lists supported configurable input ranges and their VIs and functions.

**Table 15.** Supported Configurable Input 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 input range and you request a range that differs from the ranges described in the **PXIe-4051 Specifications**, NI-DCPower selects the highest resolution (smallest) range available that accommodates the requested range. For example, on a device with only 20 mA and 200 mA current limit ranges, if you request 100 mA for the current range, NI-DCPower selects the 200 mA range.

To change the range, the configured range must be able to accommodate the configured input 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 input range and input value changes because the configuration change takes effect immediately in this state. To avoid ordering issues, NI recommends that you configure the input range and input value in the Uncommitted state and then transition to the Running state. Alternatively, you can enable autoranging for the range you want to change.

## Overranging

If the Overranging Enabled property is set to TRUE, the valid values for the programmed output (voltage level, 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 input capabilities from 100% to 105% for the output range. Overranging is applicable to input 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.

## Source Autoranging

When Source Autorange is enabled by setting the corresponding Autorange Enabled property (for example, Current Level Autorange property is set to enable autorange for the current level range), NI-DCPower automatically changes the input range based on the configured input setpoint. NI-DCPower automatically changes to the highest resolution (smallest) range that can accommodate the configured input

value. You can selectively enable input 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 a new setpoint is programmed.

## Noise

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

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 Input common LO 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 input 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 Input HI terminal and the Input common LO terminal, appearing either in series (Constant Voltage mode) or parallel (Constant Current mode) with the input of the device. Normal-mode noise can be expressed as voltage noise or current noise, depending on the control mode of the input channel.  
AC-to-DC rectification causes ripple, a type of periodic normal-mode noise.

## Verifying Input Noise Specifications

Exercise care when verifying the noise specifications of an input device such as an electronic load. 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 input noise specifications of an electronic load:

- Connect a short cable between the HI and LO terminals of the electronic load. Avoid using long leads or loose wires.
- Connect another short cable between the LO terminal and the input common/ground terminal of the appropriate channel.
- Set the bandwidth of the electronic load 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 electronic loads 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.

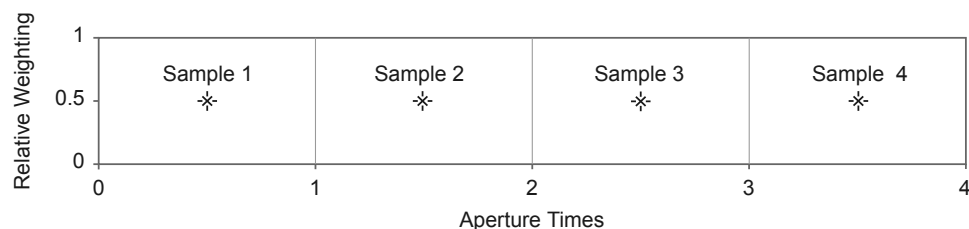
You can reject the frequency of noise by adjusting the aperture time to be a multiple of an AC noise frequency with **Period** =  $1/f$ .

### Normal DC Measurement Noise Rejection

With normal noise rejection, the instrument assigns equal weight to each sample. This setting mimics the behavior of most traditional data acquisition modules and analog input modules.

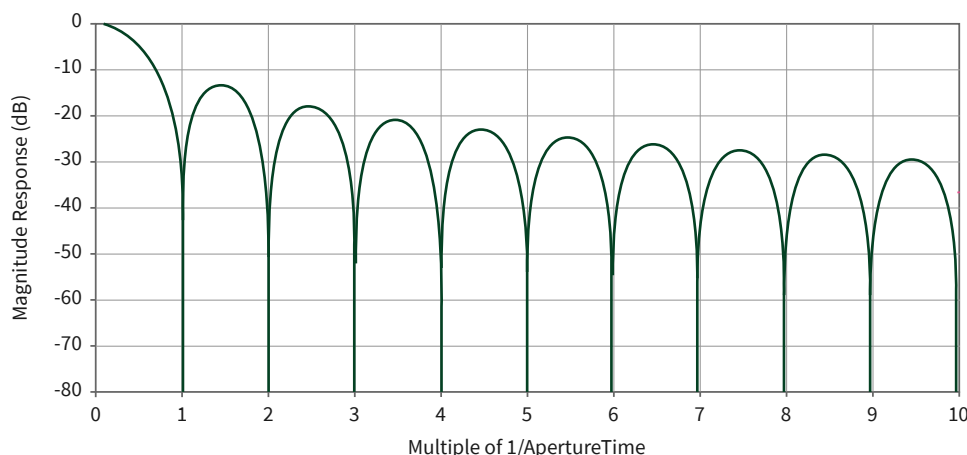
Normal noise rejection is the default behavior for all NI-DCPower instruments. The following figure shows normal weighting, with aperture times on the x-axis and relative weighting on the y-axis.

**Figure 20.** Normal Noise Rejection



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

**Figure 21.** Normal Noise Rejection by Frequency



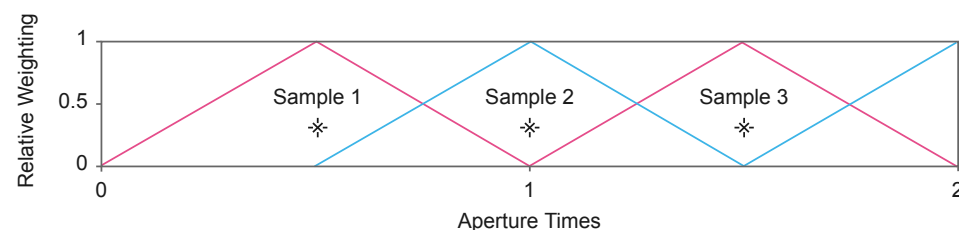
The best frequency rejection is available only near integer multiples of  $1 / \text{Aperture Time}$ . You can achieve the fastest possible readings along with good power-line noise rejection by setting the aperture to one power-line cycle (PLC) and noise rejection to Normal.

### Second-Order DC Measurement Noise Rejection

With second-order noise rejection, the instrument assigns a triangular weighting to measurement samples. Samples taken in the middle of the aperture time have more weight than samples taken at the beginning and end of that measurement.

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

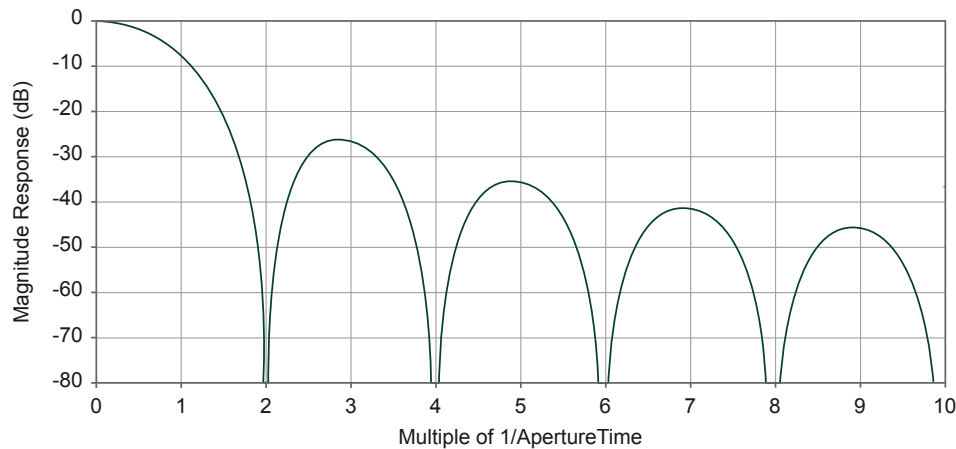
**Figure 22.** Second-Order Noise Rejection



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



**Figure 23.** Second-Order Noise Rejection by Frequency



With second-order noise rejection, the instrument provides superior noise rejection even near multiples of  $1 / \mathbf{Aperture\ Time}$ , and noise rejection increases more rapidly with frequency compared to normal noise rejection. Notches are also wider than they would be with normal weighting, which results in less sensitivity to slight variations in noise frequency.

Use second-order noise rejection if you need better power-line noise rejection or better high-frequency noise rejection than you can obtain with normal noise rejection.

You can achieve the fastest possible readings with second-order noise rejection, along with excellent power-line noise rejection, by setting the aperture to two power-line cycles (PLC) and noise rejection to Second-Order.

In this configuration, one measurement is produced in the first full aperture, followed by two measurements for each subsequent aperture time. This results in approximately the same measurement rate as normal filtering for large measure records.

### Choosing an AC Noise Rejection Profile

You have a choice of AC noise rejection profiles: **normal** and **second-order**. Normal noise rejection is the default noise rejection behavior for all NI-DCPower instruments, while second-order noise rejection can provide better frequency rejection in some situations.

The length of the measurement aperture time affects which noise frequencies are rejected. The noise rejection profile changes how frequencies are rejected with respect to the measurement aperture time and affects the minimum time required for the instrument to make a single measurement.

Choose the AC noise rejection profile that suits your application based on the following criteria.

Lowest Frequency Rejection Notch	High-Frequency Noise Rejection	Minimum Measurement Time Required	Recommended Noise Rejection Profile
1 / <b>Aperture Time</b>	Good	Shorter: <b>Aperture Time</b>	Normal (default)
2 / <b>Aperture Time</b>	Better	Longer: $2 \times$ <b>Aperture Time</b>	Second-Order

### 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.

- Choose the noise rejection profile that suits your application.
  - Normal
  - Second-Order
- Based on the aperture time units and the noise rejection profile you intend to use, calculate the aperture time required to reject the frequency  $f$  (Hz) you need to reject.
  - Aperture time units: seconds

Noise Rejection Profile	Target Aperture Time (s)
Normal (default)	<b>Aperture Time</b> = $1 / f$
Second-Order	<b>Aperture Time</b> = $2 / f$

- Aperture time units: power line cycles (PLC)

Noise Rejection Profile	Power Line Frequency	Target Aperture Time (PLC)
Normal (default)	60 Hz	<b>Aperture Time</b> = 60 Hz / $f$
	50 Hz	<b>Aperture Time</b> = 50 Hz / $f$

Noise Rejection Profile	Power Line Frequency	Target Aperture Time (PLC)
Second-Order	60 Hz	<b>Aperture Time</b> = $2 \times (60 \text{ Hz} / f)$
	50 Hz	<b>Aperture Time</b> = $2 \times (50 \text{ Hz} / f)$



**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.

3. 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.
4. Use DC Noise Rejection to set the noise rejection profile you chose.

## Power Measurements

The PXIe-4051 has two synchronized ADCs that measure voltage and current. You can use NI-DCPower to measure power flowing to the PXIe-4051.

You can use the following VIs and functions to measure both current and voltage for both channels of the PXIe-4051.

- 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. While sinking, the PXIe-4051 uses a positive convention for power measurement.

## Sinking and Measuring Terminology

Refer to the following terms when learning more about the features and usage of the PXIe-4051:

- **Aperture Time**—The period during which an ADC reads the voltage or current on an electronic load. 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 electronic loads, a channel is operating in compliance when it cannot reach the requested input level because the programmed limit has been reached.
- **Resolution**—The smallest change in the voltage or current measurement that can be detected by hardware. It is usually specified in absolute units, like  $\mu\text{V}$  or  $\text{nA}$ .
  - Measurement resolution is typically limited by the ADC used for the measurement, but may also be limited by other factors, such as noise.
  - Input 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-4051 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 an electronic load.
- **Settling Time**—Settling Time specifies the time required for an input channel to stabilize to within a specified percentage of its final value, when stepping from one setpoint to another. This value depends on the gain bandwidth settings and any additional compensation that was used.



**Note** Starting from 0A or OFF may incur additional delays. For more information, refer to Startup Delay.

- **Startup Delay**—During startup from 0 A, when the electronic load is off, or when responding to conduction mode settings at the  $V_{\text{on}}$  threshold to the programmed setpoint, there is an additional delay prior to current ramping up. This delay increases when the current setpoint is small or when gain bandwidth is set to low.

This is expected behavior. The analog loop needs time to ramp up to prevent current overshoot, voltage overshoot, and voltage undershoot.

## Calibration

Electronic loads support two types of calibration: external calibration and self-calibration.

### External Calibration

Every electronic load 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-4051 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](http://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 inputting 5 V with voltage accuracy specified at 0.05% of input + 100  $\mu$ V 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 2-year accuracy of the instrument in the 18 °C to 28 °C range:

$$0.05\% \text{ of } 5 \text{ V} + 100 \mu\text{V} = 2.6 \text{ mV}$$

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

$$\pm(2.6 \text{ mV} + ((10\% \text{ of } 2.6 \text{ mV})/\text{°C}) * 10 \text{ °C}) = \pm 5.2 \text{ mV}$$

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-4051 Calibration Procedure** for the external calibration procedure for your instrument.

## Self-Calibration

Use the self-calibration function to reduce errors caused by time and temperature drift. Self-calibration recalculates certain internal reference values, gains, and offsets to significantly improve accuracy over the full operating temperature range of the device.

When you run self-calibration, the input terminal is disconnected. Low-amplitude, low-energy glitches may appear at the input, but in most circumstances, these glitches are not noticeable.



**Note** Self-calibration is often used as the first step in debugging measurement errors.

## When to Self-Calibrate

For optimum performance, use self-calibration when the following conditions have been met:

- After first installing the PXIe-4051 in a chassis
- After any module that is in the same chassis as the PXIe-4051 is installed, uninstalled, or moved
- When the PXIe-4051 is in an environment where the ambient temperature changes. Refer to the **PXIe-4051 Specifications** to find the allowable ambient temperature for your instrument.
- When the PXIe-4051 temperature has drifted outside of the specified  $T_{cal}$  since the last self-calibration.. Refer to the **PXIe-4051 Specifications** to find the allowable difference from  $T_{cal}$  for this instrument.
- Once 24 hours elapse after a previous self-calibration

The instrument incorporates a temperature sensor that is used to determine when the temperature changes outside the specified conditions from the previous calibration. When the most recent self-calibration time and temperature are queried using `niDCPower Get Self Cal Last Date And Time` (`niDCPower_GetSelfCalLastDateAndTime`) or `niDCPower Get Self Cal Last Temp` (`niDCPower_GetSelfCalLastTemp`), the value returned is from the most recent self-calibration. When the two-year calibration interval expires, an external calibration is required.

The result is an instrument that yields full performance over its operating temperature range and recommended calibration cycle. When the recommended calibration interval expires, an external calibration is required to ensure that the device operates within specifications. Some devices, particularly those that provide self-calibration as an alternative to auto-zero, have been designed to minimize the time of self-calibration. Therefore, self-calibration can be run often to reduce offset and gain error with minimal performance penalties.

## Accuracy

A measurement or input level on an electronic load can differ from the actual or requested value.

Accuracy represents the uncertainty of a given measurement or input 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 an electronic load 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 electronic loads 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 electronic loads typically specify offset errors with absolute units (for example, mV or  $\mu$ A), 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  $\mu$ A:

$$\text{Accuracy} = (0.0003 \times 1 \text{ mA}) + 0.4 \mu\text{A} = 0.7 \mu\text{A}$$

Therefore, the reading of 1 mA should be within  $\pm 0.7 \mu\text{A}$  of the actual current.



**Note** Temperature can have a significant impact on the accuracy of an electronic load and is a common problem for precision measurements. The temperature coefficient, or tempco, expresses the error caused by temperature. Errors are calculated as  $\pm(\% \text{ of reading} + \text{offset range})/^{\circ}\text{C}$  and are added to the accuracy specification when operating outside the electronic load rated accuracy temperature range.

# Cleaning the PXIe-4051 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.