CALIBRATION PROCEDURE

NI PXI-5114

This document contains instructions for writing an external calibration procedure for NI PXI-5114 digitizers. This calibration procedure is intended for metrology labs.

Contents

NATIONAL INSTRUMENTS

Introduction

The NI 5114 supports two types of calibration: self-calibration (or internal calibration) and external calibration.

Self-Calibration

Self-calibration, also known as internal calibration, uses a software command and requires no external connections. Self-calibration improves measurement accuracy by compensating for variables such as temperature that may have changed since the last external calibration. Self-calibration retains the traceability of the external calibration. Refer to the *Self-Calibration Procedures* section for more information.

External Calibration

External calibration is generally performed with a high-precision oscilloscope calibrator at either NI or a metrology lab. This procedure replaces all calibration constants in the EEPROM and is equivalent to a factory calibration at NI. Because the external calibration procedure changes all EEPROM constants, it invalidates the original calibration certificate. If an external calibration is done with a traceable signal generator source, a new calibration certificate can be issued.

Calibration Interval

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

Caution Although you can use self-calibration repeatedly, self-calibrating the NI 5114 more than a few times a day may cause excessive wear on the relays over time.

The measurement accuracy requirements of your application determine how often you should externally calibrate the NI 5114. NI recommends that you perform a complete external calibration at least once every two years. You can shorten this interval based on the accuracy demands of your application. Refer to the *External Calibration Options* section for more information.

Software and Documentation Requirements

This section describes the software and documentation required for both self-calibration and external calibration.

Software

Calibrating the NI 5114 requires installing NI-SCOPE version 2.9 or later on the calibration system. You can download NI-SCOPE from the Instrument Driver Network at `ni.com/idnet`. NI-SCOPE supports programming the *Self-Calibration Procedures* section in a number of programming languages. However, only LabVIEW and C are supported for the *External Calibration Procedures* section.

NI-SCOPE includes all the functions and attributes necessary for calibrating the NI 5114. For LabWindows™/CVI™, the NI-SCOPE function panel `niScopeCal.fp` provides further help on the functions available in CVI. LabVIEW support is installed in `niScopeCal.llb`, and all calibration functions appear in the function palette. Refer to Table 1 for file locations.

Calibration functions are C function calls or LabVIEW VIs in the NI-SCOPE driver. In this document, the C function call is shown first, followed by the corresponding LabVIEW VI in parentheses. 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 functions and VIs, refer to the *NI-SCOPE Function Reference Help* or the *NI-SCOPE VI Reference Help*. These references can be found in the *NI High-Speed Digitizers Help*. To access this help file, go to **Start»Programs»National Instruments» NI-SCOPE»Documentation»NI High-Speed Digitizers Help**.

Table 1. Calibration File Locations after Installing NI-SCOPE 2.9 or Later

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

Table 1. Calibration File Locations after Installing NI-SCOPE 2.9 or Later (Continued)

File Name and Location	Description
`LabVIEW (version)\examples\instr\niScope`	Directory of LabVIEW NI-SCOPE example VIs, including self-calibration. You can access the calibration example from the LabVIEW palette.
`LabVIEW (version)\instr.lib\niScopeCalibrate\niScopeCal.llb`	LabVIEW VI library containing VIs for calling the NI-SCOPE calibration API. You can access calibration functions from the NI-SCOPE calibration section of the LabVIEW palette.
`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

You may find the following documentation helpful as you write your calibration procedure:

- *NI High-Speed Digitizers Getting Started Guide*
- *NI High-Speed Digitizers Help*
- *NI 5114 Specifications*
- *NI-SCOPE Function Reference Help* or *NI-SCOPE VI Reference Help*

These documents are installed with NI-SCOPE. You can also download the latest versions from `ni.com/manuals`.

Self-Calibration Procedures

The NI 5114 includes precise internal circuits and references used during self-calibration to adjust for time and temperature drift. The digitizer 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 Self-calibrate the digitizer 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 methods:

- Measurement & Automation Explorer (MAX)
- Scope Soft Front Panel (SFP)
- NI-SCOPE

MAX

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

1. Disconnect or disable any AC inputs to the digitizer.
2. Launch MAX.
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.

Scope SFP

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

1. Disconnect or disable any AC inputs to the digitizer.
2. Launch the Scope SFP (**Start»Programs»National Instruments» NI-SCOPE»Scope Soft Front Panel**).
3. Select the device you want to calibrate using the Device Configuration dialog box (**Edit»Device Configuration**).
4. Launch the Calibration dialog box (**Utility»Self Calibration**).
5. Click **OK** to begin self-calibration.

To self-calibrate the NI 5114 programmatically using NI-SCOPE, complete the following steps:

1. Disconnect or disable any AC inputs to the digitizer.
2. Call `niScope_init` (niScope Initialize VI) to obtain an instrument session handle. Set the following parameters:
   - **resourceName**: The device name assigned by MAX
   - **IDQuery**: `NISCOPE_VAL_VI_FALSE`
   - **resetDevice**: `NISCOPE_VAL_VI_FALSE`
   - **vi**: The returned session handle that you use to identify the instrument in all subsequent instrument driver function calls
3. Call `niScope_calSelfCalibrate` (niScope Cal Self Calibrate VI) with the following parameters:
   - **sessionHandle**: The instrument handle that you obtain from `niScope_init` (niScope Initialize VI)
   - **channelList**: `VI_NULL`
   - **option**: `VI_NULL`

   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 digitizer.
4. Call `niScope_close` (niScope Close VI) to close the session handle. Set the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`

External Calibration Options

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 Tables 4 through 10.

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. The *Optional Calibration* section describes alternative procedures that allow you to skip adjustment if the device already meets its calibration test limits or published specifications.

Complete Calibration

Perform a complete calibration to guarantee that the NI 5114 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.

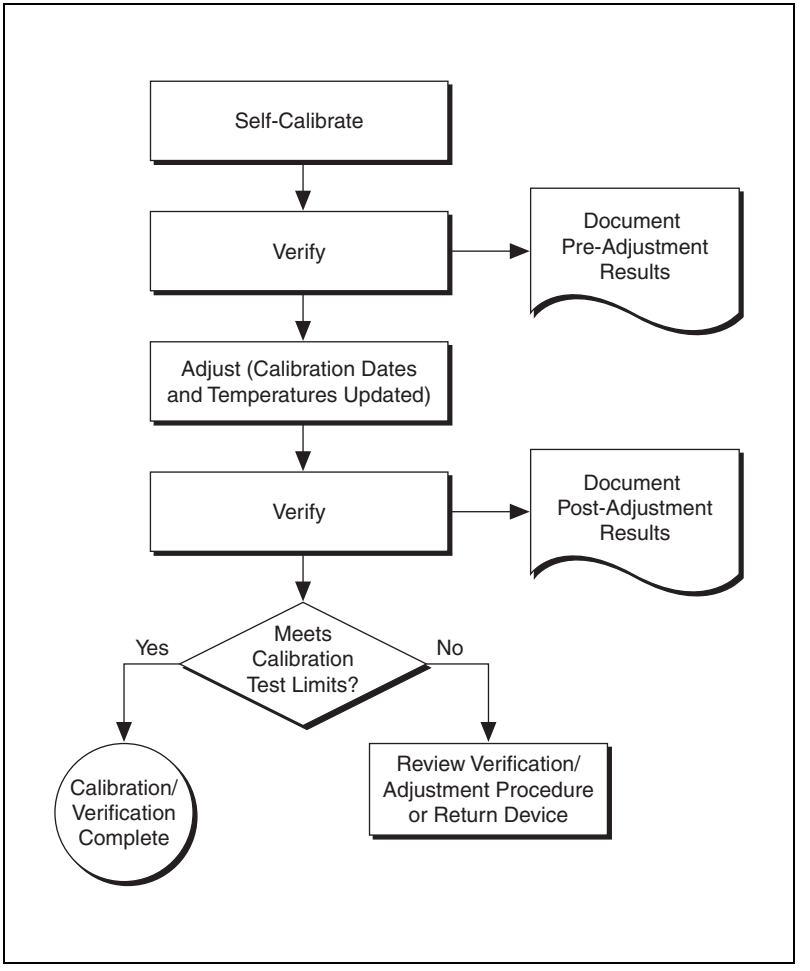

Figure 1. Complete Calibration Programming Flow

Optional Calibration

You can choose to skip the adjustment steps of the calibration procedure if the measurement error is within the calibration test limits or the published specifications during the first verification. If all of the measurement errors determined during the first verification fall within the calibration test limits, the device is guaranteed to meet or exceed its published specifications for a full calibration interval. In this case, you can update the calibration date, effectively resetting the calibration interval, without actually performing an adjustment. Refer to the *Adjusting the NI 5114* section for more information.

If all of the measurement errors determined during the first verification fall within the published specifications, but not within the calibration test limits, adjustment is also optional. However, you cannot update the calibration date, because the device will not necessarily operate within the published specifications for an additional two years.

Note Regardless of the results of the first verification, if you choose to perform an adjustment, you must verify that the measurement error falls within the calibration test limits at the end of the calibration procedure.

Figure 2 shows the programming flow for the optional calibration.

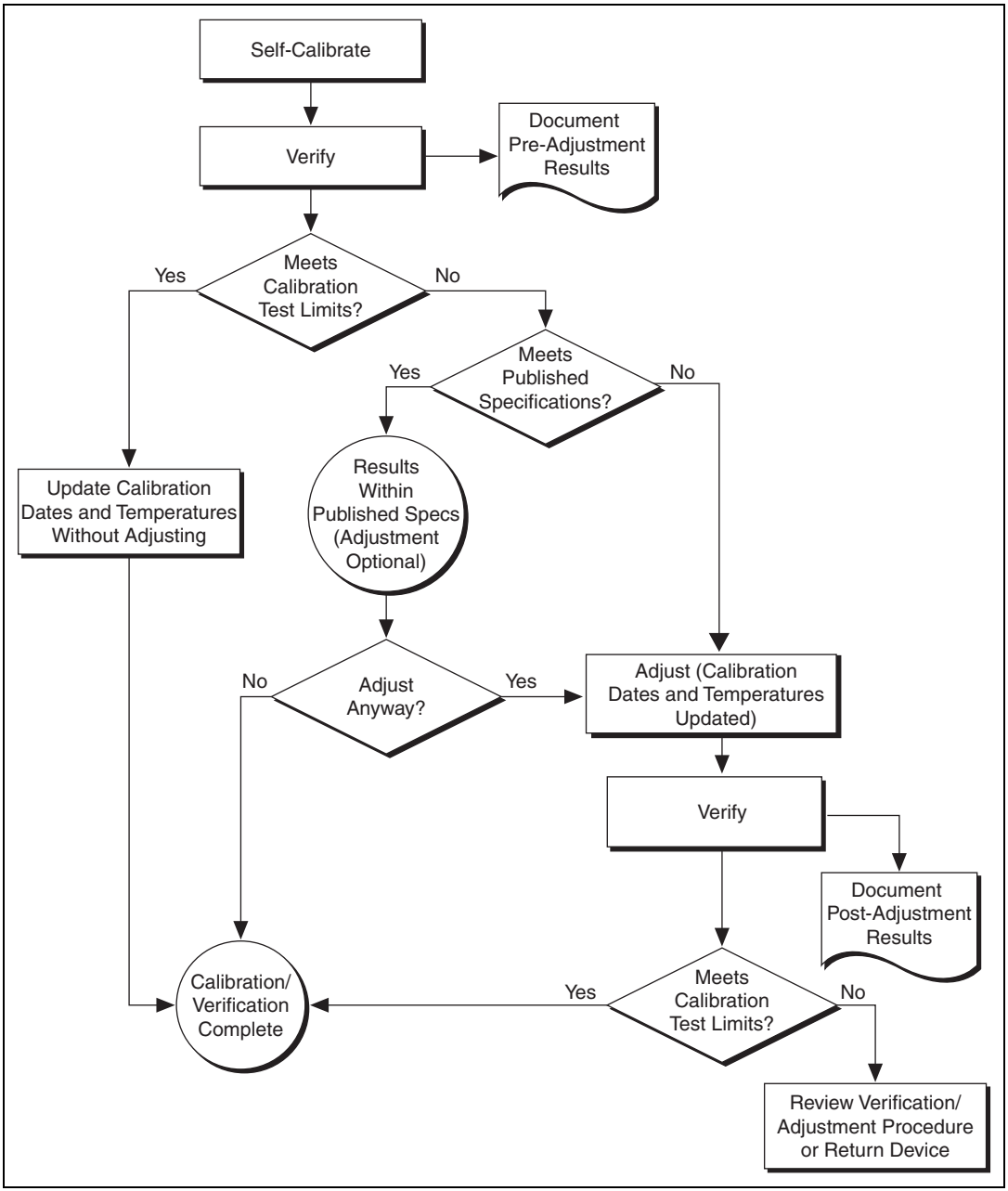

Figure 2. Optional Calibration Programming Flow

External Calibration Requirements

Test Equipment

Table 2 lists the equipment required for externally calibrating the NI 5114. If you do not have the recommended instruments, use these specifications to select a substitute calibration standard.

Table 2. Required Equipment Specifications for NI 5114 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
		Bandwidth, Trigger Sensitivity	±2% output amplitude flatness for leveled sine wave up to 131 MHz relative to 50 kHz into 50 Ω
		Timing	±2 ppm frequency accuracy
BNC cable	—	—	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.

Test Conditions

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

- Always connect the calibrator test head directly to the input BNC of the digitizer, or use a short 50 Ω BNC coaxial cable if necessary. Long cables and wires act as antennae, picking up extra noise that can affect measurements.
- Keep relative humidity between 10 and 90% non-condensing, or consult the digitizer hardware specifications for the optimum relative humidity.
- Maintain an ambient temperature of 23 ±5 °C.
- 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 5114 is at a stable operating temperature.

- Ensure that the PXI chassis fan speed is set to HI, that the fan filters are clean, and that the empty slots contain filler panels.
- Plug the PXI chassis and the calibrator into the same power strip to avoid ground loops.

External Calibration Procedures

The complete external calibration procedure consists of self-calibrating, verifying the performance of the digitizer, adjusting the calibration constants, and verifying performance again after the adjustments. In some cases, the complete calibration procedure may not be required. Refer to the *External Calibration Options* section for more information.

The external calibration procedure automatically stores the calibration date on the EEPROM to allow traceability.

Verifying NI 5114 Specifications

Note Always self-calibrate the NI 5114 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 5114. Refer to the *External Calibration Options* section to determine which limits to use in these procedures.

All verification procedures described in this section begin with `niScope_init` (niScope Initialize VI) with **resetDevice** set to `NISCOPE_VAL_TRUE`, and end with `niScope_close` (niScope Close VI).

Note If any of these tests fail immediately after you perform an external adjustment, verify that you have met the required test conditions listed in the *External Calibration Requirements* section before you return the digitizer to NI for repair.

Vertical Offset and Vertical Gain Accuracy

Table 3 contains the input parameters for verifying both vertical offset accuracy and vertical gain accuracy of the NI 5114.

To verify vertical offset accuracy, complete the procedures described in the *Vertical Offset Accuracy* section for each of the 20 iterations listed in Table 3 for channel 0, then repeat the procedures for channel 1. The *Calibration Test Limits* column and *Published Specifications* column for vertical offset accuracy are shown in Table 4.

To verify vertical gain accuracy, complete the procedures described in the *Vertical Gain Accuracy* section for each of the 20 iterations listed in Table 3 for channel 0, then repeat the procedures for channel 1. The *Calibration Test Limits* column and *Published Specifications* column for vertical gain are shown in Table 5.

Table 3. NI 5114 Input Parameters for Vertical Offset Accuracy and Vertical Gain Accuracy Verification

Iteration	Max Input Frequency (Hz)	Range
1	125,000,000	0.04
2	125,000,000	0.1
3	125,000,000	0.2
4	125,000,000	0.4
5	125,000,000	1
6	125,000,000	2
7	125,000,000	4
8	125,000,000	10
9	125,000,000	20
10	125,000,000	40
11	20,000,000	0.04
12	20,000,000	0.1
13	20,000,000	0.2
14	20,000,000	0.4
15	20,000,000	1
16	20,000,000	2
17	20,000,000	4
18	20,000,000	10
19	20,000,000	20
20	20,000,000	40

Vertical Offset Accuracy

Complete the following steps to verify vertical offset accuracy of the NI 5114. You must verify both channels with each iteration listed in Table 3.

1. Call `niScope_ConfigureChanCharacteristics` (niScope Configure Chan Characteristics VI) with the following parameters:
   - **channelList**: `"0"`
   - **inputImpedance**: `NISCOPE_VAL_1_MEG_OHM`
   - **maxInputFrequency**: The Maximum Input Frequency value for the current iteration from Table 3
2. Call `niScope_ConfigureVertical` (niScope Configure Vertical VI) with the following parameters:
   - **channelList**: `"0"`
   - **range**: The Range value in Table 3 for the current iteration
   - **offset**: `0.0`
   - **coupling**: `NISCOPE_VAL_DC`
   - **probeAttenuation**: `1.0`
   - **enabled**: `NISCOPE_VAL_TRUE`
3. Call `niScope_ConfigureHorizontalTiming` (niScope Configure Horizontal Timing VI) with the following parameters:
   - **minSampleRate**: `10,000,000`
   - **minNumPts**: `100,000`
   - **refPosition**: `50.0`
   - **numRecords**: `1`
   - **enforceRealtime**: `NISCOPE_VAL_TRUE`
4. Call `niScope_Commit` (niScope Commit VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
5. Short-circuit the channel 0 input of the digitizer by connecting the calibrator test head directly to the digitizer and grounding the output of the calibrator.
6. Wait 500 ms for the impedance matching of the calibrator to settle.
7. Call `niScope_InitiateAcquisition`. (niScope Initiate Acquisition VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`

8. Call `niScope_FetchMeasurement` (niScope Fetch Measurement VI) with the following parameters:
   - **channelList**: `"0"`
   - **timeout**: `1.0`
   - **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_AVERAGE`

   Compare the resulting average voltage to the value listed in the *Calibration Test Limits* column or the *Published Specifications* column in Table 4 that corresponds to the settings used. If the result is within the selected test limit, the device has passed this portion of the verification.
9. Repeat steps 1 through 8 for each iteration in Table 3.
10. Move the calibrator test head to digitizer input channel 1 and repeat steps 1 through 9 for every configuration in Table 3, replacing `"0"` with `"1"` for the **channelList** parameter.

You have finished verifying the vertical offset accuracy of the NI 5114.

Table 4. NI 5114 Vertical Offset Calibration Test Limits and Published Specifications

Iteration	Range	Calibration Test Limits (V)	Published Specification (V)
1	0.04	±0.00024	±0.00032
2	0.1	±0.0002	±0.0005
3	0.2	±0.0004	±0.0008
4	0.4	±0.0008	±0.0014
5	1	±0.002	±0.0032
6	2	±0.004	±0.0062
7	4	±0.008	±0.0122
8	10	±0.02	±0.0302
9	20	±0.04	±0.0602
10	40	±0.08	±0.1202

Vertical Gain Accuracy

Complete the following steps to verify the vertical gain accuracy of the NI 5114. You must verify both channels with each iteration listed in Table 3.

1. Call `niScope_ConfigureChanCharacteristics` (niScope Configure Chan Characteristics VI) with the following parameters:
   - **channelList**: `"0"`
   - **inputImpedance**: `NISCOPE_VAL_1_MEG_OHM`
   - **maxInputFrequency**: The Maximum Input Frequency value in Table 3 for the current iteration
2. Call `niScope_ConfigureVertical` (niScope Configure Vertical VI) with the following parameters:
   - **channelList**: `"0"`
   - **range**: The Range value in Table 3 for the current iteration
   - **offset**: `0.0`
   - **coupling**: `NISCOPE_VAL_DC`
   - **probeAttenuation**: `1.0`
   - **enabled**: `NISCOPE_VAL_TRUE`
3. Call `niScope_ConfigureHorizontalTiming` (niScope Configure Horizontal Timing VI) with the following parameters:
   - **minSampleRate**: `10,000,000`
   - **minNumPts**: `100,000`
   - **refPosition**: `50.0`
   - **numRecords**: `1`
   - **enforceRealtime**: `NISCOPE_VAL_TRUE`
4. Call `niScope_Commit` (niScope Commit VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
5. Make sure the calibrator test head is connected directly to the channel 0 input of the digitizer and output the positive input voltage in Table 5 that corresponds to the vertical range used. Be sure to configure the load impedance of the calibrator to match the input impedance of the digitizer.
6. Wait 2,500 ms for the impedance matching of the calibrator to settle.

7. Call `niScope_InitiateAcquisition` (niScope Initiate Acquisition VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
8. Call `niScope_FetchMeasurement` (niScope Fetch Measurement VI) with the following parameters:
   - **channelList**: `"0"`
   - **timeout**: `1.0`
   - **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_AVERAGE`
9. Using the calibrator, output the negative input voltage listed in Table 5.
10. Wait 750 ms for the output of the calibrator to settle.
11. Call `niScope_FetchMeasurement` (niScope Fetch Measurement VI) with the following parameters:
    - **channelList**: `"0"`
    - **timeout**: `1.0`
    - **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_AVERAGE`
12. 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 voltage

    d = the applied negative voltage

    Compare the resulting percent error to the *Calibration Test Limits* column or the *Published Specifications* column listed in Table 5. If the result is within the selected test limit, the device has passed this portion of the verification.
13. Repeat steps 1 through 12 for each iteration in Table 3.
14. Move the calibrator test head to the digitizer input channel 1 and repeat steps 1 through 13 for every iteration in Table 3, replacing `"0"` with `"1"` for the **channelList** parameter.

You have finished verifying the vertical gain accuracy of the NI 5114.

Table 5. NI 5114 Vertical Gain Stimuli, Calibration Test Limits, and Published Specifications

Range (V)	Positive Input (V)	Negative Input (V)	Calibration Test Limits	Published Specifications
0.04	0.018	–0.018	±1.3975%	±1.5%
0.1	0.045	–0.045	±1.3975%	±1.5%
0.2	0.09	–0.09	±1.3975%	±1.5%
0.4	0.18	–0.18	±1.3975%	±1.5%
1	0.45	–0.45	±1.3975%	±1.5%
2	0.9	–0.9	±1.3975%	±1.5%
4	1.8	–1.8	±1.3975%	±1.5%
10	4.5	–4.5	±1.3975%	±1.5%
20	9	–9	±1.3975%	±1.5%
40	18	–18	±1.3975%	±1.5%

Programmable Vertical Offset Accuracy

Complete the following steps to verify the programmable vertical offset accuracy for each digitizer channel.

1. Call `niScope_ConfigureChanCharacteristics` (niScope Configure Chan Characteristics VI) with the following parameters:
   - **channelList**: `"0"`
   - **inputImpedance**: `NISCOPE_VAL_1_MEG_OHM`
   - **maxInputFrequency**: `20,000,000`
2. Call `niScope_ConfigureVertical` (niScope Configure Vertical VI) with the following parameters:
   - **channelList**: `"0"`
   - **range**: The range value in Table 6 for the current iteration
   - **offset**: The positive offset setting value in Table 6 for the current iteration
   - **coupling**: `NISCOPE_VAL_DC`
   - **probeAttenuation**: `1.0`
   - **enabled**: `NISCOPE_VAL_TRUE`

3. Call `niScope_ConfigureHorizontalTiming` (niScope Configure Horizontal Timing VI) with the following parameters:
   - **minSampleRate**: `10,000,000`
   - **minNumPts**: `100,000`
   - **refPosition**: `50.0`
   - **numRecords**: `1`
   - **enforceRealtime**: `NISCOPE_VAL_TRUE`
4. Call `niScope_Commit` (niScope Commit VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
5. Make sure the calibrator test head is connected directly to the channel 0 input of the digitizer.
6. Output the positive output voltage listed in Table 6 for the current iteration with a 1 MΩ load impedance.
7. Wait 2,500 ms for the impedance matching of the calibrator to settle.
8. Call `niScope_InitiateAcquisition` (niScope Initiate Acquisition VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
9. Call `niScope_FetchMeasurement` (niScope Fetch Measurement VI) with the following parameters:
   - **channelList**: `"0"`
   - **timeout**: `1.0`
   - **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_AVERAGE`
10. Call `niScope_ConfigureVertical` (niScope Configure Vertical VI) with the following parameters:
    - **channelList**: `"0"`
    - **range**: The range value in Table 6 for the current iteration
    - **offset**: The negative offset setting in Table 6 for the current iteration
    - **coupling**: `NISCOPE_VAL_DC`
    - **probeAttenuation**: `1.0`
    - **enabled**: `NISCOPE_VAL_TRUE`
11. Call `niScope_Commit` (niScope Commit VI) with the following parameter:
    - **vi**: The instrument handle you obtained from `niScope_init`
12. With the calibrator, output the negative output voltage listed in Table 6 for the current iteration, with a 1 MΩ load impedance.

13. Wait 750 ms for the output of the calibrator to settle.
14. Call `niScope_InitiateAcquisition` (niScope Initiate Acquisition VI) with the following parameter:
    - **vi**: The instrument handle you obtained from `niScope_init`
15. Call `niScope_FetchMeasurement` (niScope Fetch Measurement VI) with the following parameters:
    - **channelList**: `"0"`
    - **timeout**: `1.0`
    - **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_AVERAGE`
16. Calculate the error in the programmable vertical offset as a percentage of input using the formula:

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

    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

    Compare the resulting percent to the *Calibration Test Limits* column or the *Published Specifications* column listed in Table 6. If the result is within the selected test limit, the device has passed this portion of the verification.
17. Repeat steps 1 through 16 for each iteration in Table 6.
18. Move the calibrator test head to the digitizer input channel 1 and repeat steps 1 through 17, replacing `"0"` with `"1"` for the **channelList** parameter.

You have finished verifying the programmable vertical offset accuracy of the NI 5114.

Table 6. NI 5114 Programmable Vertical Offset Accuracy Limits

Iteration	Range (V)	Positive Offset (V)	Negative Offset (V)	Calibration Test Limits	Published Specifications
1	0.04	0.8	–0.8	±1.95%	±2%
2	0.1	0.8	–0.8	±1.95%	±2%
3	0.2	0.8	–0.8	±1.95%	±2%
4	0.4	0.8	–0.8	±1.95%	±2%
5	1	8	–8	±1.95%	±2%
6	2	8	–8	±1.95%	±2%
7	4	8	–8	±1.95%	±2%
8	10	30	–30	±1.95%	±2%
9	20	25	–25	±1.95%	±2%
10	40	15	–15	±1.95%	±2%

Timing Accuracy

Complete the following steps to verify the timing accuracy for the NI 5114.

1. Call `niScope_ConfigureChanCharacteristics` (niScope Configure Chan Characteristics VI) with the following parameters:
   - **channelList**: `"0"`
   - **inputImpedance**: `NISCOPE_VAL_50_OHM`
   - **maxInputFrequency**: `20,000,000`
2. Call `niScope_ConfigureVertical` (niScope Configure Vertical VI) with the following parameters:
   - **channelList**: `"0"`
   - **range**: `2.0`
   - **offset**: `0.0`
   - **coupling**: `NISCOPE_VAL_DC`
   - **probeAttenuation**: `1.0`
   - **enabled**: `NISCOPE_VAL_TRUE`

3. Call `niScope_ConfigureHorizontalTiming` (niScope Configure Horizontal Timing VI) with the following parameters:
   - **minSampleRate**: `250,000,000`
   - **minNumPts**: `2,500,000`
   - **refPosition**: `50.0`
   - **numRecords**: `1`
   - **enforceRealtime**: `NISCOPE_VAL_TRUE`
4. Call `niScope_Commit` (niScope Commit VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
5. Make sure the calibrator test head is connected directly to the channel 0 input of the digitizer. Configure the calibrator to output an exact 11 MHz sine wave with 1 $V_{pk\text{-}pk}$ amplitude and 50 Ω load impedance.
6. Wait 750 ms for the impedance matching and frequency of the calibrator to settle.
7. Call `niScope_InitiateAcquisition` (niScope Initiate Acquisition VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
8. Call `niScope_FetchMeasurement` (niScope Fetch Measurement VI) with the following parameters:
   - **channelList**: `"0"`
   - **timeout**: `1.0`
   - **scalarMeasFunction**: `NISCOPE_VAL_FFT_FREQUENCY`
9. Calculate the error in timing as parts per million (ppm) using the formula:

   $$\text{error} = (a - 11{,}000{,}000) / 11$$

   where a is the measured frequency.

   Compare the result to the *Calibration Test Limits* column or the *Published Specifications* column listed in Table 7. If the result is within the selected test limit, the device has passed this portion of the verification.

Note The same time source is used for both channel 0 and channel 1, so you only need to verify the timing accuracy on one channel.

You have finished verifying the timing accuracy of the NI 5114.

Table 7. NI 5114 Timing Accuracy

Calibration Test Limits	Published Specifications
±5.3 ppm	±25 ppm

Bandwidth and Flatness

Complete the following steps to verify the bandwidth and flatness of the NI 5114. You must verify both channels with each iteration listed in Table 8.

1. Call `niScope_ConfigureChanCharacteristics` (niScope Configure Chan Characteristics VI) with the following parameters:
   - **channelList**: `"0"`
   - **inputImpedance**: `NISCOPE_VAL_50_OHM`
   - **maxInputFrequency**: The Maximum Input Frequency in Table 8 for the current iteration
2. Call `niScope_ConfigureVertical` (niScope Configure Vertical VI) with the following parameters:
   - **channelList**: `"0"`
   - **range**: The Range value in Table 8 or the current iteration
   - **offset**: `0.0`
   - **coupling**: `NISCOPE_VAL_DC`
   - **probeAttenuation**: `1.0`
   - **enabled**: `NISCOPE_VAL_TRUE`
3. Call `niScope_ConfigureHorizontalTiming` (niScope Configure Horizontal Timing VI) with the following parameters:
   - **minSampleRate**: `10,000,000`
   - **minNumPts**: `30,000`
   - **refPosition**: `50.0`
   - **numRecords**: `1`
   - **enforceRealtime**: `NISCOPE_VAL_TRUE`
4. Call `niScope_Commit` (niScope Commit VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`

5. Make sure the calibrator test head is connected directly to the channel 0 input of the digitizer. Configure the calibrator to output a 50 kHz sine wave with peak-to-peak voltage amplitude set to half the vertical range of the digitizer. Configure the load impedance of the calibrator to match the input impedance of the digitizer.
6. Wait 1,000 ms for the impedance matching of the calibrator to settle.
7. Call `niScope_InitiateAcquisition` (niScope Initiate Acquisition VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
8. Call `niScope_FetchMeasurement` (niScope Fetch Measurement VI) with the following parameters:
   - **channelList**: `"0"`
   - **timeout**: `1.0`
   - **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_RMS`
9. Call `niScope_ConfigureHorizontalTiming` (niScope Configure Horizontal Timing VI) with the following parameters:
   - **minSampleRate**: `250,000,000`
   - **minNumPts**: `300,000`
   - **refPosition**: `50.0`
   - **numRecords**: `1`
   - **enforceRealtime**: `NISCOPE_VAL_TRUE`
10. Repeat steps 10a through 10e for each input frequency in the current iteration.
    a. Configure the calibrator to output the Input Frequency listed in Table 8 for the current iteration.
    b. Wait 500 ms for the output of the calibrator to settle.
    c. Call `niScope_InitiateAcquisition` (niScope Initiate Acquisition VI) with the following parameter:
       - **vi**: The instrument handle you obtained from `niScope_init`
    d. Call `niScope_FetchMeasurement` (niScope Fetch Measurement VI) with the following parameters:
       - **channelList**: `"0"`
       - **timeout**: `1.0`
       - **scalarMeasFunction**: `NISCOPE_VAL_VOLTAGE_RMS`

e. Calculate the power difference using the formula:

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

where

a is the measured RMS voltage in step 10d

b is the measured RMS voltage in step 8

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

11. Repeat steps 1 through 10 for each iteration in Table 8.
12. Move the calibrator test head to the digitizer input channel 1 and repeat steps 1 through 11, replacing `"0"` with `"1"` for the **channelList** parameter.

You have finished verifying the bandwidth and flatness of the NI 5114.

Table 8. NI 5114 Bandwidth and Flatness Stimuli and Limits

Iteration	Max Input Frequency (Hz)	Range (V)	Input Frequency (Hz)	Calibration Test Limits		Published Specifications	
				Max Level (dB)	Min Level (dB)	Max Level (dB)	Min Level (dB)
1	125 MHz	0.04	50,100,000	0.83	–0.83	3	–3
			112,000,000	3	–3	3 at 100 MHz	–3 at 100 MHz
2	125 MHz	0.4	50,100,000	0.83	–0.83	3	–3
			131,000,000	3	–3	3 at 125 MHz	–3 at 125 MHz
3	125 MHz	2	50,100,000	0.83	–0.83	3	–3
			131,000,000	3	–3	3 at 125 MHz	–3 at 125 MHz
4	125 MHz	10	50,100,000	0.83	–0.83	3	–3
			131,000,000	3	–3	3 at 125 MHz	–3 at 125 MHz
5	20 MHz	1	20,100,000	1	–3	N/A	–3 at 20 MHz
			25,100,000	–3	–20	–3 at 20 MHz	N/A

Trigger Sensitivity

Complete the following steps to verify the trigger sensitivity of the NI 5114. You must verify channel 0, channel 1, and the external trigger channel using the corresponding iterations listed in Table 9. Use the following inputs:

- For channel 0, use the entries for iterations 1 and 2.
- For channel 1, use the entries for iterations 3 and 4.
- For the external trigger channel, use the entries for iterations 5 and 6.

1. Call `niScope_ConfigureChanCharacteristics` (niScope Configure Chan Characteristics VI) with the following parameters:
   - **channelList**: `"0"`
   - **inputImpedance**: `NISCOPE_VAL_50_OHM`
   - **maxInputFrequency**: `125,000,000`
2. Call `niScope_ConfigureVertical` (niScope Configure Vertical VI) with the following parameters:
   - **channelList**: `"0"`
   - **range**: `0.2`
   - **offset**: `0.0`
   - **coupling**: `NISCOPE_VAL_DC`
   - **probeAttenuation**: `1.0`
   - **enabled**: `NISCOPE_VAL_TRUE`
3. Call `niScope_ConfigureHorizontalTiming` (niScope Configure Horizontal Timing VI) with the following parameters:
   - **minSampleRate**: `250,000,000`
   - **minNumPts**: `1,000`
   - **refPosition**: `50.0`
   - **numRecords**: `50`
   - **enforceRealtime**: `NISCOPE_VAL_TRUE`
4. Call `niScope_ConfigureTriggerEdge` with the following parameters:
   - **triggerSource**: The Trigger source value from Table 9 for the current iteration
   - **level**: The Level value in Table 9
   - **slope**: The Slope value in Table 9 for the current iteration
   - **triggerCoupling**: `NISCOPE_VAL_DC`

- **holdoff**: 0
- **delay**: 0

Note The trigger level is set to center the trigger hysteresis window at 0.0 V.

5. Call `niScope_Commit` (niScope Commit VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
6. Make sure the calibrator test head is connected directly to the digitizer input for the channel you are testing. Configure the calibrator to output the appropriate signal in Table 9.
7. Wait 1,500 ms for the calibrator impedance matching and frequency to settle.
8. Call `niScope_InitiateAcquisition` (niScope Initiate Acquisition VI) with the following parameter:
   - **vi**: The instrument handle you obtained from `niScope_init`
9. Call `niScope_Fetch` (niScope Multi Fetch VI) with the following parameters:
   - **channelList**: `"0"`
   - **timeout**: `2.0`
   - **numSamples**: `-1`

   If the digitizer does not time out, the digitizer has passed this portion of the verification. If the digitizer times out, you must call `niScope_Abort` (niScope Abort VI) to end the acquisition.
10. To verify the trigger sensitivity on channel 1, repeat steps 1 through 9 using the values from Table 9, iterations 3 and 4. Make the following changes:
    - Change **channelList** to `"1"` in steps 1, 2, and 9
    - Connect the calibrator test head to channel 1 in step 6
11. To verify the trigger sensitivity on the external trigger channel, repeat steps 1 through 9 using the values from Table 9, iterations 5 and 6. Do not change the **channelList** inputs. Connect the calibrator test head to the external trigger channel (TRIG) in step 6.

You have finished verifying the trigger sensitivity for the NI 5114.

Table 9. NI 5114 Trigger Sensitivity Inputs

Iteration	Trigger Source	Level	Slope	Calibrator Signal
1	0	1 mV	NISCOPE_VAL_POSITIVE	9.7 mV_{pk-pk} 100 MHz sine wave with 50 Ω load impedance
2	0	–1 mV	NISCOPE_VAL_NEGATIVE	
3	1	1 mV	NISCOPE_VAL_POSITIVE	9.7 mV_{pk-pk} 100 MHz sine wave with 50 Ω load impedance
4	1	–1 mV	NISCOPE_VAL_NEGATIVE	
5	VAL_EXTERNAL	50 mV	NISCOPE_VAL_POSITIVE	485 mV_{pk-pk} 125 MHz sine wave with 1 MΩ load impedance
6	VAL_EXTERNAL	50 mV	NISCOPE_VAL_NEGATIVE	

Adjusting the NI 5114

If the NI 5114 successfully passed each of the verification procedures within the calibration test limits, then an adjustment is recommended but not required to guarantee the published specifications for the next two years. If the digitizer 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 digitizer. Refer to the *External Calibration Options* section to determine which procedures to perform.

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

Note If the digitizer passed the entire verification procedure within the calibration test limits and you do not want to perform an adjustment, you can update the calibration date and onboard calibration temperature without making any adjustments by completing *only* steps 2 and 14 in this section.

Complete all of the following steps to externally adjust the NI 5114.

1. Short-circuit the channel 0 input of the digitizer by connecting the calibrator test head directly to the digitizer and grounding the output of the calibrator.

2. Call `niScope_CalStart` (niScope Cal Start VI) using the user password. The factory default password for the NI 5114 is `NI`.

3. Wait 500 ms for the impedance matching of the calibrator to settle.
4. Call `niScope_CalAdjustRange` (niScope Cal Adjust Range VI) with the following parameters:
   - **channelName**: `"0"`
   - **range**: 10
   - **stimulus**: `0`
5. Configure the calibrator to output the voltage listed under the *Input (V)* column in Table 10. Configure the load impedance of the calibrator to 1 MΩ.
6. Wait 750 ms for the calibrator to settle.
7. Call `niScope_CalAdjustRange` (niScope Cal Adjust Range VI) with the following parameters:
   - **channelName**: `"0"`
   - **range**: The range value in Table 10 for the current iteration
   - **stimulus**: The input voltage in Table 10 for the current iteration
8. Repeat steps 5 through 7 for each iteration in Table 10.
9. Move the calibrator test head to the digitizer input channel 1 and repeat steps 1 through 8, replacing `"0"` with `"1"` for the **channelName** parameter.
10. Using a BNC cable, connect REF FREQUENCY OUTPUT on the back of the calibrator to the channel 0 input of the digitizer. Make sure the output of the reference frequency is enabled and set to 10 MHz. If you are not using a Fluke 9500B/Wavetek 9500 calibrator, connect a precise 10 MHz, 1 $V_{pk\text{-}pk}$ sine or square wave source to channel 0.
11. Call `niScope_CalAdjustVCXO` (niScope Cal Adjust VCXO VI) with the following parameter:
    - **stimulusFreq**: `10,000,000`

Note The 10 MHz stimulus is automatically taken from channel 0.

12. Disconnect or disable all inputs to the digitizer.
13. Call `niScope_CalSelfCalibrate` (niScope Cal Self Calibrate VI) with the following parameters:
    - **channelList**: `VI_NULL`
    - **option**: `VI_NULL`

14. Call `niScope_CalEnd` with the following parameters:
    - **sessionHandle**: The instrument handle you obtained from `niScope_CalStart`
    - **action**: `NISCOPE_VAL_ACTION_STORE` to save the results of the calibration

You have finished adjusting the NI 5114. Repeat the steps listed in the *Verifying NI 5114 Specifications* section to reverify the performance of the NI 5114 after adjustments.

Table 10. NI 5114 Input Parameters for External Adjustment

Iteration	Range (V)	Input (V)
1	40	18
2	20	9
3	10	4.5
4	4	1.8
5	2	0.9
6	1	0.45
7	0.4	0.18
8	0.2	0.09
9	0.1	0.045
10	0.04	0.018
11	40	–18
12	20	–9
13	10	–4.5
14	4	–1.8
15	2	–0.9
16	1	–0.45
17	0.4	–0.18
18	0.2	–0.09
19	0.1	–0.045
20	0.04	–0.018

Calibration Utilities

NI-SCOPE supports several calibration utilities you can use to retrieve information about adjustments performed on the NI 5114, 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»NI-DAQmx Devices**.
2. Select the **Calibration** tab in the lower right 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_CalChangePassword` (niScope Cal Change Password VI)
- `niScope_CalFetchCount` (niScope Cal Fetch Count VI)
- `niScope_CalFetchDate` (niScope Cal Fetch Date VI)
- `niScope_CalFetchMiscInfo` (niScope Cal Fetch Misc Info VI)
- `niScope_CalFetchTemperature` (niScope Cal Fetch Temperature VI)
- `niScope_CalStoreMiscInfo` (niScope Cal Store Misc Info VI)

Calibration Function References

The functions used in this procedure, including all calibration functions, are documented in the *NI-SCOPE Function Reference Help* and the *NI-SCOPE VI Reference Help*, both of which you can access from the *NI High-Speed Digitizers Help* (**Start»Programs»National Instruments»NI-SCOPE»Documentation**).

Where to Go for Support

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

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