NI 9205/9206 Calibration Procedure

This document contains information about calibrating National Instruments 9205/9206 modules using NI-DAQmx. This calibration procedure is intended for metrology labs.

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

The NI 9205 and NI 9206 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 two years. You can shorten this interval based on the accuracy demands of your application or requirements of your processes. Self-calibration can be performed as needed or when the temperature varies by 5 °C or more from the last external calibration.

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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.

NI 9205/9206 NI 9205/9206 refers to the NI 9205 and NI 9206.

Calibration Options

The NI 9205/9206 support two types of calibration: self-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 might have changed since the last external calibration. Self-calibration retains the traceability of the external calibration and can be performed as necessary to compensate for environmental changes.

External Calibration

External calibration is generally performed with a high-precision 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. This document describes specific programming steps for writing an external calibration procedure for the NI 9205/9206.

Software and Documentation Requirements

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

Software

Install NI-DAQmx 8.1 or later on the calibration computer. NI-DAQmx includes high-level function calls to simplify the task of writing software to calibrate devices. You must have the proper device driver installed on the calibration system before calibrating the device.

Note NI recommends that you install the NI-DAQmx driver software before physically installing the NI 9205/9206. NI-DAQmx, available at `ni.com/downloads`, configures and controls the NI 9205/9206.

NI-DAQmx supports a number of programming languages, including LabVIEW, LabWindows™/CVI™, Microsoft Visual C++ 6.0, Microsoft Visual Basic 6.0, Microsoft .NET, and Borland C++.

You can access the NI-DAQmx header file, `NIDAQmx.h`, like any standard library. You can find examples of how to use the NI-DAQmx driver in the `Program Files\National Instruments\NI-DAQ\Examples` directory.

Documentation

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

- *NI-DAQmx Help*—This help file contains general information about measurement concepts, key NI-DAQmx concepts, and common applications that apply to all programming environments. To access this help file, select **Start»All Programs»National Instruments» NI-DAQ»NI-DAQmx Help**.

- *NI-DAQmx C Reference Help*—This help file contains C reference and general information about measurement concepts. To access this help file, select **Start»All Programs»National Instruments»NI-DAQ» NI-DAQmx C Reference Help**.

- *DAQ Getting Started Guide* for NI-DAQ 8.0 or later—This guide describes how to install NI-DAQmx for Windows software and NI-DAQmx-supported DAQ devices, and how to confirm that your device is operating properly. To access this guide, select **Start» All Programs»National Instruments»NI-DAQ»DAQ Getting Started Guide**.

Note The documents above are installed with NI-DAQmx. You can also download the latest versions from the NI Web site at `ni.com/manuals`.

- *NI 9205 Operating Instructions/NI 9206 Operating Instructions*— These documents contain information about specific device features. The limits you use to verify the accuracy of the devices are based on the specifications found in this document. You can download the latest versions of these documents from the NI Web site at `ni.com/ manuals`.

Calibration Requirements

Password

The default password for password-protected operations is NI.

Test Equipment

National Instruments recommends that you use the following equipment for calibrating the NI 9205/9206:

- Fluke 5700A calibrator. If that instrument is unavailable, use a high-precision voltage source with an accuracy of at least 10 ppm.

- NI cDAQ-9172 chassis.

Test Conditions

Follow these guidelines to optimize the connections and the environment:

- Keep connections to the device as short as possible. Long cables and wires act as antennae, picking up extra noise that 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 an ambient temperature of 23 ±10 °C. The device temperature will be greater than the ambient temperature.

- Keep relative humidity below 80%.

- Allow a warm-up time of at least 10 minutes to ensure that the measurement circuitry is at a stable operating temperature.

Calibration Process

This section provides instructions for verifying and adjusting the NI 9205/9206.

Calibration Process Overview

The calibration process consists of the following steps:

1. *Initial Setup*—Configure the device in NI-DAQmx.

2. *Self-Calibration*—Measure the onboard reference voltage of the device and adjust the self-calibration constants.

3. *Verification Procedure*—Verify the existing operation of the device. This step confirms whether the device was operating within its specified range prior to calibration.

4. *Adjustment Procedure*—Perform an external calibration that adjusts the device calibration constants with respect to a known voltage source.

5. Perform another verification to ensure that the device operates within its specifications after adjustment.

The first four steps are explained in the following sections.

Initial Setup

You must configure the device in Measurement & Automation Explorer (MAX) to communicate with NI-DAQmx.

Complete the following steps to configure a device in MAX:

1. Install the NI-DAQmx driver software.

2. Make sure that no power is connected to the module terminals. If the system is in a nonhazardous location, the chassis power can be on when you install the module.

3. Insert the module into an available slot in the cDAQ-9172 chassis.

4. Launch MAX.

5. Right-click the device name 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 name. Each function call uses this device name to determine which DAQ device to calibrate. This document uses dev1 to refer to the device name. In the following procedures, use the device name as it appears in MAX.

Self-Calibration

Self-calibrate the device before completing the first verification, after the device has warmed up for the recommended time period. DAQmxSelfCal (DAQmx Self Calibrate VI), as shown in the following table, 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 operating environment. When you self-calibrate a device, no external signal connections are necessary.

NI-DAQmx Function Call	LabVIEW Block Diagram
Call DAQmxSelfCal with the following parameters: **deviceName**: dev1	

Verification Procedure

Verification determines how well the device is meeting its specifications. By completing this procedure, you can see how the device has drifted over time, which helps you determine the appropriate calibration interval for your application. Table 4 in the *Device Test Limits* section shows all acceptable settings for the device type. Throughout the verification process, use Table 4 to determine if the device is operating within its specified range prior to calibration. Because the NI 9205/9206 has many different ranges, you must verify measurements for each available range on these modules.

Complete the following steps to test the performance of the device:

1. Refer to Table 1 for a list of the NI connection accessories for the NI 9205/9206 and instructions on connecting the calibrator to the device.

Table 1. NI Connection Accessories

Device	Connection Accessory	Connection Instructions
NI 9205/9206	NI 9940 36-position strain relief & high voltage connector kit	Connect the positive output of the calibrator to AI0 (pin 1) and the negative output of the calibrator to AI8 (pin 19) and COM (pin 17). If the calibrator has a guard connection, connect that terminal to COM instead of connecting COM to the negative output.
NI 9205 with DSUB	NI 9933 37-pin connector kit, screw terminal connector and DSUB shell	Connect the positive output of the calibrator to AI0 (pin 1) and the negative output of the calibrator to AI8 (pin 20) and COM (pin 10). If the calibrator has a guard connection, connect that terminal to COM instead of connecting COM to the negative output.

2. Set the calibrator voltage to the Test Point value indicated in Table 4. NI recommends that you verify all values, although you can save time by verifying only the values used in your application.

3. If you use C function calls, create a task using DAQmxCreateTask, as shown in the following table. If you use LabVIEW, skip this step. The task is created in step 4 in LabVIEW.

NI-DAQmx Function Call	LabVIEW Block Diagram
Call DAQmxCreateTask with the following parameters: **taskName**: *AIVerificationTask* **taskHandle**: &taskHandle	LabVIEW does not require this step.

4. Create and configure an AI voltage channel through NI-DAQmx using `DAQmxCreateAIVoltageChan` (DAQmx Create Virtual Channel VI), as shown in the following table. Use Table 4 to determine the minimum and maximum values for the device.

NI-DAQmx Function Call	LabVIEW Block Diagram
Call `DAQmxCreateAIVoltageChan` with the following parameters: **taskHandle**: `taskHandle` **physicalChannel**: `dev1/ai0` **nameToAssignToChannel**: *myVoltageChannel* **terminalConfig**: `DAQmx_Val_Cfg_Default` **minVal**: *-10.0* **maxVal**: *10.0* **units**: `DAQmx_Val_Volts` **customScaleName**: NULL	

5. Configure the timing properties for the voltage acquisition using `DAQmxCfgSampClkTiming` (DAQmx Timing VI), as shown in the following table.

NI-DAQmx Function Call	LabVIEW Block Diagram
Call `DAQmxCfgSampClkTiming` with the following parameters: **taskHandle**: `taskHandle` **source**: NULL **rate**: 100000.0 **activeEdge**: `DAQmx_Val_Rising` **sampleMode**: `DAQmx_Val_FiniteSamps` **sampsPerChan**: 10000	

6. Start the acquisition using `DAQmxStartTask` (DAQmx Start Task VI), as shown in the following table.

NI-DAQmx Function Call	LabVIEW Block Diagram
Call `DAQmxStartTask` with the following parameter: **taskHandle**: taskHandle	

7. Acquire 10,000 points of voltage data using `DAQmxReadAnalogF64` (DAQmx Read VI), as shown in the following table.

NI-DAQmx Function Call	LabVIEW Block Diagram
Call `DAQmxReadAnalogF64` with the following parameters: **taskHandle**: taskHandle **numSampsPerChan**: –1 **timeout**: 10.0 **fillMode**: DAQmx_Val_GroupByChannel **readArray**: data **arraySizeInSamples**: 10000 **sampsPerChanRead**: &read **reserved**: NULL	

8. Average the voltage values that you acquired. Compare the resulting average to the Upper Limit and Lower Limit values in Table 4. If the result is between these values, the device passes the test.

9. Clear the acquisition using `DAQmxClearTask` (DAQmx Clear Task VI), as shown in the following table.

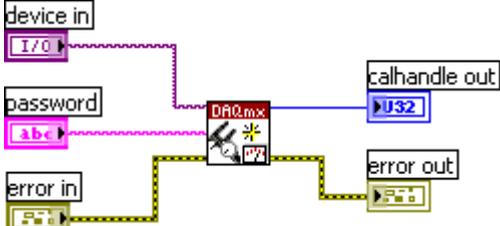| NI-DAQmx Function Call	LabVIEW Block Diagram
Call `DAQmxClearTask` with the following parameter: **taskHandle**: taskHandle	

10. Repeat steps 3 through 9 for all ranges and all values.

11. Disconnect the calibrator from the device or proceed to the *Adjustment Procedure* section to adjust the analog input calibration constants.

Adjustment Procedure

The NI 9205/9206 adjustment procedure adjusts the analog input calibration constants. At the end of each adjustment procedure, the new constants are stored in the external calibration area of the device EEPROM. These values are password-protected, which ensures that you do not accidentally access or modify any calibration constants adjusted by the metrology laboratory. The default password is NI.

Complete the following steps to adjust the device with a calibrator:

1. Refer to Table 1 for a list of the NI connection accessories for the NI 9205/9206 and instructions on connecting the calibrator to the device.

2. Set the calibrator to output 4.0 V.

3. Open a calibration session on the device using DAQmxInitExtCal (DAQmx Initialize External Calibration VI), as shown in the following table.

| NI-DAQmx Function Call	LabVIEW Block Diagram
Call DAQmxInitExtCal with the following parameters: **deviceName**: dev1 **password**: NI **calHandle**: &calHandle	

4. Perform an external adjustment using `DAQmxMSeriesCalAdjust` (DAQmx Adjust M-Series Calibration VI), as shown in the following table.

NI-DAQmx Function Call	LabVIEW Block Diagram
Call `DAQmxMSeriesCalAdjust` with the following parameters: **calHandle**: `calHandle` **referenceVoltage**: `4.0`	
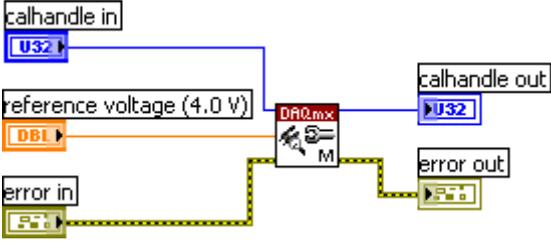
5. Save the adjustment to the EEPROM using `DAQmxCloseExtCal` (DAQmx Close External Calibration), as shown in the following table. This function also saves the date, time, and temperature of the adjustment to the onboard memory.

✎ **Note** If the device fails the calibration procedure, no constants are written to the EEPROM.

NI-DAQmx Function Call	LabVIEW Block Diagram
Call `DAQmxCloseExtCal` with the following parameters: **calHandle**: `calHandle` **action**: `DAQmx_Val_Action_Commit`	
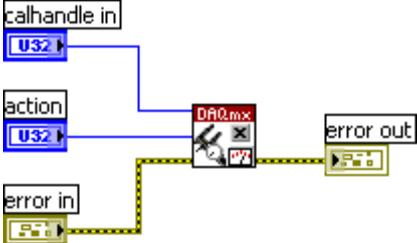
6. Disconnect the calibrator from the device.

The device is now calibrated with respect to the external source. After calibrating the device, verify the analog input operation by repeating the *Verification Procedure* section.

AI Absolute Accuracy Tables and Formulas

The values in the following tables are based on calibrated scaling coefficients, which are stored in the onboard EEPROM. The following calibration specifications are for 23 ±10 °C.

Table 2. Accuracy Summary

Nominal Range (V)	Absolute Accuracy at Full Scale[1] (µV)	Random Noise, σ (µVrms)	Sensitivity[2] (µV)
±10	3230	240	96.0
±5	1730	116	46.4
±1	390	26	10.4
±0.2	114	10	4.0

[1] Absolute accuracy values at full scale on the analog input channels assume the device is operating within 10 °C of the last external calibration and are valid for averaging 100 samples immediately following internal calibration.

[2] Sensitivity is the smallest voltage change that can be detected. It is a function of noise.

Table 3. Accuracy Details

Nominal Range (V)	Residual Gain Error (ppm of Reading)	Gain Tempco (ppm/°C)	Reference Tempco	Residual Offset Error (ppm of Range)	Offset Tempco (ppm of Range/°C)	INLError (ppm of Range)
±10	115	11	5	20	44	76
±5	135	11	5	20	47	76
±1	155	11	5	25	66	76
±0.2	215	11	5	40	162	76

AbsoluteAccuracy = Reading · (GainError) + Range · (OffsetError) + NoiseUncertainty

GainError = ResidualAIGainError + GainTempco · (TempChangeFromLastInternalCal) + ReferenceTempco · (TempChangeFromLastExternalCal)

OffsetError = ResidualAIOffsetError + OffsetTempco · (TempChangeFromLastInternalCal) + INL_Error

Noise Uncertainty = RandomNoise · $3 / \sqrt{10000}$ for a coverage factor of 3 Σ and averaging 10000 points

ResidualAIGainError = ErrorRelativetoExternalRef$_{ppm}$ + ReferenceDriftOverTime$_{ppm\_per\_year}$ · $\sqrt{CalibrationInterval_{years}}$

GainTempco = AnalogCircuitryGainTempco

ReferenceTempco = ReferenceDriftOverTime$_{ppm}$

ResidualOffsetError = OffsetErrorDueToCalibration$_{ppm}$

OffsetTempco = PreGainOffsetTempco$_{\mu V}$ / Range$_V$ + PostGainOffsetTempco

INL_Error = 2 · ADC_Dithered_INL

RandomNoise = RandomNoise$_{\mu Vrms}$

Device Test Limits

Table 4 lists the specifications that the NI 9205/9206 meets if it has been two years between calibrations.

Using the Table

The following definitions describe how to use the information from Table 4.

Range

Range refers to the minimum or maximum voltage range of an input 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. *Max* refers to maximum value, *Min* refers to minimum value, and *Mid* refers to mid-scale.

2-Year Limits

The *2-Year Limits* column contains the *Upper Limits* and *Lower Limits* for the test point value. That is, when the device is within its 2-year calibration interval, the test point value should fall between these upper and lower limit values.

Table 4. NI 9205/9206 Analog Input Values

Range (V)		Test Point		2-Year Limits	
Minimum	Maximum	Location	Value (V)	Lower Limit (V)	Upper Limit (V)
–10	10	Max	9.980000	9.976836	9.983164
–10	10	Mid	0.000000	–0.001407	0.001407
–10	10	Min	–9.980000	–9.983164	–9.976836
–5	5	Max	4.990000	4.988303	4.991697
–5	5	Mid	0.000000	–0.000718	0.000718
–5	5	Min	–4.990000	–4.991697	–4.988303
–1	1	Max	0.998000	0.997617	0.998383
–1	1	Mid	0.000000	–0.000168	0.000168
–1	1	Min	–0.998000	–0.998383	–0.997617
–0.200	0.200	Max	0.199600	0.199489	0.199711
–0.200	0.200	Mid	0.000000	–0.000056	0.000056
–0.200	0.200	Min	–0.199600	–0.199711	–0.199489

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.

National Instruments corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. National Instruments also has offices located around the world to help address your support needs. For telephone support in the United States, create your service request at `ni.com/support` and follow the calling instructions or dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

Australia 1800 300 800, Austria 43 0 662 45 79 90 0,
Belgium 32 0 2 757 00 20, Brazil 55 11 3262 3599,
Canada 800 433 3488, China 86 21 6555 7838,
Czech Republic 420 224 235 774, Denmark 45 45 76 26 00,
Finland 385 0 9 725 725 11, France 33 0 1 48 14 24 24,
Germany 49 0 89 741 31 30, India 91 80 41190000,
Israel 972 0 3 6393737, Italy 39 02 413091, Japan 81 3 5472 2970,
Korea 82 02 3451 3400, Lebanon 961 0 1 33 28 28,
Malaysia 1800 887710, Mexico 01 800 010 0793,
Netherlands 31 0 348 433 466, New Zealand 0800 553 322,
Norway 47 0 66 90 76 60, Poland 48 22 3390150,
Portugal 351 210 311 210, Russia 7 495 783 68 51,
Singapore 1800 226 5886, Slovenia 386 3 425 42 00,
South Africa 27 0 11 805 8197, Spain 34 91 640 0085,
Sweden 46 0 8 587 895 00, Switzerland 41 56 200 51 51,
Taiwan 886 02 2377 2222, Thailand 662 278 6777,
Turkey 90 212 279 3031, United Kingdom 44 0 1635 523545