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PXIe-4139 User Manual

2024-05-21

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Welcome to the PXIe-4139 User Manual

The PXIe-4139 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-4139 Specifications
- PXIe-4139 Calibration Procedure
- NI-DCPower Help
- NI-DCPower LabVIEW VI Reference
- NI-DCPower Properties
- NI-DCPower C Function Reference
- NI-DCPower .NET API Overview
- NI-DCPower Python Reference
- NI-DCPower and LabVIEW Compatibility
- Software and Driver Downloads
- Release Notes
- License Setup and Activation
- Dimensional Drawings
- Product Certifications
- Letter of Volatility
- Discussion Forums
- NI Learning Center

PXIe-4139 Overview

The PXIe-4139 is a single-channel, four-quadrant system source-measure unit (SMU) featuring enhanced capabilities including programmable compensation using SourceAdapt technology; it is designed for engineers building PXI systems that require voltage or current sourcing and measurement. Use the PXIe-4139 in applications including manufacturing test, board-level test, and lab characterization with devices such as ICs, power management ICs (PMICs), RFICs, and discrete devices including LEDs and optical transceivers.



Note In this document, the PXIe-4139 (40W) and PXIe-4139 (20W) are referred to inclusively as the PXIe-4139. The information in this document applies to all versions of the PXIe-4139 unless otherwise specified. The PXIe-4139 (40W) shows **PXIe-4139 40W System SMU**, and the PXIe-4139 (20W) shows **PXIe-4139 Precision System SMU** on the front panel.

Device Capabilities

The PXIe-4139 is a high-precision system SMU that has the following features and capabilities.

- 40 W or 20 W DC output, 500 W extended pulse boundary
- 100 fA current sensitivity
- Current ranges: 10 A (pulse), 3 A, 1 A, 100 mA, 10 mA, 1 mA, 100 µA, 10 µA, 1 µA
- Voltage ranges: 60 V, 6 V, 600 mV
- 4-wire remote sense and guard
- 1.8 MS/s maximum sampling rate and 100 kS/s maximum update rate
- SourceAdapt technology

Figure 1. PXIe-4139 (20W) Quadrant Diagram

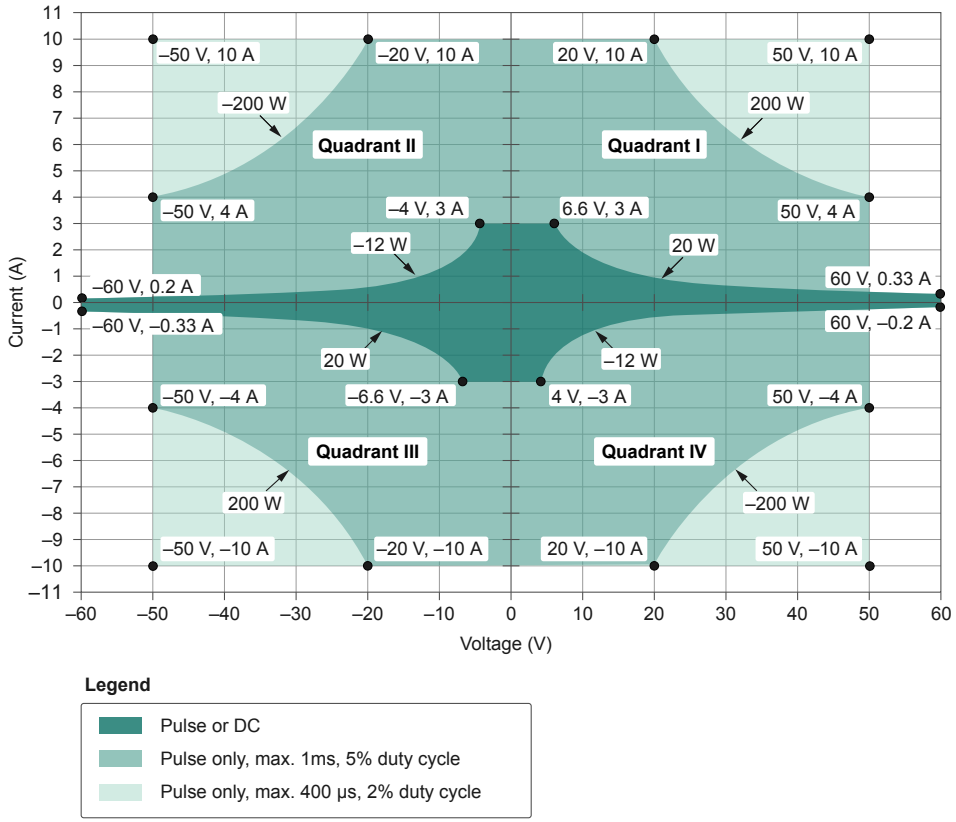
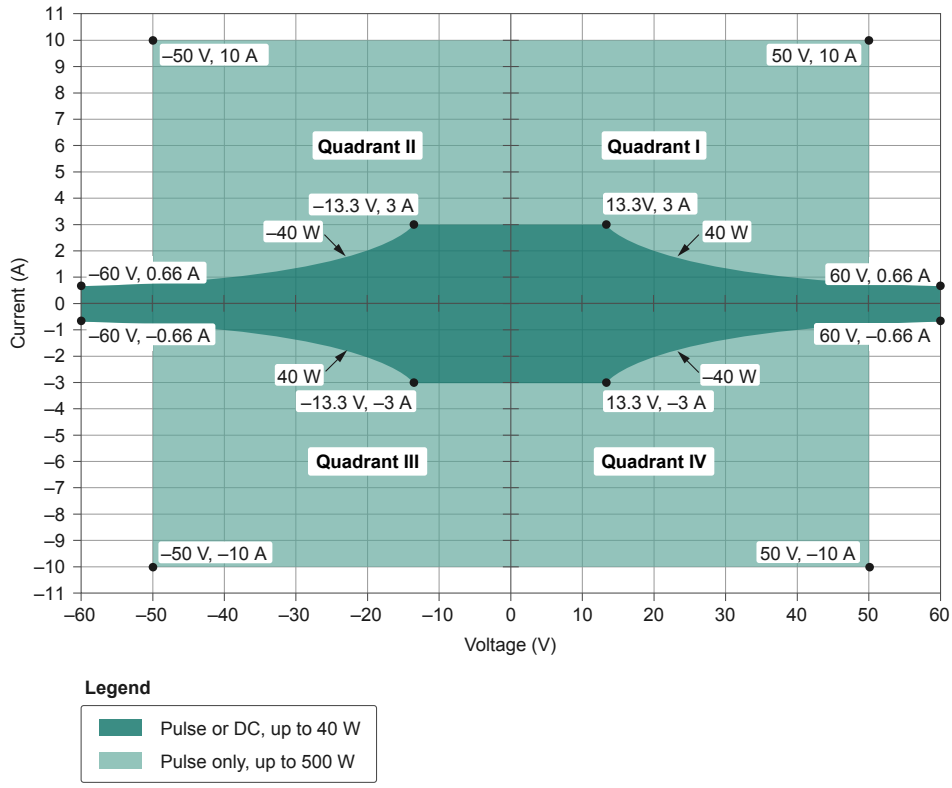


Figure 2. PXIe-4139 (40W) Quadrant Diagram



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-4139 (20 W)	NI-DCPower	1.9
PXIe-4139 (40 W)	NI-DCPower	20.5

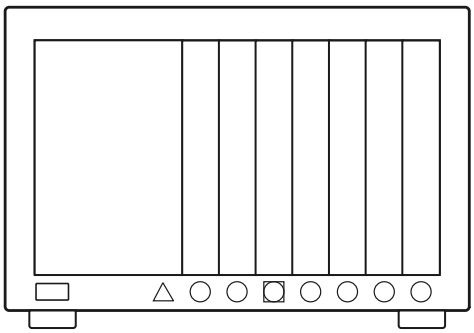
Components of a PXIe-4139 System

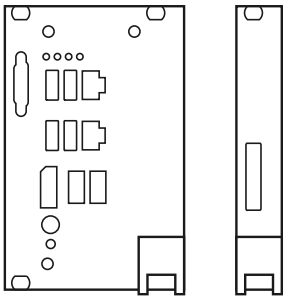
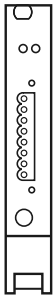
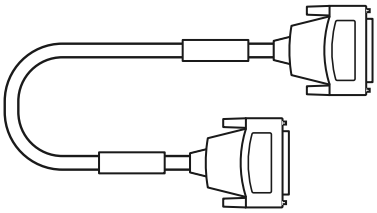
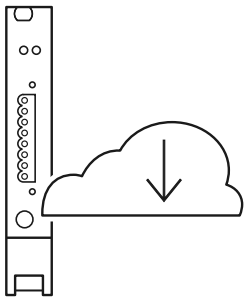
The PXIe-4139 is designed for use in a system that includes other hardware components, drivers, and software.

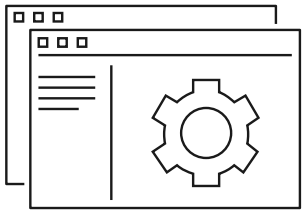
Notice A system and the surrounding environment must meet the requirements defined in the **PXIe-4139 Specifications**.

The following list defines the minimum required hardware and software for a system that includes a PXIe-4139.

Table 2. System Components

Component	Description and Recommendations
PXI Chassis 	A PXI chassis houses the PXIe-4139 and supplies power, communication, and timing for PXIe-4139 functions. **Note** NI recommends installing the PXIe-4139 (40 W) in a chassis with slot cooling capacity ≥58 W for increased module capability. **Note** When installing the PXIe-4139 in a chassis with slot cooling capacity =38 W, set the chassis fan speed to HIGH.
PXI Controller or PXI Remote Control Module	You can install a PXI controller or a PXI remote control (MXI) module depending on your system requirements. These components, installed in the same PXI chassis as the PXIe-4139, interface with the SMU using NI device drivers.

Component	Description and Recommendations
	
SMU 	Your SMU instrument.
Cables and Accessories 	Cables and accessories allow connectivity to/from your instrument for measurements. Refer to **Cables and Accessories** for recommended cables and accessories and guidance.
NI-DCPower Driver 	Instrument driver software that provides functions to interact with the PXIe-4139 and execute measurements using the PXIe-4139. **Note** NI recommends to always use the most current version of NI-DCPower with the PXIe-4139. You can find the NI-DCPower driver requirements in the **NI-DCPower Readme**.

Component	Description and Recommendations
NI Applications 	NI-DCPower offers driver support for the following applications: ▪ InstrumentStudio ▪ LabVIEW ▪ LabWindows/CVI ▪ C/C++ ▪ .NET ▪ Python

Cables and Accessories

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

Table 3. Cables and Accessories

Accessory Description	Notes	Part Number
Screw Terminal Connector Kit for PXIe-4136/7/8/9 SMUs	Ships with the PXIe-4139	784068-01
SA-413T, Triaxial Adapter for PXIe-4138/4139 SMUs	—	784000-01
SA-413B, Banana Jack Adapter for PXIe-4136/4137/4138/4139 SMUs	—	786818-01
Low-Noise Triax-Triax Cable	1 m and 3 m lengths	785659-01/03
	5 m length	788746-05
PXI slot blockers	Set of 5	199198-01

Note Visit **NI SMU Cable and Accessory Compatibility** at ni.com/r/cable-compatibility for more information about supported cables and accessories for your instrument.

Additional Cabling and Accessory Guidance

NI recommends the following:

- You can install PXI slot blockers (p/n 199198-01) to fill empty instrument slots in a PXI chassis. For more information about installing slot blockers and filler panels, go to ni.com/r/pxiblocker.
- If your PXIe-4139 (20W) is hardware revision F or earlier, a snap-on ferrite bead is required to remain in EMC compliance. To determine which revision of a device you have, open Measurement & Automation Explorer (MAX) and select the PXIe-4139 (20W) in question. The hardware revision is displayed in the settings pane on the right-hand side.
- When operating in industrial environments with high levels of radiated RF energy (>3 V/m), NI recommends adding a snap-on ferrite bead to the PXIe-4139 I/O cables, since radiated RF interference can adversely affect measurement accuracy.

Programming Options

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

- **InstrumentStudio**—When you install NI-DCPower on a 64-bit system, you can monitor, control, and record measurements from supported devices using InstrumentStudio. InstrumentStudio is a software-based soft front panel application that allows you to perform interactive measurements on several different device types in a single program.
  InstrumentStudio is automatically installed when you install the NI-DCPower driver on a 64-bit system. You can access InstrumentStudio in any of the following ways:
  - From the Windows start menu, select **National Instruments** » **[Driver] Soft Front Panel**. This launches InstrumentStudio and runs a soft front panel populated with NI-DCPower devices.

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

- **NI-DCPower Instrument Driver** —The NI-DCPower API configures and operates the module hardware and performs basic acquisition and measurement functions.
  - LabVIEW—Available on the LabVIEW Functions palette at **Measurement I/O** » **NI-DCPower**. Examples are available from the **Start** menu in the **National Instruments** folder.
  - LabVIEW NXG—Available from the diagram at **Hardware Interfaces** » **Electronic Test** » **NI-DCPower**. Examples are available from the **Learning** tab in the **Examples** » **Hardware Input and Output** folder.
  - LabWindows/CVI—Available at **Program Files** » **IVI Foundation** » **IVI** » **Drivers** » **NI-DCPower**. LabWindows/CVI examples are available from the **Start** menu in the **National Instruments** folder.
  - C/C++—Available at **Program Files** » **IVI Foundation** » **IVI**. Refer to the **Creating an Application with NI-DCPower in Microsoft Visual C and C++** topic of the **NI DC Power Supplies and SMUs Help** to manually add all required include and library files to your project. NI-DCPower does not ship with installed C/C++ examples.
  - Python—For more information about installing and using Python, refer to the **NI-DCPower Python Documentation**.

PXIe-4139 Theory of Operation

The PXIe-4139 combines a digital control loop architecture, known as SourceAdapt, with precision electronics to implement constant voltage (CV) or constant current (CC) sources with built-in measurement of voltage and current output.

One significant advantage of SourceAdapt is the ability to make precise adjustments to the control loop to customize the SMU transient response to any load, so you can achieve an ideal transient response with minimum rise times and no overshoots or oscillations.

The PXIe-4139 can operate in either CV mode or CC mode:

- In CV mode, the device acts as a precision voltage source that holds the voltage across the selected voltage sense points constant with respect to load changes as long as load current is below the programmed current limit.
- In CC mode, the device acts as a precision current source that holds the current across the load constant with respect to load changes as long as load voltage is below the programmed voltage limit.

A measurement circuit on the PXIe-4139 can simultaneously read the voltage and current values using two integrating analog-to-digital converters. Voltage is measured differentially between the HI and LO terminals (local sense) or between the Sense HI and Sense LO terminals (remote sense) based on the programmed voltage sense location. Remote sense is used to compensate for voltage drop that results from resistance in cables, connectors and switches. Current is measured using shunt resistors in series with the HI terminal.

Additionally, the PXIe-4139 features a Guard terminal on the output connector. You can use the Guard terminal to implement guarding techniques against parasitic leakage resistance and capacitance in cabling and test fixtures.

There are several protection mechanisms built into the PXIe-4139 that guard against common faults. The output has an over-current protection (OCP) circuit that will

open the Output Disconnect switch when an over-current condition is either too severe or lasts too long.

The PXIe-4139 continuously monitors voltage between HI and LO or HI Sense and LO Sense and protects against over-voltage faults. If an excessive voltage is detected, the over-voltage protection (OVP) circuit opens the Output Disconnect switch to protect the PXIe-4139 from excessive over-voltage.

The output may also be configured to automatically disconnect from the DUT if a user-defined limit is exceeded. The Output Cutoff feature supports configurable limits for voltage, voltage slew rate, current, current slew rate, and current over-range.

In the event the Sense terminals are left disconnected during remote sense operation, the 1 MΩ open-sense protection resistors provide a voltage feedback path to prevent the output voltage from saturating to a large voltage level.

The output terminals of the PXIe-4139 are electrically isolated from chassis ground through a 250 V DC, Category I isolation barrier. This allows any SMU terminal to float ±250 V DC with respect to chassis ground.

The PXIe-4139 includes flexible source and measurement units that enable multiple programming modes and timing options:

- **Single Point Source Mode**—Use for software-timed source or measurement operation.
- **Sequence Source Mode**—Use for basic hardware-timed operation where the user specifies a set of setpoint steps and source delays between each step while other parameters are held constant. You can modify this mode with the sequence step delta property to use a fixed time between points which enables sampled waveform generation.
- **Advanced Sequencing Mode**—Use for hardware-timed operation where full control of all the supported parameters is available for each step.

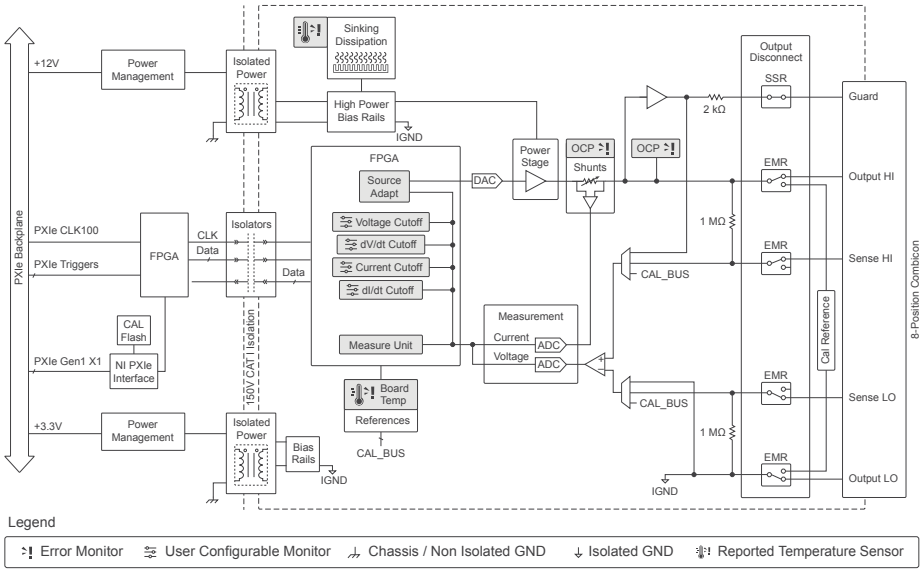
You can use hardware triggers in all modes to control operation of the source and measure units with other channels or devices in the system. The measurement

engine operation can operate in waveform acquisition mode and can be decoupled from the sequence engine. Refer to **Sourcing Voltage and Current** for more information about triggerable events in each programming mode.

PXIe-4139 Block Diagram

The following diagram illustrates the design of the PXIe-4139.

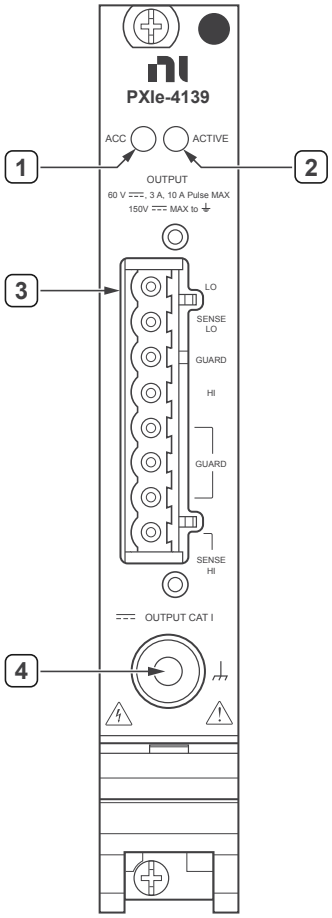
Figure 3. PXIe-4139 Block Diagram



PXIe-4139 Front Panel

Note In this document, the PXIe-4139 (40W) and PXIe-4139 (20W) are referred to inclusively as the PXIe-4139. The information in this document applies to all versions of the PXIe-4139 unless otherwise specified. The PXIe-4139 (40W) shows **PXIe-4139 40W System SMU**, and the PXIe-4139 (20W) shows **PXIe-4139 Precision System SMU** on the front panel.

Figure 4. PXIe-4139 Front Panel



1. Access LED
2. Active LED
3. Connector

4. Chassis Ground Binding Post

Chassis Ground Binding Post

Depending on your system requirements, use the chassis ground binding post to connect the PXIe-4139 to chassis ground.

PXIe-4139 Pinout

The following figure shows the terminals on the PXIe-4139 connector.

Figure 5. PXIe-4139 Connector Pinout

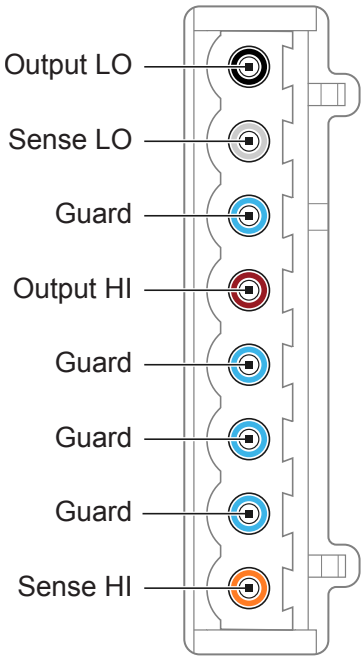


Table 4. Signal Descriptions

Signal Name	Description
Output LO	LO force terminal connected to channel power stage (generates and/or dissipates power). Positive polarity is defined as voltage measured on HI > LO.
Sense LO	Voltage remote sense input terminals. Used to compensate for **I*R** voltage drops in cable leads, connectors, and switches.
Guard	Buffered output that follows the voltage of the HI force terminal. Used to drive shield conductors surrounding HI force and Sense HI conductors to minimize effects of leakage and capacitance on low level currents.
Output HI	HI force terminal connected to channel power stage (generates and/or dissipates power).

Signal Name	Description
	Positive polarity is defined as voltage measured on HI > LO.
Sense HI	Voltage remote sense input terminals. Used to compensate for **I*R** voltage drops in cable leads, connectors, and switches.

PXIe-4139 LED Indicators

The PXIe-4139 features an Access LED and Active 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 5. 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-4139 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-4139 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.

Active LED

The Active LED, located on the module front panel, indicates the module output channel state.

The following table lists the Active LED states.

Table 6. Active LED Indicator Status

Status Indicator	Output Channel State
(Off)	Channel not operating in a programmed state
Green	Channel operating in a programmed state
Red	Channel disabled because of error, such as an overcurrent condition

PXIe-4139 Installation and Configuration

Complete the following steps to install the PXIe-4139 into a chassis and prepare it for use.

1. Unpacking the Kit
2. Installing the Software
3. Installing the PXIe-4139 into a Chassis
4. Selecting an Output Accessory for Your Application
5. Verifying the Installation in MAX
6. Self-Calibrating the PXIe-4139 in MAX
   Self-calibration adjusts the PXIe-4139 for variations in the module environment. The PXIe-4139 modules are externally calibrated at the factory, however you should perform a complete self-calibration after you install the module.

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.

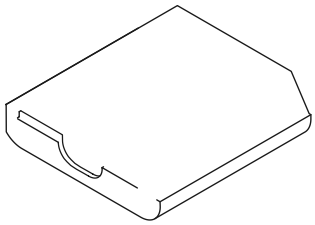
   Note Do not install a device if it appears damaged in any way.
3. Unpack any other items and documentation from the kit.

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-4139 kit.

Figure 6. PXIe-4139 Kit Contents



1. PXIe-4139 Module
2. PXIe-4139 Output Connector Assembly
3. Documentation

Installing the Software

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

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

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

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

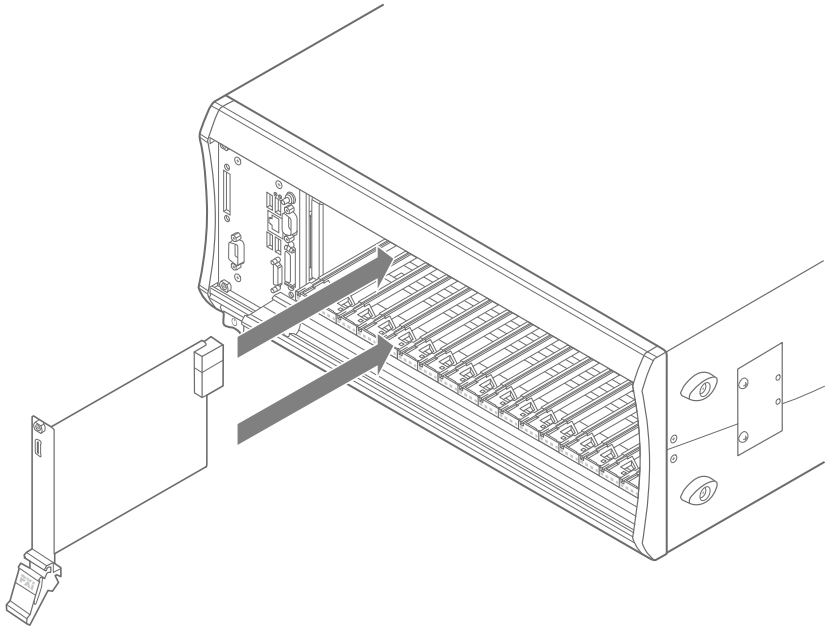
Installing the PXIe-4139 into a Chassis

Notice To prevent damage to the PXIe-4139 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-4139 module can be placed in PXI Express hybrid peripheral slots (

), PXI Express system timing slots (), or PXI Express peripheral slots ().
7. Touch any metal part of the chassis to discharge static electricity.
8. Ensure that the ejector handle is in the downward (unlatched) position.

Figure 7. Module Installation



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

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

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

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

Selecting an Output Accessory for Your Application

The PXIe-4139 offers three output accessories that can be attached to the front panel connector:

- **Output Connector**—This output connector ships with the PXIe-4139.
- **SA-413T**—This optional adapter supports easy triaxial cable connectivity.
- **SA-413B**—This optional adapter supports easy banana cable connectivity.

Installing the Output Connector Assembly onto the PXIe-4139

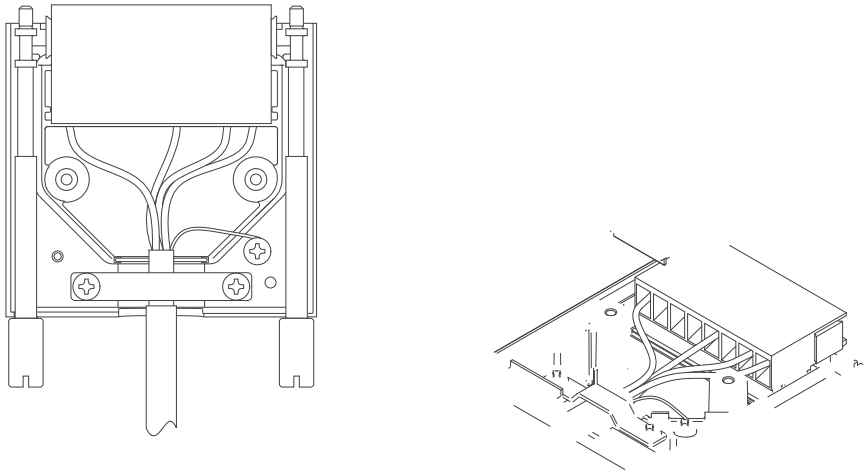
Complete the following steps to prepare the output connector and cable to ensure proper grounding, and install the output connector assembly onto the PXIe-4139.

1. Strip back the outer cable insulation to expose the cable ground shield.
2. Open the output connector assembly.
3. Using strain relief, clamp down on the ground shield.
4. Tie cable drain wire to grounding screw.
5. Close the output connector assembly, and tighten the retention screws to hold it in place.
6. Attach the output connector assembly to the connector on the PXIe-4139 front panel.
7. Tighten the thumb screws on the output connector assembly to fasten it to the PXIe-4139.
8. Power on the chassis.



Note Low energy transients can appear at the output terminals of your PXIe-4139 during certain situations, such as power-up, power-down, device driver loading, and self-calibration.

Figure 8. PXIe-4139 Output Connector Preparation



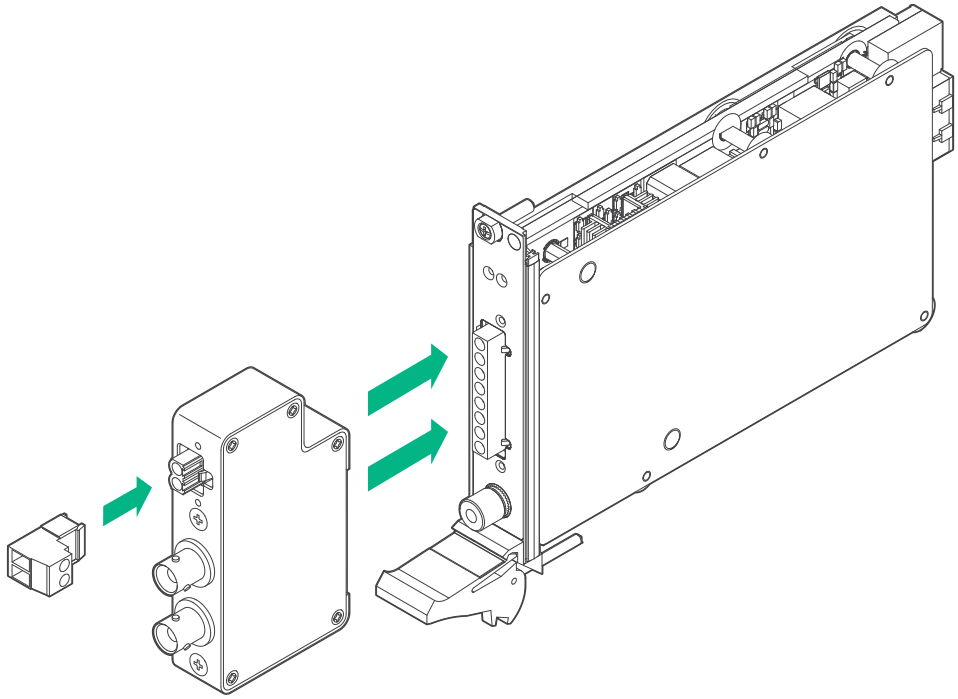
1. Strain relief clamped onto ground shield
2. Grounding screw connected to drain wire
3. Region where exposed wiring is allowed, 7.62 mm (0.30 in.)
4. Region free from exposed wiring, cable ground shield, or drain wire, 8.89 mm (0.35 in.) minimum
5. Output connector assembly

Installing the SA-413T on the PXIe-4139

The SA-413T (NI part number 784000-01) is an optional triaxial adapter that enables triaxial cable connectivity for the PXIe-4139. Complete the following steps to install the output connector assembly with a module and prepare signal connections.

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

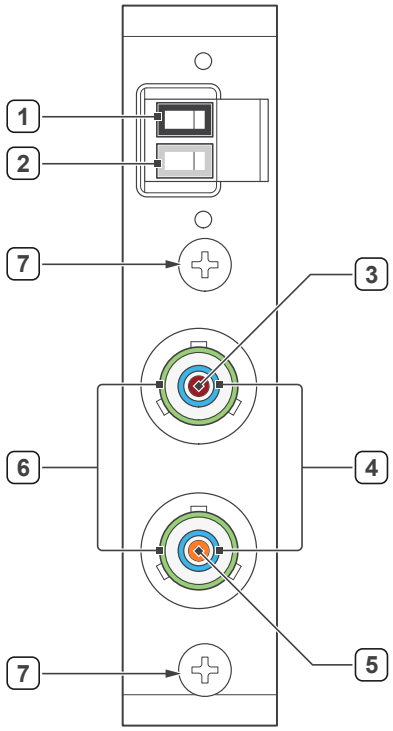
Figure 9. SA-413T Installation with a PXIe-4139



5. Using a Phillips screwdriver, tighten the mounting screws to secure the SA-413T to the PXIe-4139 front panel.
6. Attach triaxial cables to the triaxial connectors on the SA-413T.
7. Power on the chassis.

Note Low energy transients can appear at the output terminals of your PXIe-4139 during certain situations, such as power-up, power-down, device driver loading, and self-calibration.

Figure 10. SA-413T Front Panel



Item	Terminal	Description
1	Output connector, terminal 0	Output LO
2	Output connector, terminal 1	Sense LO
3	Triaxial connector pin	Output HI
4	Triaxial connector inner shield	Guard
5	Triaxial connector pin	Sense HI
6	Triaxial connector outer shield	Chassis ground
7	—	Mounting screws

Note Refer to the **SA-413T Installation Guide and Specifications** for more information about this accessory.

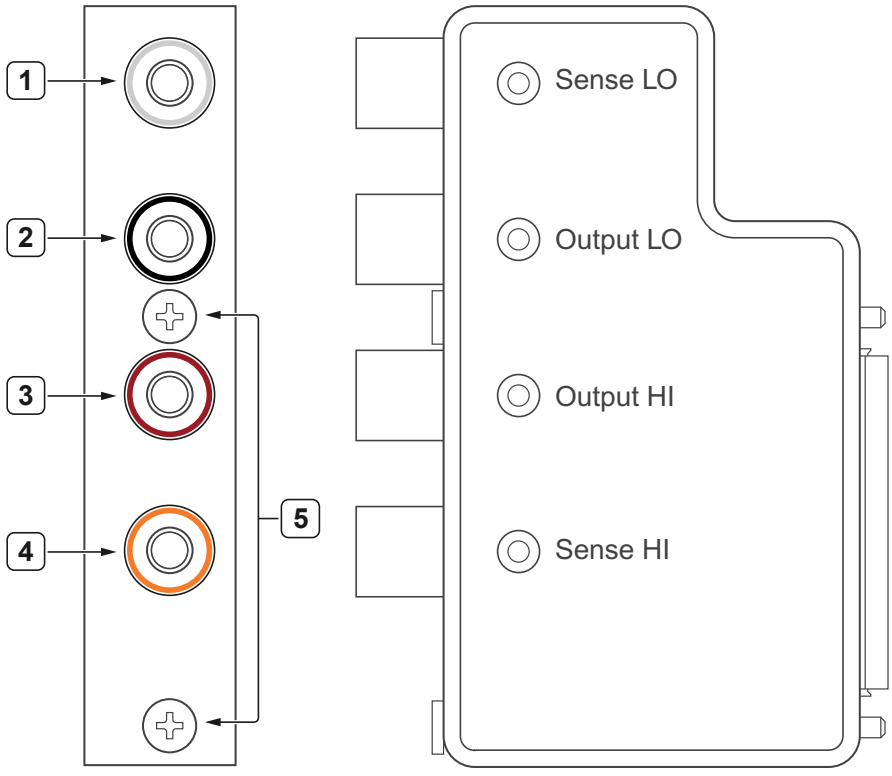
Installing the SA-413B on the PXIe-4139

The SA-413B (NI part number 786818-01) is an optional adapter that enables banana cable connectivity for the PXIe-4139. Complete the following steps to install the output connector assembly with a module and prepare signal connections.

1. Ensure the AC power source is connected to the chassis.
   The AC power cord grounds the chassis and protects it from electrical damage.
2. Touch any metal part of the chassis to discharge static electricity.
3. Attach the SA-413B on PXIe-4139 front panel.
4. Using a Phillips screwdriver, tighten the mounting screws to secure the SA-413B to the PXIe-4139 front panel.
5. Attach banana cables to the connectors on the SA-413B.
6. Power on the chassis.

> **Note** Low energy transients can appear at the output terminals of your PXIe-4139 during certain situations, such as power-up, power-down, device driver loading, and self-calibration.

Figure 11. SA-413B Front Panel



1. Sense LO

2. Output LO
3. Output HI
4. Sense HI
5. Retaining screws

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-4139 (40W) appears in MAX as NI PXIe-4139 (40W) and the PXIe-4139 (20W) appears in MAX as NI PXIe-4139.

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-4139.
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-4139 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-4139 appears in the Device Manager.
    a. Under an NI entry, confirm that a PXIe-4139 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-4139 Fails the Self-Test?

1. Reset the PXIe-4139 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-4139 in MAX

Self-calibration adjusts the PXIe-4139 for variations in the module environment. The PXIe-4139 modules are externally calibrated at the factory, however you should perform a complete self-calibration after you install the module.

1. Install the PXIe-4139 and let it warm up for the recommended warm-up time listed in the **PXIe-4139 Specifications**.

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

2. (Optional) Set properties to save the self-calibration data to the EEPROM.

> **Note** The only supported values for the niDCPower 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.

3. Self-calibrate the PXIe-4139 by clicking the **Self-Calibrate** button in MAX or calling niDCPower Cal Self Calibrate (niDCPower_CalSelfCalibrate).

> **Note** Low energy transients can appear at the output terminals of your PXIe-4139 during certain situations, such as power-up, power-down, device driver loading, and self-calibration.

Connecting Signals to the PXIe-4139

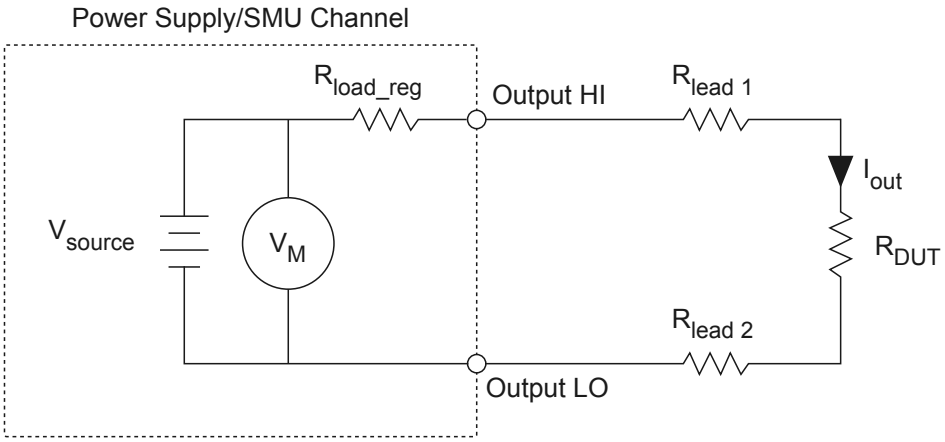
Refer to the following topics for guidance about PXIe-4139 signal connections.

- Use the Output HI and Output LO terminals for local sense measurements.
- Use the Output HI, Output LO, Sense HI, and Sense LO terminals for remote sense measurements.
- Use the Guard terminals remove the effects of leakage currents and parasitic capacitance between Output HI and Output LO and/or Sense HI and Output LO.

Making Local Sense Measurements

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

Figure 12. Connecting Signals for Local Sense Measurement



When the PXIe-4139 is operating in Constant Voltage mode, local sense forces the requested voltage at the output terminals of the module. The actual voltage at the DUT terminals is lower than the requested output because of the output lead resistance error.

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

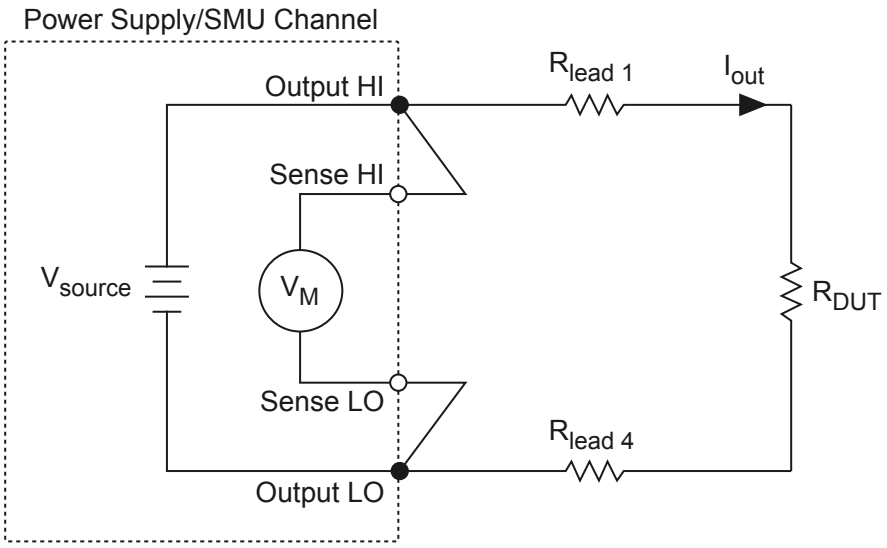
Local Sense Error (Volts) = $\mathbf{I_{out}}(\mathbf{R_{lead1}} + \mathbf{R_{lead2}} + \mathbf{R_{out.source}})$

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

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

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

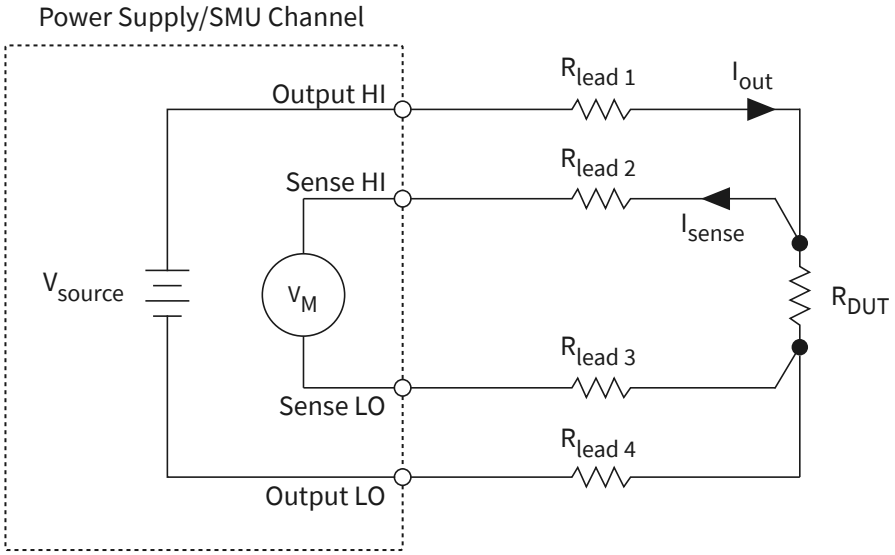
Figure 13. Connecting Local Sense Hardware with a Remote Sense Channel Configuration



Making Remote Sense Measurements

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

Figure 14. Connecting for a Remote Sense Measurement



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

Although the current flowing in the output leads can be several amps or more, depending on the instrument, a very small amount of current flows through the sense leads. This results in a much smaller voltage drop error for measurements versus the local sense error. When using remote sense in the DC Voltage output function, the output voltage is forced at the end of the sense leads instead of the output terminals. When using remote sense in the DC Current output function, the voltage limit is measured at the end of the sense leads instead of at the output terminals. Using remote sense results in a voltage at the DUT terminals that is more accurate than what can be achieved using local sense. Ideally, the sense leads should be connected as close to the DUT terminals as possible.

When using remote sense, remember that the magnitude of the voltage drop across the higher current output leads is usually limited to one or two volts per lead, depending on the power supply or SMU. When attempting to force a voltage using the DC Voltage output function, dropping more voltage across the output leads than the specified maximum in remote sense mode may result in a voltage at the load that is less than the requested level.

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

Configuring a channel for remote sense operation without connecting the sense leads to the DUT can result in measurements that do not meet the published specifications. If a channel is configured for remote sense and the remote sense leads are left open, the channel may source a voltage higher than the voltage level or voltage limit.
Refer to the **PXIe-4139 Specifications** for more information about remote sense support and the maximum output lead voltage drop allowed.
The PXIe-4139 features internal open-sense protection through a 1 MΩ resistor between the force (Output HI/LO) and sense (Sense HI/LO) lines. This protection provides a secondary measurement path to maintain the instrument output in regulation if remote sense becomes disconnected.

Using the Guard Terminals

Guarding is a technique used to remove the effects of leakage currents and parasitic capacitances between HI and LO.
Guard terminals are driven by a unity gain buffer that follows the voltage of the Output HI terminal. In a typical test system where guarding is utilized, the Guard conductor is a shield surrounding the Output HI and Sense HI conductors. By making this connection, there is effectively a 0 V drop between Output HI and Guard, or Sense HI and Guard, so no leakage current flows from the Output HI or Sense HI conductor to any surrounding conductors. Some leakage current might still flow from the Guard output to Output LO. However, because the current is being supplied by a unity gain buffer instead of Output HI, the current does not affect the output or measurement of the SMU.

Caution Do not connect Guard to the outer shield of coaxial cable if the guard potential will exceed 30 V RMS, 42.4 V peak, or 60 V DC on the outer shield. Use a triaxial cable where higher voltages are needed, and connect the Guard to the inner shield. All the Guard terminals for a given channel are equivalent and are always enabled.

Cable insulation impedance is typically high, but it can have a significant effect when measuring small currents from high-impedance loads.

- When guarding is not used, the cable insulation impedance is in parallel with the load and causes the current measured at the device ($\mathbf{I_{Measured}}$) to be the sum of the load current ($\mathbf{I_{Load}}$) and the leakage current ($\mathbf{I_L}$), hence $\mathbf{I_{Measured}} = \mathbf{I_{Load}} + \mathbf{I_L}$.
- When guarding is used, the cable insulation impedance is still present, but because the voltage between Output HI and Guard, or Sense HI and Guard is 0 V, no leakage current flows between them. The capacitance between Output HI and Guard, or Sense HI and Guard also doesn't have to charge. Some leakage current ($\mathbf{I_G}$) flows from the Guard to Output LO, but this leakage does not affect the measurement because the Guard's power is sourced from its own unity-gain buffer. The result is the device accurately measures the current through the load, hence $\mathbf{I_{Measured}} = \mathbf{I_{Load}}$.

In the following figures, the external shield of the cable could be connected to chassis ground, and the figures assume that Output LO is connected to chassis ground.

Figure 15. Leakage without Guarding ($\mathbf{I_{Measured}} = \mathbf{I_{Load}} + \mathbf{I_L}$)

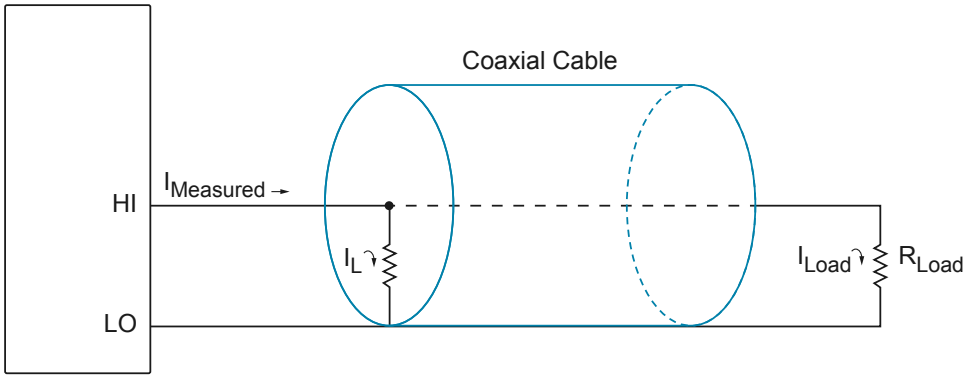
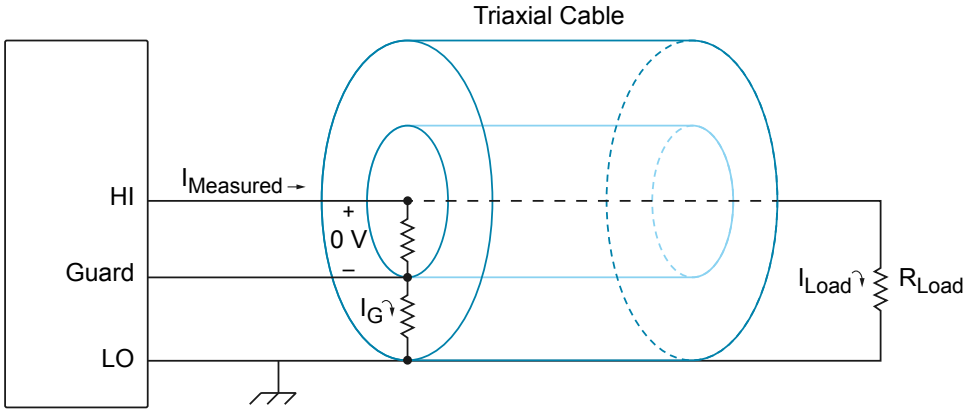


Figure 16. Reducing Leakage with Guarding ($I_{Measured} = I_{Load}$)



Minimizing Voltage Drop Loss when Cabling

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

The voltage drop due to current-resistance loss is determined by the resistance of the cabling wire (a property of the wire gauge and length) and the amount of current flowing through the wire. 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 power supply or SMU were to short circuit.

Table 7. Wire Gauge and Noise

AWG Rating	mΩ/m (mΩ/ft)
10	3.3 (1.0)
12	5.2 (1.6)

AWG Rating	mΩ/m (mΩ/ft)
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 output 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:

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

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

$V = 13.2\ mV$

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

Cabling for Low-Level Measurements

Low-level measurements require tight control over system setup and cabling. Long cables and large current loops degrade source and measurement quality even in low-noise environments.

To maintain measurement quality:

- Always limit the length of the cables involved in your system setup.

- Keep the current return path as close as possible to the current source path by using twisted pair cabling.

To reduce the susceptibility of low currents to noise and other unwanted interfering signals:

- Use shielded cables, such as coaxial cables.
- Connect the outer conductor of the shielded cable to the common or ground terminal of the channel.

To reduce the effects of leakage currents:

- Use shielded cables, such as triaxial cables.
- Connect the Guard terminal to the inner shield of the cable and Output LO to the outer shield.

Source Modes

The PXIe-4139 channels can generate voltage and current in **Single Point** or **Sequence** source mode.

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

- DC voltage
- DC current
- Pulse voltage
- Pulse current

The Source Mode With Channels function defines the source mode the PXIe-4139 channels are operating in.

Single Point Source Mode

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

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

Sequence Source Mode

In **Sequence** source mode, the source unit steps through a predetermined set of source configurations. Each sequence comprises a series of outputs for an NI-DCPower channel.

Sequence source mode encompasses two types of sequences:

- **Simple sequence**—Allows you to define a series of voltage outputs or current outputs and source delays for a single channel.

- **Advanced sequence**—Allows you to define numerous properties per sequence step, in addition to basic voltage outputs or current outputs 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.

Sequence Step Delta Time

The PXIe-4139 supports configurable step duration for sequences through the Sequence Step Delta Time property.

Note Sequence step delta time is supported with only DC voltage and DC current outputs; it is not supported with pulse voltage and pulse current outputs.

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 Set Sequence function	Set the Source Mode to Sequence; use the Create Advanced Sequence With Channels function, related advanced sequencing functions, and individual NI-DCPower properties

Task	Simple Sequencing	Advanced Sequencing
What you can configure	Voltage or current levels 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	▪ LabVIEW NXG: single channel only ▪ Other environments: 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
Importing and exporting sequences	No capability	Can be transferred between sessions with the Export Attribute Configuration and Import Attribute Configuration functions

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.

Pulse Outputs

The PXIe-4139 can output configurable current pulses and/or voltage pulses.

You can use pulse outputs in either Single Point or Sequence source mode and can configure a wide variety of pulse characteristics to suit your application.

The PXIe-4139 supports in-range pulsing and extended range pulsing.

- **In-range**—Pulses fall within DC range limits.

- **Extended range**—Pulses fall outside DC range limits for either current or power. Extended range pulsing is subject to additional limitations as described in the **PXIe-4139 Specifications**.

Sourcing Voltage and Current

The PXIe-4139 can perform operations to source and measure voltage and current. In order to perform these operations, use the NI-DCPower driver to configure software settings and execute operations.

Refer to the following table for an overview of common source and measure operations as well as the software setting combinations that enable the PXIe-4139 to perform each operation.

Table 8. Software Settings for PXIe-4139 Source and Measure Operations

PXIe-4139 Operation	Software Settings	
	Output Function	Source Mode
Source voltage	DC Voltage	Single Point or Sequence
Measure current or voltage		
Source current	DC Current	
Measure voltage or current		

Complete the following general steps to source current or voltage.

1. Initialize a Session
   Use the NI-DCPower driver to initialize a session with the PXIe-4139.
2. Configure the PXIe-4139 for Sourcing
   Use the NI-DCPower driver with the PXIe-4139 to control the output the instrument generates. Depending on the output function and source mode, you can configure the appropriate output levels and limits.
3. Configure the PXIe-4139 for Measuring
   Once you configure channels and they are in the Running state, the PXIe-4139 can take measurements.
4. Triggers and Events in NI-DCPower
5. Initiate the PXIe-4139 for Sourcing and Measuring
   Initiate the channels of the PXIe-4139 to apply a configuration and start generating.

6. Acquire Measurements
   The applied channel configuration determines how the PXIe-4139 acquires measurements.
7. Cease Generation
   NI-DCPower includes different options for stopping generation on PXIe-4139 channels and returning the channels to a known state.
8. Close the Session
   Use the NI-DCPower driver to close a session with the PXIe-4139.

Initialize a Session

Use the NI-DCPower driver to initialize a session with the PXIe-4139.

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

For any application you write, you must open a session to establish communication with the PXIe-4139 or specified channel(s) by initializing.

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

Configure the PXIe-4139 for Sourcing

Use the NI-DCPower driver with the PXIe-4139 to control the output the instrument generates. Depending on the output function and source mode, you can configure the appropriate output levels and limits.

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

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

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

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

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

4. Further define the parameters of the channel output.

The NI-DCPower API includes numerous functions and properties to exert finer control over the output. For example, among other aspects, you can specify output ranges, set asymmetric compliance limits with respect to zero, control the on and off time of pulses, or take advantage of triggering.

Configure the PXIe-4139 for Measuring

Once you configure channels and they are in the Running state, the PXIe-4139 can take measurements.

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

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

Measure When	Details
On Demand	Acquire measurements on demand using the niDCPower Measure VI and the niDCPower_Measure function to measure either the voltage or the current on a single channel. Or use the niDCPower Measure Multiple VI and the niDCPower_MeasureMultiple function to measure both the voltage and the current on multiple channels. When you call these VIs and functions, the PXIe-4139 takes a measurement and returns it.
Automatically after Source Complete	The PXIe-4139 acquires a measurement after every source operation and stores it in a buffer on the device. You can use the niDCPower Fetch Multiple VI and the niDCPower_FetchMultiple function to retrieve measurements from the buffer.
On Measure Trigger	The PXIe-4139 acquires a measurement when it receives a Measure trigger and stores it in a buffer on the device. You can use the niDCPower Fetch Multiple VI and the niDCPower_FetchMultiple function to retrieve measurements from the buffer.

Triggers and Events in NI-DCPower

Configure Triggers and Events

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

Triggers

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

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

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

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

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

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

Events

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

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

- Polarity
- Width
- Destination

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

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

NI-DCPower Named Trigger Types

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

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

- **Pulse**—Receiving a **Pulse** trigger causes a channel to transition from the pulse bias level to the pulse level.
  This trigger is available only when sourcing pulse voltage or pulse current.
- **Shutdown**—Receiving a **Shutdown** trigger causes the output relay of a channel to open, which completely interrupts output on that channel. The channel must be reset to resume operation.

Trigger Signal Conditions

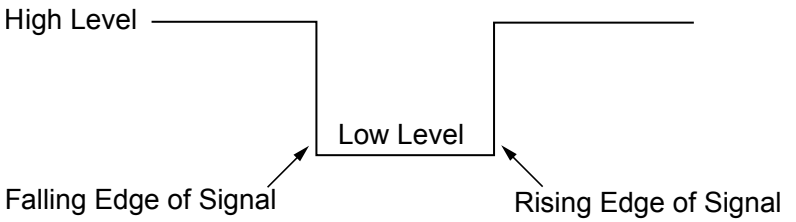
NI-DCPower includes three possible signal conditions that can serve as the stimulus for an action an instrument or channel can take: digital edge, software edge, and none (disabled).

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 18. Digital Edge Trigger



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

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

is available) from that terminal to the input terminal via a physical PXI backplane trigger line.

Software Edge

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

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

None (Disabled)

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

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

Event Types

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

- **Source Complete**—Generated by a channel when a sourcing operation, plus any configured source delay, is completed.
  In Single Point source mode, this event is generated whenever the source configuration is modified plus the associated source delay.
  In Sequence source mode, this event is generated after each step of the sequence plus the associated source delay for the step.
  The amount of configurable delay you can add depends on your instrument.
- **Sequence Iteration Complete**—Generated in Sequence source mode once all steps in a single iteration of a sequence are completed.

One event is generated per iteration of the sequence. For example, if the sequence is configured to loop ten times on a channel, the channel generates ten events.

- **Sequence Engine Done**—Generated in Sequence source mode once all iterations of a sequence are completed.
- **Measure Complete**—Generated when a measurement, plus any configured measure delay, is completed.
  The amount of configurable measure delay you can add depends on your instrument.
- **Ready for Pulse Trigger**—Generated in Sequence source mode for any step after the first step of a sequence iteration once the pulse off time elapses to indicate the channel is waiting to receive a Pulse trigger before the channel will apply the pulse level.
- **Pulse Complete**—Generated once a pulsing operation, plus any configured source delay, is completed.
  In Single Point source mode, this event is generated whenever the source configuration is modified plus the associated pulse bias delay.
  In Sequence source mode, this event is generated after each step of the sequence plus the associated pulse bias delay for the step.

NI-DCPower Event Signal Configurations

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

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

Valid Pulse Widths for Events on the PXI Platform

PXI instruments have an allowable range of pulse widths you can configure for events.
You set the pulse width in terms of the duration, in seconds, the pulse should last. Pulse width applies only to events that are connected to external physical trigger

lines, such as the PXI trigger lines. The PXIe instrument event pulse width range is [250 ns, 1.6 µs].
This range is defined by the **PXI Express Specification**.

NI-DCPower Synchronization Methods

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

- **Software-Based Synchronization**—Sends a software command from a host computer to an instrument. Not deterministic on general-purpose operating systems such as Windows.
  Accuracy: tens of milliseconds
- **Time-Based Synchronization**—Uses a time-based protocol such as GPS, 1588, or IRIG-B to coordinate events. Can be used over large distances (>10 m). Remote chassis that include a PXI synchronization module can be programmed to generate triggers on the backplane at a specific time.
  Accuracy: <100 ns + NI-DCPower instrument trigger delay and jitter
- **Signal-Based Synchronization**—Uses trigger signals to coordinate operations. Comprises the following:
  - PXI Trigger Routing—Sends a trigger signal, which corresponds to an event, from one instrument to another through the routes available in a PXI chassis (for PXIe/PXI instruments). The closer the signal paths between instruments are in length, the better the synchronization accuracy.
    Accuracy: tens of nanoseconds + NI-DCPower instrument trigger delay and jitter
  - External Triggering—Sends a signal external to a PXI chassis or, for other instrument form factors, to an instrument through I/O lines. The closer the signal paths between instruments are in length, the better the synchronization accuracy. Time locking improves determinism.

> **Note** Most NI-DCPower instruments cannot receive external digital triggers via their front panels. However, for NI-DCPower

> instruments that support triggering, you can send an external trigger to the instrument through another instrument installed in your chassis that does accept external triggers. You can route these trigger signals through the trigger lines on the chassis backplane.

Refer to the **PXIe-4139 Specifications** for the trigger delay and jitter of your instrument.

Multichannel Synchronization and Signal Routing in NI-DCPower

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

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

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

Example: Synchronizing Measure and Source Operations

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

Initiate the PXIe-4139 for Sourcing and Measuring

Initiate the channels of the PXIe-4139 to apply a configuration and start generating.

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

Acquire Measurements

The applied channel configuration determines how the PXIe-4139 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 output state.

Fetching

The PXIe-4139 automatically acquires measurements when you configure the following VIs or functions:

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

These measurements are automatically acquired by coercing the niDCPower Measure When property to Automatically After Source Complete or the NIDCPOWER_ATTR_MEASURE_WHEN attribute to NIDCPOWER_VAL_AUTOMATICALLY_AFTER_SOURCE_COMPLETE. To fetch these measurements, call the niDCPower Fetch Multiple VI or the niDCPower_FetchMultiple function. NI-DCPower returns the measurement values in an array.

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

Automatically After Source Complete or NIDCPOWER_VAL_AUTOMATICALLY_AFTER_SOURCE_COMPLETE.

Cease Generation

NI-DCPower includes different options for stopping generation on PXIe-4139 channels and returning the channels to a known state.

Option	How To	Description
Disabling the output	Set the Output Enabled property to False	Generates 0 V on a channel. ±2% of the current limit range presently configured for the channel remains on the channel.
Disconnecting the output	Set the Output Connected property to False	Disconnects a physical relay on a channel that completely interrupts generation on the channel.

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

Disabling the Output

The output of a channel is enabled by default when the channel enters the Running state. However, you can programmatically enable and disable the output channel(s) of the PXIe-4139.
When you disable the output of the PXIe-4139, the instrument is configured to output a DC voltage at 0 V with current limits at ±2% of the presently configured current limit range in, unless otherwise noted, a low-impedance state.
When you enable a previously disabled channel, levels and limits are applied to the channel depending on the output function as follows:

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

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

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

Disconnecting the Output

You can open an internal relay in order to completely disconnect the Output HI and Output LO and/or Sense terminals from the output connector of a channel.
For example, you might disconnect the output if a battery is connected to an output terminal in order to prevent the battery from discharging.

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

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

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

Close the Session

Use the NI-DCPower driver to close a session with the PXIe-4139.

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

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

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

Pulsing Voltage and Current

The PXIe-4139 can perform common SMU operations to pulse voltage and current. In order to perform these operations, use the NI-DCPower driver to configure software settings and execute operations.

Refer to the following table for an overview of common SMU source and measure operations as well as the software setting combinations that enable the PXIe-4139 to perform each operation.

Table 9. Software Settings for PXIe-4139 Pulse Operations

PXIe-4139 Operation	Software Settings	
	Output Function	Source Mode
Pulse voltage	Pulse Voltage	Single Point or Sequence
Pulse current	Pulse Current	

Complete the following general steps to pulse current or voltage.

1. Initialize a Session
   Use the NI-DCPower driver to initialize a session with the PXIe-4139.
2. Configure the PXIe-4139 for Pulsing
   Use the NI-DCPower driver with the PXIe-4139 to control the output the instrument generates. Depending on the output function and source mode, you can configure the appropriate output levels and limits.
3. Configure the PXIe-4139 for Measuring
   Once you configure channels and they are in the Running state, the PXIe-4139 can take measurements.
4. Triggers and Events in NI-DCPower
5. Initiate the PXIe-4139 for Sourcing and Measuring
   Initiate the channels of the PXIe-4139 to apply a configuration and start generating.
6. Acquire Measurements
   The applied channel configuration determines how the PXIe-4139 acquires measurements.

7. Cease Generation
   NI-DCPower includes different options for stopping generation on PXIe-4139 channels and returning the channels to a known state.
8. Close the Session
   Use the NI-DCPower driver to close a session with the PXIe-4139.

Initialize a Session

Use the NI-DCPower driver to initialize a session with the PXIe-4139.

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

For any application you write, you must open a session to establish communication with the PXIe-4139 or specified channel(s) by initializing.

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

Configure the PXIe-4139 for Pulsing

Use the NI-DCPower driver with the PXIe-4139 to control the output the instrument generates. Depending on the output function and source mode, you can configure the appropriate output levels and limits.

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

1. Use the Configure Output Function to set the output type you want to generate: DC Voltage, DC Current, Pulse Voltage, or Pulse Current.
   - Select an output type:

Option	Description
Pulse Voltage	A channel attempts to generate the output pulse voltage level, as long as the output current is below the pulse current limit. Once the pulse on time has elapsed, the

Option	Description
	channel generates a pulse bias voltage level for the pulse off time.
Pulse Current	A channel attempts to generate the output pulse current level, as long as the output voltage is below the pulse voltage limit. Once the pulse on time has elapsed, the channel generates a pulse bias current level for the pulse off time.

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

Output Function	Source Mode		Level Control	Limit Control
Pulse Voltage	Single Point		pulse voltage level input to Configure Pulse Voltage Level	pulse current limit input to Configure Pulse Current Limit
	Sequence	Simple sequence	values input to Set Sequence	pulse current limit input to Configure Pulse Current Limit
		Advanced sequence	Pulse Voltage Level, Pulse Bias Voltage Level properties	Pulse Current Limit property
Pulse Current	Single Point		pulse current level input to Configure Pulse Current Level	pulse voltage limit input to Configure Pulse Voltage Limit
	Sequence	Simple sequence	values input to Set Sequence	pulse voltage limit input to Configure Pulse Voltage Limit

Output Function	Source Mode		Level Control	Limit Control
		Advanced sequence	Pulse Current Level, Pulse Bias Current Level properties	Pulse Voltage Limit property

4. Further define the parameters of the channel output.
   The NI-DCPower API includes numerous functions and properties to exert finer control over the output. For example, among other aspects, you can specify output ranges, set asymmetric compliance limits with respect to zero, control the on and off time of pulses, or take advantage of triggering.

Configure the PXIe-4139 for Measuring

Once you configure channels and they are in the Running state, the PXIe-4139 can take measurements.

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

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

Measure When	Details
On Demand	Acquire measurements on demand using the niDCPower Measure VI and the niDCPower_Measure function to measure either the voltage or the current on a single channel. Or use the niDCPower Measure Multiple VI and the niDCPower_MeasureMultiple function to measure both the voltage and the current on multiple channels. When you call these VIs and functions, the PXIe-4139 takes a measurement and returns it.
Automatically after Source Complete	The PXIe-4139 acquires a measurement after every source operation and stores it in a buffer on the device. You can use the niDCPower Fetch Multiple VI and the niDCPower_FetchMultiple function to retrieve measurements from the buffer.

Measure When	Details
On Measure Trigger	The PXIe-4139 acquires a measurement when it receives a Measure trigger and stores it in a buffer on the device. You can use the niDCPower Fetch Multiple VI and the niDCPower_FetchMultiple function to retrieve measurements from the buffer.

Triggers and Events in NI-DCPower

Configure Triggers and Events

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

Triggers

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

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

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

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

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

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

Events

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

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

- Polarity
- Width
- Destination

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

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

NI-DCPower Named Trigger Types

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

- **Start**—In Sequence source mode, a channel waits for a **Start** trigger upon entering the Running state; receiving the Start trigger causes a channel to begin source and measure operations.
  A channel does not perform any source or measure operations until it receives this trigger.
  This trigger is not used in Single Point source mode.
- **Source**—Receiving a **Source** trigger causes a channel to modify the source configuration.
  This trigger is available only when sourcing DC voltage or DC current.

- **Measure**—Receiving a **Measure** trigger, if Measure When is set to On Measure Trigger, causes a channel to take a measurement.
  A channel ignores this trigger if a measurement is already in progress or if Measure When is set to a different value.
- **Sequence Advance**—In Sequence source mode, a channel waits for the **Sequence Advance** trigger once an iteration of a sequence completes; receiving a Sequence Advance trigger causes the channel to begin the next iteration of the sequence. Sequence Loop Count must be set to a value greater than one for a sequence to iterate, and thus for this trigger to occur.
  This trigger is not used in Single Point source mode.
- **Pulse**—Receiving a **Pulse** trigger causes a channel to transition from the pulse bias level to the pulse level.
  This trigger is available only when sourcing pulse voltage or pulse current.
- **Shutdown**—Receiving a **Shutdown** trigger causes the output relay of a channel to open, which completely interrupts output on that channel. The channel must be reset to resume operation.

Trigger Signal Conditions

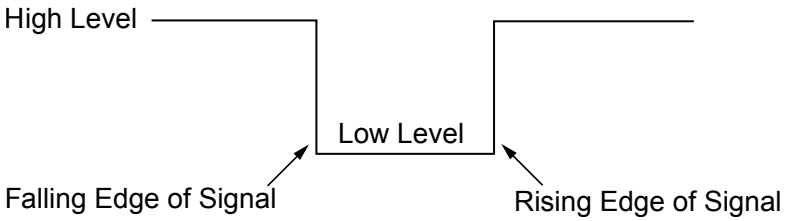
NI-DCPower includes three possible signal conditions that can serve as the stimulus for an action an instrument or channel can take: digital edge, software edge, and none (disabled).

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 18. Digital Edge Trigger



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

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

Software Edge

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

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

None (Disabled)

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

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

Event Types

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

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

NI-DCPower Event Signal Configurations

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

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

Valid Pulse Widths for Events on the PXI Platform

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

NI-DCPower Synchronization Methods

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

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

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



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

Refer to the **PXIe-4139 Specifications** for the trigger delay and jitter of your instrument.

Multichannel Synchronization and Signal Routing in NI-DCPower

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



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

Instead of explicitly exporting signals to physical trigger lines, NI-DCPower can automatically create routes for you. To have NI-DCPower automatically create

routes, set the digital edge input terminal of one channel to be the event from another channel.

Example: Synchronizing Measure and Source Operations

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

Initiate the PXIe-4139 for Sourcing and Measuring

Initiate the channels of the PXIe-4139 to apply a configuration and start generating.

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

Acquire Measurements

The applied channel configuration determines how the PXIe-4139 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 output state.

Fetching

The PXIe-4139 automatically acquires measurements when you configure the following VIs or functions:

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

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

These measurements are automatically acquired by coercing the niDCPower Measure When property to Automatically After Source Complete or the NIDCPOWER_ATTR_MEASURE_WHEN attribute to NIDCPOWER_VAL_AUTOMATICALLY_AFTER_SOURCE_COMPLETE. To fetch these measurements, call the niDCPower Fetch Multiple VI or the niDCPower_FetchMultiple function. NI-DCPower returns the measurement values in an array.



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

Cease Generation

NI-DCPower includes different options for stopping generation on PXIe-4139 channels and returning the channels to a known state.

Option	How To	Description
Disabling the output	Set the Output Enabled property to False	Generates 0 V on a channel. ±2% of the current limit range presently configured for the channel remains on the channel.
Disconnecting the output	Set the Output Connected property to False	Disconnects a physical relay on a channel that completely interrupts generation on the channel.



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

Disabling the Output

The output of a channel is enabled by default when the channel enters the Running state. However, you can programmatically enable and disable the output channel(s) of the PXIe-4139.
When you disable the output of the PXIe-4139, the instrument is configured to output a DC voltage at 0 V with current limits at ±2% of the presently configured current limit range in, unless otherwise noted, a low-impedance state.
When you enable a previously disabled channel, levels and limits are applied to the channel depending on the output function as follows:

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

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



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

Disconnecting the Output

You can open an internal relay in order to completely disconnect the Output HI and Output LO and/or Sense terminals from the output connector of a channel.
For example, you might disconnect the output if a battery is connected to an output terminal in order to prevent the battery from discharging.



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

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

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

Close the Session

Use the NI-DCPower driver to close a session with the PXIe-4139.

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

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

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

Example Programs

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

NI Example Finder

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

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

Installed Example Locations

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

Table 10. 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.
- **NI-DCPower Source DC Current**—Demonstrates how to force an output current.
- **NI-DCPower Hardware Timed Voltage Sweep**—Demonstrates how to sweep the voltage on a single channel and display the results in a graph.
- **NI-DCPower Measure Record**—Demonstrates how to take multiple measurements in succession.
- **NI-DCPower Measure Step Response**—Demonstrates how to measure the output while it is changing.

PXIe-4139 Operating Guidelines

Refer to the following sections for information about PXIe-4139 features and guidelines for operating the PXIe-4139.

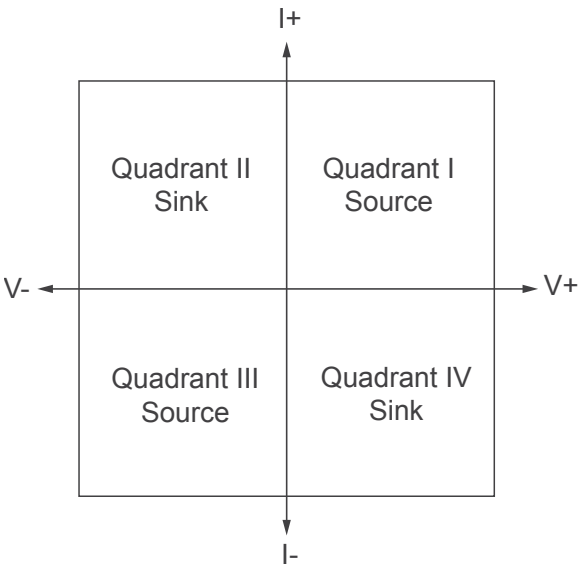
Sourcing and Sinking

The terms sourcing and sinking describe power flow into and out of a device, respectively.

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

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

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



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

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

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

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

Because of the required power dissipation, sourcing and sinking capabilities for a channel are not always identical. Refer to the **PXIe-4139 Specifications** for more information about the sourcing and sinking capabilities of your device, as well as detailed power limits.

Output Impedance

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

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

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

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

Output Capacitance

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

Output Inductance

- **Virtual Inductance**—Represents an inductance synthesized by the action of a control loop on a resistor rather than from an actual inductor. A true voltage source has an output impedance of zero. Because of the finite bandwidth of the control loop, the output behaves like a true voltage source only at DC. At higher frequencies, the output impedance approaches the value of the series resistance. In general, the output behaves like a voltage source in series with a parallel combination of the series resistance and an inductor.

- **Real Inductance**—Inductance added by components and interconnections in the device. Generally, this real inductance is smaller than the virtual inductance caused by the operation of the control loop, especially in low current ranges.

Decreasing Output Capacitance

Output capacitance has an effect on the output slew rate. You can decrease output capacitance and increase the speed of the PXIe-4139.

Decreasing Virtual Output Capacitance

Virtual output capacitance can significantly limit output slew rate. For example, consider the PXIe-4139 stepping from 0 V to 2 V in the 100 mA range with a 1 mA compliance limit. Even in the absence of a load, the 1 mA compliance current charging the virtual capacitance limits the output slew rate. You can adjust the settings of NI-DCPower to decrease the effect of virtual output capacitance.

Decreasing Real Output Capacitance

Real output capacitance can limit slew rate.

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

- Reduce the capacitance of fixtures or switches.
- Use shorter length cabling to reduce the actual capacitance of the load.

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

Using NI-DCPower to Decrease the Impact of Output Capacitance

You can perform any of the following actions in NI-DCPower to decrease the impact of output capacitance:

- Select the smallest current range consistent with the current limit using niDCPower Configure Current Limit and niDCPower Configure Current Limit Range. For instance, using the 1 mA range in the previous example decreases

the virtual capacitance by a factor of over 100, effectively removing the virtual-capacitance-related slew rate limit.

- Increase the compliance limit. The real output capacitance does not decrease, but the current available to charge it increases. Increasing the compliance limit to 100 mA in the preceding example effectively removes the output-current-related slew rate limit.
- Increase the gain-bandwidth (GBW) product in current mode by setting the transient response using the niDCPower_Transient Response property or the NIDCPOWER_ATTR_TRANSIENT_RESPONSE attribute. There are two setting options:
  - Set the transient response to **Fast** instead of **Normal**.
  - Set transient response to **Custom** and increase the current-mode GBW setting.
    Because there is no load in this example, it takes a significant change in DAC settings to cause a small change in output current. This condition means that the overall loop gain is low for current, and you can increase the current-mode GBW product to compensate without compromising stability. Setting current-mode GBW to the maximum value of 20 MHz reduces the output capacitance and results in a substantial speed increase.

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

Decreasing Output Inductance

Cable inductance has an effect on the output current slew rate. You can decrease cabling inductance and increase the speed of the PXIe-4139.
You can perform any of the following actions to decrease output inductance:

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

Setting Programmable Output Resistance

You can program the channel of the PXIe-4139 to vary the output resistance. The positive range of the output resistance allows the channel to emulate real-world devices with nonzero output resistance. The negative resistance range allows you to compensate for voltage drops due to resistive losses between the remote sense points and the DUT terminals.
Use the niDCPower Configure Output Resistance VI or the niDCPower_Configure_Output_Resistance function to set the output resistance. Refer to the **PXIe-4139 Specifications** for more information about the values to which you can set the output resistance.

Overload Protection (OLP)

The PXIe-4139 is protected against overcurrent (OCP) conditions and overvoltage (OVP) conditions.



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

Overcurrent Protection (OCP)

Overcurrent Protection (OCP) engages protection circuitry when the maximum specified current has been surpassed. This feature disables the output of the affected channel and disconnects the channel circuitry from the output connector pins. By internally disconnecting the output, it protects both the PXIe-4139 and the device under test (DUT).

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

Do not apply voltages at the output that exceed the ratings of the PXIe-4139. Refer to the **PXIe-4139 Specifications** for information about voltage ratings.

Overvoltage Protection (OVP)

Overvoltage Protection (OVP) is a feature that prevents excessive voltage from being applied to a device under test (DUT) connected to an SMU or power supply. When

voltage output exceeds a certain limit, the device output shuts down and NI-DCPower generates an error.

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

Load Regulation

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

- In constant voltage mode, variations in output current result in changes in the output voltage. This variation is expressed as a percentage of output voltage range per amp of current change, or as a change in voltage per amp of current change, and is synonymous with a series resistance.
  - When using local sense in constant voltage mode, the load regulation specification defines how close the output series resistance is to 0 Ω—the series resistance of an ideal voltage source. Many supplies have protection circuitry at the output that slightly increases the output series resistance.
  - You can use remote sense to improve the load regulation performance, even while maintaining a 2-wire configuration. Configure the channel for remote sense and connect the sense terminals externally to their respective output terminals (connect Sense LO to Output LO, and Sense HI to Output HI).
- In constant current mode, variations in load voltage result in changes to the output current. This variation is typically expressed as a percentage of output current range per volt of output change, and is synonymous with a resistance in parallel with the output channel terminals. In constant current mode, the load regulation specification defines how close the output shunt resistance is to infinity—the parallel resistance of an ideal current source. In fact, when load regulation is specified in constant current mode, parallel resistance is expressed as 1/**load regulation**.

Inductive Loads

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

Capacitive Loads

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

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

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

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

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

I is the current limit

C is the total capacitance across the load

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

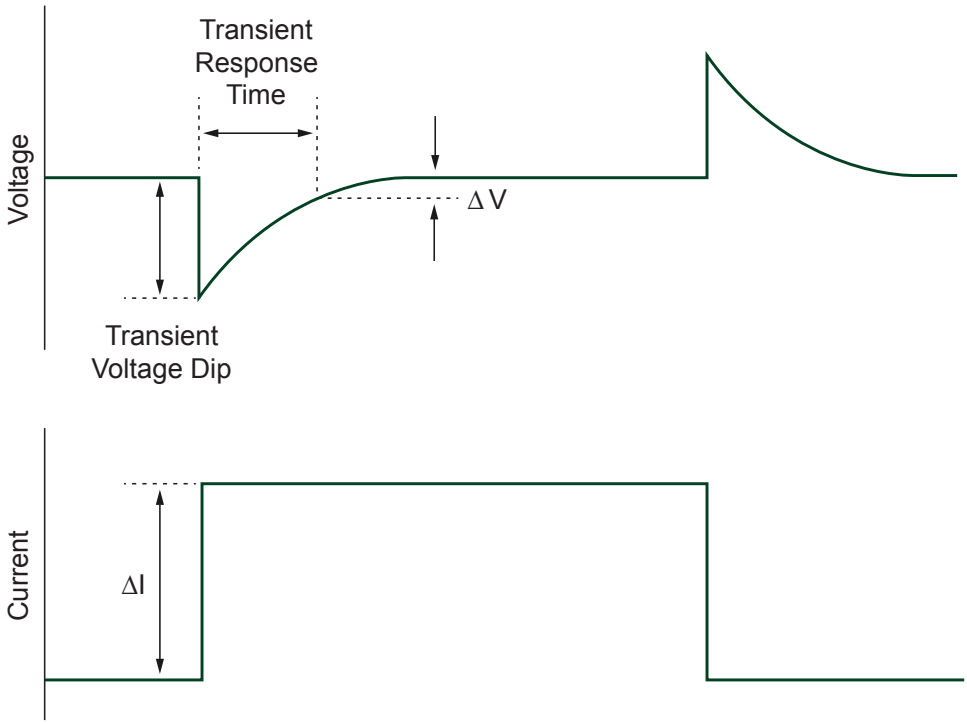
Transient Response

In reference to power supplies and SMUs, transient response describes how a supply responds to a sudden change in load.

Changes in load current, such as a current pulse, can cause large voltage transients. The transient response specifies how long it takes before the transients recover.

The following figure shows how the transient behavior is typically specified. The transient response time specifies how quickly the supply can recover to within a certain voltage ($\Delta \mathbf{V}$) when a specific change in load ($\Delta \mathbf{I}$) occurs. Some power supplies also specify a maximum transient voltage dip under the same load conditions.

Figure 19. Transient Response



There is a trade-off between transient response and the stability of the supply under a wide variety of loads. To achieve the fastest transient response, an instrument should have a high gain-bandwidth (GBW) product, but the higher GBW is, the more likely it is that the instrument will become unstable with certain loads. Thus, most instruments compromise performance to achieve stability under most conditions. Other instruments allow a degree of customization to enable optimization of performance under different circumstances.

Configuring Transient Response

Use niDCPower Transient Response to set the transient response.
The following table lists the PXIe-4139 transient response settings available in NI-DCPower.

Table 11. 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

Transient Response	Description
	of 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 niDCPower Transient Response to NIDCPOWER_VAL_CUSTOM to customize compensation on the device.
The following table lists the compensation parameter settings for the PXIe-4139. 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 12. Compensation Parameters

Compensation Parameter	Mode	Details
Gain Bandwidth (GBW)	Constant Voltage Mode	Set the GBW of the instrument. Higher values give faster response but poorer stability. 10 Hz to 20 MHz
	Constant Current Mode	Set the GBW of the instrument. Higher values give faster response but poorer stability. 10 Hz to 20 MHz
Compensation Frequency	Both	Set the geometric mean of the pole frequency and the zero frequency. It is the frequency

Compensation Parameter	Mode	Details
		of maximum phase shift caused by the pole-zero pair. 20 Hz to 20 MHz
Pole-Zero Ratio	Both	Set the ratio of the pole frequency to the zero frequency. A 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 0.125 and 8.0.



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.

Pulse Loads

Load current can vary between a minimum and a maximum value in some applications. In the case of a varying load, or pulse load, the constant current circuit of the power supply or SMU limits the output current.

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

To remain within the power supply or SMU output specifications with pulsed loads, use niDCPower Configure Current Limit to configure the current limit to a value greater than the expected peak current of the load.

In extreme situations, you may be able to parallel-connect multiple power supply channels to provide higher peak currents. Generally, instrument output channels should not be placed in parallel because these instruments are four-quadrant devices, and some combination of sourcing and sinking occurs if the output

voltages of the channels are not identical. Refer to **Connecting Multiple NI Source Measure Unit Channels in Parallel** at ni.com/r/smuparallel for more information.

Reverse Current Loads

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

Caution Power supplies not designed for four-quadrant operation may become damaged if reverse currents are applied to their output terminals. Reverse currents can cause the device to move into an unregulated mode and can damage the instrument. Refer to the **PXIe-4139 Specifications** for more information about channel capabilities.

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

Ranges

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

Use the highest resolution (smallest) range possible for a particular application to get maximum output and measurement accuracy. Refer to the **PXIe-4139 Specifications** for more information about what ranges are available for a particular channel on your device.

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

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

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

The same relationships hold true during pulsing between pulse output functions, pulse level ranges, and pulse limit ranges.

Changing Ranges

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

Table 13. Supported Configurable Output Ranges for Each Device Channel

Range	VI	Function
Voltage level range	niDCPower Configure Voltage Level Range	niDCPower_ConfigureVoltageLevelRange
Voltage limit range	niDCPower Configure Voltage Limit Range	niDCPower_ConfigureVoltageLimitRange
Current level range	niDCPower Configure Current Level Range	niDCPower_ConfigureCurrentLevelRange
Current limit range	niDCPower Configure Current Limit Range	niDCPower_ConfigureCurrentLimitRange
Pulse voltage level range	niDCPower Configure Pulse Voltage Level Range	niDCPower_ConfigurePulseVoltageLevelRange
Pulse voltage limit range	niDCPower Configure Pulse Voltage Limit Range	niDCPower_ConfigurePulseVoltageLimitRange
Pulse current level range	niDCPower Configure Pulse Current Level Range	niDCPower_ConfigurePulseCurrentLevelRange
Pulse current limit range	niDCPower Configure Pulse Current Limit Range	niDCPower_ConfigurePulseCurrentLimitRange

When you configure an output range, if you request a range that differs from the ranges described in the **PXIe-4139 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 output value. For example, if the current limit range is 1 A and the current limit is 50 mA, changing the current limit range to 20 mA is not allowed because 50 mA is not possible in the new range.



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

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

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

Overranging

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

Enabling overranging for a particular channel extends voltage and current output capabilities from 100% to 105% for the output range. Overranging is applicable to output ranges only and does not apply to measurement ranges. Measurements in

any given range may be made up to 105% of the range by default without enabling overranging.

Source Autoranging

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



Note While source autorange selects the best range based on the setpoint, it does not change the range until a new setpoint is programmed. Alternatively, you can use Measurement Autorange to have the instrument select the best measurement range. Refer to **Measurement Autoranging** for more information.

Measurement Autoranging

Use measurement autorange to allow the instrument to select the best measurement range based on the actual measurement values. Set measurement autorange by setting **Measurement:Autorange** to **On**.

With measurement autorange, the instrument can change ranges dynamically based on measurement readings; this change in range enables more accurate measurements for both large and small readings. Measurement autoranging removes the need for manual measurement range selection and eases interactive user measurements. For example, this is useful when the DUT varies significantly in current for a given voltage sweep.

Measurement readings are Current when sourcing voltage and Voltage when sourcing current.

A range change occurs after the hardware evaluates an autorange aperture sample against the configured thresholds. The autorange aperture is configurable, but is generally less than or equal to the measurement aperture setting when **Autorange Aperture Time Mode** is set to **Auto**.

The firmware automatically delays the measure trigger after a range change to improve consistency and reduce sweep test times. The delay after range change automatically increases with source delay, to allow for a longer DUT settling time before measuring. You can program the maximum delay after range change.

You can configure measurement autorange for a variety of DUTs through settings for multiple thresholds, limited autorange, and autorange.

SourceAdapt Custom Transient Response Ranges

The PXIe-4139 supports SourceAdapt custom transient response, which allows you to set compensation parameters to fine-tune the transient response of a channel for your specific application.

This instrument supports the following ranges for each custom transient response parameter. Each parameter is individually configurable for operation in constant voltage mode and in constant current mode. Valid ranges differ between modes only if noted.

- **Gain bandwidth (GBW)**— 10 Hz to 2 MHz
- **Compensation frequency**— 50 Hz to 1 MHz
- **Pole-zero ratio**—0.125 to 8.0

Noise

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

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

- **Common-mode noise**—Noise present between the Output common 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 output common/ground and chassis or earth ground, a noise current can flow in the impedance, resulting in an unexpected offset or other undesirable error.
- **Normal-mode noise**—Noise present between the Output HI terminal and the Output common LO terminal, appearing either in series (constant voltage mode)

or parallel (constant current mode) with the output of the device. Normal-mode noise can be expressed as voltage noise or current noise, depending on the control mode of the output channel.
AC-to-DC rectification causes ripple, a type of periodic normal-mode noise.

Verifying Output Noise Specifications

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

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

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

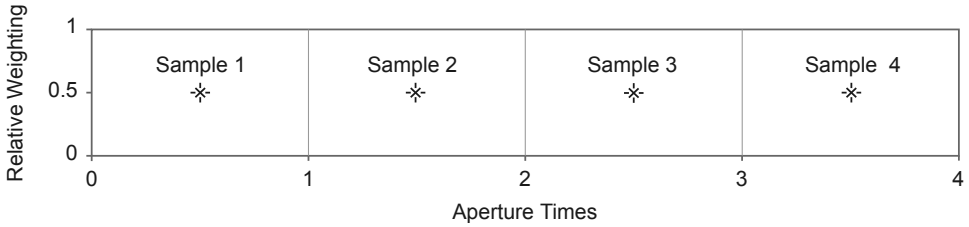
AC and DC Noise Rejection

You can manipulate the aperture time of measurements made with SMUs 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

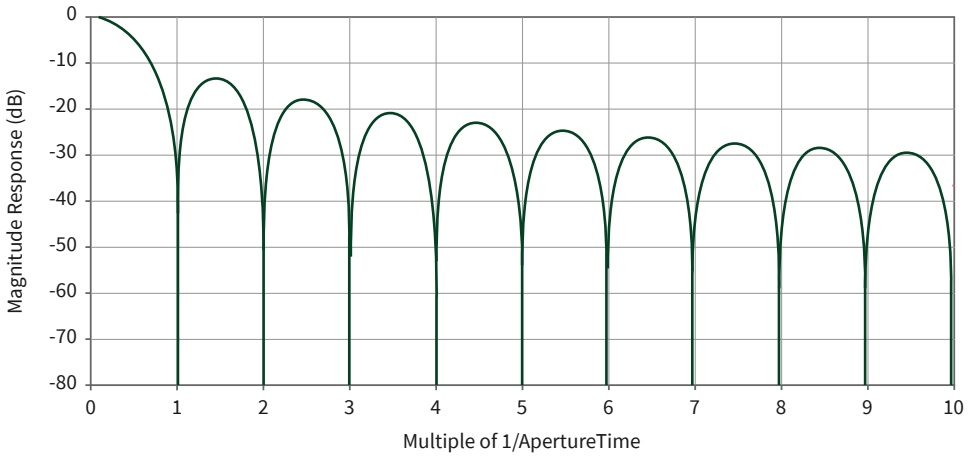
With normal noise rejection, the instrument assigns equal weight to each sample. This setting mimics the behavior of most traditional power supplies and SMUs. Normal noise rejection is the default behavior for all NI-DCPower instruments. The following figure shows normal weighting, with aperture times 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 / **Aperture Time** on the x-axis and magnitude response, in dB, on the y-axis.

Figure 21. Normal Noise Rejection by Frequency

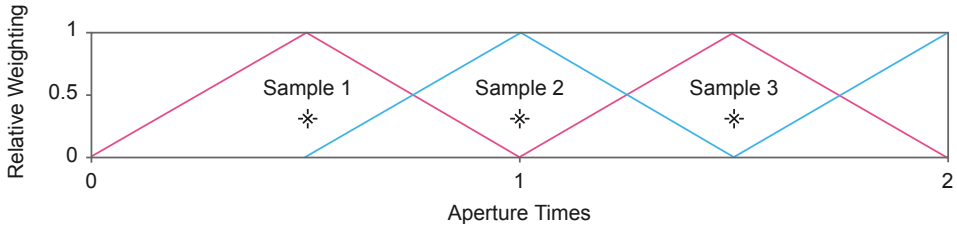


The best frequency rejection is available only near integer multiples of 1 / **Aperture Time**. You can achieve the fastest possible readings along with good power-line noise rejection by setting the aperture to one power-line cycle (PLC) and noise rejection to Normal.

Second-Order DC Measurement Noise Rejection

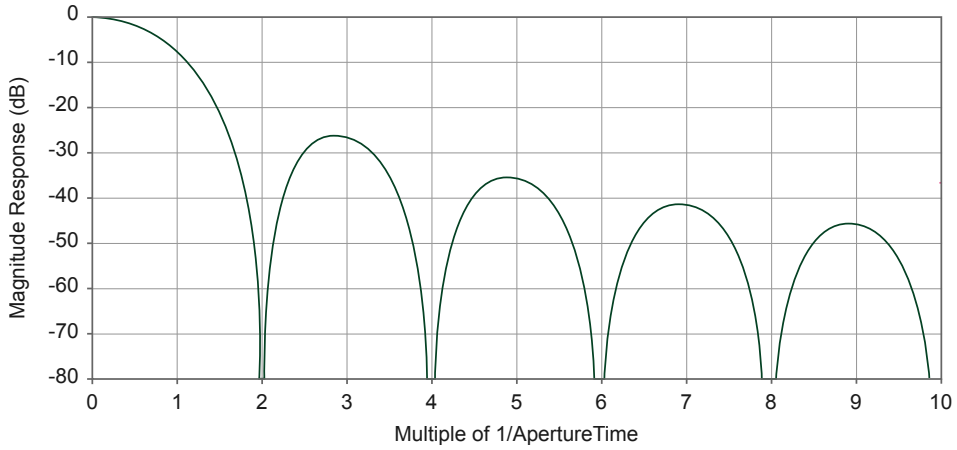
With second-order noise rejection, the instrument assigns a triangular weighting to measurement samples. Samples taken in the middle of the aperture time have more weight than samples taken at the beginning and end of that measurement.
The following figure shows second-order weighting, with aperture 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 / **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 / **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 / **Aperture Time**	Good	Shorter: **Aperture Time**	Normal (default)
2 / **Aperture Time**	Better	Longer: 2 × **Aperture Time**	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.

1. Choose the noise rejection profile that suits your application.

- Normal
- Second-Order

2. 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)	**Aperture Time** = 1 / f
Second-Order	**Aperture Time** = 2 / f

   - Aperture time units: power line cycles (PLC)

Noise Rejection Profile	Power Line Frequency	Target Aperture Time (PLC)
Normal (default)	60 Hz	**Aperture Time** = 60 Hz / f
	50 Hz	**Aperture Time** = 50 Hz / f
Second-Order	60 Hz	**Aperture Time** = 2 × (60 Hz / f)
	50 Hz	**Aperture Time** = 2 × (50 Hz / f)

> **Note** Each NI-DCPower instrument supports discrete aperture times: an instrument-specific minimum value and integer multiples of that value. When you set an unsupported aperture time, NI-DCPower coerces the value to the nearest longer supported value for your instrument.

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.

Sequence Step Delta Time

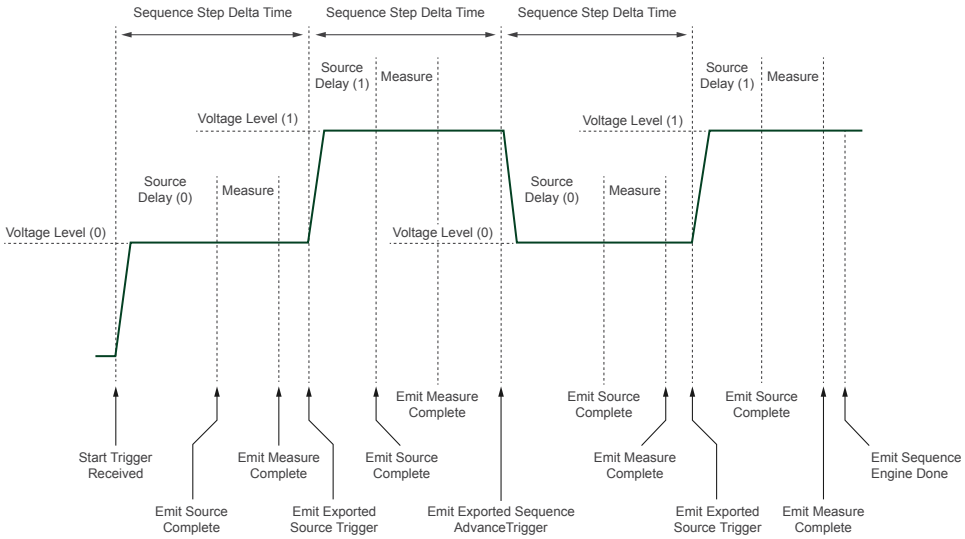
When enabled, **sequence step delta time** enforces a fixed time **dt** between the start and end of steps in a simple or advanced sequence. This level of determinism allows you to, for example, create periodic voltage waveforms with supported NI-DCPower instruments.

Note The terms **sequence step delta time** and **timed output mode** are equivalent.

The following figure illustrates using sequence step delta time to create two steps of a periodic voltage waveform for two iterations, where:

- Sequence step delta time is the same for each step;
- The voltage level and source delay alternate with each step; and
- The Measure When property is set to Automatically After Source Complete

Figure 24. Sequence Step Delta Time Source Model



When an NI-DCPower instrument uses sequence step delta time, the source unit operates according to the following steps:

1. Upon receiving a Start trigger, the source unit applies the first voltage level in the sequence.
2. Once the specified source delay elapses, the source unit generates a Source Complete event.

3. Because the Measure When property is set to Automatically After Source Complete, the following occur:
    a. The measure unit takes a measurement immediately upon receiving the Source Complete event.
    b. The measure unit generates a Measure Complete event.
4. Upon receiving the Measure Complete event, the source unit prepares for the next step of the sequence by waiting for the remainder of the time **dt** you specify with the Sequence Step dt property to elapse.
5. Once the sequence step delta time elapses, the source unit exports the Source trigger, and the next step of the sequence begins.

> **Note** The source unit exports the Sequence Advance trigger on the first step of any subsequent sequence iterations.

6. The sequence iterates until completion.

> **Note** The sequence step **dt** does not apply to the final step of the final iteration of a sequence.

You can enable sequence step delta time with the Sequence Step dt Enabled property and specify the **dt** itself with the Sequence Step dt property.
The PXIe-4139 supports configurable step duration for sequences via the Sequence Step Delta Time property for voltage levels and limits <|42.4 V| only.

> **Note** Sequence step delta time is supported with only DC voltage outputs; it is not supported with pulse voltage and pulse current outputs.

Programming Sequence Step Delta Time

Use sequence step delta time to control the duration of each step of a sequence when the step timing is important.

Configure the following properties to apply sequence step delta time to a sequence:

1. Set the Source Mode property to Sequence.

> **Note** Sequence step delta time does not apply in Single Point source mode.

2. Set the Source Trigger Type property to None.
   This is the default value.
3. Set the Sequence Advance Trigger Type property to None.
   This is the default value.
4. Set the Output Function property to DC Voltage or DC Current.
   Sequence step delta time is not compatible with pulsed outputs.
5. Enable sequence step delta time by setting the Sequence Step dt Enabled property to True.
6. Set the desired step duration **dt** with the Sequence Step dt property.

Troubleshooting Sequence Step Delta Time Timing Issues

It is possible to set values for other properties that conflict with the value for specify for sequence step delta time. In general, if a sequence step cannot be completed within the **dt** you specify, NI-DCPower returns an error.
The following topics list situations that can lead to timing conflicts between sequence step delta time and other properties and attributes.

Source Delay, Measurement Time Exceed Sequence Step Delta Time

The total Source Delay, measurement time, and programming setup time for a given sequence step must be less than the **dt** you specify.

Advanced Sequencing and Sequence Step Delta Time

The additional programming time when using both an advanced sequence and sequence step delta time may cause the total time for a step to exceed the **dt** you specify.
The likelihood that an error related to advanced sequence programming time increases with the number of properties you configure for each step in the advanced sequence.

Range Changes and Sequence Step Delta Time

If a sequence step includes a range change, the time it takes to complete the step may exceed the sequence step **dt** you specify due to the additional time involved in configuring the source unit for the new range.
The following table describes the behavior of NI-DCPower when a range change occurs in a sequence while sequence step delta time is in use.

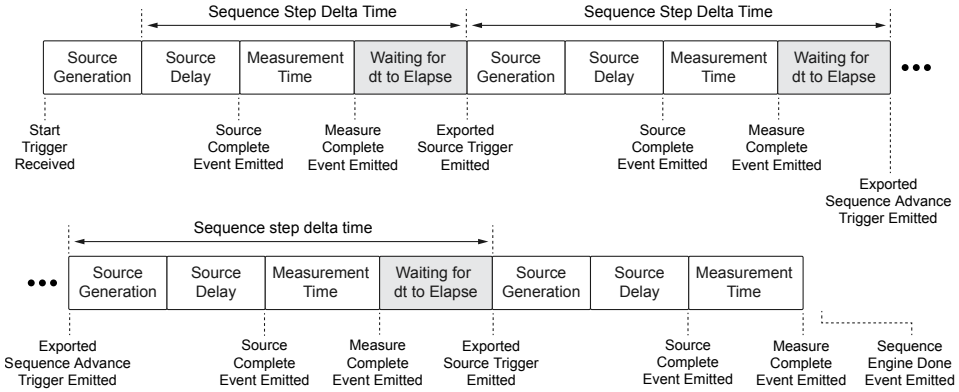
Table 14. Effect of Ranges Changes on Sequence Step Delta Time

Range Change Location	Effect of Range Change
step[0]	▪ The setpoint of the step may be generated for an amount of time that differs from the configured **dt**. ▪ NI-DCPower does not generate an error if the time required to change ranges causes the channel to exceed your **dt**.
step[i]	▪ The setpoints of step[i - 1] and step[i] may be generated for an amount of time that differs from the configured **dt**. ▪ NI-DCPower generates an error if the time required to change ranges causes the channel to exceed your **dt**.

The following figure illustrates how the **dt** you specify interacts with a sequence that comprises two steps and two iterations and that may involve range changes, where:

- Sequence step delta time is the same for each step;
- The Measure When property is set to Automatically After Source Complete; and
- The shaded sections represent the time the channel waits for the **dt** you specify to elapse.

Figure 25. Sequence Step Delta Time in NI-DCPower Sequences



Note the following:

- Source generation time increases if a voltage or current range change is required, which can delay generation of the new setpoint. The channel changes ranges if the voltage or current ranges you specify for the step differ from the previously configured ranges.
- The sequence step **dt** does not apply to the final step of the final iteration of a sequence.

Avoiding Range Changes in the First Step for Sequence Step Delta Time

The time involved in executing a range change in the first step of a sequence can cause the channel to exceed the **dt** you specify for that step.

You can place your channel in the desired voltage or current range before using Sequence Step Delta Time to ensure the channel generates the first voltage or current level in a sequence for the configured **dt**.

Complete the following steps to avoid exceeding your **dt** due to range changes in the first step.

1. Set the Source Mode property to Single Point.
2. Set the Output Function property to the desired output function, DC Voltage or DC Current.
3. Set the Source Trigger Type and Sequence Advance Trigger Type properties to None.
4. Configure the voltage or current level, level range, limit, and limit range as appropriate for your output function.

5. Call the Initiate With Channels function.
6. Call the Wait For Event With Channels function and pass the Source Complete Event to the event input.
7. Call the Abort With Channels function.
8. Continue configuring the instrument.
    a. Set the Source Mode property to Sequence.
    b. Set the Sequence Step dt Enabled property to True.
    c. Set the Sequence Step dt property to the desired **dt**.
    d. Create your sequence.
    - Create a simple sequence with the Set Sequence function.
    - Create an advanced sequence with the Create Advanced Sequence With Channels function and add steps to it.

When you initiate your sequence, any range changes will have occurred during the single point you generated.

Troubleshooting Sequence Step Delta Time Event Interactions

Certain NI-DCPower events have unique interactions with sequence step delta time. Applications that rely on these events and make use of sequence step delta time may encounter certain issues.
The following events have unique interactions with sequence step delta time:

Event	Behavior
Sequence Engine Done	For the final step of the final iteration of a sequence using sequence step delta time, the source unit does not wait for a **dt** period to elapse before emitting the Sequence Engine Done event. Therefore, this event for this step is emitted early with respect to **dt**.
Sequence Iteration Complete	When sequence step delta time is enabled, the source unit does not emit the Sequence Iteration Complete event.

These event interactions may cause issues with applications that make use of sequence step delta time if you are using the event as an input to the following functions:

- Configure Trigger With Channels
- Export Signal With Channels
- Wait For Event With Channels

Recovering from Sequence Step Delta Time Errors

To recover from a sequence step delta time error, choose one of the following error recovery methods:

- Call the Reset With Channels function.
- Call the Disable function.
- Call the Reset Device function or reset with MAX.

Sequence Step Delta Time Timing Error Conditions

The **dt** value you set to enforce a sequence step delta time can conflict with the actual time it takes the hardware to generate a sequence step.

NI-DCPower returns an error due to timing conflicts between the value of the Sequence Step dt property and actual step length, as derived from the value of other properties, based on the relationships in the following table.

Table 15. Sequence Step Delta Time Timing Error Conditions

Setting(s)	Errors When
▪ Sequence Step dt Enabled is True	**Sequence Step dt** – **Minimum Sequence Step dt** < **Source Delay**
▪ Sequence Step dt Enabled is True; ▪ Measure When is set to Automatically After Source Complete; and ▪ Measure Record Length = 1	**Sequence Step dt** – **Minimum Sequence Step dt** < **Source Delay** + **Aperture Time** + **Measure Complete Event Delay**
▪ Sequence Step dt Enabled is True;	**Sequence Step dt** – **Minimum Sequence Step dt** < **Source Delay** + **Aperture Time** + ((**Measure Record Length**

Setting(s)	Errors When
▪ Measure When is set to Automatically After Source Complete; and ▪ Measure Record Length > 1; and ▪ DC Noise Rejection is set to Normal	– 1) x **Measure Record dt**) + **Measure Complete Event Delay**
	Measure Record dt = **Aperture Time**
▪ Sequence Step dt Enabled is True; ▪ Measure When is set to Automatically After Source Complete; and ▪ Measure Record Length > 1; and ▪ DC Noise Rejection is set to Second-Order	**Minimum Sequence Step dt** – **Minimum Sequence Step dt** < **Source Delay** + **Aperture Time** + ((**Measure Record Length** – 1) x **Measure Record dt**) + **Measure Complete Event Delay**
	Measure Record dt = **Aperture Time** ÷ 2

Power Measurements

Each channel of the PXIe-4139 has two synchronized ADCs that measure voltage and current. You can use NI-DCPower to measure power flowing to or from the PXIe-4139.

You can use the following VIs and functions to measure both current and voltage for both channels of the PXIe-4139.

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

Power can be computed as the product of the voltage and the current. If the power measurement is positive, the PXIe-4139 is sourcing power. If the power measurement is negative, the PXIe-4139 is sinking power.

Resistance Measurements

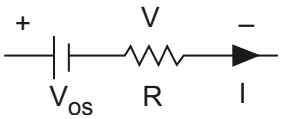
NI power supplies and SMUs can make resistance measurements because they can both generate and measure test voltages and currents. Because they can operate as precision current sources at high current levels, these devices are well suited to measure low resistance values.

To measure a resistance with an NI power supply or SMU, select a test current that creates a voltage drop within module capabilities. After the channel output is enabled and settled, use the niDCPower Measure Multiple VI or the niDCPower_MeasureMultiple function to measure the actual current being delivered to the resistor as well as the measured voltage across the resistor. To determine the

accuracy of a resistance measurement, the accuracy specifications of both current and voltage measurements for the power supply or SMU should be taken into account. For channels with remote sense capabilities, enabling this feature results in a more accurate voltage measurement at the resistor terminals.

Compensation for Offset Voltages

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



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

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

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

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

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

Sourcing and Measuring Terminology

Refer to the following terms when learning more about the features and usage of the PXIe-4139:

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

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

- **Compliance**—For power supplies and SMUs, a channel is operating in compliance when it cannot reach the requested output level because the programmed limit has been reached.
- **Line Regulation**—A measure of the ability of the power supply or SMU to maintain the output voltage given changes in the input line voltage. Line regulation is expressed as percent of change in the output voltage relative to the change in the input line voltage.
  For NI DC power supplies and SMUs, the line regulation specification only applies to devices with an auxiliary power input.
- **Load Regulation**—A measure of the ability of an output channel to remain constant given changes in the load. Load regulation expression depends on the control mode enabled on the output channel.
- **Resolution**—The smallest change in the voltage or current measurement that can be detected by hardware. It is usually specified in absolute units, like µV or nA.

  - Measurement resolution is typically limited by the ADC used for the measurement, but may also be limited by other factors, such as noise.
  - Output resolution is typically limited by the finite number of steps that are available in the device DAC circuit, but may also be limited by other factors, such as noise.

  Refer to the **PXIe-4139 Specifications** for measurement resolution and output resolution information.
- **Sensitivity**—Sensitivity is the smallest unit of a given parameter that can be meaningfully detected with an instrument under specified conditions. This unit is generally equal to the measurement resolution in the smallest range of a power supply or SMU.

- **Settling Time**—Settling time specifies the time required for an output channel to stabilize to within a specified percentage of its final value. This value is typically included in the device specifications.

Calibration

SMUs support two types of calibration: external calibration and self-calibration.

External Calibration

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

Calibration and Temperature Variation

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

Refer to the **PXIe-4139 Specifications** for the following information for your instrument:

- Recommended operating temperature range
- Calibration interval

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

If the ambient temperature is outside of the specified range, you may need to know the measurement accuracy to account for temperature variation. One way to calculate the specified accuracy outside of the temperature range is to externally calibrate the system at the desired temperature. External calibration, though inconvenient, should allow the device to attain its full rated accuracy at the calibration temperature. You can learn more about external calibration at ni.com/calibration.

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

The following equation represents the temperature coefficient (tempco).

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

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

0.05% of 5 V + 100 µV = 2.6 mV

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

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

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

Refer to the **PXIe-4139 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 output terminal is disconnected. Low-amplitude, low-energy glitches may appear at the output, 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-4139 in a chassis
- After any module that is in the same chassis as the PXIe-4139 is installed, uninstalled, or moved
- When the PXIe-4139 is in an environment where the ambient temperature changes. Refer to the **PXIe-4139 Specifications** to find the allowable ambient temperature for your instrument.
- When the PXIe-4139 temperature has drifted outside of the specified T_{cal} since the last self-calibration. Refer to the **PXIe-4139 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 one-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 output level on a power supply or SMU can differ from the actual or requested value.

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

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

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

x is the input to the system

b is the offset of the system

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

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

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

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

Determining Accuracy

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

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

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



Note Temperature can have a significant impact on the accuracy of a power supply or SMU and is a common problem for precision measurements. The temperature coefficient, or tempco, expresses the error caused by temperature. Errors are calculated as ±(**% of reading** + **offset range**)/°C and are added to the accuracy specification when operating outside the power supply or SMU rated accuracy temperature range.

Cleaning the PXIe-4139 System

NI recommends the following to clean and maintain your instrument's system:

- Clean the fan filters on the chassis regularly to prevent fan blockage and to ensure efficient air circulation. Cleaning frequency depends on the amount of use and the operating environment. For specific information about cleaning procedures and other recommended maintenance, refer to the chassis user documentation.
- Clean the hardware with a soft, nonmetallic brush. Make sure that the hardware is completely dry and free from contaminants before returning it to service.

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