CE220567 – PSoC 6 MCU with BLE Connectivity: BLE Thermometer

Objective

This code example demonstrates interfacing PSoC® 6 MCU with a thermistor circuit to read temperature information and sending the data over Bluetooth Low Energy Health Thermometer Service (HTS) to a mobile device running CySmart™ mobile application.

Overview

This code example demonstrates interfacing PSoC 6 MCU with BLE Connectivity (PSoC 6 MCU) with a thermistor circuit to read temperature information and sending the temperature data as BLE HTS indications to a mobile device running CySmart mobile application. In addition, PSoC 6 MCU's real time clock (RTC) generates alarms (interrupts) at every minute to show temperature information on the E-INK display when BLE is not connected.

In more detail:

- BLE connectivity using Health Thermometer Service and Device Information Service
- ADC scans two differential channels and averages multiple samples without the need for CPU intervention for accurate temperature measurement from a thermistor circuit
- An "always-on" E-INK display that shows the instructions to use the code example. In addition, the E-INK display refreshes at one minute intervals to show the temperature if BLE is not connected.
- Low power operation using the Deep-Sleep mode with MCWDT, RTC and GPIO interrupts

This code example assumes that you are familiar with the PSoC 6 MCU and the PSoC Creator™ Integrated Design Environment (IDE). If you are new to PSoC 6 MCU, you can find introductions in the application note AN210781 – Getting Started with PSoC 6 MCU with Bluetooth Low Energy (BLE) Connectivity.

Requirements

Tool: PSoC Creator 4.2

Programming Language: C (Arm® GCC 5.4.1)

Associated Parts: All PSoC 6 MCUs with BLE Connectivity (PSoC 6 BLE)

Related Hardware: CY8CKIT-062-BLE PSoC 6 BLE Pioneer Kit

Design

The BLE profile in this code example consists of HTS and the Device Information Service. Figure 1 shows the configuration of HTS Temperature Measurement characteristic. This characteristic contains one byte of flags and four bytes of temperature information in IEEE-11073 floating point format. The temperature measured by the ADC circuit at regular intervals is indicated to the GATT client device using the Temperature Measurement characteristic. The flags of Temperature Measurement characteristic, other characteristics of HTS, and the Device Information Service data are set during Component configuration. These are not updated during run-time. The service and characteristics configurations of the BLE Component can be found under the **GATT Settings** tab. See the GATT service specification of Health Thermometer Service and Device Information Service for more details. Note that Intermediate Temperature and Measurement Interval characteristics are not implemented in this code example.

Figure 1. BLE CapSense Slider Service Configuration

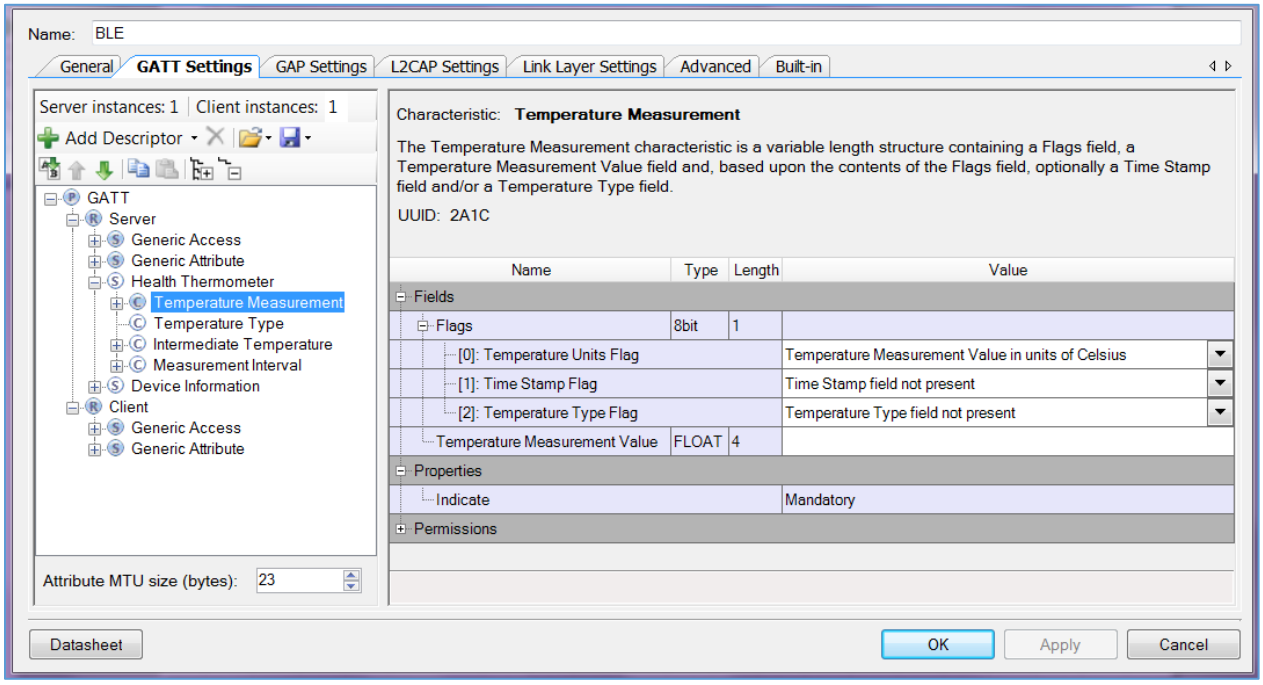


Figure 2, Figure 3, and Figure 4 show the TopDesign schematic of this code example.

The ADC measures voltages across a thermistor and a series reference resistor using two differential channels. The ADC then uses its hardware post-processing block to average 256 samples to increase the SNR without the need for CPU intervention. The temperature value is then calculated from these two voltage readings using thermistor equation. See *temperature.c* source file for details of the calculations involved.

Figure 2. TopDesign Schematic: Temperature Measurement

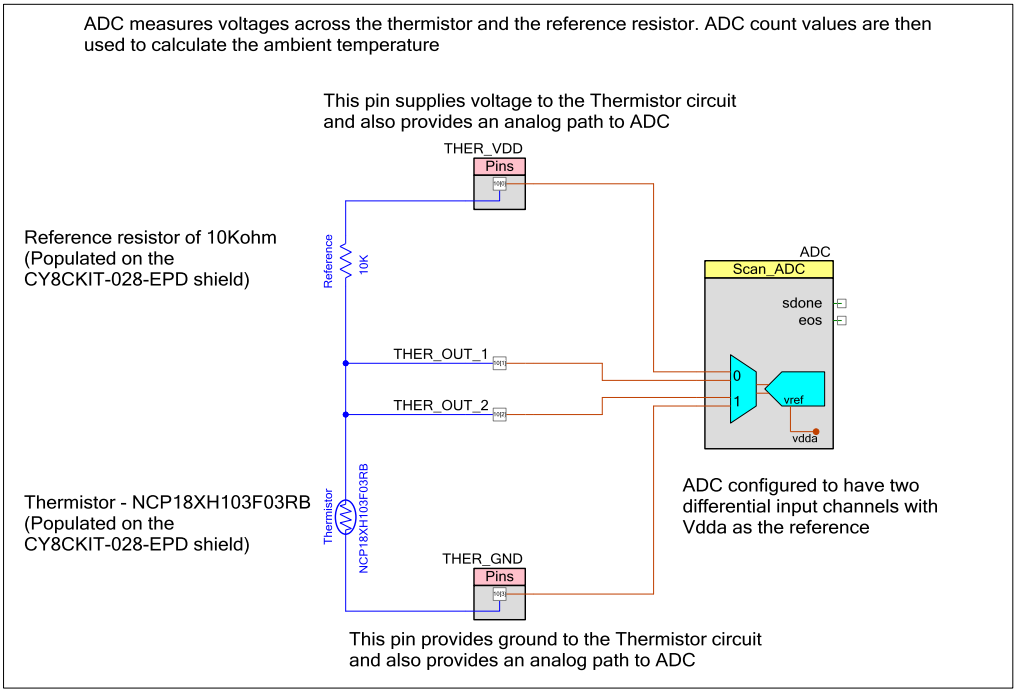


Figure 3. TopDesign Schematic: BLE and Indications

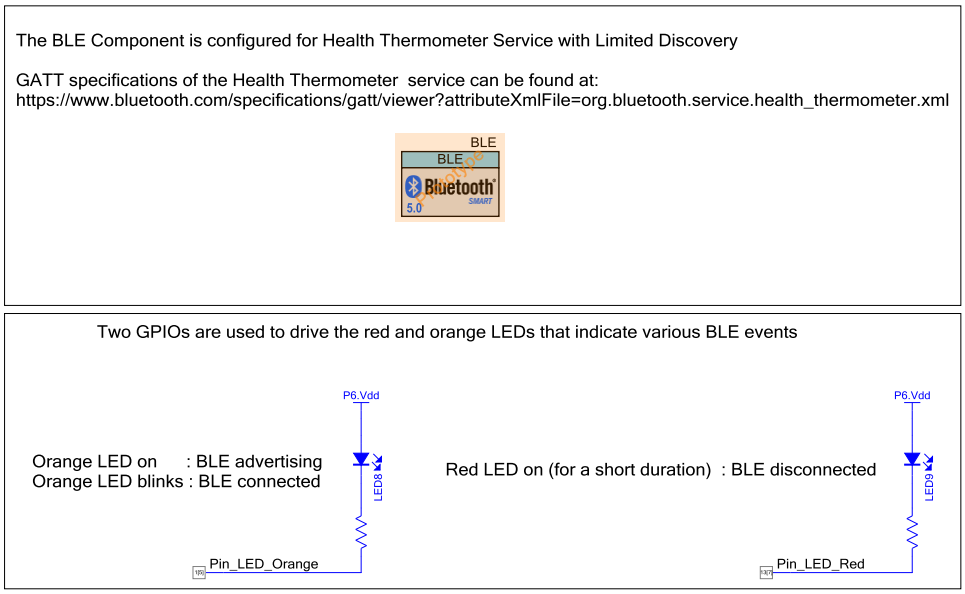
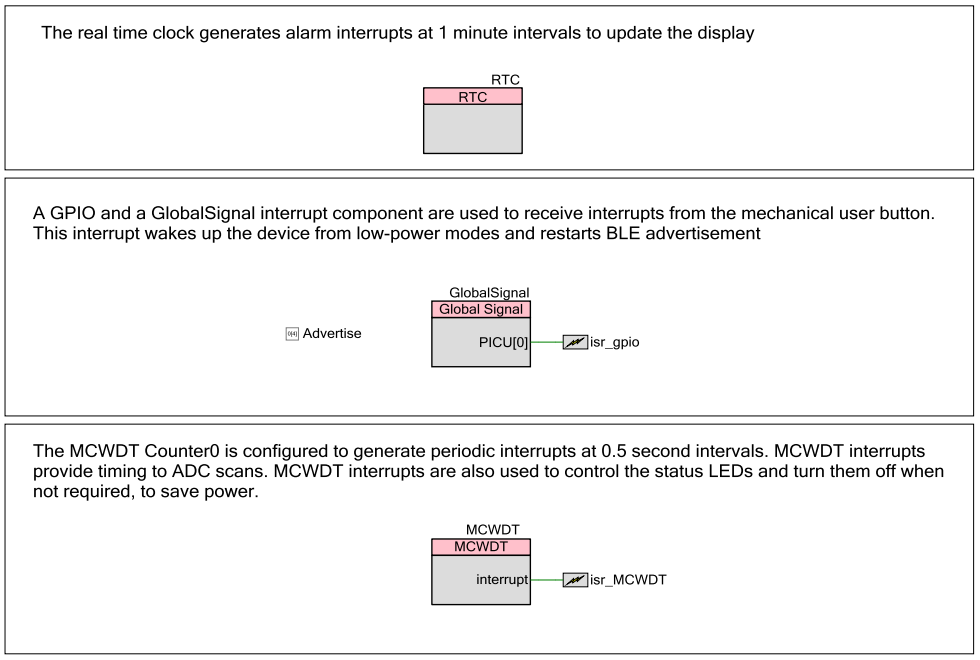


Figure 4 TopDesign Schematic: Timing and Interrupts



The E-INK display shows the instructions to use this code example at startup. The display also refreshes at one minute intervals to show the temperature if BLE is not connected. Since E-INK displays consume no power to retain the display, supply to the display is tuned OFF during the interval between display refreshes. For more details on E-INK display, see the code example CE218133 – PSoC 6 MCU E-INK Display with CapSense.

The code example consists of the following files:

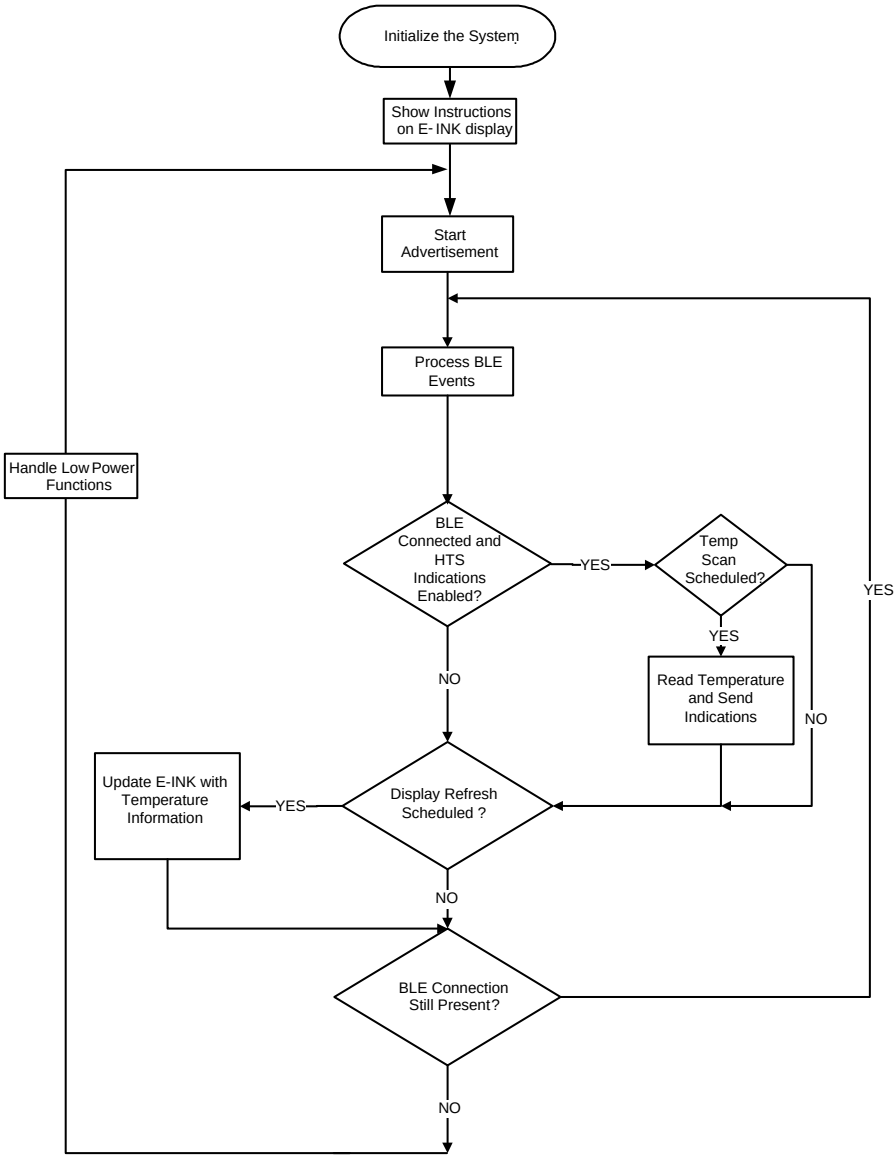
- *main_cm4.c* contains the main function, which is the entry point and execution of the firmware application. The main function calls the initializing and display functions, and continuously processes BLE, temperature and display events.
- *main_cm0p.c* contains functions that starts up the BLE controller, starts up the CM4, and services BLE stack events.

- *ble_application.c/.h* contain all the macros and function definitions related to BLE communication and operation. They include the definition of the event callback functions that are registered with the BLE Component at startup. The stack event callback function is used to send BLE-related events from the BLE stack to the application layer for processing. In addition, an HTS specific call back function handles HTS specific intervals.
- *temperature.c/h* contain the functions that are used to measure temperature.
- *led.c/.h* contain the functions that control the status LEDs.
- *display.c/.h* contain the functions that initialize the E-INK display and refresh it at periodic intervals.
- *screen_contents.c/h* contain the text and background images used by the display module.
- *low_power.c/h* contain functions to make the system enter low-power modes and turn OFF the status LEDs depending on system-level conditions.

Note: For a detailed list of files included in the E-INK Library, see the code example, CE218133 – PSoC 6 MCU E-INK Display with CapSense.

Figure 5 shows the firmware flow of this code example.

Figure 5. Firmware Flow



Components

Table 1. List of PSoC Creator Components

Component	Instance Name	Function
BLE	BLE	The BLE Component is configured for Health Thermometer and Device Information Services with Limited Discovery.
Scanning SAR ADC	ADC	ADC measures the voltages across a thermistor and a series reference resistor using two differential channels to calculate the temperature.
MCWDT	MCWDT	The MCWDT Counter0 is configured to generate periodic interrupts at 0.5 second intervals. MCWDT interrupts provide timing to ADC scans. MCWDT interrupts are also used to control the status LEDs and turn them off when not required, to save power.
Real-time clock (RTC)	RTC	The real-time clock generates alarm interrupts at 1 minute intervals to update the display.
Analog Pin	THER_OUT_1, THER_OUT_2	These GPIOs connect thermistor circuit output to ADC input
Analog + Digital Output Pin	THER_VDD, THER_GND	These GPIOs provide power / ground to the thermistor circuit and provides an analog path to ADC
Digital Output Pin	Pin_LED_Red Pin_LED_Orange	These GPIOs are configured as firmware controlled digital output pins that control status LEDs.
Digital Input Pin	Advertise	This pin is configured as a digital input pin that is used to generate interrupts when the user button (**SW2**) is pressed.
Global Signal Reference	GlobalSignal	The global signal component is configured to extract interrupts from **Advertise** pin.

Note: See the code example CE218133 – PSoC 6 MCU E-INK Display with CapSense for more details on components used by E-INK library.

See the PSoC Creator project for more details of PSoC Component configurations and design wide resource settings.

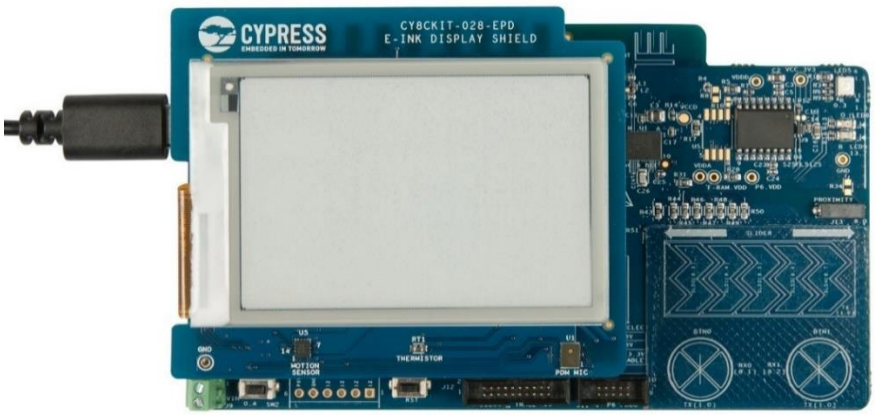
Hardware Setup

Set the switches and jumpers on the Pioneer Board as shown in Table 2.

Table 2. Switch and Jumper Selection

Switch / Jumper	Position	Location
SW5	3.3V	Front
SW6	PSoC 6 BLE	Back
SW7	V_{DDD} / KitProg2	Back
J8	Installed	Back

Figure 6. Hardware Setup



Software Setup

Install the CY8CKIT-62-BLE PSoC 6 BLE Pioneer Kit software, which contains the required software to build and program this code example. To evaluate this code example, CySmart iOS or Android mobile application is required.

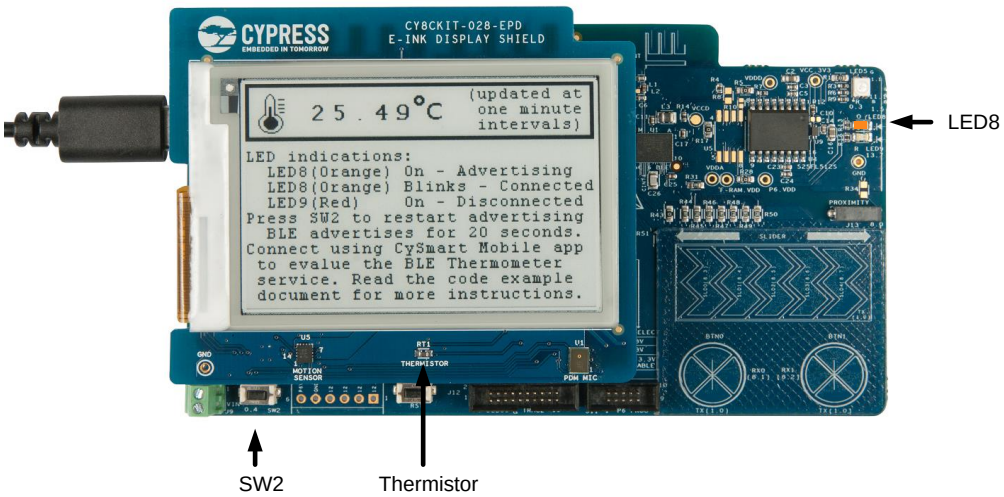
Operation

To verify this code example using the CySmart mobile application (see the CySmart Mobile App webpage), follow these steps:

1. Install the CySmart app.
2. Power the Pioneer Board through the USB connector **J10**.
3. Program the Pioneer Board with the CE220567_BLE_Thermometer project. See the Pioneer Kit guide for details on how to program firmware into the device.

   After programming successfully, the E-INK display refreshes and shows the instructions to use this project and the current temperature. After this event, BLE starts advertising. The advertising timeout is configured to be 20 seconds. The orange LED (**LED8**) remains ON during this period to indicate the BLE advertising state.

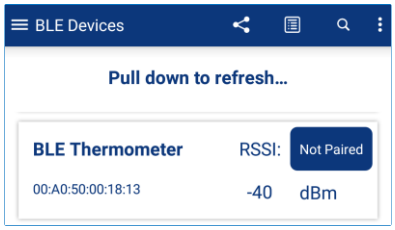
Figure 7. BLE Advertising



4. If the BLE advertisement has timed out (**LED8** is OFF), press **SW2** to restart advertisement.
5. Open the CySmart app on the mobile device. If Bluetooth is not enabled on the device, the application asks you to enable it.

6. After Bluetooth is enabled, the CySmart mobile application automatically searches for available devices and lists them. Select the **BLE Thermometer** peripheral as shown in Figure 8. A successful connection is indicated by **LED8** continuously blinking at half-second intervals.

Figure 8. BLE Thermometer Peripheral



7. When connected, the CySmart mobile application lists the services supported by the device. Scroll and select the Device Information Service icon, as shown in Figure 9. The application will now show list of device related information.

Figure 9. Device Information Service

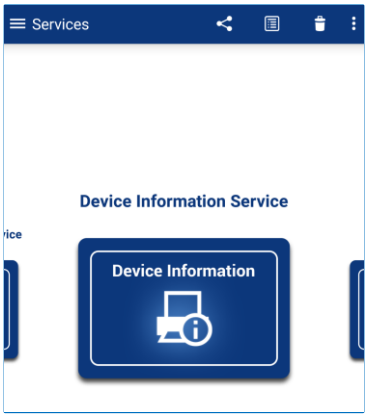
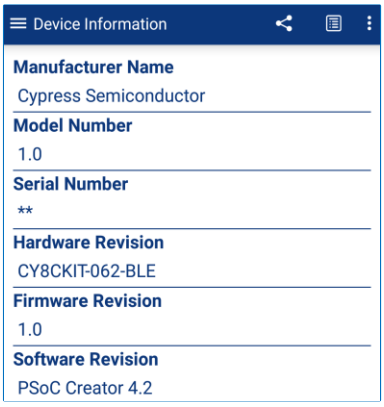


Figure 10. Device Information Service Page



8. Press the back button to return to the service selection page. Scroll and tap on the Health Thermometer service.

Figure 11. Health Thermometer Service

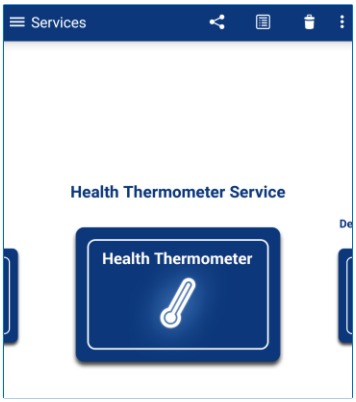
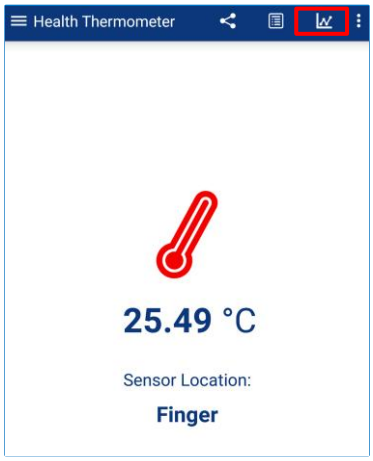
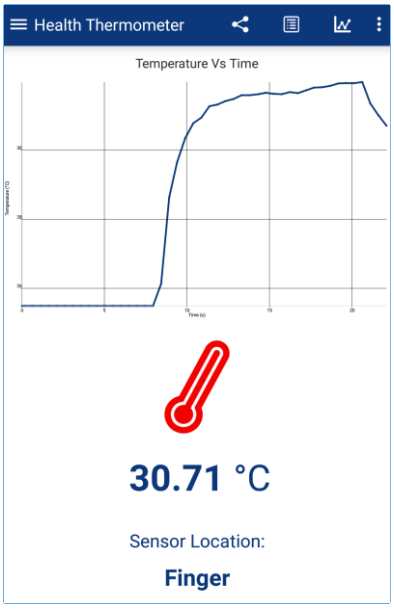


Figure 12. Health Thermometer Service Page



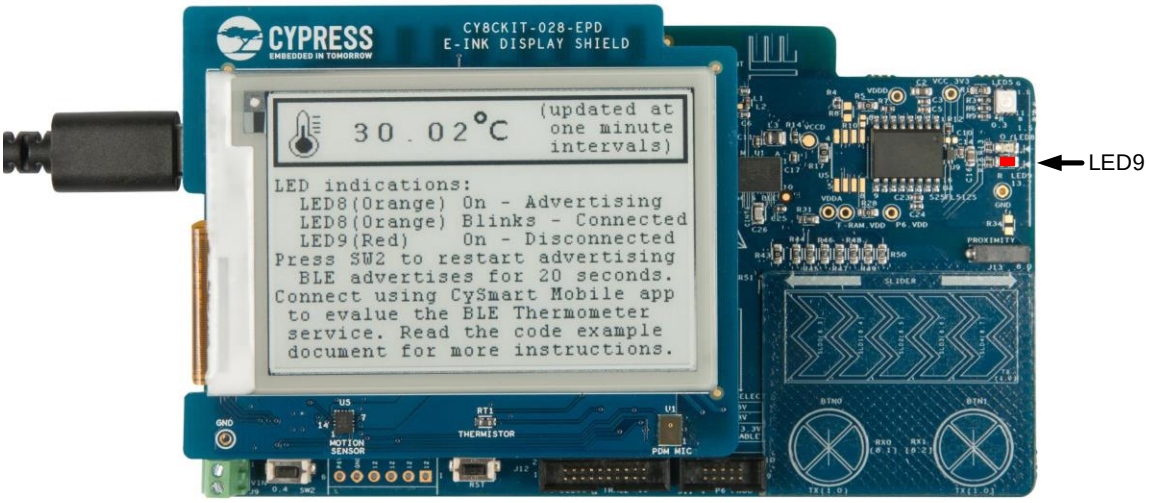
9. Enable the Temperature vs Time graph by touch the graph icon at the top-right corner of the page. Touch the Thermistor on the CY8CKIT-028-EPD E-INK Display Shield with your finger and observe an increase in Temperature indicated on the Health Thermometer Service Page (see Figure 13).

Figure 13. Health Thermometer Graph



10. On the service selection page, there is also a “GATT DB” selection, which allows you to examine the GATT database directly. From this page, you can read and write characteristics, as well as enable and disable indications.
11. If the CySmart app is closed, or Bluetooth is turned OFF, the red LED (**LED9**) will turn ON for three seconds to indicate a disconnect event. If BLE is disconnected, the E-INK display will refresh at one minute intervals to show the ambient temperature. Press **SW2** to restart the advertisement, if required.

Figure 14. Disconnect Indication



Related Documents

Application Notes	
AN210781 – Getting Started with PSoC 6 MCU with Bluetooth Low Energy (BLE) Connectivity	Describes PSoC 63 with Bluetooth Low Energy (BLE) Connectivity and how to build your first PSoC Creator project.
PSoC Creator Component Datasheets	
Bluetooth Low Energy	Facilitates designing applications requiring BLE connectivity.
Scanning SAR ADC	Provides guidelines to use the SAR ADC Component.
Device Documentation	
PSoC 6 MCU: PSoC 63 with BLE Datasheet	PSoC 6 MCU: PSoC 63 with BLE Architecture Technical Reference Manual
Development Kit (DVK) Documentation	
CY8CKIT-062-BLE PSoC 6 BLE Pioneer Kit	

Document History

Document Title: CE220567 – PSoC 6 MCU with BLE Connectivity: BLE Thermometer

Document Number: 002-20567

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	6003297	NIDH	12/13/2017	New code example.

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