Burr-Brown Products from Texas Instruments

PGA309

Quick Start System Reference Guide

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High-Precision Linear Products

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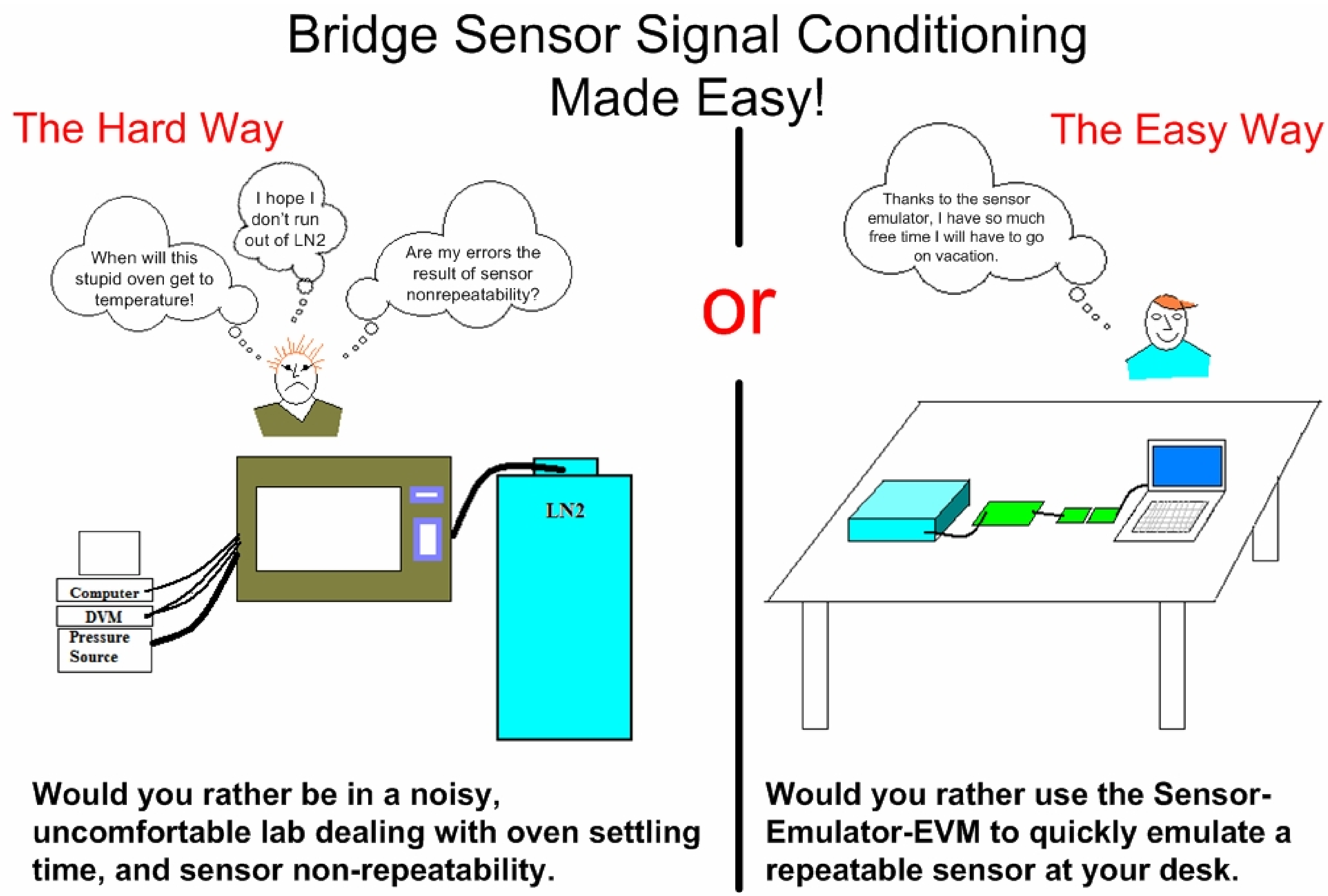
Texas Instruments

PGA309 Quick Start



Burr-Brown Products from Texas Instruments

PGA309 Quick Start Contents

Required items for Quick Start

Hardware

- **PGA309EVM** – This is an evaluation kit that allows you to communicate with and interface to the PGA309. It contains a PC Interface Board and a Sensor Interface Board combined with a PGA309 and EEPROM.
- **Sensor-Emulator-EVM** – This is an evaluation kit that uses rotary switches and trim potentiometers to generate voltage excited bridge sensor output signals and temperature sensor output signals.
- **+/-12V supply –** Any low noise dc supply for the sensor emulator.
- **Precision DVM –** Any five or six digit meter that can read into microvolts (e.g., HP3458, HP34401).
- **Slotted Jeweler's Screwdriver** – The best tool to quickly adjust the potentiometer.

Software

- **PGA309DK Board Interface** – This software is used to communicate with the PGA309EVM. See http://focus.ti.com/docs/toolsw/folders/print/pga309evm-eu.html under support software for free download.
- **PGA309 Calculator** – This software is used to do initial gain scaling and verify that the design does not violate any PGA309 specifications. Software is bundled with PGA309DK Board Interface software.
- **PGA309 Calibration Spreadsheet –** This spreadsheet uses PGA309 / Sensor readings over temperature and at different applied stimulus levels to generate the calibration table used to correct for the sensor errors. Software is bundled with PGA309DK Board Interface software.
- **Generate_Emulator_Values.xls** – This spreadsheet translates sensor specifications into voltage settings for the Sensor-Emulator-EVM. See http://focus.ti.com/docs/toolsw/folders/print/sensor-emulator-evm.html under support software for free download.

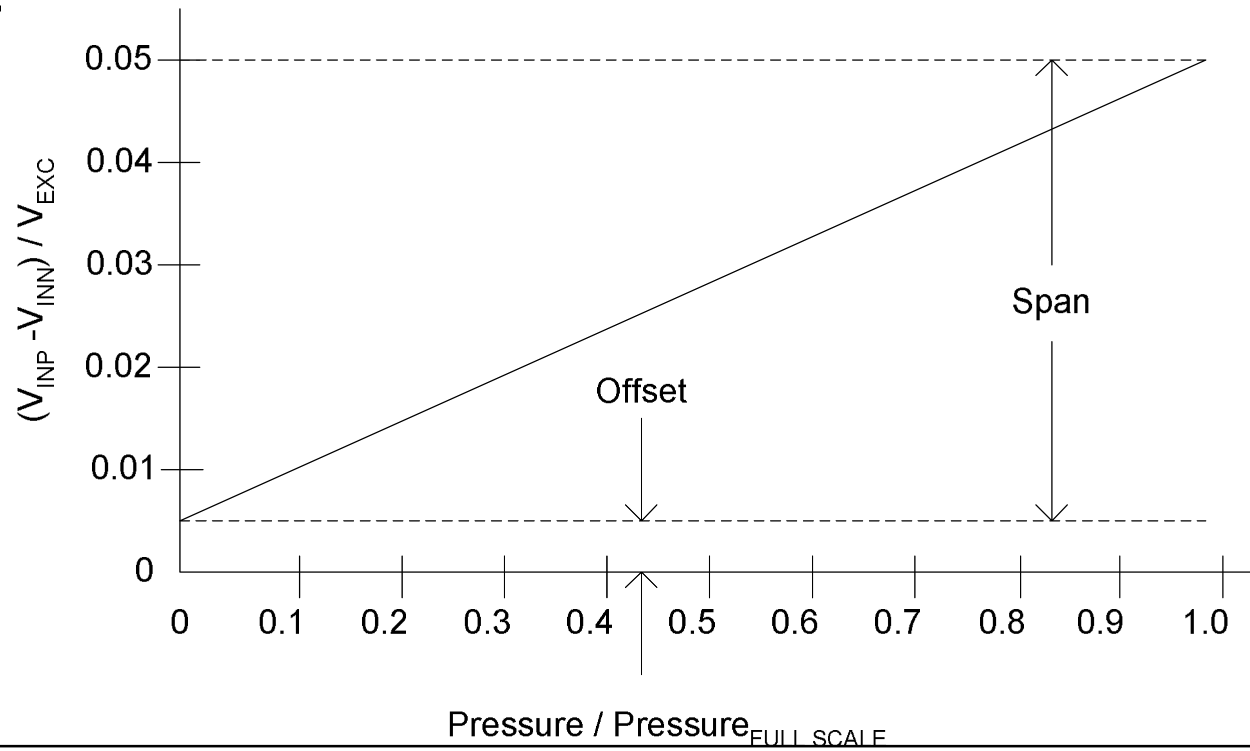
Specifications

There are several key specifications that are used throughout our literature. The mathematical definitions are listed below.

- **Offset –** the normalized output of a sensor (in V/V) with no applied stimulus.
- **OffsetTC1** – The linear drift of the sensors' offset given in % of span/^{o}C.
- **NonlinOffsetDrift** – The second order (quadratic) drift of the offset. This coefficient is in *% of span* at room temperature.
- **OffsetTC2** – The second order (quadratic) drift of the offset. This coefficient is in *% of span/^{o}C^2* at room temperature.
- **Span –** the amount of change in normalized output voltage (in V/V) of the sensor over the entire range of applied stimulus.
- **SpanTC1** – The linear drift of the sensors' span given in % of span/^{o}C.
- **NonlinSpanDrift** – The second order (quadratic) drift of the offset. This coefficient is in *% of span* at room temperature.
- **SpanTC2** – The second order (quadratic) drift of the span. This coefficient is in *% of span/^{o}C^2* at room temperature.
- **PressureNonlinearity** – The second order (quadratic) nonlinearity versus applied signal given in % of span.

Span – the amount of change in normalized output voltage (in V/V) of the sensor over the entire range of applied stimulus.

Offset – the normalized output of a sensor (in V/V) with no applied stimulus.

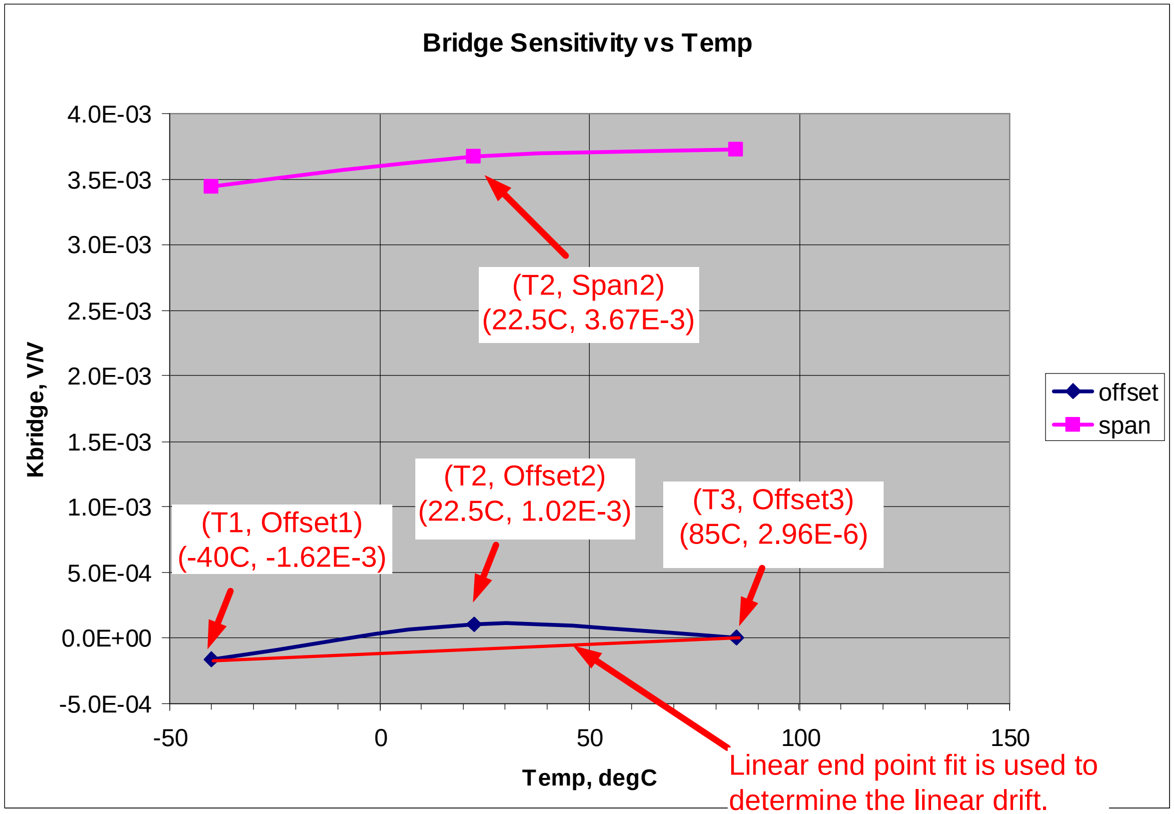


OffsetTC1

$$\text{OffsetTC1} = \frac{(\text{Offset}_3 - \text{Offset}_1)}{\text{Span}_2 \cdot (T_3 - T_1)}$$

The linear drift of the sensor's offset given in % of span/°C.

$$\text{OffsetTC1} = \frac{\left[2.963\times 10^{-6} - \left(-1.624\times 10^{-4}\right)\right]}{3.673\times 10^{-3}\cdot[85-(-40)]} = 3.602\times 10^{-4} \quad \text{\% of span/}^{o}\text{C}$$



NonlinOffsetDrift
OffsetTC2

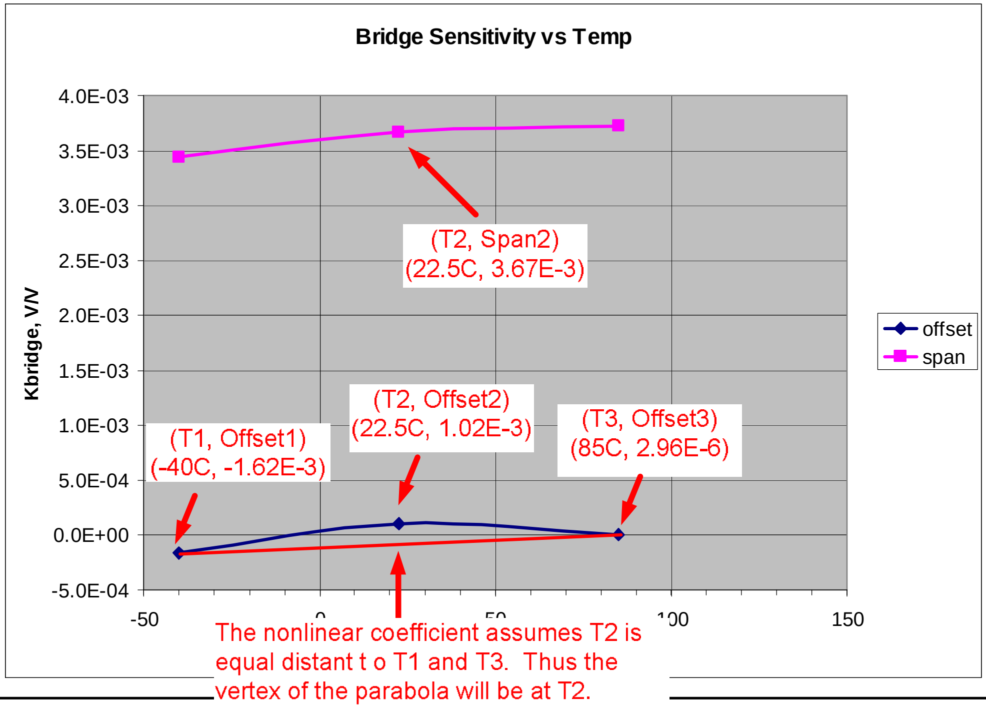
$$\text{NonLinOffsetDrift} = \frac{\left[\text{Offset}_2 - \frac{\left(\text{Offset}_1 + \text{Offset}_3\right)}{2}\right]}{\text{Span}_2}$$

$$\text{NonLinOffsetDrift} = \frac{1.023\,10^{-4} - \frac{\left[\left(-1.624\,10^{-4}\right) + \left(2.963\,10^{-6}\right)\right]}{2}}{3.673\times 10^{-3}} = 4.956\times 10^{-2} \quad \text{\% of span}$$

NonlinOffsetDrift:
The second order (quadratic) drift of the offset. This coefficient is in **% of span at room temperature.**

$$\text{OffsetTC2} = \frac{\text{NonLinOffsetDrift}}{\left[\frac{\left(T_3 - T_1\right)}{2}\right]^2} = \frac{4.956\times 10^{-2}}{\left[\frac{[85-(-40)]}{2}\right]^2} = 1.269\times 10^{-5} \quad \text{\% of span/}^{o}\text{C}^2$$

OffsetTC2:
The second order (quadratic) drift of the offset. This coefficient is in **% of span/$^{o}C^2$ at room temperature.**

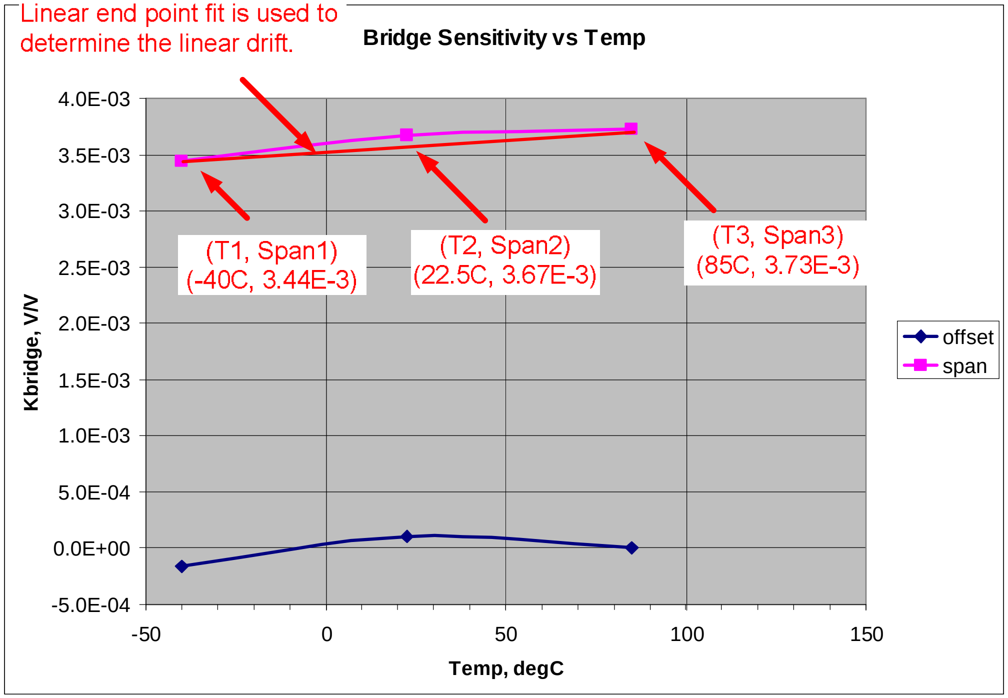


SpanTC1

$$SpanTC1 = \frac{(Span_3 - Span_1)}{Span_2 \cdot (T_3 - T_1)}$$

The linear drift of the sensors' span given in % of span/ºC.

$$SpanTC1 = \frac{(3.7284 \cdot 10^{-3} - 3.4412 \cdot 10^{-3})}{3.6734 \times 10^{-3} \cdot [85 - (-40)]} = 6.255 \times 10^{-4}$$ % of span/ºC



NonlinSpanDrift SpanTC2

$$\text{NonLinSpanDrift} = \frac{\left[\text{Span}_2 - \frac{(\text{Span}_1 + \text{Span}_3)}{2}\right]}{\text{Span}_2}$$

$$\text{NonLinSpanDrift} = \frac{3.6734\times 10^{-3} - \frac{\left[\left(3.4412\,10^{-3}\right) + \left(3.7284\,10^{-3}\right)\right]}{2}}{3.6734\times 10^{-3}} = 2.412\times 10^{-2}$$ % of span

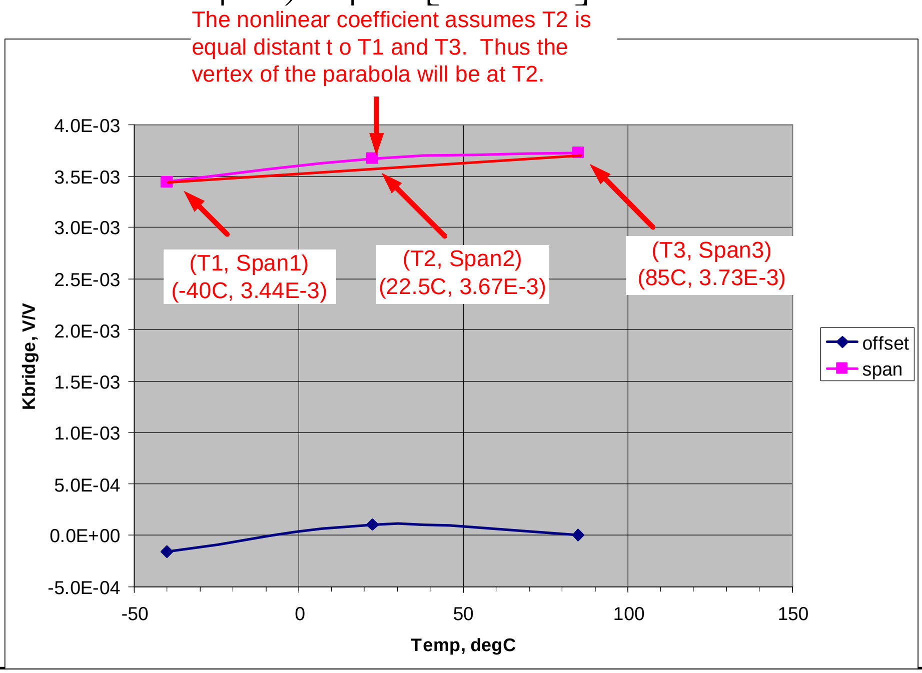
$$\text{SpanTC2} = \frac{\text{NonLinSpanDrift}}{\left[\frac{(T_3 - T_1)}{2}\right]^2} = \frac{2.412\times 10^{-2}}{\left[\frac{[85 - (-40)]}{2}\right]^2} = 6.175\times 10^{-6}$$ % of span/$^oC^2$

NonlinSpanDrift:

The second order (quadratic) drift of the offset. This coefficient is in **% of span at room temperature.**

SpanTC2:

The second order (quadratic) drift of the span. This coefficient is in **% of span/$^oC^2$ at room temperature.**



Pressure Nonlinearity

The second order (quadratic) nonlinearity versus applied signal given in % of span.

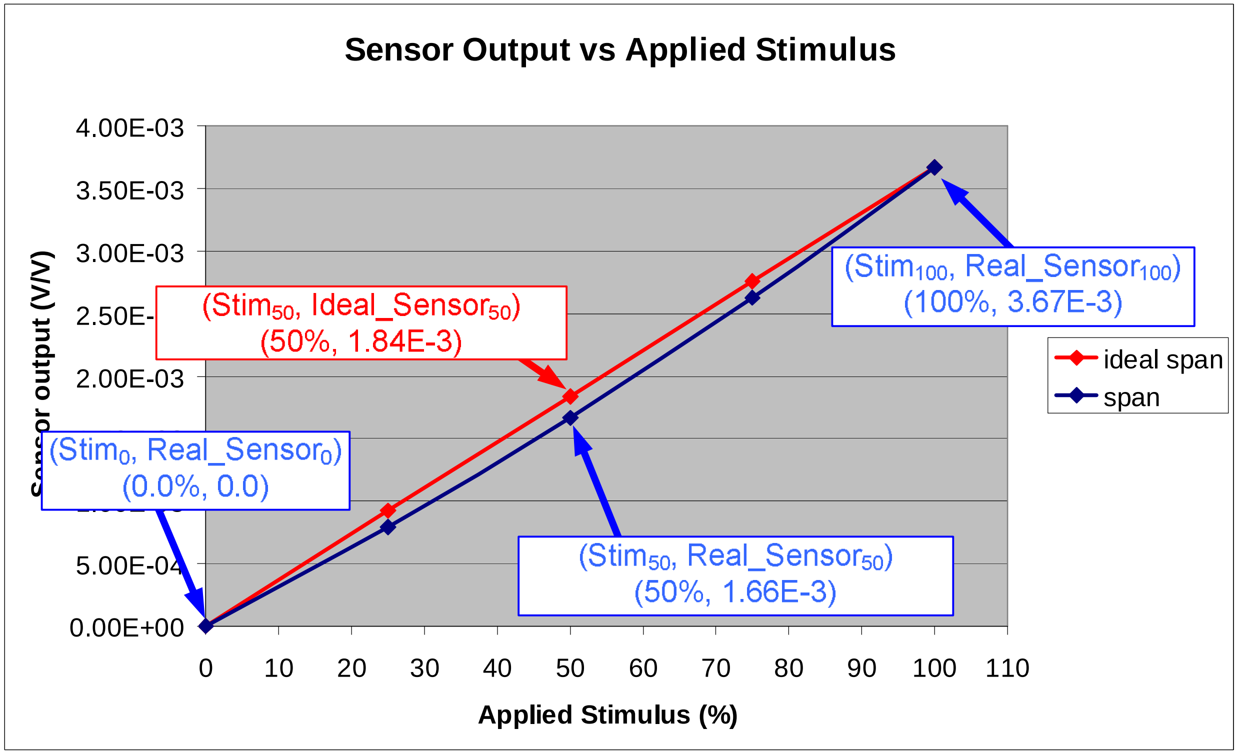
Note: These readings were all taken at room temperature. So, **real_sensor100** is the span of the sensor at room temperature.

$$\text{slope} = \frac{\left(\text{real\_sensor}_{100} - \text{real\_sensor}_{0}\right)}{\left(\text{stim}_{100} - \text{stim}_{0}\right)} = \frac{\left(3.67 \cdot 10^{-3} - 0\right)}{(100 - 0)} = 3.67 \times 10^{-5}$$

$$\text{ideal\_sensor}(\text{stim}) = \text{slope} \cdot \text{stim}$$

$$\text{ideal\_sensor}(50) = \left(3.67 \times 10^{-5}\right) \cdot 50 = 1.835 \times 10^{-3}$$

$$\text{PresureNonlinearity} = \frac{\left(\text{real\_sensor}_{50} - \text{ideal\_sensor}_{50}\right)}{\text{real\_sensor}_{100}} \cdot 100 = \frac{\left(1.66 \times 10^{-3} - 1.835 \times 10^{-3}\right)}{\left(3.67 \times 10^{-3}\right)} \cdot 100 = -4.768\%$$



Sensor Output Equations

The equations use the constants defined on the previous slides. These equations are used in the *generate_emu_settings.xls* spreadsheet* to compute the voltage settings for the Sensor-Emulator-EVM.

$$P_{nonlin}(P) = P + 4 \cdot \text{Nonlinearity\_pct} \cdot 100 \cdot \left[\frac{P}{100} - \left(\frac{P}{100}\right)^2\right]$$

$$\text{Span\_TC}(T) = \text{SpanTC1} \cdot \left(T - T_{room}\right) - \text{SpanTC2} \cdot \left(T - T_{room}\right)^2$$

$$\text{Offset\_TC}(T) = \text{OffsetTC1} \cdot \left(T - T_{room}\right) - \text{OffsetTC2} \cdot \left(T - T_{room}\right)^2$$

$$\text{SensorOutput}(P, T) = \left[\text{Offset}_{room} + \text{Span}_{room} \cdot \text{Offset\_TC}(T) + \text{Span} \cdot \left[\frac{\text{Nonlinearity\_pct}}{100} \cdot (1 + \text{Span\_TC}(T))\right]\right]$$

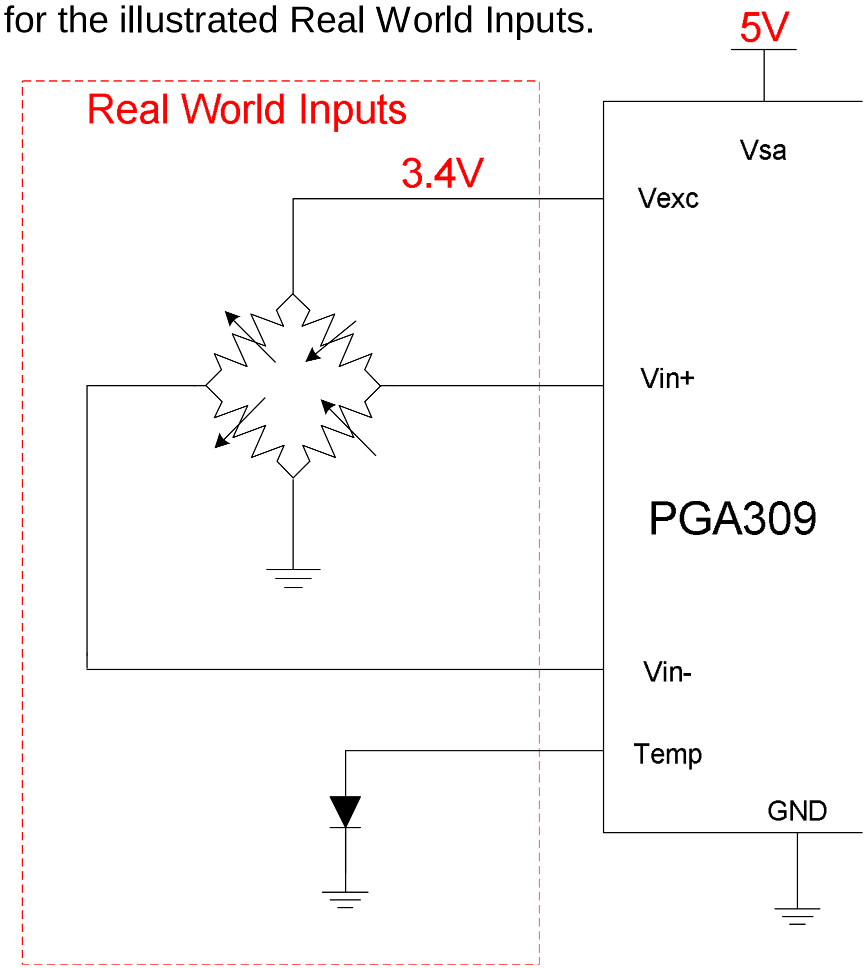
* Available for download at www.ti.com as SBOC065

PGA309 Absolute Calibration Example

For this quick start example the specifications below and the example hardware configuration will be used. The Sensor-Emulator-EVM will create an equivalent for the illustrated Real World Inputs.

Temp range:	degC
Tmin=	-45.00
Tmax=	90.00
Troom=	22.50
Vexc (V)	3.400E+00
Span (V/V)	3.509E-03
Offset (V/V)	-2.945E-04
NonlinSpanDrift (% of Span)	-5.031E-02
NonlinOffsetDrift (% of Span)	-3.077E-02
PressureNonlin (% of Span)	-3.976E-02
GainTC1 (% of Span/C)	4.682E-04
OffsetTC1 (% of Span/C)	-5.205E-04
GainTCNonlin(TC2) (% of Span/C^2)	-1.104E-05
OffsetTCNonlin(TC2) (% of Span/C^2)	-6.753E-06

“generate_sim_values.xls
“Offset and Span” Tab

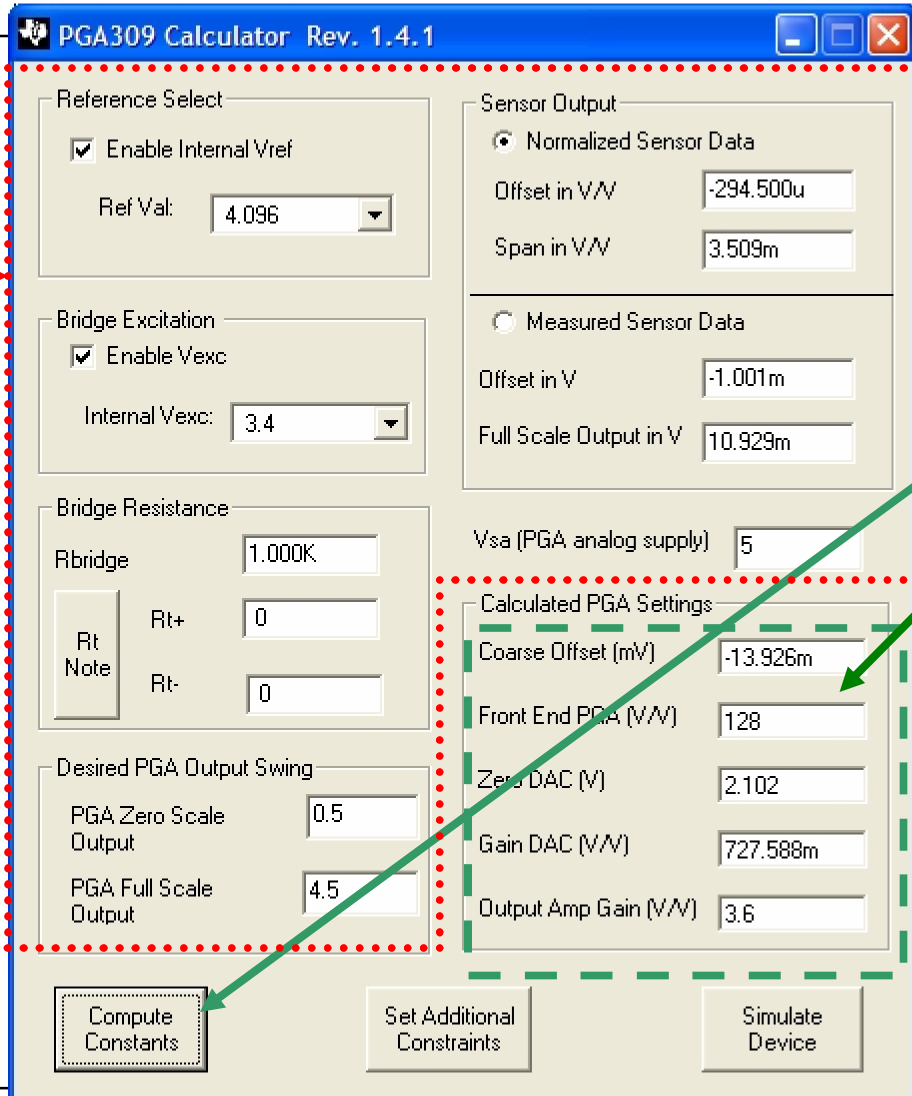


Step 1: Will the PGA309 work for my sensor?

- Use your sensor's specifications with the PGA309 Calculator software tool (SLVC073) to see if the PGA309 has the gain and offset adjustment range required to accommodate your sensor.
- Use the PGA309 Calculator software tool to verify that your design does not violate any of the most critical PGA309 specifications (internal or external nodes).

Enter your sensor parameters and your PGA309 configuration parameters to get the gain scaling.

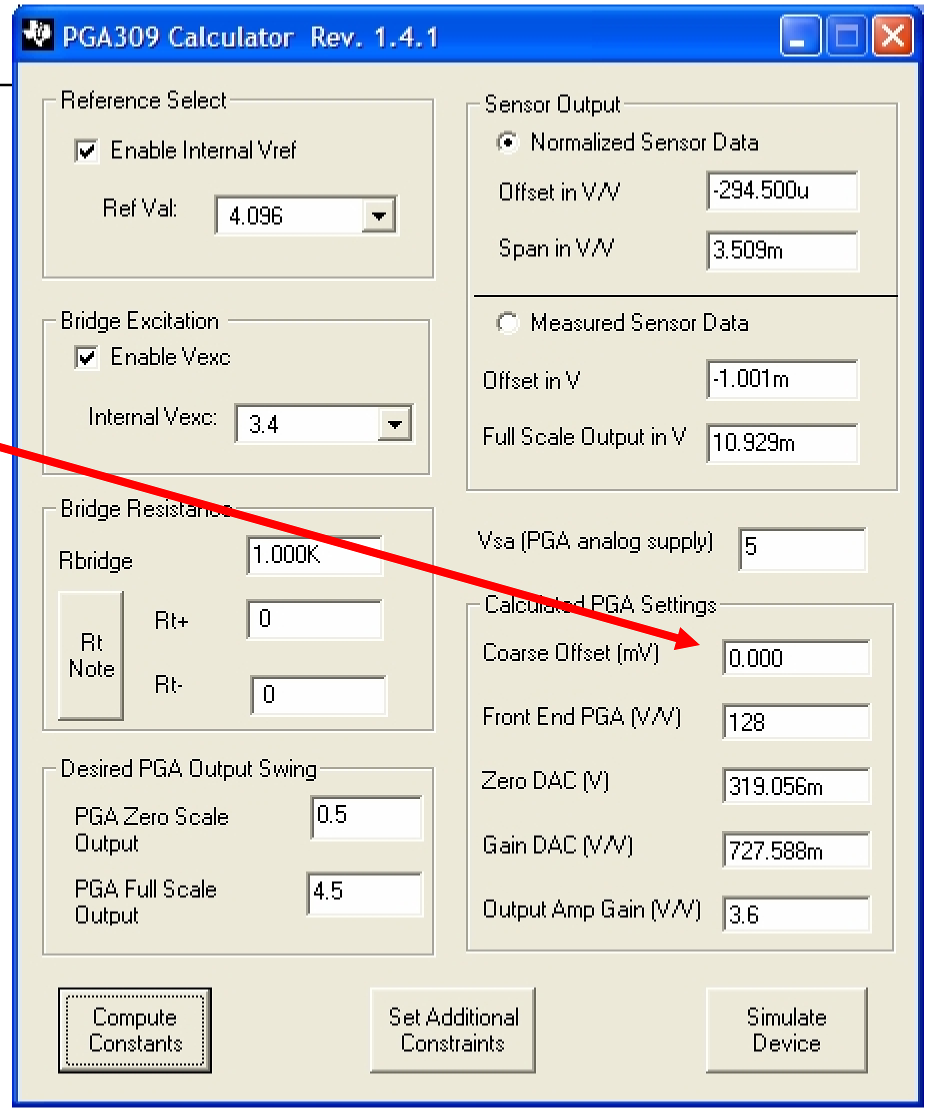
Enter information here. For example, enter the values shown.

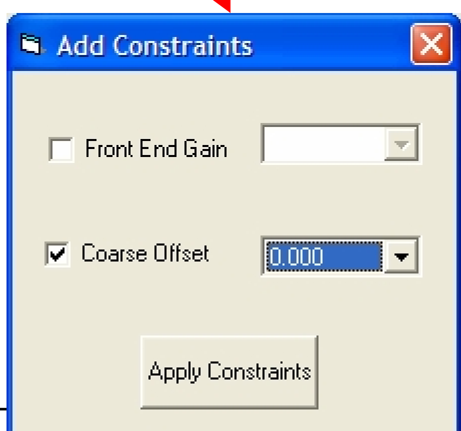


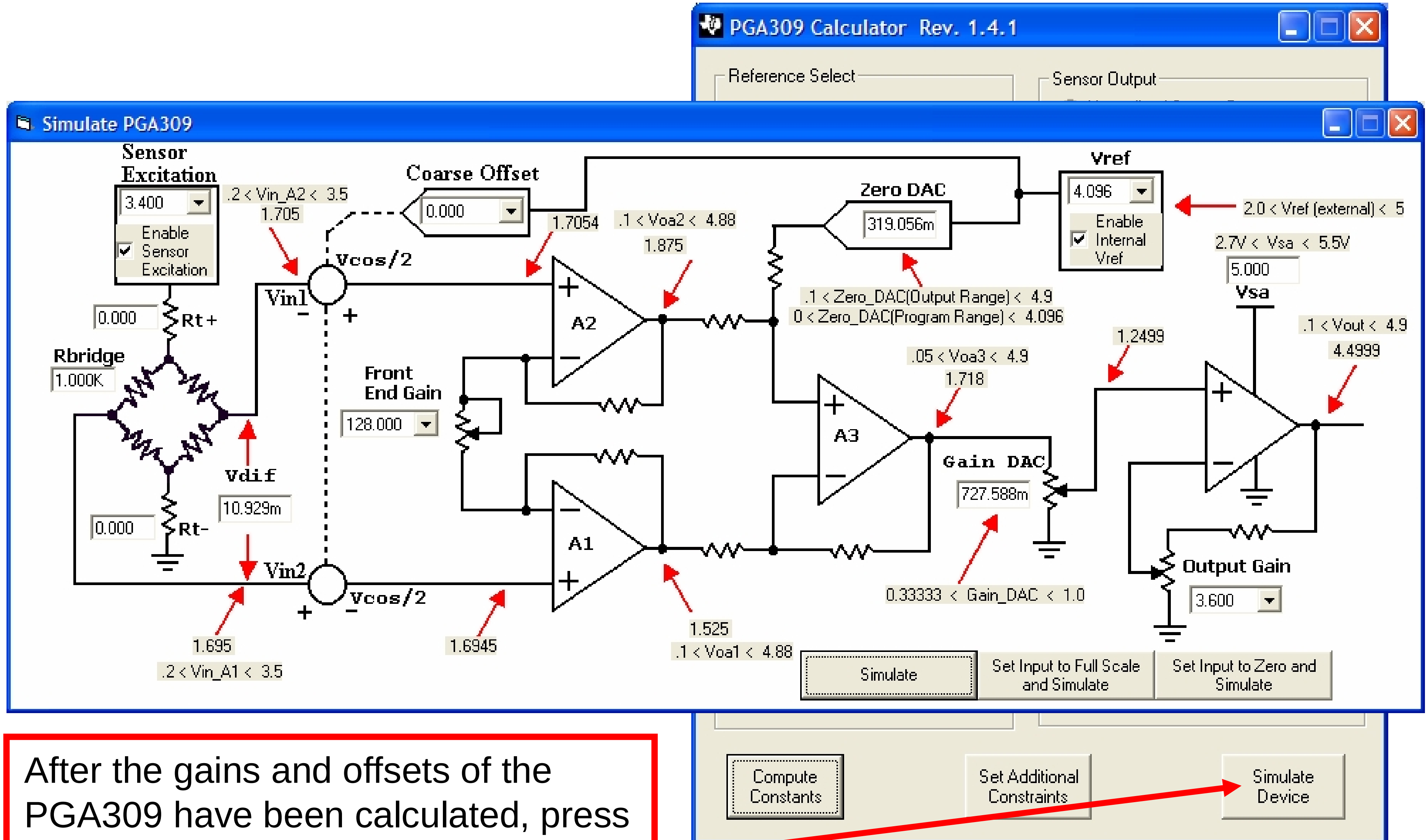
Press ***Compute Constants*** and the resulting gain settings will be displayed here.

If your design generates values for gain and offset that are out of the PGA309's range, the software will flag the problem.

The program selects values to allow the Gain DAC and Zero DAC to have the maximum adjustable range. The *Set Additional Constraints* button is a way to force the front end gain or coarse offset to a constant. For this example, set the coarse offset zero to minimize noise. Click *Apply Constraints* and then click *Compute Constants*. In this case the range of adjustment for the Zero DAC is reduced but is still adequate to correct for the sensor drift.



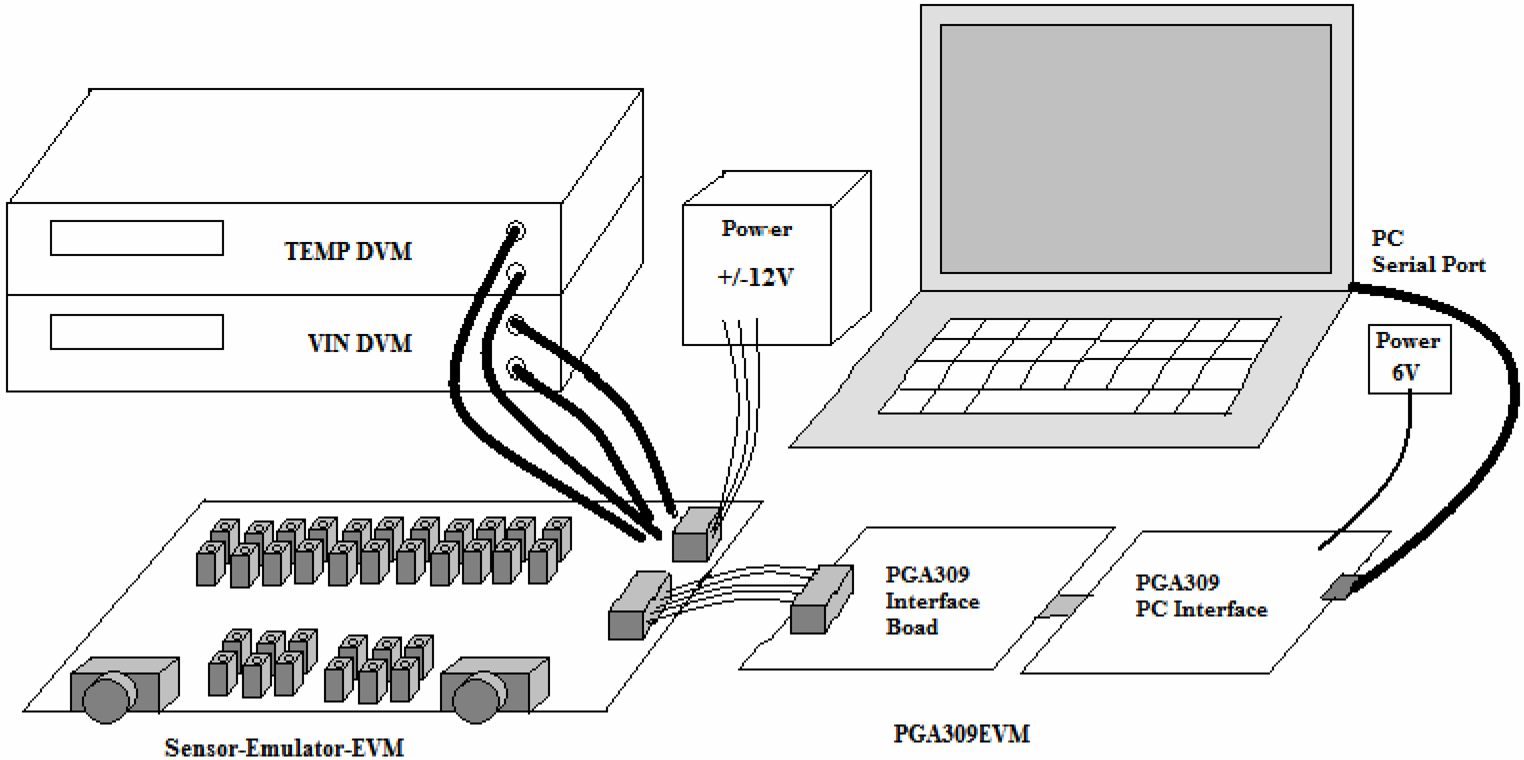




After the gains and offsets of the PGA309 have been calculated, press *Simulate Device* to see if any internal nodes are out of range.

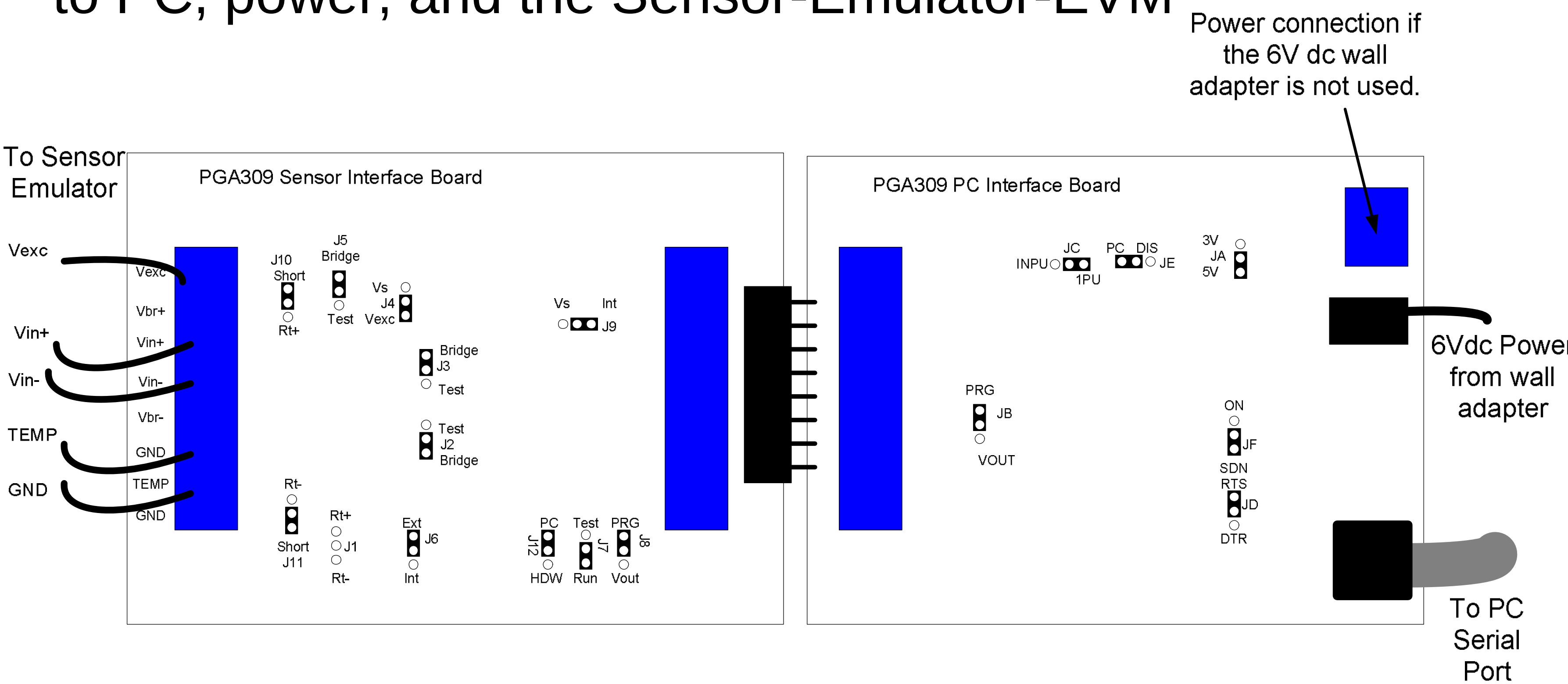
Step 2: Connect the hardware

Example of a Typical Engineering Bench Setup Using the Sensor Emulator

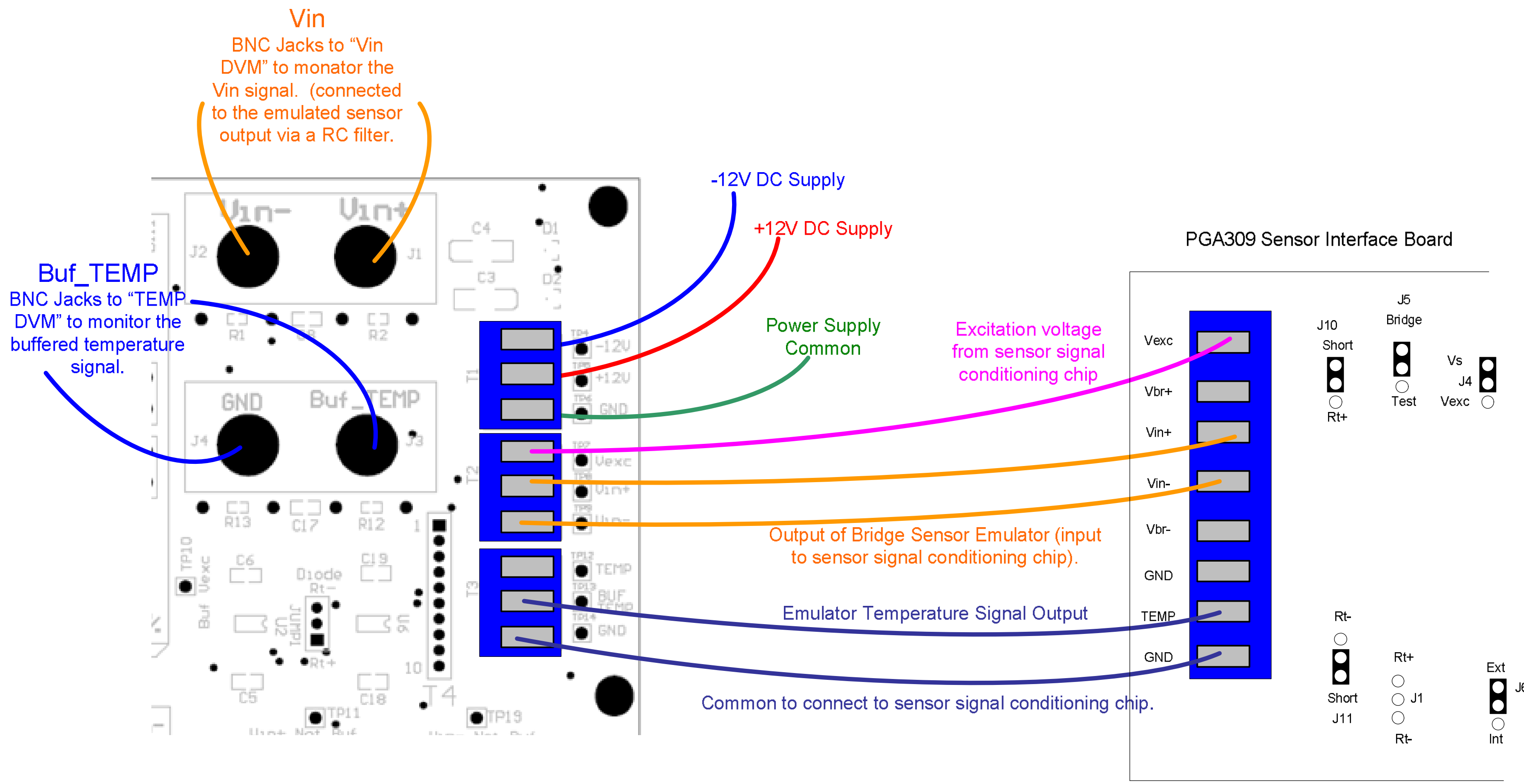


This diagram illustrates an example of how the Sensor-Emulator-EVM would be used in an engineering bench setup. The PGA309 is a programmable sensor signal conditioning chip. The Sensor-Emulator-EVM can be used in conjunction with the PGA309EVM (both versions) to facilitate the development of the PGA309 application.

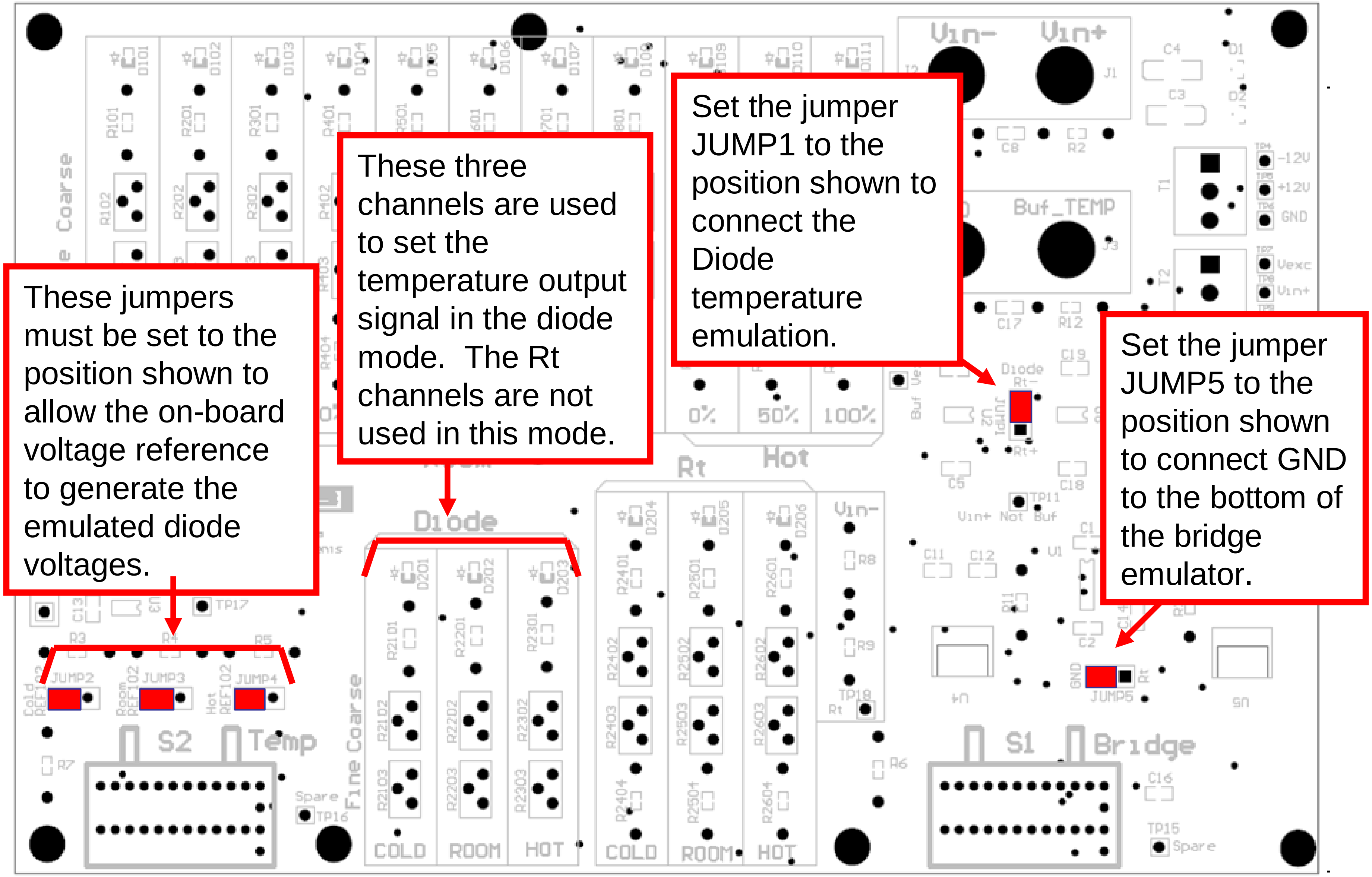
Jumper setup of PGA309EVM-xx and connections to PC, power, and the Sensor-Emulator-EVM



Required Electrical Connections to Sensor-Emulator-EVM



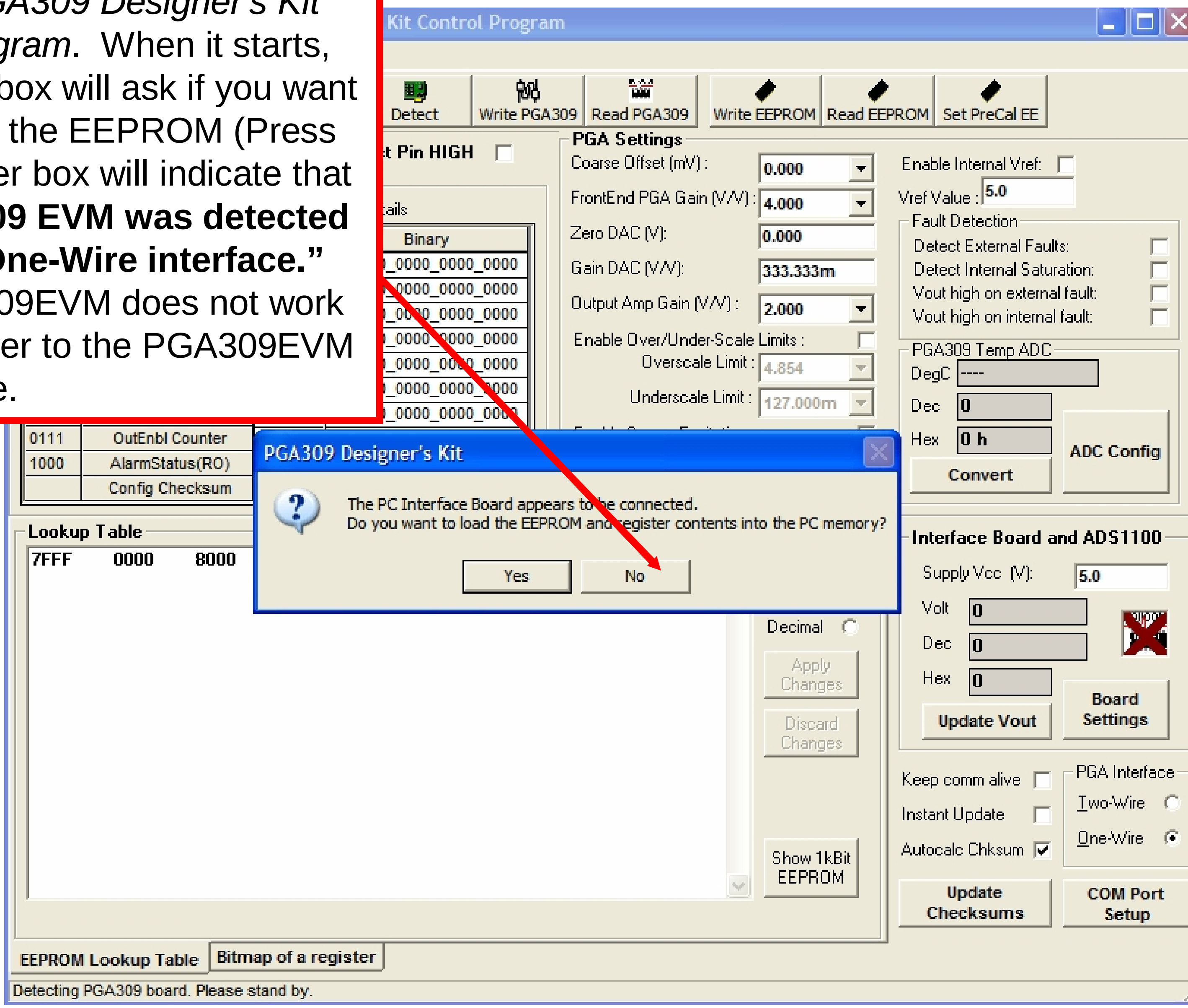
Sensor-Emulator-EVM Jumper Setup



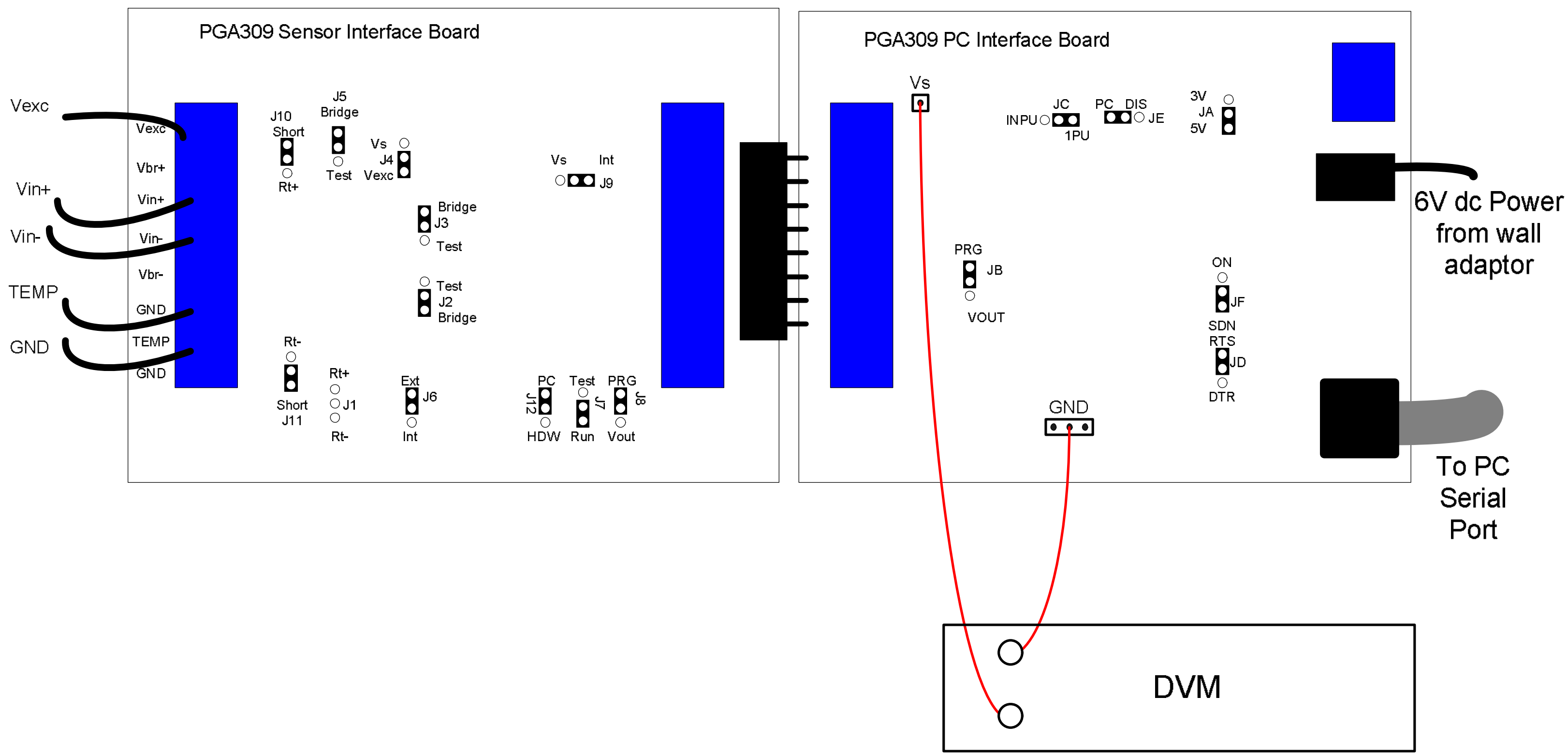
Step 3: Do initial setup of the PGA309 using the PGA309 DK Program

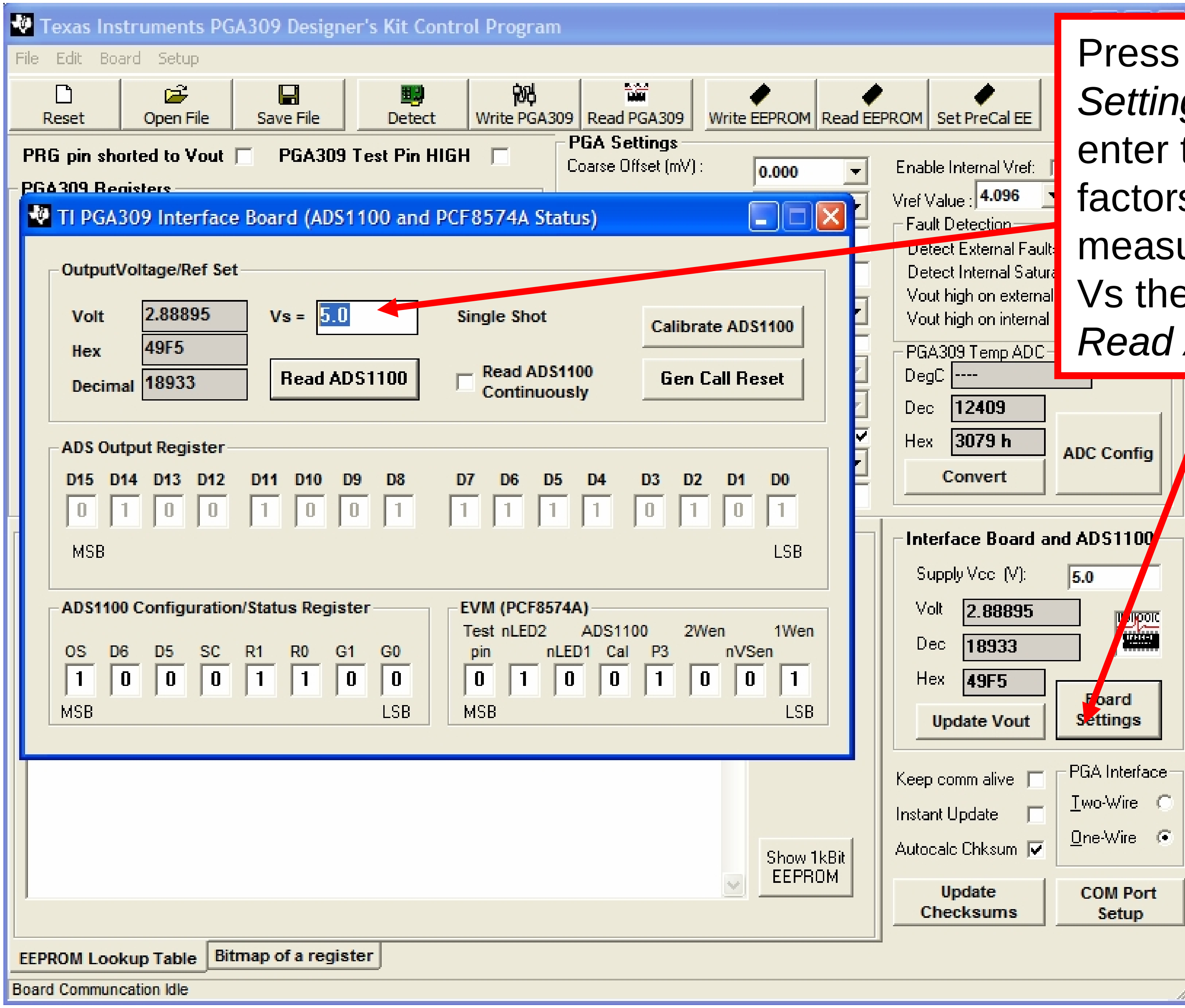
- Copy the PGA309 Calculator results into the PGA309DK software.
- Configure the PGA309 Temp ADC
- Calibrate the ADS1100 (ADC on PGA309EVM-xx PC Interface Board Used to read the PGA309 output; read via software).

Start the *PGA309 Designer's Kit Control Program*. When it starts, a message box will ask if you want to load from the EEPROM (Press No). Another box will indicate that **"the PGA309 EVM was detected using the One-Wire interface."** If the PGA309EVM does not work properly, refer to the PGA309EVM Users Guide.



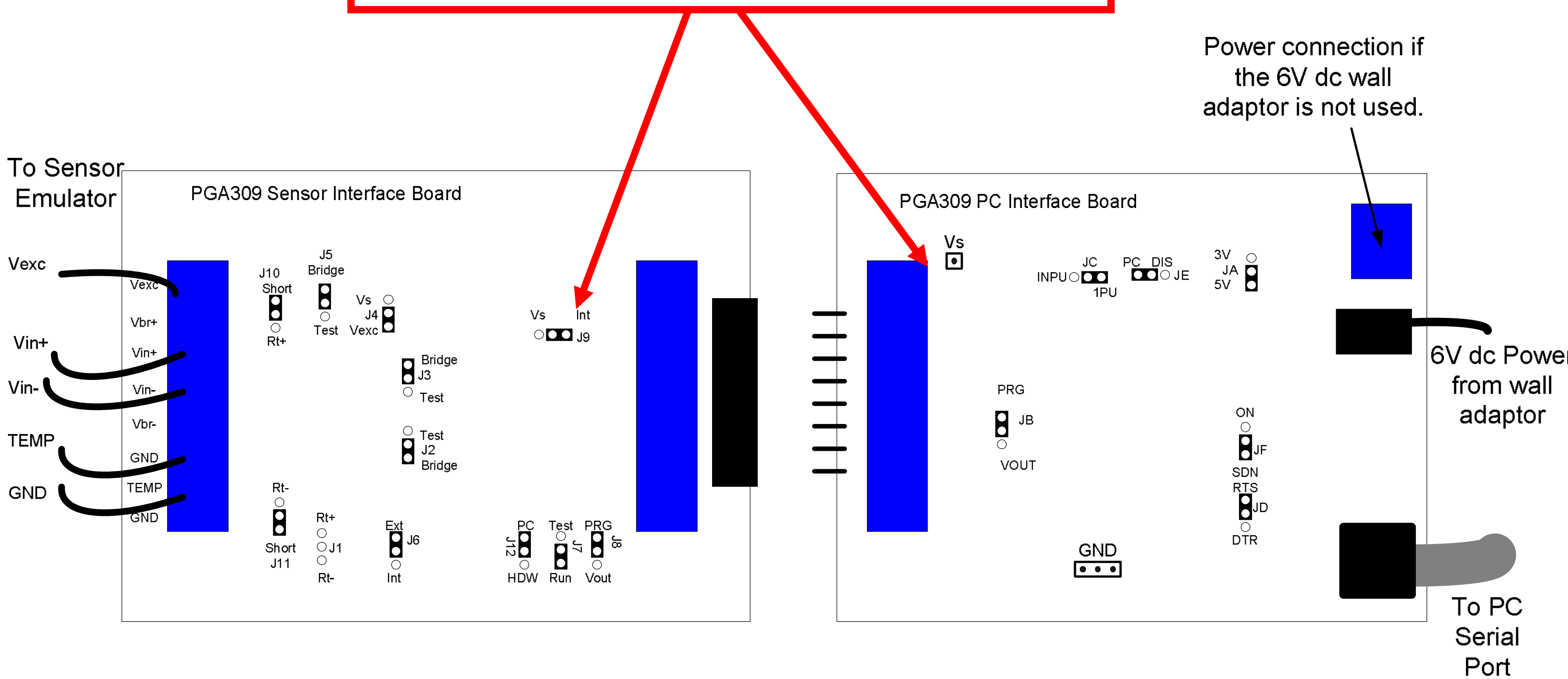
For this example, we will measure the PGA309 output voltage using an delta-sigma A/D converter on the PGA309 PC Interface Board (the ADS1100). For optimal accuracy the ADS1100 should be calibrated. To calibrate the ADS1100, measure the supply voltage Vs on the PGA309 PC Interface Board (this should be close to 5V).

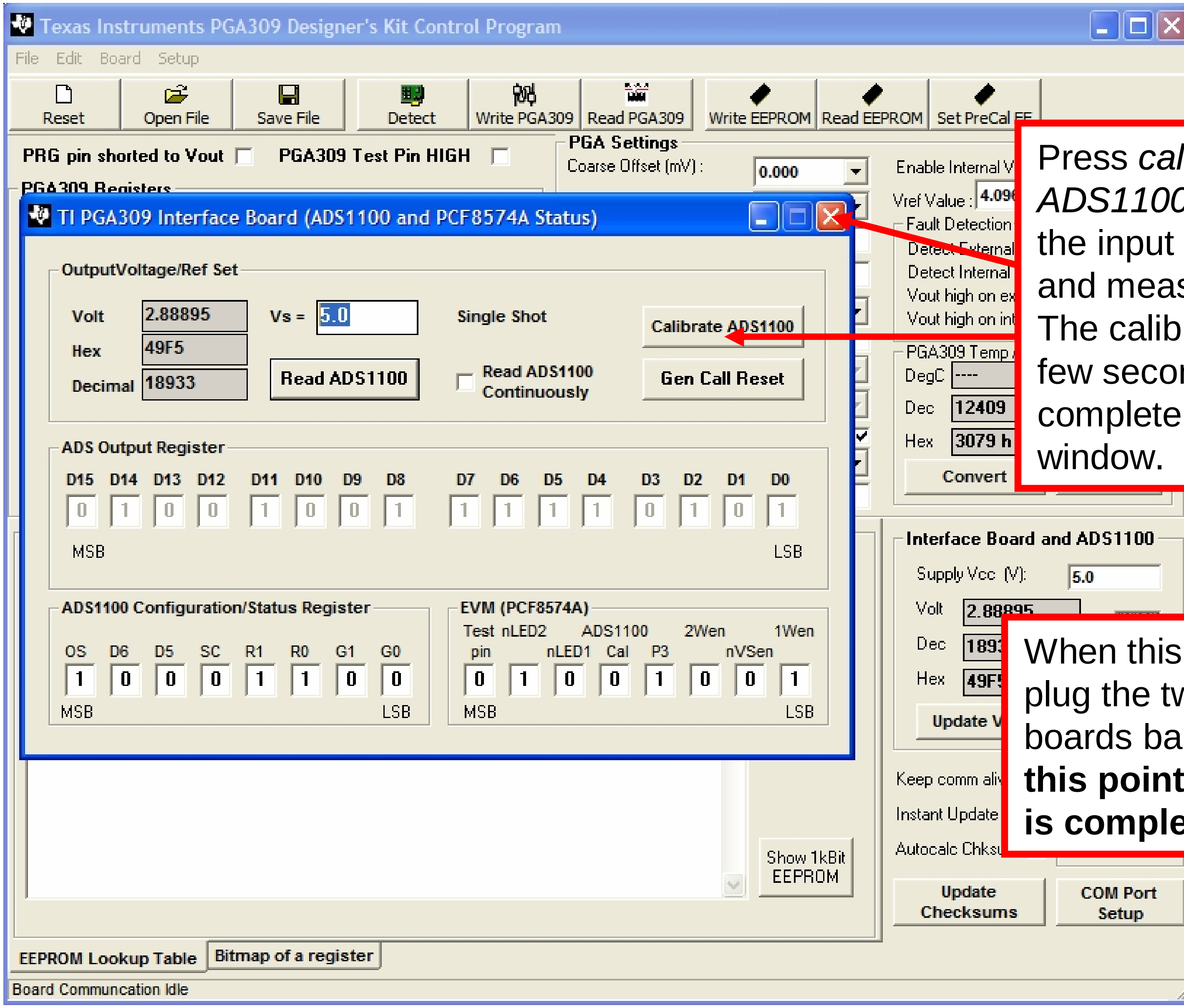




Press the *Board Settings* button to enter the calibration factors. Enter the measured value for Vs then click *Read ADS1100*.

For the next part of the ADS1100 calibration, the input of the ADS1100 is shorted. The two boards must be separated so that the PGA309 output is not shorted by the calibration.

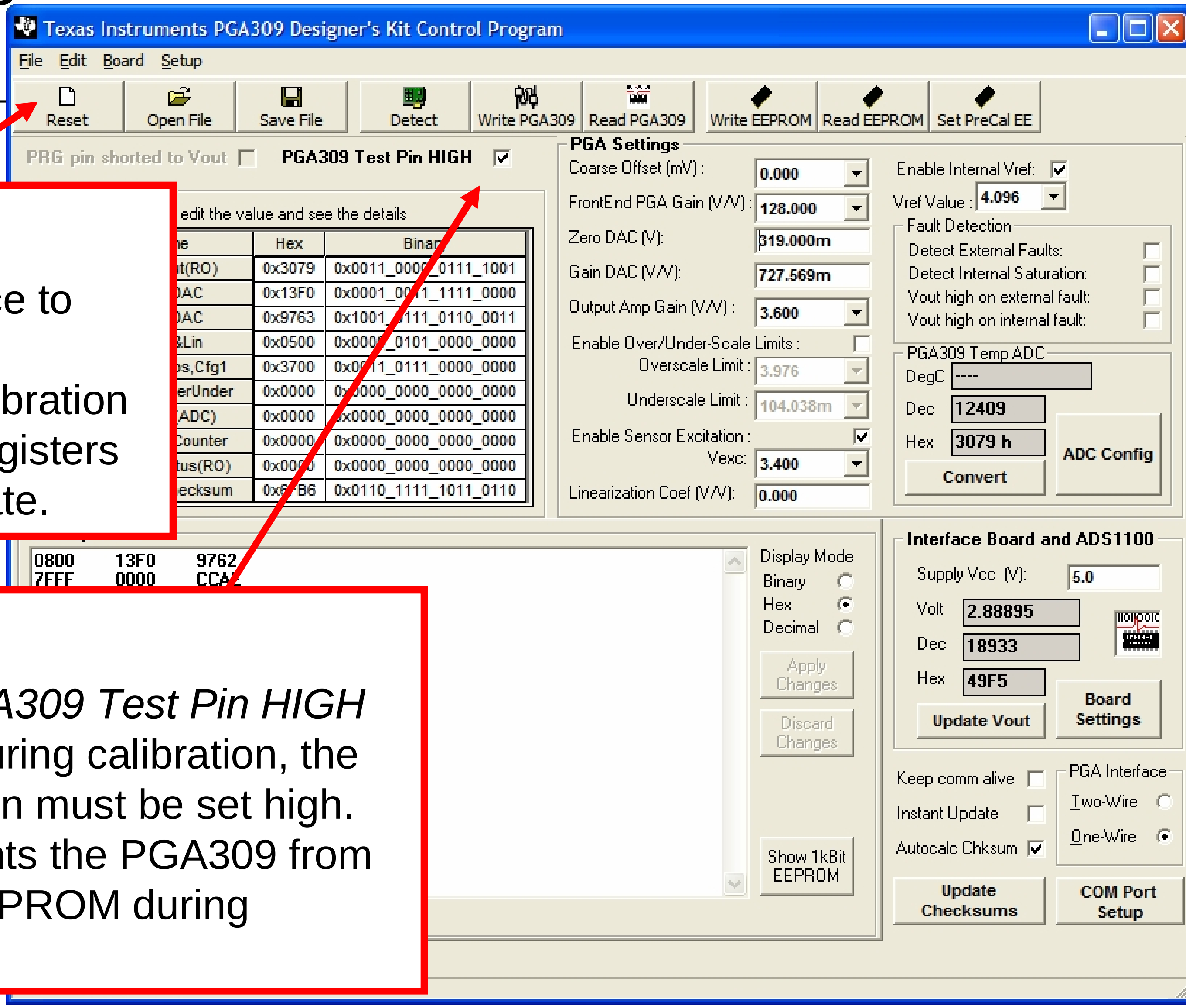




Press *calibrate ADS1100*. This will short the input to the ADS1100 and measure the offset. The calibration will take a few seconds. When it is complete close the window.

When this step is done, plug the two PGA309EVM boards back together. **At this point the calibration is complete.**

Initial Configuration for the PGA309

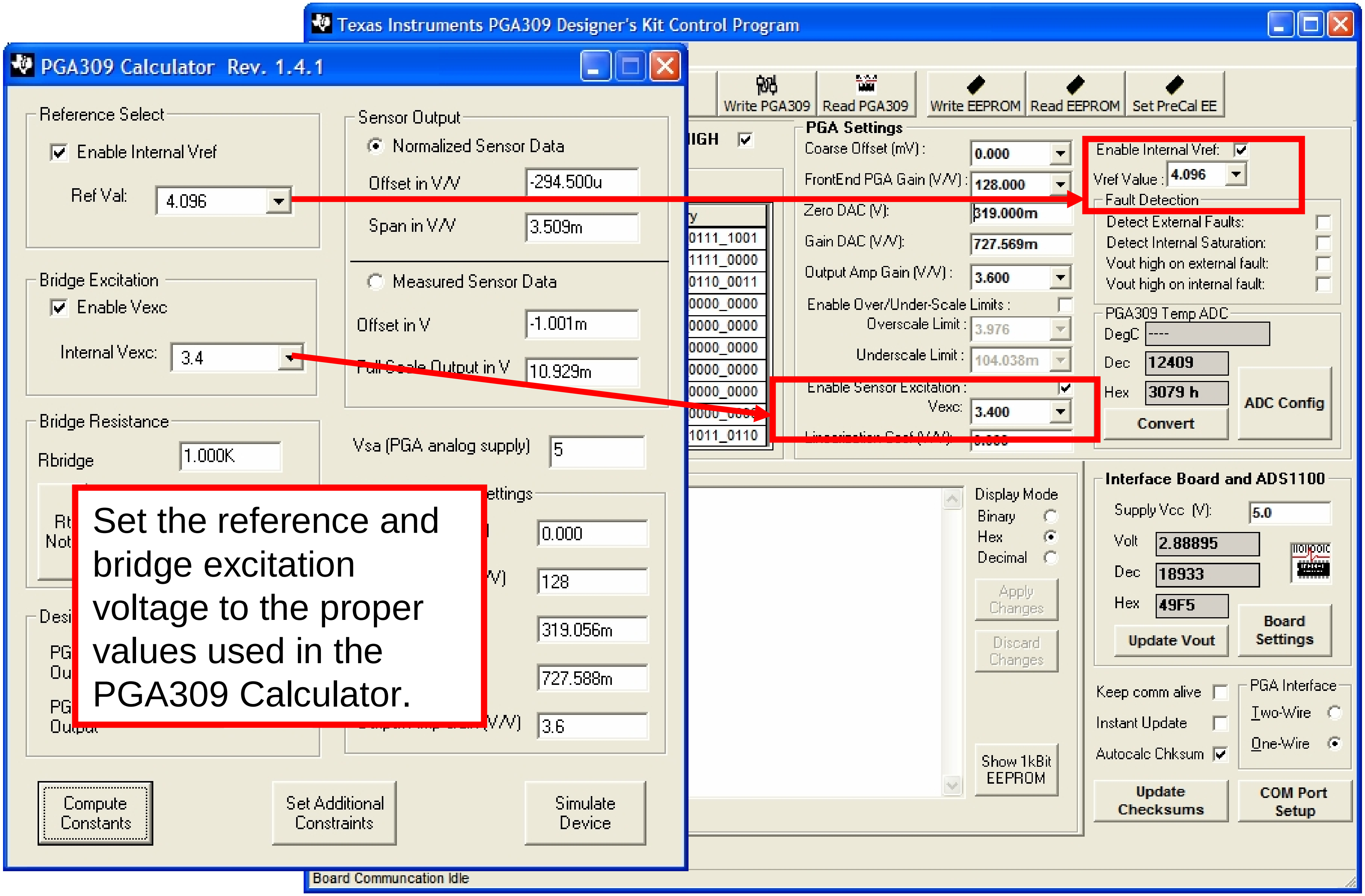


Step A:

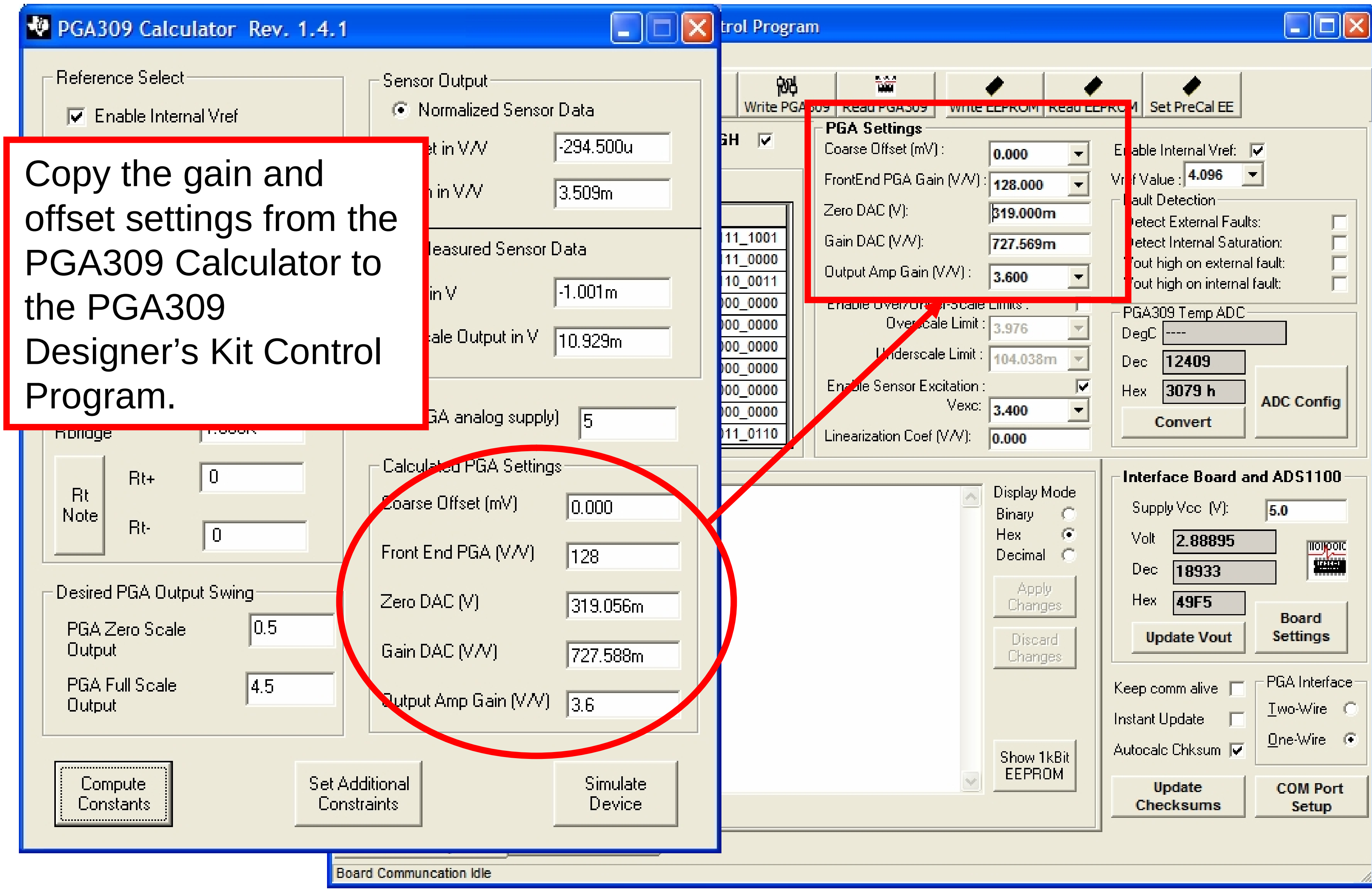
It is a good practice to press reset at the beginning of a calibration to insure all the registers are in a known state.

Step B:

Make sure *PGA309 Test Pin HIGH* is checked. During calibration, the PGA309 test pin must be set high. This pin prevents the PGA309 from reading the EEPROM during calibration.


Texas Instruments PGA309 Designer's Kit Control Program
PGA309 Calculator Rev. 1.4.1
Reference Select
Enable Internal Vref
Ref Val: 4.096
Bridge Excitation
Enable Vexc
Internal Vexc: 3.4
Bridge Resistance
Rbridge 1.000K
Sensor Output
Normalized Sensor Data
Offset in V/V -294.500u
Span in V/V 3.509m
Measured Sensor Data
Offset in V -1.001m
Full Scale Output in V 10.929m
Vsa (PGA analog supply) 5
Compute Constants
Set Additional Constraints
Simulate Device
Write PGA309
Read PGA309
Write EEPROM
Read EEPROM
Set PreCal EE
PGA Settings
Coarse Offset (mV): 0.000
FrontEnd PGA Gain (V/V): 128.000
Zero DAC (V): 319.000m
Gain DAC (V/V): 727.569m
Output Amp Gain (V/V): 3.600
Enable Over/Under-Scale Limits:
Overscale Limit: 3.976
Underscale Limit: 104.038m
Enable Sensor Excitation:
Vexc: 3.400
Enable Internal Vref:
Vref Value: 4.096
Fault Detection
Detect External Faults:
Detect Internal Saturation:
Vout high on external fault:
Vout high on internal fault:
PGA309 Temp ADC
DegC ----
Dec 12409
Hex 3079 h
ADC Config
Convert
Display Mode
Binary
Hex
Decimal
Apply Changes
Discard Changes
Show 1kBit EEPROM
Interface Board and ADS1100
Supply Vcc (V): 5.0
Volt 2.88895
Dec 18933
Hex 49F5
Update Vout
Board Settings
Keep comm alive
Instant Update
Autocalc Chksum
PGA Interface
Two-Wire
One-Wire
Update Checksums
COM Port Setup
Board Communcation Idle
Set the reference and bridge excitation voltage to the proper values used in the PGA309 Calculator.

Copy the gain and offset settings from the PGA309 Calculator to the PGA309 Designer's Kit Control Program.



Step A:

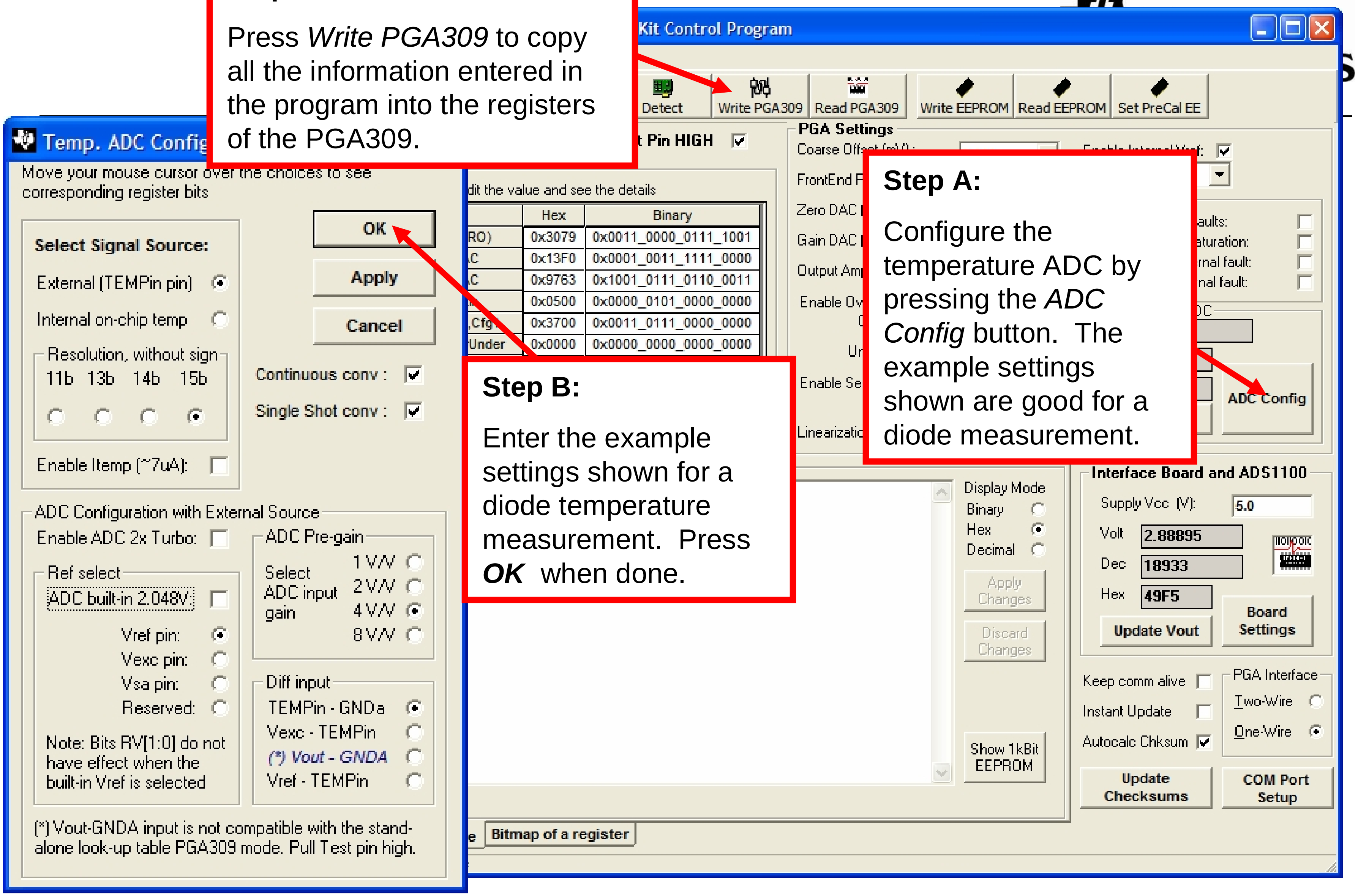
Configure the temperature ADC by pressing the *ADC Config* button. The example settings shown are good for a diode measurement.

Step B:

Enter the example settings shown for a diode temperature measurement. Press ***OK*** when done.

Step C:

Press *Write PGA309* to copy all the information entered in the program into the registers of the PGA309.



Step 4: Configure Sensor-Emulator-EVM to Emulate the Bridge Sensor

1. In order to use the Sensor-Emulator-EVM, you have to adjust a number of trim potentiometers to configure the Sensor-Emulator-EVM so that it acts like your sensor. If the sensor's raw output characteristics are known, this step is simple: you adjust the Sensor-Emulator-EVM output to mimic your sensor.

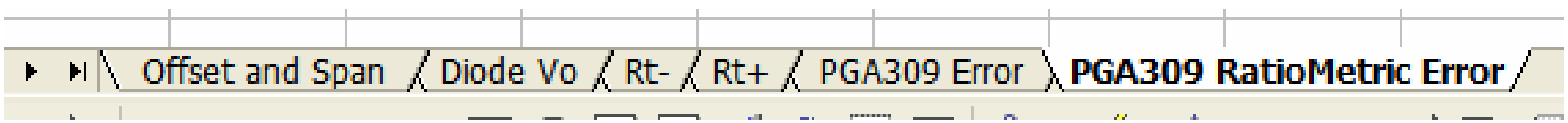
2. In the case where you want to use a sensor data sheet to configure the Sensor-Emulator-EVM, you can use the ***generate_emu_settings.xls*** to translate your specifications to Sensor-Emulator-EVM settings. Unfortunately, sensor manufacturers may have specifications that do not conform to a standard, and sometimes the specifications are difficult to understand. For our tools we will mathematically define the specifications. You may have to translate your particular specifications to our format.

Configuring the Emulator to Emulate a Real World Sensor

If the raw output of the sensor is not known, the “Generate_Sim_Values.xls” spreadsheet can be used to translate the specifications of your bridge sensor and temperature sensor to system voltage levels.   The spreadsheet contains five sections (Offset and Span, Diode Vo, Rt-, Rt+, PGA309 Error, Ratiometric Error):

1. Offset and Span: Generates the bridge output voltages.
2. Diode Vo: Generates the temperature sensor output voltages for the diode method.
3. Rt-: Generates the temperature sensor voltages for the Rt- method.
4. Rt+: Generates the temperature sensor voltages for the Rt- method.
5. PGA309 Error: Allows you to read the PGA309 via the ADS1100 (The ADS1100 is the delta-sigma A/D converter that is a part of the PGA309EVM-xx).
6. PGA309 RatioMetric Error: Allows you to read and compute error for a ratiometric PGA309 setup.

The temperature measurement methods, Diode, Rt-, and Rt+ are described in detail in the Sensor-Emulator-EVM System Reference Guide (SBOA102) and the PGA309 Users Guide (SBOU024).



Offset and Span:

Generates the bridge output voltages from sensor specifications (“Generate_Sim_Values.xls”)

All the areas shown in light blue are either sensor specifications or system requirements. Enter these values and the spreadsheet will generate output voltage settings for each channel on the sensor emulator. The next several pages will show how the voltages listed in the spreadsheet are used to program the Sensor-Emulator-EVM.

Enter these for our example

	A	B
1	Temp	degC
2	Tmin=	-45.00
3	Tmax	90.00
4	Troom=	22.50
5		
6	Vexc (V)	3.400E+00
7		
8	Span (V/V)	3.509E-03
9	Offset (V/V)	-2.945E-04
10		
11		
12		
13	NonlinSpanDrift (% of Span)	-5.031E-02
14	NonlinOffsetDrift (% of Span)	-3.077E-02
15	PressureNonlin (% of Span)	-3.976E-02
16		
17	GainTC1 (% of Span/C)	4.682E-04
18	OffsetTC1 (% of Span/C)	-5.205E-04
19	GainTCNonlin(TC2) (% of Span/C^2)	-1.104E-05
20	OffsetTCNonlin(TC2) (% of Span/C^2)	-6.753E-06
21		
22	Note: % of Span is representated as a decimal number	
23	i.e. OffsetTC1 (% of Span) = 0.1 is 10%	
24		
25		
26		

Precalibration Sensor Simulator Settings (LinDac = 0)

Cold

Pressure Input	0%	50%	100%
Sensor Output (mV)	-0.215	5.379	11.939

Room

Pressure Input	0%	25%	50%	75%	100%
Sensor Output (mV)	-1.001	1.626	4.490	7.591	10.929

Hot

Pressure Input	0%	50%	100%
Sensor Output (mV)	-1.053	4.887	11.855

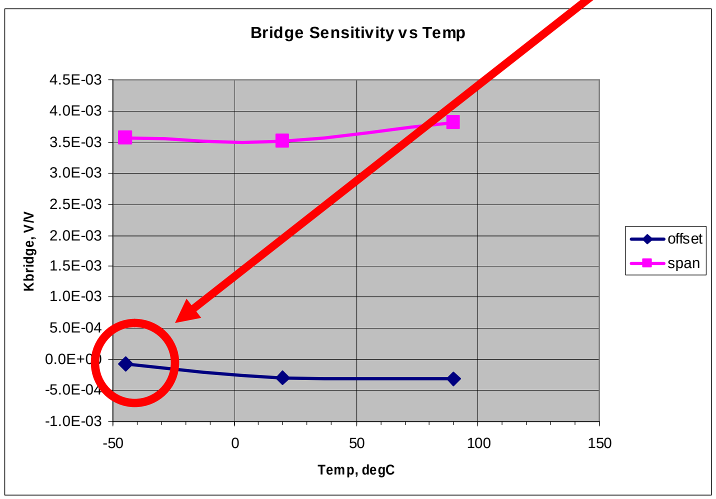
Set Sensor-Emulator-EVM potentiometers to generate these voltages as detailed in pages 35-36

Precalibration Sensor Simulator Settings (LinDac = 0)

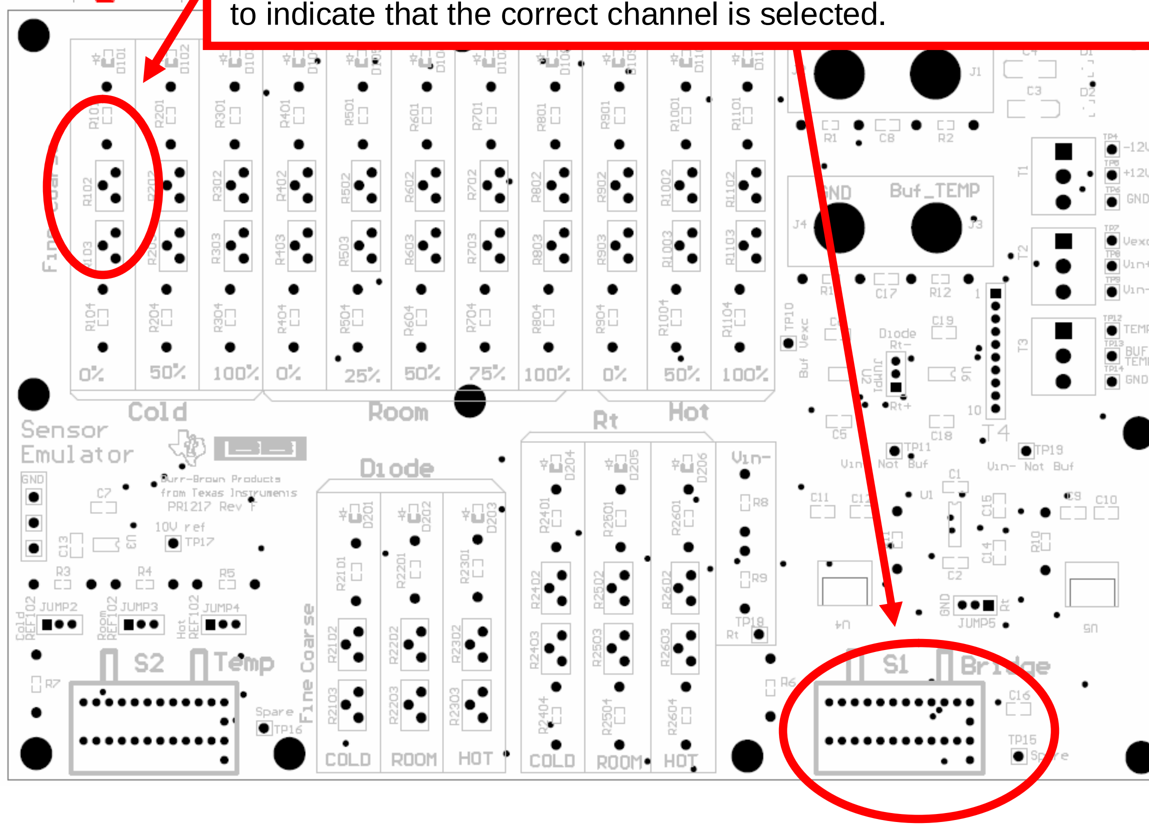
Cold			
Pressure Input	0%	50%	100%
Sensor Output (mV)	-0.215	5.379	11.939

Room					
Pressure Input	0%	25%	50%	75%	100%
Sensor Output (mV)	-1.001	1.626	4.490	7.591	10.929

Hot			
Pressure Input	0%	50%	100%
Sensor Output (mV)	-1.053	4.887	11.855



Each channel on the top section of the sensor emulator represents a applied stimulus and temperature combination for the sensor. Adjust the potentiometers coarse first, then fine, to match the values computed by the ***Generate_Sim_Values.xls*** spreadsheet for cold (0%. 50%, 100%), room (0%, 25%, 50%, 75%, 100%), and hot (0%, 50%, 100%). For example, the sensor output at cold temperature and 0% of applied stimulus is emulated by this channel. The rotary switch S1 is used to select this channel. When the channel is selected, LED D101 will light to indicate that the correct channel is selected.



Precalibration Sensor Simulator Settings (LinDac = 0)

Cold

Pressure Input	0%	50%	100%
Sensor Output (mV)	-0.215	5.379	11.939

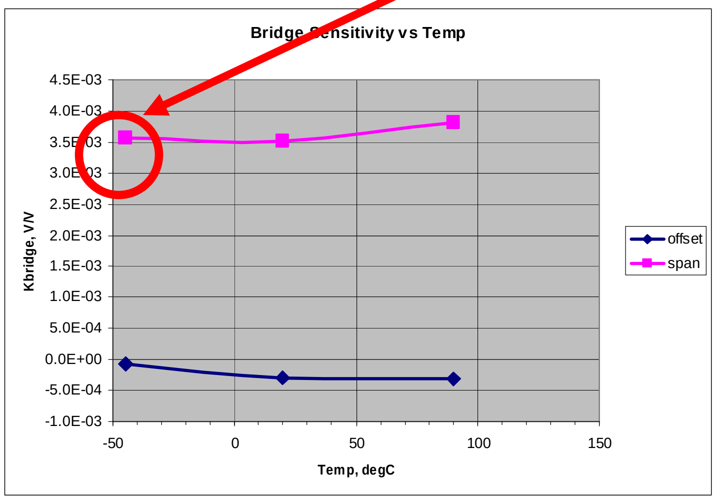
Room

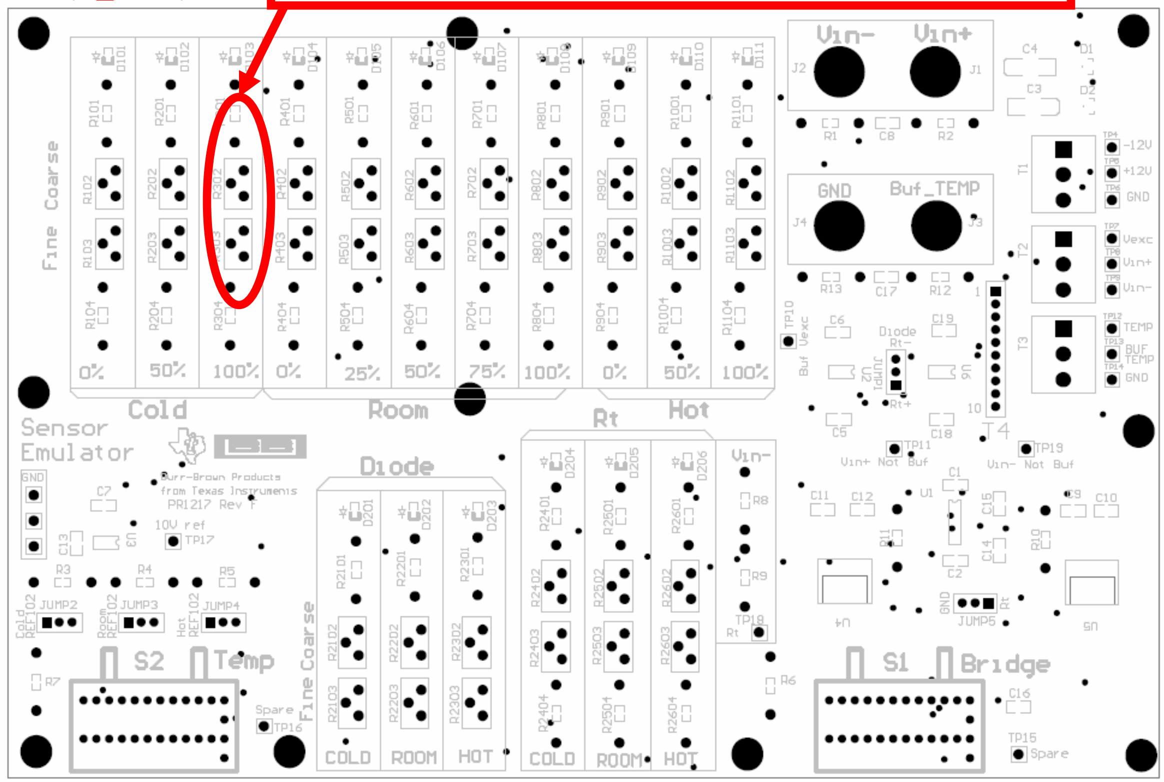
Pressure Input	0%	25%	50%	75%	100%
Sensor Output (mV)	-1.001	1.626	4.490	7.591	10.929

Hot

Pressure Input	0%	50%	100%
Sensor Output (mV)	-1.053	4.887	11.855

This is another example illustrating how a particular channel on the sensor emulator represents an applied stimulus and temperature combination for the sensor. In this example, the sensor output at cold temperature and 100% of applied stimulus is emulated by this channel. The rotary switch S1 is used to select this channel. When the channel is selected, LED D103 will light to indicate that the correct channel is selected.





Diode Vo: Generate Diode Voltages based on Operating Temperature Range

The second tab in the *Generate_Sim_Values.xls* spreadsheet allows the user to enter the temperature range and room temperature diode voltage (light blue areas). The spreadsheet calculates the diode voltages and displays the results in the yellow areas. Note that the *Temp ADC* areas are specific to the PGA309 sensor signal conditioning chip. The Temp ADC values will be used in the computation of the *Counts* for the temp ADC. The next several pages will show how the diode voltages are used to program the sensor Sensor-Emulator-EVM.

	A	B	C	D	E	F
10						
11	**Temp range:**	degC		Temp(degC)	**Diode Vbe (V)**	**Counts**
12	Tmin=	-45.00		-45.00	0.755	24160
13	Troom=	22.50		22.50	0.62	19840
14	Tmax=	90.00		90.00	0.485	15520
15						
16	**Diode**	Volts				
17	Room Temp Vbe=	0.62				
18						
19	**Temp ADC**					
20	Vref (in V) =	4.096				
21	Numb Bits	15	bits (sign bit not included)			
22	Gain=	4				
23						
24						

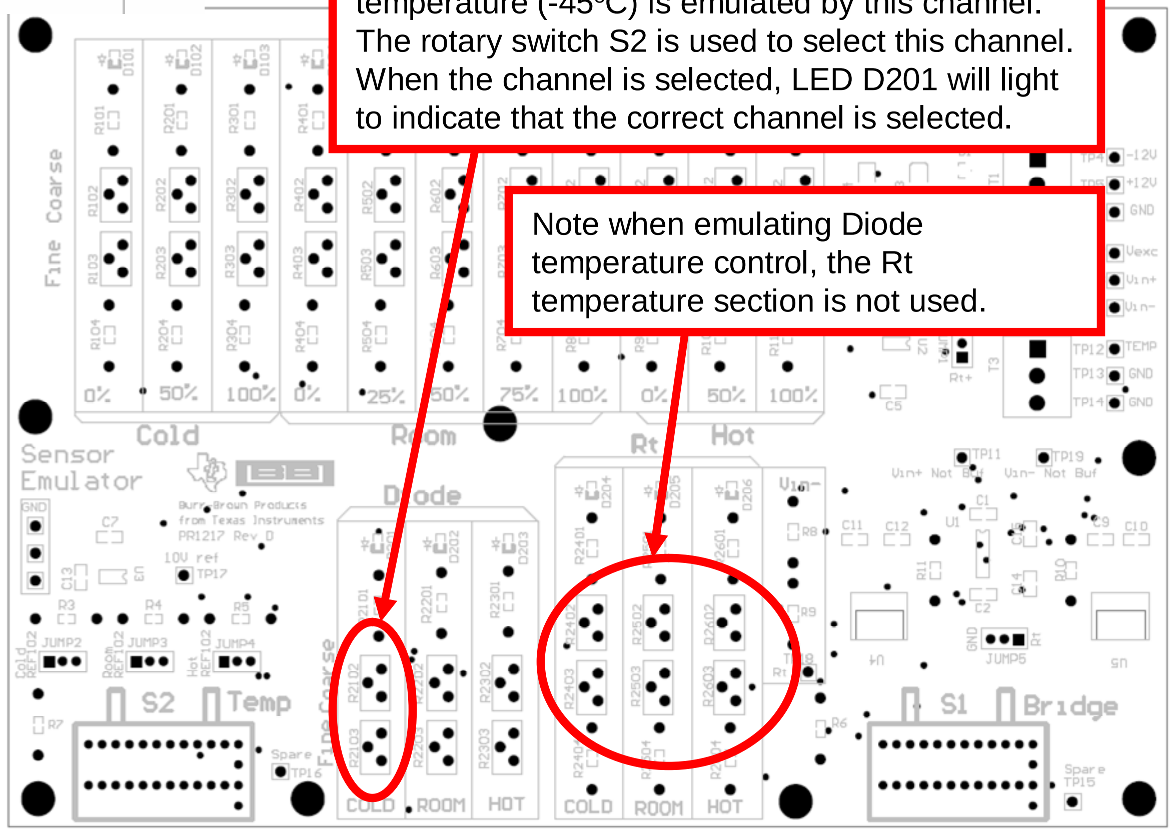
Adjust the *Diode* section potentiometer on the *Sensor-Emulator-EVM* to generate the counts as detailed on page 38.

PGA309 Temp ADC

generate_sim_values.xls
Diode Vo Tab

Temp(degC)	Diode Vbe (V)	Counts
-45.00	0.755	24160
22.50	0.62	19840
90.00	0.485	15520

Each channel on the bottom section of the Sensor-Emulator-EVM represents the output of the emulated temperature sensor. Using the Temp DVM, adjust the respective potentiometers, coarse first, the fine, to match the values computed by the ***Generate_Sim_Values.xls*** spreadsheet for Diode/Cold, Diode/Room, and Diode/Hot. For this example, the temperature output signal at cold temperature (-45ºC) is emulated by this channel. The rotary switch S2 is used to select this channel. When the channel is selected, LED D201 will light to indicate that the correct channel is selected.



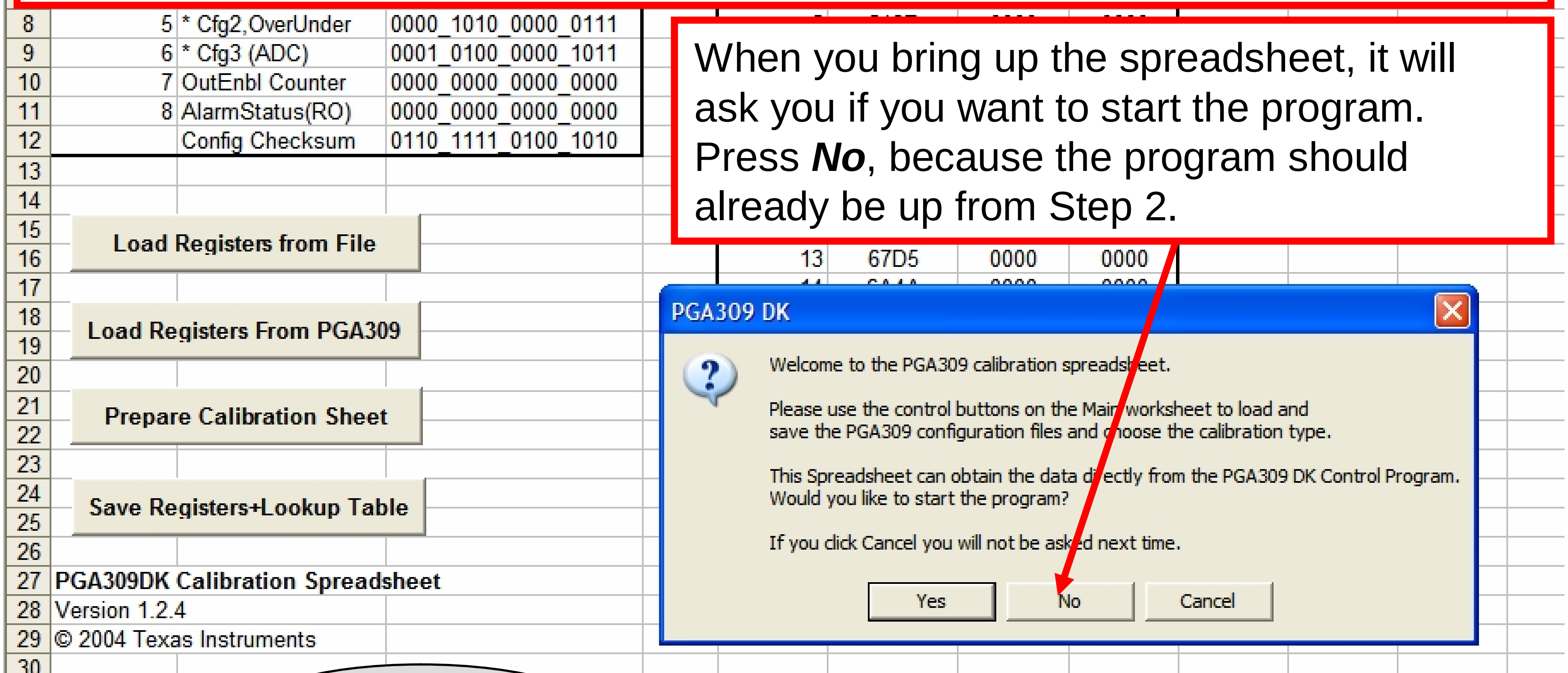
Note when emulating Diode temperature control, the Rt temperature section is not used.

Step 5: Use the PGA309 Calibration Spreadsheet

- Select the calibration algorithm
- Copy the PGA309 registers into the spreadsheet
- Use the Sensor-Emulator-EVM to generate the sensor outputs over temperature.
- Store calibration results into a file. Load this into the PGA309 external EEPROM.
- Measure the post-calibration error. Perform a second calibration to improve accuracy.

For this example, use the PGA309 Calibration Spreadsheet. This tool uses measured data (pressure and temperature) to create a lookup table that the PGA309 will use to compensate for offset and gain drift. The spreadsheet will also generate a coefficient that the PGA309 will use to correct for nonlinearity verses applied pressure. **Note: you will need to enable macros and load the analysis toolpack to get this Excel sheet to work properly**. Information regarding configuration of Excel is detailed in the ***PGA309EVM Users' Guide***.

When you bring up the spreadsheet, it will ask you if you want to start the program. Press ***No***, because the program should already be up from Step 2.



PGA309 Calibration Spreadsheet, Main Tab

PGA309 Configuration Registers		
Reg. Addr	*Name*	*Binary value*
0	ADC Out(RO)	0111_1000_0100_1100
1	ZeroDAC	0111_0000_1010_0100
2	GainDAC	0100_0000_0000_0000
3	* Ref&Lin	0000_0111_0101_1010
4	* Gain,Vos,Cfg1	0001_0111_0000_0000
5	* Cfg2,OverUnder	0000_1010_0000_0111
6	* Cfg3 (ADC)	0001_0100_0000_1011
7	OutEnbl Counter	0000_0000_0000_0000
8	AlarmStatus(RO)	0000_0000_0000_0000
	Config Checksum	0110_1111_0100_1010

PGA309 Calibrated Lookup Table			
Position	*Temp*	*ZM*	*GM*
0	47E8	70A4	4000
1	4A5C	0000	0000
2	4CD1	0000	0000
3	4F46	0000	0000
4	51BB	0000	0000
5	542F	0000	0000
6	56A4	0000	0000
7	5919	0000	0000
8	5B8E	0000	0000
9	5E02	0000	0000
10	6077	0000	0000
11	62EC	0000	0000
12	6560	0000	0000
13	67D5	0000	0000
14	6A4A	0000	0000
15	6CBF	0000	0000
16	6F33	0000	0000
ChSum	*7FFF*	*0*	*BAF6*

Load Registers from File

Load Registers From PGA309

Prepare Calibration Sheet

Save Registers+Lookup Table

PGA309DK Calibration Spreadsheet

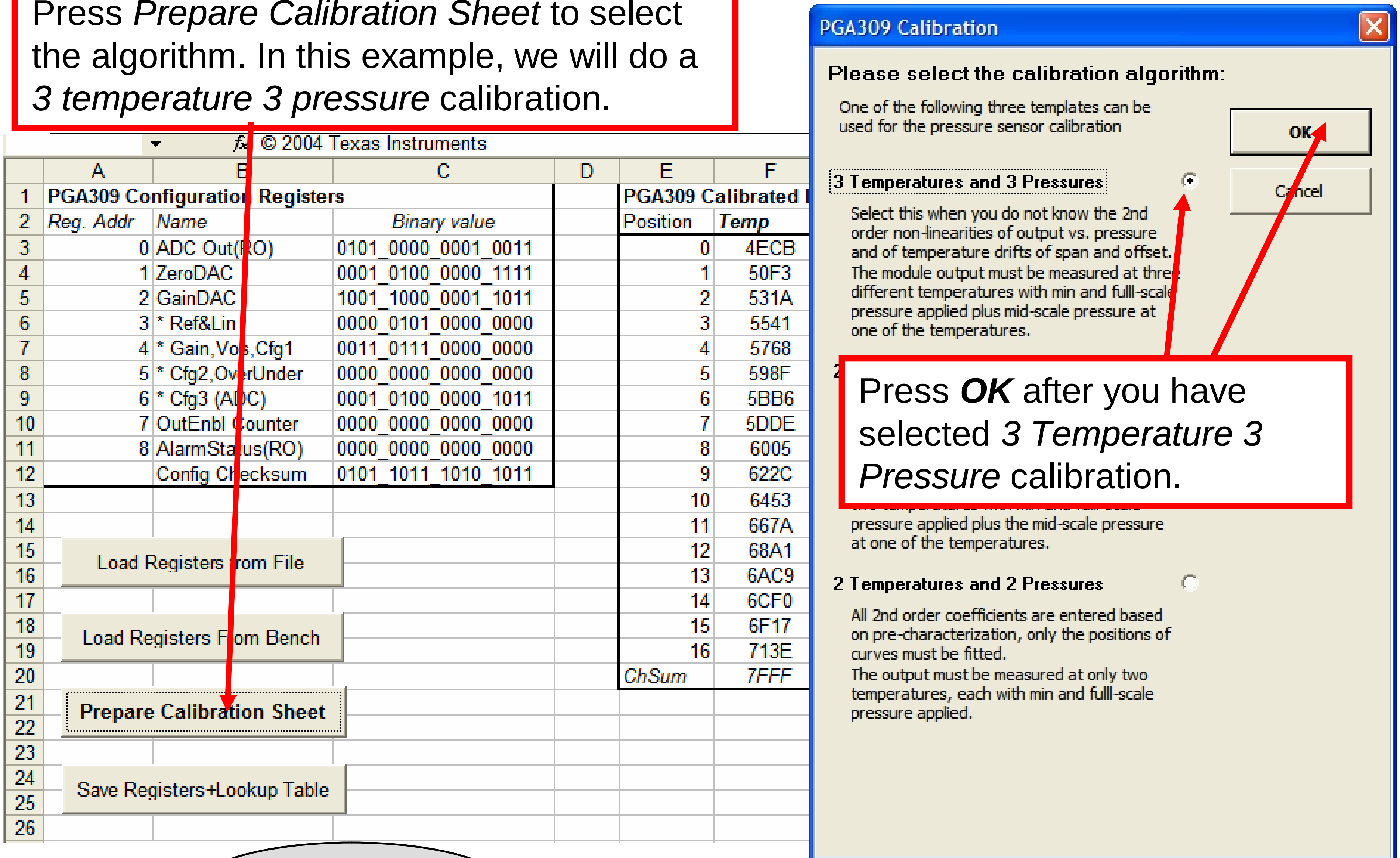
Version 1.2.4

© 2004 Texas Instruments

Press *Load registers from PGA309* to copy the registers from the evaluation fixture into the spreadsheet.

PGA309 Calibration Spreadsheet, Main Tab

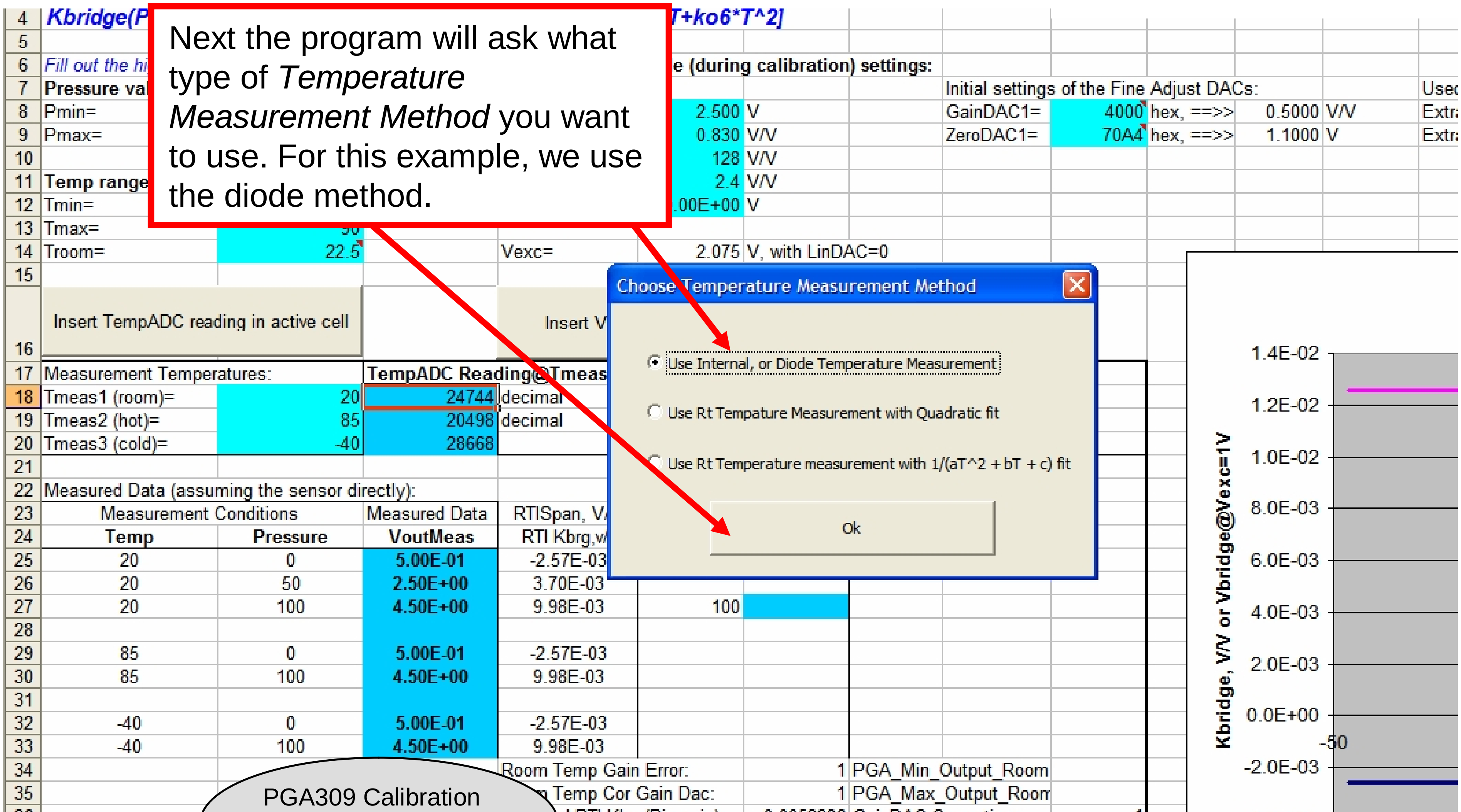
Press *Prepare Calibration Sheet* to select the algorithm. In this example, we will do a *3 temperature 3 pressure* calibration.



Press ***OK*** after you have selected *3 Temperature 3 Pressure* calibration.

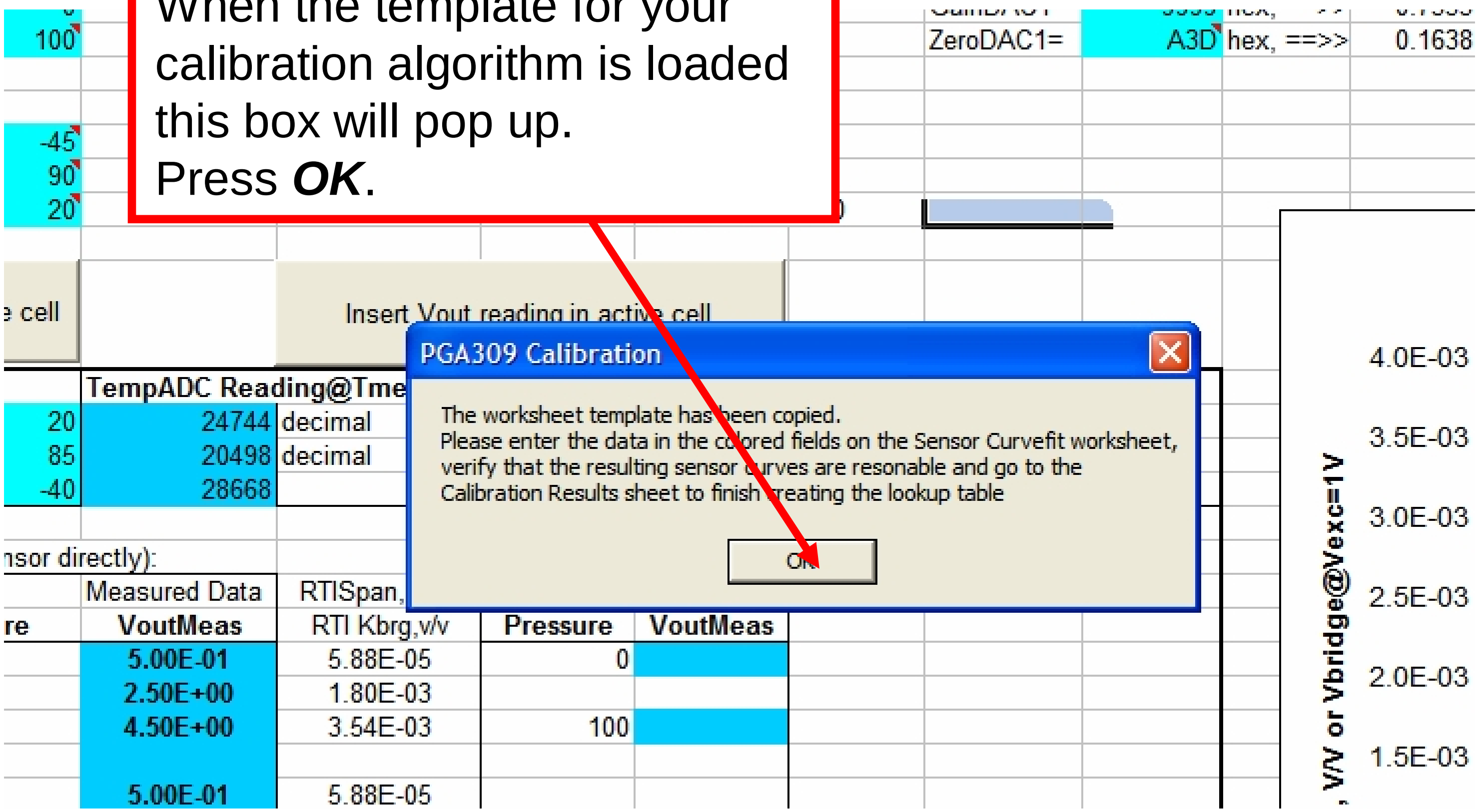
PGA309 Calibration Spreadsheet, Main Tab

Next the program will ask what type of *Temperature Measurement Method* you want to use. For this example, we use the diode method.

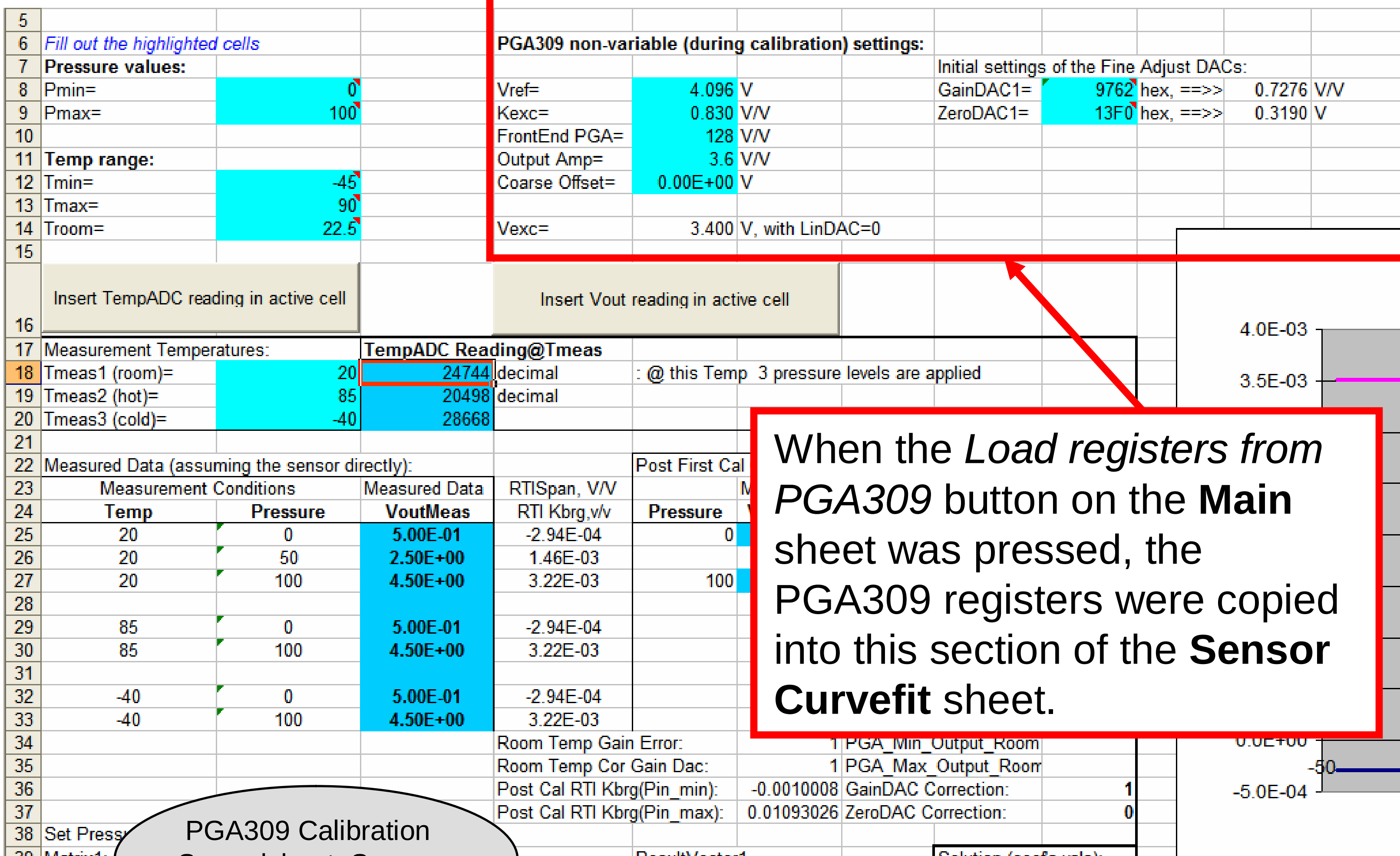


PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

When the template for your calibration algorithm is loaded this box will pop up.
Press ***OK***.



PGA309 Calibration Spreadsheet, Sensor Curvefit Tab



When the *Load registers from PGA309* button on the **Main** sheet was pressed, the PGA309 registers were copied into this section of the **Sensor Curvefit** sheet.

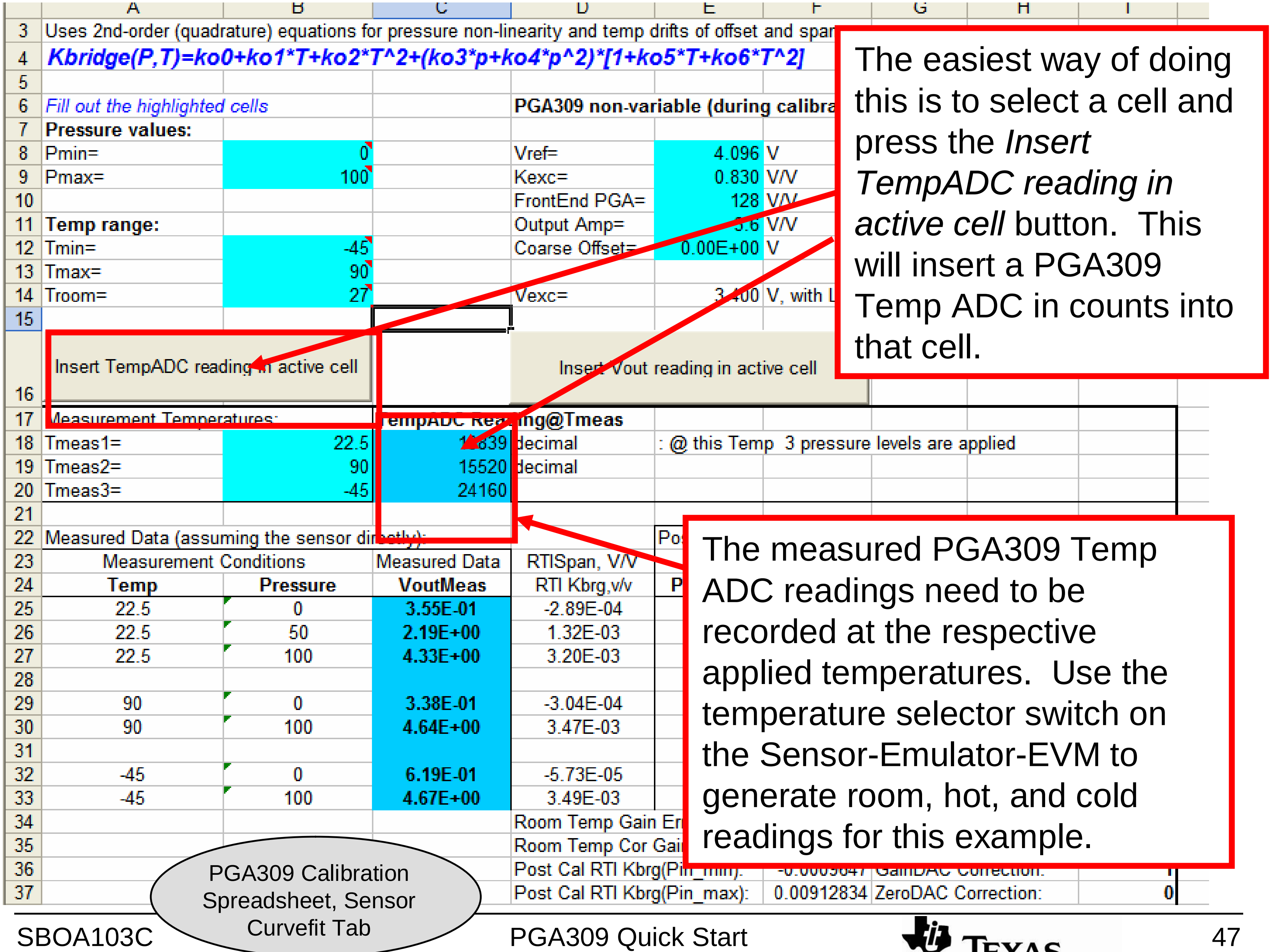
PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

	A	B	C	D	E	F	G	H	I
3	Uses 2nd-order (quadrature) equations for pressure non-linearity and temp drifts of offset and span								
4	*Kbridge(P,T)=ko0+ko1*T+ko2*T^2+(ko3*p+ko4*p^2)*[1+ko5*T+ko6*T^2]*								
5									
6	*Fill out the highlighted cells*			**PGA309 n**					
7	**Pressure values:**								
8	Pmin=	0		Vref=					
9	Pmax=	100		Kexc=					
10				FrontEnd F					
11	**Temp range:**			Output Am					
12	Tmin=	-45		Coarse Offs					
13	Tmax=	90							
14	Troom=	27		Vexc=					
15									
16	Insert TempADC reading in active cell			Insert Vout reading in active cell					
17	Measurement Temperatures:		**TempADC Reading@Tmeas**						
18	Tmeas1=	22.5	19839	decimal	: @ this Temp 3 pressure levels are applied				
19	Tmeas2=	90	15520	decimal					
20	Tmeas3=	-45	24160						
21									
22	Measured Data (assuming the sensor directly):								
23	Measurement Conditions		Measured Data	RTISp					
24	**Temp**	**Pressure**	**VoutMeas**	RTI K					
25	22.5	0	**3.55E-01**	-2.89					
26	22.5	50	**2.19E+00**	1.32					
27	22.5	100	**4.33E+00**	3.20					
28									
29	90	0	**3.38E-01**	-3.04					
30	90	100	**4.64E+00**	3.47					
31									
32	-45	0	**6.19E-01**	-5.73E-05					
33	-45	100	**4.67E+00**	3.49E-03					
34				Room Temp Gain Error:		1			
35				Room Temp Cor Gain Dac:		1			
36				Post Cal RTI Kbrg(Pin_min):		-0.0009647	GainDAC Correction:		**1**
37				Post Cal RTI Kbrg(Pin_max):		0.00912834	ZeroDAC Correction:		**0**

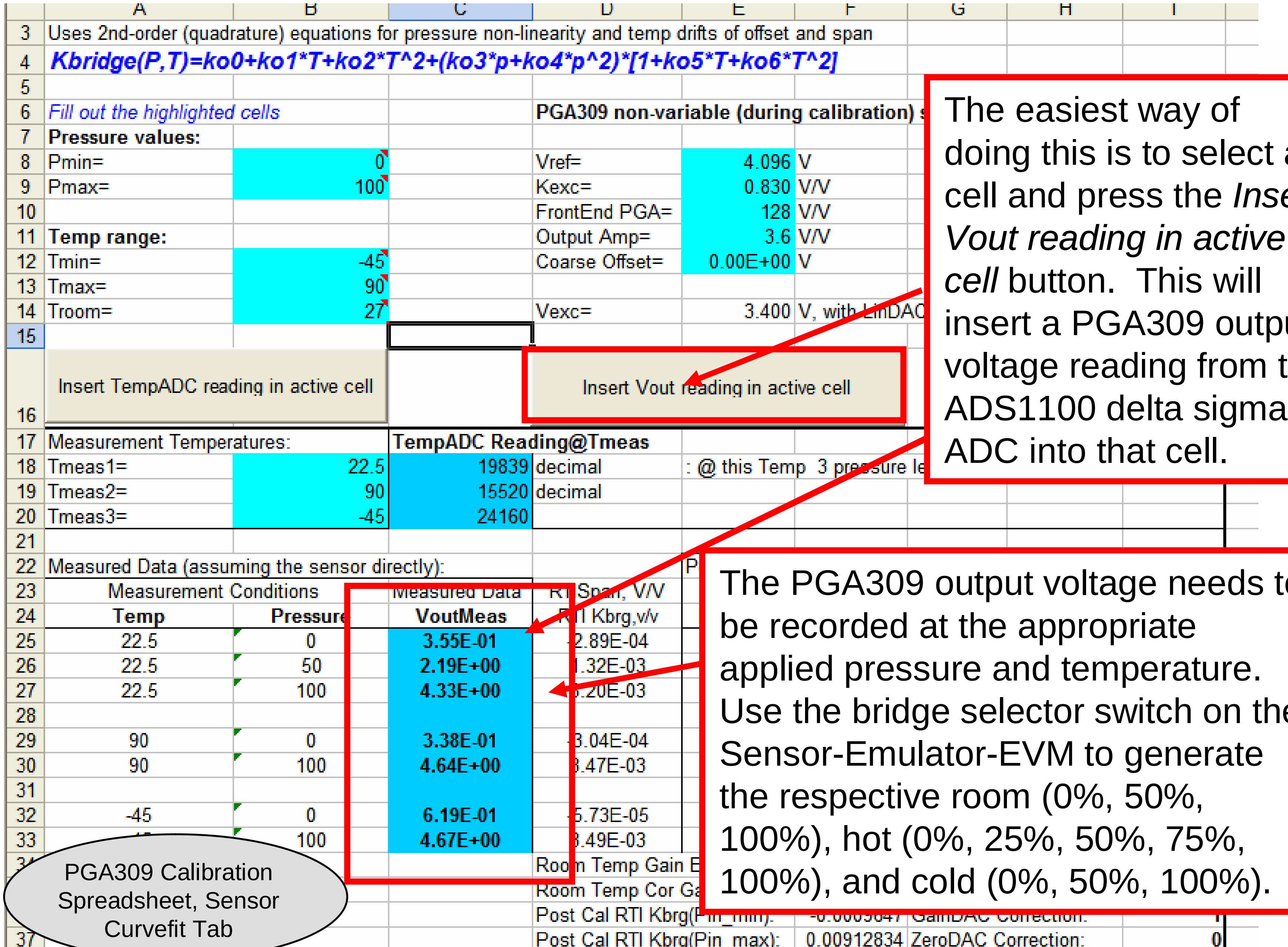
The appropriate values need to be entered manually for the temperature range. This is the range that the curve fit is done over. Enter the values shown for our example.

The appropriate values need to be entered manually for the measurement temperatures. The measurement temperatures are the temperatures that the calibration measurements are made at.

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab



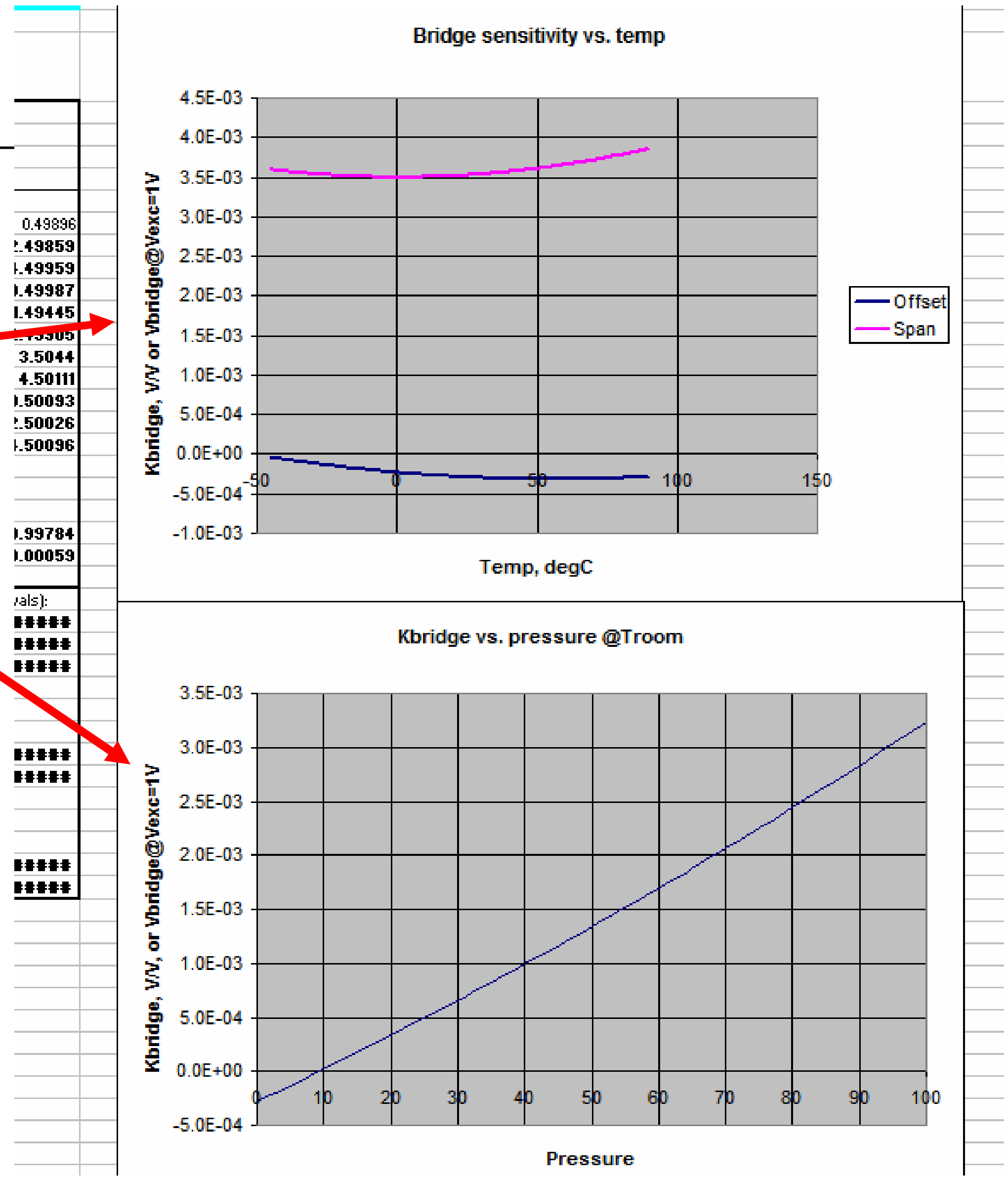
Uses 2nd-order (quadrature) equations for pressure non-linearity and temp drifts of offset and span
Kbridge(P,T)=ko0+ko1*T+ko2*T^2+(ko3*p+ko4*p^2)*[1+ko5*T+ko6*T^2]
Fill out the highlighted cells
PGA309 non-variable (during calibra
Pressure values:
Pmin= 0
Pmax= 100
Vref= 4.096 V
Kexc= 0.830 V/V
FrontEnd PGA= 128 V/V
Output Amp=
Coarse Offset= 0.00E+00 V
Temp range:
Tmin= -45
Tmax= 90
Troom= 27
Vexc=
Insert TempADC reading in active cell
Insert Vout reading in active cell
Measurement Temperatures:
TempADC Reading@Tmeas
Tmeas1= 22.5
Tmeas2= 90 15520 decimal
Tmeas3= -45 24160
@ this Temp 3 pressure levels are applied
Measured Data (assuming the sensor directly):
Measurement Conditions
Measured Data
RTISpan, V/V
Temp
Pressure
VoutMeas
RTI Kbrg,v/v
22.5 0 3.55E-01 -2.89E-04
22.5 50 2.19E+00 1.32E-03
22.5 100 4.33E+00 3.20E-03
90 0 3.38E-01 -3.04E-04
90 100 4.64E+00 3.47E-03
-45 0 6.19E-01 -5.73E-05
-45 100 4.67E+00 3.49E-03
Post Cal RTI Kbrg(Pin_max): 0.00912834 ZeroDAC Correction: 0
The easiest way of doing this is to select a cell and press the Insert TempADC reading in active cell button. This will insert a PGA309 Temp ADC in counts into that cell.
The measured PGA309 Temp ADC readings need to be recorded at the respective applied temperatures. Use the temperature selector switch on the Sensor-Emulator-EVM to generate room, hot, and cold readings for this example.
PGA309 Calibration Spreadsheet, Sensor Curvefit Tab



The easiest way of doing this is to select a cell and press the *Insert Vout reading in active cell* button. This will insert a PGA309 output voltage reading from the ADS1100 delta sigma ADC into that cell.

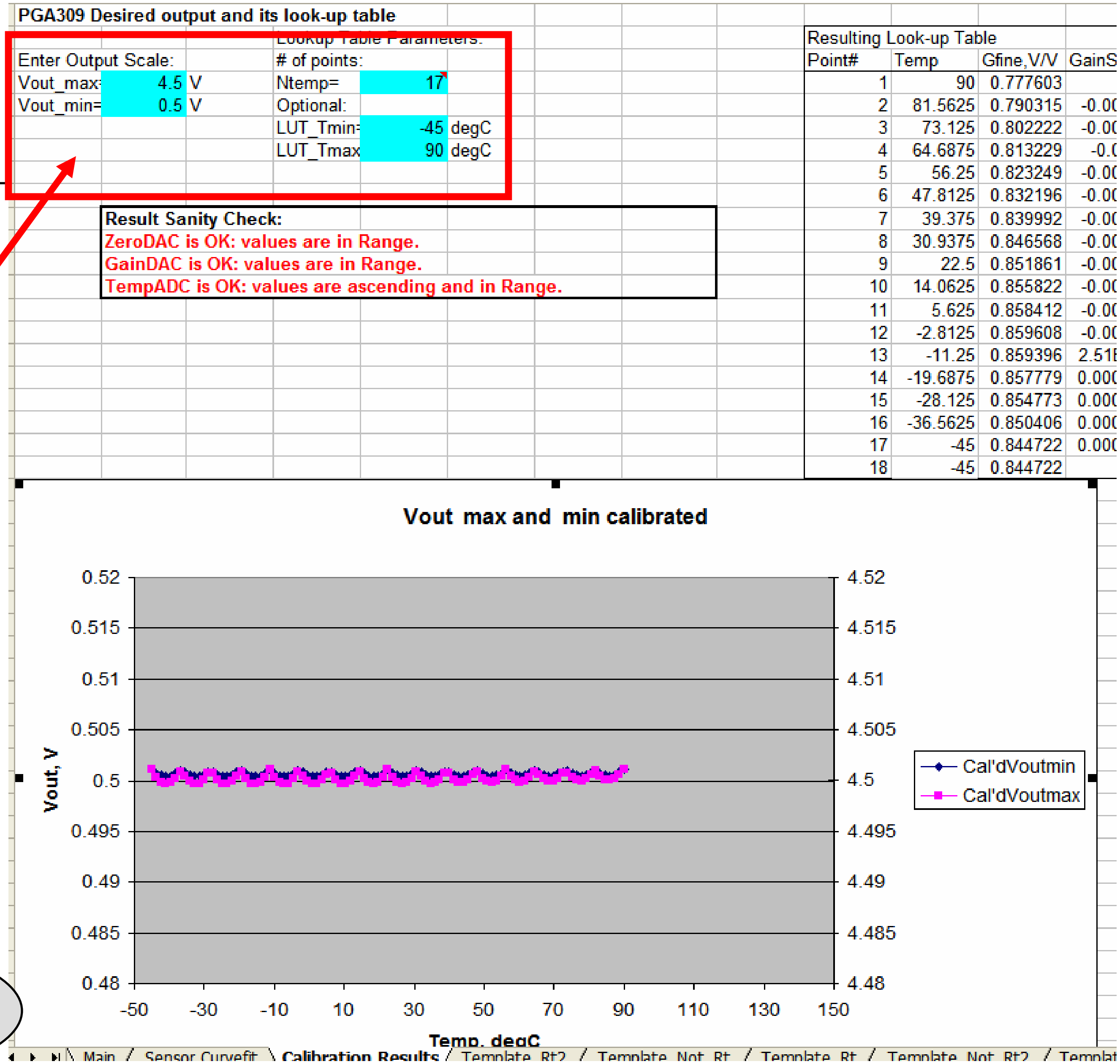
The PGA309 output voltage needs to be recorded at the appropriate applied pressure and temperature. Use the bridge selector switch on the Sensor-Emulator-EVM to generate the respective room (0%, 50%, 100%), hot (0%, 25%, 50%, 75%, 100%), and cold (0%, 50%, 100%).

After the calibration measurements are complete look at the graphs located on the ***sensor Curvefit*** sheet. These graphs are an easy way to check for gross problems. The graphs shown are indicative of typical results for example.



PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

Enter the output voltage scale, the number of points in the table, and the look up table temperature range. For our example, enter the values shown.

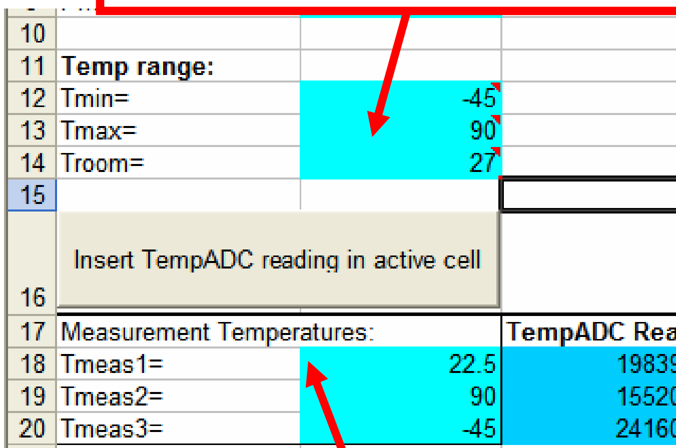


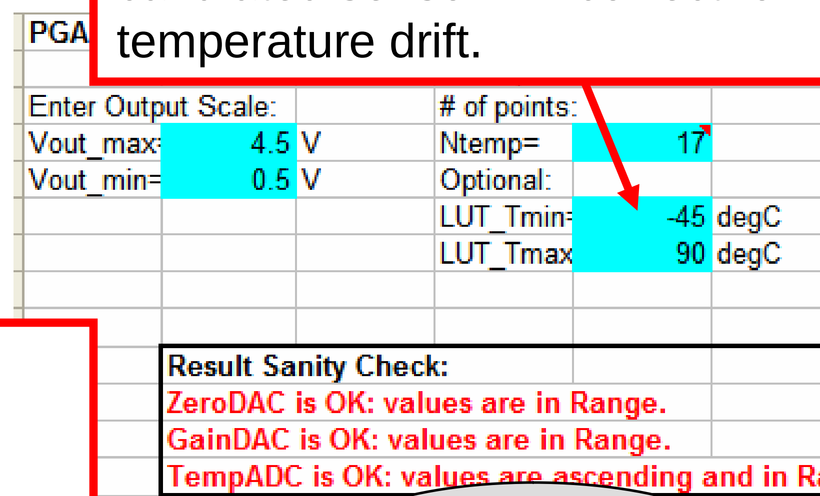
PGA309 Calibration Spreadsheet, Calibration Results Tab

Note about the temperature ranges

Range1: This is the range of the mathematical model of the sensor that is developed by the spreadsheet.

Range2: This is the range that the look up table is developed over. This range must be a subset of Range1. It is ok for Range2 and Range3 to be equivalent. This range over which the calibrated sensor will correct for temperature drift.



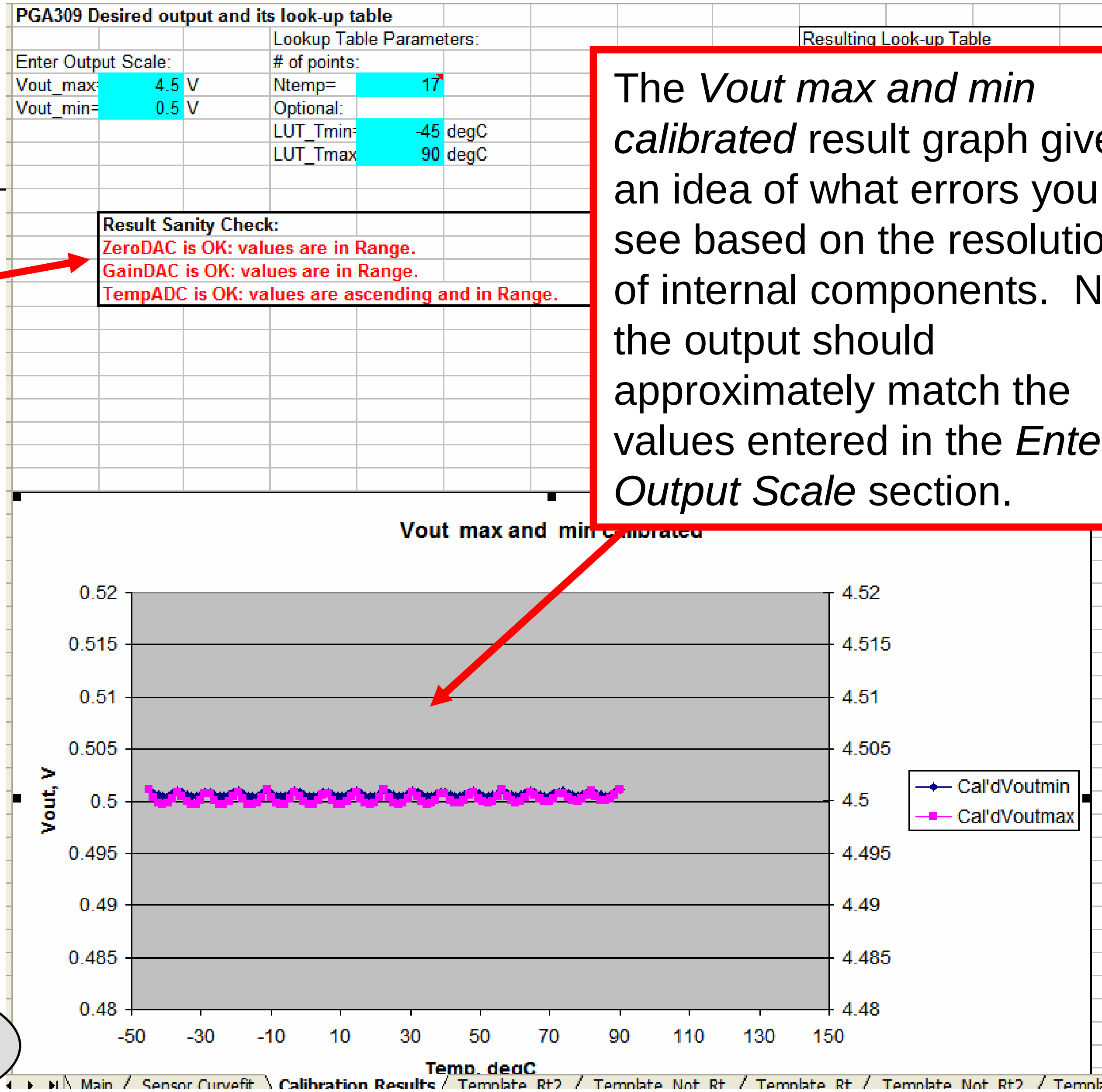


Range3: This is the range of measurements made during calibration. This range must be a subset of Range1. It is OK for range 1 and range 3 to be equivalent.

PGA309 Calibration Spreadsheet, Calibration Results Tab

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

The *Result Sanity Check* will flag any problems with gain and offset ranges in the calibration table.



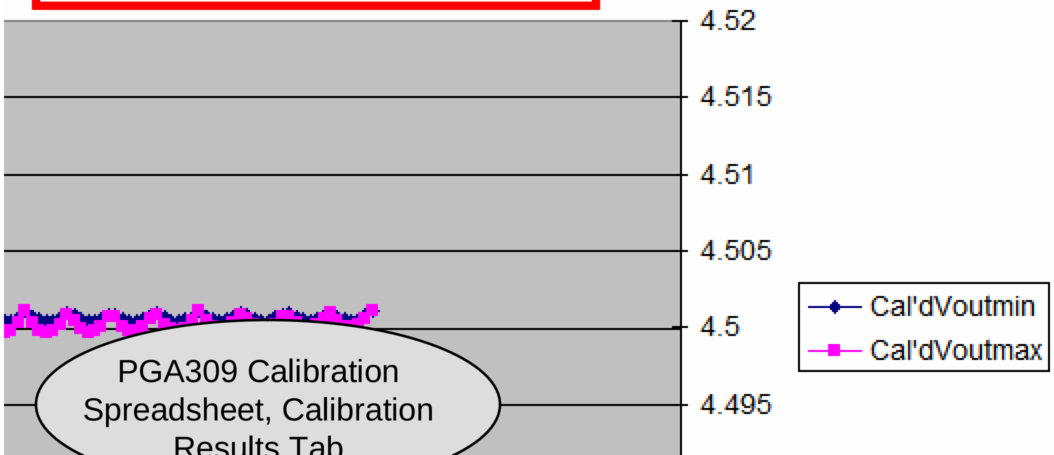
The *Vout max and min calibrated* result graph gives an idea of what errors you will see based on the resolution of internal components. Note the output should approximately match the values entered in the *Enter Output Scale* section.

PGA309 Calibration Spreadsheet, Calibration Results Tab

e Parameters:

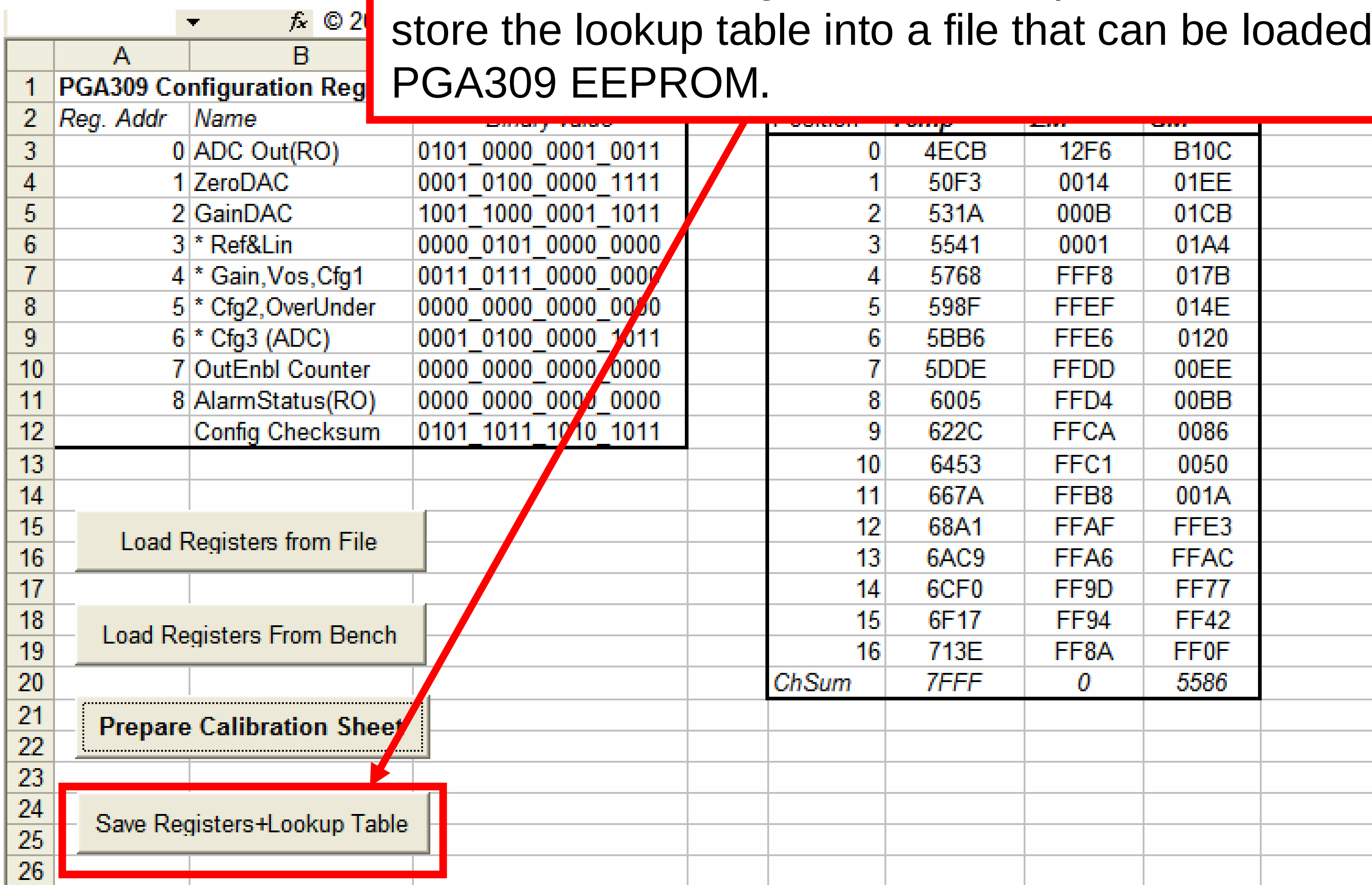
Resulting Look-up Table						Look-up table Hex		
Point#	Temp	Gfine,V/V	GainSlope	Vzero, V	ZeroSlope	***Temp***	***ZM***	***GM***
1	90	0.777603		0.301346		**4225**	**12D6**	**AA99**
2	81.5625	0.790315	-0.00151	0.304481	-0.00037	**446B**	**0016**	**0226**
3	73.125	0.802222	-0.00141	0.306193	-0.0002	**46B1**	**000C**	**0203**
4	64.6875	0.813229	-0.0013	0.306482	-3.4E-05	**48F6**	**0002**	**01DC**
5	56.25	0.823249	-0.00119	0.305348	0.000134	**4B3C**	**FFF8**	**01B2**
6	47.8125	0.832196	-0.00106	0.302791	0.000303	**4D82**	**FFEE**	**0183**
7	39.375	0.839992	-0.00092	0.29881	0.000472	**4FC7**	**FFE4**	**0152**
8	30.9375	0.846568	-0.00078	0.293407	0.00064	**520D**	**FFDA**	**011C**
9	22.5	0.851861	-0.00063	0.28658	0.000809	**5453**	**FFD0**	**00E5**
10	14.0625	0.855822	-0.00047	0.27833	0.000978	**5698**	**FFC6**	**00AC**
11	5.625	0.858412	-0.00031	0.268657	0.001146	**58DE**	**FFBC**	**0070**
12	-2.8125	0.859608	-0.00014	0.257561	0.001315	**5B24**	**FFB2**	**0034**
13	-11.25	0.859396	2.51E-05	0.245042	0.001484	**5D69**	**FFA8**	**FFF7**
14	-19.6875	0.857779	0.000192	0.231099	0.001652	**5FAF**	**FF9E**	**FFBA**
15	-28.125	0.854773	0.000356	0.215734	0.001821	**61F5**	**FF94**	**FF7E**
16	-36.5625	0.850406	0.000517	0.198945	0.00199	**643A**	**FF8A**	**FF43**
17	-45	0.844722	0.000674	0.180733	0.002158	**6680**	**FF80**	**FF0A**
18	-45	0.844722	0	0.180733	0	**7FFF**	**0000**	**0000**

The calibration table that will be loaded into the EEPROM is displayed on the *Calibration Results* tab on the spreadsheet. At this point the initial calibration is complete and the table can be uploaded into the PGA309 EEPROM.



PGA309 Calibration Spreadsheet, Calibration Results Tab

Press the *Save Registers + Lookup Table* button. This will store the lookup table into a file that can be loaded into the PGA309 EEPROM.



	A	B	
1	PGA309 Configuration Reg		
2	Reg. Addr	Name	
3	0	ADC Out(RO)	0101_0000_0001_0011
4	1	ZeroDAC	0001_0100_0000_1111
5	2	GainDAC	1001_1000_0001_1011
6	3	* Ref&Lin	0000_0101_0000_0000
7	4	* Gain,Vos,Cfg1	0011_0111_0000_0000
8	5	* Cfg2,OverUnder	0000_0000_0000_0000
9	6	* Cfg3 (ADC)	0001_0100_0000_1011
10	7	OutEnbl Counter	0000_0000_0000_0000
11	8	AlarmStatus(RO)	0000_0000_0000_0000
12		Config Checksum	0101_1011_1010_1011

0	4ECB	12F6	B10C
1	50F3	0014	01EE
2	531A	000B	01CB
3	5541	0001	01A4
4	5768	FFF8	017B
5	598F	FFEF	014E
6	5BB6	FFE6	0120
7	5DDE	FFDD	00EE
8	6005	FFD4	00BB
9	622C	FFCA	0086
10	6453	FFC1	0050
11	667A	FFB8	001A
12	68A1	FFAF	FFE3
13	6AC9	FFA6	FFAC
14	6CF0	FF9D	FF77
15	6F17	FF94	FF42
16	713E	FF8A	FF0F
ChSum	*7FFF*	*0*	*5586*

PGA309 Calibration Spreadsheet, Main Tab

Step A

Press the *Open File* button to get the file containing the calibration results.

Step D

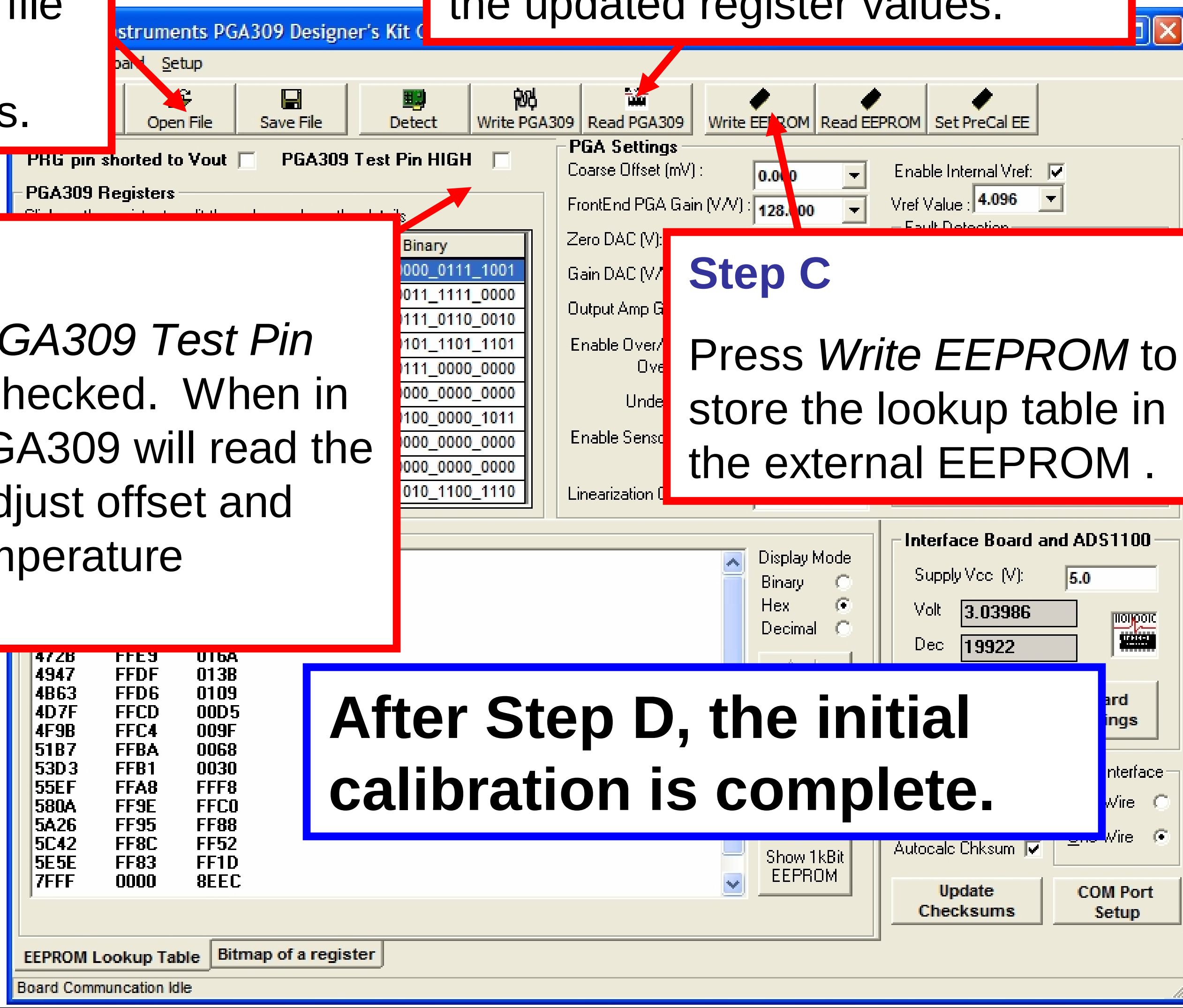
Press the *Read PGA309* to see the updated register values.

Step B

Make sure the *PGA309 Test Pin High* box is not checked. When in this mode the PGA309 will read the EEPROM and adjust offset and gain for each temperature conversion

Step C

Press *Write EEPROM* to store the lookup table in the external EEPROM .



After Step D, the initial calibration is complete.

The *PGA309 Error* tab on the ***generate_sim_values.xls*** is a convenient way to do a post calibration error analysis. To use it select the blue cell corresponding to the current setup, and press the *Insert Vout reading in active cell* button. This will insert the PGA309 output reading from the ADS1100.

The initial post calibration results will typically have errors ranging from 0.1% to 0.3%.

Insert Vout reading in active cell

Post First Calibration Results

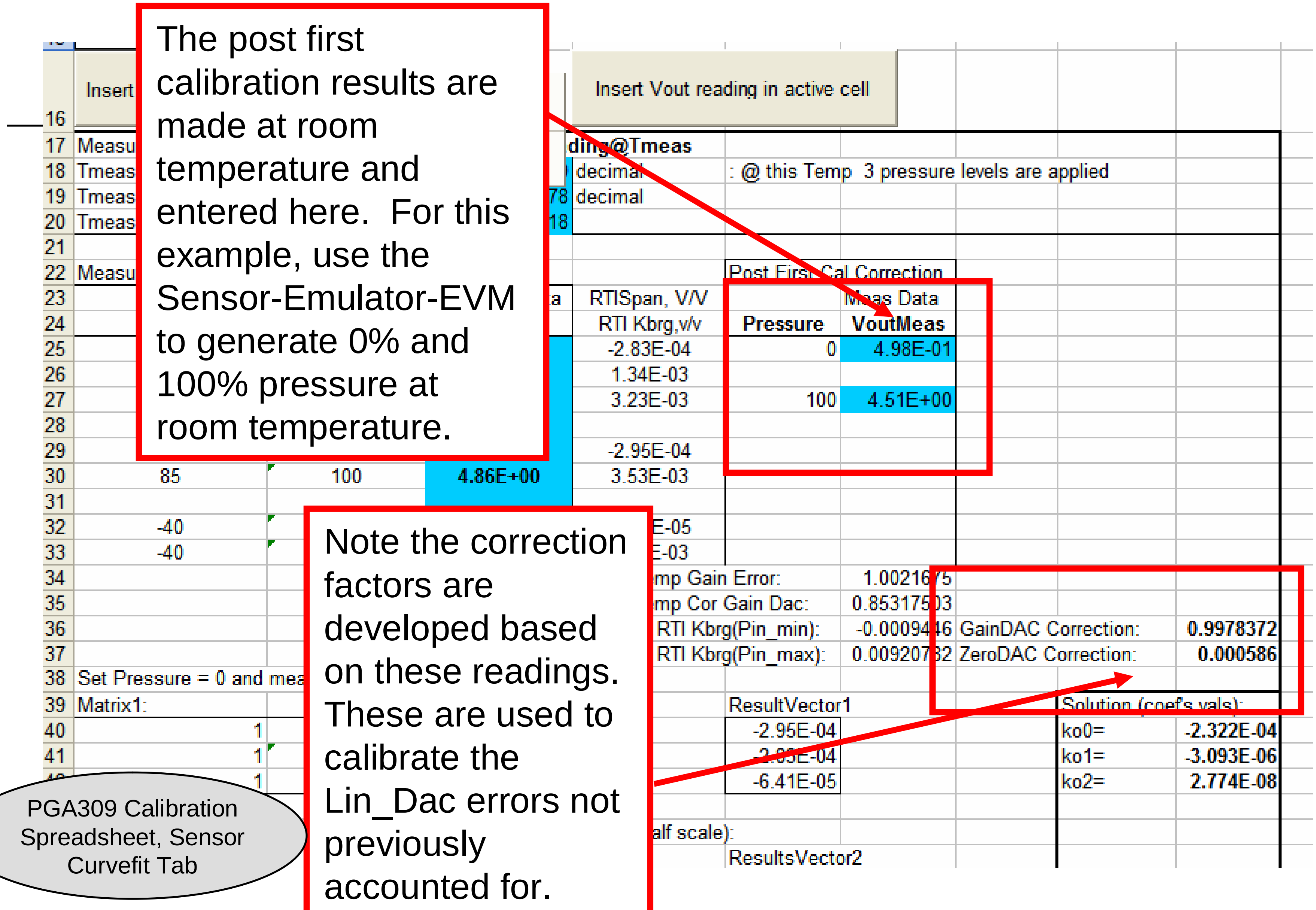
Temperature	Pressure	Ideal Result	Measured Result	Error
cold	0%	0.5	0.49684	0.03
cold	50%	2.5	2.50072	0.02
cold	100%	4.5	4.5049	0.12
Room	0%	0.5	0.4982	-0.05
Room	25%	1.5	1.49445	-0.14
Room	50%	2.5	2.50087	0.02
Room	75%	3.5	3.50835	0.21
Room	100%	4.5	4.50687	0.17
Hot	0%	0.5	0.49941	-0.01
Hot	50%	2.5	2.50229	0.06
Hot	100%	4.5	4.50748	0.19
			stdev=	0.11
			average=	0.06

Insert Vout reading in active cell

Post Second Calibration Results

Temperature	Pressure	Ideal Result	Measured Result	Error
cold	0%	0.5	0.49886	-0.03
cold	50%	2.5	2.49859	-0.04
cold	100%	4.5	4.49859	-0.04
Room	0%	0.5	0.49959	-0.01
Room	25%	1.5	1.49445	-0.14
Room	50%	2.5	2.49905	-0.02
Room	75%	3.5	3.5044	0.11
Room	100%	4.5	4.50111	0.03
Hot	0%	0.5	0.50026	0.01
Hot	50%	2.5	2.50026	0.01
Hot	100%	4.5	4.50096	0.02
			stdev=	0.06
			average=	-0.01

generate_sim_values.xls, PGA309 Error Tab

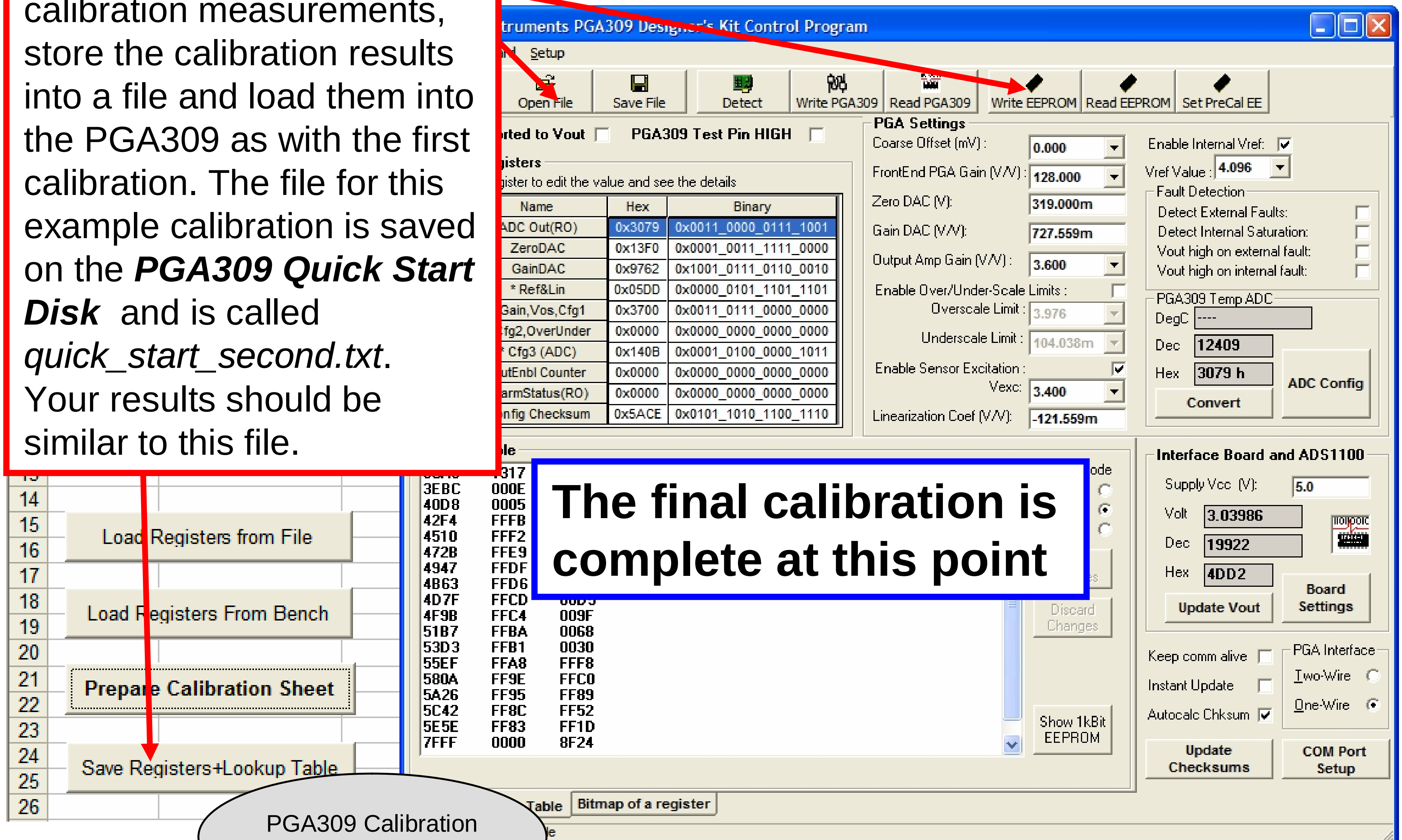


The post first calibration results are made at room temperature and entered here. For this example, use the Sensor-Emulator-EVM to generate 0% and 100% pressure at room temperature.

Note the correction factors are developed based on these readings. These are used to calibrate the Lin_Dac errors not previously accounted for.

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

After making the secondary calibration measurements, store the calibration results into a file and load them into the PGA309 as with the first calibration. The file for this example calibration is saved on the ***PGA309 Quick Start Disk*** and is called *quick_start_second.txt*. Your results should be similar to this file.



The final calibration is complete at this point

PGA309 Calibration Spreadsheet, Main Tab

Insert Vout reading in active cell

Post First Calibration Results

Temperature	Pressure	Ideal Result	Measured Result	Error
cold	0%	0.5	0.49684	0.03
cold	50%	2.5	2.50072	0.02
cold	100%	4.5	4.5049	0.12
Room	0%	0.5	0.4982	-0.05
Room	25%	1.5	1.49445	-0.14
Room	50%	2.5	2.50087	0.02
Room	75%	3.5	3.50835	0.21
Room	100%	4.5	4.50687	0.17
Hot	0%	0.5	0.49941	-0.01
Hot	50%	2.5	2.50229	0.06
Hot	100%	4.5	4.50748	0.19
			stdev=	0.11
			average=	0.06

The secondary calibration can be done to significantly reduce the error. Post-secondary calibration errors are typically on the order of 0.05%. The secondary calibration involves making two measurements at room temperature.

Insert Vout reading in active cell

Post Second Calibration Results

Temperature	Pressure	Ideal Result	Measured Result	Error
cold	0%	0.5	0.49886	-0.03
cold	50%	2.5	2.49859	-0.04
cold	100%	4.5	4.49859	-0.04
Room	0%	0.5	0.49959	-0.01
Room	25%	1.5	1.49445	-0.14
Room	50%	2.5	2.49905	-0.02
Room	75%	3.5	3.5044	0.11
Room	100%	4.5	4.50111	0.03
Hot	0%	0.5	0.50026	0.01
Hot	50%	2.5	2.50026	0.01
Hot	100%	4.5	4.50096	0.02
			stdev=	0.06
			average=	-0.01

generate_sim_values.xls, PGA309 Error Tab

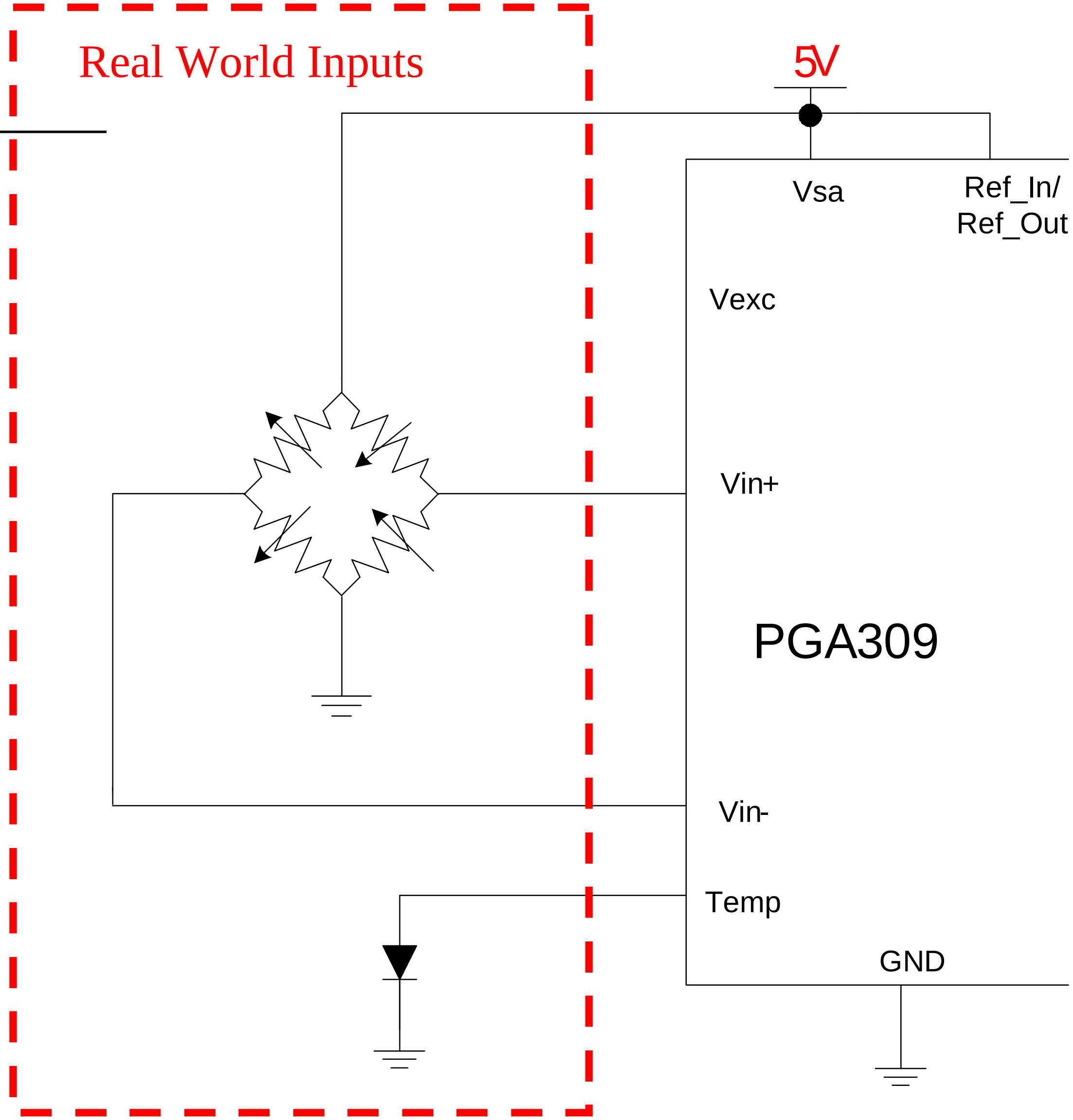
PGA309 Ratiometric Calibration Example

This example walks through the PGA309 ratiometric calibration technique. The PGA309 Absolute Calibration example is a more detailed description of a calibration, and so, it is recommended that you review this example first. This document describes the key elements that are required in a ratiometric calibration, but does not fully explain how to use the PGA309 Gain Calculator, Sensor-Emulator-EVM, or the Designers Kit Control Program.

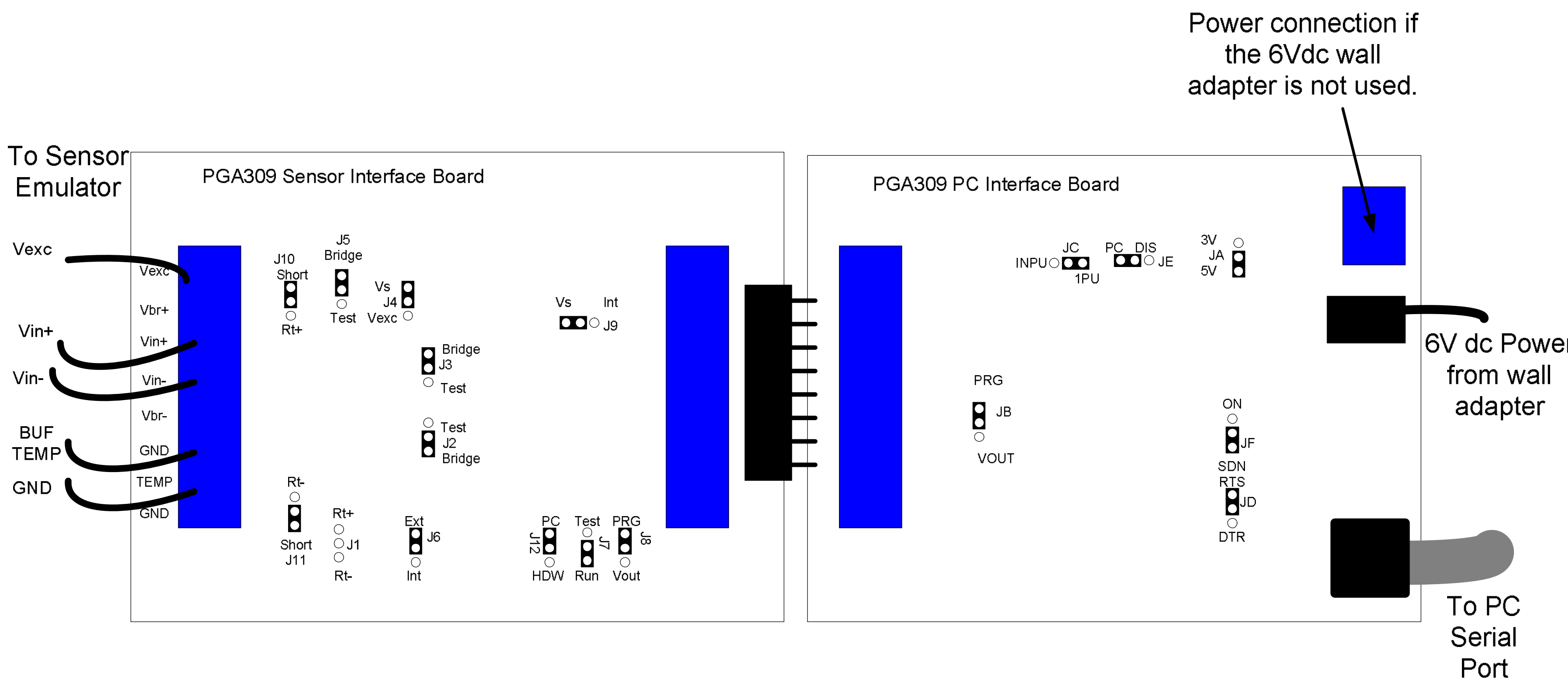
For information on these development tools, please see the PGA309 Product Folder on the TI website, at www.ti.com.

PGA309 Ratiometric Example

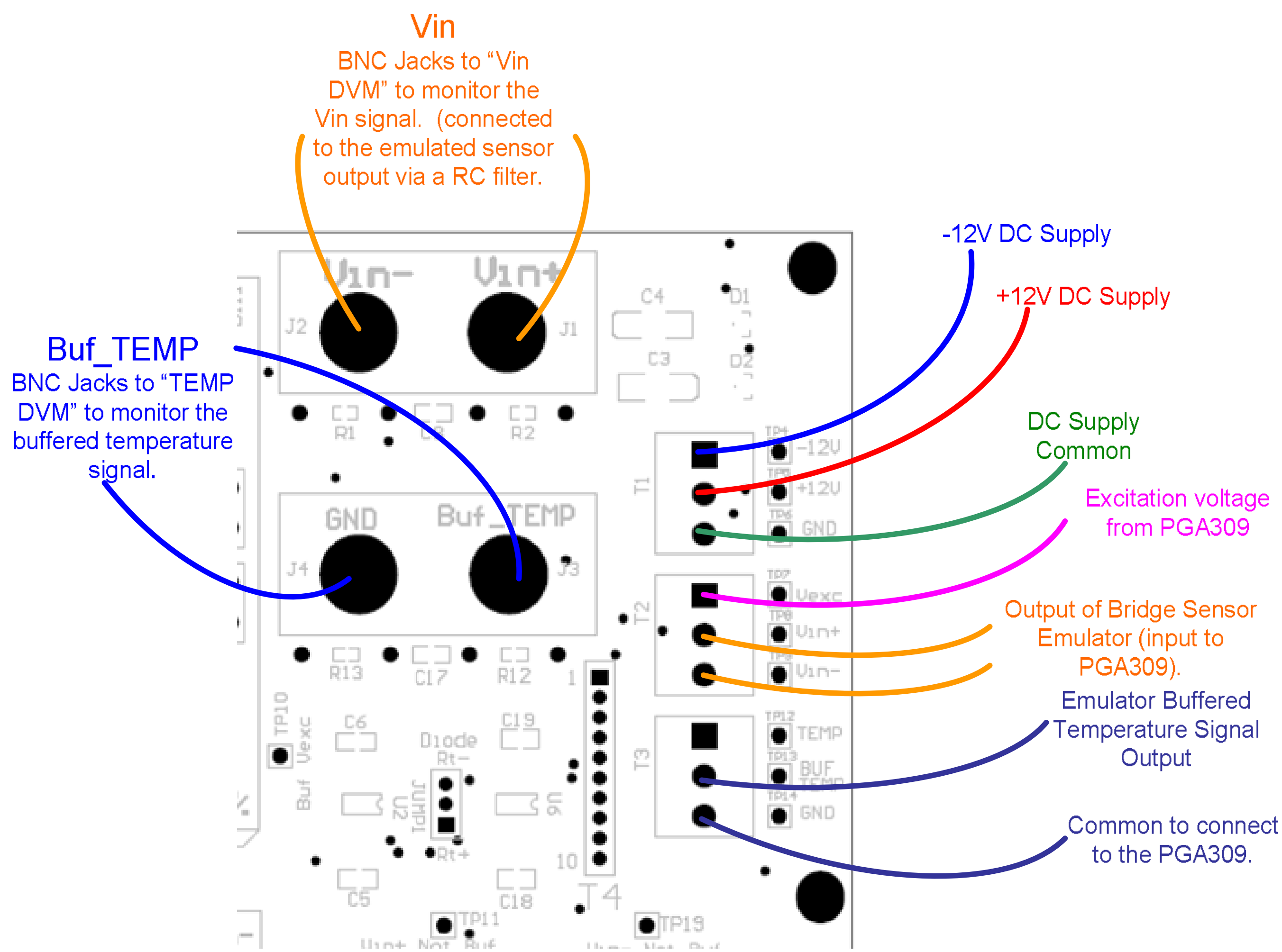
This is the hardware configuration that this ratiometric calibration example details. In this example, the Sensor-Emulator-EVM is used to emulate the bridge sensor and the Diode. Note that the device power supply is used to provide excitation for the sensor. So for this configuration, the Vexc pin on the PGA309 is not used and consequently, the PGA309 cannot correct for nonlinearity verses applied stimulus. Temperature nonlinearities of span and offset will still be corrected.



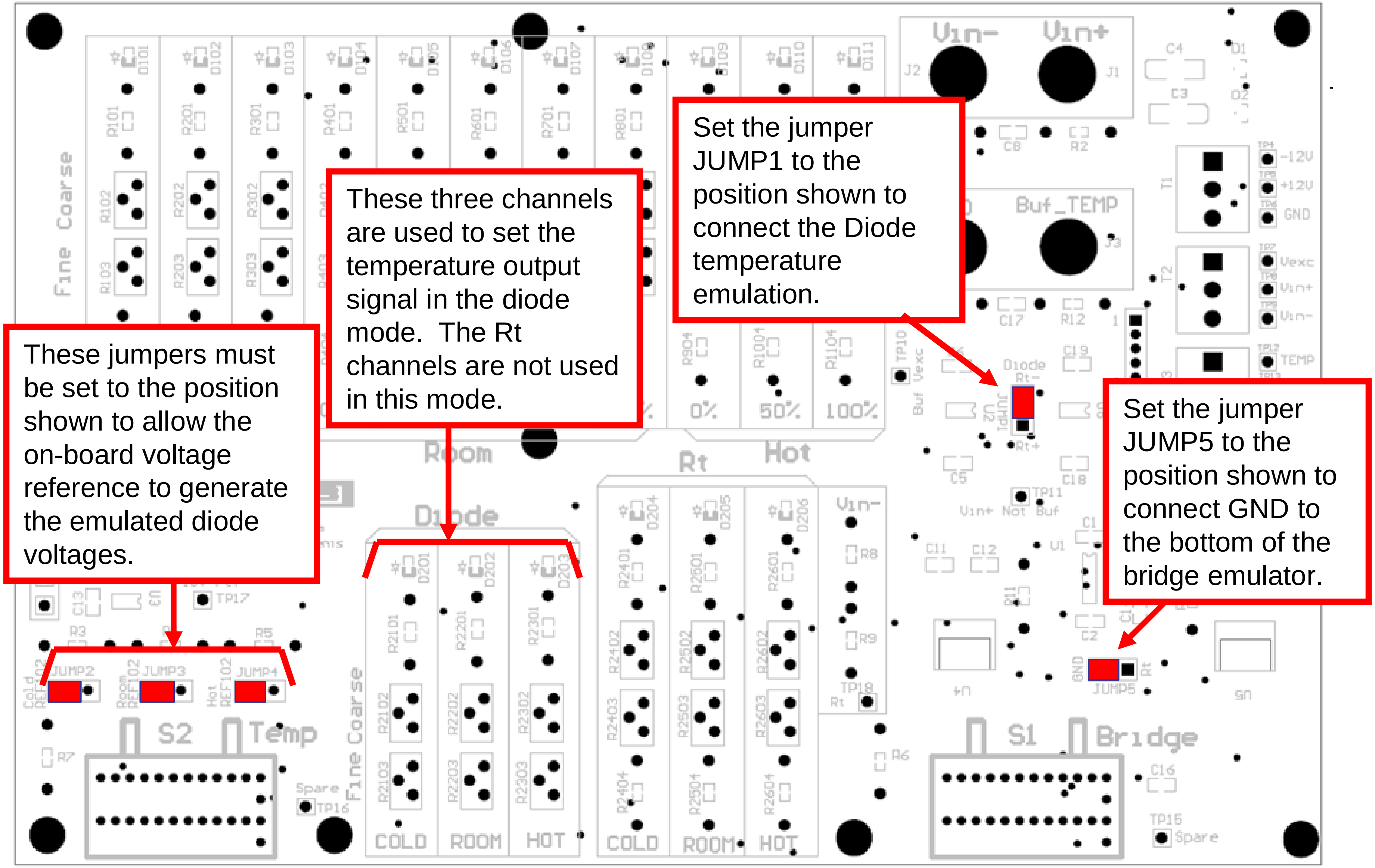
This diagram illustrates PGA309EVM jumper settings for a ratiometric system. Sensor-Emulator-EVM connections and power connections are also shown.



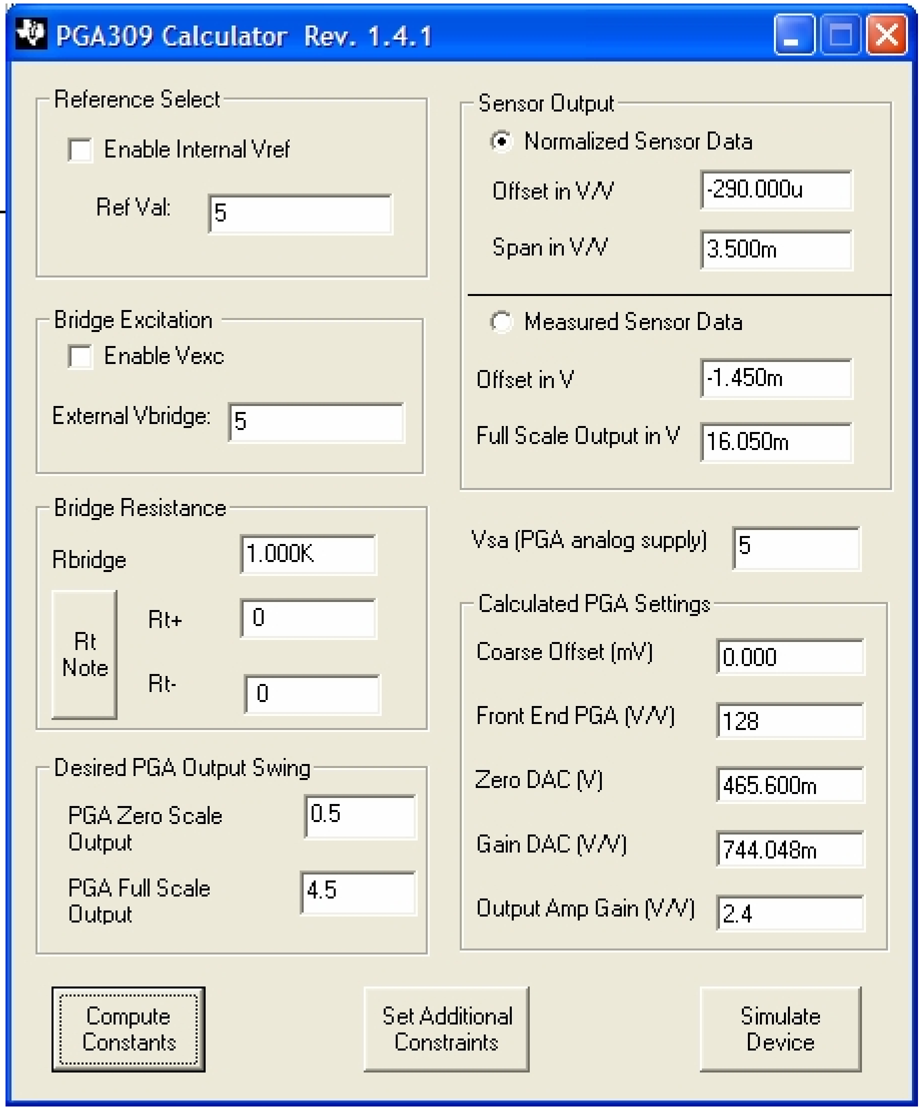
Required Electrical Connections to Sensor-Emulator-EVM



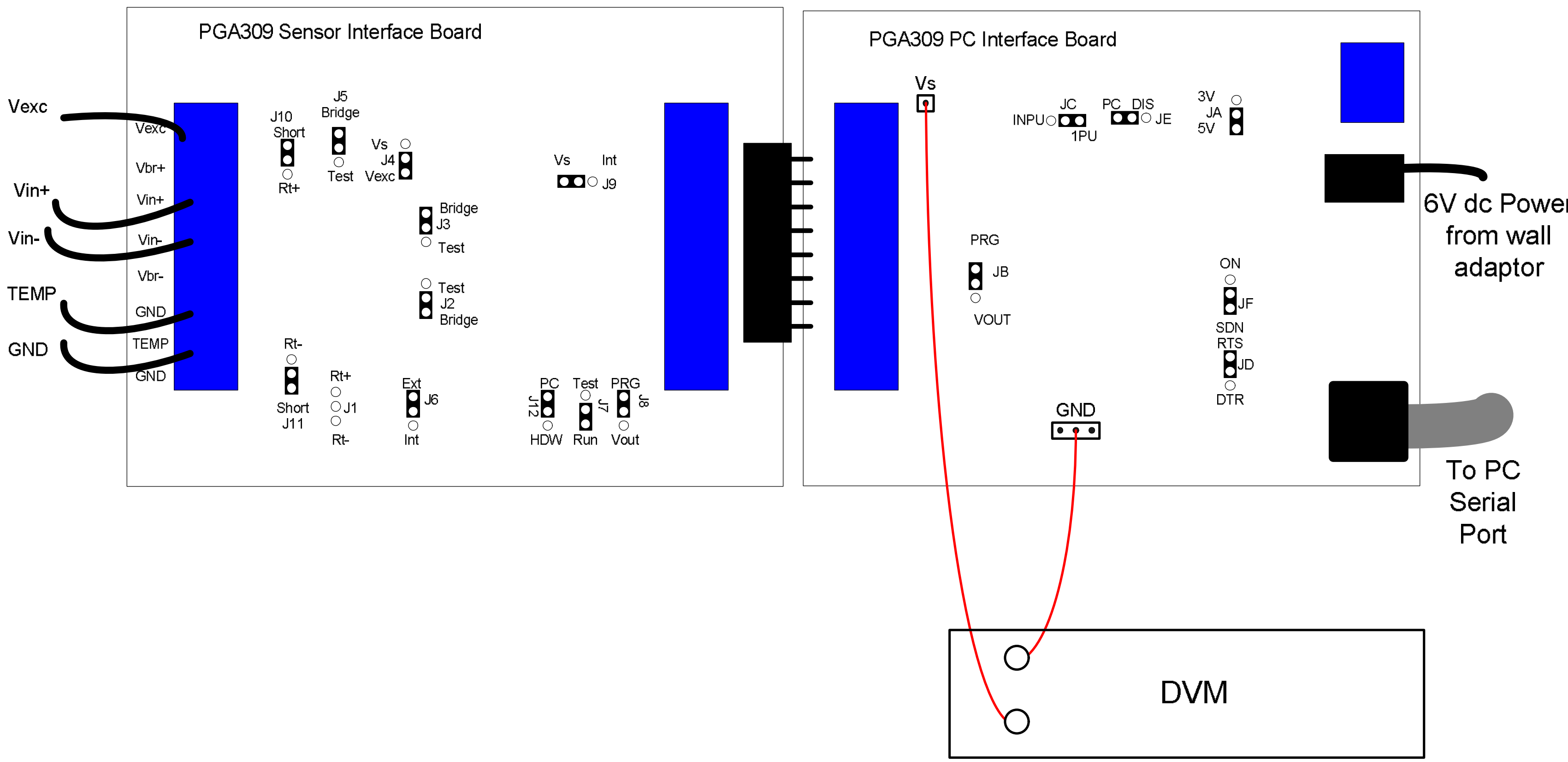
Sensor-Emulator-EVM Jumper Setup



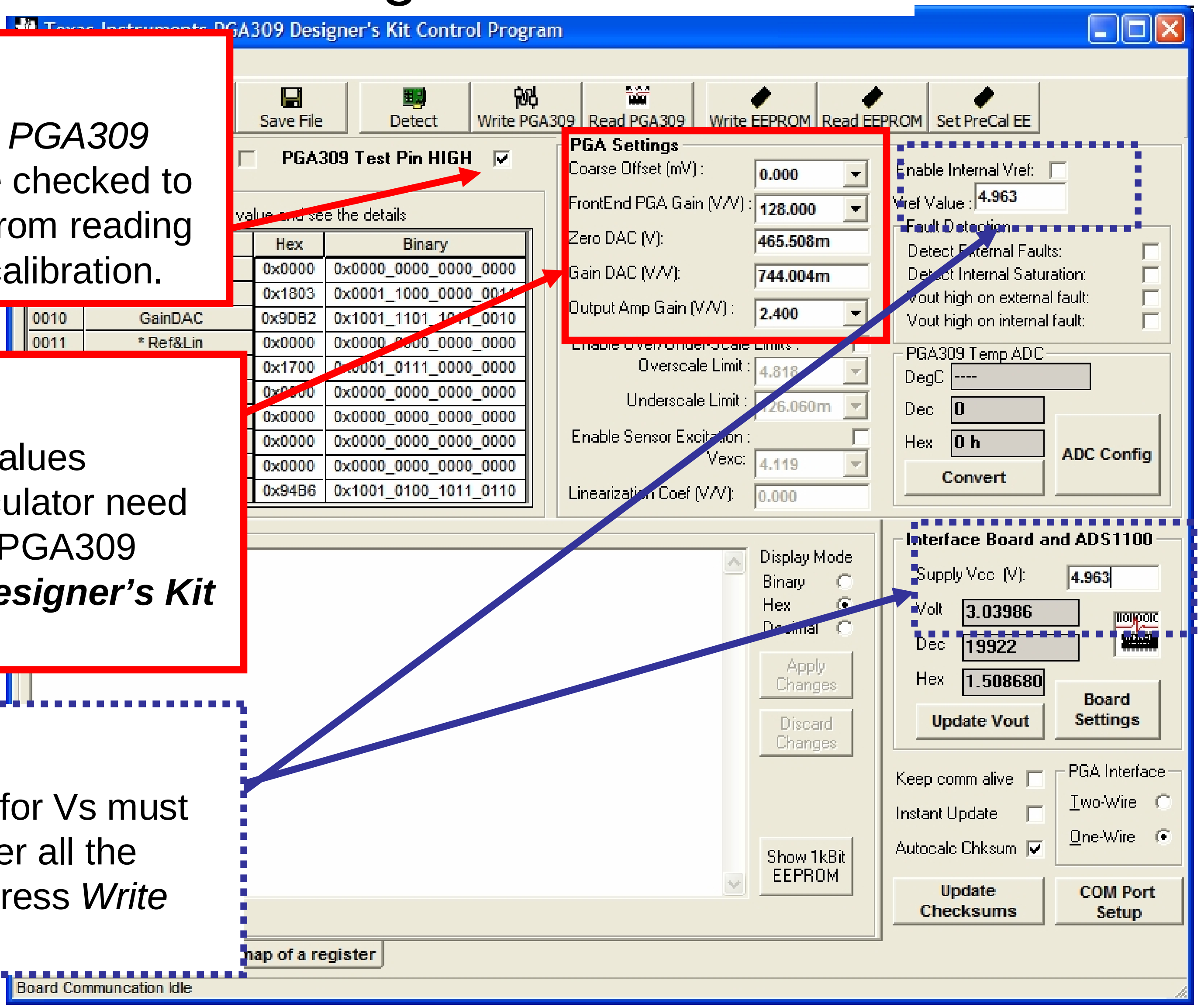
The PGA309 Calculator can be used to compute the gain and offset settings for the PGA309. These are the values used for this ratiometric example configuration.



In the ratiometric configuration, the power supply (Vs) is being used as the reference. Thus, it is very important that the supply is measured during calibration.



Configure the initial settings of the PGA309



Step A

During calibration, the *PGA309 Test Pin High* must be checked to prevent the PGA309 from reading the EEPROM during calibration.

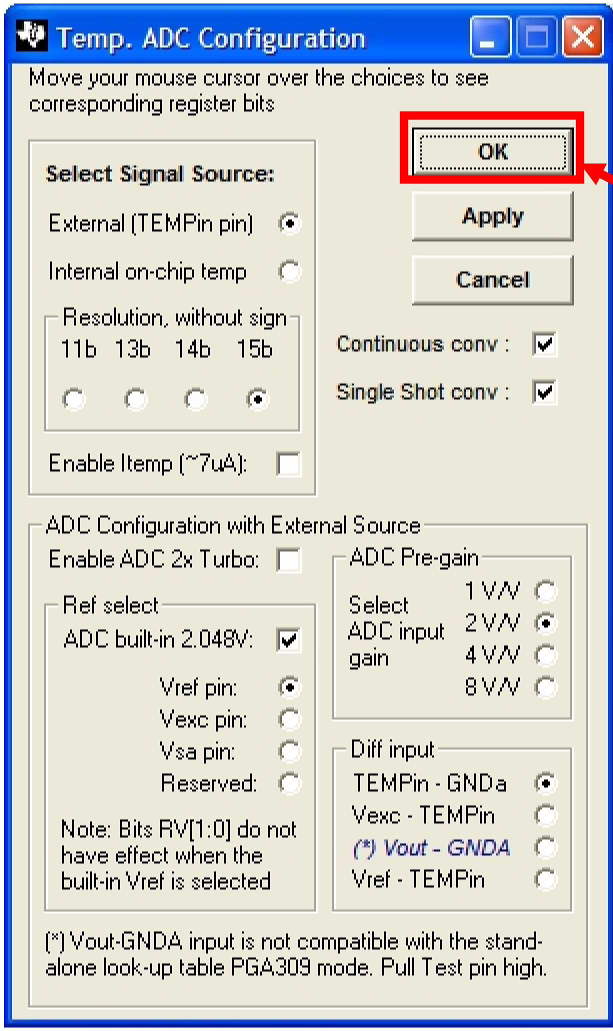
Step B

The gain and offset values computed by the calculator need to be written into the PGA309 using the ***PGA309 Designer's Kit Control Program***.

Step C

The value measured for Vs must be typed in here. After all the values are entered, press *Write PGA309*.

Set up the PGA309 Temperature ADC



Configure the Temp ADC as shown and click ***OK***. From the main window, press *Write PGA309*.

The configuration shown was selected for this example (diode measurement using the built-in 2.048V reference). It is important to use the built in ADC reference because the diode measurement is absolute and all the other references are relative to the power supply for this configuration.

The sensor specifications are entered here. The definitions of the different parameters is described earlier in this document.

The sensor's raw output is computed and displayed here. These values are used to setup the sensor emulator. The sensor emulator EVM will need to be adjusted to these levels.

	A	B
1	**Temp range:**	degC
2	Tmin=	-40.00
3	Tmax=	85.00
4	Troom=	22.50
5		
6	Vexc (V)	5.000E+00
7		
8		3.509E-03
9		-2.945E-04
10		
11		
12		
13	NonlinSpanDrift (% of Span)	-5.031E-02
14	NonlinOffsetDrift (% of Span)	-3.077E-02
15	PressureNonlin (% of Span)	0.000E+00
16		
17	GainTC1 (% of Span/C)	4.682E-04
18	OffsetTC1 (% of Span/C)	-5.205E-04
19	GainTCNonlin(TC2) (% of Span/C^2)	-1.288E-05
20	OffsetTCNonlin(TC2) (% of Span/C^2)	-7.877E-06
21		
22	Note: % of Span is representated as a decimal number	
23	i.e. OffsetTC1 (% of Span) = 0.1 is 10%	
24		
25	Rev B, Dec 10, 2004	

Enter these for our example.

Precalibration Sensor Simulator Settings (LinDac = 0)

Cold

Pressure Input	**0%**	**50%**	**100%**
Sensor Output (mV)	**-0.362**	**8.595**	**17.552**

Room

Pressure Input	**0%**	**25%**	**50%**	**75%**	**100%**
Sensor Output (mV)	**-1.473**	**2.914**	**7.300**	**11.686**	**16.07**

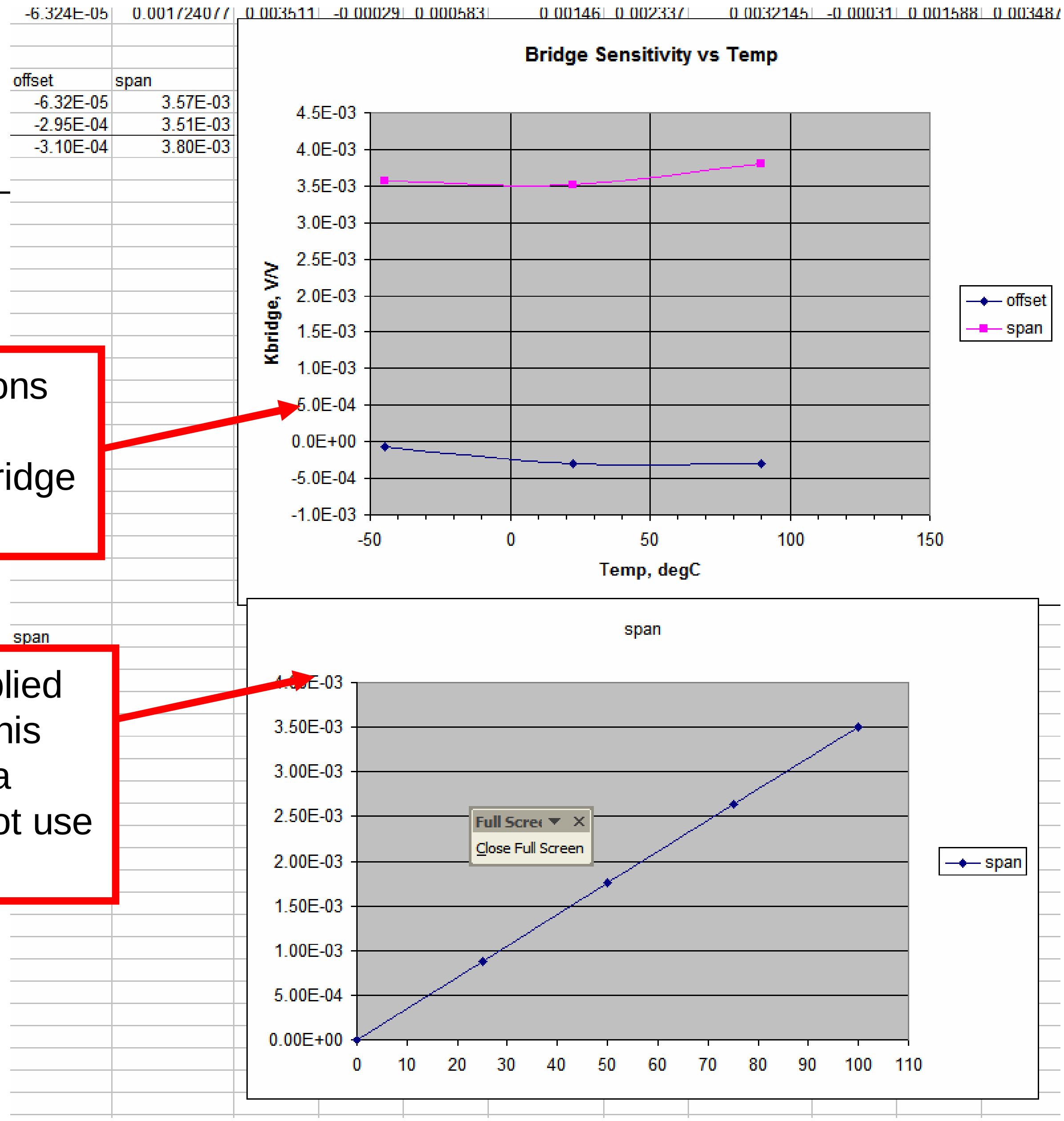
Hot

Pressure Input	**0%**	**50%**	**100%**
Sensor Output (mV)	**-1.503**	**7.967**	**17.438**

Note that Vexc = Vs for ratiometric.

Note that ***Pressure Nonlin*** is zero. The sensor must be linear for this configuration because the sensor excitation is the power supply and so the nonlinearity correction circuit cannot be used.

generate_sim_values.xls, Offset and Span Tab



When the sensor's specifications have been entered, the spreadsheet will display the bridge output versus temperature.

The bridge output versus applied stimulus is also displayed. This must be a linear function for a ratiometric setup that does not use Vexc for bridge excitation.

generate_sim_values.xls, Offset and Span Tab

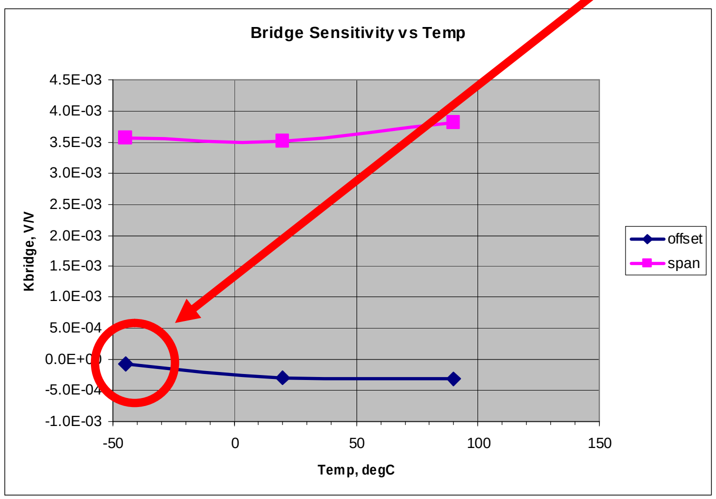
Precalibration Sensor Simulator Settings (LinDac = 0)

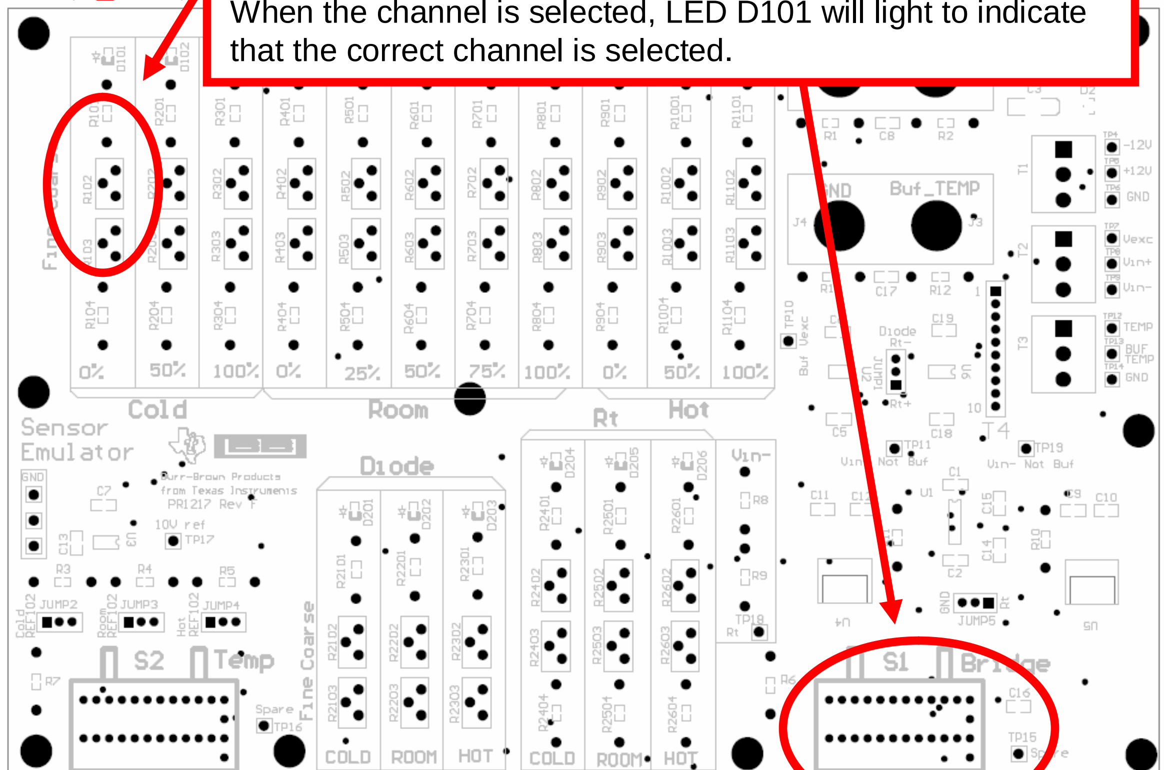
Cold			
Pressure Input	0%	50%	100%
Sensor Output (mV)	-0.215	5.379	11.939

Room					
Pressure Input	0%	25%	50%	75%	100%
Sensor Output (mV)	-1.001	1.626	4.490	7.591	10.929

Hot			
Pressure Input	0%	50%	100%
Sensor Output (mV)	-1.053	4.887	11.855

Each channel on the top section of the sensor emulator represents a applied stimulus and temperature combination for the sensor. Adjust the potentiometers coarse first, then fine, to match the values computed by the ***Generate_Sim_Values.xls*** spreadsheet for cold (0%. 50%, 100%), room (0%, 25%, 50%, 75%, 100%), and hot (0%, 50%, 100%). For example, the sensor output at cold temperature and 0% of applied stimulus is emulated by this channel. The rotary switch S1 is used to select this channel. When the channel is selected, LED D101 will light to indicate that the correct channel is selected.

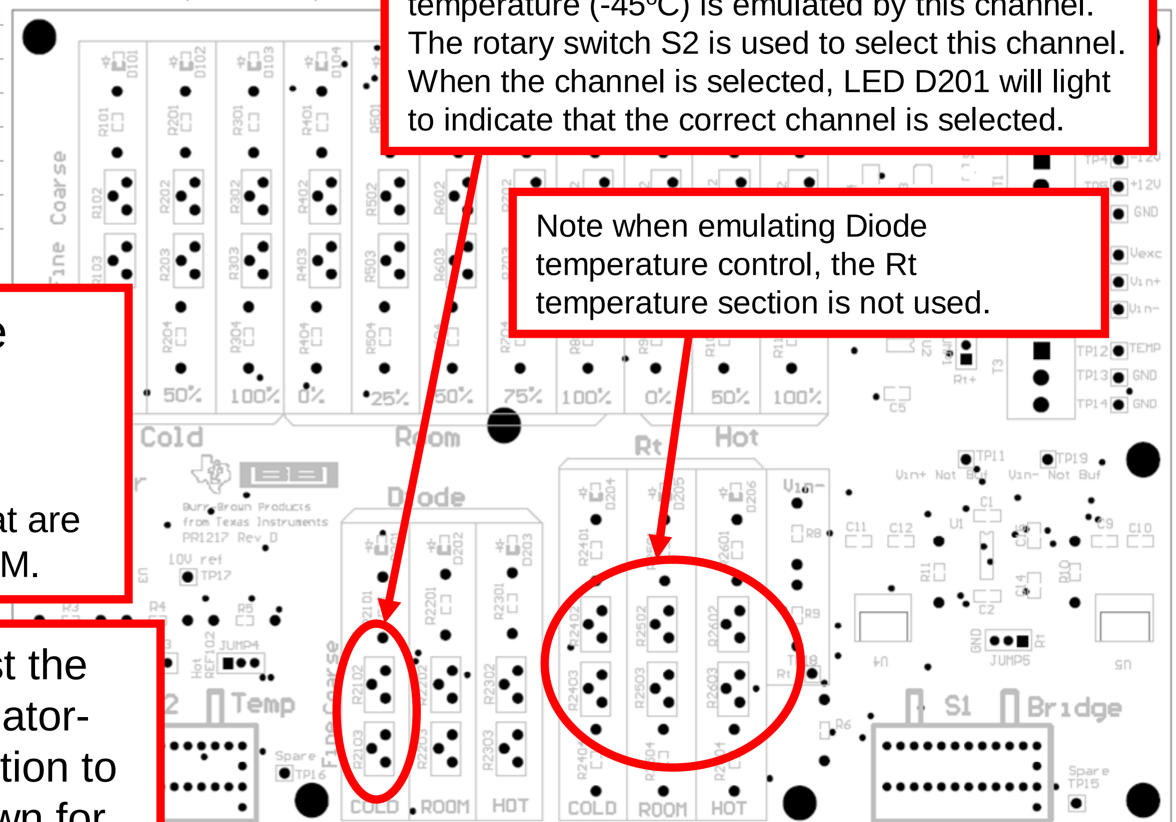




For this ratiometric example adjust the potentiometer on the Sensor-Emulator-EVM to the bridge section to produce the respective voltages shown.

	A	B	C	D	E	F
10						
11	**Temp range:**	degC		Temp(degC)	**Diode Vbe (V)**	**Counts**
12	Tmin=	-40.00		-40.00	0.745	23840
13	Troom=	22.50		22.50	0.62	19840
14	Tmax=	85.00		85.00	0.495	15840
15						
16	**Diode**	Volts				
17	Room Temp Vbe=	0.62				
18						
19	**Temp ADC**					
20	Vref (in V) =	2.048				
21	Numb Bits	15	bits (sign bit not included)			
22	Gain=	2				
23						
24						

Each channel on the bottom section of the Sensor-Emulator-EVM represents the output of the emulated temperature sensor. Using the *Temp DVM* adjust the respective potentiometers, coarse first, the fine, to match the values computed by the ***Generate_Sim_Values.xls*** spreadsheet for Diode/Cold, Diode/Room, and Diode/Hot. For this example, the temperature output signal at cold temperature (-45ºC) is emulated by this channel. The rotary switch S2 is used to select this channel. When the channel is selected, LED D201 will light to indicate that the correct channel is selected.



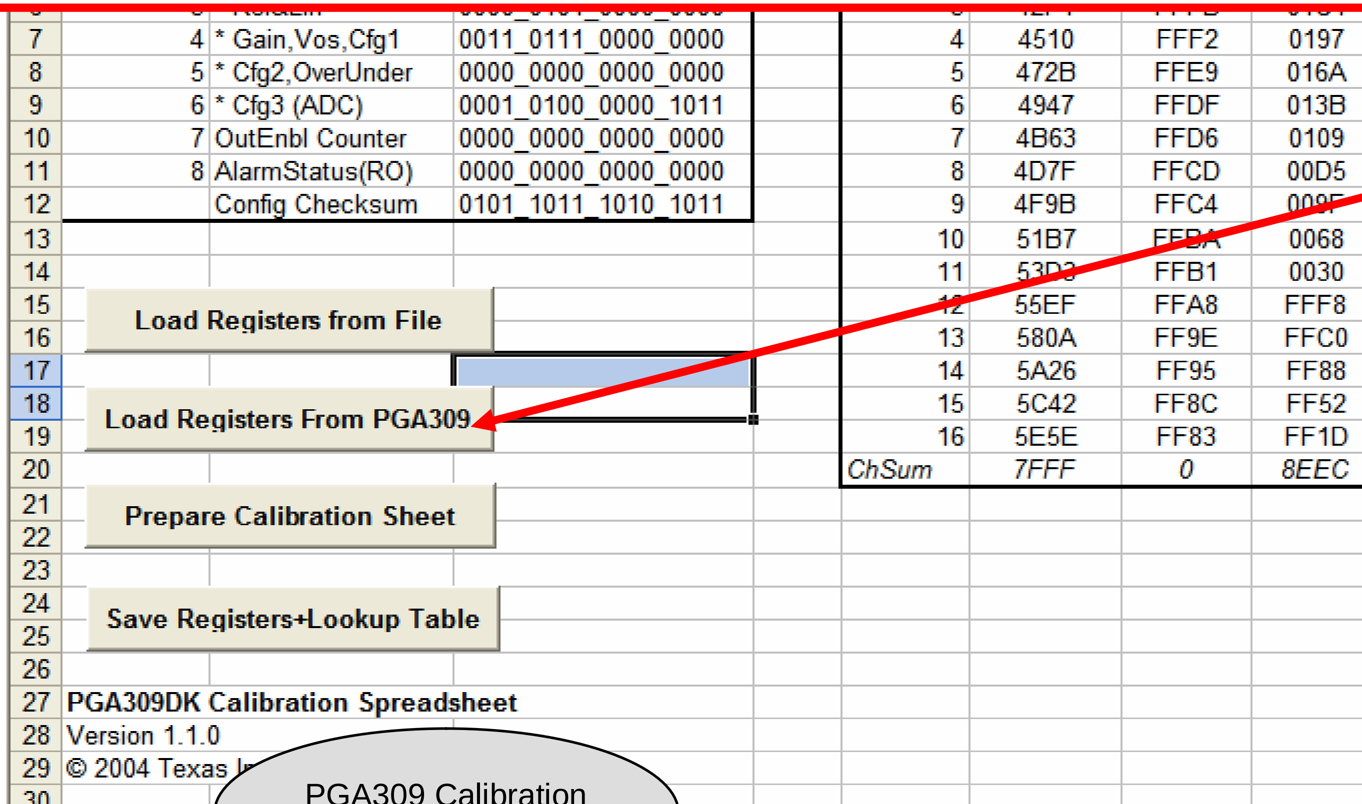
Note when emulating Diode temperature control, the Rt temperature section is not used.

This is the *Diode Vo* tab on the ***Generate_Sim_Values.xls*** spreadsheet.

It is used to compute diode voltages that are used to set up the Sensor-Emulator-EVM.

For this ratiometric example, adjust the potentiometer on the Sensor-Emulator-EVM to the diode temperature section to product the respective counts shown for temperature.

For this ratiometric example, use the ***PGA309 Calibration Spreadsheet***. This tool uses measured data (pressure and temperature) to create a lookup table that the PGA309 will use to compensate for offset and gain drift. The spreadsheet will also generate a coefficient that the PGA309 will use to correct for nonlinearity verses applied pressure. **Note: you will need to enable macros and load the analysis toolpack to get this Excel sheet to work properly**. Information regarding configuration of Excel is detailed in the ***PGA309EVM Users Guide***.



Press *Load registers from PGA309* to copy the registers from the evaluation fixture into the spreadsheet.

PGA309 Calibration Spreadsheet, Main Tab

Press *Prepare Calibration Sheet* to select the algorithm. In this example, we will do a *3 pressure 3 temperature* calibration.

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	A	B	C	D	E	F
1	**PGA309 Configuration Registers**				**PGA309 Calibrated**	
2	*Reg. Addr*	*Name*	*Binary value*		Position	***Temp***
3	0	ADC Out(RO)	0101_0000_0001_0011		0	4ECB
4	1	ZeroDAC	0001_0100_0000_1111		1	50F3
5	2	GainDAC	1001_1000_0001_1011		2	531A
6	3	* Ref&Lin	0000_0101_0000_0000		3	5541
7	4	* Gain,Vos,Cfg1	0011_0111_0000_0000		4	5768
8	5	* Cfg2,OverUnder	0000_0000_0000_0000		5	598F
9	6	* Cfg3 (ADC)	0001_0100_0000_1011		6	5BB6
10	7	OutEnbl Counter	0000_0000_0000_0000		7	5DDE
11	8	AlarmStatus(RO)	0000_0000_0000_0000		8	6005
12		Config Checksum	0101_1011_1010_1011		9	622C
13					10	6453
14					11	667A
15					12	68A1
16					13	6AC9
17					14	6CF0
18					15	6F17
19					16	713E
20					*ChSum*	*7FFF*
21						
22						
23						
24						
25						
26						

Load Registers from File

Load Registers From Bench

Prepare Calibration Sheet

Save Registers+Lookup Table

PGA309 Calibration

Please select the calibration algorithm:

One of the following three templates can be used for the pressure sensor calibration

OK

Cancel

3 Temperatures and 3 Pressures

Select this when you do not know the 2nd order non-linearities of output vs. pressure and of temperature drifts of span and offset. The module output must be measured at three different temperatures with min and fulll-scale pressure applied plus mid-scale pressure at one of the temperatures.

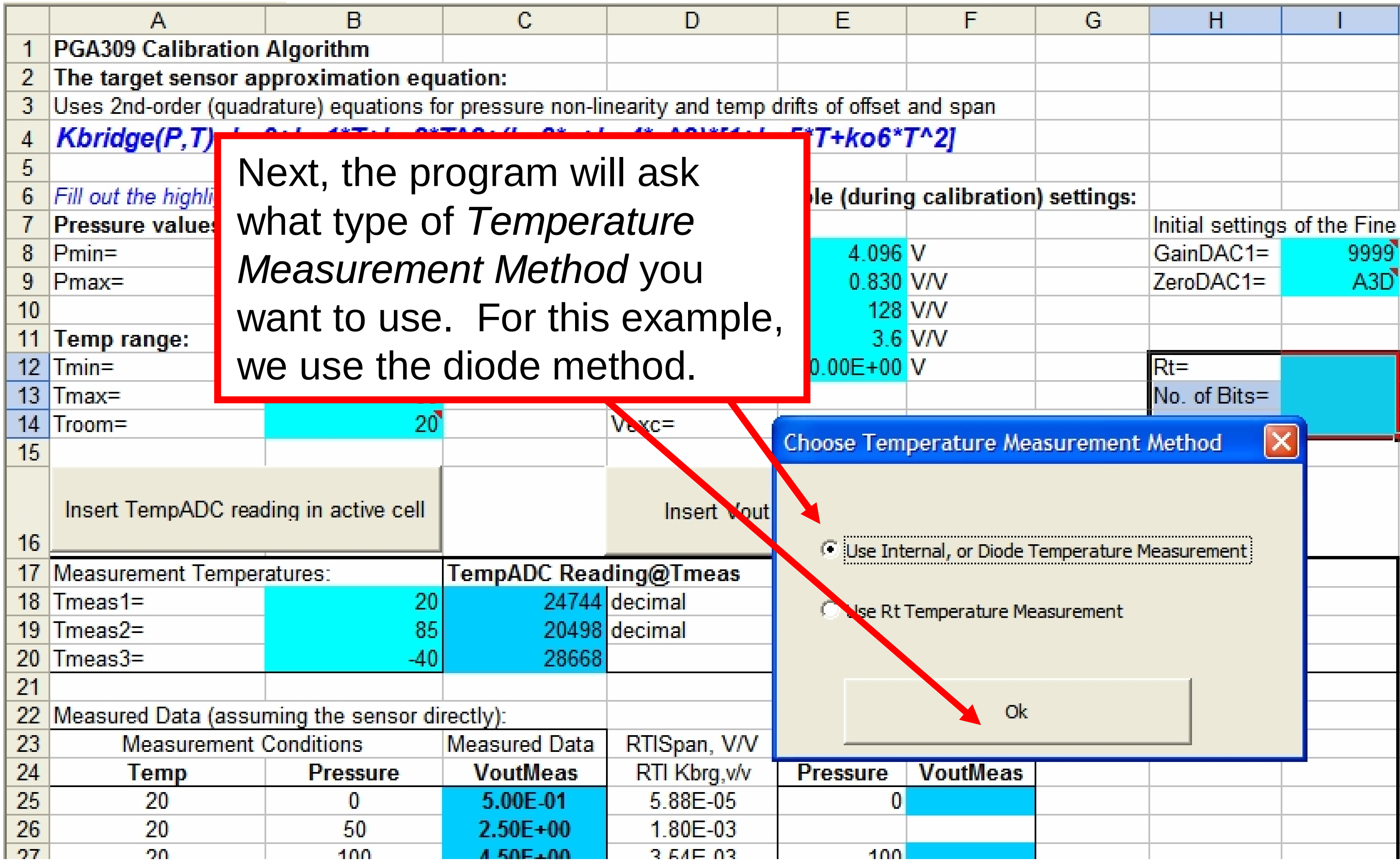
Press ***OK*** after you have selected *3 Temperature 3 Pressure* calibration.

pressure applied plus the mid-scale pressure at one of the temperatures.

2 Temperatures and 2 Pressures

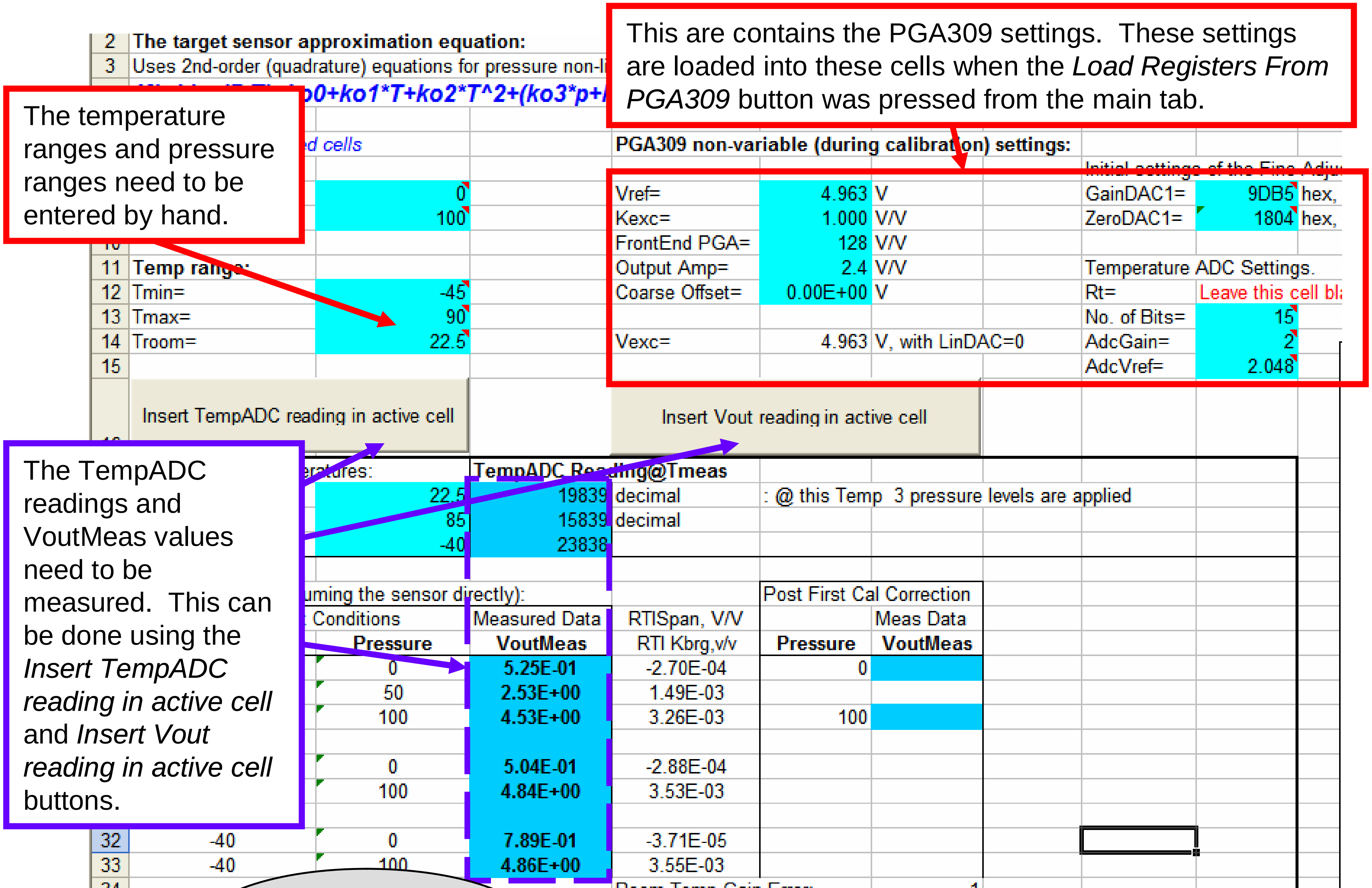
All 2nd order coefficients are entered based on pre-characterization, only the positions of curves must be fitted.
The output must be measured at only two temperatures, each with min and fulll-scale pressure applied.

PGA309 Calibration Spreadsheet, Main Tab



Next, the program will ask what type of *Temperature Measurement Method* you want to use. For this example, we use the diode method.

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab



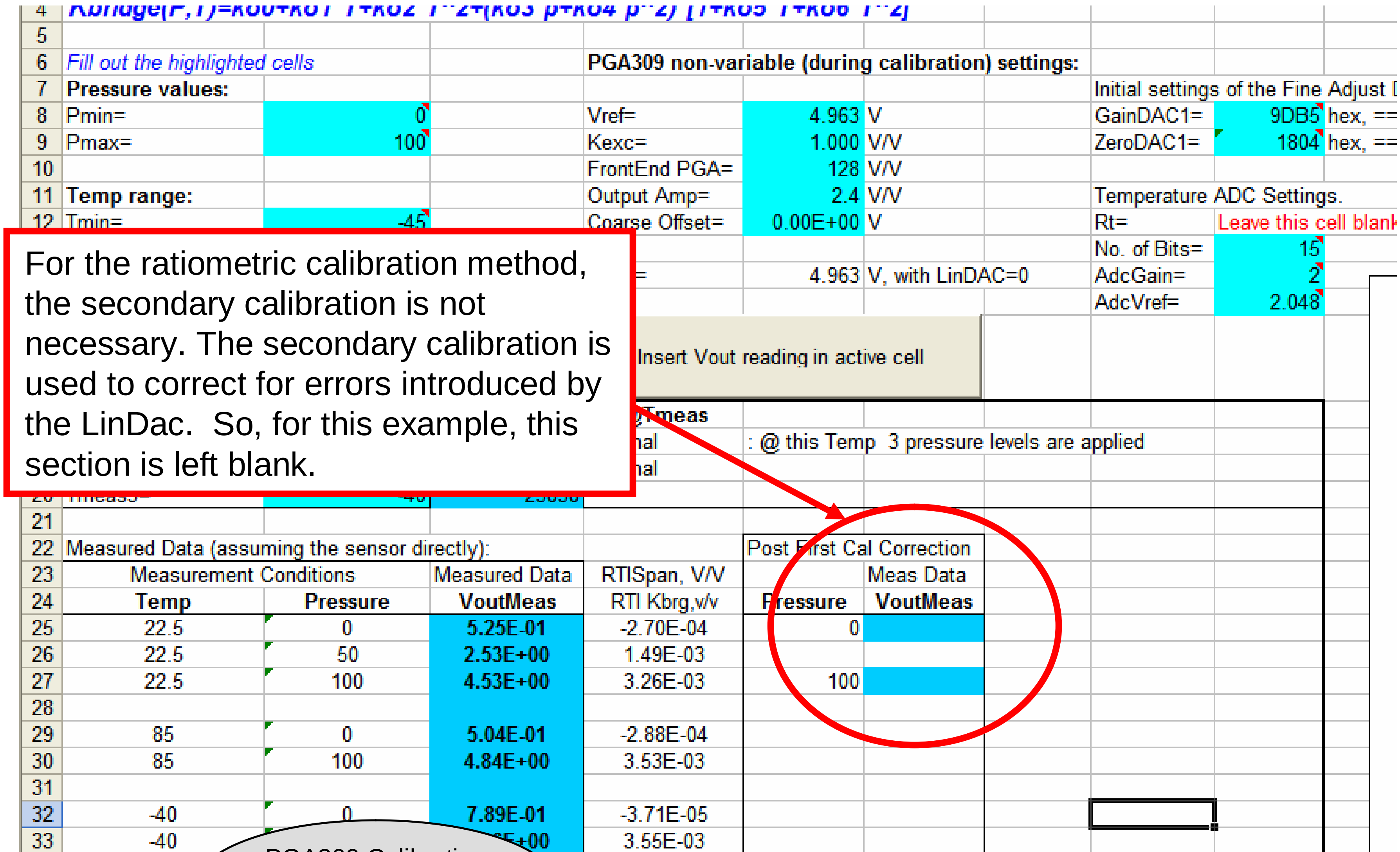
PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

Note that the *3 pressure 3 temperature* calibration algorithm will compute values for nonlinearity error. This value needs to be very small for this configuration because nonlinearity correction is not used. This value will not be used to generate the calibration tables in the EEPROM.

The value of Klin stored in the EEPROM will be zero for this mode because Vexc is disabled.

	A	B	C	D	E	F	G	H	I
					sultsVector3		Solution		
50	1	85	7225		3.82E-03		3.51E-03		
51	1	-40	1600		3.59E-03		-1.29E-07	ko5=	-3.681E-05
52	1	22.5	506.25		3.53E-03		4.41E-08	ko6=	1.256E-05
53									
54	**Calculated value:**								
55	Sensor Pressure non-linearity @Troom:								
56	Bv=	*-0.000737266*	=>>	-0.073726625	% ==>>	**Klin=**	**0**		
57	TempADC linear parameters:								
58	ktemp=	-64							
59	btemp=	21279							
60	GainDAC correction factor								
61	Gdac_factor=	1							
62	ZeroDAC correction factor								
63	Zdac_factor=	0							
64									
65	Calculated gain non-linearity								

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab



For the ratiometric calibration method, the secondary calibration is not necessary. The secondary calibration is used to correct for errors introduced by the LinDac. So, for this example, this section is left blank.

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

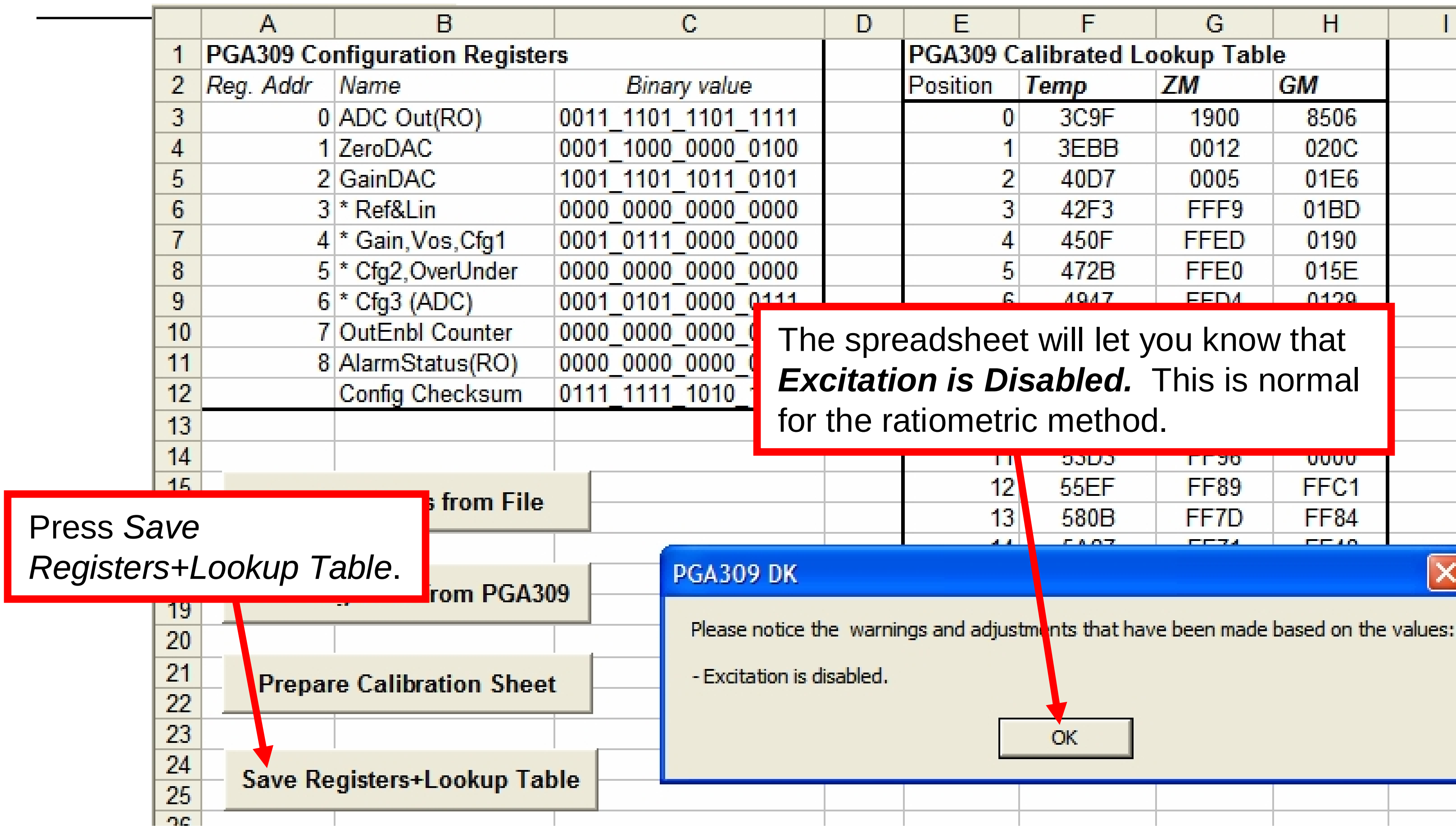
Select the desired post-calibration output range.

Select the temperature range of the look-up-table.

Make sure the *Result Sanity Check* passes.

4	Vout_max=	4.5	V	Ntemp=	17		1	90	0.679747		0.484677
5	Vout_min=	0.5	V	Optional:			2	81.5625	0.690988	-0.00133	0.48753
6				LUT_Tmin=	-45	degC	3	73.125	0.701426	-0.00124	0.488401
7				LUT_Tmax	90	degC	4	64.6875	0.710972	-0.00113	0.48729
8							5	56.25	0.719539	-0.00102	0.484196
9							6	47.8125	0.727047	-0.00089	0.479121
10		**Result Sanity Check:**					7	39.375	0.733423	-0.00076	0.472063
11		ZeroDAC is OK: values are in Range.					8	30.9375	0.738603	-0.00061	0.463024
12		GainDAC is OK: values are in Range.					9	22.5	0.742534	-0.00047	0.452002
13		TempADC is OK: values are ascending and in Range.					10	14.0625	0.745175	-0.00031	0.438998
14							11	5.625	0.746498	-0.00016	0.424012
15							12	-2.8125	0.746489	1.11E-06	0.407043
16							13	-11.25	0.745147	0.000159	0.388093
17							14	-19.6875	0.742488	0.000315	0.367161
18							15	-28.125	0.738539	0.000468	0.344246
19							16	-36.5625	0.733342	0.000616	0.319349
20							17	-45	0.726949	0.000758	0.292471
21							18	-45	0.726949	0	0.292471

PGA309 Calibration Spreadsheet, Calibration Results Tab



PGA309 Calibration Spreadsheet, Main Tab

Step A

Press the *Open File* button to get the file containing the calibration results.

Step B

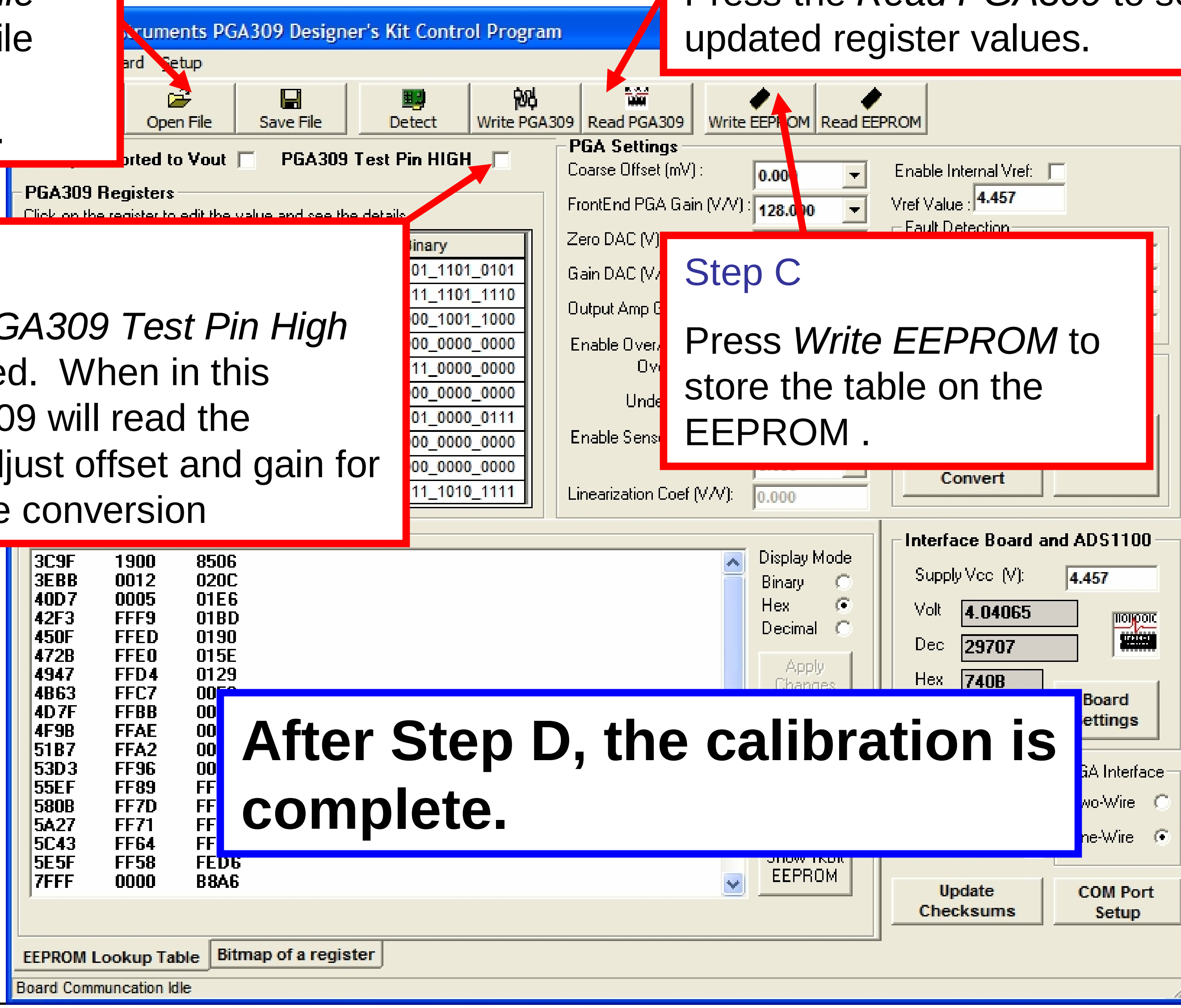
Make sure the *PGA309 Test Pin High* box is not checked. When in this mode, the PGA309 will read the EEPROM and adjust offset and gain for each temperature conversion

Step C

Press *Write EEPROM* to store the table on the EEPROM .

Step D

Press the *Read PGA309* to see the updated register values.



After Step D, the calibration is complete.

The *PGA309 RatioMetric Error* tab on the ***generate_sim_values.xls*** is a convenient way to do a post-calibration error analysis. To use it, select the blue cell corresponding to the current setup, and press the *Insert Vout reading in active cell* button. This will insert the PGA309 output reading from the ADS1100. This spreadsheet page provides for error calculations at two different power supply voltages. The initial supply is Vs= 4.963V (you need to enter your measured Vs).

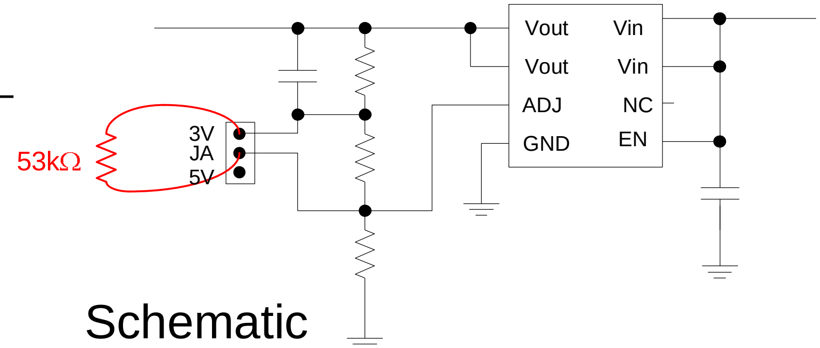
Insert Vout reading in active cell

	A	B	C	D	E	F
1						
2						
3						
4						
5						
6			Ideal Output Min=		0.5	V
7			Ideal Output Max=		4.5	V
8			Initial Vsupply=		4.963	V
9		Temperatu	Pressure	Ideal Resu	Measured	Error
10		cold	0%	0.5	0.49739	-0.07
11		cold	50%	2.5	2.49543	-0.11
12		cold	100%	4.5	4.49636	-0.09
13		Room	0%	0.5	0.49921	-0.02
14		Room	25%	1.5	1.4949	-0.13
15		Room	50%	2.5	2.49619	-0.10
16		Room	75%	3.5	3.49567	-0.11
17		Room	100%	4.5	4.49878	-0.03
18		Hot	0%	0.5	0.49997	0.00
19		Hot	50%	2.5	2.49998	0.00
20		Hot	100%	4.5	4.49954	-0.01
21						
22					stdev=	0.05
23					average=	-0.06
24						

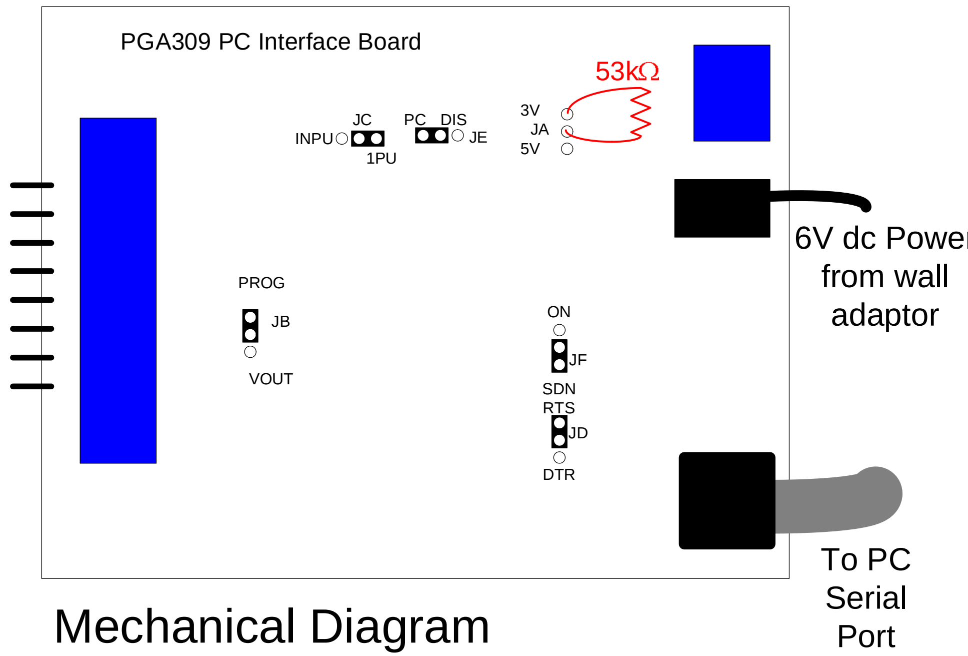
The post-calibration results will typically have errors less than 0.1%.

generate_sim_values.xls, PGA309 Ratiometric Error Tab

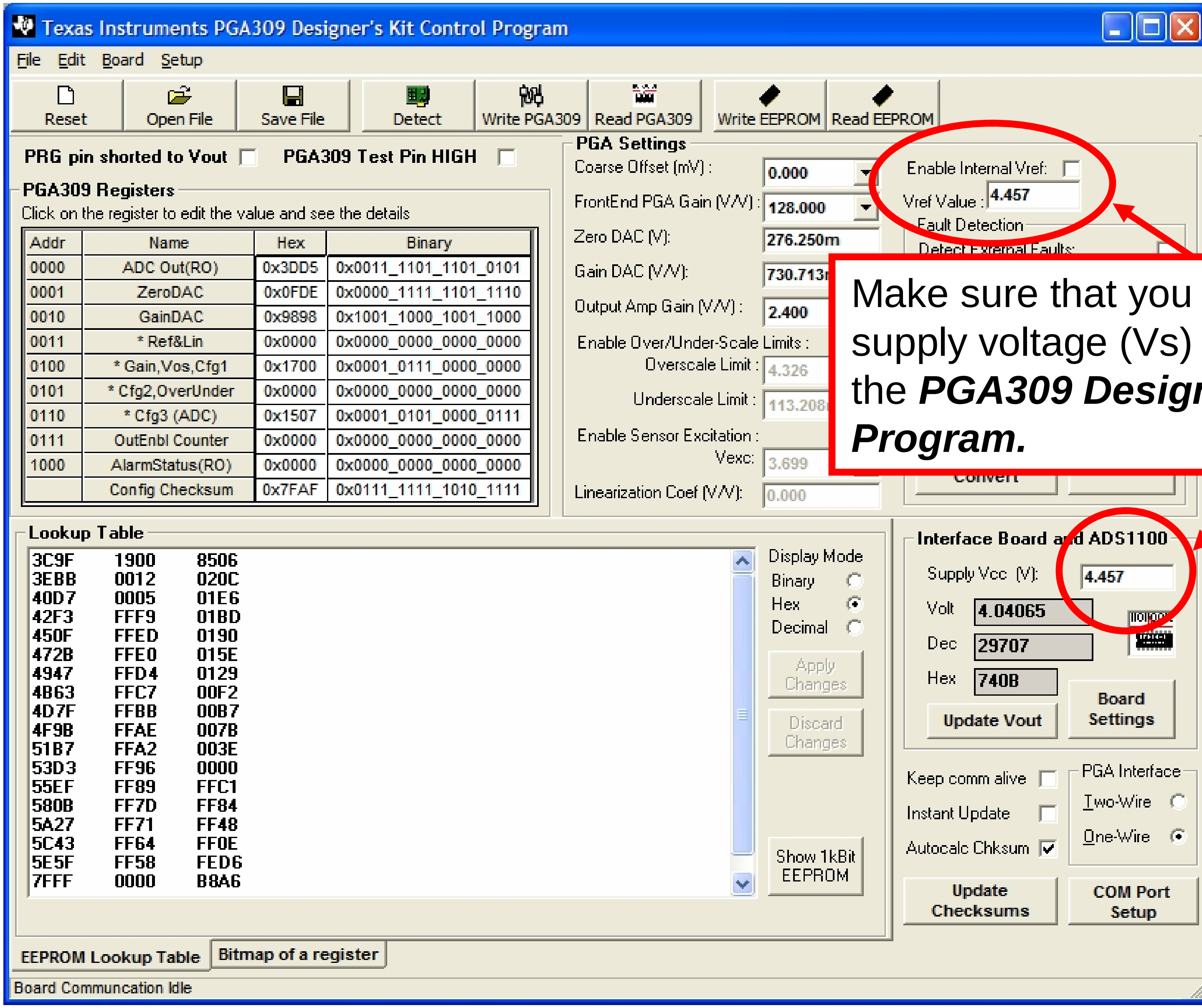
For the ratiometric calibration method it is useful to adjust the power supply to see how PSR affects the PGA309 calibrated accuracy. A 10% power supply deviation is used in this example because it is a typical worst case deviation for ratiometric systems. Connecting a 53kΩ resistor between the 3V pin and the center pin on JA will cause the power supply to shift from 5V to 4.5V. You can adjust the value of the shunt resistance to get more or less power supply deviation. A short will cause the power supply to deviate from 5V to 3V.



Schematic

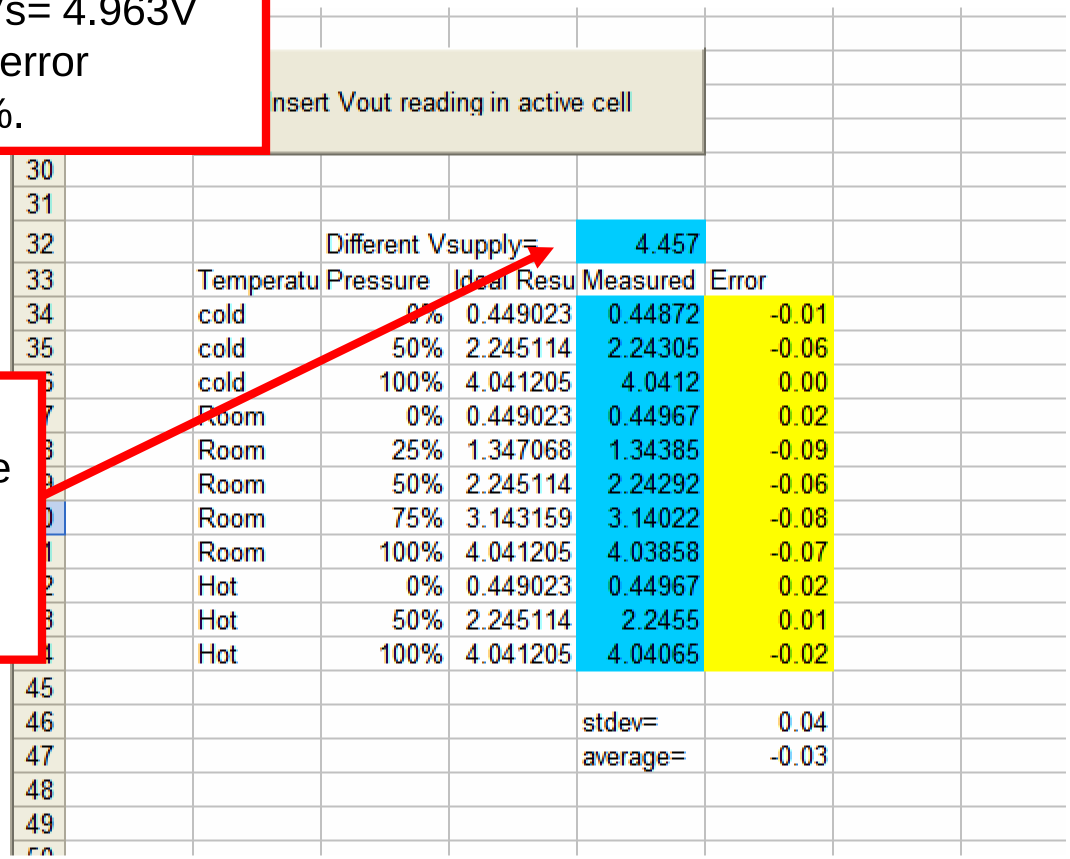


Mechanical Diagram



Make sure that you measure the supply voltage (Vs) and enter it into the ***PGA309 Designer's Kit Control Program.***

Measure the PGA309 post calibration error at a different supply voltage to see the affect of PSR on error. For this example, the supply was changed from Vs= 4.963V to Vs=4.457V and the average error changed from -0.06% to -0.03%.



Insert Vout reading in active cell

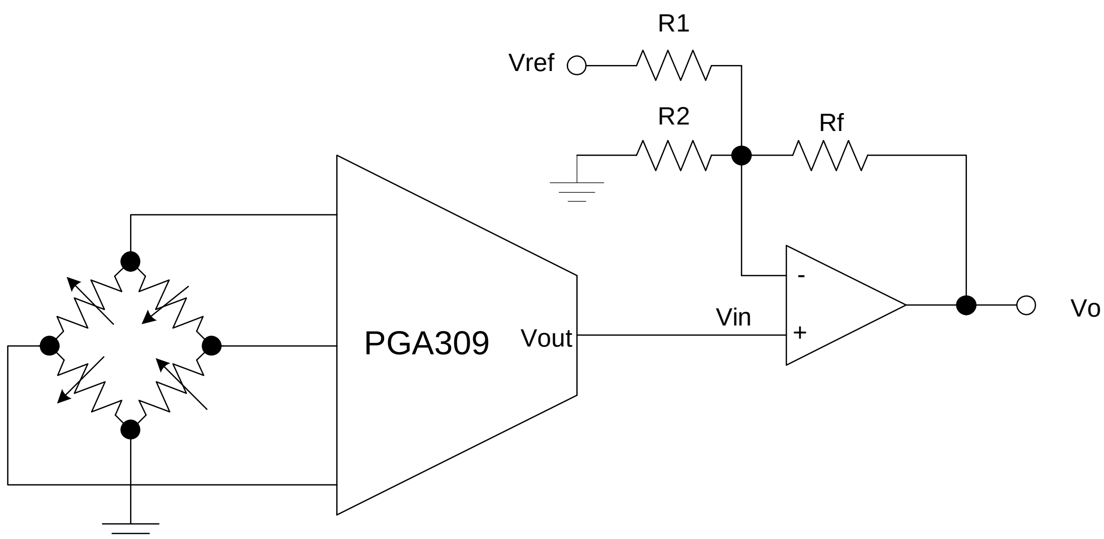
	Different Vsupply=		4.457		
Temperatu	Pressure	Ideal Resu	Measured	Error	
cold	0%	0.449023	0.44872	-0.01	
cold	50%	2.245114	2.24305	-0.06	
cold	100%	4.041205	4.0412	0.00	
Room	0%	0.449023	0.44967	0.02	
Room	25%	1.347068	1.34385	-0.09	
Room	50%	2.245114	2.24292	-0.06	
Room	75%	3.143159	3.14022	-0.08	
Room	100%	4.041205	4.03858	-0.07	
Hot	0%	0.449023	0.44967	0.02	
Hot	50%	2.245114	2.2455	0.01	
Hot	100%	4.041205	4.04065	-0.02	
			stdev=	0.04	
			average=	-0.03	

Make sure that you measure the supply voltage (Vs) and enter it into the ***PGA309 Designer's Kit Control Program***.

generate_sim_values.xls, PGA309 Ratiometric Error Tab

PGA309 With Output Scaling
(0 to 10V)

In many applications an external gain stage is used to get an output swing beyond the range of the PGA309. The circuit shown below is a typical example of gain scaling with an offset shift. The PGA309 calibration spreadsheet can accommodate external gain and offset scaling. Doing the calibration by measuring the output of the external gain stage will calibrate out errors caused by resistor tolerance in the external stage.



$$V_o = \left(\frac{R_f}{R_1} + \frac{R_f}{R_2} + 1\right) \cdot V_{in} - \left(\frac{R_f}{R_1}\right) \cdot V_{ref}$$

$$V_o = (\text{ExtraGain}) \cdot V_{in} + (\text{ExtraOffset}) \cdot V_{ref}$$

PGA309 With Output Scaling

(0 to 10V)

This calculation shows how the example configuration shown on the previous page can be used to take the 0.5V to 4.5V output of the PGA309 and re-scale it to 0V to 10V.

Let $R_1 := 10 \cdot 10^3$

$$0 = \left(\frac{R_f}{10 \cdot 10^3} + \frac{R_f}{R_2} + 1 \right) \cdot 0.5 - \left(\frac{R_f}{10 \cdot 10^3} \right) \cdot 2.5$$

Equation 1: Vin = 0.5V, Vo = 0V

$$R_f = 2500 \cdot \frac{R_2}{R_2 - 2500.}$$

Equation 2: solve Equation 1 for Rf

$$10 = \left(\frac{R_f}{10 \cdot 10^3} + \frac{R_f}{R_2} + 1 \right) \cdot 4.5 - \left(\frac{R_f}{10 \cdot 10^3} \right) \cdot 2.5$$

Equation 3: Vin=4.5V, Vo = 10V

$R_2 = 5000.$

Substitute equation 2 into equation 3 and solve for R2

$R_f = 5000.$

Substitute the value of R2 into equation 2 to solve for Rf

This equation must be broken down into an “ExtraGain” and “ExtraOffset” factor for the spreadsheet.

For the spreadsheet you need to break the function into "extra gain" and "extra offset" as shown below.

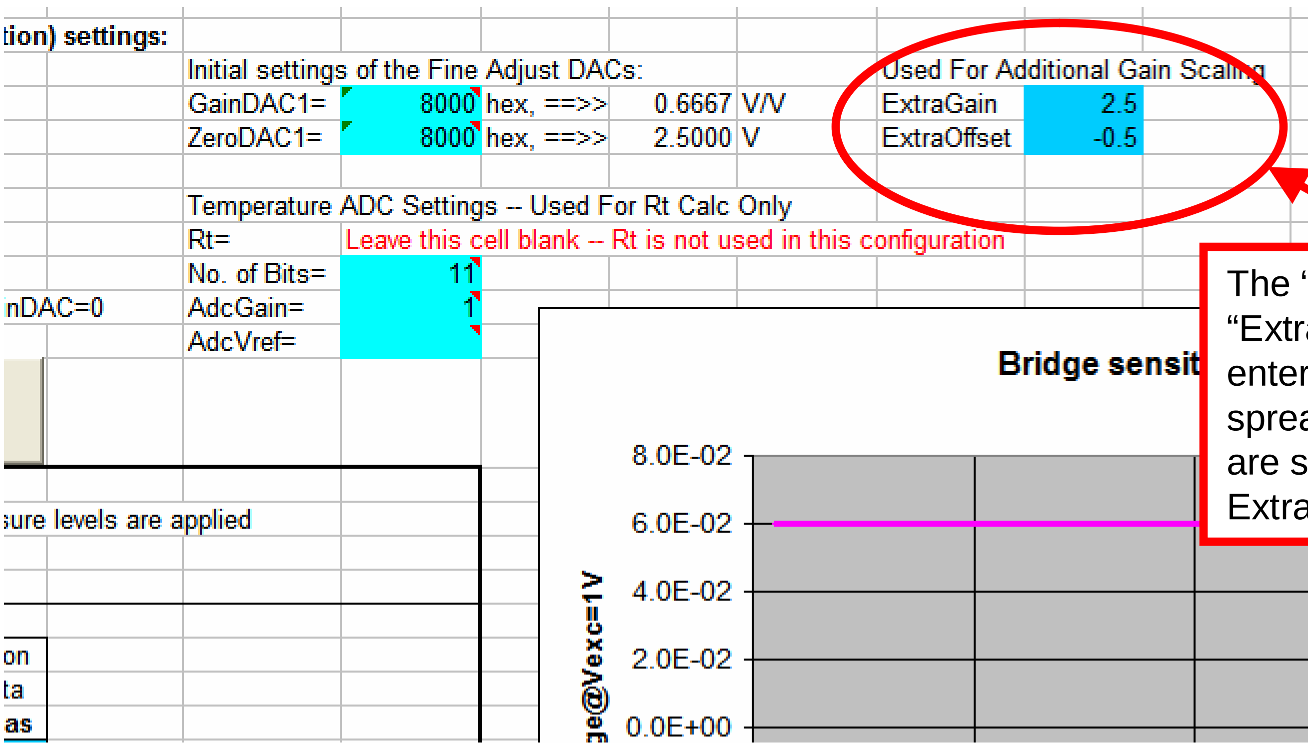
$$\text{ExtraGain} := \left(\frac{R_f}{R_1} + \frac{R_f}{R_2} + 1 \right)$$

ExtraGain = 2.5

$$\text{ExtraOffset} := \frac{-R_f}{10 \cdot 10^3}$$

ExtraOffset = –0.5

PGA309 With Output Scaling
(0 to 10V)



The "ExtraGain" and "ExtraOffset" factor are entered here on the spreadsheet. Normally these are set to ExtraGain = 1.0 and ExtraOffset = 0.0.

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

PGA309 With Output Scaling
(0 to 10V)

Row	A	B	C	D	E	F	G
16							
17	Measurement Temperatures:		TempADC Reading@Tmeas				
18	Tmeas1 (room)=	20	24744	decimal	: @ this Temp 3 pressure levels are app		
19	Tmeas2 (hot)=	85	20498	decimal			
20	Tmeas3 (cold)=	-40	28668				
21							
22	Measured Data (assuming the sensor directly):				Post First Cal Correction		
23	Measurement Conditions		Measured Data	RTISpan, V/V		Meas Data	
24	Temp	Pressure	VoutMeas	RTI Kbrg,v/v	Pressure	VoutMeas	
25	20	0	1.00E-01	-1.05E-01	0	2.00E-02	
26	20	50	4.30E+00	-4.18E-02			
27	20	100	9.90E+00	4.23E-02	100	9.94E+00	
28							
29	85	0	2.00E-01	-1.03E-01			
30	85	100	1.01E+01	4.53E-02			
31							
32	-40	0	-1.00E-01	-1.08E-01			
33	-40	100	9.80E+00	4.08E-02			
34				Room Temp Gain Error:		2.48	
35				Room Temp Cor Gain Dac:		0.10972131	
36				Post Cal RTI Kbrg(Pin_min):		-0.52375	
37				Post Cal RTI Kbrg(Pin_max):		0.21125	
38	Set Pressure = 0 and measurements at 3 temperatures:						
39	Matrix1:				ResultVector1		S
40		1	7225		-1.03E-01		k
41			400		-1.05E-01		k

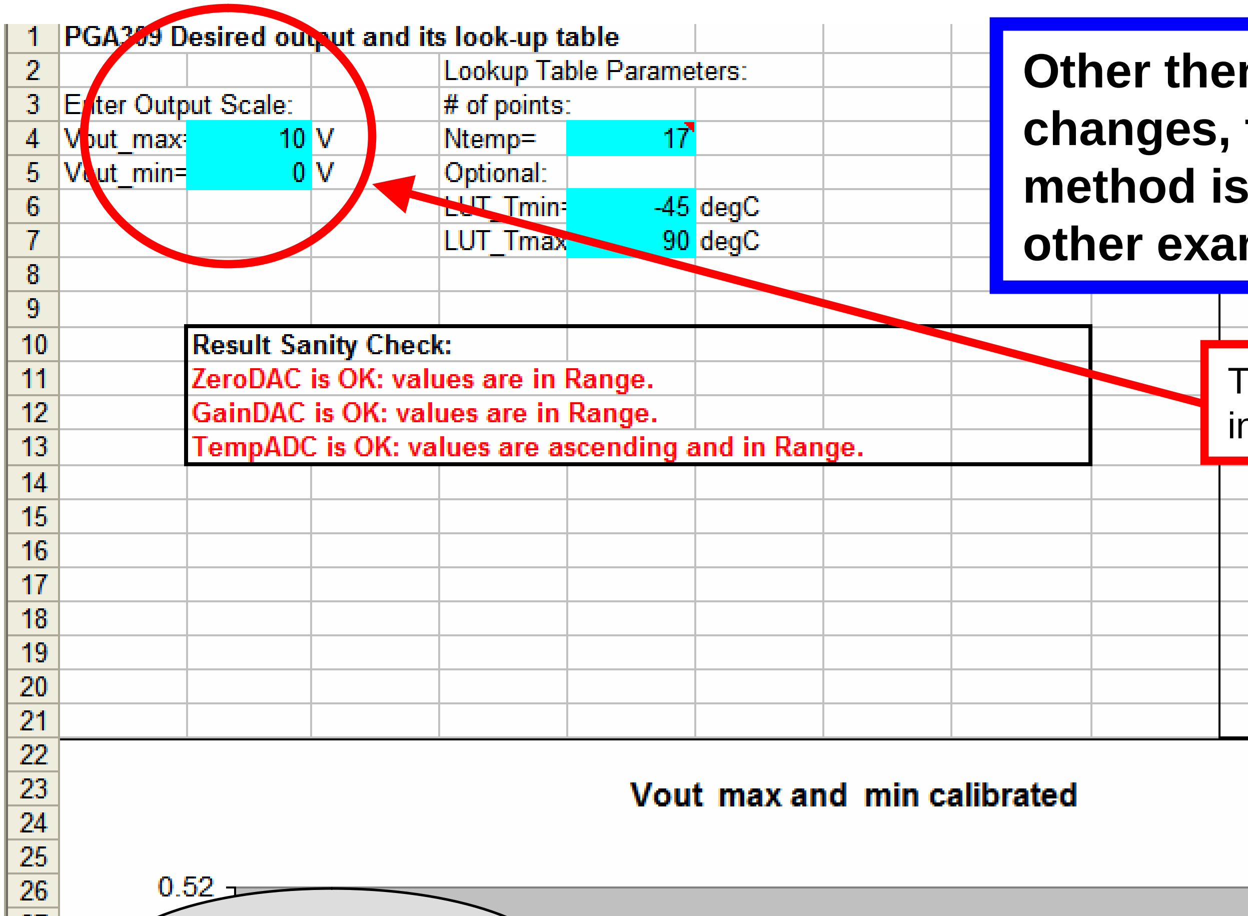
Mai | Template_Rt2 | Template_Not_Rt | Template_Rt | Temp

The data that is measured at the output of the external amplifier is entered directly into the spreadsheet.

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

PGA309 With Output Scaling

(0 to 10V)



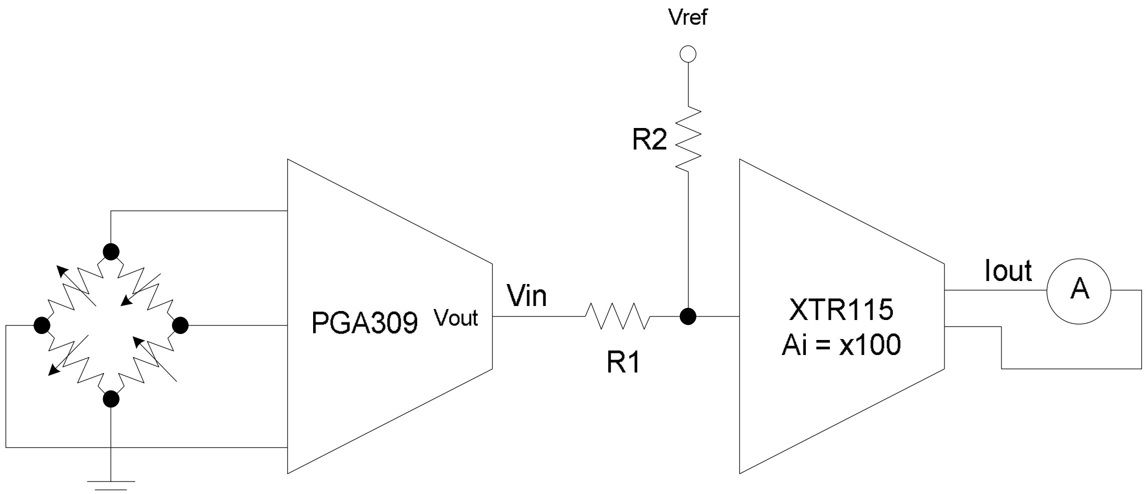
Other then these few minor changes, the calibration method is the same as the other examples.

The output range must be include the scaling stage.

PGA309 Calibration Spreadsheet, Calibration Results Tab

PGA309 With Output Scaling
(4mA to 20mA)

The spreadsheet can also be used to calibrate a system using a PGA309 with a 4mA to 20mA output scaling.



$$I_{out} = \left(I_{in} + I_{ref}\right)\cdot 100$$

$$I_{out} = \left(\frac{V_{in}}{R_1} + \frac{V_{ref}}{R_2}\right)\cdot 100$$

$$I_{out} = \left(\frac{100}{R_1}\right)\cdot V_{in} + \left(\frac{100}{R_2}\right)\cdot V_{ref}$$

$$I_{out} = (\text{ExtraGain})\cdot V_{in} + (\text{ExtraOffset})\cdot 2.5$$

PGA309 With Output Scaling
(4mA to 20mA)

This calculation shows how the example configuration shown on the previous page can be used to take the 0.5V to 4.5V output of the PGA309 and re-scale it to 4mA to 20mA.

$$4 \cdot 10^{-3} = \left(\frac{0.5}{R_1} + \frac{2.5}{R_2} \right) \cdot 100$$

Equation 1: Vin = 0.5V, Iout = 4mA

$$R_1 = 12500 \cdot \frac{R_2}{R_2 - 62500.}$$

Equation 2: solve Equation 1 for R1

$$20 \cdot 10^{-3} = \left(\frac{4.5}{R_1} + \frac{2.5}{R_2} \right) \cdot 100$$

Equation 3: Vin=4.5V, Iout = 20mA

$$R_2 = 125 \cdot 10^{3}$$

Substitute equation 2 into equation 3 and solve for R2

$$R_1 = 25 \cdot 10^{3}$$

Substitute the value of R2 into equation 2 to solve for R1

This equation must be broken down into an “ExtraGain” and “ExtraOffset” factor for the spreadsheet.

For the spreadsheet you need to break the function into "extra gain" and "extra offset" as shown below.

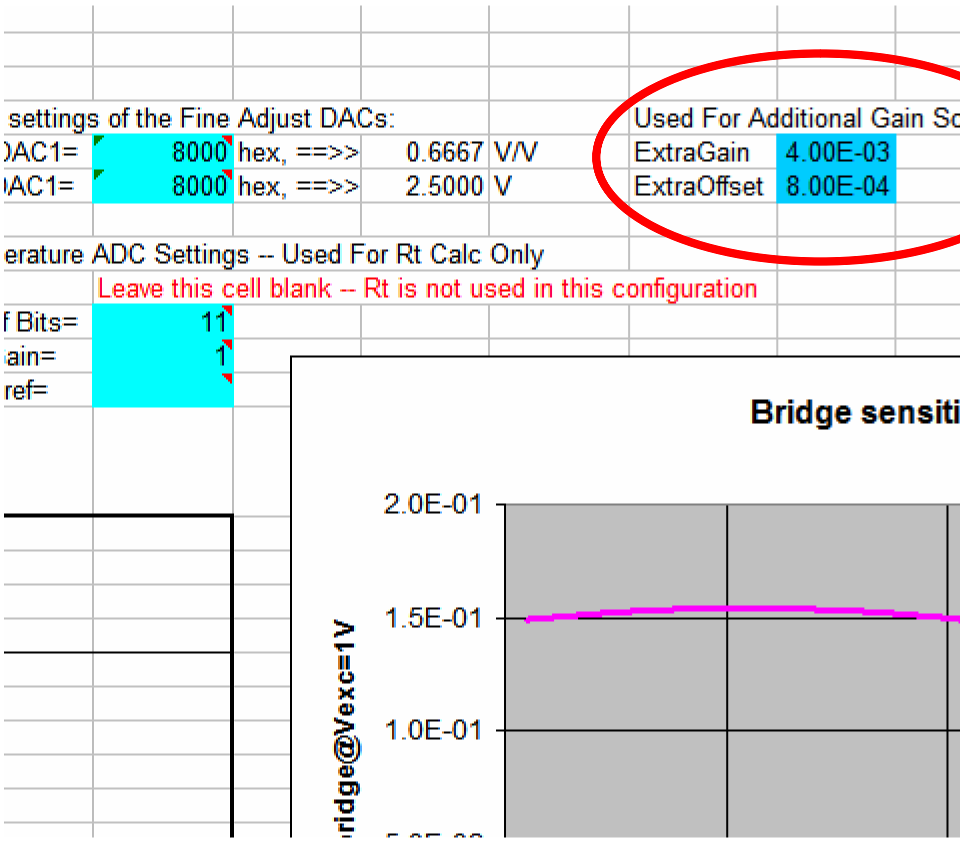
$$I_{out} = \left(\frac{100}{R_1} \right) \cdot V_{in} + \left(\frac{100}{R_2} \right) \cdot V_{ref}$$

$$I_{out} = \left(\frac{100}{25 \cdot 10^{3}} \right) \cdot V_{in} + \left(\frac{100}{125 \cdot 10^{3}} \right) \cdot 2.5$$

$$I_{out} = (\text{ExtraGain}) \cdot V_{in} + (\text{ExtraOffset}) \cdot 2.5$$

$$I_{out} = \left(4 \times 10^{-3}\right) \cdot V_{in} + \left(800 \times 10^{-6}\right) \cdot 2.5$$

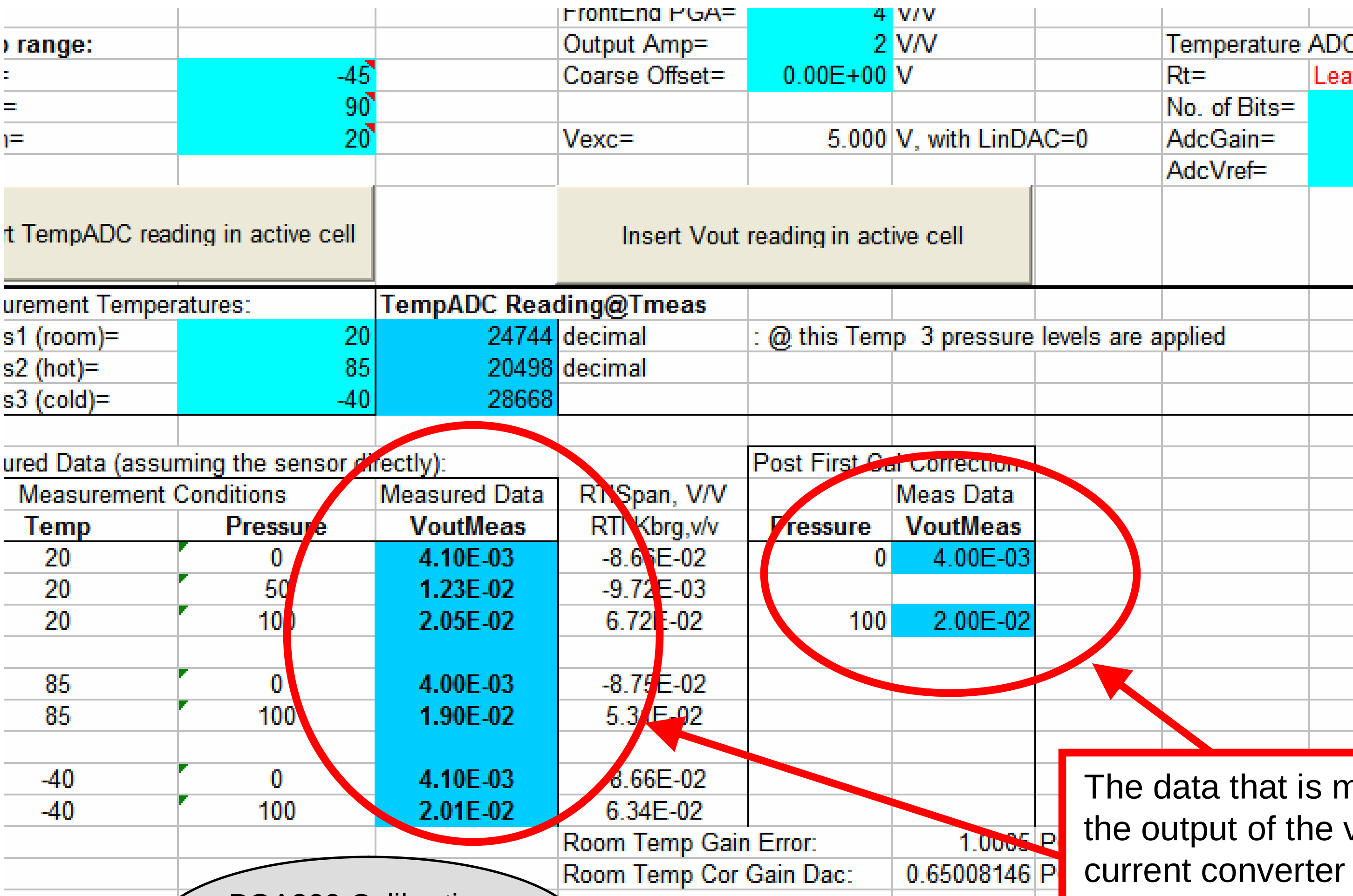
PGA309 With Output Scaling
(4mA to 20mA)



The “ExtraGain” and “ExtraOffset” factor are entered here on the spreadsheet. Normally these are set to ExtraGain = 1.0 and ExtraOffset = 0.0.

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

PGA309 With Output Scaling
(4mA to 20mA)



			FrontEnd PGA=	4	V/V				
range:			Output Amp=	2	V/V		Temperature ADC		
=	-45		Coarse Offset=	0.00E+00	V		Rt=	Leav	
=	90						No. of Bits=		
n=	20		Vexc=	5.000	V, with LinDAC=0		AdcGain=		
							AdcVref=		
t TempADC reading in active cell			Insert Vout reading in active cell						
urement Temperatures:		TempADC Reading@Tmeas							
s1 (room)=	20	24744	decimal	: @ this Temp 3 pressure levels are applied					
s2 (hot)=	85	20498	decimal						
s3 (cold)=	-40	28668							

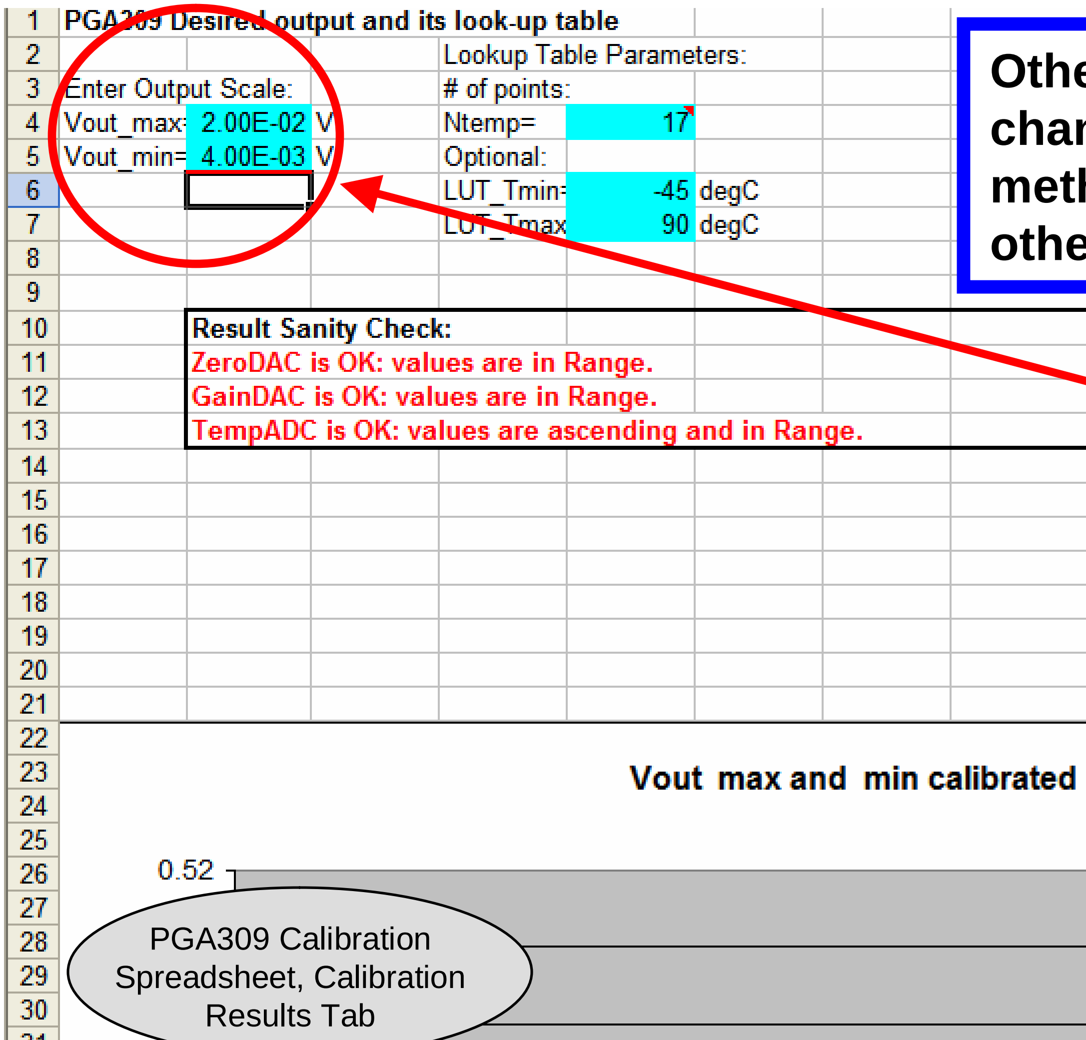
ured Data (assuming the sensor directly):				Post First Cal Correction		
Measurement Conditions		Measured Data	RTI Span, V/V		Meas Data	
Temp	Pressure	VoutMeas	RTI Kbrg,v/v	Pressure	VoutMeas	
20	0	4.10E-03	-8.66E-02	0	4.00E-03	
20	50	1.23E-02	-9.72E-03			
20	100	2.05E-02	6.72E-02	100	2.00E-02	
85	0	4.00E-03	-8.75E-02			
85	100	1.90E-02	5.31E-02			
-40	0	4.10E-03	8.66E-02			
-40	100	2.01E-02	6.34E-02			
			Room Temp Gain Error:		1.0005	P
			Room Temp Cor Gain Dac:		0.65008146	P

PGA309 Calibration Spreadsheet, Sensor Curvefit Tab

The data that is measured at the output of the voltage to current converter is entered directly into the spreadsheet (in Amps).

PGA309 With Output Scaling

(4mA to 20mA)



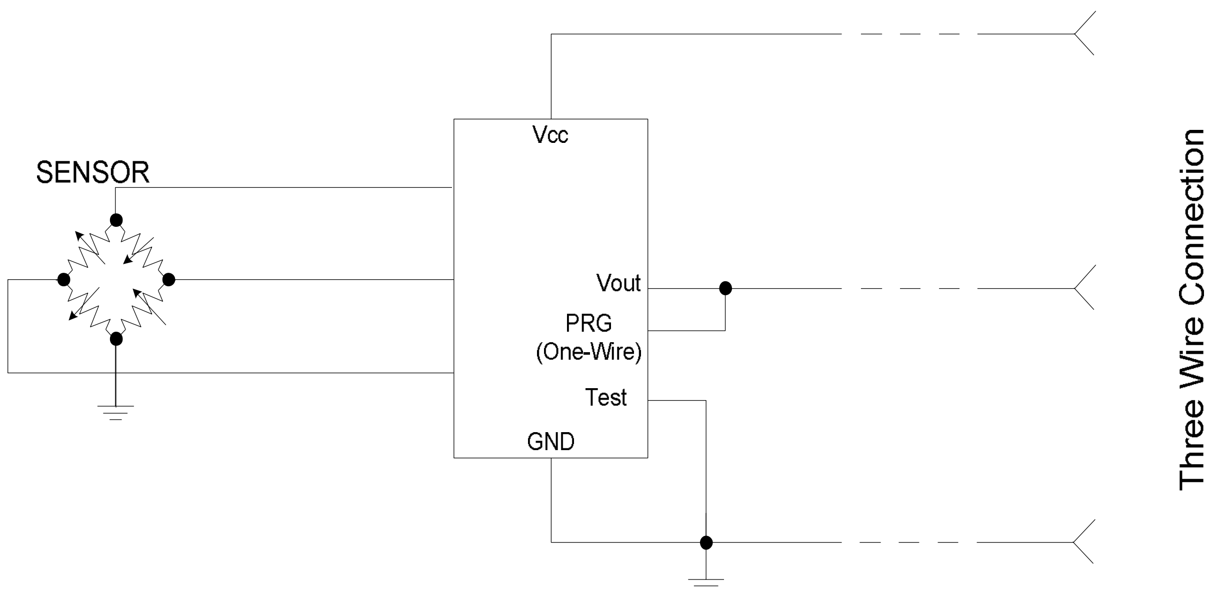
PGA309 Calibration Spreadsheet, Calibration Results Tab

Other then these few minor changes, the calibration method is the same as the other examples.

The output range must be include the scaling stage (in Amps).

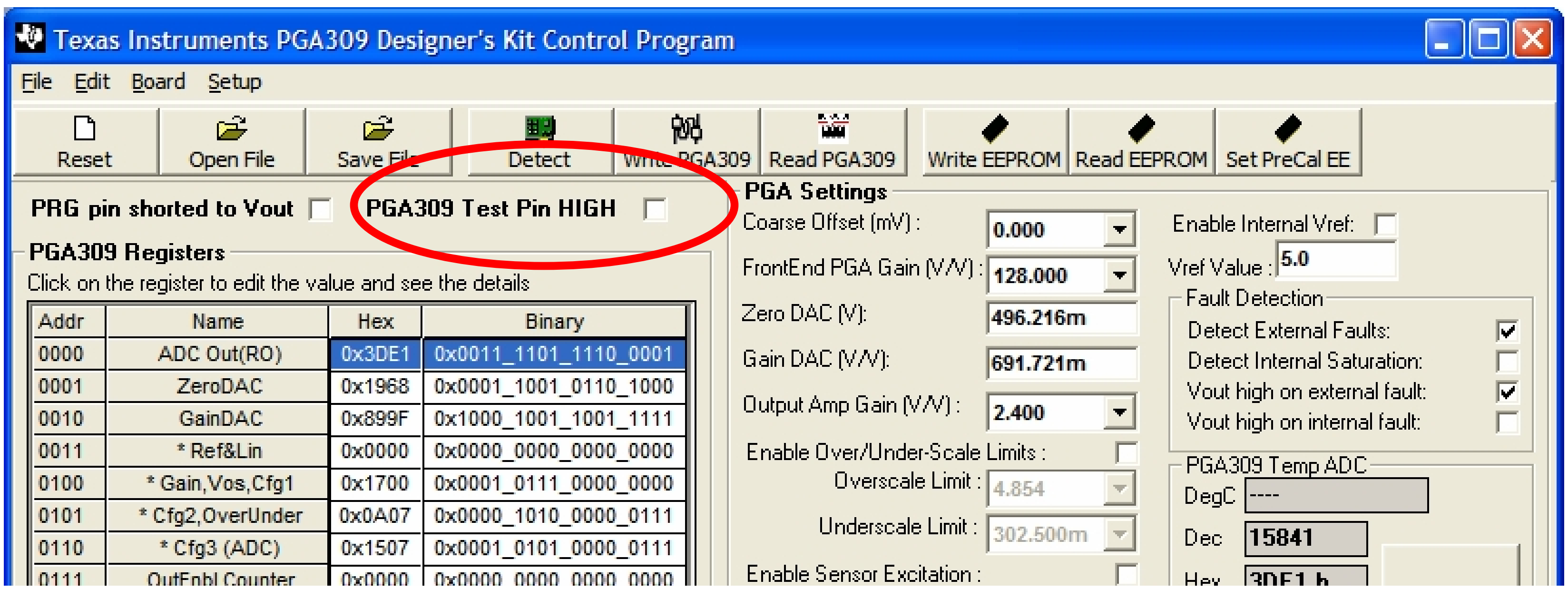
PGA309 In Three Wire Mode

In many cases the PGA309 is connected in a configuration referred to as a three wire connection. In this configuration the only wires that need to connect to the sensor module are power, ground, and Vout. In this configuration the One-Wire digital communication line is connected to the Vout pin. When the PGA309 is initially powered up, the Vout pin is placed in a high impedance mode for 15mS. If communication is established using the One-Wire during this time, the PGA309 will keep Vout in high impedance until the communications is complete. After the communication is complete the PGA309 Vout pin will become active and remain active until power is cycled again. While using the EVM to communicate in Three Wire Mode, the EVM will cycle power before each One-Wire communication.



PGA309 In Three Wire Mode

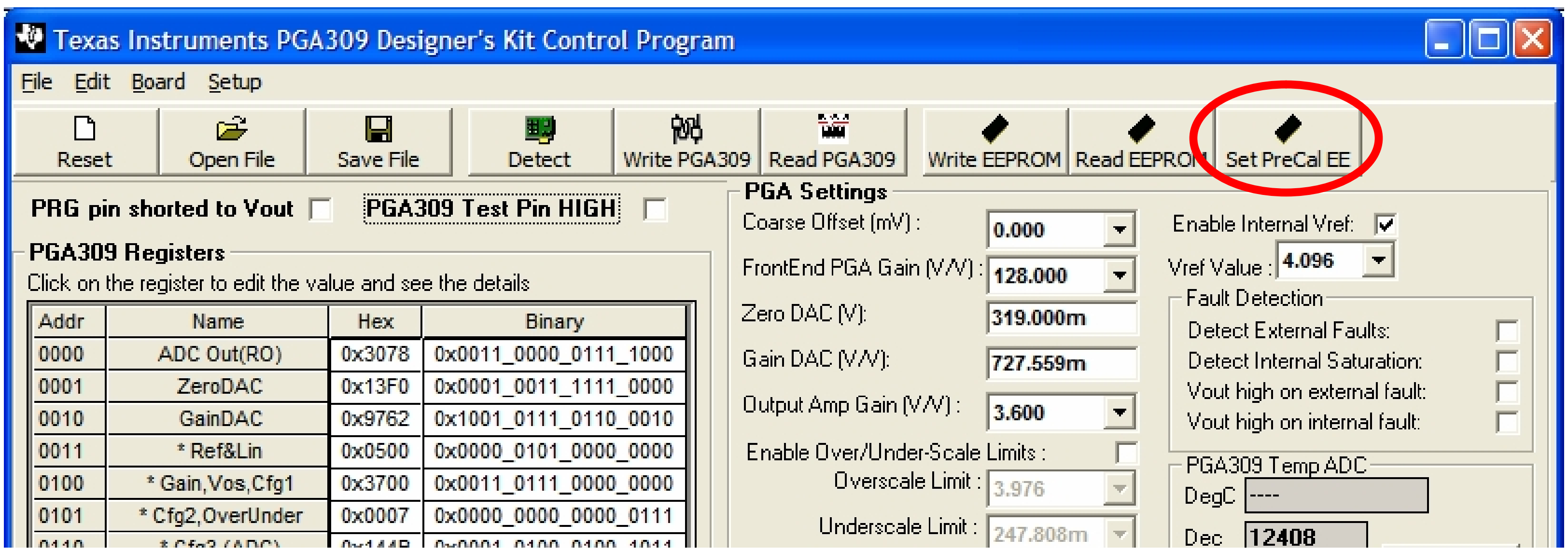
If the "Set PreCal EE" feature is used the test pin is normally grounded (leave "PGA309 Test Pin HIGH" box unchecked).



PGA309 In Three Wire Mode

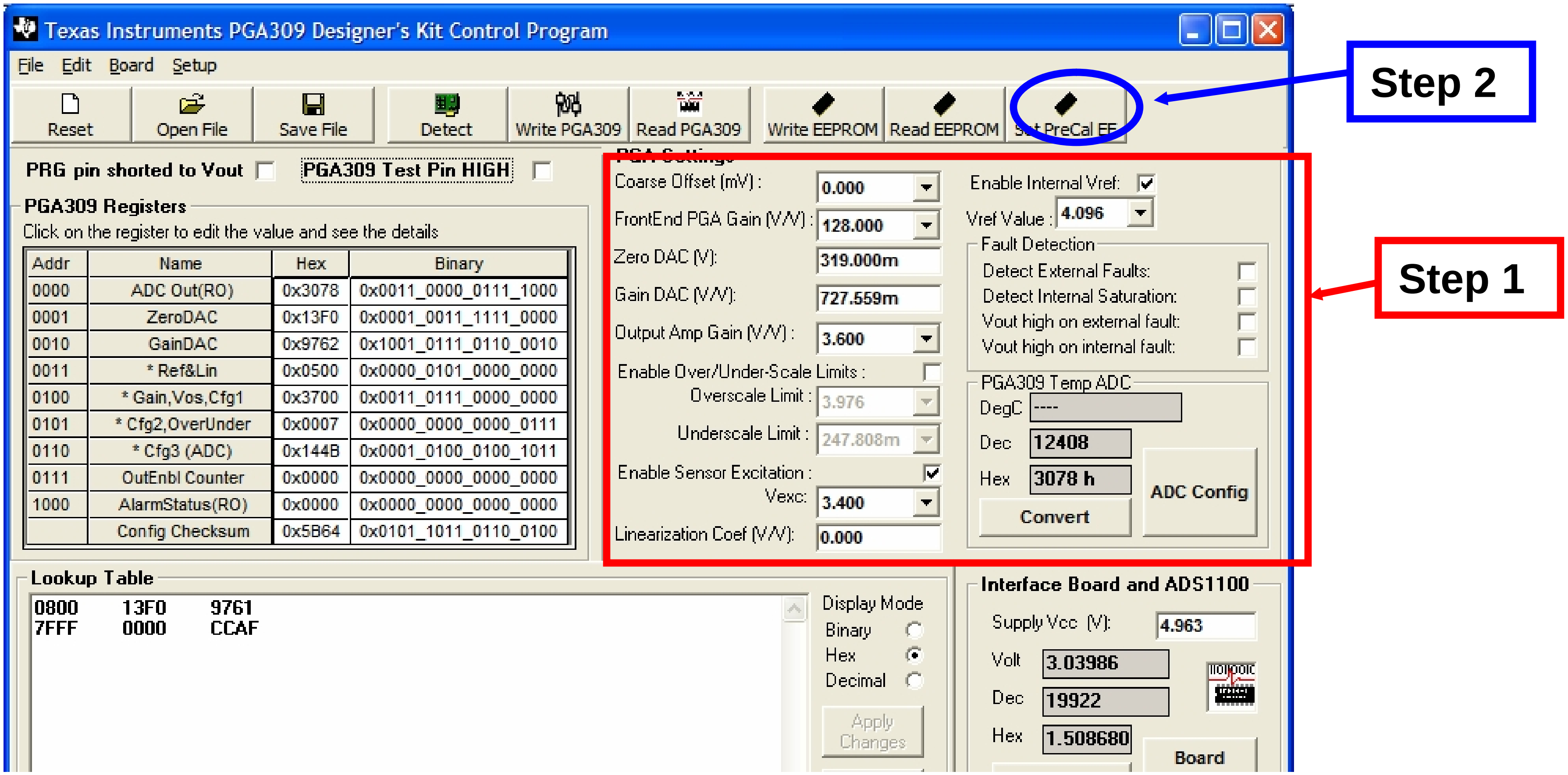
A key technique used in calibration is to use the test pin on the PGA309. The test pin is typically used during calibration to place the PGA309 into test mode. The main benefit of test mode is that the Gain DAC and Offset DAC are forced to remain at the last values written to their respective registers.

In the case of three wire mode the test pin is grounded and cannot be used. In this case, an EEPROM table can be built that will force that Gain DAC and Offset DAC to be constant. The PGA309 Designers Kit Control Program "Set Precal EE" feature simplifies the creation of this table.



PGA309 In Three Wire Mode

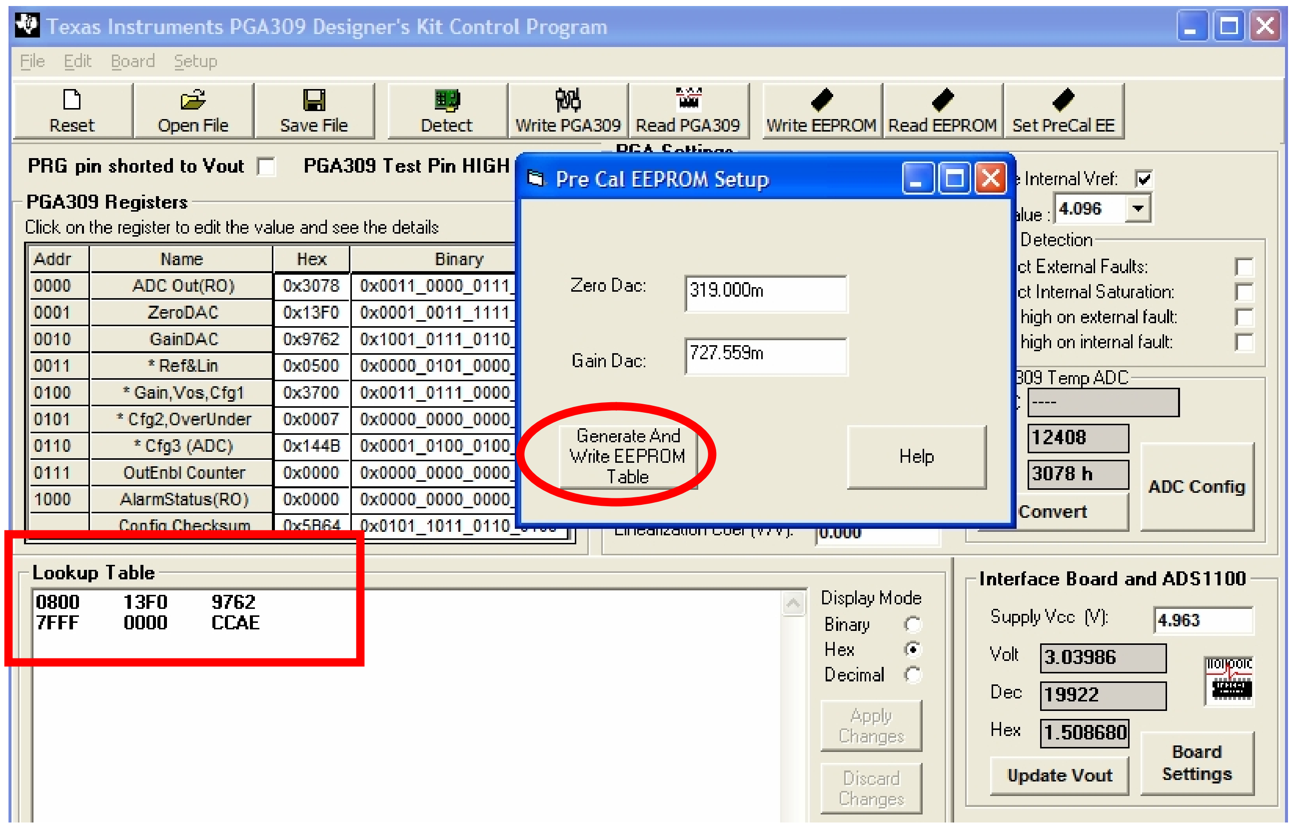
When using this feature, first set all the registers to values your application requires. Then press the "Set PreCal EE" button.



PGA309 In Three Wire Mode

After Pressing the “Set PreCal EE” a dialogue box will pop up that verifies the value of the Zero DAC and Gain Dac you want in your EEPROM configuration. After creating the EEPROM table, the PGA309 Designer’s Kit Control Program is ready for to be used with the calibration spreadsheet.

After pressing Generate and Write EEPROM Table, the lookup table will be updated to force a constant Gain Dac and Zero Dac for PreCal settings.



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