![Texas Instruments logo]

XTR108EVM-USB Evaluation Board and Software Tutorial

This user's guide describes the characteristics, operation and use of the XTR108EVM-USB evaluation module (EVM). This EVM is designed to evaluate the performance of the XTR108, an SPI™-programmable, current- or voltage-output, two-wire transmitter designed for temperature and bridge sensors. Throughout this document, the terms *evaluation board*, *evaluation module*, and *EVM* are synonymous with the XTR108EVM-USB. This user's guide also includes information regarding operating procedures and input/output connections, an electrical schematic, printed circuit board (PCB) layout drawings, and a parts list for the EVM.

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1   Overview

This document provides the information needed to set up and operate the XTR108EVM-USB evaluation module, which is a test platform for the XTR108 programmable two-wire transmitter and sensor conditioner. For a more detailed description of the XTR108, refer to the product data sheet (SBOS187) available from the Texas Instruments web site at www.ti.com.

The XTR108EVM-USB is an evaluation module that is used to fully evaluate the XTR108. The XTR108 is an integrated circuit that provides correction of zero, span, and linearization errors for RTDs (resistive thermal devices) and bridge sensors. Overall system accuracy of 0.1% error (relative to full-scale output span) or less is easily achievable using a two-point calibration algorithm. The XTR108EVM-USB consists of three PCBs. One board (the USB DAQ Platform) generates the digital signals required to communicate with the XTR108. The second board (XTR108EVM-USB Interface Board) provides a convenient interface to standard multimeters and includes an onboard RTD emulator circuit to facilitate calibration. The third board (XTR108EVM-USB Sensor Board) contains the XTR108 device as well as support and configuration circuitry. Once calibrated, the XTR108EVM-USB Sensor Board can be used as a fully-functional, stand-alone system. Similarly, the USB-DAQ Platform and XTR108EVM-USB Interface Board can be connected to other stand-alone XTR108 circuitry for quick calibration, making the XTR108EVM-USB a capable production tool.

1.1   XTR108EVM-USB Kit Contents

Figure 1 shows the hardware included with the XTR108EVM-USB kit. Table 1 describes each item included in the kit. Contact the Texas Instruments Product Information Center nearest you if any component is missing. It is highly recommended that you also check the XTR108 product folder to verify that you have the latest version of the related software.
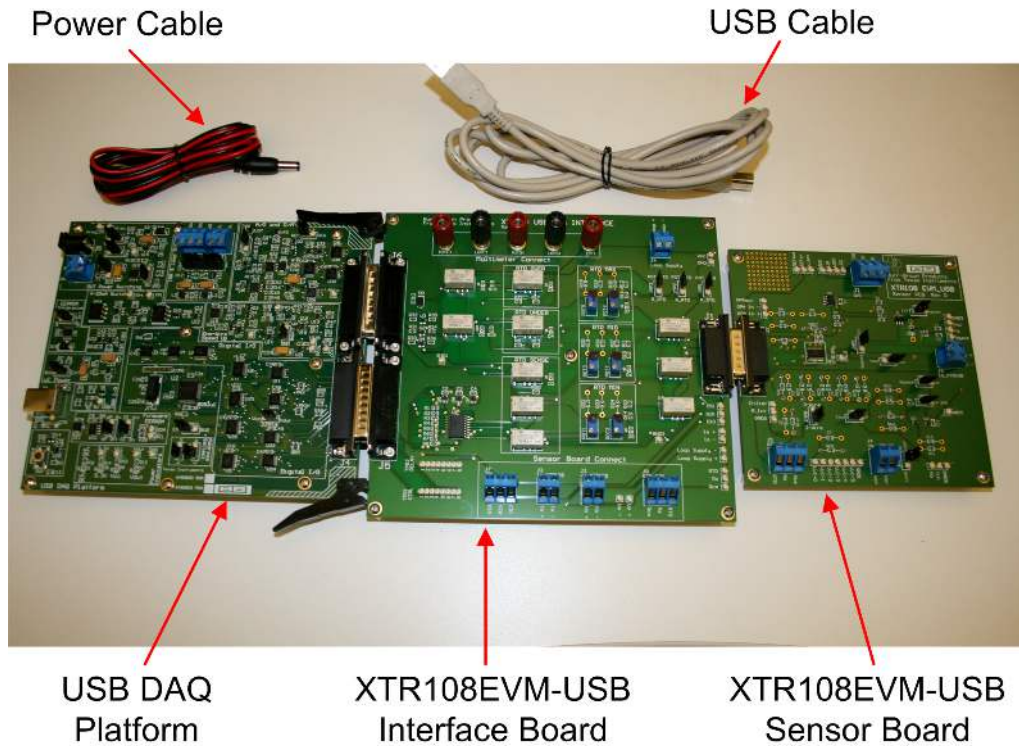
Figure 1. Hardware Included With the XTR108EVM-USB

Table 1. XTR108EVM-USB Kit Contents

Quantity	Item	Description
1	USB DAQ Platform	Digital communications board
1	XTR108EVM-USB Interface Board	XTR108EVM-USB Interface Board with required populated components
1	XTR108EVM-USB Sensor Board	XTR108EVM-USB Sensor Board with required populated components
1	USB cable	Connects PC to USB DAQ Platform
1	Power Cable	Connects external supply to USB DAQ Platform

1.2   *Related Documentation from Texas Instruments*

The documents listed in Table 2 provide information regarding Texas Instruments' hardware used in assembly of the XTR108EVM-USB. This user's guide is available from the TI web site under literature number SBOU123. Any letter appended to the literature number corresponds to the document revision that is current at the time of the writing of this document. Newer revisions may be available from the TI web site at www.ti.com, or contact the Texas Instruments Product Information Center. Identify the document by both title and literature number.

Table 2. Related Documentation

Document	Literature Number
USB DAQ Platform user's guide	SBOU056
XTR108 product data sheet	SBOS187

2   Hardware Overview

Figure 2 shows the XTR108EVM-USB system setup. The Windows™ PC runs software that communicates with the USB DAQ Platform. The USB DAQ Platform generates the digital signals used to communicate with the XTR108. The XTR108EVM-USB Interface Board routes digital communication and analog input signals to the XTR108, provides a convenient interface to standard multimeters, and includes an onboard RTD emulator circuit to facilitate calibration. The XTR108EVM-USB Sensor Board contains the XTR108 device as well as support and configuration circuitry.
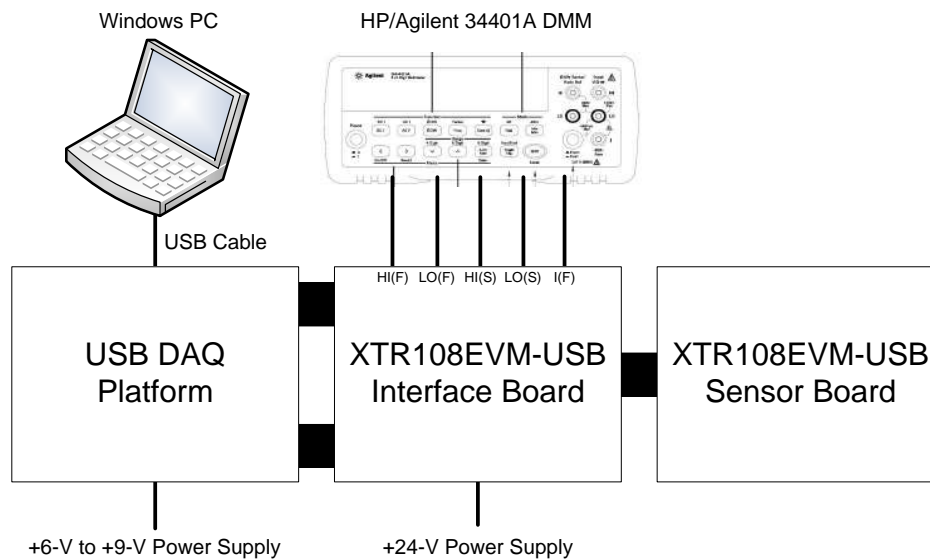
Figure 2. XTR108EVM-USB Hardware Setup

2.1 XTR108EVM-USB Theory of Operation

Figure 3 shows the block diagram of the XTR108EVM-USB Interface Board and Sensor Board.
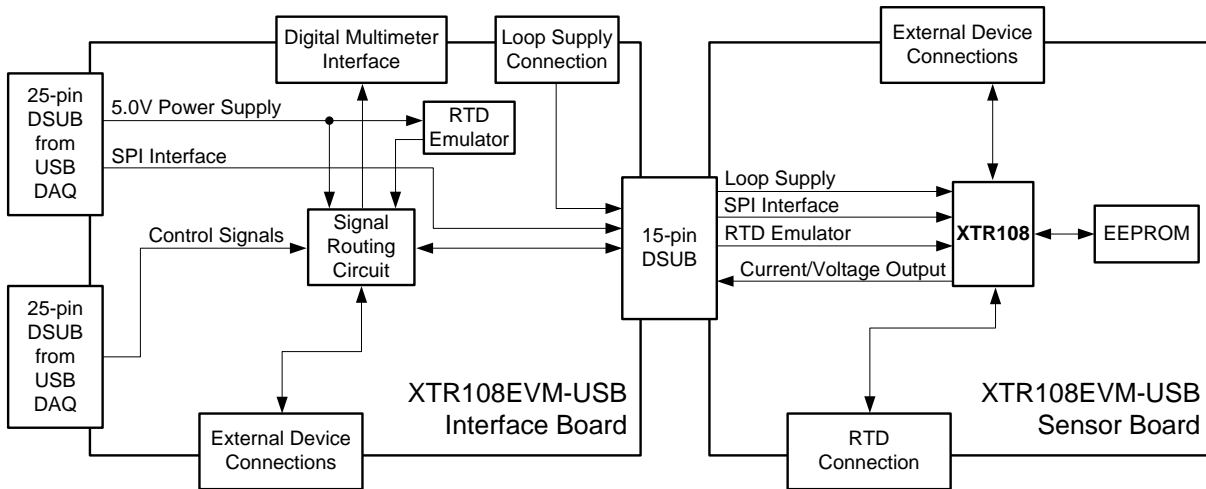
Figure 3. XTR108EVM-USB Block Diagram

The XTR108EVM-USB Interface Board provides connections to the SPI interface and 5.0-V power supply on the USB DAQ Platform and also provides a convenient interface to an external digital multimeter (DMM). The Interface Board also contains a network of signal-controlled relays from the USB DAQ that handles the routing of all EVM input and output signals.

The Interface Board also includes a user-configurable RTD emulator circuit that simulates the behavior of a RTD (resistive thermal device) using potentiometers and surface-mount resistors. Using the RTD emulator allows the user to more quickly achieve a deeper understanding of the XTR108EVM-USB hardware and software. When the XTR108EVM-USB capabilities and functions are fully understood, the user can connect a real-world sensor to the EVM and perform a full calibration. Note that calibrations with real-world sensors are time-consuming because devices such as these are normally calibrated at multiple temperatures in an environmental chamber. It is not unusual for temperature calibration to require 12 hours.

The XTR108EVM-USB Sensor board contains the XTR108 device as well as support and configuration circuitry. The configuration circuitry includes a 4Kb EEPROM used to store the XTR108 power-on settings. When the XTR108 is powered on it automatically reads the EEPROM and programs its internal registers with the values stored in the EEPROM.

2.2 Interface Board Overview

Figure 4 shows the location of all XTR108EVM-USB Interface Board connectors and jumpers.
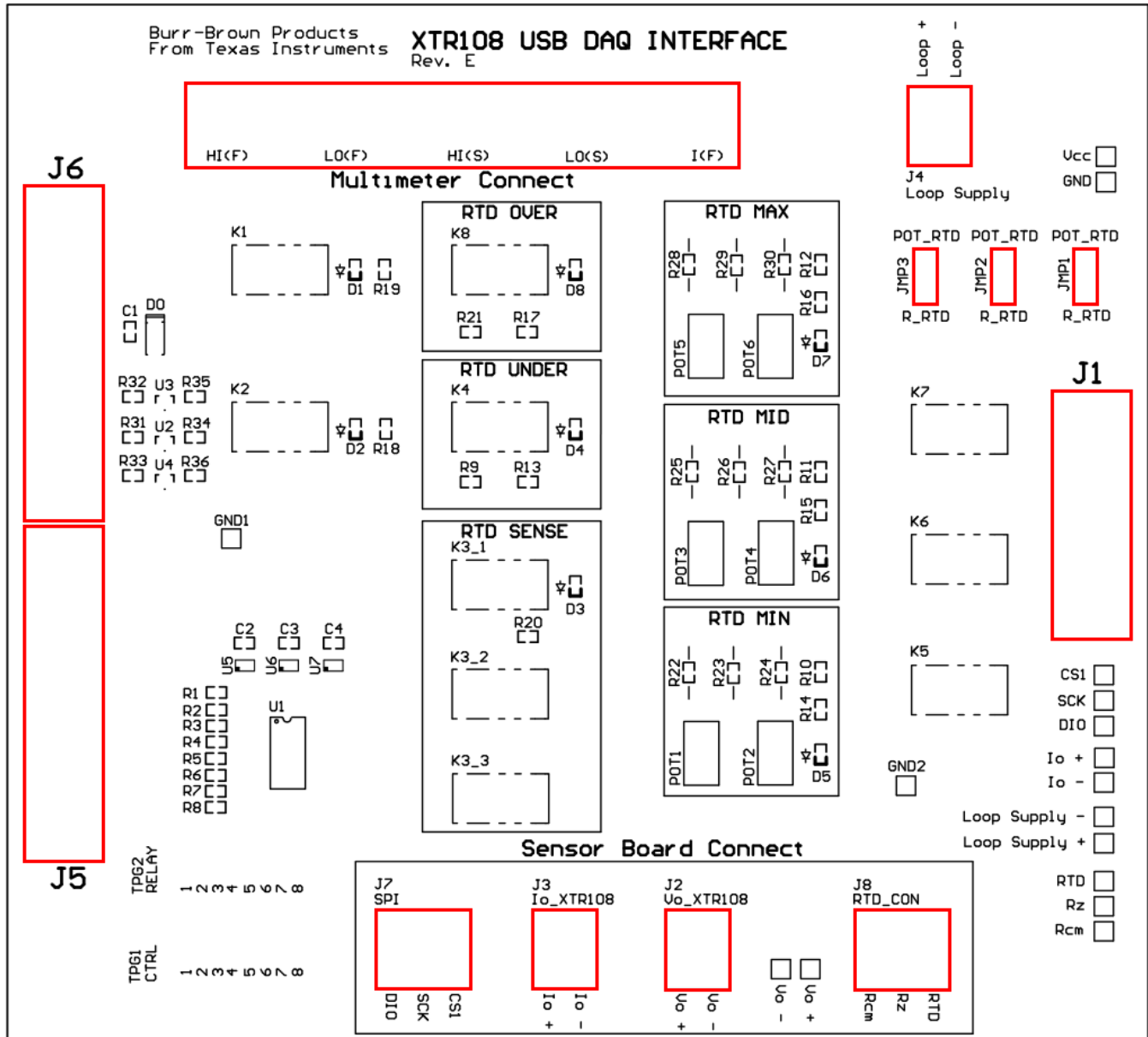
Figure 4. XTR108EVM-USB Interface Board Connectors and Jumpers

2.2.1 Interface Board: Signal Definitions and Pinouts

This section provides the signal definitions for all XTR108EVM-USB Interface Board connectors.

2.2.1.1 Multimeter Connect

Table 3 shows the signals connected to the Multimeter Connect interface on the Interface Board.

Table 3. Multimeter Connect Pinout

Name	Description
HI(F)	Voltage and resistance measurement; high-side forced connection
LO(F)	Voltage and resistance measurement; low-side forced connection
HI(S)	Voltage and resistance measurement; high-side sensed connection
LO(S)	Voltage and resistance measurement; low-side sensed connection
I(F)	Current output measurement connection

2.2.1.2 J1 (15-Pin Female DSUB)

Table 4 shows the signals connected to J1 on the Interface Board. J1 is the connection for all input and output signals between the Interface Board and Sensor Board.

Table 4. J1 Pinout (15-Pin Female DSUB)

Pin	Name	Description
1	SPI_DIO	SPI data input/output
2	SPI_SCK	SPI clock
3	SPI_CS1	SPI chip select
4	RCM	R_{CM} (common-mode resistor)
5	RZ	R_Z (zero-scale resistor)
6	RTD	RTD resistance
7	IO–	Low-side current output from the XTR108
8	IO+	High-side current output from the XTR108
9	VO–	Low-side voltage output from the XTR108
10	VO+	High-side voltage output from the XTR108
11	GND	Ground
12-15	NC	No connection

2.2.1.3 J2 (Vo_XTR108)

Table 5 shows the signals connected to J2 on the Interface Board. J2 is used to connect the voltage output of an external XTR108 system to the Interface Board.

Table 5. J2 Pinout (Vo_XTR108)

Pin	Name	Description
1	VO+	High-side voltage output from the XTR108
2	VO–	Low-side voltage output from the XTR108

2.2.1.4 J3 (Io_XTR108)

Table 6 shows the signals connected to J3 on the Interface Board. J3 is used to connect the current output of an external XTR108 system to the Interface Board.

Table 6. J3 Pinout (Io_XTR108)

Pin	Name	Description
1	IO+	High-side current output from the XTR108
2	IO–	Low-side current output from the XTR108

2.2.1.5 J4 (Loop Supply)

Table 7 shows the signals connected to J4 on the Interface Board. J4 provides the loop power supply to the XTR108.

Table 7. J4 Pinout (Loop Supply)

Pin	Name	Description
1	LOOP–	Low-side loop power supply
2	LOOP+	High-side loop power supply

2.2.1.6 J5 (25-Pin Female DSUB)

Table 8 shows the signals connected to J5 on the Interface Board. J5 is used to connect the USB DAQ control signals to the Interface Board.

Table 8. J5 Pinout (25-Pin Female DSUB)

Pin	Name	Description	Used
1	NC	No connection	No
2	CTRL1	Control signal 1	**Yes**
3	CTRL2	Control signal 1	**Yes**
4	CTRL3	Control signal 1	**Yes**
5	CTRL4	Control signal 1	**Yes**
6	CTRL5	Control signal 1	**Yes**
7	CTRL6	Control signal 1	**Yes**
8	CTRL7	Control signal 1	**Yes**
9	CTRL8	Control signal 1	**Yes**
10	MEAS1	Measure input 1	No
11	MEAS2	Measure input 1	No
12	MEAS3	Measure input 1	No
13	MEAS4	Measure input 1	No
14	MEAS5	Measure input 1	No
15	MEAS6	Measure input 1	No
16	MEAS7	Measure input 1	No
17	MEAS8	Measure input 1	No
18	SPI_SCK	SPI clock, channel 2	No
19	SPI_CS2	SPI chip select, channel 2	No
20	SPI_DOUT2	SPI data output, channel 2	No
21	SPI_DIN2	SPI data input, channel 2	No
22	VDUT	Switched power supply	No
23	VCC	USB DAQ power supply	No
24, 25	GND	Ground	No

2.2.1.7   J6 (25-Pin Male DSUB)

Table 9 shows the signals connected to J6 on the Interface Board. J6 is used to connect the SPI interface and 5.0-V power supply from the USB DAQ to the Interface Board.

Table 9. J6 Pinout (25-Pin Male DSUB)

Pin	Name	Description	Used
1	DAC_A	DAC_A output	No
2	DAC_B	DAC_B output	No
3	DAC_C	DAC_C output	No
4	DAC_D	DAC_D output	No
5	ADS1_VIN+	ADS1 positive input	No
6	ADS1_VIN–	ADS1 negative input	No
7	ADS2_VIN+	ADS2 positive input	No
8	ADS2_VIN–	ADS2 negative input	No
9	I2C_SCK	I^2C clock	No
10	I2C_SDA	I^2C data	No
11	ONE_WIRE	One-wire communication line	No
12	I2C_SDA_ISO	I^2C data (isolated)	No
13	I2C_SCK_ISO	I^2C clock (isolated)	No
14	XTR +LOOP	Current-loop high-side input	No
15	XTR –LOOP	Current-loop low-side input	No
16	INA–	INA negative input	No
17	VDUT	Selectable 3.3-V or 5.0-V power supply	No
18	VCC	5.0-V power supply	**Yes**
19	+15V	+15-V power supply	No
20	–15V	–15-V power supply	No
21	GND	Ground	**Yes**
22	SPI_SCK	SPI clock, channel 1	**Yes**
23	SPI_CS1	SPI chip select, channel 1	**Yes**
24	SPI_DOUT	SPI data output, channel 1	**Yes**
25	SPI_DIN1	SPI data input, channel 1	**Yes**

2.2.1.8   J7 (SPI)

Table 10 shows the signals connected to J7 on the Interface Board. J7 is used to connect the SPI interface to an external XTR108 system.

Table 10. J7 Pinout (SPI)

Pin	Name	Description
1	DIO	SPI data input/output
2	SCK	SPI clock
3	CS1	SPI chip select

2.2.1.9   J8 (RTD_CON)

Table 11 shows the signals connected to J8 on the Interface Board. J8 is used to connect the RTD emulator circuit to an external XTR108 system.

Table 11. J8 Pinout (RTD_CON)

Pin	Name	Description
1	RCM	R_{CM} (common-mode resistor)
2	RZ	R_Z (zero-scale resistor)
3	RTD	RTD resistance

2.2.2   Interface Board Jumper Settings

Table 12 explains the function of the XTR108EVM-USB Interface Board jumpers.

Table 12. Interface Board Jumper Functions

Jumper	Default	Description
JMP1	POT_RTD	This jumper selects which resistor string is used for the RTD emulator minimum-scale output. Set the jumper to the POT_RTD position to use potentiometers POT1 and POT2. Set the jumper to the R_RTD position to use surface-mount resistors R22-R24 (not installed by default).
JMP2	POT_RTD	This jumper selects which resistor string is used for the RTD emulator mid-scale output. Set the jumper to the POT_RTD position to use potentiometers POT3 and POT4. Set the jumper to the R_RTD position to use surface-mount resistors R25-R27 (not installed by default).
JMP3	POT_RTD	This jumper selects which resistor string is used for the RTD emulator maximum-scale output. Set the jumper to the POT_RTD position to use potentiometers POT5 and POT6. Set the jumper to the R_RTD position to use surface-mount resistors R28-R30 (not installed by default).

2.3 Sensor Board Overview

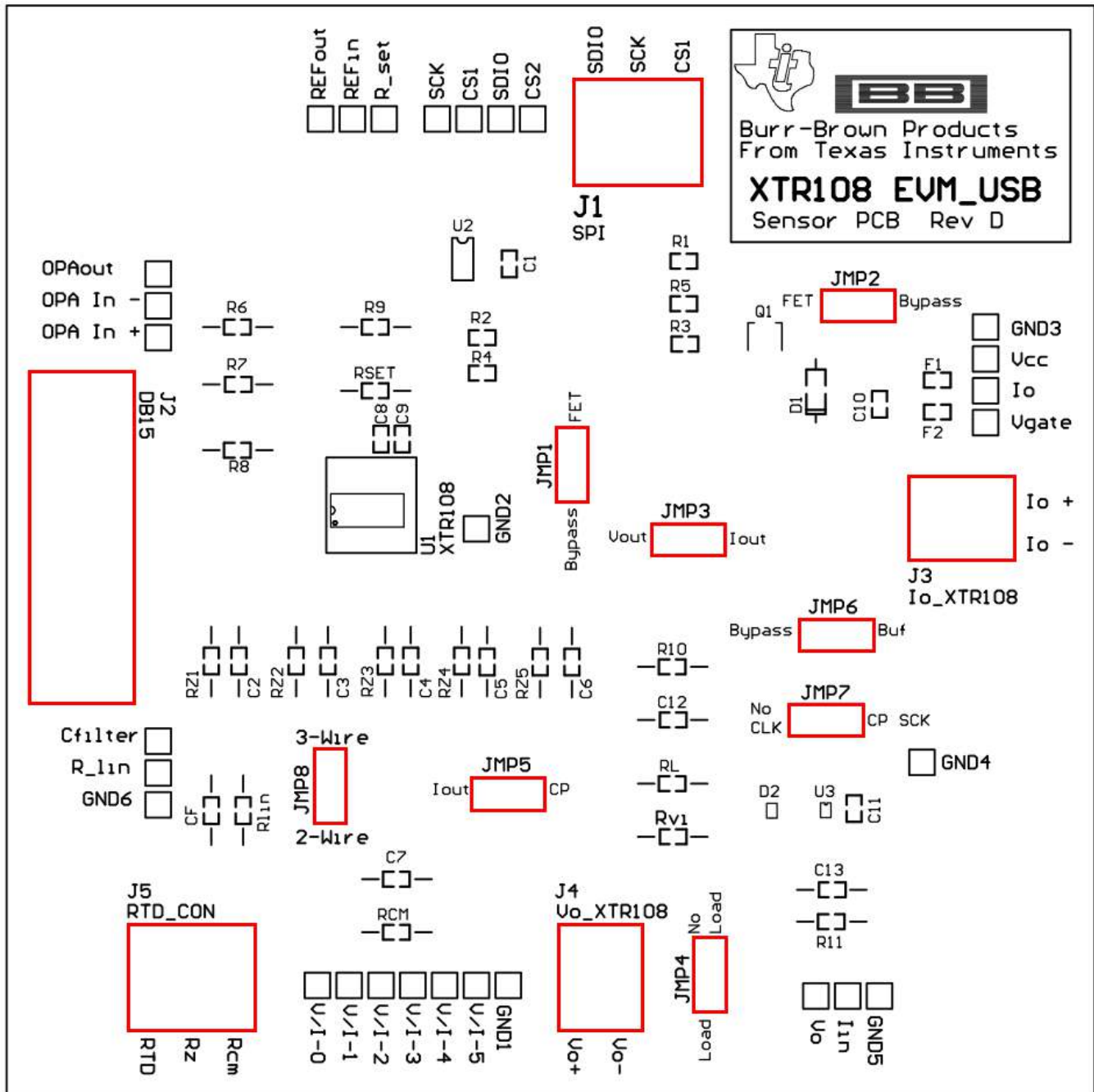Figure 5 shows the location of all XTR108EVM-USB Sensor Board connectors and jumpers.

Figure 5. XTR108EVM-USB Sensor Board Connectors and Jumpers

2.3.1 Sensor Board Connections

This section provides signal definitions for all XTR108EVM-USB Interface Board connectors.

2.3.1.1 J1 (SPI)

Table 13 shows the signals connected to J1 on the Sensor Board. J1 is used to connect an external SPI interface to the Sensor Board.

Table 13. J1 Pinout (SPI)

Pin	Name	Description
1	CS1	SPI chip select
2	SCK	SPI clock
3	SDIO	SPI data input/output

2.3.1.2 J2 (15-pin Male DSUB)

J2 is the connection for all input and output signals between the Interface Board and Sensor Board. See Table 4 for pinout information.

2.3.1.3 J3 (Io_XTR108)

Table 14 shows the signals connected to J3 on the Sensor Board. J3 is used to connect an external loop power supply to the Sensor Board and to connect the XTR108 current output to an external ammeter.

Table 14. J3 Pinout (Io_XTR108)

Pin	Name	Description
1	IO–	Low-side loop power-supply and current output from the XTR108
2	IO+	High-side loop power-supply and current output from the XTR108

2.3.1.4 J4 (Vo_XTR108)

Table 15 shows the signals connected to J4 on the Sensor Board. J4 is used to connect the XTR108 voltage output to an external voltmeter.

Table 15. J4 Pinout (Vo_XTR108)

Pin	Name	Description
1	VO+	High-side voltage output from the XTR108
2	VO–	Low-side voltage output from the XTR108

2.3.1.5 J5 (RTD_CON)

Table 16 shows the signals connected to J5 on the Sensor Board. J5 is used to connect an external RTD to the Sensor Board.

Table 16. J5 Pinout (RTD_CON)

Pin	Name	Description
1	RTD	RTD resistance. Connect the red wire of a two- or three-wire RTD here.
2	RZ	R_Z (zero-scale resistor). Connect the black wire of a two- or three-wire RTD here.
3	RCM	R_{CM} (common-mode resistor). Short to pin 2 (RZ) if using a two-wire RTD. Connect the second black wire here if using a three-wire RTD.

2.3.2 Sensor Board Jumper Settings

Table 17 explains the function of the XTR108EVM-USB Interface Board jumpers.

Table 17. Sensor Board Jumper Functions

Jumper	Default	Description
JMP1	FET	This jumper selects whether to enable or bypass the depletion-mode transistor Q1. Set the jumper to the FET position when using current-output mode. Set the jumper to the BYPASS position when using voltage-output mode.
JMP2	FET	This jumper selects whether to enable or bypass the depletion-mode transistor Q1. Set the jumper to the FET position when using current-output mode. Set the jumper to the BYPASS position when using voltage-output mode.
JMP3	IOUT	This jumper selects between current-output mode or voltage-output mode. Set the jumper to the IOUT position when using current-output mode. Set the jumper to the VOUT position when using voltage-output mode.
JMP4	NO LOAD	This jumper selects whether to connect or disconnect a load resistor (R_L, not installed by default) from the voltage output of the XTR108. Set the jumper to the NO LOAD position when using current-output mode. Set the jumper to the LOAD position when using voltage-output mode (optional).
JMP5	IOUT	This jumper selects between the current-output or voltage-mode charge pump input at the XTR108 I_IN pin. Set the jumper to the IOUT position when using current-output mode. Set the jumper to the CP position when using voltage-output mode.
JMP6	BYPASS	This jumper enables or disables the SPI clock buffer in the voltage-output mode charge pump. Set the jumper to the BYPASS position when using current-output mode. Set the jumper to the BUF position when using voltage-output mode.
JMP7	NO CLK	This jumper enables or disables the voltage-output mode charge pump. Set the jumper to the NO CLK position when using current-output mode. Set the jumper to the CP SCK position when using voltage-output mode.
JMP8	2-WIRE	This jumper selects what type of RTD is connected to the XTR108. Set the jumper to the 2-WIRE position when using the RTD emulator on the Interface Board or when connecting an external two-wire RTD. Set the jumper to the 3-WIRE position when connecting an external three-wire RTD.

2.3.3 Test Points and Miscellaneous Breadboard Area

There are multiple points available on the Sensor Board, including several connections to I_{RET}. I_{RET} is common (labeled as GND on the board) for most XTR108 applications, and is provided for ease of measuring analog signals. Reserved areas with plated-through, standard-spacing, 0.1-inch holes for miscellaneous proof-of-concept breadboarding are also provided on the board. Most of the surface-mount components have *pin sockets* associated with them. These pin sockets allow the replacement of a surface-mount component with a through-hole component.

The pin sockets provide good contact with the leads of a component without solder, thus enabling quick reconfiguration of the board for many different XTR108 designs, as shown in Figure 6.
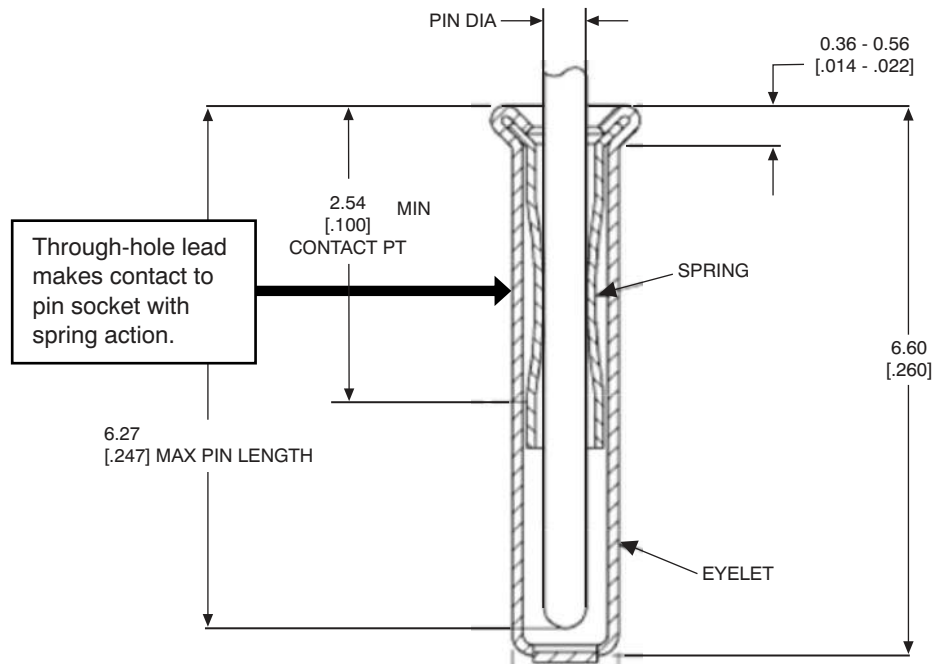

Figure 6. Pin Socket Mechanical Description

3 Hardware Setup

The XTR108EVM-USB hardware setup involves connecting the three EVM boards together, applying power to the USB DAQ platform, connecting the USB cable, applying power to the Interface Board, and setting the jumpers. This section covers the details of this procedure.

3.1 *Electrostatic Discharge Warning*

> **CAUTION**
>
> Many of the components on the XTR108EVM-USB are susceptible to damage by electrostatic discharge (ESD). Customers are advised to observe proper ESD handling precautions when unpacking and handling the EVM, including the use of a grounded wrist strap at an approved ESD workstation.

3.2   Connecting the Hardware

When first setting up the EVM hardware, It is recommended to first connect the USB DAQ Platform to the XTR108EVM-USB Interface Board. To connect the two PCBs together, gently push on both sides of the 25-pin D-SUB connectors as shown in Figure 7. Make sure that the connectors are completely pushed together because loose connections may cause intermittent operation.
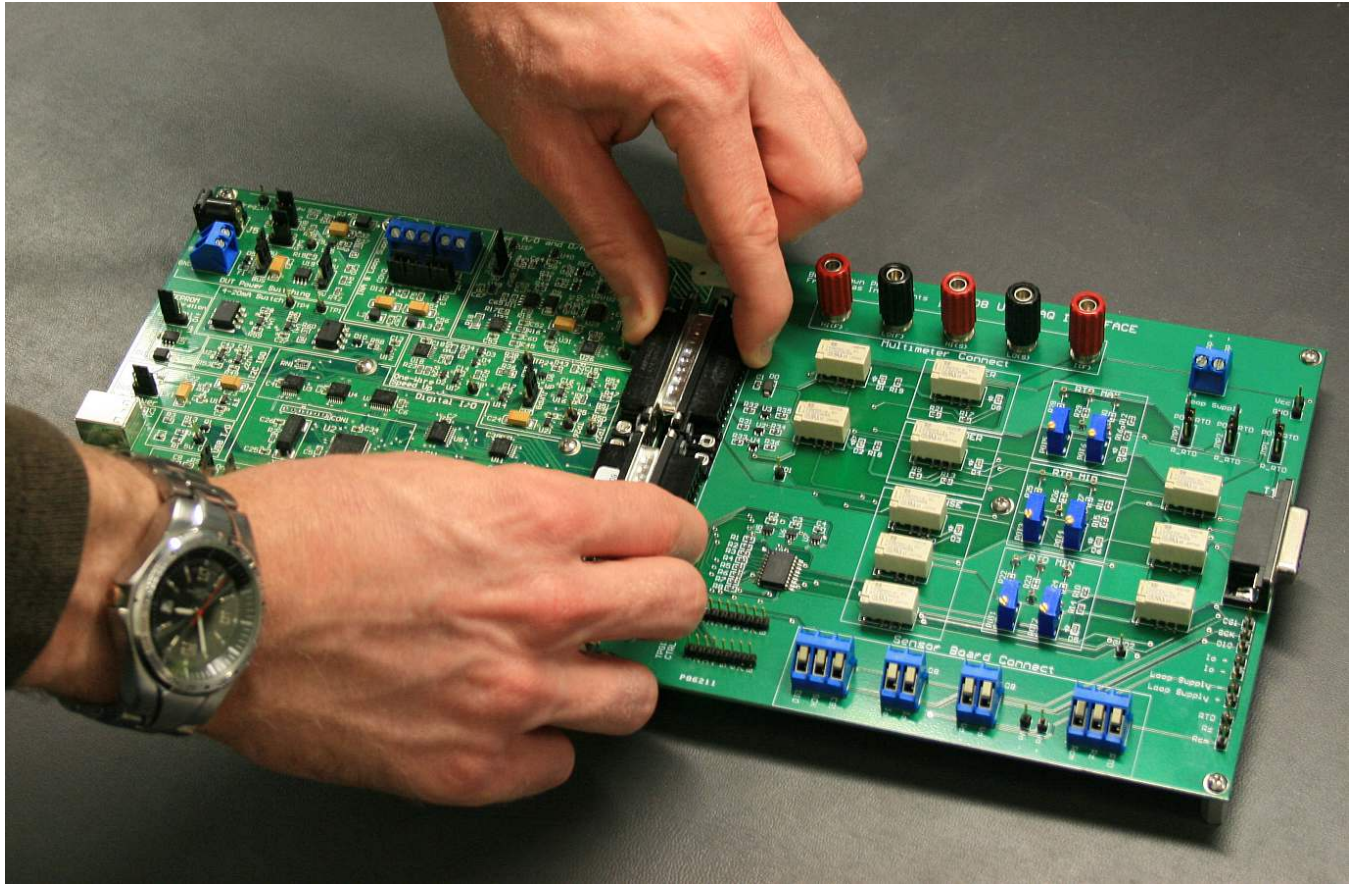

Figure 7. Connecting the USB DAQ Platform to the XTR108EVM-USB Interface Board

Next, connect the XTR108EVM-USB Sensor Board to the XTR108EVM-USB Interface Board by gently pushing on both sides of the 15-pin DSUB connector. Once the XTR108EVM-USB Sensor Board is connected, the system looks like the one in Figure 8.
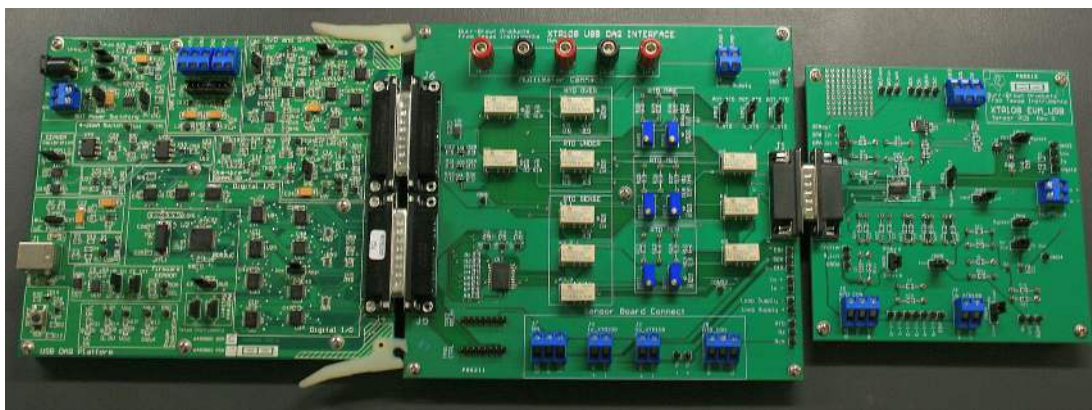

Figure 8. All Boards Connected

3.3 Connecting Power and USB to the USB DAQ Platform

After the three XTR108EVM-USB boards are connected, connect a 6Vdc to 9Vdc power supply to J5 or T3 of the USB DAQ platform. A power cable is included that fits J5. Caution: Be sure to observe correct polarity. If connected properly, the µC OK, 3.3-V, and VCC LEDs on the USB DAQ illuminate as shown in Figure 9. Always connect power before connecting the USB cable. If you connect the USB cable before connecting the power, the computer attempts to communicate with an unpowered device that is unable to respond.
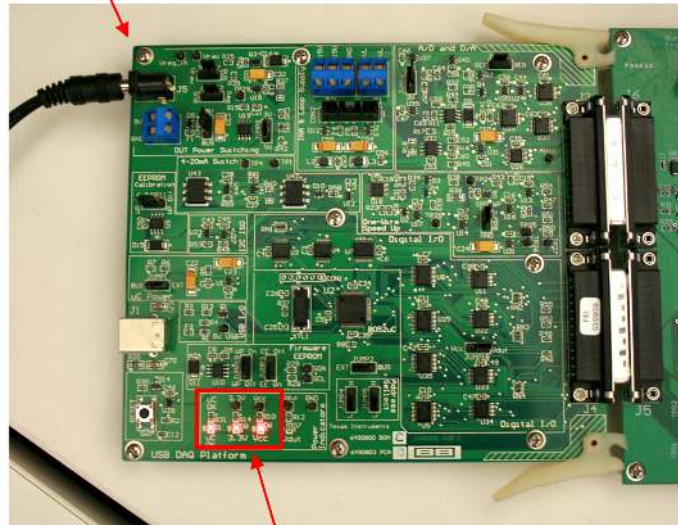
Figure 9. Connecting Power to the USB DAQ Platform

Once power has been applied to the USB DAQ Platform, you can connect one end of the USB cable to the USB DAQ and the other end to a PC USB port, as shown in Figure 10. Figure 11 shows the typical response to connecting the USB DAQ Platform to a PC USB port for the first time. Typically, the computer responds with a **Found New Hardware**, **USB Device** pop-up message. The pop-up message typically changes to **Found New Hardware**, **USB Human Interface Device** shortly after. This message indicates that the device is ready to be used. The USB DAQ Platform uses the Human Interface Device drivers that are part of the Microsoft® Windows® operating system.

In some cases, the Windows **Add Hardware Wizard** pops up. If this prompt occurs, allow the system device manager to install the Human Interface Device drivers by clicking **Yes** when requested to install the drivers.

Figure 10. Connecting the USB Cable to the USB DAQ Platform

Figure 11. Found New Hardware Pop-up Message

3.4   Connecting Loop Power Supply to the XTR108EVM-USB Interface Board

Connect a dc lab power supply to J4 on the Interface Board as shown in Figure 12. When operating in current-output mode, the loop-supply input voltage range is 12 V to 24 V. In general, you must consider the power dissipated in the external transistor and the operating temperature of the transistor in order to determine the maximum loop voltage and current. This calculation is determined in the XTR108 data sheet. When operating in voltage-output mode, the loop-supply input voltage range is (3.0 V to 5.5 V) + V_{D1}.

Connect DC Lab I_{OUT} Mode: 12V to 24V
Power Supply to J4 V_{OUT} Mode: 3V to 5.5V
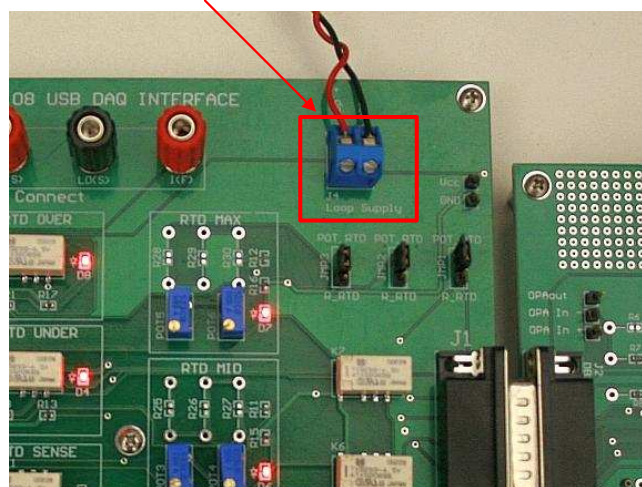
Figure 12. Connecting a Loop Power Supply to the XTR108EVM-USB Interface Board

3.5 Connecting Outputs to a Digital Multimeter (DMM)

The XTR108EVM-USB contains circuitry that routes the current output, voltage output, and RTD emulator signals to the multimeter connect terminals on the XTR108EVM-USB Interface Board. Any standard lab multimeter that supports dc voltage, dc current, and four-wire resistance measurements is compatible with the XTR108EVM-USB. This EVM is designed and tested with the Agilent 34401A multimeter.

To properly connect the XTR108EVM-USB Interface Board to the 34401A multimeter, follow the instructions given in Figure 13. Use the same connections for any other compatible multimeter.

Figure 13. 34401A Multimeter Connections

3.6 USB DAQ Platform Default Jumper Settings
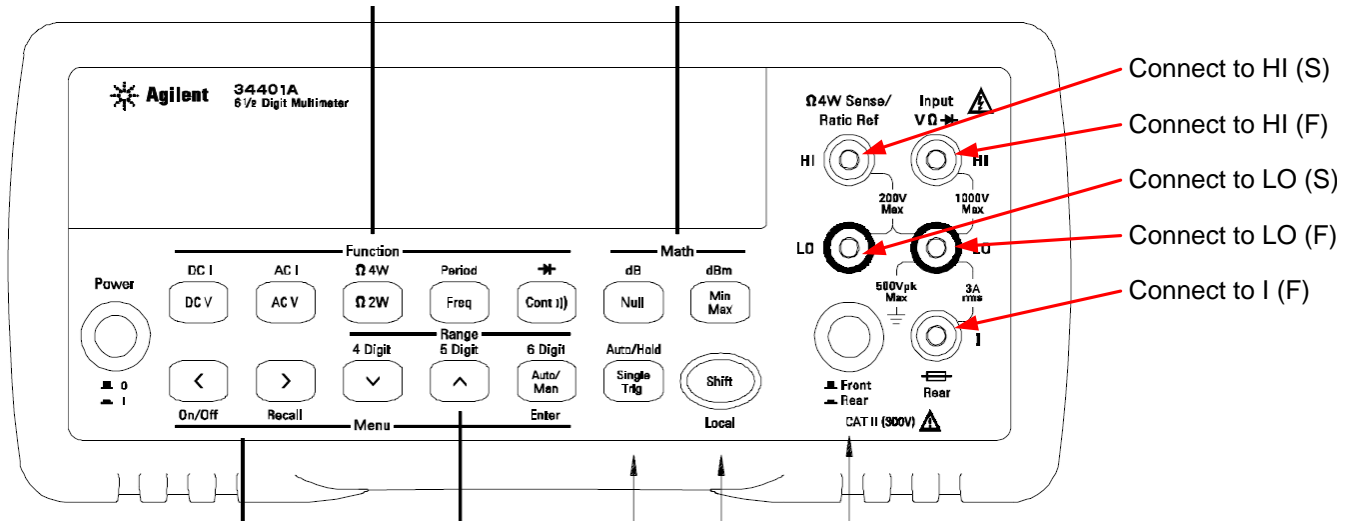
Figure 14 shows the default USB DAQ Platform jumper configuration. In general, these jumpers should not be changed. For more information about the function of these jumpers, refer to the USB DAQ Platform User's Guide.
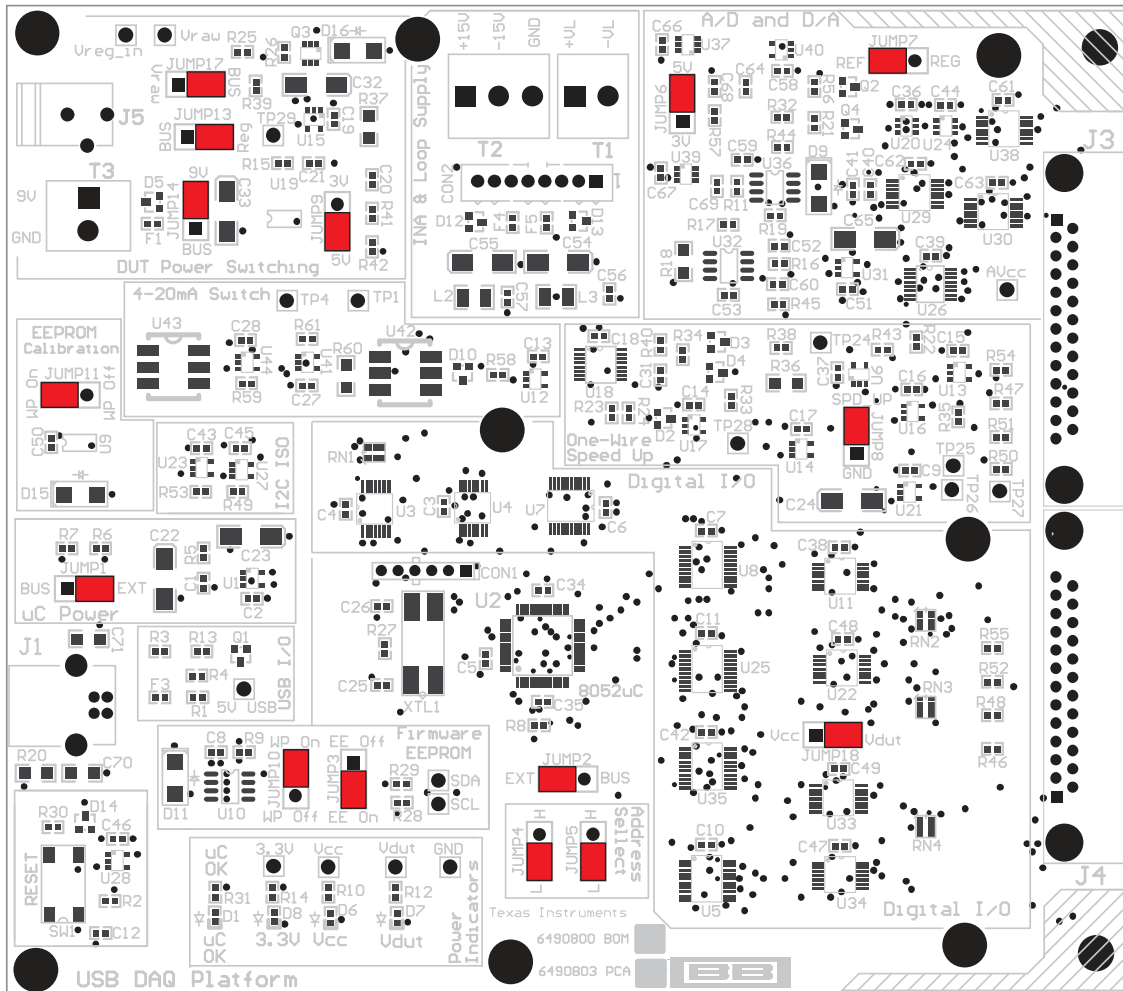
Figure 14. USB DAQ Platform Default Jumper Settings

3.7   XTR108EVM-USB Interface Board Default Jumper Settings

Figure 15 shows the default XTR108EVM-USB Interface Board jumper configuration. Table 18 summarizes the default jumper configuration. For more information about the jumpers on the Interface Board, see Table 12.

Figure 15. XTR108EVM-USB Interface Board Default Jumper Settings

Table 18. XTR108EVM-USB Interface Board Default Jumper Settings

Jumper	Position	Description
JMP1	POT_RTD	Use POT1, POT2 for the RTD emulator minimum-scale output
JMP2	POT_RTD	Use POT3, POT4 for the RTD emulator mid-scale output
JMP3	POT_RTD	Use POT5, POT6 for the RTD emulator maximum-scale output

3.8 XTR108EVM-USB Sensor Board Default Jumper Settings

Figure 16 shows the default XTR108EVM-USB Sensor Board jumper configuration. Table 19 summarizes the default jumper configuration. For more information about the jumpers on the Sensor Board, see Table 17.
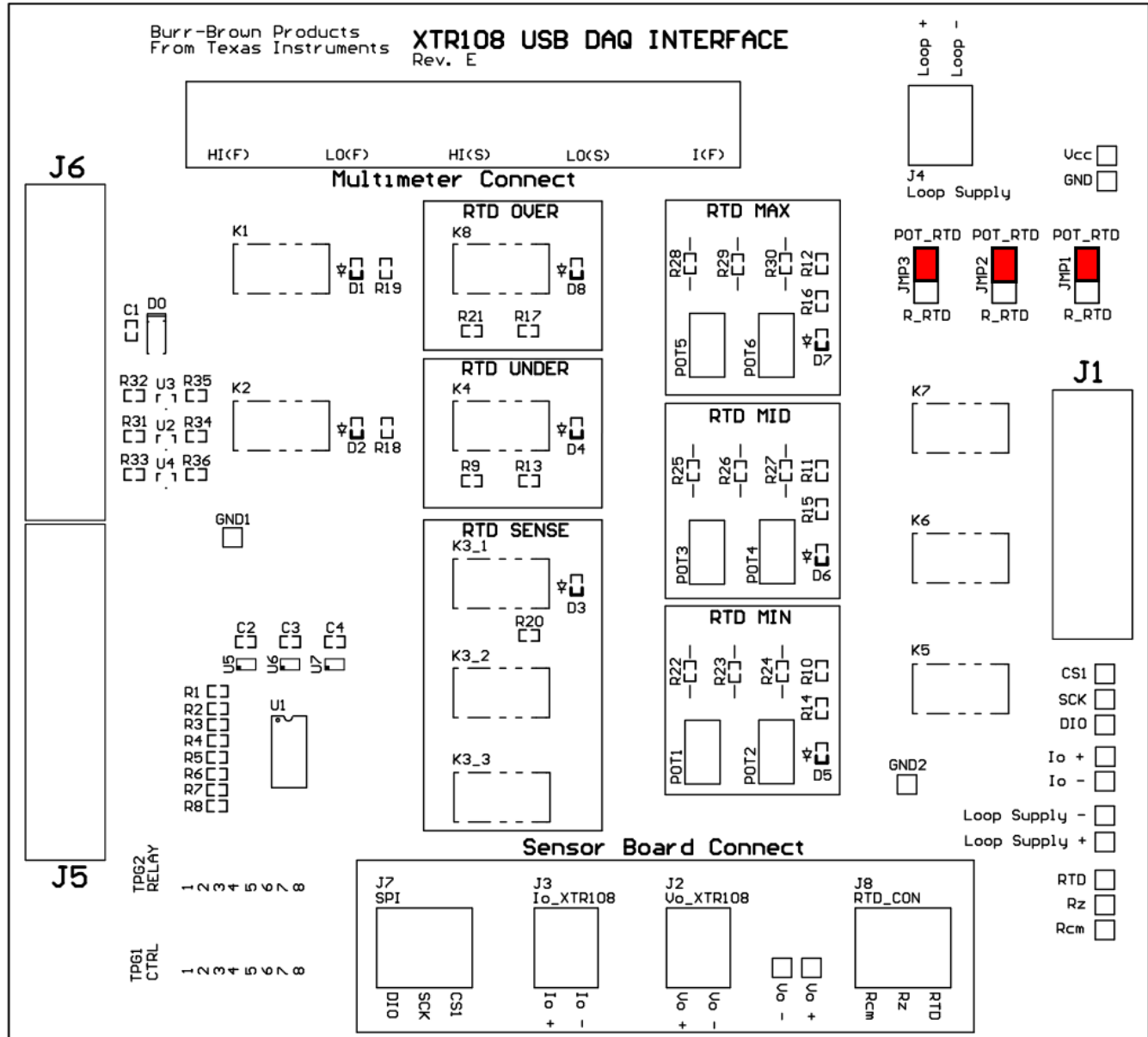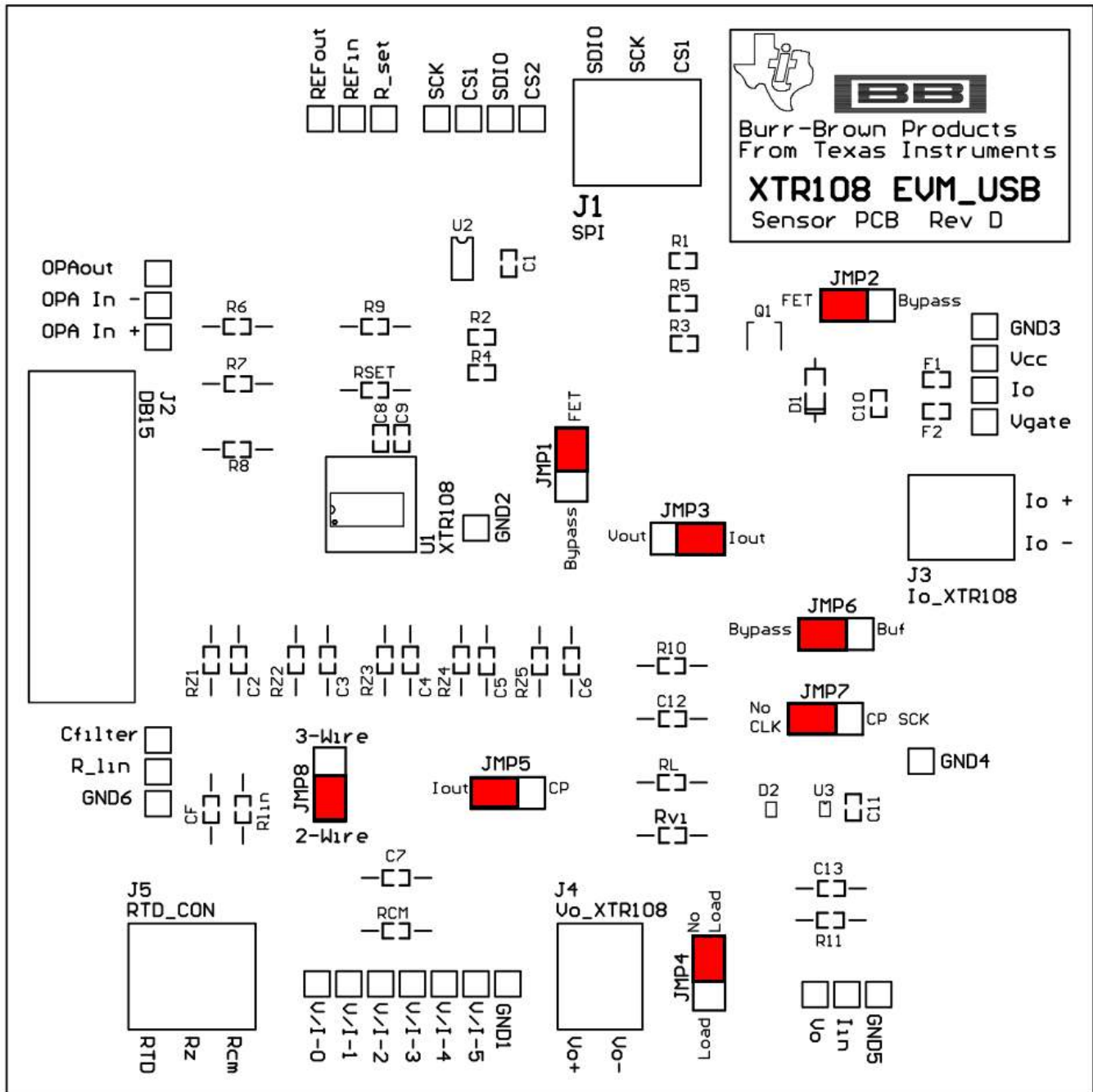

Figure 16. XTR108EVM-USB Sensor Board Default Jumper Settings

Table 19. XTR108EVM-USB Sensor Board Default Jumper Settings

Jumper	Position	Description
JMP1	FET	Enable FET sub regulator
JMP2	FET	Enable FET sub regulator
JMP3	IOUT	Current-output mode
JMP4	NO LOAD	Load resistor disconnected
JMP5	IOUT	Current-output mode
JMP6	BYPASS	Bypass SPI clock buffer on charge pump
JMP7	NO CLK	Disable charge pump
JMP8	2-WIRE	Select two-wire RTD

4   Software Setup

This section describes how to install the XTR108EVM-USB software.

4.1   Operating Systems for XTR108EVM-USB Software

The XTR108EVM-USB software is tested on the Microsoft Windows XP operating system (OS) with United States and European regional settings. The software should also function on other Windows operating systems. Please report any OS compatibility issues to the Precision Amplifiers E2E forum.

4.2   XTR108EVM-USB Software Installation

Follow these steps to install the XTR108EVM-USB software:

1. Software can be downloaded from the XTR108EVM-USB product folder, or from the disk included with the XTR108EVM-USB that includes a folder called *Install_software/*.
2. Find the file called *setup.exe*. Double-click the file to start the installation process.
3. Follow the on-screen prompts to install the software.
4. To remove the application, use the Windows *Add/Remove Software* control panel utility.

4.3   Starting the XTR108EVM-USB Software

The XTR108EVM-USB software can be started through the Windows *Start* menu. Click *Start → All Programs → XTR108EVM-USB → XTR108EVM-USB* to start the program, as shown in Figure 17.
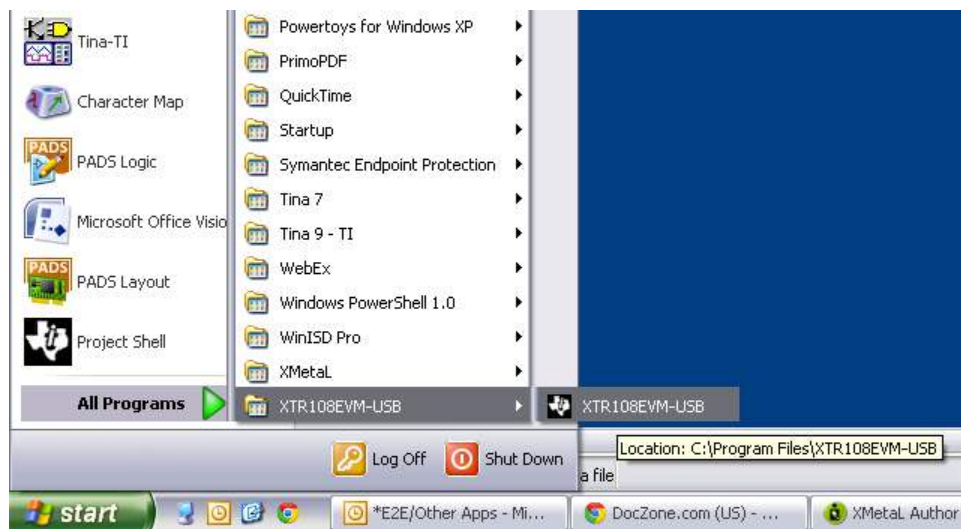
Figure 17. Starting the XTR108EVM-USB Software

5 Software Overview

Once the XTR108EVM-USB starts up, several SPI communications take place to initialize the Interface Board and read the XTR108 register values. Refer to Figure 18 for a screen shot of how the software should appear if the EVM is functioning properly. The actual values of the fields inside the XTR108 block diagram (such as PGA gain or I_{LIN} DAC Linearization) may vary.

Figure 18. XTR108EVM-USB Software Start-up, Block Diagram Tab

If there is an error in the communication between the PC and the USB-DAQ, an error message pops up as shown in Figure 19. In this case, it is recommended to close the EVM software, disconnect the power and USB cables from the USB-DAQ, and wait a few moments. Next reconnect the power cable, then reconnect the USB cable. After a few moments, start the XTR108EVM-USB software again.

Figure 19. USB Communication Error

5.1 Block Diagram Tab

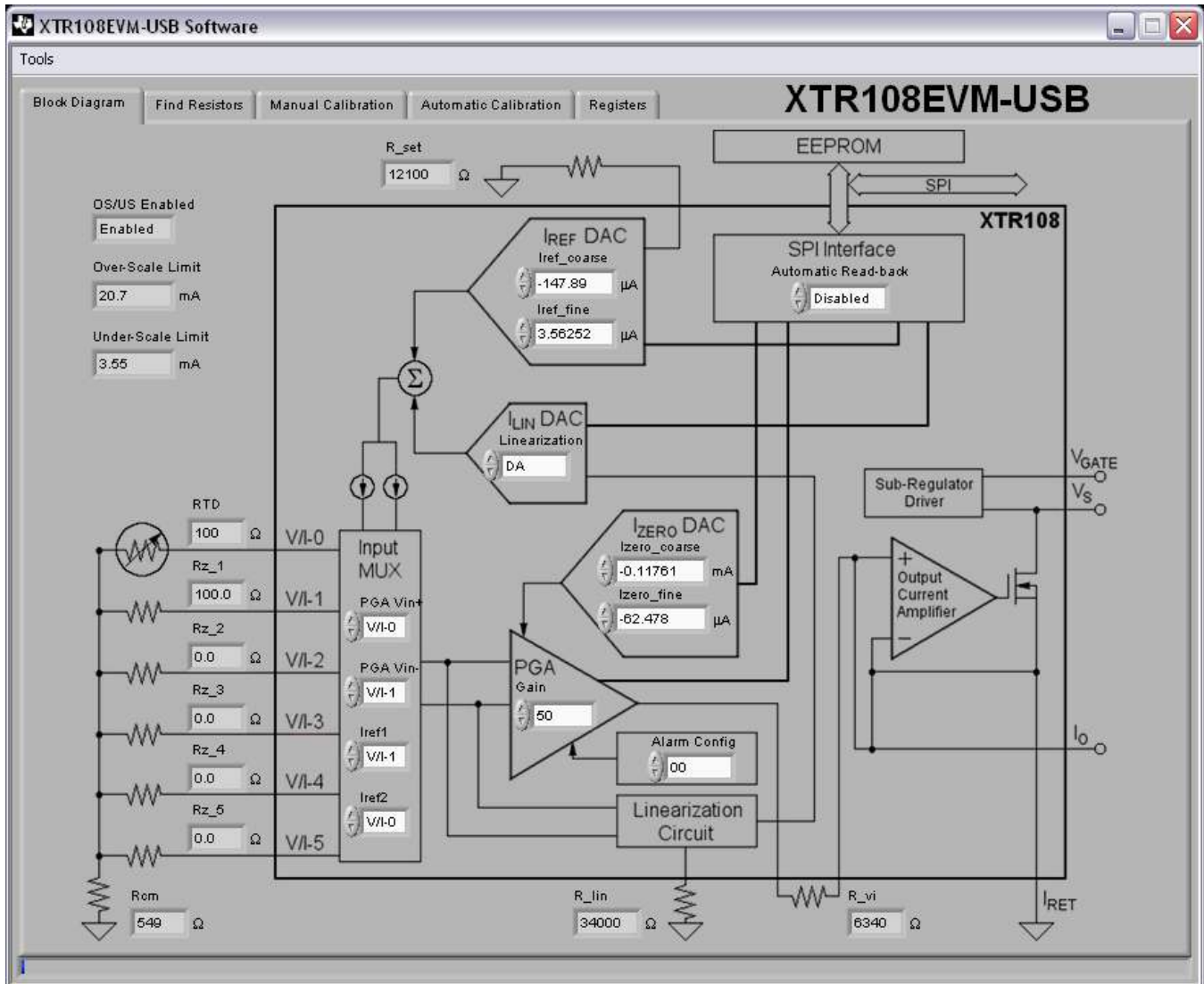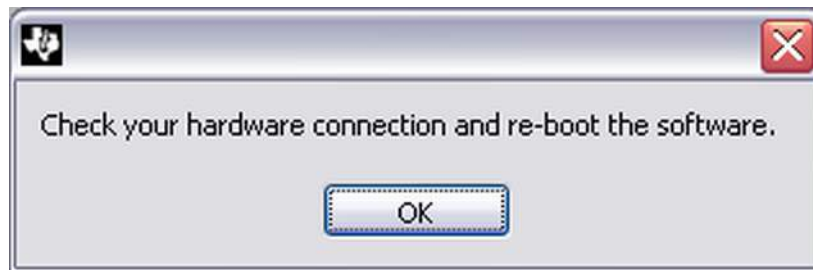The **Block Diagram** tab shown in Figure 18 is loaded by default during the XTR108EVM-USB software start-up. This tab primarily serves to display the XTR108 register values in a way that is easy to interpret because nearly every register hexadecimal value is converted to the real-world setting that the register represents. Other indicators display the supporting circuitry values for the current configuration. The remainder of this section provides an in-depth explanation of the function of each group of controls and indicators in the **Block Diagram** tab. All fields located internal to the XTR108 are controls that can be manipulated by the user, but it is recommended that only advanced users make changes to the controls in the **Block Diagram** tab.

For more information about any of the circuitry mentioned in the *Block Diagram Tab* section, see the *Theory of Operation* section in the XTR108 data sheet.

5.1.1 Input MUX

The Input MUX section of the block diagram shows the connections for the RTD sensor, zero-scale resistors (R_{Z1} through R_{Z5}), and common-mode resistor (R_{CM}). This section also displays the XTR108 input multiplexer settings. The multiplexer controls which input channels are connected to the excitation current sources and the input PGA. The default setting for the multiplexer is to connect the excitation current source (I_{REF2}) and PGA input (V_{IN+}) to input channel V/I-0 (RTD channel) and to connect the excitation current source (I_{REF1}) and PGA input (V_{IN-}) to input channel V/I-1.

5.1.2 PGA

The differential input voltage created by the current sources I_{REF1} and I_{REF2} flowing through the RTD and R_Z resistances is applied to the input pins of a programmable-gain instrumentation amplifier (PGA). The PGA has seven voltage-gain settings in binary steps from 6.25 V/V to 400 V/V. The input common-mode range of the PGA is 0.2 V to 3.5 V above the I_{RET} potential.

For common applications that require a 4-mA to 20-mA transmission, the PGA output voltage range should be set to V_{ZERO} = 0.5 V and V_{FS} = 2.5 V. Connecting an external voltage-to-current resistor (R_{VI} = 6.34 kΩ) between pin 9 (V_O) and pin 10 (I_{IN}) converts this voltage to a current that passes to the 50-A/A fixed-gain output current amplifier which produces a 4-mA to 20-mA output. In this mode, the PGA voltage gain converts to an overall transconductance in the range of 50 mA/V to 3200 mA/V (approximately). Table 20 shows the gain to transconductance relationship. For voltage-output applications, the PGA can be set for rail-to-rail output (for example, V_{ZERO} = 0.5 V and V_{FS} = 4.5 V). The PGA section of the block diagram shows the PGA voltage gain setting in V/V.

Table 20. PGA Gain, Loop Transconductance, and Input Full-Scale Differential Voltage

Voltage Gain (V/V)	Output Transconductance (mA/V)	Full-Scale Differential V_{IN} (mV)
6.25	49	320
12.5	99	160
25	197	80
50	394	40
100	789	20
200	1577	10
400	3155	5

5.1.3 I_ZERO DAC

The zero-output level of the XTR108 input PGA is controlled by two DACs (coarse and fine). These digital-to-analog converters (DACs) compensate for the initial offset at the PGA input as a result of sensor and resistor mismatches as well as sensor non-idealities. Both the coarse and fine DAC are bidirectional (positive or negative) and allow the output level to be set above or below a preset pedestal. The equations that define the output of these DACs are given in Table 21. Note that the external resistor R_{VI} (voltage-to-current conversion resistor) is used to convert the DAC reference voltage (V_{REF}) into a current. The I_{ZERO} DAC section of the block diagram shows the value of the coarse and fine zero-scale output DACs.

Table 21. Equations for Calculating Zero Output[1]

DAC Output	Voltage Referred to V_O Pin with Respect to I_{RET}	Current Referred to I_{OUT} Pin
Overall	$V_{ZERO} = V_{Z\_PROGRAM} + V_{Z\_COARSE} + V_{Z\_FINE}$	$I_{ZERO} = I_{OUT\_MIN} - \dfrac{50 \cdot A_{PGA} \cdot I_{REF} \cdot (RTD_{MIN} - R_Z)}{R_{VI}}$
Program	$V_{Z\_PROGRAM} = \dfrac{3.5 \cdot V_{REF}}{8}$	$I_{Z\_PROGRAM} = \dfrac{175 \cdot V_{REF}}{8 \cdot R_{VI}}$
Coarse DAC	$V_{Z\_COARSE} = \dfrac{V_{REF}}{80} \cdot \dfrac{N_{13}}{4}$	$I_{Z\_COARSE} = \dfrac{5 \cdot V_{REF}}{8 \cdot R_{VI}} \cdot \dfrac{N_{13}}{4}$
Fine DAC	$V_{Z\_FINE} = \dfrac{V_{REF}}{80} \cdot \dfrac{N_{12}}{64}$	$I_{Z\_FINE} = \dfrac{5 \cdot V_{REF}}{8 \cdot R_{VI}} \cdot \dfrac{N_{12}}{64}$

[1] N_{13} and N_{12} are the decimal values of registers 13 and 12, respectively.

5.1.4   I_REF DAC

The XTR108 contains two matched, adjustable, reference current sources for sensor excitation. Each current source is controlled by a coarse DAC and fine DAC that together adjust the overall output. The equations that define the output of these current sources are given in Table 22. Note that the external resistor (R_{SET}) is used to convert the DAC reference voltage (V_{REF}) into the reference current. The I_{REF} DAC section of the block diagram shows the values of the coarse and fine excitation current DACs and the value of R_{SET} (current set resistor).

Table 22. Equations for Calculating I_{REF} Current[1]

Current Source Output	Reference Current
Overall	$I_{REF1,2} = I_{REF\_PROGRAM} + I_{REF\_COARSE} + I_{REF\_FINE}$
Program	$I_{REF\_PROGRAM} = \dfrac{5 \cdot V_{REF}}{R_{SET}}$
Coarse DAC	$I_{REF\_COARSE} = \dfrac{V_{REF}}{R_{SET}} \cdot \dfrac{N_{11}}{64}$
Fine DAC	$I_{REF\_FINE} = \dfrac{V_{REF}}{R_{SET}} \cdot \dfrac{N_{10}}{1024}$

[1] N_{11} and N_{10} are the decimal values of registers 11 and 10, respectively.

5.1.5   I_LIN DAC

The XTR108 incorporates circuitry for correcting second-order RTD sensor nonlinearity by up to a 40:1 ratio. To achieve this, a current is added to the sensor excitation current (I_{REF}) that is proportional to the voltage at the PGA input. The current is scaled by the linearization DAC (I_{LIN}) that uses the external resistor (R_{LIN}) to convert voltage into current. The I_{LIN} DAC section of the block diagram shows the hexadecimal value of the linearization register (register 14). The recommended value for the external resistor R_{LIN} is also shown at the bottom of the block diagram.

5.1.6   Overscale/Underscale

The XTR108 incorporates circuitry to set adjustable limits at the output in cases when the sensor signal goes above or below the specified range. The circuit is designed for compliance with the NAMUR NE43 recommendation for sensor interfaces. There are 16 levels for overscale output adjustment and eight levels for underscale output adjustment. The limit levels are listed in Table 23 and Table 24, including the settings of bits in the over- and underscale register (register 5) that are required for each step. Because of the large step sizes, units that use this feature should be checked if the value is critical. Note that the underscale limit circuit overrides the I_{ZERO} DAC level if it is set lower and if there is not enough sensor offset at the PGA input.

It may be necessary to disable limiting if the XTR108 is used in applications other than a 4-mA to 20-mA transmitter (such as voltage-output mode) where the PGA output is between 0.5 V and 4.5 V. The overscale and underscale section of the block diagram shows whether overscale and underscale limiting is enabled or disabled as well as the current overscale and underscale output levels. These indicators are set by the values read from the XTR108 registers and EEPROM, not by the values selected in the *Find Resistors* tab in the EVM software.

Table 23. Overscale Threshold

OS3	OS2	OS1	OS0	V$_O$ Overscale Threshold	I$_O$ Overscale Threshold R$_{VI}$ = 6.34 kΩ
0	0	0	0	2.625 V	20.7 mA
0	0	0	1	2.6875 V	21.2 mA
0	0	1	0	2.75 V	21.7 mA
0	0	1	1	2.8125 V	22.2 mA
0	1	0	0	2.875 V	22.7 mA
0	1	0	1	2.9375 V	23.2 mA
0	1	1	0	3.0 V	23.7 mA
0	1	1	1	3.0625 V	24.2 mA
1	0	0	0	3.125 V	24.6 mA
1	0	0	1	3.1875 V	25.1 mA
1	0	1	0	3.25 V	25.6 mA
1	0	1	1	3.3125 V	26.1 mA
1	1	0	0	3.375 V	26.6 mA
1	1	0	1	3.4375 V	27.1 mA
1	1	1	0	3.5 V	27.6 mA
1	1	1	1	3.5625 V	28.1 mA

Table 24. Underscale Threshold

US2	US1	US0	V$_O$ Underscale Threshold	I$_O$ Underscale Threshold R$_{VI}$ = 6.34 kΩ
0	0	0	450 mV	3.55 mA
0	0	1	425 mV	3.35 mA
0	1	0	400 mV	3.15 mA
0	1	1	375 mV	2.96 mA
1	0	0	350 mV	2.76 mA
1	0	1	325 mV	2.56 mA
1	1	0	300 mV	2.37 mA
1	1	1	275 mV	2.17 mA

5.1.7 SPI Interface

In normal operation, the XTR108 reads data from an external EEPROM to retrieve calibrated register settings. This operation is accomplished by a read-back controller on the XTR108. The read-back controller defaults to being active when the XTR108 is powered on and is continuously active unless disabled. In other words, it starts a new read operation as soon as the previous operation is completed. A control bit (RBD) in Control Register 2 (register 4) is provided to allow the XTR108 to read the EEPROM once and then stop.

When calibrating the XTR108EVM-USB, it is required that the automatic EEPROM read-back be disabled, so that new values written to the XTR108 registers during the calibration procedure are not immediately overwritten. The calibration functions built into the XTR108EVM-USB software also write new register values to the EEPROM so that post-calibrated values are automatically loaded at power-up. The SPI Interface section of the block diagram shows whether the automatic EEPROM read-back is enabled or disabled.

5.1.8 Alarm Config

The XTR108 Alarm Configuration register (register 7) determines whether the XTR108 goes overscale or underscale for various detected fault conditions at the PGA input. Table 25 defines the behavior of these settings. If a bit corresponding to the particular error is set to '1', the output goes overscale when the error occurs. If a bit corresponding to the particular error is set to '0', the output goes underscale when the error occurs. The Alarm Config section of the block diagram shows the hexadecimal value of the Alarm Configuration register.

Table 25. Alarm Configuration Register[1]

BIT	AC7	AC6	AC5	AC4	AC3	AC2	AC1	AC0
V_{INN}	High	Low	Low	High	N	N	Low	High
V_{INP}	Low	High	Low	High	Low	High	N	N

[1] A high reading indicates that the input exceeds the positive common-mode range; a low reading indicates that the input exceeds the negative common-mode range; and N indicates that the input is within the common-mode range.

5.2 Find Resistors Tab

The **Find Resistors** tab in the XTR108EVM-USB software allows the user to enter the desired XTR108 operating conditions. Based on the user input, the software calculates the appropriate values for the supporting circuitry and performs error-checking to determine if the desired conditions exceed system capabilities. This tab also allows the user to save a custom configuration as a model file that is used as the basis for calibration.

Figure 20 shows the **Find Resistors** tab with default values. The following sections explain the use of each section of the tab.
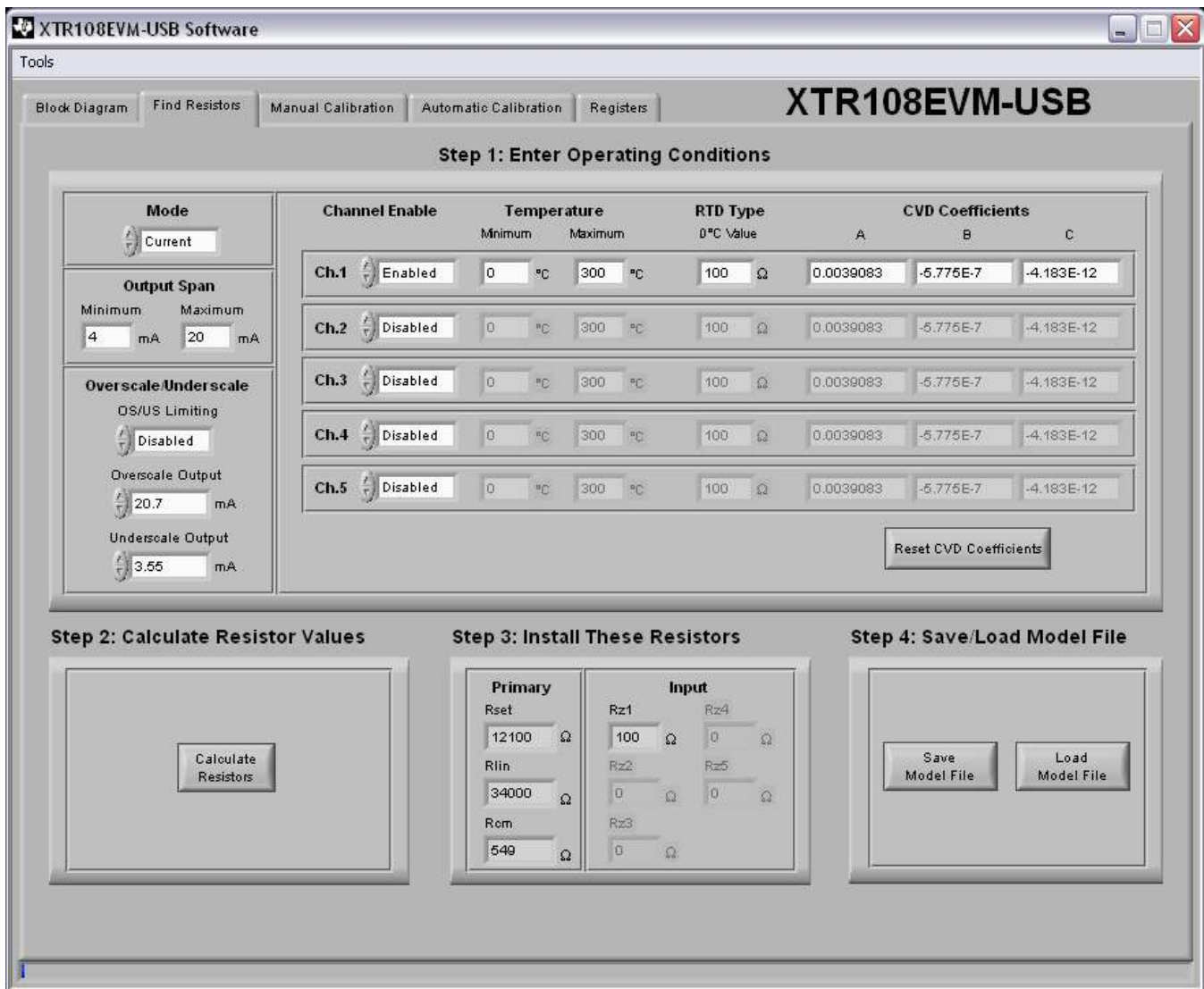

Figure 20. XTR108EVM-USB Software, Find Resistors Tab

5.2.1 Step 1: Enter Operating Conditions

This area of the **Find Resistors** tab allows the user to input system operating conditions, including the global system conditions as well as individual conditions for each channel. Global conditions consist of current- or voltage-output mode, output span, and overscale and underscale limiting. Channel-specific conditions include channel enable or disable, temperature span, RTD type, and Callendar-van Dusen (CVD) coefficients.

5.2.1.1 Mode

This control allows the user to select current-output mode or voltage-output mode. Ensure that the proper power-supply voltage is applied for each mode (see the *Connecting Loop Power Supply to the XTR108EVM-USB Interface Board* section) and that the correct Sensor Board jumper settings are used (see Table 17).

5.2.1.2 Output Span

This control allows the user to set the desired XTR108 output span. The most common output span settings are 4 mA to 20 mA for current-output mode and 0.5 V to 4.5 V for voltage-output mode. These controls automatically update the units (mA or V) to reflect the status of the *Mode* control.

5.2.1.3 Overscale and Underscale

This control allows the user to enable or disable overscale and underscale limiting as well as set the overscale and underscale output levels. The current and voltage levels available in the overscale and underscale output controls correspond to the values listed in Table 23 and Table 24. These controls automatically update the units (mA or V) to reflect the status of the *Mode* control.

5.2.1.4 Channel Enable

The XTR108 supports up to five input channel configurations, allowing the same board design to be used for multiple input conditions. Only one channel can be calibrated at a time. The *Channel Enable* control allows the user to enable or disable the five input channels, as required by their application.

5.2.1.5 Temperature

This control allows the user to input the minimum and maximum RTD temperature of each input channel in °C. The lowest possible minimum temperature is –200°C and the highest possible maximum temperature is +850°C and matches the operating temperature ranges of most commercially-available RTDs.

5.2.1.6 RTD Type

The XTR108 is primarily designed to interface to PT100- and PT1000-type RTDs. PT100 RTDs have a resistance of 100 Ω at 0°C; PT1000 RTDs have a resistance of 1000 Ω (1 kΩ) at 0°C. The *RTD Type* control allows the user to specify what type of RTD is used at each input channel.

5.2.1.7 CVD Coefficients

The resistance of an RTD across its temperature range is defined by a set of polynomial equations, as shown in Table 26. A, B, and C are known as Callendar-van Dusen (CVD) coefficients. The industry-standard values for A, B, and C are loaded into the XTR108EVM-USB software by default, but custom values for each channel can be entered in the *CVD Coefficients* control. The **Reset CVD Coefficients** button restores the default values when clicked.

Table 26. Standard RTD Equations[1]

If –200°C < T < 0°C	If T > 0°C
$R_t = R_0 [1 + A \times T + B \times T^2 + C \times T^3(T - 100°C)]$	$R_t = R_0 [1 + A \times T + B \times T^2]$

[1] A = 3.9083E-3, B = –5.775E-7, C = –4.183E-12, R_0 = RTD value at 0°C (typically 100 Ω or 1 kΩ), and T = temperature in °C.

5.2.2 Step 2: Calculate Resistor Values

When the **Calculate Resistors** button is clicked, the XTR108EVM-USB software uses the operating conditions entered in *Step 1: Enter Operating Commands* to calculate the best values for R_{SET}, R_{LIN}, R_{CM}, and R_Z (for each enabled channel).

The R_{SET} value is critical to proper XTR108 operation (see the *I_REF DAC* section). If the software cannot find a suitable R_{SET} value, an error message is displayed as shown in Figure 21. This error is typically caused by narrow or conflicting temperature ranges on multiple channels. If you encounter this error, widen your temperature ranges slightly and click the **Calculate Resistors** button again.
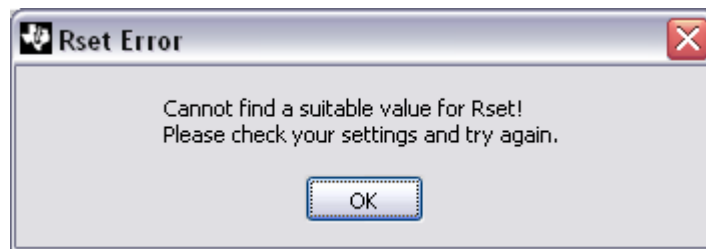
Figure 21. R_{SET} Error

The XTR108EVM-USB software also performs a linearity check as part of the *Calculate Resistors* functionality. If the software predicts that a post-calibrated error less than 0.1% of full-scale is not possible, a warning message is displayed as shown in Figure 22. This error is typically caused by very wide temperature ranges on multiple channels. If you encounter this warning, narrow your temperature ranges slightly and click the **Calculate Resistors** button again.
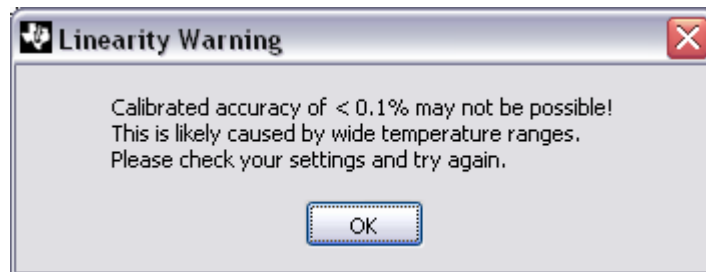

Figure 22. Linearity Warning

5.2.3 Step 3: Install These Resistors

This area of the **Find Resistors** tab displays the calculated resistor values for R_{SET}, R_{LIN}, R_{CM}, and R_Z (for each enabled channel). Install these resistors on the XTR108EVM-USB Sensor Board, either by soldering surface-mount resistors or installing through-hole resistors in the pin sockets. The R_Z indicator for disabled channels is grayed out.

5.2.4   Step 4: Save or Load Model File

The XTR108EVM-USB software allows the user to save operating conditions and sensor board resistor values to a model file to facilitate calibration. Click the **Save Model File** button to open the *Save Model File* dialog box, as shown in Figure 23. Enter a descriptive file name that contains the output span and some basic configuration information, such as *4-20mA, CH1 0-300C* in the image below. This naming allows for easy differentiation between model files when loading a file for calibration. The default save location for model files is in the *Model_files* folder within the XTR108EVM-USB install directory (typically at C:\Program Files\XTR108EVM-USB\).
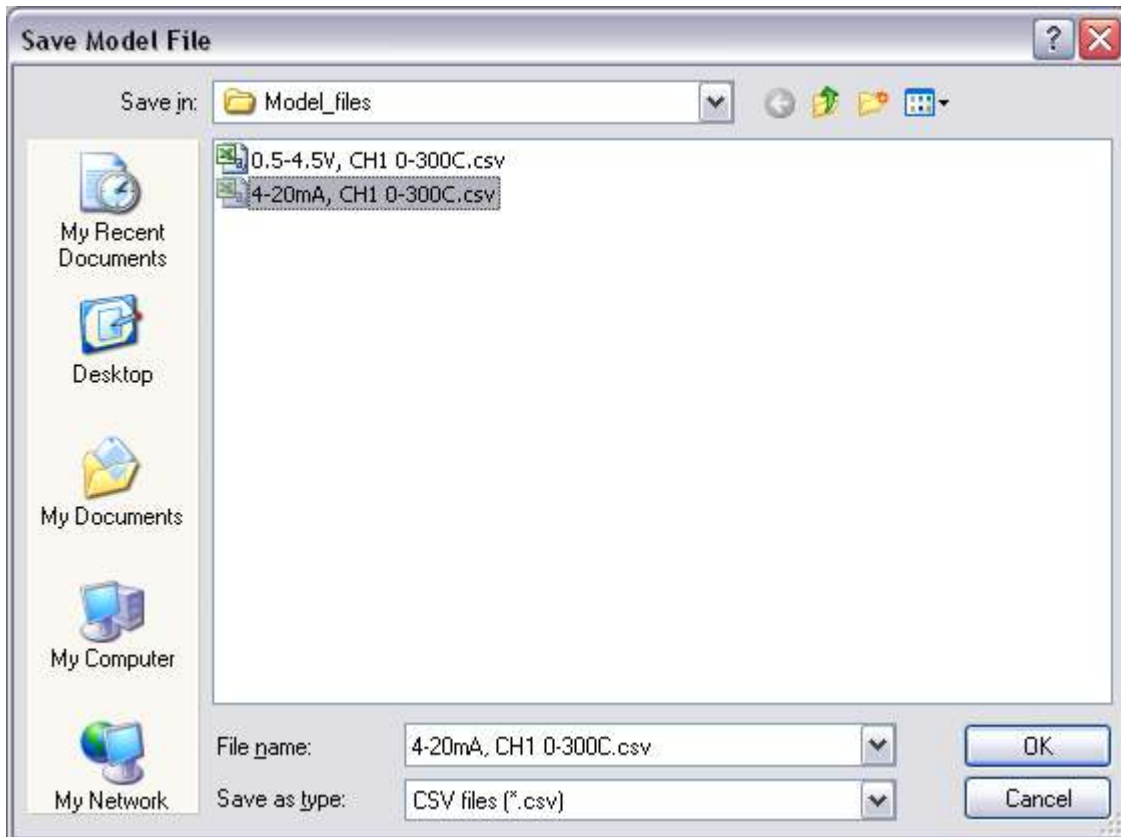

Figure 23. Save Model File

Similarly, the **Load Model File** button opens the *Load Model File* dialog box. This functionality allows the user to select a previously-saved model file for editing or loading for calibration.

5.3 Manual Calibration Tab

The **Manual Calibration** tab in the XTR108EVM-USB software allows the user to program the XTR108 using a model file, perform a two-point calibration, calculate the post-calibrated error of the system, and calibrate the overscale and underscale output values.

Figure 24 shows the **Manual Calibration** tab with default values. The following sections explain the use of each section of the tab.

NOTE: The XTR108EVM-USB includes functionality to automatically control the Agilent 34401A Multimeter. This functionality requires that the multimeter is connected to the user PC using the NI GPIB-USB-HS controller, available separately.

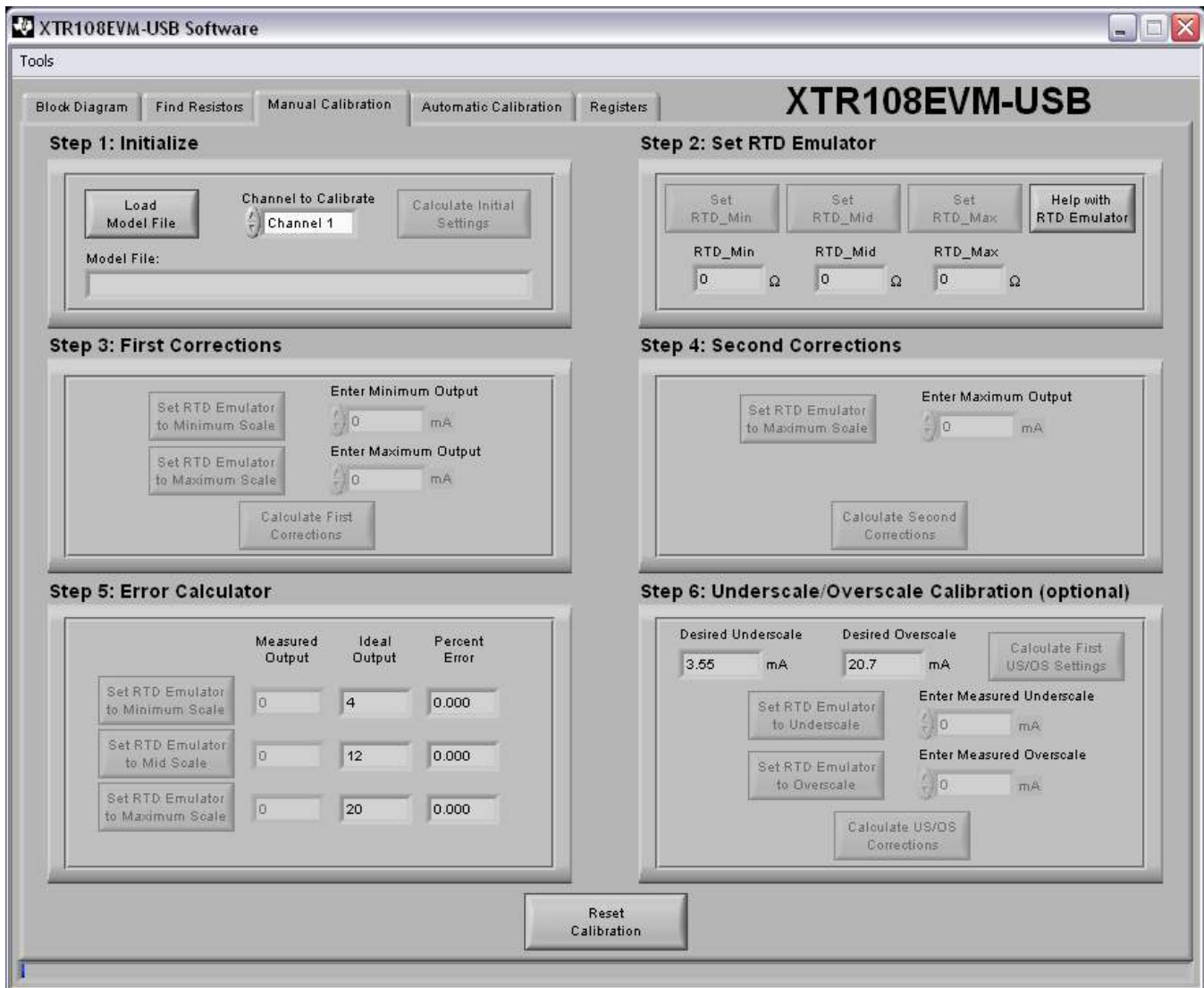

Figure 24. XTR108EVM-USB Software, Manual Calibration Tab

5.3.1 Step 1: Initialize

Before calibration can take place, a model file must be loaded into the software. The XTR108EVM-USB software automatically loads the most recent model file into memory at startup, but a different model file can be selected by clicking the **Load Model File** button. The path of the loaded model file is shown in the *Model File* indicator.

After loading a model file, use the channel-to-calibrate control to select which channel should be calibrated. Disabled channels in the model file are grayed out and unable to be selected. After selecting a channel to calibrate, click the **Calculate Initial Settings** button to write the initial configuration to the XTR108 and EEPROM.

5.3.2 Step 2: Set RTD Emulator

The next step in the calibration procedure is to set the XTR108EVM-USB Interface Board RTD Emulator. Once the **Calculate Initial Settings** button is pressed in *Step 1: Initialize*, the **Set RTD_Min**, **Set RTD_Mid**, and **Set RTD_Max** buttons are enabled and the calculated resistance values for each channel are displayed. As shown in Figure 25, the resistance value of each RTD Emulator channel can be set by adjusting the trim pots of each channel with a small flat-head screwdriver.
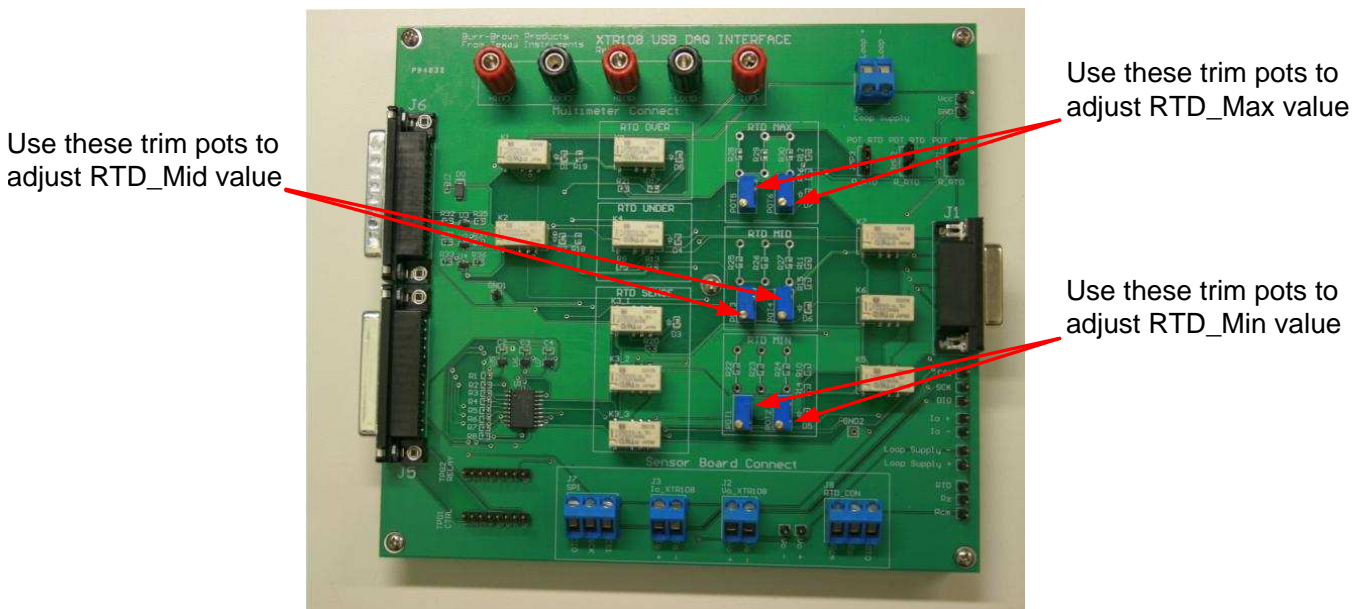

Figure 25. Adjust RTD Emulator

Click the **Set RTD_Min** button to set the resistance of the RTD_Min channel. This button configures the XTR108EVM-USB Interface Board to route the RTD_Min resistance to the DMM through the multimeter connect terminals. Configure the DMM for four-wire resistance (Ω 4W) measurement, then adjust POT1 (coarse) and POT2 (fine) until the resistance measured by the DMM matches the value shown by the *RTD_Min* indicator in the XTR108EVM-USB software.

Next, click the **Set RTD_Mid** button to set the resistance of the RTD_Mid channel. Adjust POT3 (coarse) and POT4 (fine) until the resistance measured by the DMM matches the value shown by the *RTD_Mid* indicator in the XTR108EVM-USB software.

Finally, click the **Set RTD_Max** button to set the resistance of the RTD_Max channel. Adjust POT5 (coarse) and POT6 (fine) until the resistance measured by the DMM matches the value shown by the *RTD_Max* indicator in the XTR108EVM-USB software.

> **NOTE:** If the 34401A multimeter is connected to the PC by the NI GPIB-USB-HS controller, the XTR108EVM-USB software automatically configures the 34401A for four-wire resistance measurement.

5.3.3 Step 3: First Corrections

Once the initial settings have been written to the XTR108 and the RTD Emulator has been configured, output measurements can be taken at the minimum- and maximum-scale values.

Configure the DMM for dc current or dc voltage measurement, depending on which mode is being used. Click the **Set RTD Emulator to Minimum Scale** button to route the minimum-scale output signal to the DMM. Observe the output measured by the DMM and enter the result into the *Enter Minimum Output* control.

Next, click the *Set RTD Emulator to Maximum Scale* button to route the maximum-scale output signal to the DMM. Observe the output measured by the DMM and enter the result into the *Enter Maximum Output* control.

Finally, click the **Calculate First Corrections** button to perform the first corrections based on these measurements and write the updated configuration to the XTR108 and EEPROM.

> **NOTE:** If the 34401A multimeter is connected to the PC by the NI GPIB-USB-HS controller, the XTR108EVM-USB software automatically configures the 34401A for dc voltage or dc current measurement, measures 10 samples of the output over a 5-second interval, and enters the average output value into the *Enter Minimum Output* and *Enter Maximum Output* controls.

5.3.4 Step 4: Second Corrections

A second maximum-scale output measurement is required to complete calibration. Click the **Set RTD Emulator to Maximum Scale** button to once again route the maximum-scale output signal to the DMM. Observe the output measured by the DMM and enter the result into the *Enter Maximum Output* control. Click the **Calculate Second Corrections** button to perform the second corrections based on this measurement and write the updated configuration to the XTR108 and EEPROM.

5.3.5 Step 5: Error Calculator

The *Error Calculator* section allows the user to determine the error (expressed as a percentage of full-scale) at minimum-scale, mid-scale, and maximum-scale output levels. Click the **Set RTD Emulator to Minimum Scale** button to route the calibrated minimum-scale output signal to the DMM. Observe the output measured by the DMM and enter the result into the adjacent *Measured Output* control. The *Percent Error* indicator automatically updates with the calculated error value. Repeat this process for the mid-scale and maximum-scale values.

5.3.6 Step 6: Underscale and Overscale Calibration

Once the normal output span of the XTR108 has been calibrated, the underscale and overscale output can also be calibrated. The *Desired Underscale* and *Desired Overscale* indicators display the output levels set by the loaded model file. Click the **Calculate First US/OS Settings** button to write the desired underscale and overscale settings to the XTR108 and EEPROM.

Next, click the **Set RTD Emulator to Underscale** button to configure the RTD Emulator for underscale output and route the underscale output signal to the DMM. Observe the output measured by the DMM and enter the result into the *Enter Measured Underscale* control.

Next, click the **Set RTD Emulator to Overscale** button to configure the RTD Emulator for overscale output and route the overscale output signal to the DMM. Observe the output measured by the DMM and enter the result into the *Enter Measured Underscale* control.

Finally, click the **Calculate US/OS Corrections** button to perform the underscale and overscale corrections based on these measurements and write the updated configuration to the XTR108 and EEPROM. The calibrated values can be verified by clicking on the **Set RTD Emulator to Underscale** and **Set RTD Emulator to Overscale** buttons after the calibration is complete.

5.3.7 Verify Calibration

After successfully completing the manual calibration procedure, the minimum-scale, mid-scale, and maximum-scale *Percent Error* indicators should be less than or equal to 0.1%. See Figure 26 for an example of a successful post-calibration screen.
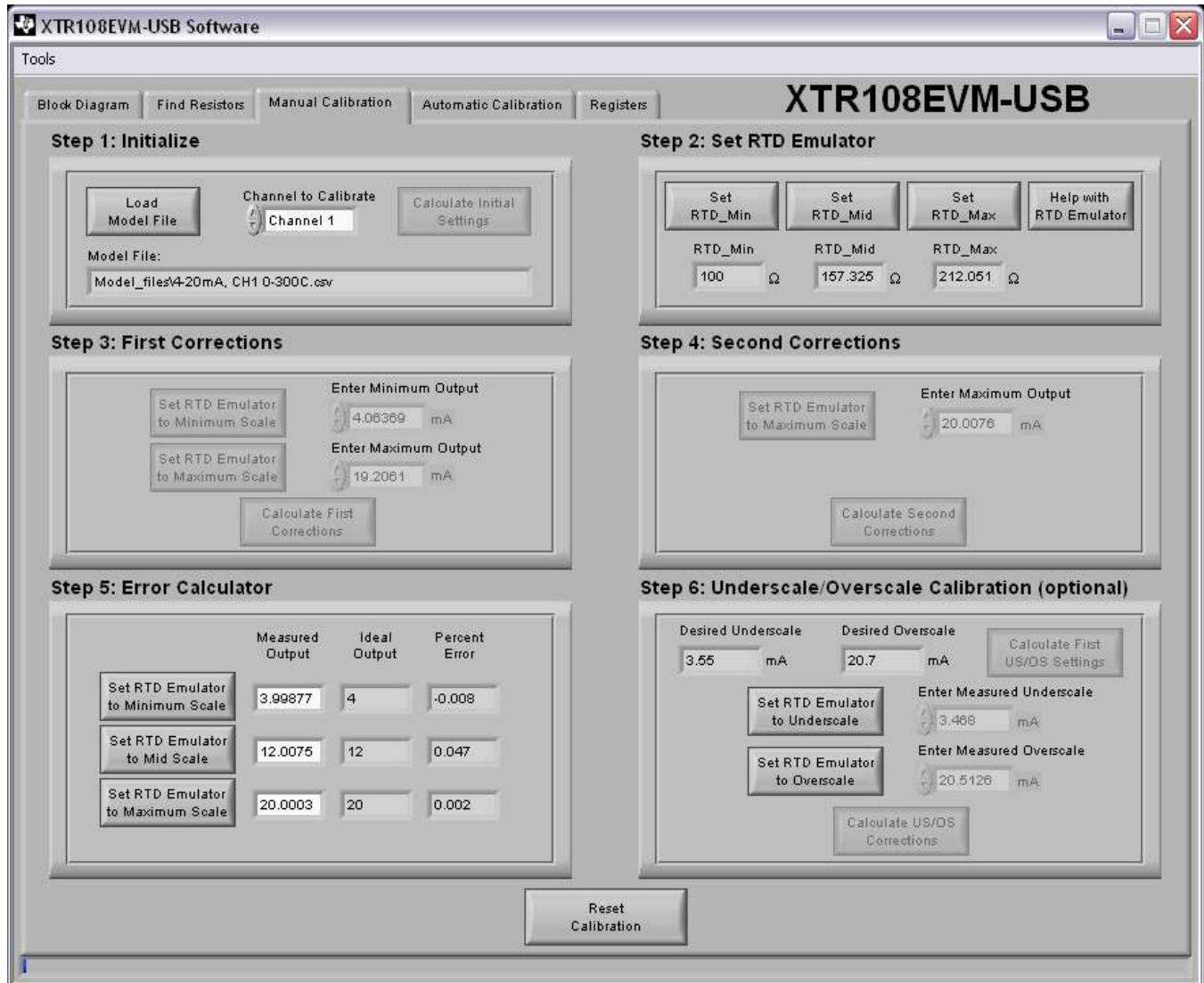

Figure 26. Manual Calibration Tab, Post-Calibration

5.3.8 Reset Calibration

The **Reset Calibration** button can be clicked at any time in order to cancel the current calibration and reset the **Manual Calibration** tab to the initial state. At this point, a new calibration can be performed with either the current model file or a newly loaded model file.

5.4 Automatic Calibration Tab

The **Automatic Calibration** tab in the XTR108EVM-USB software allows the user to perform a completely automated calibration of the XTR108 using a previously-saved model file. The entire procedure takes less than a minute to complete and only requires the user to click one button.

Figure 27 shows the **Automatic Calibration** tab. The following sections explain the use of each section of the tab.

> **NOTE:** Use of the **Automatic Calibration** tab requires that an Agilent 34401A multimeter be connected to the user PC using the NI GPIB-USB-HS controller, available separately.
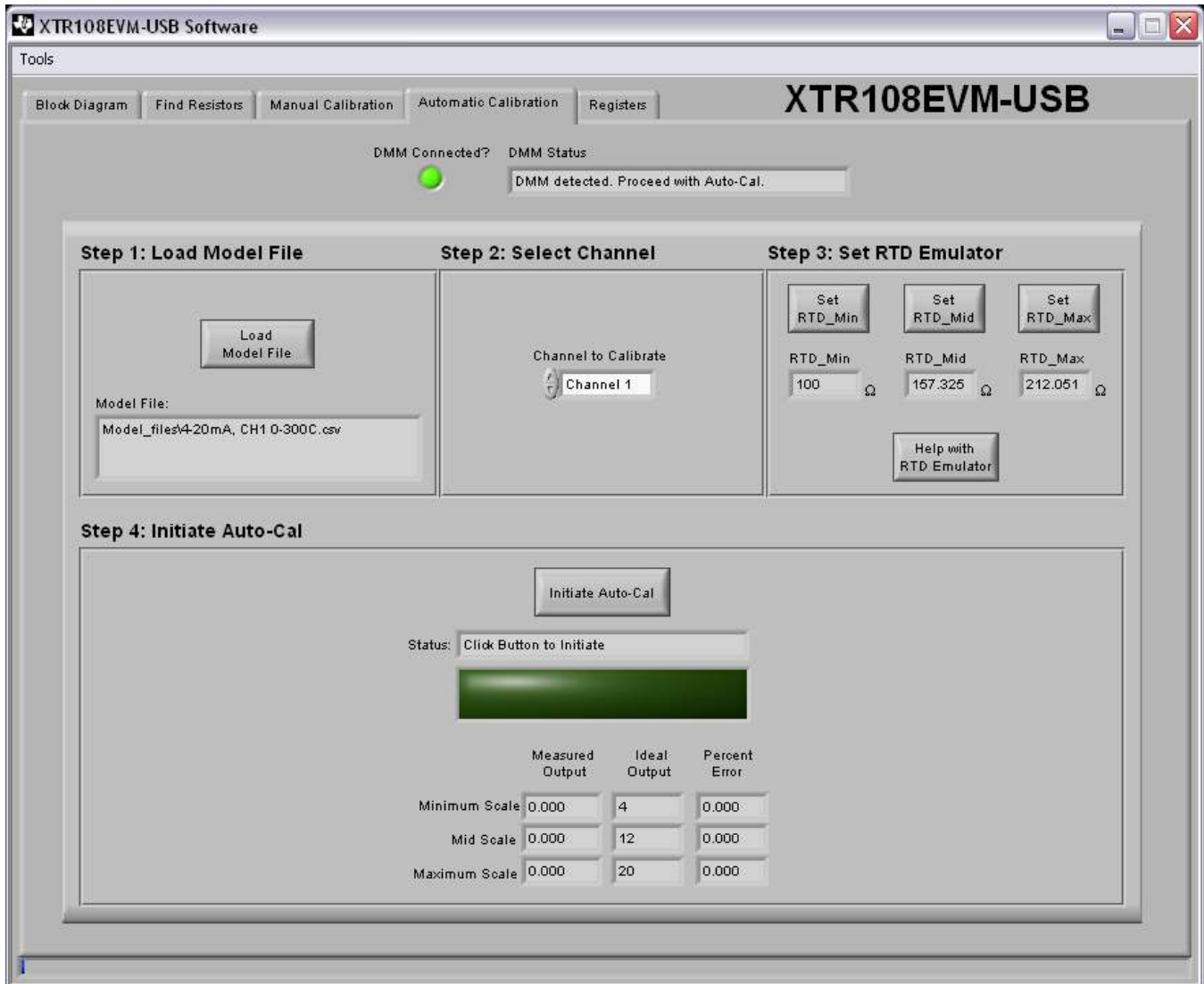
Figure 27. XTR108EVM-USB Software, Automatic Calibration Tab

5.4.1 DMM Connection

At startup, the XTR108EVM-USB software automatically detects if an Agilent 34401A multimeter is connected over the GPIB-to-USB interface. If a 34401A is detected, the *DMM Connected?* LED turns on, the *DMM Status* indicator displays the message *DMM detected. Proceed with Auto-Cal*, and the **Initiate Auto-Cal** button is enabled. If a 34401A is not detected, the *DMM Connected?* LED remains off, the *DMM Status* indicator displays the message *DMM not detected. Auto-Cal unavailable*, and the **Initiate Auto-Cal** button is disabled and grayed out. If the XTR108EVM-USB software does not detect a connected 34401A, close the software, verify the hardware connections, check that the GPIB-to-USB controller is detected by Windows, and then restart the software.

5.4.2 Step 1: Load Model File

Before calibration can take place, a model file must be loaded into the software. The XTR108EVM-USB software automatically loads the most recent model file into memory at startup, but a different model file can be selected by clicking the **Load Model File** button. The path of the loaded model file is shown in the *Model File* indicator.

5.4.3 Step 2: Select Channel

Use the *Channel to Calibrate* control to select which channel should be calibrated. Disabled channels in the model file are grayed out and cannot be selected.

5.4.4 Step 3: Set RTD Emulator

The RTD emulator must be adjusted to match the resistance values shown in the *RTD_Min*, *RTD_Mid*, and *RTD_Max* indicators. See *Step 2: Set RTD Emulator* for detailed instructions on how to set the RTD emulator. If the RTD emulator has already been configured in a previous step, this process can be skipped.

5.4.5 Step 4: Initiate Auto-Cal

Click the **Initiate Auto-Cal** button to begin the automatic calibration procedure. Remember, this button can only be enabled if the XTR108EVM-USB software has successfully detected an Agilent 34401A connected over the GPIB-to-USB interface. During the automatic calibration procedure, the *Status* indicator displays the current calibration step, such as *Measuring Minimum-Scale Output*, *Performing Second Corrections*, or *Calculating Error*.

5.4.6 Verify Calibration

If the percentage of minimum-scale, mid-scale, and maximum-scale error after calibration is less than or equal to 0.1%, the *Status* indicator displays the message *Calibration successful! Error < 0.1%* and the square status LED turns on (bright green). Figure 28 shows an example of a successful post-calibration screen.
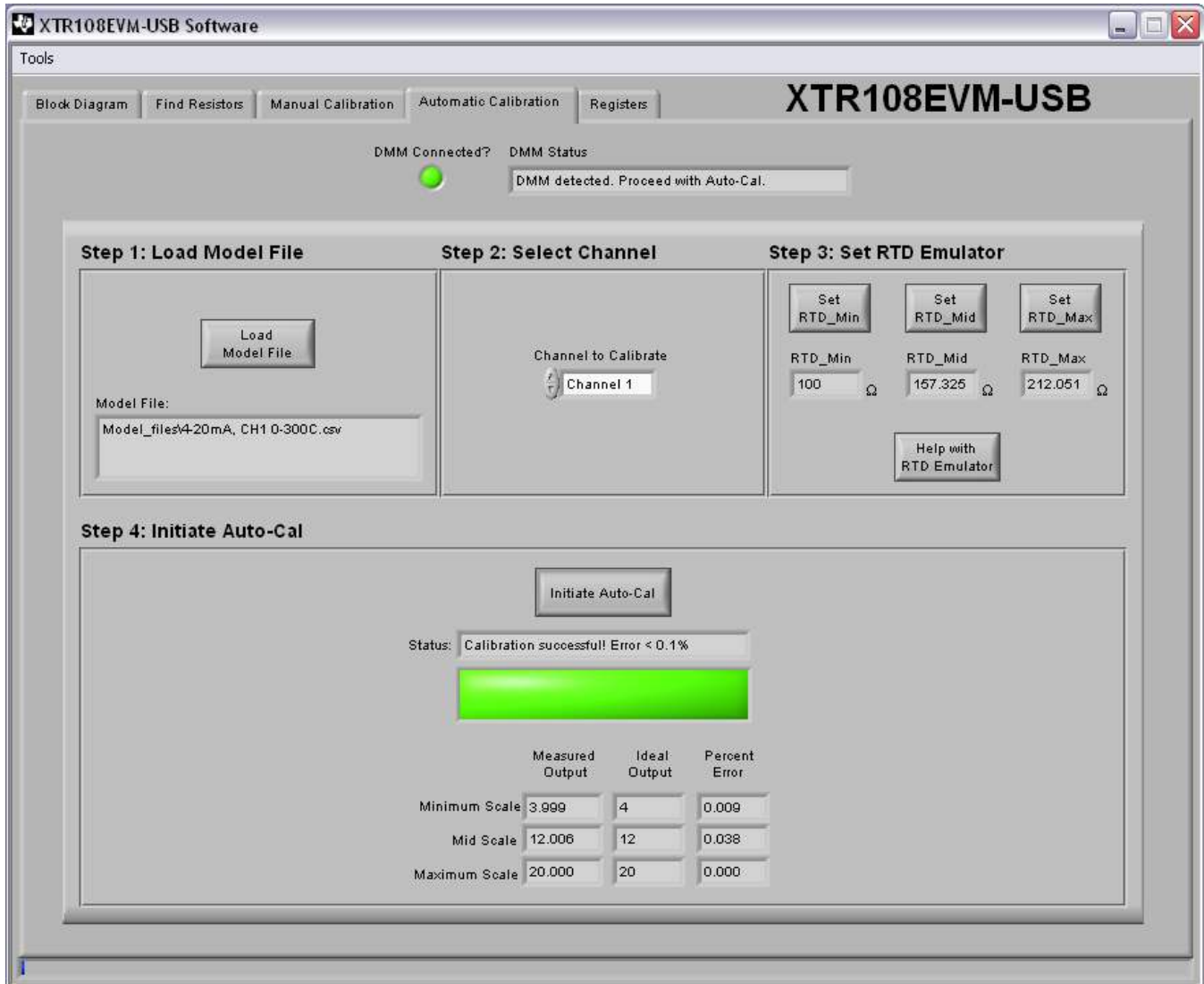
If the percentage of error after calibration is greater than 0.1%, the *Status* indicator displays the message *Calibration unsuccessful. Error > 0.1%* and the square status LED turns on (red).

Figure 28. Automatic Calibration Tab, Post-Calibration

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5.5   Registers Tab

The **Registers** tab in the XTR108EVM-USB software enables the user to view and edit the contents of each register internal to the XTR108. Similar to the **Block Diagram** tab, it is recommended that only advanced users make bit-level changes using this tab. However, for debugging purposes this capability can be extremely useful.

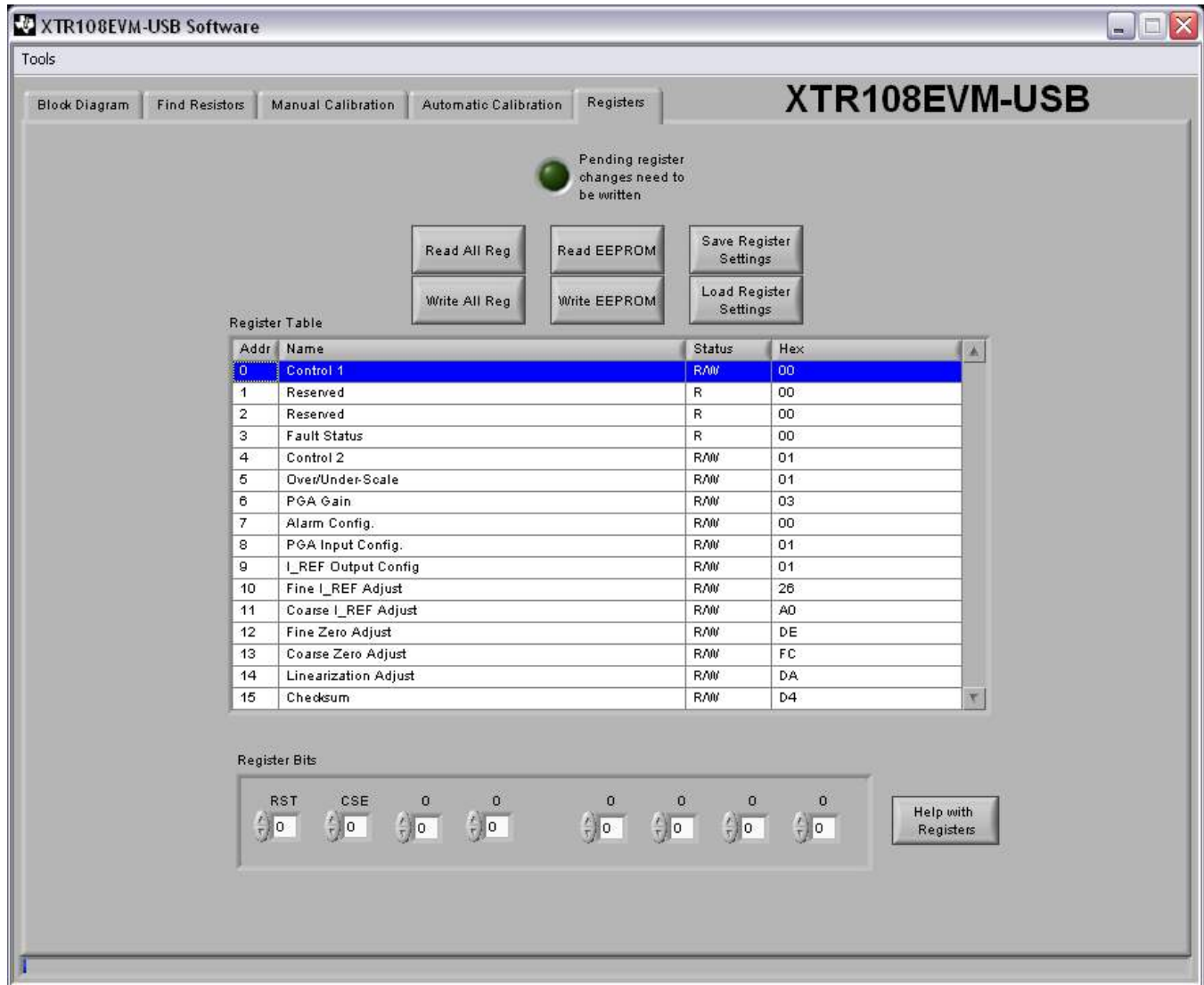Figure 29 shows the **Registers** tab. The actual values of each register may vary.

Figure 29. XTR108EVM-USB Software, Registers Tab

5.5.1 Register and EEPROM Communications

The six buttons at the top of the **Registers** tab allow the user to perform read/write operations between the XTR108EVM-USB software and the XTR108 registers and the EEPROM.

When clicked, The **Read All Reg** button reads the current XTR108 register values and loads them into software, overwriting any current values. Similarly, the **Write All Reg** button writes the current software register values to the actual registers within the XTR108.

The **Read EEPROM** button, when clicked, reads the current EEPROM values and loads them into software, overwriting any current values. Similarly, the **Write EEPROM** button writes the current software register values to the EEPROM.

If the XTR108EVM-USB software has made changes to the XTR108 register array within the software but has not written those changes to the XTR108 registers, the *Pending register changes need to be written* LED turns on. Once the registers have been written, the LED turns off.

5.5.2 Save/Load Register Settings

The **Save Register Settings** button allows the user to save the current values of the register array as a .csv file. The default save location for register files is in the *Register_files* folder within the XTR108EVM-USB install directory (typically C:\Program Files\XTR108EVM-USB\). The **Load Register Settings** button allows the user to load a previously-saved register file, which can be useful for loading a set of calibrated register values during production if calibration is not required for each board.

5.5.3 Register Table and Register Bits

Each register value is displayed in two forms: as a hexadecimal number within the *Register Table* indicator, and as a sequence of binary bits in the *Register Bits* control. Clicking on the row of a register within the *Register Table* indicator updates the contents of the *Register Bits* control to show the currently-selected register. Each bit is labeled in accordance with the register map given in the XTR108 data sheet.

If the selected register supports read/write operations, then each bit in the register can be set high or low ('1' or '0', respectively) by using the arrow controls on the desired bit. Changes to the registers must be written using the **Write All Reg** button before taking effect.

Additional help for each register is available by selecting a register and clicking the **Help with Registers** button, which opens a help document specific to that register.

5.6   Tools Menu

The **Tools** menu, located in the menu bar in the upper-left corner of the XTR108EVM-USB software, contains additional features useful for debugging or troubleshooting. The following sections explain the use of each option within the **Tools** menu.

5.6.1   Control Bits

The *Control Bits* window, as shown in Figure 30, enables manual control of the signals that enable and disable the XTR108EVM Interface Board relays. The control signals are off when the control is equal to '0' and are on when the control is equal to '1'. The functionality of each control bit is given by Table 27.
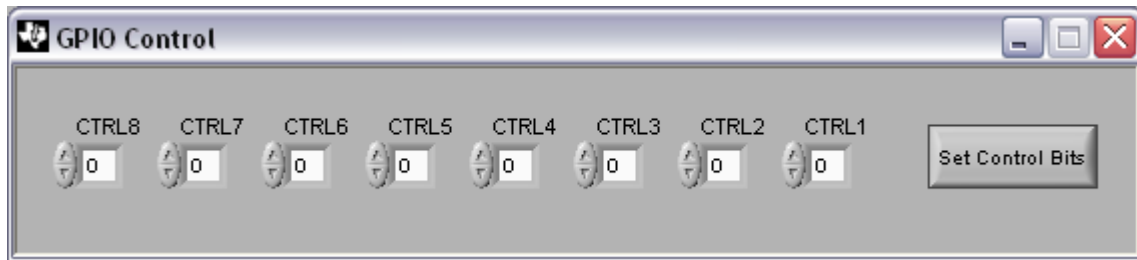
Figure 30. GPIO Control Window

Table 27. Control Bits Functions

BIT	FUNCTION	NOTES
CTRL1	Enables current measurement relay	When CTRL1 is enabled, the voltage measurement and resistance measurement relays are disabled by circuit protection logic
CTRL2	Enables voltage measurement relay	When CTRL1 is enabled, the voltage measurement and resistance measurement relays are disabled by circuit protection logic
CTRL3	Enables resistance measurement relay	When CTRL1 is enabled, the voltage measurement and resistance measurement relays are disabled by circuit protection logic
CTRL4	Enables RTD_UNDER relay	Enabling multiple RTD relays causes the resistances of each enabled RTD Emulator channel to be connected in parallel
CTRL5	Enables RTD_MIN relay	Enabling multiple RTD relays causes the resistances of each enabled RTD Emulator channel to be connected in parallel
CTRL6	Enables RTD_MID relay	Enabling multiple RTD relays causes the resistances of each enabled RTD Emulator channel to be connected in parallel
CTRL7	Enables RTD_MAX relay	Enabling multiple RTD relays causes the resistances of each enabled RTD Emulator channel to be connected in parallel
CTRL8	Enables RTD_OVER relay	Enabling multiple RTD relays causes the resistances of each enabled RTD Emulator channel to be connected in parallel

5.6.2 Debug Window

The *Debug* window, as shown in Figure 31, displays the input and output of all SPI communications. The command lines follow the syntax of the tioScript mnemonic commands. More information on the mnemonic commands is available in the *Mnemonic Commands* section.

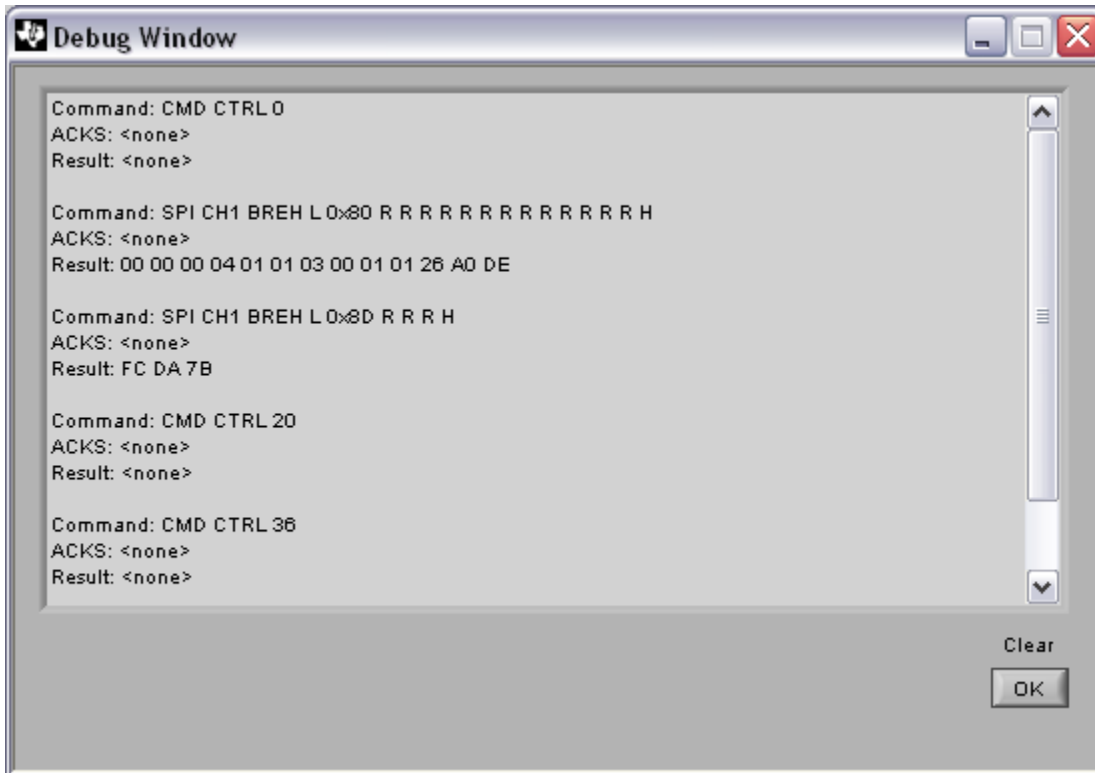Pressing the **Clear** button clears the strings displayed in the Debug Window until new communications take place.

Figure 31. Debug Window

5.6.3 About Window

The *About* window, as shown in Figure 32, lists the version, build date, and author of the currently-installed version of the XTR108EVM-USB software.

Figure 32. About Window

6   General Operating Tips

6.1   Voltage Output Mode

In many applications, it is desirable to bypass the FET and connect the XTR108 directly to the power supply. This configuration can be completed by positioning jumpers JMP2 and JMP3 in the *Bypass* position.

> **NOTE:** You must be careful in this mode to not apply an overvoltage to the XTR108. The XTR108 maximum supply voltage is 5.5 V. The voltage drop across D1 reduces the XTR108 supply voltage by approximately 0.7 V. To get an accurate idea of the XTR108 supply voltage while in this mode, you should measure at the XTR108 V_s pin.

6.2   Charge Pump

When the XTR108 is in voltage-output mode, a small negative voltage must be applied to the XTR108 I_{IN} pin to prevent the input offset voltage of the XTR108 current output stage from turning on the output stage. A simple discrete charge pump circuit, shown in Figure 33, can be used to generate this small negative voltage. The charge pump input is the SPI clock to the XTR108.
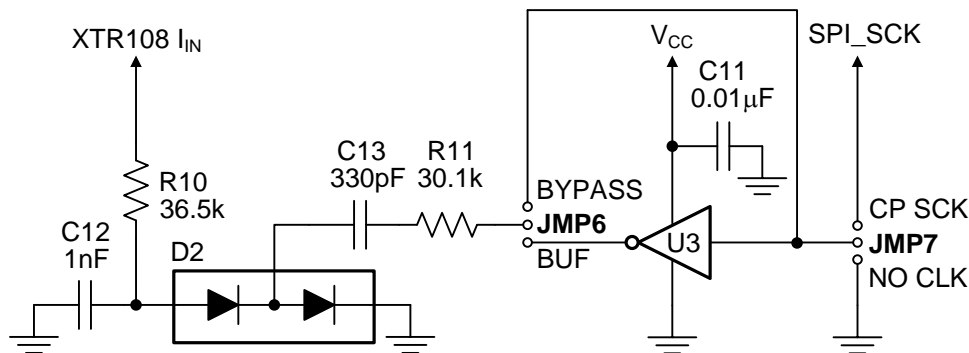
Figure 33. Discrete Charge Pump on Sensor Interface Board

For this circuit to work, the XTR108 clock must toggle continuously. This toggling can be accomplished by keeping the XTR108 in continuous EEPROM read mode. JMP6 can be used to connect or disconnect an external buffer to the XTR108 clock signal. More information regarding this charge pump is located in the XTR108 data sheet and the XTR108 Quick Start System Reference Guide.

7 Hardware Documentation

This section provides the hardware documentation for the XTR108EVM-USB, including board schematics, layouts, and bill of materials.

7.1 Schematics

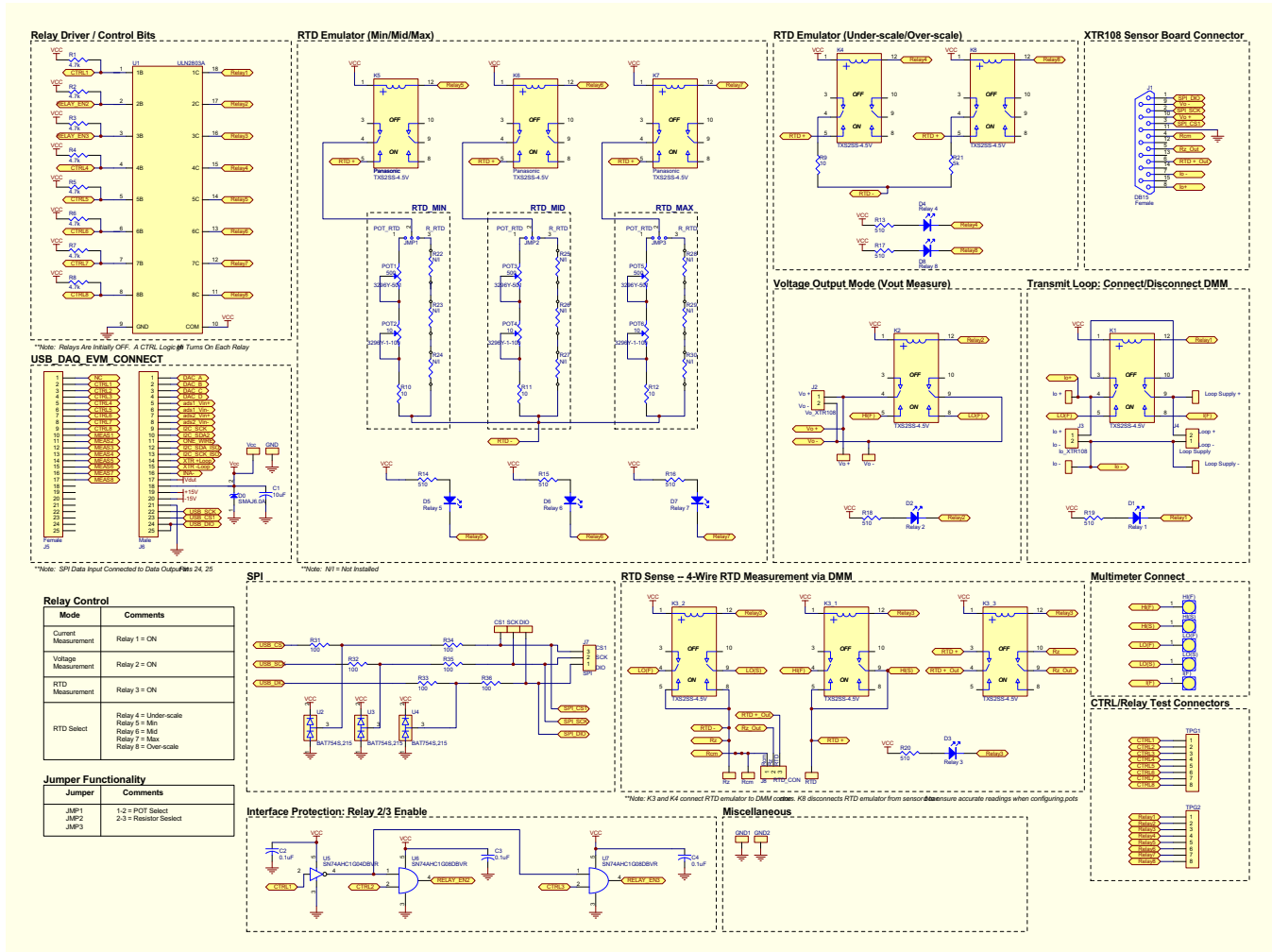Figure 34 shows the XTR108EVM-USB Interface Board schematic.

Figure 34. XTR108EVM-USB Interface Board Schematic

Figure 35 shows the XTR108EVM-USB Sensor Board schematic.

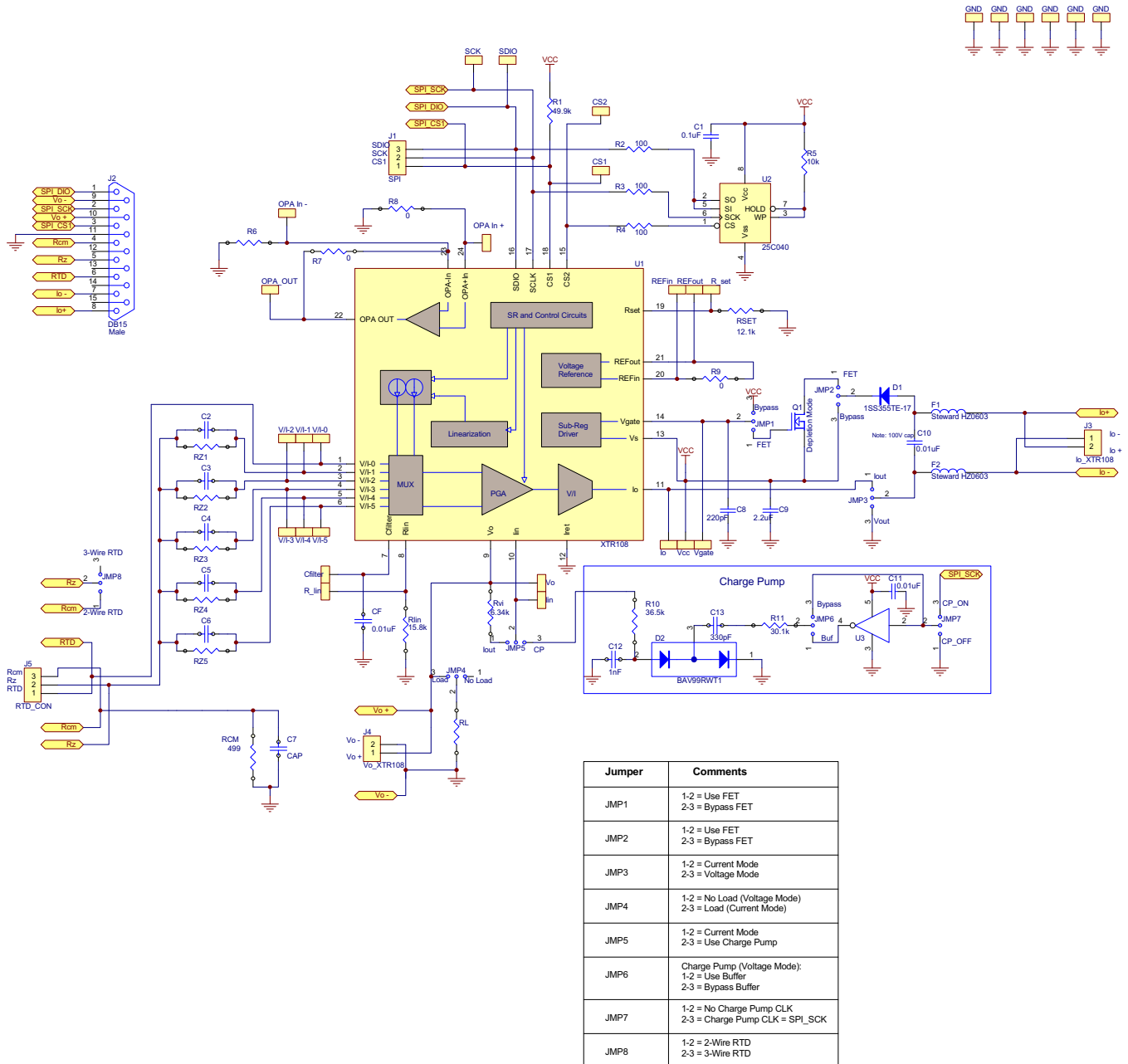**Figure 35. XTR108EVM-USB Sensor Board Schematic**

7.2 Layouts

Refer to Figure 15 for the XTR108EVM-USB Interface Board component-side layout. Refer to Figure 16 for the XTR108EVM-USB Sensor Board component-side layout.

7.3 Bill of Materials (BOM)

Table 28 gives the XTR108EVM-USB Interface Board bill of materials. Table 29 gives the XTR108EVM-USB Sensor Board bill of materials.

Table 28. XTR108EVM-USB Interface Board Bill of Materials

Qty	Value	Ref Des	Description	Vendor	Part Number
1	10µF	C1	CAP CERAMIC 10UF 10V 0603 X5R ±20%	TDK Corporation	C1608X5R1A106M
3	0.1µF	C2-C4	CAP .10UF 16V CERAMIC X7R 0603	Yageo	CC0603KRX7R7BB104
8	4.7kΩ	R1-R8	RES 4.70K OHM 1/10W 1% 0603 SMD ±100ppm/°C	Panasonic - ECG	ERJ-3EKF4701V
4	10Ω	R9-R12	RES 10.0 OHM 1/10W 0.1% 0603	Vishay/Dale	TNPW060310R0BEEA
8	510Ω	R13-R20	RES 510 OHM 1/10W 1% 0603 SMD ±100ppm/°C	Panasonic - ECG	ERJ-3EKF5100V
1	4.99kΩ	R21	RES 4.99K OHM 1/10W 1% 0603 SMD	Panasonic - ECG	ERJ-3EKF4991V
6	100Ω	R31-R36	RES 100 OHM 1/10W 1% 0603 SMD ±100ppm/°C	Panasonic - ECG	ERJ-3EKF1000V
0	OMIT	R22-R30	Omit; not installed	N/A	N/A
3	500Ω Potentiometer	POT1, POT3, POT5	POT 500 OHM 3/8" SQ CERM SL MT	Bourns Inc	3296Y-1-501LF
3	10Ω Potentiometer	POT2, POT4, POT6	POT 10 OHM 3/8" SQ CERM SL MT	Bourns Inc	3296Y-1-100LF
1	TVS Diode	D0	TRANSIL 400W 6V UNIDIR SMA	STMicroelectronics	SMAJ6.0A-TR
8	LED (Red)	D1-D8	LED RED HI BRT SS TYPE LO CUR SM	Panasonic - SSG	LNJ208R8ARA
10	TXS2SS-4.5V	K1, K2, K3_1-K3_3, K4- K8	LOW SIGNAL RELAYS - PCB 1A 4.5VDC DPDT NON-LATCHING SMD	Panasonic Electric Works	TXS2SS-4.5V
1	ULN2803	U1	IC DUAL TRANS ARRAY HV 18-SOIC	Texas Instruments	ULN2803ADW
3	BAT754S	U2-U4	DIODE SCHOTTKY 30V 200MA SOT-23	NXP Semiconductors	BAT754S,215
1	SN74AHC1G04	U5	IC SINGLE INVERTER GATE SOT23-5	Texas Instruments	SN74AHC1G04DBVR
2	SN74AHC1G08	U6, U7	IC SGL 2IN POS-AND GATE SOT23-5	Texas Instruments	SN74AHC1G08DBVR
1	DSUB15F	J1	CONN DB15 FEMAL .318" R/A NICKEL	Norcomp Inc	182-015-213R531
3	2-pin Terminal	J2-J4	TERMINAL BLOCK 5MM 2POS	On Shore Technology Inc	ED300/2
1	DSUB25M	J5	CONN D-SUB RCPT R/A 25POS 30GOLD	Tyco Electronics	5747846-4
1	DSUB25F	J6	CONN D-SUB PLUG R/A 25POS 30GOLD	Tyco Electronics	5747842-4
2	3-pin Terminal	J7, J8	TERMINAL BLOCK 5MM 3POS	On Shore Technology Inc	ED300/3
2	8-position Header	TPG1, TPG2	CONN HEADER 8POS .100" SGL GOLD	Samtec	TSW-108-07-G-S
17	TP Cut to Size	GND, GND1, GND2, Rz, RTD, Io+, Io–, Loop Supply+, Loop Supply–, Vo+, Vo–, CS1, SCK, DIO, Rcm, GND, Vcc	CONN. HEADER .100 SNGL 1POS	Samtec	TSW-101-07-G-S
3	3-position Jumper	JMP1-JMP3	CONN HEADER .100 SNGL 3POS	Samtec	TSW-103-07-G-S
3	Jumper Shunts	JMP1-JMP3	JUMPER SHORTING UNITS	Tyco Electronics	881545-2
3	Banana Plug (Red)	I(F), HI(S), HI(F)	BANANA AND BINDING POST CONNECTORS BINDING POST RED	Emerson/Johnson	111-0702-001
2	Banana Plug (Black)	LO(S), LO(F)	BANANA AND BINDING POST CONNECTORS BINDING POST BLACK	Emerson/Johnson	111-0703-001
4	Screws	N/A	SCREW MACHINE PHILLIPS 4-40X3/8	B&F Fastener Supply	PMS 440 0038 PH
4	Standoffs	N/A	STANDOFF HEX 4-40THR ALUM .500"L	Keystone Electronics	2203

Table 29. XTR108EVM-USB Sensor Board Bill of Materials

Qty	Value	Ref Des	Description	Vendor	Part Number
1	0.1µF	C1	CAP CER .10UF 25V X7R 10% 0603	TDK Corporation	C1608X7R1E104K
1	220pF	C8	CAP CER 220PF 50V X7R 10% 0603	TDK Corporation	C1608X7R1H221K
1	2.2µF	C9	CAP CER 2.2UF 16V Y5V 0603	TDK Corporation	C1608Y5V1C225Z
3	10000pF	C10, C11, CF	CAP CER 10000PF 100V X7R 10% 0603	TDK Corporation	C1608X7R2A103K
1	1000pF	C12	CAP CER 1000PF 50V 10% X7R 0603	Murata Electronics	GRM188R71H102KA01D
1	330pF	C13	CAP CERAMIC 330PF 50V NP0 0603	Yageo	CC0603JRNP09BN331
1	49.9kΩ	R1	RES 49.9K OHM 1/10W 1% 0603 SMD	Panasonic - ECG	ERJ-3EKF4992V
3	100Ω	R2-R4	RES 100 OHM 1/10W 1% 0603 SMD	Panasonic - ECG	ERJ-3EKF1000V
1	10kΩ	R5	RES 10.0K OHM 1/10W 1% 0603 SMD	Panasonic - ECG	ERJ-3EKF1002V
3	0Ω	R7-R9	RES 0.0 OHM 1/10W 5% 0603 SMD	Yageo	RC0603JR-070RL
1	36.5kΩ	R10	RES 36.5K OHM 1/10W 1% 0603 SMD	Panasonic - ECG	ERJ-3EKF3652V
1	30.1kΩ	R11	RES 30.1K OHM 1/10W 1% 0603 SMD	Panasonic - ECG	ERJ-3EFK3012V
1	549Ω	RCM	RES 549 OHM 1/10W 1% 0603 SMD	Panasonic - ECG	ERJ-3EKF5490V
1	34kΩ	RLIN	RES 34K OHM 1/16W .5% 0603 SMD	Susumu Co Ltd	RR0816P-3402-D-52C
1	12.1kΩ	RSET	RES 12.1K OHM 1/16W .5% 0603 SMD	Susumu Co Ltd	RR0816P-1212-D-09C
1	6.34kΩ	RVI	RES 6.34K OHM 1/16W .5% 0603 SMD	Susumu Co Ltd	RR0816P-6341-D-78H
1	100.0Ω	RZ1	RES 100 OHM 1/10W .1% 0603 SMD	Panasonic - ECG	ERA-3AEB101V
0	OMIT	RZ2-RZ5, RL, R6, C2-C7	Omit; not installed	N/A	N/A
1	1SS355TE-17	D1	DIODE SWITCH 90V 100MA SOT-323	Rohm Semiconductor	1SS355TE-17
1	BAV99	D2	DIODE SWITCH SS DUAL 70V SOT323	ON Semiconductor	BAV99RWT1G
2	Ferrite	F1, F2	FERRITE 300MA 600 OHM 0603 SMD	Laird-Signal Integrity Products	HZ0603C601R-10
1	NFET	Q1	MOSFET, N CHANNEL, DEPLETION MODE	Supertex	DN2540N8
1	XTR108	U1	IC 4-20MA 2-WIRE TRNSMTR 24-QSOP	Texas Instruments	XTR108EA
1	25C040/SN	U2	IC EEPROM 4KBIT 3MHZ 8SOIC	Microchip Technology	25C040/SN
1	SN74LVC1G04	U3	IC SINGLE INVERTER-GATE SC-70	Texas Instruments	SN74LVC1G04DCKT
9	Pin Socket	RZ1-RZ5, RCM, RLIN, RSET	CONN SOCKET RCPT .014-.026 30AU	Tyco Electronics	5050863-5
2	3-pin Terminal	J1, J5	TERMINAL BLOCK 5MM 3POS	On Shore Technology Inc	ED300/3
1	DSUB15M	J2	CONN DB15 MALE .318" R/A NICKEL	Norcomp Inc	182-015-113R531
2	2-pin Terminal	J3, J4	TERMINAL BLOCK 5MM 2POS	On Shore Technology Inc	ED300/2
29	TP Cut to Size	REFout, REFin, R_set, SCK, CS1, CS2, SDIO, Vcc, Io, Vgate, GND1-GND6, Iin, Vo, V/I-0 to V/I-5, R_lin, Cfilter, OPA In+, OPA In–, OPAout	CONN. HEADER .100 SNGL 1POS	Samtec	TSW-101-07-G-S
8	3-position Jumper	JMP1-JMP8	HEADER, 3 POSITION, SINGLE ROW, GOLD, 0.100"	Samtec	TSW-103-07-G-S
8	Jumper Shunts	JMP1-JMP8	JUMPER SHORTING UNITS	Tyco Electronics	881545-2
4	Screws	N/A	SCREW MACHINE PHILLIPS 4-40X3/8	B&F Fastener Supply	PMS 440 0038 PH
4	Standoffs	N/A	STANDOFF HEX 4-40THR ALUM .500"L	Keystone Electronics	2203

8 Appendix

This section contains information related to the operation of the XTR108, the equations used during the calibration procedure, and the mnemonic command syntax displayed by the *Debug* window.

8.1 XTR108 Operation

This section describes the operation of key XTR108 functional blocks.

8.1.1 Input MUX

The primary function of the XTR108 input multiplexer (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 other channels remain for different ranges. R_{Z1} through R_{Z5} are used to the set the minimum temperature (T_{MIN}) of a particular range. In the example shown below, where $T_{MIN} = -200°C$, R_{Z1} is selected to match the resistance of the RTD at this temperature (18.7 Ω is the closest standard value). This setting forces the PGA differential input voltage to be approximately 0 V at T_{MIN}. R_{CM} generates a common-mode voltage so that the XTR108 common-mode input voltage range is not violated.
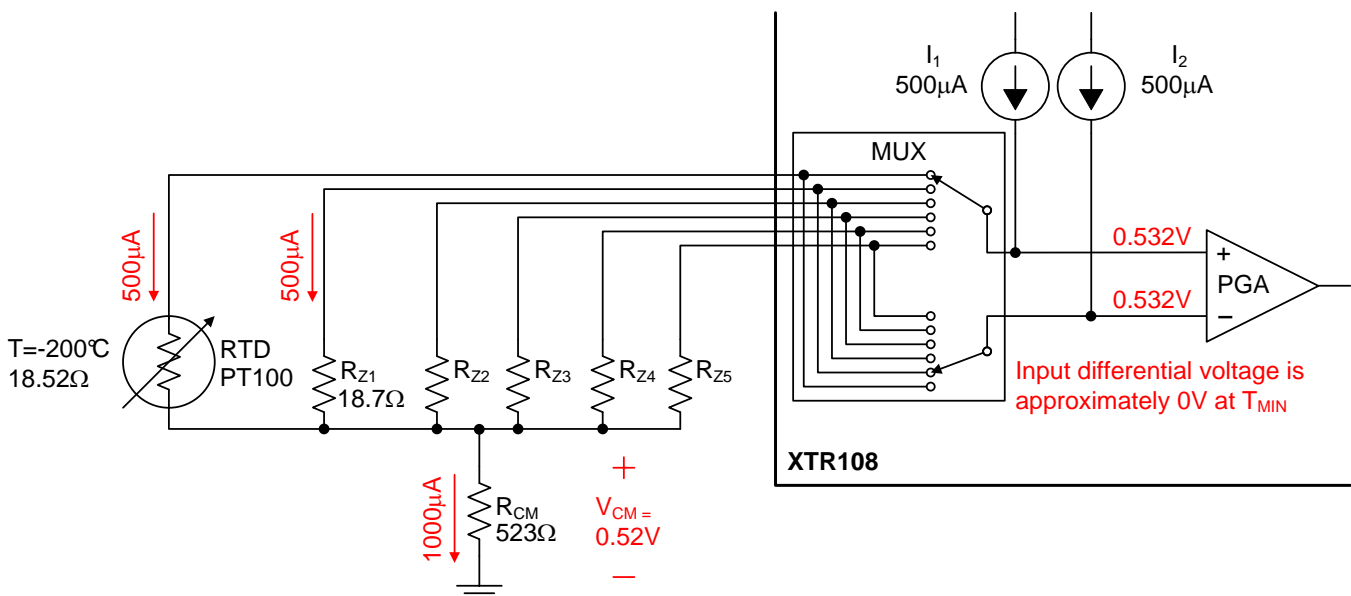
Figure 36. XTR108 Input MUX Example ($T_{MIN} = -200°C$, PT100 RTD)

Figure 37 shows the same multiplexer configuration with the RTD at maximum temperature, where T_{MAX} = +850°C. At this point, the differential input voltage to the PGA is equal to 186 mV, the maximum value for this configuration.
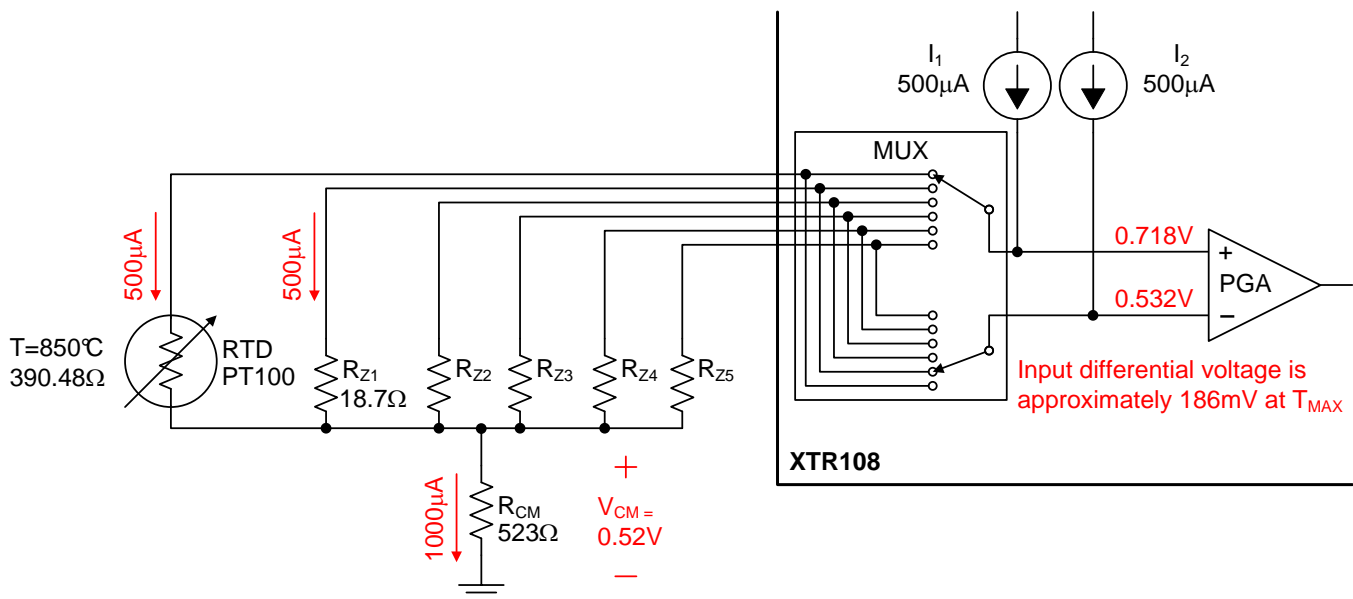
Figure 37. XTR108 Input MUX Example (T_{MAX} = +850°C, PT100 RTD)

Figure 38 shows how the current sources can be programmed to accommodate different types of RTDs. The previous example used a 100-Ω RTD, or PT100. In this example the RTD type has been changed to 1000 Ω, or PT1000. The current sources I_1 and I_2 are scaled from 500 μA to 50 μA to accommodate this new resistance. R_{Z1} and R_{CM} are also scaled appropriately. Note that I_1 and I_2 are matched current sources that are programmed by one set of DACs (an 8-bit coarse DAC and 8-bit fine DAC). These current sources are programmed during the calibration procedure.
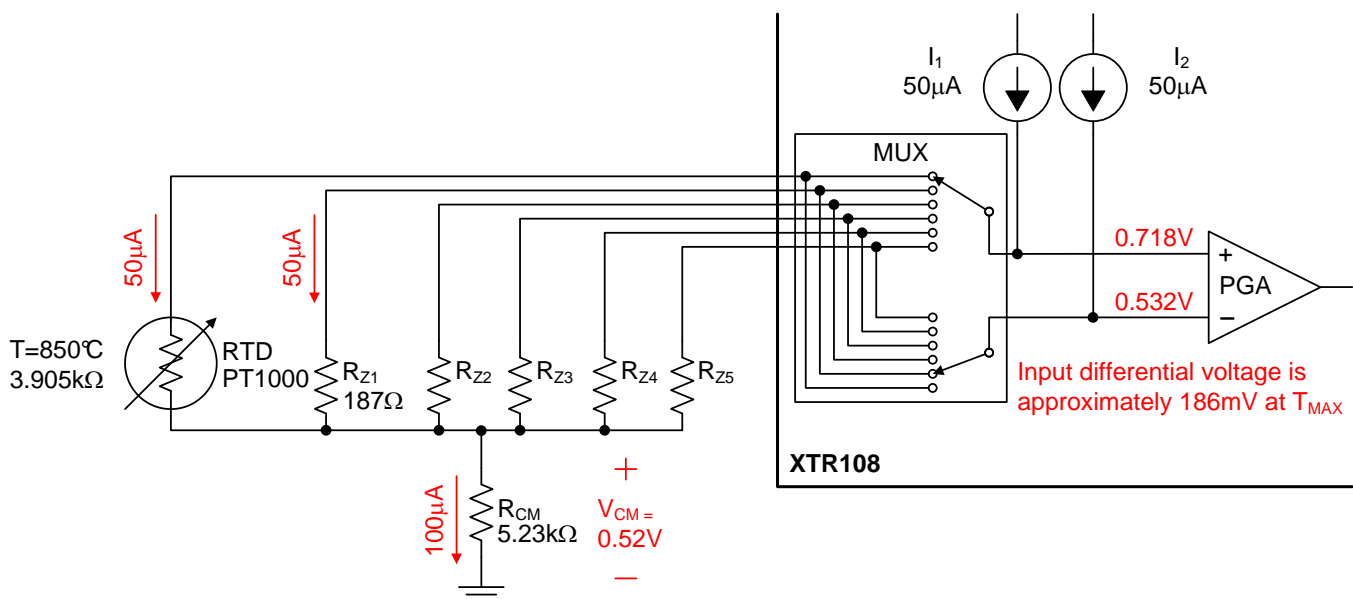
Figure 38. XTR108 Input MUX Example (T_{MAX} = +850°C, PT1000 RTD)

8.1.2 R$_{SET}$

The range of the I$_{REF}$ DAC that controls the current sources I$_1$ and I$_2$ is set by the external resistor R$_{SET}$. For example, with a value of R$_{SET}$ = 12.1 kΩ, the range of I$_{REF}$ is 480 μA to 510 μA. If R$_{SET}$ = 121 kΩ, the range of I$_{REF}$ becomes 48 μA to 51 μA. The **Find Resistors** tab within the XTR108EVM-USB software helps to determine the appropriate R$_{SET}$ value.
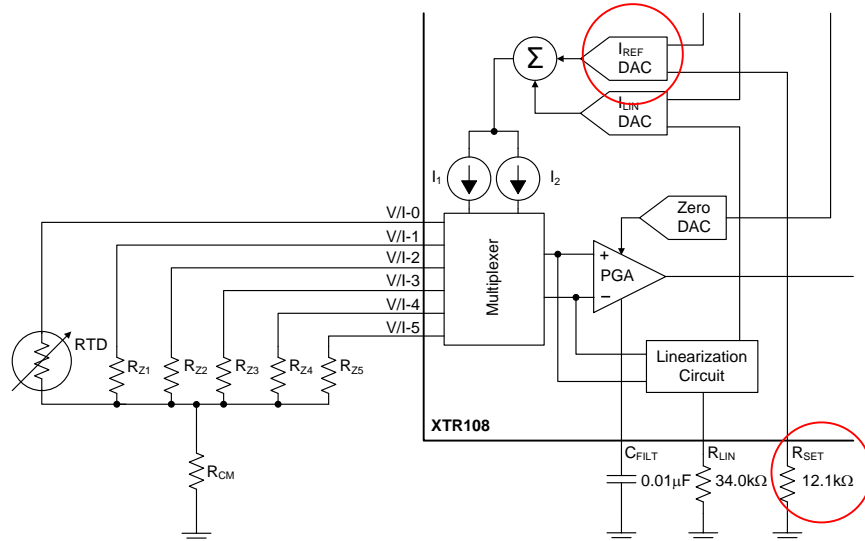
Figure 39. R$_{SET}$ Circuitry

8.1.3 R$_{LIN}$

All RTDs have a nonlinear response over temperature. Typically, this nonlinearity can be approximated as a second-order function, and therefore can be calibrated out by modulating the excitation current with the RTD input signal. The range of this linearity correction is set by external resistor, R$_{LIN}$.
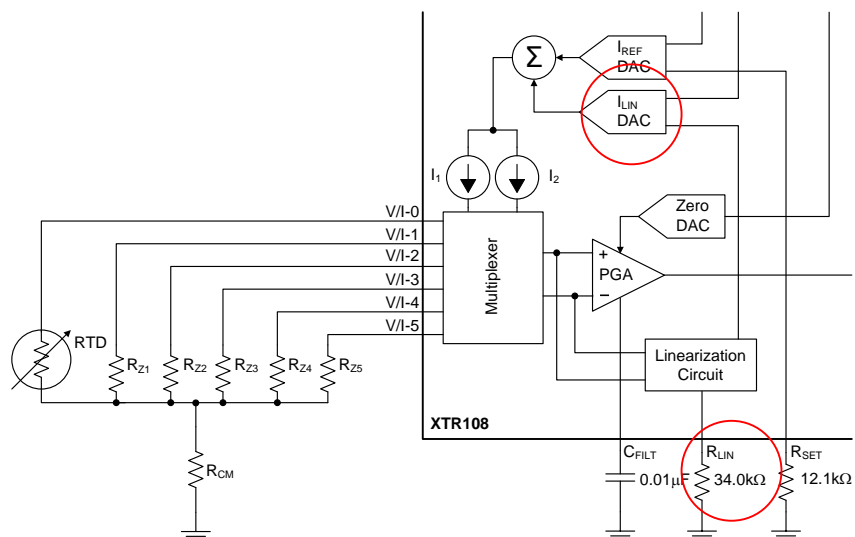
Figure 40. R$_{LIN}$ Circuitry

8.1.4 Linearity Correction

Figure 41 illustrates how the XTR108 linearity correction works. The RTD has a response that is approximately quadratic (gray line). The positive feedback of the input signal through the linearity DAC I_{LIN} generates a response that is also approximately quadratic (black line). The two responses counteract each other to generate a linear output (red line).
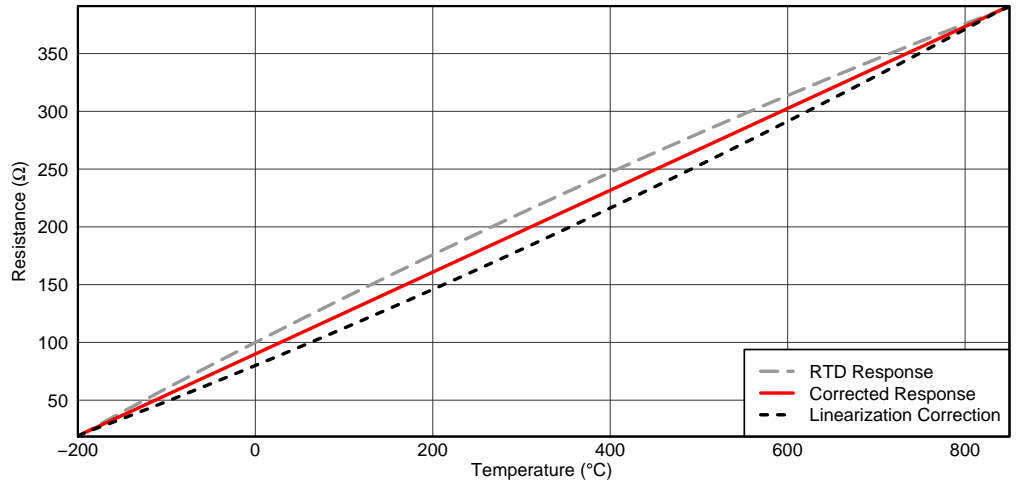
Figure 41. Linearity Correction Method

Figure 42 shows the uncorrected and corrected nonlinearity for a typical RTD. Normally a 40:1 improvement is achieved using this method.
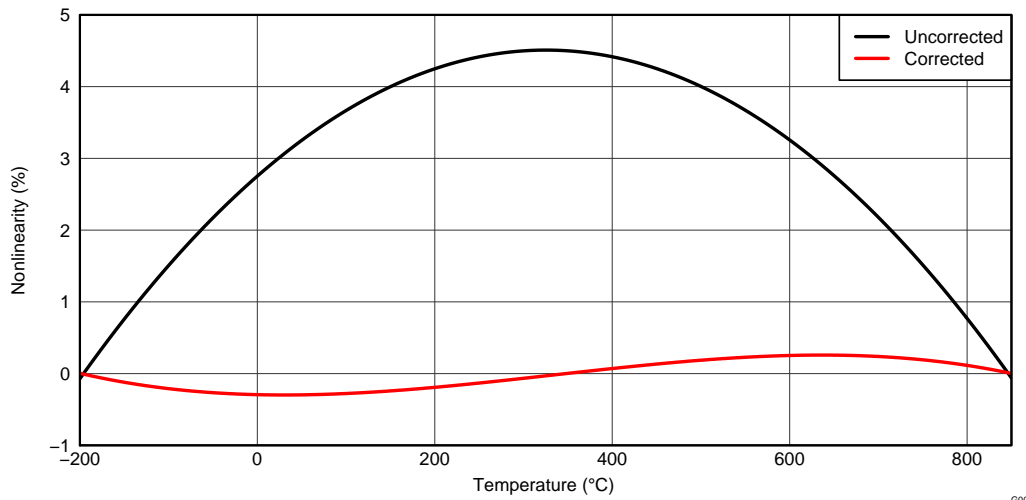
Figure 42. Linearity Improvement

8.2 *XTR108 Calibration Equations (Current-Output Mode)*

The following section gives the equations used during the calibration procedure for current-output mode.

8.2.1 Initial Calculations

8.2.1.1 *RTD Resistance*

The equations in Table 30 are used to calculate the RTD resistance at the minimum temperature (RTD_{MIN}), medium temperature (RTD_{MID}), and maximum temperature (RTD_{MAX}). Pick an external zero resistor, R_Z, that is the closest standard value to RTD_{MIN}.

Table 30. Standard RTD Equations[1]

If –200°C < T < 0°C	If T > 0°C
$R_t = R_0 [1 + A \times T + B \times T^2 + C \times T^3(T - 100°C)]$	$R_t = R_0 [1 + A \times T + B \times T^2]$

[1] A = 3.9083E-3, B = –5.775E-7, C = –4.183E-12, R_0 = RTD value at 0°C (typically 100 Ω or 1 kΩ), and T = temperature in °C.

8.2.1.2 *Relative Nonlinearity*

Calculate the relative nonlinearity, B_V, by using the RTD values calculated in the previous step.

$$B_V = \frac{RTD_{MID} - \dfrac{RTD_{MAX} + RTD_{MIN}}{2}}{RTD_{MAX} - RTD_{MIN}}$$

8.2.1.3 *Linearization Coefficient*

Calculate the linearization coefficient, G_{LIN}.

$$G_{LIN} = \frac{2*B_V}{(0.5 + B_V)*RTD_{MAX} - (0.5 - B_V)*RTD_{MIN} - 2*B_V*R_Z}$$

Calculate G_{LIN_MAX}. If G_{LIN} is larger than G_{LIN_MAX}, the external resistor R_{LIN} must be changed.

$$G_{LIN\_MAX} = \frac{16}{R_{LIN}}$$

8.2.1.4 *I_{REF} DAC (Excitation Current Source)*

Choose the minimum and maximum output current values (I_{OUT_MIN} and I_{OUT_MAX}). Select an initial PGA gain setting (A_{PGA}) and calculate the initial excitation current I_{REF}. Ensure that the PGA gain is selected such that $I_{REF\_MIN} < I_{REF} < I_{REF\_MAX}$.

$V_{REF} = 1.193V$

$$I_{SET} = \frac{V_{REF}}{R_{SET}}$$

$I_{REF\_MIN} = 0.65*(5*I_{SET})$

$I_{REF\_MAX} = 1.35*(5*I_{SET})$

$$I_{REF} = \frac{(I_{OUT\_MAX} - I_{OUT\_MIN})*[1 - G_{LIN}*(RTD_{MAX} - R_Z)]*R_{VI}}{50*A_{PGA}*(RTD_{MAX} - RTD_{MIN})}$$

8.2.1.5 I_{ZERO} DAC (Zero Offset)

Calculate the required I_{ZERO} DAC value.

$$I_{ZERO} = I_{OUT\_MIN} - \frac{50*A_{PGA}*I_{REF}*(RTD_{MIN} - R_Z)}{R_{VI}}$$

8.2.1.6   Calculate DAC Codes

The I_{REF} and I_{ZERO} DACs are controlled by registers 10, 11, 12, and 13 in the XTR108. Use the following equations to determine the values to be written to these registers. N_{10}, N_{11}, N_{12}, and N_{13} are decimal values that must be converted to hexadecimal before being written.

$$I_{ZPGM} = \frac{5*V_{REF}}{8*R_{VI}}$$

$$N_{11} = round\left[64 * \frac{I_{REF} - 5*I_{SET}}{I_{SET}} \right]$$

$$N_{10} = round\left[1024 * \frac{I_{REF} - 5*I_{SET} - \dfrac{N_{11}*I_{SET}}{64}}{I_{SET}} \right]$$

$$N_{13} = round\left[4 * \frac{I_{ZERO} - 35*I_{ZPGM}}{I_{ZPGM}} \right]$$

$$N_{12} = round\left[64 * \frac{I_{ZERO} - 35*I_{ZPGM} - \dfrac{N_{13}*I_{ZPGM}}{4}}{I_{ZPGM}} \right]$$

8.2.2   First Corrections

First, measure the output current at the minimum and maximum temperatures ($I_{OUT\_MIN\_MEAS}$ and $I_{OUT\_MAX\_MEAS}$).

8.2.2.1   Linearization Register

Calculate the corrections for the linearization register. N_{14} is a decimal value that must be converted to hexadecimal before being written.

$$I_{REF\_A} = \frac{(I_{OUT\_MAX\_MEAS} - I_{OUT\_MIN\_MEAS})*R_{VI}}{50*A_{PGA}*(RTD_{MAX} - RTD_{MIN})}$$

$$dR_Z = \frac{(I_{ZERO} - I_{OUT\_MIN\_MEAS})*R_{VI}}{50*A_{PGA}*I_{REF\_A}}$$

$$R_{Z\_A} = RTD_{MIN} + dR_Z$$

$$G_{LIN\_A} = \frac{2*B_V}{(0.5 + B_V)*RTD_{MAX} - (0.5 - B_V)*RTD_{MIN} - 2*B_V*R_{Z\_A}}$$

$$N_{14} = round(16*G_{LIN\_A}*R_{LIN})$$

8.2.2.2 I_{REF} Registers

Calculate the corrections for the I_{REF} registers.

$$I_{REF\_B} = \frac{(I_{OUT\_MAX} - I_{OUT\_MIN})*[1 - G_{LIN\_A}*(RTD_{MAX} - R_{Z\_A})]*R_{VI}}{50*A_{PGA}*(RTD_{MAX} - RTD_{MIN})}$$

$$I_{REF\_REG} = I_{SET}*\left[5 + \frac{N_{11}}{64} + \frac{N_{10}}{1024}\right]$$

$$dI_{REF} = (I_{REF\_REG} - I_{REF\_A}) + (I_{REF\_REG} - I_{REF\_B})$$

$$N_{10\_A} = N_{10} + round\left[\frac{1024*dI_{REF}*R_{SET}}{V_{REF}}\right]$$

$$N_{11\_A} = N_{11}$$

> **NOTE:** If the adjusted value for register 10 (N_{10_A}) is outside of the possible range of $-127 < N_{10\_A} < 128$, then use the following equations to adjust both register 10 and register 11.

$$I_{REF\_ADJ} = I_{REF\_REG} + dI_{REF}$$

$$N_{11\_A} = round\left[64*\frac{I_{REF\_ADJ} - 5*I_{SET}}{I_{SET}}\right]$$

$$N_{10\_A} = round\left[1024*\frac{I_{REF\_ADJ} - 5*I_{SET} - \dfrac{N_{11\_A}*I_{SET}}{64}}{I_{SET}}\right]$$

8.2.2.3 I_{ZERO} Registers

Calculate the corrections for the I_{ZERO} registers.

$$dI_{ZERO} = I_{OUT\_MIN} - I_{ZERO} - \left[\frac{50*A_{PGA}*I_{REF\_B}*(RTD_{MIN} - R_{Z\_A})}{R_{VI}}\right]$$

$$N_{12\_A} = round\left[N_{12} + \frac{512*dI_{ZERO} - 35*I_{ZPGM}}{I_{ZPGM}}\right]$$

$$N_{13\_A} = N_{13}$$

> **NOTE:** If the adjusted value for register 12 (N_{12_A}) is outside of the possible range of $-127 < N_{12\_A} < 128$, then use the following equations to adjust both register 12 and register 13.

$$N_{13\_A} = round\left[4*\frac{I_{ZERO} + dI_{ZERO} - 35*I_{ZPGM}}{I_{ZPGM}}\right]$$

$$N_{12\_A} = round\left[64*\frac{I_{ZERO} + dI_{ZERO} - 35*I_{ZPGM} - \dfrac{I_{ZPGM}*N_{13\_A}}{4}}{I_{ZPGM}}\right]$$

8.2.3   Second Corrections

Measure the output current at the maximum temperature ($I_{OUT\_MAX\_MEAS\_2}$).

8.2.3.1   Linearization Register

Calculate the final corrections for the linearization register. This step completes the calibration procedure.

$$I_{LIN\_A} = \frac{I_{REF\_B}*A_{PGA}*50*(RTD_{MAX}-RTD_{MIN})}{R_{VI}}$$

$$I_{LIN\_B} = I_{OUT\_MAX\_MEAS\_2} - I_{OUT\_MIN}$$

$$G_{LIN\_MEAS\_A} = \frac{I_{LIN\_B} - I_{LIN\_A}}{(RTD_{MAX}-R_{Z\_A})*I_{LIN\_B}}$$

$$G_{LIN\_FINAL} = G_{LIN\_A}* \frac{G_{LIN\_A}}{G_{LIN\_MEAS\_A}}$$

$$N_{14\_A} = round(16*G_{LIN\_FINAL}*R_{LIN})$$

8.3   XTR108 Calibration Equations (Voltage-Output Mode)

The calibration procedure for voltage-output mode is exactly the same as for current-output mode. The only difference is that output voltage must be converted to output current in order to satisfy the same sets of equations. Use the following equation to convert output voltage to output current.

$$I_{OUT} = \frac{V_{OUT}*50}{R_{VI}}$$

8.4   Mnemonic Commands

The USB-DAQ platform uses a set of mnemonic commands to perform SPI communications to the XTR108EVM-USB. These commands are given in Table 31.

Table 31. Mnemonic Commands

Command	Description
SPI	Always the first mnemonic in an SPI command.
CH1 CH2	Always the second mnemonic in an SPI command. This mnemonic identifies which SPI channel is used. The USB-DAQ platform contains two SPI channels to allow for the connection of two different SPI devices.
BREH BREL AFEH AFEL	Always the third mnemonic in an SPI command. This mnemonic identifies different modes of SPI data capture. For example, BREL means that the data are captured before the clock rising edge and the clock is active low. Further details are included in Table 32.
L	Drive chip select ($\overline{CS}$) line low
H	Drive chip select ($\overline{CS}$) line high
R	Read an 8-bit word
Example: 01h, 3Ah, and 9Ch	Write an 8-bit word (any hexadecimal two-character byte)

The USB-DAQ Platform SPI protocol supports four clock and data line modes of operation. These modes are summarized in Table 32. The first mode, BREH, is used by the XTR108EVM-USB.

Table 32. SPI Modes of Operation

Mode	Clock Polarity Description (CPOL)	Clock Transition for Data Polarity Description (CPHA)
BREH	Clock idles low CPOL = 0	Data are read by the USB-DAQ on the clock rising edge. Data are changed by the USB-DAQ on the clock falling edge. Data are sampled on the first clock edge. CPHA = 0.
BREL	Clock idles low CPOL = 0	Data are read by the USB-DAQ on the clock falling edge. Data are changed by the USB-DAQ on the clock rising edge. Data are sampled on the second clock edge. CPHA = 1.
AFEH	Clock idles high CPOL = 1	Data are read by the USB-DAQ on the clock falling edge. Data are changed by the USB-DAQ on the clock rising edge. Data are sampled on the first clock edge. CPHA = 0.
AFEL	Clock idles high CPOL = 1	Data are read by the USB-DAQ on the clock rising edge. Data are changed by the USB-DAQ on the clock falling edge. Data are sampled on the second clock edge. CPHA = 1.

The USB-DAQ also supports a set of generic commands used to enable or disable power supplies, read from internal ADCs, set the output of internal DACs, and set the voltage of control pins. The XTR108EVM-USB uses the GPIO pin functionality to control the relay driver U1 on the Interface Board. These commands are given in Table 33.

Table 33. General USB-DAQ Commands

Command	Description
CMD	Always the first mnemonic in a general USB-DAQ command.
Example: CTRL 0, CTRL 3, CTRL 128, CTRL 255	Sets the eight control pins according to the value written. Each control pin is assigned a location in the 8-bit control word, where CTRL8 is the MSB and CTRL1 is the LSB. For example, write CTRL 0 to turn off all control pins. To turn on the CTRL1 and CTRL2 pins, write CTRL 3. To turn on only the CTRL8 pin, write CTRL 128.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (March, 2012) to A Revision **Page**

• Deleted all references to included power supply. A power supply is no longer included with this EVM. 1

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- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

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  3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

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