CALIBRATION PROCEDURE

NI 5112

Introduction

This document contains step-by-step instructions for calibrating the National Instruments 5112 digitizer. This calibration procedure is intended for metrology labs. It includes instructions for self-calibrating the NI 5112 and for verifying its performance using a variety of programming environments.

What Is Calibration?

Calibration is the process of verifying the measurement accuracy of a device and adjusting for any measurement error. *Verification* consists of measuring the performance of a device and comparing the results to the factory specifications for the device. This document describes self-calibration (or internal calibration) and external verification. External adjustment procedures are not included in this document because the calibration constants of the NI 5112 are not externally adjustable.

Why Should You Calibrate?

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

How Often Should You Calibrate?

The measurement accuracy requirements of your application determine how often you should verify the performance of the NI 5112 digitizer. 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

This section describes the equipment, test conditions, documentation, and software required for calibrating the NI 5112.

Test Equipment

Table 1. NI 5112 Calibration Equipment Specifications

Required Equipment	Recommended Equipment	Parameter Measured	Necessary Specifications
Signal Generator/ Ohmmeter	Fluke 9500B Oscilloscope Calibrator	Vertical Gain	DC ±25 mV to ±22.5 V, ±0.25% into 1 MΩ
		AC Coupling	sine wave 9–13 Hz ±100 ppm, 1.8 Vpp, ±2% into 1 MΩ
		Bandwidth	±2% amplitude flatness for leveled sine wave 100 kHz–100 MHz ±50 ppm, 1.5 Vpp, ±2% into 50 Ω
		Input Impedance	2-wire resistance accuracy of 0.25% for 50 Ω and 1 MΩ measurements
		Timing/RIS	sine wave 10 kHz–10 MHz ±15 ppm, 1.8 Vpp, ±2% into 1 MΩ
		Trigger Sensitivity	sine wave 100 kHz–10 MHz ±100 ppm, 300 mVpp, ±2% into 1 MΩ with CH0 and CH1; 750 mVpp with external trigger
5 1/2 Digit Digital Multimeter (DMM)	NI 4060	Internal Reference	DC voltage accuracy of ±0.25% (±12.5 mV) when measuring ±5 V
BNC Cable	—	—	50 Ω
BNC Shorting Cap	—	Vertical Offset	0 VDC, ±0.6 mV

Test Conditions

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

- Keep connections to the NI 5112 short. Long cables and wires act as antennae, picking up extra noise that can affect measurements.
- Use a 50 Ω BNC coaxial cable for all connections to the digitizer.
- Keep relative humidity between 10% and 90% noncondensing, or consult the digitizer hardware manual for the optimum relative humidity.
- Maintain the temperature between 5 °C and 40 °C, or consult the digitizer hardware manual for the optimum temperature range.
- Allow a warm-up time of at least 15 minutes to ensure that the measurement circuitry of the NI 5112 is at a stable operating temperature.

Documentation

This section describes the documentation you need for self-calibrating and externally verifying the NI 5112 digitizer. In addition to this calibration document, you may find the following documents helpful:

- *NI High-Speed Digitizers Help* (**Start»Programs»National Instruments»NI-SCOPE»Documentation**)
- *NI High-Speed Digitizers Getting Started Guide*
- *NI-SCOPE Quick Reference Guide*

The calibration functions used in this procedure are described in the *NI-SCOPE Function Reference Help* and the *NI-SCOPE VI Reference Help*, which you can access through the *NI High-Speed Digitizers Help*.

You can download the latest versions of all documentation from `ni.com/manuals`.

Software

This section describes the software you need to calibrate the NI 5112. Calibration requires the latest version of the NI-SCOPE driver on the calibration system. The calibration functions are C function calls located in the NI-SCOPE instrument driver. These function calls are also 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, you must include `niScopeCal.h` in your code when you write your calibration procedure.

NI-SCOPE supports programming for all NI digitizers in the following programming languages: National Instruments LabVIEW and LabWindows™/CVI™, Microsoft Visual C++, Microsoft Visual Basic, and Console C. You can download the latest version of NI-SCOPE from the Instrument Driver Network at `ni.com/idnet`. For installation instructions, refer to the *NI High-Speed Digitizers Getting Started Guide*.

Writing Your Calibration Procedure

NI-SCOPE 2.7 includes all functions necessary for calibrating NI digitizers. Because calibration support is included in `niScope_32.dll`, you can access it through any compiler capable of calling into a 32-bit DLL. If you use a C compiler, include the `niScopeCal.h` header file, which defines all calibration-specific functions and briefly explains the parameters. LabVIEW support is installed in `niScopeCal.llb`, and all calibration functions appear in the function palette. Refer to Table 2 for file locations.

Table 2. Calibration File Locations After Installing NI-SCOPE

File Name and Location	Description
`Program Files\IVI\Bin\niScope_32.dll`	NI-SCOPE driver containing the entire NI-SCOPE API, including calibration functions
`Program Files\IVI\Lib\msc\niscope.lib`	NI-SCOPE library containing the entire NI-SCOPE API, including calibration functions
<*LabVIEW*>`\examples\instr\niScope`	Directory of LabVIEW NI-SCOPE example VIs, including self-calibration; access the examples from the LabVIEW function palette
<*LabVIEW*>`\instr.lib\niScope\Calibrate\niScopeCal.llb`	LabVIEW VI library containing VIs for calling the NI-SCOPE calibration API; access calibration functions from the **NI-SCOPE Calibration** section of the LabVIEW function palette
`Program Files\IVI\Include\niscopeCal.h`	Calibration header file that 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
`Program Files\IVI\Drivers\niScope\niScope.fp`	LabWindows/CVI function panel file that includes function prototypes and help using NI-SCOPE in the LabWindows/CVI environment

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

File Name and Location	Description
`Program Files\IVI\Drivers\niScope\niScopeCal.fp`	LabWindows/CVI function panel file that includes external verification function prototypes and help on using NI-SCOPE in the LabWindows/CVI environment
`Program Files\IVI\Drivers\niScope\Examples`	Directory of NI-SCOPE examples for LabWindows/CVI, Console C, Visual C++, and Visual Basic

Self-Calibration Procedures

The NI 5112 includes an internal voltage source that is more than 10 times as accurate as the 8-bit digitizer resolution. Self-calibration (or internal calibration) uses this internal reference source to do the following:

- Calibrate vertical range and offset for each input range
- Calibrate AC flatness over the entire bandwidth to within specifications
- Calibrate analog trigger levels
- Calibrate the time-to-digital converter (TDC) used for random interleaved sampling (RIS) measurements

The internal reference source is not user-adjustable, but you can verify the value of the source using a high-precision DMM to provide traceability. Absolute accuracy is ensured by verifying the internal reference voltage using a digital voltmeter.

Self-calibrate the NI 5112 digitizer before you perform an external verification. NI-SCOPE includes self-calibration example programs for LabVIEW, LabWindows/CVI, and Console C. Table 2 shows the locations of these example programs.

Self-Calibrating the NI 5112 Digitizer

To self-calibrate the NI 5112, complete the following steps:

1. Call `niScope_init` to obtain an instrument session handle.
2. Call `niScope_calSelfCalibrate` with **option** set to `VI_NULL`. The new calibration constants are immediately stored in the EEPROM, so you can include this procedure in any application that uses the digitizer.
3. Call `niScope_close` to close the session handle and deallocate system resources.

Verification Procedures

This section describes how to externally verify the performance of the NI 5112 digitizer.

External verification of the NI 5112 tests the following specifications:

- Internal reference
- Vertical offset
- Vertical gain
- Input impedance
- Full bandwidth
- 20 MHz bandwidth
- AC coupling cutoff frequency
- Timing
- Trigger sensitivity
- RIS distribution

All verification procedures start by calling `niScope_init` with **resetDevice** set to `VI_TRUE`, and end by calling `niScope_close`.

The internal reference verification includes function calls to record the measured internal reference value in the EEPROM. External verification automatically stores the date and external verification count to provide traceability. External verification is equivalent to the factory production tests that verify the performance of the NI 5112.

Note Self-calibrate the NI 5112 before beginning these verification procedures. If any of the verification tests fail immediately after you self-calibrate the NI 5112, return it to NI for repair.

Verifying the Internal Reference

Complete the following steps to verify the internal reference.

1. Connect the DMM to the input on the front panel of the NI 5112.
2. Open a calibration session by calling `niScope_CalStart` with the calibration password, which is initially set to `0` or the empty string, `""`.
3. Route the internal reference out of the digitizer by calling `niScope_CalRouteInternalReference` with the following parameters:
    - **whichReference** = `NISCOPE_VAL_CAL_10V_CH0`
    - **option** = `NISCOPE_VAL_CAL_POSITIVE`

4. Measure the internal reference voltage with the DMM and record this value (y in this document).
5. Route the internal reference out of the digitizer by calling `niScope_CalRouteInternalReference`. Set the following parameters:
   - **whichReference** = `NISCOPE_VAL_CAL_10V_CH0`
   - **option** = `NISCOPE_VAL_CAL_NEGATIVE`
6. Measure the internal reference voltage with the DMM and record this value (z in this document).
7. Calculate the value of the onboard reference x using the following formula:

$$x = y - z$$

8. Compare x to the Success Condition value in Table 3. If the reference is outside of specification, return the digitizer to NI for repair.
9. If the digitizer passes the test, store the measured value to the driver by calling `niScope_CalStoreInternalReference`. Set the following parameters:
   - **whichReference** = `NISCOPE_VAL_CAL_10V_CH0`
   - **internalReference** = x from step 7
10. Call `niScope_CalRouteInternalReference` to write the internal reference value to the EEPROM. Set the following parameters:
    - **whichReference** = `NISCOPE_VAL_CAL_10V_CH0`
    - **option** = `NISCOPE_VAL_CAL_UNROUTE_SIGNAL`
11. Call `niScope_CalEnd` to end the verification session. Set **action** to `NISCOPE_VAL_CAL_ACTION_STORE`. Closing the calibration session stores the date and the incremented external verification count. While this value is not used by NI-SCOPE during operation, storing the value in the EEPROM provides traceability of the verification.

You have completed verifying the internal reference specifications for the NI 5112.

Table 3. NI 5112 Internal Reference Specifications

Digitizer Parameters	Success Condition
whichReference = `NISCOPE_VAL_CAL_10V_CH0` **option** = `NISCOPE_VAL_CAL_POSITIVE`	$9.99 < x < 10.01$ V

Verifying Vertical Offset

Complete the following steps to verify NI 5112 vertical offset specifications.

1. Short-circuit channel 0 on the front panel of the of the NI 5112 with the BNC shorting cap.
2. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
   - **minSampleRate** = `100,000,000`
   - **minNumPts** = `30,000`
   - **refPosition** = `50.0`
   - **numRecords** = `1`
   - **enforceRealtime** = `VI_TRUE`
3. Call `niScope_ConfigureVertical` with the following parameters:
   - **channelList** = `0`
   - **range** = The Digitizer Parameters value in Table 4
   - **offset** = `0.0`
   - **coupling** = `NISCOPE_VAL_DC`
   - **probeAttenuation** = `1.0`
   - **enabled** = `VI_TRUE`
4. Wait 10 ms for the input stage to settle.
5. Call `niScope_InitiateAcquisition`.
6. Call `niScope_FetchMeasurement` with the following parameters:
   - **channelList** = `0`
   - **scalarMeasFunction** = `NISCOPE_VAL_VOLTAGE_AVERAGE`
   - **timeout** = `30`

   Compare the resulting average voltage to the Success Condition listed in Table 4. If the result is outside the Success Condition range, the digitizer has failed this portion of the verification. Return the digitizer to NI for repair.
7. Repeat steps 1 through 6 for each vertical offset entry in Table 4.
8. Move the shorting cap to channel 1.
9. Repeat steps 1 through 7 for channel 1. Change **channelList** to `1` when calling the functions `niScope_ConfigureVertical` and `niScope_fetchMeasurement`.

You have completed verifying the vertical offset specifications for the NI 5112.

Table 4. NI 5112 Vertical Offset Specifications

Name	Digitizer Parameters	Stimulus Parameters	Success Condition
Vertical Offset	**range** = 50 V	Short-Circuit Input	$|x| < 1.25$ V
Vertical Offset	**range** = 5 V	Short-Circuit Input	$|x| < 0.125$ V
Vertical Offset	**range** = 0.5 V	Short-Circuit Input	$|x| < 0.0125$ V

Verifying Vertical Gain

Complete the following steps to verify the NI 5112 vertical gain specifications:

1. Connect the signal generator to the channel 0 input of the digitizer.
2. Configure the signal generator for a 1 MΩ load.
3. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
    - **minSampleRate** = `100,000,000`
    - **minNumPts** = `30,000`
    - **refPosition** = `50.0`
    - **numRecords** = `1`
    - **enforceRealtime** = `VI_TRUE`
4. Call `niScope_ConfigureVertical` with the following parameters:
    - **channelList** = `0`
    - **range** = The first Digitizer Parameters value in Table 5
    - **offset** = `0.0`
    - **coupling** = `NISCOPE_VAL_DC`
    - **probeAttenuation** = `1.0`
    - **enabled** = `VI_TRUE`
5. Wait 10 ms for the input stage to settle.
6. Apply the positive DC stimulus voltage listed under Stimulus Parameters in Table 5.
7. Call `niScope_InitiateAcquisition`.
8. Call `niScope_FetchMeasurement` with the following parameters:
    - **channelList** = `0`
    - **scalarMeasFunction** = `NISCOPE_VAL_VOLTAGE_AVERAGE`
    - **timeout** = `30`

9. Apply the negative DC stimulus voltage listed under Stimulus Parameters in Table 5.
10. Call `niScope_InitiateAcquisition`.
11. Call `niScope_FetchMeasurement` with the following parameters:
    - **scalarMeasFunction** = `NISCOPE_VAL_VOLTAGE_AVERAGE`
    - **channelList** = `0`
    - **timeout** = `30`
12. Calculate the error in the vertical gain using the following formula:

$$error = (a - b) - (c - d)$$

where

a is the measured positive voltage

b is the measured negative voltage

c is the applied positive voltage

d is the applied negative voltage

13. Compare the value from step 12 to the Success Condition in Table 5. If the error is outside the range of the Success Condition, return the digitizer to NI for repair.
14. Repeat steps 2 through 13 for each Vertical Gain entry in Table 5.
15. Move the signal generator connection to the channel 1 input of the digitizer.
16. Repeat steps 2 through 14 for channel 1. Change **channelList** to `1` when calling the functions `niScope_ConfigureVertical` and `niScope_FetchMeasurement`.

You have completed verifying the vertical gain specifications for the NI 5112.

Table 5. NI 5112 Vertical Gain Specifications

Name	Digitizer Parameters	Stimulus Parameters	Success Condition
Vertical Gain	**range** = 50 V	±22.5 VDC	$|x| < 1.25$ V
Vertical Gain	**range** = 50 V	±5.0 VDC	$|x| < 1.25$ V
Vertical Gain	**range** = 5 V	±2.25 VDC	$|x| < 0.125$ V
Vertical Gain	**range** = 5 V	±0.25 VDC	$|x| < 0.125$ V
Vertical Gain	**range** = 0.5 V	±0.22 VDC	$|x| < 0.0125$ V
Vertical Gain	**range** = 0.5 V	±0.022 VDC	$|x| < 0.0125$ V

Verifying Full Bandwidth

Complete the following steps to verify the NI 5112 full bandwidth specifications.

1. Connect the signal generator to the channel 0 input of the digitizer.
2. Configure the signal generator for a 50 Ω load.
3. Set the signal generator to the frequency and amplitude listed under Stimulus Parameters in Table 6 for the Reference Full Bandwidth entry.
4. Call `niScope_ConfigureVertical` with the following parameters:
    - **channelList** = `0`
    - **range** = `2.0`
    - **offset** = `0`
    - **coupling** = `NISCOPE_VAL_DC`
    - **probeAttenuation** = `1.0`
    - **enabled** = `VI_TRUE`
5. Wait 300 ms for input stage to settle.
6. Call `niScope_ConfigureChanCharacteristics` with the following parameters:
    - **channelList** = `0`
    - **inputImpedance** = `NISCOPE_VAL_50_OHM`
    - **maxInputFrequency** = `0.0`
7. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
    - **minSampleRate** = The Digitizer Parameters value for Reference Full Bandwidth in Table 6
    - **minNumPts** = `30,000`
    - **refPosition** = `50.0`
    - **numRecords** = `1`
    - **enforceRealtime** = `VI_TRUE`
8. Call `niScope_InitiateAcquisition`.
9. Call `niScope_FetchMeasurement` with the following parameters:
    - **channelList** = `0`
    - **scalarMeasFunction** = `NISCOPE_VAL_AC_ESTIMATE`
    - **timeout** = `30`

    Record this value to use as *reference AC estimate* in step 14.

10. Apply the signal specified in the first Full Bandwidth entry in Table 6.
11. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
    - **minSampleRate** = The Digitizer Parameters value for Full Bandwidth in Table 6
    - **minNumPts** = `30,000`
    - **refPosition** = `50.0`
    - **numRecords** = `1`
    - **enforceRealTime** = `VI_TRUE`
12. Call `niScope_InitiateAcquisition`.
13. Call `niScope_FetchMeasurement` with the following parameters:
    - **scalarMeasFunction** = `NISCOPE_VAL_AC_ESTIMATE`
    - **channelList** = `0`
    - **timeout** = `30`

    Record this value to use as *AC estimate* in step 14.
14. Calculate the response in decibels using the following formula:

$$response = 20\log_{10}\left[\frac{AC\ estimate}{reference\ AC\ estimate}\right]$$

15. Compare the response to the Success Condition in Table 6. If the response is outside the range of the Success Condition, return the digitizer to NI for repair.
16. Repeat steps 10 through 15 for the remaining Full Bandwidth entries in Table 6.
17. Repeat steps 2 through 16 with **coupling** set to `NISCOPE_VAL_AC` when calling `niScope_ConfigureVertical`.
18. Move the signal generator connection to the channel 1 input of the digitizer.
19. Repeat steps 1 through 17 for channel 1. Change **channelList** to `1` for `niScope_ConfigureVertical`, `niScope_FetchMeasurement`, and `niScope_ConfigureChanCharacteristics`.

You have completed verifying the full bandwidth specifications for the NI 5112.

Table 6. NI 5112 Full Bandwidth Specifications

Name	Digitizer Parameters	Stimulus Parameters	Success Condition
Reference Full Bandwidth	**minSampleRate** = 20,000,000 S/s	100 kHz, 1.5 Vpp	—
Full Bandwidth	**minSampleRate** = 100,000,000 S/s	1 MHz, 1.5 Vpp	$\|x\| < 3$ dB
Full Bandwidth	**minSampleRate** = 50,000,000 S/s	49 MHz, 1.5 Vpp (intentionally aliased)	$\|x\| < 3$ dB
Full Bandwidth	**minSampleRate** = 100,000,000 S/s	99 MHz, 1.5 Vpp (intentionally aliased)	$\|x\| < 3$ dB

Verifying 20 MHz Bandwidth

Complete the following steps to verify the NI 5112 20 MHz bandwidth specifications.

1. Connect the signal generator to the channel 0 input of the digitizer.
2. Configure the signal generator for a 50 Ω load.
3. Set the signal generator to the frequency and amplitude listed in Table 7 for the Reference 20 MHz Bandwidth entry.
4. Call `niScope_ConfigureVertical` with the following parameters:
   - **channelList** = `0`
   - **range** = `2.0`
   - **offset** = `0`
   - **coupling** = `NISCOPE_VAL_DC`
   - **probeAttenuation** = `1.0`
   - **enabled** = `VI_TRUE`
5. Wait 300 ms for the input stage to settle.
6. Call `niScope_ConfigureChanCharacteristics` with the following parameters:
   - **channelList** = `0`
   - **inputImpedance** = `NISCOPE_VAL_50_OHM`
   - **maxInputFrequency** = `20,000,000`

7. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
   - **minSampleRate** = The Digitizer Parameters value for Reference 20 MHz Bandwidth in Table 7
   - **minNumPts** = `30,000`
   - **refPosition** = `50.0`
   - **numRecords** = `1`
   - **enforceRealTime** = `VI_TRUE`
8. Call `niScope_InitiateAcquisition`.
9. Call `niScope_FetchMeasurement` with the following parameters:
   - **channelList** = `0`
   - **scalarMeasFunction** = `NISCOPE_VAL_AC_ESTIMATE`
   - **timeout** = `30`

   Record this value to use as *reference AC estimate* in step 14.
10. Apply the signal specified in the 20 MHz Bandwidth entry in Table 7.
11. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
    - **minSampleRate** = The Digitizer Parameters value for the 20 MHz Bandwidth entry in Table 7
    - **minNumPts** = `30,000`
    - **refPosition** = `50.0`
    - **numRecords** = `1`
    - **enforceRealtime** = `VI_TRUE`
12. Call `niScope_InitiateAcquisition`.
13. Call `niScope_FetchMeasurement` with the following parameters:
    - **channelList** = `0`
    - **scalarMeasFunction** = `NISCOPE_VAL_AC_ESTIMATE`
    - **timeout** = `30`

    Record this value to use as *AC estimate* in step 14.
14. Calculate the response in decibels using the following formula:

$$response = 20\log_{10}\left[\frac{AC\ \ estimate}{reference\ AC\ estimate}\right]$$

15. Compare the response to the Success Condition in Table 7. If the response is outside the range of the Success Condition, return the digitizer to NI for repair.

16. Repeat steps 10 through 15 for the remaining bandwidth entries in Table 7.
17. Repeat steps 2 through 16 with **coupling** set to `NISCOPE_VAL_AC` for the function `niScope_ConfigureVertical`.
18. Move the signal generator connection to the channel 1 input on the front panel of the digitizer.
19. Repeat steps 2 through 17 for channel 1. Change **channelList** to `1` for `niScope_ConfigureVertical`, `niScope_FetchMeasurement`, and `niScope_ConfigureChanCharacteristics`.

You have completed verifying the 20 MHz bandwidth specifications for the NI 5112.

Table 7. NI 5112 20 MHz Bandwidth Specifications

Name	Digitizer Parameters	Stimulus Parameters	Success Condition
Reference 20 MHz Bandwidth	**minSampleRate** = 20,000,000 S/s	100 kHz, 1.5 Vpp	—
20 MHz Bandwidth	**minSampleRate** = 100,000,000 S/s	1 MHz, 1.5 Vpp	$\|x\| < 3$ dB
20 MHz Bandwidth	**minSampleRate** = 20,000,000 S/s	15 MHz, 1.5 Vpp (intentionally aliased)	$\|x\| < 3$ dB
20 MHz Bandwidth	**minSampleRate** = 20,000,000 S/s	25 MHz, 1.5 Vpp (intentionally aliased)	$\|x\| > 3$ dB

Verifying Input Impedance

Complete the following steps to verify NI 5112 input impedance specifications.

1. Connect the ohmmeter to the channel 0 input of the digitizer.
2. Call `niScope_ConfigureVertical` with the following parameters:
   - **channelList** = `0`
   - **range** = The Digitizer Parameters value in Table 8
   - **offset** = `0.0`
   - **coupling** = `NISCOPE_VAL_DC`
   - **probeAttenuation** = `1.0`
   - **enabled** = `VI_TRUE`
3. Wait 10 ms for the input stage to settle.

4. Call `niScope_ConfigureChanCharacteristics` with the following parameters:
   - **channelList** = `0`
   - **inputImpedance** = The Digitizer Parameters value in Table 8
   - **maxInputFrequency** = `0.0`
5. Call `niScope_Read` to ensure the hardware is programmed. Set the following parameters:
   - **channelList** = `0`
   - **timeout** = `30`
   - **numSamples** = `128`
6. Measure the impedance with the ohmmeter and compare it to the Success Condition in Table 8. If the impedance is outside the range of the Success Condition, return the digitizer to NI for repair.
7. Repeat steps 2 through 6 for each input impedance entry in Table 8.
8. Move the ohmmeter connection to the channel 1 of the digitizer.
9. Repeat steps 2 through 7 for channel 1. Change **channelList** to `1` when calling the functions `niScope_configureVertical` `niScope_ConfigureChanCharacteristics`, and `niScope_Read`.

You have completed verifying the input impedance specifications for the NI 5112.

Table 8. NI 5112 Input Impedance Specifications

Name	Digitizer Parameters	SuccessCondition
Input Impedance	**range** = 40.0 V **inputImpedance** = `NISCOPE_VAL_1_MEG_OHM`	$990{,}000 < x < 1{,}010{,}000\ \Omega$
Input Impedance	**range** = 4.0 V **inputImpedance** = `NISCOPE_VAL_1_MEG_OHM`	$990{,}000 < x < 1{,}010{,}000\ \Omega$
Input Impedance	**range** = 0.4 V **inputImpedance** = `NISCOPE_VAL_1_MEG_OHM`	$990{,}000 < x < 1{,}010{,}000\ \Omega$
Input Impedance	**range** = 4.0 V **inputImpedance** = `NISCOPE_VAL_50_OHM`	$49.5 < x < 50.5\ \Omega$
Input Impedance	**range** = 0.4 V **inputImpedance** = `NISCOPE_VAL_50_OHM`	$49.5 < x < 50.5\ \Omega$

Verifying AC Coupling Cutoff Frequency

Complete the following steps to verify NI 5112 AC coupling specifications.

1. Connect a the signal generator to channel 0 of the digitizer.
2. Configure the signal generator for a 1 MΩ load.
3. Set the signal generator to the frequency and amplitude listed in the Stimulus Parameters column in Table 9.
4. Call `niScope_ConfigureVertical` with the following parameters:
   - **channelList** = `0`
   - **range** = `2.0`
   - **offset** = `0.0`
   - **coupling** = `NISCOPE_VAL_DC`
   - **probeAttenuation** = `1.0`
   - **enabled** = `VI_TRUE`
5. Wait 10 ms for the input stage to settle.
6. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
   - **minSampleRate** = `10,000`
   - **minNumPts** = `10,000`
   - **refPosition** = `50.0`
   - **numRecords** = `1`
   - **enforceRealtime** = `VI_TRUE`
7. Call `niScope_InitiateAcquisition`.
8. Call `niScope_FetchMeasurement` with the following parameters:
   - **channelList** = `0`
   - **scalarMeasFunction** = `NISCOPE_VAL_AC_ESTIMATE`
   - **timeout** = `30`

   Record this value to use as *AC estimate with DC coupling* in step 13.
9. Call `niScope_ConfigureVertical` with the following parameters:
   - **channelList** = `0`
   - **range** = `2.0`
   - **offset** = `0.0`
   - **coupling** = `NISCOPE_VAL_AC`
   - **probeAttenuation** = `1.0`
   - **enabled** = `VI_TRUE`

10. Wait 300 ms for the input stage to settle.
11. Call `niScope_InitiateAcquisition`.
12. Call `niScope_FetchMeasurement` with the following parameters:
    - **channelList** = `0`
    - **scalarMeasFunction** = `NISCOPE_VAL_AC_ESTIMATE`
    - **timeout** = `30`

    Record this value to use as *AC estimate with AC coupling* in step 13.
13. Calculate the response in decibels using the following formula:

$$response = 20\log_{10}\left[\frac{AC\ estimate\ with\ AC\ coupling}{AC\ estimate\ with\ DC\ coupling}\right]$$

14. Compare the response to the Success Condition in Table 9. If the response is outside the listed range, return the digitizer to NI for repair.
15. Repeat steps 2 through 14 for each AC Coupling entry in Table 9.
16. Move the signal generator connection to the channel 1 input of the digitizer.
17. Repeat steps 2 through 15 for channel 1. Change **channelList** to `1` when calling the functions `niScope_ConfigureVertical` and `niScope_FetchMeasurement`.

You have completed verifying the AC coupling cutoff frequency specifications for the NI 5112.

Table 9. NI 5112 AC Coupling Specifications

Name	Stimulus Parameters	Success Condition
AC Coupling	12.1 Hz, 1.8 Vpp	$\lvert x \rvert < 3$ dB
AC Coupling	9.9 Hz, 1.8 Vpp	$\lvert x \rvert > 3$ dB

Verifying Timing

Complete the following steps to verify the NI 5112 timing specifications.

1. Connect the signal generator to the channel 0 input of the digitizer.
2. Configure the signal generator for a 1 MΩ load.
3. Generate a 10 kHz, 1.8 Vpp sine wave.

4. Call `niScope_ConfigureVertical` with the following parameters:
   - **channelList =** `0`
   - **range** = `2.0`
   - **offset** = `0.0`
   - **coupling** = `NISCOPE_VAL_DC`
   - **probeAttenuation** = `1.0`
   - **enabled** = `VI_TRUE`
5. Wait 10 ms for the input stage to settle.
6. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
   - **minSampleRate** = `1,000,000`
   - **minNumPts** = `100,000`
   - **refPosition** = `50.0`
   - **numRecords** = `1`
   - **enforceRealtime** = `VI_TRUE`
7. Call `niScope_InitiateAcquisition`.
8. Call `niScope_FetchMeasurement` with the following parameters:
   - **channelList** = `0`
   - **scalarMeasFunction** = `NISCOPE_VAL_AVERAGE_FREQUENCY`
   - **timeout** = `30`
9. If the returned frequency value does not fall between 9,999 and 10,001 Hz, a hardware error exists. If the digitizer fails this step, terminate the verification procedure and return it to NI for repair.
10. Generate a 1.8 Vpp, 10 MHz sine wave. This wave is intentionally undersampled, where the sampling rate is an even multiple of the sine wave frequency.
11. Call `niScope_InitiateAcquisition`.
12. Call `niScope_FetchMeasurement` with the following parameters:
    - **channelList** = `0`
    - **scalarMeasFunction** = `NISCOPE_VAL_AVERAGE_PERIOD`
    - **timeout** = `30`

    Record the *period* measurement to use in step 14.
13. If the returned status is `NISCOPE_ERROR_UNABLE_TO_PERFORM_MEASUREMENT`, call `niScope_errorHandler` with **errorCode** set to the returned error value. If the timing is perfectly aliased, the waveform is a DC level and the period measurement fails. Therefore, if the error description

indicates the measurement failed due to insufficient crosspoints, the digitizer passed the test.

14. If the returned status is anything other than `NISCOPE_ERROR_UNABLE_TO_PERFORM_MEASUREMENT`, calculate the actual sample rate (x), assuming a perfect source, with the following formula:

$$x = \frac{\mathit{specified\ sample\ rate} \times \mathit{source\ frequency} \times \mathit{period}}{\mathit{source\ frequency} \times \mathit{period} - 1}$$

which is:

$$x = \frac{10^{13} \times \mathit{period}}{10^{7} \times \mathit{period} - 1}$$

15. Compare the actual sample rate (x) to the Success Condition, $999{,}950 < x < 1{,}000{,}050$ Hz. If x is outside the Success Condition range, return the digitizer to NI for repair.
16. Move the signal generator connection to the channel 1 input of the digitizer.
17. Repeat steps 2 through 15 for channel 1. Change **channelList** to `1` when calling `niScope_ConfigureVertical` and `niScope_FetchMeasurement`.

You have completed verifying the timing specifications for the NI 5112.

Verifying Trigger Sensitivity

To verify trigger sensitivity, you must determine the smallest signal on which the digitizer can trigger by trying all possible trigger levels. Complete the following steps:

1. Connect the signal generator to the trigger channel input of the digitizer.
2. Configure the signal generator for a 1 MΩ load.
3. Apply a 1 MHz sine wave with zero vertical offset, and peak-to-peak voltage as listed in Table 10.
4. Call `niScope_ConfigureVertical` with the following parameters:
   - **channelList** = `0`
   - **range** = `20`
   - **offset** = `0.0`
   - **coupling** = `NISCOPE_VAL_DC`
   - **probeAttenuation** = `1.0`
   - **enabled** = `VI_TRUE`

5. Wait 10 ms for the input stage to settle.
6. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
   - **minSampleRate** = `20,000,000`
   - **minNumPts** = `128`
   - **refPosition** = `50.0`
   - **numRecords** = `1`
   - **enforceRealtime** = `VI_TRUE`
7. Call `niScope_ConfigureTriggerEdge` with the following parameters:
   - **triggerSource** = `NISCOPE_VAL_EXTERNAL`
   - **level** = The low trigger level from Table 10
   - **slope** = `NISCOPE_VAL_POSITIVE`
   - **triggerCoupling** = `NISCOPE_VAL_AC`
   - **holdoff** = `0`
   - **delay** = `0`
   - **channelList** = `0`
   - **timeout** = `1`
8. Call `niScope_Read` to read a waveform with the following parameters:
   - **channelList =** `0`
   - **timeout** = `0.1`
   - **numSamples** = `128`

   If this function returns a maximum time exceeded error, proceed to step 9. If the digitizer did not time out, skip to step 11.
9. Call `niScope_Abort` to stop the test.
10. If the digitizer timed out, increment the **level** setting by the trigger level delta specified in Table 10, then repeat step 7. The digitizer fails this test if incrementing the trigger level causes the trigger sensitivity to be higher than the high trigger level entry in Table 10. If the digitizer fails the test, return it to NI for repair. Otherwise, repeat steps 7 and 8 for the remaining trigger levels.
11. Repeat steps 2 through 10 to test the trigger sensitivity on channel 0. Make the following changes:
   - Change **channelList** to `0` when calling `niScope_Read` and `niScope_ConfigureVertical`
   - Change **triggerSource** to `0` when calling `niScope_ConfigureTriggerEdge`

12. Repeat steps 2 through 11 to test the trigger sensitivity on channel 1. Make the following changes:
    - Change **channelList** to `1` when calling `niScope_Read` and `niScope_ConfigureVertical`
    - Change **triggerSource** to `1` when calling `niScope_ConfigureTriggerEdge`

The digitizer passes the trigger sensitivity test if all channels pass the trigger susceptivity test. If any channel fails the test, return the digitizer to NI for repair.

You have completed verifying the trigger sensitivity for the NI 5112.

Table 10. NI 5112 Trigger Sensitivity Specifications

Name	Digitizer Parameters	Stimulus Parameters	Success Condition
Trigger Sensitivity	**low trigger level** = –5.0 **high trigger level** = 5.0 **trigger level delta** = 0.02	750 mVpp	digitizer triggers with any valid trigger level

Verifying Random Interleaved Sampling Distribution (RIS)

The TDC provides an extremely accurate trigger time resolution between two samples. This trigger should happen with a uniform distribution between two digitizer samples to accurately reconstruct the periodic signal. This method of trigger distribution is called RIS. Complete the following steps to measure RIS.

1. Connect the signal generator to the channel 0 input of the digitizer. This test requires a signal generator that is completely independent of the digitizer. The source cannot be a signal derived from the digitizer, and it cannot be the output of a function generator that is synchronized with the digitizer.
2. Configure the signal generator for a 1 MΩ load.
3. Apply the signal listed in the Stimulus Parameters column of Table 11.
4. Call `niScope_ConfigureVertical` with the following parameters:
    - **channelList** = `0`
    - **range** = `2`
    - **offset** = `0`
    - **coupling** = `NISCOPE_VAL_DC`
    - **probeAttenuation** = `1.0`
    - **enabled** = `VI_TRUE`

5. Call `niScope_ConfigureHorizontalTiming` with the following parameters:
    - **minSampleRate** = `100,000,000`
    - **minNumPts** = `128`
    - **refPosition** = `50.0`
    - **numRecords** = `1`
    - **enforceRealtime** = `VI_TRUE`
6. Call `niScope_ConfigureTriggerEdge` with the following parameters:
    - **triggerSource** = `0`
    - **level** = `0`
    - **slope** = `NISCOPE_VAL_POSITIVE`
    - **triggerCoupling** = `NISCOPE_VAL_DC`
    - **holdoff** = `0`
    - **delay** = `0`
7. Call `niScope_CalMeasureRISDistribution` with the following parameters:
    - **channelName** = `0`
    - **distributionSize** = The Digitizer Parameters value in Table 11
    - **maxTime** = `10,000`
    - **distribution** = A pointer to an array of **distributionSize** number of elements

    If you do not want **distribution** returned, set **distribution** to `VI_NULL`. The function `niScope_CalMeasureRISDistribution` performs 2,000 acquisitions and creates a probability distribution based on the initial *x* value, which includes the TDC value.
8. Compare the returned **minimumBinPercent** (*x*) to the Success Condition in Table 11. If the returned value is outside the range of the Success Condition, return the digitizer to NI for repair.
9. Move the signal generator connection to the channel 1 input of the digitizer.
10. Repeat steps 2 through 8 for channel 1 with the following changes:
    - Change **channelList** to `1` when calling `niScope_ConfigureVertical`
    - Change **triggerSou**rce to `1` when calling `niScope_ConfigureTriggerEdge`
    - Change **channelName** to `1` when calling `niScope_CalMeasureRISDistribution`

You have completed verifying the RIS distribution for the NI 5112.

Table 11. NI 5112 RIS Distribution Specifications

Digitizer Parameters	StimulusParameters	Success Condition
distributionSize = 25	1 MHz, ±100 kHz, 1.8 Vpp	$x > 0.8$

Note If the NI 5112 digitizer fails any of the verification procedures immediately after a self-calibration, return it to NI for repair or replacement.

370328C-01 Aug04