

# CALIBRATION PROCEDURE

# SCXI™-1122

This document contains information and step-by-step instructions for calibrating the National Instruments SCXI-1122 module.

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# Introduction

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## What Is Calibration?

*Calibration* consists of verifying the measurement accuracy of a module and adjusting for any measurement error. *Verification* is measuring the performance of the module and comparing these measurements to the factory specifications. During calibration, you supply and read voltage levels using external standards, then you adjust the module calibration constants. The new calibration constants are stored in the EEPROM. These calibration constants are loaded from memory as needed to adjust for the error in the measurements taken by the module.

## Why Should You Calibrate?

The accuracy of electronic components drifts with time and temperature, which can affect measurement accuracy as a module ages. Calibration restores these components to their specified accuracy and ensures that the module still meets NI standards.

## How Often Should You Calibrate?

The measurement requirements of your application determine how often you must calibrate the SCXI-1122 module to maintain accuracy. NI recommends that you perform a complete calibration at least once every year. You can shorten this interval to 90 days or six months based on the demands of your application.

## Equipment and Other Test Requirements

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This section describes the test equipment, software, documentation, and test conditions required for calibrating the SCXI-1122 module.

### Test Equipment

Calibration requires a high-precision voltage source with at least 50 ppm accuracy, a multiranging 5 1/2-digit digital multimeter (DMM) with 15 ppm accuracy, a 15  $\Omega \pm 10\%$  resistor, and a 16-bit NI E Series data acquisition (DAQ) device.

## Instruments

NI recommends the following instruments for calibrating the SCXI-1122 module:

- Calibrator—Fluke 5700A
- DMM—NI 4060 or HP 34401A

If these instruments are not available, use the accuracy requirements listed above to select substitute calibration instruments.

## Connectors

If you do not have custom connection hardware, you need the following equipment:

- SCXI-1322 terminal block
- Shielded 68-pin connector cable
- 50-pin ribbon cable
- 50-pin breakout box
- SCXI-1349 adapter

These components give easy access to the individual pins on the SCXI-1122 module front and rear connectors.

## Software and Documentation

This section describes the software and documentation you need to calibrate the SCXI-1122 module.

### Software

This calibration procedure requires the latest version of the Traditional NI-DAQ (Legacy) driver software on the calibration system. The driver supports a number of programming languages, including LabVIEW and Measurement Studio. If you do not have the latest version of Traditional NI-DAQ (Legacy), you can download it from the NI Web site at [ni.com/download](http://ni.com/download). When you install the driver, you only need to install support for the programming language used in your application.

### Documentation

- *Traditional NI-DAQ Function Reference Help*
- *Traditional NI-DAQ User Manual*

The *Traditional NI-DAQ Function Reference Help* and the *Traditional NI-DAQ User Manual* contain detailed information about using Traditional NI-DAQ (Legacy). The help file includes detailed information about the

driver functions. You can access the help file by selecting **Start»All Programs»National Instruments»NI-DAQ»Traditional NI-DAQ Function Reference Help**.

The user manual provides instructions on installing and configuring NI-DAQ devices. It also includes detailed information about creating applications that use Traditional NI-DAQ (Legacy). You can access the user manual by selecting **Start»All Programs»National Instruments»NI-DAQ»Traditional NI-DAQ User Manual**.

These documents are your primary references for writing your calibration utility. For more information about the products you are calibrating, refer to the device documentation.

## Test Conditions

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

- Keep connections to the SCXI-1122 module and the terminal block short. Long cables and wires act as antennae, picking up extra noise and thermal offsets that can affect measurements.
- Use shielded copper wire for all cable connections to the device. Use twisted-pair wire to eliminate noise and thermal offsets.
- Maintain the temperature between 18 °C and 28 °C.
- Keep relative humidity below 80%.
- Allow a warm-up time of at least 15 minutes for the SCXI-1122 module and 30 minutes for the E Series DAQ device to ensure the measurement circuitry is at a stable operating temperature.

## Calibration

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The calibration process has the following steps:

1. Set up the SCXI-1122 module for verification.
2. Verify the existing operation of the module to determine whether the module is operating within its test limits.
3. Adjust the module with respect to a known voltage source.
4. Verify that the module is operating within its test limits after adjustments.

## Setting Up the Module

Complete the following steps to set up the SCXI-1122 module for verification:

1. Install the SCXI-1122 module in slot 4 of the SCXI chassis.
2. Connect a 68-to-68-pin cable between the SCXI-1122 module and the E Series DAQ device.
3. Configure the hardware with Measurement & Automation Explorer (MAX). For more information about configuring the calibration system, refer to the E Series DAQ device and SCXI-1122 module documentation.

## Verifying the Operation of the Module

These verification procedures determine how well the SCXI-1122 module is meeting its test limits. You can use this information to select the appropriate calibration interval for your application.

### Verifying Analog Input Offsets

Complete the following steps to verify the analog input offsets:

1. Read the *Test Conditions* section in this document.
2. Refer to Table 3 for the limits to verify. Although NI recommends verifying all ranges and gains, you can save time by checking only those ranges used in your application.
3. Ensure that the E Series DAQ device is connected to the SCXI-1122 module.
4. Call `Calibrate_E_Series` to minimize the uncertainty associated with the E Series DAQ device. Set the following parameters:
  - **deviceNumber**—The value assigned by MAX
  - **calOp**—`ND_SELF_CALIBRATE`
  - **setOfCalConstants**—`ND_USER_EEPROM_AREA`
  - **calRefVolts**—0.0
5. Call `AI_Configure` to set the E Series DAQ device in bipolar mode. Set the following parameters:
  - **deviceNumber**—The value assigned by MAX
  - **chan**—0
  - **inputMode**—0
  - **inputRange**—0
  - **polarity**—0
  - **driveAIS**—0

6. Call `MIO_Config` to enable dithering on the E Series DAQ device. Set the following parameters:
  - **deviceNumber**—The value assigned by MAX
  - **dither**—1
  - **useAmux**—0
7. Call `SCXI_Configure_Filter` to configure the filter mode of the SCXI-1122 module. Set the following parameters:
  - **assigned bySCXIchassisId**—The value assigned by MAX
  - **moduleSlot**—1
  - **channel**— -1
  - **filterMode**—1
  - **freq**—4.0
  - **cutoffDivDown**—0
  - **and outClkDivDown**—2
  - **ActualFreq**—This is a return value
8. Call `SCXI_Single_Chan_Setup` to configure the SCXI-1122 module for single channel measurements. Set the following parameters:
  - **SCXIchassisID**—The value assigned by MAX
  - **moduleSlot**—1
  - **moduleChan**—0
  - **DAQdeviceNumber**—The device number assigned by MAX for the E Series DAQ device
9. Call `SCXI_Calibrate_Setup` to auto-zero the SCXI-1122 module. Set the following parameters:
  - **SCXIchassisID**—The value assigned by MAX
  - **moduleSlot**—1
  - **calOp**—2
10. Call `SCXI_Set_Gain` to set the selected gain on the SCXI-1122 module. Set the following parameters:
  - **SCXIchassisID**—The value assigned by MAX
  - **moduleSlot**—1
  - **channel**— -1
  - **gain**—The gain value you want to test  
Acceptable gain values are listed in Table 3.

11. If you have an SCXI-1322 terminal block, connect the calibrator to the CH0+ and CH0– inputs of the terminal block. If you are not using a terminal block, connect the calibrator to analog input channel 0.

Refer to Table 1 to determine the pins on the 96-pin front connector that correspond to the positive and negative inputs of the specified channel. For example, the positive input for channel 0 is pin A32, which is labeled CH0+. The negative input for channel 0 is pin C31, which is labeled CH0–.

**Table 1.** SCXI-1122 Front Connector Pin Assignments

Pin Number	Column A	Column B	Column C
32	NC	CH0+	NC
31	RSVD	NC	CH0–
30	NC	CH1+	NC
29	NC	NC	CH1–
28	NC	CH2+	NC
27	NC	NC	CH2–
26	NC	CH3+	NC
25	NC	NC	CH3–
24	NC	CH4+	NC
23	IEX+	NC	CH4–
22	NC	CH5+	NC
21	IEX–	NC	CH5–
20	NC	CH6+	NC
19	VEX+	NC	CH6–
18	NC	CH7+	NC
17	SENSE+	NC	CH7–
16	NC	CH8+	NC
15	SENSE–	NC	CH8–
14	NC	CH9+	NC
13	VEX–	NC	CH9–
12	NC	CH10+	NC

**Table 1.** SCXI-1122 Front Connector Pin Assignments (Continued)

Pin Number	Column A	Column B	Column C
11	VEX/2	NC	CH10–
10	NC	CH11+	NC
9	NC	NC	CH11–
8	NC	CH12+	NC
7	+5 V	NC	CH12–
6	NC	CH13+	NC
5	NC	NC	CH13–
4	NC	CH14+	NC
3	TEMP+	NC	CH14–
2	NC	CH15+	NC
1	TEMP–	NC	CH15–
NC — No connect			

12. Set the calibrator voltage to the Test Point value in Table 3 that corresponds to the gain from step 10.
13. Call `DAQ_Op` to retrieve measurement data from the SCXI-1122 module.  
Set the following parameters:
  - **deviceNumber**—The value assigned by MAX
  - **chan**—0
  - **gain**—1
  - **count**—100
  - **sampleRate**—100
 The data is returned to the buffer variable.
14. Call `SCXI_Scale` to convert the acquired readings into scaled voltage values. Set the following parameters:
  - **SCXIChassisID**—The value assigned by MAX
  - **moduleSlot**—0
  - **channel**—0
  - **SCXIgain**—The gain from step 10
  - **TBgain**—1
  - **DAQBoard**—The value assigned by MAX



- **DAQchannel**—0
- **DAQgain**—1
- **numPoints**—100

Average the resulting scaled data to obtain the final voltage measurement.

15. Compare the measurement result to the upper and lower limits shown in Table 3. If the measurement value falls between the Upper Limit and Lower Limit values, the SCXI-1122 module passed the test.
16. Repeat steps 5 through 15 for the two other test points of the gain setting. You only need to check channel 0 on the SCXI-1122 module because all inputs are multiplexed back through the same amplifier and filter combination.
17. Repeat steps 5 through 16 for each of the remaining gain settings. After you have checked all gains for Table 3, continue with step 18.
18. Repeat steps 4 through 17 using Table 3, but set the **freq** input to 4000.0 in step 7.



**Note** If all channels fall within the upper and lower limits, the module does *not* need adjustment.

You have completed verifying the analog input offsets of the SCXI-1122 module.

## Verifying Excitation Limits

Complete the following steps to verify the excitation limits:

1. Connect a 15  $\Omega$  resistor between VEX+ and VEX– on the front of the SCXI module.



**Note** If you are not using the SCXI-1322 terminal block, make sure that the SENSE+ terminal is connected to the VEX+ terminal and the SENSE– terminal to the VEX– terminal.

2. Set the DMM to voltage mode and connect it across the resistor.
3. Compare the DMM reading to the upper and lower limits for voltage excitation shown in Table 2. If the reading falls between the Upper Limit and Lower Limit values, the SCXI-1122 module passed the test.

**Table 2.** Excitation Test Limits

<b>Excitation Type</b>	<b>Test Point</b>	<b>Upper Limit</b>	<b>Lower Limit</b>
Voltage	3.333 V	3.3343 V	3.3317 V
Current	1.00 mA	1.0004 mA	0.9996 mA

4. Set the DMM to current mode and connect it between the IEX+ and IEX– pins of the SCXI-1122 module.
5. Compare the DMM reading to the upper and lower limits for the current excitation shown in Table 2. If the reading falls between the Upper Limit and Lower Limit values, the SCXI-1122 module passed the test.

## Adjusting the Module

This section contains three adjustment procedures: one for adjusting gain and offset errors, one for adjusting calibration constants, and one for adjusting excitation.

### Adjusting Gain and Offset Errors

Complete the following steps to adjust gain and offset errors:

1. Ensure that the E Series DAQ device is connected to the SCXI-1122 module.
2. Call `SCXI_Configure_Filter` to configure the filter mode of the SCXI-1122 module. Set the following parameters:
  - **SCXIchassisId**—The value assigned by MAX
  - **moduleSlot**—1
  - **channel**—–1
  - **filterMode**—1
  - **freq**—4.0
  - **cutoffDivDown**—0
  - **outClkDivDown**—2
  - **ActualFreq**—This is a return value

3. Call `SCXI_Single_Chan_Setup` to configure the SCXI-1122 module for single channel measurements. Set the following parameters:
  - **SCXIchassisID**—The value assigned by MAX
  - **moduleSlot**—1
  - **moduleChan**—0
  - **DAQdeviceNumber**—The device number assigned by MAX for the E Series DAQ device
  
4. Call `SCXI_Calibrate_Setup` to auto-zero the SCXI-1122 module. Set the following parameters:
  - **SCXIchassisID**—The value assigned by MAX
  - **moduleSlot**—1
  - **calOp**—2
  
5. Call `SCXI_Set_Gain` to set the selected gain on the SCXI-1122 module. Set the following parameters:
  - **SCXIchassisID**—The value assigned by MAX
  - **moduleSlot**—0
  - **channelSet**— -1
  - **gainSet**—The first gain value you want to adjust

Acceptable gain values are listed in Table 3.
  
6. Connect the calibrator to analog input channel 0. If you are using an SCXI-1322 terminal block connected to the SCXI-1122 module, connect the calibrator to the CH0+ and CH0- inputs.
 

Refer to Table 1 to determine the pins on the 96-pin front connector that correspond to the positive and negative inputs of the specified channel. For example, the positive input for channel 0 is pin A32, which is labeled *CH0+*. The negative input for channel 0 is pin C31, which is labeled *CH0-*.
  
7. Connect the DMM to the output of channel 0 by using the 50-pin breakout connector on the SCXI-1349 adapter.
 

Refer to Figure 1 to determine the pins on the 50-pin rear connector that correspond to the positive and negative outputs for the specified channel. For example, the positive output for channel 0 is pin 3, which is labeled *MCH0+*. The negative output for channel 0 is pin 4, which is labeled *MCH0-*.

AOGND	1	2	AOGND
MCH0+	3	4	MCH0-
	5	6	
	7	8	
	9	10	
	11	12	
	13	14	
	15	16	
	17	18	
OUTREF	19	20	
	21	22	
	23	24	DIGGND
SERDATIN	25	26	SERDATOUT
DAQD*/A	27	28	
SLOT0SEL	29	30	
	31	32	
DIGGND	33	34	
	35	36	SCANCLK
SERCLK	37	38	
	39	40	
	41	42	
RSVD	43	44	
	45	46	RSVD
	47	48	
	49	50	

**Figure 1.** SCXI-1122 Rear Connector Pin Assignments

8. Set the calibrator voltage to the test point value specified by the Test Point entry on Table 3.
9. Read the voltage from the DMM. Record the actual DMM reading, which is *output1*, and the calibrator output voltage, which is *volt1*, for later use.
10. Set the calibrator to the negative test point value for the same gain. Skip any test point voltages that are specified as 0 V. You need only upper and lower limits for adjustment.
11. Read the voltage from the DMM. Record the actual DMM reading, which is *output2*, and the calibrator output voltage, which is *volt2*, for later use.

- Convert the DMM voltage reading to a binary reading by using one of the following equations:

$$\text{binary reading for 12-bit products} = \left( \frac{\text{DMM voltage} \times \text{gain}}{20} \right) \times 2^{12}$$

$$\text{binary reading for 16-bit products} = \left( \frac{\text{DMM voltage} \times \text{gain}}{20} \right) \times 2^{16}$$

For example, using a 12-bit product, such as a PCI-MIO-16E-1, and obtaining a DMM reading of 9.9 V, you would have the following equation:

$$\text{binary reading} = (9.9/20) \times 2^{12} = 2027.52$$

Repeat steps 5 through 12 for the remaining input ranges.

When you are finished, you have a table of calibrator voltages and the corresponding binary readings.

You have now finished adjusting the offset and gain errors on the SCXI-1122 module.

## Adjusting Calibration Constants

Complete the following steps to adjust the calibration constants:

- Call `SCXI_Cal_Constants` to create and store the new calibration constants in the memory of the SCXI-1122 module. Call this function for each gain setting. Set the following parameters:
  - **SCXIchassisID**—The ID assigned by MAX
  - **ModuleSlot**—1, unless you have installed the module in a different slot
  - **channel**—-1
  - **opCode**—2
  - **calibrationArea**—0
  - **rangeCode**—0 (not used for the SCXI-1122 module)
  - **SCXIgain**—The appropriate gain for the pair of constants you are about to save on the SCXI-1122 module
  - **DAQboard**—Device number assigned by MAX
  - **DAQChan**—0
  - **DAQGain**—1 for 16-bit devices, -1 for 12-bit devices
  - **Tbgain**—1

- **volt1** and **volt2**—The first and second calibrator voltage readings for the gain values you are saving on the SCXI-1122 module
- **binary1** and **binary2**—The first and second binary readings for the gain values you are saving on the SCXI-1122 module
- **calConst1** and **calConst2**—These are return values

Repeat this step with **calibrationArea** set to 1, and then again with **calibrationArea** set to 3.

2. Repeat step 1 for all remaining gain values.

You have now finished adjusting the calibration constants of the SCXI-1122 module.

## Adjusting Excitation Limits

Complete the following steps to adjust the excitation limits:

1. Refer to Table 2 for the specific limits to test.
2. Ensure that the E Series DAQ device is connected to the SCXI-1122 module.
3. Connect a 15  $\Omega$  resistor to the VEX+ and VEX– pins, which make up the voltage excitation channel.



**Note** If you are not using the SCXI-1322 terminal block, make sure that the SENSE+ terminal is connected to the VEX+ terminal and the SENSE– terminal to the VEX– terminal.

4. Set the DMM to voltage mode and connect it across the 15  $\Omega$  load.
5. Measure the voltage and use the measurement as **calConst2**.
6. Set the DMM to DC current mode and connect it across the current excitation channel (pin IEX+ and IEX–).
7. Measure the DC current and use the measurement as **calConst1**.
8. Call `SCXI_Cal_Constants` to create and store the new calibration constants. Set the following parameters:
  - **SCXIchassisID**—The ID assigned by MAX
  - **ModuleSlot**—1, unless the module is in a different slot
  - **channel**—–2
  - **opCode**—3
  - **calibrationArea**—0
  - **rangeCode**—0 (not used for the SCXI-1122 module)
  - **SCXIgain**—0
  - **DAQboard**—Device number assigned by MAX

- **DAQChan**—0
- **DAQGain**—1
- **Tbgain**—1
- **volt1**—0
- **binary1**—0
- **volt2**—0
- **binary2**—0
- **calConst1**—This is the value obtained in step 7
- **calConst2**—This is the value obtained in step 5

Repeat this step with **calibrationArea** set to 1, and again with **calibrationArea** set to 3.

You have now finished adjusting the excitation channels of the SCXI-1122 module.

## Verifying Adjusted Values

After you complete the adjustment procedure, it is important that you verify the accuracy of the adjusted values by repeating the procedure in the [Verifying the Operation of the Module](#) section. Verifying the adjusted values ensures the SCXI-1122 module is operating within its test limits after adjustments.

## Test Limits

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Table 3 contains test limits for the SCXI-1122 module. If the module was calibrated within the last year, the output from the module should fall between the Upper Limit and Lower Limit values.

**Table 3. SCXI-1122 Module Test Limits**

Gain	Test Point (V) <sup>1</sup>	4 Hz Ranges		4 kHz Ranges	
		Upper Limit (V)	Lower Limit (V)	Upper Limit (V)	Lower Limit (V)
0.0100	245.0000	245.6546212	244.3453788	245.6645421	244.3354579
	0.0000	0.280261209	-0.280261209	0.290182066	-0.290182066
	-245.0000	-244.3453788	-245.6546212	-244.3354579	-245.6645421
0.0200	245.0000	245.5146676	244.4853324	245.519628	244.480372
	0.0000	0.140307605	-0.140307605	0.145268033	-0.145268033
	-245.0000	-244.4853324	-245.5146676	-244.480372	-245.519628
0.0500	98.0000	98.20607944	97.79392056	98.20806361	97.79193639
	0.0000	0.056335442	-0.056335442	0.058319613	-0.058319613
	-98.0000	-97.79392056	-98.20607944	-97.79193639	-98.20806361
0.1000	49.0000	49.10321672	48.89678328	49.10420881	48.89579119
	0.0000	0.028344721	-0.028344721	0.029336807	-0.029336807
	-49.0000	-48.89678328	-49.10321672	-48.89579119	-49.10420881
0.2000	24.5000	24.55178536	24.44821464	24.5522814	24.4477186
	0.0000	0.01434936	-0.01434936	0.014845403	-0.014845403
	-24.5000	-24.44821464	-24.55178536	-24.4477186	-24.5522814
0.5000	9.8000	9.820926544	9.779073456	9.821124961	9.778875039
	0.0000	0.005952144	-0.00592144	0.006150561	-0.006150561
	-9.8000	-9.779073456	-9.820926544	-9.778875039	-9.821124961
1.0000	4.9000	4.905639272	4.894360728	4.905738481	4.894261519
	0.0000	0.002807072	-0.002807072	0.002906281	-0.002906281
	-4.9000	-4.894360728	-4.905639272	-4.894261519	-4.905738481
2.0000	2.4500	2.452823636	2.447176364	2.45287324	2.44712676
	0.0000	0.001407536	-0.001407536	0.00145714	-0.00145714
	-2.4500	-2.447176364	-2.452823636	-2.44712676	-2.45287324
5.0000	0.9800	0.981134254	0.978865746	0.981154096	0.978845904
	0.0000	0.000567814	-0.000567814	0.000587656	-0.000587656
	-0.9800	-0.978865746	-0.1981134254	-0.978845904	-0.981154096
10.0000	0.49	0.490571127	0.489428873	0.490581048	0.489418952
	0.0000	0.000287907	-0.000287907	0.000297828	-0.000297828
	-0.49	-0.489428873	-0.490571127	-0.489418952	-0.490581048



**Table 3. SCXI-1122 Module Test Limits (Continued)**

Gain	Test Point (V) <sup>1</sup>	4 Hz Ranges		4 kHz Ranges	
		Upper Limit (V)	Lower Limit (V)	Upper Limit (V)	Lower Limit (V)
20.0000	0.2450	0.245289564	0.244710436	0.245300686	0.244699314
	0.0000	0.000147954	-0.000147954	0.000159076	-0.000159076
	-0.245	-0.244710436	-0.245289564	-0.244699314	-0.245300686
50.0000	0.0980	0.098121183	0.097878817	0.098131902	0.097868098
	0.0000	6.45391E-05	-6.45391E-05	7.52582E-05	-7.52582E-05
	-0.098	-0.097878817	-0.098121183	-0.097868098	-0.098131902
100.0000	0.0490	0.049065034	0.048934966	0.049069951	0.048930049
	0.0000	3.6712E-05	-3.6712E-05	4.16291E-05	-4.16291E-05
	-0.0490	-0.048934966	-0.049065034	-0.048930049	-0.049069951
200.0000	0.0245	0.024536751	0.024463249	0.024538976	0.024461024
	0.0000	2.25901E-05	-2.25901E-05	2.48145E-05	-2.48145E-05
	-0.0245	-0.024463249	-0.024536751	-0.024461024	-0.024538976
500.0000	0.0098	0.009819644	0.009780356	0.00982039	0.00977961
	0.0000	1.39798E-05	-1.39798E-05	1.47258E-05	-1.47258E-05
	-0.0098	-0.009780356	-0.009819644	-0.00977961	-0.00982039
1000.0000	0.0049	0.004913822	0.004886178	0.004914195	0.004885805
	0.0000	1.09899E-05	-1.09899E-05	1.13629E-05	-1.13629E-05
	-0.0049	-0.004886178	-0.004913822	-0.004885805	-0.004914195
2000.0000	0.00245	0.002460984	0.002439016	0.002461098	0.002438902
	0.0000	9.56784E-06	-9.56784E-06	9.68145E-06	-9.68145E-06
	-0.00245	-0.002439016	-0.002460984	-0.002438902	-0.002461098

<sup>1</sup> The *test point* is the voltage value that you use for verification purposes.

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