# CE223621 – Interfacing PSoC 4 with a Temperature Sensor

## Objective

This code example demonstrates how to implement an analog front end (AFE) for a thermistor using PSoC 4100PS.

## 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 I²C to a host PC running Cypress's Bridge Control Panel (BCP) software. Refer to the Related Documents section for a list of application notes that discuss AFE implementation for different types of sensors.

## Requirements

**Tools:** PSoC Creator 4.2 or later versions, Bridge Control Panel (part of PSoC Programmer™) 1.18 or later versions

**Programming Language:** C (Arm® GCC 5.4)

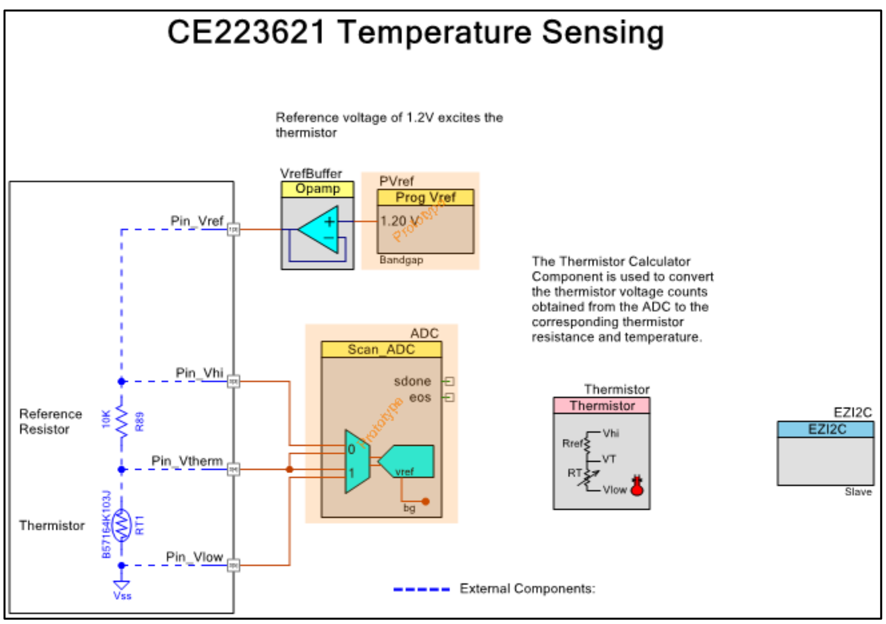
**Associated Parts:** PSoC 4100PS

**Related Hardware:** CY8CKIT-147 PSoC 4100PS Prototyping Kit

## Design

Figure 1 shows the PSoC Creator schematic for interfacing a thermistor with the PSoC 4100PS.

Figure 1. Temperature Sensing Schematic




A 10-kΩ reference resistor is connected in series with the thermistor (B57164K103J).

The thermistor and $R_{ref}$ are excited using a 1.2 V bandgap voltage 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.

## 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.

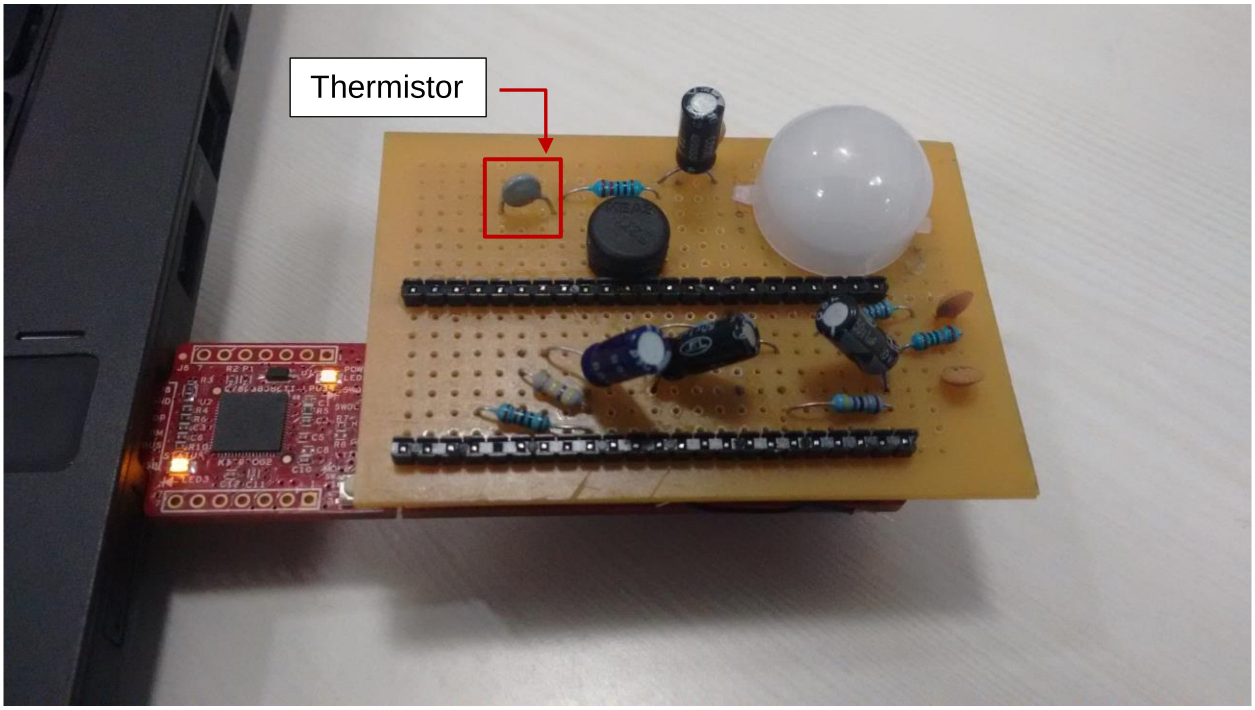
This code example is designed for the PSoC 4100PS Prototyping Kit. The design is easily portable to other kits and PCBs, typically by just changing the sensor or $I^2C$ pin assignments.

## Hardware Setup

This code example uses the sensor and reference resistor mounted on a general-purpose PCB (used as customized shield hardware) to make the connection shown in Figure 1.

Stack up the custom shield and CY8CKIT-147 PSoC 4100PS Prototyping Kit and connect it to your computer's USB port as Figure 2 shows.

Figure 2. Hardware Connection



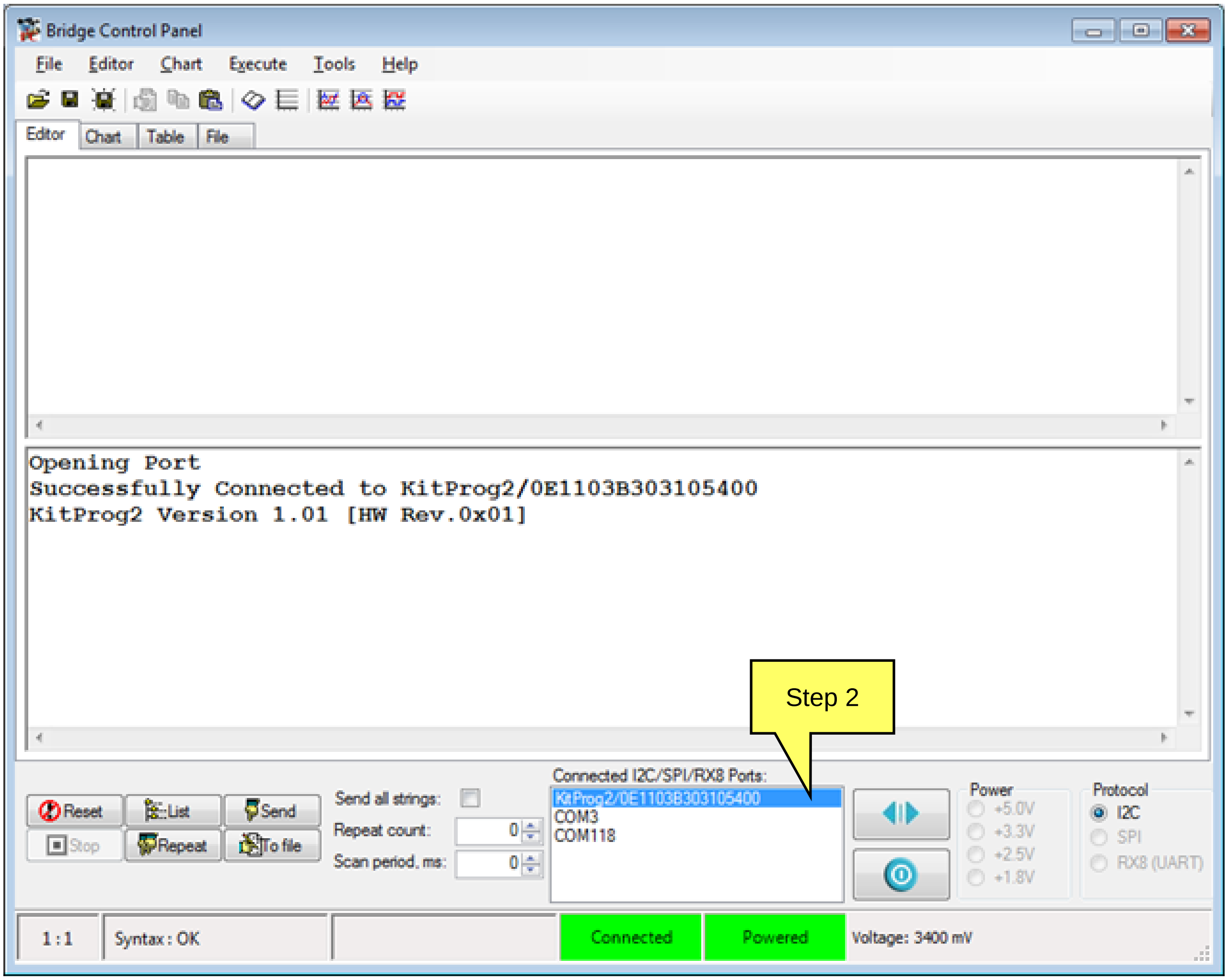

## Software Setup

This section describes how to set up the Cypress BCP software to view 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 4100PS Prototyping Kit must be connected to the USB port of your computer.

Figure 3. Bridge Control Panel

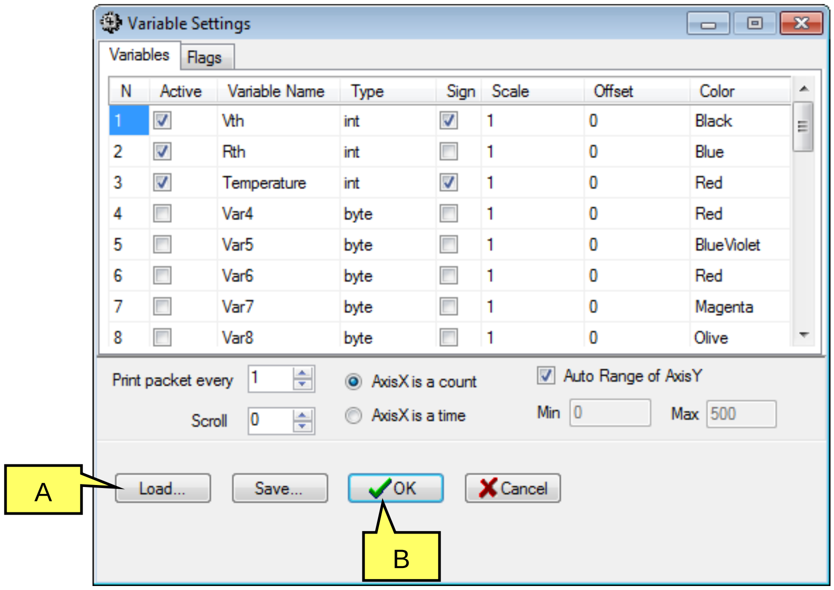



3. Select the menu item **Tools** > **Protocol Configuration**, navigate to the **I2C** tab, and set the **I2C speed** to ‘100 kHz’. Click **OK**.

4. Select the menu item **Chart** > **Variable Settings**, and
   A. **Load** the *CE223621_Temperature_Sensing.ini* file from the following path: `CE223621_Temperature_Sensing\CE223621_Temperature_Sensing.cydsn\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$^2$C.

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

Table 1. List of PSoC Creator Components

| Component | Instance Name | Version | Hardware Resources |
|---|---|---|---|
| Scanning SAR ADC | ADC | v2.20 | 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 | v4.0 | Serial Communication Block (SCB) |
| Analog Pin | Pin_Vhi, Pin_Vtherm, Pin_Vlow, Pin_Vref | v2.20 | I/O |

### Parameter Settings

Table 2 lists the nondefault settings of all the Components used in the design.

Table 2. Component Parameters

| Component Instance Name | Settings (Non-Default) |
|---|---|
| ADC | Free-run scan rate (SPS): 1000 |
| PVref | - |
| VrefBuffer | Mode: Follower<br>Output: Output to pin<br>Power/Bandwidth: High |
| Thermistor | Implementation: LUT<br>Temperature ><br>Max: 125 °C<br>Min: -40 °C<br>Temperature and Resistance ><br>Max: 260 Ω<br>Min: 41,9380 Ω |
| EZI2C | - |
| Pin_Vhi, Pin_Vtherm, Pin_Vlow, Pin_Vref | External terminal: Enabled |

**Note:** EZI2C pins are embedded within the Component.

### Design-Wide Resources

Table 3 lists the physical pins used.

Table 3. Pin Names and Locations

| Pin Name | Location |
|---|---|
| EZI2C: SCL | P3[6] |
| EZI2C: SDA | P3[7] |
| Pin_Vhi | P3[3] |
| Pin_Vlow | P3[5] |
| Pin_Vref | P1[3] |
| Pin_Vtherm | P3[4] |

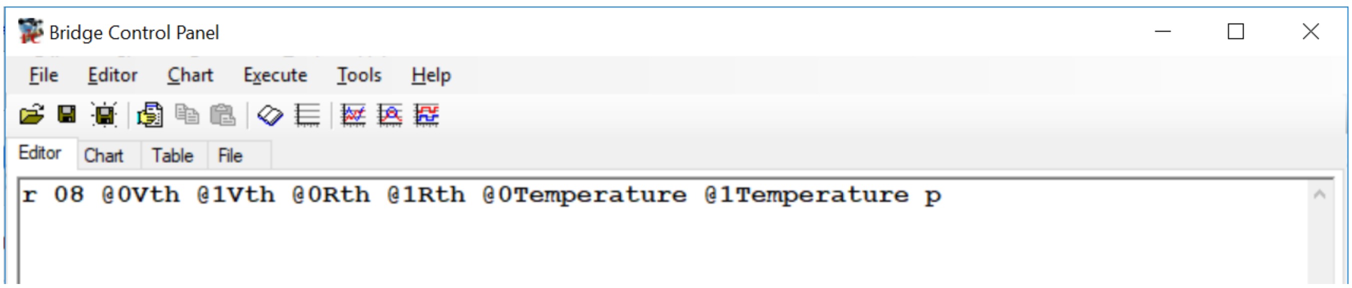
## Operation

Follow these steps:

1. Open the project attached with this code example in PSoC Creator.
2. Build the project; select the PSoC Creator menu item **Build** > **Build CE223621_Temperature_Sensing**.
3. Connect the PSoC 4100PS Prototyping Kit to your computer's USB port as described in the Hardware Setup section.
4. Program the PSoC 4100PS device; select **Debug** > **Program**.
5. Configure the BCP software as described in the Software Setup section.
6. Select **File** > **Open File**. Open the *CE223621_Temperature_Sensing.iic* file from the following path: `CE223621_Temperature_Sensing\CE223621_Temperature_Sensing.cydsn\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.

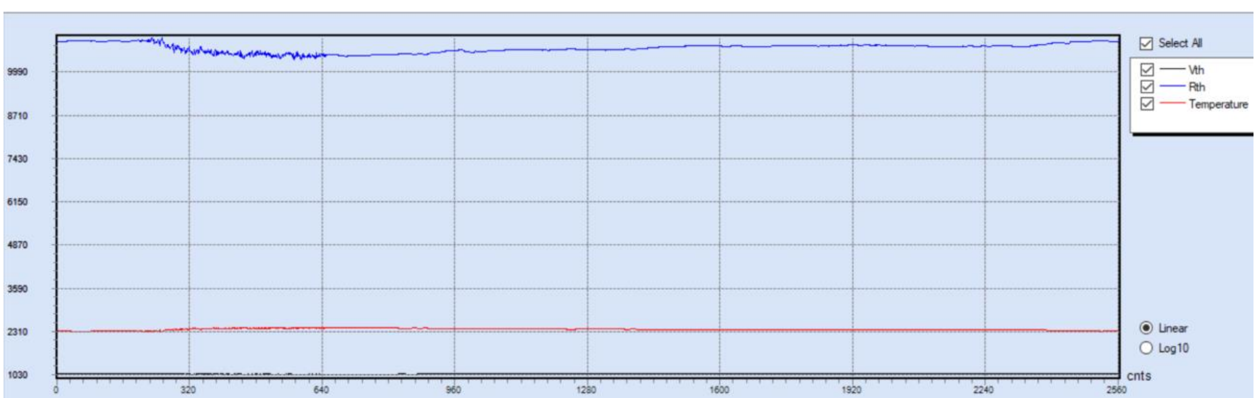
Figure 5. Read Command in the Bridge Control Panel




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 4100PS 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



## Related Documents

Table 4 lists all relevant application notes, device datasheets, technical reference manuals, Component datasheets, and development kits.

Table 4. Related Documents

| | | |
|---|---|---|
| **Application Notes** | | |
| AN79953 | Getting Started with PSoC 4 | Describes the PSoC 4100PS |
| AN223616 | AFE Implementation Using PSoC 4 | 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 4100PS Datasheet | | |
| PSoC 4100PS Architecture Technical Reference Manual | | |
| PSoC 4100PS Register Technical Reference Manual | | |
| **Development Kit (DVK) Documentation** | | |
| CY8CKIT-147 PSoC 4100PS Prototyping Kit | | |

# Document History

Document Title: CE223621 - Interfacing PSoC 4 with a Temperature Sensor

Document Number: 002-23621

| Revision | ECN | Orig. of Change | Submission Date | Description of Change |
|---|---|---|---|---|
| ** | 6153503 | DIMA | 04/25/2018 | New code example. |

## Worldwide Sales and Design Support

Cypress maintains a worldwide network of offices, solution centers, manufacturers' representatives, and distributors. To find the office closest to you, visit us at Cypress Locations.

### Products

| | |
|---|---|
| Arm® Cortex® Microcontrollers | cypress.com/arm |
| Automotive | cypress.com/automotive |
| Clocks & Buffers | cypress.com/clocks |
| Interface | cypress.com/interface |
| Internet of Things | cypress.com/iot |
| Memory | cypress.com/memory |
| Microcontrollers | cypress.com/mcu |
| PSoC | cypress.com/psoc |
| Power Management ICs | cypress.com/pmic |
| Touch Sensing | cypress.com/touch |
| USB Controllers | cypress.com/usb |
| Wireless Connectivity | cypress.com/wireless |

### PSoC® Solutions

PSoC 1 | PSoC 3 | PSoC 4 | PSoC 5LP | PSoC 6 MCU

### Cypress Developer Community

Community Forums | Projects | Videos | Blogs | Training | Components

### Technical Support

cypress.com/support

PSoC Creator is a trademark of Cypress Semiconductor Corp.

Cypress Semiconductor
198 Champion Court
San Jose, CA 95134-1709