

CALIBRATION PROCEDURE

NI PXIe-4145

PXIe, 4-Channel, ± 6 V, 500 mA Precision PXI Source Measure Unit

This document contains the verification and adjustment procedures for the NI 4145. Refer to ni.com/calibration for more information about calibration solutions.

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

Contents

Verification.....	2
Required Software.....	2
Related Documentation.....	2
Password.....	2
Calibration Interval.....	2
Test Equipment.....	2
Test Conditions.....	3
Calibration Overview.....	4
Self-Calibrating.....	5
Voltage Output and Measurement.....	5
Current Output and Measurement.....	7
Remote Sense.....	9
Adjustment.....	11
Adjusted Specifications.....	11
Self-Calibrating.....	11
Initiating the Adjustment Session.....	11
Connecting and Configuring Equipment for Voltage Adjustment.....	12
Adjusting Voltage Measurement.....	12
Connecting and Configuring Equipment for Current Adjustment.....	13
Adjusting Current Measurement.....	13
Connecting and Configuring Equipment to Adjust Residual Offset Voltage.....	14
Adjusting Residual Voltage Offset.....	15
Adjusting Residual Current Offset.....	15
Closing the Adjustment Session.....	15
Alternative to Adjustment Procedures.....	15
Reverification.....	16
Setting the Calibration Due Date.....	16
Revision History.....	17
NI Services.....	17



Verification

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

Related Information

[Reverification](#) on page 16

Repeat the *Verification* section to determine the as-left status of the device.

Required Software

Calibrating the NI 4145 requires you to install the following software on the calibration system:

- NI-DCPower. The NI 4145 was first supported in NI-DCPower 1.7.5.
- Supported application development environment (ADE)—LabVIEW or LabWindows™/CVI™
- Supported operating system—Windows

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

Related Documentation

You might find the following documents helpful as you perform the calibration procedure:

- *NI DC Power Supplies and SMUs Getting Started Guide*
- *NI DC Power Supplies and SMUs Help*
- *NI PXIe-4145 Specifications*
- *NI-DCPower Readme*

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)	Where Used	Minimum Specifications
Digital multimeter (DMM)	Keysight 3458 A ¹	All parameters	Voltage: $\leq \pm 26$ ppm accuracy and < 1 μ V resolution Current: $\leq \pm 100$ ppm accuracy and < 5 pA resolution
Two 50 Ω resistors	Vishay PTF5650R000BZEK	Voltage remote sense	0.1% tolerance, 1/8 W
500 Ω resistor	Vishay PTF56500R00BYEK	Voltage remote sense	0.1% tolerance, 1/4 W to 1/8 W

Test Conditions

The following setup and environmental conditions are required to ensure the NI 4145 meets published specifications:

- 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 NI 4145, 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 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 NI 4145. The warm-up time ensures that the NI 4145 and test instrumentation are at a stable operating temperature.
- Use shielded copper wire for all cable connections to the module. Use twisted-pair wire to eliminate noise and thermal offsets.
- 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.
- Keep relative humidity between 10% and 70%, noncondensing.

¹ To take measurements in the 10 μ A range with the Keysight 3458A, you must send your device to the Keysight Primary Standards Lab for a special calibration to verify the 10 μ A, 1 μ A, and 100 nA ranges.

- Recalculate the test limits if they differ from the newest device specifications. Test limits in this document are based on the October 2013 edition of the *NI PXIe-4145 Specifications*.
- When making measurements, configure the following aperture time-related settings:
 - Set the **niDCPower Aperture Time** property or `NIDCPOWER_ATTR_APERTURE_TIME` attribute to 2 power-line cycles (PLCs) on the module.
 - Set the **niDCPower Aperture Time Units** property or `NIDCPOWER_ATTR_APERTURE_TIME_UNITS` to power line cycles.
 - Set the **niDCPower Configure Power Line Frequency** property or the `NIDCPOWER_ATTR_POWER_LINE_FREQUENCY` attribute to either 50 or 60 depending on the frequency of the AC power line in your location.
- 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 module that are not specified in calibration procedures are set to their default values.
- When making measurements, configure any specified digital multimeters (DMMs) with the best available levels and limits for each specified test point.
- Disconnect any input signals and perform ACAL ALL function on Keysight 3458A every 24 hours or when the multimeter's temperature changes by ± 1 °C from when it was last externally calibrated or from the last autocal. Use the `TEMP?` command for the current internal temperature and compare it to the calibration temperature from executing the command `CAL? 59` for DCV and `CAL? 60` for OHMS.
- Configure Keysight 3458A to 7 ½ digits of resolution and 10 NPLC.

Temperature conditions specific to verification procedures:

- Maintain an ambient temperature of $23\text{ °C} \pm 5\text{ °C}$. Maintain an internal device temperature range of $T_{\text{cal}} \pm 1\text{ °C}$.²

Temperature conditions specific to adjustment procedures:

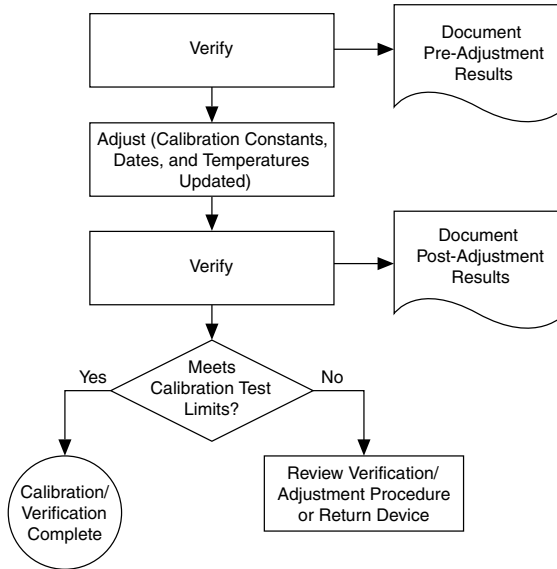
- Maintain an ambient temperature of $23\text{ °C} \pm 1\text{ °C}$. The NI 4145 internal temperature is greater than the ambient temperature.

Calibration Overview

Calibration includes the steps shown in the following figure.

² T_{cal} is the internal device temperature recorded by the NI 4145 at the completion of the last self-calibration. Call the niDCPower Get Self Cal Last Temp VI to query T_{cal} from the NI 4145.

Figure 1. Calibration Overview



1. Initial Setup—Install the NI 4145 and configure it in Measurement & Automation Explorer (MAX) .
2. Verification—Verify the existing operation of the NI 4145.
This step confirms whether the device is operating within the published specifications prior to adjustment.
3. Adjustment—Adjust the calibration constants of the NI 4145.
4. Reverification—Repeat the Verification procedure to ensure that the device is operating within the published specifications after adjustment.

Self-Calibrating

Complete the following steps to self-calibrate the device.

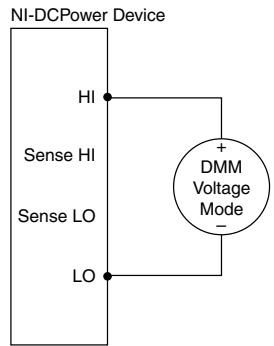
1. Disconnect or disable all connections to the device.
2. Ensure the device had 30 minutes to warm up with the PXI chassis fans set to HIGH.
3. Initialize an NI-DCPower session.
4. Call the self-calibration function.
5. Close the NI-DCPower session.

Voltage Output and Measurement

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 NI 4145.

Verifying Voltage Output and Measurement

Compare a set of voltages measured by the external DMM to both a set of voltage test points requested by the NI 4145 and to the measured voltages reported by the NI 4145.

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	DMM Range	As-Found Output Test Limit (% of Voltage + Offset)	As-Found Measurement Test Limit (% of Voltage + Offset)
6 V	1 mA	-6 V	10 V	0.013% + 200 μ V	0.013% + 200 μ V
		-4.5 V	10 V		
		-3 V	10 V		
		-1.5 V	10 V		
		0 V	100 mV		
		1.5 V	10 V		
		3 V	10 V		
		4.5 V	10 V		
		6 V	10 V		

1. Set the first specified level range, limit range, and limit on the NI 4145.

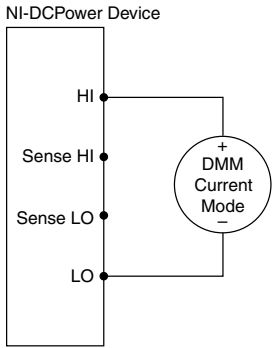
2. Set the level on the NI 4145 to the first specified test point.
3. Take a voltage measurement using the DMM, and take a voltage measurement using the NI 4145.
4. Record the values from the previous step.
5. Calculate the lower and upper voltage output test limits using the following formula: $n = \text{Test Point} \pm (|\text{Test Point}| \times \% \text{ of Voltage} + \text{Offset})$
6. Verify that the recorded DMM value falls within the test limits.
7. Calculate the lower and upper voltage measurement test limits using the following formula: $\text{Voltage Measurement Test Limits} = \text{DMM Measured Voltage} \pm (|\text{DMM Measured Voltage}| \times \% \text{ of Voltage} + \text{Offset})$. Record the test limits.
8. Verify that the recorded NI 4145 value falls within the test limits.
9. 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 NI 4145 up to this step.
10. If more than one level range is specified, repeat the previous steps using the values specified in each level range.

Current Output and Measurement

Connecting and Configuring Equipment for Current Verification

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

Figure 3. Current Verification or Adjustment Connection Diagram



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Current for the NI 4145.

Verifying Current Output and Measurement

Compare a set of currents measured by the external DMM to both a set of current test points requested by the NI 4145 and to the measured currents reported by the NI 4145.

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

Table 3. Current Output and Measurement Verification

Level Range	Limit Range and Limit	Test Point	DMM Range	As-Found Output Test Limit (% of Current + Offset)	As-Found Measurement Test Limit (% of Current + Offset)
10 μ A	6 V	-10 μ A	10 μ A	0.03% + 1.2 nA	0.03% + 1.2 nA
		0 μ A	1 μ A		
		10 μ A	10 μ A		
100 μ A	6 V	-100 μ A	100 μ A	0.03% + 6.0 nA	0.03% + 6.0 nA
		0 μ A	1 μ A		
		100 μ A	100 μ A		
1 mA	6 V	-1 mA	1 mA	0.03% + 60 nA	0.03% + 60 nA
		-750 μ A	1 mA		
		-500 μ A	1 mA		
		-250 μ A	1 mA		
		0 mA	1 μ A		
		250 μ A	1 mA		
		500 μ A	1 mA		
		750 μ A	1 mA		
		1 mA	1 mA		
10 mA	6 V	-10 mA	10 mA	0.03% + 600 nA	0.03% + 600 nA
		0 mA	10 μ A		
		10 mA	10 mA		
100 mA	6 V	-100 mA	100 mA	0.03% + 6.0 μ A	0.03% + 6.0 μ A
		0 mA	100 μ A		
		100 mA	100 mA		

Table 3. Current Output and Measurement Verification (Continued)

Level Range	Limit Range and Limit	Test Point	DMM Range	As-Found Output Test Limit (% of Current + Offset)	As-Found Measurement Test Limit (% of Current + Offset)
500 mA	6 V	-250 mA	1 A	0.1% + 30 μ A	0.1% + 30 μ A
		0 mA	100 μ A		
		250 mA	1 A		

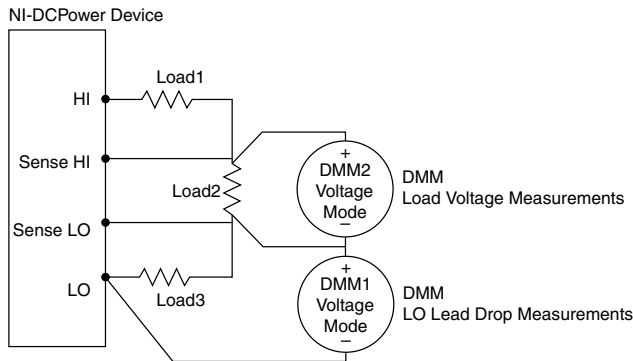
1. Set the first specified level range, limit range, and limit on the NI 4145.
2. Set the level on the NI 4145 to the first specified test point.
3. Take a current measurement using the DMM, and take a current measurement using the NI 4145.
4. Record the values from the previous step.
5. Calculate the lower and upper current output test limits using the following formula:
Current Output Test Limits = Test Point $\pm$ ($|Test Point| \times \% of Current + Offset$)
6. Verify that the recorded DMM value falls within the test limits.
7. Calculate the lower and upper current measurement test limits using the following formula: *Current Measurement Test Limits = DMM Measured Current $\pm$ ($|DMM Measured Current| \times \% of Current + Offset$)*.
8. Verify that the recorded NI 4145 value falls within the test limits.
9. 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 NI 4145 up to this step. For zero current test points, disconnect all external equipment from the I/O connector on the NI 4145 and take a current measurement solely with the NI 4145, in order to ensure that the output current is zero. In calculations for zero current test points, substitute 0 A for the *DMM Measured Current*.
10. If more than one level range is specified, repeat the previous steps using the values specified in each level range.

Remote Sense

Connecting and Configuring Equipment for Voltage Remote Sense Accuracy Verification

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

Figure 4. Voltage Remote Sense Output Verification Connection Diagram



2. Set the **niDCPower Sense** property or `NIDCPOWER_ATTR_SENSE` attribute to **Remote**.
3. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to **DC Voltage** for the NI 4145.

Verifying Voltage Remote Sense Accuracy

Use the NI 4145 in constant voltage 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.

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	DMM Range	Load ₁	Load ₂	Load ₃
6 V	100 mA	5 V	10 V	50 Ω	500 Ω	50 Ω

1. Set the first specified level range, limit range, and limit on the NI 4145.
2. Set the level on the NI 4145 to the first specified test point.
3. Measure the LO lead drop with *DMM1* from the negative terminal of the device to the negative side of *Load2*. Record the measurement as *Lead Drop*.
4. Measure the load voltage with *DMM2* across *Load2* where the sense leads connect. Record the measurement as *Load Voltage*.
5. Calculate the upper and lower voltage remote sense test limits using the following equation: $\text{Voltage Remote Sense Test Limit} = 5 \text{ V} \pm (0.00085 \text{ V} + \text{LO Lead Drop} \times 0.001)$. Record the test limits.
6. Verify the *Load Voltage* measurement falls within the voltage remote sense test limits.
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 NI 4145 up to this step.
8. If more than one level range is specified, repeat the previous steps using the values specified in each level range.

Adjustment

This section describes the steps needed to adjust the NI 4145 to meet published specifications.

Related Information

For information on VIs and functions used in adjustment, refer to the [NI DC Power and SMUs Help](#)

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 NI 4145 ensures that if measurement is accurate, then output is as well, and vice versa.

Self-Calibrating

Complete the following steps to self-calibrate the device.

1. Disconnect or disable all connections to the device.
2. Ensure the device had 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.

Initiating the Adjustment Session

Initiate an external calibration session (a special type of NI-DCPower session) by calling the `niDCPower Initialize External Calibration VI` or `niDCPower_InitExtCal` function.

(Optional) You can close the session and commit the new constants to hardware after you complete each adjustment procedure.

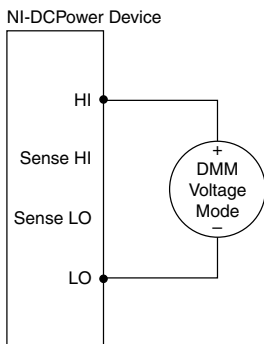
Related Information

[Closing the Adjustment Session](#) on page 15

Connecting and Configuring Equipment for Voltage Adjustment

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

Figure 5. Voltage Verification or Adjustment Connection Diagram



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the NI 4145.

Adjusting Voltage Measurement

Compare a set of measured voltages reported by the NI 4145 to the voltages measured by a DMM. You do not need to separately verify both measurement and output. The architecture of the NI 4145 ensures that if measurement is accurate, then output is as well, and vice versa.

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

Table 5. Voltage Measurement Adjustment

Level Range	Limit Range and Limit	Test Point
6 V	1 mA	6 V
		-6 V

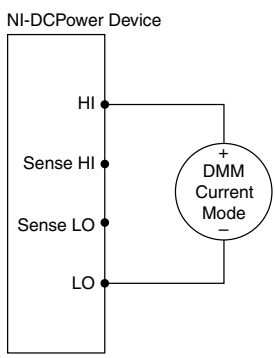
1. Set the first specified level range, limit range, and limit on the NI 4145.
2. Set the level on the NI 4145 to the first specified test point.
3. Take a voltage measurement using the DMM, and take a voltage measurement using the NI 4145.
4. Store the values from the previous step as inputs for the `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 NI 4145 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.

7. Update the measurement calibration constants by configuring and calling the niDCPower Cal Adjust Voltage Measurement VI or niDCPower_CalAdjustVoltageMeasurement function.
- a) Input the DMM measurements as the **measured outputs**.
 - b) Input the NI 4145 measurements as the **reported outputs**.
 - c) Input the specified level range as the **range**.

Connecting and Configuring Equipment for Current Adjustment

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

Figure 6. Current Verification or Adjustment Connection Diagram



2. Set the **niDCPower Output Function** property or NIDCPOWER_OUTPUT_FUNCTION attribute to DC Current for the NI 4145.

Adjusting Current Measurement

Compare a set of measured currents reported by the NI 4145 to the currents measured by an external DMM.

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

Table 6. Current Measurement Adjustment

Level Range	Limit Range and Limit	Test Point
10 μ A	6 V	10 μ A
		-10 μ A
100 μ A	6 V	100 μ A
		-100 μ A

Table 6. Current Measurement Adjustment (Continued)

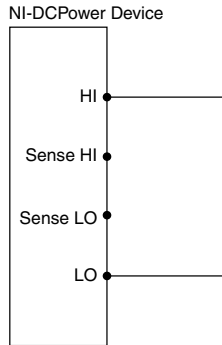
Level Range	Limit Range and Limit	Test Point
1 mA	6 V	1 mA
		-1 mA
10 mA	6 V	10 mA
		-10 mA
100 mA	6 V	100 mA
		-100 mA
500 mA	6 V	500 mA
		-500 mA

1. Set the first specified level range, limit range, and limit on the NI 4145.
2. Set the level on the NI 4145 to the first specified test point.
3. Take a current measurement using the DMM, and take a current measurement using the NI 4145.
4. Store the values from the previous step as inputs 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 NI 4145 up to this step. For zero current test points, disconnect all external equipment from the I/O connector on the NI 4145 and take a current measurement solely with the NI 4145, in order to ensure that the output current is zero. In calculations for zero current test points, substitute 0 A for the *DMM Measured Current*.
6. If more than one level range is specified, repeat the previous steps using the values specified in each level range.
7. Update the measurement calibration constants by configuring and calling the VI niDCPower Cal Adjust Current Measurement or niDCPower_CalAdjustCurrentMeasurement function.
 - a) Input the DMM measurements as the **measured outputs**.
 - b) Input the NI 4145 measurements as the **reported outputs**.
 - c) Input the specified level range as the **range**.

Connecting and Configuring Equipment to Adjust Residual Offset Voltage

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

Figure 7. Residual Voltage Adjustment Diagram



2. Set the **niDCPower Output Function** property or `NIDCPOWER_OUTPUT_FUNCTION` attribute to DC Voltage for the NI 4145.

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.

Adjusting Residual Current Offset

1. Disconnect all equipment from the output of the NI 4145.
2. Eliminate offset current at 0 A by configuring and calling the `niDCPower Cal Adjust Residual Current Offset VI` or `niDCPower_CalAdjustResidualCurrentOffset` 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 Adjustment Procedures

If your device passes all 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 one of the following:
 - `niDCPower Initialize External Calibration VI`
 - `niDCPower_InitExtCal` function

2. Call one of the following, specifying Commit in **calibration close action**:
 - niDCPower Close External Calibration VI
 - niDCPower_CloseExtCal function

Reverification

Repeat the *Verification* section to determine the as-left status of the device.



Note If no as-left test limits are specified in a procedure, reuse the as-found test limits.



Note If any test fails reverification after performing an adjustment, verify that you have met the *Test Conditions* before returning your device to NI. Refer to the *Worldwide Support and Services* section for information about support resources or service requests.

Related Information

[Test Conditions](#) on page 3

[Verification](#) on page 2

Setting the Calibration Due Date

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

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

Revision History

Revision	Edition Date	Section	Changes
375064B-01	November 2020	Required Equipment for Calibration	The recommended DMM was changed from the Agilent 3458A to the Keysight 3458A.
		Voltage Output and Measurement, Current Output and Measurement, Remote Sense	DMM range was added to all verification tables.

NI Services

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

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

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

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

Information is subject to change without notice. Refer to the *NI Trademarks and Logo Guidelines* at ni.com/trademarks for information on NI trademarks. Other product and company names mentioned herein are trademarks or trade names of their respective companies. For patents covering NI products/technology, refer to the appropriate location: **Help»Patents** in your software, the `patents.txt` file on your media, or the *National Instruments Patent Notice* at ni.com/patents. You can find information about end-user license agreements (EULAs) and third-party legal notices in the readme file for your NI product. Refer to the *Export Compliance Information* at ni.com/legal/export-compliance for the NI global trade compliance policy and how to obtain relevant HTS codes, ECCNs, and other import/export data. NI MAKES NO EXPRESS OR IMPLIED WARRANTIES AS TO THE ACCURACY OF THE INFORMATION CONTAINED HEREIN AND SHALL NOT BE LIABLE FOR ANY ERRORS. U.S. Government Customers: The data contained in this manual was developed at private expense and is subject to the applicable limited rights and restricted data rights as set forth in FAR 52.227-14, DFAR 252.227-7014, and DFAR 252.227-7015.

© 2013—2020 National Instruments Corporation. All rights reserved.

375064B-01 October 16, 2020