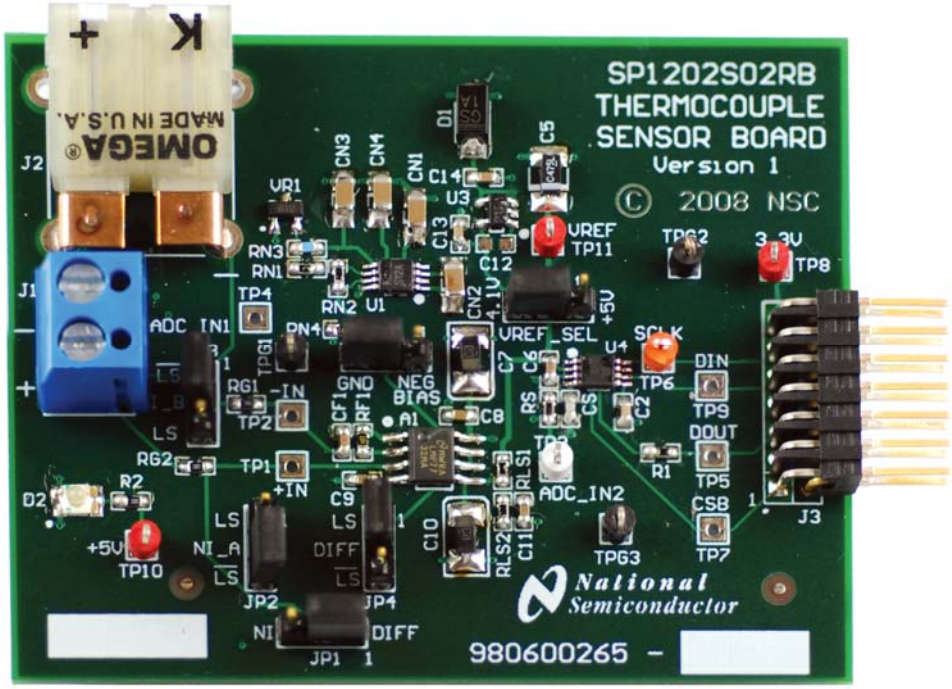
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Thermocouple Sensor Board Version 1
SP1202S02RB
Users' Guide



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1.0 Introduction

The Thermocouple Sensor Board Version 1 (SP1202S02RB) along with the Sensor Signal Path Control Panel (Sensor Panel) software and SPUSI2 USB Interface Dongle are designed to ease the design of circuits using various thermocouple sensors with National's amplifiers and Analog-to-Digital converters (ADCs). Use the WEBENCH® Thermocouple Sensor Designer tool to determine appropriate IC's and passives to achieve your signal path requirements: http://www.national.com/analog/webench/sensors/thermocouple

See *Figure 1* for component placement and *Figure 2* for example board schematic. The thermocouple sensor can be connected to header J1 or J2. The differential voltage at the thermocouple sensor output is digitized and can be captured and displayed on the computer monitor with the accompanying Sensor Panel software, which operates under Microsoft Windows XP. The amplified thermocouple sensor voltage may be measured at TP3 relative to ground. The software can provide gain and offset correction for the entire circuit, including the sensor.

2.0 Board Assembly

This Thermocouple Sensor Board Version 1 comes as a bare board that must be assembled. Refer to an example Bill of Materials for a description of component values, to *Figure 1* for major component placement and to *Figure 2* for the example Board schematic.

3.0 Quick Start

Refer to *Figure 1* for locations of test points and major components.

1. Place the jumpers on the following positions

Table 1 – NI Amplifier Jumper Positions

Jumper	Pins Shorted	FUNCTION
JP1	2 - 3	NI/Diff Select
JP2	2 - 3	NI Level Shifting (a)
JP3	1 - 2	NI Level Shifting (b)
JP4	Open	Diff Level Shifting
JP5	2 - 3	Negative Bias Generator
JP6	2 - 3	ADC Reference Select

2. Connect the Thermocouple Sensor Board Version 1 to a SPUSI2 (USB Interface Dongle) via 14-pin header J3 and connect a USB cable between the SPUSI2 board and a PC USB port. Red LEDs D2 on the Thermocouples Sensor Board Version 1 and D1 on the SPUSI2 board should come on if the PC is on.
4. Connect the thermocouple sensor to connector J1 or J2 of the board.
5. If not already installed, install the Sensor Panel software on the PC. Run the software.

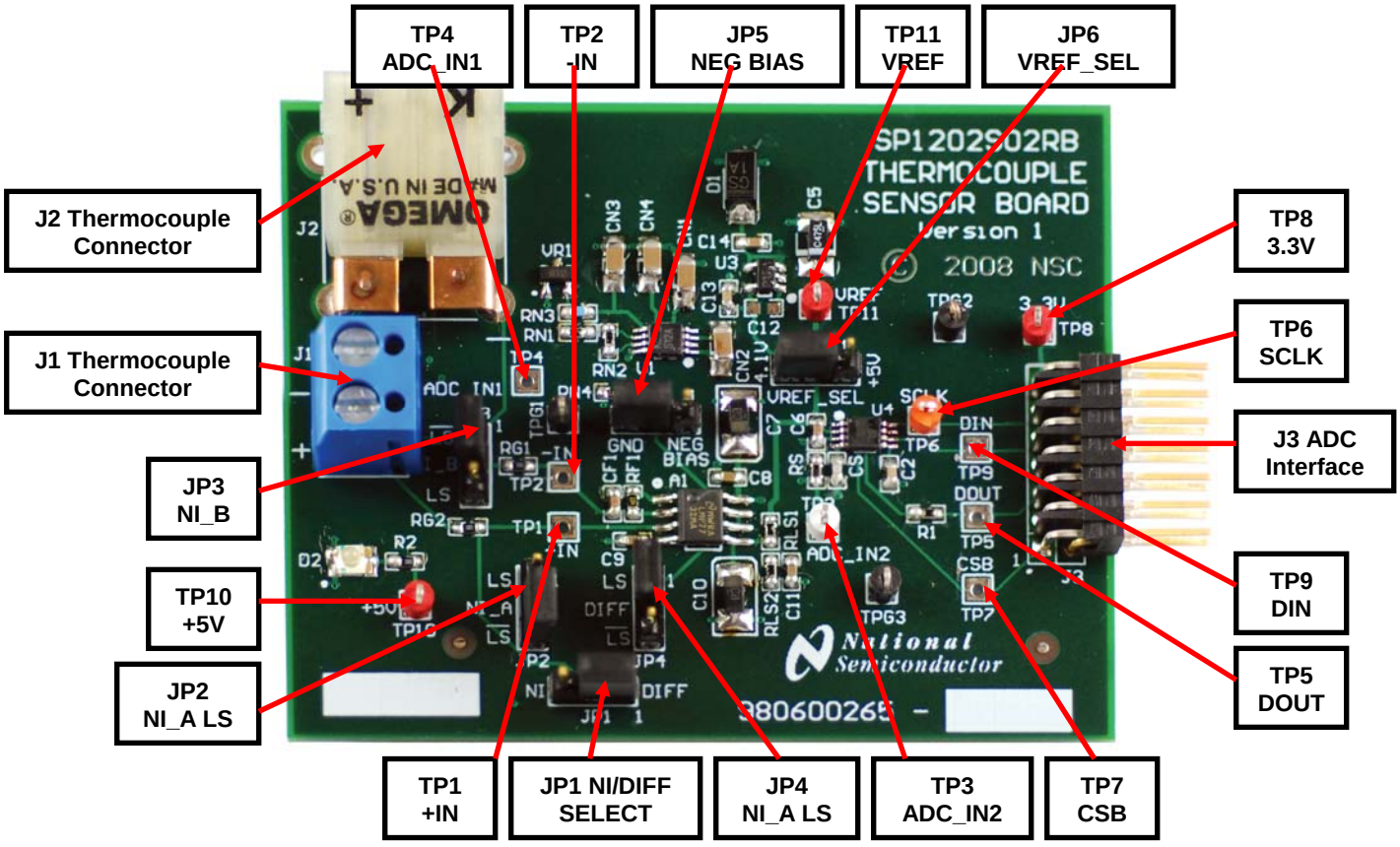


Figure 1. Component and Test Point Locations

4.0 Functional Description

The Thermocouple Board Version 1 component and test point locations are shown in *Figure 1*. The board schematic is shown in *Figure 2*.

4.1 Operational Modes

This board may be use in one of two modes: the Computer Mode using the SPUSI2 USB Interface Dongle or the Stand-Alone Mode without the use of the SPUSI2 USB Interface Dongle and a PC.

4.1.1 The Computer Mode

The board is intended for use in the Computer Mode with a SPUSI2 board. The Sensor Panel software controls the measurements by communicating with the ADC via the device's SPI interface. Power to both boards is provided via USB.

4.1.2 The Stand-Alone Mode

The Stand-Alone Mode does not use the SPUSI2 board to capture data and upload it to a PC. To use the board this way, the user must provide +5V at pin 14 of header J3 as well as provide ADC clock, Chip Select, and Data In signals to the ADC at pins 3, 1, and 7 respectively, of J3. ADC data output is available at pin 5 of J3. Test Points TP6, TP7, TP9 and TP5 may also be used to insert/read these signals. The range of frequencies for the ADC clock is 1 MHz to 4 MHz. The CS rate can be as low as desired, but no faster than 17 times the ADC clock rate.

4.2 Signal Conditioning Circuitry

The sensor output voltage is amplified and digitized by U4, an ADC. The full-scale value of this voltage after amplification will depend upon the maximum sensor output and the component values. This amplified voltage is presented to the ADC (U4), whose output is at header J3.

4.2.1 Non-inverting (NI) Amplifier Configuration

When minimal noise pickup is expected on the thermocouple sensor line a non-inverting amplifier configuration can be used. To set up the board in the non-inverting amplifier configuration without supplying negative bias to the amplifier or level shifting the thermocouple sensor voltage ensure the jumpers are in the following position

Table 2 – NI Amplifier Jumper Positions

Jumper	Pins Shorted	FUNCTION
JP1	2 - 3	NI/Diff Select
JP2	2 - 3	NI Level Shifting (a)
JP3	1 - 2	NI Level Shifting (b)
JP4	Open	Diff Level Shifting
JP5	2 - 3	Negative Bias Generator
JP6	2 - 3	ADC Reference Select

Amplifier A1A amplifies the output of the thermocouple sensor. The gain of the non-inverting amplifier is

$$\text{Gain} = 1 + RF1 / RG1.$$

A low pass filter is formed by RG2 and C1 which has a cutoff frequency of

$$\text{Cutoff Frequency} = 1 / (2 * \pi * RG2 * C1)$$

The WEBENCH Thermocouple Sensor Designer tool will provide appropriate component values to achieve your application gain and cutoff frequency requirements.

4.2.2 Differential Amplifier Configuration

If moderate noise pickup is expected on the thermocouple sensor line a differential amplifier configuration will offer increased common mode rejection (CMR). To set up the board in the differential amplifier configuration without supplying negative bias to the amplifier or level shifting the thermocouple sensor voltage ensure the jumpers are in the following position

Table 2 – Differential Amplifier Jumper Positions

Jumper	Pins Shorted	FUNCTION
JP1	1 - 2	NI/Diff Select
JP2	Open	NI Level Shifting (a)
JP3	1 - 2	NI Level Shifting (b)
JP4	2 - 3	Diff Level Shifting
JP5	2 - 3	Negative Bias Generator
JP6	2 – 3	ADC Reference Select

Amplifier A1A amplifies the differential output of the thermocouple sensor. The gain of the differential amplifier, assuming RG1 = RG2 and RF1 = RF2 is

$$\text{Gain} = RF1 / RG1$$

A low pass filter is formed by CF1 = CF2, and RF1 = RF2 which has a cutoff frequency of

$$\text{Cutoff Frequency} = 1 / (2 * \pi * RF1 * CF1)$$

The Webench® Thermocouple Sensor Designer tool will provide appropriate component values to achieve your application gain and cutoff frequency requirements.

4.2.3 Level Shifting

In many thermocouple applications the thermocouple sensor is used in a temperature range where only a positive output at the (+) terminal with respect to the (-) terminal or only a negative output is expected. If both positive and negative voltage is expected the board allows for an offset which is provided from a level shifting circuit. The level shifting voltage is set up by VREF and the RLS1-RLS2 voltage divider, then buffered through amplifier A1B. The level shifting voltage is

VLS = (VREF * RLS2) / (RLS2 + RLS1)

The Webench® Thermocouple Sensor Designer tool will provide appropriate component values to achieve your application level shifting requirements.

To add level shifting to the differential amplifier configuration change the following jumper

Table 4 – Diff Amp Level Shifting Jumper Positions		
Jumper	**Pins Shorted**	**FUNCTION**
JP4	1 - 2	Diff Level Shifting

To add level shifting to the non-inverting amplifier configuration change the following jumper

Table 5 – NI Amp Level Shifting Jumper Positions		
Jumper	**Pins Shorted**	**FUNCTION**
JP2	1 - 2	NI Level Shifting (a)

4.2.4 Offset and Gain Correction

The circuitry does not provide adjustment for offset voltages. However, the Sensor Panel software does allow for this correction.

4.3 Cold Junction Reference Temperature Sensor

A thermocouple sensor has the ability to measure a temperature differential between the measured temperature point and the reference temperature point at the reference junction often referred to as the cold junction. Due to this fact in order to determine the correct absolute temperature at the measuring point it is necessary to know the cold junction reference temperature. This is accomplished on board by the LM94022 Analog Temperature Sensor, U2, who's output is fed to the first channel of the ADC, U4. The Sensor Panel software takes this data then calculates the correct absolute temperature at the measuring point. The LM94022 mV/C transfer function can be found in the LM94022 datasheet. The sensor is hard wired for gain setting GS = 11.

4.4 Power Supply

In Computer Mode, power to this board is supplied through header J3 and ultimately from the host PC via USB. In most cases, the only voltage needed for the Thermocouple Sensor Board Version 1 is the +5V from the USB connection. Diode D1 provides protection against reverse polarity in the Stand-Alone mode where an external supply is used.

The supply voltage source for the ADC (VREF on the schematic) is selected with JP6 to be either the 4.1V from U3, or +5V from J3.

4.5 Negative Bias Generation

In the case where the measured temperature is close to the ambient cold junction reference temperature and the output voltage of the amplifying amplifier A1A is very low it is possible that the amplifier output may saturate. To avoid amplifier output saturation the board allows for a negative bias to be applied to the V- terminal of the amplifier. An external negative bias source can be connected to the V- terminal of the amplifier at pin 2 of JP5. Pin 3 of JP5 which is ground can be used as a reference. Alternatively see the Appendix to see how you can use the unpopulated LM2687 circuit as a negative bias generator.

4.6 ADC Reference Circuitry

The single-ended dual channel ADCXX2SXX1 uses its supply voltage as its reference, so it is important that its supply voltage be stable and quiet. A 4.1V reference voltage is provided by U3, an accurate LM4120-4.1.

4.7 ADC Serial Clock

The ADC clock signal (SCLK) is provided external to the board at header J3 on pin 3 or TP6. The requirements for SCLK can be found in the respective ADC datasheet.

4.8 ADC Chip Select Bar

The ADC chip select bar (CSB) is provided external to the board at header J3 on pin 1 or on TP7. The requirements for CSB with respect to SCLK can be found in the respective ADC datasheet.

4.9 Digital Data Output/Input

The digital output data from the ADC is available at 14-pin header J3 on pin 5 or on TP5. The digital input data to the ADC is available at 14-pin header J3 on pin 7 or on TP9.

4.10 Power Requirements

Voltage and current requirements for the Thermocouple Sensor Board Version 1 are:

- Pin 14 of J3: +5.0V at 30 mA
- Pins 2 and 4 of J3: Ground

5.0 Installing and Using the Thermocouple Sensor Board Version 1

The Thermocouple Sensor Board Version 1 requires power as described above. The thermocouple sensor should be connected to J1 or J2.

5.1 Board Set-up

Refer to *Figure 1* for locations of connectors, test points and jumpers on the board.

1. Connect The Thermocouple Sensor Board Version 1 to a SPUSI2 USB Interface Dongle.
2. Be sure all jumpers are in place per *Table 2* for Differential Amplifier or *Table 3* for Non-inverting Amplifier.
3. Connect the thermocouple sensor to J1 or J2.

4. Connect a USB cable to the SPUSI2 board and a PC.
5. Confirm that Red LED D2 on the Thermocouple Sensor Board Version 1 is on, indicating the presence of power to the board.

5.2 Quick Check of Analog Functions

Refer to *Figure 1* for locations of connectors and test points and jumpers on the board. If at any time the expected response is not obtained, see Section 5.5 on Troubleshooting.

1. Perform steps 1 through 4 of Section 5.1.
2. Check for 5.0V at TP10 and for 4.1V at TP11.
3. Apply a known voltage, Vin, at J1 or J2 connector and based on chosen gain, Av, of circuit confirm that voltage, Vout, at TP3 is as expected (Vin x Av = Vout).
4. Check temperature sensor output voltage at TP4 is as expected according to the transfer table found in the LM94022 datasheet. Room temp is apx. 2.3V.
5. Check negative bias generator output voltage at pin 1 of JP5 is apx. -0.25V.
6. Check level shifting output voltage at pin 1 of JP2 is VLS = (VREF * RLS2) / (RLS2 + RLS1)

This completes the quick check of the analog portion of the evaluation board.

5.3 Quick Check of Software and Computer Interface Operation

1. Perform steps 1 through 4 of Section 5.1.
2. Run the Sensor Panel software.
3. Select the SPI202S02RB
4. Manually enter the following data:
   - Thermocouple Type
   - Amplifier Configuration (Always select “Instr/Diff”)
   - Gain
   - Level Shifting Voltage
   - Number of bits
   - ADC Reference Voltage

The software will display the cold junction reference temperature and the thermocouple measured temperature.

This completes the quick check of the software and computer interface.

5.4 Sensor Panel Software

The Sensor Panel software is available on the web at http:\\www.national.com

Upon loading the software and running it, it is necessary to configure it for the board you are using. See the Sensor Panel software User’s Guide for more details.

5.5 Troubleshooting

If there is no output from the board, check the following:

- Be sure that the proper voltages and polarities are present at TP10 (+5V) and TP11 (+4.1V or +5V, as selected with JP6).
- Be sure there is a clock signal at TP6 when trying to capture data.
- Confirm thermocouple sensor is connected properly.

If the ADC output is zero or a single code, check the following:

- Be sure that the proper voltages and polarities are present at TP10 (+5V) and TP11 (+4.1V or +5V, as selected with JP6).
- Be sure that J3 is properly connected to a SPUSI2 USB Interface Dongle, and that there is a jumper on JP6.
- Confirm thermocouple sensor is connected properly.

6.0 Evaluation Board Specifications

Board Size:	2.85" x 2.30" (7.2 cm x 5.8 cm)
Power Requirements:	+5V (30mA) at J3 pin 14

7.0 Example Hardware Schematic

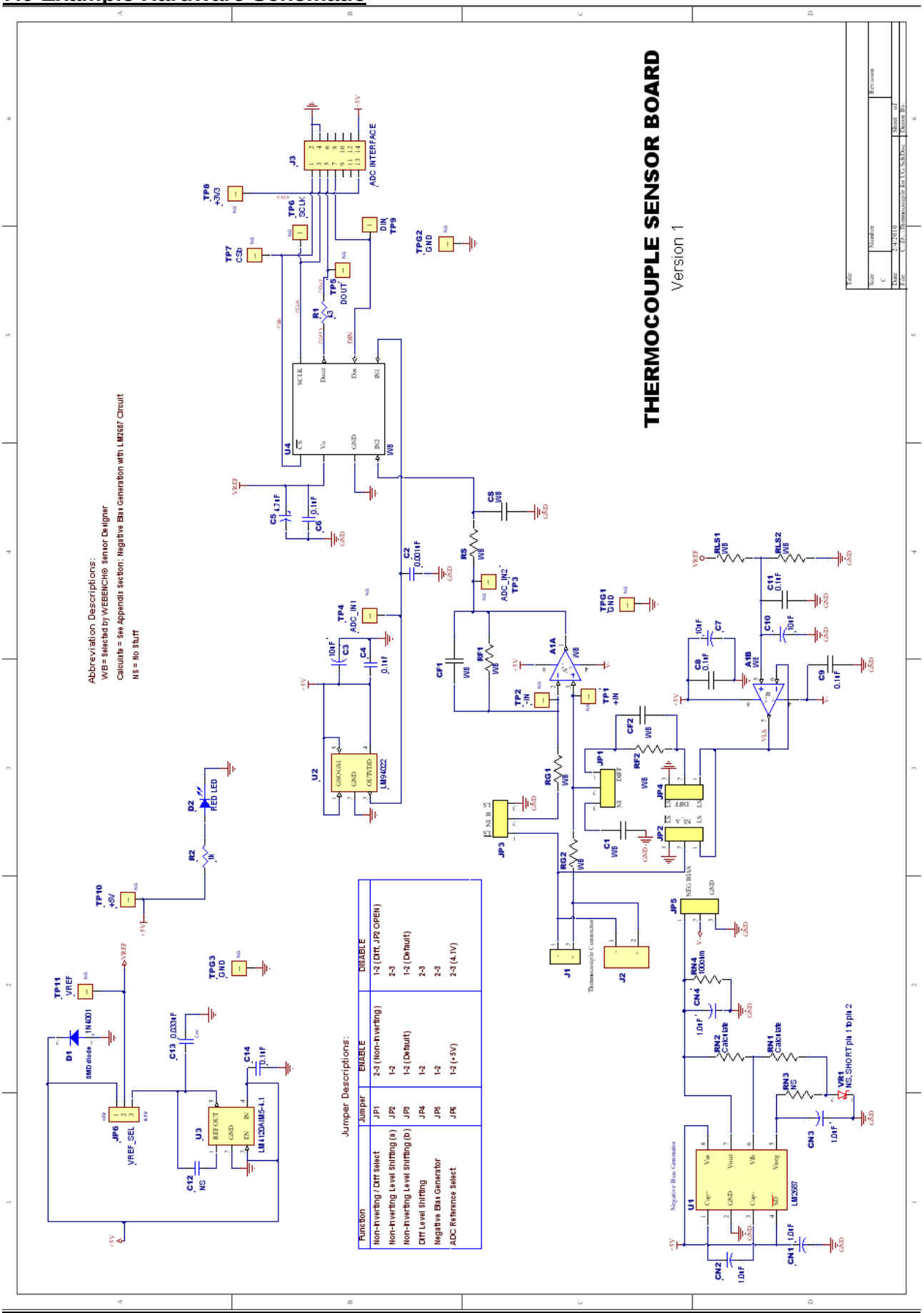


Figure 2. Thermocouple Sensor Board Version 1 Schematic

8.0 Thermocouple Sensor Board Version 1 Example Bill of Materials

Item #	Quantity	Reference	Part	Reference
1	6	C4, C6, C8, C9, C11, C14	Capacitor, Ceramic, 0.1uF, SMT, 0603, X7R, 25V, 10%	TDK # C1608X7R1E104K Digi-key # 445-1316-1-ND
2	1	C2	Capacitor, Ceramic, 0.001uF, SMT, 0603, X7R, 50V, 10%	KEMET # C0603C102K5RACTU Digi-key # 399-1082-1-ND
3	3	C3, C7, C10	Capacitor, Tantalum, 10uF, SMT, 3528, 10V, 10%	VISHAY # 293D106X9010B2TE3 Digi-key # 718-1122-1-ND
4	1	C5	Capacitor, Tantalum, 4.7uF, SMT, 3528, 10V, 10%	VISHAY # 293D475X9010B2TE3 Digi-Key # 718-1147-1-ND
5	1	C1	Selected by WEBENCH® Sensor Designer	
6	1	CS	Selected by WEBENCH® Sensor Designer	
7	2	CF1, CF2	Selected by WEBENCH® Sensor Designer	
8	1	C12	NOT STUFFED	
9	1	C13	Capacitor, Ceramic, 0.033uF, SMT, 0603, X7R, 50V, 10%	MURATA # GRM188R71H333KA61D Digi-key # 490-3286-1-ND
10	4	CN1, CN2, CN3, CN4	Capacitor, Ceramic, 1uF, SMT, 1206, 16V, 10%	JOHANSON # 160R18W105KV4E Digi-key # 709-1068-1-ND
11	1	D1	DIODE, 50V, 1A	MCC # GS1A-TP Digi-key # GS1A-TPCT-ND
12	1	D2	RED LED	LITE-ON # LTST-C930KAKT Digi-key # 160-1461-1-ND
13	1	J1	Terminal Block	ON SHORE # ED120/2DS Digi-key # ED1609-ND
14	1	J2	Thermocouple Connector	OMEGA #PCC-SMP
15	1	J3	ADC INTERFACE	TYCO # 87230-7 Digi-key # A26599-ND
16	6	JP1 - JP6	3-PIN HEADER	Waldom/Molex # 22-28-4033 Digi-key # WM6503-ND
17	1	R1	Resistor, SMT, 0603, 1%, 43.0 ohm	Panasonic # ERJ-3EKF43R0V Digi-key # P43.0HCT-ND
18	2	RLS1, RLS2	Selected by WEBENCH® Sensor Designer	
19	1	RN1	See Appendix - Negative Bias Generation with LM2687 Circuit	
20	1	RN2	See Appendix - Negative Bias Generation with LM2687 Circuit	
21	2	RF1, RF2	Selected by WEBENCH® Sensor Designer	
22	1	RN4	Resistor, SMT, 0603, 1%, 100ohm	Panasonic #ERJ-3EKF1000V Digi-key # P100HCT-ND
23	1	RN3	NOT STUFFED	
24	1	RS	Selected by WEBENCH® Sensor Designer	
25	1	R2,	Resistor, SMT, 0603, 1%, 1.00Kohm	Panasonic # ERJ-3EKF1001V Digi-key # P1.00KHCT-ND
26	2	RG1, RG2	Selected by WEBENCH® Sensor Designer	
27	13	TP1-TP10, TPG1-TPG3	TEST POINTS (NOT STUFFED)	
28	1	U1	LM2687	NSC # LM2687MM/NOPB Digi-key # LM2687MMCT-ND
29	1	U2	LM94022	NSC # LM94022QBIMG/NOPB Digi-key # LM94022QBIMGCT-ND
30	1	U3	LM4120AIM5-4.1	NSC # LM4120AIM5-4.1/NOPB Digi-key # LM4120AIM5-4.1CT-ND
31	1	U4	Selected by WEBENCH® Sensor Designer	
32	1	VR1	NOT STUFFED. Short pins 1 & 2.	
33	1	A1	Selected by WEBENCH® Sensor Designer	

APPENDIX

Summary Tables of Test Points and Connectors

Test Points on the Thermocouple Sensor Board Version 1

Identifier	Name	Function
TP 1	+IN	+IN of A1A amplifier
TP 2	-IN	-IN of A1A amplifier
TP 3	ADC_IN2	ADC Channel 2 input voltage
TP 4	ADC_IN1	ADC Channel 1 input voltage
TP 5	DOUT	DOUT output from ADC
TP 6	SCLK	SCLK input for ADC
TP 7	CSb	CSb input for ADC
TP 8	+3V3	+3.3V from SPUSI2 Board (not used on this board)
TP 9	DIN	DIN input for ADC
TP 10	+5V	Overall supply for board from SPUSI2 Board
TP 11	VREF	Supply/Reference voltage of ADC

J1/J2 Connector - Sensor Interface

Identifier	Name	Function
J1/J2-1	-Out	- Output from Sensor
J1/J2-2	+Out	+ Output from Sensor

J3 Connector - Connection to SPUSI2 Board

J3 Pin Number	Voltage or Signal
1	CSb input to ADC
2	Ground
3	SCLK input to ADC
4	Ground
5	SDATA output from ADC
6	no connection
7	DIN input to ADC
8	no connection
9	no connection
10	no connection
11	no connection
12	no connection
13	+3.3V from SPUSI2 USB Interface Dongle
14	+5V from SPUSI2 USB Interface Dongle

Summary Tables of Test Points and Connectors (cont'd)

JP1 Jumper – NI/Diff Select

Shorted Positions	Results
1 - 2	Non-inverting amplifier configuration
2 - 3	Differential amplifier configuration

JP2 Jumper – NI Level Shifting (a)

Shorted Positions	Results
1 - 2	Non-inverting amplifier level shifting enabled
2 - 3	Non-inverting amplifier level shifting disabled

JP3 Jumper – NI Level Shifting (b)

Shorted Positions	Results
1 - 2	Default
2 - 3	Not used

JP4 Jumper – Diff Level Shifting

Shorted Positions	Results
1 - 2	Differential amplifier level shifting enabled
2 - 3	Differential amplifier level shifting disabled

JP5 Jumper – Negative Bias Generator

Shorted Positions	Results
Open	Negative bias generation enabled – Connect external supply to pin 2
1 - 2	Negative bias generation enabled – LM2687 Circuit
2 - 3	Negative bias generation disabled

JP6 Jumper – ADC Reference Select

Shorted Positions	Results
1 - 2	+5V for ADC supply and reference voltage
2 - 3	+4.1V for ADC supply and reference voltage

Negative Bias Generation with LM2687 Circuit

To avoid amplifier output saturation the board allows for a negative bias from the unpopulated LM2687 circuit to be applied to the V- terminal of the amplifier. The regulated output for the LM2687 voltage inverter, U1, is adjustable between −1.5V and −5.2V. When selecting a negative voltage for the V- terminal of the amplifier be aware not to exceed the max supply voltage operating ratings for the amplifier selected. The output voltage can be selected using the equation

$$Vout = (RN2 / RN1) * (VFB – VADJ) + VFB$$

Where the feedback pin is held at a constant voltage VFB which equals −1.2V and on this board VADJ will be shorted to ground. This simplifies the equation to

$$Vout = (RN2 / RN1) * (-1.2V) – 1.2V$$

For example to set Vout = -1.5V one could select RN2 = 20 kΩ and RN1 = 78.7 kΩ.

To set up the circuit on board do not populate RN3 or VR1. Short pad 1 to pad 2 of VR1. To connect output of LM2687 circuit to V- terminal of the amplifier short pins 1 and 2 of jumper 5 (JP5).

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