Burr-Brown Products
from Texas Instruments

XTR108

Quick Start System Reference Guide

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TEXAS INSTRUMENTS

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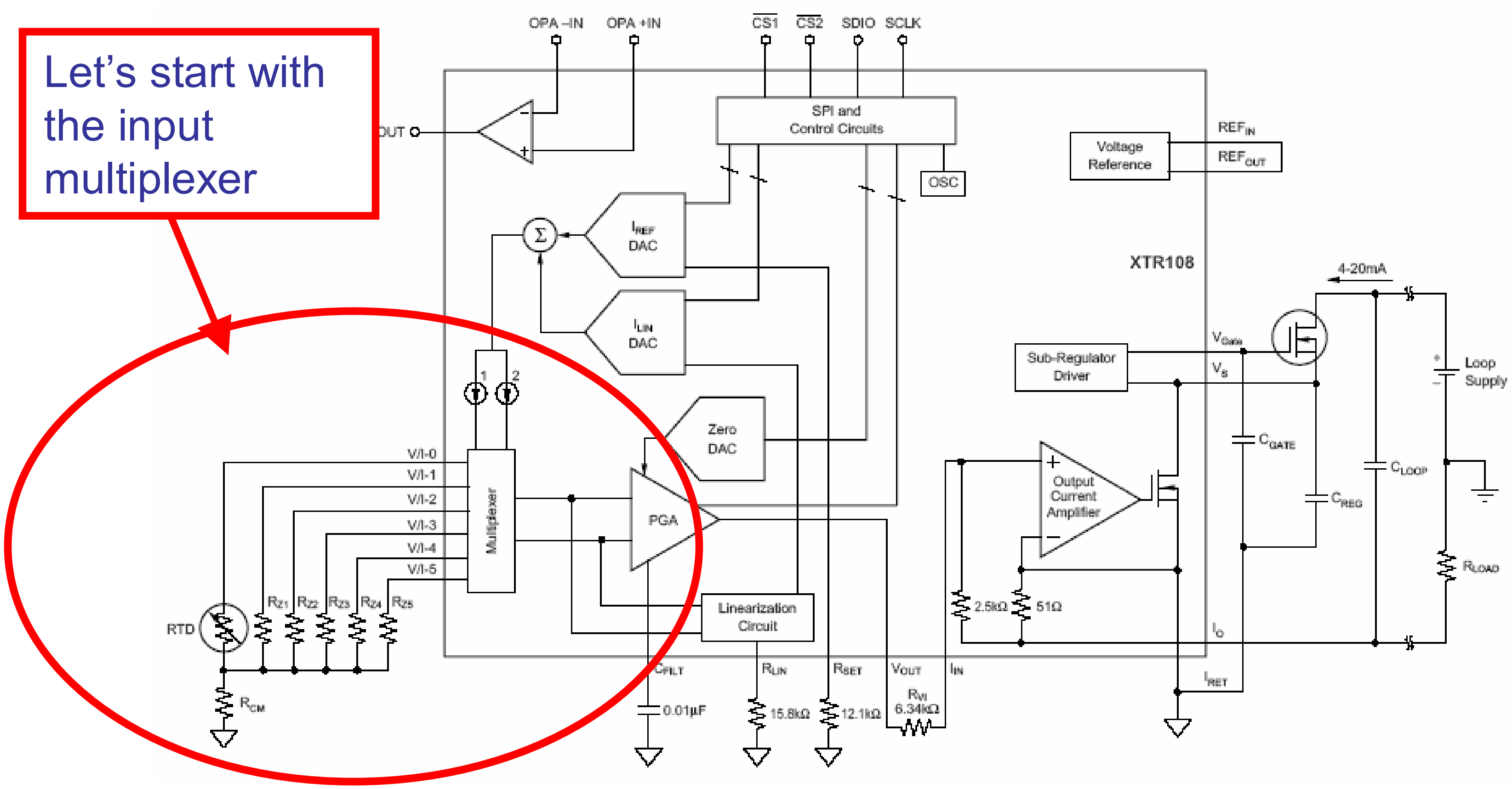
XTR108 Quick Start Contents

Short Background on XTR108

XTR108 Operation

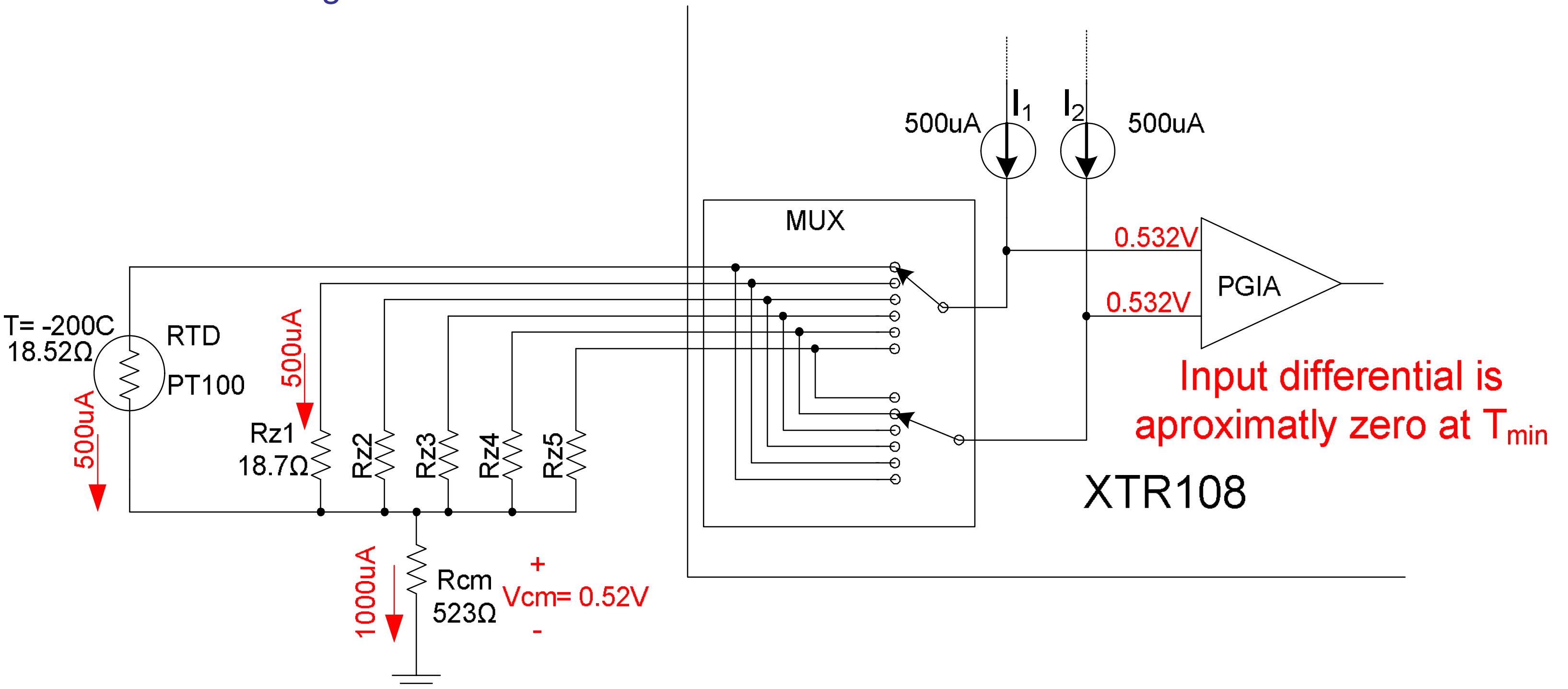
The figure below shows a simple block diagram of the XTR108. This section of the Quick Start Guide will give a brief description of the major sections.

Let's start with the input multiplexer



XTR108 Operation – Input Mux

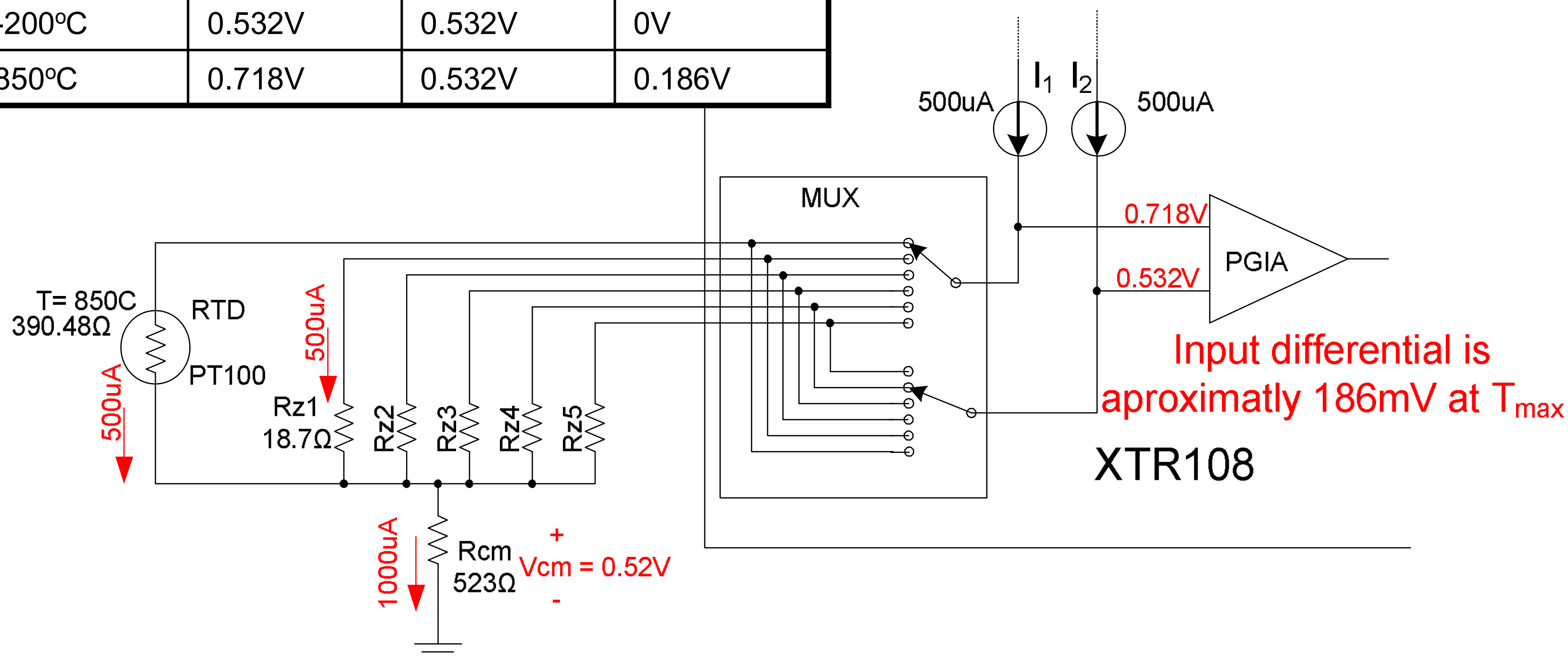
The primary function of the XTR108 Input MUX is to allow a single hardware module to function for multiple RTD ranges, and types. In the typical XTR108 configuration one MUX channel is used for the RTD and five different channels remain for different ranges. Rz1 through Rz5 are used to set the minimum temperature (T_{min}) of a particular range. In the example shown below, T_{min} = -200C, Rz1 is selected to match the resistance of the RTD at this temperature (i.e. 18.7Ω closest standard value). This will force the differential input voltage of the PGIA to be approximately zero at T_{min}. R_{cm} generates a common mode voltage so that the common mode range of the XTR108 is not violated.



XTR108 Operation – Input Mux

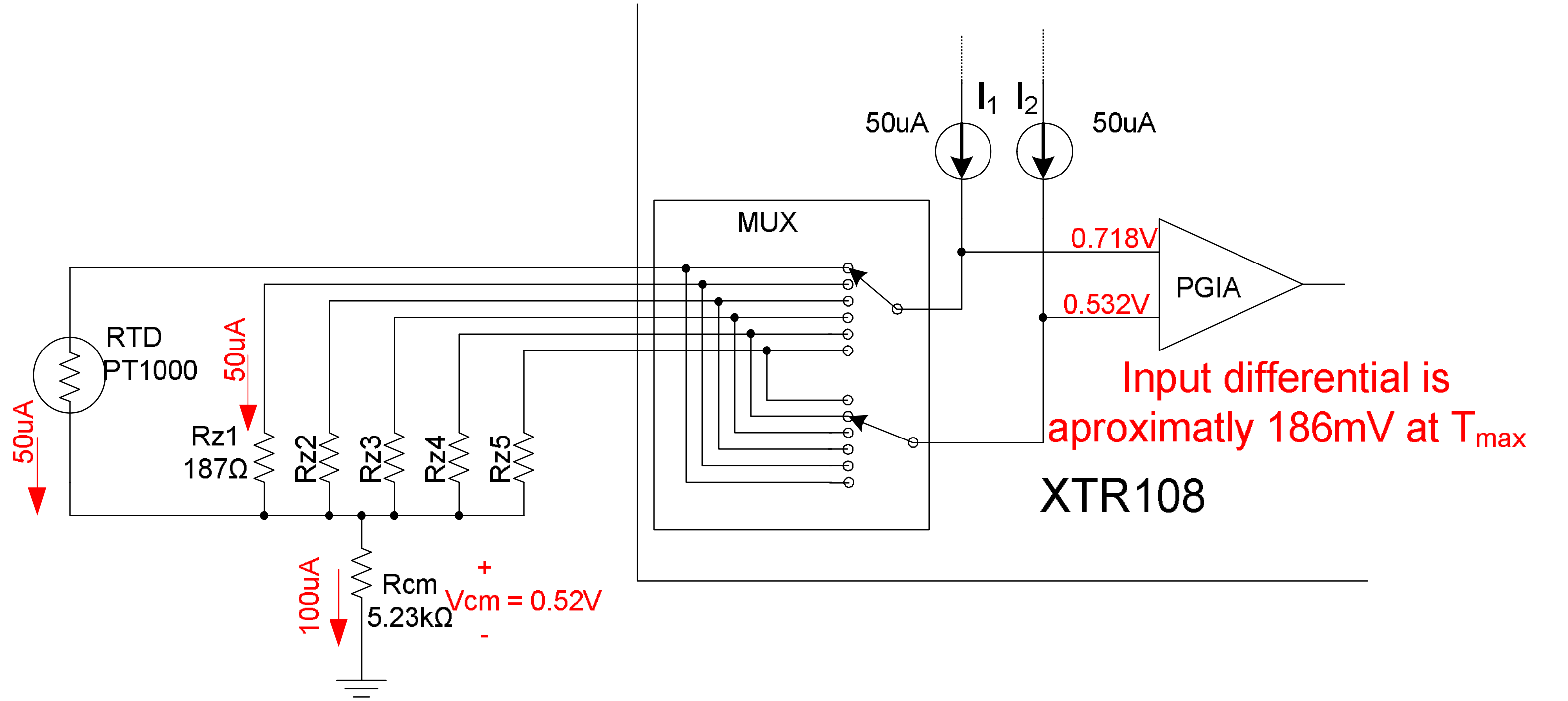
The figure below shows the same multiplexer configuration with the RTD at maximum temperature T_{max}=850C. At this point the differential input to the PGIA is maximum (e.g. 186mV). This example range is summarized in the table below.

Temperature	V_{RTD} to Ground	V_{RZ1} to Ground	Vin to PGIA
-200ºC	0.532V	0.532V	0V
850ºC	0.718V	0.532V	0.186V



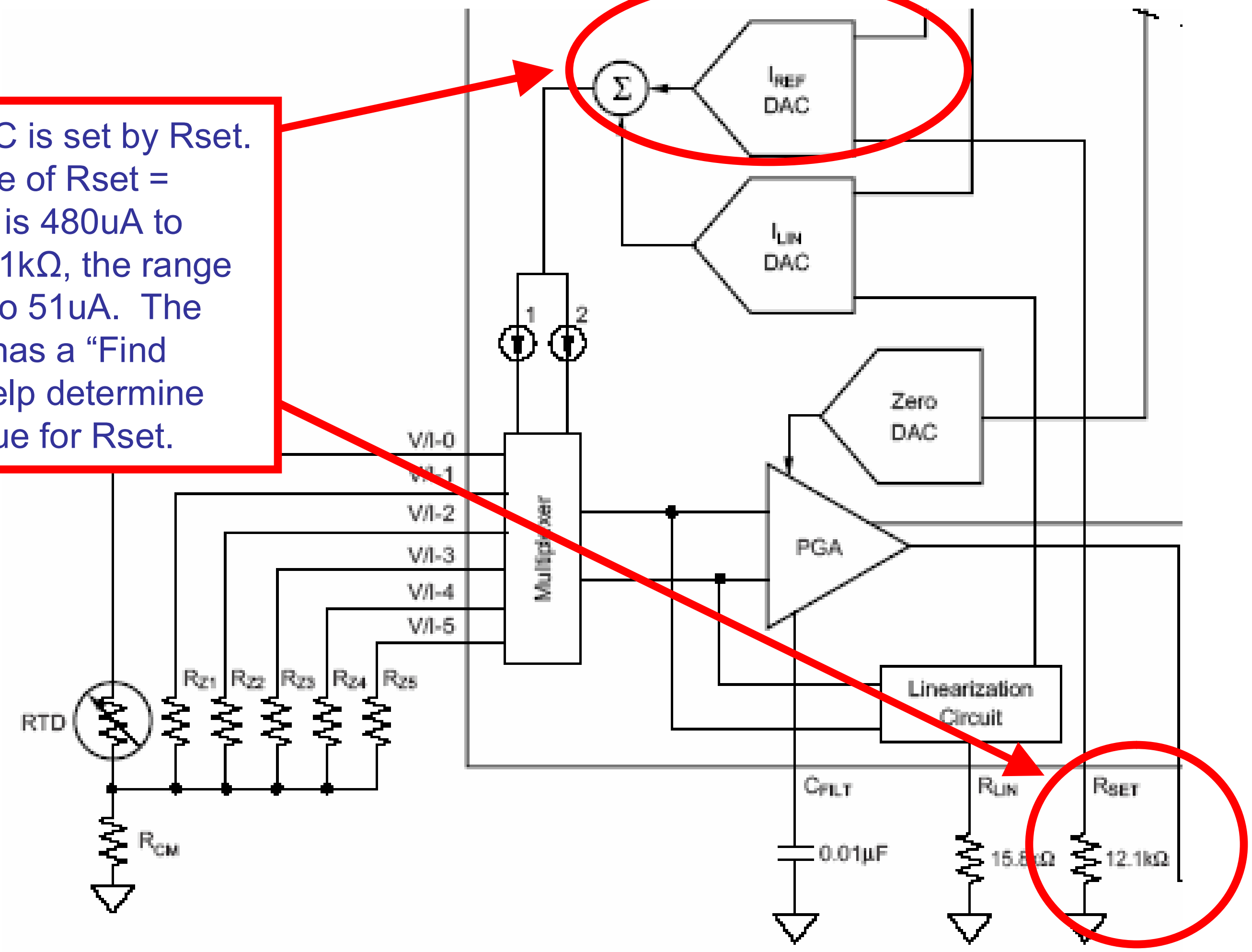
XTR108 Operation – Input Mux

The figure below shows how the current sources can be programmed to accommodate different types of RTD's. The previous example used a 100Ω RTD (PT100). In this example we changed the RTD to 1000Ω (i.e. PT1000). The current sources I_1 and I_2 are scaled to accommodate this new resistor (i.e. they are changed from 500uA to 50uA). Rz1 and Rcm are also scaled to accommodate this new RTD type. Note that I1 and I2 are matched current sources programmed by one set of DACs (7 bit plus sign CoarseDac, 7 bit plus sign FineDac). These current sources will be programmed during calibration.



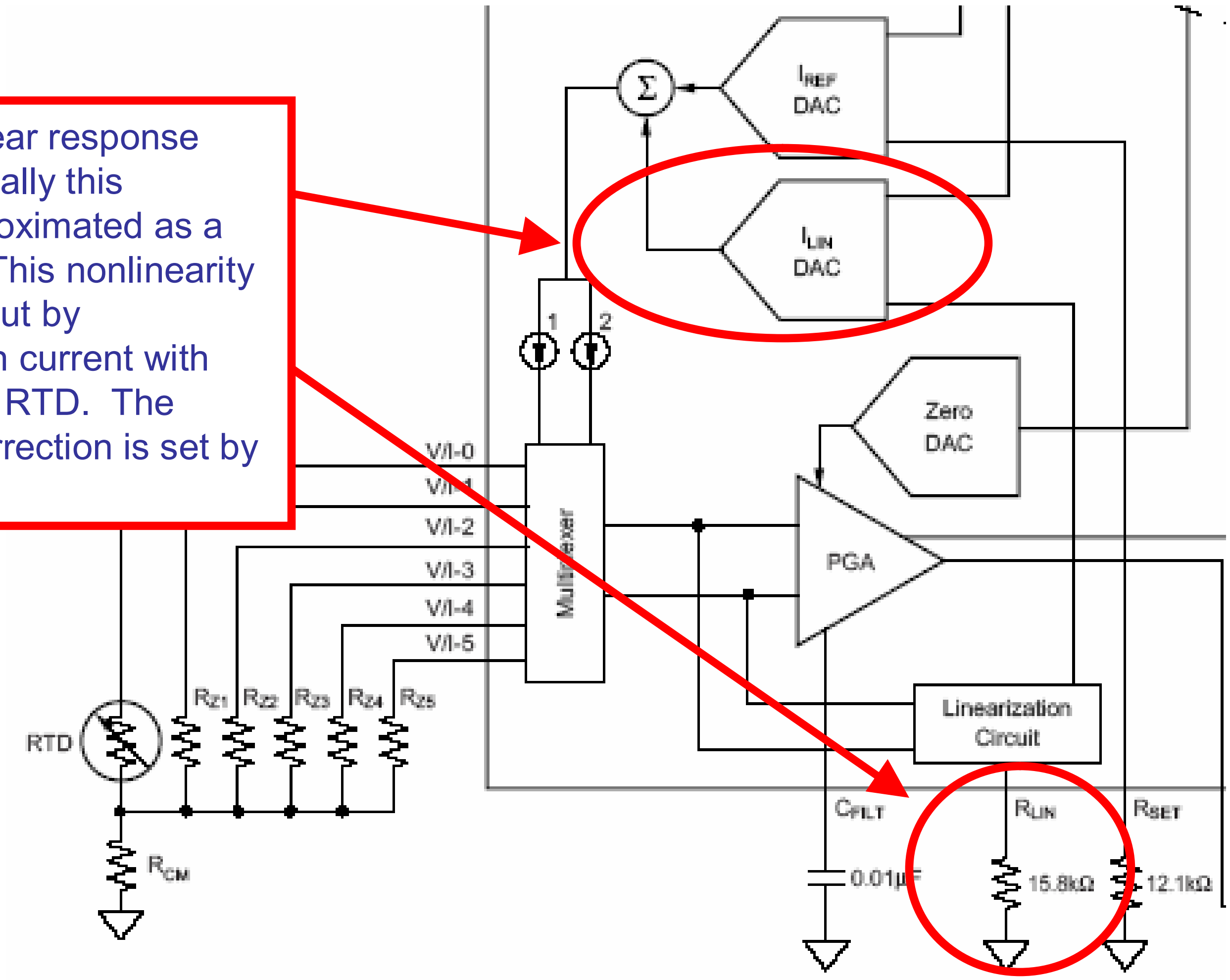
XTR108 Operation – Rset

The range of the Iref DAC is set by Rset. For example, with a value of Rset = 12.1kΩ, the range of Iref is 480uA to 510uA. Using Rset = 121kΩ, the range of Iref changes to 48uA to 51uA. The XTR108 EVM Software has a “Find Resistors” tab that will help determine what the appropriate value for Rset.



XTR108 Operation – Rlin

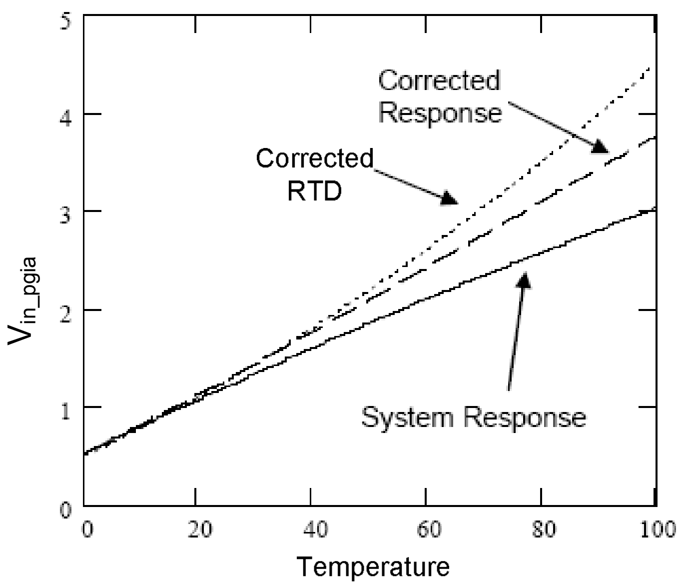
All RTD's have a nonlinear response over temperature. Typically this nonlinearity can be approximated as a second order function. This nonlinearity error can be calibrated out by modulating the excitation current with the input signal from the RTD. The range of this linearity correction is set by Rlin.



XTR108 Operation – Linearity Correction

How it works!

The graph below illustrates how the linearity correction works. The RTD has a system response that is approximately quadratic. The positive feedback of the input signal through the LinDac generates a system response that is also approximately quadratic. The two responses counteract each other to generate a linear output.

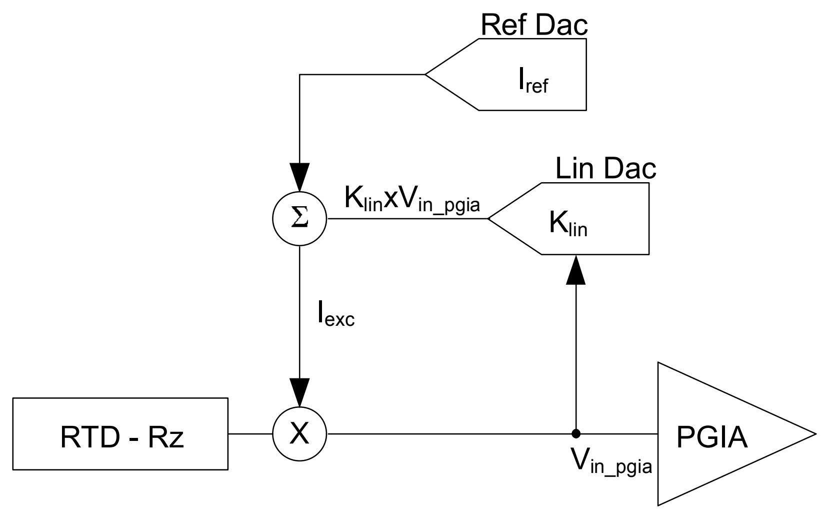


$$V_{in\_pgia} = \left(K_{lin} \cdot V_{in\_pgia} + I_{ref}\right) \cdot \left(RTD - R_Z\right)$$

$$V_{in\_pgia} = \frac{I_{ref}\left(RTD - R_Z\right)}{1 + K_{lin}\left(RTD - R_Z\right)}$$

If you do a Taylor Expanson the response can b
aproximated as a second order

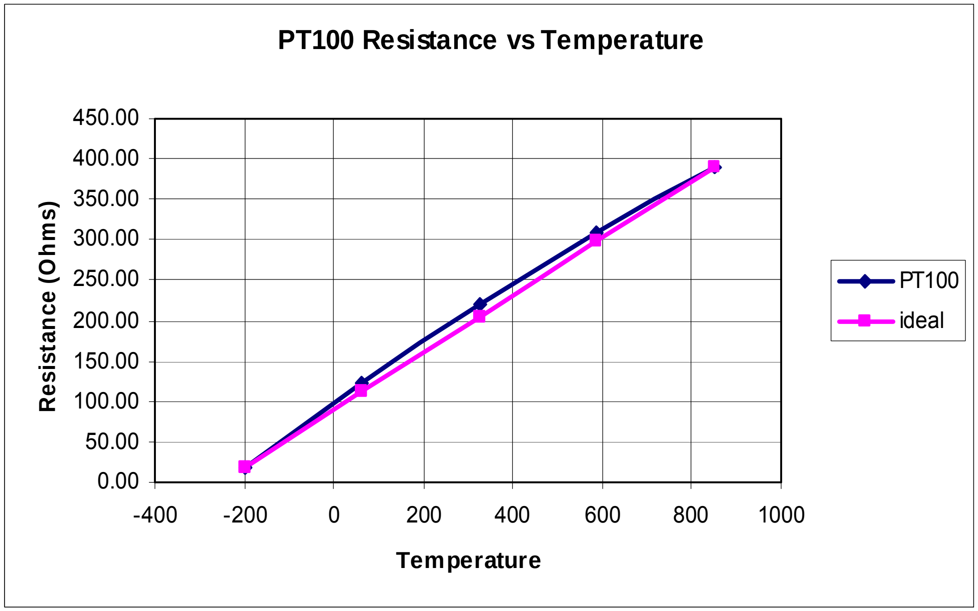
$$V_{in\_pgia} = a + b \cdot \left(RTD - R_Z\right) + c \cdot \left(RTD - R_Z\right)^2$$

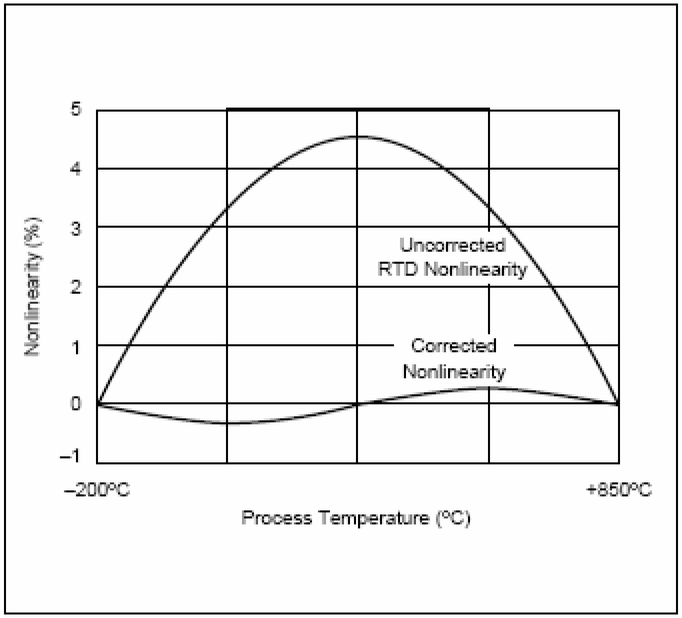


XTR108 Operation – Linearity Correction

How much will it improve the nonlinearity?

The graph below shows pre and post correction for a typical RTD. Normally you can expect a 40:1 improvement in linearity.





Current Output Mode Calibration Example

Selecting Components for Your Application

There are several external components that are used to set the type of RTD used, and the temperature range that it can be used over. The XTR108 "Find Resistor" tab on the XTR108 Software is a tool that helps select resistors to accommodate five ranges on the XTR108. These components are located on the XTR108-EVM Sensor Board.

R_{z1} through R_{z5} – sets the zero temperature for the multiplexer channels 1 through 5.

R_{LIN} – sets the range of linearity correction.

R_{cm} – the common mode resistor. This resistor ensures that the lowest common mode voltage is greater then the data sheet specification.

R_{set} – this resistor sets the range for the current references.

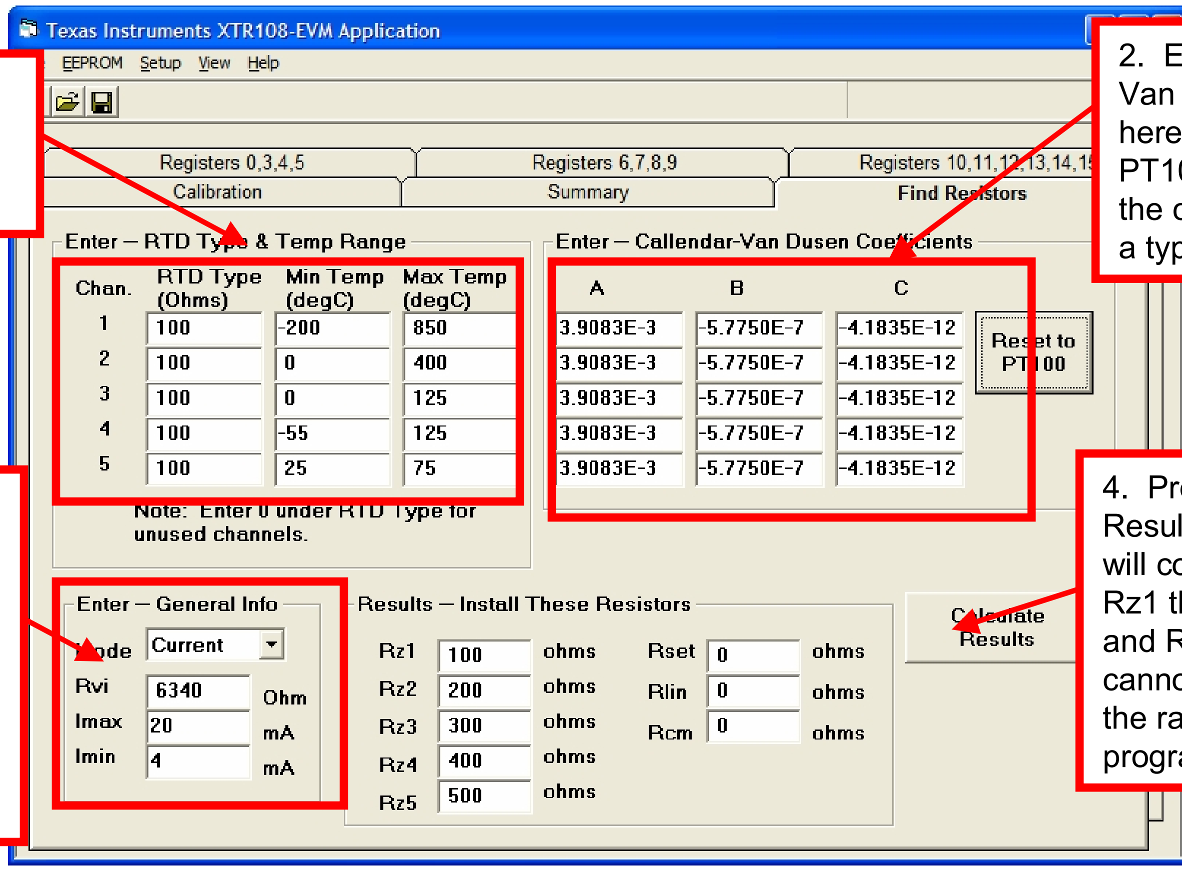
R_{vi} – the voltage to current resistor. This resistor is always selected to be 6.34k by the spreadsheet because this is the optimal value for the zero adjust circuit to work for 4mA to 20mA.

Selecting Components – Find Resistors

The "Find Resistors" tab on the XTR108 EVM Software can be used to determine what external resistors are required to configure the XTR108 for different RTD ranges.

1. Enter the RTD resistance at 0 degC and the temperature range.

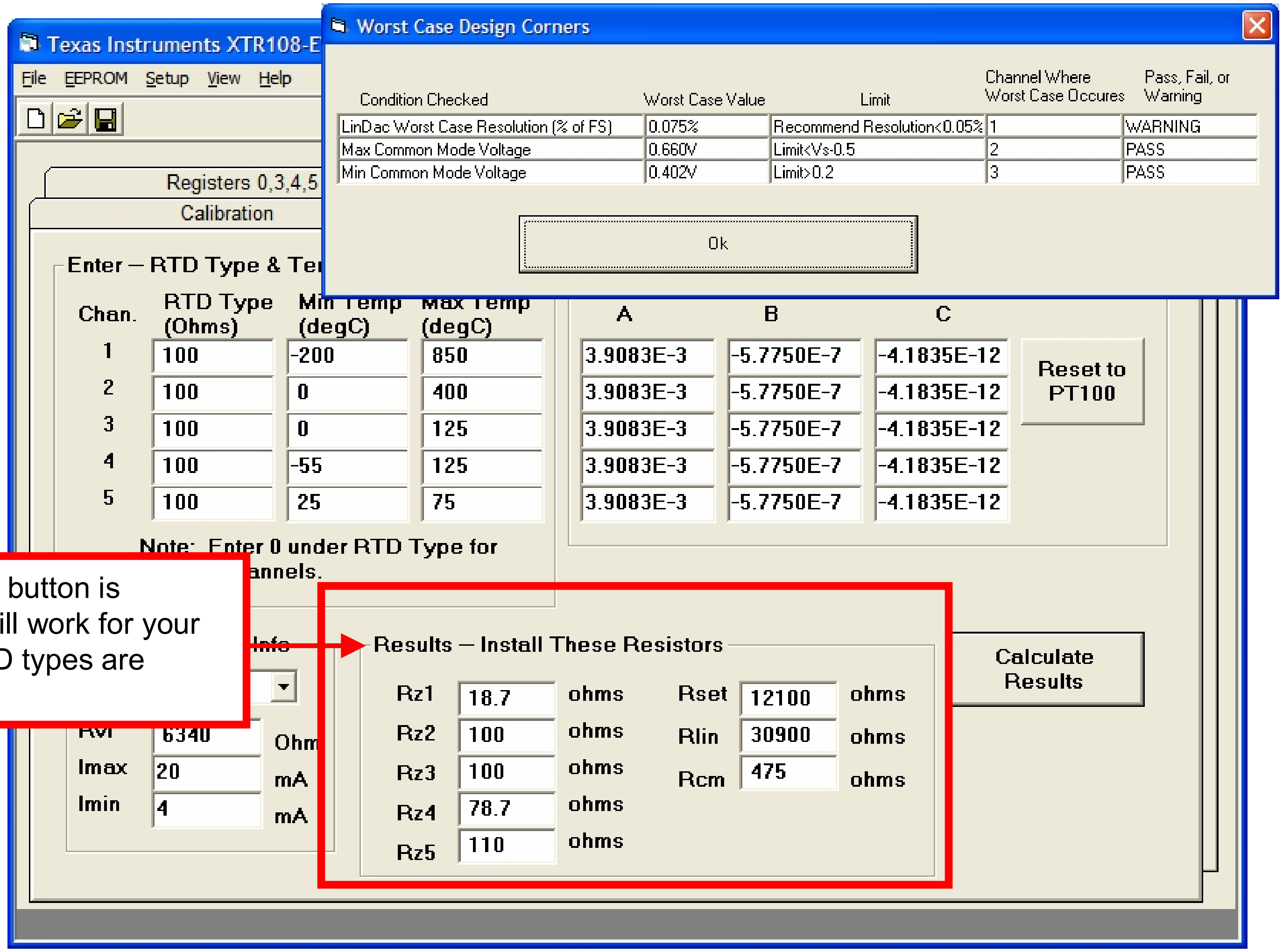
2. Enter the Callendar-Van Dusen Coefficients here. The "Reset to PT100" button will reset the coefficients to that of a typical PT100 RTD.



3. Select current mode or voltage mode. Enter Rvi. Rvi is typically 6340Ω for most applications. The output at Max Temperature (Imax) and the output at minimum temperature (Imin).

4. Press the "Calculate Results" button. This will compute values for Rz1 through Rz5, Rset, and Rcm. If the XTR108 cannot accommodate all the ranges, then the program will give errors.

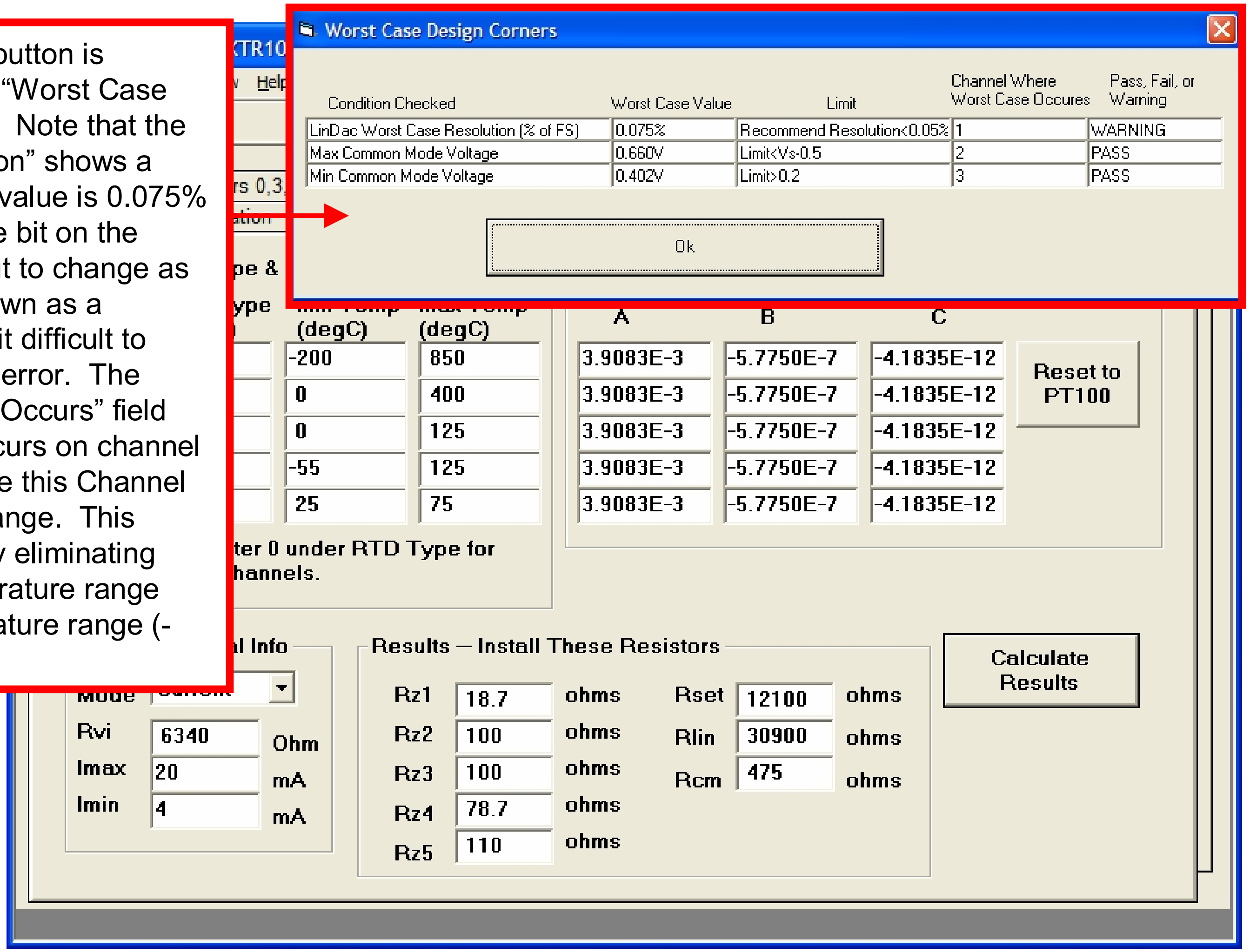
Selecting Components – Find Resistors



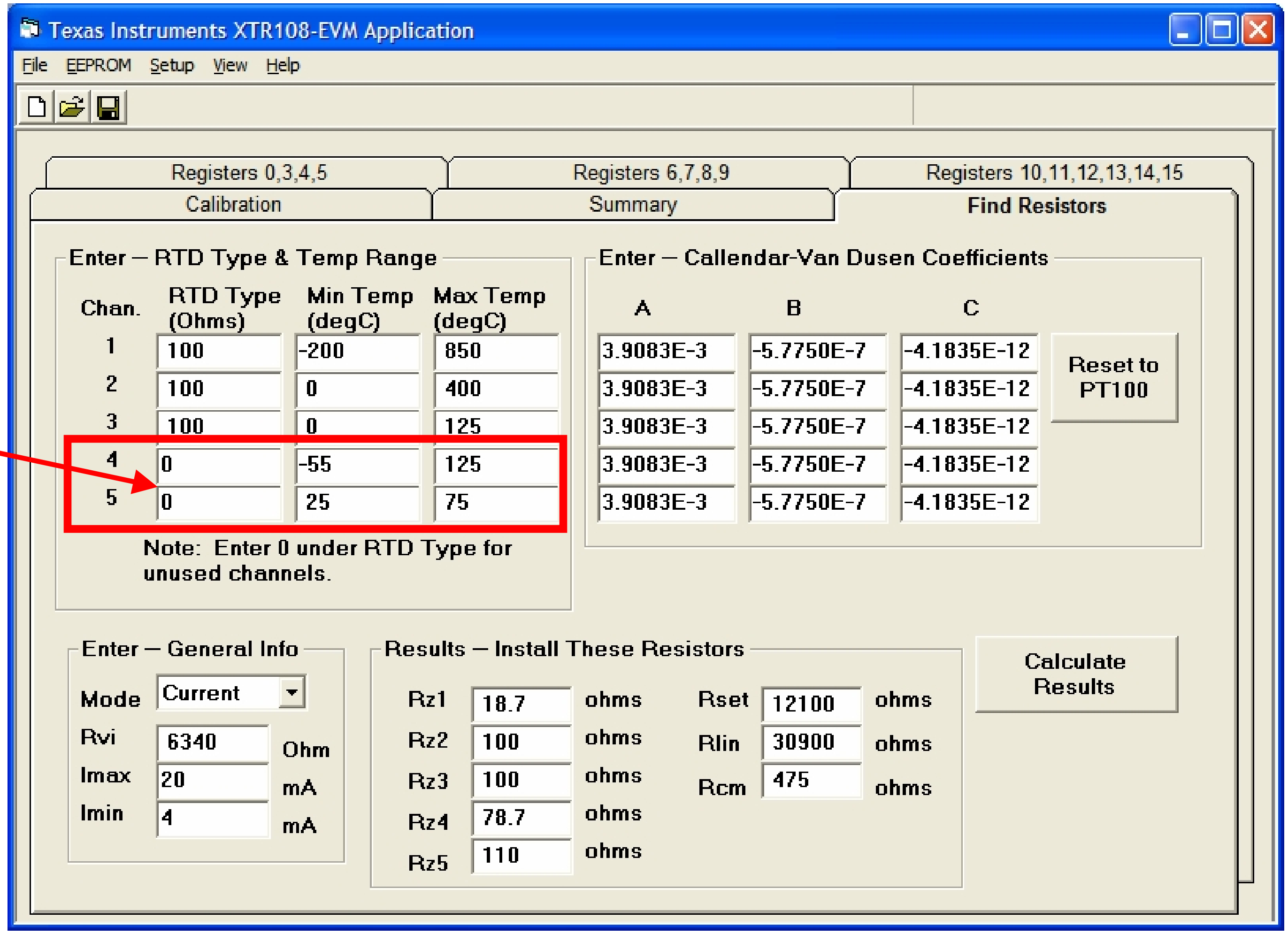
After the "Calculate Results" button is pressed, the resistors that will work for your temperature ranges and RTD types are calculated.

Selecting Components – Find Resistors

After the “Calculate Results” button is pressed, this summary of the “Worst Case Design Corners” is displayed. Note that the “LinDac Worst Case Resolution” shows a warning in this example. The value is 0.075% indicates that a change of one bit on the LinDac could cause the output to change as much as 0.075%. This is shown as a warning because it will make it difficult to attain a 0.1% post calibration error. The “Channel Where Worst Case Occurs” field indicates that the problem occurs on channel 1. This makes sense because this Channel has the widest temperature range. This problem can be moderated by eliminating either the most narrow temperature range (25, 75) or the widest temperature range (-200, 850).

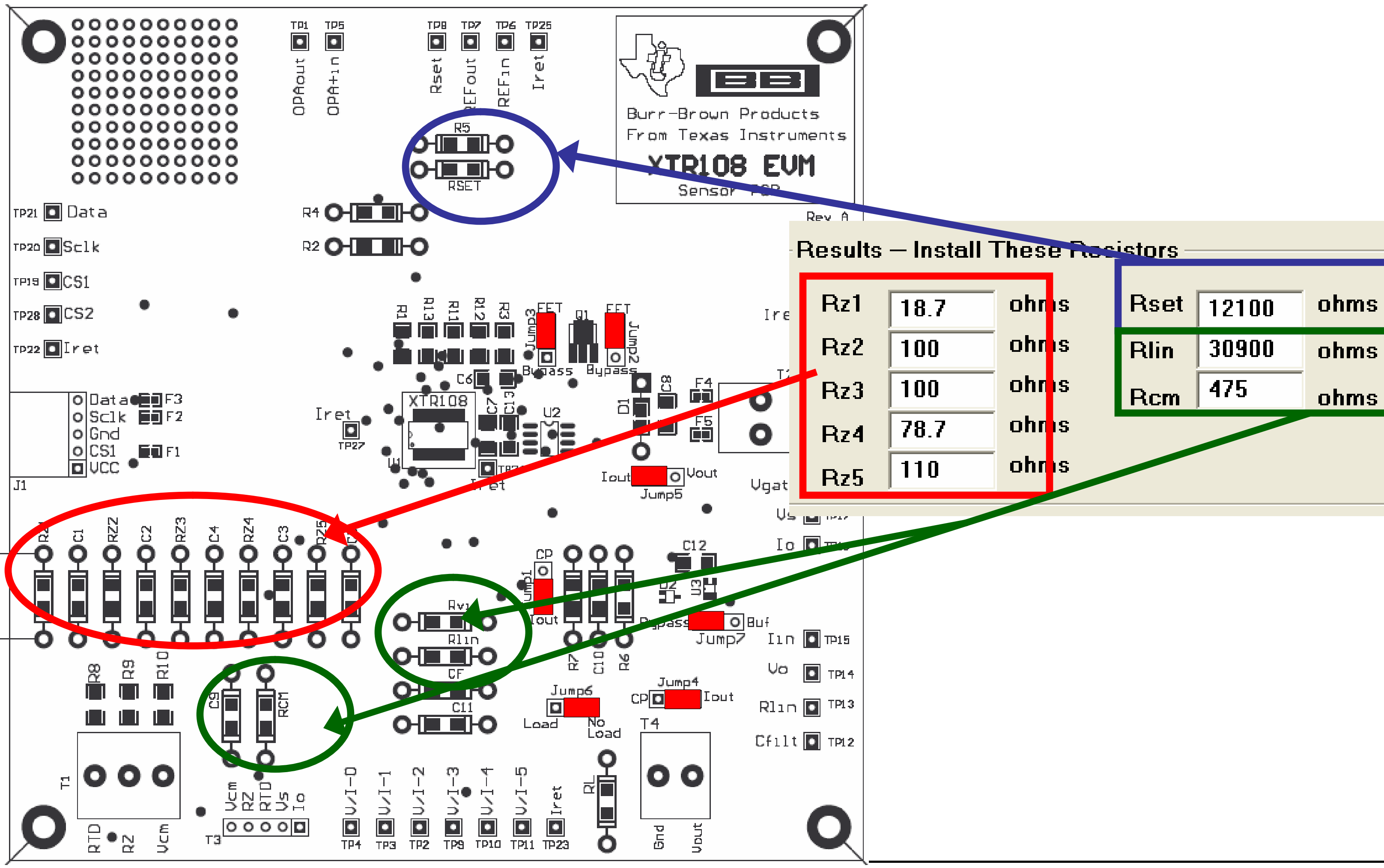


Selecting Components – Find Resistors



In some cases, you may not want to use all of the channels available on the XTR108. In this case, you can enter 0 for the RTD Type. This will disable the channel.

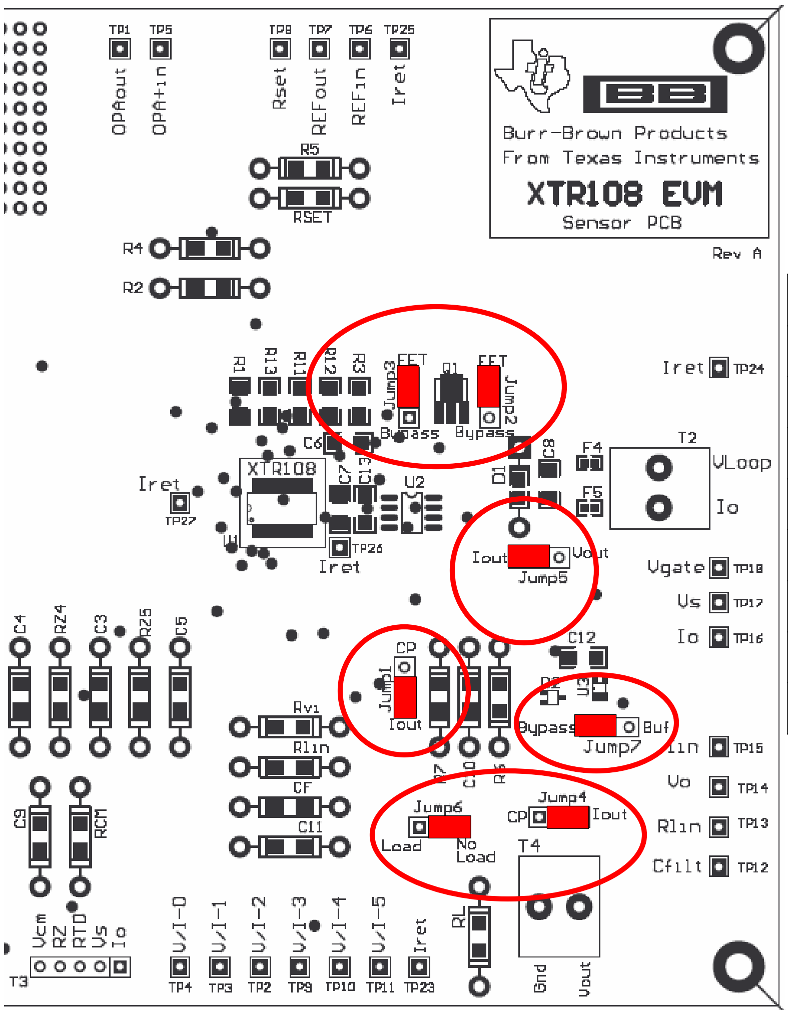
Install The Resistors



Install The Resistors

The figure below shows a typical component footprint on the XTR108 Sensor Board. The footprint is a surface mount resistor inside of a through hole resistor. The through hole resistor pads have “pin sockets” installed in them to allow easy replacement of the resistors. The pin sockets have gold plated springs internally that provide excellent contact with the resistor leads. The XTR108 EVM has surface mount resistors installed for a typical PT100 application. If you want to change the configuration, de-solder these surface mount resistors and connect the through hole resistors via the pin sockets.

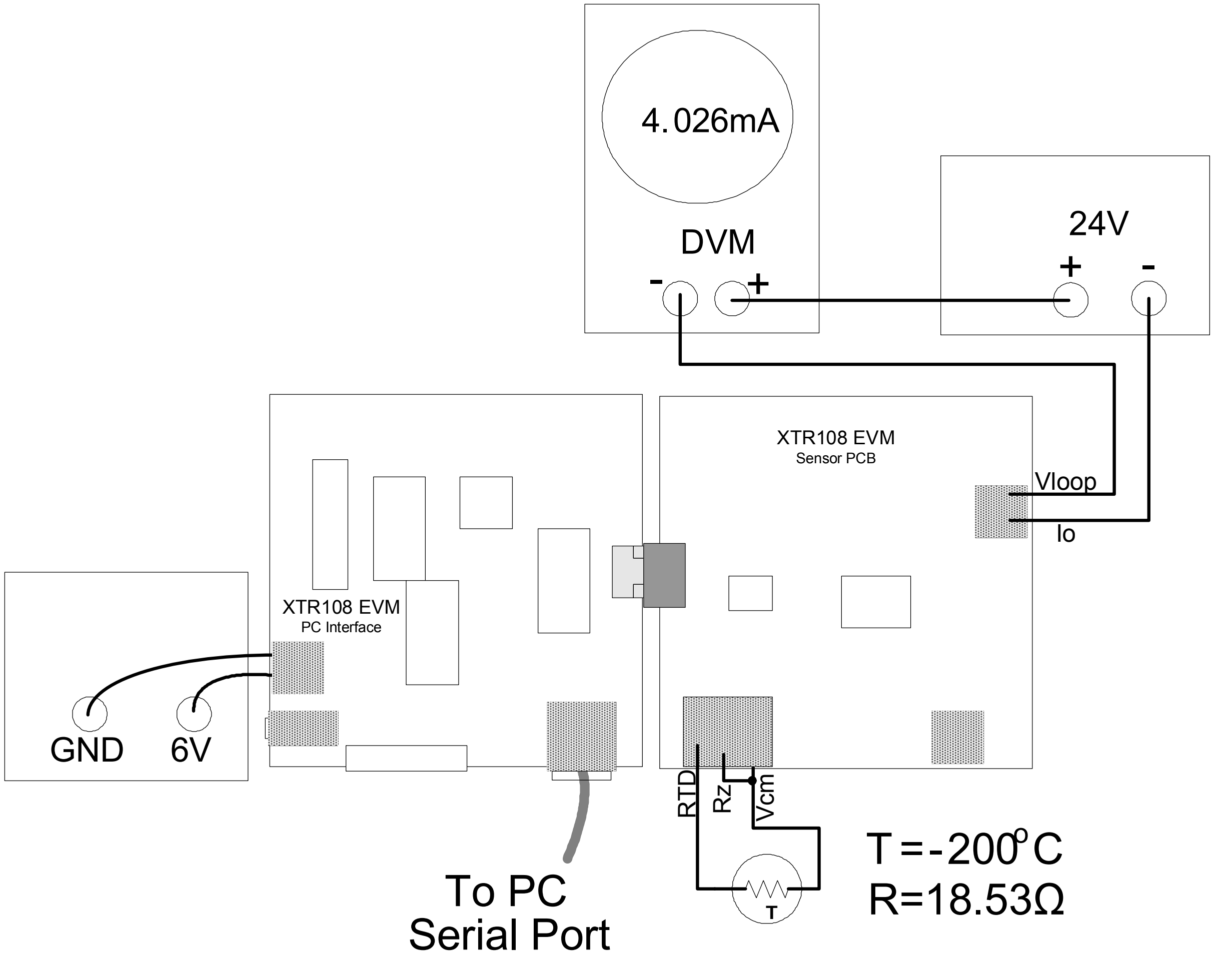
Set the Jumpers



The table below and the figure illustrate the jumper settings for current output mode calibration.

XTR108 Sensor Interface Board – Factory Jumper Settings		
Jumper	**Position**	
JUMP1	Iout	Use current output mode
JUMP2	FET	Use FET Subregulator
JUMP3	FET	Use FET Subregulator
JUMP4	Iout	Use current output mode
JUMP5	Iout	Use current output mode
JUMP6	No Load	Do not connect load to Voltage Output
JUMP7	Bypass	Bypass Voltage Mode Charge Pump

Connect the power

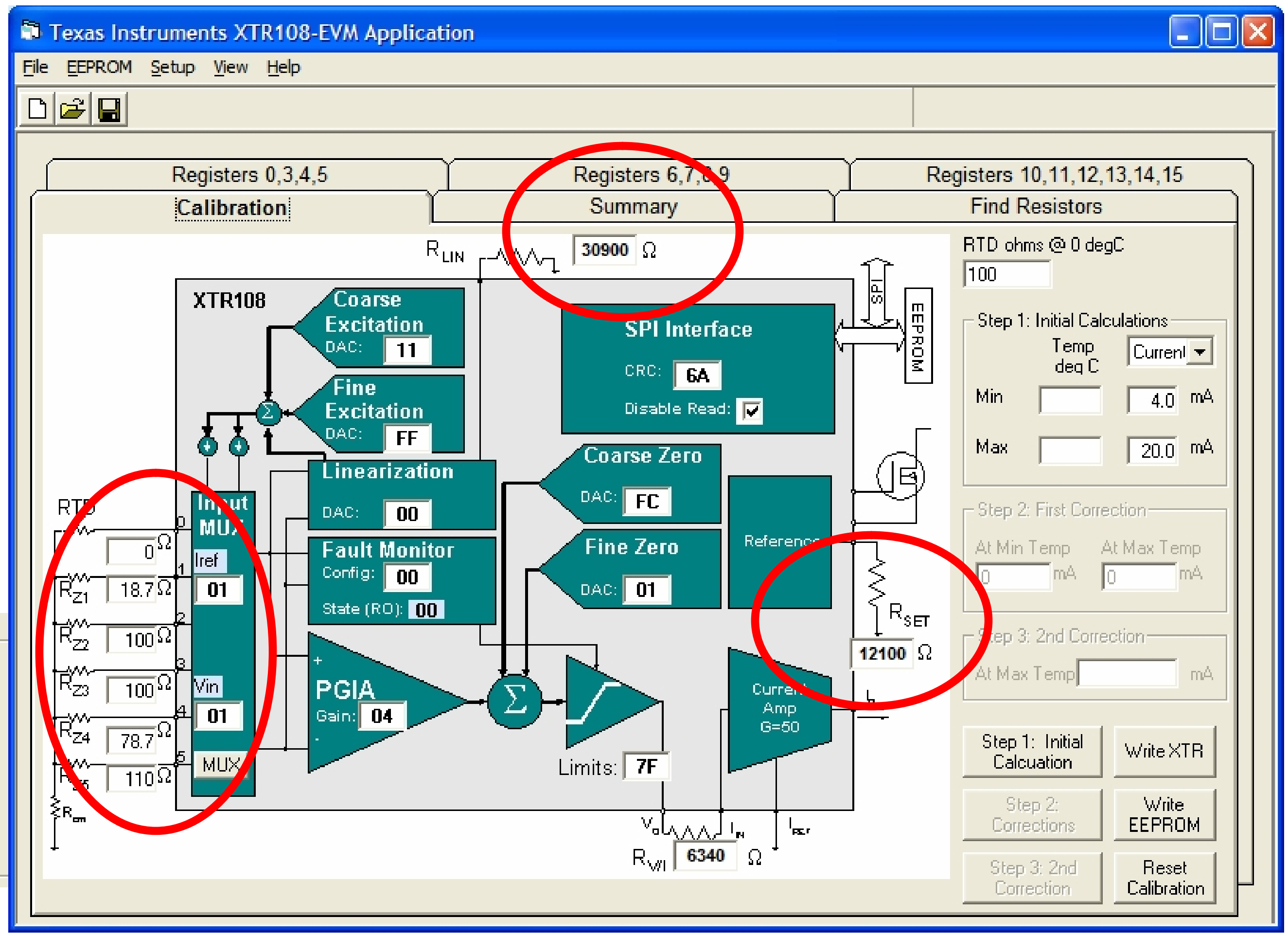


Example Calibration: Step by Step Calibration
Enter The Resistor Values

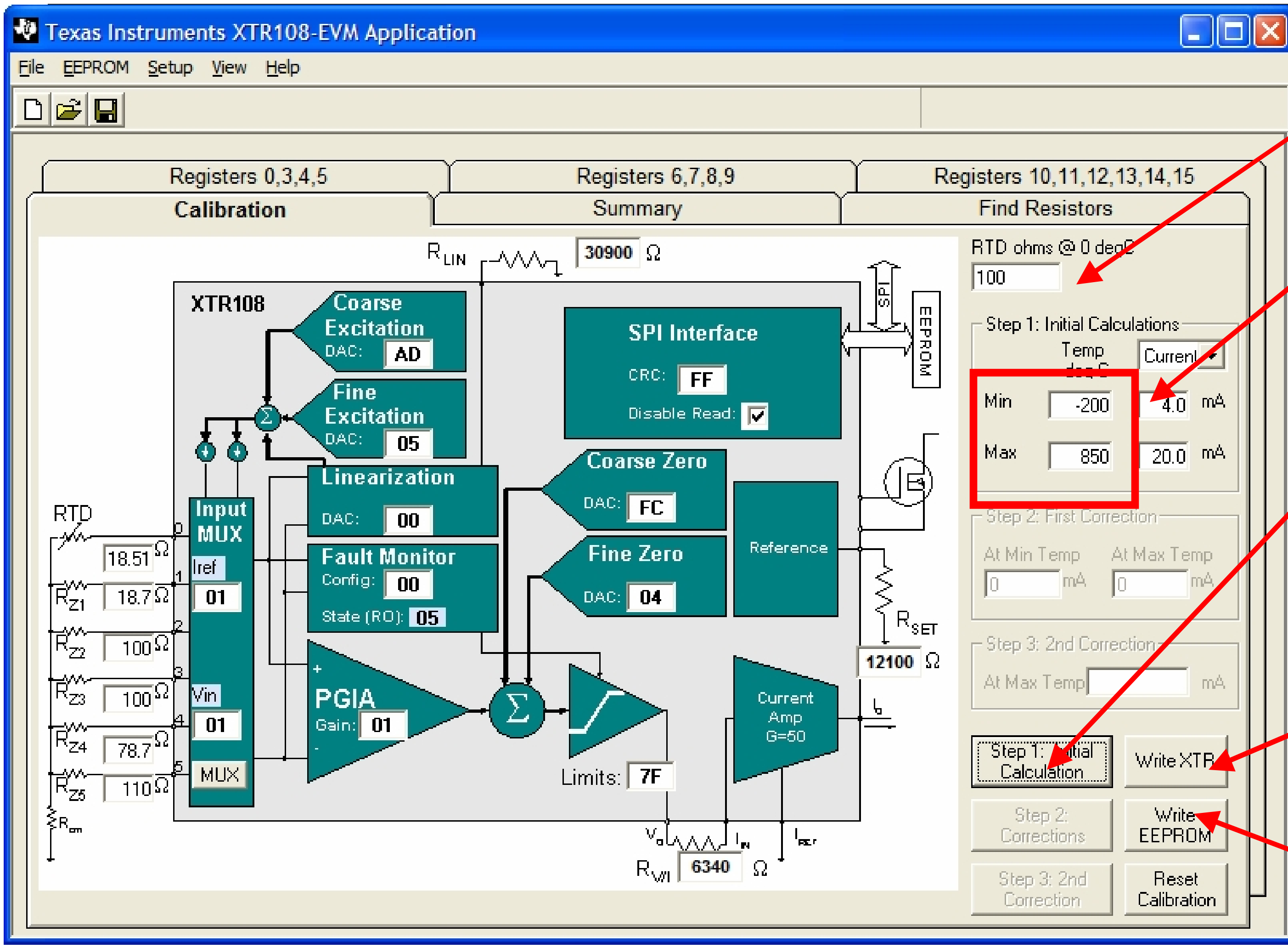
Note that the values of the resistors computed in the find resistors tab are automatically copied to the calibration tab. Resistors can be entered manually if you are not using the Find Resistors feature.

Results – Install These Resistors

Rz1	18.7	ohms	Rset	12100	ohms
Rz2	100	ohms	Rlin	30900	ohms
Rz3	100	ohms	Rcm	475	ohms
Rz4	78.7	ohms			
Rz5	110	ohms			



Example Calibration: Enter the temperature range and Press “Step1: Initial Calculation”.



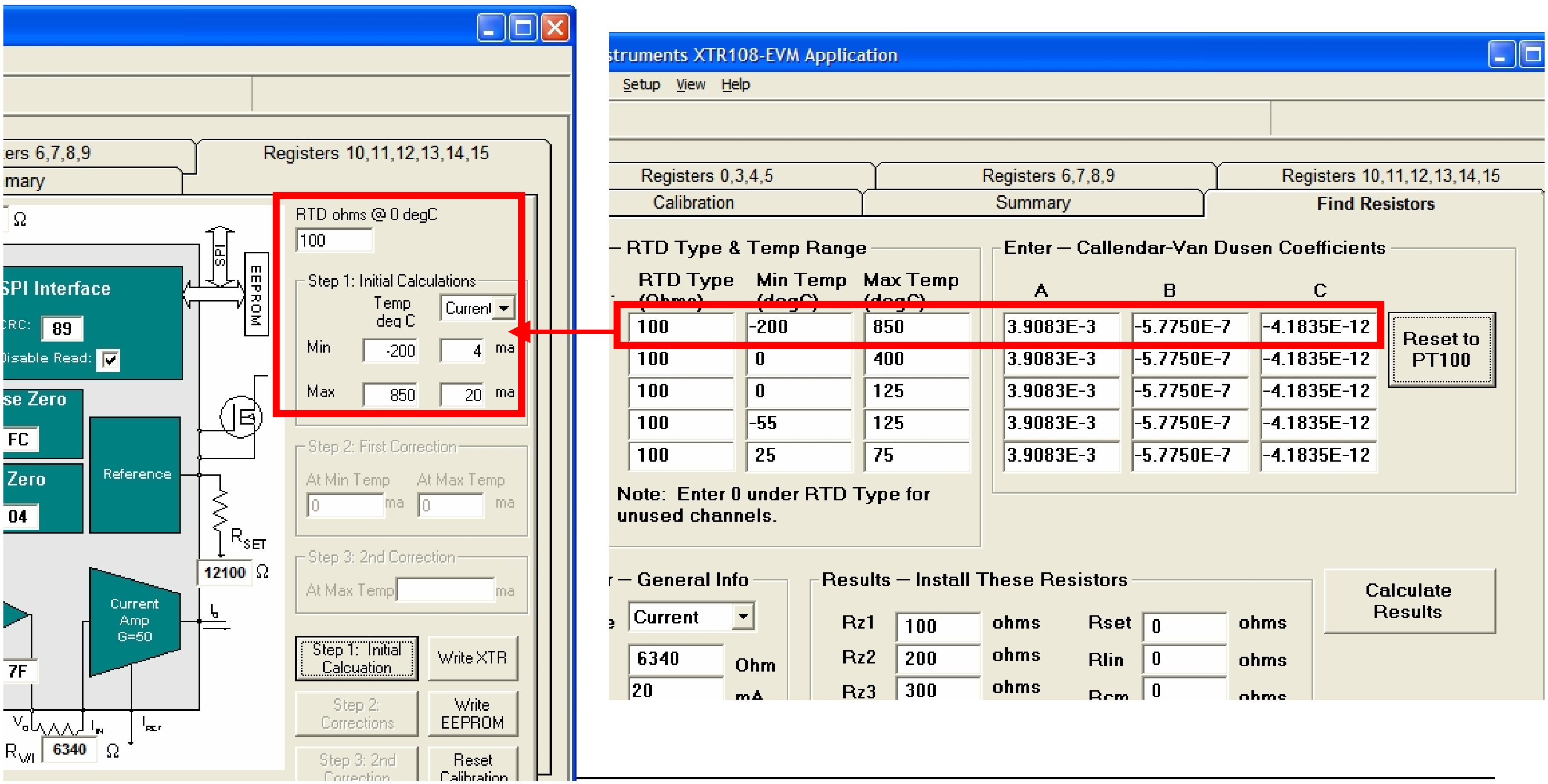
Enter the RTD resistance at 0 degC.

Enter the temperature range that you want to calibrate over.

Press “Step 1: Initial Calculation”. This will calculate register values for the XTR108 (e.g. the MUX channel, gain, Iref).

Press “Write XTR” and “Write EEPROM”. This will copy all the calculated register values into the XTR108 and into the EEPROM.

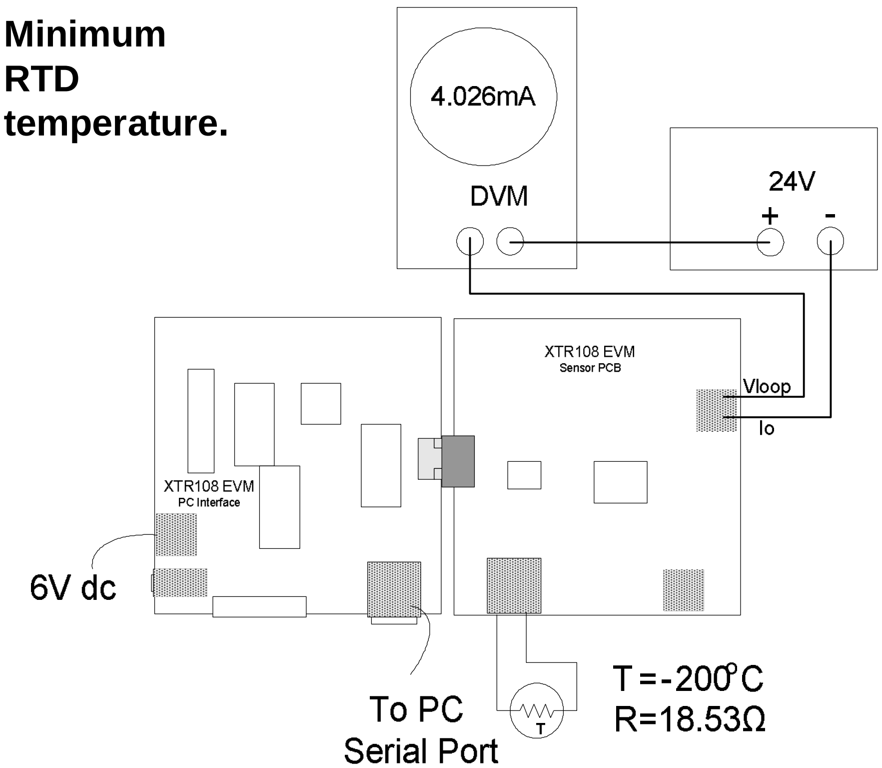
Example Calibration: The Callendar-Van Dusen Coefficients are taken from the table in the “Find Resistors” Tab



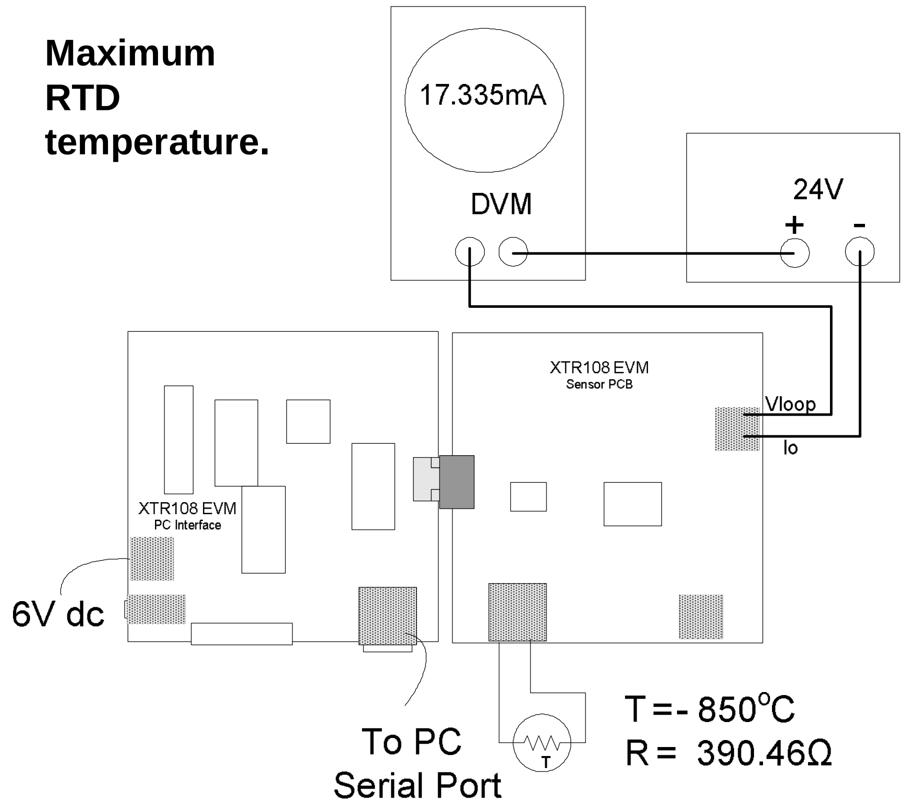
Measure the Output

After the “Step 1: Initial Calculation” results are written into the XTR108, you will need to read the output at minimum and maximum RTD temperature. Note that linearity correction is turned off during this step and so, you should not expect to see an accurate 4mA to 20mA.

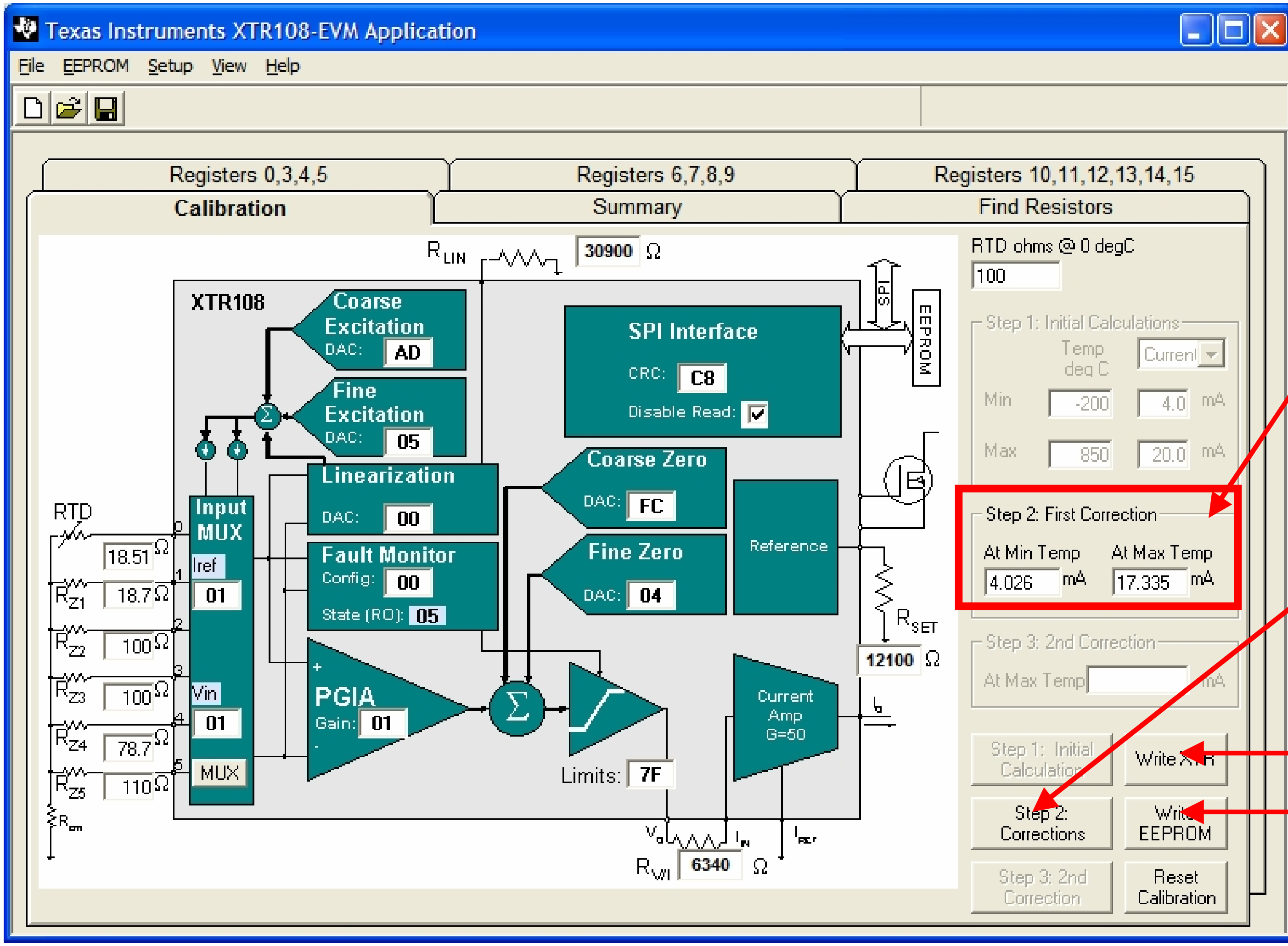
Minimum RTD temperature.



Maximum RTD temperature.



Example Calibration: Enter First Correction

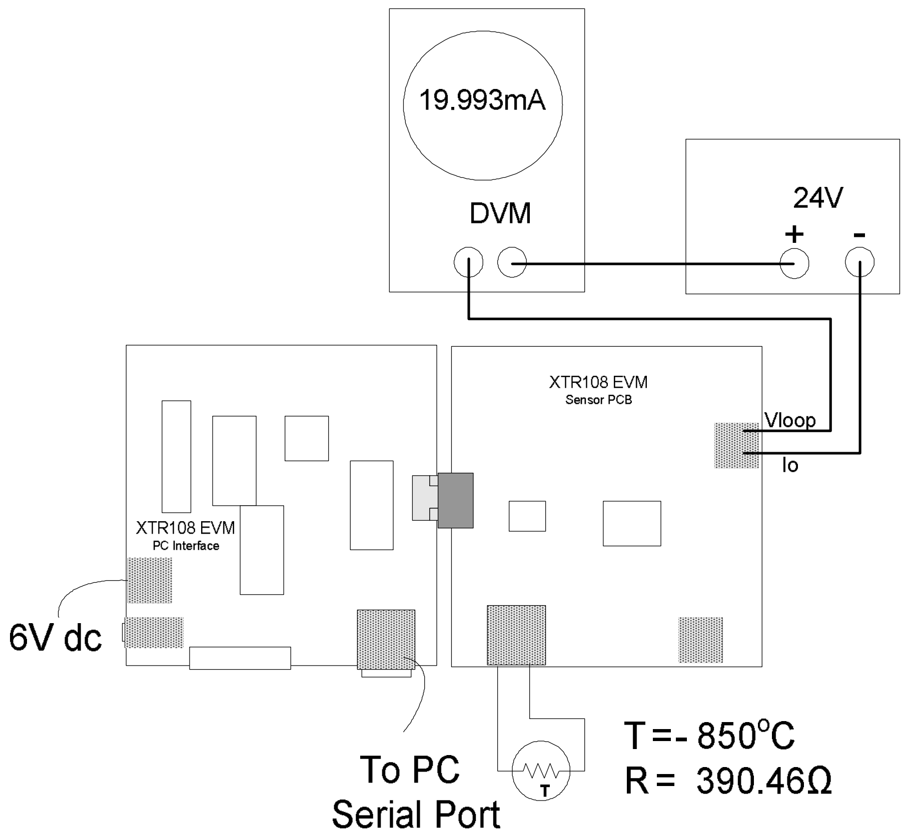


Enter the current measurements at min and max temperature.

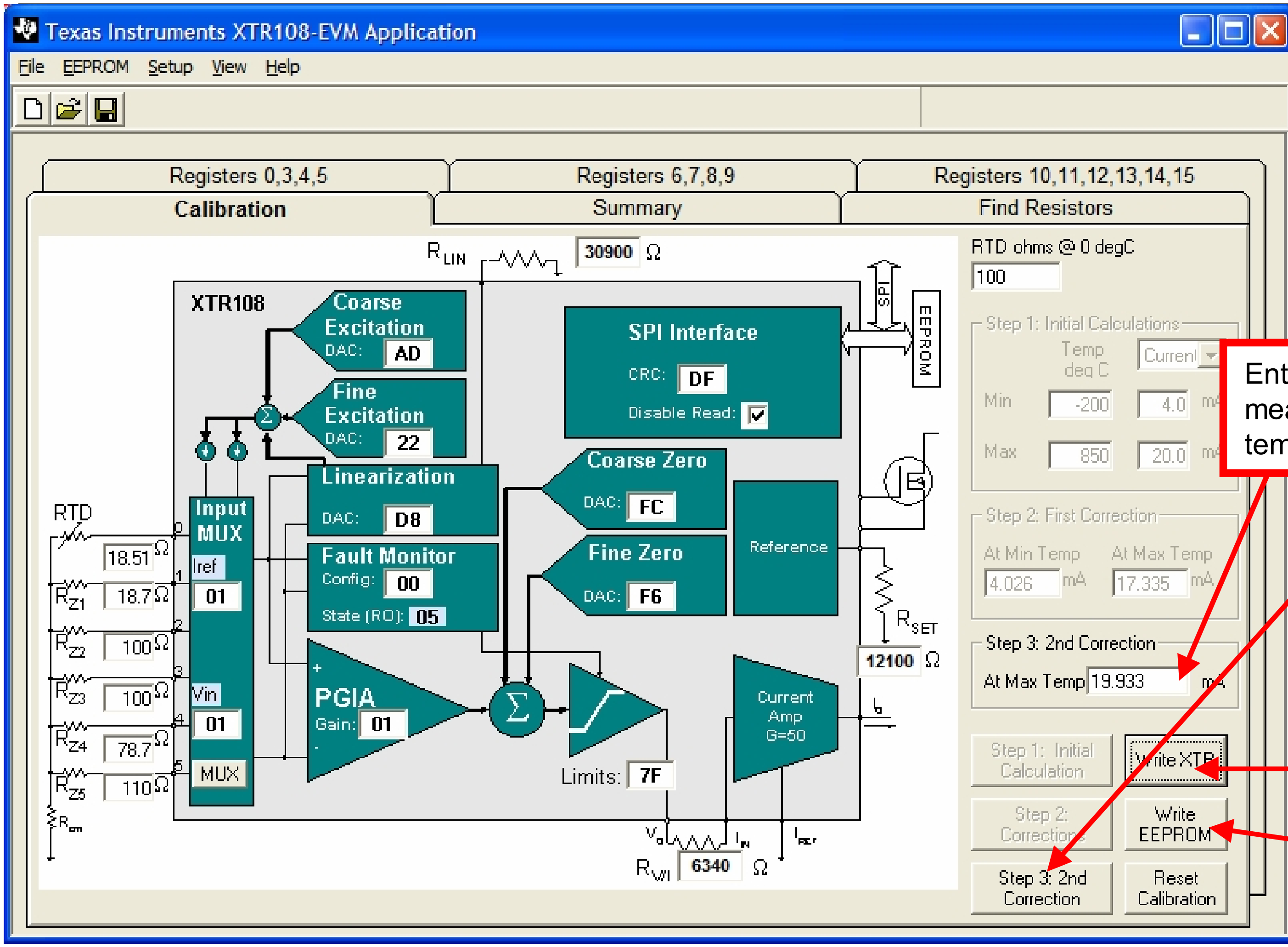
Press "Step 2: Corrections" to calculate minor corrections in the register values.

Press "Write XTR" and "Write EEPROM". This will copy all the calculated register values into the XTR108 and into the EEPROM.

Measure the Output at Full Scale to Correct for Linearity DAC Errors



Measure the Output at Full Scale to Correct for Linearity DAC Errors

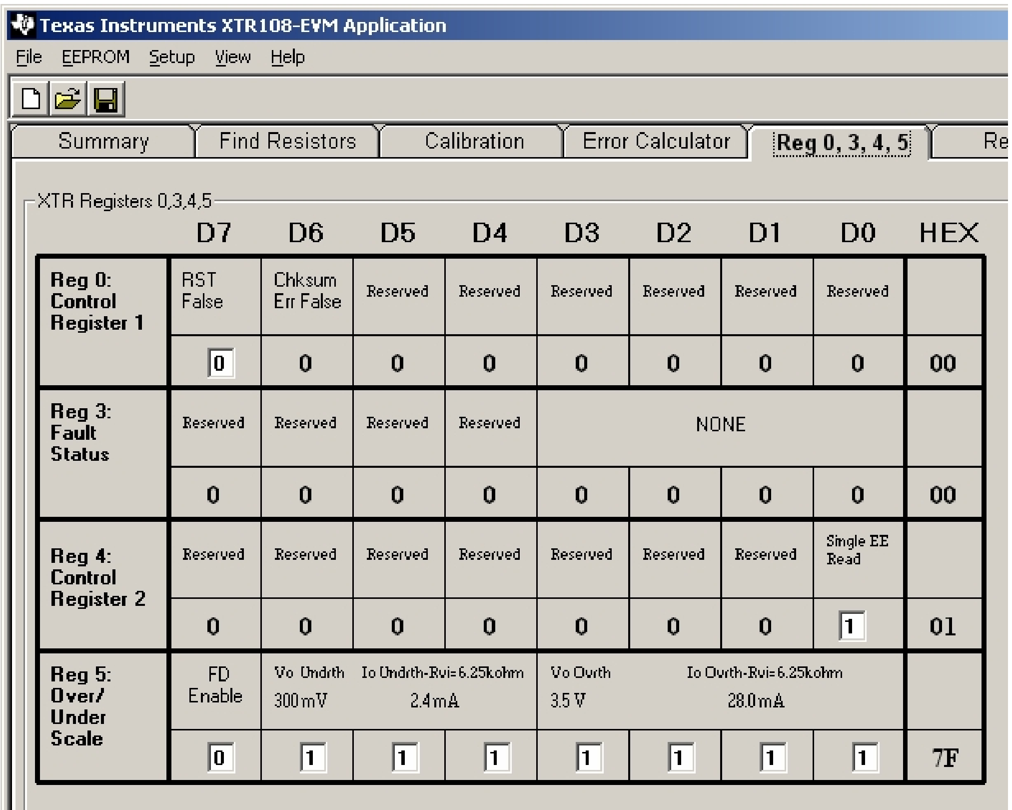


Enter the current measurement at max temperature.

Press “Step 3: 2nd Correction” to calculate the Lin DAC corrections.

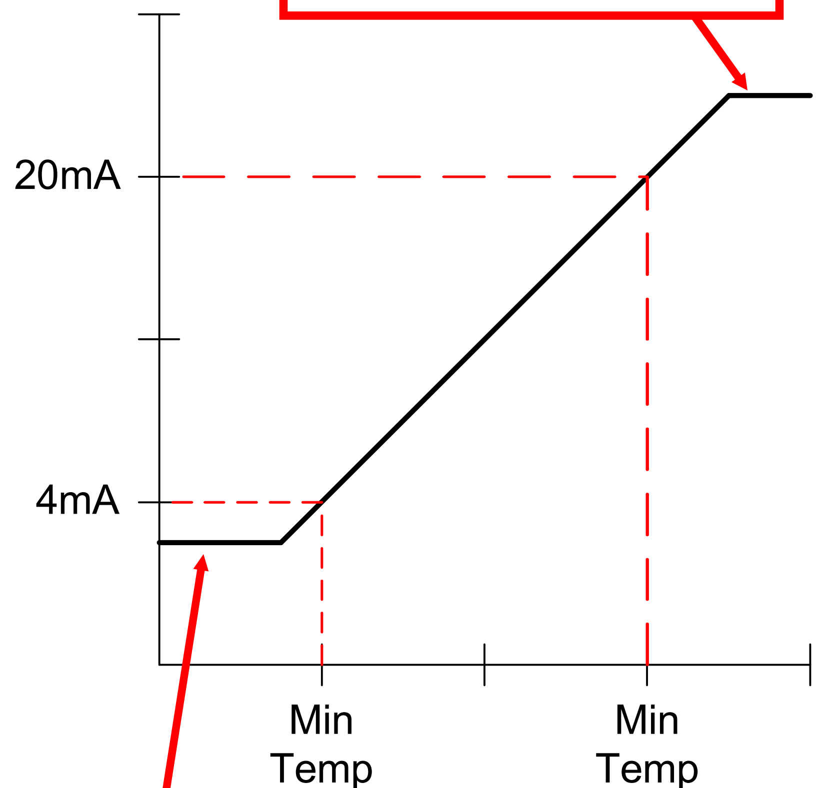
Press “Write XTR” and “Write EEPROM”. This will copy all the calculated register values into the XTR108 and into the EEPROM.

Calibrating the Over/Under Scale



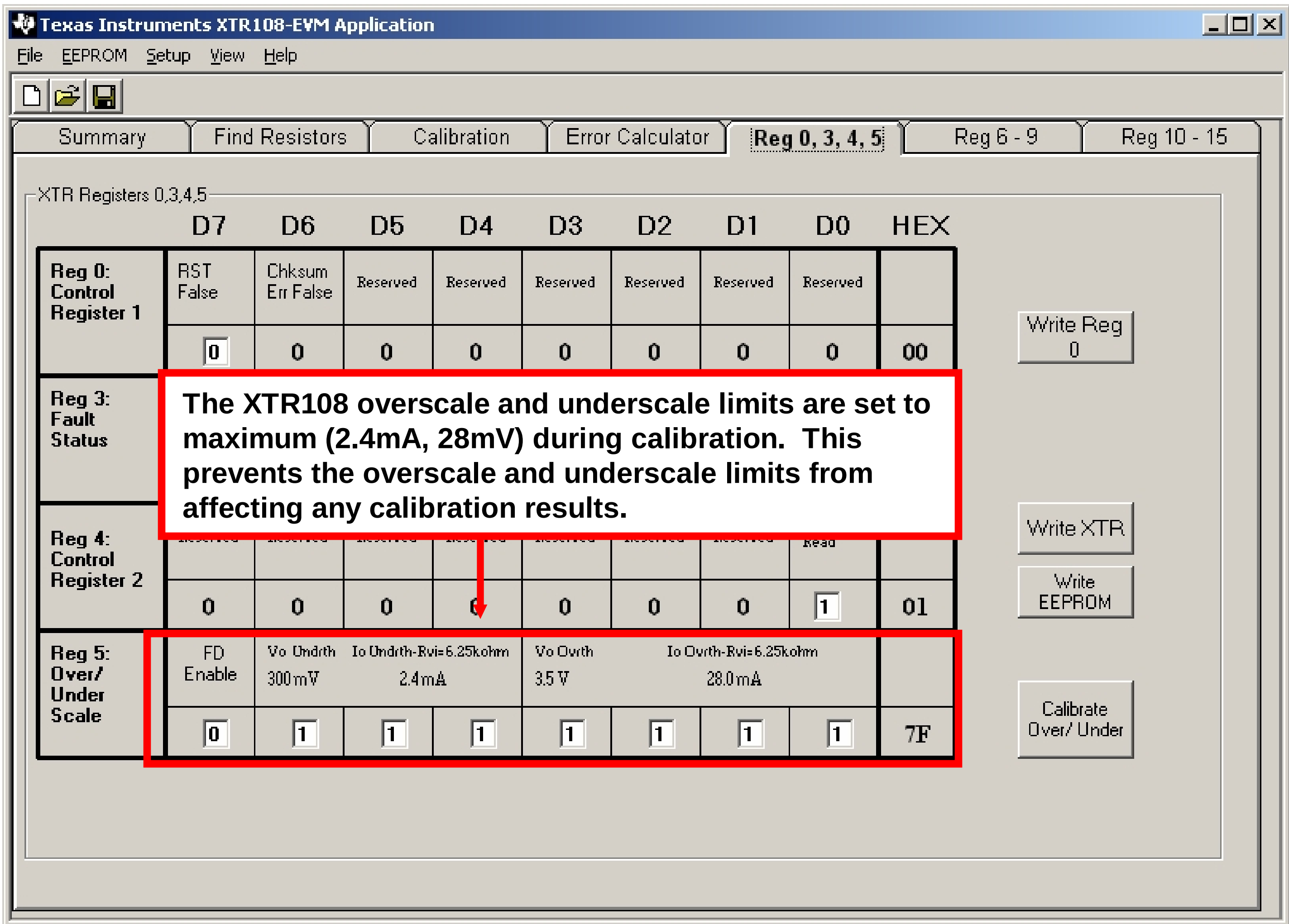
The underscale, and overscale is a programmable limit for the min and maximum value of the XTR108.

Overscale = 28mA

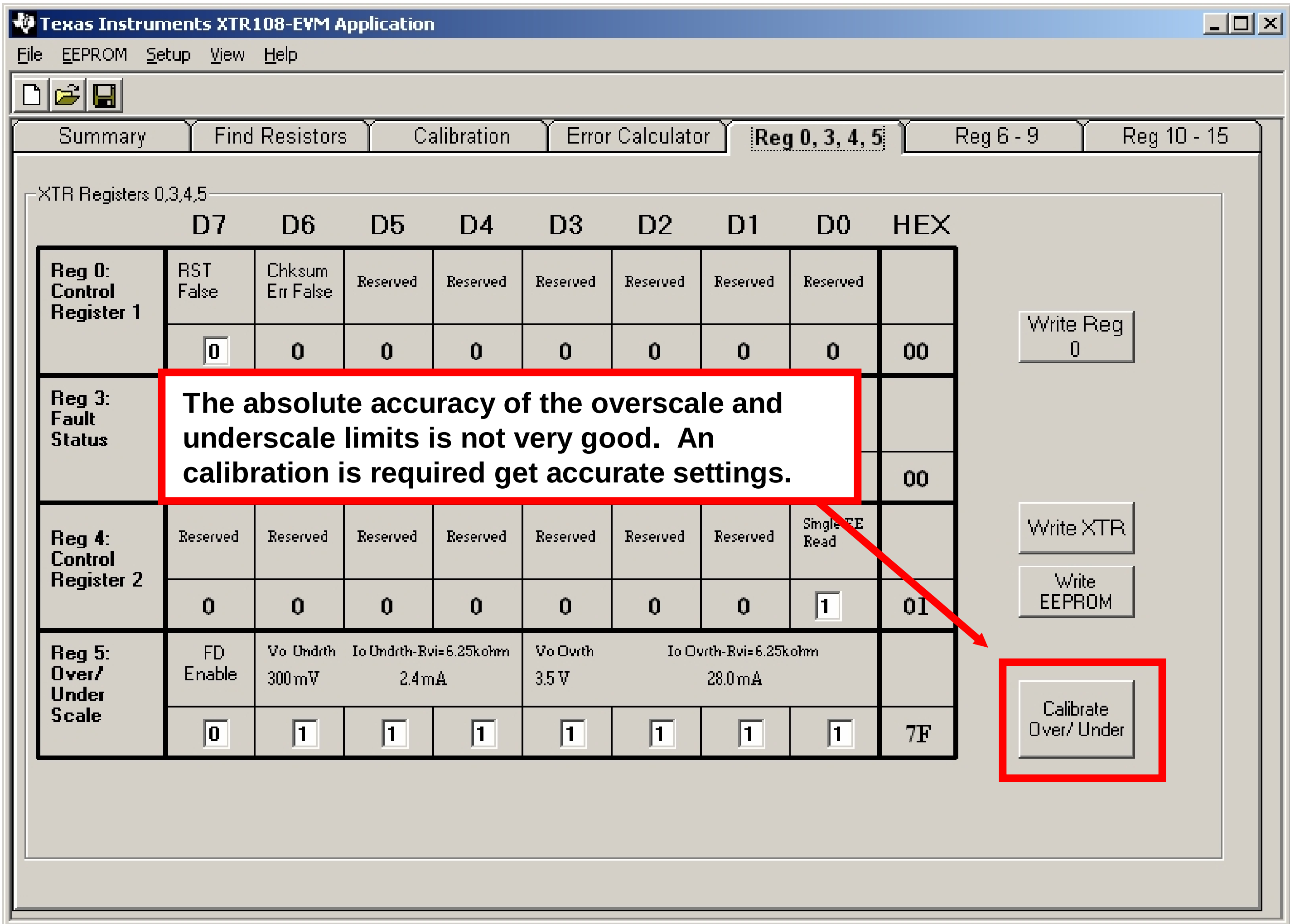


Underscale = 2.4mA

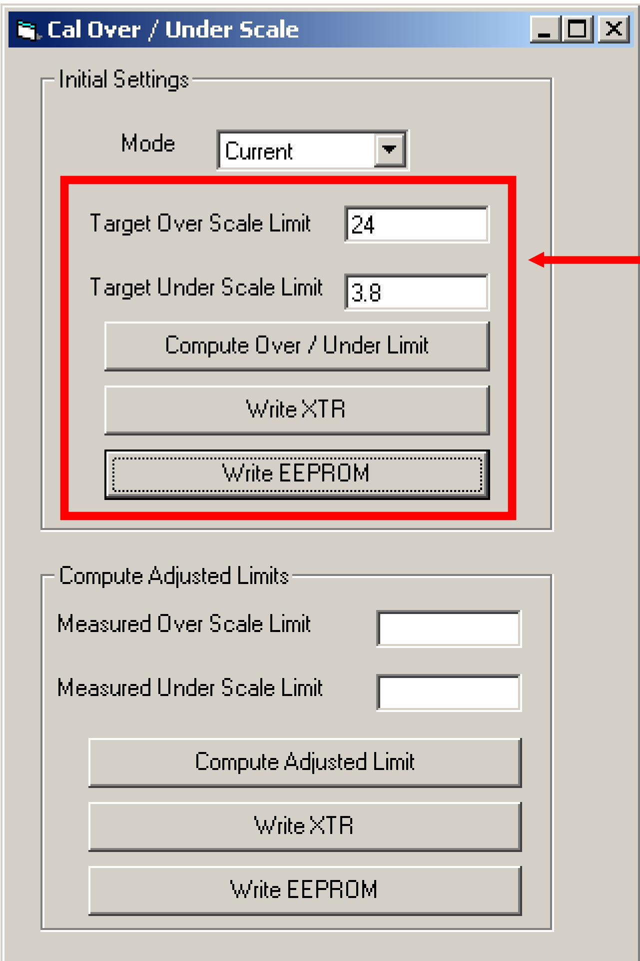
Calibrating the Over/Under Scale

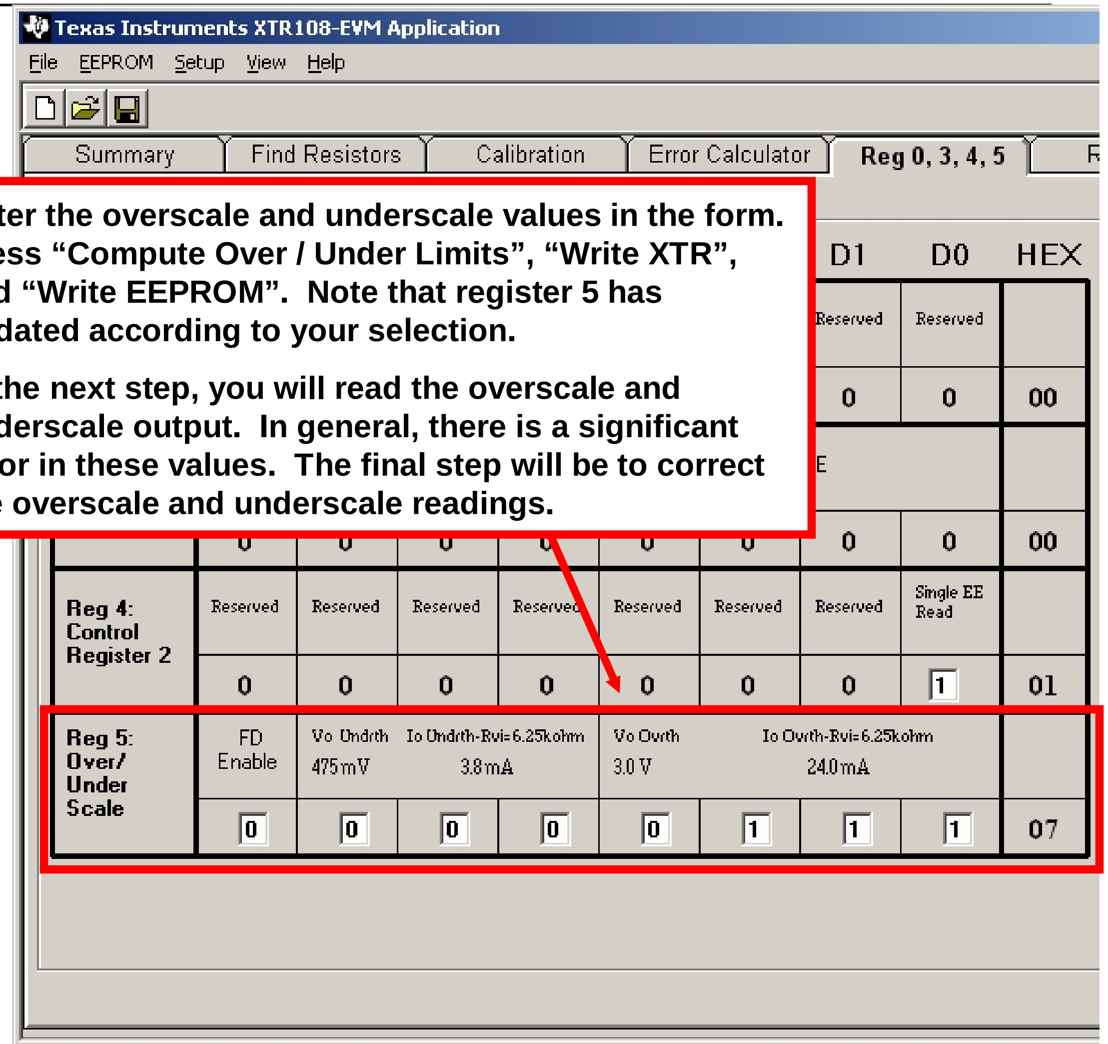


Calibrating the Over/Under Scale



Calibrating the Over/Under Scale



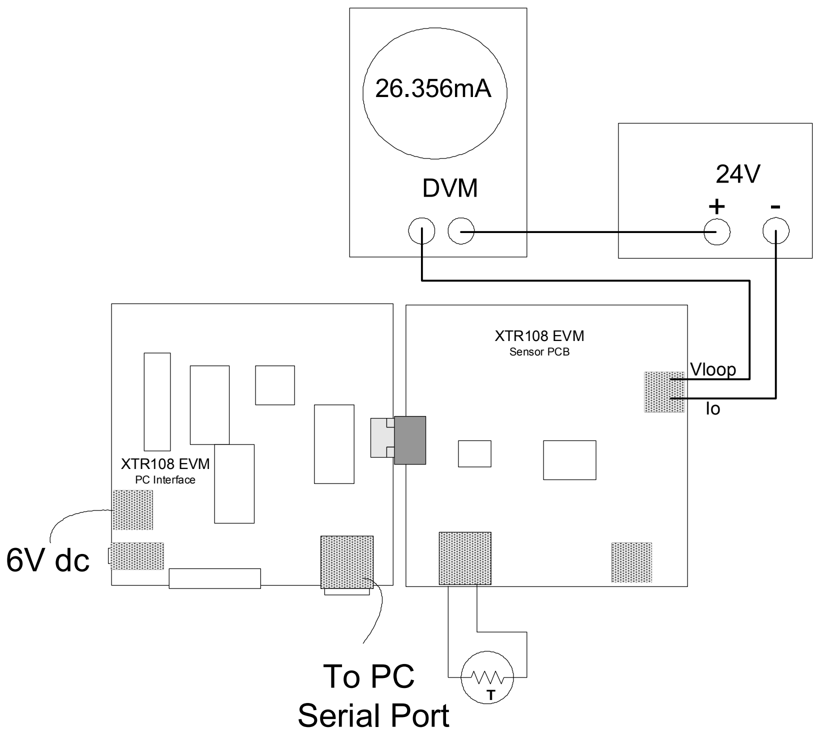


Enter the overscale and underscale values in the form. Press "Compute Over / Under Limits", "Write XTR", and "Write EEPROM". Note that register 5 has updated according to your selection.

In the next step, you will read the overscale and underscale output. In general, there is a significant error in these values. The final step will be to correct the overscale and underscale readings.

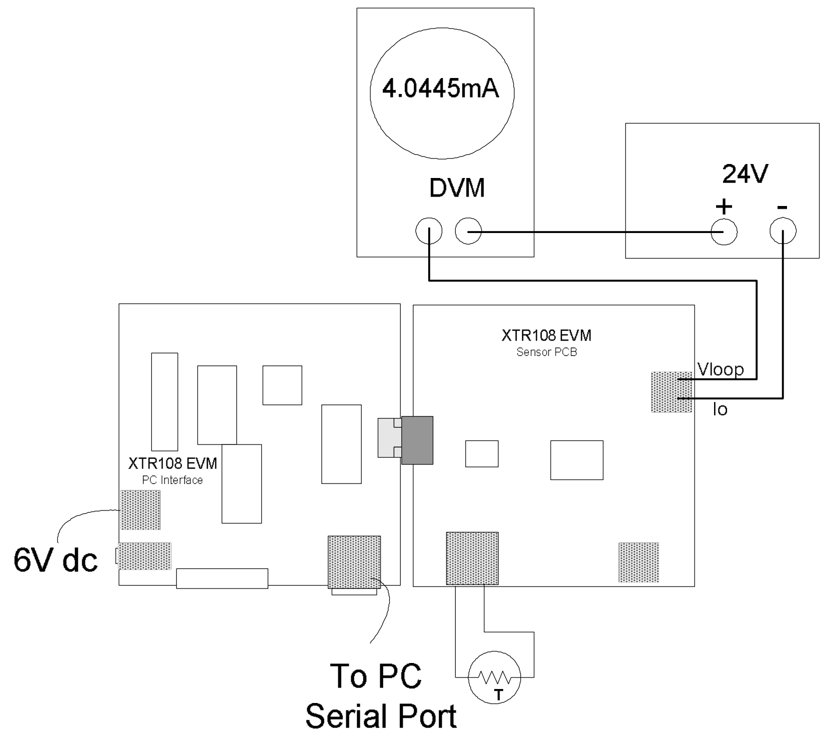
Calibrating the Over/Under Scale

Read Overscale



Set RTD to Overscale Value

Read Underscale



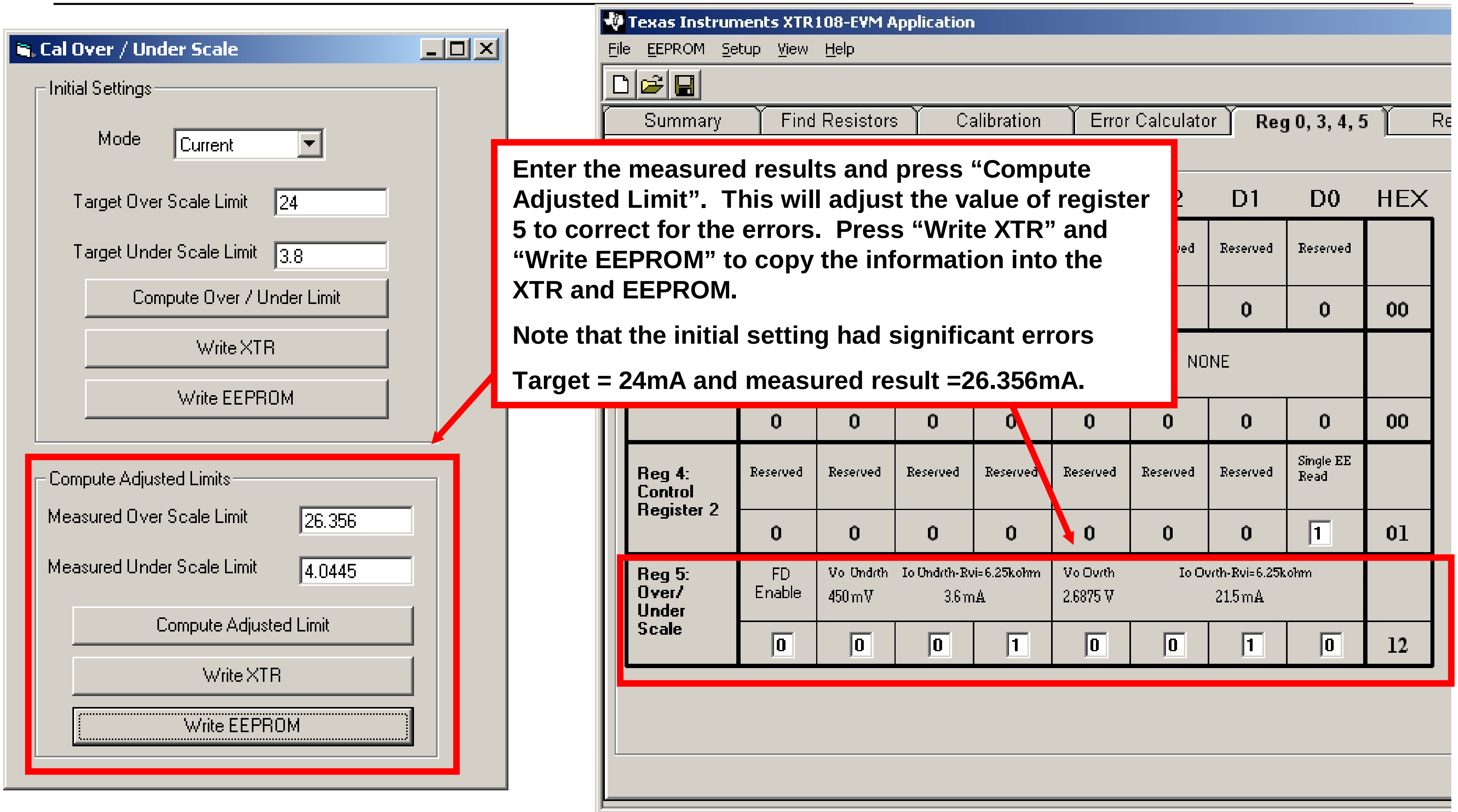
Set RTD to Underscale Value

Calibrating the Over/Under Scale

Enter the measured results and press "Compute Adjusted Limit". This will adjust the value of register 5 to correct for the errors. Press "Write XTR" and "Write EEPROM" to copy the information into the XTR and EEPROM.

Note that the initial setting had significant errors

Target = 24mA and measured result =26.356mA.



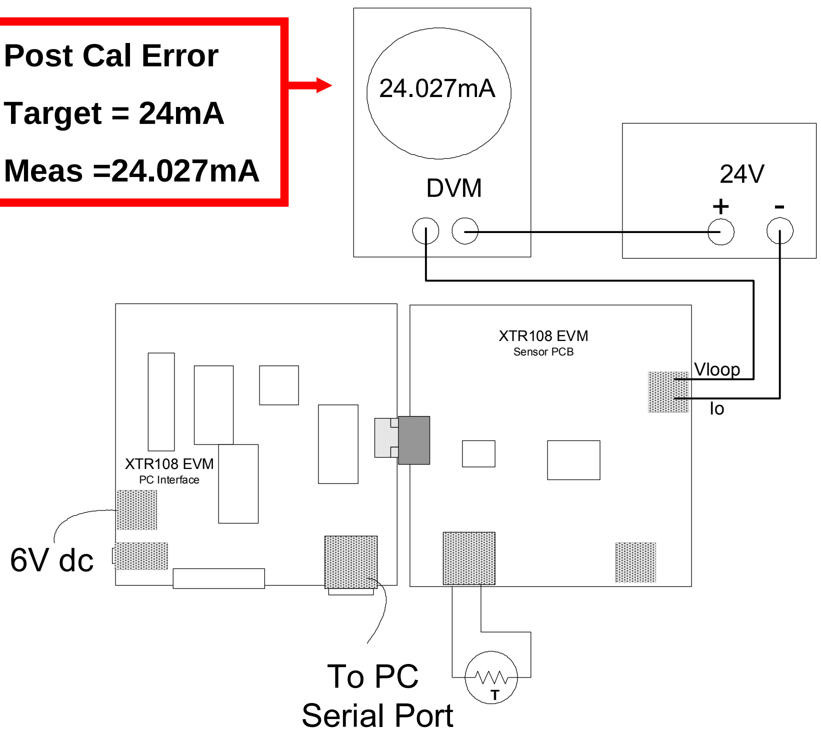
Calibrating the Over/Under Scale

Read Corrected Overscale

Post Cal Error

Target = 24mA

Meas =24.027mA



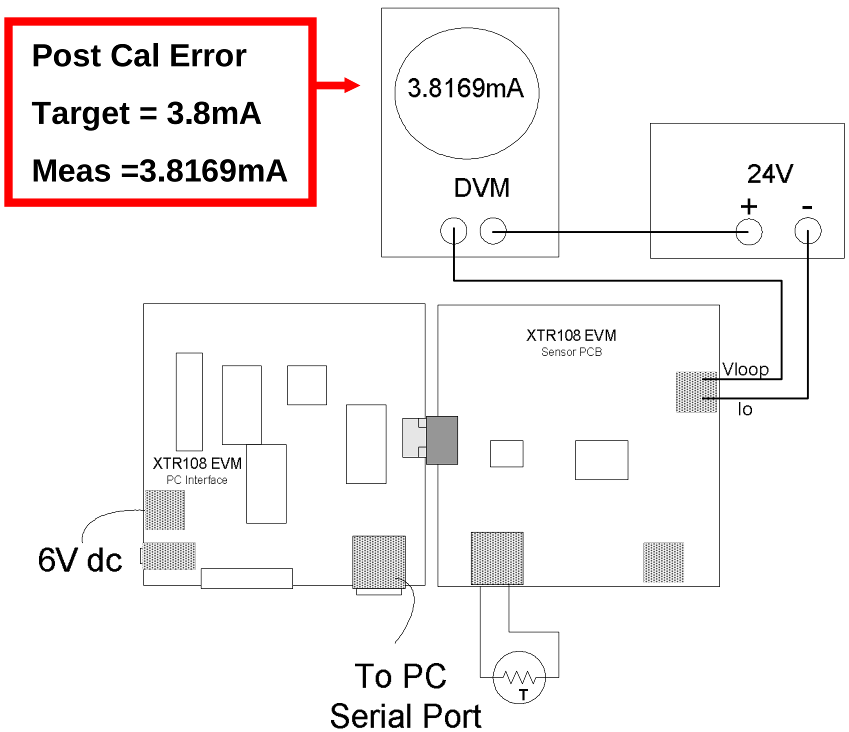
Set RTD to Overscale Value

Read Corrected Underscale

Post Cal Error

Target = 3.8mA

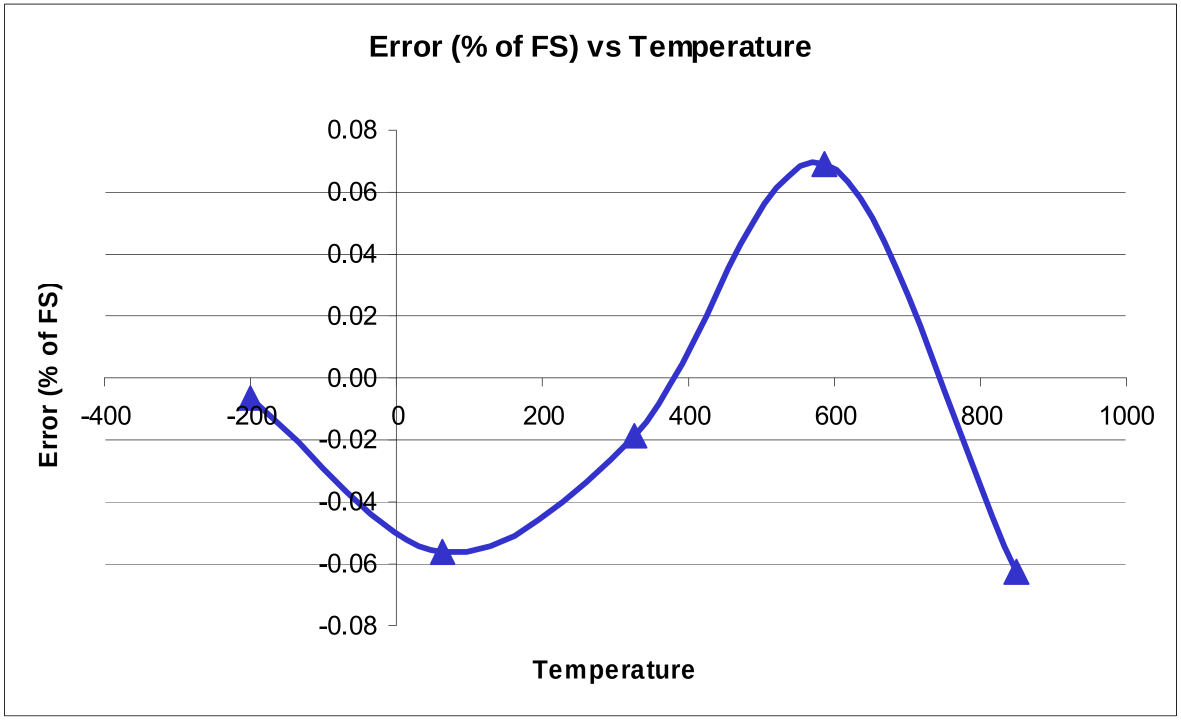
Meas =3.8169mA



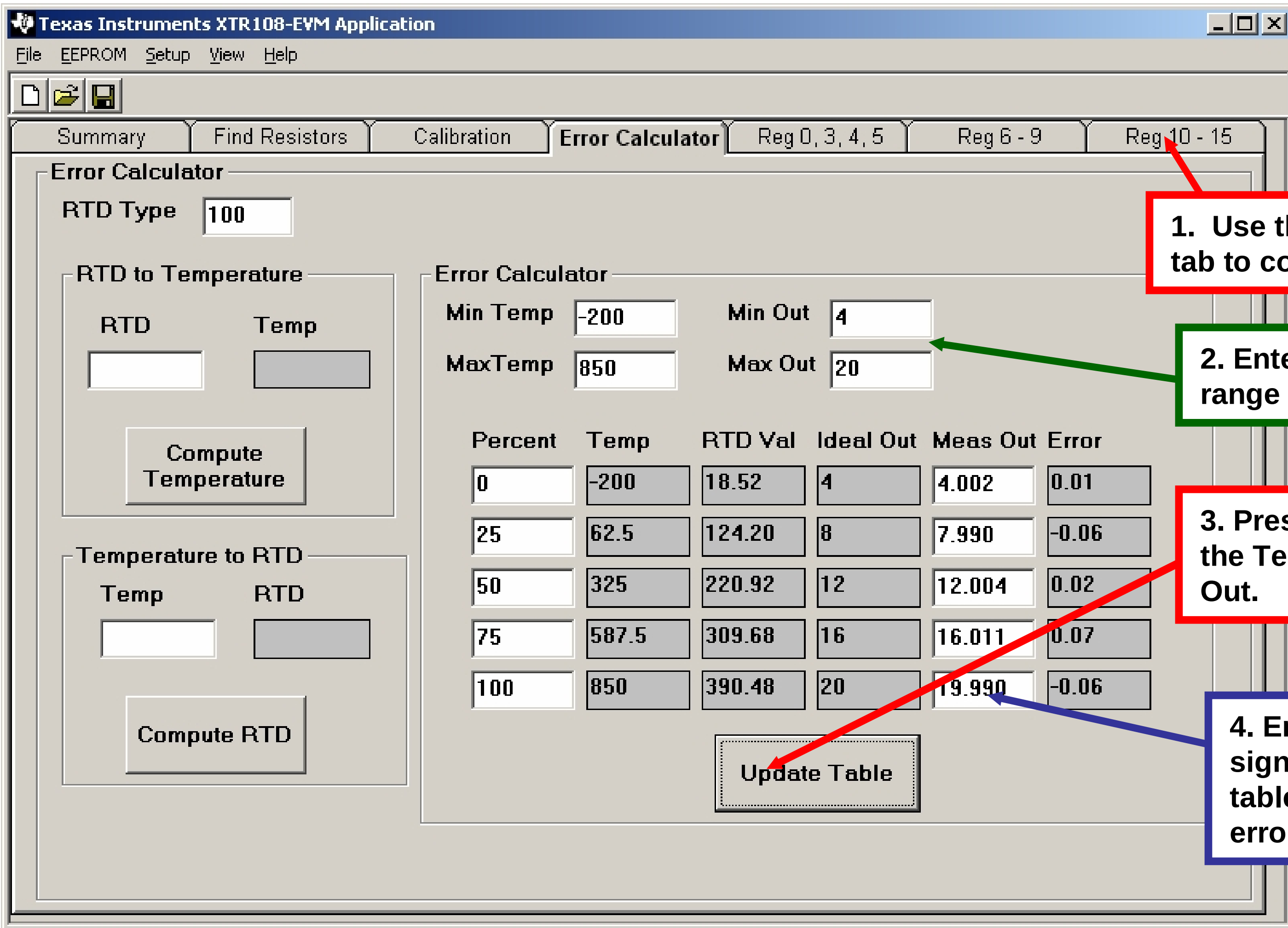
Set RTD to Underscale Value

Example Calibration Done: Post Calibration Error is less then 0.1%

Temp	I_meas	I_ideal	error (%)
-200	4.00	4.00	-0.01
62.5	7.99	8.00	-0.06
325	12.00	12.00	-0.02
587.5	16.01	16.00	0.07
850	19.99	20.00	-0.06



Example Calibration Done: Post Calibration Error is less then 0.1%



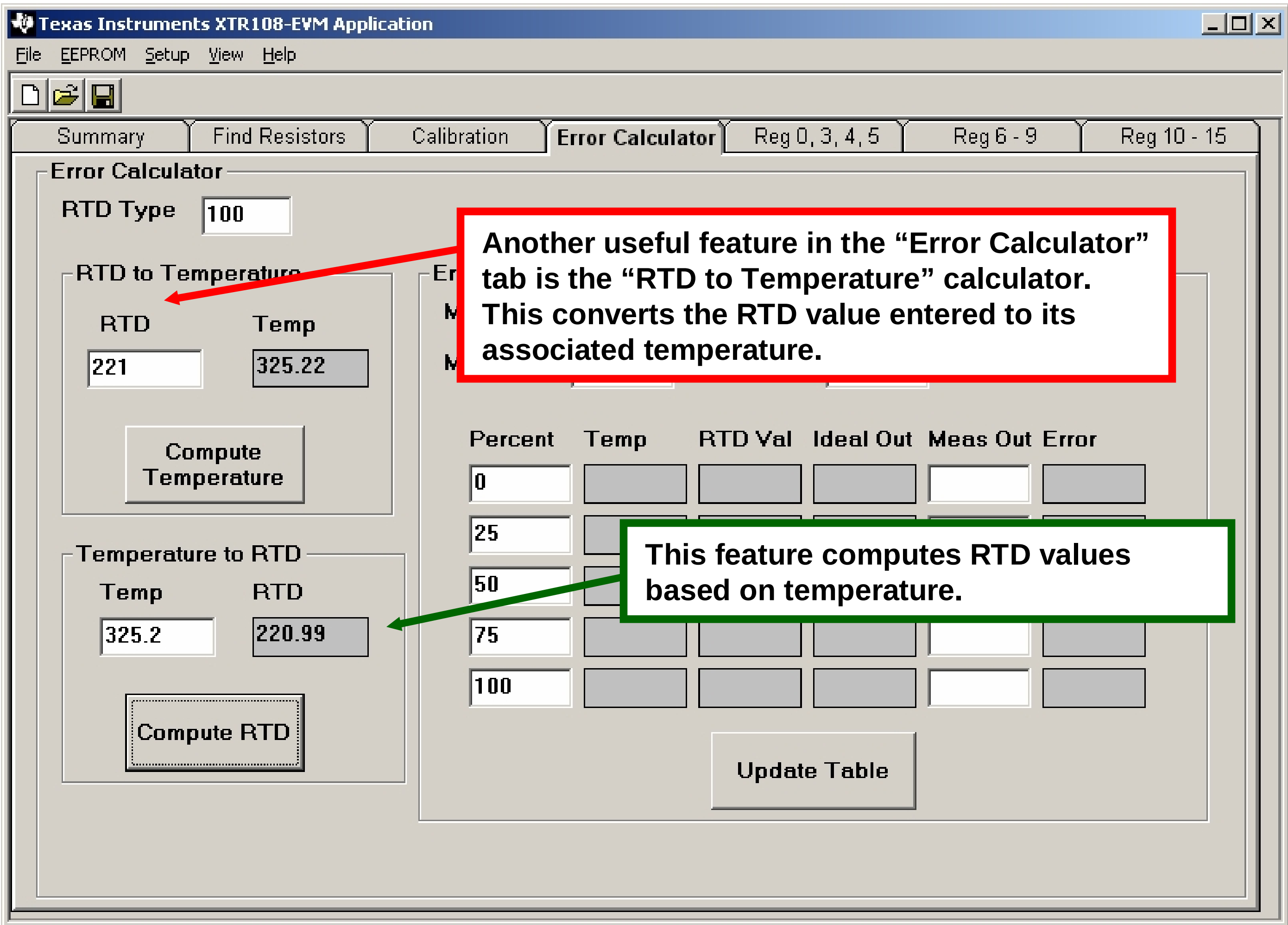
1. Use the "RTD calculator" tab to compute the error.

2. Enter the temperature range and the output range.

3. Press Update table to fill in the Temp, RTD Val, and Ideal Out.

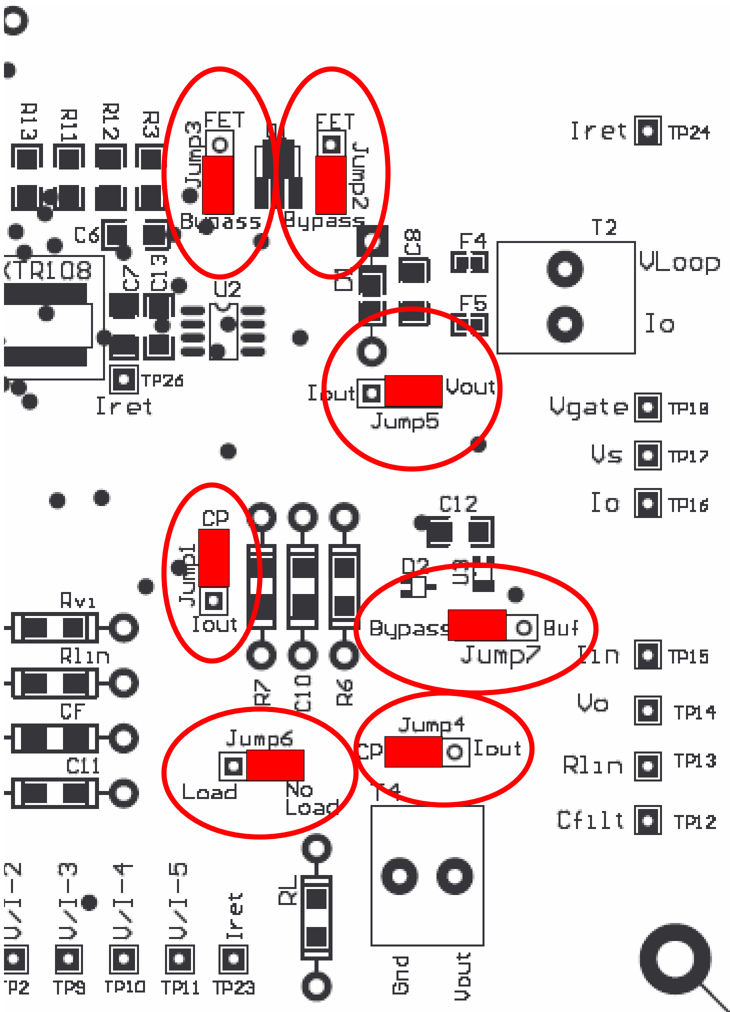
4. Enter the measured output signal and press update table. This will compute the error.

Example Calibration Done: Post Calibration Error is less then 0.1%



Voltage Output Mode Calibration Example

Voltage Output Mode
Set the Jumpers

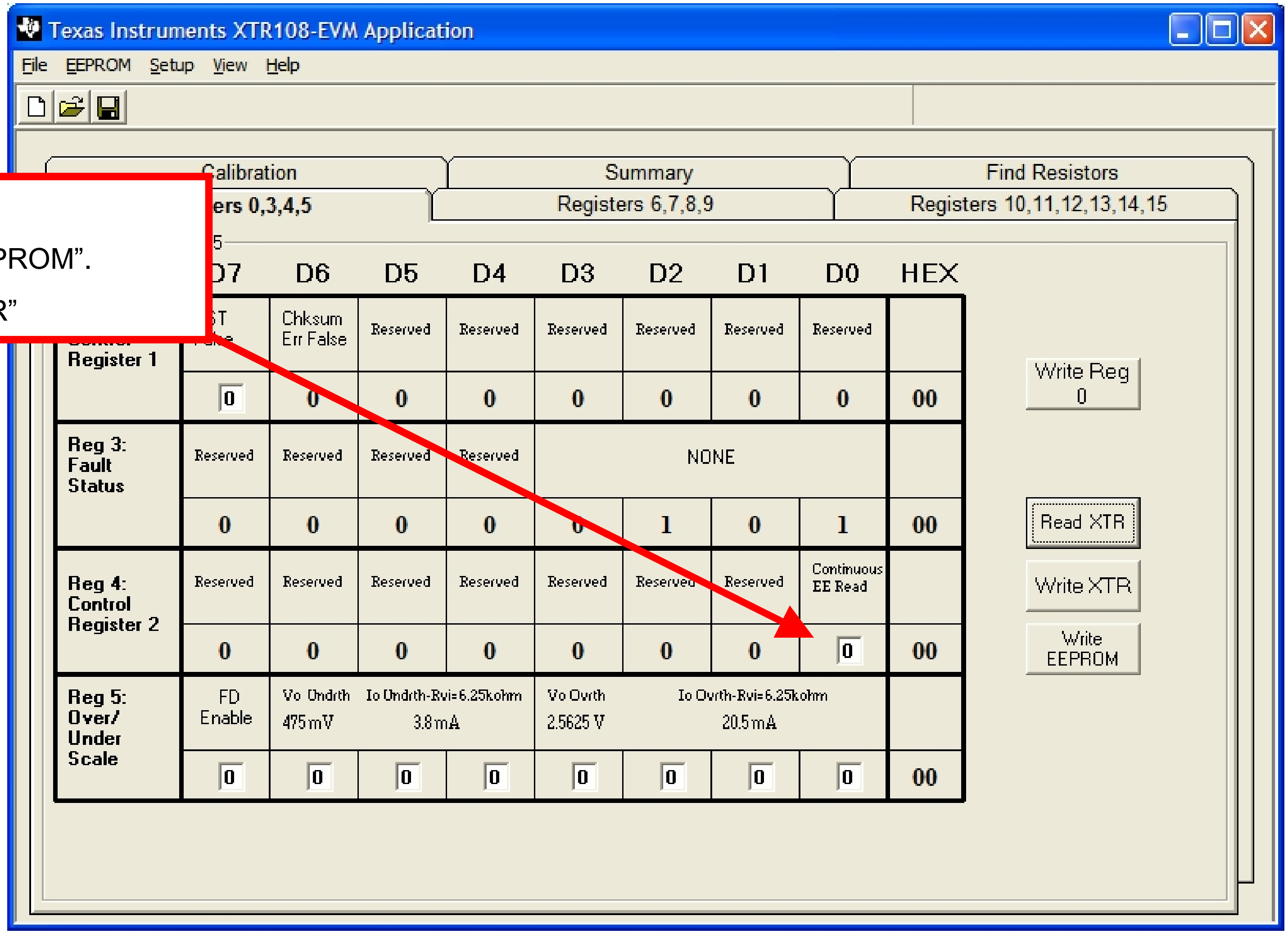


The table below illustrates a typical Voltage output mode jumper configuration. Note that Jump2 and Jump3 are configured so that the sub-regulator is not being used. In this mode, the supply must be adjusted to 5V. Keep in mind that the diode D1 will drop Vloop by approximately 0.7V. It is recommended that a small negative voltage is connected to the input of the XTR108 V/I amplifier when the XTR108 is used in voltage output mode. The jumper configuration shown generates this voltage (-50mV) by connecting a small discrete charge pump to the clock signal. The XTR108 must be put in “continuous EE read mode” (see register 4, D0).

XTR108 Sensor Interface Board – Factory Jumper Settings		
Jumper	**Position**	
JUMP1	Vout	Use current output mode
JUMP2	Bypass	Bypass FET Sub-regulator
JUMP3	Bypass	Bypass FET Sub-regulator
JUMP4	CP	Use current output mode
JUMP5	Vout	Use current output mode
JUMP6	No Load	Do not connect load to Voltage Output
JUMP7	Bypass	Bypass Voltage Mode Charge Pump

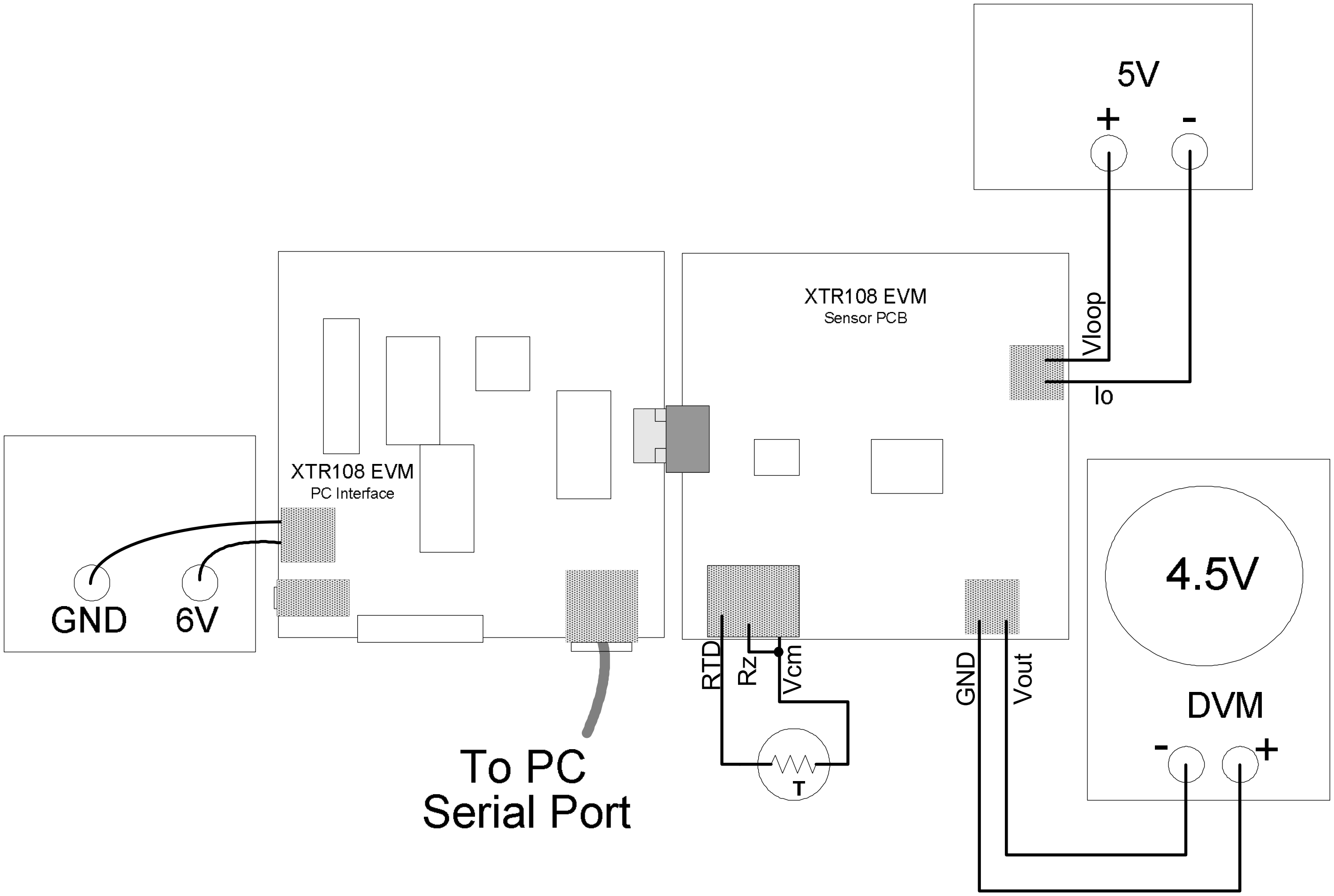
Voltage Output Mode:
Continuous Read Mode to Generate Charge Pump Voltage

1. Set D0 = '0'.
2. Press "Write EEPROM".
3. Press "Write XTR"

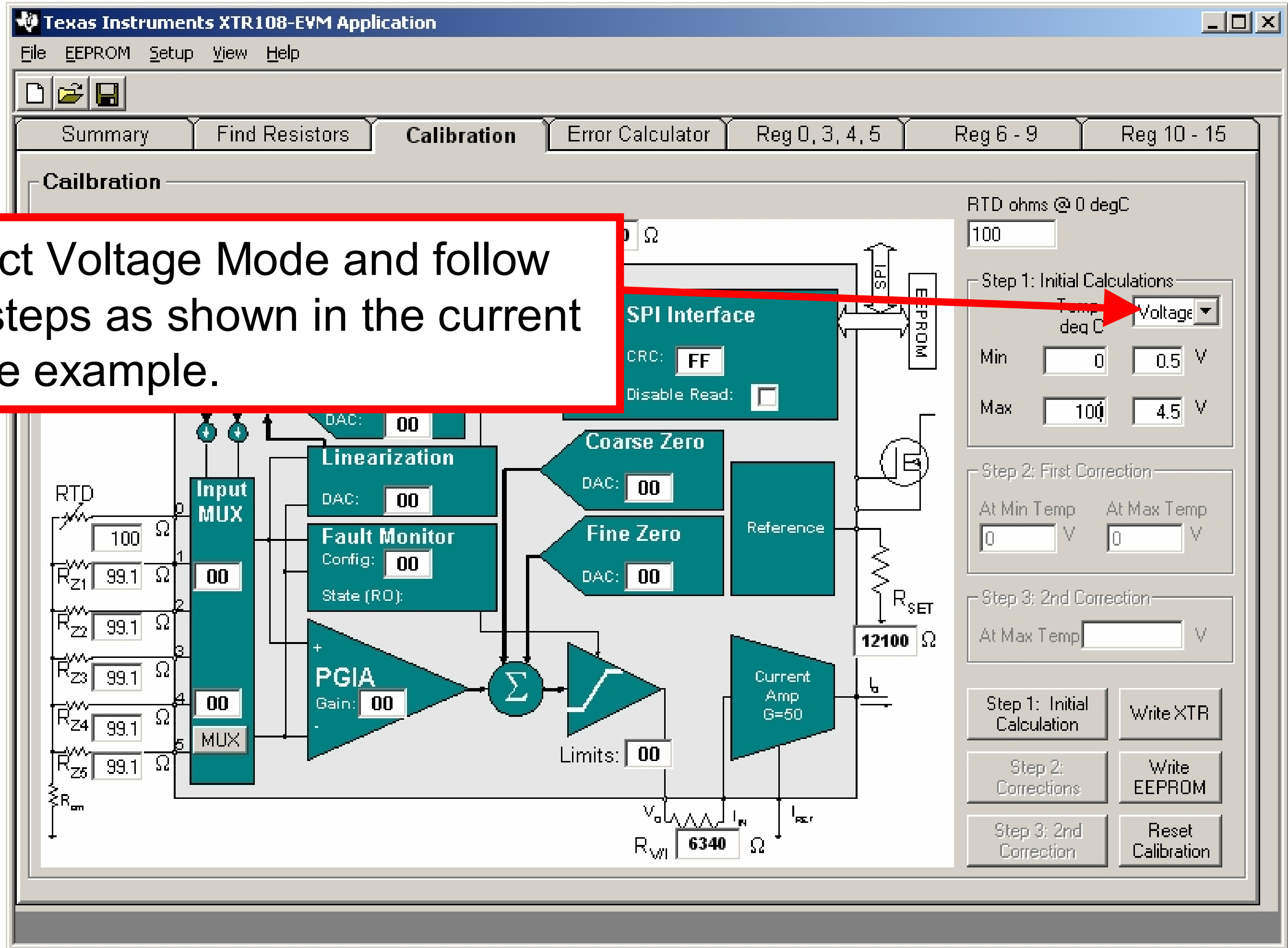


Voltage Mode

Connect the power



Select Voltage Mode

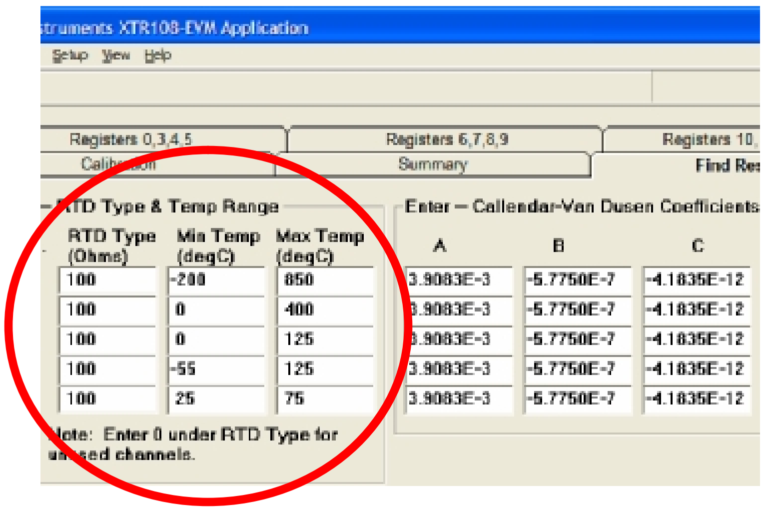


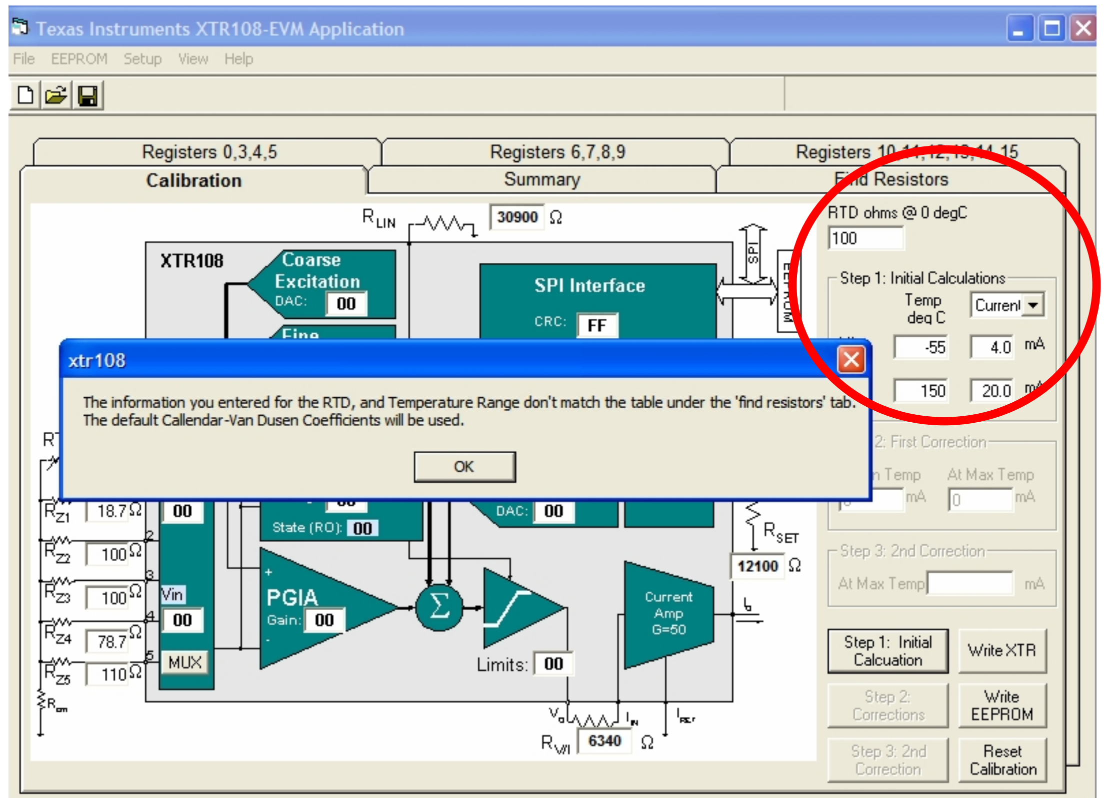
Select Voltage Mode and follow the steps as shown in the current mode example.

Appendix 1: General Software Information

Software Note: When Ranges Don't Match the table, Use the Default Coefficients

In some cases you may wish to use the program to calibrate an RTD without using the "Find Resistors" tab. In this case, the program will display the error message shown below. The default Callendar-Van Dusen Coefficients can be entered through the "Setup" menu.

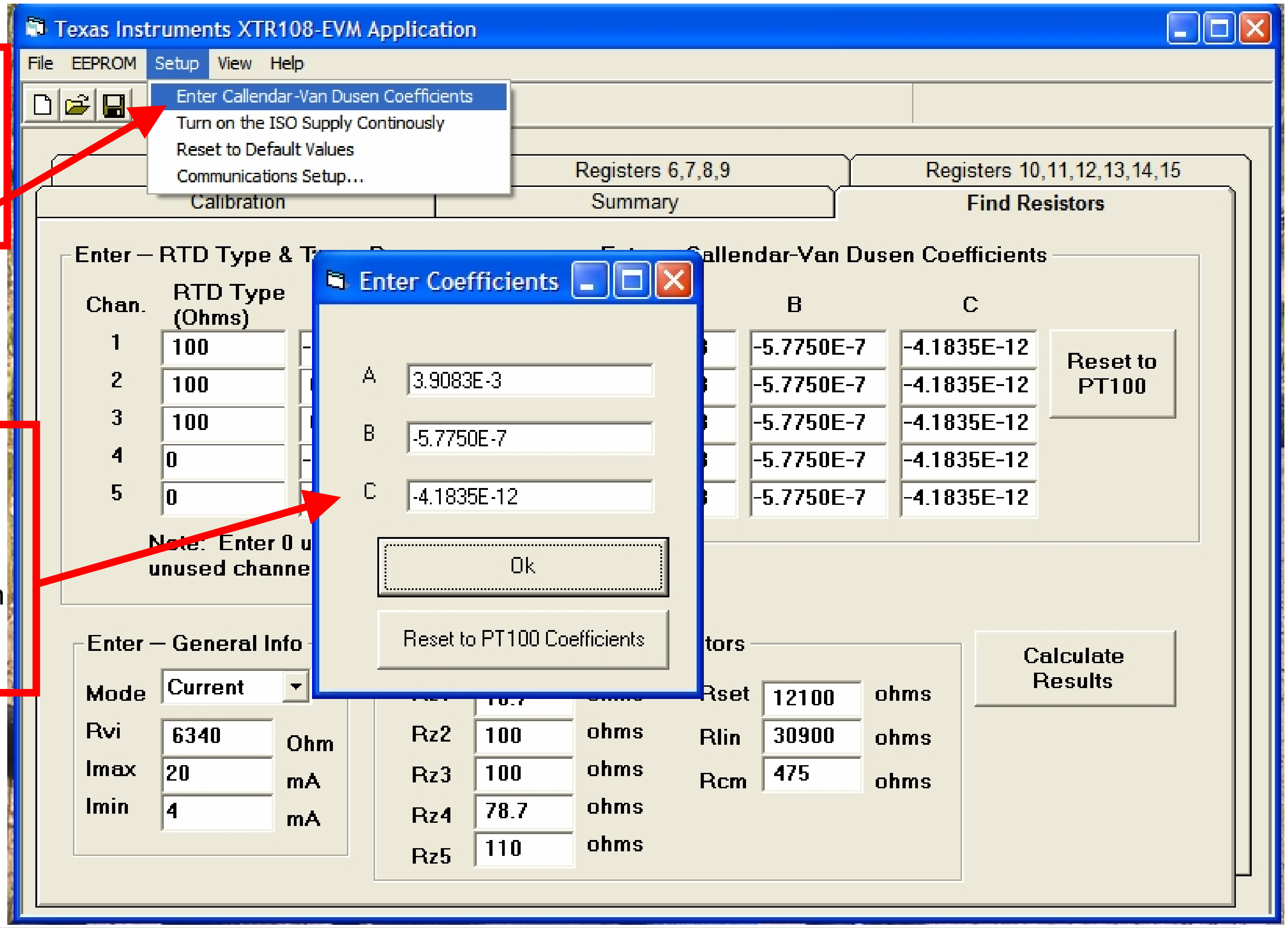




Calibration Note: When Ranges Don't Match the table, Use the Default Coefficients

The "Enter Callendar-Van Dusen Coefficients" option under "Setup" allows you to change the default coefficients.

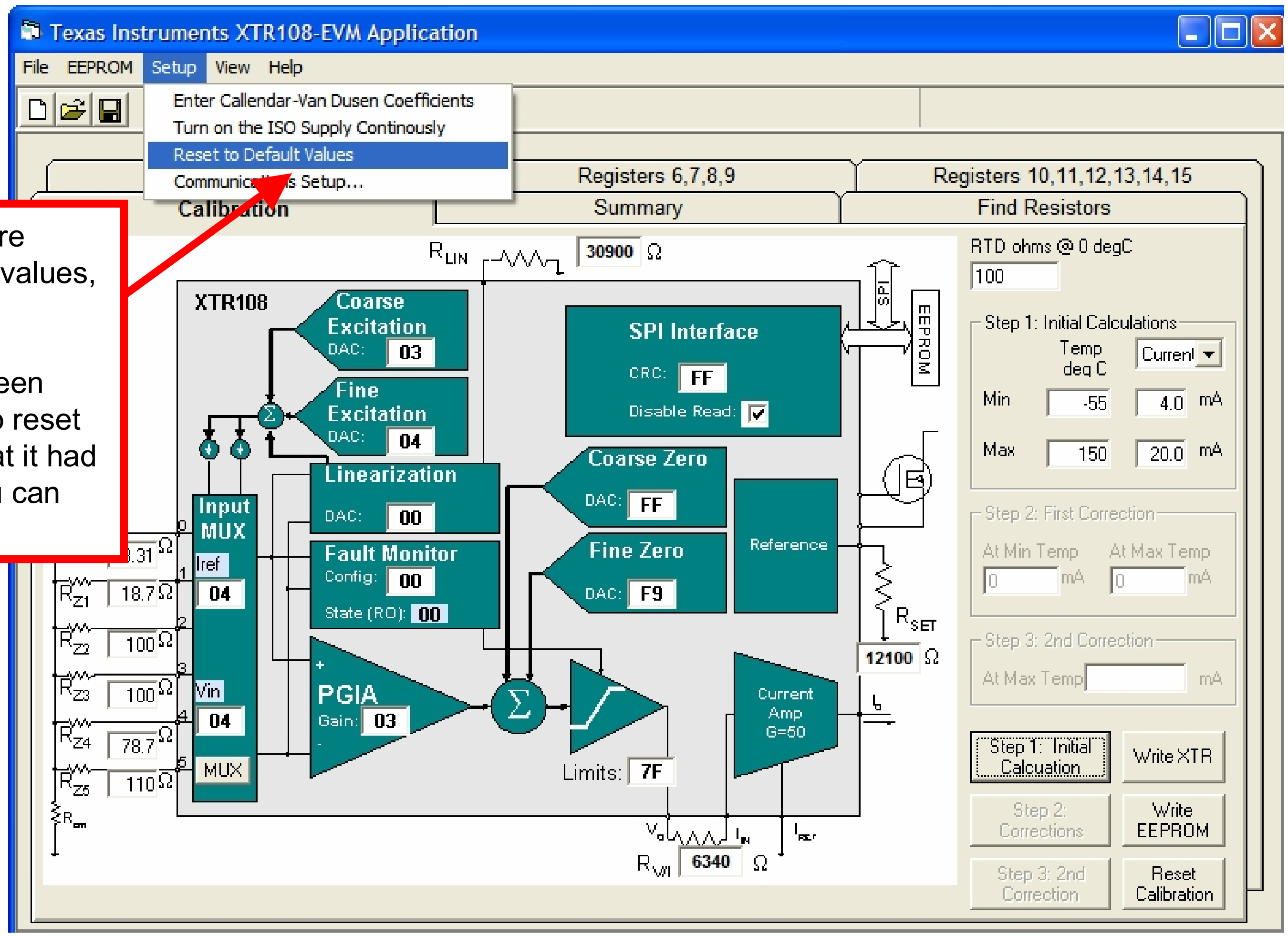
The default coefficients that the software uses is for a PT100 RTD. The "Enter Callendar-Van Dusen Coefficients" option under "Setup" allows you to change the coefficients.



Software Note:

Reset to Default

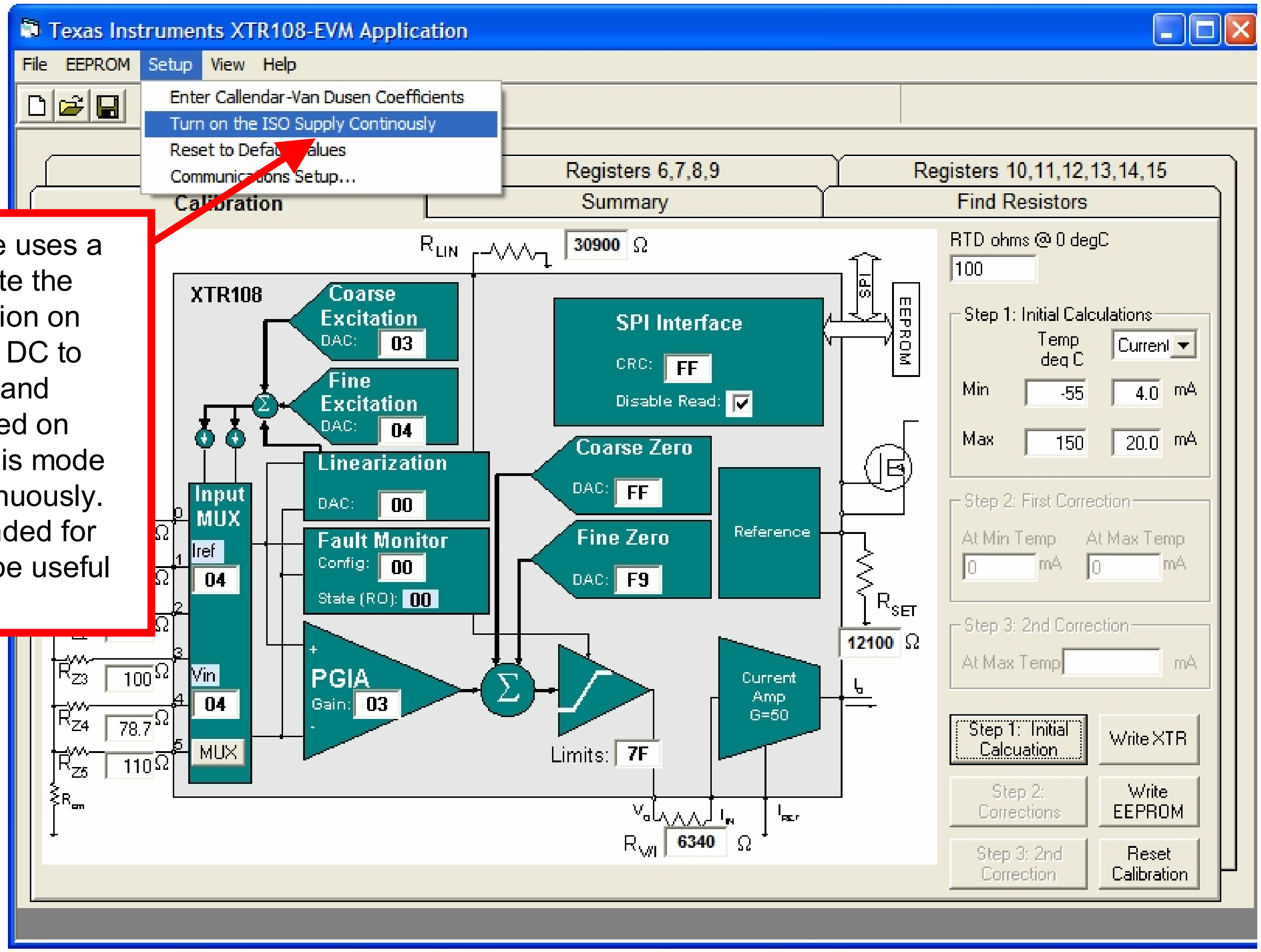
The XTR108EVM Software "remembers" the resistor values, temperature ranges, and Callendar-Van Dusen Coefficients after it has been shut down. If you want to reset it to the default values that it had when it was installed, you can use this option.



Software Note:

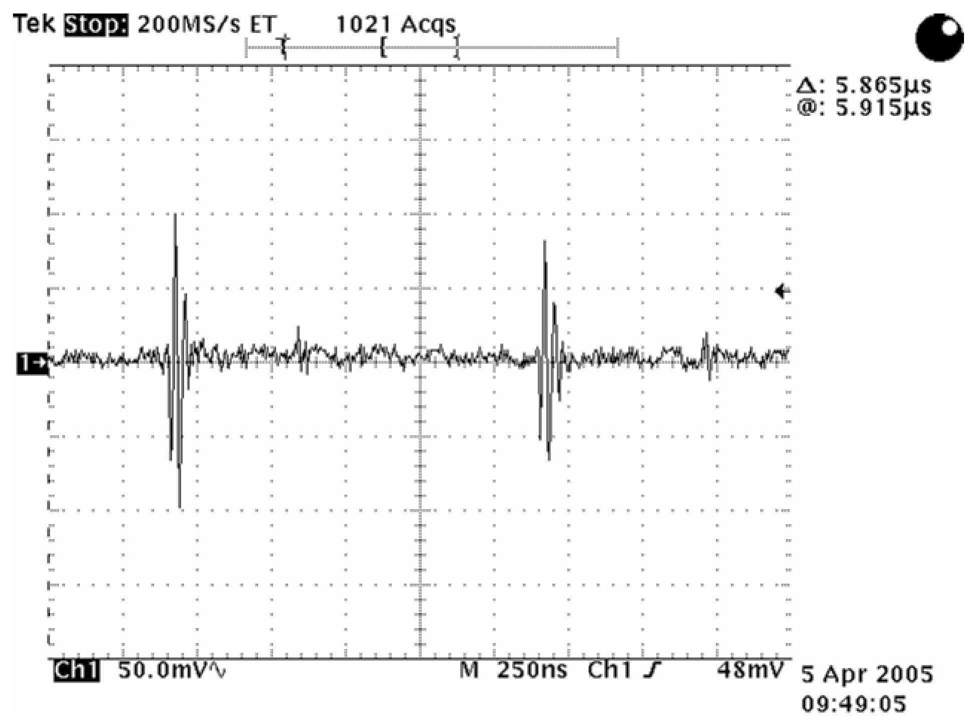
DC to DC Converter.

The XTR108EVM Hardware uses a DC to DC converter to isolate the digital communications section on the PC Interface PCB. The DC to DC converter is very noisy, and consequently, it is only turned on during communications. This mode will turn on the supply continuously. This mode is not recommended for normal operation, but may be useful for debug.

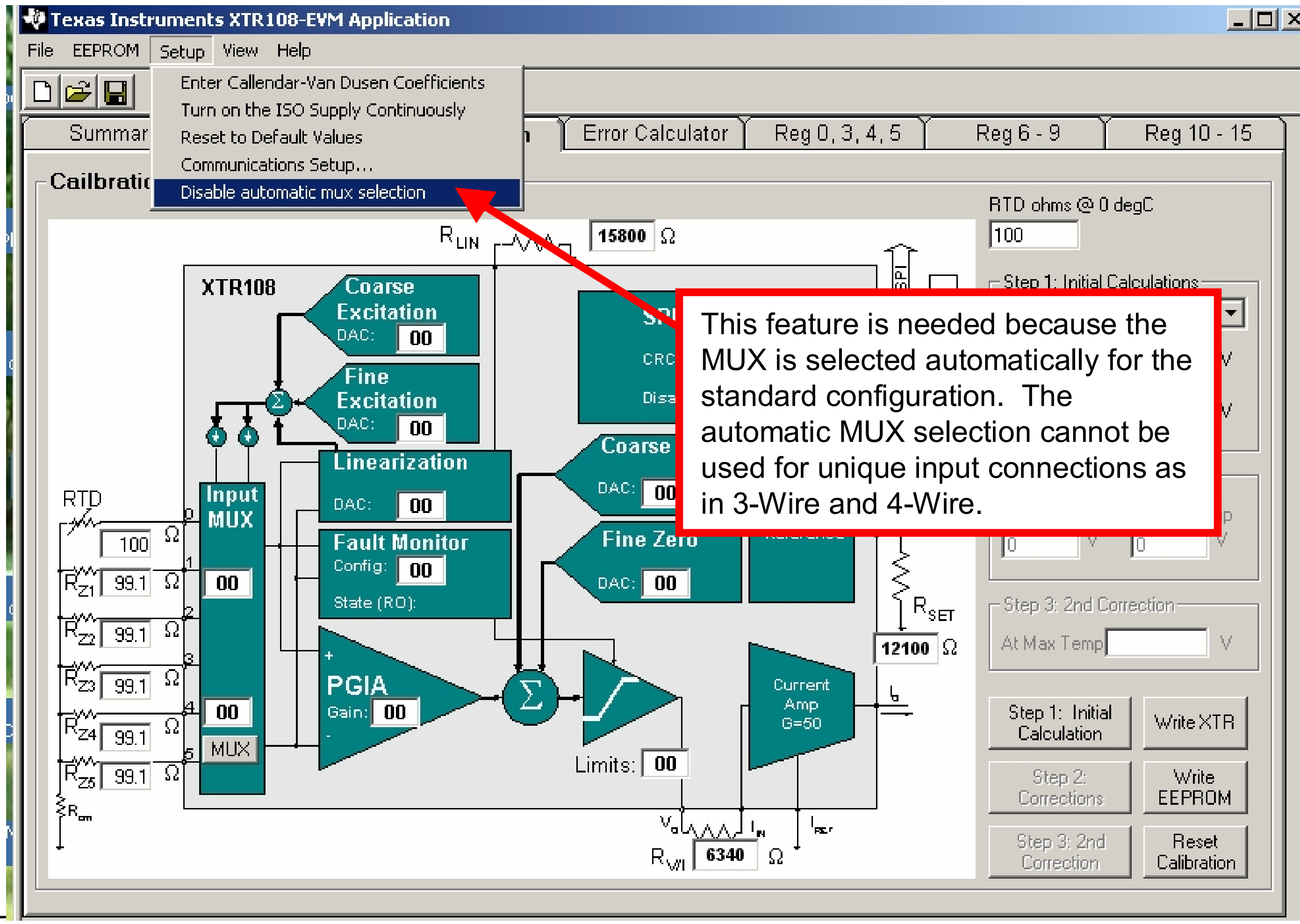


Noise from the DCR010505P

This scope shot illustrates the noise at the output of the DC/DC Converter (DCR01505P on the PC Interface Board) when turned on.

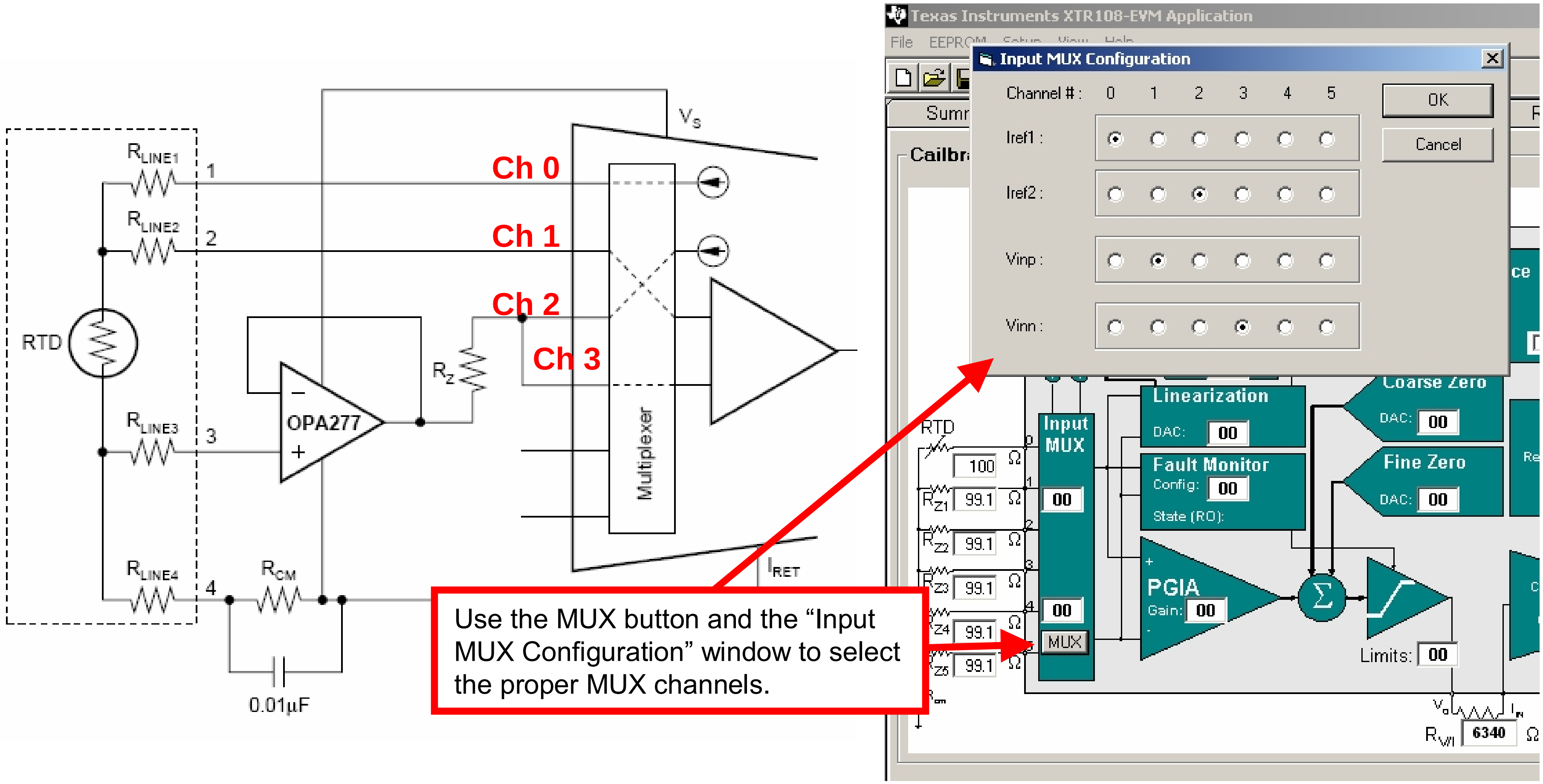


Unique MUX Settup: 3-Wire and 4-Wire



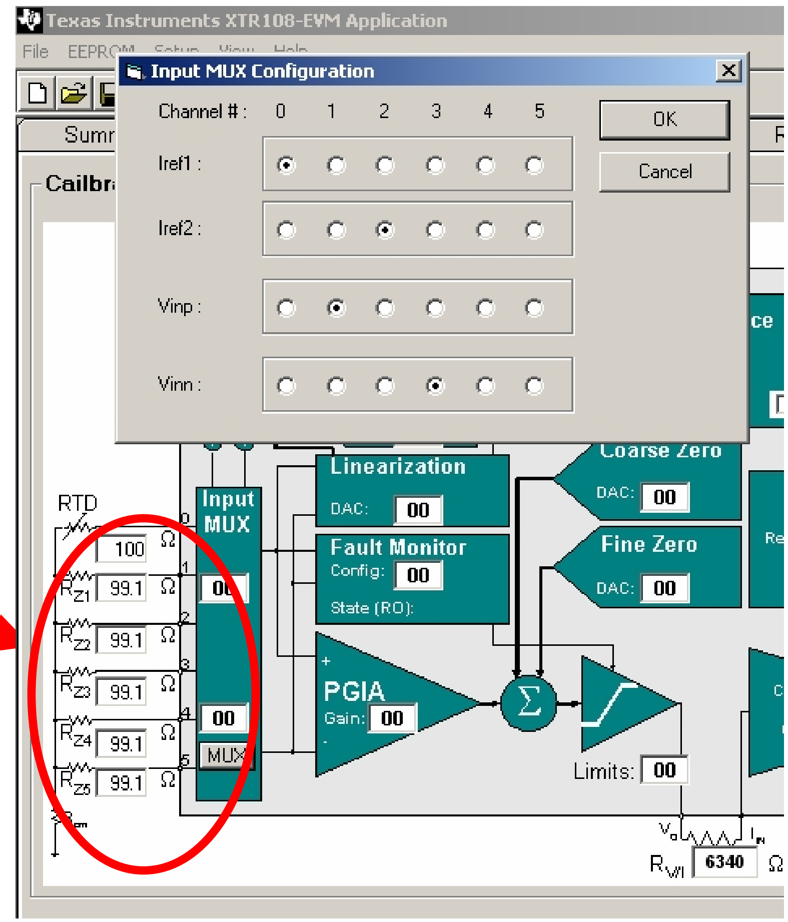
This feature is needed because the MUX is selected automatically for the standard configuration. The automatic MUX selection cannot be used for unique input connections as in 3-Wire and 4-Wire.

4 – Wire Manually Select Channels



Rz Selection with Automatic MUX Selection Off

When automatic MUX selection is off, you must enter the same value for all values of Rz. This forces Rz to be the correct value regardless of the MUX channel used.



Appendix 2: Equations Used in Software
Step 1: Calculate Initial XTR108 Settings

RTD resistance as a function of Temperature in deg C

$A_o := 3.9083 \cdot 10^{-3}$ $R_o := 100$

$B_o := -5.775 \cdot 10^{-7}$

$C_o := -4.183 \cdot 10^{-12}$

$$RTD(T) := \begin{cases} R_o \cdot \left[1 + A_o \cdot T + B_o \cdot T^2 + C_o \cdot (T - 100) \cdot T^3\right] & \text{if } T < 0 \\ R_o \cdot \left(1 + A_o \cdot T + B_o \cdot T^2\right) & \text{otherwise} \end{cases}$$

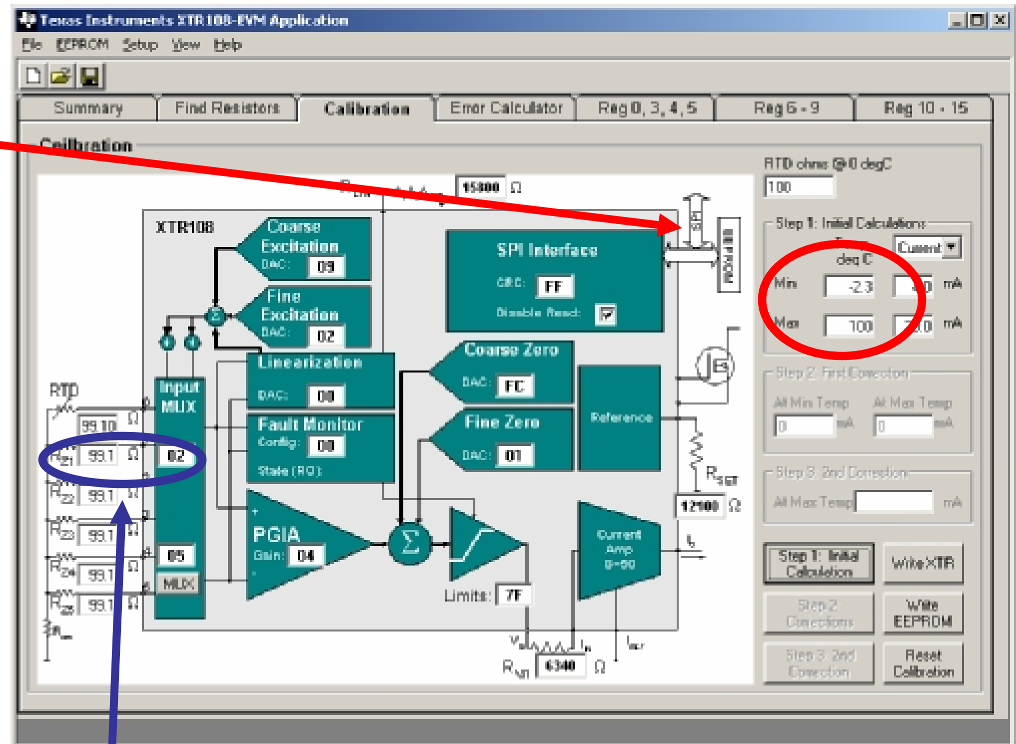
Enter Temperature Range / Select Rz

Choose Temperature range

$T_{min} := -2.3$

$T_{max} := 100$

$T_{mid} := \frac{T_{max} + T_{min}}{2}$ $\quad T_{mid} = 48.85$



Calculate RTD at Tmin, Tmid, Tmax

$RTD_{min} := RTD(T_{min})$ $\quad RTD_{min} = 99.101$

$RTD_{mid} := RTD(T_{mid})$ $\quad RTD_{mid} = 118.954$

$RTD_{max} := RTD(T_{max})$ $\quad RTD_{max} = 138.505$

Choose Rz as closest standard value.

$R_z := 99.1$

Compute Nonlinearity

$$B_v := \frac{RTD_{mid} - \frac{RTD_{max} + RTD_{min}}{2}}{RTD_{max} - RTD_{min}}$$

$$B_v = 3.834 \times 10^{-3}$$

$$G_{lin} := \frac{2 \cdot B_v}{\left(0.5 + B_v\right) \cdot RTD_{max} - \left(0.5 - B_v\right) RTD_{min} - 2 \cdot B_v \cdot R_z}$$

$$G_{lin} = 3.863 \times 10^{-4}$$

Iref as a function of Front End PGA Voltage Gain (Av)

$R_{set} := 12100$ $I_{out\_min} := 0.004$ $I_{out\_max} := 0.02$

$R_{vi} := 6340$ $R_{lin} := 2.94 \times 10^{4}$ $V_{ref} := 1.193$

Values in this example.

$$I_{set} := \frac{V_{ref}}{R_{set}}$$

$$I_{set} = 98.595 \times 10^{-6}$$

$$V_{out\_max} := \frac{I_{out\_max} \cdot R_{vi}}{50} \qquad V_{out\_max} = 2.536$$

$$V_{out\_min} := \frac{I_{out\_min} \cdot R_{vi}}{50} \qquad V_{out\_min} = 0.507$$

$$Iref(A_V) := \frac{(V_{out\_max} - V_{out\_min}) \cdot \left[1 - G_{lin} \cdot (RTD_{max} - R_z)\right]}{A_V \cdot (RTD_{max} - RTD_{min})}$$

Find Av that gives good Iref Range

$I_{ref\_max} := 1.35\,(5 \cdot I_{set})$ $I_{ref\_min} := 0.65\,(5 \cdot I_{set})$

$I_{ref\_max} = 665.517 \times 10^{-6}$ $I_{ref\_min} = 320.434 \times 10^{-6}$

$Iref(6.25) = 8.112 \times 10^{-3}$

$Iref(12.5) = 4.056 \times 10^{-3}$

$Iref(25) = 2.028 \times 10^{-3}$

$Iref(50) = 1.014 \times 10^{-3}$

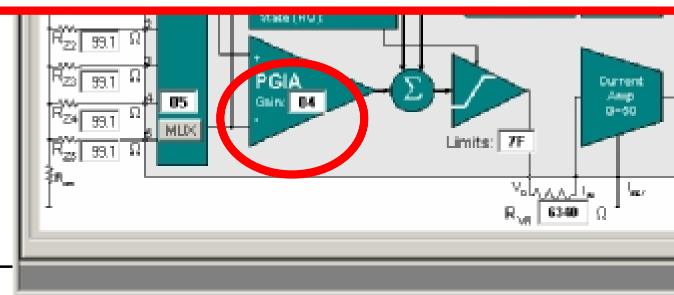
$Iref(100) = 507.025 \times 10^{-6}$ Choose $A_{v\_sel} := 100$

$Iref(200) = 253.513 \times 10^{-6}$

$Iref(400) = 126.756 \times 10^{-6}$

The PGA gain should be chosen such that the Iref value is within +/-35% of 5*Iset to allow for room for calibration adjustments without having to go to another span step. The values Iref_max and Iref_min define the range.

Note that Iref_min <Iref(100) < Iref_max



Find initial values for Reg11, and Reg10

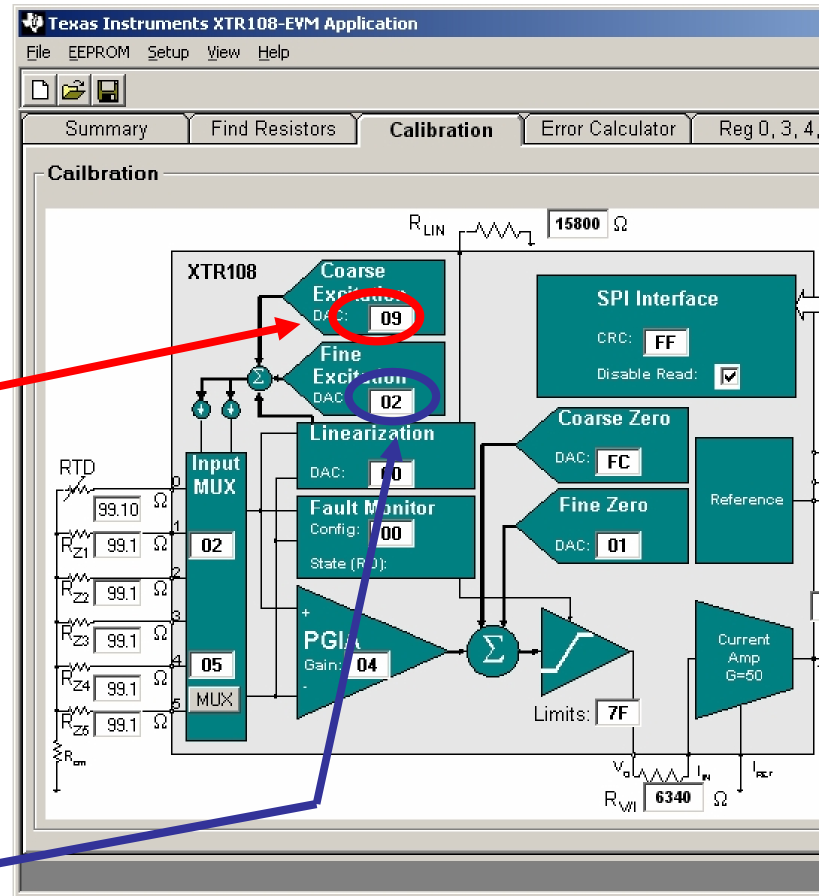
$$I_{ref} := \mathrm{Iref}(100) \qquad I_{ref} = 5.07\times 10^{-4}$$

$$\mathrm{Reg11} := \mathrm{round}\left[\frac{64\cdot\left(I_{ref} - 5\cdot I_{set}\right)}{I_{set}}\right]$$

$$\mathrm{Reg11} = 9$$

$$\mathrm{Reg10} := \mathrm{round}\left[\frac{1024\left[I_{ref} - 5\cdot I_{set} - \left(\frac{\mathrm{Reg11}\cdot I_{set}}{64}\right)\right]}{I_{set}}\right]$$

$$\mathrm{Reg10} = 2$$



Compute Registers Reg12 and Reg13

$$I_o := I_{out\_min} - \frac{50 \cdot A_{v\_sel} \cdot I_{ref} \cdot (RTD_{min} - R_z)}{R_{vi}}$$

$$I_o = 4 \times 10^{-3}$$

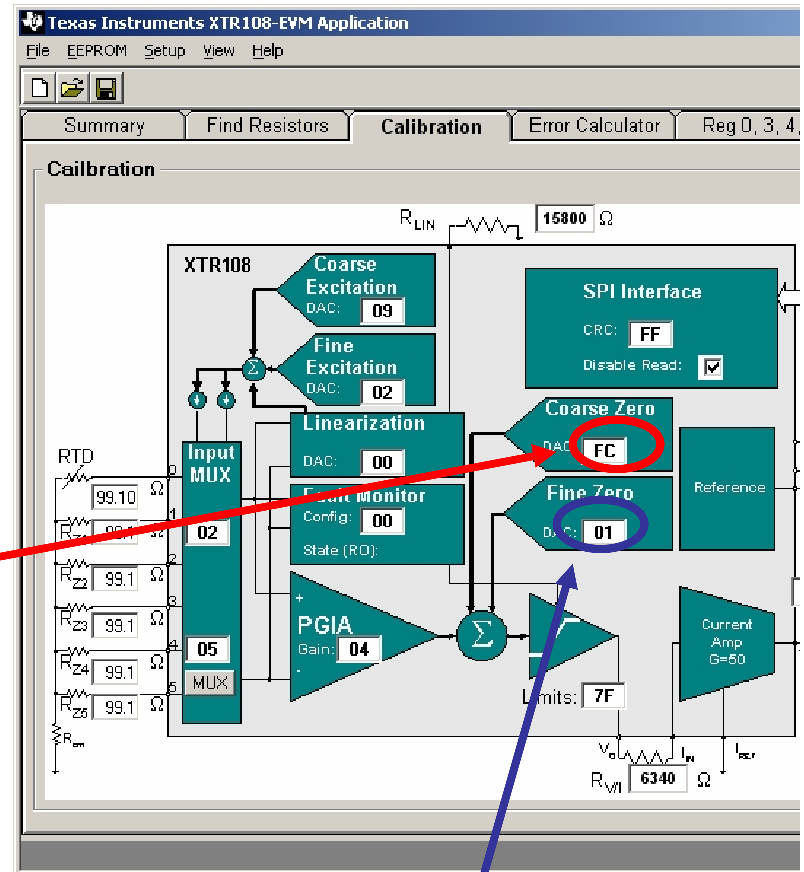
$$I_{zpgm} := \frac{5V_{ref}}{8 \cdot R_{vi}}$$

$$Reg13 := \mathrm{round}\left[\frac{4(I_o - 35 \cdot I_{zpgm})}{I_{zpgm}}\right]$$

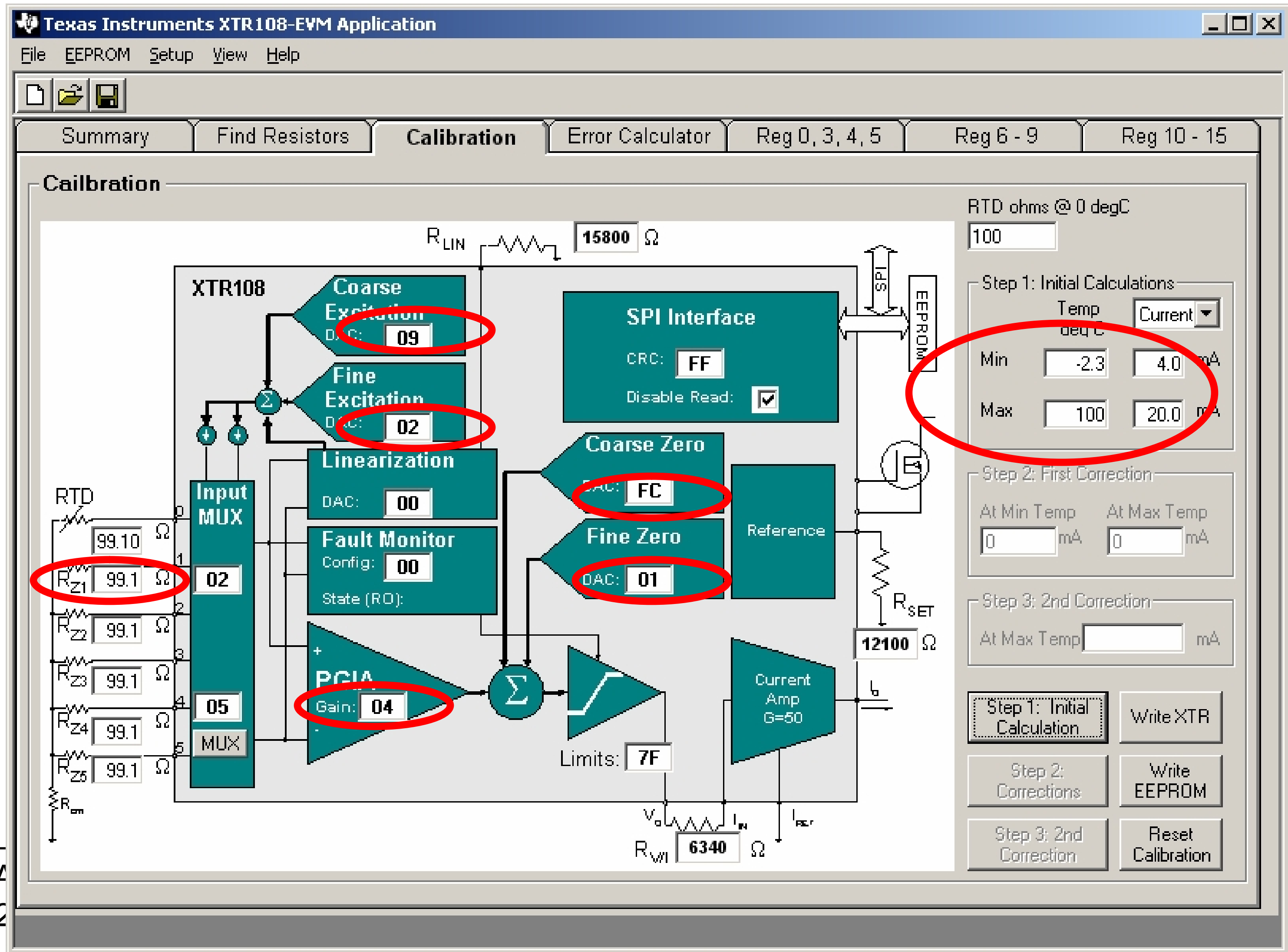
$$Reg13 = -4 = \text{FCh}$$

$$Reg12 := \mathrm{round}\left[\frac{64\left[I_o - 35 \cdot I_{zpgm} - \left(I_{zpgm} \cdot \frac{Reg13}{4}\right)\right]}{I_{zpgm}}\right]$$

$$Reg12 = 1$$



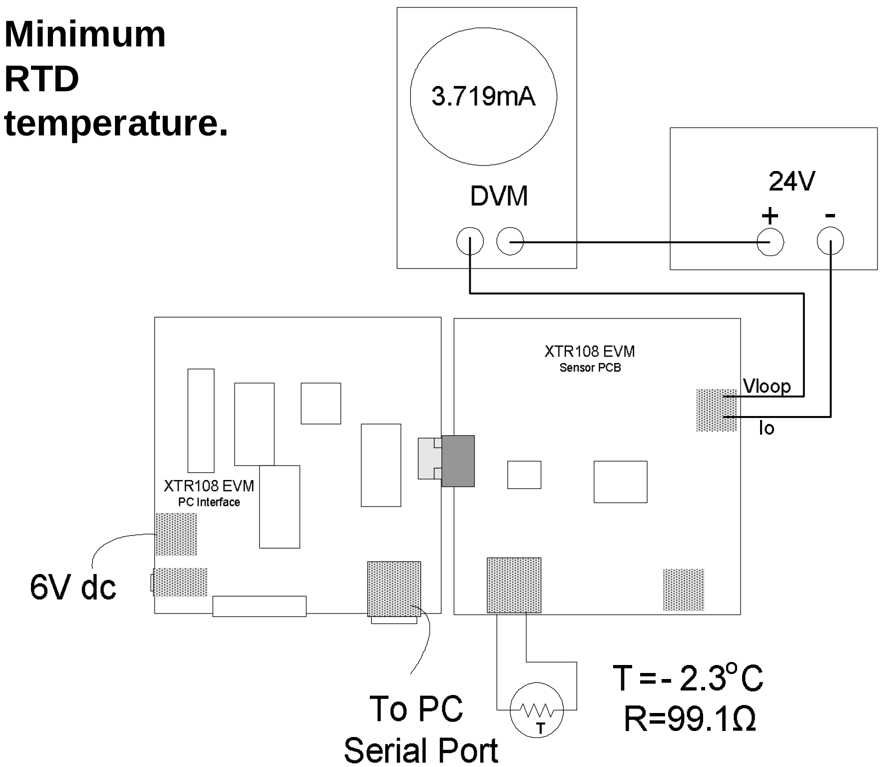
Done With Step 1: See Results



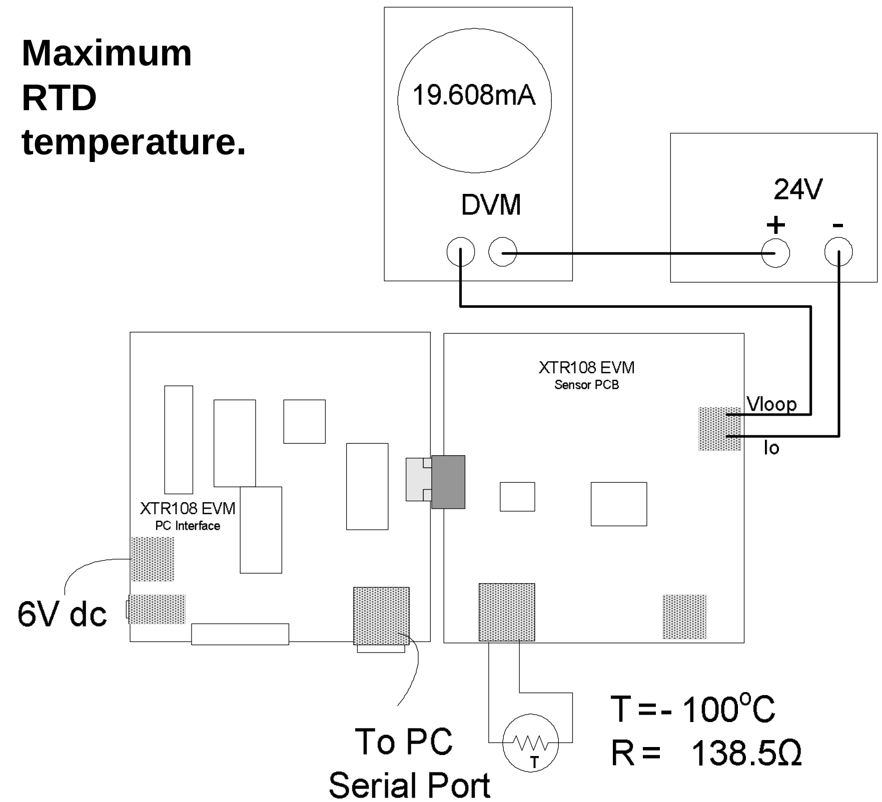
Step 2: Measure and Correct Gain and Offset

Step 2: Measure Output at Minimum and Maximum

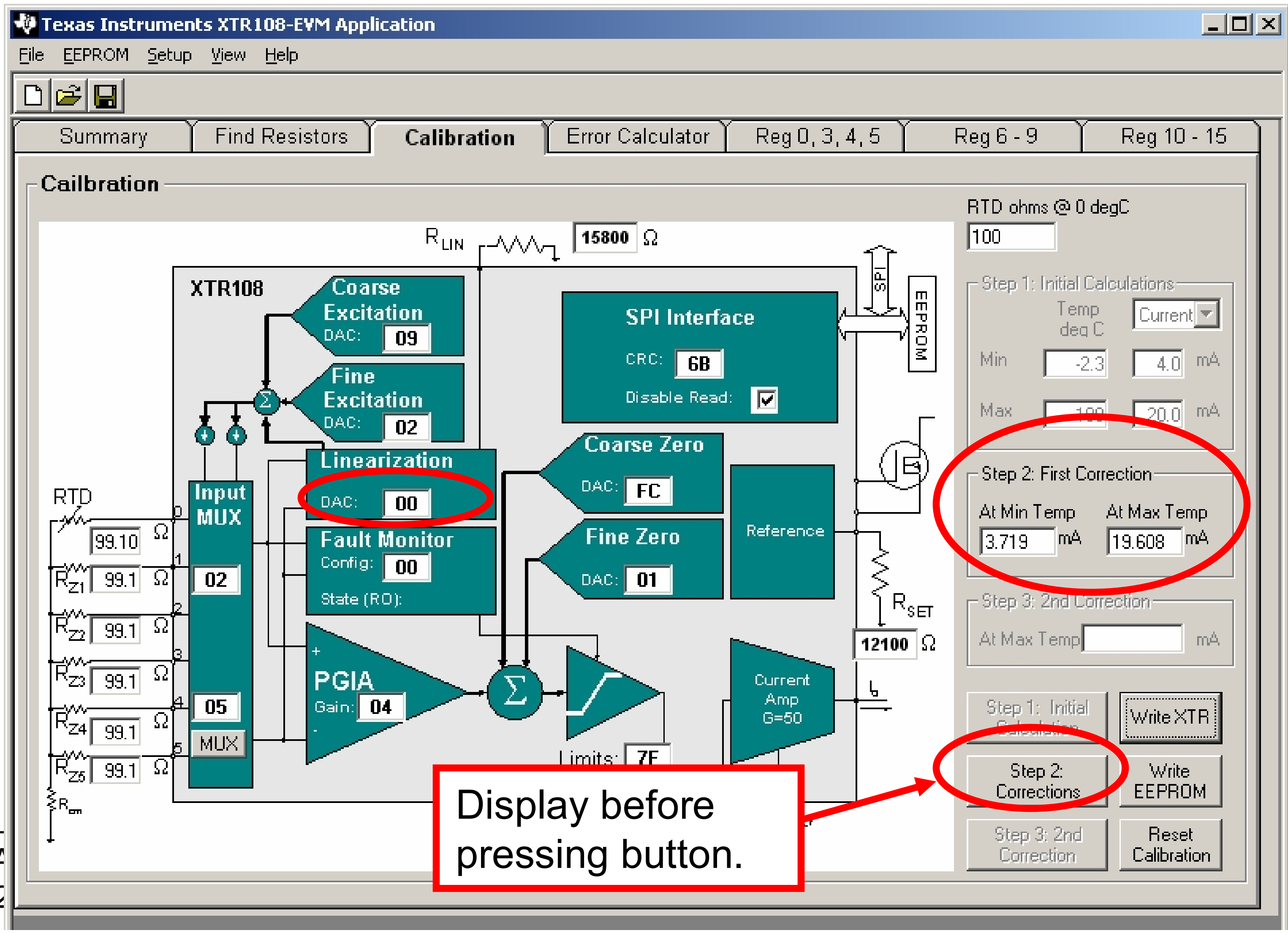
Minimum RTD temperature.



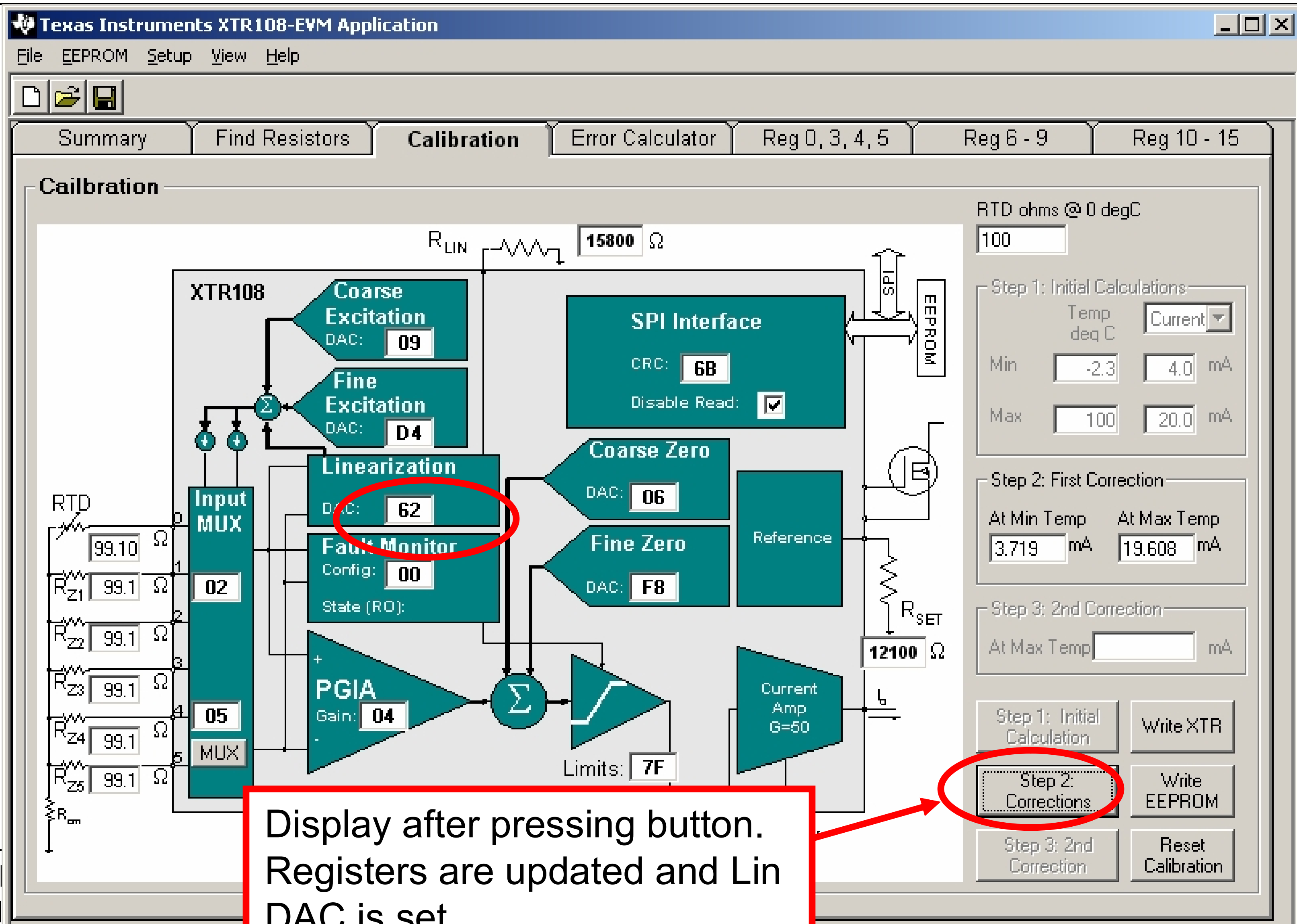
Maximum RTD temperature.



Step 2: Uses Registers Calculated in Step 1 with Linearity Dac Turned off



This is the settings after step 2 calculations



Display after pressing button. Registers are updated and Lin DAC is set.

Step 2: Compute IA_{refAdj}

Measure Iout min and max

$$I_{out\_min\_meas} := 3.719 \cdot 10^{-3}$$

$$I_{out\_max\_meas} := 19.608 \cdot 10^{-3}$$

$$I_{ref\_reg} := I_{set} \cdot \left(5 + \frac{Reg11}{64} + \frac{Reg10}{1024}\right)$$

$$I_{ref\_reg} = 5.07 \times 10^{-4}$$

$$IA_{RefAdj} := \frac{\left(I_{out\_max\_meas} - I_{out\_min\_meas}\right) \cdot R_{vi}}{50 \cdot A_{v\_sel} \cdot \left(RTD_{max} - RTD_{min}\right)}$$

$$IA_{RefAdj} = 5.113 \times 10^{-4}$$

Step 2: R_{z_adj} and G_{lin_adj}

$$dRz := \frac{(I_o - I_{out\_min\_meas}) \cdot R_{vi}}{50 \cdot A_{v\_sel} \cdot IA_{RefAdj}}$$

$$dRz = 0.696$$

$$R_{z\_adj} := RTD_{min} + dRz$$

$$R_{z\_adj} = 99.797$$

$$G_{lin\_adj} := \frac{2 \cdot B_v}{(0.5 + B_v) \cdot RTD_{max} - (0.5 - B_v) RTD_{min} - 2 \cdot B_v \cdot R_{z\_adj}}$$

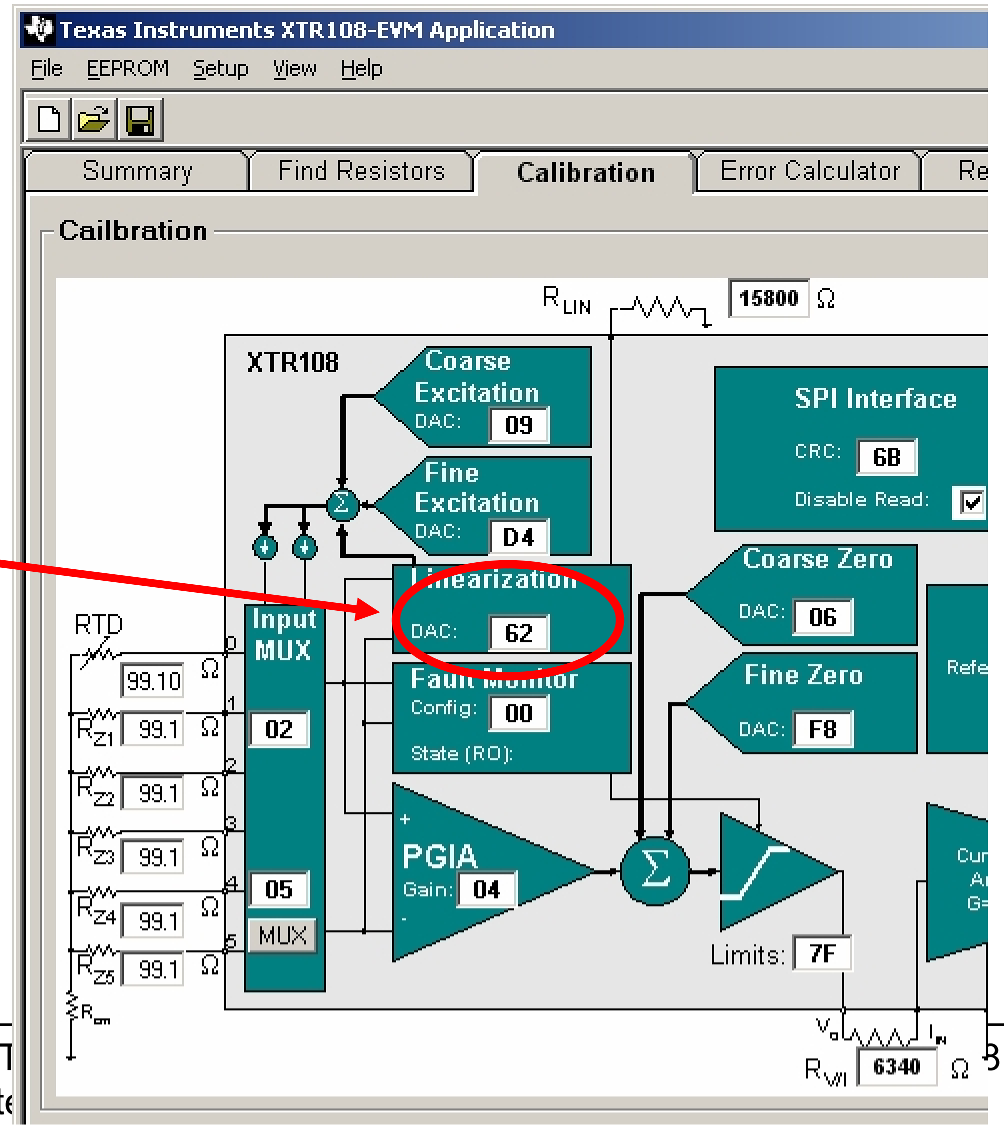
$$G_{lin\_adj} = 3.864 \times 10^{-4}$$

$$Reg14 := round(16 \cdot G_{lin\_adj} \cdot R_{lin})$$

$$G_{lin\_adj} = 3.863 \times 10^{-4}$$

$$Reg14 := round\left(16 \cdot G_{lin\_adj} \cdot R_{lin}\right)$$

$$Reg14 = 98 \;\; = 62h$$



Step 2: Compute $I_{BrefAdj}$ and dIref

$$IB_{RefAdj} := \frac{\left(I_{out\_max} - I_{out\_min}\right)\cdot\left[1 - G_{lin\_adj}\cdot\left(RTD_{max} - R_{z\_adj}\right)\right]\cdot R_{vi}}{50\cdot A_{v\_sel}\cdot\left(RTD_{max} - RTD_{min}\right)}$$

$$IB_{RefAdj} = 5.072\times 10^{-4}$$

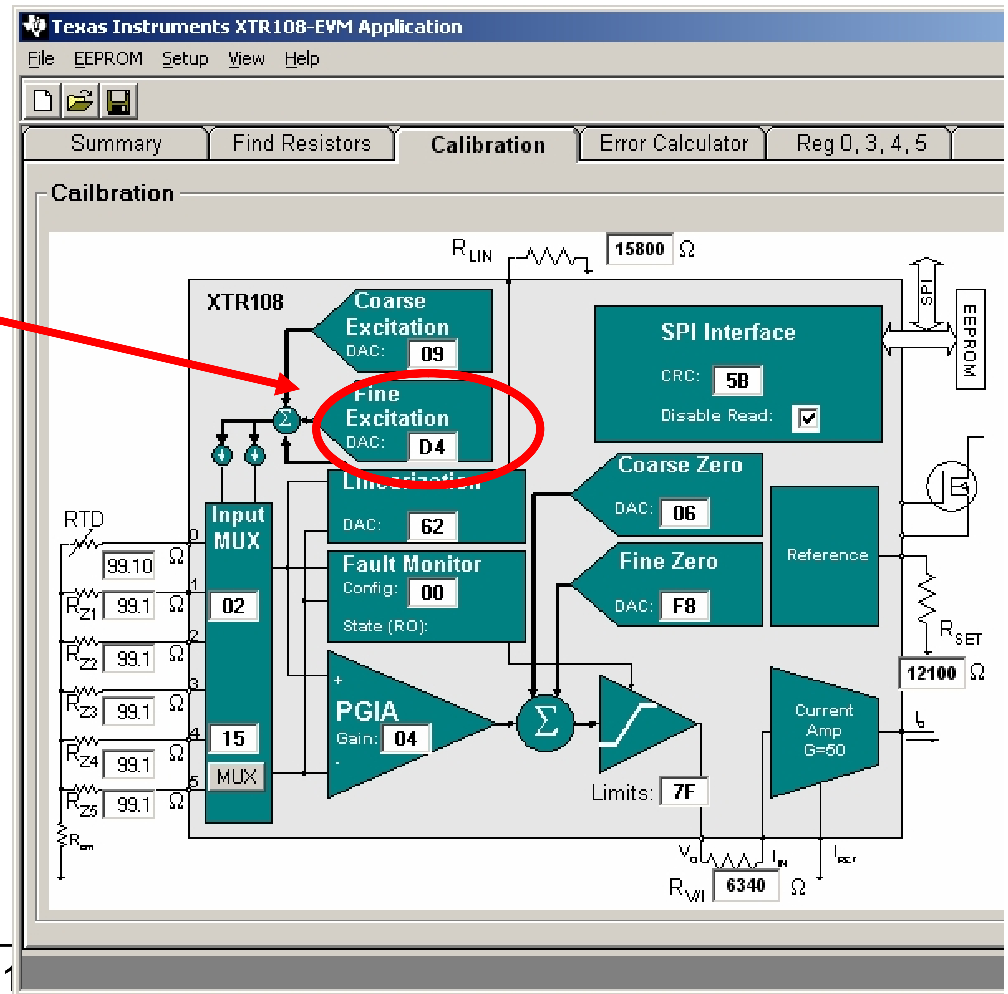
$$dIref := \left(I_{ref\_reg} - IA_{RefAdj}\right) + \left(I_{ref\_reg} - IB_{RefAdj}\right)$$

$$dIref = -4.387\times 10^{-6}$$

Step 2: New Value for Reg10

$$Reg10_{adj} := Reg10 + \text{round}\left(1024\,dIref \cdot \frac{R_{set}}{V_{ref}}\right)$$

$$Reg10_{adj} = -44 = \text{D4h}$$



Step 2: New Value for Reg10, Reg11

$$Reg10_{adj} := Reg10 + \mathrm{round}\left(1024\, dIref \cdot \frac{R_{set}}{V_{ref}}\right)$$

$$Reg10_{adj} = -44$$

Note that the change in Iref required in this case was relatively small, so Reg11 (coarse ref adjust) was not adjusted. If the adjusted value of Reg10 out of range (i.e. Reg10<-127 or Reg10>128) , both Reg10 and Reg11 are adjusted as shown below.

if Reg10adj < -127 or Reg10adj>128 then

$$I_{refadj} = I_{ref\_reg} + dIref$$

$$Reg11_{adj} = \mathrm{round}\left[\frac{64 \cdot \left(I_{refadj} - 5 \cdot I_{set}\right)}{I_{set}}\right]$$

$$Reg10_{adj} = \mathrm{round}\left[\frac{1024 \cdot \left[I_{refadj} - 5 \cdot I_{set} - \left(\frac{Reg11_{adj2} \cdot I_{set}}{64}\right)\right]}{I_{set}}\right]$$

end if

Step 2: If the R10, R11 adjustment doesn't work, it may be necessary to adjust Gain

if Reg10adj>128 then

$$A_{v\_sel} = (A_{v\_sel}) \cdot 2$$

$$Reg11_{adj2} = \text{round}\left[\frac{64 \cdot \left[\left(\frac{I_{refadj}}{2}\right) - 5 \cdot I_{set}\right]}{I_{set}}\right]$$

$$Reg10_{adj2} = \text{round}\left[\frac{1024 \cdot \left[\left(\frac{I_{refadj}}{2}\right) - 5 \cdot I_{set} - \left(\frac{Reg11_{adj2} \cdot I_{set}}{64}\right)\right]}{I_{set}}\right]$$

end if

if Reg10adj<128 then

$$A_{v\_sel} = \frac{A_{v\_sel}}{2}$$

$$Reg11_{adj2} = \text{round}\left[\frac{64 \cdot \left[(I_{refadj}) \cdot 2 - 5 \cdot I_{set}\right]}{I_{set}}\right]$$

$$Reg10_{adj2} = \text{round}\left[\frac{1024 \cdot \left[(I_{refadj}) \cdot 2 - 5 \cdot I_{set} - \left(\frac{Reg11_{adj2} \cdot I_{set}}{64}\right)\right]}{I_{set}}\right]$$

end if

Step 2: Compute dI_{zero}

$$dI_{zero} := I_{out\_min} - I_o - \frac{50 \cdot A_{v\_sel} \cdot IB_{RefAdj} \cdot \left(RTD_{min} - R_{z\_adj}\right)}{R_{vi}}$$

$$dI_{zero} = 2.787 \times 10^{-4}$$

Step 2: Compute Reg12, Reg13

$$Reg12_{adj} := round\left(Reg12 + \frac{512 \cdot dI_{zero} \cdot R_{vi}}{5 \cdot V_{ref}}\right)$$

$$Reg12_{adj} = 153$$

Note that the change in Izero required in this case was relatively large, so Reg12 (coarse Io adjust) needs to be adjusted. i.e. in this case Reg12<-127 or Reg12>128.

If Reg12adj<-127 or Reg12adj>128 Then

$$Reg13_{adj} := round\left[\frac{4\left(I_o + dI_{zero} - 35 \cdot I_{zpgm}\right)}{I_{zpgm}}\right]$$

$$Reg13_{adj} = 6$$

$$Reg12_{adj2} := round\left[\frac{64\left[I_o + dI_{zero} - 35 \cdot I_{zpgm} - \left(I_{zpgm} \cdot \frac{Reg13_{adj}}{4}\right)\right]}{I_{zpgm}}\right]$$

$Reg12_{adj2} = -8$ = F8h

End if

Step 2: Compute Reg12, Reg13

$$Reg12_{adj} := \mathrm{round}\left(Reg12 + \frac{512 \cdot dI_{zero} \cdot R_{vi}}{5 \cdot V_{ref}}\right)$$

$$Reg12_{adj} = 153$$

If Reg12adj<-127 or Reg12adj>128 Then

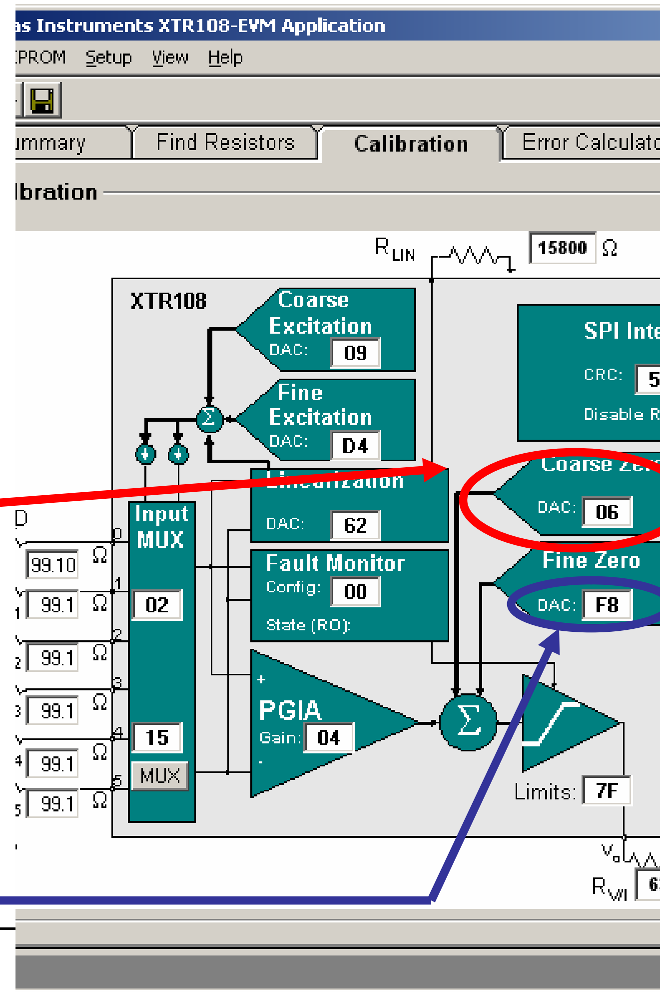
$$Reg13_{adj} := \mathrm{round}\left[\frac{4\left(I_o + dI_{zero} - 35 \cdot I_{zpgm}\right)}{I_{zpgm}}\right]$$

$$Reg13_{adj} = 6$$

$$Reg12_{adj2} := \mathrm{round}\left[\frac{64\left[I_o + dI_{zero} - 35 \cdot I_{zpgm} - \left(I_{zpgm} \cdot \frac{Reg13_{adj}}{4}\right)\right]}{I_{zpgm}}\right]$$

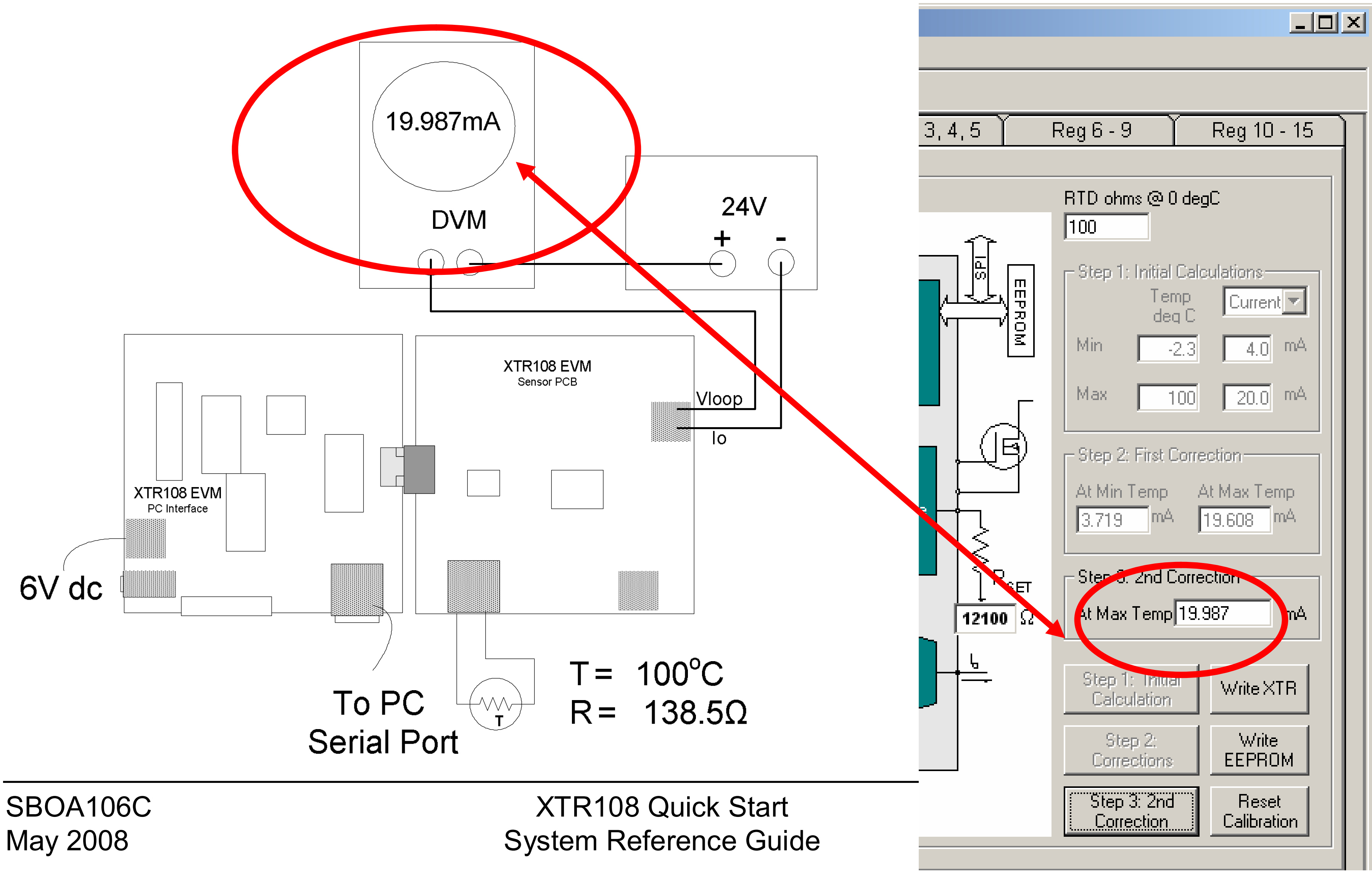
$Reg12_{adj2} = -8$ = F8h

End if



Step 3: Measure and Correct for Lin-DAC Error

Measure Full Scale Output



Step 3: Measure Iout Full Scale and compute factors used in Lin-Dac correction

part 3 calibration

$$I_{max\_post\_cal\_meas} := 0.019987$$

$$I_{cat} := \frac{IB_{RefAdj} \cdot A_{v\_sel} \cdot 50 \cdot \left(RTD_{max} - RTD_{min}\right)}{R_{vi}}$$

$$I_{cat} = 15.761 \times 10^{-3}$$

$$I_{dog} := I_{max\_post\_cal\_meas} - I_{out\_min}$$

$$I_{dog} = 15.987 \times 10^{-3}$$

Step 3: Calculate Reg14

$$Meas\_G_{linadj} := \frac{I_{dog} - I_{cat}}{\left(RTD_{max} - R_{z\_adj}\right)\cdot\left(I_{max\_post\_cal\_meas} - I_{out\_min}\right)}$$

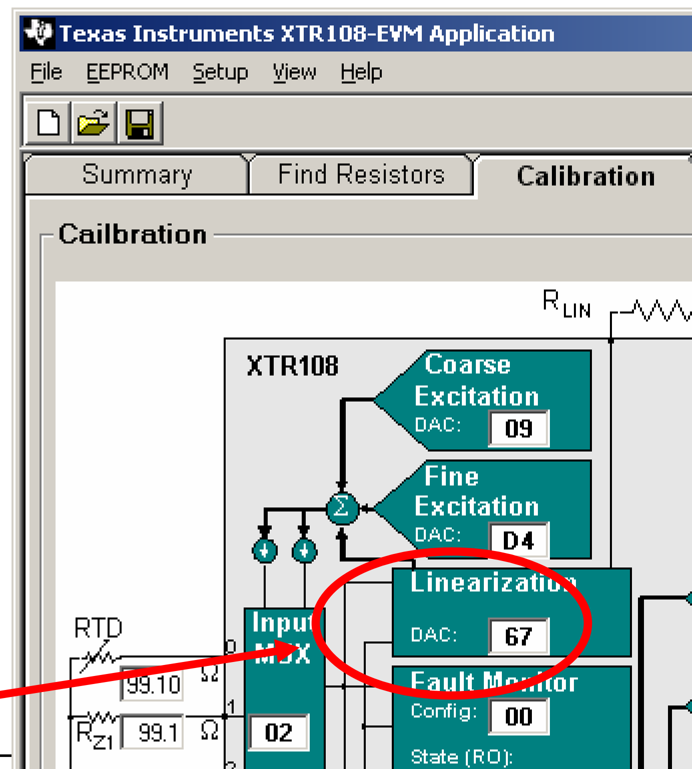
$$Meas\_G_{linadj} = 3.657\times 10^{-4}$$

$$G_{lin\_final} := \frac{G_{lin\_adj}}{Meas\_G_{linadj}}\cdot G_{lin\_adj}$$

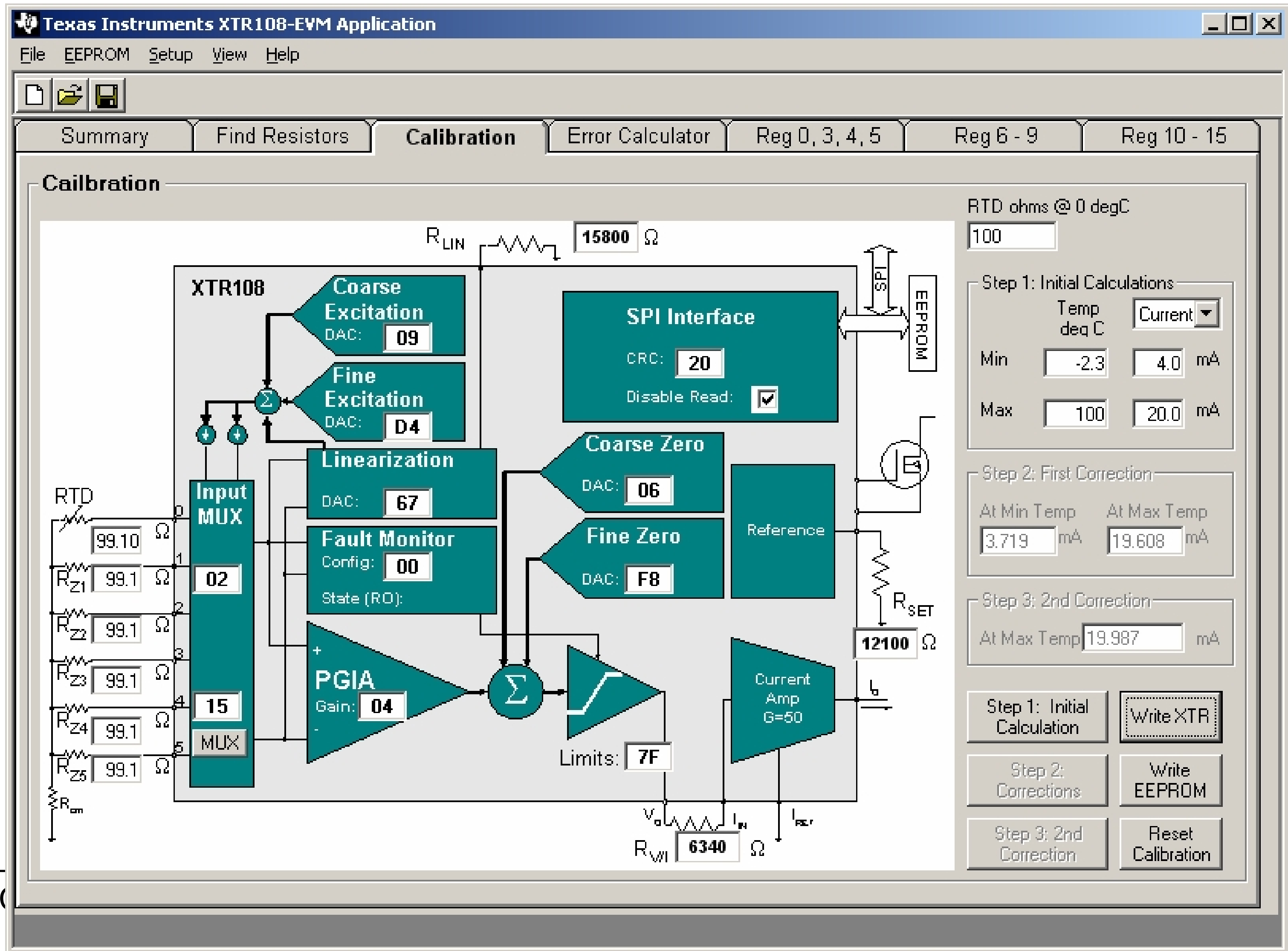
$$G_{lin\_final} = 4.082\times 10^{-4}$$

$$Reg14_{adj} := round\left(16\cdot G_{lin\_final}\cdot R_{lin}\right)$$

$Reg14_{adj} = 103$ = 67h

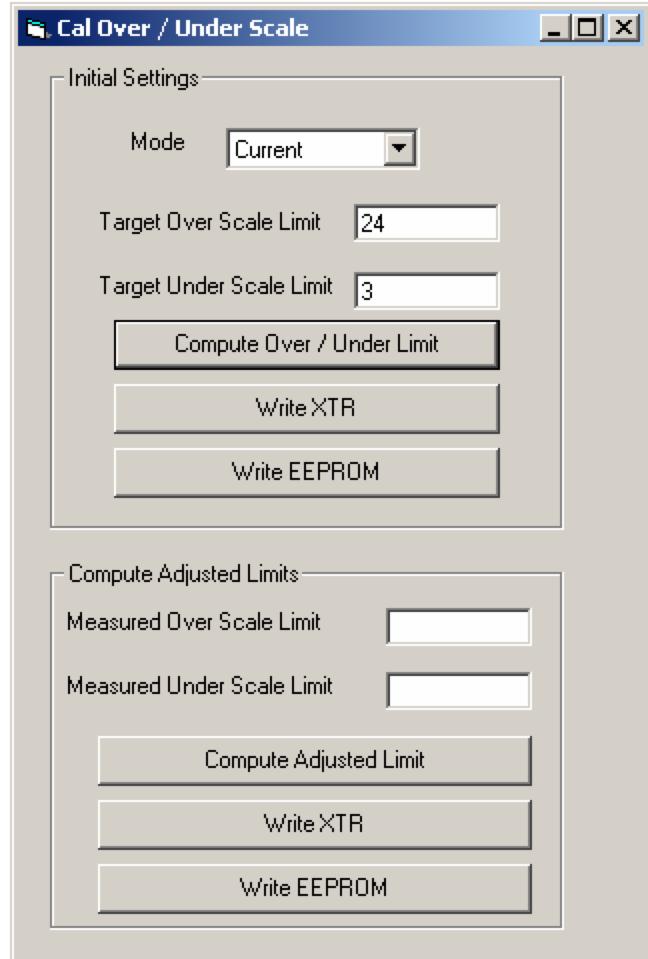


Step 3: Final Result



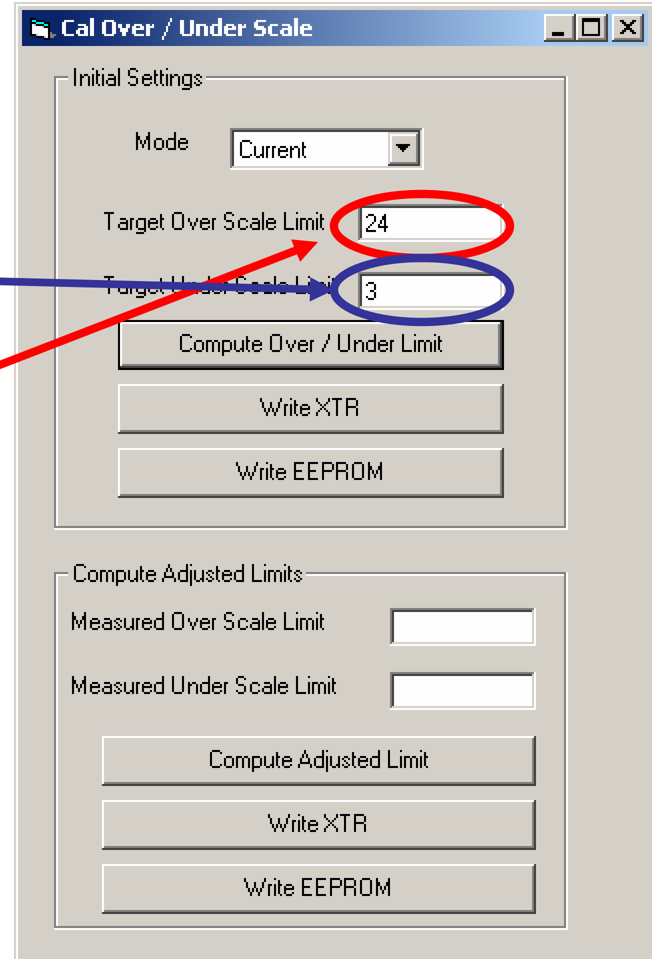
Step 4: (optional) Calibrate Over/Under Scale Limit

Choose Overscale and Underscale Target



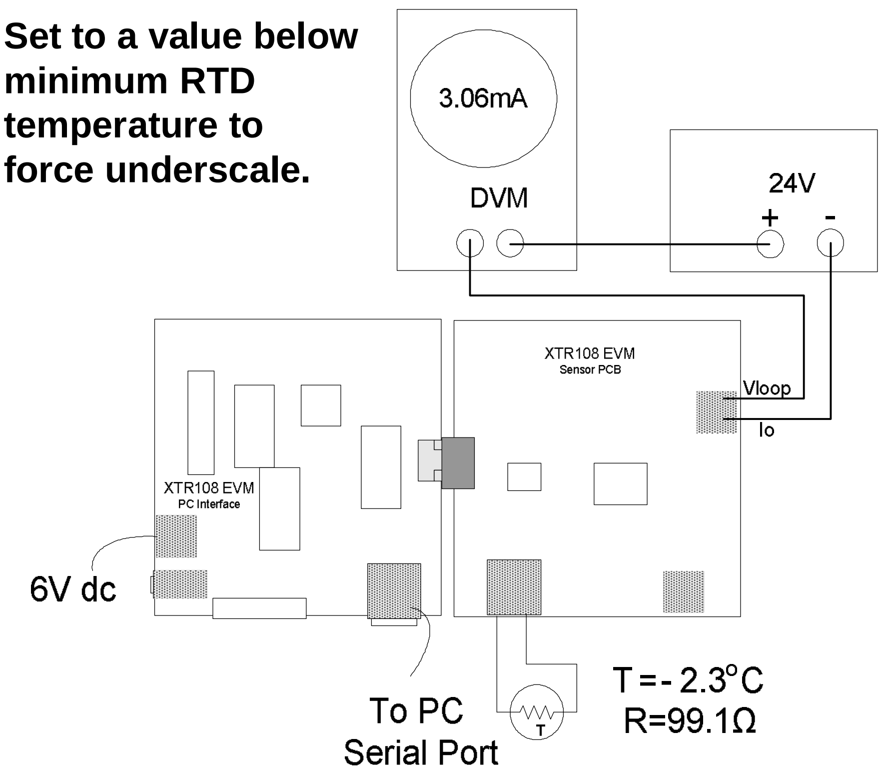
Choose Overscale and Underscale Target

Underscale	Overscale
3.55	20.7
3.35	21.2
3.15	21.7
2.96	22.2
2.76	22.7
2.56	23.2
2.37	23.7
2.17	24.2
	24.6
	25.1
	25.6
	26.1
	26.6
	27.1
	27.6
	28.1

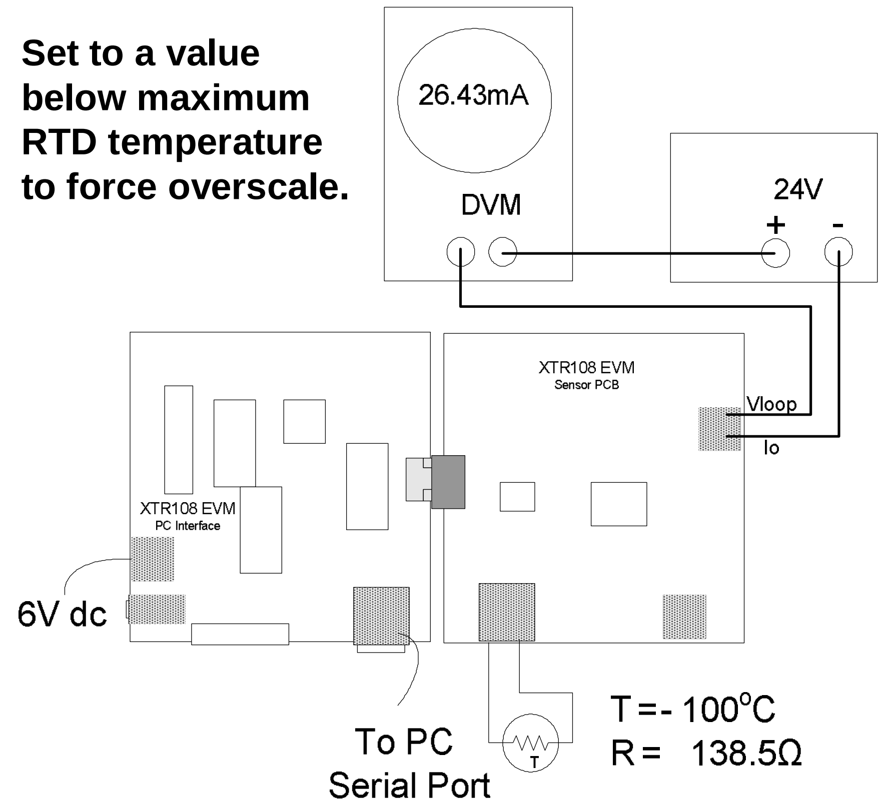


Measure Overscale / Underscale Limit

Set to a value below minimum RTD temperature to force underscale.



Set to a value below maximum RTD temperature to force overscale.



Compute the Adjusted Target

Overscale_Targ = 24
Overscale_Meas = 26.43
AdjOverTarget = Overscale_Targ - (Overscale_Meas - Overscale_Targ)
AdjOverTarget = 21.57

Underscale_Targ = 3
Underscale_Meas = 3.06
AdjUnderTarget = Underscale_Targ - (Underscale_Meas - Underscale_Targ)
AdjUnderTarget = 2.94

Choose Overscale and Underscale Target

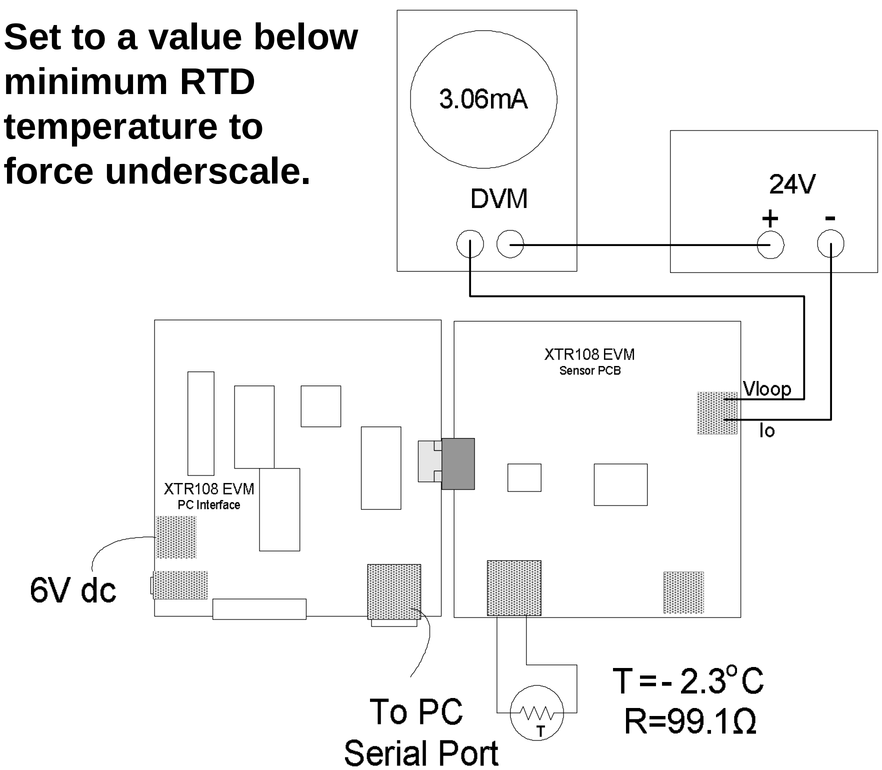
Underscale	Overscale
3.55	20.7
3.35	21.2
3.15	21.7
2.96	22.2
2.76	22.7
2.56	23.2
2.37	23.7
2.17	24.2
	24.6
	25.1
	25.6
	26.1
	26.6
	27.1
	27.6
	28.1

AdjOverTarget = 21.57

AdjUnderTarget = 2.94

Check Error

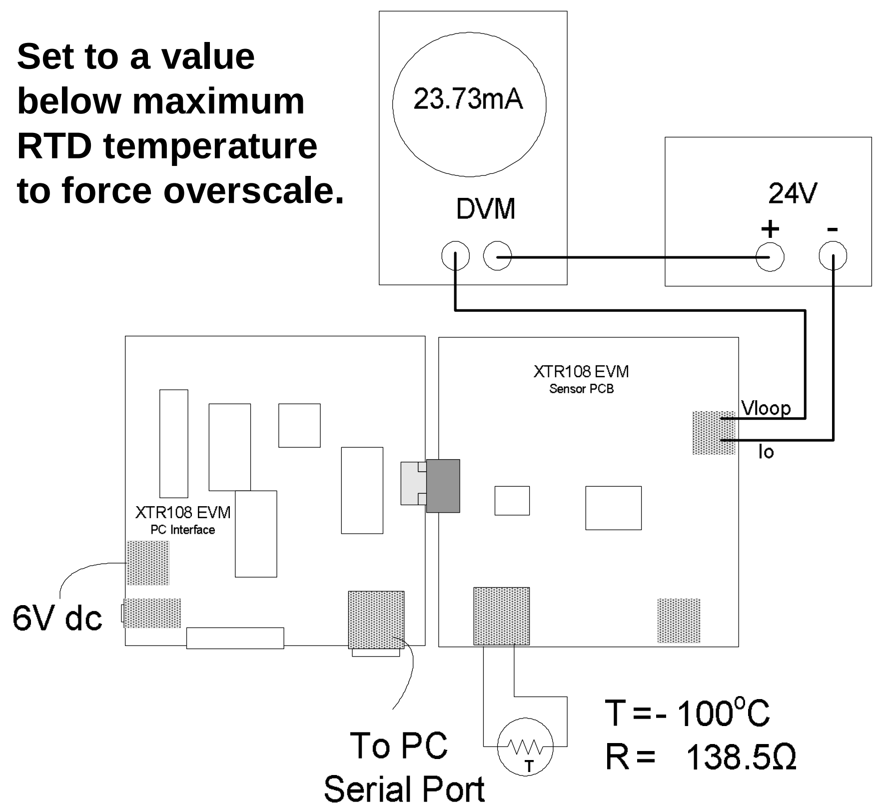
Set to a value below minimum RTD temperature to force underscale.



Target = 3mA

Error = 0.06mA

Set to a value below maximum RTD temperature to force overscale.



Target = 24mA

Error = -0.27mA

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