

Thermocouple Reference Design

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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 Thermocouple 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 Thermocouple 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"** – Important information about the Thermocouple Reference Design.
- **Chapter 2. "Installation and Operation"** – This chapter includes a detailed description of each function of the demo board and instructions for how to begin using the board.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the Thermocouple Reference Design.
- **Appendix B. "Bill of Materials"** – Lists the parts used to build the Thermocouple 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) { ... }`

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RECOMMENDED READING

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

MCP3421 Data Sheet, *"18-Bit Analog-to-Digital Converter with I^2C Interface and On-Board Reference"* (DS22003).

This data sheet provides detailed information regarding the MCP3421 device.

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
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- Technical Support

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

DOCUMENT REVISION HISTORY

Revision A (December 2009)

- Initial Release of this Document.

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Chapter 1. Product Overview

1.1 INTRODUCTION

The following name and assembly number are found on the Thermocouple Reference Design's Printed Circuit Board (PCB):

- 102-00114

1.2 WHAT IS THE THERMOCOUPLE REFERENCE DESIGN?

The Thermocouple Reference Design demonstrates how to instrument a Thermocouple and accurately sense temperature over the entire Thermocouple measurement range. This solution uses the MCP3421 18-Bit Analog-to-Digital Converter (ADC) to measure voltage across the Thermocouple. The ADC has an internal 2.048V reference voltage and a Programmable Gain Amplifier with 1, 2, 4, 8V/V. At a Gain of 8V/V the PGA effectively adds 3LSb to the ADC. This increases the ADC resolution to 21-bit or 2 µV/LSb. Therefore, the Thermocouple EMF voltage is measured with 2 µV resolution. For K-type Thermocouple, measurement system provides a ±0.05°C resolution. The cold-junction compensation is done using a ±1°C accurate 0.0625°C resolution silicon temperature sensor, the MCP9804. This solution provides a reliable and accurate Thermocouple instrumentation without the need for extensive circuit compensation and calibration routines.

The ADC output is read using a PICmicro Microcontroller. This controller is also connected to a PC using USB interface. The Thermal Management software is used to plot the Thermocouple temperature data in stripchart format.

1.3 WHAT THE THERMOCOUPLE REFERENCE DESIGN KIT INCLUDES

This Thermocouple Reference Design Kit includes:

- Thermocouple Reference Design, 102-00114
- K-type Thermocouple
- Important Information Sheet

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Chapter 2. Installation and Operation

2.1 INTRODUCTION

The Thermocouple Reference Design demonstrates Microchip's solution to accurately measure temperature using a Thermocouple and an 18-bit ADC, MCP3421. This solution eliminates the need for the traditional analog instrumentation system calibration or gain and offset trimming techniques. In addition, the Thermocouple linearization techniques can be implemented in firmware or software.

The Thermocouple Reference Design allows user to evaluate Microchip's solution to accurately measure the temperature. When measuring temperature using a Thermocouple cold junction compensation is critical. It provides a reference to the thermocouple measurement. The MCP9804 provides the cold junction compensation at ±1°C accuracy. If the Thermocouple is compensated using the compensation equation provided by National Institute of Standards and Technology (NIST ITS-90), then temperature can be measured with ±1°C accuracy over the entire measurement range.

The MCP3421 and the MCP9804 serial output lines are connected to a PICMicro Microcontroller. This controller communicates with a PC via the USB interface and commands the ADC to convert voltage. The serial data is then displayed on the PC using the Thermal Management software in stripchart format.

2.2 FEATURES

The Thermocouple Reference Design has the following features:

- K-type Thermocouple
- Thermocouple connector
- Thermal Management GUI
- MCP9804 Temperature sensor with ±0.25°C (typical) accuracy from -40°C to +125°C
- 18-Bit ADC MCP3421
- PIC18F2550 PIC® Microcontroller
- USB interface to PC

2.3 GETTING STARTED

This section describes how to quickly configure the Thermocouple Reference Design. A simplified block diagram of the configuration is provided in Figure 2-1.

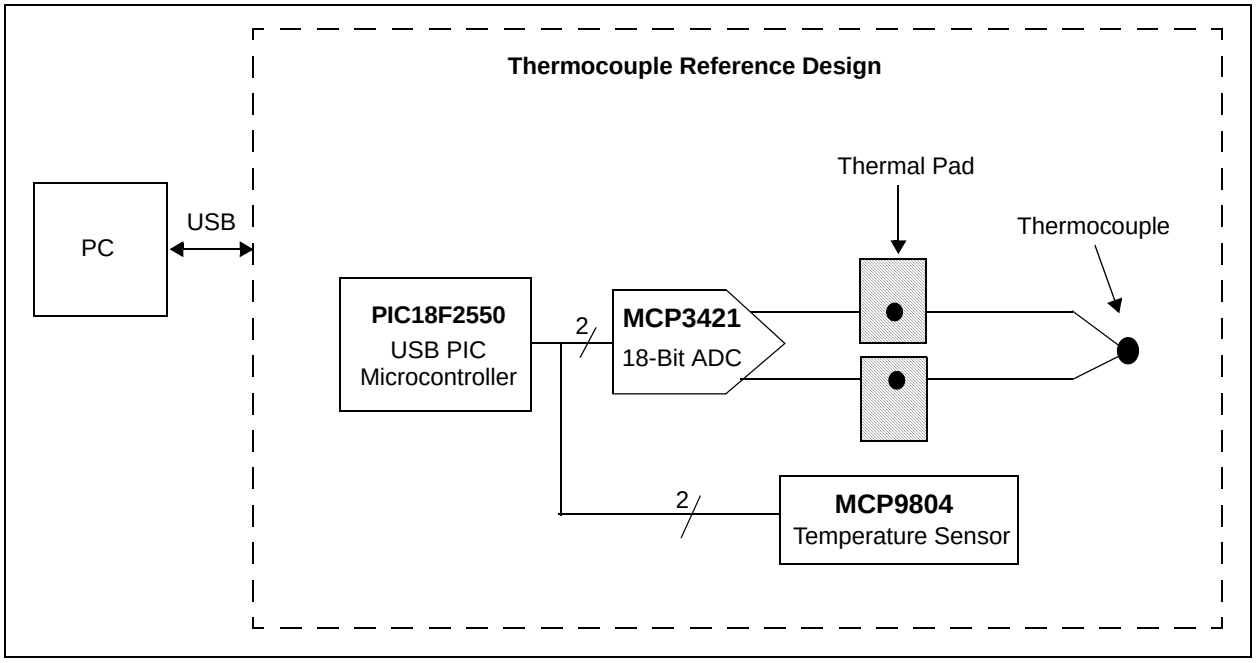


FIGURE 2-1: *Thermocouple Reference Design Simplified Block Diagram.*

2.3.1 Hardware Setup

1. Connect the USB cable to PC.
2. Start the Thermal Management software.
3. Click the **Start** icon to start acquisition and measure temperature from the Thermocouple.

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2.3.2 Software Setup

Once the USB interface is secured, start the Thermal Management Software. When the software starts, if the hardware is successfully detected then the GUI will be displayed.

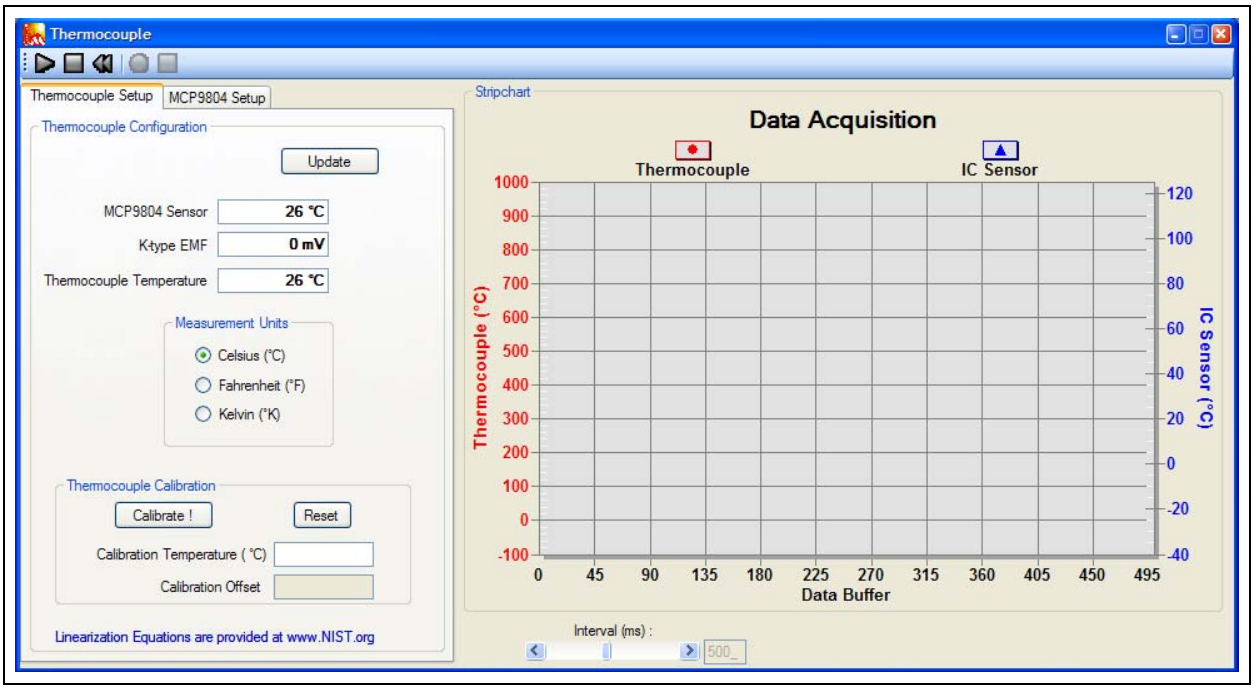


FIGURE 2-2: *Thermocouple Reference Design GUI.*

This configuration window allows the user to set some of parameters, such as measurement unit and calibration temperature.

The **Play**, **Stop** and **Reset** icons can be used to perform continuous data-log. The **Record** icon enables the user to data-log to an external file. The logging interval can be adjusted using the Interval Scroll bar from 100 ms to 30s.

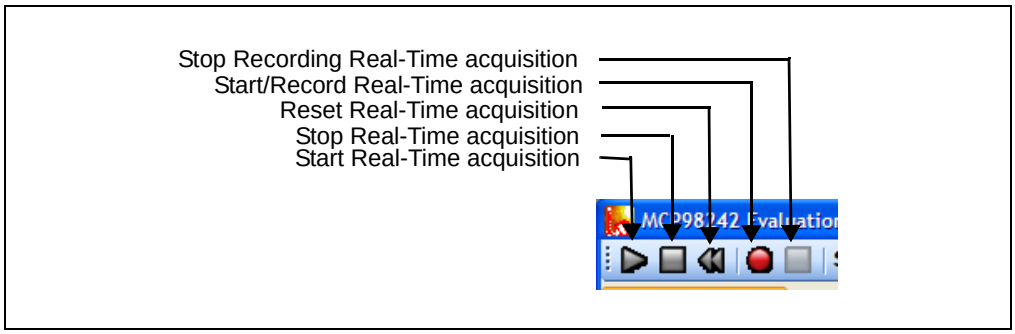


FIGURE 2-3: *Real-Time Acquisition.*

Thermocouple output is using the compensation equation provided by National Institute of Standards and Technology (NIST ITS-90). The linearization is implemented in the PICmicro microcontroller.

The Data Acquisition charting tool can be customized by double clicking the chart, as shown in Figure 2-4. Additional options are available by right-clicking the chart. The user can also zoom into a specific plot range by clicking and dragging the section. The data in the chart can also be exported using the **Export** button.

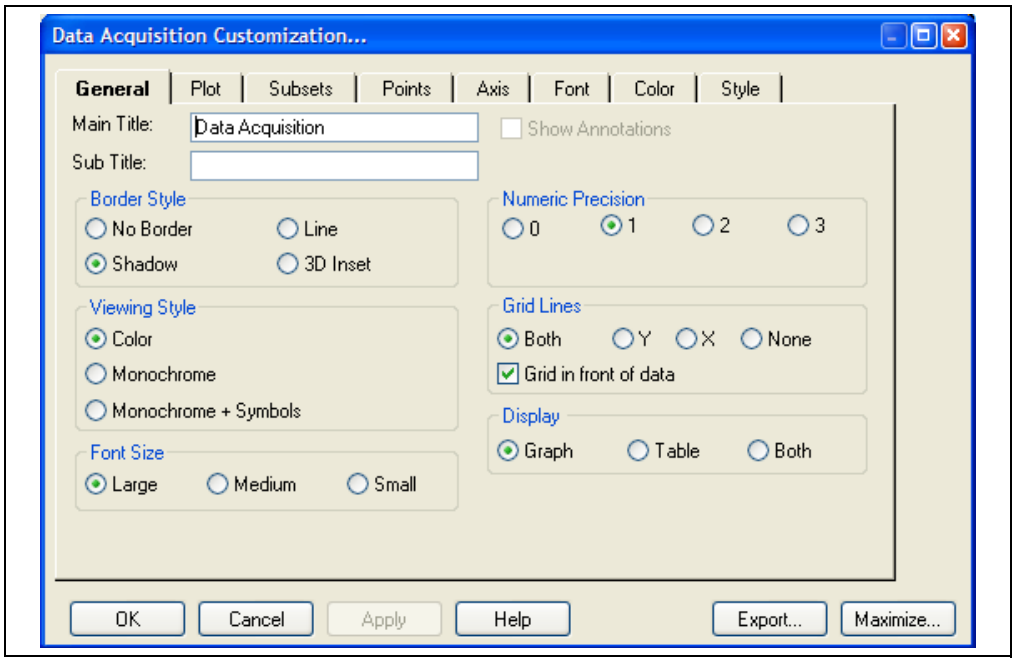


FIGURE 2-4: *Chart Setup Options.*

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2.3.3 Sensor Calibration and Setup

2.3.3.1 THERMOCOUPLE CALIBRATION

The Thermocouple sensor can be calibrated using the GUI. Once the Thermocouple sensor is exposed to the desired calibration temperature, simply type in the temperature in the Calibration Temperature field and click the **Calibrate** button. When the temperature is calibrated and the calibration offset is stored in the PIC Microcontroller EEPROM, the calibration offset is displayed in the RTD Calibration Offset text box. The **Reset** button resets the calibration offset to 0.

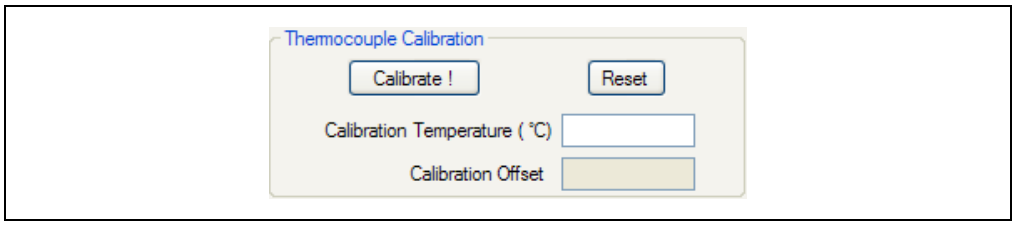


FIGURE 2-5: *Sensor Calibration.*

2.3.3.2 MCP9804 SETUP

The MCP9804 is a silicon temperature sensor which measures temperature with ±0.25°C nominal and ±1°C maximum accuracy from -40°C to +125°C. This sensor has multiple user programmable features such as Alert Output limits, output hysteresis and mode. The output mode can be set up as comparator or interrupt output with an active high or active low levels. The temperature measurement resolution can also be set up.

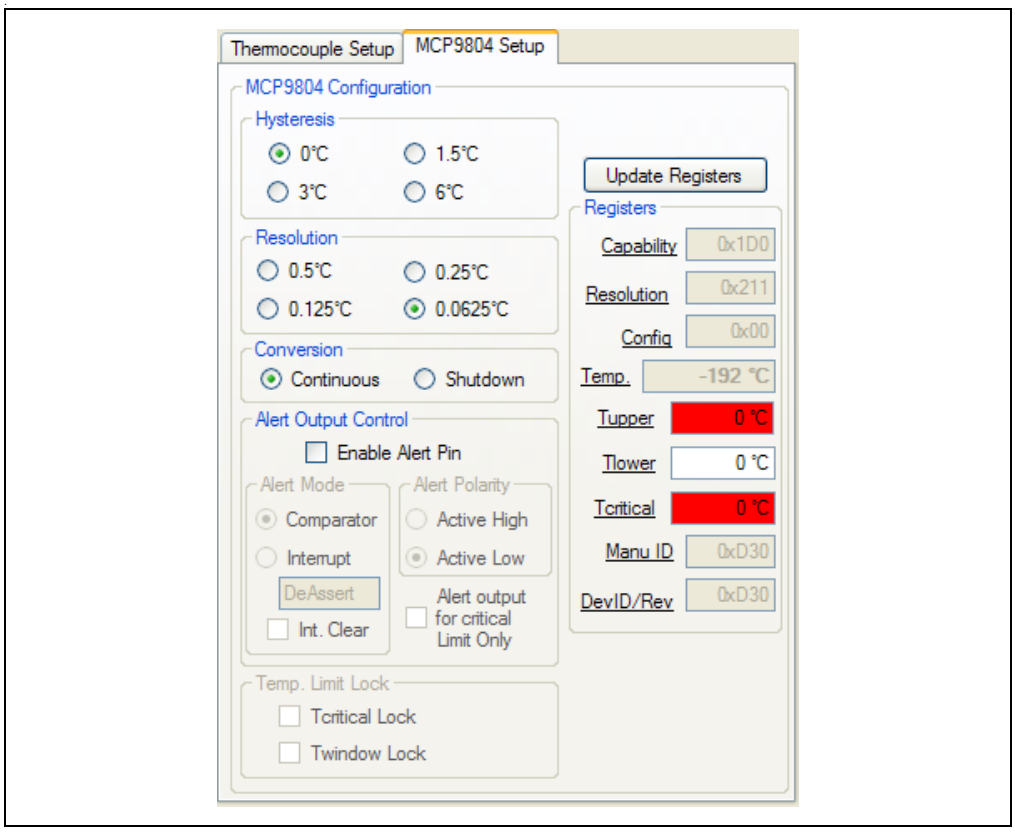


FIGURE 2-6: *MCP9804 Setup.*

NOTES:

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Appendix A. Schematic and Layouts

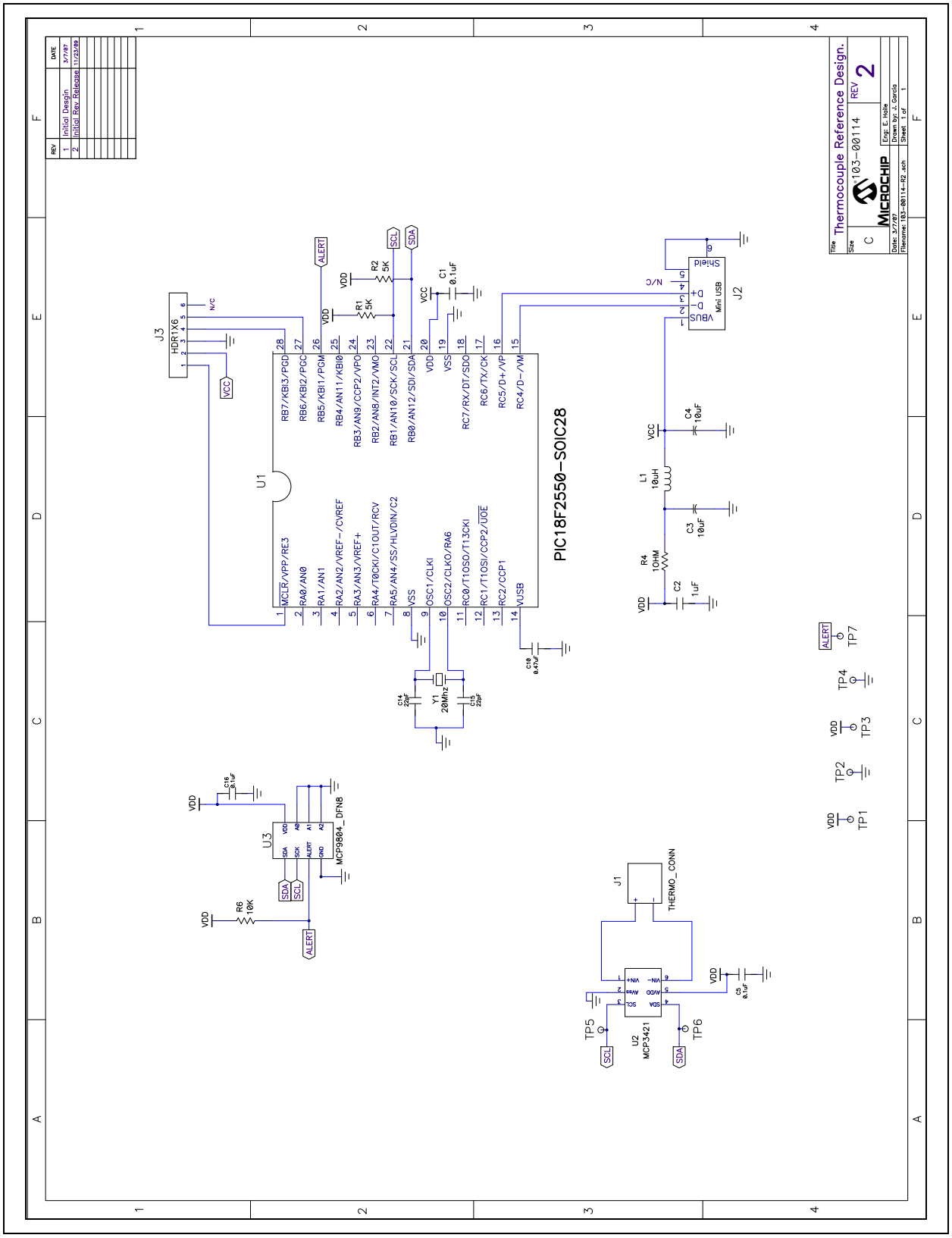
A.1 INTRODUCTION

This appendix contains the following schematics and layouts for the Thermocouple Reference Design:

- Board - Schematic
- Board -Top Silk and Pads
- Board - Internal V_{DD} Layer
- Board - Internal Ground Layer
- Board - Bottom Silk and Pads

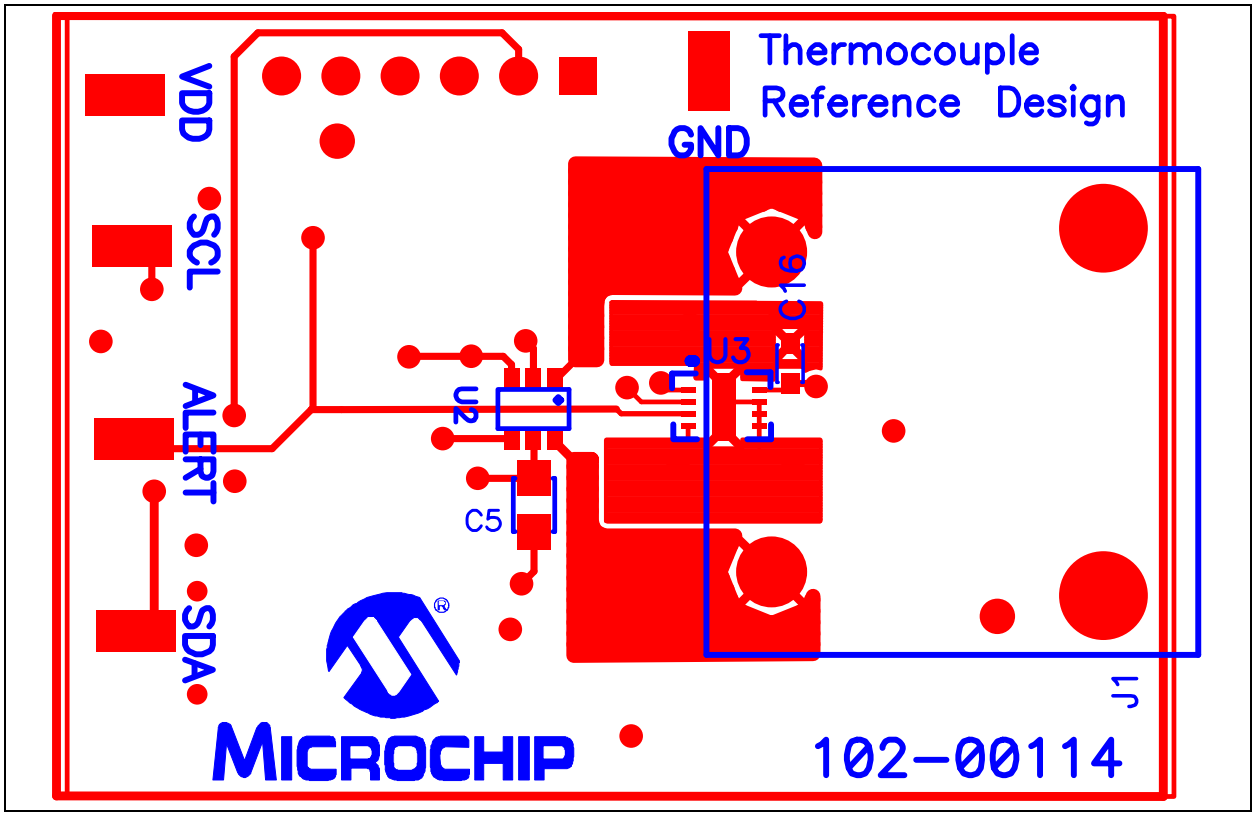
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A.2 BOARD - SCHEMATIC

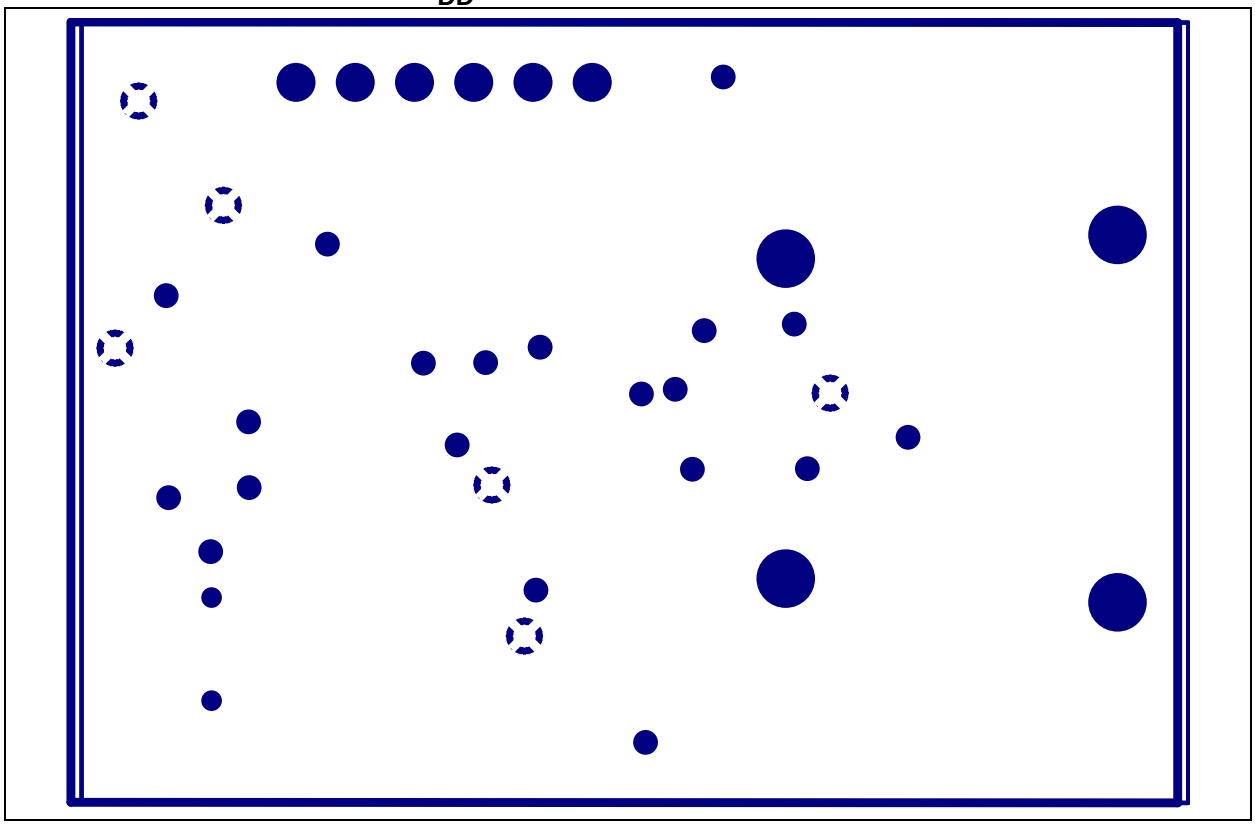


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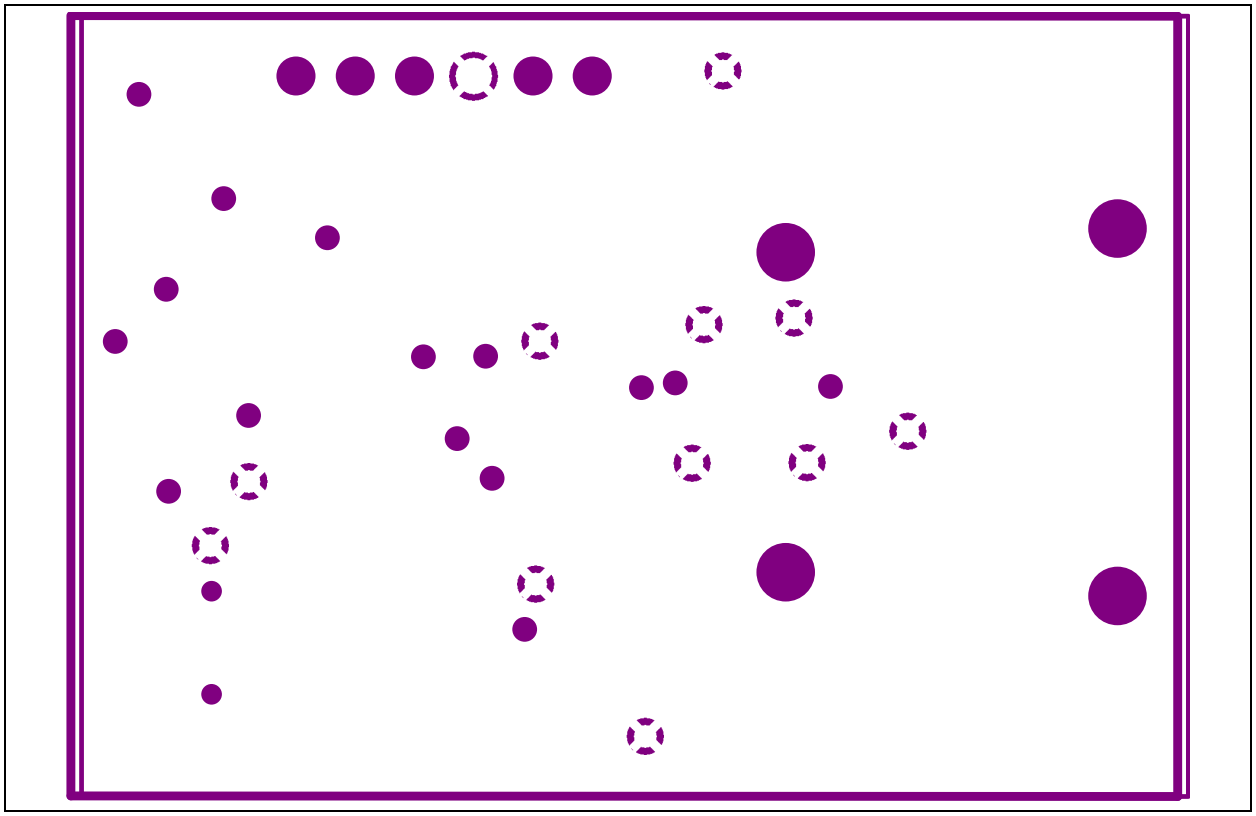
A.3 BOARD -TOP SILK AND PADS



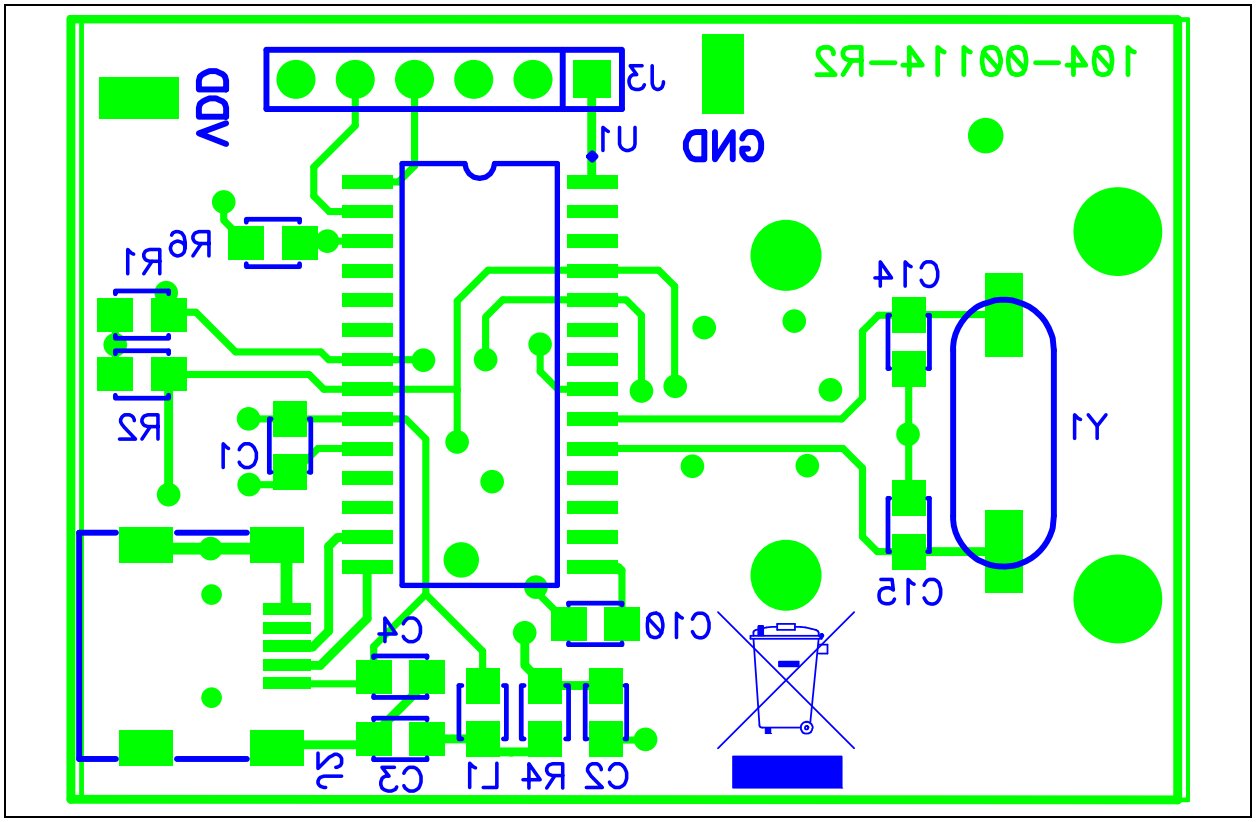
A.4 BOARD - INTERNAL V_{DD} LAYER



A.5 BOARD - INTERNAL GROUND LAYER



A.6 BOARD - BOTTOM SILK AND PADS



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Appendix B. Bill of Materials

TABLE B-1: BILL OF MATERIALS

Qty	Reference Designator	Description	Manufacturer	Manufacturer Part Number
1	—	Ready-Made Insulated Thermocouples with Kapton, PFA, Glass Braid Insulation and Molded Connectors	OMEGA®	5SRTC-GG-K-24-36
3	C1, C5, C16	CAP .1UF 25V CERAMIC X7R 0805	Panasonic® - ECG	ECJ-2VB1E104K
1	C2	CAP 1.0UF 16V CERAMIC X7R 0805	Kemet® Electronics Corp.	C0805C105K4RACTU
2	C3, C4	CAP CER 10UF 16V Y5V 0805	Murata Electronics®	GRM21BF51C106ZE15L
1	C10	CAP .47UF 16V CERAMIC X7R 0805	Panasonic - ECG	ECJ-2YB1C474K
2	C14,C15	CAP 22PF 50V CERM CHIP 0805 SMD	Panasonic - ECG	ECJ-2VC1H220J
1	J1	Circuit Board Thermocouple Connectors, Standard PCC-SMP-K-100"	OMEGA	PCC-SMP-K-100
1	J2	CONN MINI USB RCPT RA TYPE B SMD	Tyco® Electronics	1734035-2
1	J3	HEADER 1X6 - DO NOT POPULATE	—	—
1	L1	INDUCTOR 10UH 100MA 0805	Murata Electronics	LQM21FN100M70L
1	PCB	RoHS Compliant Bare PCB, Thermocouple Reference Design	Microchip Technology Inc.	104-00114
2	R1, R2	RES 4.99K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF4991V
1	R4	RES 1.0 OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6RQF1R0V
1	R6	RES 10.0K OHM 1/8W 1% 0805 SMD	Panasonic - ECG	ERJ-6ENF1002V
7	TP1-TP7	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	MCP3421, 18-Bit Analog-to-Digital Converter with I^2C Interface and On-Board Reference	Microchip Technology Inc.	**MCP3421A0T-E/OT**
1	U3	MCP9804, Memory Module Digital Temperature Sensor	Microchip Technology Inc.	**MCP9804T-E/MC**
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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