

Circuits from the Lab™ Reference Circuits

Circuits from the Lab® reference designs are engineered and tested for quick and easy system integration to help solve today's analog, mixed-signal, and RF design challenges. For more information and/or support, visit www.analog.com/CN0325.

Devices Connected/Referenced

AD7795	16-Bit, Sigma-Delta ADC, 40 nV Noise	ADP1720	50 mA, High Voltage Linear Regulator
AD8226	36 V Instrumentation Amplifier, >90 dB CMRR	ADR441	Ultralow Noise, LDO XFET®, 2.5 V Voltage Reference
ADT7310	±0.5°C Digital Temperature Sensor	ADuM1311	Triple-Channel Digital Isolator
ADP2441	36 V, 1 A, Step-Down, DC-to-DC Regulator	ADuM3471	Quad Isolator with Integrated Transformer Driver and PWM
ADG442	LC ² MOS Quad SPST Switch		

PLC and DCS Universal Analog Input Using Either 4-Pin or 6-Pin Terminal Block

EVALUATION AND DESIGN SUPPORT

Circuit Evaluation Boards

- [CN-0325 Evaluation Board \(EVAL-CN0325-SDPZ\)](#)
- [System Demonstration Platform \(EVAL-SDP-CB1Z\)](#)

Design and Integration Files

- [Schematics, Layout Files, Bill of Materials](#)

CIRCUIT FUNCTION AND BENEFITS

The circuit shown in Figure 1 provides two, 16-bit, fully isolated, universal analog input channels suitable for programmable logic controllers (PLCs) and distributed control system (DCS) modules. Both channels are software programmable and support a number of voltage, current ranges, thermocouple, and RTD types, as shown in Figure 1.

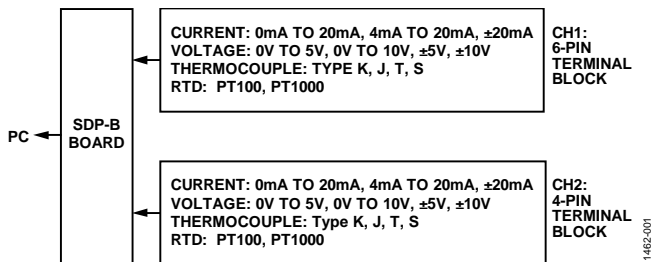


Figure 1. Universal Analog Input Overview

The evaluation board contains two different fully isolated universal input channels, one with a 4-pin terminal block (CH2), and one with a 6-pin terminal block (CH1).

For the 4-terminal block channel (CH2), the voltage, current, thermocouple, and RTD inputs all share the same 4 terminals, thus minimizing the number of terminal pins required. For the 6-pin terminal block channel (CH1), the voltage and current inputs share a set of 3 terminals, and the thermocouple and RTD inputs share another set of 3 terminals; this configuration requires more terminals but has a lower part count and component cost. Figure 2 shows a photo of the printed circuit board (PCB), and Figure 3 shows a more detailed schematic of the circuit.

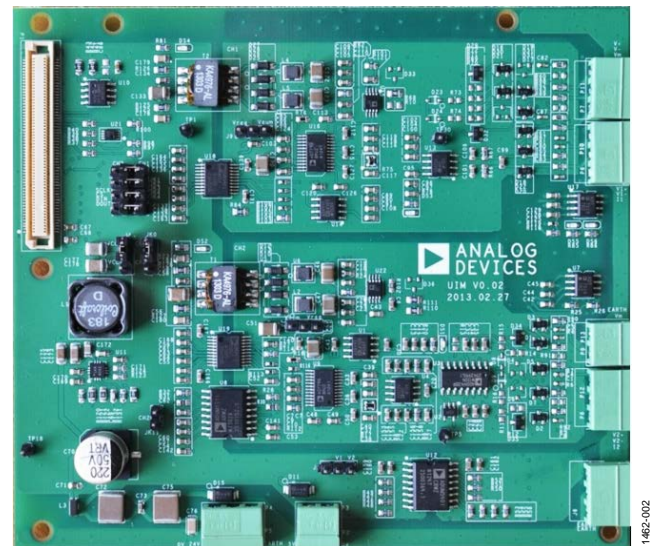
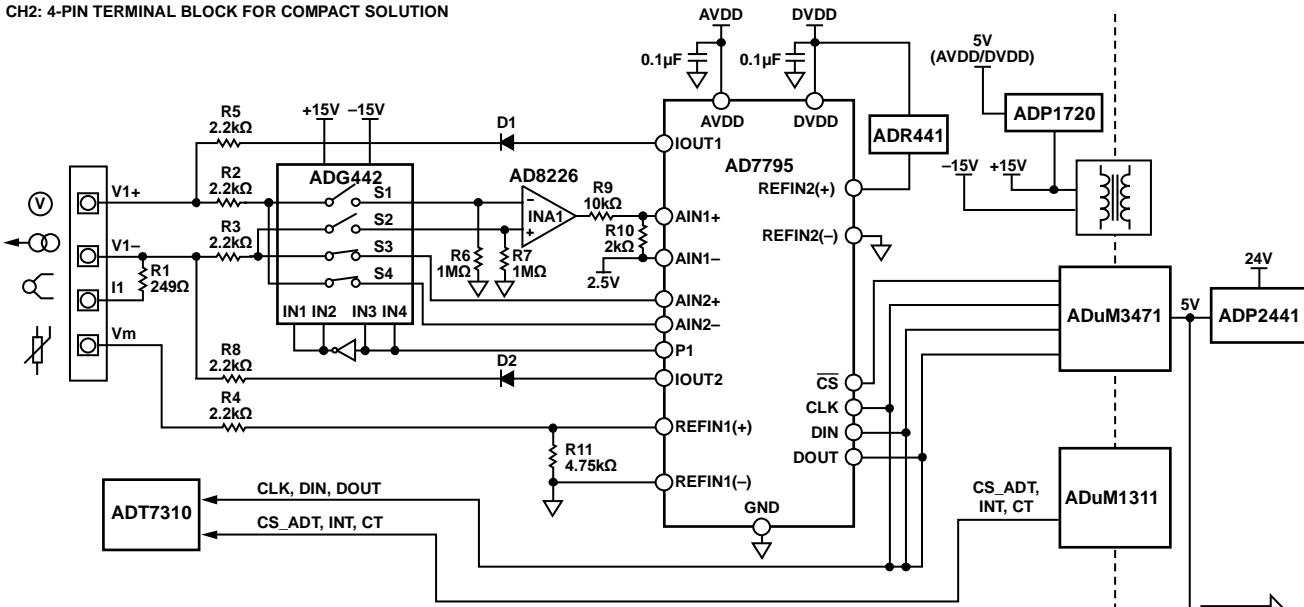


Figure 2. Universal Analog Input Board

Rev. 0

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CH2: 4-PIN TERMINAL BLOCK FOR COMPACT SOLUTION



CH1: 6-PIN TERMINAL BLOCK FOR FURTHER COST SAVING

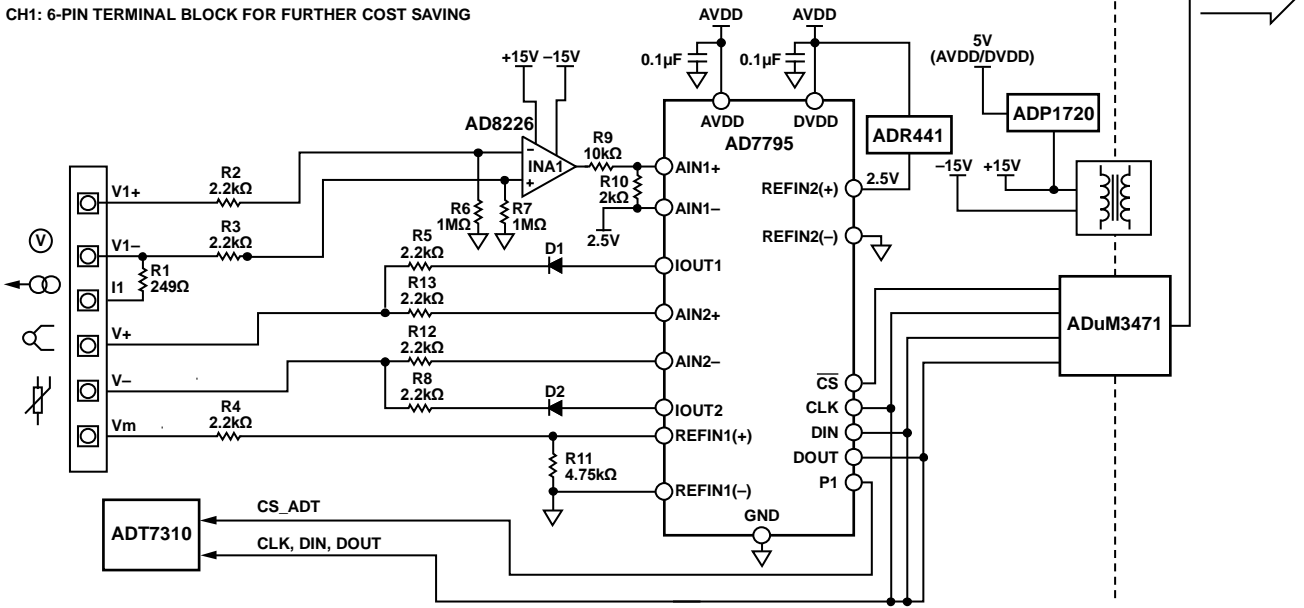


Figure 3. Functional Block Diagram (Simplified Schematic: All Connections and Decoupling Not Shown)

CIRCUIT DESCRIPTION

The **AD7795** low noise, 16-bit, Σ - Δ ADC with on-chip in-amp and reference is used for the data conversion. The on-chip in-amp and current sources provide a complete solution for RTD and thermocouple measurement. For the voltage and current inputs, the **AD8226** instrumentation amplifier with >90 dB CMRR is used to provide a high input impedance and reject any common-mode interference. The voltage and current signals are scaled to the range of the ADC using a precision resistor divider.

The **ADR441**, an ultralow noise, low dropout XFET® 2.5 V voltage reference is used as the reference for the ADC.

For the 4-pin terminal block channel (CH2), the **ADG442**, low R_{ON} , latch-up proof switch is used to switch between voltage, current, thermocouple, and RTD input modes.

Digital and power isolation is achieved using **ADuM3471**, a PWM controller and transformer driver with quad-channel isolator which is used to generate an isolated ± 15 V supply using an external transformer. The **ADuM1311**, triple-channel digital isolator is also used in the 4-pin terminal block circuit to isolate the control lines for the **ADG442** switches.

The **ADP2441**, 36 V step-down dc-to-dc regulator has a wide tolerance on its input supply making it ideal for accepting a 24 V industrial supply. It accepts up to 36 V, thereby making reliable transient protection of the supply input more easily achievable. It steps the input voltage down to 5 V to power the **ADuM3471** as well as all other controller-side circuitry. The circuit also includes standard external protection on the 24 V supply terminals.

The ADP2441 also features a number of other safety and reliability functions, such as undervoltage lockout (UVLO), a precision enable, a power good pin, and overcurrent-limit protection. It also can achieve up to 90% efficiency in the 24 V input, 5 V output configuration.

HARDWARE

Figure 4 shows the location of the channel containing the 4-pin terminal block and the channel with the 6-pin terminal block. It also shows the location of the 24 V supply input, 5 V output configuration.

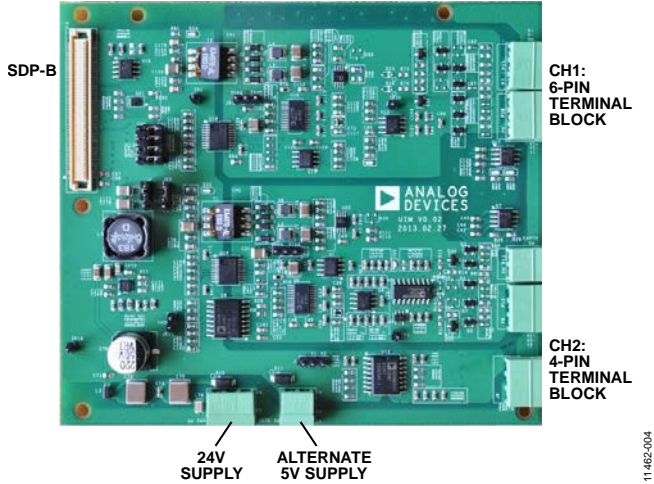


Figure 4. Channel Locations

Channel Selection

Jumpers need to be inserted and switched to configure both supply and SPI signals between CH1 and CH2, as shown in Table 1.

Table 1. Channel Selection Configuration Settings

Link No.	Digital Function	Link Position to Select CH1, 6-Pin Terminal Block	Link Position to Select CH2, 4-Pin Terminal Block
JK0	5 V supply	CH1	CH2
JK1	SCLK	CH1	CH2
JK2	\overline{CS}	CH1	CH2
JK3	D _{IN}	CH1	CH2
JK4	D _{OUT}	CH1	CH2
JK11	TEMP_CS	Not inserted	Inserted

Power Configurations

A 24 V supply powers the controller side of the board. Alternately, a 5 V supply can be used, bypassing the ADP2441 circuitry. This 5 V input has no overvoltage protection and must not exceed 6 V. The supply used must be configured using the J4 link option as described in Table 2.

Table 2. External Power Supply Configuration Settings

Link No.	Link Position to Select 24 V Input (Default)	Link Position to Select 5 V Input (Default)
J4	VCC1	VCC2

For the analog input side of the isolation barrier, there are two options for powering a regulated 5 V for the analog circuitry. Either the ADP1720 linear regulator can be used to step the 15 V down to 5 V, or else the internal 5 V regulator of the ADuM3471 can be used. The link configurations for each is shown in Table 3.

Table 3. Field 5 V Supply Configuration Settings

Link No.	Link Position for ADP1720, 5 V Regulator (Default)	Link Position for ADuM3471 5 V Regulator
J3	Vreg	Vaum
J9	Vreg	Vaum

CH2: 4-PIN TERMINAL BLOCK CHANNEL

Input Connectors

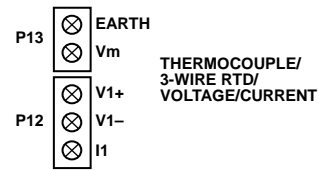


Figure 5. CH2 Input Connectors

Voltage and Current

The P12 connector is used for voltage and current input connections. Figure 11 and Figure 12 show simplified schematics for this input connection and configuration. This configuration allows differential inputs in the ranges of 0 V to 5 V, 0 V to 10 V, ±5 V, ±10 V, 0 mA to 20 mA, 4 mA to 20 mA, and ±20 mA. Connect voltage or current inputs between V1+ and V1-, because current inputs also short the V1+ and I1 pins together. Shorting V1+ to I1 allows the 249 Ω, 0.1%, 0.25 W to be used as a current sensing resistor.

Thermocouple

The P12 connector is also used for thermocouple inputs. Various thermocouple types can be connected including J, K, T, and S types. The thermocouple is connected between the V1+ and V1- inputs (see Figure 5). Figure 6 shows how to connect a thermocouple (Type T, in this example) to the universal analog input board. See Figure 13 for a simplified schematic of the thermocouple input.

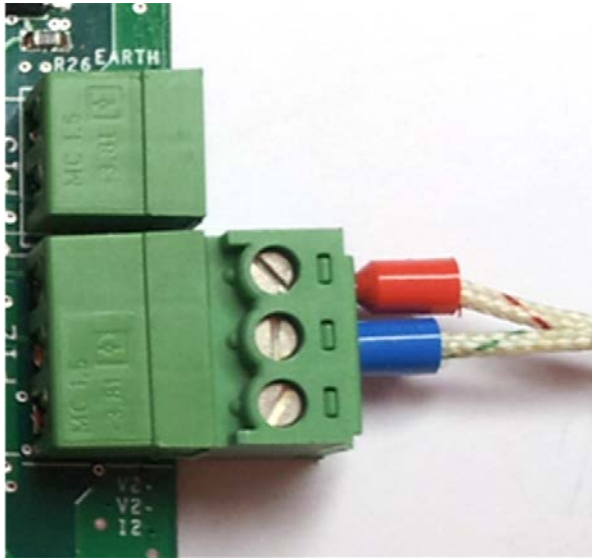


Figure 6. CH2 Thermocouple Connector

RTD

The P12, P13 connectors are used for RTD inputs. The hardware can support both 1000 Ω and 100 Ω platinum RTD inputs. For 3-wire mode, the two common wires are connected to V1+ and V1-, and the return is connected to Vm (see Figure 5). Figure 7 shows how to connect a 3-wire RTD sensor to the universal analog input board. See Figure 14 for a simplified schematic of the RTD input.

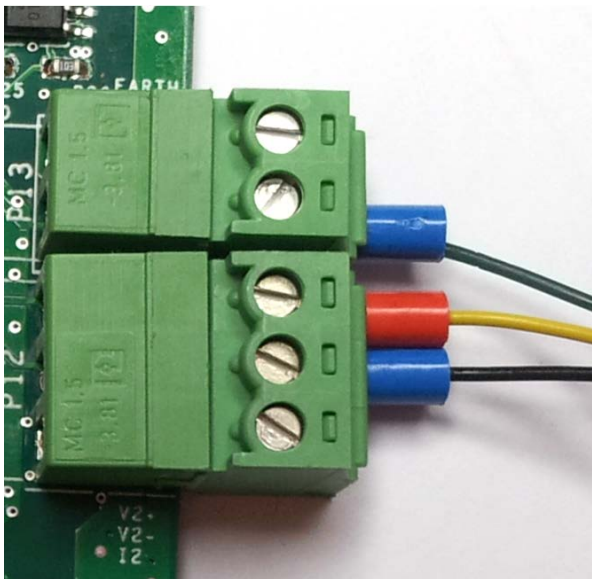


Figure 7. CH2 RTD Connector

CH1: 6-PIN TERMINAL BLOCK CHANNEL

Input Connectors

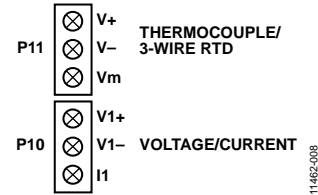


Figure 8. CH1 Channel Input Connectors;
See Figure 13 for a Simplified Input Diagram

Voltage and Current

The P10 connector is used for voltage and current input connections. This allows differential inputs in the ranges of 0 V to 5 V, 0 V to 10 V, ±5 V, ±10 V, 0 mA to 20 mA, 4 mA to 20 mA, and ±20 mA. Connect voltage or current inputs between V1+ and V1- (see Figure 13). For current inputs, also short V1+ and I1 pins together, thereby connecting a 249 Ω precision current sensing resistor with 0.1% accuracy and 0.25 W rating.

Thermocouple

The P11 connector is used for thermocouple inputs. Various thermocouple types can be connected including J, K, T, and S types. The thermocouple is connected between the V+ and V- inputs (see Figure 8). Figure 9 shows how to connect a thermocouple (Type T in this example) to the universal analog input board.

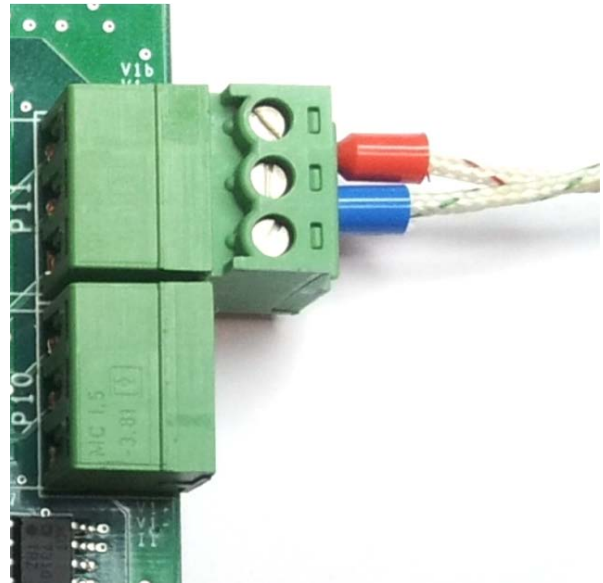


Figure 9. CH1 Thermocouple Connector

RTD

The P11 connector is also used for RTD input. The hardware can support both 1000 Ω and 100 Ω platinum RTD inputs. For 3-wire mode, the two common wires are connected to V+ and V-, and the return is connected to Vm (see Figure 8). Figure 10 shows how to connect a 3-wire RTD sensor to the universal analog input board.

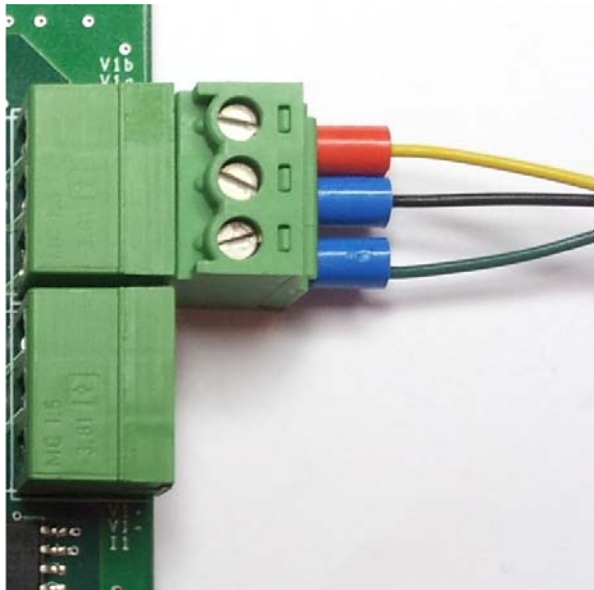


Figure 10. CH1 RTD Connector

System Resolution for 4-Pin Terminal Block Channel

With chop enable or disable selected and the data update rate selected, Table 4 shows the 4-pin terminal block channel system resolution measured with effective resolution and peak-to-peak resolutions for each input type. Note that all resolution measurements are based on the full-scale ranges as follows:

- ± 10 V: full-scale range referred to 20 V
- 0 V to 5 V: full-scale range referred to 5 V
- Type K: full-scale range referred to 1520°C
- Type J: full-scale range referred to 900°C
- Type T: full-scale range referred to 550°C
- Type S: full-scale range referred to 1765°C
- PT100: full-scale range referred to 850°C
- PT1000: full-scale range referred to 850°C

Table 4. Measured RMS Noise, Peak-to-Peak Noise, RMS Resolution, and Peak-to-Peak Resolution

Range	Data Update Rate (Hz)	Chop	Samples	RMS Noise (V/°C)	Peak-to-Peak Noise (V/°C)	RMS Resolution (Bits)	Peak-to-Peak Resolution (Bits)
-10 V to +10 V	470	Disable	2700	1.14E-04	6.72E-04	16.0	15.2
	470	Enable	1759	8.17E-05	6.72E-04	16.0	15.2
	16.7	Disable	1024	0.00E+00	0.00E+00	16.0	16.0
	16.7	Enable	1020	0.00E+00	0.00E+00	16.0	16.0
0 V to 5 V	470	Disable	1660	1.08E-04	5.04E-04	15.8	13.6
	470	Enable	2263	8.73E-05	5.04E-04	16.0	13.6
	16.7	Disable	2872	5.40E-05	1.68E-04	16.0	15.2
	16.7	Enable	1325	0.00E+00	0.00E+00	16.0	16.0
Type K (°C)	16.7	Disable	1010	1.14E-02	5.17E-02	16.0	15.1
	16.7	Enable	1032	3.23E-03	5.17E-02	16.0	15.1
Type J (°C)	16.7	Disable	1020	7.98E-03	4.01E-02	16.0	14.7
	16.7	Enable	1858	2.17E-03	4.01E-02	16.0	14.7
Type T (°C)	16.7	Disable	1041	6.44E-03	2.95E-02	16.0	14.5
	16.7	Enable	1048	5.98E-03	2.95E-02	16.0	14.5
Type S (°C)	16.7	Disable	1025	3.97E-02	2.11E-01	15.7	13.3
	16.7	Enable	1013	4.38E-02	2.10E-01	15.6	13.3
PT100 (°C)	16.7	Disable	1025	1.30E-02	2.80E-02	16.0	15.2
	16.7	Enable	594	0.00E+00	0.00E+00	16.0	16.0
PT1000 (°C)	16.7	Disable	1034	1.67E-03	2.68E-02	16.0	15.3
	16.7	Enable	589	0.00E+00	0.00E+00	16.0	16.0

System Resolution for 6-Pin Terminal Block Channel

With chop enable or disable selected and the data update rate selected, Table 5 shows the 6-pin terminal block channel system resolution measured with effective resolution and peak-to-peak resolutions for each input type. Note that all resolution measurements are based on the full scale ranges as follows:

- ±10 V: full-scale range referred to 20 V
- 0 V to 5 V: full-scale range referred to 5 V
- Type K: full-scale range referred to 1520°C
- Type J: full-scale range referred to 900°C
- Type T: full-scale range referred to 550°C
- Type S: full-scale range referred to 1765°C
- PT100: full-scale range referred to 850°C
- PT1000: full-scale range referred to 850°C

Table 5. Measured RMS Noise, Peak-to-Peak Noise, RMS Resolution, and Peak-to-Peak Resolution

Range	Data Update Rate (Hz)	Chop	Samples	RMS Noise (V/°C)	Peak-to-Peak Noise (V/°C)	RMS Resolution (Bits)	Peak-to-Peak Resolution (Bits)
-10 V to +10 V	470	Disable	2229	1.44E-04	6.72E-04	16.0	15.2
	470	Enable	1309	1.67E-04	3.36E-04	16.0	16.0
	16.7	Disable	1067	0.00E+00	0.00E+00	16.0	16.0
	16.7	Enable	1047	0.00E+00	0.00E+00	16.0	16.0
0 V to 5 V	470	Disable	2598	9.31E-05	5.04E-04	16.0	13.6
	470	Enable	1412	6.36E-05	3.36E-04	16.0	14.2
	16.7	Disable	593	8.22E-05	1.68E-04	16.0	15.2
	16.7	Enable	400	0.00E+00	0.00E+00	16.0	16.0
Type K (°C)	16.7	Disable	1280	2.33E-02	5.14E-02	16.0	15.1
	16.7	Enable	1280	6.60E-03	5.16E-02	16.0	15.1
Type J (°C)	16.7	Disable	1104	4.65E-03	4.00E-02	16.0	14.7
	16.7	Enable	452	1.98E-02	4.06E-02	15.8	14.7
Type T (°C)	16.7	Disable	1643	6.12E-03	2.95E-02	16.0	14.5
	16.7	Enable	1043	6.77E-03	2.95E-02	16.0	14.5
Type S (°C)	16.7	Disable	579	4.60E-02	3.16E-01	15.5	12.7
	16.7	Enable	548	3.37E-02	2.09E-01	16.0	13.3
PT100 (°C)	16.7	Disable	528	1.40E-02	2.80E-02	16.2	15.2
	16.7	Enable	359	1.40E-02	2.80E-02	16.0	15.2
PT1000 (°C)	16.7	Disable	658	1.01E-02	2.68E-02	16.0	15.3
	16.7	Enable	4506	4.87E-03	2.68E-02	16.0	15.3

SIMPLIFIED INPUT CIRCUIT DIAGRAMS

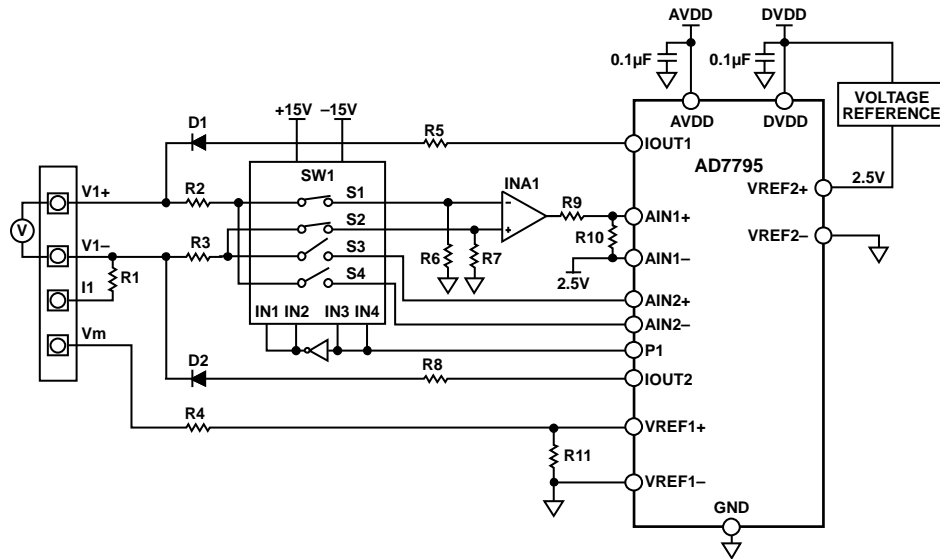


Figure 11. CH2 Simplified Voltage Input Diagram

11462-011

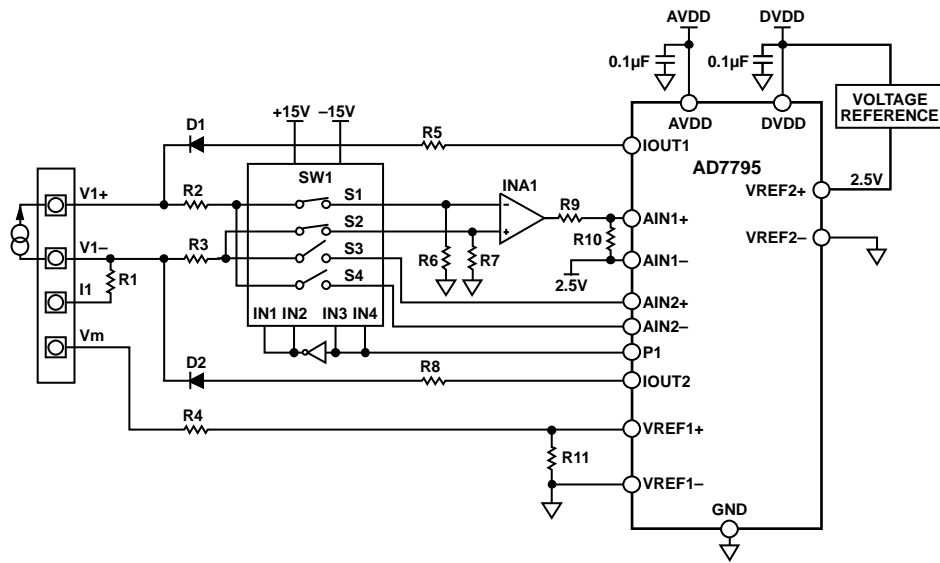


Figure 12. CH2 Simplified Current Input Diagram

11462-012

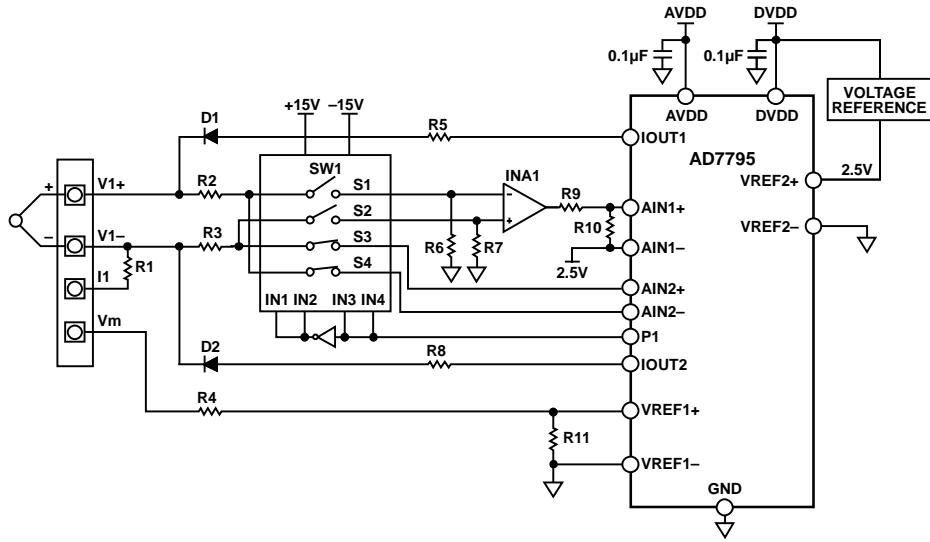


Figure 13. CH2 Simplified Thermocouple Input Diagram

11462-013

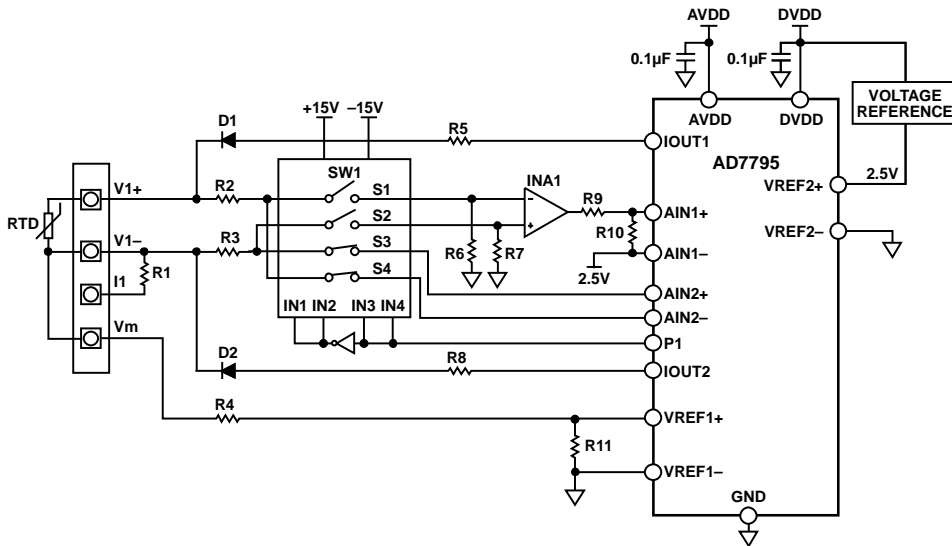


Figure 14. CH2 Simplified RTD Input Diagram

11462-014

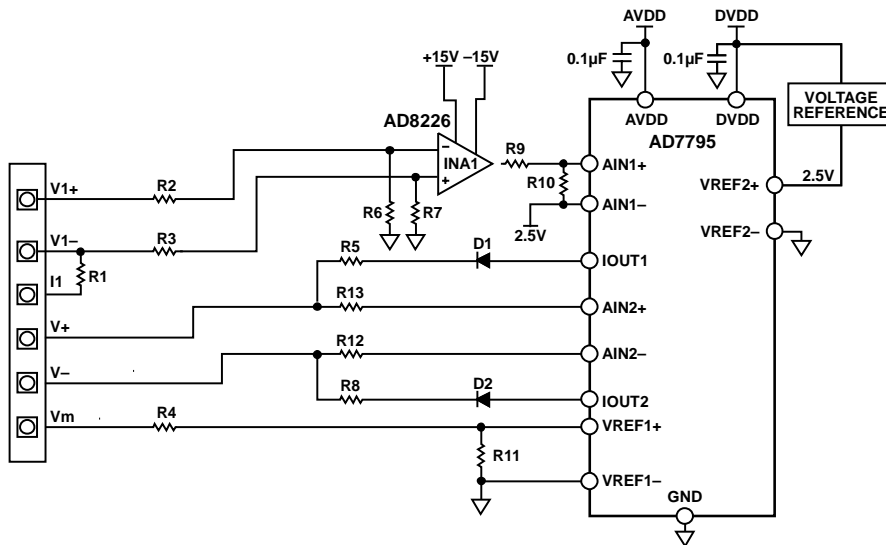


Figure 15. CH1 Simplified Input Diagram

11462-015

SOFTWARE DESCRIPTION

The universal analog input board is shipped with a CD-ROM containing the [CN0325 Evaluation Software](#) designed using LabVIEW®. This evaluation software can be installed onto a standard PC with Windows® XP (SP2), Windows Vista (32-bit and 64-bit), or Windows 7 (32-bit and 64-bit). To use the evaluation software, the Analog Devices, Inc., System Demonstration Platform—Blackfin® (SDP-B) board is required.

When the evaluation software runs, the optimized default configurations as well as the calibrated parameters from the on-board EEPROM are loaded into the software. The evaluation software allows the user to acquire data from the universal analog input board, which can be analyzed or saved to a file. The analysis results are displayed on the screen in plots and in digital format. The user can set up their own configuration and calibration values and save these into the on-board EEPROM; the software records the configuration and uploads it automatically the next time the software runs.

Software Installation

To install the evaluation software, do the following:

1. Insert the CD-ROM into the PC, or download the software installation package from the following location: <ftp://ftp.analog.com/pub/cftl/CN0325/>.
2. Locate the **setup.exe** file. Double-click the **setup.exe** file to start the installation procedure.
3. Follow the on-screen instructions to complete the installation.

Install the evaluation software before connecting the evaluation board and SDP-B board to the USB port of the PC to ensure that the evaluation system and SDP-B board are correctly recognized when connected to the PC.

After the evaluation software is installed, do the following:

1. Connect the SDP-B board to the USB port of the PC using the supplied cable.
2. Connect the [EVAL-CN0325-SDPZ](#) evaluation board to either of the SDP connectors (CON A or CON B).
3. Power up the evaluation board. Ensure that the jumpers are set up correctly, as described in the Hardware section.
4. Start the [CN-0325](#) evaluation software (**CN0325.exe**) and proceed through any dialog boxes that appear. This step completes the installation.

USING THE SOFTWARE

The main window of the software is shown in Figure 16. The hardware is configured via the **Configuration** tab, which is divided into three separate subtabs: **Hardware Configuration**, **AD7795 Configuration**, and **ADT7310 Configuration**. The **Acquisition Result** tab shows all the data from the ADC and converts results to the relevant units. The **Calibration** tab allows the user to calibrate any of the ranges. Details about the connected SDP-B board and evaluation software can be found in the **S/W Version Info** tab.

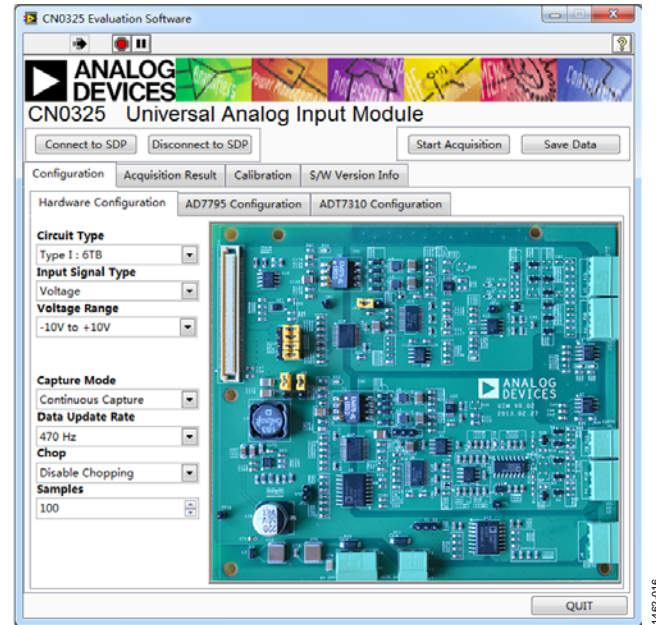


Figure 16. Evaluation Software Main Window

Main Window Buttons

The main window contains several buttons. Their functions are as follows:

- **Connect to SDP:** click to set up the connection between the SDP-B board and the evaluation board.
- **Disconnect to SDP:** click to stop the connection between the SDP-B board and the evaluation board.
- **Capture Mode:** select **Single Capture** for single capture, or **Continuous Capture** for continuous capture.
- **Start Acquisition/Stop Acquisition:** click to start or stop data capture.
- **Save Data:** save the data shown from the software into a file for further analysis.
- **QUIT:** quit the application.

Configuration Tab

Hardware Configuration Tab

The screenshot of the **Configuration** tab (see Figure 17) shows the correct jumper settings and wire connections based on the input selection. To ensure correct results, the jumper settings on the hardware must be the same as the settings in the software. The different input selection options are as follows:

- **Circuit Type:** there are two, fully isolated, universal analog input circuits to choose from. The 6-terminal block is the lowest cost solution with six terminals for sensor and signal connection. The 4-terminal block is a more compact solution with 4-pin terminals for sensor and signal connections.
- **Input Signal Type:** the evaluation board can convert multiple types of signals including voltage, current, thermocouple, and RTD. After the input signal type is selected, the desired range of the thermocouple/RTD type must also be chosen.
- **Capture Mode:** the user must set the method for capturing the data. In single capture mode, only the specified number of samples are captured. In continues capture mode, data is continuously captured until the user stops the acquisition.

AD7795 Configuration Tab

For each type of input signal range selected in the **Hardware Configuration** tab, there is a default configuration loaded to the universal analog input board. The **AD7795 Configuration** tab (see Figure 17) allows more advanced configurations and provides the flexibility to evaluate the board with a different configuration than the default value.

Using this tab requires specific knowledge of the **AD7795** registers, functions, and hardware structure. An incorrect configuration can cause acquisition and operation error. Click **Recover All range to Default** to recover the default configurations for the range(s).

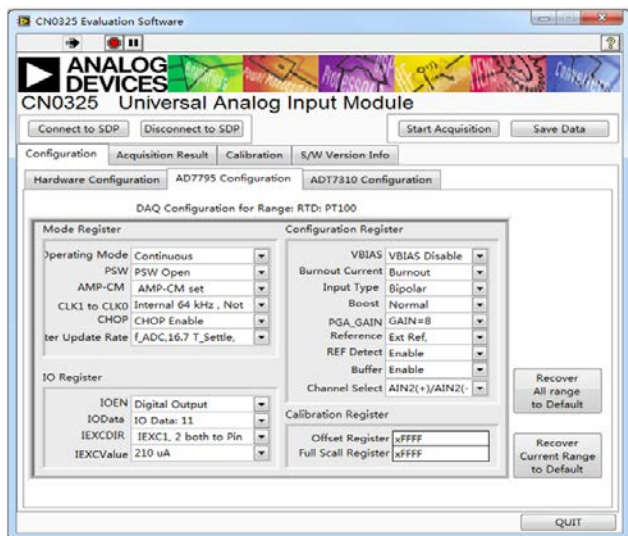


Figure 17. AD7795 Configuration Tab

ADT7310 Configuration Tab

An on-board temperature sensor chip, the **ADT7310**, is placed close to the terminal blocks for cold-junction compensation during thermocouple measurements. In a typical measurement setup, a default configuration is loaded to the universal analog input board. The **ADT7310 Configuration** tab (see Figure 18) allows more advanced configuration and provides the flexibility to evaluate the board with a different configurations than the default value. Using this tab requires specific knowledge of the **ADT7310** registers, functions, and hardware structure.

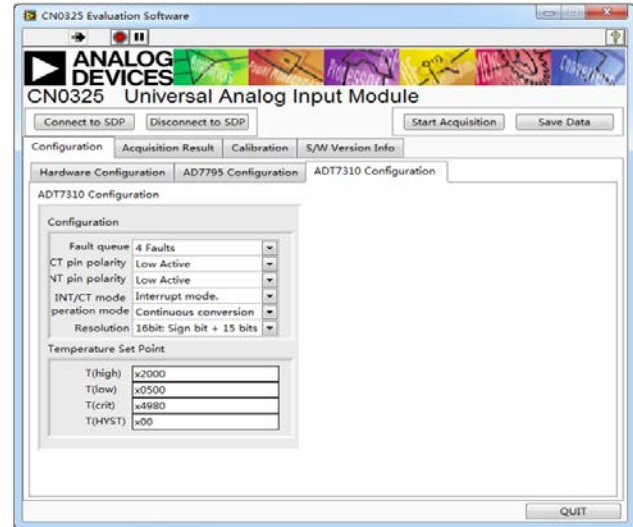


Figure 18. ADT7310 Configuration Tab

Acquisition Result Tab

Converted Result Tab

A result is converted to the relevant units based on the raw data from the data converter along with the channel configuration and calibration values. The data is shown in a waveform chart in the **Converted Result** tab (see Figure 19). The data is also analyzed to provide the number of samples, the mean, the minimum and maximum values, the RMS and peak-to-peak noise, as well as the RMS and peak-to-peak resolution.

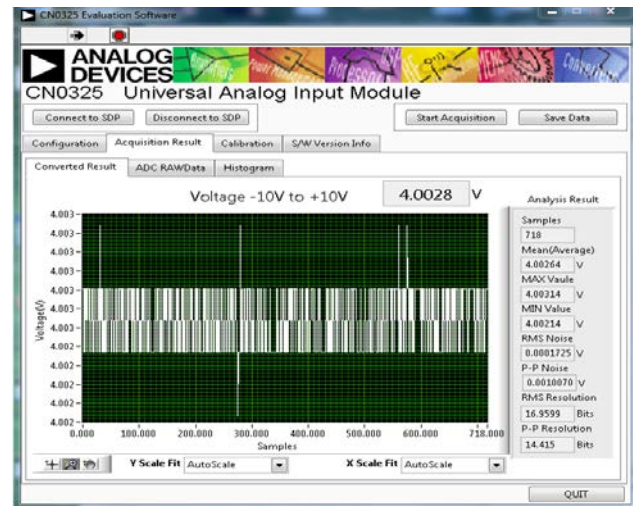


Figure 19. Converted Result Tab

ADC RAWData Tab

The acquisition data read directly from ADC is shown in the waveform chart in the **ADC RAWData** tab. The data is also analyzed to provide the number of samples, the mean, the minimum and maximum values, the RMS and peak-to-peak noise, as well as the RMS and peak-to-peak resolution.

Histogram Tab

The **Histogram** tab (see Figure 20) shows the distribution of the raw ADC data that has been captured. This histogram graph can be used to evaluate the noise and acquisition stability.

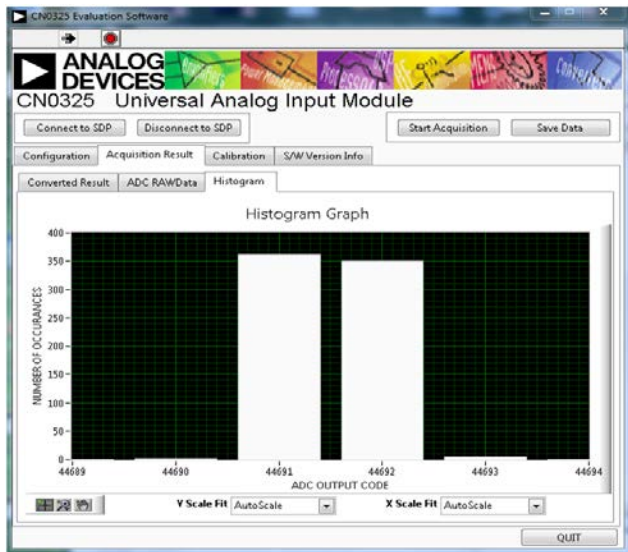


Figure 20. **Histogram Tab**

Calibration Tab

The evaluation software also provides independent calibrated parameters for each input signal and sensor type, which allows the user to accurately calibrate the offset and gain of the system to achieve a high level of dc precision for the system (see Figure 21). The calibrated parameters can be stored into the on-board EEPROM for later reuse. A complete calibration requires both a zero-scale calibration and a full-scale calibration.

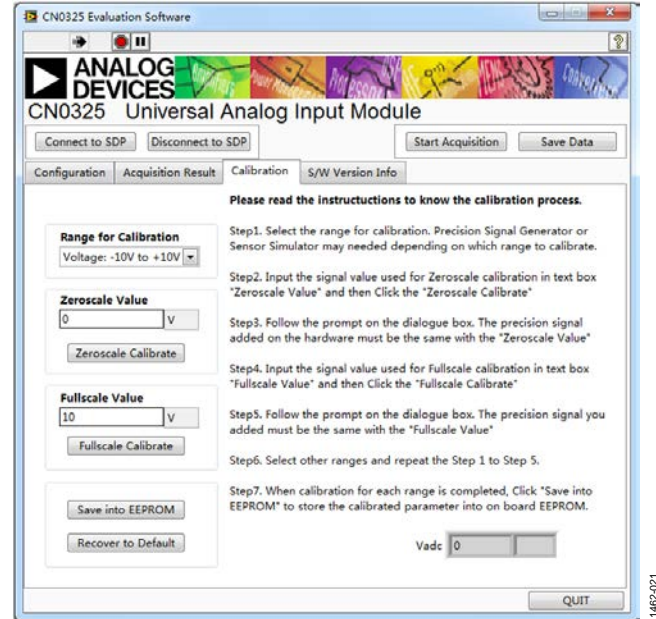


Figure 21. **Calibration Tab**

To ensure a proper calibration, take the following steps:

1. From the **Range for Calibration** drop-down box, select the desired input range.
2. Apply the correct input signal specified in **Zeroscale Value** and click **Zeroscale Calibrate**. Follow the prompt to complete the zero-scale calibration.
3. Apply the correct input signal specified in **Fullscale Value** and click **Fullscale Calibrate**. Follow the prompt to complete the full-scale calibration.
4. Click **Save into EEPROM**.

The calibrated parameters are placed into the internal calibration register of ADC. When the user clicks **Save into EEPROM**, the new calibration values are permanently saved to the EEPROM, and these values are loaded the next time this range is selected.

Copies of the factory default calibrated values are stored in the on-board EEPROM. Click **Recover to Default** to return all the calibrated values to their factory default values.

S/W Version Info Tab

Figure 22 shows the **S/W Version Info** tab. This tab provides information about the connected SDP-B board.

Clicking **Flash LED** flashes the LED on the SDP-B board, which indicates that the connection between the SDP-B and evaluation boards is successfully set up.

Clicking **Read Firmware** reads the information about the current code on the SDP-B board.

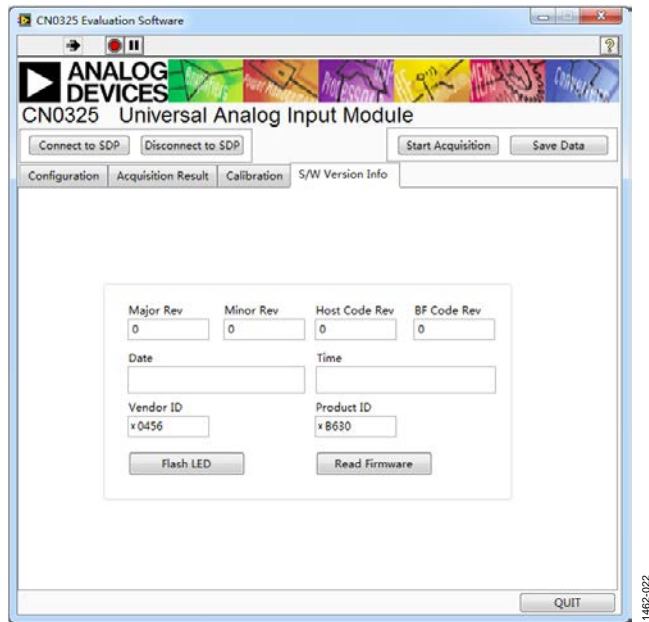


Figure 22. Software Version Information Tab

The fields in the **S/W Version Info** tab are as follows:

- **Major Rev:** the major code revision number
- **Minor Rev:** the minor code revision number
- **Host Code Rev:** the version of the host code with which the firmware was developed
- **BF Code Rev:** the Blackfin code revision number of the firmware
- **Date:** the date the code was compiled
- **Time:** the time the code was compiled

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CN-0325 Design Support Package:

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AD779x Instrumentation Converters—Frequently Asked Questions

MT-004 Tutorial. *The Good, the Bad, and the Ugly Aspects of ADC Input Noise—Is No Noise Good Noise?* Analog Devices.

MT-022 Tutorial. *ADC Architectures III: Sigma-Delta ADC Basics.* Analog Devices.

MT-023 Tutorial. *ADC Architectures IV: Sigma-Delta ADC Advanced Concepts and Applications.* Analog Devices.

MT-031 Tutorial. *Grounding Data Converters and Solving the Mystery of "AGND" and "DGND".* Analog Devices.

MT-101 Tutorial. *Decoupling Techniques.* Analog Devices.

Chen, Baoxing. *iCoupler Products with isoPower Technology: Signal and Power Transfer Across Isolation Barrier Using Microtransformers.* Analog Devices, 2006.

Zhao, Flow. *Inside iCoupler® Technology: ADuM347x PWM Controller and Transformer Driver with Quad-Channel Isolators Design Summary.* Analog Devices, 2010.

Slattery, Colm, Derrick Hartmann and Li Ke. "PLC Evaluation Board Simplifies Design of Industrial Process Control Systems." Analog Dialogue. Analog Devices, April 2009.

Data Sheets and Evaluation Boards

AD7795 Data Sheet

AD8226 Data Sheet

ADT7310 Data Sheet

ADP2441 Data Sheet

ADR441 Data Sheet

ADP1720 Data Sheet

ADuM3471 Data Sheet

System Demonstration Platform (EVAL-SDP-CB1Z)

REVISION HISTORY

11/15—Revision 0: Initial Version

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CN11462-0-11/15(0)



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