CALIBRATION PROCEDURE

NI PXIe-4154

This document contains information for calibrating the National Instruments PXIe-4154 Battery Simulator. For more information about calibration, visit `ni.com/calibration`.

Contents

NATIONAL INSTRUMENTS™

Conventions

The following conventions are used in this document:

» — The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **Options»Settings»General** directs you to pull down the **Options** menu, select the **Settings** item, and select **General** from the last dialog box.

This icon denotes a note, which alerts you to important information.

When symbol is marked on a product, it denotes a warning advising you to take precautions to avoid electrical shock.

When symbol is marked on a product, it denotes a component that may be hot. Touching this component may result in bodily injury.

bold — Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names.

italic — Italic text denotes variables, emphasis, a cross-reference, or an introduction to a key concept. Italic text also denotes text that is a placeholder for a word or value that you must supply.

`monospace` — Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.

Software Requirements

Calibrating the NI PXIe-4154 requires installing NI-DCPower version 1.5 or later on the calibration system. You can download the NI-DCPower instrument driver from the Instrument Driver Network Web site at `ni.com/idnet`. NI-DCPower supports programming an External Calibration in the C and LabVIEW application development environments (ADEs). When you install NI-DCPower, you only need to install support for the ADE that you intend to use.

LabVIEW support is in the `niDCPower.llb` file, and all calibration VIs are accessible from the NI-DCPower Calibration palette. For LabWindows™/CVI™ users, the NI-DCPower function panel (`niDCPower.fp`) provides access to the calibration functions. For the locations of files you may need to calibrate your device, refer to the

NI-DCPower Readme, accessible at **Start»All Programs»National Instruments»NI DCPower»Documentation»NI-DCPower Readme**.

Documentation Requirements

For information about NI-DCPower and the NI PXIe-4154, you can consult the following documents:

- *NI DC Power Supplies and SMUs Getting Started Guide*—provides instructions for installing and configuring NI power supplies and SMUs.
- *NI DC Power Supplies and SMUs Help*—includes detailed information about the NI PXIe-4154 and NI-DCPower LabVIEW VI and C function programming references.
- *NI PXIe-4154 Specifications*—provides the published specification values for the NI PXIe-4154. Refer to the most recent *NI PXIe-4154 Specifications* online at `ni.com/manuals`.

These documents are installed with NI-DCPower. You also can find the latest versions of the documentation at `ni.com/manuals`.

Password

The default calibration password is `NI`.

Calibration Interval

National Instruments recommends a calibration interval of one year for the NI PXIe-4154. You should adjust the recommended calibration interval based on the measurement accuracy demands of your application.

Test Equipment

National Instruments recommends that you use the equipment in Table 1 for calibrating the NI PXIe-4154. If you do not have the recommended equipment, select a substitute calibration standard using the minimum requirements listed.

Table 1. Recommended Equipment

Equipment	Recommended Model	Parameter Measured	Minimum Requirements
Two Digital Multimeters (DMM)	National Instruments PXI-4071	All Parameters	Voltage: better than ±50 ppm accuracy and better than 30 µV resolution
100 mΩ Precision Current Shunt	Guildline 9230A-15R or Ohm Labs CS10	Current Output and Measurement	±50 ppm stability. ±5 ppm/°C temperature coefficient. Minimum current 10 A.
100 Ω Precision Current Shunt	Vishay Y1453100R000T9L	Current Output and Measurement	±100 ppm tolerance. ±5 ppm/°C temperature coefficient. Minimum power rating 0.5 W.
External Current Source	Fluke 5500A or Fluke 5520A	Current Measurement	Current output of at least 3 A. Less than 8 µA RMS Normal Mode Current Noise.
Programmable Electronic Load with Dynamic Current Capability	Agilent N3302A	Load Regulation, Transient Response, Output Resistance	Constant Current mode with the ability to sink at least 3 A. Dynamic mode capable of doing a 0.1 A to 1.5 A step with a period of 5 mS and slew rate of at least 200 mA/µS.
Digital Oscilloscope	National Instruments PXI-5124	Transient Response	Sampling rate of at least 200 MS/s. Edge triggering capability.
Two 22.6 Ω Resistors	Vishay PTF22R600FYBF	Remote Sense Output	1% tolerance, ¼ W, ±10 ppm/°C
200 Ω Resistor	Vishay PTF65200R00AZEB	Remote Sense Output	0.05% tolerance, ¼ W, ±10 ppm/°C
Two 3-Foot, 18 AWG Cables	Belden 8760-BEL	Transient Response	18 AWG, twisted-pair

Test Conditions

Follow these guidelines to optimize the equipment and the environment during calibration:

- Keep connections to the device as short as possible. Long cables and wires act as antennae, picking up extra noise that can affect measurements.
- Verify that all connections to the device, including front panel connections, are secure.
- Ensure that the PXI chassis fan speed is set to HI, that the fan filters are clean, and that the empty slots contain filler panels. For more information, refer to the *Maintain Forced-Air Cooling Note to Users* document available at `ni.com/manuals`.
- Keep relative humidity between 10% and 70%, noncondensing.
- Allow a warm-up time of at least 30 minutes after the NI-DCPower driver is loaded. Unless manually disabled, the NI-DCPower driver automatically loads with the operating system and enables the device. Allow the recommended warm-up time for all additional test equipment.
- Perform all measurements using **Local Sense** unless otherwise noted.
- Perform all measurements with the niDCPower Samples to Average property/attribute set to `20000`.
- Use characterized values in all instances where precision shunt resistance is measured.

- Use shielded copper wire for all cable connections to the device. Use twisted-pair wire to eliminate noise and thermal offsets. Use separate twisted-pair wires for Output + and Output – pins and Sense + and Sense – pins. Figure 1 shows an example of this connection.

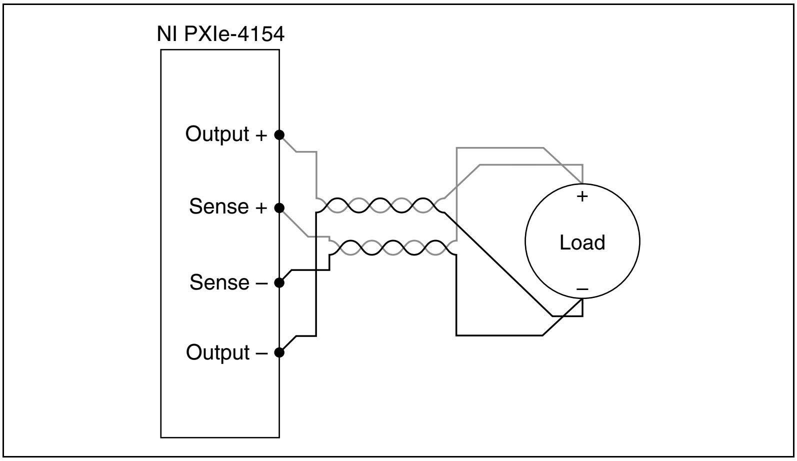

Figure 1. Twisted-Pair Connection

- Plug the chassis and the instrument standard into the same power strip to avoid ground loops.

Calibration Procedures

The complete calibration procedure consists of verifying the performance of the NI PXIe-4154, adjusting calibration coefficients, and verifying performance again after the adjustments. In some cases, a complete calibration procedure may not be required.

Verification

Note Verification must be performed after adjustment to ensure the NI PXIe-4154 is operating within the manufacturer's specifications.

This section provides instructions for verifying the NI PXIe-4154 specifications.

Verification should be performed under the following conditions:

- Adherence to the guidelines listed in the *Test Conditions* section.
- Ambient temperature is Tcal ±5 °C. Tcal is the temperature recorded by the NI PXIe-4154 at the completion of the last adjustment. Tcal can be queried from the NI PXIe-4154 by using the niDCPower Get Ext Cal Last Temp VI.

The NI-DCPower API or Soft Front Panel (SFP) can be used to verify operation of the NI PXIe-4154. For additional information on how to use this API, refer to the *NI DC Power Supplies and SMUs Help*. The latest version of NI-DCPower can be downloaded at `ni.com/idnet`.

For example programs that can be used to verify the NI PXIe-4154, refer to the example programs installed with NI-DCPower or download example programs at `ni.com/devzone`.

Note Limits in the following tables are based upon the September 2010 edition of the *NI PXIe-4154 Specifications.* Refer to the most recent *NI PXIe-4154 Specifications* online at `ni.com/manuals`. If a more recent edition of the specifications is available, recalculate the limits based upon the latest specifications.

Voltage Output Verification

To verify voltage output, compare a set of requested voltage set points to measurements of the actual voltage at the output by an external DMM. Refer to Figure 2 for the necessary connections.

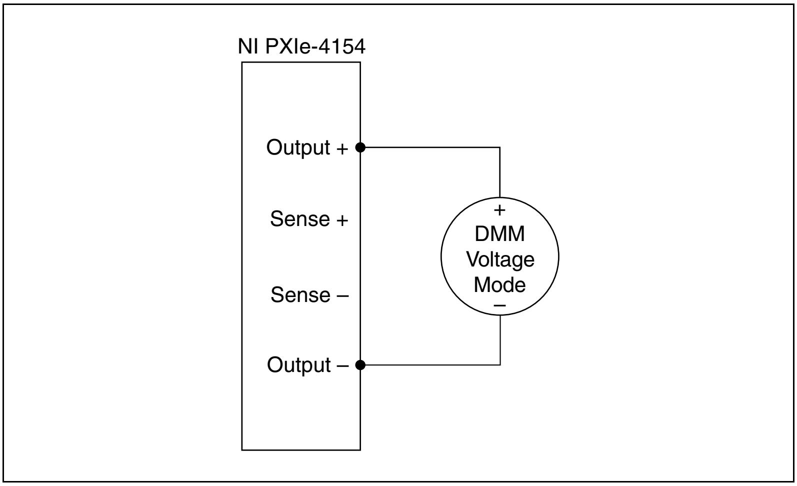

Figure 2. Voltage Verification Connection Diagram

Note Use separate twisted-pair cables for connections from Output + and Output – to the DMM, as shown in Figure 1.

Table 2 lists the voltage set points that you must request and measure for each range to complete verification. For example, the 6 V range on Channel 0 requires the verification application to separately request 6 V, 4.5 V, 3 V, 1.5 V, and 0 V outputs from the NI PXIe-4154. Take measurements using the DMM voltmeter at each point.

To ensure the system has had adequate time to settle, wait one second after requesting a new voltage before taking a measurement with the DMM.

Table 2. NI PXIe-4154 Voltage Output Verification Points

Channel	Range	Test Point	Limits of Accuracy		Measured	
			Lower Limit	Upper Limit	As Found	As Left
0	6 V	0 V	–0.005 V	0.005 V		
		1.5 V	1.4944 V	1.5056 V		
		3 V	2.9938 V	3.0062 V		
		4.5 V	4.4932 V	4.5068 V		
		6 V	5.9926 V	6.0074 V		
1	8 V	0 V	–0.006 V	0.006 V		
		2 V	1.9932 V	2.0068 V		
		4 V	3.9924 V	4.0076 V		
		6 V	5.9916 V	6.0084 V		
		8 V	7.9908 V	8.0092 V		

Current Output Verification

To verify current output, compare a set of requested current set points to measurements of the actual current at the output, which is calculated by dividing the voltage measured across the precision shunt by the actual resistance of the precision shunt. Refer to Figure 3 or Figure 4 for the necessary connections.

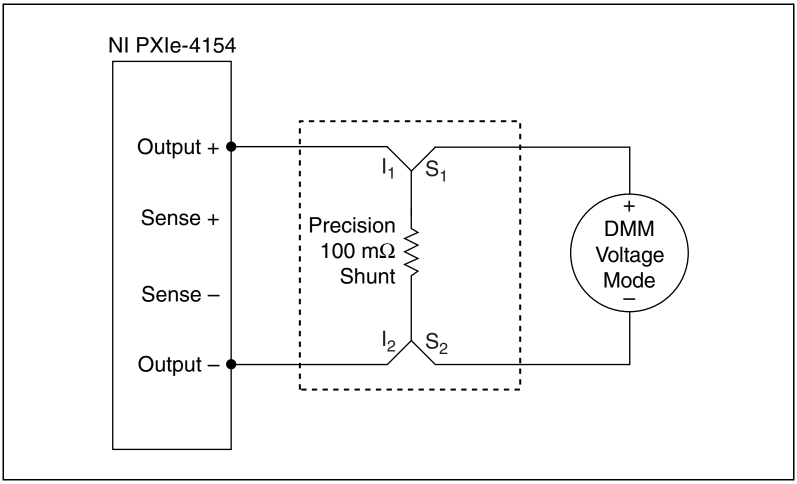

Figure 3. Current Verification Connection Diagram with 100 mΩ Precision Shunt

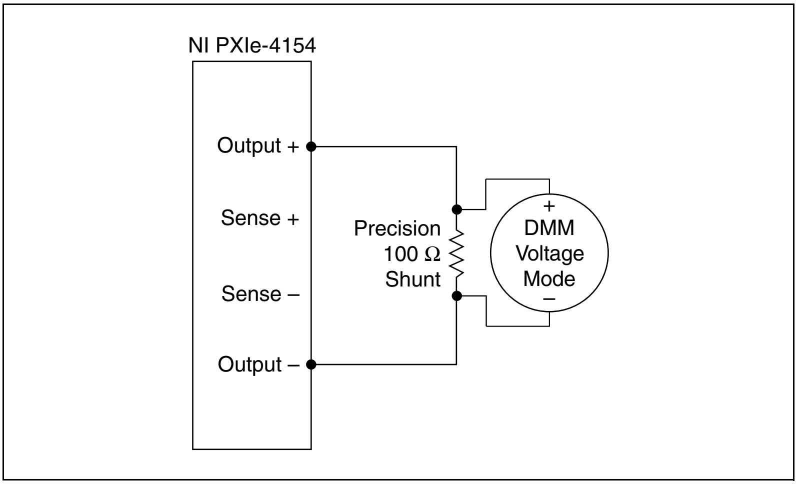

Figure 4. Current Verification Connection Diagram with 100 Ω Precision Shunt

Note Use separate twisted-pair cables for connections from Output + and Output – to the DMM, as shown in Figure 1.

Table 3 lists the current set points that you must request and measure for each range to complete verification. For example, in the 30 mA range on Channel 0 requires the verification application to separately request 30 mA, 22.5 mA, 15.0 mA, 7.5 mA, and 0.1 mA outputs from the NI PXIe-4154 while setting the voltage level to its maximum value. Take measurements using the DMM voltmeter at each point, dividing by the characterized value of the precision shunt each time.

To ensure the system has had adequate time to settle, wait one second after requesting a new current before taking a measurement with the DMM.

Note Total output current for both channels combined cannot exceed 3.1 A. Thus, the current setpoints for each channel—current limits when in Constant Voltage mode or the current levels when in Constant Current mode—must add up to no more than 3.1 A.

Table 3. NI PXIe-4154 Current Output Verification Points

Channel	Range	Precision Shunt Value	Test Point	Limits of Accuracy		Measured	
				Lower Limit	Upper Limit	As Found	As Left
0	30 mA	100 Ω	0.1 mA	0.064880 mA	0.135120 mA		
			7.5 mA	7.456000 mA	7.544000 mA		
			15.0 mA	14.947000 mA	15.053000 mA		
			22.5 mA	22.438000 mA	22.562000 mA		
			30 mA	29.929000 mA	30.071000 mA		
0	3 A	100 mΩ	0.01 A	0.006488 A	0.013512 A		
			0.75 A	0.745600 A	0.754400 A		
			1.50 A	1.494700 A	1.505300 A		
			2.25 A	2.243800 A	2.256200 A		
			3.00 A	2.992900 A	3.007100 A		
1	1.5 A	100 mΩ	0.01 A	0.006484 A	0.013516 A		
			0.35 A	0.345940 A	0.354060 A		
			0.75 A	0.745300 A	0.754700 A		
			1.25 A	1.244500 A	1.255500 A		
			1.50 A	1.494100 A	1.505900 A		

Voltage Measurement Verification

To verify voltage measurement, compare a set of voltage set points as measured by an external DMM to the measured voltage reported by the NI PXIe-4154. Refer to Figure 2 for the necessary connections.

Table 4 lists the voltage set points for each range that you must measure and request with both an external DMM and the NI PXIe-4154 to complete verification. For example, in the 6 V range on Channel 0, program the NI PXIe-4154 to output 6 V, 4.5 V, 3 V, 1.5 V, and 0 V. You will take voltage measurements at each test point using the DMM, and then compare these values to the voltage measurements taken at each test point using the NI PXIe-4154.

To ensure the system has had adequate time to settle, wait one second after requesting a new voltage before taking a measurement with the DMM and the NI PXIe-4154. The verification limits for voltage measurement will depend on the actual voltage measured with the external DMM, and are expressed as a percentage of DMM reading plus offset voltage in Table 4.

Table 4. NI PXIe-4154 Voltage Measurement Verification Points

Channel	Range	Test Point	Measured Voltage		Test Limit	Reported Voltage	
			As Found	As Left		As Found	As Left
0	6 V	0 V			0.025% + 2 mV		
		1.5 V					
		3 V					
		4.5 V					
		6 V					
1	8 V	0 V			0.05% + 2.5 mV		
		2 V					
		4 V					
		6 V					
		8 V					

Current Measurement Verification

To verify current measurement, measure a set of current test points with a DMM and a precision shunt by dividing the voltage across the precision shunt by the actual resistance of the precision shunt. You will then compare these values to the values of the current measured at the same current test points using the NI PXIe-4154. To verify current measurements while sourcing, use the configuration shown in Figure 3 or Figure 4. To verify current measurement while sinking, use the configuration shown in Figure 5 or Figure 6.

Table 5 lists the current test points for each range that you must measure and request with both an external DMM voltmeter/precision shunt and the NI PXIe-4154 in order to complete verification. To verify positive currents, use the NI PXIe-4154 channel as a source. For example, in the 1.5 A range on Channel 1, program the NI PXIe-4154 to output 375 mA, 750 mA, 1.125 A, and 1.5 A while setting the voltage limit to its maximum value. Take a current measurement at each set point using both the DMM voltmeter/precision shunt and the NI PXIe-4154, and then compare the measured values against each other.

To verify negative currents, use an external current source to force Channel 0 of the NI PXIe-4154 to sink current. For example, in the 3 A range on Channel 0, program the NI PXIe-4154 channel for 0 V output and program the external current source to output 750 mA, 1.5 A, 2.25 A, and 3 A. Channel 0 will be sinking current, so its measurements will be negative currents. Take a current measurement at each set point using both the DMM voltmeter/precision shunt and the NI PXIe-4154, and then compare the measured values against each other.

Note The zero current test point is verified only with the measurement returned by the NI PXIe-4154. To ensure no current is flowing while taking this zero current measurement, disconnect all external equipment from the I/O connector and take a current measurement with the NI PXIe-4154. When you verify the zero current test points this way, the measured current is always zero.

To ensure the system has had adequate time to settle, wait one second after requesting a new current before taking a measurement with the DMM and the NI PXIe-4154. The verification limits for current measurement will depend on the actual current measured with the external DMM, and are expressed as a percentage of DMM reading plus offset current in Table 5.

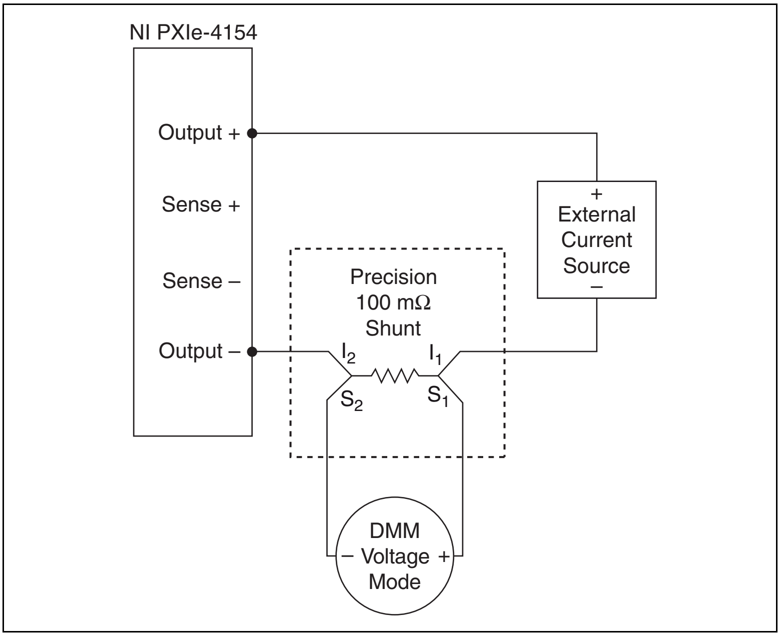

Figure 5. Current Measurement Verification Connection Diagram Using External Current Source with 100 mΩ Precision Shunt

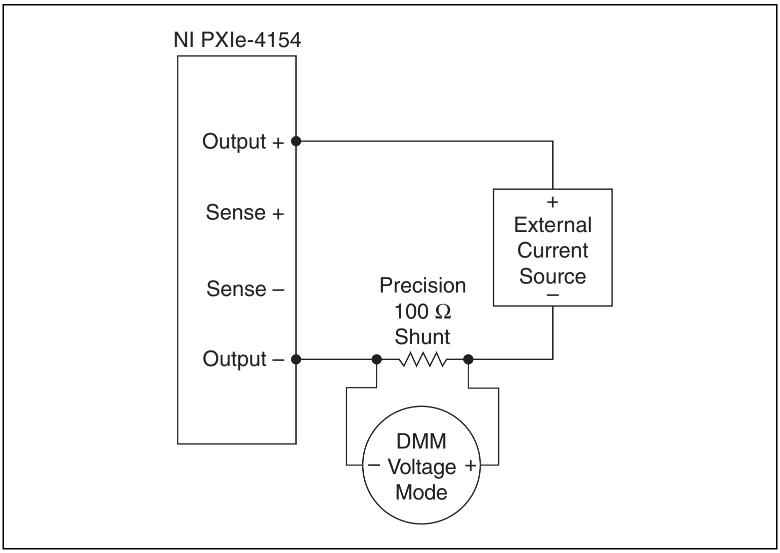

Figure 6. Current Measurement Verification Connection Diagram Using External Current Source with 100 Ω Precision Shunt

Note Use separate twisted-pair cables for connections from Output + and Output – to the DMM or external current source, as shown in Figure 1.

Table 5. NI PXIe-4154 Current Measurement Verification Points

Channel	Range	Precision Shunt Value	Test Point	Measured Current		Test Limit	Reported Current	
				As Found	As Left		As Found	As Left
0	30 mA	100 Ω	–30 mA			0.04% + 7 µA		
			–22.5 mA					
			–15 mA					
			–7.5 mA					
			0 mA					
			7.5 mA					
			15 mA					
			22.5 mA					
			30 mA					
0	3 A	100 mΩ	–3 A			0.14% + 0.7 mA		
			–2.25 A			0.1025% + 0.7 mA		
			–1.5 A			0.065% + 0.7 mA		
			–750 mA			0.04% + 0.7 mA		
			0 A			0.04% + 0.7 mA		
			750 m			0.04% + 0.7 mA		
			1.5 A			0.065% + 0.7 mA		
			2.25 A			0.1025% + 0.7 mA		
			3 A			0.14% + 0.7 mA		
1	1.5 A	100 mΩ	0 A			0.12% + 0.35 mA		
			375 mA			0.12% + 0.35 mA		
			750 mA			0.17% + 0.35 mA		
			1.125 A			0.245% + 0.35 mA		
			1.5 A			0.32% + 0.35 mA		

Output Resistance Verification (Channel 0 Only)

To verify output resistance, compare a set of requested resistance set points to measurements of the actual resistance at the output, which is calculated using two external DMMs and a 100 mΩ precision shunt. Refer to Figure 7 for the necessary connections.

Note Ensure that **Remote Sense** is enabled during output resistance verification.

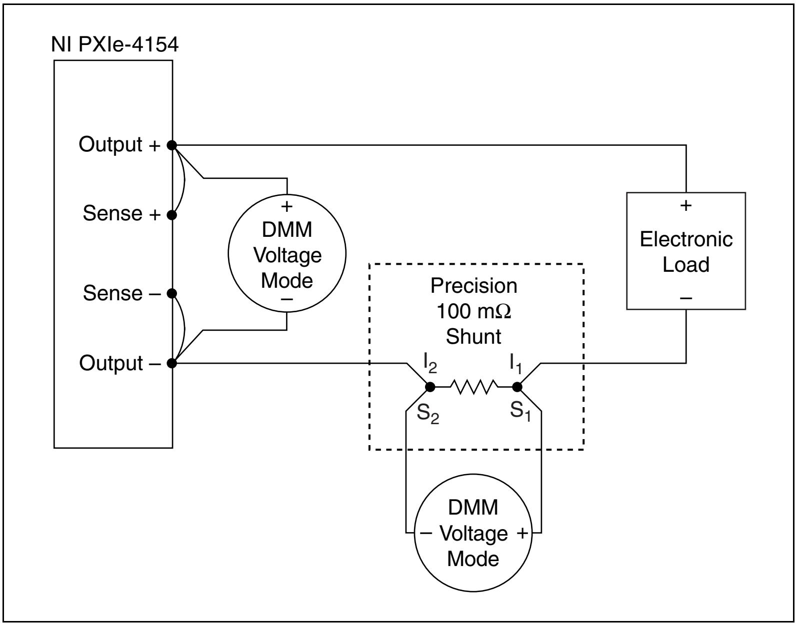

Figure 7. Output Resistance and Load Regulation Verification Connection Diagram with 100 mΩ Precision Shunt

Note Use twisted-pair cables for connections from Output + and Output – to the electronic load, as shown Figure 1. Use short wires to jumper Sense + to Output + and Sense – to Output –.

Table lists the output resistance set points that you must request and measure to complete verification. For example, program the adjustment application to separately request –0.04 Ω, 0 Ω, 0.25 Ω, 0.5 Ω, 0.75 Ω, and 1 Ω outputs from the NI PXIe-4154. Take measurements at each test point using two external DMMs.

To ensure the system has had adequate time to settle, wait one second after requesting a new output resistance before taking a measurement with the DMMs. Configure the NI PXIe-4154 to output 4 V with a current limit of 3 A.

Use the following steps to calculate the output resistance for each set point.

1. Set the electronic load for 100 mA constant current and record the DMM voltage at the Output + and Output – terminals of Channel 0 of the NI PXIe-4154 (V_1).
2. Calculate the current I_1 by dividing the voltage measured across the 100 mΩ precision shunt by the characterized value of the 100 mΩ precision shunt.
3. Increase the electronic load to 1 A constant current and record the DMM voltage at the Output + and Output – terminals of Channel 0 of the NI PXIe-4154 (V_2).
4. Calculate the current I_2 by dividing the voltage measured across the 100 mΩ precision shunt by the characterized value of the 100 mΩ precision shunt.
5. Calculate the output resistance using the following formula:

$$\textit{Output Resistance}\ (\Omega) = (V_1 - V_2) / (I_2 - I_1)$$

Note Output resistance is requested on the NI PXIe-4154 using NI DCPower Output Resistance Property Node.

Table 6. NI PXIe-4154 Output Resistance Verification Points

				Measured Voltages		Measured Currents		Limits of Accuracy		Calculated Resistance	
Channel	V Level	I Limit	Test Point	V_1	V_2	I_1	I_2	Lower Limit	Upper Limit	As Found	As Left
0	4 V	3 A	–40 mΩ					–0.04312 Ω	–0.03688 Ω		
			0 Ω					–0.003 Ω	0.003 Ω		
			250 mΩ					0.24625 Ω	0.25375 Ω		
			500 mΩ					0.4955 Ω	0.5045 Ω		
			750 mΩ					0.74475 Ω	0.75525 Ω		
			1 Ω					0.994 Ω	1.006 Ω		

Load Regulation Verification

The load regulation test verifies that the output voltage falls within specified limits when the load current changes, or that the output current falls within specified limits when the load voltage changes. For each test, two loads of different values are needed to vary the load voltage or current. Validation of load regulation should be performed after successfully validating the voltage and current measurement accuracy as well as the output resistance.

Note Ensure that **Remote Sense** is enabled during load regulation verification.

Voltage Load Regulation

To verify voltage load regulation, use the NI PXIe-4154 in Constant Voltage mode and confirm the output voltage change falls within calculated limits while varying the load current using an electronic load. Table 7 lists the load current values and measurements needed to complete verification. Refer to Figure 7 for the necessary connections.

Note For Channel 0 of the NI PXIe-4154, ensure that output resistance is set to 0 Ω during voltage load regulation verification.

Complete the following steps to verify voltage load regulation:

1. Configure the electronic load in constant current mode and set it to *Load Current 1* as shown in Table 7. Record the DMM voltage at the Output + and Output – terminals of the NI PXIe-4154 (V_1).
2. Calculate the current (I_1) by dividing the voltage measured across the 100 mΩ precision shunt by the characterized value of the 100 mΩ precision shunt.
3. Increase the electronic load to *Load Current 2* as shown in Table 7. Record the DMM voltage at the Output + and Output – terminals of the NI PXIe-4154 (V_2).
4. Calculate the current (I_2) by dividing the voltage measured across the the 100 mΩ precision shunt by the characterized value of the 100 mΩ precision shunt.
5. Calculate the voltage change limit using the following formulas:
   $$\textit{Channel 0 Voltage Change Limit} = \pm (I_1 - I_2) * 0.003 \text{ V}$$
   $$\textit{Channel 1 Voltage Change Limit} = \pm (I_1 - I_2) * 0.001 \text{ V}$$
6. Subtract the two voltage measurements $V_1 - V_2$ to calculate the *Voltage Change*.

The test passes if the *Voltage Change* is less than or equal to the calculated *Voltage Change Limit*.

Table 7. NI PXIe-4154 Voltage Load Regulation Verification Points

Channel	V Range	I Range	I Limit	V Level	Load Current 1	Load Current 2	Measured				Voltage Change Limit (V)	Voltage Change (V)
							I_1 (A)	V_1 (V)	I_2 (A)	V_2 (V)		
0	6 V	3 A	3 A	6 V	0.03 A	2.7 A						
1	8 V	1.5 A	1.5 A	8 V	0.015 A	1.35 A						

Current Load Regulation

To verify current load regulation, use the NI PXIe-4154 in Constant Current mode and confirm the output current change falls within calculated limits while varying the load voltage using an electronic load. Table 8 lists the resistance values and measurements needed to complete verification. Refer to Figure 7 for the necessary connections.

Complete the following steps to verify current load regulation:

1. Configure the electronic load in constant voltage mode and set it to *Load Voltage 1* as shown in Table 8. Record the DMM voltage at the Output + and Output – terminals of the NI PXIe-4154 (V_1).
2. Calculate the current (I_1) by dividing the voltage measured across the 100 mΩ precision shunt by the characterized value of the 100 mΩ precision shunt.
3. Decrease the electronic load to *Load Voltage 2* as shown in Table 7. Record the DMM voltage at the Output + and Output – terminals of the NI PXIe-4154 (V_2).
4. Calculate the current (I_2) by dividing the voltage measured across the the 100 mΩ precision shunt by the characterized value of the 100 mΩ precision shunt.
5. For each test, the units for all current measurements and calculations should be the same as the *I Range* unit.
6. Calculate the current change limit using the following formula: *Current Change Limit* = ±0.0001 * *I Range* * ($V_1 - V_2$).
7. Subtract the two current measurements $I_1 - I_2$ to calculate the *Current Change*.

The test passes if the *Current Change* is less than or equal to the calculated *Current Change Limit*.

Table 8. NI PXIe-4154 Current Load Regulation Verification Points

Channel	V Range	I Range	V Limit	I Level	Precision Shunt Value	Load Voltage 1	Load Voltage 2	Measured				Current Change Limit (A)	Current Change (A)
								I_1 (A)	V_1 (V)	I_2 (A)	V_2 (V)		
0	6 V	3 A	6 V	1.5 A	100 mΩ	5 V	2 V						
	6 V	30 mA	6 V	15 mA	100 Ω	5 V	2 V						
1	8 V	1.5 A	8 V	0.75 A	100 mΩ	7 V	2 V						

Remote Sense Accuracy Verification

To verify Remote Sense, complete the following steps using a test circuit of three resistors that simulate the voltage drop between the device and a load. Channels 0 and 1 should be tested separately, using the same method.

Note Ensure that **Remote Sense** is enabled during remote sense output verification.

Validation of remote sense accuracy should be performed only after successfully validating the voltage and current measurement accuracy and the load regulation.

1. Connect a 22.6 Ω (R_1), 200 Ω (R_2), and 22.6 Ω (R_3) resistor in series, with the 200 Ω resistor being the center resistor, as shown in Figure 8.

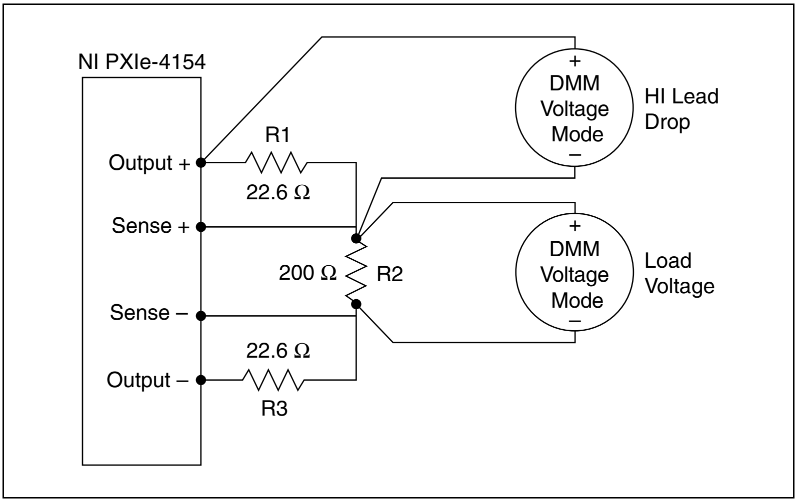

Figure 8. Remote Sense Output Verification Connection Diagram

Note Use separate twisted-pair cables for connections from Output + and Output – to the load and from Sense + and Sense – to the load, as shown Figure 1.

2. Connect the resistors to the Output + and Output – terminals on the NI PXIe-4154 as shown in Figure 8. Connect the Remote Sense leads directly across the 200 Ω resistor (R_2).
3. With Remote Sense *ON*, set the voltage level and current limit to the values listed in Table 9.
4. Measure the Output + Lead Drop with a DMM (*HI Lead Drop*) from the Output + terminal of the NI PXIe-4154 to the 200 Ω resistor, as shown in Figure 8.
5. Measure the load voltage with a DMM (*Load Voltage*) across the 200 Ω resistor where the sense leads connect, as shown in Figure 8.

6. Calculate the accuracy limit for the load voltage using the following equations and the V Level listed in Table 9:

$$\text{Channel 0 } \textit{Load Voltage Limit} = \textit{V Level} \pm (\textit{V Level} * 0.04\% + 0.005) - (\textit{HI Lead Drop} * 0.002)\ \text{V}$$

$$\text{Channel 1 } \textit{Load Voltage Limit} = \textit{V Level} \pm (\textit{V Level} * 0.04\% + 0.006) - (\textit{HI Lead Drop} * 0.002)\ \text{V}$$

where *V Level* and *HI Lead Drop* are given in volts.

The test passes if the *Load Voltage* measurement falls within the calculated *Load Voltage Limit*.

Table 9. NI PXIe-4154 Remote Sense Output Verification Points

Channel	V Range	I Range	V Level	I Limit	Measured		Load Voltage Limit (V)
					HI Lead Drop (V)	Load Voltage (V)	
0	6 V	3 A	6 V	0.1 A			
1	8 V	1.5 A	8 V	0.1 A			

Transient Response Verification (Channel 0 Only)

To verify transient sense, complete the following steps using a digital oscilloscope and a programmable electronic load with dynamic current capability.

Note Ensure that **Remote Sense** is enabled during transient response verification.

Validation of transient response should be performed only after successfully validating the voltage and current measurement accuracy and the load regulation.

Note Use one 3-foot, 18 AWG twisted-pair cable to connect Output + and Output – to the electronic load, and another 3-foot, 18 AWG twisted-pair cable to connect Sense + and Sense – to the electronic load, similar to the connection shown in Figure 1.

1. To verify channel 0 *FAST* and *NORMAL* transient response, connect a digital oscilloscope and electronic load as shown in Figure 9.

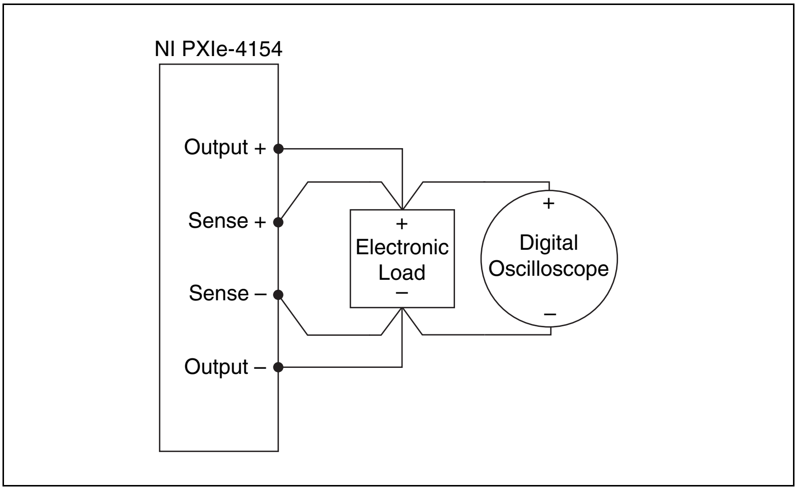

Figure 9. Channel 0 Transient Response Connection Diagram

2. Configure the electronic load in current control dynamic mode with the settings listed in Table 10.
3. Configure the oscilloscope to acquire a waveform according to the settings listed in Table 10.
4. Configure the NI PXIe-4154 according to the settings listed in Table 10.

5. Measure the transient response recovery time and transient response dip as displayed in Figure 10. The transient response recovery time is measured from the time the dip begins until the time at which the waveform crosses above the final voltage minus 20 mV. For more information on transient response, refer the *Transient Response* topic in the *Fundamentals* section of the *NI DC Power Supplies and SMUs Help*.

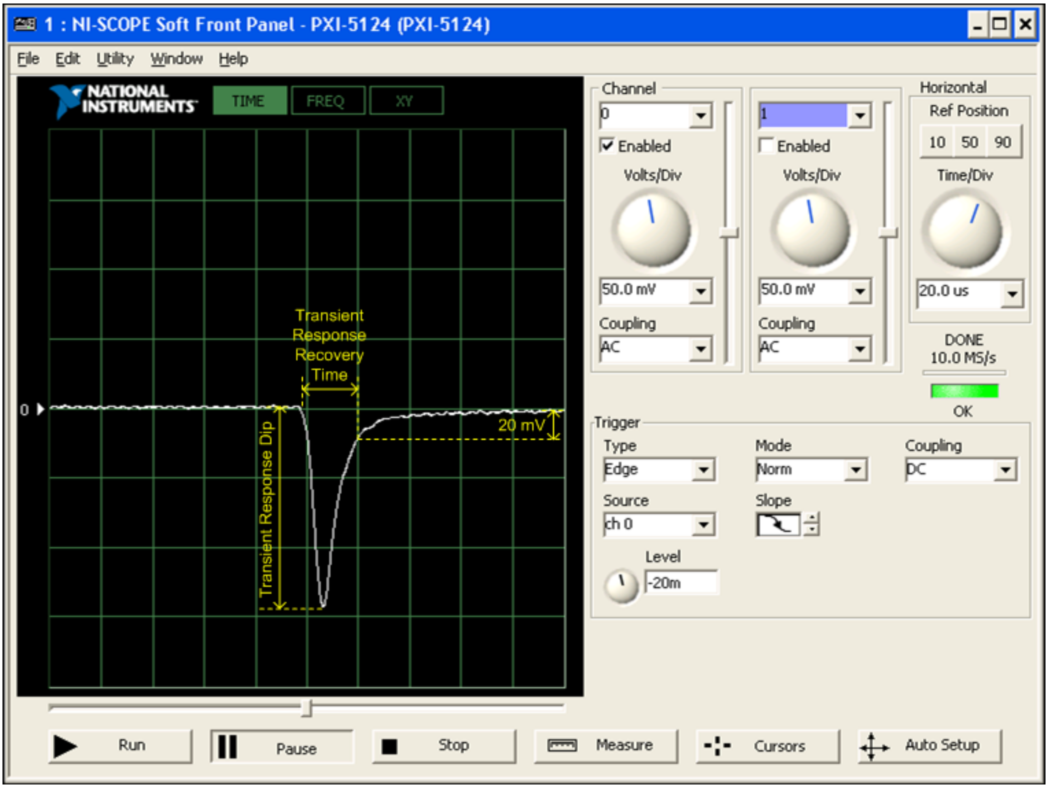

Figure 10. Example Transient Response Dip and Transient Response Recovery Time Waveform

The test passes if the *Transient Response Dip* and *Transient Response Recovery Time* measurements fall within the limits listed on Table 11.

Table 10. NI PXIe-4154 Transient Response Verification Setup

Channel	V Range	I Range	V Level	I Limit	Transient Response Speed	Load High Current	Load Low Current	Load Period	Load Slew Rate	Oscilloscope Volts/ Division	Oscilloscope Time/ Division	Oscilloscope Trigger Slope	Oscilloscope Trigger Level
0	6 V	3 A	6 V	3 A	Normal	1.5 A	0.1 A	1 ms	200 mA/µs	50 mV	20 µS	Negative Edge	–20 mV
0	6 V	3 A	6 V	3 A	Fast	1.5 A	0.1 A	1 ms	200 mA/µs	50 mV	20 µS	Negative Edge	–20 mV

Table 11. NI PXIe-4154 Transient Response Verification Limits

Channel	Transient Response Speed	Measured		Transient Response Dip Limit	Transient Response Recovery Time Limit
		Transient Response Dip	Transient Response Recovery Time		
0	Normal			250 mV	40 µs
0	Fast			70 mV	20 µs

Adjustment

Following the adjustment procedure automatically updates the calibration date and temperature on the NI PXIe-4154.

Note National Instruments recommends a complete adjustment of your device to renew the calibration interval. However, if all verification steps were successful and you do not want to perform an adjustment, you can update the calibration date and onboard calibration temperature without making any adjustments by calling only the niDCPower Initialize External Calibration VI or the `niDCPower_InitExtCal` function and the niDCPower Close External Calibration VI or `niDCPower_CloseExtCal` function with the action of **Commit**.

Adjustment corrects the following NI PXIe-4154 specifications:

- Voltage programming accuracy
- Current programming accuracy
- Voltage measurement accuracy
- Current measurement accuracy
- Output resistance accuracy

The adjustment components of the NI-DCPower API require the NI PXIe-4154 be programmed using the voltage output function (this is the default configuration). You must adjust each range with a separate call to an niDCPower Cal Adjust VI or function.

Note Do not use the NI-DCPower Soft Front Panel (SFP) to request set points for any adjustment functions.

Adjustment should be performed under the following conditions:

- Adherence to the guidelines listed in the *Test Conditions* section.
- Ambient room temperature should be kept at 23 °C during adjustment.

Considerations

Figure 11 represents the general flow of an application used to adjust a range on the NI PXIe-4154.

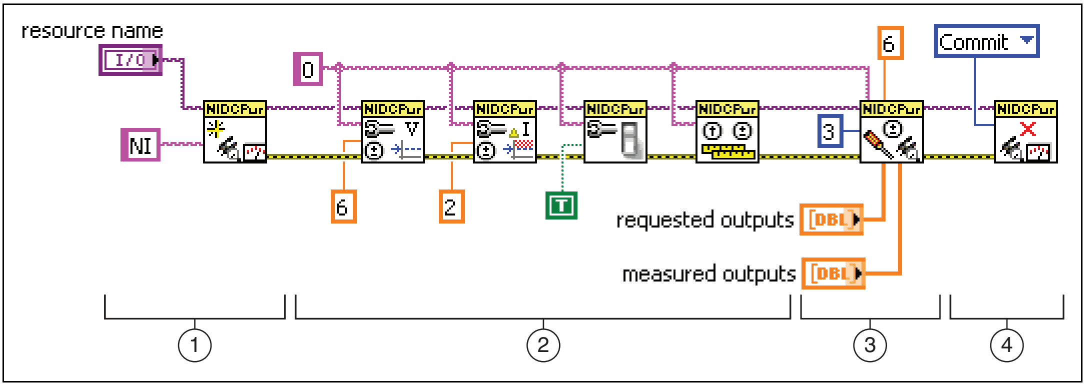

Figure 11. LabVIEW Block Diagram Illustrating Range Adjustment on the NI PXIe-4154

1. **Initialize External Calibration Session**: To adjust the NI PXIe-4154, call the niDCPower Initialize External Calibration VI or the `niDCPower_InitExtCal` function to initiate a special type of NI-DCPower session.
2. **Configure the instrument**: Call a series of standard NI-DCPower VIs/functions specific to the adjustment of a particular range. These calls vary depending on the requirements of the range being adjusted. Typical operations in this step include configuring ranges, setting output levels, or taking measurements. Measurements made by external equipment required for adjustment also occur during this step. For assistance configuring the NI PXIe-4154 to a particular output or measurement mode, refer to the example programs installed with NI-DCPower.
3. **Call niDCPower Cal Adjust function(s)**: When the measurements required for adjustment of a range are complete, call one of the niDCPower Cal Adjust VIs or functions to calculate new calibration coefficients and store them in memory on the host. Calling these VIs/functions does *not* commit the new coefficients to hardware.
4. **Close session and commit new calibration coefficients**: To complete adjustment of the range, call the niDCPower Close External Calibration VI or `niDCPower_CloseExtCal` function to close the session. To write new calibration coefficients to the hardware, specify an action of **Commit**. At this time, the calibration date and temperature stored on board are also updated.

Note You can adjust any voltage or current range individually by opening a calibration session, adjusting, and then closing the session with an action of **Commit**. To adjust all voltage and current ranges at one time, open a single calibration session, execute multiple adjustment steps, and then close the session with an action of **Commit** to write coefficients for multiple ranges simultaneously.

Adjusting Current Measurement

To adjust current measurement, compare a set of current set points as measured with a DMM voltmeter used in conjunction with a precision shunt to the measured current reported by the NI PXIe-4154. To adjust current measurement while sourcing, use a configuration as shown in Figure 3 or Figure 4, and to adjust current measurement while sinking, use the configuration shown in Figure 5 or Figure 6.

Table 12 outlines the current set points that you must measure and request with both an external DMM and the NI PXIe-4154 to adjust a given range. For example, the 30 mA on Channel 0 requires the adjustment application to separately request 27 mA, 0 mA, and –27 mA outputs from the NI PXIe-4154. For positive currents, the voltage level should be set to the maximum value. Take measurements using the DMM voltmeter/precision shunt and NI PXIe-4154 at each point. To calculate the current value using the DMM voltmeter/precision shunt, divide the voltage measured with the DMM by the characterized value of the precision shunt.

For negative current adjustment points, an external current source is required to provide the necessary current. The voltage level for the NI PXIe-4154 should be set to 0 V. Refer to Table 1 for external current source equipment recommendations and requirements.

To ensure the system has had adequate time to settle while also minimizing self-heating effects of the internal measurement circuitry, wait 3 ms after requesting a new voltage before taking a measurement with the DMM and the NI PXIe-4154.

Table 12. NI PXIe-4154 Current Measurement Adjustment Points

Channel	I Range	Required Adjustment Points			Precision Shunt Value
0	30 mA	–27 mA	0 mA	27 mA	100 Ω
0	3 A	–2 A	0 A	2 A	100 mΩ
1	1.5 A	0 A	0.75 A	1.35 A	100 mΩ

Note When measuring a 0 A set point, remove any connections to the front panel I/O connector to ensure no current is flowing through the output.

After all set points have been measured for a range, call the niDCPower Cal Adjust Current Measurement VI or the `niDCPower_CalAdjustCurrentMeasurement` function to calculate updated calibration coefficients. Some parameters to this VI/function are specific to adjustment applications and are explained in Table 13. Others are common to many VIs/functions within the NI-DCPower API that are explained in more detail in the programming references included in the *NI DC Power Supplies and SMUs Help*.

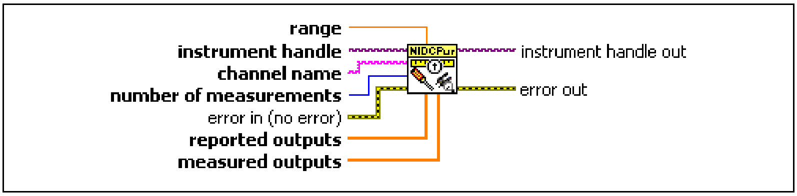

Figure 12. NI-DCPower Cal Adjust Current Measurement VI

Table 13. NI PXIe-4154 Current Measurement Adjustment Points

VI/Function Parameter	Description
range	The range to be adjusted with these settings
reported outputs	Array of measurements taken by the NI PXIe-4154 corresponding to required adjustment set points in Table 12
measured outputs	Array of measurements made by external DMM corresponding to required adjustment set points in Table 12. For zero current set points, a measured output of exactly zero should be entered as all connections to the NI PXIe-4154 should be removed to take this measurement.
number of measurements	The number of elements in *reported outputs* and *measured outputs*

When the new coefficients have been calculated, commit them to the hardware using the process described in the *Considerations* section.

Adjusting Voltage Output

To adjust voltage output, compare a set of requested voltage set points to measurements of the actual voltage at the output by an external DMM. Refer to Figure 2 for the necessary connections.

Table 13 outlines the voltage set points that you must request and measure for each range. For example, the 6 V range on Channel 0 requires the adjustment application to separately request 0.1 V, 3 V, and 6 V outputs from the NI PXIe-4154. Take measurements using the external DMM at each voltage set point.

Note Do not use the NI-DCPower Soft Front Panel (SFP) to request set points for adjusting voltage outputs.

Table 14. NI PXIe-4154 Voltage Output Adjustment Points

Channel	V Range	Required Adjustment Points		
0	6 V	0.1 V	3 V	6 V
1	8 V	0.1 V	4 V	8 V

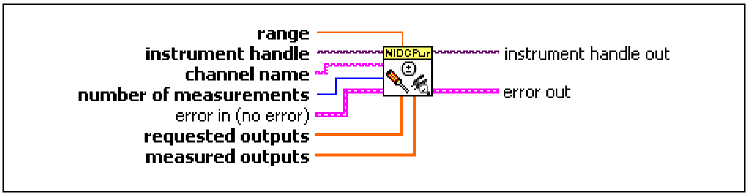

Figure 13. NI-DCPower Cal Adjust Voltage Level VI

To ensure the system has had adequate time to settle, wait one second after requesting a new voltage before taking a measurement with the DMM.

After all set points have been measured for a range, call the niDCPower Cal Adjust Voltage Level VI or the `niDCPower_CalAdjustVoltageLevel` function to calculate updated calibration coefficients. Some notable parameters to this VI/function are specific to adjustment applications and are explained in Table 15. Others are common to many VIs/functions within the NI-DCPower API that are explained in more detail in the programming references included in the *NI DC Power Supplies and SMUs Help*.

Table 15. NI-DCPower Cal Adjust Voltage Level VI/Function Parameter Descriptions

VI/Function Parameter	Description
range	The range to be adjusted with these settings
requested outputs	Array of requested voltage set points required for adjustment of a range. For example, this would be 0, 3, and 6 for the 6 V range on Channel 0.
measured outputs	Array of measurements made by external DMM corresponding to *requested outputs*
number of measurements	The number of elements in *requested outputs* and *measured outputs*

When the new coefficients have been calculated, commit them to the hardware using the process described in the *Considerations* section.

Adjusting Current Output

To adjust current output, compare a set of requested current set points to measurements of the actual current at the output by a DMM voltmeter/precision shunt. Refer to Figure 3 or Figure 4 for the necessary connections.

Table 16 lists the current set points that you must request and measure for each range. For example, the 30 mA range on Channel 0 requires the adjustment application to acquire data from ten set points using a DMM voltmeter/precision shunt with the voltage level set to the maximum value. To calculate the current value using the DMM voltmeter/precision shunt, divide the voltage measured with the DMM by the characterized value of the precision shunt.

To ensure the system has had adequate time to settle while also minimizing self-heating effects of the internal measurement circuitry, wait 3 ms after requesting a new current before taking a measurement with the DMM.

Table 16. NI PXIe-4154 Current Output Adjustment Points

Channel	I Range	Required Adjustment Points					Precision Shunt Value
0	30 mA	0.3 mA	3.6 mA	6.9 mA	10.2 mA	13.5 mA	100 Ω
		16.8 mA	20.1 mA	23.4 mA	26.7 mA	30 mA	
0	3 A	0.030 A	0.327 A	0.624 A	0.921 A	1.218 A	100 mΩ
		1.515 A	1.812 A	2.109 A	2.406 A	2.7 A	
1	1.5 A	0.015A	0.164 A	0.312 A	0.461 A	0.609 A	100 mΩ
		0.758 A	0.906 A	1.055 A	1.203 A	1.35 A	

After all set points have been measured for a range, call the niDCPower Cal Adjust Current Limit VI or the `niDCPower_CalAdjustCurrentLimit` function to calculate updated calibration coefficients. Some parameters to this VI/function are specific to adjustment applications and are explained in Table 17. Others are common to many VIs/functions within the NI-DCPower API that are explained in more detail in the programming references included in the *NI DC Power Supplies and SMUs Help*.

Note Adjust positive and negative current polarities with separate calls to the niDCPower Cal Adjust Current Limit VI or the `niDCPower_CalAdjustCurrentLimit` function.

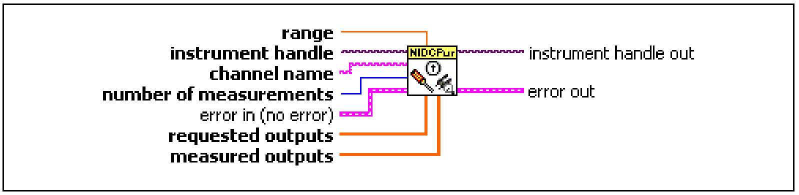

Figure 14. NI-DCPower Cal Adjust Current Limit VI

Table 17. NI-DCPower Cal Adjust Current Limit VI/Function Parameter Descriptions

Parameter	Description
range	The range to be adjusted with these settings
requested outputs	Array of requested currents required for adjustment of a range. For example, this would be the ten set points listed in Table 16 for each range.
measured outputs	Array of measurements made by external DMM corresponding to *requested outputs*.
number of measurements	The number of elements in *requested outputs* and *measured outputs*

When the new coefficients have been calculated, commit them to the hardware using the process described in the *Considerations* section.

Adjusting Voltage Measurement

To adjust voltage measurement, compare a set of voltage set points as measured by an external DMM to the measured voltage reported by the NI PXIe-4154. Refer to Figure 2 for the necessary connections.

Table 18 lists the voltage set points that you must measure and request with both an external DMM and the NI PXIe-4154 to adjust a given range. For example, the 8 V range on Channel 1 requires the adjustment application to separately request 0.1 V, 4 V, and 8 V outputs from the NI PXIe-4154. Take measurements using the external DMM and NI PXIe-4154 at each point.

To ensure the system has had adequate time to settle, wait one second after requesting a new voltage before taking a measurement with the DMM and the NI PXIe-4154.

Table 18. NI PXIe-4154 Voltage Measurement Adjustment Points

Channel	V Range	Required Adjustment Set Points		
0	6 V	0.1 V	3 V	6 V
1	8 V	0.1 V	4 V	8 V

After all set points have been measured for a range, use the niDCPower Cal Adjust Voltage Measurement VI or the `niDCPower_CalAdjustVoltageMeasurement` function to calculate updated calibration coefficients. Some notable parameters to this VI/function are specific to adjustment applications and are explained in Table 19. Others are common to many VIs/functions within the NI-DCPower API that are explained in more detail in the programming references included in the *NI DC Power Supplies and SMUs Help*.

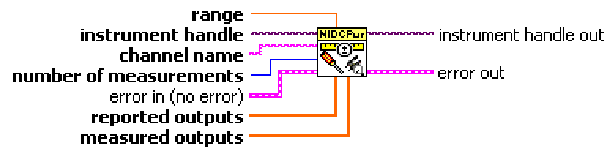

Figure 15. NI-DCPower Cal Adjust Voltage Measurement VI

Table 19. NI-DCPower Cal Adjust Voltage Measurement VI/Function Parameter Descriptions

VI/Function Parameter	Description
range	The range to be adjusted with these settings
reported outputs	Array of measurements taken by the NI PXIe-4154 corresponding to required adjustment set points in Table 18
measured outputs	Array of measurements taken by an external DMM corresponding to *requested outputs*
number of measurements	The number of elements in *requested outputs* and *measured outputs*

When the new coefficients have been calculated, commit them to the hardware using the process described in the *Considerations* section.

Adjusting Output Resistance (Channel 0 Only)

To adjust output resistance, compare a set of requested output resistance set points to measurements of the actual resistance at the output calculated by using two external DMMs and a precision shunt. Use an electronic load to control the output current. Refer to Figure 7 for the necessary connections.

Note Ensure that Remote Sense is enabled during output resistance adjustment.

Table 20 outlines the resistance set points that you must request and measure for each range. For example, Channel 0 requires the adjustment application to separately request 0 Ω, 0.5 Ω, and 0.9 Ω outputs from the NI PXIe-4154. Take measurements using the external DMMs and precision shunt at each output resistance set point.

To ensure the system has had adequate time to settle, wait one second after requesting a new output resistance before taking a measurement with the DMMs. Set the electronic load to an initial constant current of 100 mA. Obtain V_1 and I_1 by measuring the voltage and calculating the current using the external DMMs and precision shunt.

Use the following steps to calculate the output resistance for each set point.

1. Reconfigure the electronic load to a constant current of 1 A. Ensure that Remote Sense on the NI PXIe-4154 remains *ON*.
2. Obtain V_2 and I_2 by measuring the voltage and calculating the current using the external DMMs and precision shunt.
3. Repeat steps 1 and 2 for each output resistance required adjustment point listed in Table 20.
4. Calculate the output resistance at each point using the following formula:

$$\textit{Output Resistance}\ (\Omega) = (V_1 - V_2) / (I_2 - I_1)$$

Note Output resistance is requested on the NI PXIe-4154 using the NI DCPower Property Node.

Table 20. NI PXIe-4154 Output Resistance Adjustment Points

Channel	V Range	V Level	I Limit	Required Adjustment Points		
0	6 V	4 V	3 A	0 Ω	0.5 Ω	0.9 Ω

After all set points have been measured for a range, call the niDCPower Cal Adjust Output Resistance VI or the `niDCPower_CalAdjustOutputResistance` function to calculate updated calibration coefficients. Some notable parameters to this VI/function are specific to adjustment applications and are explained in Table 21. Others are common to many VIs/functions within the NI-DCPower API that are explained in more detail in the programming references included in the *NI DC Power Supplies and SMUs Help*.

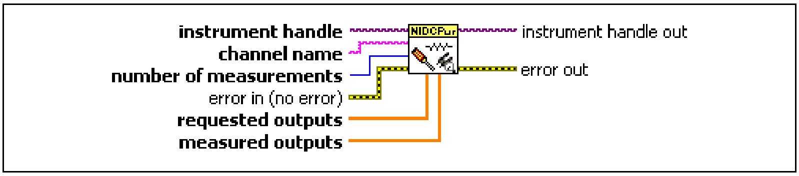

Figure 16. Figure 15. NI-DCPower Cal Adjust Output Resistance VI

Table 21. NI-DCPower Cal Adjust Output Resistance VI/Function Parameter Descriptions

VI/Function Parameter	Description
range	The range to be adjusted with these settings
requested outputs	Array of requested output resistance set points required for adjustment. For example, this would be –0.04 Ω, 0 Ω, and 1 Ω for Channel 0.
measured outputs	Array of measurements made by external DMMs corresponding to *requested outputs*
number of measurements	The number of elements in *requested outputs* and *measured output*s

When the new coefficients have been calculated, commit them to the hardware using the process described in the *Considerations* section.

Where to Go for Support

The National Instruments Web site 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.

National Instruments corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. National Instruments also has offices located around the world to help address your support needs. For telephone support in the United States, create your service request at `ni.com/support` and follow the calling instructions or dial 512 795 8248. For telephone support outside the United States, visit the Worldwide Offices section of `ni.com/niglobal` to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

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