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CALIBRATION PROCEDURE

PXIe-4135

Single-Channel System Source-Measure Unit (SMU)

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

Contents

NATIONAL INSTRUMENTS

Required Software

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

- NI-DCPower 15.2 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 using the minimum requirements listed in the table.

Table 1. Required Equipment for Calibration

Required Equipment	Recommended Model(s)	Parameter Measured	Minimum Specifications
Digital multimeter (DMM)	Agilent 3458 A	All parameters except remote sense 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	<10 ppm accuracy, <5 ppm / °C tempco.
1 MΩ current shunt	IET Labs SRL-1M/1Triax	1 µA current accuracy	<4 ppm accuracy, <0.2 ppm / °C tempco.
1 Ω current shunt	Ohm Labs CS-1	1 A and 3 A current accuracy	<65 ppm accuracy, <5 ppm / °C tempco.
HI Sense Verification Assembly	143229A-01	Remote Sense Accuracy	N/A
LO Sense Verification Assembly	143230A-01	Remote Sense Accuracy	N/A
Output Shorting Assembly	144574A-01	Voltage Load Regulation Verification, Residual Offset Voltage Adjustment	N/A

Test Conditions

Follow the setup and environmental information below to ensure the PXIe-4135 meets the published specifications. Test limits in this document are based on the July 2016 edition of the *PXIe-4135 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 speed is set to HIGH, that the fan filters (if present) are clean, and that the empty slots contain slot blockers and filler panels. 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 device.
  - 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.
- Do not use the NI-DCPower Soft Front Panel (SFP) to request test points for any adjustment functions because you cannot set aperture time using the SFP.
- Ensure that properties or attributes for the device 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 Vpk ±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.

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 exists 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.

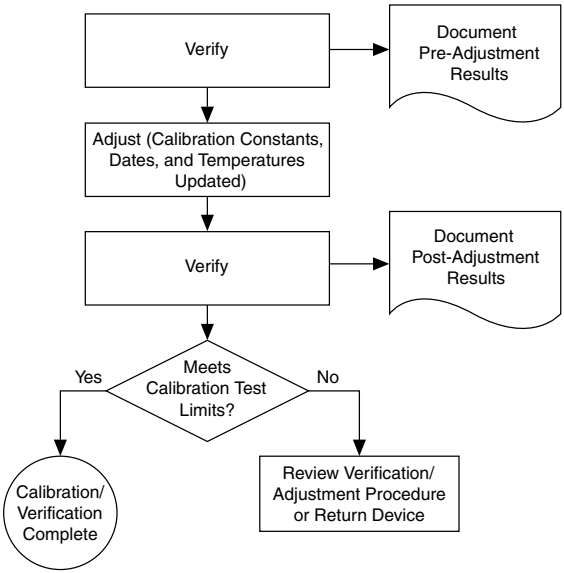
The *as-left limits* are equal to the published NI specifications for the device, less guard bands for measurement uncertainty, temperature drift, and drift over time. NI uses these limits to determine whether the device will meet the device specifications over its calibration interval.

[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.

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 device 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 device is operating within the published specifications after adjustment.

Verification

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

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.

Related Information

Reverification on page 28

Repeat the *Verification* 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

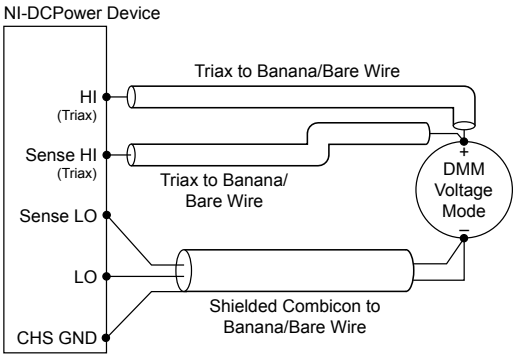
1. Disconnect the output connector from the PXIe-4135 front panel.
2. Ensure that the safety interlock input on the test fixture is closed.
3. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the PXIe-4135.
4. Set the voltage level range to 200 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 (% of Voltage + Offset)	As-Left Measurement Test Limit (% of Voltage + Offset)
600 mV	1 mA	-600 mV	0.017% + 30 µV	0.0040% + 11.5 µV
		0 mV		
		600 mV		
6 V	1 mA	-6 V	0.017% + 90 µV	0.0027% + 50 µV
		0 V		
		6 V		
20 V	1 mA	-20 V	0.017% + 400 µV	0.0040% + 165 µV
		0 V		
		20 V		

Table 2. Voltage Output and Measurement Verification (Continued)

Level Range	Limit Range and Limit	Test Point	As-Found Measurement Test Limit (% of Voltage + Offset)	As-Left Measurement Test Limit (% of Voltage + Offset)
200 V[2]	1 mA	-200 V	0.020% + 2.5 mV	0.0065% + 1.25 mV
		0 V		
		200 V		

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) If the internal device temperature exceeds T_{cal} ±1 °C, wait up to five minutes for the temperature to stabilize to within T_{cal} ±1 °C.
   b) If after five minutes the stable 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.
   b) Calculate the lower and upper voltage measurement test limits using the following formula:

      Voltage Measurement Test Limits = *Test Point* ± (|*Test Point*| * *% of Voltage* + *Offset*)
   c) Verify the DMM measurement falls within the test limits.
6. If more than one test point per level range is specified, repeat the previous steps for each test point, from setting the level to the test point on the PXIe-4135 up to this step.
7. If more than one level range is specified, repeat the previous steps using the values specified in 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:

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

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. If more than one test point per level range is specified, repeat the previous steps for each test point, from setting the level to the test point on the PXIe-4135 up to this step.
6. If more than one level range is specified, repeat the previous steps using the values specified in 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.

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

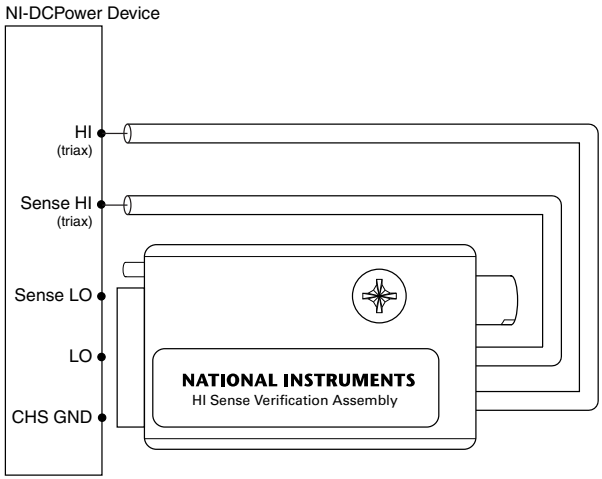
Refer to the following table as you complete the following steps:

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:

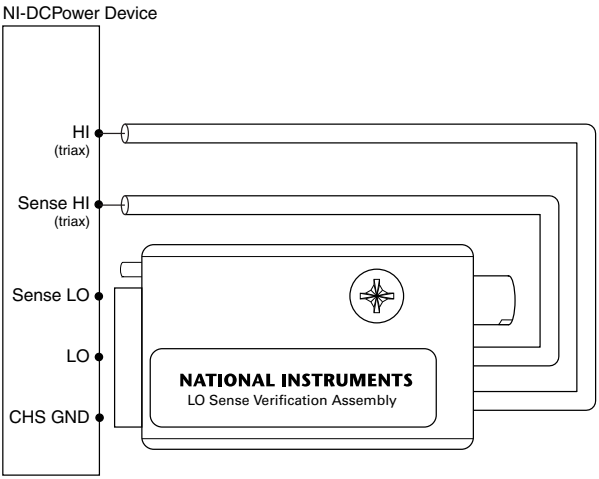
Figure 3. Voltage Remote Sense Diagram, HI Sense Verification Assembly



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. Measure the internal device temperature and perform self-calibration if necessary.
   a) If the internal device temperature exceeds T_{cal} ±1 °C, wait up to five minutes for the temperature to stabilize to within T_{cal} ±1 °C.
   b) If after five minutes the stable 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 and enable the output.
7. Take a voltage measurement using the PXIe-4135.
8. Record the voltage from the previous step as *V1*.
9. Repeat the previous three steps for the other test point specified in the level range. This time, record the value as *V2*.
10. Calculate the remote sense error using the following formula, and then record the value.

    Remote Sense Error = *V*2 - *V*1
11. Verify that the recorded value falls within the test limits.
12. Configure the PXIe-4135 output to disable.
13. 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



Verifying Current Offset

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 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	± 25 pA
	100 µA	100 µA		±2 nA	±1.5 nA
	1 mA	1 mA		±20 nA	±15 nA
	10 mA	10 mA		±200 nA	±150 nA
	100 mA	100 mA		±2 µA	±1.5 µA
	1 A	1 A		±20 µA	±15 µA
	3 A	1 A		±600 µA	±500 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. Measure the internal device temperature and perform self-calibration if necessary.
   a) If the internal device temperature exceeds T_{cal} ±1 °C, wait up to five minutes for the temperature to stabilize to within T_{cal} ±1 °C.
   b) If after five minutes the stable temperature still exceeds T_{cal} ±1 °C, call the self-calibration VI or function.
3. Take a current measurement using the PXIe-4135.
4. Record the value from the previous step.
5. Verify that the recorded value falls within the test limits.
6. If more than one limit range is specified, repeat the previous steps using the values specified in each limit range.
7. If more than one level range is specified, repeat the previous steps using the values specified in 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).

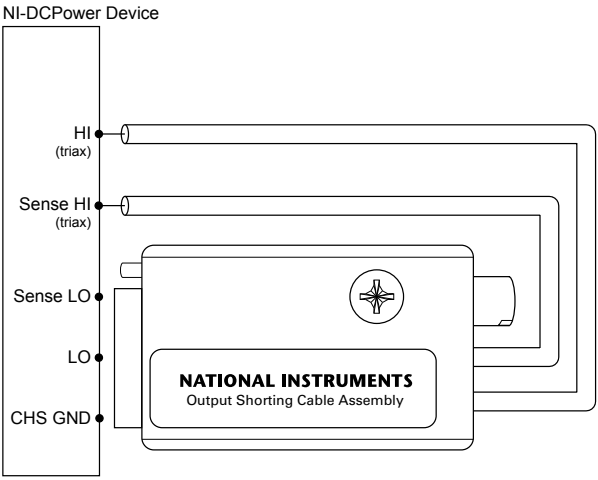
Refer to the following table as you complete the following steps:

Table 6. 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) If the internal device temperature exceeds T_{cal} ±1 °C, wait up to five minutes for the temperature to stabilize to within T_{cal} ±1 °C.
   b) If after five minutes the stable 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 Table 6.
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 7. 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) If the internal device temperature exceeds T_{cal} ±1 °C, wait up to five minutes for the temperature to stabilize to within T_{cal} ±1 °C.
    b) If after five minutes the stable 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 Table 7.
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.

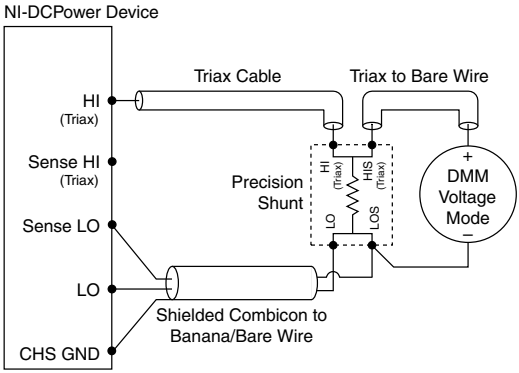
Refer to the following table as you complete the following steps:

Table 8. 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

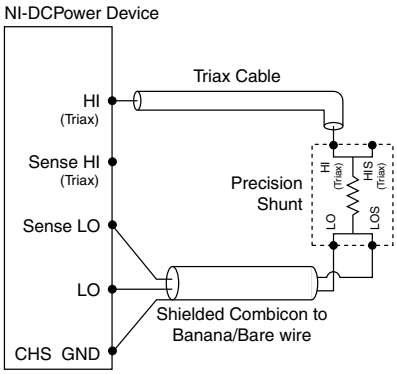


2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the PXIe-4135.
3. Set the specified level range, limit range (part 1), and limit (part 1) on the PXIe-4135.
4. Measure the internal device temperature and perform self-calibration if necessary.
   a) If the internal device temperature exceeds T_{cal} ±1 °C, wait up to five minutes for the temperature to stabilize to within T_{cal} ±1 °C.
   b) If after five minutes the stable 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.

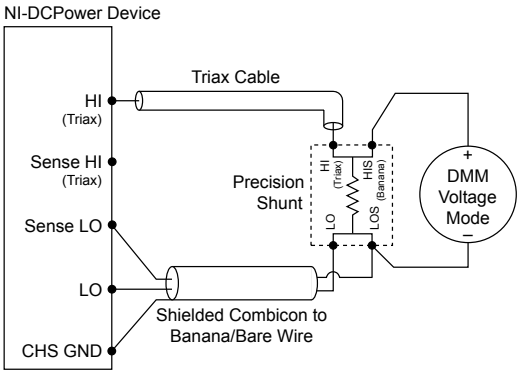
Refer to the following table as you complete the following steps:

Table 9. 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

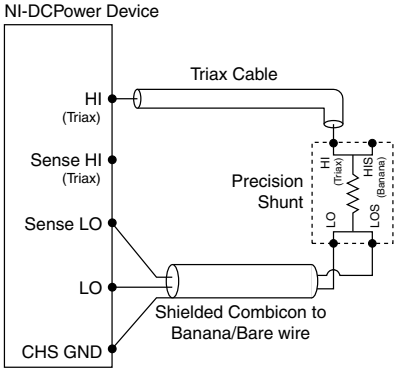


2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the PXIe-4135.
3. Set the first specified level range, limit range, and limit on the PXIe-4135.
4. Measure the internal device temperature and perform self-calibration if necessary.
   a) If the internal device temperature exceeds T_{cal} ±1 °C, wait up to five minutes for the temperature to stabilize to within T_{cal} ±1 °C.
   b) If after five minutes the stable 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 10. 100 µA to 100 mA Current Output and Measurement Verification

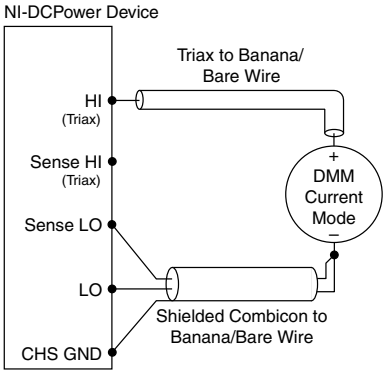
Level Range	Limit Range and Limit	Test Point	As-Found Measurement Test Limit (% of Current + Offset)	As-Left Measurement Test Limit (% of Current + Offset)
100 µA	6 V	-100 µA	0.022% + 2 nA	0.0070% + 970 pA
		100 µA		
1 mA	6 V	-1 mA	0.022% + 20 nA	0.0070% + 9.7 nA
		1 mA		

Table 10. 100 µA to 100 mA Current Output and Measurement Verification (Continued)

Level Range	Limit Range and Limit	Test Point	As-Found Measurement Test Limit (% of Current + Offset)	As-Left Measurement Test Limit (% of Current + Offset)
10 mA	6 V	-10 mA	0.022% + 200 nA	0.0071% + 97 nA
		10 mA		
100 mA	6 V	-100 mA	0.022% + 2 µA	0.0102% + 970 nA
		100 mA		

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) If the internal device temperature exceeds T_{cal} ±1 °C, wait up to five minutes for the temperature to stabilize to within T_{cal} ±1 °C.
   b) If after five minutes the stable 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) Calculate the lower and upper current measurement test limits using the following formula:

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

c) Verify the DMM measurement falls within the test limits.

8. If more than one test point per level range is specified, repeat the previous steps for each test point, from setting the level to the test point on the PXIe-4135 up to this step.
9. If more than one level range is specified, repeat the previous steps using the values specified in 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:

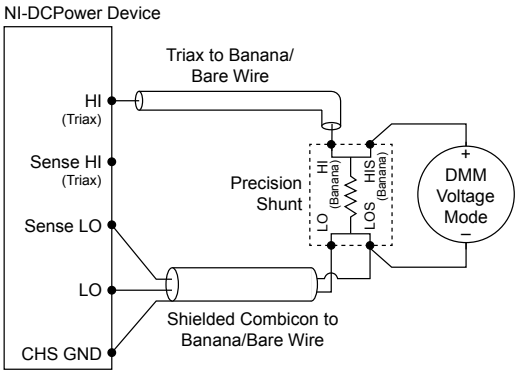
Table 11. 1 A and 3 A Current Output and Measurement Verification

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)
1 A	6 V	1 Ω	-1 A	0.035% + 20 µA	0.0051% + 8.5 µA[3]
			1 A		
3 A	6 V	1 Ω	-1 A	0.075% + 600 µA	0.0051% + 85 µA[3]
			1 A		

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

[3] As-left measurements for the 1 A and 3 A level range are relative to the external calibration source.

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) If the internal device temperature exceeds T_{cal} ±1 °C, wait up to five minutes for the temperature to stabilize to within T_{cal} ±1 °C.
   b) If after five minutes the stable 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. Calculate the lower and upper current measurement test limits using the following formula:

   Current Measurement Test Limits = Test Point ± (|*Test Point*| * *% of Current* + *Offset*)
9. Verify that the calculated *DMM Measured Current* value falls within the test limits.
10. If more than one test point per level range is specified, repeat the previous steps for each test point, from setting the level to the test point on the PXIe-4135 up to this step.
11. If more than one level range is specified, repeat the previous steps using the values specified in each level range.
12. 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 special 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:

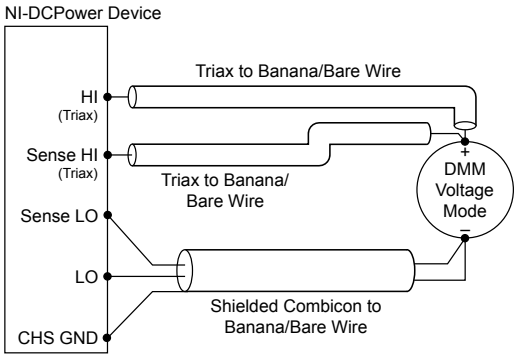
- Keep the calibration session open until you complete all adjustment procedures.
- Complete all adjustment procedures within 15 minutes or less after initiating the external calibration session.
- Complete all adjustment procedures in the specified order.
- Do not self-calibrate the device except as 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.
3. Set the **niDCPower Sense** property or `NIDCPOWER_ATTR_SENSE` attribute to Remote.

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 12. 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. If more than one test point per level range is specified, repeat the previous steps for each test point, from setting the level to the test point on the PXIe-4135 up to this step.
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.

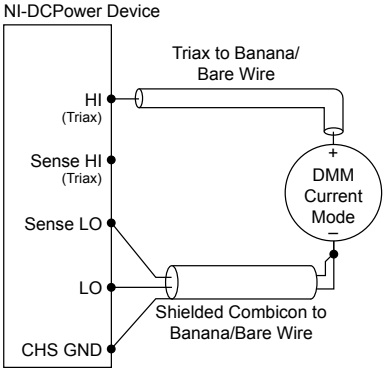
Refer to the following table as you complete the following steps:

Table 13. 10 nA to 100 mA Current Output and Measurement Adjustment[4]

Level Range	Limit Range and Limit	Test Point
100 µA	6 V	100 µA
		-100 µA
1 mA	6 V	100 µA[5]
		-100 µA[5]

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.
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. If more than one test point per level range is specified, repeat the previous steps for each test point, from setting the level to the test point on the PXIe-4135 up to this step.

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

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

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. If more than one level range is specified, repeat the previous steps using the values specified in 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.

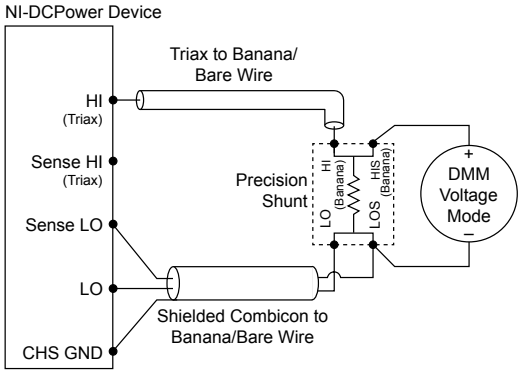
Refer to the following table as you complete the following steps:

Table 14. 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.

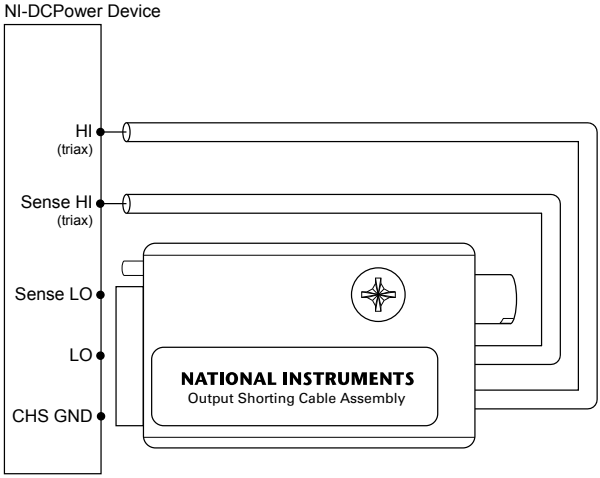
3. Set the first specified level range, limit range, and limit on the PXIe-4135.
4. Set the level on the PXIe-4135 to the first specified test point.
5. Calculate the current through the shunt by completing the following steps.
   a) Take a voltage measurement across the shunt using the DMM.
   b) Divide 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. If more than one test point per level range is specified, repeat the previous steps for each test point, from setting the level to the test point on the PXIe-4135 up to this step.
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. If more than one level range is specified, repeat the previous steps using the values specified in each level range.
10. Configure the PXIe-4135 output to disable.

Residual Offset Voltage

Connecting and Configuring Equipment to Adjust Residual Offset Voltage

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

Figure 15. Residual Voltage Offset Diagram



2. 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* 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 *Worldwide Support and Services* section for information about support resources or service requests.

Related Information

Test Conditions on page 4
Verification on page 6

Worldwide Support and Services

The NI website is your complete resource for technical support. At *ni.com/support*, you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

Visit *ni.com/services* for NI Factory Installation Services, repairs, extended warranty, and other services.

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

A Declaration of Conformity (DoC) is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electromagnetic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting *ni.com/certification*. If your product supports calibration, you can obtain the calibration certificate for your product at *ni.com/calibration*.

NI corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. NI also has offices located around the world. For telephone support in the United States, create your service request at *ni.com/support* or dial 1 866 ASK MYNI (275 6964). For telephone support outside the United States, visit the *Worldwide Offices* section of *ni.com/niglobal* to access the branch office websites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

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