CALIBRATION PROCEDURE

PXIe-4135

PXIe, ±200 V, ±1 A (DC)/±3 A (Pulsed), 10 fA Precision System PXI Source Measure Unit

This document contains the verification and adjustment procedures for the PXIe-4135. Refer to *ni.com/calibration* for more information about calibration solutions.

Note In this document, the PXIe-4135 (40W) and PXIe-4135 (20W) are referred to inclusively as the PXIe-4135. The information in this document applies to all versions of the PXIe-4135 unless otherwise specified. To determine which version of the module you have, locate the device name in one of the following places:

- **In MAX**—The PXIe-4135 (40W) shows *NI PXIe-4135 (40W)*, and the PXIe-4135 (20W) shows as *NI PXIe-4135*.
- **Device front panel**—The PXIe-4135 (40W) shows *PXIe-4135 40W System SMU*, and the PXIe-4135 (20W) shows *NI PXIe-4135 Precision System SMU* on the front panel.

Please review and become familiar with the entire procedure before beginning the calibration process.

Contents

Required Software

Calibrating the PXIe-4135 requires you to install the following software on the calibration system:

- Supported driver software
  - For PXIe-4135 (40W), install NI-DCPower 20.5 or later
  - For PXIe-4135 (20W), install NI-DCPower 15.1 or later
- Supported application development environment (ADE)—LabVIEW or LabWindows™/CVI™.
- Supported operating system—Windows.

When you install NI-DCPower, you need to install support only for the application software that you intend to use. Access calibration support in the locations shown in the following table:

ADE	Calibration Support Location
LabVIEW	NI-DCPower Calibration palette
LabWindows/CVI	NI-DCPower function panel (`niDCPower.fp`)

You can download all required software from *ni.com/downloads*.

Related Documentation

For additional information, refer to the following documents as you perform the calibration procedure:

- *PXIe-4135 Getting Started Guide*
- *NI DC Power Supplies and SMUs Help*
- *PXIe-4135 Specifications*

- *NI-DCPower Readme*
- *LabVIEW Help*

Visit *ni.com/manuals* for the latest versions of these documents.

Password

The default password for password-protected operations is `NI`.

Calibration Interval

Recommended calibration interval	1 year

Test Equipment

The following table lists the equipment NI recommends for the performance verification and adjustment procedures. If the recommended equipment is not available, select a substitute that meets the minimum required specifications listed in the table.

Table 1. Required Equipment for Calibration

Required Equipment	Recommended Model(s)	Parameter Measured	Minimum Specifications
Digital multimeter (DMM)	Keysight 3458A	Voltage Measurement and Output Accuracy, Remote Sense Voltage Offset Accuracy, Current Measurement and Output Accuracy	Voltage: <±9 ppm accuracy and <100 nV resolution. Current: < ±25 ppm accuracy and <10 pA resolution.
100 MΩ current shunt	IET Labs SRL-100M/Pom5219	10 nA current accuracy	<20 ppm accuracy, <5 ppm / °C tempco.
1 MΩ current shunt	IET Labs SRL-1M/1Triax	1 µA current accuracy	<8 ppm accuracy, <0.2 ppm / °C tempco.

Table 1. Required Equipment for Calibration (Continued)

Required Equipment	Recommended Model(s)	Parameter Measured	Minimum Specifications
1 Ω current shunt	Ohm Labs CS-1	1 A and 3 A current accuracy	<50 ppm accuracy, <5 ppm / °C tempco.
PXIe-4135 Calibration Accessories Kit	NI 787170-01, including: • HI Sense Verification Assembly • LO Sense Verification Assembly • Output Shorting Assembly	Remote Sense Accuracy, Voltage Load Regulation Verification, and Residual Offset Voltage Adjustment	—
PXIe-4135 Screw Terminal Connector Kit	NI 784484-01	Voltage Accuracy, 10 nA and 1 µA, 100 µA to 100 mA, and 1 A and 3 A Current Accuracy, Voltage Adjustment, Current Output and Measurement Adjustment	—
Low thermal test leads	Fluke 5440A-7003 24 inch	1 µA, 1 A and 3 A Current Accuracy, Current Output and Measurement Adjustment	Low Thermal Copper EMF Plug-In Cables, Spade Connectors
BNC 3 Lug Triax to BNC 3 Lug Triax	Pomona 5223-36	10 nA and 1 µA Current Output and Measurement Verification	—
Triaxial (F) to BNC (M) Adapter	Pomona 5299	10 nA and 1 µA Current Output and Measurement Verification	—

Table 1. Required Equipment for Calibration (Continued)

Required Equipment	Recommended Model(s)	Parameter Measured	Minimum Specifications
BNC (F) to Single Banana Plug Adapter	Pomona 1894	Voltage Accuracy, 100 µA to 100 mA and 1 A and 3 A Current Accuracy, Voltage Adjustment Measurement Verification, Current Output and Measurement Adjustment	—
Shielded, 2 Conductor 22 AWG, Silver Plated Copper Cables	Belden 83319E	Voltage Accuracy, 10 nA and 1 µA, 100 µA to 100 mA, and 1 A and 3 A Current Accuracy, Voltage Adjustment Measurement Verification, Current Output and Measurement Adjustment	—

Table 1. Required Equipment for Calibration (Continued)

Required Equipment	Recommended Model(s)	Parameter Measured	Minimum Specifications
Banana Plug Adapter	Pomona 4892-0	Voltage Measurement and Output Accuracy, Remote Sense Voltage Offset Accuracy, Current Measurement and Output Accuracy	—
Solderless Banana Plug	Pomona 122505A	Voltage Measurement and Output Accuracy, Remote Sense Voltage Offset Accuracy, Current Measurement and Output Accuracy	—

Test Conditions

Follow the setup and environmental information below to ensure the PXIe-4135 meets the published specifications.

- Ensure that the safety interlock terminal is open during verification procedures unless specifically required. Ensure proper operator safety procedures when using the PXIe-4135 with the interlock closed.
- Keep cabling as short as possible. Long cables act as antennas, picking up extra noise that can affect measurements.
- Verify that all connections to the PXIe-4135, including front panel connections and screws, are secure.
- Ensure that the PXI chassis fan filters, if present, are clean, and that the empty slots contain filler panels.
- For chassis with slot cooling capacity = 38 W, ensure that the PXI chassis fan speed is set to HIGH. For more information about cooling, refer to the *Maintain Forced-Air Cooling Note to Users* document available at *ni.com/manuals*.
- Allow a warm-up time of at least 30 minutes after the chassis is powered on and NI-DCPower is loaded and recognizes the PXIe-4135. The warm-up time ensures that the PXIe-4135 and test instrumentation are at a stable operating temperature.

- Use low noise triax cabling for all HI and HI Sense connections. For LO and LO Sense connections, use shielded twisted pair copper wire for all cable connections to the device.
- To ensure the system has had adequate time to settle, wait one second after requesting a new current or voltage or after changing a load before taking a measurement.
- When making measurements, configure the following aperture time-related settings:
  - Set the **niDCPower Aperture Time** property or `NIDCPOWER_ATTR_APERTURE_TIME` attribute to 2 power-line cycles (PLCs) on the module.
  - Set the **niDCPower Aperture Time Units** property or `NIDCPOWER_ATTR_APERTURE_TIME_UNITS` to power line cycles.
  - Set the **niDCPower Configure Power Line Frequency** property or the `NIDCPOWER_ATTR_POWER_LINE_FREQUENCY` attribute to either 50 or 60 depending on the frequency of the AC power line in your location.
- Ensure that properties or attributes for the module that are not specified in calibration procedures are set to their default values.
- When making measurements, configure any specified digital multimeters (DMMs) with the best available ranges and measurement settings for each specified test point.
- Keep relative humidity between 10% and 70%, noncondensing.
- For verification procedures, maintain an ambient temperature of 23 °C ± 5 °C. Maintain an internal device temperature range of T_{cal} ± 1 °C.[1]
- For adjustment procedures, maintain an ambient temperature of 23 °C ± 1 °C. The PXIe-4135 internal temperature is greater than the ambient temperature.

Safety Guidelines for System Operation

Caution Hazardous voltages of up to the maximum voltage of the PXIe-4135 may appear at the output terminals if the safety interlock terminal is closed. Open the safety interlock terminal when the output connections are accessible. With the safety interlock terminal open, the output voltage level/limit is limited to ±40 V DC, and protection will be triggered if the voltage measured between the device HI and LO terminals exceeds ±(42 V peak ±0.4 V).

Attention Des tensions dangereuses allant jusqu'à la tension maximale du PXIe-4135 peuvent apparaître aux terminaux de sortie si le terminal de verrouillage de sécurité est fermé. Ouvrez le terminal de verrouillage de sécurité lorsque les connexions de sortie sont accessibles. Lorsque le terminal de verrouillage de sécurité est ouvert, le niveau ou la limite de tension de sortie est limité à ± 40 V CC, et la

[1] T_{cal} is the internal device temperature recorded by the PXIe-4135 at the completion of the last self-calibration. Call the niDCPower Get Self Cal Last Temp VI to query T_{cal} from the PXIe-4135.

protection se déclenchera si la tension mesurée entre les terminaux HI et LO de l'appareil dépasse ± (42 Vpic ± 0,4 V).

Caution Do not apply voltage to the safety interlock connector inputs. The interlock connector is designed to accept passive, normally open contact closure connections only.

Attention N'appliquez pas de tension aux entrées du connecteur de verrouillage de sécurité. Le connecteur de verrouillage est conçu pour accepter uniquement des connexions à fermeture de contact passives, normalement ouvertes.

To ensure a system containing the PXIe-4135 is safe for operators, components, or conductors, take the following safety precautions:

- Ensure proper warnings and signage exist for workers in the area of operation.
- Provide training to all system operators so that they understand the potential hazards and how to protect themselves.
- Inspect connectors, cables, switches, and any test probes for any wear or cracking before each use.
- Before touching any of the connections to the high terminal or high sense on the PXIe-4135, discharge all components connected to the measurement path. Verify with a DMM before interaction with connections.

As-Found and As-Left Limits

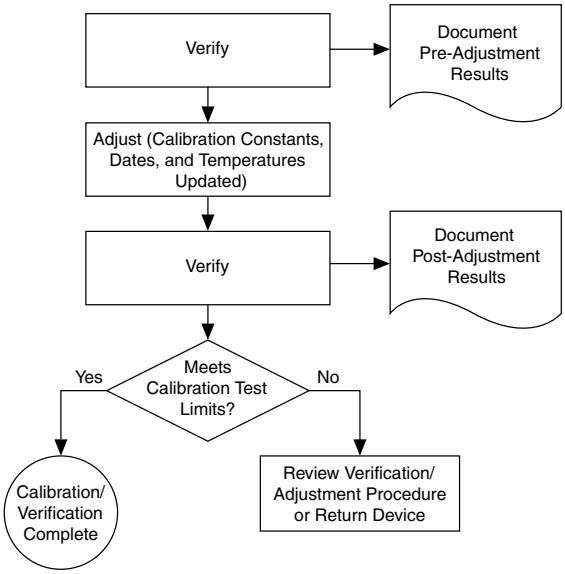
The *as-found limits* are the published specifications for the device. NI uses these limits to determine whether the device meets the device specifications when it is received for calibration.

The *as-left limits* are equal to the published NI specifications for the device, less guard bands for measurement uncertainty, temperature drift, and drift over time. NI uses these limits to determine whether the device will meet the device specifications over its calibration interval.

Calibration Overview

Calibration includes the steps shown in the following figure.

Figure 1. Calibration Overview



1. Initial setup—Install the PXIe-4135 and configure it in Measurement & Automation Explorer (MAX).
2. Verification—Verify the existing operation of the PXIe-4135.

   This step confirms whether the PXIe-4135 is operating within the published specifications prior to adjustment.
3. Adjustment—Adjust the calibration constants of the PXIe-4135.
4. Reverification—Repeat the Verification procedure to ensure that the PXIe-4135 is operating within the published specifications after adjustment.

Verification

This section provides instructions for verifying the PXIe-4135 specifications.

You must complete all verification procedures in the specified order.

You do not need to separately verify both measurement and output. The architecture of the PXIe-4135 ensures that if measurement is accurate, then output is as well, and vice versa.

Note The performance verification procedures assume that adequate traceable uncertainties are available for the calibration references.

Related Information

Reverification on page 32

Repeat the *Verification* on page 9 section to determine the as-left status of the PXIe-4135.

Self-Calibrating the PXIe-4135

Complete the following steps to self-calibrate the PXIe-4135.

1. Disconnect or disable all connections to the PXIe-4135.
2. Allow the PXIe-4135 30 minutes to warm up with the PXI chassis fans set to HIGH.
3. Initialize an NI-DCPower session.
4. Call the self-calibration function.
5. Close the NI-DCPower session.

Testing the Safety Interlock

In order to ensure safe operation of the PXIe-4135, test the safety interlock for proper functionality before completing any verification procedures.

Testing with an Application Development Environment

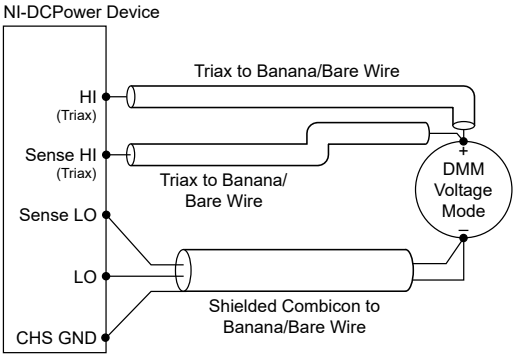
1. Disconnect the output connector from the PXIe-4135 front panel.
2. Ensure that the safety interlock input on the test fixture is closed.
3. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the PXIe-4135.
4. Set the voltage level range to 200 V, and set the voltage level to 42.4 V.
5. Set the current limit range to 1 mA, and set the current limit to 1 mA.
6. Initiate the session.
7. Verify that the Voltage Status Indicator is amber.
8. Open the safety interlock input using the test fixture.
9. Verify that the Voltage Status Indicator is red.
10. Reset the device using the niDCPower Reset VI or the `niDCPower Reset` function.
11. Verify that the Voltage Status Indicator is green.

Caution If the PXIe-4135 fails the safety interlock test, discontinue use of the device and contact an authorized NI service representative to request a Return Material Authorization (RMA).

Connecting and Configuring Equipment for Voltage Verification

1. Make the necessary connections for this procedure, as shown in the following figure:

Figure 2. Voltage Verification or Adjustment Connection Diagram



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the PXIe-4135.

Verifying Voltage Measurement and Output

Compare a set of voltages measured by a DMM to the voltage test points requested by the PXIe-4135.

Verify level ranges in the specified order.

Refer to the following table as you complete the following steps:

Table 2. Voltage Output and Measurement Verification

Level Range	Limit Range and Limit	Test Point	As-Found Measurement Test Limit		As-Left Measurement Test Limit	
			Lower	Upper	Lower	Upper
600 mV	1 mA	-600 mV	-600.132 mV	-599.868 mV	-600.0355 mV	-599.9645 mV
		0 mV	-0.03 mV	0.03 mV	-0.0115 mV	0.0115 mV
		600 mV	599.868 mV	600.132 mV	599.9645 mV	600.0355 mV
6 V		-6 V	-6.00111 V	-5.99889 V	-6.000212 V	-5.999788 V
		0 V	-0.00009 V	0.00009 V	-0.00005 V	0.00005 V
		6 V	5.99889 V	6.00111 V	5.999788 V	6.000212 V
20 V		-20 V	-20.0038 V	-19.9962 V	-20.000965 V	-19.999035 V
		0 V	-0.0004 V	0.004 V	-0.000165 V	0.000165 V
		20 V	19.9962 V	20.0038 V	19.999035 V	20.000965 V
200 V[2]		-200 V	-200.0425 V	-199.9575 V	-200.01425 V	-199.98575 V
		0 V	-0.0025 V	0.0025 V	-0.00125 V	0.00125 V
		200 V	199.9575 V	200.0425 V	199.9875 V	200.01425 V

Note The lower and upper voltage measurement test limits are calculated using the following formula:

Voltage Measurement Test Limits = *Test Point* ± (|*Test Point*| * *% of Voltage* + *Offset*)

1. Set the first specified level range, limit range, and limit on the PXIe-4135.
2. Set the **niDCPower Sense** property or `NIDCPOWER_ATTR_SENSE` attribute to Local.
3. Measure the internal device temperature and perform self-calibration if necessary.
   a) After measuring the internal device temperature, wait for the internal device temperature to stabilize. Temperature is considered stable when it has not changed by more than ±1 °C in the previous 5 minutes.
   b) After the internal temperature has stabilized, if the temperature still exceeds T_{cal} ± 1 °C, call the self-calibration VI or function.
4. Set the level on the PXIe-4135 to the first specified test point.
5. Compare a DMM voltage measurement to the voltage measurement test limits.
   a) Take a voltage measurement using the DMM.

[2] Ensure that the safety interlock terminal is closed when verifying the 200 V range.

b) Verify the DMM measurement falls within the test limits in the *Voltage Output and Measurement Verification* table.

6. Repeat step 4 through step 5 for each test point.
7. Repeat step 1 through step 6 for each level range.

Verifying Remote Sense Voltage Offset

Compare a set of voltages measured by a DMM to the voltage test points requested by the PXIe-4135.

Verify level ranges in the specified order. Use the same connections as the previous test.

Refer to the following table as you complete the following steps:

Table 3. Remote Sense Voltage Offset Verification

Level Range	Limit Range and Limit	Test Point	As-Found Measurement Test Limit	As-Left Measurement Test Limit
600 mV	1 mA	0 V	±30 µV	±11.5 µV
6 V			±90 µV	±50 µV
20 V			±400 µV	±165 µV
200 V			±2.5 mV	±1.25 mV

1. Set the first specified level range, limit range, and limit on the PXIe-4135.
2. Set the **niDCPower Sense** property or `NIDCPOWER_ATTR_SENSE` attribute to Remote.
3. Set the level on the PXIe-4135 to the first specified test point.
4. Compare a DMM voltage measurement to the voltage measurement test limits.
   a) Take a voltage measurement using the DMM.
   b) Verify the DMM measurement falls within the test limits.
5. Repeat step 1 through step 6 for each level range.

Verifying Voltage Remote Sense

Use the PXIe-4135 in constant current mode with a test circuit to simulate the voltage drop between the device and a load.

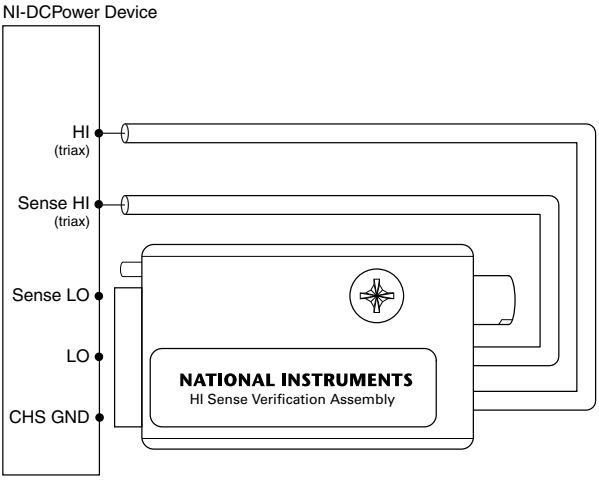
Refer to the following table as you complete the following steps:

Table 4. Voltage Remote Sense Output Verification

Level Range	Limit Range and Limit	Test Point	Voltage Remote Sense Test Limit
1 mA	600 mV	0 mA	±6 µV
		1 mA	

1. Make the necessary connections for this procedure, as shown in the following figure:

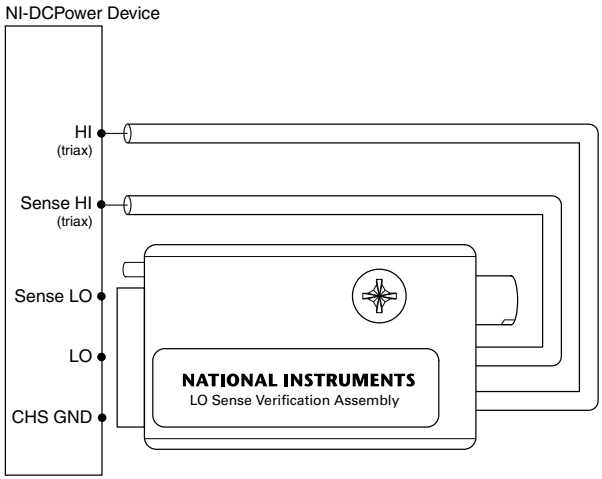
Figure 3. Voltage Remote Sense Diagram, HI Sense Verification Assembly



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Current for the PXIe-4135.
3. Set the **niDCPower Sense** property or `NIDCPOWER_ATTR_SENSE` attribute to Remote.
4. Set the first specified level range, limit range, and limit on the PXIe-4135.
5. Set the level on the PXIe-4135 to the first specified test point and enable the output.
6. Take a voltage measurement using the PXIe-4135.
7. Record the voltage from the previous step as *V1*.
8. Repeat step 6 through step 8 for the other test points specified in the level range, This time, record the value as *V2*.
9. Calculate the remote sense error using the following formula, and then record the value.

   Remote Sense Error = V2 - V1
10. Verify that the recorded value falls within the test limits.
11. Configure the PXIe-4135 output to disable.
12. Repeat the previous steps. This time, make the necessary connections as shown in the following figure:

Figure 4. Voltage Remote Sense Diagram, LO Sense Verification Assembly[3]



Verifying Current Offset Null

Remove all connections from the PXIe-4135 and confirm that the current measured into an open circuit falls within the test limits.

Complete this procedure only after successfully completing all previous verification procedures. Verify level ranges in the order listed in the table.

Refer to the following table as you complete the following steps:

Table 5. Current Offset Null Verification

Level Range	Limit Range	Limit	Test Point	As-Found/As-Left Offset Test Limit
600 mV	10 nA	10 nA	0 mV	750 fA[4]

1. Disconnect all equipment from the output of the PXIe-4135.
2. Measure the internal device temperature and perform self-calibration if necessary.
   a) After measuring the internal device temperature, wait for the internal device temperature to stabilize. Temperature is considered stable when it has not changed by more than ±1 °C in the previous 5 minutes.
   b) After the internal temperature has stabilized, if the temperature still exceeds T_{cal} ± 1 °C, call the self-calibration VI or function.
3. Wait 30 seconds for thermal EMF to stabilize.

[3] Follow industry best practices for minimizing thermal electromotive force (EMF) when making the necessary connections for this procedure.

[4] Specifications in this row are typical for the following PXIe-4135 (20 W) revisions: 157420C-03L, 157420D-03L, and 157420E-03L.

4. Set the **niDCPower Aperture Time** property or `NIDCPOWER_ATTR_APERTURE_TIME` attribute to 10 power-line cycles (PLCs) on the PXIe-4135.
5. Collect 11 current measurements using the PXIe-4135 and calculate the median.
   a) Repeat this step 10 times in order to collect 10 median calculated values.
   b) Calculate the max-min of all 10 median calculated values. The result should fall within the test limits specified in the above table.

Verifying Current Offset

Remove all connections from the PXIe-4135 and confirm the current measured by the PXIe-4135 at 0 V falls within the test limits.

Refer to the following table as you complete the following steps. Complete this procedure only after succesfully completing all previous verification procedures. Verify ranges in the order listed in the table.

Table 6. Current Offset Verification

Level Range	Limit Range	Limit	Test Point	As-Found Offset Test Limit	As-Left Offset Test Limit
600 mV	10 nA	10 nA	0 mV	±5 pA	±1 pA
	1 µA	1 µA		±40 pA	± 17 pA
	100 µA	100 µA		±2 nA	±970 pA
	1 mA	1 mA		±20 nA	±9.7 nA
	10 mA	10 mA		±200 nA	±97 nA
	100 mA	100 mA		±2 µA	±970 nA
	1 A	1 A		±20 µA	±8.5 µA
	3 A	1 A		±600 µA	±85 µA
200 V	10 nA	10 nA	40 V	±5 pA	±1 pA

1. Disconnect all equipment from the output of the PXIe-4135.
2. Set the first specified level range, limit range, and limit on the PXIe-4135.
3. Measure the internal device temperature and perform self-calibration if necessary.
   a) After measuring the internal device temperature, wait for the internal device temperature to stabilize. Temperature is considered stable when it has not changed by more than ±1 °C in the previous 5 minutes.
   b) After the internal temperature has stabilized, if the temperature still exceeds T_{cal} ± 1 °C, call the self-calibration VI or function.
4. Set the **niDCPower Aperture Time** property or `NIDCPOWER_ATTR_APERTURE_TIME` attribute to 2 power-line cycles (PLCs) on the PXIe-4135.

5. Take a current measurement using the PXIe-4135.
6. Record the value from the previous step.
7. Verify that the recorded value falls within the test limits.
8. Repeat step 2 through step 7 for each limit range.
9. Repeat step 2 through step 8 for each level range.

Verifying Load Regulation

Note Although load regulation is listed as a typical specification for the PXIe-4135, verification is required to ensure the procedures listed for verifying other specifications are correct. If the PXIe-4135 fails the load regulation verification procedure, discontinue use of the device and contact an authorized NI service representative to request a Return Material Authorization (RMA).

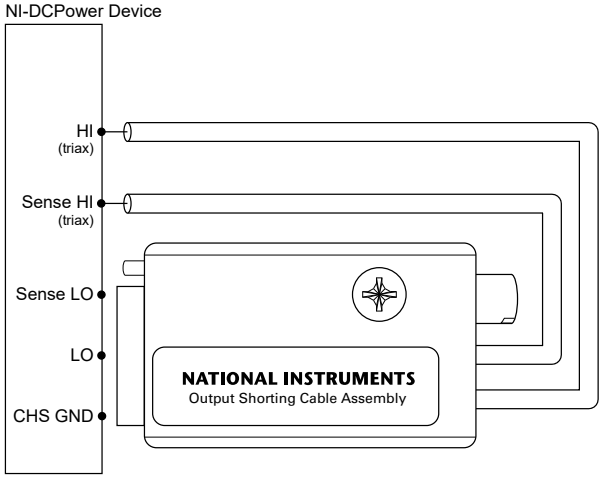
Refer to the following table as you complete the following steps:

Table 7. Load Regulation Verification

Level Range	Limit Range and Limit	Test Point	As-Found/As-Left Limit
10 mA	600 mV	10 mA	2.25 mV

1. Make the necessary connections for this procedure, as shown in the following figure:

Figure 5. Voltage Measurement Load Regulation



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Current for the PXIe-4135.
3. Set the **niDCPower Sense** property or `NIDCPOWER_ATTR_SENSE` attribute to Local.
4. Set the first specified level range, limit range, and limit on the PXIe-4135.

5. Measure the internal device temperature and perform self-calibration if necessary.
   a) After measuring the internal device temperature, wait for the internal device temperature to stabilize. Temperature is considered stable when it has not changed by more than ±1 °C in the previous 5 minutes.
   b) After the internal temperature has stabilized, if the temperature still exceeds T_{cal} ± 1 °C, call the self-calibration VI or function.
6. Set the level on the PXIe-4135 to the first specified test point.
7. Take a voltage measurement using the PXIe-4135.
8. Record the value from the previous step.
9. Verify that the recorded value falls within the test limit listed in the table above.
10. Set the **niDCPower Sense** property or `NIDCPOWER_ATTR_SENSE` attribute to Remote.

    Refer to the following table as you complete the following steps:

Table 8. Voltage Measurement Load Regulation Verification

Level Range	Limit Range and Limit	I1	I2	I3	As-Found/As-Left Limit
1 µA	6 V	-1 µA	1 µA	0 µA	±20 µV

11. Set the first specified level range, limit range, and limit on the PXIe-4135.
12. Measure the internal device temperature and perform self-calibration if necessary.
    a) After measuring the internal device temperature, wait for the internal device temperature to stabilize. Temperature is considered stable when it has not changed by more than ±1 °C in the previous 5 minutes.
    b) After the internal temperature has stabilized, if the temperature still exceeds T_{cal} ± 1 °C, call the self-calibration VI or function.
13. Complete the following steps within five minutes or less to ensure the internal device temperature remains stable:
    a) Set the level on the PXIe-4135 to the value specified by I1 in the table above.
    b) Take a voltage measurement using the PXIe-4135 and record the value as V1.
    c) Set the level on the PXIe-4135 to the value specified by I2 in the table above.
    d) Take a voltage measurement using the PXIe-4135 and record the value as V2.
    e) Set the level on the PXIe-4135 to the value specified by I3 in the table above.
    f) Take a voltage measurement using the PXIe-4135 and record the value as V3.
    g) Calculate the change in output voltage versus change in output current using the following formulas: *Error 1* = *V*1 - *V*3, *Error 2* = *V*2 - *V*3
14. Record the values for *Error 1* and *Error 2* from the previous step.
15. Verify that both recorded values fall within the test limits listed in the *Voltage Measurement Load Regulation Verification* table.
16. Configure the PXIe-4135 output to disable.

Verifying 10 nA Current Measurement and Output

Compare a set of measured currents reported by the PXIe-4135 to the currents measured by a DMM.

Complete this procedure only after successfully completing all previous verification procedures. Verify level ranges in the order listed in the table.

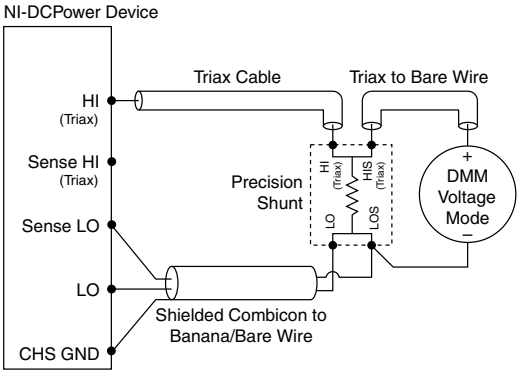
Refer to the following table as you complete the following steps:

Table 9. 10 nA Current Output and Measurement Verification

Level Range	Limit Range and Limit (Part 1)	Limit Range and Limit (Part 2)	Shunt	Test Point	As-Found Measurement Test Limit (% of Current + Offset)	As-Left Measurement Test Limit (% of Current + Offset)
6 V	1 mA	10 nA	100 MΩ	-0.9 V	0.05% + 5 pA	0.021% + 1 pA
				0.9 V		

1. Make the necessary connections for this procedure, as shown in the following figure:

Figure 6. Current Connection Diagram, Part 1



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the PXIe-4135.
3. Set the specified level range, limit range (part 1), and limit (part 1) on the PXIe-4135.
4. Measure the internal device temperature and perform self-calibration if necessary.
   a) After measuring the internal device temperature, wait for the internal device temperature to stabilize. Temperature is considered stable when it has not changed by more than ±1 °C in the previous 5 minutes.
   b) After the internal temperature has stabilized, if the temperature still exceeds T_{cal} ± 1 °C, call the self-calibration VI or function.

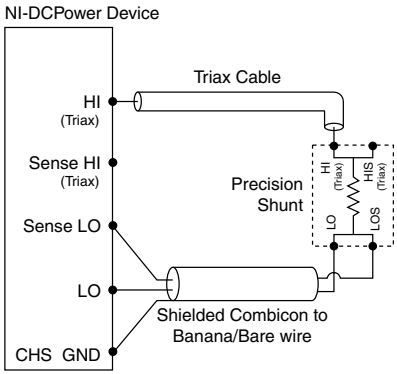
5. Set the level on the PXIe-4135 to the first specified test point.

   Complete the following 4 steps within 5 minutes or less of completing the previous step in order to ensure the internal device temperature remains stable.

6. Calculate the current through the shunt by completing the following steps.
   a) Take a voltage measurement across the shunt using the DMM.
   b) Divide the voltage measurement by the calibrated value of the shunt.
   c) Record the calculated value as *DMM Measured Current*.
7. Calculate the lower and upper current measurement test limits using the following formula:

   Current Measurement Test Limits = DMM Measured Current ± (|*DMM Measured Current*| * *% of Current* + *Offset*)
8. Disconnect the DMM as shown in the following figure. Leave the PXIe-4135 output on.

Figure 7. Current Connection Diagram, Part 2



9. Set the specified level range, limit range (part 2), and limit (part 2) on the PXIe-4135.
10. Take a current measurement using the PXIe-4135.
11. Record the value from the previous step.
12. Verify that the recorded PXIe-4135 value falls within the test limits.
13. Repeat steps 1-12 for each test point in the previous table.

Verifying 1 µA Current Measurement and Output

Compare a set of measured currents reported by the PXIe-4135 to the currents measured by a DMM.

Complete this procedure only after successfully completing all previous verification procedures. Verify level ranges in the order listed in the table.

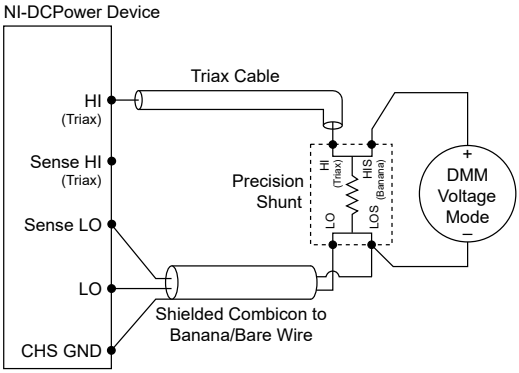
Refer to the following table as you complete the following steps:

Table 10. 1 µA Current Output and Measurement Verification

Level Range	Limit Range and Limit	Shunt	Test Point	As-Found Measurement Test Limit (% of Current + Offset)	As-Left Measurement Test Limit (% of Current + Offset)
6 V	1 µA	1 MΩ	-0.9 V	0.022% + 40 pA	0.0071% + 17 pA
			0.9 V		

1. Make the necessary connections for this procedure, as shown in the following figure:

Figure 8. Current Connection Diagram, Part 1



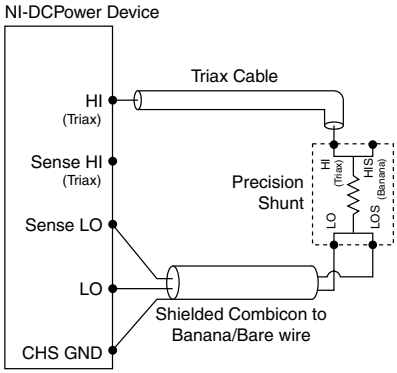
2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the PXIe-4135.
3. Set the first specified level range, limit range, and limit on the PXIe-4135.
4. Measure the internal device temperature and perform self-calibration if necessary.
   a) After measuring the internal device temperature, wait for the internal device temperature to stabilize. Temperature is considered stable when it has not changed by more than ±1 °C in the previous 5 minutes.
   b) After the internal temperature has stabilized, if the temperature still exceeds T_{cal} ± 1 °C, call the self-calibration VI or function.
5. Set the level on the PXIe-4135 to the first specified test point.

   Complete the following 4 steps within 5 minutes or less of completing the previous step in order to ensure the internal device temperature remains stable.
6. Calculate the current through the shunt by completing the following steps.
   a) Take a voltage measurement across the shunt using the DMM.
   b) Divide the voltage measurement by the calibrated value of the shunt.
   c) Record the calculated value as *DMM Measured Current*.
7. Calculate the lower and upper current measurement test limits using the following formula:

Current Measurement Test Limits = DMM Measured Current ± (|*DMM Measured Current*| * *% of Current + Offset*)

8. Disconnect the DMM as shown in the following figure. Leave the PXIe-4135 output on.

Figure 9. Current Connection Diagram, Part 2



9. Take a current measurement using the PXIe-4135.
10. Record the value from the previous step.
11. Verify that the recorded PXIe-4135 value falls within the test limits.
12. Repeat steps 1-11 for each test point in the previous table.

Verifying 100 µA to 100 mA Current Measurement and Output

Compare a set of currents measured by a DMM to the current test points requested by the PXIe-4135.

Complete this procedure only after successfully completing all previous verification procedures. Verify level ranges in the order listed in the table.

Refer to the following table as you complete the following steps:

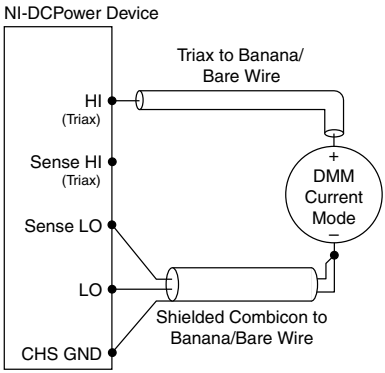
Table 11. 100 µA to 100 mA Current Output and Measurement Verification

Level Range	Limit Range and Limit	Test Point	As-Found Measurement Test Limit		As-Left Measurement Test Limit	
			Lower	Upper	Lower	Upper
100 µA	6 V	-100 µA	-100.024 µA	-99.976 µA	-100.00797 µA	-99.99203 µA
		100 µA	99.976 µA	100.024 µA	99.99203 µA	100.00797 µA
1 mA		-1 mA	-1.00024 mA	-0.99976 mA	-1.0000797 mA	-0.9999203 mA
		1 mA	0.99976 mA	1.00024 mA	0.9999203 mA	1.0000797 mA
10 mA		-10 mA	-10.0024 mA	-9.9976 mA	-10.000807 mA	-9.999193 mA
		10 mA	9.9976 mA	10.0024 mA	9.999193 mA	10.000807 mA
100 mA		-100 mA	-100.024 mA	-99.976 mA	-100.01117 mA	-99.98883 mA
		100 mA	99.976 mA	100.024 mA	99.98883 mA	100.01117 mA

Note The lower and upper voltage measurement test limits are calculated using the following formula:
Current Measurement Test Limits = *Test Point* ± (|*Test Point*| * *% of Current* + *Offset*)

1. Make the necessary connections for this procedure, as shown in the following figure:

Figure 10. Current Verification Connection Diagram



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Current for the PXIe-4135.
3. Set the first specified level range, limit range, and limit on the PXIe-4135.
4. Measure the internal device temperature and perform self-calibration if necessary.
   a) After measuring the internal device temperature, wait for the internal device temperature to stabilize. Temperature is considered stable when it has not changed by more than ±1 °C in the previous 5 minutes.
   b) After the internal temperature has stabilized, if the temperature still exceeds T_{cal} ± 1 °C, call the self-calibration VI or function.
5. Set the level on the PXIe-4135 to the first specified test point.
6. Complete the following 4 steps within 5 minutes or less of completing the previous step in order to ensure the internal device temperature remains stable.
7. Compare a DMM current measurement to the current measurement test limits.
   a) Take a current measurement using the DMM.
   b) Verify the DMM measurement falls within the test limits in the *100 µA to 100 mA Current Output and Measurement Verification* table.
8. Repeat step 5 through step 7 for each test point.
9. Repeat step 3 through step 8 for each level range.
10. Configure the PXIe-4135 output to disable.

Verifying 1 A and 3 A Current Measurement and Output

Compare a set of currents measured by a DMM to the current test points requested by the PXIe-4135.

Complete this procedure only after successfully completing all previous verification procedures. Verify level ranges in the order listed in the table.

Refer to the following table as you complete the following steps:

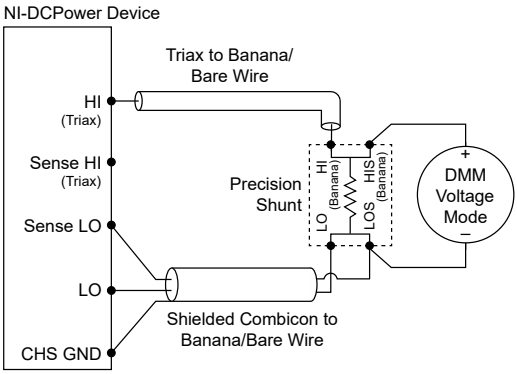
Table 12. 1 A and 3 A Current Output and Measurement Verification

Level Range	Limit Range and Limit	Test Point	As-Found Measurement Test Limit		As-Left Measurement Test Limit	
			Lower	Upper	Lower	Upper
1 A	6 V	-1 A	-1.00037 A	-0.99963 A	-1.0000595 A	-0.9999405 A
		1 A	0.99963 A	1.00037 A	0.9999405 A	1.0000595 A
3 A		-1 A	-1.00135 A	-0.99865 A	-1.000136 A	-0.999864 A
		1 A	0.99865 A	1.00135 A	0.999864 A	1.000136 A

Note Calculate the lower and upper current measurement test limits using the following formula:
Current Measurement Test Limits = Test Point ± (|*Test Point*| * *% of Current* + *Offset*)

1. Make the necessary connections for this procedure, as shown in the following figure:

Figure 11. Current Verification Connection Diagram



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Current for the PXIe-4135.
3. Set the first specified level range, limit range, and limit on the PXIe-4135.
4. Measure the internal device temperature and perform self-calibration if necessary.
   a) After measuring the internal device temperature, wait for the internal device temperature to stabilize. Temperature is considered stable when it has not changed by more than ±1 °C in the previous 5 minutes.
   b) After the internal temperature has stabilized, if the temperature still exceeds T_{cal} ± 1 °C, call the self-calibration VI or function.
5. Set the level on the PXIe-4135 to the first specified test point.

6. Complete the following 4 steps within 5 minutes or less of completing the previous step in order to ensure the internal device temperature remains stable.
7. Calculate the current through the shunt by completing the following steps.
   a) Take a voltage measurement across the shunt using the DMM.
   b) Divide the voltage measurement by the calibrated value of the shunt.
   c) Record the calculated value as *DMM Measured Current*.
8. Verify that the calculated *DMM Measured Current* value falls within the test limits.
9. Repeat step 5 through step 8 for each test point.
10. Repeat step 3 through step 9 for each level range.
11. Configure the PXIe-4135 output to disable.

Adjustment

This section describes the steps needed to adjust the PXIe-4135 to meet published specifications.

Adjusted Specifications

Adjustment corrects the following specifications for the device:

- Voltage programming accuracy
- Current programming accuracy
- Voltage measurement accuracy
- Current measurement accuracy

Following the adjustment procedure automatically updates the calibration date and temperature on the device.

Note You do not need to separately adjust both measurement and output. The architecture of the PXIe-4135 ensures that if measurement is accurate, then output is as well, and vice versa.

Initiating the Adjustment Session

1. After completing verification, wait a minimum of five minutes for the internal device temperature to stabilize.
2. Initiate an external calibration session (a specific type of NI-DCPower session) by calling the niDCPower Initialize External Calibration VI or `niDCPower_InitExtCal` function.
3. Call the self-calibration function.

Follow the actions below during adjustment:

- Keep the calibration session open until you complete all adjustment procedures.
- Complete all adjustment procedures within 15 minutes or less after initiating the external calibration session.

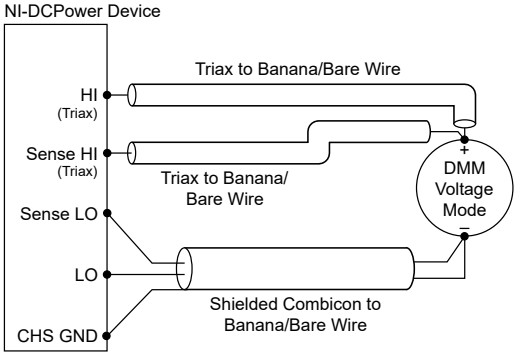
- Complete all adjustment procedures in the specified order.
- Do not self-calibrate the device except as specified in a procedure.

Voltage and Current Output

Connecting and Configuring Equipment for Voltage Adjustment

1. Make the necessary connections for this procedure, as shown in the following figure:

Figure 12. Voltage Verification or Adjustment Connection Diagram



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the PXIe-4135.

Adjusting Voltage Output and Measurement

Compare a set of measured voltages reported by the PXIe-4135 to the voltages measured by a DMM.

Refer to the following table as you complete the following steps:

Table 13. Voltage Output and Measurement Adjustment

Level Range	Limit Range and Limit	Test Point
6 V	100 mA	5 V
		-5 V

1. Set the first specified level range, limit range, and limit on the PXIe-4135.
2. Set the level on the PXIe-4135 to the first specified test point.
3. Take a voltage measurement using the DMM.
4. Store the value from the previous step to use as an input for the niDCPower Cal Adjust VI or function called in the following steps.
5. Repeat step 2 through step 4 for each test point.

6. Update the output calibration constants by configuring and calling the niDCPower Cal Adjust Voltage Level VI or `niDCPower_CalAdjustVoltageLevel` function.
   a) Input the DMM measurements as the **measured outputs**.
   b) Input the test points as the **requested outputs**.
   c) Input the specified level range as the **range**.
7. Configure the PXIe-4135 output to disable.

Adjusting 10 nA to 100 mA Current Output and Measurement

Complete this procedure only after successfully completing all previous adjustment procedures. Adjust ranges in the specified order.

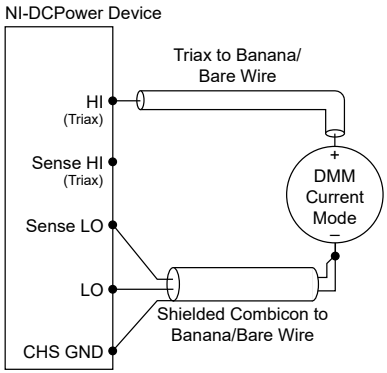
Refer to the following table as you complete the following steps:

Table 14. 10 nA to 100 mA Current Output and Measurement Adjustment[5]

Level Range	Limit Range and Limit	Test Point
100 µA	6 V	100 µA
		-100 µA
1 mA [6]	6 V	100 µA
		-100 µA

1. Make the necessary connections for this procedure, as shown in the following figure:

Figure 13. Current Output and Measurement Adjustment Connection Diagram



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Current for the PXIe-4135.
3. Set the first specified level range, limit range, and limit on the PXIe-4135.

[5] Adjusting the 100 µA and 1 mA level ranges automatically adjusts the following ranges: 10 nA, 1 µA, 10 mA, and 100 mA.

[6] The PXIe-4135 requires that you use ±100 µA test points in the 1 mA level range.

4. Set the level on the PXIe-4135 to the first specified test point.
5. Take a current measurement using the DMM.
6. Store the value from the previous step to use as an input for the niDCPower Cal Adjust VI or function called in the following steps.
7. Repeat step 4 through step 6 for each test point.
8. Update the output calibration constants by configuring and calling the niDCPower Cal Adjust Current Limit VI or `niDCPower_CalAdjustCurrentLimit` function.
   a) Input the calculated shunt current measurements as the **measured outputs**.
   b) Input the test points as the **requested outputs**.
   c) Input the specified level range as the **range**.
9. Repeat step 3 through step 8 for each level range.
10. Configure the PXIe-4135 output to disable.

Adjusting 1 A and 3 A Current Output and Measurement

Compare a set of measured currents reported by the PXIe-4135 to the currents measured by a DMM.

Complete this procedure only after successfully completing all previous adjustment procedures. Adjust ranges in the specified order.

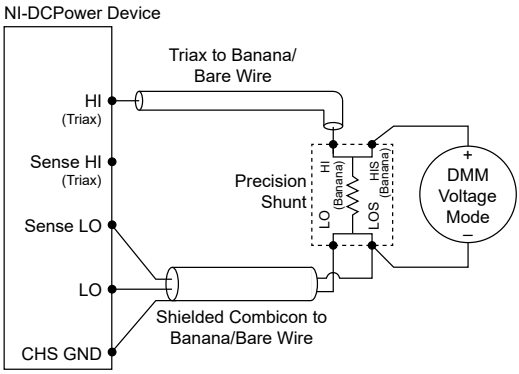
Refer to the following table as you complete the following steps:

Table 15. 1 A and 3 A Current Output and Measurement Adjustment

Level Range	Limit Range and Limit	Shunt	Test Point
1 A	6 V	1 Ω	1 A
			-1 A
3 A	6 V	1 Ω	1 A
			-1 A

1. Make the necessary connections for this procedure, as shown in the following figure:

Figure 14. Current Output and Measurement Adjustment Connection Diagram



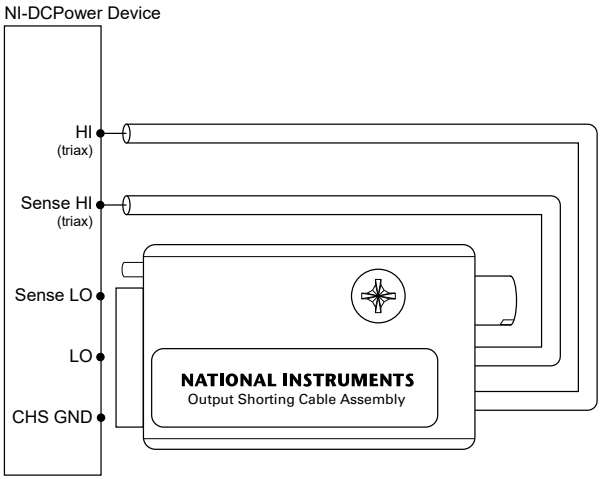
2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Current for the PXIe-4135.
3. Set the first specified level range, limit range, and limit on the PXIe-4135.
4. Set the level on the PXIe-4135 to the first specified test point.
5. Calculate the current through the shunt by completing the following steps.
   a) Take a voltage measurement across the shunt using the DMM.
   b) Divide the voltage measurement by the calibrated value of the shunt.
6. Store the value from the previous step to use as an input for the niDCPower Cal Adjust VI or function called in the following steps.
7. Repeat step 4 through step 6 for each test point.
8. Update the output calibration constants by configuring and calling the niDCPower Cal Adjust Current Limit VI or `niDCPower_CalAdjustCurrentLimit` function.
   a) Input the calculated shunt current measurements as the **measured outputs**.
   b) Input the test points as the **requested outputs**.
   c) Input the specified level range as the **range**.
9. Repeat steps 3 through step 8 for each level range.
10. Configure the PXIe-4135 output to disable.

Residual Offset Voltage

Connecting and Configuring Equipment to Adjust Residual Offset Voltage

1. Before completing adjustment of residual offset voltage, wait a minimum of 5 minutes for the internal device temperature to stabilize.
2. Make the necessary connections for this procedure, as shown in the following figure:

Figure 15. Residual Voltage Offset Diagram



3. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the PXIe-4135.

Adjusting Residual Voltage Offset

Eliminate residual offset voltage at 0 V by configuring and calling the niDCPower Cal Adjust Residual Voltage Offset VI or `niDCPower_CalAdjustResidualVoltageOffset` function.

Closing the Adjustment Session

Close the session and commit the new constants to hardware by calling the niDCPower Close External Calibration VI or `niDCPower_CloseExtCal` function and specifying Commit as the **calibration close action**.

Alternative to Performing Adjustment Procedures

If your device passes all as-left limits in the verification procedures successfully and you want to skip updating the calibration constants, you can update solely the calibration date by completing the following steps.

Note NI recommends following all adjustment procedures in order to update the calibration constants and renew the device calibration interval.

1. Call either the niDCPower Initialize External Calibration VI or the `niDCPower_InitExtCal` function.
2. Call either the niDCPower Close External Calibration VI or the `niDCPower_CloseExtCal` function, specifying Commit in **calibration close action**.

Reverification

Repeat the *Verification* on page 9 section to determine the as-left status of the PXIe-4135.

Note If any test fails reverification after performing an adjustment, verify that you have met the test conditions before returning your PXIe-4135 to NI. Refer to the *NI Services* section for information about support resources or service requests.

Related Information

Verification on page 9

Setting the Calibration Due Date

Use either Measurement & Automation Explorer (MAX) or NI System Configuration API to set or clear a calibration due date for your device. NI suggests a minimum calibration due date of the date of external calibration plus the external calibration interval for the device.

1. In MAX, navigate to the External Calibration section of the Settings tab to update the **Calibration Due Date** entry.
2. Alternatively, use the Update Calibration VI in the NI System Configuration API to set the calibration due date for either a specific date or an interval in months.

Revision History

Revision	Section	Changes
374877B-01 August 2020	Test Equipment	Updated parameters of digital multimeter (DMM) and updated PXIe-4135 Calibration Accessories Kit information.
	Verifying Current Offset Null	Added Verifying Current Offset Null task.
	Verifying Current Offset	Updated as-left offset test limits and added instructions to reset PLCs.

Revision	Section	Changes
374877C-01 September 2021	Various	Verbiage to include the PXIe-4135 (40W) variant into the calibration procedure.
	Required Software	Added driver software version for PXIe-4135 (40W).
	Test Equipment	Added more line items and updated the minimum specifications for required equipment.
	Test Conditions	Updated content regarding the chassis fan.

NI Services

Visit *ni.com/support* to find support resources including documentation, downloads, and troubleshooting and application development self-help such as tutorials and examples.

Visit *ni.com/services* to learn about NI service offerings such as calibration options, repair, and replacement.

Visit *ni.com/register* to register your NI product. Product registration facilitates technical support and ensures that you receive important information updates from NI.

NI corporate headquarters is located at 11500 N Mopac Expwy, Austin, TX, 78759-3504, USA.

374877C-01 August 31, 2021