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CALIBRATION PROCEDURE

NI 5105

This document contains instructions for writing an external calibration procedure for the NI PXI/PXIe/PCI-5105. For more information about calibration, visit `ni.com/calibration`.

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NATIONAL INSTRUMENTS

Software

To calibrate the NI 5105, install the following versions of NI-SCOPE.

Table 1. Required Software for NI 5105 Calibration

Device	NI-SCOPE Version
NI PXI-5105	3.1 or later
NI PCI-5105	3.2 or later
NI PXIe-5105	14.1 or later

You can download NI-SCOPE from the Instrument Driver Network at `ni.com/idnet`. NI-SCOPE supports programming the *Self-Calibration* and *Verification* sections in a number of programming languages; however, only LabVIEW and C are supported for the *Adjustment* section of this procedure.

NI-SCOPE includes all the functions and attributes necessary for calibrating the NI 5105. LabVIEW support is installed in `niScopeCal.llb`, and all calibration functions appear in the function palette. For LabWindows™/CVI™, the NI-SCOPE function panel `niScopeCal.fp` provides further help on the functions available in CVI. Refer to Table 2 for installed file locations.

Calibration functions are LabVIEW VIs or C function calls in the NI-SCOPE driver. The C function calls are valid for any compiler capable of calling a 32-bit DLL. Many of the functions use constants defined in the `niScopeCal.h` file. To use these constants in C, you must include `niScopeCal.h` in your code when you write the calibration procedure.

For more information on the calibration VIs and functions, refer to the *NI-SCOPE Function Reference Help* or the *NI-SCOPE LabVIEW Reference Help*. These references can be found in the *NI High-Speed Digitizers Help*. Refer to the *NI-SCOPE Readme* for the installed locations of these documents.

Table 2. Calibration File Locations after Installing NI-SCOPE

File Name and Location	Description
`IVI\Bin\niscope_32.dll`	NI-SCOPE driver containing the entire NI-SCOPE API, including calibration functions
`IVI\Lib\msc\niscope.lib`	NI-SCOPE library for Microsoft C containing the entire NI-SCOPE API, including calibration functions
`<LabVIEW>\examples\instr\niScope`	Directory of LabVIEW NI-SCOPE example VIs, including self-calibration.

Table 2. Calibration File Locations after Installing NI-SCOPE (Continued)

File Name and Location	Description
<LabVIEW>\instr.lib\niScope\Calibrate\niScopeCal.llb	LabVIEW VI library containing VIs for calling the NI-SCOPE calibration API.
IVI\Drivers\niScope\niScopeCal.fp	CVI function panel file that includes external calibration function prototypes and help on using NI-SCOPE in the CVI environment.
IVI\Include\niScopeCal.h	Calibration header file, which you must include in any C program accessing calibration functions. This file automatically includes niScope.h, which defines the rest of the NI-SCOPE interface.
IVI\Drivers\niScope\Examples	Directory of NI-SCOPE examples for CVI, C, Visual C++, and Visual Basic.

Documentation

Consult the following documents for information about the NI PXI/PXIe/PCI-5105, NI-SCOPE, and your application software. All documents are available on ni.com, and the Help files install with the software.

NI High-Speed Digitizers Getting Started Guide

Contains: NI-SCOPE installation, hardware installation, and hardware programing

NI 5105 Specifications

Contains: NI PXI/PXIe/PCI-5105 specifications and calibration intervals

NI-SCOPE Readme

Contains: Operating system and application software support in NI-SCOPE

NI High-Speed Digitizers Help

Contains: Detailed information about the NI PXI/PXIe/PCI-5105

NI-SCOPE LabVIEW Reference Help

Contains: LabVIEW programming concepts and reference information about NI-SCOPE VIs and functions

NI-SCOPE Function Reference Help

Contains: Reference information for NI-SCOPE C functions and NI-SCOPE C properties

Password

The default calibration password is `NI`.

Calibration Interval

External Calibration

The external calibration interval for the NI 5105 is two years; however, the measurement accuracy requirements of your application determine how often you should perform external calibration. You can shorten this interval based on your application. Refer to *Appendix A: Calibration* for more information.

Self-Calibration

Self-calibration can be performed whenever necessary to compensate for environmental changes.

Caution Although you can use self-calibration repeatedly, self-calibrating the NI 5105 more than a few times a day may cause excessive wear on the relays over time.

Test Equipment

Table 3 lists the equipment required for externally calibrating the NI 5105. If you do not have the recommended instruments, use these specifications to select a substitute calibration standard.

Table 3. Required Equipment Specifications for NI 5105 External Calibration

Required Equipment	Recommended Equipment	Parameter Measured	Specification
Signal Generator	Fluke 9500B Oscilloscope Calibrator or Wavetek 9500 (with high-stability reference option) Fluke 9510 Test Head	DC Accuracy	DC ±(0.025% + 25 µV) into 1 MΩ or 50 Ω
		Bandwidth	±2% output amplitude flatness for leveled sine wave up to 60 MHz relative to 50 kHz into 50 Ω
		Timing	±2 ppm frequency accuracy
BNC to SMB adapter	—	—	50 Ω

Note The delay times indicated in this procedure apply specifically to the Fluke 9500B calibrator. If you use a different calibrator, you may need to adjust these delay times.

Calibration Procedures

The calibration process includes the following steps:

1. *Initial Setup*—Install the device and configure it in Measurement & Automation Explorer (MAX).
2. *Adjust the Digital Clock Manager (DCM)*—Complete this mandatory adjustment periodically, even if you do not do a complete calibration.
3. *Self-Calibration*—Adjust the self-calibration constants of the device.
4. *Verification*—Verify the existing operation of the device. This step confirms whether the device is operating within its specified range prior to calibration.
5. *Adjustment*—Perform an external adjustment of the device that adjusts the calibration constants with respect to a known reference. The adjustment procedure automatically stores the calibration date on the EEPROM to allow traceability.
6. *Reverification*—Repeat the verification procedure to ensure that the device is operating within its specifications after adjustment.

These steps are described in more detail in the following sections.

Note In some cases, the complete calibration procedure may not be required. Refer to *Appendix A: Calibration* for more information.

Initial Setup

Refer to the *NI High-Speed Digitizers Getting Started Guide* for information about how to install the software and hardware, and how to configure the device in MAX.

Test Conditions

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

- Always connect the calibrator test head directly to the input SMB of the device using the BNC to SMB adapter. Long cables and wires act as antennas, picking up extra noise that can affect measurements.

Note Make sure the calibration test head has mechanical support to prevent unnecessary strain on the SMB connector of the device.

- Keep relative humidity between 10 and 90% non-condensing, or consult the device hardware specifications for the optimum relative humidity.
- Maintain an ambient temperature of 23 ±5 °C. The device temperature will be greater than the ambient temperature.
- Allow a warm-up time of at least 15 minutes after the NI-SCOPE driver is loaded. Unless manually disabled, the NI-SCOPE driver automatically loads with the operating system and enables the device. The warm-up time ensures that the measurement circuitry of the NI 5105 is at a stable operating temperature.
- Plug the PXI chassis or PC and the calibrator into the same power strip to avoid ground loops.
- **(PXI/PXIe)** Ensure that the PXI chassis fan speed is set to HIGH, 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`.
- Verify that all connections to the device, including front panel connections, are secure.
- Use shielded copper wire for all cable connections to the device. Use twisted-pair wire to eliminate noise and thermal offsets.

Adjust the Digital Clock Manager (DCM)

Adjusting the digital clock manager for the NI 5105 is required in the calibration procedure. NI recommends that you adjust the DCM at least once every two years, regardless of whether you choose to perform a verification or adjustment of the device. Completing this procedure does not affect the measurements in offset, gain, timing, or bandwidth verification sections described later in this document.

Caution Failing to adjust the DCM at least once every two years can result in invalid measurements from the NI 5105.

Complete the following steps to adjust the digital clock manager (DCM) of the NI 5105.

1. Obtain an instrument session handle using the niScope Cal Start VI.

Note Throughout the procedure, refer to the C/C++ function call parameters for the LabVIEW input values.

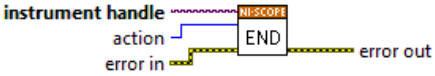
LabVIEW VI	C/C++ Function Call
	Call `niScope_CalStart` with the following parameters: **resourceName**: The name of the device to calibrate. You can find this name under Devices and Interfaces in MAX **password:** The password required to open an external calibration session. If this password has not been changed since manufacturing, the password is "`NI`"

2. Connect the calibrator test head directly to the PFI 1 input of the device. Configure the calibrator to output a sine wave with 3.0 $V_{pk\text{-}pk}$ amplitude, 50 Ω load impedance, and the *Input Frequency* listed in Table 4 for the current iteration.
3. Wait 2,500 ms for the impedance matching and frequency of the calibrator to settle.
4. Adjust the digital clock manager (DCM) using the niScope Cal Adjust DCM VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_CalAdjustDCM` with the following parameters: **sessionHandle**: The session handle from `niScope_CalStart` **channelName**: "" (empty string) **stimulusFreq**: The input frequency in Table 4 for the current iteration

5. Repeat steps 2 through 4 for each iteration listed in Table 4.

6. End the session and save the results using the niScope Cal End VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_CalEnd` with the following parameters: **sessionHandle**: The session handle from `niScope_CalStart` **action**: `NISCOPE_VAL_ACTION_STORE`

7. Perform a self-calibration on the device after adjusting the DCM.

Table 4. Input Frequencies for Adjusting NI 5105 External Clock DCM

Iteration	Input Frequency (MHz)
1	8
2	15
3	22
4	29
5	36
6	43
7	50
8	55
9	60
10	65

Self-Calibration

The NI 5105 includes precise internal circuits and references used during self-calibration to adjust for time and temperature drift. The device gain, offset, flatness, and trigger timing are all corrected in self-calibration. Measuring the accuracy of these internal calibration circuits with another instrument during external calibration provides traceability for the verification procedure. Absolute accuracy is ensured by compensating for any error measured in the internal references.

Note Always self-calibrate the device before you perform *Verification*. NI-SCOPE includes self-calibration example programs for LabVIEW, CVI, and Microsoft Visual C.

You can initiate self-calibration using the following programs:

- MAX
- NI-SCOPE Soft Front Panel (SFP)
- NI-SCOPE

Note The device must be installed in MAX before it can be used in another program.

MAX

To initiate self-calibration from MAX, complete the following steps:

1. Disconnect or disable any AC inputs to the device.
2. Launch MAX using the NI MAX desktop icon.
3. Select **My System»Devices and Interfaces»NI-DAQmx Devices**.
4. Select the device that you want to calibrate.
5. Initiate self-calibration using one of the following methods:
   - Click **Self-Calibrate** in the upper right corner of MAX.
   - Right-click the name of the device in the MAX configuration tree and select **Self-Calibrate** from the drop-down menu.

NI-SCOPE Soft Front Panel

To initiate self-calibration from the NI-SCOPE Soft Front Panel (SFP), complete the following steps:

1. Disconnect or disable any AC inputs to the device.
2. Launch the NI-SCOPE SFP by selecting **Start»All Programs»National Instruments» NI-SCOPE»NI-SCOPE Soft Front Panel**.
3. Select the device you want to calibrate from the Select Device dialog box. The Select Device dialog box automatically opens when you launch the NI-SCOPE SFP.

Note To change the device, select **Edit»Change Device**, and select the new device that you want to calibrate.

4. Launch the Calibration dialog box by selecting **Utility»Self Calibration**.
5. Click **OK** to begin self-calibration.

NI-SCOPE

To self-calibrate the NI 5105 programmatically using NI-SCOPE, complete the following steps:

1. Disconnect or disable any AC inputs to the device.
2. Open a session and obtain a session handle using the niScope Initialize VI.

Note Throughout the procedure, refer to the C/C++ function call parameters for the LabVIEW input values.

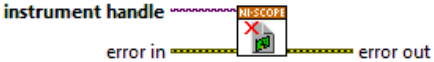
LabVIEW VI	C/C++ Function Call
	Call `niScope_init` with the following parameters: **resourceName**: The device name assigned by MAX **idQuery**: `VI_FALSE` **resetDevice**: `VI_TRUE`

3. Self-calibrate the device using niScope Cal Self Calibrate VI.

LabVIEW VI	C/C++ Function Call
 Note: Wiring the Channel Name and Option inputs is not required for this step.	Call `niScope_CalSelf Calibrate` with the following parameters: **vi**: The instrument handle from `niScope_init` **channelList**: `VI_NULL` **option**: `VI_NULL`

Note Because the session is a standard session rather than an external calibration session, the new calibration constants are immediately stored in the EEPROM. Therefore, you can include this procedure in any application that uses the device.

4. End the session using the niScope Close VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_close` with the following parameters: **vi**: The instrument handle from `niScope_init`

Verification

Note After the 15 minute warm-up period, always self-calibrate the NI 5105 before beginning a verification procedure.

This section describes the program you must write to verify either the calibration test limits or the published specifications for the NI 5105.

Note If any of these tests fail immediately after you perform an external adjustment, make sure that you have met the requirements listed in the *Test Equipment* and *Calibration Procedures* sections before you return the device to National Instruments for repair.

Vertical Offset Accuracy

Table 5 contains the input parameters for verifying vertical offset accuracy, the calibration test limits, and the published specifications of the NI 5105.

To verify vertical offset accuracy, complete the procedures described in this section for each of the 18 iterations listed in Table 5 for channel 0, then repeat the procedure for each of the remaining 7 channels on the NI 5105.

1. Open a session and obtain a session handle using the niScope Initialize VI.

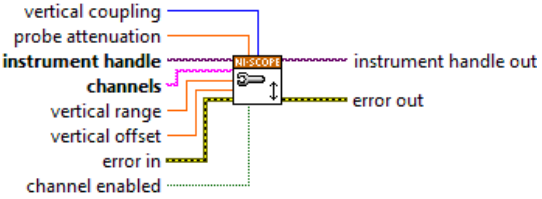
Note Throughout the procedure, refer to the C/C++ function call parameters for the LabVIEW input values.

LabVIEW VI	C/C++ Function Call
	Call `niScope_init` with the following parameters: **resourceName**: The device name assigned by MAX **idQuery**: `VI_FALSE` **resetDevice**: `VI_TRUE`

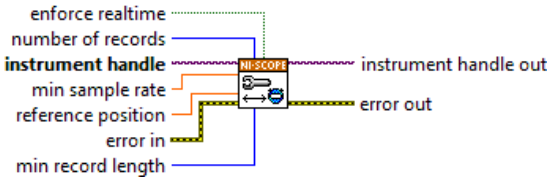
2. Configure the input impedance and the maximum input frequency using the niScope Configure Chan Characteristics VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureChan Characteristics` with the following parameters: **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **inputImpedance**: The *Input Impedance* value listed in Table 5 for the current iteration **maxInputFrequency**: The *Max Input Frequency* value listed in Table 5 for the current iteration

3. Configure the common vertical properties using the niScope Configure Vertical VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Configure Vertical` with the following parameters: **coupling**: `NISCOPE_VAL_DC` **probeAttenuation**: `1.0` **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **range**: The *Range* value listed in Table 5 for the current iteration **offset**: `0.0` **enabled**: `NISCOPE_VAL_TRUE`

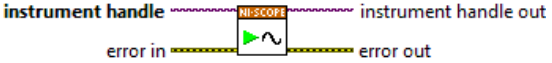
4. Configure the horizontal properties using the niScope Configure Horizontal Timing VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureHorizontalTiming` with the following parameters: **enforceRealtime**: `NISCOPE_VAL_TRUE` **numRecords**: `1` **vi**: The instrument handle from `niScope_init` **minSampleRate**: `10,000,000` **refPosition**: `50.0` **minNumPts**: `100,000`

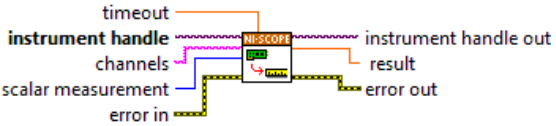
5. Commit all the parameter settings to hardware using the niScope Commit VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Commit` with the following parameter: **vi**: The instrument handle from `niScope_init`

6. Short-circuit the channel input of the device by connecting the calibrator test head directly to the device and grounding the output of the calibrator.
7. Wait 500 ms for the calibrator to ground its output.
8. Initiate a waveform acquisition using the niScope Initiate Acquisition VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_InitiateAcquisition` with the following parameter: **vi**: The instrument handle from `niScope_init`

9. Fetch a waveform from the device and perform a voltage average measurement using the niScope Fetch Measurement Poly VI. Select the Measurement Scalar DBL instance of the VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Fetch Measurement` with the following parameters: **timeout**: `1.0` **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE _AVERAGE`

Compare the resulting average voltage to the value listed in the *Published Specifications* column in Table 5 that corresponds to the settings used.

10. Repeat steps 2 through 9 for each iteration listed in Table 5.
11. Move the calibrator test head to the next device input channel.
12. Repeat steps 2 through 11 for each of the remaining channels, updating the **channelList** parameter with the appropriate channel number.
13. End the session using the niScope Close VI.

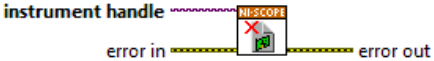
LabVIEW VI	C/C++ Function Call
	Call `niScope_close` with the following parameters: **vi**: The instrument handle from `niScope_init`

Table 5. NI 5105 Vertical Offset Accuracy Limits

Iteration	Max Input Frequency (MHz)	Range (V)	Input Impedance (Ohms)	Calibration Test Limits (V)		Published Specification (V)	
				PXI/PXIe-5105	PCI-5105	PXI/PXIe-5105	PCI-5105
1	60	0.05	50	±0.00055	±0.0015	±0.000725	±0.001525
2	60	0.20	50	±0.0009	±0.0018	±0.0011	±0.0019
3	60	1.00	50	±0.0026	±0.0034	±0.0031	±0.0039
4	60	6.00	50	±0.0108	±0.0134	±0.0156	±0.0164
5	60	0.05	1,000,000	±0.00055	±0.0015	±0.000725	±0.001525
6	60	0.20	1,000,000	±0.0009	±0.0018	±0.0011	±0.0019
7	60	1.00	1,000,000	±0.0026	±0.0034	±0.0031	±0.0039
8	60	6.00	1,000,000	±0.0108	±0.0134	±0.0156	±0.0164
9	60	30.00	1,000,000	±0.0606	±0.0614	±0.0756	±0.0764
10	24	0.05	50	±0.00055	±0.0015	±0.000725	±0.001525
11	24	0.20	50	±0.0009	±0.0018	±0.0011	±0.0019
12	24	1.00	50	±0.0026	±0.0034	±0.0031	±0.0039
13	24	6.00	50	±0.0108	±0.0134	±0.0156	±0.0164
14	24	0.05	1,000,000	±0.00055	±0.0015	±0.000725	±0.001525
15	24	0.20	1,000,000	±0.0009	±0.0018	±0.0011	±0.0019
16	24	1.00	1,000,000	±0.0026	±0.0034	±0.0031	±0.0039

Table 5. NI 5105 Vertical Offset Accuracy Limits

Iteration	Max Input Frequency (MHz)	Range (V)	Input Impedance (Ohms)	Calibration Test Limits (V)		Published Specification (V)	
				PXI/PXIe-5105	PCI-5105	PXI/PXIe-5105	PCI-5105
17	24	6.00	1,000,000	±0.0108	±0.0134	±0.0156	±0.0164
18	24	30.00	1,000,000	±0.0606	±0.0614	±0.0756	±0.0764

Vertical Gain Accuracy

Table 6 contains the input parameters for verifying vertical gain accuracy, the calibration test limits, and the published specifications of the NI 5105.

To verify vertical gain accuracy, complete the procedures described in this section for each of the 12 iterations listed in Table 6 for channel 0, then repeat for each of the remaining 7 channels on the NI 5105.

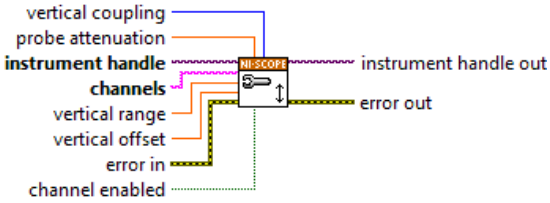
1. Open a session and obtain a session handle using the niScope Initialize VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_init` with the following parameters: **resourceName**: The device name assigned by MAX **idQuery**: `VI_FALSE` **resetDevice**: `VI_TRUE`

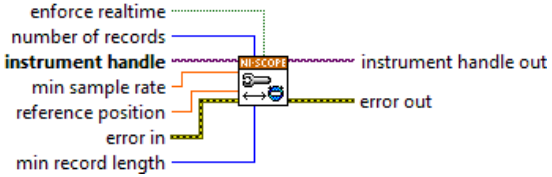
2. Configure the input impedance and the maximum input frequency using the niScope Configure Chan Characteristics VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureChan Characteristics` with the following parameters: **channelList**: The name of the channel being tested **inputImpedance**: The *Input Impedance* value listed in Table 6 for the current iteration **maxInputFrequency**: The *Max Input Frequency* value listed in Table 6 for the current iteration

3. Configure the common vertical properties using the niScope Configure Vertical VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureVertical` with the following parameters: **coupling**: `NISCOPE_VAL_DC` **probeAttenuation**: `1.0` **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **range**: The *Range* value listed in Table 6 for the current iteration **offset**: `0.0` **enabled**: `NISCOPE_VAL_TRUE`

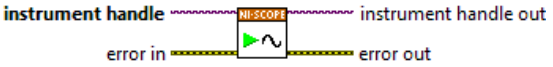
4. Configure the horizontal properties using the niScope Configure Horizontal Timing VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureHorizontalTiming` with the following parameters: **enforceRealtime**: `NISCOPE_VAL_TRUE` **numRecords**: `1` **vi**: The instrument handle from `niScope_init` **minSampleRate**: `10,000,000` **refPosition**: `50.0` **minNumPts**: `100,000`

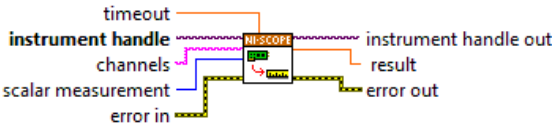
5. Commit all the parameter settings to hardware using the niScope Commit VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Commit` with the following parameter: **vi**: The instrument handle from `niScope_init`

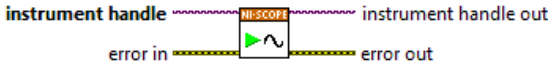
6. Connect the calibrator test head directly to the channel input of the device and output the *Positive Input* voltage listed in Table 6 for the current iteration. Configure the load impedance of the calibrator to match the input impedance of the device.
7. Wait 2,500 ms for the impedance matching and frequency of the calibrator to settle.
8. Initiate a waveform acquisition using the niScope Initiate Acquisition VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Initiate Acquisition` with the following parameter: **vi**: The instrument handle from `niScope_init`

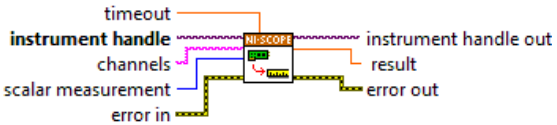
9. Fetch a waveform from the device and perform a voltage average measurement using the niScope Fetch Measurement Poly VI. Select the Measurement Scalar DBL instance of the VI. This value is the *Measured Positive Voltage*, which is used in step 14.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Fetch Measurement` with the following parameters: **timeout**: `1.0` **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **scalarMeasFunction**: `NISCOPE_ VAL_VOLTAGE_AVERAGE`

10. Using the calibrator, output the *Negative Input* voltage for the current iteration listed in Table 6.
11. Wait 2,500 ms for the impedance matching and frequency of the calibrator to settle.
12. Initiate a waveform acquisition using the niScope Initiated Acquisition VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Initiate Acquisition` with the following parameter: **vi**: The instrument handle from `niScope_init`

13. Fetch a waveform from the device and perform a voltage average measurement using the niScope Fetch Measurement Poly VI. Select the Measurement Scalar DBL instance of the VI. This value is the *Measured Negative Voltage* used in step 14.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Fetch Measurement` with the following parameters: **timeout**: `1.0` **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_AVERAGE`

14. Calculate the error in the vertical gain as a percentage of input using the following formula:

$$error = \left(\left(\frac{a-b}{c-d}\right) - 1\right) \times 100$$

where

a = the *Measured Positive Voltage*

b = the *Measured Negative Voltage*

c = the applied *Positive Input Voltage*

d = the applied *Negative Input Voltage*

Compare the resulting percent error to the *Published Specifications* listed in Table 6.

15. Repeat steps 2 through 14 for each iteration listed in Table 6.
16. Move the calibrator test head to the next device input channel and repeat steps 2 through 15 for each of the remaining channels, updating the **channelList** parameter with the appropriate channel number.
17. End the session using the niScope Close VI.

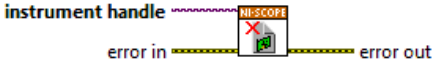
LabVIEW VI	C/C++ Function Call
	Call `niScope_close` with the following parameter: **vi**: The instrument handle from `niScope_init`

Table 6. NI 5105 Vertical Gain Accuracy Stimuli, Calibration Test Limits, and Published Specifications

Iteration	Max Input Frequency (MHz)	Range (V)	Input Impedance (Ohms)	Positive Input (V)	Negative Input (V)	Calibration Test Limits (V)	Published Specification (V)
1	60	0.05	1,000,000	0.0225	-0.0225	±0.60%	±1.00%
2	60	0.20	1,000,000	0.09	-0.09	±0.40%	±0.65%
3	60	1.00	1,000,000	0.45	-0.45	±0.40%	±0.65%
4	60	6.00	1,000,000	2.7	-2.7	±0.40%	±0.65%
5	60	30.00	1,000,000	13.5	-13.5	±0.50%	±0.75%
6	60	1.00	50	0.45	-0.45	±0.75%	±1.00%
7	24	0.05	1,000,000	0.0225	-0.0225	±0.60%	±1.00%
8	24	0.20	1,000,000	0.09	-0.09	±0.40%	±0.65%
9	24	1.00	1,000,000	0.45	-0.45	±0.40%	±0.65%
10	24	6.00	1,000,000	2.7	-2.7	±0.40%	±0.65%
11	24	30.00	1,000,000	13.5	-13.5	±0.50%	±0.75%
12	24	1.00	50	0.45	-0.45	±0.75%	±1.00%

Timing Accuracy

Complete the following steps to verify the timing accuracy for the NI 5105:

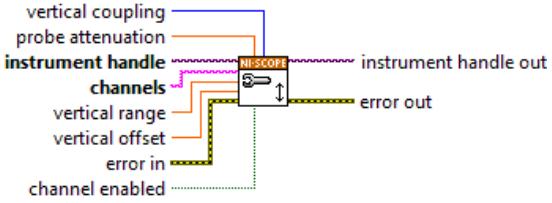
1. Open a session and obtain a session handle using the niScope Initialize VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_init` with the following parameters: **resourceName**: The device name assigned by MAX **idQuery**: `VI_FALSE` **resetDevice**: `VI_TRUE`

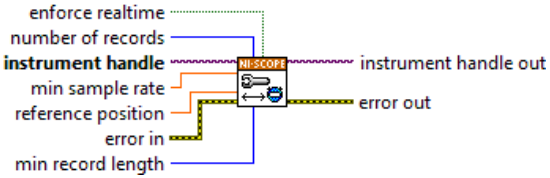
2. Configure the input impedance and the maximum input frequency using the niScope Configure Chan Characteristics VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureChan Characteristics` with the following parameters:. **channelList**: `"0"` **inputImpedance**: `NISCOPE_VAL_50_OHM` **maxInputFrequency**: `20,000,000`

3. Configure the common vertical properties using the niScope Configure Vertical VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Configure Vertical` with the following parameters: **coupling**: `NISCOPE_VAL_DC` **probeAttenuation**: `1.0` **vi**: The instrument handle from `niScope_init` **channelList**: `"0"` **range**: `6.0` **offset**: `0.0` **enabled**: `NISCOPE_VAL_TRUE`

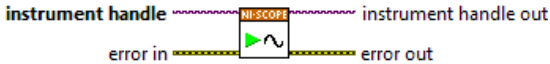
4. Configure the horizontal properties using the niScope Configure Horizontal Timing VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureHorizontalTiming` with the following parameters: **enforceRealtime**: `NISCOPE_VAL_TRUE` **numRecords**: `1` **vi**: The instrument handle from `niScope_init` **minSampleRate**: `60,000,000` **refPosition**: `50.0` **minNumPts**: `1,000,000`

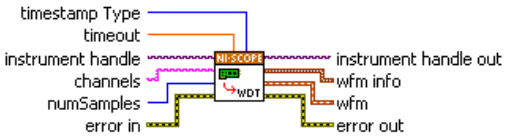
5. Commit all the parameter settings to hardware using the niScope Commit VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Commit` with the following parameter: **vi**: The instrument handle from `niScope_init`

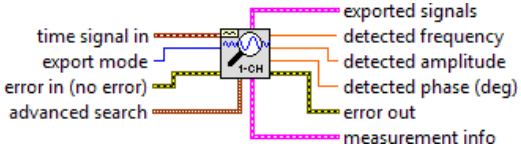
6. Connect the scope calibrator test head directly to the channel 0 input of the device. Configure the calibrator to output an exact 5 MHz sine wave with 1 $V_{pk\text{-}pk}$ amplitude and 50 Ω load impedance.
7. Wait 2,500 ms for the impedance matching and frequency of the calibrator to settle.
8. Initiate a waveform acquisition using the niScope Initiate Acquisition VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_InitiateAcquisition` with the following parameter: **vi**: The instrument handle from `niScope_init`

9. Retrieve a waveform using the niScope Fetch (poly) VI. Select the WDT instance of the VI. Use the default value for the **timestamp Type** parameter.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Fetch Measurement` with the following parameters: **timeout**: `5.0` **vi**: The instrument handle from `niScope_init` **channelList**: `"0"` **numSamples**: `-1`

10. Measure the exact frequency of the peak around 5 MHz using the Extract Single Tone Information VI with the following inputs.
    - **advanced search»approx freq.**: -1
    - **advanced search»search**: 5
    - **export signals**: 0 (none)

LabVIEW VI	C/C++ Function Call
	Perform an FFT on the array of data from step 9.

11. Calculate the error in timing as parts per million (ppm) using the following formula:

$$\text{error} = (a - 5{,}000{,}000) / 5$$

    where *a* is the measured frequency.

    Compare the result to the *Published Specifications* column listed in Table 7.

12. End the session using the niScope Close VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_close` with the following parameters: **vi**: The instrument handle from `niScope_init`

Note The same time source is used for all channels, so you only need to verify the timing accuracy on one channel.

Table 7. NI 5105 Timing Accuracy

Calibration Test Limits	Published Specifications
±5.3 ppm	±25 ppm

Bandwidth

Table 8 contains the input parameters for verifying the bandwidth and the published specifications of the NI 5105.

To verify bandwidth, complete the procedures described in this section for each of the 6 iterations listed in Table 8 for channel 0, then repeat for each of the remaining 7 channels on the NI 5105.

Note Verification of bandwidth is optional.

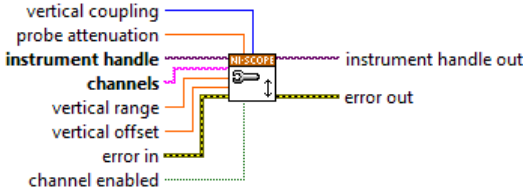
1. Open a session and obtain a session handle using the niScope Initialize VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_init` with the following parameters: **resourceName**: The device name assigned by MAX **idQuery**: `VI_FALSE` **resetDevice**: `VI_TRUE`

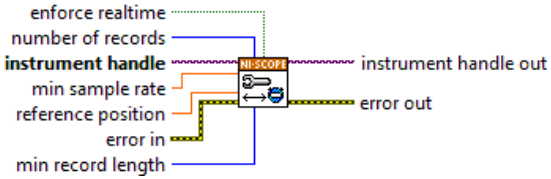
2. Configure the input impedance and the maximum input frequency using the niScope Configure Chan Characteristics VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureChan Characteristics` with the following parameters: **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **inputImpedance**: `NISCOPE_VAL_50_OHM` **maxInputFrequency**: The *Max Input Frequency* value listed in Table 8 for the current iteration

3. Configure the common vertical properties using the niScope Configure Vertical VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureVertical` with the following parameters: **coupling**: `NISCOPE_VAL_DC` **probeAttenuation**: `1.0` **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **range**: The *Range* value listed in Table 8 for the current iteration **offset**: `0.0` **enabled**: `NISCOPE_VAL_TRUE`

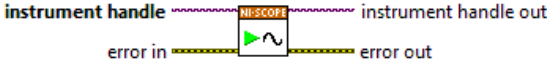
4. Configure the horizontal properties using the niScope Configure Horizontal Timing VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_ConfigureHorizontalTiming` with the following parameters: **enforceRealtime**: `NISCOPE_VAL_TRUE` **numRecords**: `1` **vi**: The instrument handle from `niScope_init` **minSampleRate**: `10,000,000` **refPosition**: `50.0` **minNumPts**: `30,000`

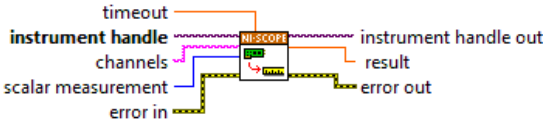
5. Commit all the parameter settings to hardware using the niScope Commit VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Commit` with the following parameter: **vi**: The instrument handle from `niScope_init`

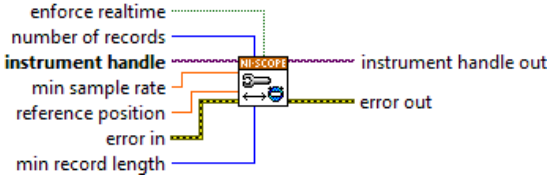
6. Connect the calibrator test head directly to the channel input of the device. Configure the calibrator to output a 50 kHz sine wave with peak-to-peak voltage amplitude set to half the vertical range of the device. Configure the load impedance of the calibrator to 50 Ω.
7. Wait 2,500 ms for the impedance matching and frequency of the calibrator to settle.
8. Initiate a waveform acquisition using the niScope Initiate Acquisition VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_InitiateAcquisition` with the following parameter: **vi**: The instrument handle from `niScope_init`

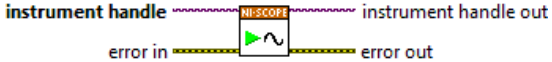
9. Fetch a waveform from the device and perform a voltage RMS measurement using the niScope Fetch Measurement Poly VI. Select the Measurement Scalar DBL instance of the VI. This value is the *Measured RMS Voltage of 50 kHz Sine Wave*, which is used in step 15.

LabVIEW VI	C/C++ Function Call
	Call `niScope_FetchMeasurement` with the following parameters: **timeout**: `1.0` **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_RMS`

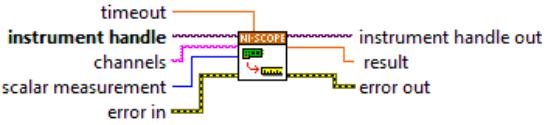
10. Configure the horizontal properties using the niScope Configure Horizontal Timing VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Configure HorizontalTiming` with the following parameters: **enforceRealtime**: `NISCOPE_VAL_TRUE` **numRecords**: `1` **vi**: The instrument handle from `niScope_init` **minSampleRate**: `60,000,000` **refPosition**: `50.0` **minNumPts**: `300,000`

11. Configure the calibrator to output the *Input Frequency* listed in Table 8 for the current iteration.
12. Wait 2,500 ms for the impedance matching and frequency of the calibrator to settle.
13. Initiate a waveform acquisition using the niScope Initiate Acquisition VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_Initiate Acquisition` with the following parameter: **vi**: The instrument handle from `niScope_init`

14. Fetch a waveform from the device and perform a voltage RMS measurement using the niScope Fetch Measurement Poly VI. Select the Measurement Scalar DBL instance of the VI. This value is the *Measured RMS Voltage of Generated Sine Wave* used in step 15.

LabVIEW VI	C/C++ Function Call
	Call `niScope_FetchMeasurement` with the following parameters: **timeout**: `1.0` **vi**: The instrument handle from `niScope_init` **channelList**: The name of the channel being tested **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_RMS`

15. Calculate the power difference using the formula:

$$\text{power} = (20\log_{10} a) - (20\log_{10} b)$$

where

a is the *Measured RMS Voltage of Generated Sine Wave*

b is the *Measured RMS Voltage of the 50 kHz Sine Wave*

If the result is within the test limits in Table 8, the device has passed this portion of the verification.

16. Repeat steps 2 through 15 for each iteration listed in Table 8.
17. Move the calibrator test head to the next device input channel and repeat steps 2 through 16 for each of the remaining 7 channels. Update the **channelList** parameter to the appropriate channel number each time.
18. End the session using the niScope Close VI.

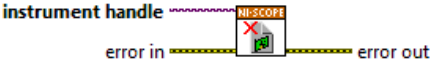
LabVIEW VI	C/C++ Function Call
	Call `niScope_close` with the following parameters: **vi**: The instrument handle from `niScope_init`

Table 8. NI 5105 Bandwidth Limits

Iteration	Max Input Frequency (MHz)	Range (V)	Input Frequency (MHz)	Published Specifications	
				Max (dB)	Min (dB)
1	60	0.05	54.9	3	-3
2	60	0.20	59.9	3	-3
3	60	1.00	59.9	3	-3
4	60	6.00	59.9	3	-3
5	24	1.00	22.4	N/A	-3*
6	24	1.00	29.9	-3*	N/A

* Published specifications value listed for validation of noise filter only. The specification is not included in the device specifications document. Verification of these limits is optional.

Adjustment

If the NI 5105 successfully passed each of the verification procedures within the calibration test limits, an adjustment is recommended but not required to guarantee the published specifications for the next two years. If the device was not within the calibration test limits for each of the verification procedures, you can perform the adjustment procedure to improve the accuracy of the device. Refer to *Appendix A: Calibration* to determine which procedures to perform.

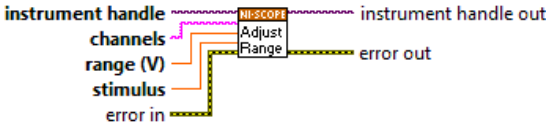
An adjustment is required only once every two years. Completing the adjustment procedure automatically updates the calibration date and temperature in the EEPROM of the device.

Complete all of the following steps to externally adjust the NI 5105.

1. Obtain an instrument session handle using the niScope Cal Start VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_CalStart` with the following parameters: **resourceName**: The name of the device to calibrate. You can find this name under Devices and Interfaces in MAX **password:** The password required to open an external calibration session. If this password has not been changed since manufacturing, the password is "`NI`"

2. Connect the scope calibrator test head directly to the channel input of the device. Configure the calibrator to output the voltage listed under the *Input (V)* column in Table 9. Configure the load impedance of the calibrator to 1 MΩ.
3. Wait 2,500 ms for the impedance matching and frequency of the calibrator to settle.
4. Adjust the vertical range using the niScope Cal Adjust Range VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_CalAdjustRange` with the following parameters: **sessionHandle**: The session handle from `niScope_CalStart` **channelName**: The channel being adjusted **range**: The *Range* value listed in Table 9 for the current iteration **stimulus**: The *Input Voltage* value listed in Table 9 for the current iteration

5. Repeat steps 2 through 4 for each iteration listed in Table 9.
6. Move the calibrator test head to the next device input channel and repeat steps 2 through 5. Update the **channelName** parameter for each channel being adjusted.
7. Connect the calibrator test head directly to the channel 0 input of the device. Configure the calibrator to output an exact 3.0 MHz sine wave with 1 $V_{pk\text{-}pk}$ amplitude and 50 Ω load impedance.
8. Adjust the sample rate of the device using the niScope Cal Adjust VCXO VI.

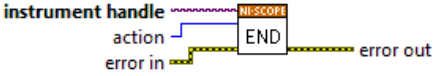
LabVIEW VI	C/C++ Function Call
	Call `niScope_CalAdjustVCXO` with the following parameters: **sessionHandle:** The session handle from `niScope_CalStart` **stimulusFreq**: `3,000,000`

Note The 3 MHz stimulus is automatically taken from channel 0.

9. Disconnect or disable all inputs to the device.
10. Self-calibrate the device using the niScope Cal Self Calibrate VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_CalSelfCalibrate` with the following parameters: **session handle:** The instrument handle from `niScope_CalStart` **channelList**: `VI_NULL` **option**: `VI_NULL`

11. End the session and save the results using the niScope Cal End VI.

LabVIEW VI	C/C++ Function Call
	Call `niScope_CalEnd` with the following parameters: **sessionHandle**: The session handle from `niScope_CalStart` **action**: `NISCOPE_VAL_ACTION_STORE`

You have finished adjusting the NI 5105. Repeat the *Verification* section to reverify the performance of the NI 5105 after adjustments. Use the calibration test limits to verify the performance of the product after adjustment, and compare the results with the calibration test limits.

Table 9. NI 5105 Input Parameters for External Adjustment

Iteration	Range (V)	Input (V)
1	0.05	0.02
2	0.20	0.09
3	1.00	0.425
4	6.00	1
5	30.00	2.5
6	0.05	-0.02
7	0.20	-0.09
8	1.00	-0.425

Table 9. NI 5105 Input Parameters for External Adjustment (Continued)

Iteration	Range (V)	Input (V)
9	6.00	-1
10	30.00	-2.5

Appendix A: Calibration

External calibration involves verification and, if necessary, adjustment and reverification. Adjustment is the process of measuring and compensating for device performance to improve the measurement accuracy. Performing an adjustment updates the calibration date, effectively resetting the calibration interval. The device is guaranteed to meet or exceed its published specifications for the duration of the calibration interval. Verification is the process of testing the device to ensure that the measurement accuracy is within certain specifications. Verification can be used to ensure that the adjustment process was successful or to determine if the adjustment process needs to be performed at all. During verification, you must compare the measurement error to the limits given in each section.

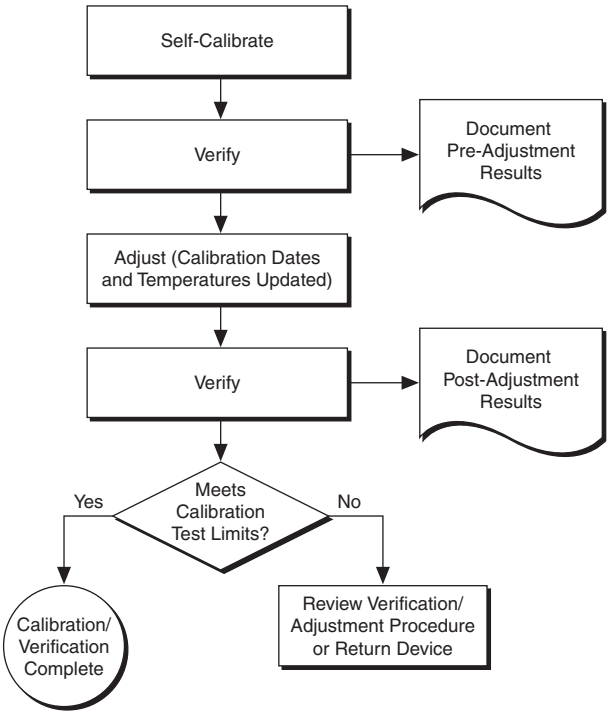
This document provides two sets of test limits for most verification stages—the *calibration test limits* and the *published specifications*. The calibration test limits are more restrictive than the published specifications. If all of the measurement errors determined during verification fall within the calibration test limits, the device is guaranteed to meet or exceed its published specifications for a full calibration interval (two years). For this reason, you must verify against the calibration test limits when performing verification after adjustment. If all of the measurement errors determined during verification fall within the published specifications, but not within the calibration test limits, the device is meeting its published specifications. While the device does not necessarily remain within these specifications for an additional two years, it will meet published specifications for the remainder of the current calibration interval. In this case, you can perform an adjustment if you want to further improve the measurement accuracy or reset the calibration interval. If some measurement errors determined during verification do not fall within the published specifications, you must perform an adjustment to restore the device operation to its published specifications.

The *Complete Calibration* section describes the recommended calibration procedure.

Complete Calibration

Perform a complete calibration to guarantee that the NI 5105 meets or exceeds its published specifications for a two-year calibration interval. At the end of the complete calibration procedure, verify that the measurement error falls within the calibration test limits. Figure 1 shows the programming flow for a complete calibration.

Figure 1. Complete Calibration Programming Flow



Appendix B: Calibration Utilities

NI-SCOPE supports several calibration utilities you can use to retrieve information about adjustments performed on the NI 5105, change the external calibration password, and store small amounts of information in the onboard EEPROM. Although you can retrieve some data using MAX, you can retrieve all the data programmatically using NI-SCOPE functions.

MAX

To retrieve data using MAX, complete the following steps:

1. Select the device from which you want to retrieve information from **My System»Devices and Interfaces**.
2. Select the **Settings** tab in the lower left corner.

You should see information about the last date and temperature for both external and self-calibration.

NI-SCOPE

NI-SCOPE provides a full complement of calibration utility functions and VIs. Refer to the *NI High-Speed Digitizers Help* for the complete function reference and VI reference. The utility functions include:

- niScope Cal Change Password VI (`niScope_CalChangePassword`)
- niScope Cal Fetch Count VI (`niScope_CalFetchCount`)
- niScope Cal Fetch Date VI (`niScope_CalFetchDate`)
- niScope Cal Fetch Misc Info VI (`niScope_CalFetchMiscInfo`)
- niScope Cal Fetch Temperature VI (`niScope_CalFetchTemperature`)
- niScope Cal Store Misc Info VI (`niScope_CalStoreMiscInfo`)

Where to Go for Support

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

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

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

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

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