Application Report

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Achieving True Universal Input Capability Using ADS1248 and ADS1148

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ABSTRACT

In this application report, we design a simple connection scheme which can be used to connect multiple transducers to ADS1248/1148. The scheme utilizes features of the devices such as current sources, internal reference, and so forth, while allowing same circuitry on each channel; thus realizing true universal input capability.

Contents

1 Introduction 2
1.1 ADS1146/7/8 and ADS1246/7/8 2
1.2 ADS1248 Operation 2
2 Application Schematic 4
3 Operation 6
3.1 Two-Wire RTD 6
3.2 Three-Wire RTD 6
3.3 Four-Wire RTD 7
3.4 Thermocouple Connections (without CJC) 8
3.5 Thermocouple Connections (with CJC) 8
3.6 Analog Input Connections (0–10 V) 9
3.7 Input Current Connections (4-20 mA) 10
4 Test Results 10
4.1 2-Wire RTD Emulation 11
4.2 3-Wire RTD Emulation 12
4.3 4-Wire RTD Emulation 13
4.4 Current Input Emulation 4–10 mA 14
5 Conclusion 15
6 Reference 15

List of Figures

1 Block Diagram 2
2 Multiplexer 3
3 Universal Input Connection Scheme 4
4 Two-Wire RTD Connections 6
5 Three-Wire RTD Connections 7
6 Four-Wire RTD Connections 7
7 Thermocouple Connections (Without CJC) 8
8 Thermocouple Connections (with CJC) 9
9 Analog Input (0–10 V) Connections 9
10 Current (4–20 mA) Connections 10
11 Resistance Directly Connected to EVM Board 11
12 Resistance Connected Through Switch Scheme (Internal Reference Used) 11
13 Resistance Directly Connected to EVM board 12

14 Resistance Connected Through Switch Scheme (Internal Reference Used) 12
15 Resistance Directly Connected to EVM Board 13
16 Resistance Connected Through Switch Scheme (Internal Reference Used) 13
17 ADC Excitation Current On (Drop Across R4 = 300 mV) 14
18 ADC Excitation Current On (Drop Across R4 = 900 mV) 14
19 ADC Excitation Current On (Drop Across R4 = 1.9 V) 15

List of Tables

1 Switch Positions........ 5
2 Test Data 10

1 Introduction

1.1 *ADS1146/7/8 and ADS1246/7/8*

The ADS1146, ADS1147, and ADS1148 are highly-integrated, precision, 16-bit analog-to-digital converters (ADCs). The ADS1146/7/8 feature an onboard, low-noise, programmable gain amplifier (PGA), a precision delta-sigma ADC with a single-cycle settling digital filter, and an internal oscillator. The ADS1147 and ADS1148 also provide a built-in voltage reference with 10-mA output capacity, and two matched programmable current digital-to-analog converters (DACs). The ADS1146/7/8 provide a complete front-end solution for temperature sensor applications including thermal couples, thermistors, and resistance temperature detectors (RTDs).

The ADS1246, ADS1247, and ADS1248 are similar devices with 24-bit analog-to-digital converters (ADCs).

We will now discuss the detailed operation of the ADS1248. Similarities can be drawn to other devices.

1.2 *ADS1248 Operation*

The block diagram for ADS1248 is shown in Figure 1.

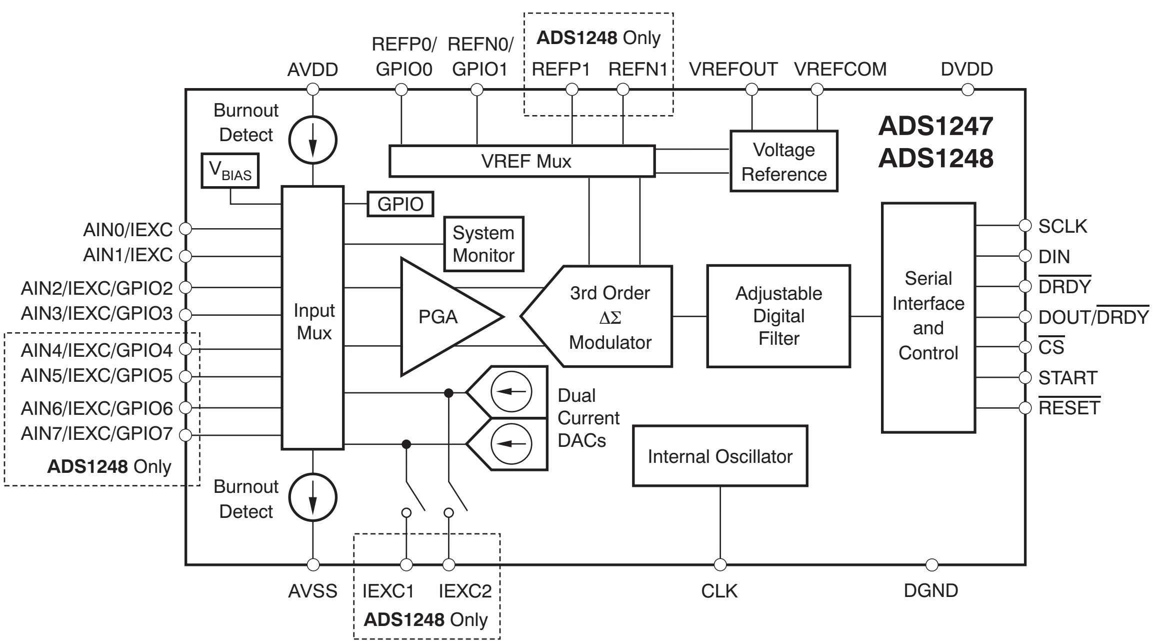

Figure 1. Block Diagram

The ADS1246, ADS1247, and ADS1248 are highly integrated 24-bit data converters. They include a low-noise, high-impedance programmable gain amplifier (PGA), a delta-sigma (ΔΣ) ADC with an adjustable single-cycle settling digital filter, internal oscillator, and a simple but flexible SPI-compatible serial interface.

The ADS1247 and ADS1248 also include a flexible input multiplexer with system monitoring capability and general-purpose I/O settings, a very low-drift voltage reference, and two matched current sources for sensor excitation.

The block diagram for the multiplexer is shown in the Figure 2.

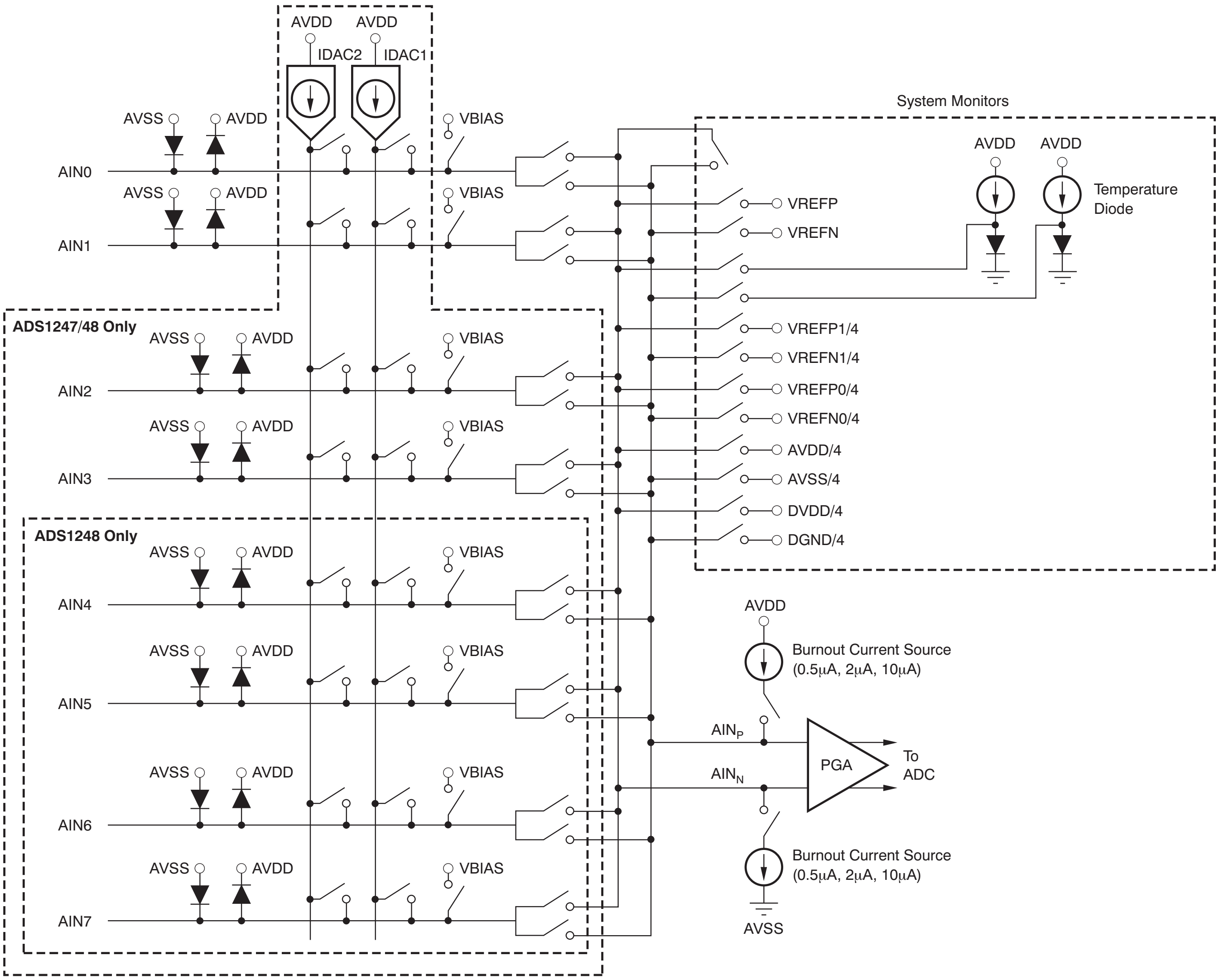

Figure 2. Multiplexer

2 Application Schematic

Figure 3 gives the proposed application schematic which shows the different connections required for implementing a universal input scheme.

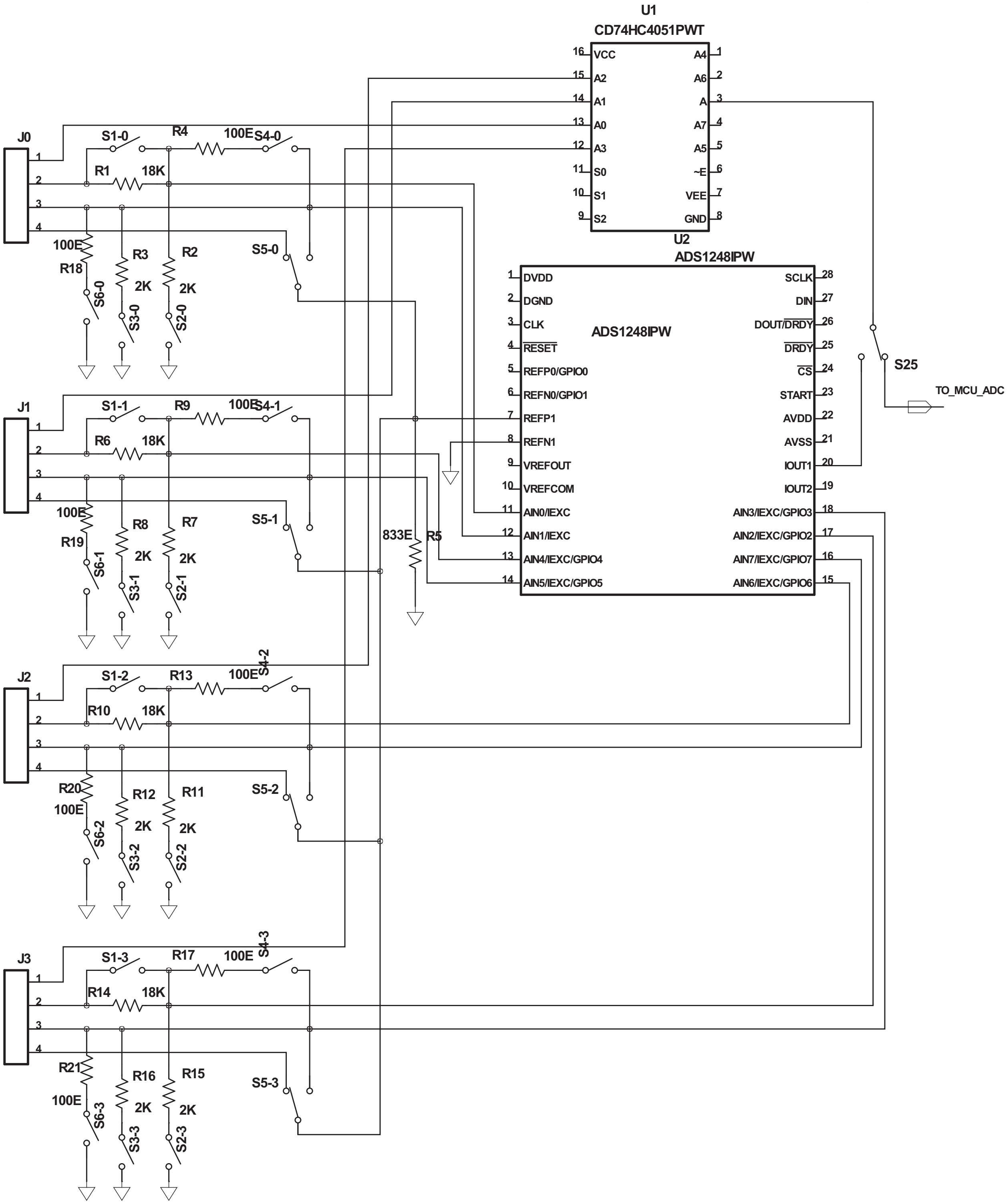

Figure 3. Universal Input Connection Scheme

Using this scheme, each device can be used to connect 4 differential inputs, thus enabling 4 transducer connections. A total of 20 SPST and 5 SPDT switches are required in the scheme. These can be manually operated DIP switches or electronically controlled FET switches, depending on the accessibility of the unit.

The sheet in Table 1 details on the different switch positions for different transducer options:

Table 1. Switch Positions

Input Type	Termination	S/W Connections							U1 MUX	Reference Int/Ext	Internal Current Connection	Internal Current Value	MCU ADC
		S1	S2	S3	S4	S5	S6	S25					
2-wire RTD	(2,3) RTD	Close	Open	Open	Open	N/O	Open	Do not care	Do not care	External	Ch 0	15 mA	NA
3-wire RTD	(2,3) RTD, 4 Exc	Close	Open	Open	Open	N/C	Open	Do not care	Do not care	External	Ch 0 and 1	15 mA	NA
4-wire RTD	(2,3) RTD, (1,4) Exc	Close	Open	Open	Open	N/C	Open	N/O	A0	External	IOUT 1 (pin 20)	15 mA	NA
TC	(2,3) TC	Close	Open	Open	Open	N/O	Open	Do not care	Do not care	External	Ch 1	15 mA	NA
TC with CJC	(2,3) TC, 1 Temp	Close	Open	Open	Open	N/O	Open	N/C	A0	External	Ch 1	15 mA	For cold jn temp
0–10 V	2	Open	Close	Close	Open	N/C	Open	Do not care	Do not care	Internal	Ch 0 and1	0.1 mA	NA
4–20 mA	2	Close	Open	Open	Close	N/C	Close	Do not care	Do not care	Internal	Ch 1	1 mA	NA

3 Operation

Now we take a look at the operation of the scheme for different switch positions for a few of the transducers.

3.1 Two-Wire RTD

Figure 4 shows the connection diagram for a 2-wire RTD connection. The dotted red lines show the current flow path. The excitation current flows out of Ch0 of the device, through the RTD and into the 833-Ω resistor to ground. The magnitude is set to 1.5 mA, thus giving a drop of 1.25 V across the resistor. This voltage is used as the reference to eliminate any inaccuracies due to variation of the excitation current value.

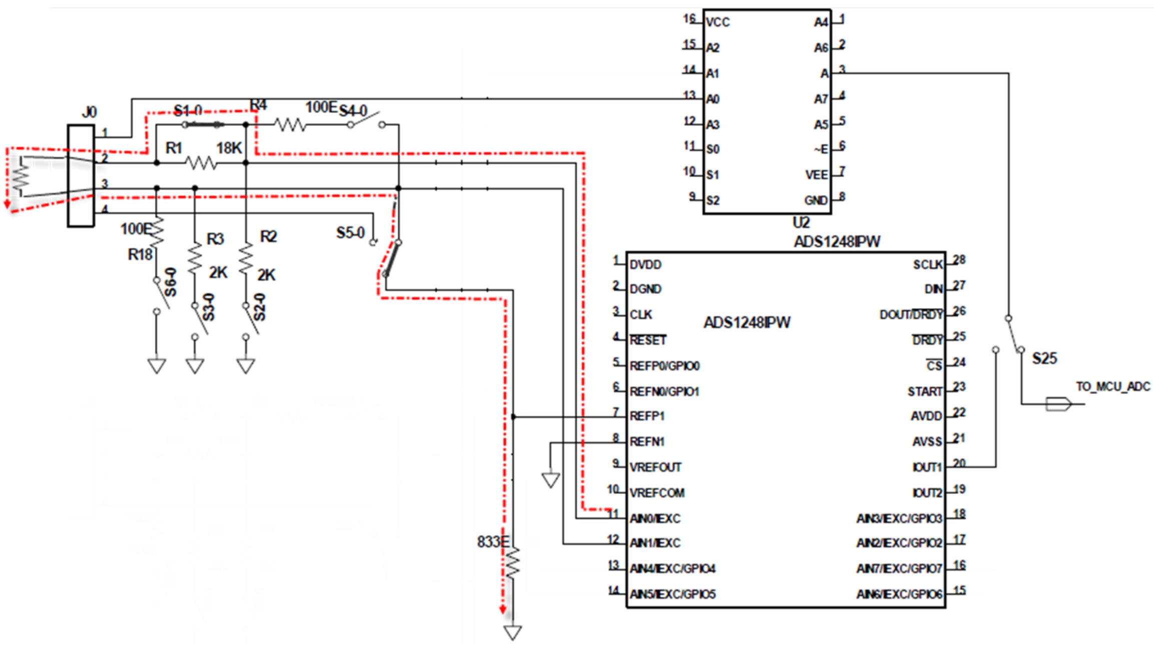

Figure 4. Two-Wire RTD Connections

3.2 Three-Wire RTD

Figure 5 shows the connection diagram for a 3-wire RTD connection. The dotted red lines show the current flow path. The excitation current flows out of Ch0 and Ch1 of the device. The current from Ch0 flows into the RTD and then into the 833-Ω resistor to ground. The current from Ch1 flows into one of the leads of the RTD, then through the 833-Ω resistor into ground.

Differential measurement between Ch0 and Ch1 gives the RTD drop. This includes the drop because of the leads.

The single channel reading of Ch1 gives the drop of the leads which can be used to offset the differential reading for better accuracy.

The voltage across the 833-Ω resistor is 2.5 V and can be used as a reference to eliminate any inaccuracies due to variation in the excitation current value.

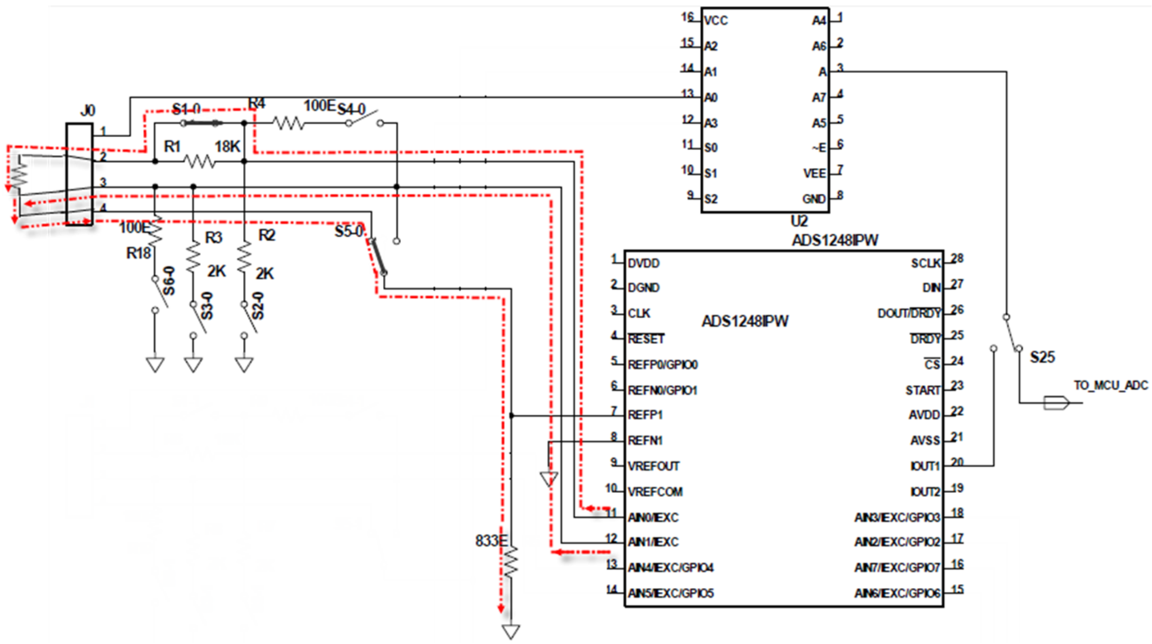

Figure 5. Three-Wire RTD Connections

3.3 Four-Wire RTD

Figure 6 shows the connection diagram for a 4-wire RTD connection. The dotted red lines show the current flow path. The excitation current flows out of excitation current pin 1. This flows through the RTD, then through the 833-Ω resistor, into ground. Thus, there is no current flow through the measurement leads connected on Ch1 and Ch1, eliminating any drops. Here as well, the drop across the 833-Ω resistor can be used as the reference.

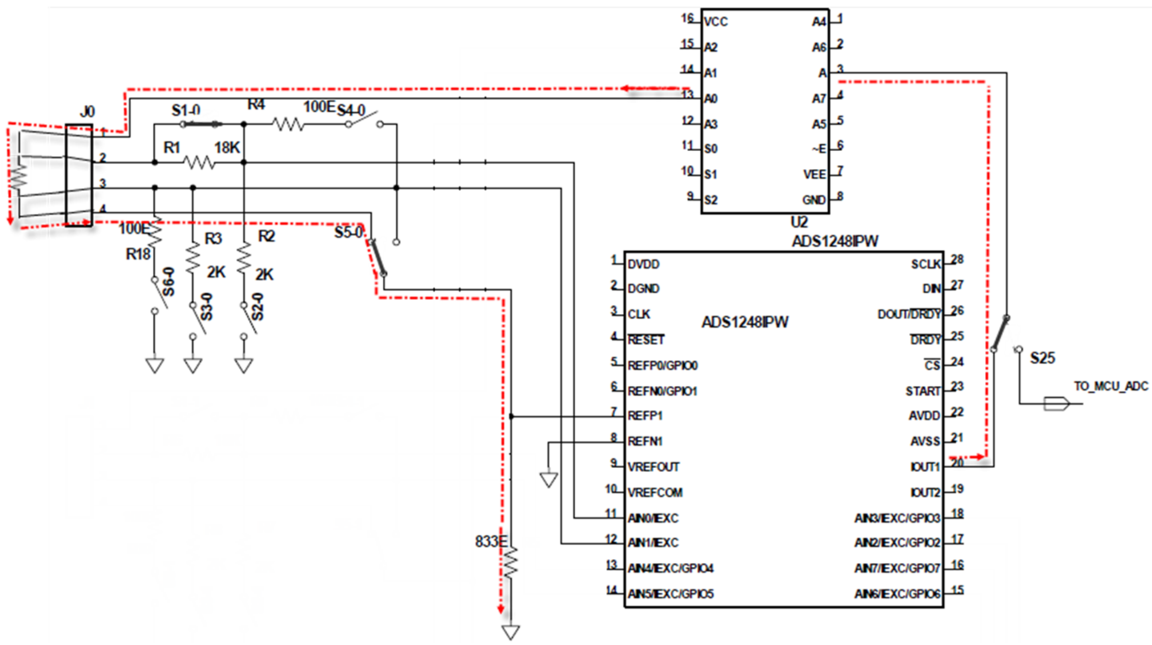

Figure 6. Four-Wire RTD Connections

3.4 Thermocouple Connections (without CJC)

Figure 7 shows the connection diagram for a thermocouple without cold junction compensation. The dotted red lines show the current flow path. The excitation current flows out of Ch1 of the device. This current flows through the 833-Ω resistor to ground and is used to generate a common mode voltage greater than 100 mV to meet the minimum requirement of the device (page 3 of device data sheet).

The voltage across the thermocouple adds on to this voltage and care should be taken to ensure that the total value does not exceed the maximum value of common mode voltage.

However, this does not impact the temperature measurement as the thermocouple voltage is differential across Ch0 and Ch1.

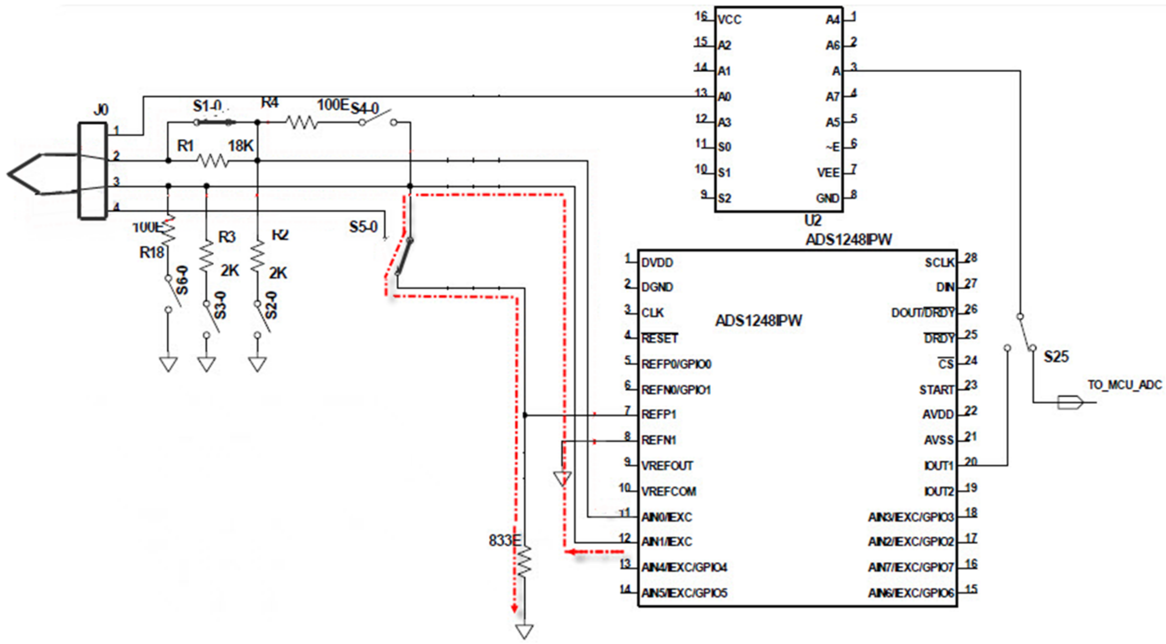

Figure 7. Thermocouple Connections (Without CJC)

3.5 Thermocouple Connections (with CJC)

Figure 8 shows the connection diagram for a thermocouple with cold junction compensation. The connection scheme is the same as in the previous case of measurement without CJC. The only additional connection is that of CJC input which is routed to the MCU ADC through the external multiplexer and switch S25. The CJC input is connected on pin 1 of external connector J0.

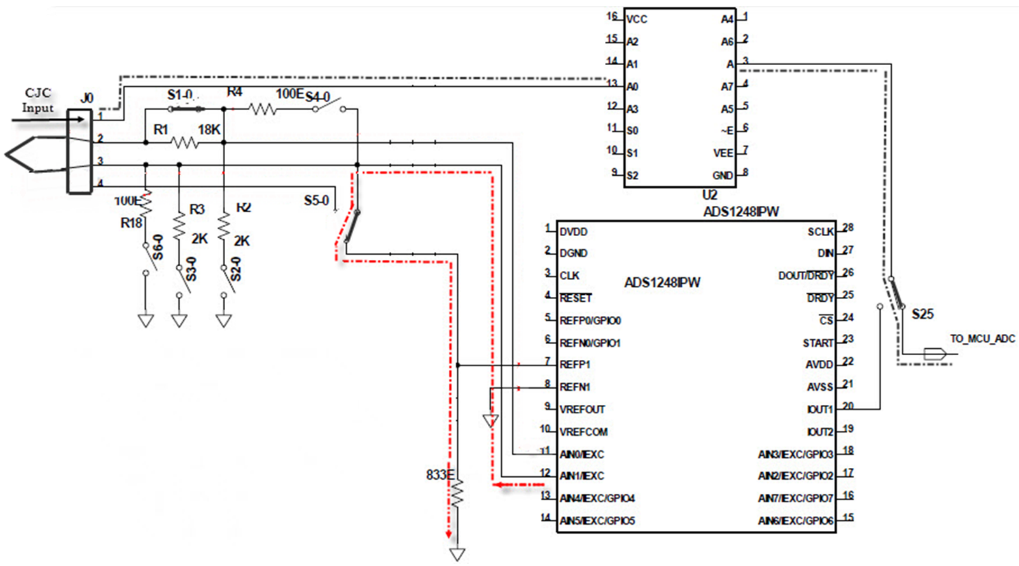

Figure 8. Thermocouple Connections (with CJC)

3.6 Analog Input Connections (0–10 V)

Figure 9 shows the connection diagram for an analog voltage from 0–10 V. The scheme steps down the input voltage by a factor of 10. This is done through the voltage divider formed by resistors R1 and R2. The 0- to 10-V input is scaled down to 0–1 V. It also ensures that the minimum common-mode voltage requirement is met.

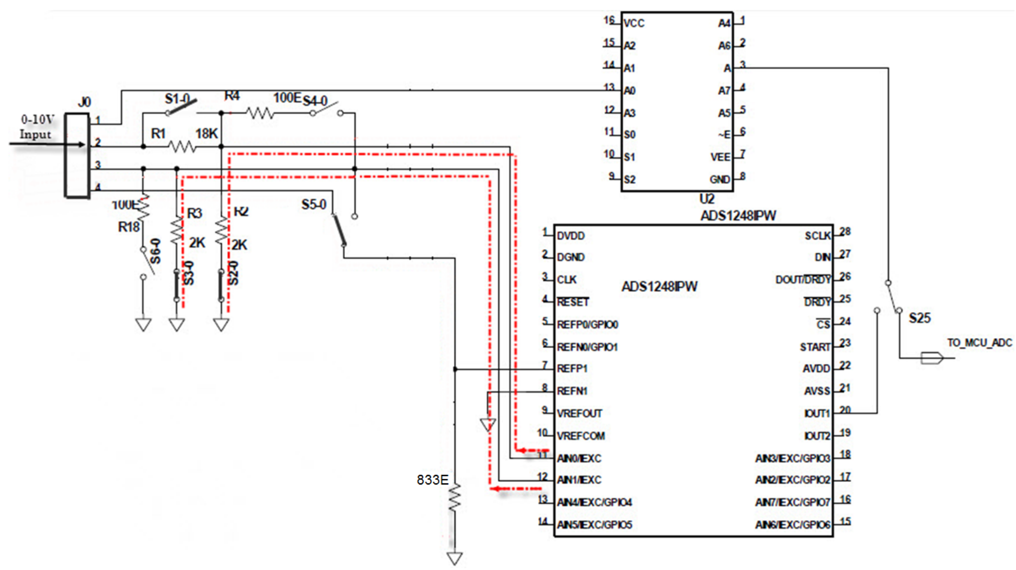

Figure 9. Analog Input (0–10 V) Connections

3.7 Input Current Connections (4-20 mA)

Figure 10 shows the connection diagram for a 4- to 20-mA current voltage. The scheme converts input current into voltage across the resistor (R4).The same is measured through Ch0 and Ch1 of ADS1248.

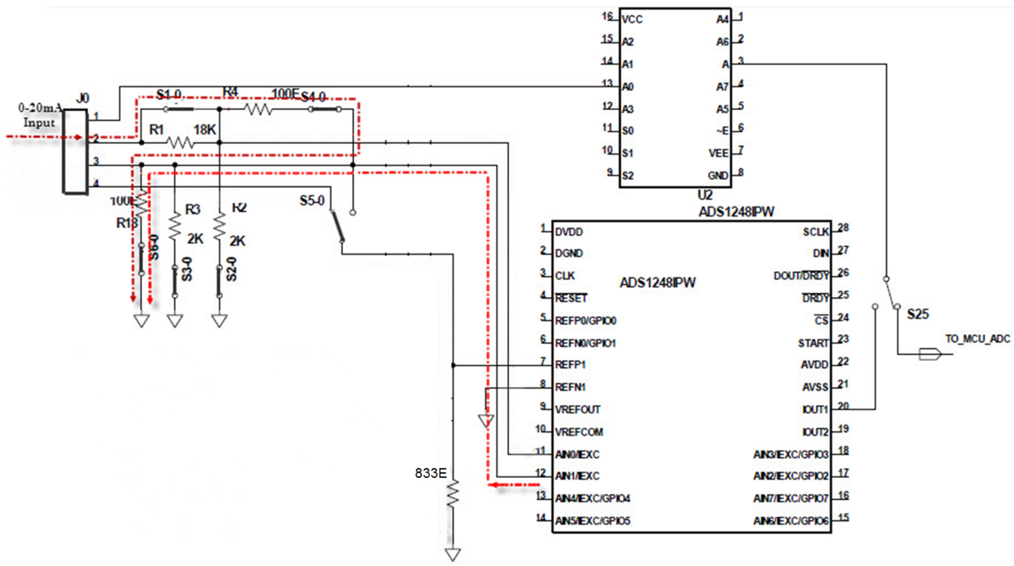

Figure 10. Current (4–20 mA) Connections

4 Test Results

A few of the previously mentioned transducer connections have been emulated and tested. The details for the emulated test setup and the summarized readings are given in Table 2.

Table 2. Test Data

Sr. No.	Emulated Input Scenario	Measured Value - Connection Directly to EVM	Measured Value - Connection Through Proposed Scheme	Test Setup Comments
1	2-wire RTD	49.8 mV	50.8 mV	470-Ω resistor (5% tolerance) connected between Ch0 and Ch1; 100-µA current into Ch0; Ch0 and Ch1 connected as inputs to ADC; internal reference used, external reference (generated by Ch0 current into 833-Ω resistor) use should help improve results.
2	3-wire RTD	49.8 mV	50.8 mV	470-Ω resistor (5% tolerance) connected between Ch0 and Ch1; 100-µA current into Ch0 and Ch1; Ch0 and Ch1 connected as inputs to ADC; internal reference used, external reference (generated by Ch0,1 currents into 833-Ω resistor) use should help improve results.
3	4-wire RTD	45.2 mV	46.1 mV	470-Ω resistor (5% tolerance) connected between Ch0 and Ch1; 100-µA current into Iout0; Ch0 and Ch1; connected as inputs to ADC; internal reference used, external reference (generated by Iout0 current into 833-Ω resistor) use should help improve results.
4	**4 to 20-mA current input**	**Differential voltage measured - decimal**	**Differential voltage measured - analog value**	**Test Setup Comments**
4.1	4 mA input	4750	298 mV	800 mV supply connected to channel 2 of external connector J0, drop measure across R4 = 100 Ω
4.2	10 mA input	14412	904 mV	2-V supply connected to channel 2 of external connector J0, drop measure across R4 = 100 Ω
4.3	20 mA	30207	1.9 V	4-V supply connected to channel 2 of external connector J0, drop measure across R4 = 100 Ω

4.1 2-Wire RTD Emulation

Figure 11 and Figure 12 use **100 µA current into Ch0; Ch0 and Ch1 inputs**.

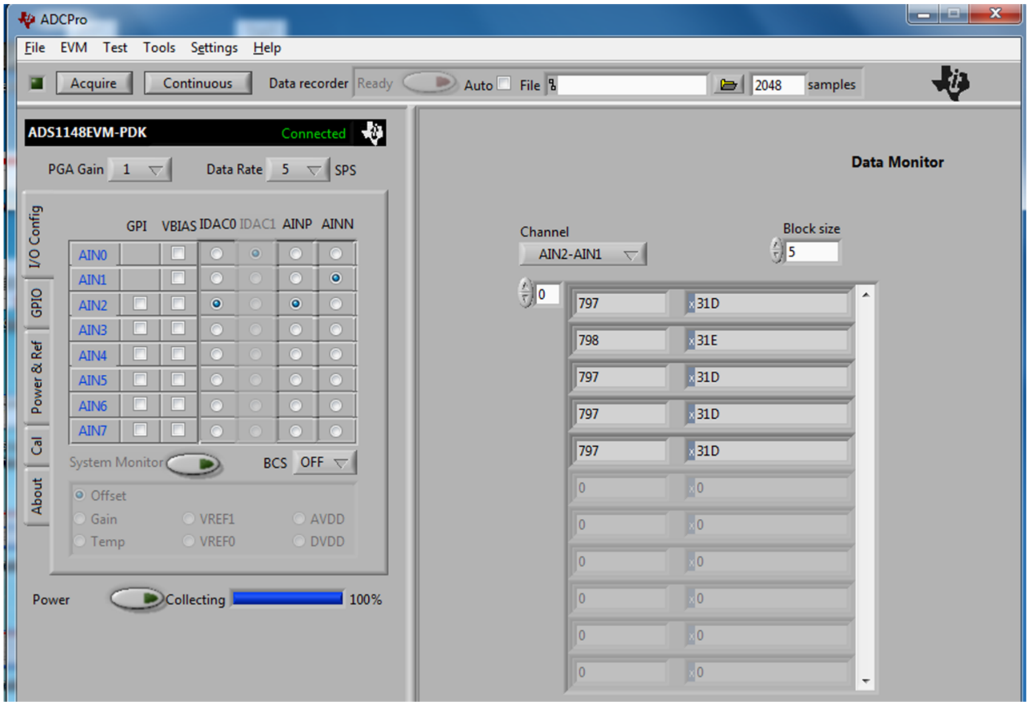

Figure 11. Resistance Directly Connected to EVM Board

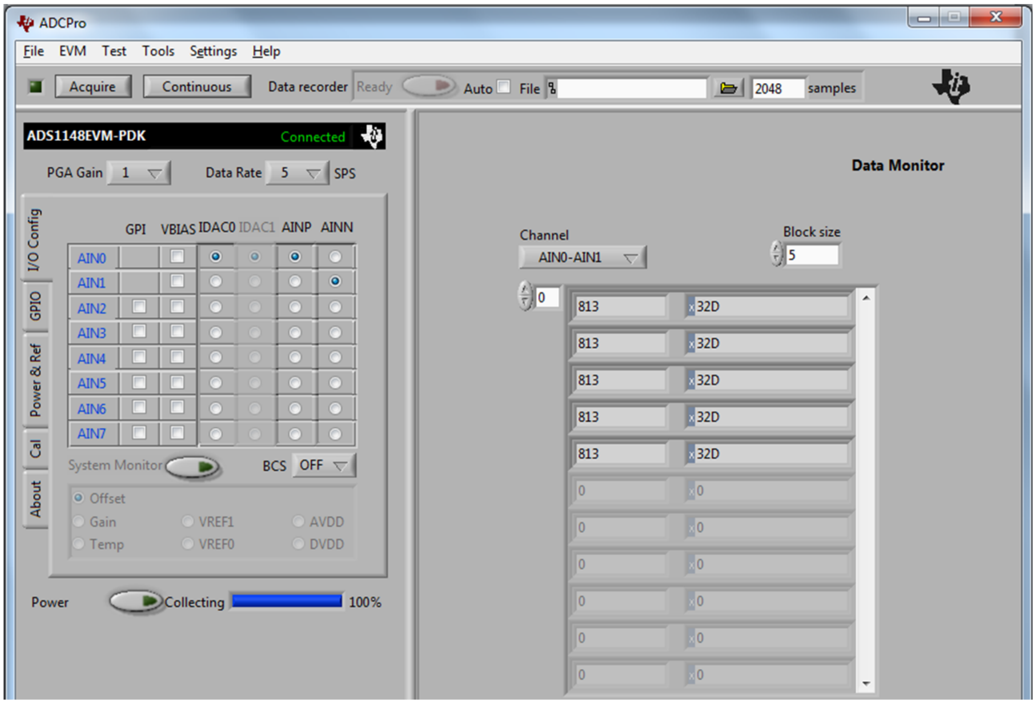

Figure 12. Resistance Connected Through Switch Scheme (Internal Reference Used)

4.2 3-Wire RTD Emulation

Figure 13 and Figure 14 use **100 µA current into Ch0; Ch0 and Ch1 inputs; one terminal of external resistance directly connected to ground**.

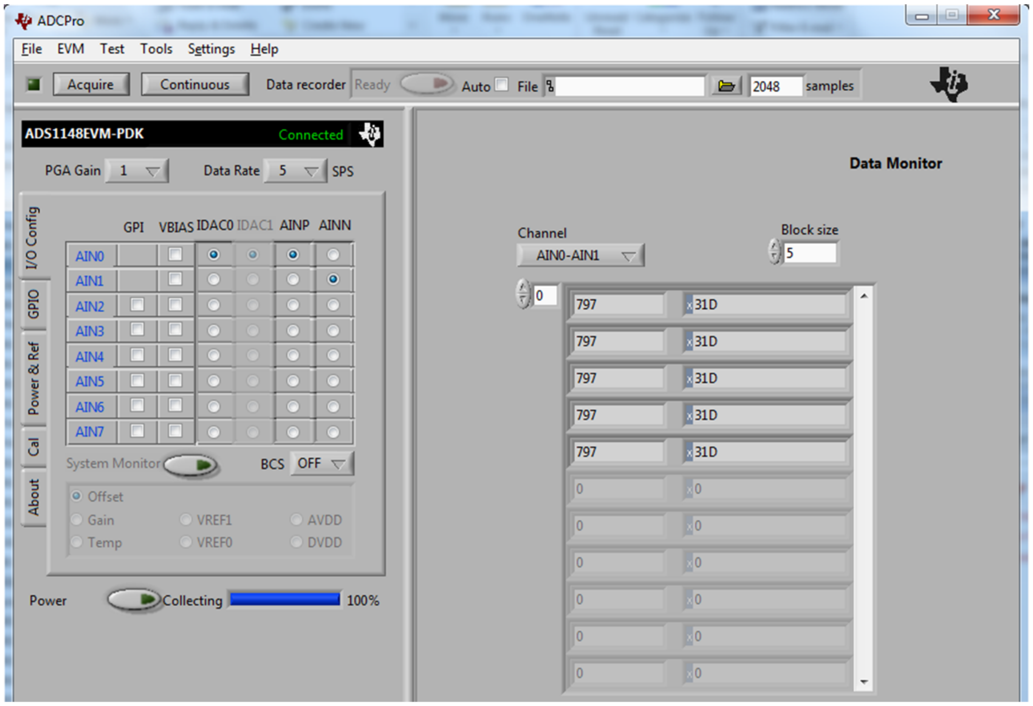

Figure 13. Resistance Directly Connected to EVM board

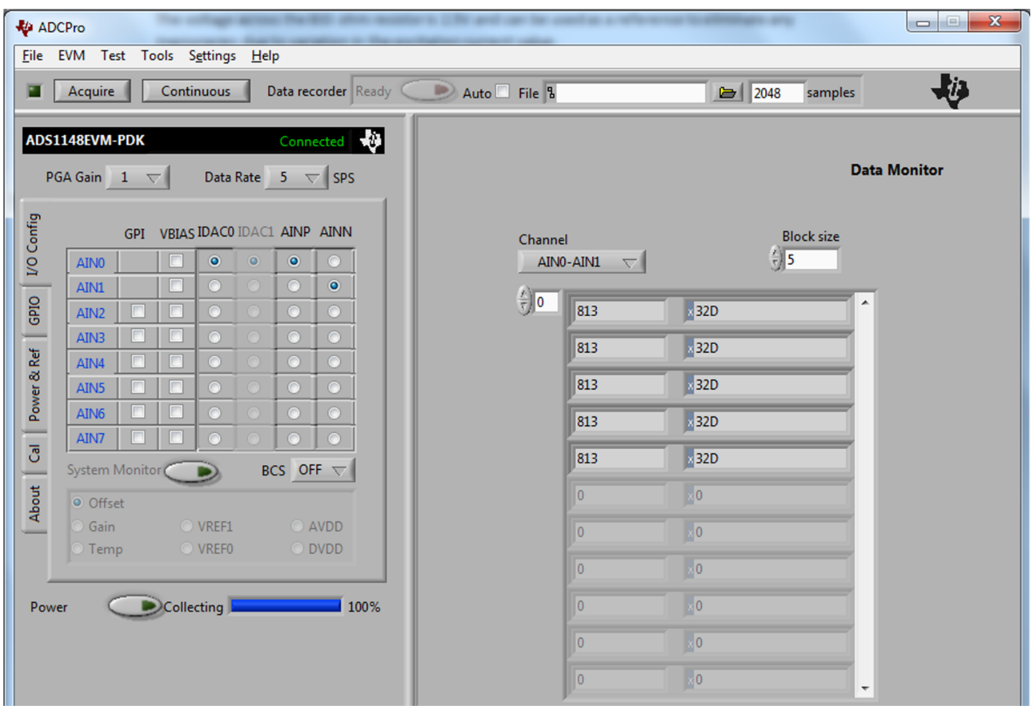

Figure 14. Resistance Connected Through Switch Scheme (Internal Reference Used)

4.3 4-Wire RTD Emulation

Figure 15 and Figure 16 use **100 µA connected to channel from current source- Iout0**.

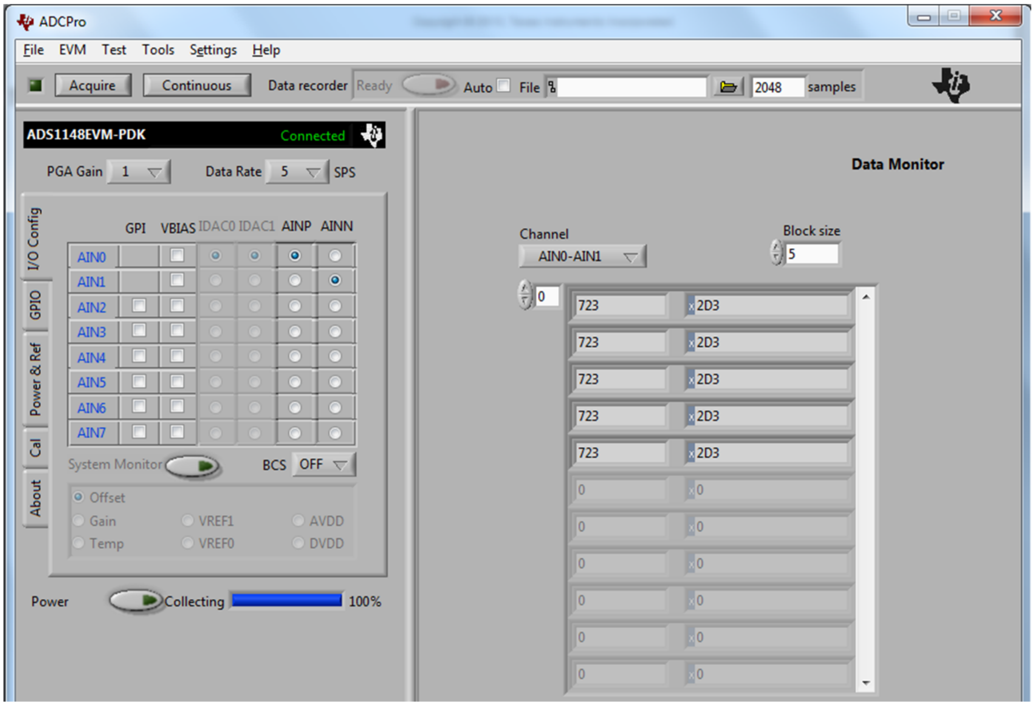

Figure 15. Resistance Directly Connected to EVM Board

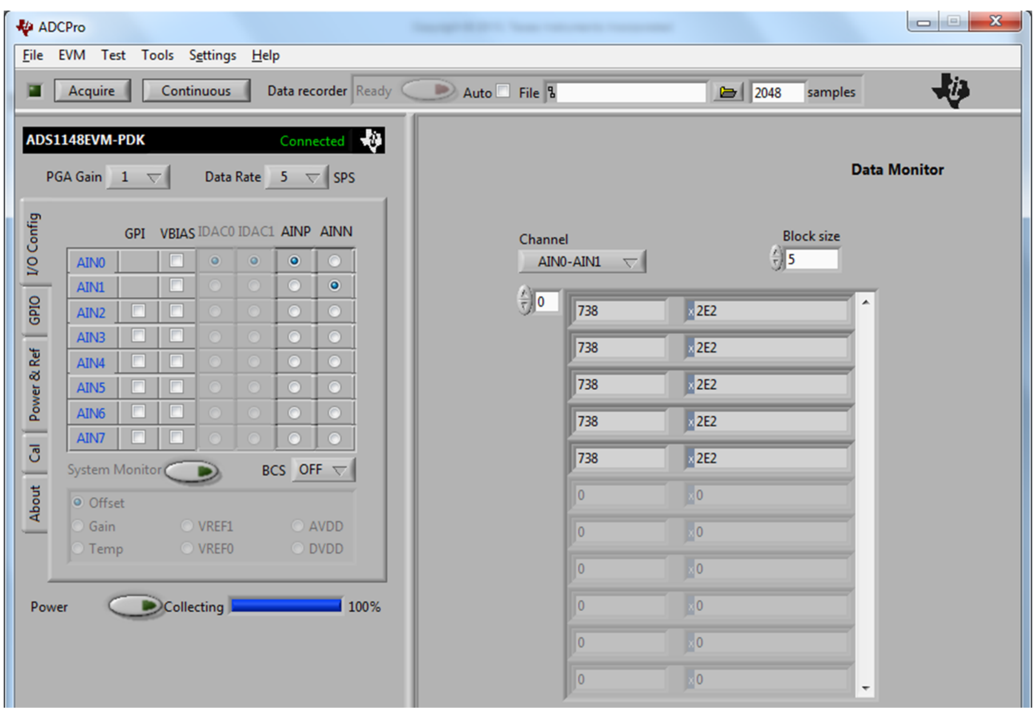

Figure 16. Resistance Connected Through Switch Scheme (Internal Reference Used)

4.4 Current Input Emulation 4–10 mA

Figure 17 shows the current input emulation settings for **4-mA input**.

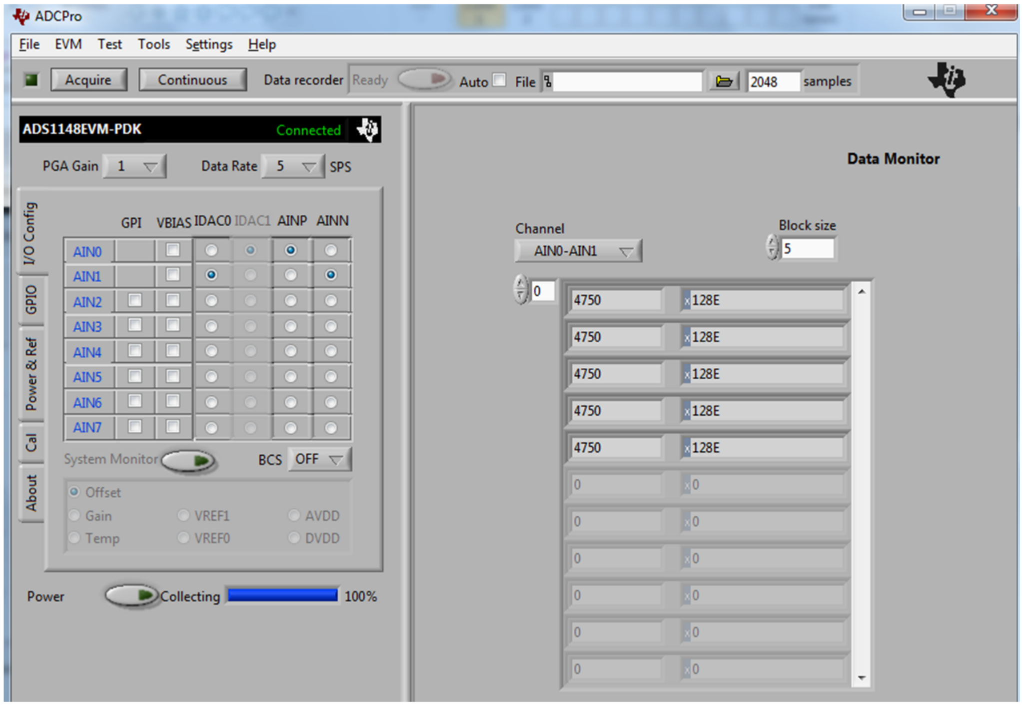

Figure 17. ADC Excitation Current On (Drop Across R4 = 300 mV)

Figure 18 shows the current input emulation settings for **10-mA input**.

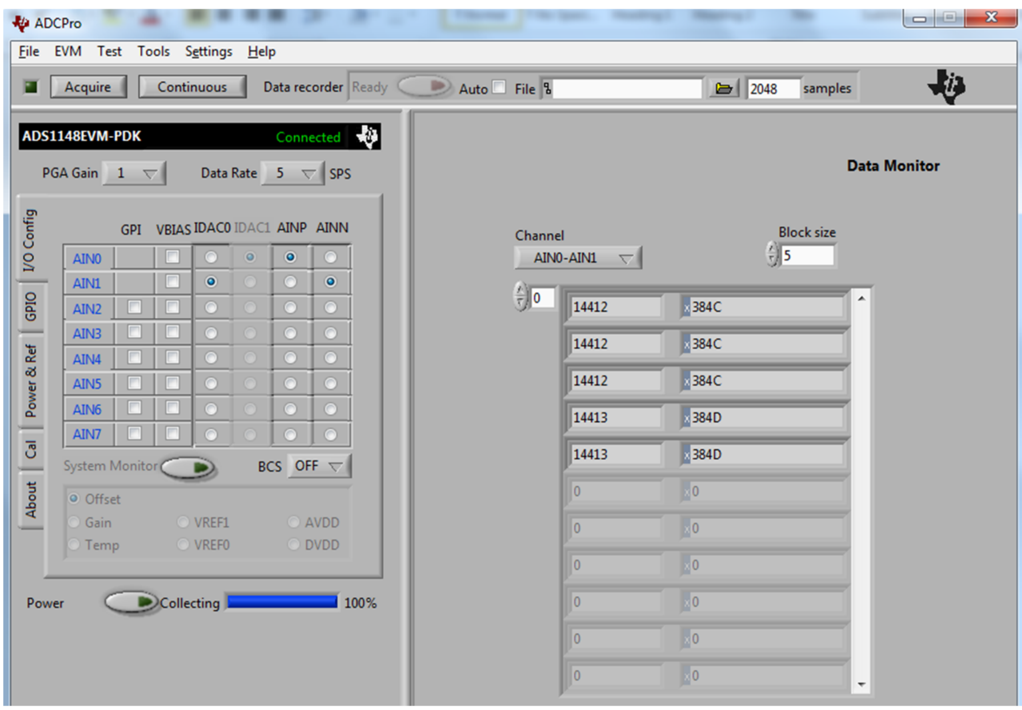

Figure 18. ADC Excitation Current On (Drop Across R4 = 900 mV)

Figure 19 shows the current input emulation settings for **20-mA input**.

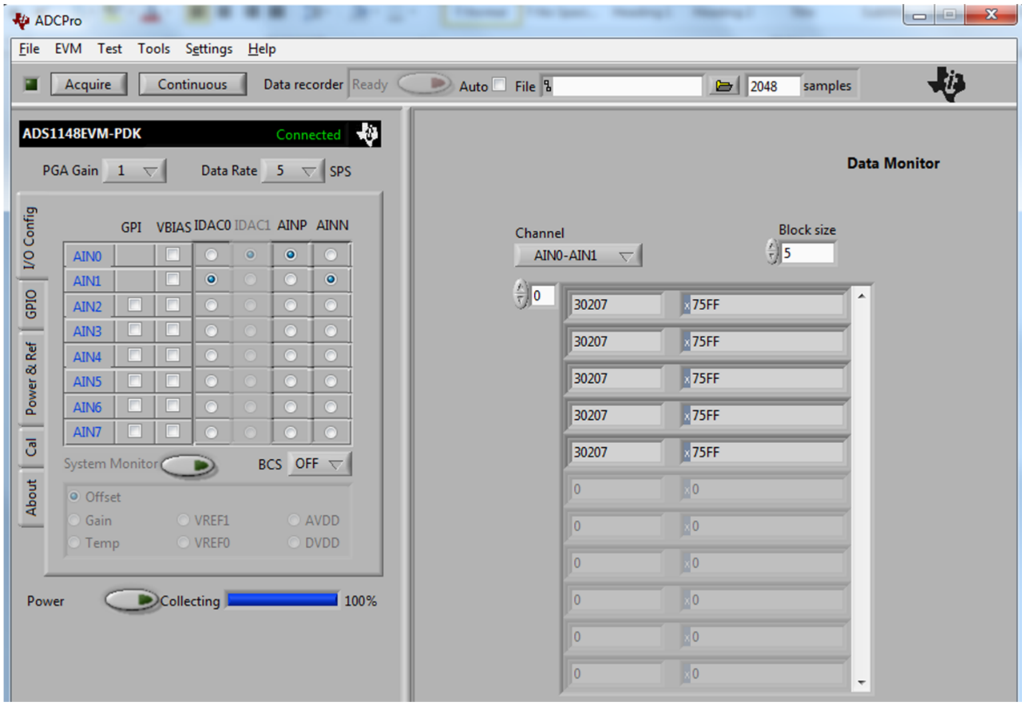

Figure 19. ADC Excitation Current On (Drop Across R4 = 1.9 V)

5 Conclusion

Using the arrangement shown in this report, ADS1248/1148 and other similar devices can be used to design a universal input terminal.

Further transducers can be made compatible by making additions on similar lines.

6 Reference

1. ADS1248 data sheet (SBAS426G)
2. ADS1148 data sheet (SBAS453F) (http://www.ti.com/lit/ds/symlink/ads1148.pdf)