

NI 783xR/784xR/785xR Calibration Procedure for NI-RIO

This document contains information about calibrating National Instruments 7830R/7831R/7833R/7841R/7842R/7851R/7852R/7853R/7854R devices.

NI R Series 78xxR devices should be calibrated at a regular interval as defined by the measurement accuracy requirements of your application. National Instruments recommends that you routinely perform a complete calibration at least once every year. You can shorten this interval based on the accuracy demands of your application or requirements of your processes.

This document also provides LabVIEW programming examples showing how to perform the various calibration steps. For detailed information on writing programs for the NI 78xxR devices, refer to your LabVIEW, LabVIEW FPGA Module, and NI-RIO help files and documentation.

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Conventions

The following conventions appear in this manual:

» The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.



This icon denotes a note, which alerts you to important information.

bold

Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names and hardware labels.

italic

Italic text denotes variables, emphasis, a cross-reference, or an introduction to a key concept. Italic text also denotes text that is a placeholder for a word or value that you must supply.

monospace

Monospace text denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.

Software

Calibration requires the following:

- LabVIEW 8.6 or later
- NI-RIO driver software
 - Version 3.1
 - Version 3.0 or later with patch¹

¹ To run the calibration VIs in this document, NI-RIO 3.0 or later must be installed. If you use NI-RIO 3.0, you must also install the software patch provided beneath the PDF link on ni.com/manuals page for this document. NI-RIO 3.1 includes this software update, so no further action is required if you have already installed NI-RIO 3.1.

Documentation

If you are using the NI-RIO driver, the following documents provide additional information to help write your calibration utility:

- The *NI R Series Intelligent DAQ User Manual* provides information about the R Series hardware including specifications and wiring diagrams.
- The *NI R Series Intelligent DAQ Specifications* provides the specifications of the NI 781xR/783xR/784xR/785xR R Series devices.
- The *LabVIEW Help* provides information about writing LabVIEW applications, including applications that communicate with R Series devices.

Password

The default password for password-protected operations is `NI`.

Test Equipment

National Instruments recommends that you use the following instruments for calibrating an NI 78xxR device.

Table 1. Recommended Equipment

Equipment	Recommended Model	Requirements
Calibrator	Fluke 5700A	If that instrument is unavailable, use a high-precision voltage source that is at least 10 ppm accurate.
DMM	NI 4070	If that instrument is unavailable, use a multiranging 6½-digit DMM with an accuracy of 40 ppm.
Counter	Hewlett-Packard 53131A	If that instrument is unavailable, use a counter accurate to 0.01%.
Low thermal copper EMF plug-in cables	Fluke 5440A-7002	Do <i>not</i> use standard banana cables.
Shielded MIO cable	NI SHC68-68-RMIO	Use this high-performance shielded cable, designed specifically for R Series devices, when calibrating the NI 78xxR.

Table 1. Recommended Equipment (Continued)

Equipment	Recommended Model	Requirements
Accessory	NI SCB-68	The SCB-68 is a shielded I/O connector block with 68 screw terminals for easy signal connection to the R Series devices.
	NI CB-68LP, NI TBX-68, NI CB-68LPR	The CB-68LP, CB-68LPR, and TBX-68 are low-cost termination accessories with 68 screw terminals for easy signal connection to the R Series devices.

Test Considerations

Connection and environmental considerations:

- Keep connections to the device as short as possible. Long cables and wires can act as antennae, which could pick up extra noise that would affect measurements.
- Use shielded copper wire for all cable connections to the device. Use twisted-pair wire to eliminate noise and thermal offsets.
- Maintain the ambient temperature between 18–28 °C. The device temperature will be greater than the ambient temperature.
- Keep relative humidity below 80%.
- Allow a warm-up time of at least 15 minutes to ensure that the measurement circuitry is at a stable operating temperature.
- (PXI Devices) Ensure that the PXI chassis fan speed is set to HIGH, the fan filters are clean, and the empty PXI slots contain filler panels.

Calibration Process

This section provides instructions for verifying and adjusting your device.

Calibration Process Overview

The calibration process has four steps.

1. *Initial Setup*—Configure your device in NI-RIO.
2. *NI 78xxR Verification Procedure*—Verify the existing operation of the device. This step allows you to confirm that the device is operating within its specified range prior to adjustment.

3. *NI 78xxR Adjustment Procedure*—Adjust the device calibration constants with respect to a known voltage source.
4. Perform another verification to ensure that the device is operating within its specifications after adjustment.

These steps are described in detail in the following sections.

Initial Setup

The device must be configured in Measurement & Automation Explorer (MAX) to communicate with NI-RIO.

Complete the following steps to configure a device in MAX.

1. Install the NI-RIO driver software.
2. Power off the computer that will hold the device and install the device in an available slot.
3. Power on the computer and launch MAX.
4. In the left pane of MAX, expand **Devices and Interfaces**»**NI-RIO Devices** to locate your device. Note the Resource Name for the device (for example, RIO0).



Note When a RIO device is configured with MAX, it is assigned a Resource Name. This Resource Name is used to communicate with the device during calibration.

Finding the Calibration VIs

The calibration application is written in LabVIEW and calls VIs installed with NI-RIO to perform the calibration operations. The NI 78xxR calibration VIs are installed into the following location within the LabVIEW installation directory:

```
C:\Program Files\National Instruments\LabVIEW\vi.lib\  
LabVIEW Targets\FPGA\RIO\R Series\78XXR\783XR\  
Calibration\Public
```

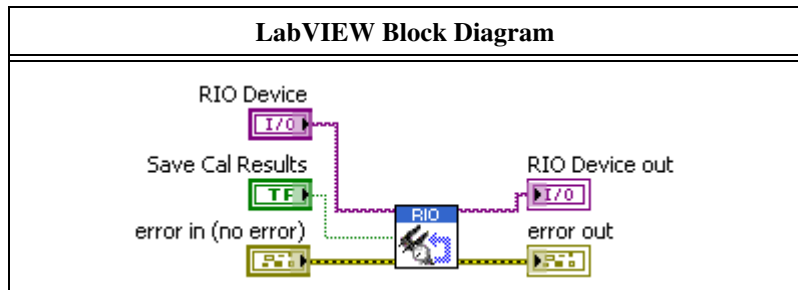
All of the calibration VIs referenced in this document can be found in this location.



Note All LabVIEW calibration VIs stored in this directory can be run on any NI 783xR/784xR/785xR target.

Self-Calibration

Self-calibration should be performed after the device has warmed up for the recommended time period. The self-calibration VI is `nirio78xxCalibrationSelfCal.vi`. Call self-calibration before doing the first verification. This function measures the onboard reference voltage of the device and adjusts the self-calibration constants to account for any errors caused by short-term fluctuations in the environment. Self-calibration requires no external signal connections. Pass a TRUE to `Save Cal Results` to save the constants to the user portion of the flash memory. For NI 783xR devices, the device automatically loads the saved constants to the calibration DAC at power-on. For NI PXI-784xR/785xR devices, the saved constants are loaded to the calibration DAC every time a VI is downloaded to the FPGA.



NI 78xxR Verification Procedure

Verification determines how well the R Series device is meeting its specifications. Performing this procedure allows you to see how your device has operated over time. You can use this information to help determine the appropriate calibration interval for your application.

The verification procedure is divided into the major functions of the device. Throughout the verification process, use the tables in the [Device Test Limits](#) section to determine if your device needs to be adjusted. Refer also to Figure 1 for the pin assignments for NI 783xR/784xR/785xR devices.

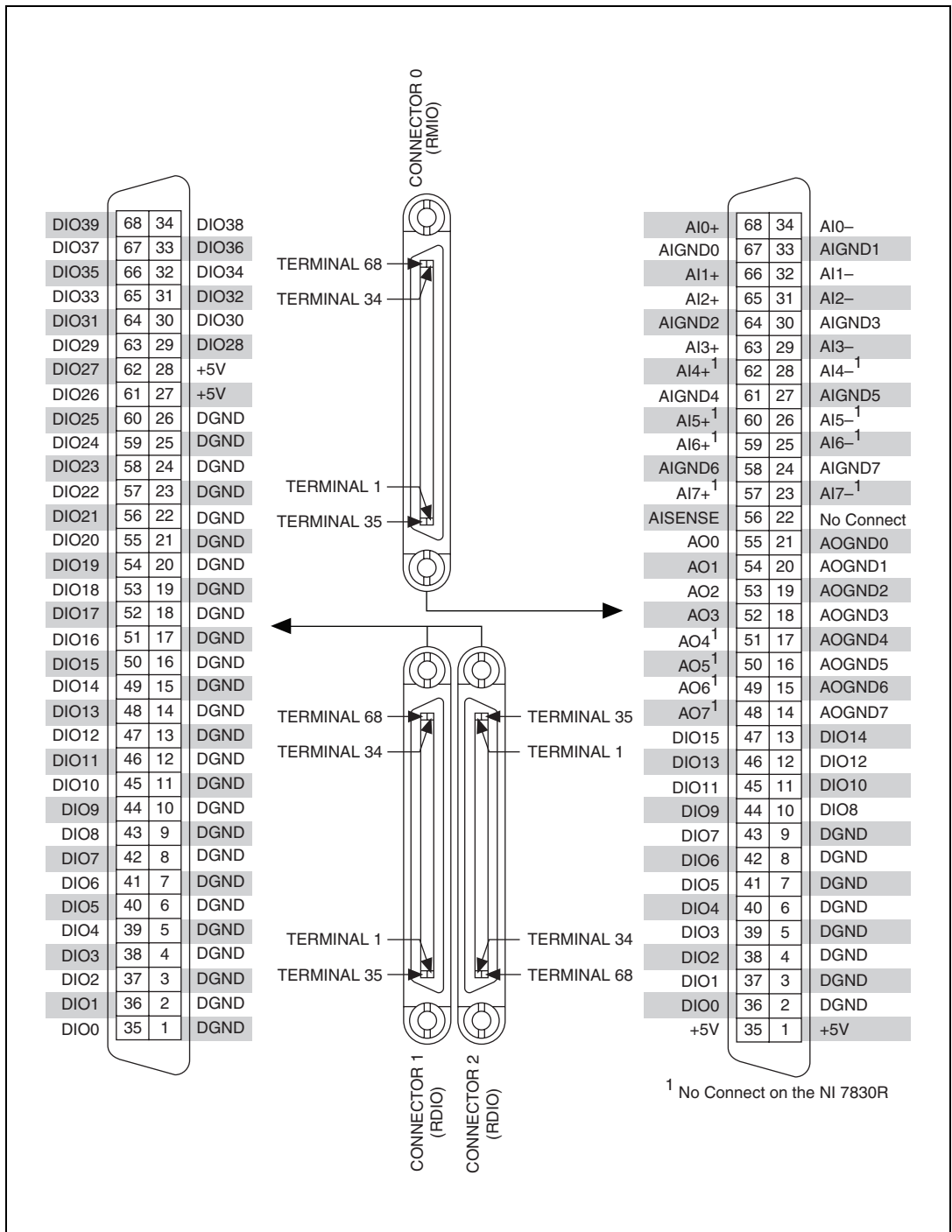


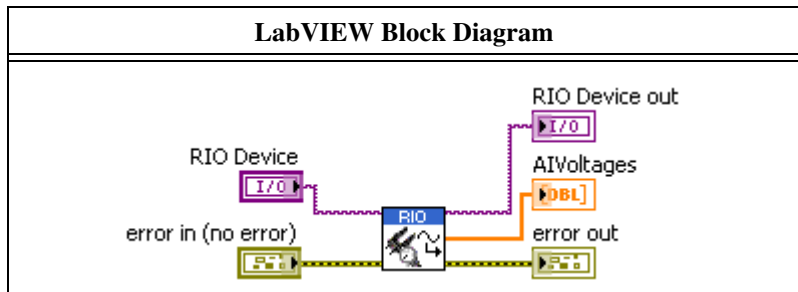
Figure 1. NI 783xR/784xR/785xR I/O Connector Pin Assignments

Analog Input Verification

The R Series devices contain independent analog input circuitry for each channel. Consequently, each channel needs to be independently verified.

Complete the following steps to verify the performance of the analog input. Refer to Table 2 for all analog input test points that need to be verified for this device.

1. Make the following connections between the NI 78xxR device and your calibrator:
 - Connect the LO output of the calibrator to the negative input on each channel of the NI 78xxR device, for example, AI0-, AI1-, and so on.
 - If your calibrator has a guard connection, connect that terminal to AI GND.
 - Connect the HI output of the calibrator to the positive input on each channel of the NI 78xxR device, for example, AI0+, AI1+, and so on.
2. Set the calibrator voltage to the first test values indicated in Table 2.
3. Measure the analog input voltage on each channel by calling `nirio78xxCalibrationReadAIVoltage.vi`. Compare the measured voltage with the limits from Table 2 to verify the input accuracy.



4. Repeat steps 2 through 3 until all values have been verified.
5. Disconnect the calibrator from the device.

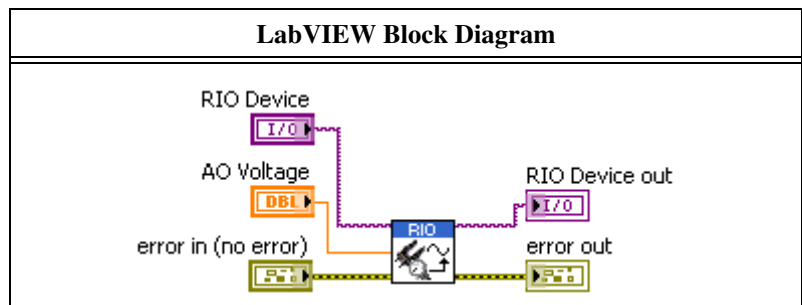
You have finished verifying the analog input levels on your device.

Analog Output Verification

This procedure checks the performance of the analog output. Each analog output channel needs to be independently verified.

Complete the following steps to verify the performance of the analog output. Refer to Table 3 for all analog output test points that need to be verified for this device.

1. Connect the LO DMM input to AOGND0. Connect AO0 to the HI input of the DMM.
2. Set the NI 78xxR device to output the first test points from Table 3 on analog output channel 0. This can be done by calling `nirio78xxCalibrationSetAOVoltage.vi`. This VI configures all of the analog output channels to output the specified voltage.



3. Compare the resulting value shown by the DMM to the upper and lower limits in Table 3. If the value is between these limits, the device passes the test.
4. Repeat steps 2 through 3 until all values have been tested on this channel.
5. Disconnect the DMM from AO0. Reconnect the LO DMM input to AOGND1 and the HI DMM input to AO1.
6. Repeat steps 2 through 5 for all AO channels on the device.
7. Disconnect your DMM from the device.

You have finished verifying the analog output levels on your device.

Counter Verification

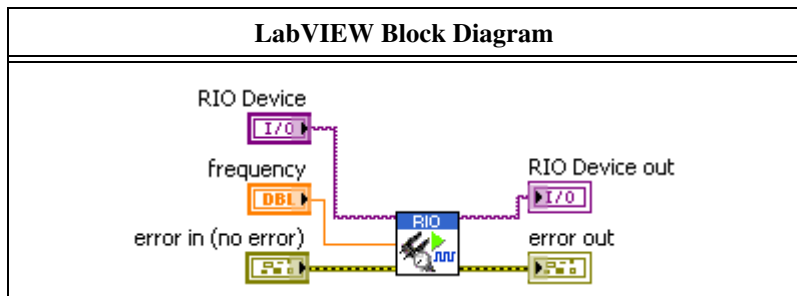
This procedure verifies the performance of the onboard clock. This clock is used as the timebase for all AI, AO, and digital operations performed by the NI 783xR/784xR/785xR devices. It is not possible to adjust this timebase. Consequently, only verification can be performed. During verification, the NI 78xxR device is configured to output a frequency on a digital output line while an external counter device measures this frequency to confirm the accuracy of the NI 78xxR timebase.

Complete the following steps to verify the counter. Refer to Table 4 for all counter test points that need to be verified for this device.



Note The HP 53131A counter uses BNC connectors on its channels and has no HI or LO inputs. Connections on the HP 53131A must be made using BNC (50 Ω) to the patch cords or adapter.

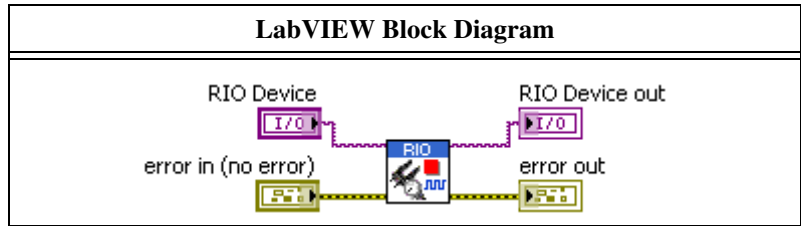
1. Connect your counter negative input to Connector0/DGND and your counter positive input to Connector0/DIO0.
2. Start generating the counter output signal by calling `nirio78xxCalibrationStartCounter.vi`.



This VI causes the device to begin outputting a square-wave on Connector0/DIO0 at the frequency that you specify in Hz.

3. Compare the value read by your counter to the test limits shown in Table 4. If the value falls between these limits, the device passes the test.

4. Stop the generation by calling `nirio78xxCalibrationStopCounter.vi`.



5. Disconnect the counter from your device.

You have verified the counter on your device.

After verification, you can proceed to the adjustment procedure in the *NI 78xxR Adjustment Procedure* section.

NI 78xxR Adjustment Procedure

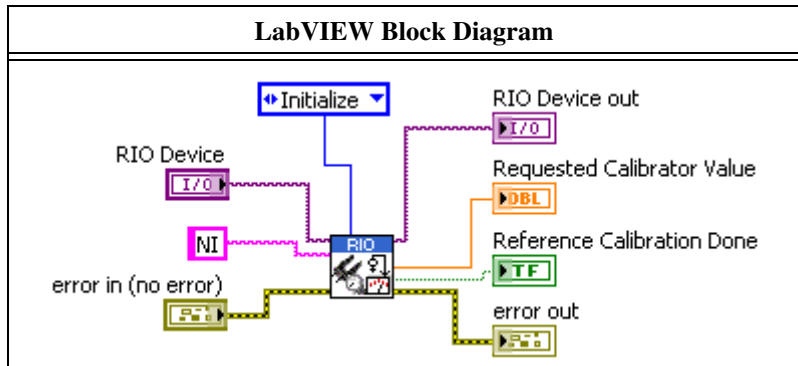
Use the NI 783xR/784xR/785xR adjustment procedure to adjust the analog input and output calibration constants. At the end of each calibration procedure, these new constants are stored in the external calibration area of the onboard flash memory. These values are password-protected, which prevents the accidental access or modification of any calibration constants adjusted by the metrology laboratory. The default password is NI.

If the NI 78xxR device successfully passed each of the verification procedures within the 24-hour test limits, then an adjustment is not required. If the NI 78xxR device is not within the 1-year test limits, then adjustment is recommended to guarantee the published specifications for the next year. If the NI 78xxR device was not within the 24-hour test limits for each of the verification procedures, you can perform the adjustment procedure to improve the accuracy of the device.

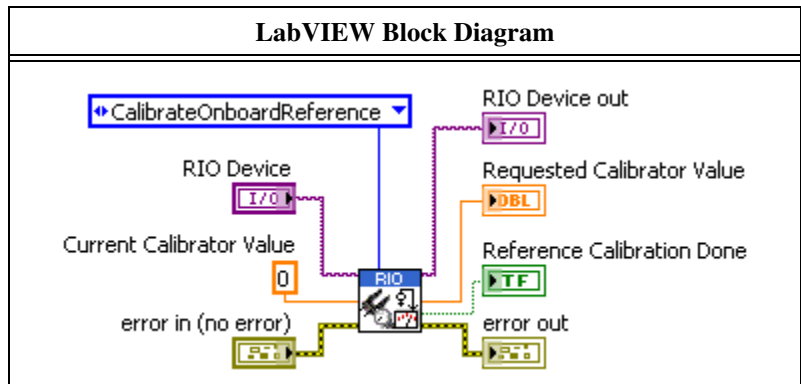
An adjustment is recommended only once every year. Following the adjustment procedure automatically updates the calibration date and temperature in the external calibration area of the onboard flash memory of the NI 78xxR device.

Using a calibrator, complete the following steps to adjust the device calibration constants.

1. Make the following connections between your device and the calibrator.
 - Connect the LO output of the calibrator to the negative input on each channel of the NI 78xxR device, for example, AI0-, AI1-, and so on.
 - If your calibrator has a guard connection, connect that terminal to AI GND.
 - Connect the HI output of the calibrator to the positive input on each channel of the NI 78xxR device, for example, AI0+, AI1+, and so on.
2. Initialize the external calibration process by calling `nirio78xxRCalibrationAdjustExtCal.vi`. Set the **Action** to **Initialize**. This action is password-protected. The default password is **NI**. You do not need to input values for **Comments** or **Current Calibrator Value** for this action.



3. Determine the value of the NI 78xxR onboard reference. This is an iterative process performed by repeatedly calling `nirio78xxCalibrationAdjustExtCal.vi` with an action of `CalibrateOnboardReference`. Complete the following steps to perform this process.
 - a. Call `nirio78xxCalibrationAdjustExtCal.vi`. Set the **Action** to `CalibrateOnboardReference` and pass the **Current Calibrator Value** of 0 V to the VI for the first iteration. `nirio78xxCalibrationAdjustExtCal.vi` then performs some measurements and determines a new **Requested Calibrator Value**. You do not need to input a password or comments for this action.

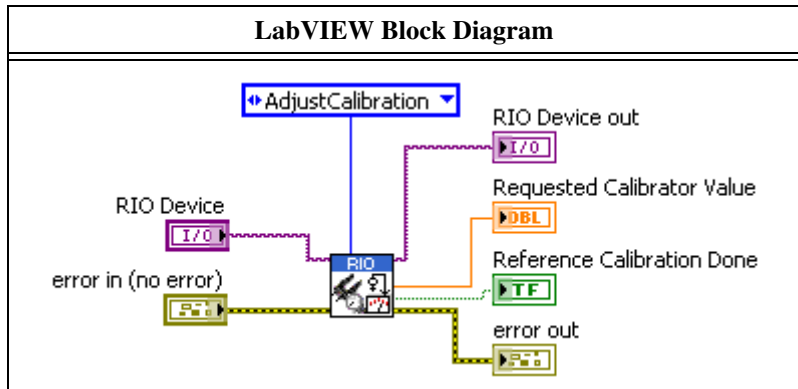


- b. Program the calibrator to output this requested value. At this point, you must wait to ensure that the calibrator output has settled completely.
- c. Repeat steps a and b until the `Reference Calibration Done` output becomes `TRUE`. With each new iteration of these steps, input the `Requested Calibrator Value` returned from the previous iteration.



Note `nirio78xxCalibrationAdjustExtCal.vi` ensures that this loop does not run indefinitely.

- Adjust the NI 78xxR device external calibration constants by calling `nirio78xxCalibrationAdjustExtCal.vi`. Set the **Action** to `AdjustCalibration`. You do not need to input a password, calibrator value, or comments for this action.



- Save the calibration adjustment values to the onboard flash memory using `nirio78xxCalibrationAdjustExtCal.vi`. Set the **Action** to `CommitAndClose`.

If you would prefer to cancel the calibration, you call this VI and set the **Action** to `CancelandClose`. The password and calibrator value inputs are ignored for these actions. A comment input is provided for storing any comments related to your calibration.



Note If the device fails the calibration procedure, no constants will be written to the flash memory.

- Disconnect the calibrator from the device.

The device is now calibrated with respect to your external source.

After calibrating the device, you may want to verify the analog input and output operation. To do this, repeat the [NI 78xxR Verification Procedure](#) section.

Device Test Limits

The tables in this section list the specifications for NI 78xxR devices. The specifications are divided into analog input, analog output, and counter/timer tables of values.

The tables display the specifications for both 1-year and 24-hour calibration intervals. The 1-year limits display the specifications that the devices should meet if it has been one year between calibrations. When a

device has been calibrated with an external source, the values shown in the 24-hour tables are the valid specifications.

Using the Tables

The following definitions describe how to use the information from the tables in this section.

Range

Range refers to the maximum allowable voltage range of an input or output signal.

Test Point

The *Test Point* is the voltage value that is input or output for verification purposes. This value is broken down into two columns—*Location* and *Value*. *Location* refers to where the test value fits within the test range. *Value* refers to the voltage value to be verified and is in volts. *Pos FS* stands for positive full-scale and *Neg FS* stands for negative full-scale.

24-Hour Limits

The *24-Hour Limits* column contains the *Upper Limits* and *Lower Limits* for the test point value. That is, when the device is within its 24-hour calibration interval, the test point value should fall between the upper and lower limit values. Upper and lower limits are expressed in volts.

1-Year Limits

The *1-Year Limits* column contains the *Upper Limits* and *Lower Limits* for the test point value. That is, when the device is within its 1-year calibration interval, the test point value should fall between the upper and lower limit values. Upper and lower limits are expressed in volts.

Counters

It is not possible to adjust the resolution of the counter/timers. Therefore, these values do not have a 1-year or 24-hour calibration period. However, the test point and upper and lower limits are provided for verification purposes.

NI 783xR/784xR/785xR Device Test Limits

The following tables include values for the NI 7830R/7831R/7833R/7841R/7842R/7851R/7852R/7853R/7854R devices.

Table 2. NI 783xR/784xR/785xR Analog Input Values

Range (V)	Test Point		24-Hour Limits		1-Year Limits		
	Maximum	Location	Value (V)	Lower Limit (V)	Upper Limit (V)	Lower Limit (V)	Upper Limit (V)
-10	10	Pos FS	9.90	9.892386	9.907614	9.892270	9.907730
-10	10	0	0.0	-0.002707	0.002707	-0.002707	0.002707
-10	10	Neg FS	-9.90	-9.907614	-9.892386	-9.907730	-9.892270

Table 3. NI 783xR/784xR/785xR Analog Output Values

Range (V)	Test Point		24-Hour Limits		1-Year Limits		
	Maximum	Location	Value (V)	Lower Limit (V)	Upper Limit (V)	Lower Limit (V)	Upper Limit (V)
-10	10	Pos FS	9.90	9.894320	9.905680	9.894155	9.905845
-10	10	0	0.0	-0.002366	0.002366	-0.002366	0.002366
-10	10	Neg FS	-9.90	-9.905680	-9.894320	-9.905845	-9.894155

Table 4. NI 783xR/784xR/785xR Counter Values

Set Point (MHz)	Lower Limit (MHz)	Upper Limit (MHz)
5.0	4.999500	5.000500

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