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6110E/6111E

Version 1.0

Introduction—Document Scope

The following procedure for verifying and calibrating the National Instruments 6110E/6111E board contains three main sections:

- *Calibration Overview*—This introductory section tells you what calibration is, why you should calibrate, and how often you should do it.
- *Equipment and Other Test Requirements*—This section describes what you need to do before you can calibrate your device, including an overview of the test equipment, software, calibration functions, and environment needed for calibration.
- *Calibration Process Overview*—This section provides detailed step-by-step instructions for verifying and calibrating your device.

This document is intended for metrology labs. It does not cover programming technique or compiler configuration because of the number of programming languages and styles you can use to calibrate your module. However, the National Instruments data acquisition driver, NI-DAQ, has many online help files that contain compiler-specific instructions and detailed function explanations. You can add these help files when you install NI-DAQ on your calibration computer.

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Calibration Overview

This section defines calibration, describes why it is necessary, explains when you should do it, and what to expect.

What Is Calibration?

Calibration is a procedure of reading offset and gain errors from a DAQ board and updating special analog calibration circuitry that will correct these errors. Every E Series product is calibrated at the factory. During the factory-calibration procedure, the calibration constant (values used to update the analog calibration circuitry) are stored in the nonvolatile memory on the board—the EEPROM. From memory, these values are loaded and used as needed.

Why Calibrate?

Offset and gain errors may drift with time and temperature. As a result, the factory-set calibration constants may become invalid, requiring calibration to achieve the specified accuracy of the board.

How Often Should You Calibrate?

E Series products 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 6 months, if desired.

What Can You Expect from External Calibration?

Automated calibration procedures can reduce the total time required to perform calibration and verification to approximately 10 minutes. However, manual calibration and verification can take as long as 1 hour. You can automate the adjustment and verification procedure if you have access to programmable standards such as the Fluke 5700A or HP 3458A. You can control these devices via a GPIB connection. You can then program the entire procedure to save time and effort.

Equipment and Other Test Requirements

This section describes the equipment and environmental conditions needed for calibration.

Test Equipment

When performing calibration, National Instruments recommends that you use the following instruments for calibration of an 6110E/6111E:

- Calibrator—Fluke 5700A
- Digital Multimeter (DMM)—NI 4060 or HP 34401A
- Counter—HP 53131A

If the exact instrument is not available, use the following accuracy requirements to select a substitute calibration standard:

- A high-precision voltage source that is at least 50 ppm accurate
- A multiranging 5 1/2-digit DMM with an accuracy of 15 ppm
- A counter accurate to 0.01%

Note If you do not have custom connection hardware available, you may need a connector block such as the National Instruments TBX-68 and a shielded 68-pin connector cable. These components give easy access to the individual pins on the 68-pin board I/O connector.

Software and Documentation

The following software and documentation are required to calibrate the 6110E/6111E. You can obtain these from the National Instruments web site at `www.ni.com/calibration`:

- The latest version of the National Instruments NI-DAQ driver
- `niECal.dll`, `niECal.lib`, and `niECal.h` files
- *NI-DAQ Function Reference Manual for PC Compatibles*
- *NI-DAQ User Manual for PC Compatibles*

Software

The 6110E/6111E calibration procedure requires that the latest version of the National Instruments NI-DAQ driver be installed on the calibration system. This driver configures and controls the 6110E/6111E. The driver supports a number of programming languages, including LabVIEW, LabWindows/CVI, Microsoft Visual C++, Microsoft Visual Basic, and Borland C++. When you install the driver, you only need to install support for the programming language that you intend to use.

You also need a copy of the `niECal.dll`, `niECal.lib`, and `niECal.h` files. This `.dll` provides calibration functionality that does not reside in the standard NI-DAQ driver. This functionality includes protecting the calibration constants and updating the calibration date. You can access the functions in this `.dll` through any 32-bit compiler.

Documentation

The NI-DAQ function reference and user manuals contain detailed information on using the NI-DAQ driver. The function reference manual includes detailed information on the functions in the driver. The user manual provides instructions on installing and configuring National Instruments DAQ devices. This manual also includes detailed information on creating applications that use the NI-DAQ driver. These manuals are your primary references for writing your calibration utility. For further information on the products you are calibrating, you may also want to install the device user manuals.

Test Considerations

You need to be aware of several connection and environmental concerns during calibration:

- Keep connections to the 6110E/6111E board 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. It is often advisable to use twisted-pair wire to eliminate noise and thermal offsets.
- Maintain the temperature between 18–28 °C.
- Keep relative humidity below 80%.
- Allow a warm-up time of at least 15 minutes for PXI/PCI/AT bus devices and 30 minutes for PCMCIA cards to ensure that the measurement circuitry is at a stable operating temperature.

Calibration Process Overview

Writing Your Calibration Procedure

The calibration process is described in the *Calibration Process* section later in this document, including step-by-step instructions on calling the appropriate calibration functions. Unless otherwise specified, the calibration functions are C function calls in the NI-DAQ driver. These function calls are also valid for Visual Basic programs. While LabVIEW virtual instruments (VIs) are not discussed in this procedure, the translation from NI-DAQ function calls to LabVIEW VIs is straightforward, as many of the VIs have the same names as the listed function calls. Refer to *Flowcharts for Creating Verification and Calibration Code* for flowcharts detailing the code used at each step of the calibration procedure.

There are a number of compiler-specific steps you must follow to create an application using the NI-DAQ driver. The *NI-DAQ User Manual for PC Compatibles* details the required steps for each of the supported compilers.

Be aware that many of the functions listed in the calibration procedure in the *Calibration Process* section of this document use variables that are defined in the `nidaqcns.h` file. To use these variables, you must include the `nidaqcns.h` file in your code. If you do not wish to use these variable definitions, you can examine the function call listings in the NI-DAQ documentation and the `nidaqcns.h` file to determine what input values are required.

Calibration Process

The calibration process is divided into three steps:

1. *6110E/6111E Verification Procedure*—Verify the existing operation of the module. This step allows you to confirm that the module is in specification prior to calibration.
2. *6110E/6111E Adjustment Procedure*—Perform calibration with respect to a known voltage source.
3. Perform another verification to ensure the module is operating within its specifications after calibration.

These steps are described in detail in the following sections. As a complete verification of all of the board's gains and ranges can take some time, you may wish to verify only the gains and ranges of interest to you.

Initial Setup

Measurement & Automation Explorer automatically detects all 6110E/6111E devices. However, for the driver to communicate with the boards, it must be configured in Measurement & Automation Explorer. The following sections provide a brief description of the configuration procedure. For further information on configuration problems, refer to Chapter 2, *Installation and Configuration Issues*, *PCI-6110E/6111E User Manual*. The following procedure describes how to configure a board in NI-DAQ:

1. Install the NI-DAQ driver software.
2. Turn off the power to the computer that will hold the board and install the board in an available slot.
3. Turn on the power to the computer and launch Measurement & Automation Explorer.
4. Configure the board device number and click the **Test Resources** button to ensure that the board is working properly.

Your board installation and setup is complete.



Note Once a board is configured with Measurement & Automation Explorer, the board is assigned a device number. Each function call uses this number to identify which DAQ board to calibrate.

6110E/6111E Verification Procedure

The verification procedure shows you how well the 6110E/6111E board is meeting its specifications.

Analog Input Verification

Use the following procedure to check the performance of the analog input:

1. Read the *Equipment and Other Test Requirements* section earlier in this document.
2. Calibrator connections depend on the channel you are verifying. Use the following guide to determine the connections between the board and the calibrator for analog input verification.
   a. Starting with channel 0, connect the positive output of the calibrator to analog input:
      - Channel 0 (pin 68)
      - Channel 1 (pin 33)
      - Channel 2 (pin 65)
      - Channel 3 (pin 30)

b. Connect the negative output of the calibrator to analog input:
   - Channel 0 (pin 34)
   - Channel 1 (pin 66)
   - Channel 2 (pin 31)
   - Channel 3 (pin 63)

3. If your calibrator and computer are floating with respect to each other, connect the negative output of the calibrator to the analog input channel ground:
   - ACH0GND (pin 67)
   - ACH1GND (pin 32)
   - ACH2GND (pin 64)
   - ACH3GND (pin 29)
4. Refer to the *6110E/6111E Board Specifications* section later in this document. This section shows all acceptable settings for the board type. Although it is recommended that you verify all ranges, you may save time by checking only those ranges that your application uses.
5. Set the calibrator voltage to the test point value indicated in Table 2, *Analog Input Values for the 6110E/6111E*.
6. Run the `AI_Configure` function to configure the board for the appropriate device number, input range, and polarity. Obtain these settings from the Table 2.
7. Run the `DAQ_Op` function to acquire 1000 points of voltage data. Set gain to the value specified by Table 2.
8. Run the `DAQ_VScale` function to convert the buffer of acquired binary values into voltage values.
9. Average the 1000 voltage values. Compare the resulting average to the upper and lower limits listed in the data sheet. If the result falls between these values, the test is considered to have passed.
10. Repeat steps 4 through 9 until all values have been verified.
11. Make the appropriate connections as per steps 2 and 3, and proceed with the next channel from step 4.

You have now verified the analog input levels on your board.

Analog Output Verification

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

1. Read the *Equipment and Other Test Requirements* section earlier in this document.
2. 6110E/6111E boards have two analog outputs: DAC0OUT and DAC1OUT. This test will check both analog output channels. Connect your DMM to DAC0OUT as shown in Table 1.

Table 1. Connections to Analog Outputs

Analog Output	DMM Positive Input	DMM Negative Input
DAC0OUT	DAC0OUT (pin 22)	AOGND (pin 54)
DAC1OUT	DAC1OUT (pin 21)	AOGND (pin 55)

3. Refer to Table 3, *Analog Output Values for the 6110E/6111E* in the *6110E/6111E Board Specifications* section later in this document. This table shows all acceptable settings for the board.
4. Run the `AO_Configure` function to configure the board for the appropriate device number, channel, and output polarity. Use channel 0 as the channel to verify. Get the remaining settings from Table 3.
5. Run the `AO_VWrite` function to update the analog output channel with the appropriate voltage. Use the voltage value to be tested as shown in Table 3.
6. Compare the resulting value shown by the DMM to the upper and lower limits on the data sheet. If the value falls between these limits, the test is considered to have passed.
7. Repeat steps 4 through 6 to test all values.
8. Disconnect the DMM from DAC0OUT, and reconnect it to DAC1OUT, making the connections as shown in Table 1.
9. Repeat steps 4 through 7, changing the channel from 0 to 1.
10. Disconnect your DMM from the board.

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

Counter Verification

This procedure verifies the performance of the counter. The 6110E/6111E boards have only one timebase to verify, so only counter 0 needs to be checked. Adjusting the timebase is not possible, so you can only verify the counter's performance. Perform checks using the following procedure:

1. Read the *Equipment and Other Test Requirements* section earlier in this document.
2. Connect your counter positive input to `GPCTR0_OUT` (pin 2) and your counter negative input to `DGND` (pin 35).
3. Run the `GPCTR_Control` function with the action set to `ND_RESET`. This places the counter in a default state.
4. Run the `GPCTR_Set_Application` function with **application** set to `ND_PULSE_TRAIN_GNR` to configure the counter for pulse-train generation.
5. Run the `GPCTR_Change_Parameter` function with **paramID** set to `ND_COUNT_1` and **paramValue** set to 2. This configures the counter to output a pulse with an off time of 100 ns.
6. Run the `GPCTR_Change_Parameter` function with **paramID** set to `ND_COUNT_2` and paramValue set to 2. This configures the counter to output a pulse with an on time of 100 ns.
7. Run the `Select_Signal` function with signal and source variables set to `ND_GPCTR0_OUTPUT`. This will route the counter signal to the `GPCTR0_OUT` pin on the board connector.
8. Run the `GPCTR_Control` function with action set to `ND_PROGRAM` to start the generation of a square wave.
9. The board will begin to generate a 5 MHz square wave when the `GPCTR_Control` function completes execution. Compare the value read by your counter to the test limits shown on the board data sheet. If the value falls between these limits, the test is considered to have passed.
10. Disconnect the counter from your board.

You have verified the counter on your board.

6110E/6111E Adjustment Procedure

You use the 6110E/6111E calibration procedure to adjust the analog input and output calibration constants. At the end of each calibration procedure, these new constants are stored in the factory area of the board EEPROM. The user cannot modify these values. This limitation provides a level of security that ensures users will not accidentally access or modify any calibration constants adjusted by the metrology laboratory.

This section in the calibration process calls functions from the NI-DAQ driver as well as functions from the `niECal.dll`. For further information on the functions in the `niECal.dll`, refer to the comments in the `niECal.h` file.

Perform adjustment of the analog inputs with a calibrator using the following procedure:

1. Read the *Equipment and Other Test Requirements* section earlier in this document.
2. Connect the positive output of the calibrator to analog input channel 0+ (pin 68).
3. Connect the negative output of the calibrator to analog input channel 0– (pin 34) and to ACH0GND (pin 67).
4. To obtain the date of the last calibration, run the `Get_Cal_Date` function included in the `niECal.dll`. Once run, CalDate will contain the date when the board was last calibrated.
5. Run the `Calibrate_E_Series` function with calOP set to `ND_SELF_CALIBRATE` and setOfCalConst set to `ND_USER_EEPROM_AREA`. This step will perform an internal calibration of the board. It may take as long as 60 seconds to complete this function call.
6. Set your calibrator to output a voltage of 7.50 V.
7. Run the `Calibrate_E_Series` function with calOP set to `ND_EXTERNAL_CALIBRATE` and setOfCalConst set to `ND_USER_EEPROM_AREA`. Set calRefVolts to 7.50 V. If the voltage supplied by your source does not maintain a steady 7.50 V, you will receive an error. If your voltage source is floating with respect to the computer, and you have not connected the calibrator GND to ACH0GND, you will receive an error.
8. Run the `Copy_Const` function included in the `niECal.dll`. This function enables and copies the new calibration constants to the protected factory portion of the EEPROM. This function will also update the calibration date.
9. Run the `Calibrate_E_Series` function with calOP set to `ND_SET_DEFAULT_LOAD_AREA` and setOfCalConst set to `ND_FACTORY_EEPROM_AREA`. This step sets the factory-calibration constants as the default constants.
10. Disconnect the calibrator from the board.

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

After the board is calibrated, you may want to verify the analog input and output operation. To do this, repeat the *6110E/6111E Verification Procedure* section of this document.

Flowcharts for Creating Verification and Calibration Code

This section shows the basic flowcharts for creating the verification and calibration code the 6110E/6111E calibration procedure requires. These flowcharts only refer to the appropriate NI-DAQ function calls. You may want to refer to the *Calibration Process* section of this document, to the *NI-DAQ Function Reference Manual for PC Compatibles*, and to the *NI-DAQ User Manual for PC Compatibles* for additional information on the software structure and for function explanations.

Analog Input Verification

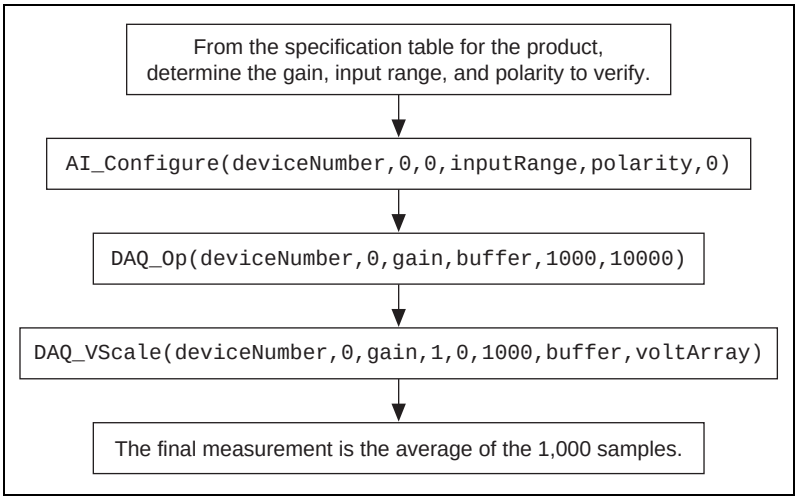


Figure 1. Analog Input Verification

Analog Output Verification

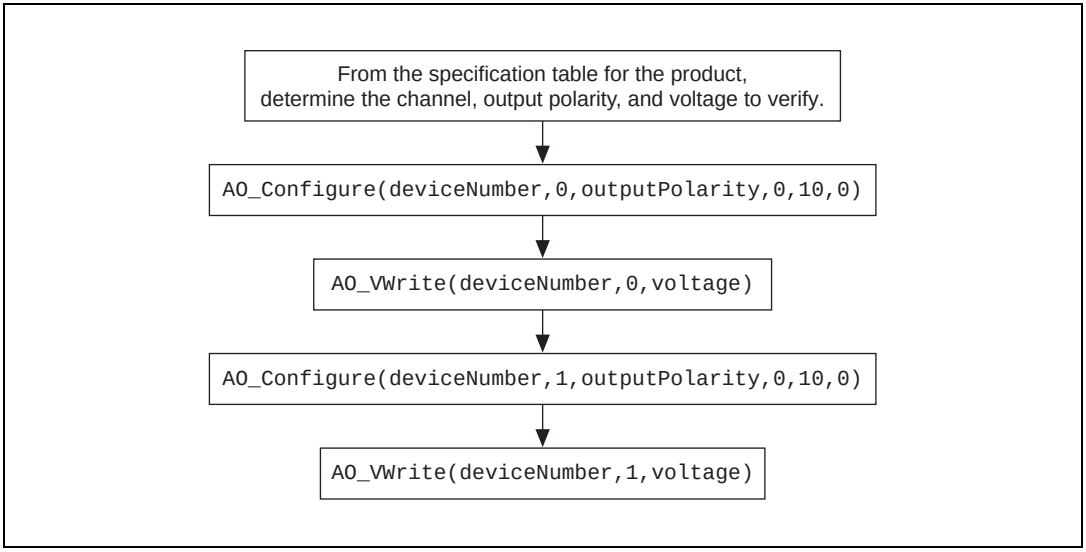


Figure 2. Analog Output Verification

Counter Verification

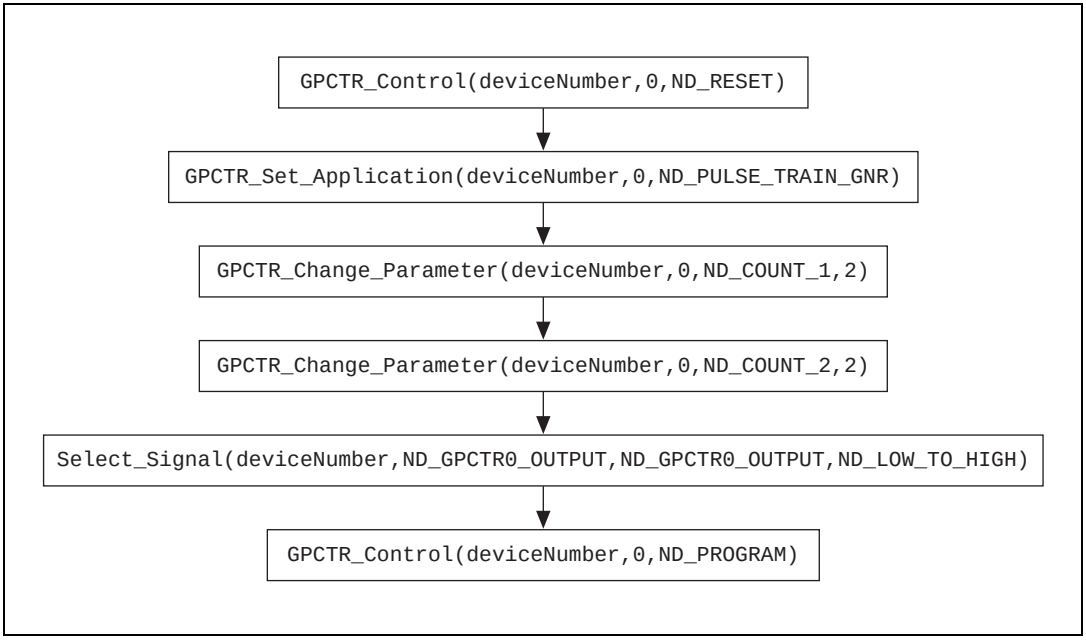


Figure 3. Counter Verification

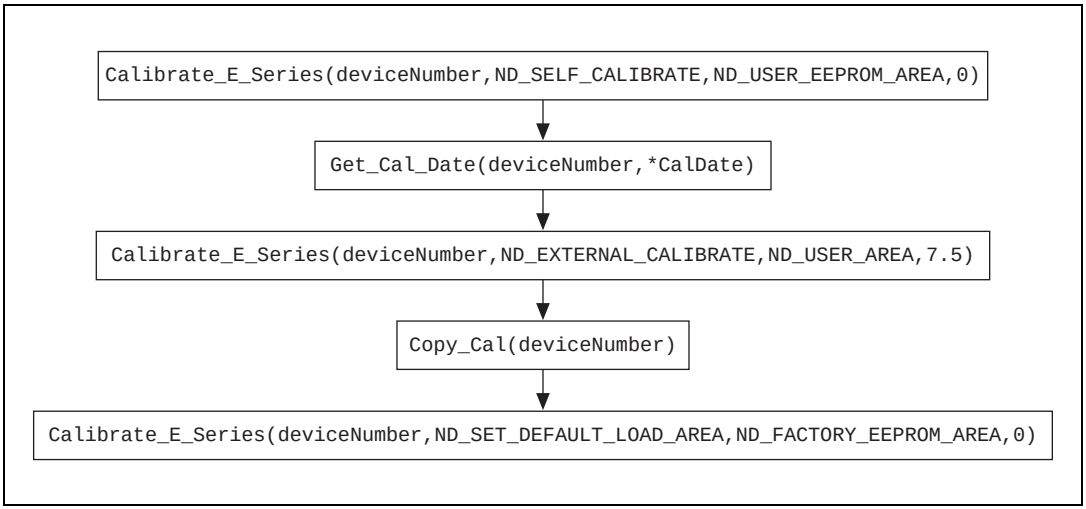


Figure 4. E Series Calibration

6110E/6111E Board Specifications

The tables in this section are the specifications for the 6110E/6111E products. 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. That is, the 1-year ranges display the specifications that the boards should meet if it has been 1 year between calibrations. Once a board 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. For example, if a board is configured in bipolar mode with a range of 20 V, the board can sense signals between +10 V and –10 V.

Polarity

Polarity refers to the polarity of the input signal that can be read. In bipolar configuration, the board reads both positive and negative voltages. In unipolar mode, the board reads only positive voltages.

Gain

The *Gain* value is applied to an input voltage prior to sending the voltage to the ADC, which requires a 10 V signal. The input voltage level, multiplied by the gain, should not exceed the voltage range of the board. For instance, for a gain of two with the board configured in bipolar mode, the maximum input voltage can be 4.995 V, because $4.995 \times 2.0 = 9.990$ V.

Note There are no gain settings for analog output, as the analog output gain is fixed at one.

Test Point

The *Test Point* is the voltage value that is input or output for verification purposes. This value is divided 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 Range* column contains the *Upper Limits* and *Lower Limits* for the test point value. That is, when the board 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 board 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 in Table 4, *Counter Values for the 6110E/6111E*, for verification purposes.

Table 2. Analog Input Values for the 6110E/6111E

Range	Polarity	Gain	Test Point		24-Hour Ranges		1-Year Ranges	
			Location	Value (V)	Lower Limit (V)	Upper Limit (V)	Lower Limit (V)	Upper Limit (V)
±42	Bipolar	0.2	PosFS	41.5800	41.3331	41.8269	41.3324	41.8276
±42	Bipolar	0.2	Zero	0.0000	–0.2469	0.2469	–0.2476	0.2476
±42	Bipolar	0.2	NegFS	41.5800	–41.8269	–41.3331	–41.8276	–41.3324
±20	Bipolar	0.5	PosFS	19.8000	19.6792	19.9208	19.6788	19.9212
±20	Bipolar	0.5	Zero	0.0000	–0.1208	0.1208	–0.1212	0.1212
±20	Bipolar	0.5	NegFS	19.8000	–19.9208	–19.6792	–19.9212	–19.6788
±10	Bipolar	1	PosFS	9.9000	9.8834	9.9166	9.8832	9.9168
±10	Bipolar	1	Zero	0.0000	–0.0166	0.0166	–0.0168	0.0168
±10	Bipolar	1	NegFS	9.9000	–9.9166	–9.8834	–9.9168	–9.8832
±5	Bipolar	2	PosFS	4.9500	4.94406	4.95594	4.94398	4.95602
±5	Bipolar	2	Zero	0.0000	–0.00594	0.00594	–0.00602	0.00602
±5	Bipolar	2	NegFS	4.9500	–4.95594	–4.94406	–4.95602	–4.94398
±2	Bipolar	5	PosFS	2.4750	2.47226	2.47774	2.47222	2.47778
±2	Bipolar	5	Zero	0.0000	–0.00274	0.00274	–0.00278	0.00278
±2	Bipolar	5	NegFS	2.4750	–2.47774	–2.47226	–2.47778	–2.47222
±1	Bipolar	10	PosFS	0.9900	0.98871	0.99129	0.98869	0.99131
±1	Bipolar	10	Zero	0.0000	–0.00129	0.00129	–0.00131	0.00131
±1	Bipolar	10	NegFS	0.9900	–0.99129	–0.98871	–0.99131	–0.98869
±0.5	Bipolar	20	PosFS	0.4950	0.494297	0.495703	0.494289	0.495711
±0.5	Bipolar	20	Zero	0.0000	–0.000703	0.000703	–0.000711	0.000711
±0.5	Bipolar	20	NegFS	0.4950	–0.495703	–0.494297	–0.495711	–0.494289
±0.2	Bipolar	50	PosFS	0.1980	0.197671	0.198329	0.197669	0.198331
±0.2	Bipolar	50	Zero	0.0000	–0.000329	0.000329	–0.000331	0.000331
±0.2	Bipolar	50	NegFS	0.1980	–0.198329	–0.197671	–0.198331	–0.197669

Table 3. Analog Output Values for the 6110E/6111E

Range	Polarity	Test Point		24-Hour Ranges		1-Year Ranges	
		Location	Value (V)	Lower Limit (V)	Upper Limit (V)	Lower Limit (V)	Upper Limit (V)
20	Bipolar	PosFS	9.990000	9.982296	9.997704	9.981875	9.998125
20	Bipolar	Zero	0.000000	–0.007704	0.007704	–0.008125	0.008125
20	Bipolar	NegFS	9.990000	–9.997704	–9.982296	–9.998125	–9.981875

Table 4. Counter Values for the 6110E/6111E

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

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