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CE211321 - Interfacing the PSoC® Analog Coprocessor with a Temperature Sensor

Objective

This code example demonstrates how to implement an analog front end (AFE) for a thermistor using the PSoC Analog Coprocessor.

Overview

This code example demonstrates how to measure the thermistor resistance and calculate temperature. The PSoC Creator Thermistor Calculator Component simplifies the math-intensive resistance-to-temperature conversion. The measured thermistor resistance and calculated temperature are sent over I^2C to a host PC running Cypress's Bridge Control Panel (BCP) software. The temperature value is used to control the color of the RGB LED on the CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit. Refer the Kit Guide of CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit for details on the hardware involved in interfacing PSoC Analog Coprocessor with a thermistor. Refer the Related Documents section to get the list of Application Notes that discuss AFE implementation for different types of sensors.

Requirements

Tools: PSoC® Creator™ 3.3 CP3 or later versions, Bridge Control Panel (part of PSoC Programmer™) 1.14 or later versions

Programming Language: C (ARM® GCC 4.9.3)

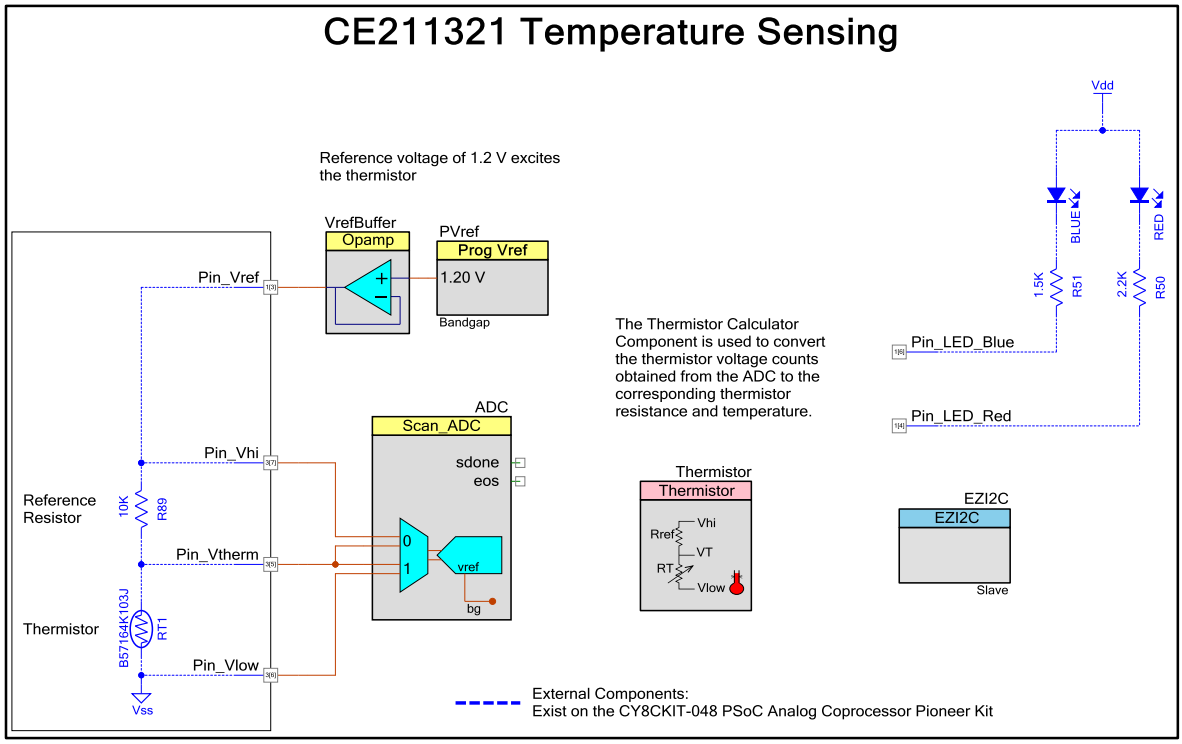
Associated Parts: All PSoC Analog Coprocessor parts

Related Hardware: CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit

Design

Figure 1 shows the PSoC Creator schematic for interfacing a thermistor with the PSoC Analog Coprocessor.

Figure 1. Temperature Sensing Schematic



The CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit has a thermistor RT1 (B57164K103J). A 10 kΩ reference resistor, R89 (R_{ref}), is connected in series with the thermistor.

The thermistor and R_{ref} are excited using a 1.2 V bandgap voltage used as the reference voltage. The bandgap voltage is independent of supply voltage fluctuations and therefore provides a stable voltage reference. This voltage is generated using the programmable reference Component PV_{ref}, and is buffered using an Opamp. The same bandgap voltage is used as the ADC reference. This enables measurement in the full-scale range of the ADC and results in an increased resolution of the voltage measurement.

Three voltage signals (V_{therm}, V_{low}, and V_{hi}) from the resistor divider are connected to two differential channels of the Scanning successive approximation register (SAR) ADC Component. The thermistor resistance (R_T) is calculated from the ADC count using the following equation:

$$R_T = R_{ref} \times \left(\frac{V_{therm} - V_{low}}{V_{hi} - V_{therm}}\right)$$

The temperature value is then derived by passing the measured resistance to the Thermistor Calculator Component. The Thermistor Calculator Component uses a lookup table to calculate the temperature with a resolution of 0.1 °C.

The measured thermistor voltage ($V_{therm} - V_{low}$), the thermistor resistance, and the temperature value are sent over I^2C to a host PC. When the temperature is less than 25 °C, the blue LED is turned ON; when the temperature is between 25 °C and 30 °C, both the blue LED and red LED are turned ON; and when the temperature exceeds 30 °C, the red LED is turned ON.

Design Considerations

This design can be adapted to other thermistor sensors. You may need to change the R_{ref} Value depending on the thermistor characteristics.

This code example is designed for the PSoC Analog Coprocessor Pioneer Kit. The design is easily portable to other kits and PCBs, typically by just changing the sensor, I^2C, or LED pin assignments.

Hardware Setup

Set the SW4 switch on the PSoC Analog Coprocessor Pioneer Kit to the 'REG' position to select the regulator as the V_{DD} source. Set jumper J9 to 1-2 for 3.3 V device operation. If you want to use a different power source or a different V_{DD} value, select the SW4 and J9 settings based on Table 1.

Table 1. PSoC Analog Coprocessor Pioneer Kit Power Supply Source and V_{DD} Selection

Power Supply Source	V_{DD} (volts)	SW4 (switch position)	J9 (jumper position)
USB	1.8	REG	open
	3.3	REG	1-2
	5.0	USB	Any position except 2-3
	1.8-3.3	REG	4-2
External VIN	1.8	REG	open
	3.3	REG	1-2
	5.0	REG	2-3
Arduino baseboard	1.8	REG	open
	3.3	REG	1-2
Coin Cell	3.0	BAT	NA

Connect the PSoC Analog Coprocessor Pioneer Kit to your computer's USB port using the USB cable provided with the kit as Figure 2 shows.

Figure 2. Hardware Connection



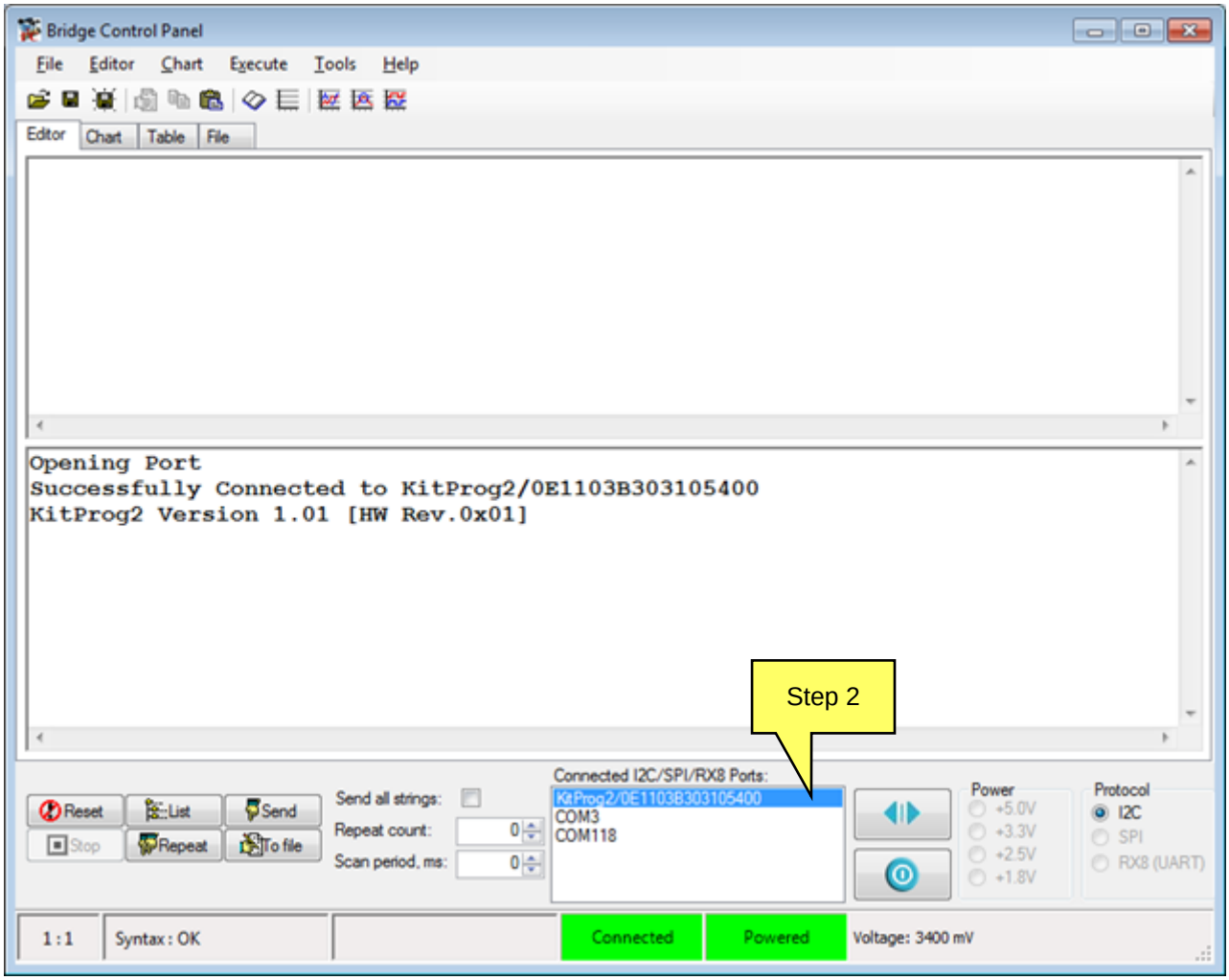
Software Setup

This section describes how to set up the Cypress BCP software for viewing the sensor data sent over I^2C.

The BCP software is installed automatically as part of the kit software installation. It can also be downloaded as part of PSoC Programmer software. Follow these steps to configure the BCP software:

1. Open the BCP software from: **Start** > **All Programs** > **Cypress** > **Bridge Control Panel <version>** > **Bridge Control Panel <version>.**
2. Under **Connected I2C/SPI/RX8 Ports,** select **KitProg2/<serial number>** as Figure 3 shows. Note that the PSoC Analog Coprocessor Pioneer Kit must be connected to the USB port of your computer.

Figure 3. Bridge Control Panel

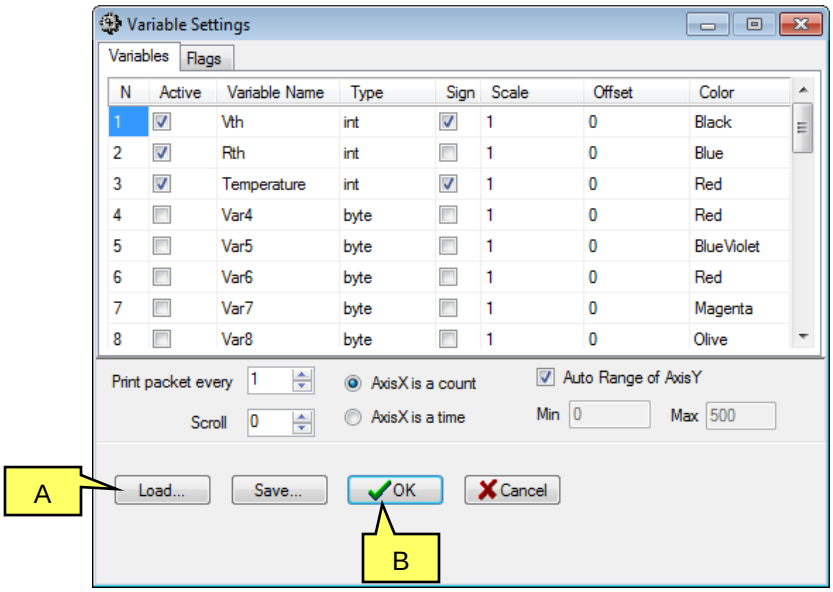


3. Select the menu item **Tools** > **Protocol Configuration**, navigate to the **I2C** tab, and set the **I2C speed** to '100 kHz'. Click **OK**.

4. Select the menu item **Chart** > **Variable Settings**, and
   A. **Load** the *CE211321_Temperature_Sensing.ini* file from the following path: `<Install_Directory>\CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit\<version>\Firmware\PSoC Analog Coprocessor\BCP Command\`.
   B. Click **OK** as Figure 4 shows.

   This file includes the variable names, their data type, and their signs to represent the data sent over I^2C.

Figure 4. Variable Settings in Bridge Control Panel Software



The BCP software is now ready for reading and displaying the sensor data. Refer to the Operation section for the testing procedure.

Components

Table 2 lists the PSoC Creator Components used in this example, and the hardware resources used by each Component.

Table 2. List of PSoC Creator Components

Component	Instance Name	Version	Hardware Resources
Scanning SAR ADC	ADC	v1.10	SAR ADC
PVref	PVref	v1.0	Programmable Reference Block (PRB)
Opamp	VrefBuffer	v1.20	Continuous Time Block (CTB)
Thermistor Calculator	Thermistor	v1.20	-
EZI2C Slave (SCB mode)	EZI2C	v3.20	Serial Communication Block (SCB)
Analog Pin	Pin_Vhi, Pin_Vtherm, Pin_Vlow, Pin_Vref	v2.20	I/O
Digital Output Pin	Pin_LED_Blue, Pin_LED_Red	v2.20	I/O

Parameter Settings

Table 3 lists the nondefault settings of all the Components used in the design.

Table 3. Component Parameters

Component Instance Name	Settings (Non-Default)
ADC	Free-run scan rate (SPS): 1000
PVref	-
VrefBuffer	Mode : Follower Output: Output to pin Power/Bandwidth: High
Thermistor	Implementation: LUT Temperature > Max: 125 °C Min: -40 °C Temperature and Resistance > Max: 260 Ω Min: 41,9380 Ω
EZI2C	-
Pin_Vhi, Pin_Vtherm, Pin_Vlow, Pin_Vref	External terminal: Enabled
Pin_LED_Blue, Pin_LED_Red	External terminal: Enabled Digital output > HW connection: Disabled Initial drive state: High (1)

Note: EZI2C pins are embedded within the Component.

Design-Wide Resources

Table 4 lists the physical pins used.

Table 4. Pin Names and Locations

Pin Name	Location
EZI2C: SCL	P4[0]
EZI2C: SDA	P4[1]
Pin_LED_Blue	P1[6]
Pin_LED_Red	P1[4]
Pin_Vhi	P3[7]
Pin_Vlow	P3[6]
Pin_Vref	P1[3]
Pin_Vtherm	P3[5]

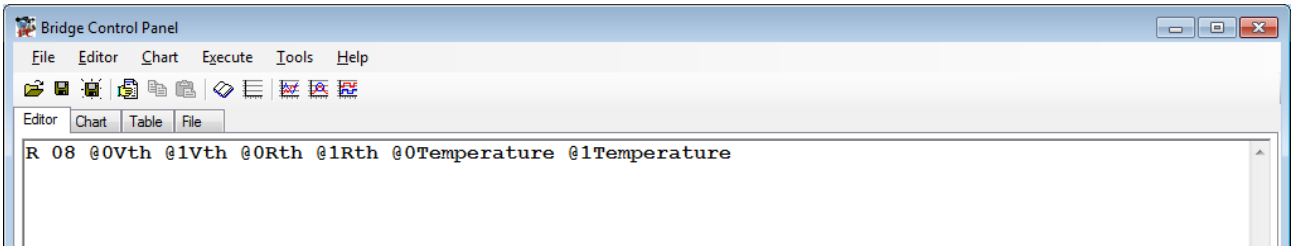
Operation

Follow these steps:

1. Select the *CE211321_Temperature_Sensing.cywrk* file in the PSoC Creator Start page under **Examples and Kits** > **Kits** > **CY8CKIT-048**. Select a location to save the code example.
2. Build the project; select the PSoC Creator menu item **Build** > **Build CE211321_Temperature_Sensing**.
3. Connect the PSoC Analog Coprocessor Pioneer Kit to your computer's USB port as described in the section Hardware Setup.
4. Program the PSoC Analog Coprocessor device; select **Debug** > **Program**.
5. Configure the BCP software as described in the Software Setup section.
6. Select **File** > **Open File**. Open the *CE211321_Temperature_Sensing.iic* file from the following path:
   `<Install_Directory>\CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit\<version>\Firmware\PSoC Analog Coprocessor\BCP Command\`

   This file contains the read command to be executed by the BCP software. The command appears on the BCP software as Figure 5 shows.

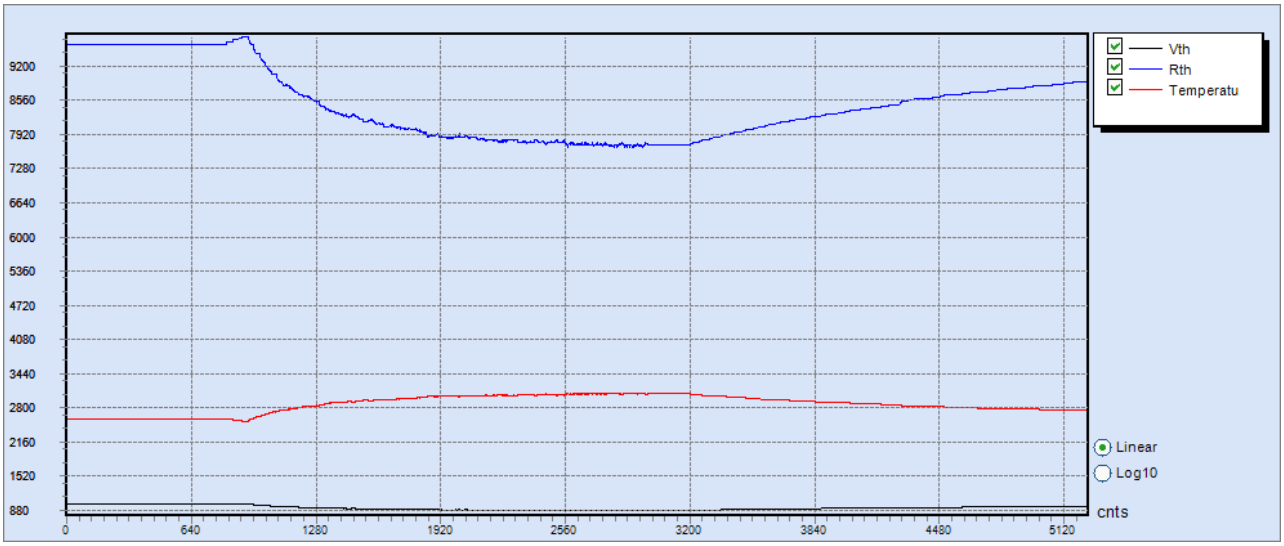
Figure 5. Read Command in the Bridge Control Panel



7. Click the read command on the **Editor** tab. Then click the **Repeat** button to read the sensor data continuously.
8. Go to the **Chart** tab and observe the plot of the three values – thermistor voltage, thermistor resistance, and temperature – that are read from the PSoC Analog Coprocessor device. See Figure 6.

   Notice that the temperature value is scaled by 100. For example, if the temperature is 25 °C, then the displayed count is 2500. V_{th} is the ADC count that corresponds to the voltage across the thermistor. R_{th} is the calculated thermistor resistance in ohms.

Figure 6. Temperature Sensor Values Displayed on the Bridge Control Panel Chart



9. Notice that the blue and red LED turn ON/OFF with respect to the temperature. See Table 5 for reference.

Table 5. LED Status

Temperature	LED Status
<25°C	Blue color
25°C to 30°C	Violet color
>30°C	Red color

Related Documents

Table 6 lists all relevant application notes, device datasheets, technical reference manuals, Component datasheets, and development kits.

Table 6. Related Documents

Application Notes		
AN211293	Getting Started with PSoC Analog Coprocessor	Describes the PSoC Analog Coprocessor
AN211294	AFE Implementation Using PSoC Analog Coprocessor	Discusses the AFE implementation of different types of sensors
AN66477	PSoC 3, PSoC 4, and PSoC 5LP - Temperature Measurement with a Thermistor	Describes thermistor temperature measurement using PSoC 3, PSoC 4, and PSoC 5LP devices.
PSoC Creator Component Datasheets		
Scanning SAR ADC	Supports multiple-channel hardware scan with single-ended and differential input modes	
PVref	Generates configurable voltage references using the internal bandgap voltage or supply voltage V_{DDA}	
Opamp	Supports the voltage follower mode and the Opamp mode with configurable power	
Thermistor Calculator	Supports the Steinhart-Hart equation and LUT method to calculate the temperature	
EZI2C Slave	Simplified I2C slave implementation	
Pins	Supports the connection of hardware resources to physical pins	
Device Documentation		
PSoC Analog Coprocessor Datasheets		
PSoC Analog Coprocessor Architecture Technical Reference Manual		
PSoC Analog Coprocessor Register Technical Reference Manual		
Development Kit (DVK) Documentation		
CY8CKIT-048 PSoC Analog Coprocessor Pioneer Kit		

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Document History

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Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	5301099	DIMA	08/18/2016	New code example.

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