MCP6V01
Thermocouple Auto-Zeroed Reference Design

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MCP6V01 THERMOCOUPLE AUTO-ZEROED REFERENCE DESIGN

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NOTES:

Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXA", where "XXXXX" is the document number and "A" is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE on-line help. Select the Help menu, and then Topics to open a list of available on-line help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the MCP6V01 Thermocouple Auto-Zeroed Reference Design. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Web Site
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document describes how to use the MCP6V01 Thermocouple Auto-Zeroed Reference Design as a development tool to emulate and debug firmware on a target board. The manual layout is as follows:

- **Chapter 1. "Product Overview"** - Provides the important information about the MCP6V01 Thermocouple Auto-Zeroed Reference Design.
- **Chapter 2. "Installation and Operation"** – Covers the installation and operation of the MCP6V01 Thermocouple Auto-Zeroed Reference Design. It shows how to set up the board, and demonstrates how to verify the operation.
- **Appendix A. "Schematic and Layout"** – Shows the schematic and board layouts for the MCP6V01 Thermocouple Auto-Zeroed Reference Design.
- **Appendix B. "Bill Of Materials (BOM)"** – Lists the parts used to build the MCP6V01 Thermocouple Auto-Zeroed Reference Design.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	*File>Save*
Bold characters	A dialog button	Click **OK**
	A tab	Click the **Power** tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	`#define START`
	Filenames	`autoexec.bat`
	File paths	`c:\mcc18\h`
	Keywords	`_asm, _endasm, static`
	Command-line options	`-Opa+, -Opa-`
	Bit values	`0, 1`
	Constants	`0xFF, 'A'`
Italic Courier New	A variable argument	*`file`*`.o`, where *`file`* can be any valid filename
Square brackets [ ]	Optional arguments	`mcc18 [options]` *`file`* `[options]`
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; an OR selection	`errorlevel {0|1}`
Ellipses...	Replaces repeated text	`var_name [, var_name...]`
	Represents code supplied by user	`void main (void) { ... }`

RECOMMENDED READING

This user's guide describes how to use MCP6V01 Thermocouple Auto-Zeroed Reference Design. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

MCP6V01/2/3/6/7/8 Data Sheet, *"Auto-Zeroed Op Amps"* (DS51738)

This data sheet provides detailed information regarding the MCP6V0X Op Amps.

MCP6001/2/4 Data Sheet, *"1 MHz, Low-Power Op Amps"* (DS21733)

This data sheet provides detailed information regarding the MCP600X Op Amps.

MCP1525/41 Data Sheet, *"2.5V and 4.096V Voltage References"* (DS21653)

This data sheet provides detailed information on the MCP15XX Voltage References.

MCP9800/1/2/3 Data Sheet, *"2-Wire High-Accuracy Temperature Sensor"* (DS21909)

This data sheet provides detailed information regarding the MCP980X Temperature Sensors.

PIC18F2455/2550/4455/4550 Data Sheet, *"28/40/44-Pin, High-Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology"* (DS39632)

This data sheet provides detailed information regarding the PIC18F2455/2550/4455/4550 Microcontrollers.

AN679, *"Temperature Sensing Technologies"* (DS00679)

This application note covers the most popular temperature sensor technologies and helps determine the most appropriate sensor for an application.

AN684, *"Single Supply Temperature Sensing with Thermocouples"* (DS00684)

This application note focuses on thermocouple circuit solutions. It builds from signal conditioning components to complete application circuits.

AN699, *"Anti-Aliasing, Analog Filters for Data Acquisition Systems"* (DS00699)

A tutorial on active analog filters and their most common applications.

***"Signal Chain Design Guide"* (DS21825)**

THE MICROCHIP WEB SITE

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- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: http://support.microchip.com

DOCUMENT REVISION HISTORY

Revision B (December 2008)

- Updated the Bottom Metal Layer print.
- Updated Product Review.

Revision A (May 2008)

- Initial Release of this Document.

Chapter 1. Product Overview

1.1 INTRODUCTION

The MCP6V01 Thermocouple Auto-Zeroed Reference Design is described by the following:

- Assembly # : 114-00169
- Order # : MCP6V01RD-TCPL
- Name: MCP6V01 Thermocouple Auto-Zeroed Reference Design Board

Items discussed in this chapter include:

- MCP6V01 Thermocouple Auto-Zeroed Reference Design Board Kit Contents
- MCP6V01 Thermocouple Auto-Zeroed Reference Design Board Description
- Associated Tools

1.2 MCP6V01 THERMOCOUPLE AUTO-ZEROED REFERENCE DESIGN KIT CONTENTS

- MCP6V01 Thermocouple Auto-Zeroed Reference Design (102-00169)
- Important “Read First” Information
- Accessory Bag - Contains a K-type thermocouple and an USB cable
- Analog and Interface Products Demonstration Boards CD-ROM (DS21912) includes:
  - MCP6V01 Thermocouple Auto-Zeroed Reference Design (D51738)
  - Thermal Management Software
  - Firmware for PIC18F2550

FIGURE 1-1: *MCP6V01 Thermocouple Auto-Zeroed Reference Design Kit.*

1.3 MCP6V01 THERMOCOUPLE AUTO-ZEROED REFERENCE DESIGN DESCRIPTION

1.3.1 Function Block Diagram Description

The MCP6V01 Thermocouple Auto-Zeroed Reference Design demonstrates how to measure electromotive force (EMF) voltage at the cold junction of the thermocouple in order to accurately measure temperature at the hot junction. This can be done by using the MCP6V01 auto-zeroed op amp because of its ultra low offset voltage (V_{OS}) and high common mode rejection ratio (CMRR).

- The difference amplifier is implemented using the MCP6V01 and 0.1% tolerance resistors. It amplifies the EMF voltage at the cold junction of the thermocouple.
- The MCP9800 senses temperature at the type K thermocouple's connector. It should be located as close as possible to the connector on the PCB. This measurement is used to perform cold junction compensation for the thermocouple measurement.
- The MCP1541 provides a V_{REF} (4.1V) to the internal 10-Bit ADC of the PIC18F2550 and sets the reference voltage for the difference amplifier.
- The CV_{REF} is the internal comparator voltage reference of PIC18F2550, which is a 16-tap resistor ladder network that provides a selectable reference voltage. The MCP6001 buffer amplifier eliminates the voltage reference output impedance problem and produces the voltage V_{SHIFT}.
- The 2^{nd} order RC low-pass filter that is implemented in this circuit can remove the high frequency noise and aliasing at the ADC input. The ADC of PIC18F2550 completes the analog-to-digital conversion. The data will be transferred to the PC using the USB interface.
- The Thermal Management Software on PC is used to perform data display to show the real-time temperature and apply cold junction compensation and data linearization to determine the actual temperature of the thermocouple's hot junction (weld bead).

Figure 1-2 shows the function block diagram of the MCP6V01 Thermocouple Auto-Zeroed Reference Design.

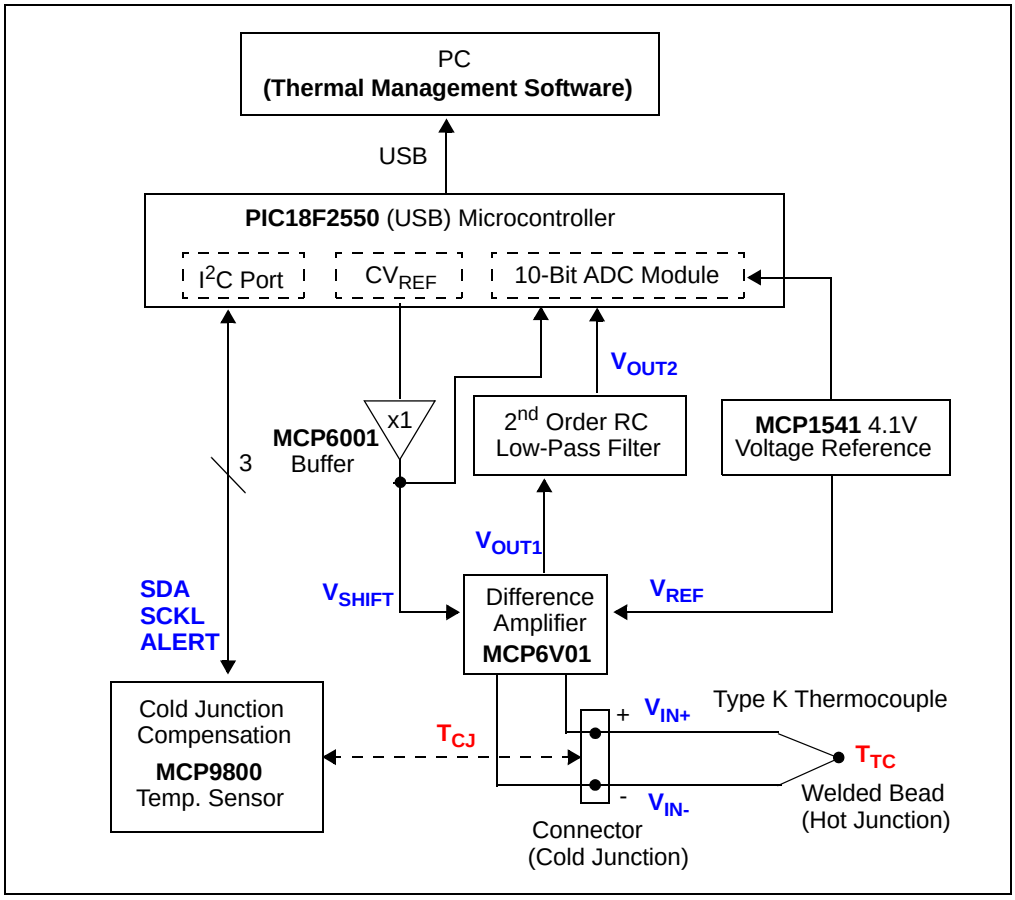


FIGURE 1-2: *Function Block Diagram of the MCP6V01 Thermocouple Auto-Zeroed Reference Design.*

1.3.2 Analog Sensing Circuit Diagram Description

- Difference Amplifier
  - Uses a MCP6V01 auto-zeroed op amp (U5)
  - Two 0.1% tolerance gain resistors (R8 and R11)
  - Two 0.1% tolerance input resistors for shifting V_{OUT1} (R9 and R10)
  - Two 0.1% tolerance input resistors for the thermocouple output (R6 and R7)
- Buffer Amplifier
  - Uses a MCP6001 standard op amp (U4)
  - Outputs V_{SHIFT} which shifts V_{OUT1} by 16 different values
  - Sends V_{SHIFT} back to PIC's internal ADC to make calculated result more accurate
- 2nd Order RC Low-Pass Filter
  - Fast enough to quick changes in temperature
  - Double pole for anti-aliasing and removing high-frequency noise
  - No DC offset and simple architecture

Figure 1-3 shows the analog sensing circuit diagram of MCP6V01 Thermocouple Auto-Zeroed Reference Design.

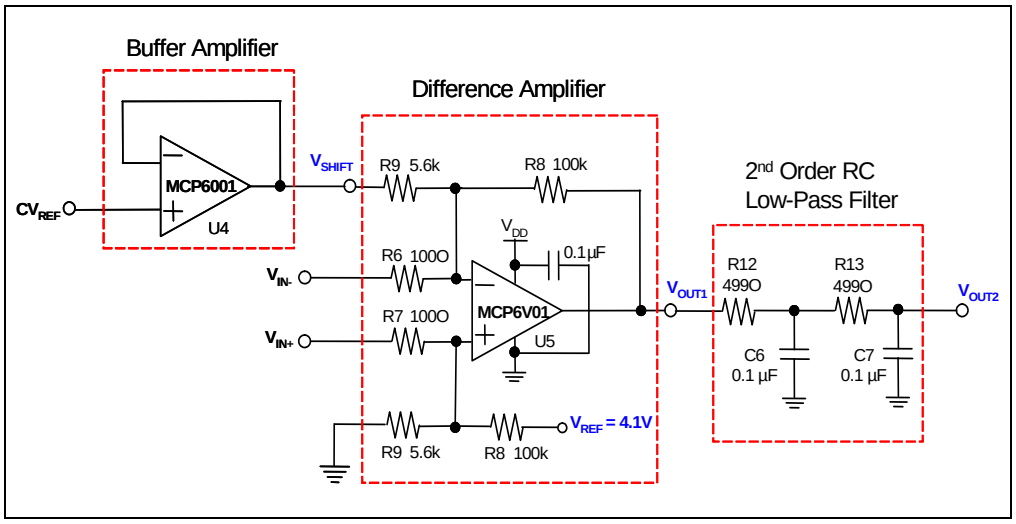


FIGURE 1-3: *Analog Sensing Circuit Diagram of the MCP6V01 Thermocouple Auto-Zeroed Reference Design.*

1.3.3 V_{SHIFT} Operation Description

CV_{REF} produces V_{SHIFT} through the buffer amplifier. V_{SHIFT} is brought back to the PIC18F2550 so that it can be sampled by the ADC, then used to adjust the measured V_{OUT1}. This makes the V_{SHIFT} values accurate to the 10-Bit ADC's capability. The values within each range also have a resolution of 10 bits. Thus, this gives 14 bits of resolution in total.

- 14-Bit Resolution, 10-Bit ADC
  - PIC18F2550's CV_{REF} (16 levels) subdivides input ranges
  - PIC18F2550's internal 10-Bit ADC converts result and calibrates CV_{REF}
  - The firmware automatically searches for correct CV_{REF} value
- This solution minimizes cost by using resources internal to the PIC to achieve reasonable resolution without an external ADC. Further savings could be achieved by using a voltage reference internal to the PIC instead of the external MCP1541.

Note: V_{OUT1}, V_{SHIFT1} and V_{IN+} - V_{IN-} are not drawn to scale. This is a conceptual diagram only.

Figure 1-4 shows the conceptual diagram of the V_{SHIFT} operation.

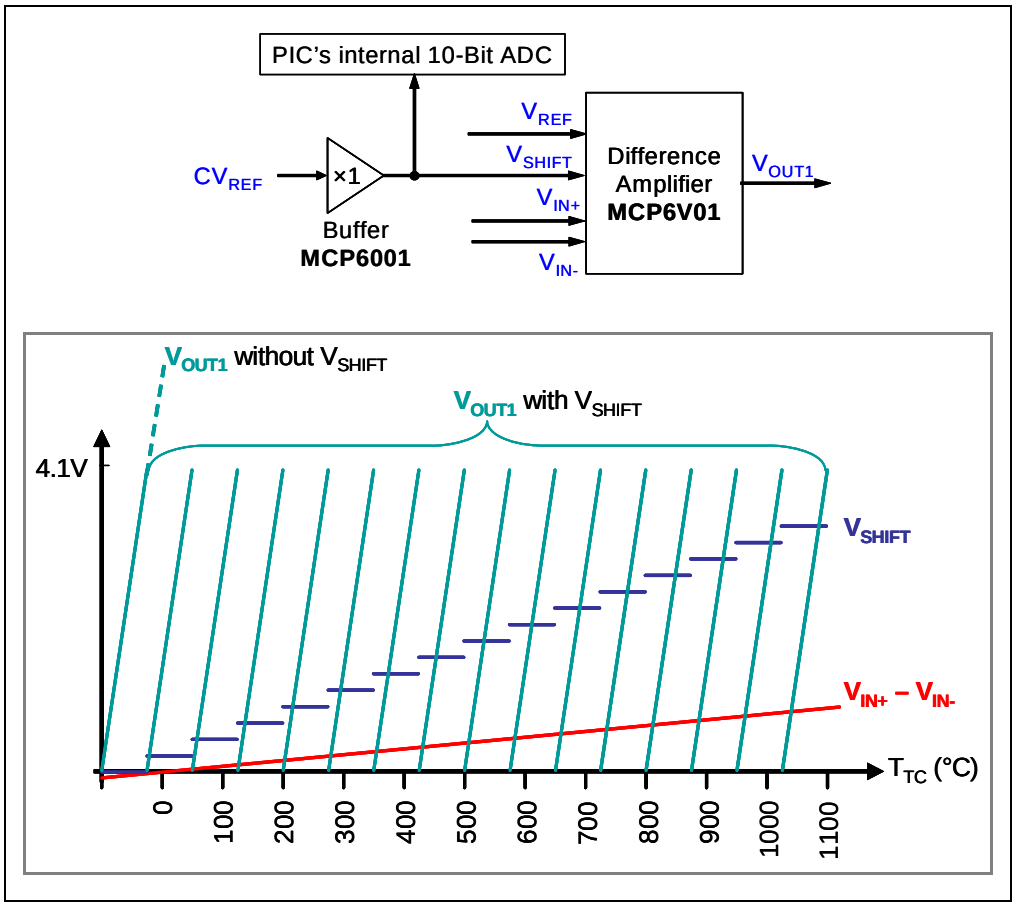


FIGURE 1-4: *V_{SHIFT} Operation Conceptual Diagram.*

MCP6V01 Thermocouple Auto-Zeroed Reference Design

The MCP6V01 Thermocouple Auto-Zeroed Reference Design has the following features:

- Uses a MCP6V01 difference amplifier as an analog sensor conditioning circuit
- Uses the K-type thermocouple to sense temperature
- Temperature range is from -100°C to +1000°C
- Uses the MCP9800 Temperature Sensor for cold junction compensation
- Uses the USB interface to transfer data to PC
- 14-Bit Resolution, 10-Bit ADC
- Test points for bench work

Chapter 2. Installation and Operation

2.1 INTRODUCTION

This chapter shows how to set up the MCP6V01 Thermocouple Auto-Zeroed Reference Design and explores the operation of a temperature measurement application.

Items discussed in this chapter include:

- Required Tools
- MCP6V01 Thermocouple Auto-Zeroed Reference Design Setup
- MCP6V01 Thermocouple Auto-Zeroed Reference Design Operation

2.2 REQUIRED TOOL

- The Personal Computer (PC) shown in Figure 1-2 needs to run on Windows® 98 SE or later. It provides a convenient interface for the user, communicates with the boards, and provides power through the USB connection.

2.3 MCP6V01 THERMOCOUPLE AUTO-ZEROED REFERENCE DESIGN SETUP

1. Connect the type K thermocouple and the USB cable to the MCP6V01 Thermocouple Auto-Zeroed Reference Design.

   An exploded view is shown in the Figure 2-1.

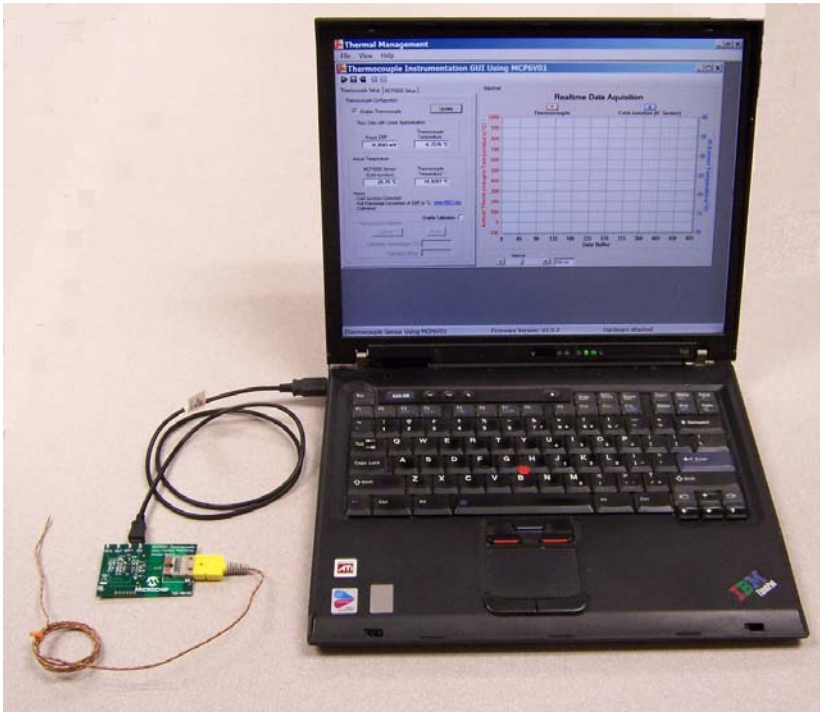


FIGURE 2-1: *MCP6V01 Thermocouple Auto-Zeroed Reference Design Setup.*

2.4 MCP6V01 THERMOCOUPLE AUTO-ZEROED REFERENCE DESIGN OPERATION

1. Start the Thermal Management Software on the PC.

   If the hardware is connected properly, the software will recognize the hardware and this is confirmed by showing the Thermocouple Instrumentation GUI Using MCP6V01 panel, as indicated in Figure 2-2. Otherwise, the software will show the Hardware Not Detected message box, as indicated in Figure 2-3.

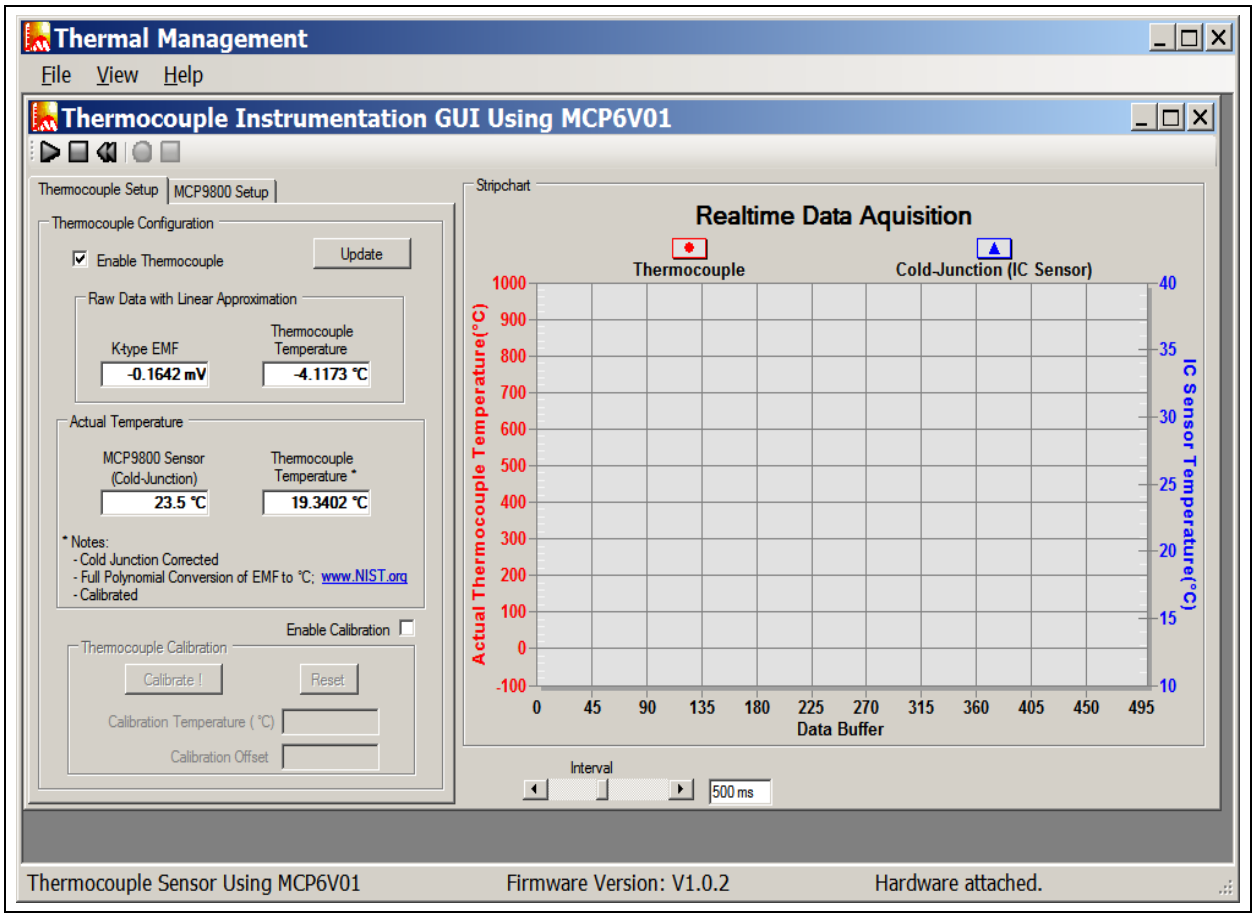


FIGURE 2-2: *Thermocouple Instrumentation GUI Using MCP6V01.*

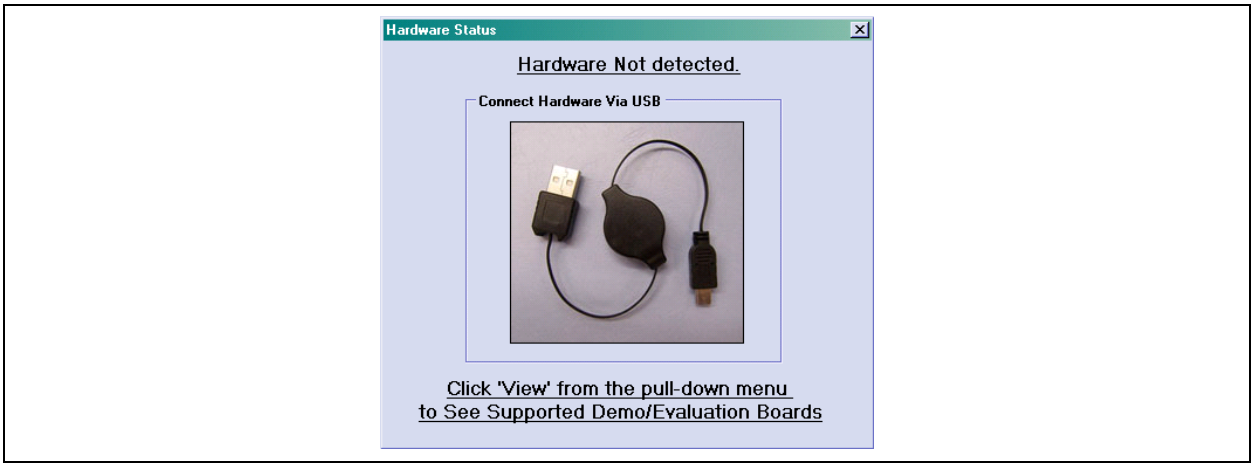


FIGURE 2-3: *Hardware Not Detected Message Box.*

2.4.1 Set Up the MCP9800 Temperature Sensor Configuration

1. Click the **MCP9800 Setup** tab.
2. The **MCP9800 Configuration** can be modified from the default values.
3. Click the **Update Temp.** button to complete the modifications.

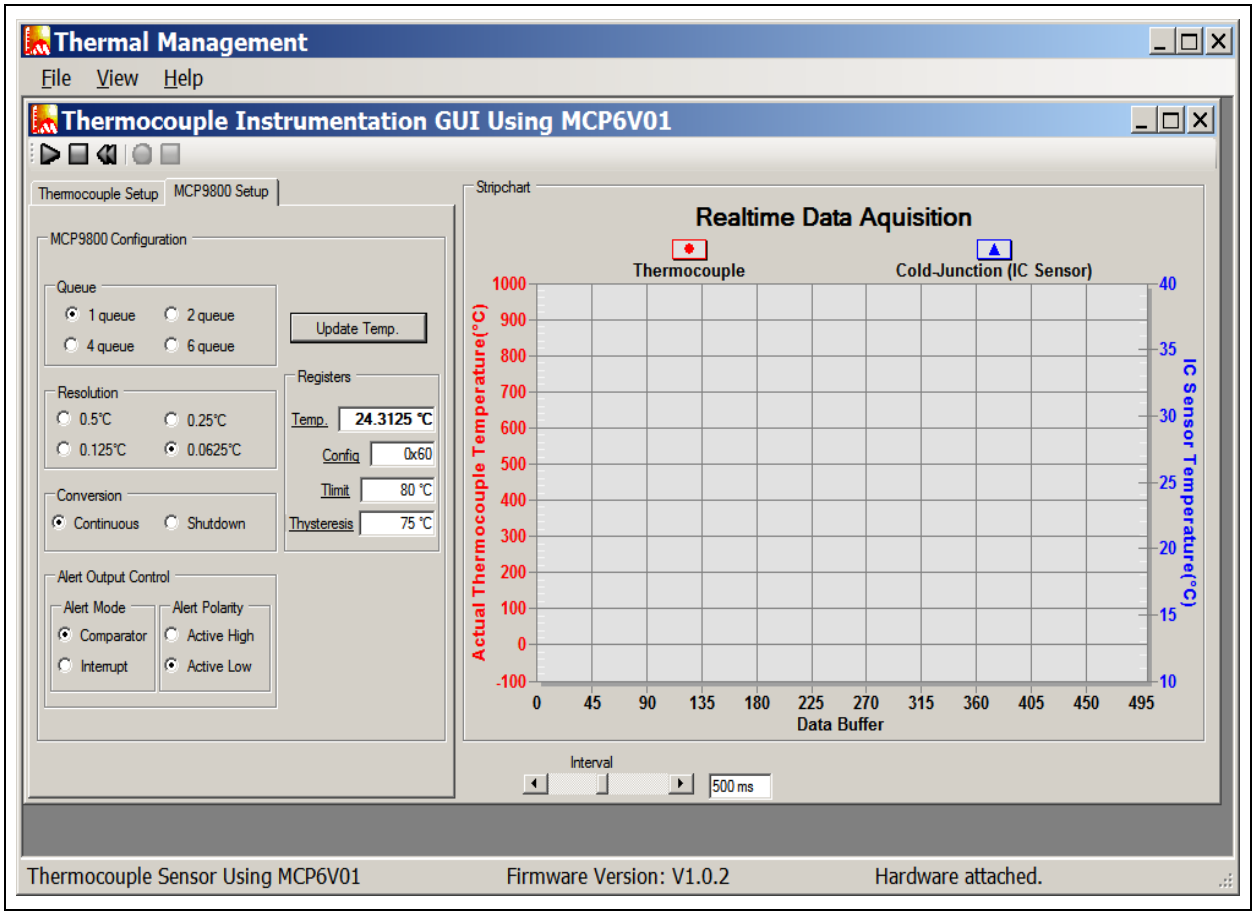


FIGURE 2-4: *MCP9800 Setup.*

2.4.2 Set Up the Thermocouple Configuration

1. Click the **Thermocouple Setup** tab.
2. **Enable thermocouple** is selected as default. **Enable Calibration** also can be selected.
3. Click the **Update** button to complete the setup.

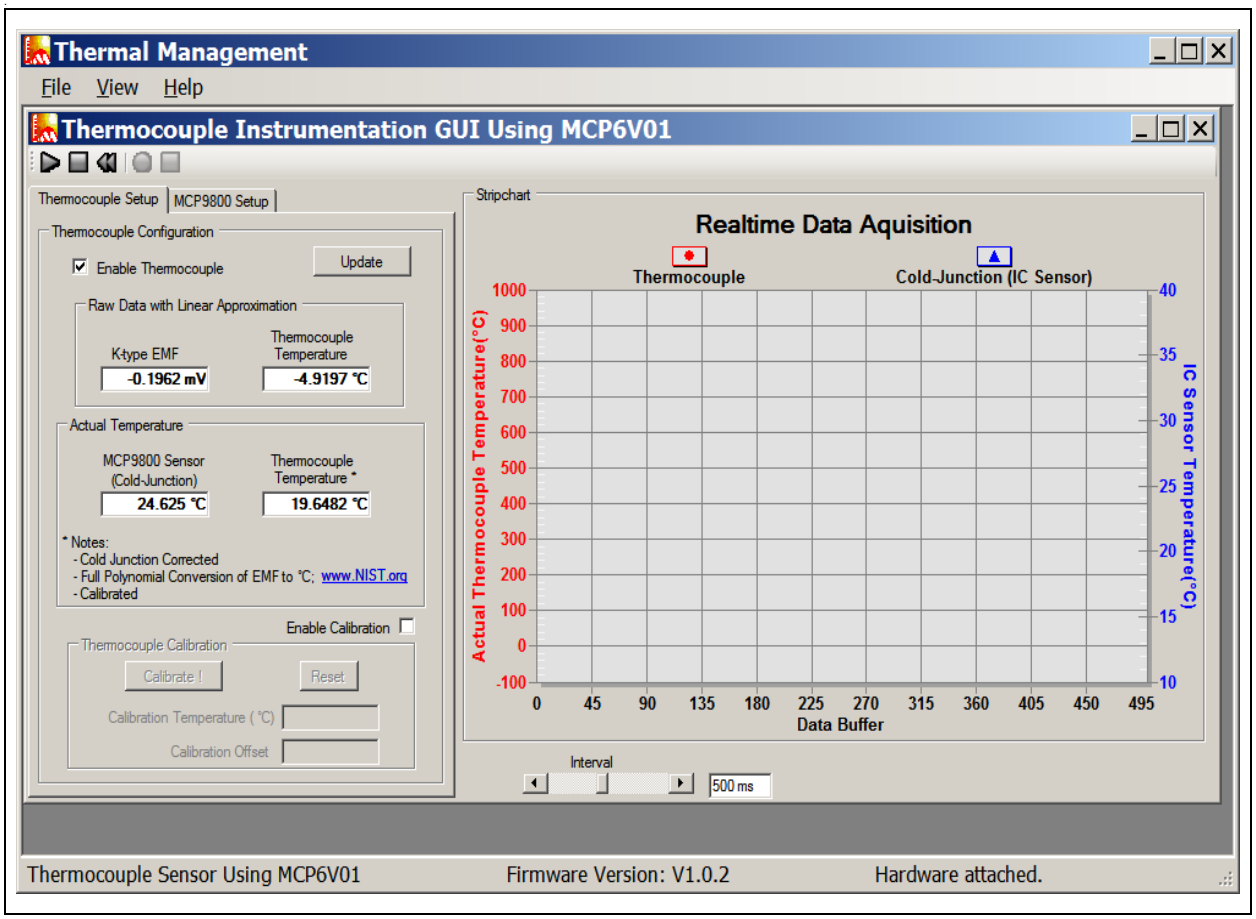


FIGURE 2-5: *Thermocouple setup.*

2.4.3 Customize the Realtime Data Aquisition

1. Double click on the region of the stipchart to customize the Realtime Data Aquisition.

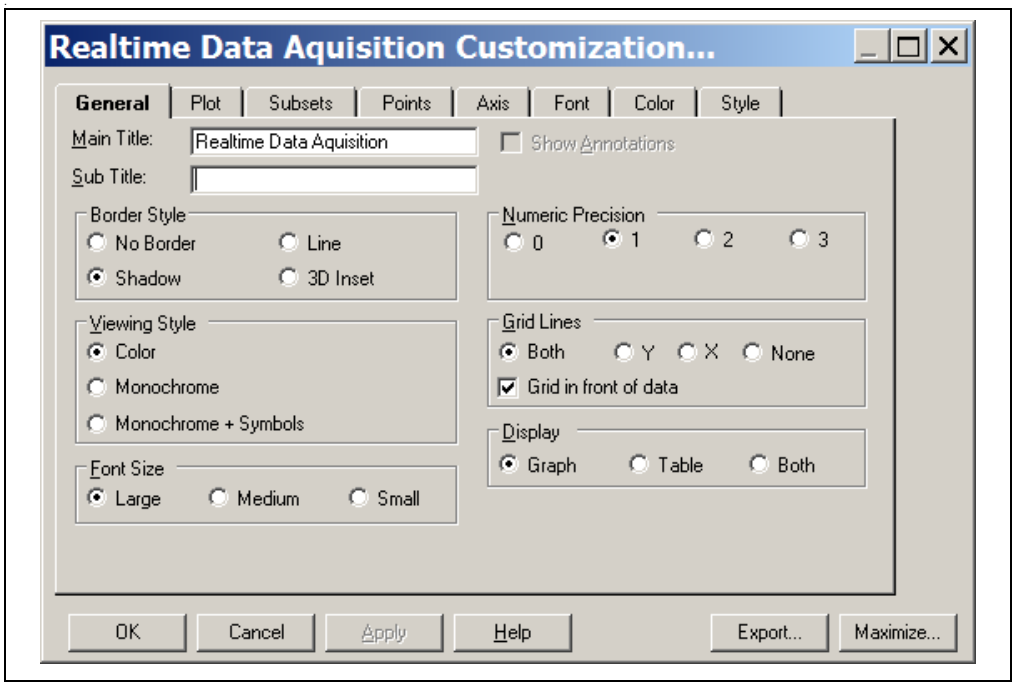


FIGURE 2-6: *Realtime Data Aquisition Customization.*

2.4.3.1 START THE REALTIME DATA AQUISITION

1. Click the **PLAY** button to start the Realtime Data Aquisition.

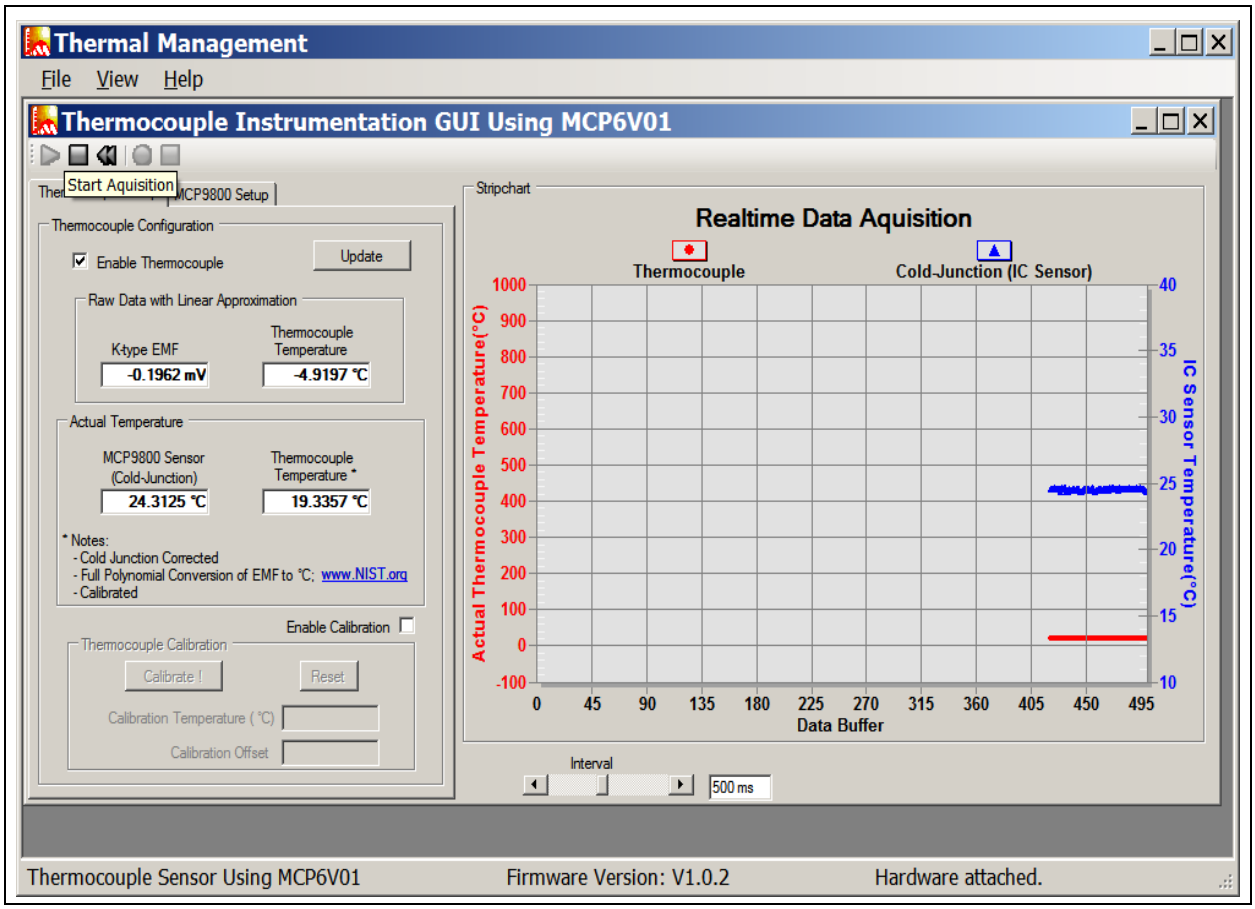


FIGURE 2-7: *Start Realtime Data Aquisition.*

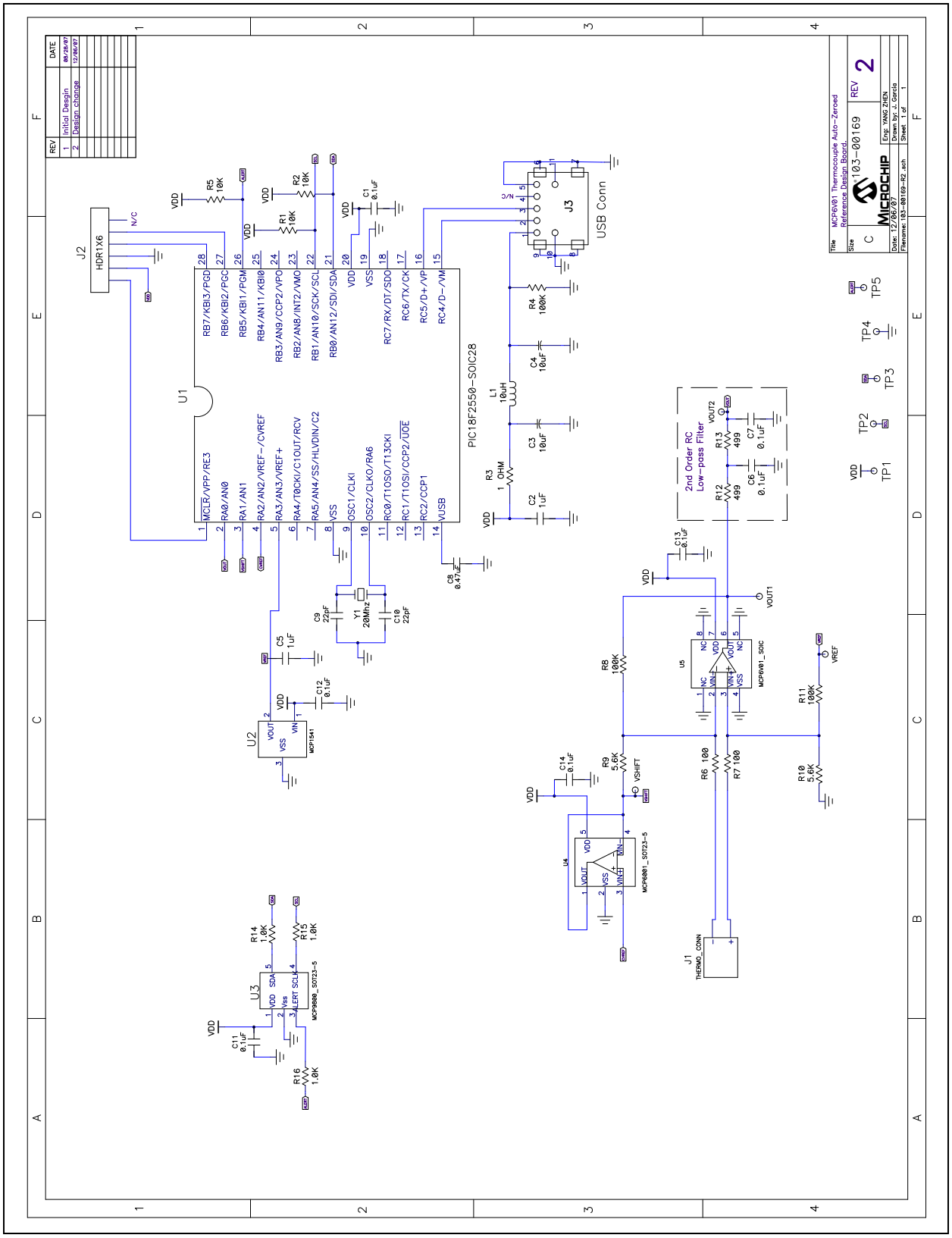
Appendix A. Schematic and Layout

A.1 INTRODUCTION

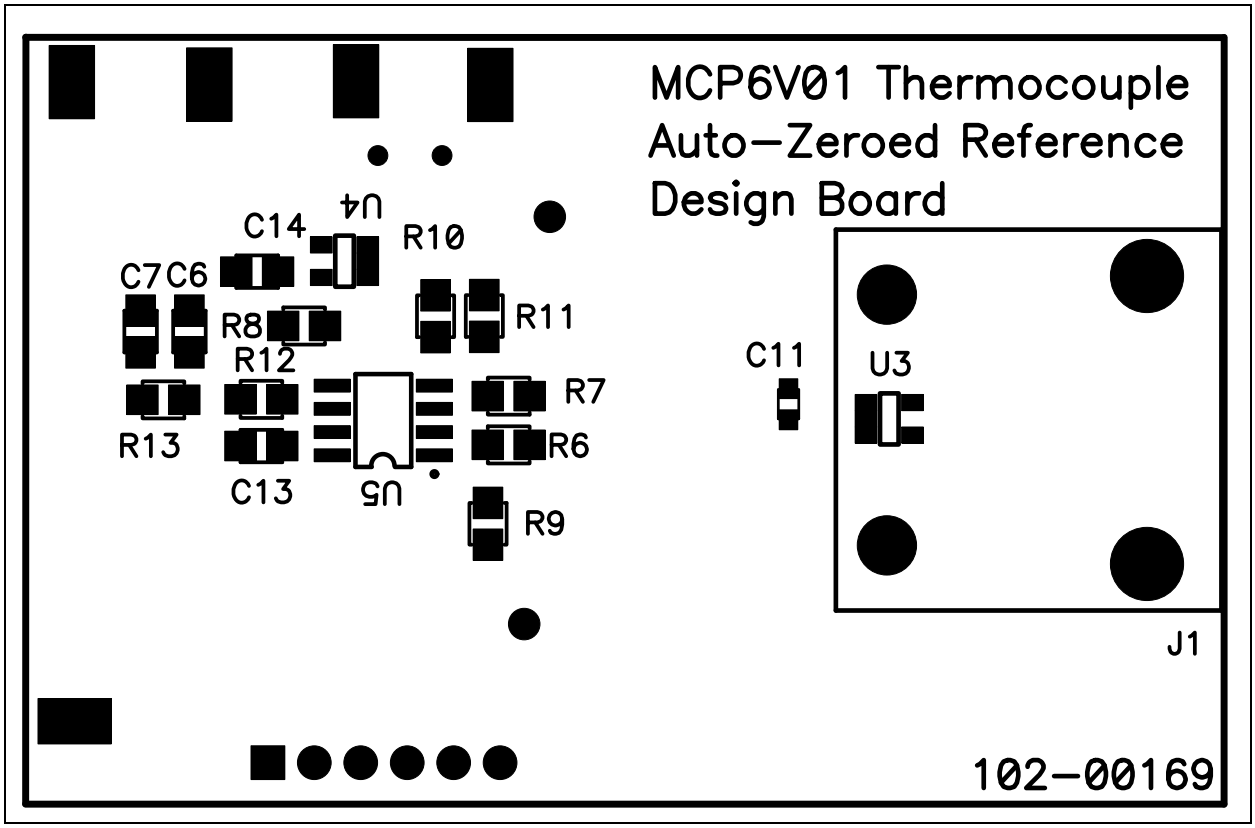
This appendix contains the following schematics and layouts for the MCP6V01 Thermocouple Auto-Zeroed Reference Design:

- Board – Schematic
- Board – Top Silk Layer
- Board – Top Metal Layer
- Board – Metal Layer 2
- Board – Metal Layer 3
- Board – Bottom Silk Layer
- Board – Bottom Metal Layer

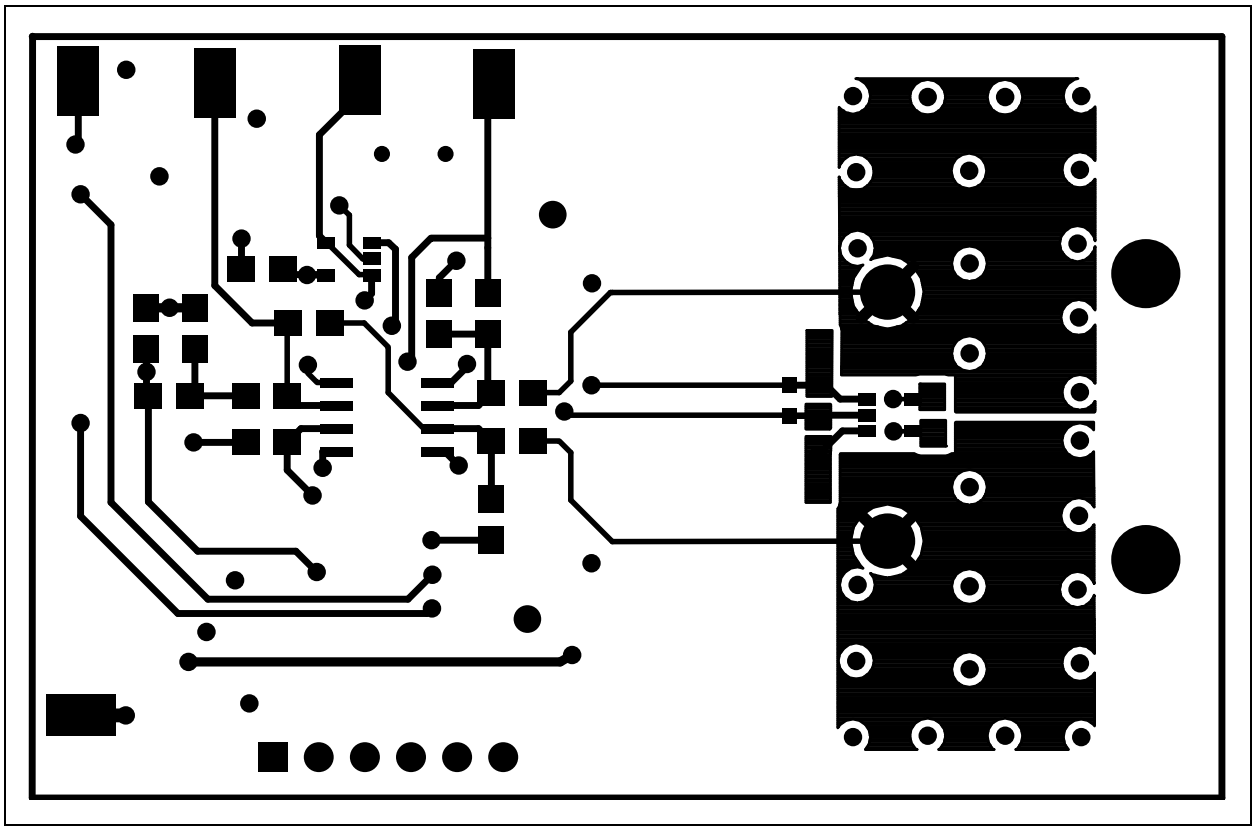
A.2 BOARD - SCHEMATIC



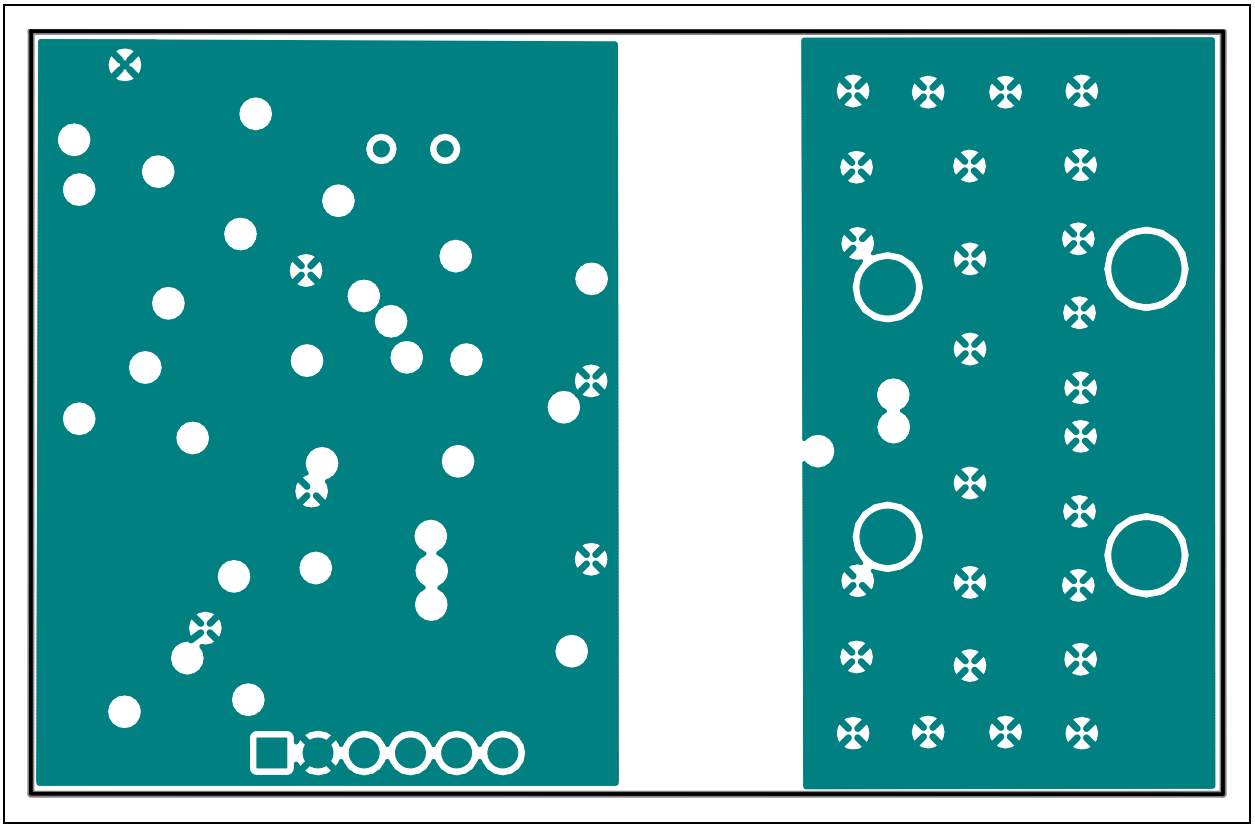
A.3 BOARD - TOP SILK LAYER



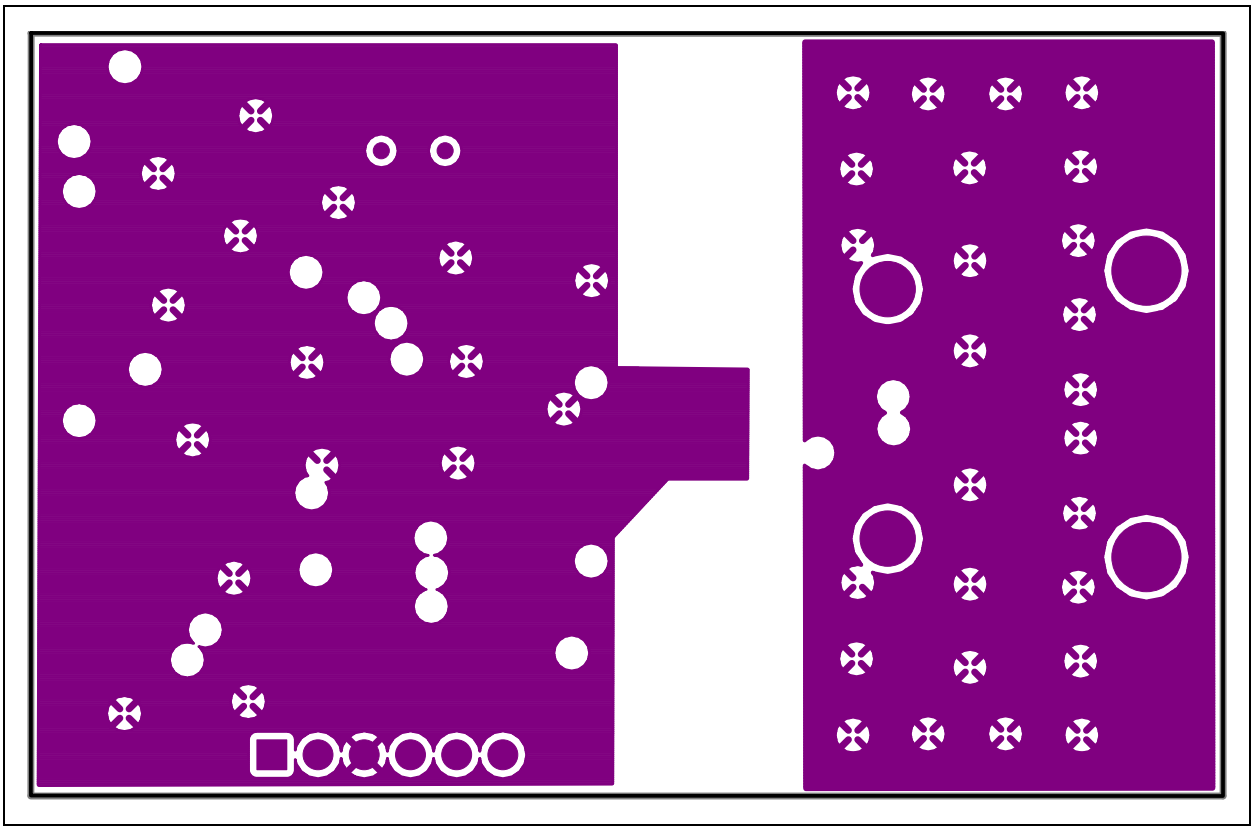
A.4 BOARD - TOP METAL LAYER



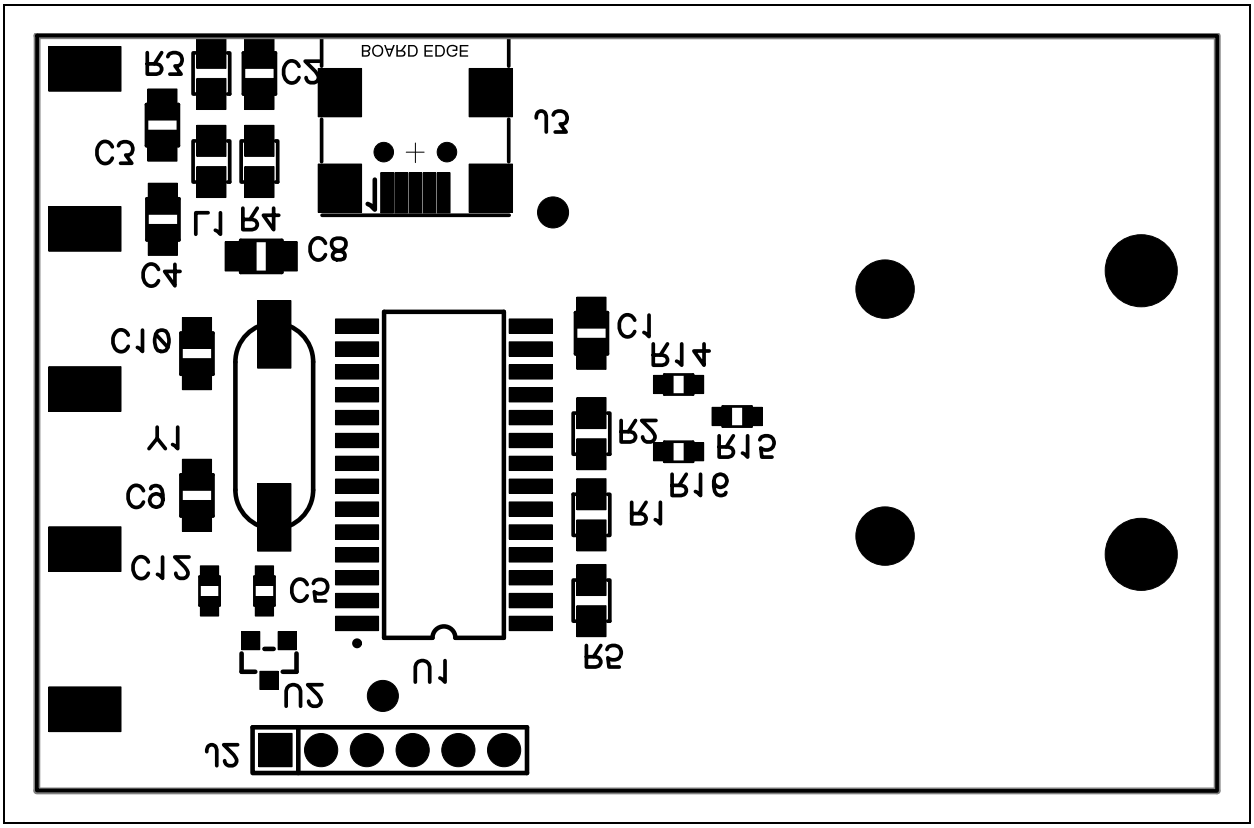
A.5 BOARD - METAL LAYER 2



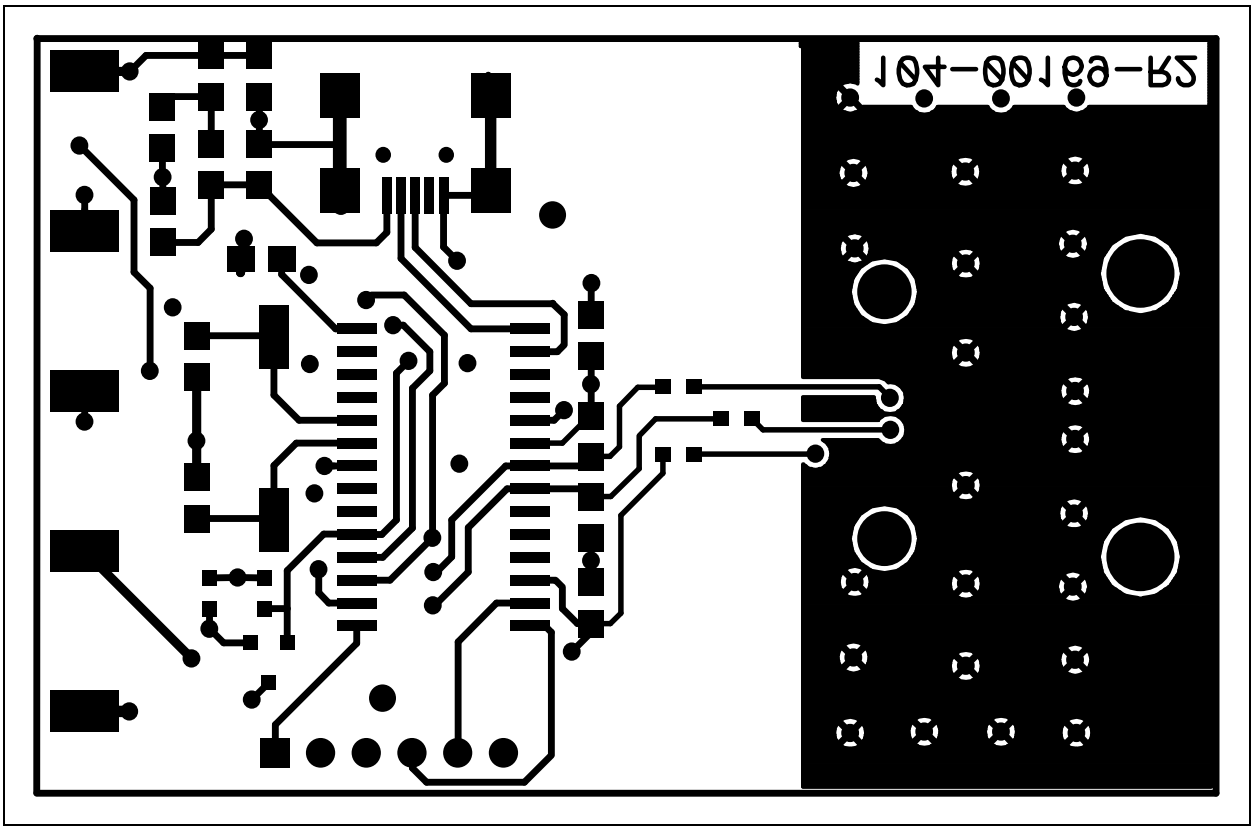
A.6 BOARD - METAL LAYER 3



A.7 BOARD - BOTTOM SILK LAYER (BOTTOM VIEW)



A.8 BOARD - BOTTOM METAL LAYER



NOTES:

Appendix B. Bill Of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)

Qty	Reference	Description	Manufacturer	Part Number
5	C1, C6, C7, C13, C14	CAP .1UF 25V CERAMIC X7R 0805	Panasonic® - ECG	ECJ-2VB1E104K
1	C2	CAP 1.0UF 25V CERAMIC F 0805	Panasonic - ECG	ECJ-2FF1E105Z
2	C3, C4	CAP CER 10UF 16V Y5V 0805	Murata Electronics® North America	GRM21BF51C106ZE15L
1	C5	CAP 1.0UF 25V CERAMIC F 0603	Panasonic - ECG	ECJ-1VF1E105Z
1	C8	CAP .47UF 25V CERAMIC Y5V 0805	Panasonic - ECG	ECJ-2YF1E474Z
2	C9, C10	CAP 22PF 50V CERM CHIP 0805 SMD	Panasonic - ECG	ECJ-2VC1H220J
2	C11, C12	CAP .1UF 25V CERAMIC X7R 0603	Panasonic - ECG	ECJ-1VB1E104K
1	J1	Circuit Board Thermocouple Connectors, Standard	OMEGA	PCC-SMP-K-100
1	J2	HEADER 1X6 DO NOT POPULATE	—	—
1	J3	CONN RECEPT MINI USB2.0 5POS	Hirose Electronic Co Ltd	UX60-MB-5ST
1	L1	INDUCTOR 10UH 100MA 0805	Murata Electronics North America	LQM21FN100M70L
1	PCB	RoHS Compliant Bare PCB, Thermocouple Auto-Zero RD Board	—	104-00169
3	R1, R2, R5	RES 10.0K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF1002V
1	R3	RES 1.0 OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6RQF1R0V
1	R4	RES 100K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF1003V
2	R6, R7	RES 100 OHM 1/10W 0.1% 0805 SMD	Panasonic - ECG	ERA-6AEB101V
2	R8, R11	RES 100K OHM 1/10W 0.1% 0805 SMD	Panasonic - ECG	ERA-6AEB104V
2	R9, R10	RES 5.6K OHM 1/10W 0.1% 0805 SMD	Panasonic - ECG	ERA-6AEB562V
2	R12, R13	RES 499 OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF4990V

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-1: BILL OF MATERIALS (BOM) (CONTINUED)

Qty	Reference	Description	Manufacturer	Part Number
3	R14, R15, R16	RES 1.0K OHM 1/10W 1% 0603 SMD	Panasonic - ECG	ERJ-3EKF1001V
1	Thermocouples (5 Per Pack)	Ready-Made Insulated Thermocouples with Kapton, PFA, Glass Braid Insulation and Molded Connectors	OMEGA	5SRTC-TT-K-24-36 (5 Pcs. Per Pack)
10	TP1---TP10	TEST POINT PC COMPACT SMT	Keystone Electronics®	5016
1	U1	28/40/44-Pin, High-Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology	Microchip Technology Inc.	PIC18F2550-I/SO
1	U2	4.096V Voltage Reference	Microchip Technology Inc.	MCP1541T-I/TT
1	U3	Memory Module Digital Temperature Sensor, MCP9800	Microchip Technology Inc.	MCP9800A0T-M/OTG
1	U4	MCP6001, SOT-23-5	Microchip Technology Inc.	MCP6001T-I/OT
1	U5	MCP60V1, SOIC-8	Microchip Technology Inc.	MCP6V01T-E/SN
1	Y1	CRYSTAL 20.0000 MHZ SERIES SMT	CTS-Frequency Controls	ATS200SM

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

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