TI Designs

**Multi-Standard CC2650 SensorTag Design Guide**

**TI Designs**

TI Designs provide the foundation that you need including methodology, testing and design files to quickly evaluate and customize the system. TI Designs help you accelerate your time to market.

**Design Features**

- Offers Cloud Connectivity Out of Box
  - Access and Control Your SensorTag From Anywhere and Explore a Seamless Integration With Mobile Applications and Web Pages Through Javascript and MQTT
- Supports Multi-Standard Wireless MCU
  - Bluetooth® Smart
  - ZigBee®
  - IPv6 over low-power wireless personal area networks (6LoWPAN)
- Offers Low Power
- Supports 10 Low-Power Sensors
  - Ambient Light
  - Infrared Temperature
  - Ambient Temperature
  - Accelerometer
  - Gyroscope
  - Magnetometer
  - Pressure
  - Humidity
  - Microphone
  - Magnetic Sensor
- Based on the Extremely Low-Power and High-Performance ARM® Cortex®-M3 CC2650 Wireless MCU
- Can Use Dev Packs to Expand the Functionality of the SensorTag to Fit Your Design Ideas
  - The Emulator Debug DevPack With a Free Code Composer Studio™ IDE License, Provides a Complete Development System.

**Featured Applications**

- Handsets for Smart Phones
- Home Automation
- Sensor Nodes
- Smart Watches
- Weather Stations

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1 System Description

1.1 Multi-Standard CC2650 SensorTag

The SensorTag kit invites you to realize your cloud-connected product idea. The new SensorTag includes 10 low-power MEMS sensors in a small package and is expandable with DevPacks that make adding your own sensors or actuators easy.

Connect to the cloud with Bluetooth Smart and get your sensor data online in three minutes. The SensorTag is ready to use right out the box with an iOS™ and Android™ application and require no programming experience to get started.

The SensorTag is based on the low-power and high-performance CC2650 wireless MCU, which offers 75% lower power consumption than previous Bluetooth Smart products. This rate of power consumption lets the SensorTag use battery power and offers years of battery life from a single coin cell battery.

The Bluetooth Smart SensorTag includes iBeacon™ technology. This technology allows your phone to launch applications and customize content based on SensorTag data and your physical location.

The SensorTag can be enabled with ZigBee / 6LoWPAN technology.

Visit www.ti.com/SensorTag for more information on SensorTag technology.

1.1.1 Block Diagram

![Figure 1. Block Diagram](image-url)
2 **Highlighted Products**

The design features the following devices:

- CC2650
- OPT3001
- TMP007
- HDC1000

For more information on these devices, see the product folders at [www.TI.com](http://www.TI.com).

### 2.1 CC2650 – Wireless MCU

The CC2650 device is a wireless MCU targeting Bluetooth Smart, ZigBee and 6LoWPAN, and ZigBee RF4CE remote control applications.

The device is a member of the CC26xx family of cost-effective, ultra-low power, 2.4-GHz RF devices. The ability to consume very low active RF and MCU currents and low-power mode currents provides excellent battery life for the device. This ability also lets the device operate on small coin cell batteries and in energy-harvesting applications.

![CC2650 Functional Block Diagram](image)

**Figure 2. CC2650 Functional Block Diagram**
2.2  **OPT30001 – Ambient Light Sensor**

The OPT3001 sensor measures the intensity of visible light. The spectral response of the sensor closely matches the photopic response of the human eye and includes infrared rejection.

Figure 3. OPT3001 Functional Block Diagram
### 2.3 TMP007 – Infrared Thermopile Temperature Sensor

The TMP007 sensor is an IR thermopile sensor that measures the temperature of an object without direct contact with it. The integrated thermopile absorbs the infrared energy from the object in the field of view of the sensor. The device digitizes the thermopile voltage and then provides it and the die temperature as inputs to the integrated math engine. The math engine then computes the temperature of the corresponding object.

![Figure 4. TMP007 Functional Block Diagram](image)

### 2.4 HDC1000 – Humidity Sensor With Integrated Temperature Sensor

The HDC1000 sensor is a factory-calibrated digital humidity sensor with an integrated temperature sensor that provide accurate measurements at very low power. The HDC1000 sensor measures humidity based on a novel capacitive sensor and functions within the temperature range of –40°C to 125°C. The innovative WLCSP (wafer-level chip scale package) simplifies board design with an ultra compact package and the sensing element on the bottom of the HDC1000 device protects against dirt, dust, and other contaminants.

![Figure 5. HDC1000 Functional Block Diagram](image)
3 System Design Theory

The SensorTag is a complete development kit that requires no knowledge of embedded software to get started testing with the kit. Connect the SensorTag to your smart phone using Bluetooth Smart; then use your phone to connect to the cloud and access your latest workout data online in a matter of minutes. iBeacon lets your phone launch applications and customize content based on SensorTag data and your physical location.

Get started quickly using your applications, the supporting iOS and Android applications, or the SensorTag to develop your own product using the low-power sensors.

3.1 Application and Web Development

Access data from your SensorTag through cloud providers or use JavaScript and jQuery examples to access data directly. Use Android and iOS mobile applications as starting points for your own Internet of Things (IoT) projects or write HTML5 platform-independent code based on the source code from sample web application projects.

3.2 Embedded Software Development

The SensorTag offers open hardware and software reference design for low-power IoT nodes at a low cost. The SensorTag with the Debug DevPack provide the most affordable platform for developing hardware. Port the SensorTag application between radio standards to quickly evaluate which wireless technology is right for your application.

3.3 Hardware Development

Use the SensorTag hardware as the development platform for your IoT project. The open hardware demonstrates how to use 10 low-power sensors. The DevPack interface makes it easy to develop and test your own sensors and actuators on the IoT cloud.
4 Getting Started

4.1 Hardware
The SensorTag kit includes everything needed to get started. Download the free SensorTag application from the Apple App Store™ or Google Play™ and get started with your IoT development.

4.2 Firmware


4.2.2 SensorTag ZigBee Firmware
The ZigBee stack (Z-STACK-HOME) includes download links for the SensorTag ZigBee firmware.

4.2.3 SensorTag 6LowPAN Firmware
The Contiki stack includes download links for the SensorTag 6LowPAN firmware.

5 Test Setup
We measured the antenna radiation pattern in a 3-m long RF shielded room (an anechoic chamber). The device under test (DUT) was set in transmit mode and rotated around to create a 360° antenna radiation pattern. The measurement antenna was placed in the opposite side of the chamber. The DUT transmitted a continuous wave (CW) at 2440 MHz and the antenna measured the wave with 15° steps in azimuth and elevation. Figure 6, Figure 7, and Figure 8 show the test set up.
Figure 6. Antenna Radiation Pattern
Figure 7. DUT Mounted On Rotating Arm
Figure 8. Measurement Antenna
Figure 9. \( \text{Theta} = 0, \text{Phi} = 0 \)
Figure 10. Theta = 180, Phi = 0
Theta = 90, Phi = 0

Figure 11. Theta = 90, Phi = 0
Figure 12. Theta = 90, Phi = 180
Figure 13. Theta = 90, PHI = 270
Theta = 90, Phi = 90

Figure 14. Theta = 90, Phi = 90
## 7 Design Files

### 7.1 Schematics

To download the schematics for each board, see the design files at [SWRR134](#).

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**Figure 15. CC2650STK Schematics**

![CC2650STK Schematics](#)

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Copyright © 2015, Texas Instruments Incorporated
Figure 16. CC2650STK Schematics
Figure 17. CC2650STK Schematics
Reed Relay

Pressure Sensor

Infrared Thermopile Sensor

Humidity

Gyroscope and accelerometer

Digital Microphone

Light Sensor

Figure 18. CC2650STK Schematics
7.2 **Bill of Materials**

To download the bill of materials (BOM), see the design files at [SWRR135](#).

### Table 1. BOM

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<td>IC, Analog, SPDT Switch Single-channel 2:1 Multiplexer / Demultiplexer, 4.5 V to 5.5 V, DSBGA6, SMD</td>
<td>TSSA3159AYZPR</td>
<td>TI</td>
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<tr>
<td>46</td>
<td>U3</td>
<td>1</td>
<td>BMP280</td>
<td>IC, Transducer Pressure, 300 hPa to 110 hPa, 1.71 V to 3.6 V, LGA8, SMD</td>
<td>BMP280</td>
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<tr>
<td>47</td>
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<td>TMP007</td>
<td>IC, Transducer, Infrared Thermopile Sensor, 2.5 V to 5.5 V, DSBGA8, SMD</td>
<td>TMP007AYZFR</td>
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<td>48</td>
<td>U6</td>
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<td>SPH0641LU4H</td>
<td>IC, Digital, Microphone with Multiple Performance Mode, 1.62 V to 3.6 V, SMD</td>
<td>SPH0641LU4H</td>
<td>Knowles</td>
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<td>49</td>
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<td>OPT3001</td>
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<td>OPT3001</td>
<td>TI</td>
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<td>50</td>
<td>U8</td>
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<td>MPU-9250</td>
<td>IC, Transducer, 3-AXIS Accelerometer, 3-AXIS Gyroscope, 2.4 V to 3.6 V, QFN24, SMD</td>
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<td>Invensense</td>
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<td>51</td>
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<td>HDC1000YPA</td>
<td>IC, Transducer, Low-power, High-accuracy Digital Humidity Sensor with Integrated Temperature Sensor, 2.7 V TO 5.5 V, DSBGA8, SMD</td>
<td>HDC1000YPA</td>
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<td>52</td>
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<td>Winbond</td>
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<td>53</td>
<td>U11</td>
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<td>DNMT</td>
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Table 1. BOM (continued)

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<th>PART REFERENCE</th>
<th>QUANTITY</th>
<th>VALUE</th>
<th>DESCRIPTION</th>
<th>MPN</th>
<th>MANUFACTURER</th>
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<td>55</td>
<td>Y2</td>
<td>1</td>
<td>24 MHz</td>
<td>Crystal, Crystal Oscillator, 24 MHz, –15 PPM / °C / 15 PPM / °C, –40°C / 85°C, SMD</td>
<td>TSX-3225 24.0000MF15X-AC3</td>
<td>Epson</td>
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</table>
7.3 PCB Layout Recommendations

7.3.1 Layout Considerations for CC2650 – Wireless MCU

Ensure the following layout considerations:

- Ensure that the layout of the RF components follows the reference designs.
- Ensure that RF components connected to the ground have multiple ground vias close to their ground pads to minimize ground impedance.
- Ensure that an uninterrupted and solid ground plane exists under all the RF components (from the antenna and to the ground vias in the exposed ground pad).
- Place the balun and/or RF filter as close to the CC2650 device as possible to ensure no traces are under the RF path.
- Place the antenna matching components as close to the antenna as possible.
- Place the decoupling capacitors as close to their VDD pins as possible.
- Ensure that the ground return path from the decoupling capacitors to the EGP is as short and direct as possible.
- Place the DCDC components (L1 and C7) close to the DCDC_SW pin.
- Ensure that the ground connection of the DCDC-capacitor is as short and direct as possible to avoid ground-switching noise.
- Position the humidity and IR temperature sensors away from hot points on the board like the battery, display, or microcontroller because they are dependent on temperature.
- Use the slots around the device to reduce the thermal mass for a quicker response to environmental changes.

Figure 19. RF Layout Considerations
Figure 20. DCDC Layout Considerations
7.3.2 Layout Considerations for Humidity Sensor – HDC1000

Figure 21. HDC1000
7.3.3 Layout Considerations for the IR Temperature Sensor – TMP007
For layout assembly considerations for the TMP007, see SBOU143.

7.3.4 Layout Prints
To download the layout prints for each board, see the design files at SWRC304
Figure 23. Top Silkscreen

Figure 24. Top Solder Mask
Figure 25. Top Layer

Figure 26. Layer 2
Figure 27. Layer 3

Figure 28. Bottom Layer
Figure 29. Bottom Solder Mask

Figure 30. Bottom Silkscreen
Figure 31. Mechanical Dimensions and Drill Holes
7.4 Cadence Allegro Project

Download the Allegro project files for the SensorTag at SWRC304.

Figure 32. SensorTag Allegro project
7.5 Layout Guidelines

- Place antenna matching components close to the antenna.
- Place balun and filter close to the wireless MCU.
- Place decoupling capacitors to the VDD pins and make sure to have a short GND return path.
- No copper pour around the antenna section – on any layer.
- Ensure solid GND under all RF components.
- Follow HDC1000 and TMP007 layout guidelines.
- Place L1 and C7 close to the DCDC_SW pin.

Figure 33. CC2650 SensorTag Layout Guidelines
7.6 Gerber Files

To download the Gerber files, see the design files at SWRC304.

* SURFACE - AIR 0 MM
L1: TOP CONDUCTOR - COPPER 0.035 MM
* DIELECTRIC - FR-4 0.175 MM
L2: L2 PLANE - COPPER 0.035 MM
* DIELECTRIC - FR-4 1.01 MM
L3: L3 PLANE - COPPER 0.035 MM
* DIELECTRIC - FR-4 0.175 MM
L4: BOTTOM CONDUCTOR - COPPER 0.035 MM
* SURFACE - AIR 0 MM

DESIGN CROSS SECTION CHART
TOTAL THICKNESS 1.5 MM

Figure 34. CC2650STK Mechanical Drawing

<table>
<thead>
<tr>
<th>FIGURE</th>
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<th>QTY</th>
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<td>PLATED</td>
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<tr>
<td>·</td>
<td>0.6</td>
<td>NON-PLATED</td>
<td>1</td>
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<tr>
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<td>NON-PLATED</td>
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<tr>
<td>·</td>
<td>0.9</td>
<td>NON-PLATED</td>
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<td>3.0x1.0</td>
<td>PLATED</td>
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Figure 35. Assembly Drawing (Top)  Figure 36. Assembly Drawing 2 (Bottom Side Mirrored)

7.7 Assembly Drawings

To download the assembly drawings for each board, see the design files at SWRC304.

7.8 Software Files

For information regarding software, see Section 4.2.
8 References

4. TI Application Note, *TMP007 Layout and Assembly User Guide*, SBOU143
5. TI Application Note, *Humidity Sensor*, SNA216
9 About the Author

ESPEN SLETTE is a systems application engineer at TI, where he develops reference design solutions for wireless connectivity (that is, Wi-Fi, Bluetooth Smart, RF4CE, ZigBee / 6LoWPAN, and sub-1GHz). Espen Slette has experience in application support for wireless products and RF design. Espen Slette earned his Master of Science in Electrical Engineering (MSEE) from NTNU in Trondheim, Norway.
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