# CE210528 – PSoC 3 and PSoC 5LP Thermistor Calibration

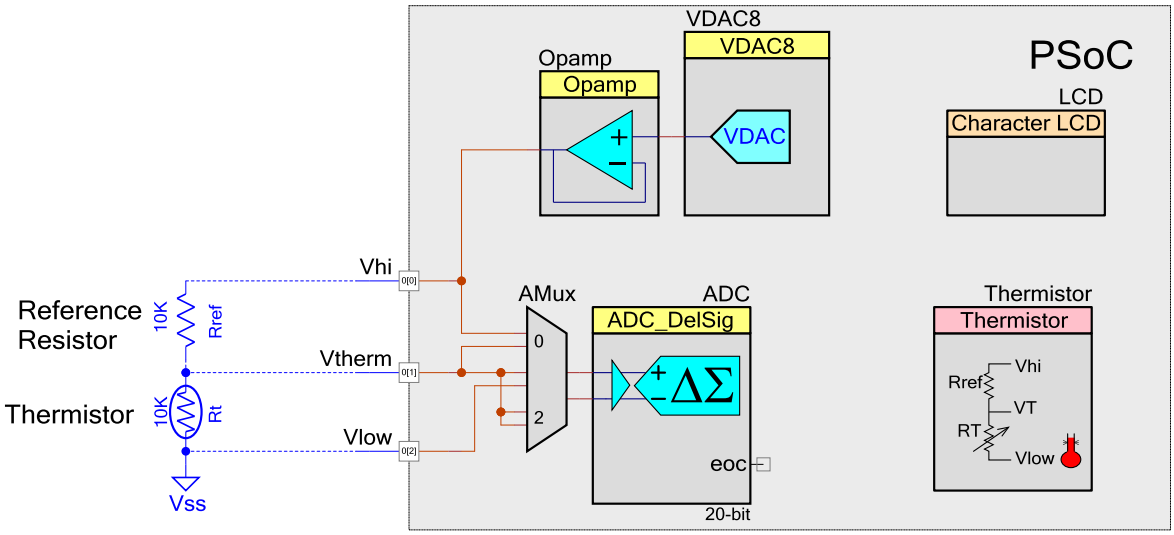
## Objective

This example shows how to use a PSoC® 3 or PSoC 5LP to calibrate a thermistor for better temperature measurement accuracy.

## Overview

Figure 1 shows a typical circuit for thermistor temperature measurement.

Figure 1. Thermistor Temperature Measurement




The resistance of the thermistor is obtained by the following equation:

$$Rt = Rref * \frac{Vhi - Vtherm}{Vtherm - Vlow}$$

Most applications hard-code Rref to its nominal value, such as 10 kΩ. Any error in Rref results in an error in this calculation, which in turn causes errors in temperature measurement. AN66477 shows that this error can be as high as 0.5 °C. The best way to overcome this error is to determine the actual value of Rref and use that instead of a hard-coded value. This code example demonstrates how that can be done.

Also, the thermistor itself can have errors. This code example demonstrates how to remove any offset errors associated with the thermistor.

## Requirements

**Tool:** PSoC Creator™ 4.2 or newer

**Programming Language:** C (Arm® GCC 5.4.1, Arm MDK 5.22, DP8051 Keil 9.51)

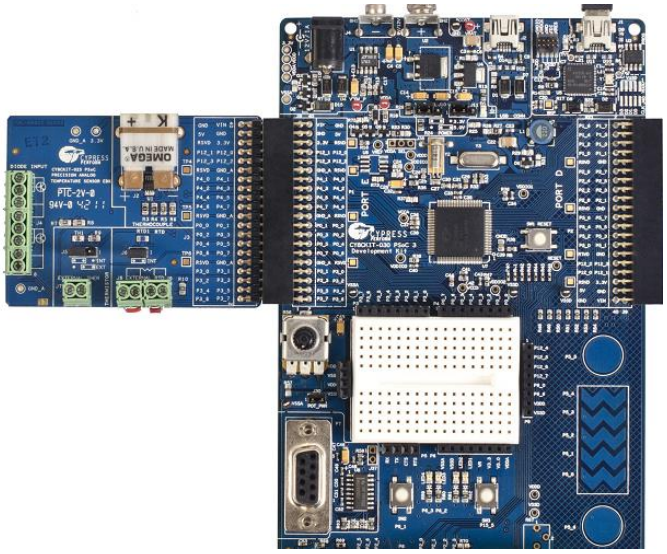
**Associated Parts:** All PSoC 3 and PSoC 5LP parts

**Related Hardware:** CY8CKIT-050, CY8CKIT-030, CY8CKIT-025

## Hardware Setup

1. Plug CY8CKIT-025 into PORT E of either CY8CKIT-030 or CY8CKIT-050, as Figure 2 shows.

Figure 2. CY8CKIT-025 Plugged into CY8CKIT-050



2. (Optional) Plug an external thermistor into J7 and set J5 to INT on CY8CKIT-025.
3. (Optional) Connect an LCD to the LCD port on CY8CKIT-030 or CY8CKIT-050.
4. Connect P3[7] to TX on the P5 connector and P3[6] to RX on the P5 connector on CY8CKIT-030 or 050. This connects the UART to the DB9 connector.
5. Connect a DB9 cable from CY8CKIT-030 or CY8CKIT-050 to a PC.

## Software Setup

This example firmware supports a terminal emulator interface. A UART interface outputs the temperature data to a terminal program on a PC.

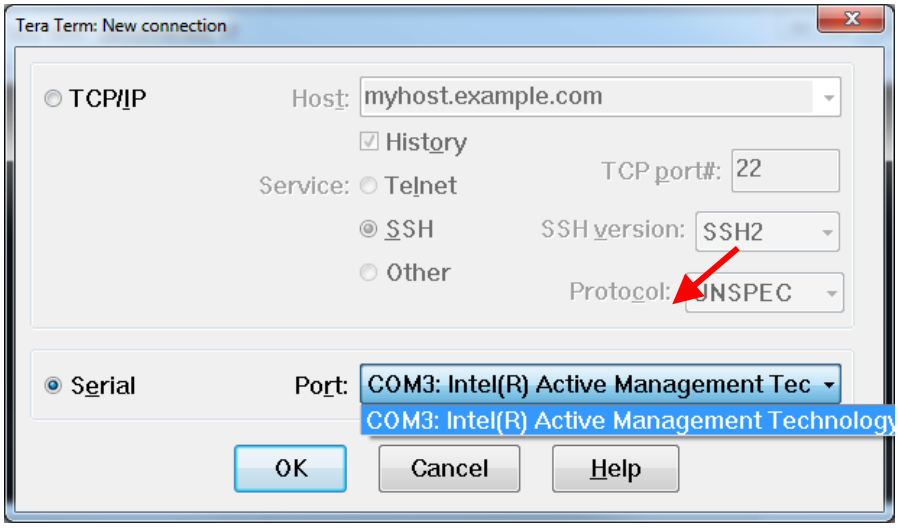
### Serial Terminal

The documentation for setting up a terminal emulator for this example uses TeraTerm, but any terminal emulator software that you can configure with the standard UART settings shown in Figure 4 may be used. TeraTerm is open source and downloadable directly from the author's website, https://en.osdn.jp/projects/ttssh2/.

1. Create new connection.

   Launch TeraTerm and select **File** > **New connection**. Select **Serial** as the connection type, and choose the COM port where you connected the DB9 cable, as Figure 3 shows.

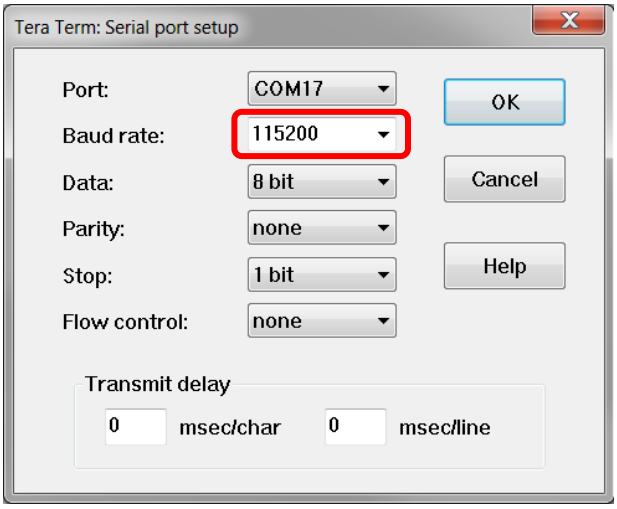
Figure 3. New Connection Creation




2. Set up serial port parameters.

   Open TeraTerm Serial port setup dialog (**Setup** > **Serial port…**). Only the **Baud rate:** should require changing to 115200, but you should also confirm the other settings are as Figure 4 shows.

Figure 4. Terminal Emulator Setup Parameters




## Math Library

The Thermistor Calculator component used in this design requires the math library to be linked into the design. That step is already done for you in the attached example.

If you are creating a new Creator project and using the Thermistor Calculator component right click on your project click on **Build Settings…** expand the complier by pressing the + button. The name of the compiler will depend on which compiler is used in the design; for Creator 4.2 it is **ARM GCC 5.4-2016-q2-update.** Click on **Linker**, in **Additional Libraries** add m, click **Apply**.

When using third party IDEs the math library will need to be added as well. The steps to do this are specific to each IDE and not described in this document. Consult help documentation for the IDE.

## Operation

1. Load the workspace into PSoC Creator by opening `<Install_Directory>\CE210528\CE210528.cywrk`.
2. Build the code example by navigating to **Build** > **Build *CE210528_Thermistor_Calibration*** in PSoC Creator.
3. Connect the device/board to a programmer connected to a PC. On-board KitProgs are already connected to the programming pins of the on-board device.
4. Program the example project to the device by navigating to **Debug** > **Program**.
5. Open a terminal program by following the instructions in the Serial Terminal section.
6. Power the device.
7. Follow the on-screen instructions to calibrate the thermistor.
   a. To calibrate the reference resistor, you must use an external, known resistance. This means removing the thermistor from the circuit.
   b. To calibrate the thermistor, you must bring the thermistor to a known temperature.
   c. To let the main project use the calibration values, you must store these values in EEPROM.

## Design

CE210514 shows how basic thermistor temperature measurement is performed using PSoC devices. This code example uses the same basic setup but adds calibration.

Calibration is done on startup. The PSoC device sends a message over UART to a terminal emulator program on a PC. First, it prompts you to confirm if you want to calibrate. To calibrate, you must replace the thermistor with a known resistor, ideally around the value of the reference resistor, which is typically 10 kΩ. Next, this resistance must be entered into the terminal program. The PSoC device uses this value to calculate the actual value of Rref. The calculated Rref is stored in EEPROM and used in all subsequent thermistor resistance calculations.

Next, the PSoC device prompts you if you want to calibrate out the temperature offset of the thermistor. To do this, you must do the following:

1. Put the thermistor back into the system.
2. Measure the exact temperature of the thermistor with an accurate temperate sensor.
3. Enter the measured temperature value into the terminal emulator program.

The PSoC device then measures the thermistor and calculates the offset between the entered temperature and the measured temperature. This offset is stored in EEPROM and subtracted from all subsequent temperature measurements.

**Note:** This project only works for PSoC 3 and PSoC 5LP. In PSoC 4, the primary cause of error is integral nonlinearity (INL), which cannot be calibrated out; therefore, calibration is not applied in PSoC 4.

## Components

Table 1 lists the PSoC Creator Components used in this example, as well as the hardware resources and parameter settings used by each.

Table 1. List of PSoC Creator Components for PSoC 3 or PSoC 5LP

| Component | Name | Hardware Resources | Non-default Parameter Settings |
|---|---|---|---|
| ADC_DelSig | ADC | 1 DelSig ADC Block | Config1<br>Conversion Mode: 0 - Single Sample<br>Resolution(bits): 20<br>Conversion rate (SPS): 46<br>Input Rage: +/- 2.048 V (-Input +/- 2 *Vref)<br>Buffer Mode: Level Shift<br>Common<br>Number of Configurations: 1 |
| Voltage DAC (8-bit) | VDAC8 | 1 ViDAC | Speed: Slow Speed<br>Range: 0 – 4.08 V<br>Value: 1600 mV |
| Thermistor_Calculator | Thermistor | None | Reference Resistor 10000<br>Implementation: Equation<br>Temperature Max: 125 °C – 531 Ω<br>Temperature Mid : 25 °C – 10000 Ω<br>Temperature Mid : -40 °C – 195652 Ω |
| UART | UART | ~2 UDBs | Configure:<br>Mode: TX + RX<br>Bits per second: 115200 |
| Character LCD | LCD | 7 pins | N/A |
| EEPROM | EEPROM | EEPROM | N/A |

### Design-Wide Resources

Table 2 lists pin physical pin assignments for PSoC 3 and PSoC 5LP.

Table 2. Pin Locations for PSoC 3 and PSoC 5LP Devices

| Pin Name | PSoC 3/ PSoC 5LP Location |
|---|---|
| LCD | P2[6:0] |
| Vhi | P0[0] |
| Vtherm | P0[1] |
| Vlow | P0[2] |
| TX | P3[7] |
| RX | P3[6] |

## Related Documents

Table 3 lists all relevant application notes, code examples, knowledge base articles, device datasheets, and Component datasheets.

Table 3. Related Documents

| | | |
|---|---|---|
| Application Notes | | |
| AN66477 | PSoC 3, PSoC 4, and PSoC 5LP Temperature Measurement with a Thermistor | Theory behind thermistor temperature measurement. |
| Code Examples | | |
| CE210514 | PSoC 3, PSoC 4, and PSoC 5LP Thermistor Temperature Measurement | Demonstrates how to measure thermistor temperature. |
| CE211321 | Interfacing the PSoC Analog Coprocessor with a Temperature Sensor | Demonstrates how to implement an analog front end (AFE) for a thermistor using the PSoC Analog Coprocessor. |
| PSoC Creator Component Datasheets | | |
| Thermistor Calculator | Component Datasheet for Thermistor Calculator Component | |
| ADC DelSig | Component Datasheet for ADC DelSig Component. | |
| UART | Component datasheet for UDB based UART Component | |
| LCD | Component datasheet for LCD Component | |
| VDAC8 | Component datasheet for VDAC8 Component | |
| Opamp | Component datasheet for Opamp Component | |
| EEPROM | Component datasheet for EEPROM Component | |
| Device Documentation | | |
| PSoC 3 Datasheets | PSoC 3 Technical Reference Manuals | |
| PSoC 5LP Datasheets | PSoC 5LP Technical Reference Manuals | |
| Development Kit (DVK) Documentation | | |
| CY8CKIT-025 PSoC Precision Analog Temperature Sensor Expansion Board | | |
| PSoC 3 and PSoC 5LP Kits | | |

## Document History

Document Title: CE210528 - PSoC 3 and PSoC 5LP Thermistor Calibration
Document Number: 002-10528

| Revision | ECN | Orig. of Change | Submission Date | Description of Change |
|---|---|---|---|---|
| ** | 5077566 | TDU | 01/08/2016 | New spec |
| *A | 6076854 | TDU | 02/18/2018 | Updated code example to new template |

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