NATIONAL INSTRUMENTS™

FP-AO-210

Version 2.0

Introduction

This document contains step-by-step instructions for calibrating the FP-AO-210 module. Use this calibration procedure in conjunction with the Calibration Software Library that is included with this document. The software library contains specific functions required for calibrating the FP-AO-210 module.

What Is Calibration?

Calibration consists of verifying the measurement accuracy of a device and adjusting for any measurement error. *Verification* is measuring the performance of the device and comparing these measurements to the factory specifications. During calibration, you supply and read voltage levels using external standards, then you adjust the module calibration constants. The new calibration constants are stored in the EEPROM. These calibration constants are loaded from memory as needed to adjust for the error in the measurements taken by the device.

Why Should You Calibrate?

The accuracy of electronic components drifts with time and temperature, which can affect measurement accuracy as the device ages. Calibration restores these components to their specified accuracy and ensures that your device still meets National Instruments (NI) standards.

How Often Should You Calibrate?

The measurement requirements of your application indicate how often the FP-AO-210 module needs to be calibrated to maintain accuracy. NI recommends that you perform a complete calibration at least once every year. You can shorten this interval to 90 days or six months based on the demands of your application.

Equipment and Other Test Requirements

This section describes the equipment, test conditions, documentation, and software you need to calibrate the FP-AO-210 module.

Test Equipment

Make sure you have the following instruments for calibration:

❑ Digital Multimeter (DMM)—Hewlett-Packard 3458A; if an HP 3458A is not available, choose a substitute DMM that is accurate to at least 300 ppm

❑ FP-1000 network module

❑ FieldPoint calibration base—model FP-TB-CAL, part number 777519–90, which allows you to write new calibration constants to the module EEPROM

❑ 11–24 V power supply—FP-PS-4 or NI PS-2

❑ 15–30 VDC loop power supply

❑ RS-232 straight serial cable

Test Conditions

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

• Keep connections to the module short. 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 a temperature between 18–28 °C. To operate your module at a specific temperature outside this range, calibrate your module 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.

Reference Documents

In addition to this calibration procedure, you may need to refer to the following documents to calibrate the FP-AO-210 module:

• *FP-1000/1001 Programmer Reference Manual*
• *FP-AO-210 Operating Instructions*

You can download these documents from `ni.com/manuals`.

Calibration Software

Use the calibration functions from the Calibration Software Library, which you downloaded or received with this documentation. The Calibration Software Library consists of the `fpCalibration.dll` and the `fpCalibration.h` files. If you do not have the Calibration Software Library, you can download the files from `ni.com/calibration`.

You need to use the FieldPoint calibration functions and FieldPoint Optomux commands, which are both described in the following sections.

FieldPoint Calibration Functions

This section describes the FieldPoint calibration functions that you use to calibrate the FP-AO-210. The parameters for these functions are described in detail in the *Calibrating the FP-AO-210* section.

int fp_CalStart

```
int fp_CalStart(int portNum, int device, unsigned long baudrate,
char* password, int passwordSize, char reserved, sessionHandle*
m_session);
```

This function starts the calibration session. Use this function every time you need to verify or calibrate a module.

int fp_CalVerify

```
int fp_CalVerify(sessionHandle m_session, int measurementMode,
int range, int channel, double* data, int dataSize);
```

This function uses the data from one channel and verifies that it is within the acceptable operating ranges. The function returns a 0 if the data is within specifications, or a 1 if the data is outside the acceptable specifications. The **data** parameter is a pointer to an array of data in the format shown in Figure 1.

Full-Scale (FS)
Zero-Scale (ZS)

Figure 1. Array Used by `fp_CalVerify`

int fp_CalAdjust

```
int fp_CalAdjust(sessionHandle m_session, int measurementMode,
int range, int channel, double* data, int dataSize);
```

This function uses the data from one channel to calculate new calibration constants. The function returns a 0 if the new constants for the channel you are calibrating were calculated successfully. The **data** parameter is a pointer to a two-element array of data in the format shown in Figure 2.

10 V Actual
100 mV Actual

Figure 2. Array Used by `fp_CalAdjust`

int fp_CalEnd

```
int fp_CalEnd(sessionHandle m_session, int action);
```

This function terminates the calibration or verification session. A 0 is returned if the module is calibrated. If the action parameter is 0 (store), new constants are written to the EEPROM. If the action parameter is 1 (abort), the calibration constants remain unchanged and the returned value is **FP_CAL_WARNING_SESSION_ABORTED**.

FieldPoint Optomux Commands

This section describes the FieldPoint Optomux commands that you use to calibrate the FP-AO-210.

Note Refer to the *FP-1000/1001 Programmer Reference Manual* to better understand these and other FieldPoint Optomux commands.

All FieldPoint commands have similar syntax and contain the following five fields:

```
[start][address][command][checksum][end]
```

Power Up Clear Command

The **Power Up Clear** command is the first command you send after applying power to your module. This command prevents the FieldPoint module from returning error **N00: Power up clear expected**. This command functions only if it is the first command you send after power-up.

Syntax

```
A
```

Example

```
>01A??[cr]
```

> *where*

>	=	the [start] character of any FieldPoint command
01	=	the module address
A	=	the actual command
??	=	the checksum
[cr]	=	the carriage return

Set Attributes Command

The **Set Attributes** command sets the specified attributes and range for each specified channel of the module you are addressing.

Syntax

```
!D[positions]{[attrMask][rangeMask][settings]}
```

Example

Assume you are changing the channel 3 range ID to 04 (0–10 V).

```
>01!D00080000104??[cr]
```

> *where*

>	=	the [start] character of any FieldPoint command
01	=	the module address
!D	=	the actual command
0008	=	four ASCII-hex characters representing [positions], or the channels you are targeting with this command (channel 3 in this example)
0000	=	four ASCII-hex characters representing [attrMask]
1	=	one ASCII-hex character representing [rangeMask]; a 0 in this field indicates that the range is not affected
04	=	two ASCII-hex characters representing [settings]; 04 corresponds with the 0–10 V range

??	=	the checksum
[cr]	=	the carriage return

Table 1 lists the ASCII-hex conversions to use in the **positions** parameter.

<div align="center">

Table 1. Values for the **positions** Parameter

</div>

Channel	ASCII Characters
0	0001
1	0002
2	0004
3	0008
4	0010
5	0020
6	0040
7	0080

Write 16-bit Data Command

The **Write 16-bit Data** command writes data to targeted output channels of the module you are addressing. Each data value is a 16-bit value.

Syntax

```
!H[positions][data]
```

Example

Assume you are writing the ASCII-hex value FAFA (the ASCII-hex value for 10 V) to channel 3.

```
>01!H0008FAFA??[cr]
```

where

>	=	the [start] character of any FieldPoint command
01	=	the module address
!H	=	the actual command
0008	=	four ASCII-hex characters representing [positions], or the channels you are targeting with this command (channel 3 in this example)

FAFA	=	four ASCII-hex characters representing the actual [data] to be written
??	=	the checksum
[cr]	=	the carriage return

Calibrating the FP-AO-210

This section provides instructions for calibrating the FP-AO-210 module.

Verifying the Operation of the Hardware and the Connections

To verify the operation of the hardware and the connections, complete the following steps:

1. Build a FieldPoint bank with an FP-1000, an FP-TB-CAL, and a power supply. Do not attach any other terminal bases to the bank.

2. Place the FP-AO-210 module in the calibration terminal base.

3. Connect the bank to the host computer using an RS-232 serial cable.

4. Launch FieldPoint Explorer. Right-click **FieldPoint** and select **Add a comm resource to this server**.

5. Make sure the correct communication port and baud rate appear in the dialog box. Click **Find Devices**.

6. Expand the view to show the devices found. You should see the FP-AO-210. If you do not, the network module is not communicating correctly with either the host or the FP-AO-210.

7. Close FieldPoint Explorer.

⚠ **Caution** FieldPoint Explorer must remain closed for the remainder of the calibration procedure to prevent a system crash.

You have finished configuring the FP-AO-210 module and verifying communication between the module and the calibration system. If you need additional information on configuring an FP-AO-210 module, refer to the *FP-AO-210 Operating Instructions* or the *FP-1000/1001 Quick Start Guide*.

Verifying the Performance of the FP-AO-210 Module

This procedure determines if the FP-AO-210 module is meeting its specifications. Figure 3 shows the flowchart of the program for analog output verification of the FP-AO-210 module. Use this flowchart as a guide to design and write your verification program.
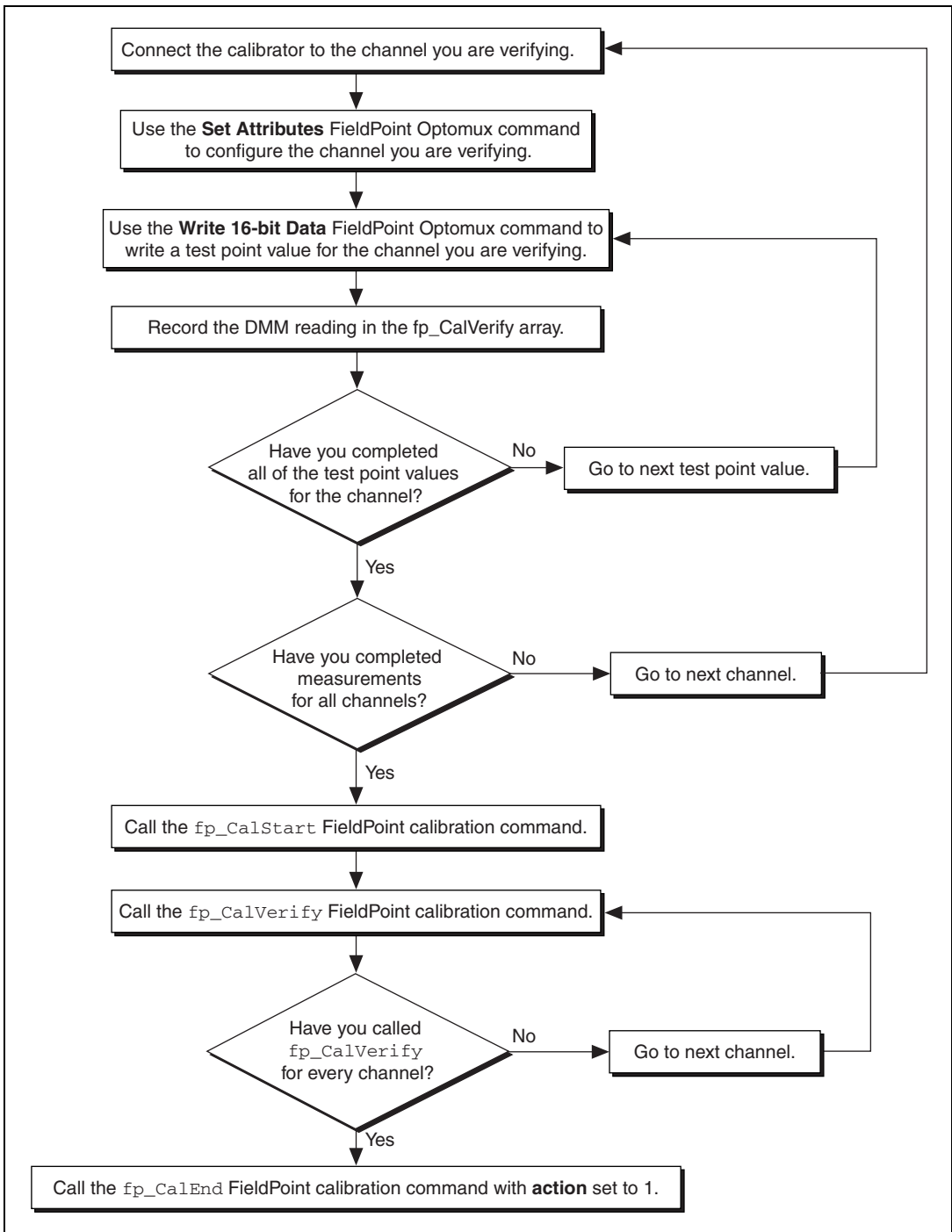
Figure 3. FP-AO-210 Analog Output Verification Flowchart

Refer to Table 2 throughout the calibration procedure.

Table 2. FP-AO-210 Module Specifications

Range	Range ID	Test Point		Limits	
		Location	Value (V)	Lower Limit (V)	Upper Limit (V)
0–10 V	04	FS	10	9.978	10.022
		ZS	0.1	0.0856	0.1144

To verify the performance of the FP-AO-210 module, complete the following steps:

1. Configure and open a connection to the FP-AO-210 module through your program. Opening a connection allows you to send FieldPoint commands to the FP-AO-210.

2. Connect the positive lead of the loop power supply (15–30 VDC) to either V terminal on the FP-TB-CAL.

3. Connect the negative lead of the loop power supply to either C terminal on the FP-TB-CAL.

4. Configure the DMM to measure DC voltage.

5. Connect the positive lead of the DMM to the V_{out} terminal on the FP-TB-CAL for channel 0 (terminal 1). Refer to Table 3 for the terminal assignments for each channel.

Table 3. FP-AO-210 Terminal Assignments

Channel	Terminal Numbers	
	V_{out}	COM
CH0	1	2
CH1	3	4
CH2	5	6
CH3	7	8
CH4	9	10
CH5	11	12
CH6	13	14
CH7	15	16

6. Connect the negative lead of the DMM to the COM terminal on the FP-TB-CAL for channel 0 (terminal 2).

7. Make sure all other terminals on the FP-TB-CAL are open.

8. In your calibration program, use the **Set Attributes** FieldPoint Optomux command to configure the channel for the 0–10 V range using 04 for the range ID as defined in Table 2. Set the following parameters:

   - **positions**—The correct value from Table 1 for the channel you are targeting
   - **attrMask**—0000
   - **rangeMask**—1
   - **settings**—04

9. Use the **Write 16-bit Data** FieldPoint Optomux command to write FAFA (the ASCII-hex value for 10 V) to the channel connected to the DMM. Set the following parameters:

   - **positions**—The correct value from Table 1 for the channel you are targeting
   - **data**—FAFA

10. Record the reading from the DMM as *Full-Scale* in units of volts in the fp_CalVerify array for this channel. You can record this reading in a .txt file.

11. Use the **Write 16-bit Data** FieldPoint Optomux command to write 0283 (the ASCII-hex value for 0.1 V) to the channel connected to the DMM. Set the following parameters:

    - **positions**—The correct value from Table 1 for the channel you are targeting
    - **data**—0283

12. Record the reading from the DMM in as *Zero-Scale* in units of volts in the fp_CalVerify array for this channel. You can record this reading in a .txt file.

13. Connect the positive lead of the DMM to the V_{out} terminal and the negative lead of the DMM to the COM terminal for the next channel.

14. Repeat steps 8–13 to gather data from all channels. You do not need to change the V or C terminal connections for the other channels.

15. Close any open software connections to the FP-AO-210 module.

16. Call fp_CalStart to open a connection to the module and to obtain a session handle. Set the following parameters:

    - **portNum**—The serial port used to connect to the FP-1000 network module: 1 for COM1, 2 for COM2, and so on
    - **device**—1

- **baudrate**—The baud rate used to communicate with the network module

- **password**—A four-character string containing the module password; the default password is NATI

- **passwordSize**—The number of characters in the password; the passwordSize is 4 for the password NATI

- **reserved**—0

- **m_session**—The handle that references the communications session; use this handle with the rest of the calibration functions to reference the same calibration session

17. In a loop, call `fp_CalVerify` for each channel. Set the following parameters:

- **m_session**—The session handle obtained with the `fp_CalStart` function

- **measurementMode**—2 (voltage mode)

- **range**—The range ID from Table 2; the range ID is 4

- **channel**—The channel you are verifying

- **data**—A pointer to a two-element array of data in the format shown in Figure 1; you obtained this data in steps 9–13 of this section

- **dataSize**—The number of elements in the fp_CalVerify array; the dataSize is 2

If the `fp_CalVerify` function returns a 0, the channel is within specifications. If the function returns a 1, the channel is out of specification and requires adjustment.

18. Call `fp_CalEnd` to end the calibration session. Set the following parameters:

- **m_session**—The session handle obtained with the `fp_CalStart` function

- **action**—1 to end the session without writing to the EEPROM

You have finished verifying the performance of the FP-AO-210 module. If all of the ranges and channels are within the specifications, the module does not need to be adjusted and you do not need to continue to the next section. If the ranges and channels are not within the specifications, continue to the *Measuring Output Values* section.

Measuring Output Values

In this section, you measure the output values to use for the **data** parameter in the *Adjusting Calibration Constants* section. Figure 4 shows the flowchart of the process for measuring the output values for the FP-AO-210 module. Use this flowchart as a guide to design and write your program to measure the output values.
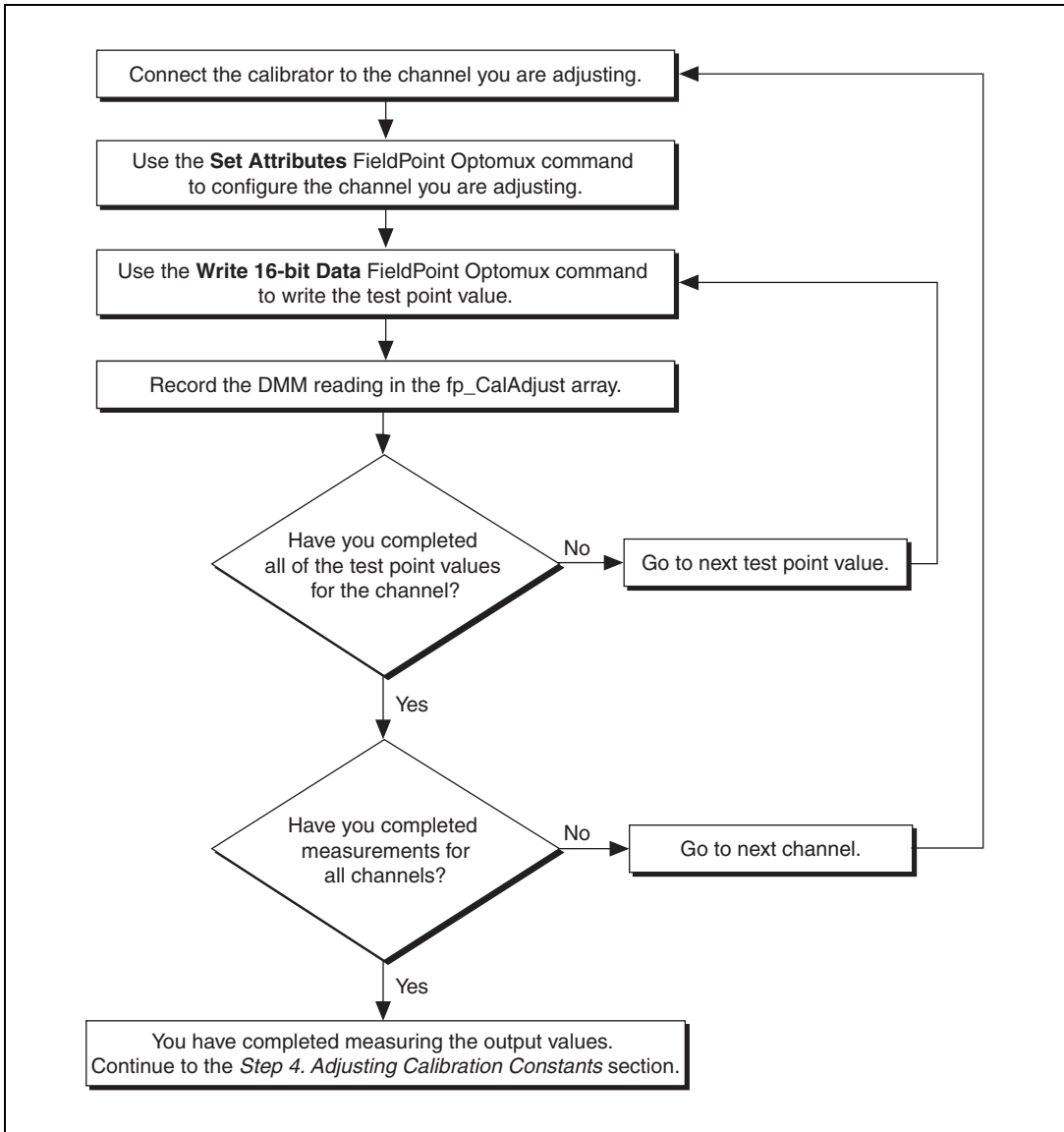

Figure 4. FP-AO-210 Measuring Output Values Flowchart

To measure the analog output values from the FP-AO-210 module, complete the following steps:

1. Configure and open a connection to the FP-AO-210 through your program. Opening a connection allows you to send FieldPoint commands to the FP-AO-210.

2. Connect the positive lead of the loop power supply (15–30 VDC) to the V terminal on the FP-TB-CAL.

3. Connect the negative lead of the loop power supply to the C terminal on the FP-TB-CAL.

4. Configure the DMM to measure DC voltage.

5. Connect the positive lead of the DMM to the V_{out} terminal on the FP-TB-CAL for channel 0 (terminal 1). Refer to Table 3 for terminal assignments.

6. Connect the negative lead of the DMM to the COM terminal on the FP-TB-CAL for channel 0 (terminal 2).

7. Make sure all other terminals on the base are open.

8. In your calibration program, use the **Set Attributes** FieldPoint Optomux command to configure the channel for the 0–10 V range, using 04 for the range ID from Table 2. Set the following parameters:

   • **positions**—The correct value from Table 1 for the channel you are targeting

   • **attrMask**—0000

   • **rangeMask**—1

   • **settings**—04

9. Use the **Write 16-bit Data** FieldPoint Optomux command to write FAFA (the ASCII-hex value for 10 V) to the channel connected to the DMM. Set the following parameters:

   • **positions**—The correct value from Table 1 for the channel you are targeting

   • **data**—FAFA

10. Record the reading from the DMM as *10V_Actual* in units of volts in the fp_CalAdjust array for this channel. You can record this reading in a .txt file.

11. Use the **Write 16-bit Data** FieldPoint Optomux command to write 0283 (the ASCII-hex value for 0.1 V) to the channel connected to the DMM. Set the following parameters:

   • **positions**—The correct value from Table 1 for the channel you are targeting

   • **data**—0283

12. Record the reading from the DMM as *100mV_Actual* in units of volts in the fp_CalAdjust array for this channel. You can record this reading in a `.txt` file.

13. Connect the positive lead of the DMM to the V_{out} terminal and the negative lead of the DMM to the COM terminal for the next channel.

14. Repeat steps 8–13 for all channels. You do not need to change the V or C terminal connections for the other channels.

You have finished measuring the output values for the FP-AO-210. Continue to the next section.

Adjusting Calibration Constants

In this section, you adjust the calibration constants of the FP-AO-210 module. Figure 5 shows the flowchart of the process for adjusting the calibration constants for the FP-AO-210 module. Use this flowchart as a guide to design and write your program to adjust the calibration constants.
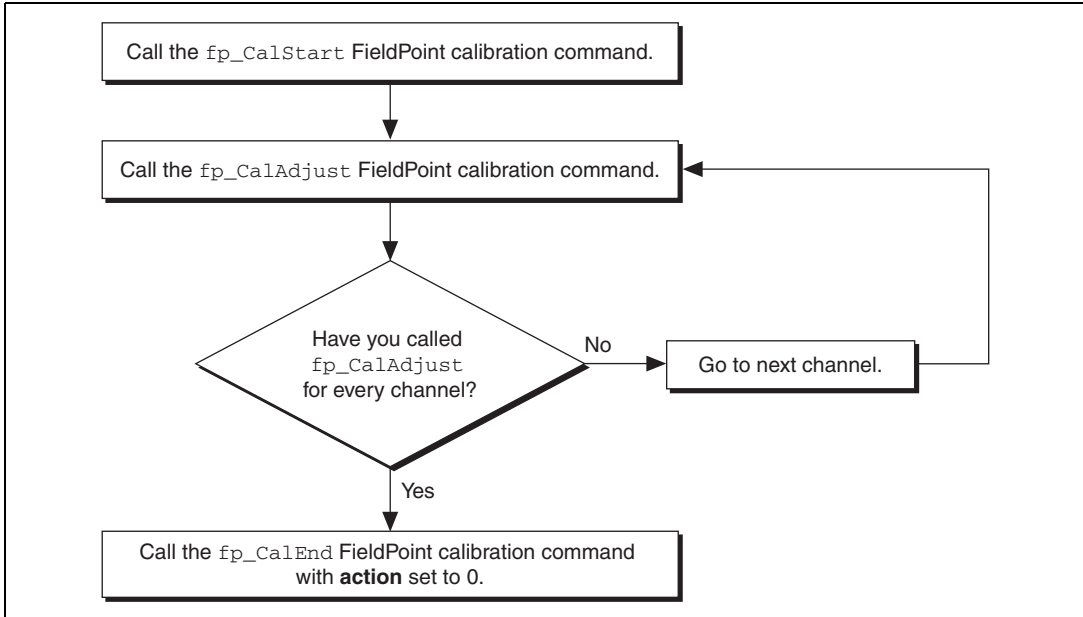

Figure 5. FP-AO-210 Adjust Calibration Constants Flowchart

To adjust the calibration constants, complete the following steps:

1. Close any open software connections to the FP-AO-210 module.

2. Call fp_CalStart to open a connection to the module and to obtain a session handle. Set the following parameters:

    • **portNum**—The serial port used to connect to the FP-1000 network module: 1 for COM1, 2 for COM2, and so on

- **device**—1

- **baudrate**—The baud rate used to communicate with the network module

- **password**—A four-character string containing the module password; the default password is NATI

- **passwordSize**—The number of characters in the password; the passwordSize is 4 for the password NATI

- **reserved**—0

- **m_session**—The handle that references the communications session; use this handle with the rest of the calibration functions to reference the same calibration session

3. In a loop, call fp_CalAdjust for each channel. Set the following parameters:

   - **m_session**—The session handle you obtained with the fp_CalStart function

   - **measurementMode**—2 (voltage mode)

   - **range**—The range ID from Table 2; the range ID is 4

   - **channel**—The channel you are adjusting

   - **data**—A pointer to a two-element array of data in the format shown in Figure 2; you obtained this data in the *Measuring Output Values* section

   - **dataSize**—The number of elements in the fp_CalAdjust array; the dataSize is 2

4. Call fp_CalEnd to end the calibration session. Set the following parameters:

   - **m_session**—The session handle obtained with the fp_CalStart function

   - **action**—0 to write the new calibration constants to the EEPROM

   If the adjustment is successful, fp_CalEnd returns a 0. If the calibration is not successful, the function returns one of the errors or warnings listed in the *FieldPoint Calibration-Specific Errors and Warnings* section.

You have finished adjusting the calibration constants of the FP-AO-210 module. Continue to the next section.

Verifying the Performance of the FP-AO-210 Module After Adjustments

After you have completed adjusting the calibration constants, verify the performance of the FP-AO-210 module again to ensure that you are using the new calibration constants.

1. Remove the FP-AO-210 module from the FP-TB-CAL terminal base and reinsert it. You do not need to disconnect the power before removing the module.

2. Repeat the procedure described in the *Verifying the Performance of the FP-AO-210 Module* section.

You have finished calibrating the FP-AO-210 module.

Additional FP-AO-210 FieldPoint Calibration Functions

In addition to the FieldPoint calibration functions used in the previous sections, you can call several other utility functions that are within the `fpCalibration.dll`. This section describes these additional FieldPoint calibration functions.

fp_CalChangePassword

```
fp_CalChangePassword(sessionHandle m_session, char* oldpass,
char* newpass)
```

This function changes the password on the module. Set the following parameters:

- **m_session**—The session handle obtained with the `fp_CalStart` function

- **oldpass**—A pointer to the old four-character password

- **newpass**—A pointer to the new four-character password that you program into the module

fp_CalFetchCount

```
fp_CalFetchCount(sessionHandle m_session, int* count)
```

This function returns the number of times the module has been calibrated in the count variable. Set the following parameters:

- **m_session**—The session handle obtained with the `fp_CalStart` function

- **count**—A pointer to an 8-bit variable that returns the number of times the module has been calibrated; count returns to 0 after the module has been calibrated 255 times

fp_CalFetchDate

```
fp_CalFetchDate(sessionHandle m_session, int* year, int* month,
int* day)
```

This function returns the year, month, and day the module was last calibrated. Set the following parameters:

- **m_session**—The session handle obtained with the `fp_CalStart` function
- **year**—A pointer to a variable that contains the year the module was last calibrated
- **month**—A pointer to a variable that contains the month the module was last calibrated
- **day**—A pointer to a variable that contains the day the module was last calibrated

fp_CalFetchMiscInfo

```
fp_CalFetchMiscInfo(sessionHandle m_session, char* miscInfo,
int buffersize)
```

This function returns the data stored in the miscellaneous information area of the EEPROM within the module. Set the following parameters:

- **m_session**—The session handle obtained with the `fp_CalStart` function
- **miscInfo**—The pointer to the data stored in the miscellaneous information area of the EEPROM
- **bufferSize**—The size of the **miscInfo** data, which is 12 bytes for the FP-AO-210

fp_CalStoreMiscInfo

```
fp_CalStoreMiscInfo(sessionHandle m_session, char* miscInfo
int miscBufSize)
```

This function takes the data in the **miscInfo** array and stores it to the miscellaneous information area of the EEPROM. Set the following parameters:

- **m_session**—The session handle obtained with the `fp_CalStart` function
- **miscInfo**—The pointer to the data stored in the miscellaneous information area of the EEPROM
- **miscBufSize**—The size of the **miscInfo** array, which is equal to or less than 12 bytes

fp_CalReset

```
fp_CalReset (sessionHandle m_session)
```

This function resets the calibration constants to 0. Set the **m_session** parameter to the session handle obtained with the fp_CalStart function.

FieldPoint Calibration-Specific Errors and Warnings

Table 4 is a list of FieldPoint calibration-specific errors. If a function returns an error that is not listed in Table 4, it is either an Optomux error or a FieldPoint error that is not related to calibration.

Table 4. FieldPoint Calibration-Specific Errors

Error	Description
0	Success—Module calibrated without problems
–1	Invalid handle
–2	Invalid session handle
–3	Communications error
–4	Null buffer parameter
–5	Improper module
–6	Unexpected internal error
–7	Handle is already in use
–8	Calibration incomplete
–9	Calibration data is corrupted
–10	Buffer parameter is too large
–11	Invalid channel
–12	Invalid range
–13	Invalid mode
–14	Invalid baud rate
–15	Data size error
–16	Memory allocation failure
–17	Data not initialized
–18	Password mismatch

Table 4. FieldPoint Calibration-Specific Errors (Continued)

Error	Description
–19	Old calibration constants are out of range; you must reset to nominal values using `fp_CalReset`
–20	Calibration constant is out of range; verify that the correct data was passed to the `fp_CalAdjust` function

Table 5 is a list of FieldPoint calibration-specific warnings.

Table 5. FieldPoint Calibration-Specific Warnings

Warning	Description
51	One or more module ranges or channels are not calibrated
52	Calibration session has been aborted