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**TBX-68**

# AO Waveform Calibration Procedure for NI-DAQ™ mx

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# Conventions

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The following conventions appear in this manual:

<>

Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, P0.<0..7>.

»

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. This font 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.

*monospace italic*

Italic text in this font denotes text that is a placeholder for a word or value that you must supply.

## Introduction

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This document contains instructions for calibrating NI 671X/672X/673X for PCI/PXI/CompactPCI analog output (AO) devices.

This document does not discuss programming techniques or compiler configuration. The National Instruments DAQmx driver contains help files that have compiler-specific instructions and detailed function explanations. You can add these help files when you install NI-DAQmx on the calibration computer.

AO devices should be calibrated at a regular interval as defined by the measurement accuracy requirements of your application. National Instruments recommends that you perform a complete calibration at least once every year. You can shorten this interval to 90 days or six months.

# Software

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Calibration requires the latest NI-DAQmx driver. NI-DAQmx includes high-level function calls to simplify the task of writing software to calibrate devices. The driver supports many programming languages, including LabVIEW, LabWindows™/CVI™, Microsoft Visual C++, Microsoft Visual Basic, and Borland C++.

# Documentation

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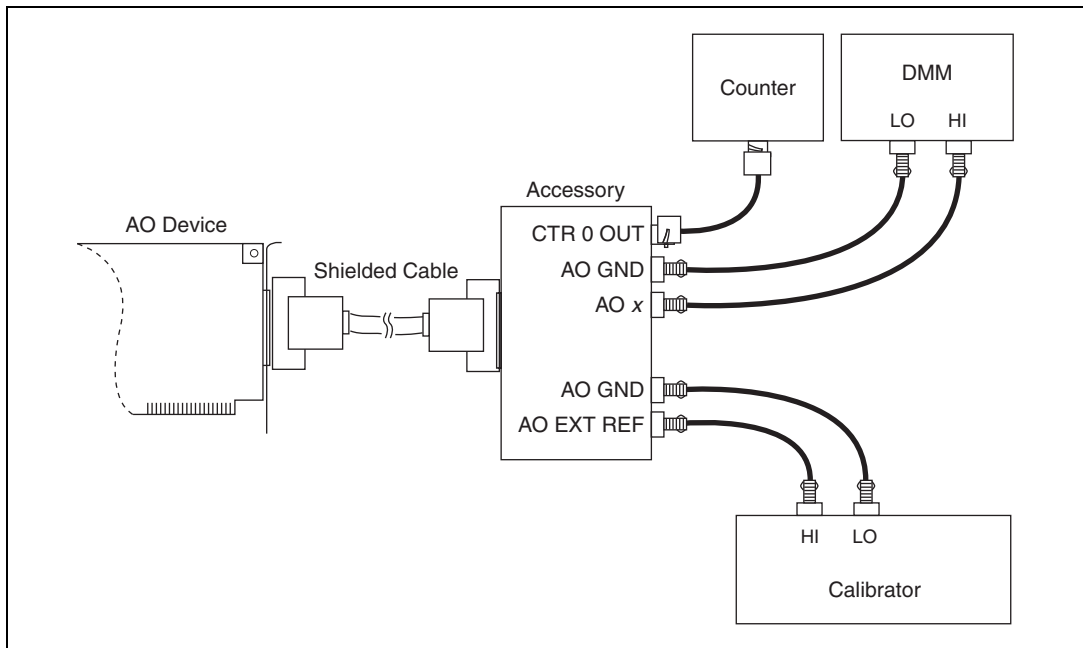
If you are using the NI-DAQmx driver, the following documents are your primary references for writing your calibration utility:

- The *NI-DAQmx C Reference Help* includes information about the functions in the driver.
- The *DAQ Quick Start Guide* for NI-DAQ 7.3 or later provides instructions for installing and configuring NI-DAQ devices.
- The *NI-DAQmx Help* includes information about creating applications that use the NI-DAQmx driver.

For more information about the device you are calibrating, refer to the *Analog Output Series Help*.

# Test Equipment

Figure 1 shows the test equipment you need to calibrate your device. The specific DMM, calibrator, and counter connections are described in the [Calibration Process](#) section.



**Figure 1.** Calibration Connections

When performing calibration, National Instruments recommends that you use the following instruments for calibrating an AO device:

- Calibrator—Fluke 5700A. If that instrument is unavailable, use a high-precision voltage source that is at least 50 ppm accurate for 12- and 13-bit boards and 10 ppm for 16-bit boards.
- DMM—NI 4070. If that instrument is unavailable, use a multi-ranging 5.5-digit DMM with an accuracy of 40 ppm (0.004%).
- 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 not use standard banana cables.
- DAQ cable—NI recommends using shielded cables, such as the SH68-68-EP with the NI 671X/673X or the SH68-C68-S with the NI 672X.

- One of the following DAQ accessories:
  - SCB-68—The SCB-68 is a shielded I/O connector block with 68 screw terminals for easy signal connection to 68- or 100-pin DAQ devices.
  - CB-68LP/CB-68LPR/TBX-68—The CB-68LP, CB-68LPR, and TBX-68 are low-cost termination accessories with 68 screw terminals for easy connection of field I/O signals to 68-pin DAQ devices.

## Test Considerations

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Follow these guidelines to optimize connections and test conditions during calibration:

- Keep connections to the NI 671X/672X/673X short. Long cables and wires act as antennae, picking up extra noise, which can affect measurements.
- Use shielded copper wire for all cable connections to the device.
- Use twisted-pair wire to eliminate noise and thermal offsets.
- Maintain a temperature between 18 and 28 °C. To operate the module at a specific temperature outside this range, calibrate the device at that 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.

## Calibration Process

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This section provides instructions for verifying and calibrating your device.

### Calibration Process Overview

The calibration process has four steps:

1. Initial Setup—Configure your device in NI-DAQmx.
2. AO Verification Procedure—Verify the existing operation of the device. This step allows you to confirm that the device was operating within its specified range prior to calibration.
3. AO Adjustment Procedure—Perform an external calibration that adjusts 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. Because a complete verification of all of the device's ranges can take some time, you may wish to verify only the ranges of interest to you.

## Initial Setup

NI-DAQmx automatically detects all AO devices. However, for the driver to communicate with the device, it must be configured in NI-DAQmx.

To configure a device in NI-DAQmx, complete the following steps:

1. Install the NI-DAQmx 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 Measurement & Automation Explorer (MAX).
4. Configure the device identifier and select **Self-Test** to ensure that the device is working properly.



**Note** When a device is configured with MAX, it is assigned a device identifier. Each function call uses this identifier to determine which DAQ device to calibrate.

## AO Verification Procedure

Verification determines how well the DAQ device is meeting its specifications. By performing this procedure, you can 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 [AO Device Test Limits](#) section to determine if your device needs to be adjusted.

### Analog Output Verification

This procedure checks the performance of the analog output. Check measurements using the following procedure:

1. Connect your DMM to AO 0 as shown in Table 1.

**Table 1.** Connecting the DMM to AO <0..7>

Output Channel	DMM Positive Input	DMM Negative Input
AO 0	AO 0 (pin 22)	AO GND (pin 56)
AO 1	AO 1 (pin 21)	AO GND (pin 55)
AO 2	AO 2 (pin 57)	AO GND (pin 23)

**Table 1.** Connecting the DMM to AO <0..7> (Continued)

<b>Output Channel</b>	<b>DMM Positive Input</b>	<b>DMM Negative Input</b>
AO 3	AO 3 (pin 25)	AO GND (pin 59)
AO 4	AO 4 (pin 60)	AO GND (pin 26)
AO 5	AO 5 (pin 28)	AO GND (pin 61)
AO 6	AO 6 (pin 30)	AO GND (pin 64)
AO 7	AO 7 (pin 65)	AO GND (pin 31)

**Table 2.** Connecting the DMM to AO <8..31> on the NI 6723

<b>Output Channel</b>	<b>DMM Positive Input</b>	<b>DMM Negative Input</b>
AO 8	AO 8 (pin 68)	AO GND (pin 34)
AO 9	AO 9 (pin 33)	AO GND (pin 67)
AO 10	AO 10 (pin 32)	AO GND (pin 66)
AO 11	AO 11 (pin 65)	AO GND (pin 31)
AO 12	AO 12 (pin 30)	AO GND (pin 64)
AO 13	AO 13 (pin 29)	AO GND (pin 63)
AO 14	AO 14 (pin 62)	AO GND (pin 28)
AO 15	AO 15 (pin 27)	AO GND (pin 61)
AO 16	AO 16 (pin 26)	AO GND (pin 60)
AO 17	AO 17 (pin 59)	AO GND (pin 25)
AO 18	AO 18 (pin 24)	AO GND (pin 58)
AO 19	AO 19 (pin 23)	AO GND (pin 57)
AO 20	AO 20 (pin 55)	AO GND (pin 21)
AO 21	AO 21 (pin 20)	AO GND (pin 54)
AO 22	AO 22 (pin 19)	AO GND (pin 53)
AO 23	AO 23 (pin 52)	AO GND (pin 18)
AO 24	AO 24 (pin 17)	AO GND (pin 51)
AO 25	AO 25 (pin 16)	AO GND (pin 50)
AO 26	AO 26 (pin 49)	AO GND (pin 15)



**Table 2.** Connecting the DMM to AO <8..31> on the NI 6723 (Continued)

Output Channel	DMM Positive Input	DMM Negative Input
AO 27	AO 27 (pin 14)	AO GND (pin 48)
AO 28	AO 28 (pin 13)	AO GND (pin 47)
AO 29	AO 29 (pin 46)	AO GND (pin 12)
AO 30	AO 30 (pin 11)	AO GND (pin 45)
AO 31	AO 31 (pin 10)	AO GND (pin 44)

- Choose the table from the *AO Device Test Limits* section that corresponds to the device you are verifying. This table shows all acceptable settings for the device. Although NI recommends that you verify all ranges, you may want to save time by checking only the ranges used in your application.
- Create a task using DAQmxCreateTask.

NI-DAQ Function Call	LabVIEW Block Diagram
<p>Call DAQmxCreateTask with the following parameters:</p> <p><b>taskName:</b> <i>MyAOVoltageTask</i></p> <p><b>taskHandle:</b> &amp;taskHandle</p>	<p>LabVIEW does not require this step.</p>

- Add an AO voltage task using DAQmxCreateAOVoltageChan (DAQmx Create Virtual Channel VI) and configure the channel, AO 0. Use the tables in the *AO Device Test Limits* section to determine the minimum and maximum values for your device.

NI-DAQ Function Call	LabVIEW Block Diagram
<p>Call DAQmxCreateAOVoltageChan with the following parameters:</p> <p><b>taskHandle:</b> taskHandle</p> <p><b>physicalChannel:</b> dev1/ao0</p> <p><b>nameToAssignToChannel:</b> AOVoltageChannel</p> <p><b>minVal:</b> -10.0</p> <p><b>maxVal:</b> 10.0</p> <p><b>units:</b> DAQmx_Val_Volts</p> <p><b>customScaleName:</b> NULL</p>	<p>The diagram illustrates the configuration of the DAQmx Create Virtual Channel VI. It shows the following connections:</p> <ul style="list-style-type: none"> <li><b>Minimum Value:</b> Connected to an orange DBI block.</li> <li><b>Maximum Value:</b> Connected to an orange DBI block.</li> <li><b>Physical Channel:</b> Connected to a purple I/O block.</li> <li><b>AO Voltage:</b> A dropdown menu is set to 'AO Voltage'.</li> <li><b>Task out:</b> Connected to the 'task/channels in' input of the next VI.</li> <li><b>Error out:</b> Connected to the 'error in' input of the next VI.</li> </ul>

- Start the acquisition using DAQmxStartTask (DAQmx Start Task VI).

NI-DAQ Function Call	LabVIEW Block Diagram
Call DAQmxStartTask with the following parameters: <b>taskHandle:</b> taskHandle	

- Write a voltage to the AO channel using DAQmxWriteAnalogF64 (DAQmx Write VI) using the table for your device in the [AO Device Test Limits](#) section.

NI-DAQ Function Call	LabVIEW Block Diagram
Call DAQmxWriteAnalogF64 with the following parameters: <b>taskHandle:</b> taskHandle <b>numSampsPerChan:</b> 1 <b>autoStart:</b> 1 <b>timeout:</b> 10.0 <b>dataLayout:</b> DAQmx_Val_GroupByChannel <b>writeArray:</b> &data <b>sampsPerChanWritten:</b> &samplesWritten <b>reserved:</b> NULL	

- Compare the resulting value shown by the DMM to the upper and lower limits in the table. If the value is between these limits, the test is considered to have passed.
- Clear the acquisition using DAQmxClearTask (DAQmx Clear Task VI).

NI-DAQ Function Call	LabVIEW Block Diagram
Call DAQmxClearTask with the following parameter: <b>taskHandle:</b> taskHandle	

9. Repeat steps 4 through 8 until all values have been tested.
10. Disconnect the DMM from AO 0, and reconnect it to the next channel, making the connections as shown in Table 1.
11. Repeat steps 4 through 10 until you have verified all channels.
12. 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 counter. AO devices have only one timebase to verify, so only counter 0 needs to be checked. It is not possible to adjust this timebase, so only verification can be performed. Perform checks using the following procedure:

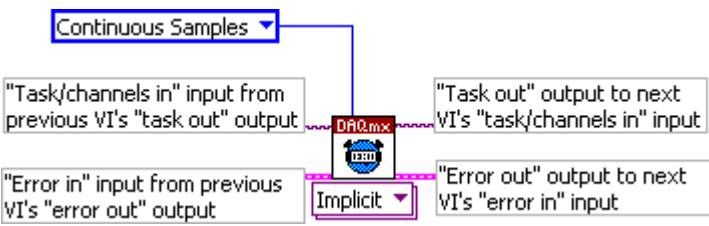
1. Connect your counter positive input to CTR 0 OUT (pin 2) and your counter negative input to D GND (pin 35).
2. Create a task using `DAQmxCreateTask`.

NI-DAQ Function Call	LabVIEW Block Diagram
Call <code>DAQmxCreateTask</code> with the following parameters: <b>taskName:</b> <code>MyCounterOutputTask</code> <b>taskHandle:</b> <code>&amp;taskHandle</code>	LabVIEW does not require this step.

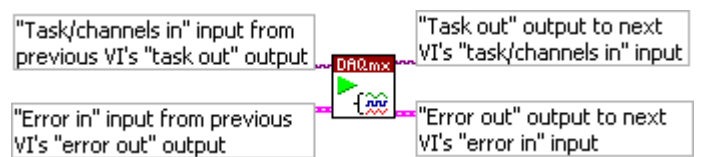
3. Add a counter output channel to the task using `DAQmxCreateCOPulseChanFreq` (**DAQmx Create Virtual Channel VI**) and configure the channel.

NI-DAQ Function Call	LabVIEW Block Diagram
Call <code>DAQmxCreateCOPulseChanFreq</code> with the following parameters: <b>taskHandle:</b> <code>taskHandle</code> <b>counter:</b> <code>dev1/ctr0</code> <b>nameToAssignToChannel:</b> <code>CounterOutputChannel</code> <b>units:</b> <code>DAQmx_Val_Hz</code> <b>idleState:</b> <code>DAQmx_Val_Low</code> <b>initialDelay:</b> <code>0.0</code> <b>freq:</b> <code>5000000.0</code> <b>dutyCycle:</b> <code>.5</code>	

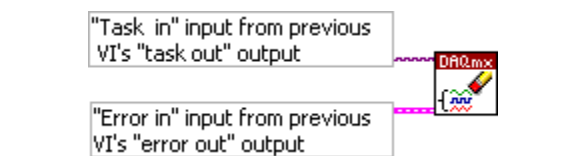
- Configure the counter for continuous square wave generation using DAQmxCfgImplicitTiming (**DAQmx Timing VI**).

NI-DAQ Function Call	LabVIEW Block Diagram
<p>Call DAQmxCfgImplicitTiming with the following parameters:</p> <p><b>taskHandle:</b> taskHandle</p> <p><b>sampleMode:</b> DAQmx_Val_ContSamps</p> <p><b>sampsPerChan:</b> 10000</p>	

- Start the generation of a square wave using DAQmxStartTask (**DAQmx Start Task VI**).

NI-DAQ Function Call	LabVIEW Block Diagram
<p>Call DAQmxStartTask with the following parameter:</p> <p><b>taskHandle:</b> taskHandle</p>	

- The device will begin to generate a 5 MHz square wave when the DAQmxStartTask function completes execution. Compare the value read by your counter to the test limits shown on the device table. If the value falls between these limits, the test is considered to have passed.
- Clear the generation using DAQmxClearTask (**DAQmx Clear Task VI**).

NI-DAQ Function Call	LabVIEW Block Diagram
<p>Call DAQmxClearTask with the following parameter:</p> <p><b>taskHandle:</b> taskHandle</p>	

- Disconnect the counter from your device.

You have verified the counter on your device.

# AO Adjustment Procedure

Use the AO adjustment procedure to adjust the analog output calibration constants. At the end of each calibration procedure, these new constants are stored in the external calibration area of the EEPROM. 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.

To perform adjustment of the device with a calibrator, complete the following steps:

1. Connect the calibrator to the device according to Table 3.

**Table 3.** Connecting the Calibrator to the Device

671X/672X/673X Pins	Calibrator
AO EXT REF (pin 20)	Output High
AO GND (pin 54)	Output Low

2. Set your calibrator to output a voltage of 5 V.
3. Open a calibration session on your device using DAQmxInitExtCal (**DAQmx Initialize External Calibration VI**). The default password is NI.

NI-DAQ Function Call	LabVIEW Block Diagram
<p>Call DAQmxInitExtCal with the following parameters:</p> <p><b>deviceName:</b> dev1  <b>password:</b> NI  <b>calHandle:</b> &amp;calHandle</p>	

- Perform an external calibration adjustment using DAQmxESeriesCalAdjust (**DAQmx Adjust AO-Series Calibration VI**).

NI-DAQ Function Call	LabVIEW Block Diagram
<p>Call DAQmxAOSeriesCalAdjust with the following parameters:</p> <p><b>calHandle:</b> calHandle  <b>referenceVoltage:</b> 5</p>	

- Save the adjustment to the EEPROM, or onboard memory, using DAQmxCloseExtCal (**DAQmx Close External Calibration**). This function also saves the date, time, and temperature of the adjustment to the onboard memory.

NI-DAQ Function Call	LabVIEW Block Diagram
<p>Call DAQmxCloseExtCal with the following parameters:</p> <p><b>calHandle:</b> calHandle  <b>action:</b> DAQmx_Val_Action_Commit</p>	

- Disconnect the calibrator from the device.

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

After adjusting the device, you may want to verify the analog output operation. To do this, repeat the steps in the [AO Verification Procedure](#) section using the 24-hour test limits in the [AO Device Test Limits](#) section.

# AO Device Test Limits

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The tables in this section list the accuracy specifications to use when verifying and adjusting the NI 671X/672X/673X. The tables display the specifications for both 1-year and 24-hour calibration intervals. The 1-year ranges 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 output signal.

### Test Point

The *Test Point* is the voltage value that is generated 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. *Pos FS* stands for positive full-scale and *Neg FS* stands for negative full-scale. *Value* refers to the voltage value to be verified and is in volts.

### 24-Hour Ranges

The *24-Hour Ranges* 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 Ranges

The *1-Year Ranges* 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 6711/6713—12-Bit Resolution

**Table 4.** NI 6711/6713 Analog Output Values

Range (V)		Test Point		24-Hour Ranges		1-Year Ranges	
Minimum	Maximum	Location	Value (V)	Lower Limit (V)	Upper Limit (V)	Lower Limit (V)	Upper Limit (V)
-10	10	0	0.0	-0.0059300	0.0059300	-0.0059300	0.0059300
-10	10	Pos FS	9.9900000	9.9822988	9.9977012	9.9818792	9.9981208
-10	10	Neg FS	-9.9900000	-9.9977012	-9.9822988	-9.9981208	-9.9818792

**Table 5.** NI 6711/6713 Counter Values

Set Point (MHz)	Upper Limit (MHz)	Lower Limit (MHz)
5	5.0005	4.9995

## NI 6722/6723—13-Bit Resolution

**Table 6.** NI 6722/6723 Analog Output Values

Range (V)		Test Point		24-Hour Ranges		1-Year Ranges	
Minimum	Maximum	Location	Value (V)	Lower Limit (V)	Upper Limit (V)	Lower Limit (V)	Upper Limit (V)
-10	10	0	0.0	-0.0070095	0.0070095	-0.0070095	0.0070095
-10	10	Pos FS	9.9000000	9.8896747	9.9103253	9.8892582	9.9107418
-10	10	Neg FS	-9.9000000	-9.9103253	-9.8896747	-9.9107418	-9.8892582

**Table 7.** NI 6722/6723 Counter Values

Set Point (MHz)	Upper Limit (MHz)	Lower Limit (MHz)
5	5.0005	4.9995



# NI 6731/6733—16-Bit Resolution

**Table 8.** NI 6731/6733 Analog Output Values

Range (V)		Test Point		24-Hour Ranges		1-Year Ranges	
Minimum	Maximum	Location	Value (V)	Lower Limit (V)	Upper Limit (V)	Lower Limit (V)	Upper Limit (V)
-10	10	0	0.0	-0.0010270	0.0010270	-0.0010270	0.0010270
-10	10	Pos FS	9.9900000	9.9885335	9.9914665	9.9883636	9.9916364
-10	10	Neg FS	-9.9900000	-9.9914665	-9.9885335	-9.9916364	-9.9883636

**Table 9.** NI 6731/6733 Counter Values

Set Point (MHz)	Upper Limit (MHz)	Lower Limit (MHz)
5	5.0005	4.9995

