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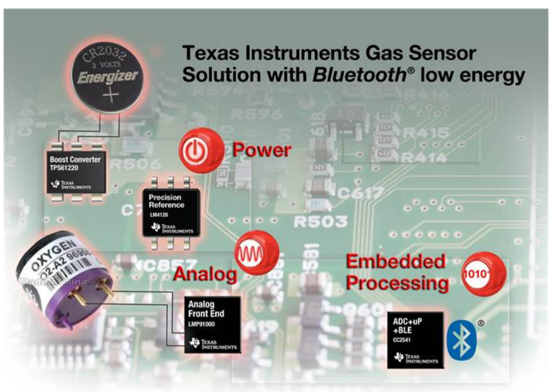
# *TI Designs*
# *Gas Sensor Platform Reference Design*

## TI Designs

TI Designs are analog solutions created by TI's analog experts. Reference Designs offer the theory, part selection, simulation, complete PCB schematic & layout, bill of materials, and measured performance of useful circuits. Circuit modifications that help to meet alternate design goals are also discussed.

## Design Resources

| | |
|---|---|
| GasSensorEVM | Tool Folder Containing Design Files |
| CC2541 | Product Folder |
| LM4120 | Product Folder |
| LMP91000 | Product Folder |
| TPS61220 | Product Folder |




## Design Features

- Monitors a wide range of gases
  - Carbon monoxide, oxygen, ammonia, fluorine, hydrogen sulfide, and others
  - Supports 2- and 3-lead electrochemical gas sensors
- Coin cell battery operation
- Bluetooth Low Energy radio and a 8051 microcontroller core within CC2541 provides interactivity with a smartphone or tablet
- Firmware and application software provided as open source to enable quick time to market for customers
- Complies with FCC and IC regulatory standards

## Featured Applications

- Mining
- Healthcare facilities
- Industrial processes and controls
- Building Technology and Comfort
- Household CO sensing

TI E2E™ Community

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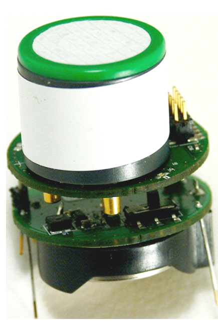
WEBENCH® Calculator Tools



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# 1 Introduction

The intent of this reference guide is to describe in detail the Gas Sensor Platform with *Bluetooth*® Low-Energy Reference Design from Texas Instruments. After reading this reference design, a user should better understand the features and usage of this reference design platform.

The Gas Sensor Platform with *Bluetooth* low-energy (BLE) is intended as a reference design that customers can use to develop end-products for consumer and industrial applications to monitor gases like carbon monoxide (CO), oxygen ($O_2$), ammonia, fluorine, chlorine dioxide and others. BLE adds a wireless feature to the platform that enables seamless connectivity to an iPhone® or an iPad®. Customers can easily replace the targeted gas sensor based on their application, while keeping the same analog front-end (AFE) and BLE design. The system runs on a CR2032 coin-cell battery. AFE from TI — LMP91000 — interfaces directly with the electrochemical cell. The LMP91000 interfaces with CC2541, which is a BLE system on a chip from TI.

An iOS application running on an iPhone 4S® and newer generations or an iPad 3® and newer generations lets customers interface with this reference platform. Customers can use and customize the iOS application, the hardware files and firmware source code of CC2541, which TI provides as an open source. The Gas Sensor Platform with BLE provides customers with a low-power, configurable AFE and the option to integrate wireless features in gas-sensing applications. This platform helps customers access the market faster and helps differentiate from performance, power, and feature sets.

The platform complies with the following standards:

- EN 300 328
- FCC 15.247
- IC RSS-210
- EN 301 489-17

FCC and IC Regulatory Compliance standards:

- FCC – Federal Communications Commission Part 15, Class A
- IC – Industry Canada ICES-003 Class A

The heart of this reference platform is the AFE from TI, the LMP91000. The LMP91000 is perfect for use in micropower, electrochemical-sensing applications. The LMP91000 provides a complete signal-path solution between a sensor and a microcontroller that generates an output voltage proportional to the cell-current. This device provides all of the functionality for detecting changes in gas concentration based on a delta current at the working electrode.

The LMP91000 is programmed to support multiple electrochemical sensors, such as 3-lead toxic gas sensors (see Figure 4) and 2-lead galvanic cell sensors (see Figure 5) with a single design as opposed to multiple discrete solutions. The AFE supports gas sensitivities over a range of 0.5 to 9500 nA/ppm. The AFE also allows for an easy conversion of current ranges from 5 to 750 µA, full scale.

The adjustable cell-bias and transimpedance amplifier (TIA) gain are programmed through the $I^2C$ interface. The $I^2C$ interface can also be used for sensor diagnostics. An integrated temperature sensor can be read by the user through the VOUT pin and used to provide additional signal correction in the microcontroller or monitored to verify temperature conditions at the sensor. The AFE is optimized for micropower applications, and operates over a voltage range of 2.7 to 5.25 V. The total current consumption can be less than 10 µA. Additional power-saving capabilities are possible by switching off the TIA and shorting the reference electrode to the working electrode with an internal switch

The LMP91000 supports many different toxic gases and sensors, and is configured to address the critical parameters of each gas.

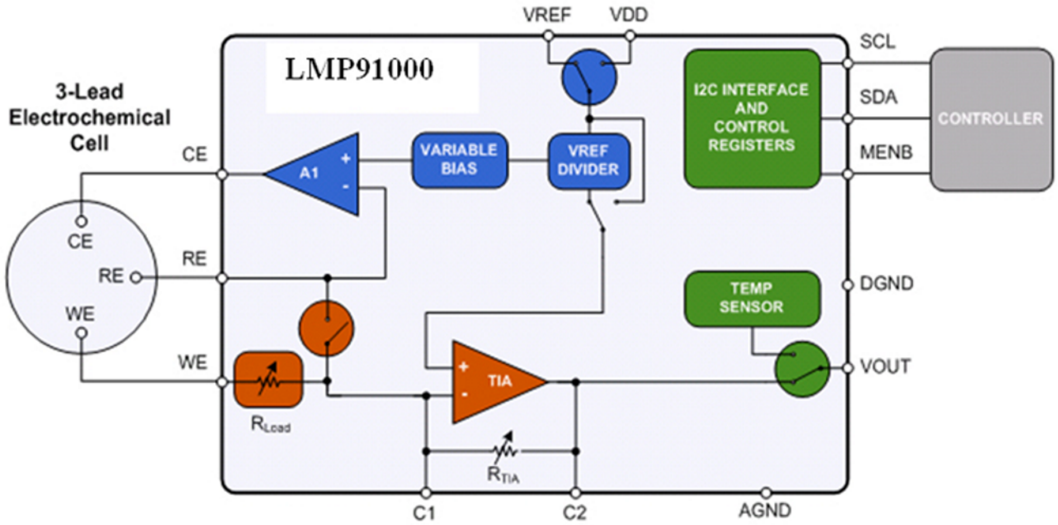



**Figure 1. Sensor Design**

## 1.1 Fundamental Blocks of LMP91000

**Transimpedance Amplifier —** TIA provides an output voltage that is proportional to the cell current. TIA provides seven programmable internal-gain resistors and allows the external-gain resistor to connect to the LMP91000.

$$(V_{ref\_div} – V_{out}) / (RTIA) = I_{we} \quad (1)$$

$$V_{out} = (V_{ref\_div}) – (RTIA \times I_{we}) \quad (2)$$

**Input —** The LMP91000 provides a 3-electrode solution — counter electrode (CE), reference electrode (RE), working electrode (WE) (see Figure 4), as well as a 2-electrode solution — short the CE and RE (see Figure 5).

**Variable Bias —** Variable bias provides the amount of bias voltage required by a biased gas sensor between RE and WE. This bias voltage can be programmed to be 1% to 24% of the supply, or it can be VREF. The bias can also be negative or positive depending on the type of sensing element.

**$V_{ref}$ Divider —** This is the voltage at the noninverting pin at TIA. This voltage can be programmed to be either 20%, 50%, or 67% of the supply, or it can be VREF. The $V_{ref}$ divider provides the best use of the full-scale input range of the analog-to-digital converter (ADC) and sufficient headroom for the CE of the sensor to swing in case of sudden changes in the gas concentration.

- How to select the appropriate $V_{ref}$ divider:
  - If the current at pin WE ($I_{we}$) is flowing into the TIA, then the $V_{ref}$ divider should be set to 67% of $V_{ref}$.
  - If $I_{we}$ is flowing out of the TIA, then the $V_{ref}$ divider should be set to 20% of $V_{ref}$.
    - Assume $V_{ref\_divider}$ is set to 20% of $V_{ref}$.
    - Assume variable bias is set to 2% of $V_{ref}$.
    - Assume $V_{ref}$ = 4.1 V.

    The $V_{ref}$ divider in that case would be 0.82 V. The noninverting input to A1 is 0.902 V, which is 22% of $V_{ref}$.

**Control Amplifier A1 —** A1 is a differential amplifier used to compare the potential between WE and RE. The error signal is amplified and applied to the CE. Changes in the impedance between the WE and RE cause a change in the voltage applied to CE in order to maintain the constant voltage between WE and RE.

**Temperature Sensor —** An on-board temperature sensor provides a ±3˚C accuracy. The sensor can be used by an external microcontroller to correct for performance over temperature.

**Serial Interface —** Calibration and programming is done through the $I^2C$ digital interface. The $I^2C$ interface enables calibration and state-of-health monitoring. As mentioned before, health monitoring is very important because chemical cells can degrade over time.

## *1.2 Examples of Firmware and iOS Calculation*

This section explains the signal path and signal processing as implemented in the Gas Sensor Platform, from the sensor to LMP91000, to CC2541 and to the iOS application.

### 1.2.1 $O_2$ Sensor Example

The following example uses the $O_2$ sensor from the Alphasense A2 series (see Section 1.4.1).

A change in µA current of the sensor indicates a change in gas concentration. The LMP91000 processes the current and uses the linear TIA stage to convert the current to analog voltage (see Figure 1). The analog voltage is then sent to the CC2541. The CC2541 then converts the raw analog voltage to a digital signal through a 12-bit ADC and transmits the signal through the *Bluetooth* radio to an iOS device. The iOS device then performs postprocessing.

#### *1.2.1.1 Postprocessing Steps as Implemented in the iOS*

- Covert voltage (binary to decimal).
  - In this example, assume that the CC2541 transmits 0348h in its VOUT field. iOS software converts this hexadecimal voltage into a decimal value:

$$0348h = 840 \quad (3)$$

- The ADC inside the CC2541 is a 12-bit resolution (2s complementary).
  - Thus, the ADC resolution inside the CC2541 is:

$$2.5\text{ V} / (2^{11}–1) = 0.001221 \quad (4)$$

**NOTE:** LM4120 provides a fixed 2.5-V precision reference to both the LMP91000 and the CC2541 in this reference platform. Because of this fixed precision reference, 2.5 V is used in Equation 4 to calculate the ADC resolution inside the CC2541.

- Multiply the decimal value from Equation 3 with the ADC resolution:

$$840 \times 0.001221 = 1.025\text{ V} \quad (5)$$

$$(V_{ref\_div} – V_{out}) / (RTIA) = I_{we\_fresh\ air}$$

where
  - $V_{ref\_div}$ is 67% of $V_{ref}$.
  - RTIA is set to 7000. (6)

  Thus, based on Equation 6, current at the WE pin ($I_{we}$) flowing into the TIA is approximately 91 µA (fresh air calibration).

- To change the $O_2$ concentration, exhale, or breathe out, on the $O_2$ sensor to increase VOUT. Assume that the CC2541 transmits 03B0h in its VOUT field. 03B0h translates to 944 in decimal (see Equation 3).

$$944 \times 0.001221 = 1.152\text{ V} \quad (7)$$

  In this case, based on Equation 7, the current at the WE pin ($I_{we}$) flowing into the TIA is (1.667– 1.152) / 7000 = 73.5 µA.

- In Equation 6, the calibrated fresh air WE ($I_{we}$) value is 91 µA. For calibration, this value can be set to correspond to 20.9%.
- Exhale, or breathe out, on the $O_2$ sensor; the normalized $O_2$ percentage is:

$$(73.5 \times 20.9) / 91 = 16.88\% \quad (8)$$

### *1.3 CO Sensor Example*

The following example uses the CO sensor from the Alphasense CO-AF series (see Section 1.4.1).

A change in µA current of the sensor indicates a change in gas concentration. The LMP91000 processes the current and uses the linear TIA stage to convert the current to analog voltage (see Figure 1). The analog voltage is then sent to the CC2541. The CC2541 then converts the raw analog voltage to a digital signal through a 12-bit ADC and transmits the signal through the *Bluetooth* radio to an iOS device. The iOS device then performs postprocessing.

#### 1.3.1 Postprocessing Steps as Implemented in the iOS

- Covert voltage (binary to decimal).
  - In this example, assume that the CC2541 transmits 019Fh in its VOUT field. iOS software converts this hexadecimal voltage into a decimal value:

$$019Fh = 415 \quad (9)$$

- The ADC inside the CC2541 is a 12-bit resolution (2s complementary).
  - Thus, the ADC resolution inside the CC2541 is:

$$2.5\ V / (2^{11} - 1) = 0.001221 \quad (10)$$

**NOTE:** The LM4120 provides a fixed 2.5-V precision reference to both the LMP91000 and the CC2541 in this reference platform. Because of this fixed precision reference, 2.5 V is used in Equation 10 to calculate the ADC resolution inside the CC2541.

- Multiply the decimal value from Equation 3 with the ADC resolution:

$$415 \times 0.001221 = 0.506\ V \quad (11)$$

$$(V_{ref\_div} - V_{out}) / (RTIA) = - I_{we\_fresh\ air}$$

where

  - The $V_{ref}$ divider is set to 20% of $V_{ref}$ as $I_{we}$ is flowing out of the TIA (in the case of a CO sensor).
  - RTIA is set to 7000. (12)

Thus, based on Equation 12, the current at the WE pin ($I_{we}$) flowing out of the TIA is approximately 857 nA (fresh air calibration).

- Based on the CO-AF specification, the sensitivity of the sensor is 55 to 90 nA/ppm. In the iOS software, the sensitivity is set to 70 nA/ppm, which is the approximate average of the range.

$$857\ nA \times 70\ nA/ppm = approximately\ 12\ ppm \quad (13)$$

**NOTE:** The RTIA for the CO-AF sensor is set to 7000, which ensures that the full range of the CO-AF sensor (0 to 5000 ppm) can be used without clipping.

## 1.4 Supported Sensor Types

The Gas Sensor Platform from TI can be used with either a 3-lead amperometric cell (not included) (see Figure 4) or a 2-lead galvanic cell (not included) in potentiostat configuration (see Figure 5) by a minor resistor change shown in Figure 25.

- For a 3-lead amperometric cell (CO), R43 must be uninstalled.
- For a 2-lead galvanic cell ($O_2$) R43 must be installed.

**Figure 2. CO Setup**

**Figure 3. $O_2$ Setup**

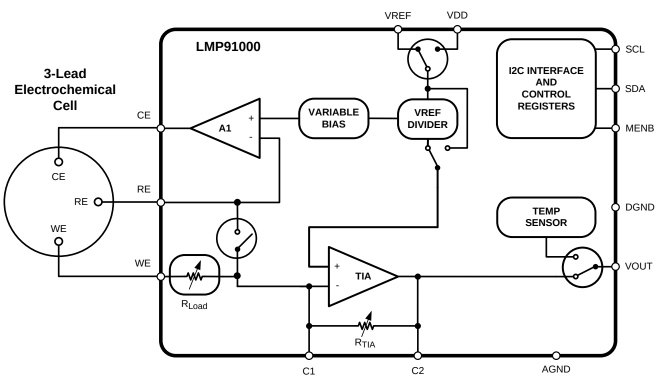



**Figure 4. 3-Lead Amperometric Cell**

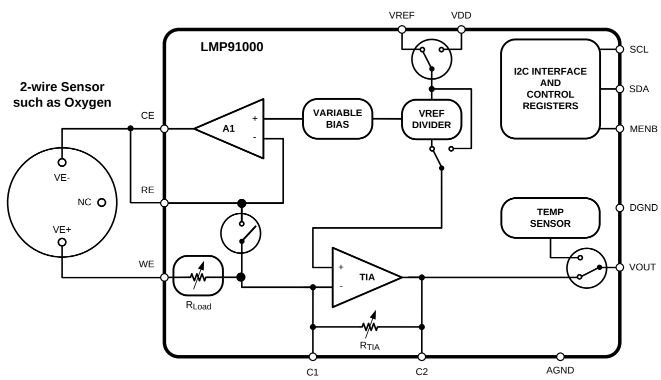



**Figure 5. 2-Lead Galvanic Cell In Potentiostat Configuration**

### 1.4.1 WEBENCH® Support

TI recommends that customers use WEBENCH for their sensor-type design. Refer to Figure 6, Figure 7, and the WEBENCH open design tool at http://www.ti.com/product/lmp91000. The WEBENCH tool lists all of the sensor types compatible with LMP91000.

**NOTE:** The default firmware and the iOS software in the Gas Sensor Platform from TI are designed to support the CO-AF from Alphasense (http://www.alphasense.com/industrial-sensors/alphasense_sensors.html) as well as the O2-A2 from Alphasense. Customers can easily update the firmware and the iOS software to support additional sensor types. For firmware updates, see Section 7.2.

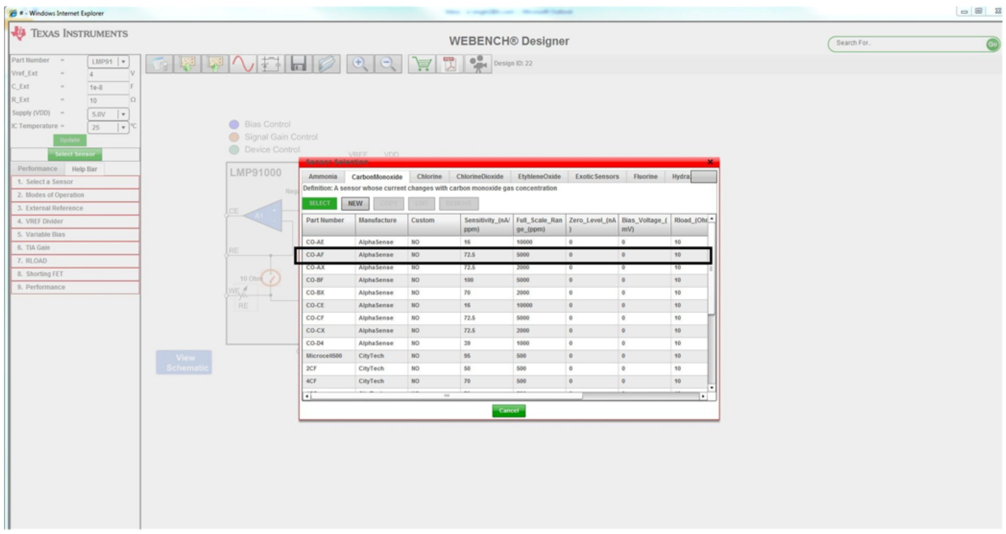



**Figure 6. WEBENCH CO**

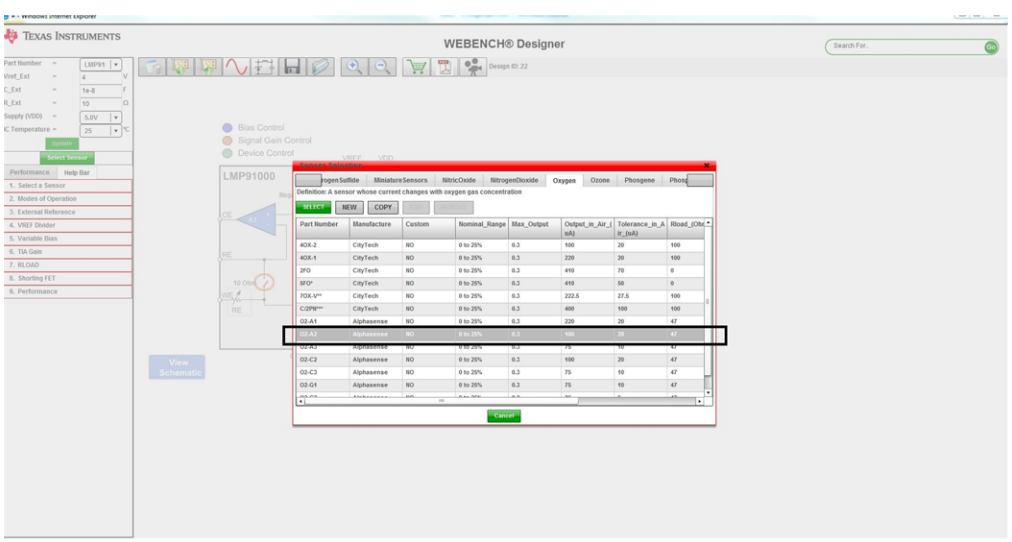



**Figure 7. WEBENCH $O_2$**

# 2 Features

## 2.1 Gas Sensor Platform With BLE Design Features

- Coin-cell operation (CR2032)
- Low-power configurable AFE (LMP91000) that provides flexibility for customers to use the same AFE for different gas-sensing platforms and configure different platforms with a simple firmware update
- Provides reference design for BLE antenna design - leveraging low-cost trace antenna
- Enables customers to use the platform to incorporate wireless features in gas-sensing applications
- TI provides BLE firmware and iOS application software as open-source to help customers get to the market faster.
- The platform is comprised of two boards that are stacked together and are referred to as SAT0009 (power board) and SAT0010 (AFE and *Bluetooth* board).

**LMP91000**

- Supply voltage 2.7 to 5.25 V
- Supply current (average over time) <10 µA
- Cell-conditioning current up to 10 mA
- Reference electrode bias-current (85°C) 900 pA (max)
- Output drive-current 750 µA
- Complete potentiostat circuit to interface to most chemical cells
- Programmable cell-bias voltage
- Low-bias voltage drift
- Programmable TIA gain 2.75 to 350 kΩ
- Sink and source capability
- $I^2C$-compatible digital interface
- Ambient operating temperature –40°C to +85°C
- Package: 14-pin WSON
- Supported by WEBENCH Sensor AFE Designer

**LM4120**

- Small SOT23-5 package
- Low dropout voltage: 120 mV Typ at 1 mA
- High output voltage accuracy: 0.2%
- Source and sink current output: ±5 mA
- Supply current: 160 µA Typ
- Low temperature coefficient: 50 ppm/°C
- Enable pin
- Fixed output voltages: 1.8, 2.048, 2.5, 3, 3.3, 4.096 and 5 V
- Industrial temperature range: –40°C to +85°C

**TPS61220**

- Up to 95% efficiency at typical operating conditions
- 5.5-µ quiescent current
- Startup into load at 0.7-V input voltage
- Operating input voltage from 0.7 to 5.5 V
- Pass-through function during shutdown
- Minimum switching current 200 mA
- Output overvoltage, overtemperature, input undervoltage lockout protection
- Adjustable output voltage from 1.8 to 5.5 V

- Fixed output voltage versions
- Small 6-pin SC-70 package

**CC2541**

- Radio
  - 2.4-GHz low-energy compliant and Proprietary RF System-on-Chip (SoC)
  - Supports data rates of 250 kbps, 500 kbps, 1 Mbps, and 2 Mbps
  - Excellent link budget, enabling long-range applications without external front-end
  - Programmable output power up to 0 dBm
  - Excellent receiver sensitivity (–94 dBm at 1 Mbps), selectivity and blocking performance
  - Suitable for systems-targeting compliance with worldwide radio frequency regulations
  - ETSI EN 300 328 and EN 300 440 Class 2 (Europe), FCC CFR47 Part 15 (US), and ARIB STD-T66 (Japan)
- Layout
  - Few external components
  - Reference design provided
  - 6-mm × 6-mm QFN-40 package
  - Pin-compatible with the CC2540 (when not using USB or $I^2C$)
- Low power
  - Active-mode RX down to: 17.9 mA
  - Active-mode TX (0 dBm): 18.2 mA
  - Power mode 1 (4-µs wake up): 270 µA
  - Power mode 2 (sleep timer on): 1 µA
  - Power mode 3 (external interrupts): 0.5 µA
  - Wide supply-voltage range (2 V – 3.6 V)
  - TPS62730-compatible low power in active mode
  - RX down to: 14.7 mA (3-V supply)
  - TX (0 dBm): 14.3 mA (3-V supply)
- Peripherals
  - Powerful 5-channel direct memory access (DMA)
  - General-purpose timers (one, 16-bit; two, 8-bit)
  - IR generation circuitry
  - 32-kHz sleep timer with capture
  - Accurate digital RSSI support
  - Battery monitor and temperature sensor
  - 12-bit ADC with eight channels and configurable resolution
  - AES security coprocessor
  - Two powerful UARTs with support for several serial protocols
  - 23 general-purpose I/O pins
    - (21 × 4 mA, 2 × 20 mA)
  - An $I^2C$ interface
  - Two I/O pins with LED-driving capabilities
  - Watchdog timer
  - Integrated high-performance comparator
- Development tools
  - CC2541 Evaluation Module Kit (CC2541EMK)

- – CC2541 Mini Development Kit (CC2541DK-MINI)
- – SmartRF™ software
- – IAR Embedded Workbench® available

## 2.2 Featured Applications

The Gas Sensor Platform with BLE Reference Platform is designed to demonstrate how a configurable AFE can be used with a low-power wireless radio to provide a reference platform that helps customers develop next-generation gas-sensing solutions for the following applications:

- Industrial: gas-sensing application
- Consumer: carbon monoxide-sensing application
- Healthcare facilities: gas-sensing application

## 2.3 Highlighted Products

The Gas Sensor Platform with BLE Reference Design features the following devices:

- LMP91000: Sensor AFE System: Configurable AFE potentiostat for low-power chemical-sensing applications
- CC2541: –2.4-GHz *Bluetooth* low-energy and proprietary SoC
- LM4120: Precision micropower low dropout voltage reference
- TPS61220: Low input voltage, 0.7-V boost converter with 5.5-μA quiescent current

For more information on each of these devices, go to the respective product folders at www.TI.com.

## 2.4 Block Diagram

Figure 8 shows the block diagram for TI's Gas-Sensor Solution with BLE.

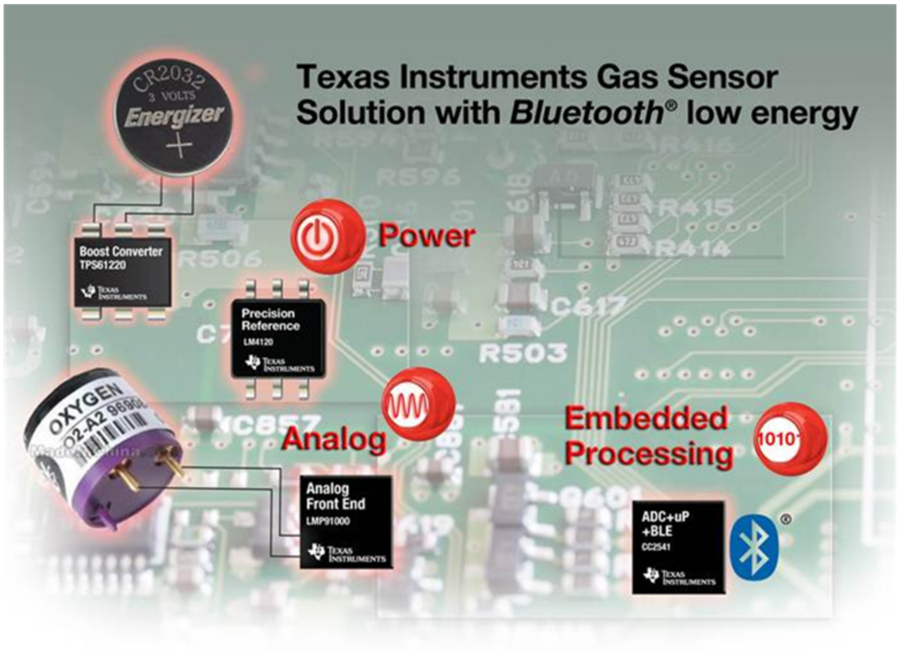



**Figure 8. Block Diagram of Gas-Sensing Platform With *Bluetooth* Low Energy**

# 3 Hardware Description

## 3.1 Getting Started

Requirements:

- Gas sensor: use the recommended CO-AF from Alphasense.
- CR2032: Coin-cell

**NOTE:** Use a UL-compliant CR2032 coin-cell battery with nominal voltage 3 V, nominal capacity 225 mAh, and nominal continuous standard load 0.2 mA.

- An iOS device: iPhone 4S and newer generations; iPad 3 and newer generations; fifth generation iPod (www.Apple.com)
  Download the *TI Gas Sensor* application from the Apple App Store™ at iTunes.Apple.com/us/app/TI-Gas-Sensor/id663441630.

**NOTE:** CC-DEBUGGER is the debug tool to load the firmware to the CC2541 (ti.com/tool/cc-debugger). The debug tool is needed only if changes to the firmware are required.

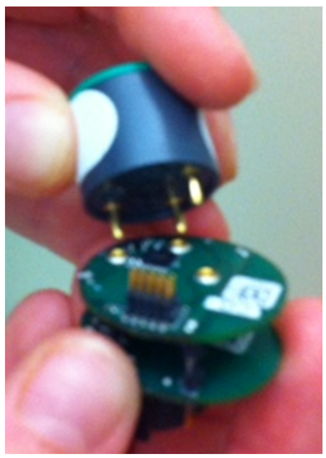


**Figure 9. Installing the Sensor on the Platform**


**Figure 10. CR2032 Battery**

By default the Gas Sensor Platform supports the 3-lead amperometric cell (R43 not installed, see Section 1.4). By default, the firmware and iOS software support the Alphasense CO-AF sensor. TI recommends installing the CO-AF sensor (not included) from Alphasense into the socket on the SAT0010 board (see Figure 10).

1. Install the sensor onto the platform (see Figure 9).
2. Load the CR2032 (not included in the kit) into the coin-cell holder on the SAT0009 board.
3. Turn the On/Off switch to the right (with respect to the orientation shown in Figure 11).

**NOTE:** A blue LED flashes when the default firmware is loaded.

4. Download the application from the App Store.
5. Use an iOS device to access the Gas Sensor Platform and interface with the platform (see Section 7.1).
6. If needed, connect the CC-DEBUGGER (not included in the kit) to the 10-pin header as shown in Figure 11. If changes to the default firmware are needed, see Section 7.2.

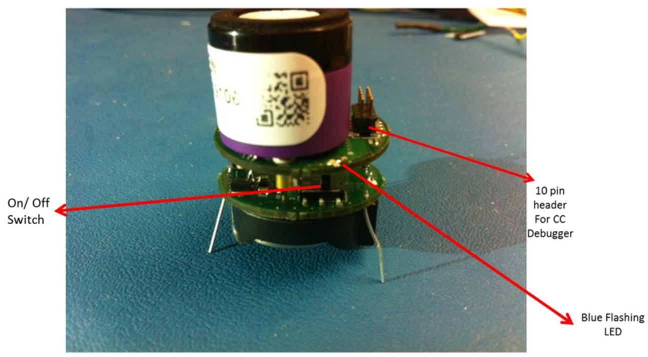



**Figure 11. System Running With LED Flashing**

## 3.2 Battery Life Calculation

For battery life calculations, TI highly recommends that the user reviews *CC2541 Battery Life Calculation*, SWRA347.

Comparing the power consumption of a BLE device to another device using a single metric is impossible. For example, a device gets rated by its peak current. While the peak current plays a part in the total power consumption, a device running the BLE stack only consumes current at the peak level during transmission. Even in very high throughput systems, a BLE device is transmitting for only a small percentage of the total time that the device is connected (see Figure 12).

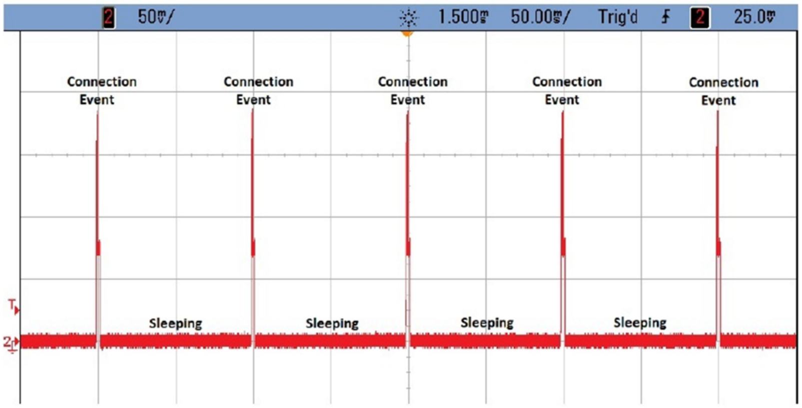



**Figure 12. Current Consumption**

In addition to transmitting, there are other factors to consider when calculating battery life. A BLE device can go through several other modes, such as receiving, sleeping, and waking up from sleep. Even if the current consumption of a device in each different mode is known, there is not enough information to determine the total power consumed by the device. Each layer of the BLE stack requires a certain amount of processing to remain connected and to comply with the specifications of the protocol. The MCU takes time to perform this processing, and during this time, current is consumed by the device. In addition, some power might be consumed while the device switches between modes (see Figure 13). All of this must be considered to get an accurate measurement of the total current consumed.

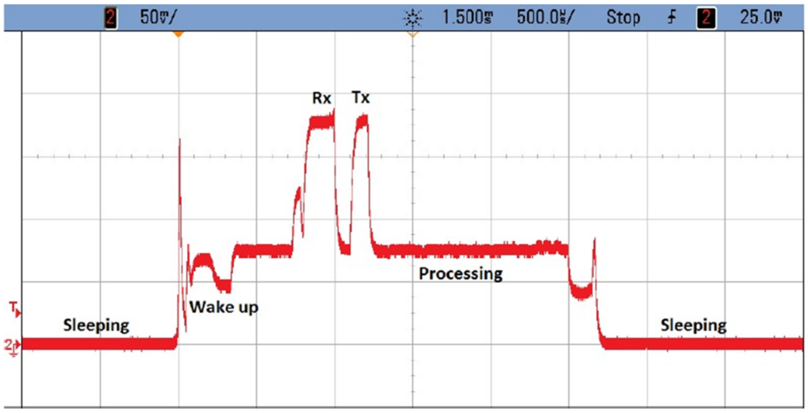



**Figure 13. Current Consumption-Active versus Sleep Modes**

# 4 Antenna Simulations

The following data was simulated using the High-Frequency Structural Simulator (HFSS) from ANSYS (www.ansys.com/hfss).

The Gas Sensor Platform with BLE platform is a stack of two 1-inch diameter boards (see Figure 14).

The goals of the antenna simulations include the following:

- Validate that the 2.45-GHz antenna performs as expected.
- Estimate the influence of the battery board, by running simulations with and without the battery board.

## *4.1 Simulations With the Battery Board (SAT0009)*

Both boards were used in the first simulation to determine the affect of the power board (SAT0009) on the BLE antenna located on SAT0010 (see Figure 15, Figure 16, and Figure 17).

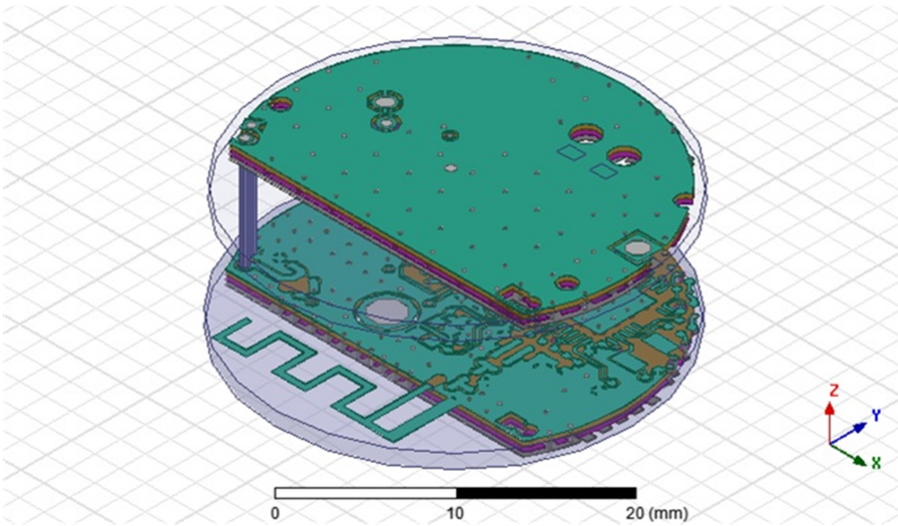
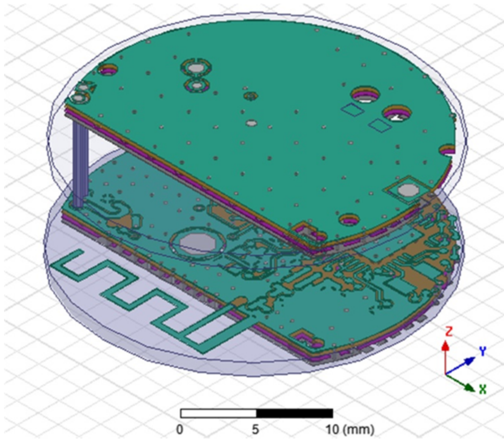



**Figure 14. ANSYS Antenna Simulation Setup**




Antenna Parameters:

| | Quantity | Value | Units |
|---|---|---|---|
| | Max U | 0.00039551 | W/sr |
| | Peak Directivity | 1.1973 | |
| | Peak Gain | 0.64792 | |
| | Peak Realized Gain | 0.49703 | |
| | Radiated Power | 0.0041511 | W |
| | Accepted Power | 0.0076711 | W |
| | Incident Power | 0.01 | W |
| | Radiation Efficiency | 0.54114 | |
| | Front to Back Ratio | -N/A- | |
| | Decay Factor | 0 | |

**Figure 15. Antenna Simulations With Power Board**

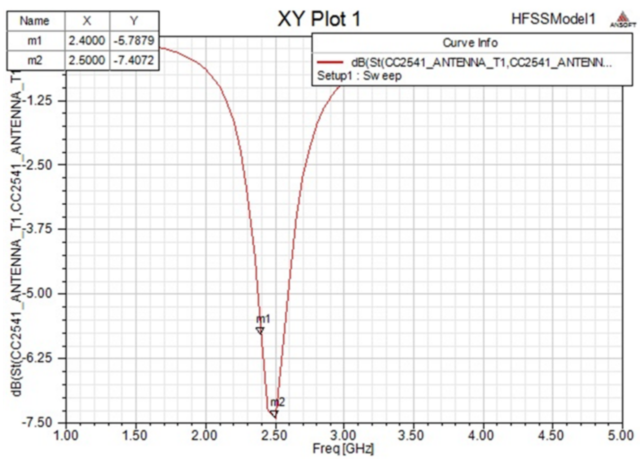



**Figure 16. Antenna Simulations Matching With Power Board**

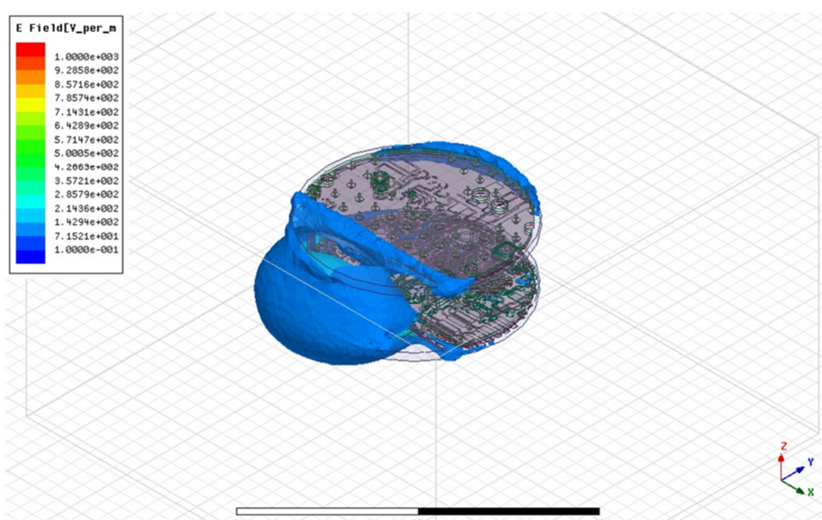



**Figure 17. Antenna Simulations Electrical Field Propagation With Power Board**

The power board (SAT0009) was used in the next simulation to determine if the BLE antenna resulted in an improvement to the performance of SAT0010 (see Figure 18, Figure 19, and Figure 20).

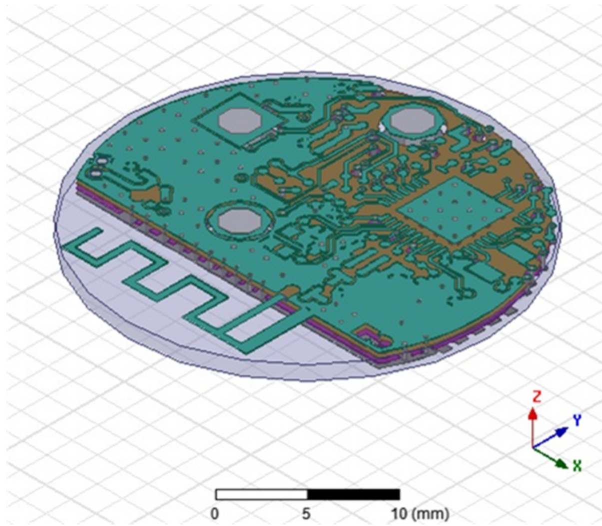



**Figure 18. Antenna Simulations Setup Without Battery Board**

**Table 1. Antenna Simulations Results Without Battery Board**

| Quantity | Value | Units |
|---|---|---|
| Max U | 0.00043244 | W/sr |
| Peak directivity | 1.1138 | |
| Peak gain | 0.66408 | |
| Peak realized gain | 0.54344 | |
| Radiated power | 0.0048793 | W |
| Accepted power | 0.0081833 | W |
| Incident power | 0.01 | W |
| Radiation efficiency | 0.59625 | |
| Front-to-back ratio | Not applicable | |
| Decay factor | 0 | |

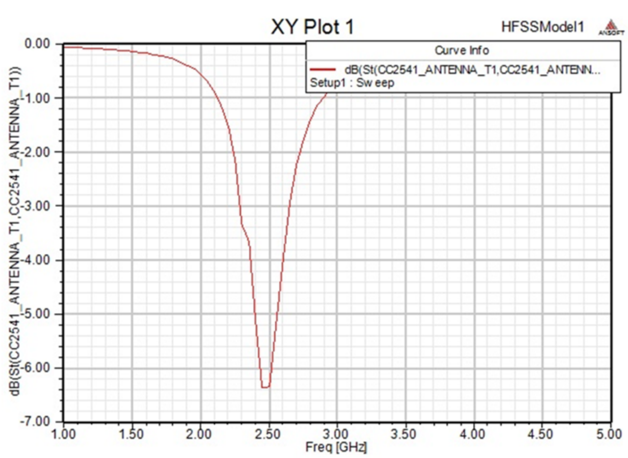



**Figure 19. Antenna Simulations Matching Without Battery Board**

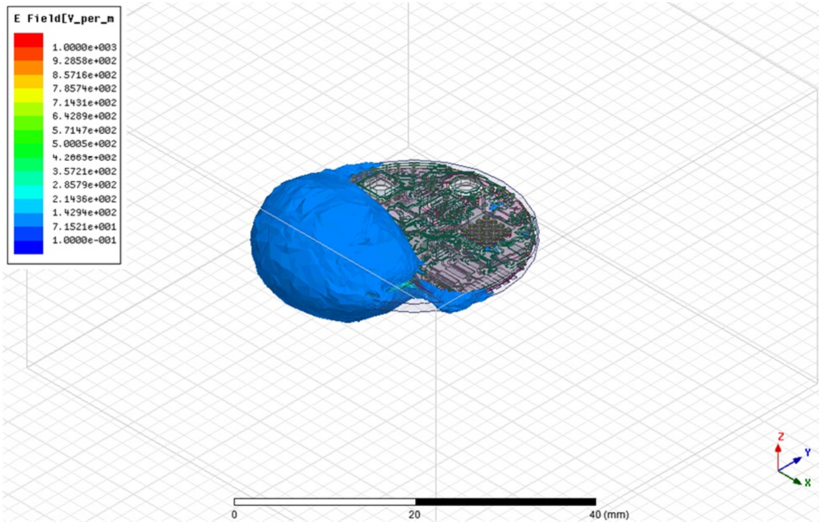



**Figure 20. Antenna Simulations Field Propagation Without Battery Board**

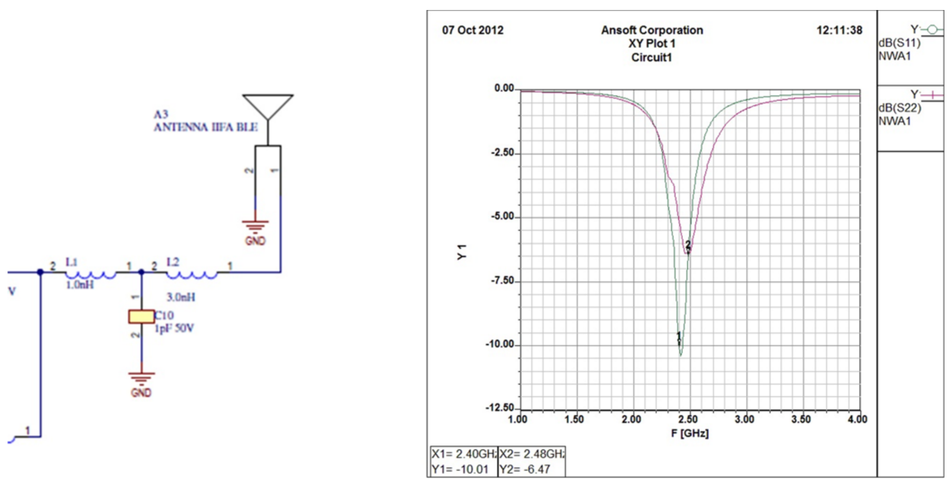



**Figure 21. Improved Antenna Matching**

Antenna matching was improved by increasing the inductor from 3 to 5 nH (see Figure 21). The increase resulted in a better return loss value of 10 dB.

## 4.2 Summary of Findings

- The battery board does not significantly influence the antenna (see Table 1).
- Good omnidirectional radiation pattern is found.
  - Low peak gain of 1.2.
- Antenna radiation efficiency is estimated at 54%.

## 4.3 Conclusion

- Overall board size is very small.
  - Reduces the antenna efficiency from an estimated 70% to 54%.
  - Influences the match of the antenna to become only 6 dB.
- By increasing the last inductor from 3 to 5 nH, the match is improved.

## 4.4 FCC Reports

The Gas Sensor Platform is compliant with FCC and EU radiation requirements. For additional information, see the following documents (SNVC129 and SNVC130):

- *ETSI EN 301 489-17, v2.1.1,*
- *FCC part 15, subpart B & ICES-003, Issue 4,*
- *EN 300 328: v1.7.1,*

# 5 Schematics and Bill of Materials

## 5.1 SAT Gas Sensor Platform With BLE

### 5.1.1 Power Board Schematic and BOM

See SNVC103 for additional schematic files for the SAT0009 (Power Board), and SNVC101 for the BOM.

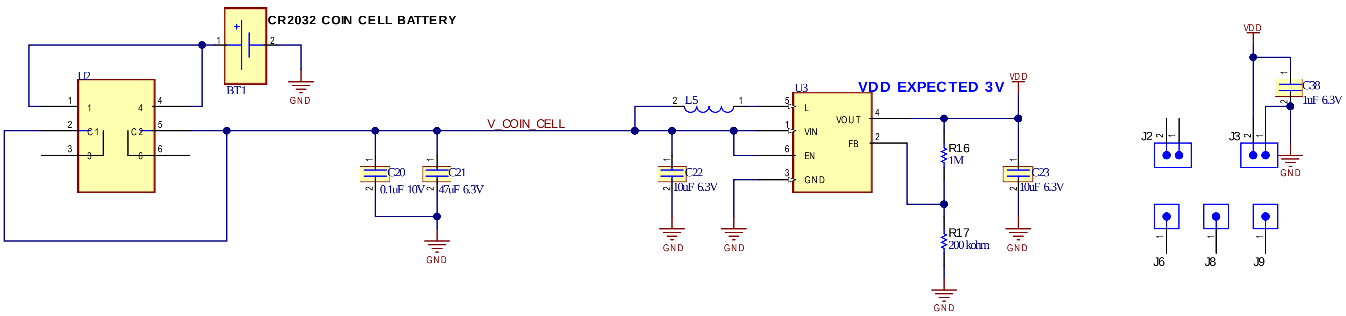



**Figure 22. Power Section**

## Table 2. Power Section BOM

| Comment | Description | Designator | Footprint | LibRef | Qty | Manufacturer | Part No. | Supplier | Part No. |
|---|---|---|---|---|---|---|---|---|---|
| BS-7-ND | Battery Holder | BT1 | BATTHOLD-BS-7-CR2032 | BS-7-ND | 1 | | | Digi-Key | BS-7-ND |
| GRM155R71A104KA01D | Cap Cer 0.1 µF 10 V 10 | C20 | C402-25RD | GRM155R71A104KA01 | 1 | | GRM155R71A | Digi-Key | GRM155R71A104KA01 D-ND |
| TSW-101-07-G-S | Conn Header 1POS | C21, J6, J8, J9 | JUMP1X1-382650CTR | TSW-101-07-G-S | 4 | Samtec, Inc. | | Digi-Key | SAM1029-01-ND |
| GRM188R60J106ME47 | Cap Cer 10 µF 6.3 V 20 | C22, C23 | C603-35X45 | GRM188R60J106ME47 | 2 | | GRM188R60J1 | Digi-Key | 490-3896-2-ND |
| GRM155R60J105KE190 | Cap Cer 1 µF 6.3 V 10% | C38 | C402-25RD | GRM155R60J105KE190 | 1 | | GRM155R60J1 | Digi-Key | 490-1320-2-ND |
| TBSTC-501-D-200-22-G | Major League Elec 0.05 | J2, J3 | JUMP1X2-3826-50CTR | TBSTC-501-D-200-22-G | 2 | Major League Elec | TBSTC-501-D-2 | | |
| EPL3015 | Power Inductor, Shielder | L5 | EPL3015-INDUCTOR | EPL3015 | 1 | Coilcraft | EPL3015-427M | | |
| CRCW04021M00JNED | Res 1.0 mΩ 1/6W | R16 | R402-25RD | CRCW04021M00JNED | 1 | | | Digi-Key | 541-1.0MJCT-ND |
| CRCW0402200KJNED | Res 200 kΩ 1/6W | R17 | R402-25RD | CRCW0402200KJNED | 1 | | | Digi-Key | 541-200KJDKR-ND |
| EG1390B | | U2 | EG1390-SWITCH | EG1390B | 1 | | | Digi-Key | EG4633TR-ND |
| TPS6120DCK | | U3 | DCK6 | TPS61220DCK | 1 | | | Digi-Key | 296-32505-2-ND |

## 5.2 BLE and AFE Section

See SNVC103 for additional schematics of the SAT0010 AFE (LMP91000) and BLE (CC2541), and SNVC101 for the BOM.

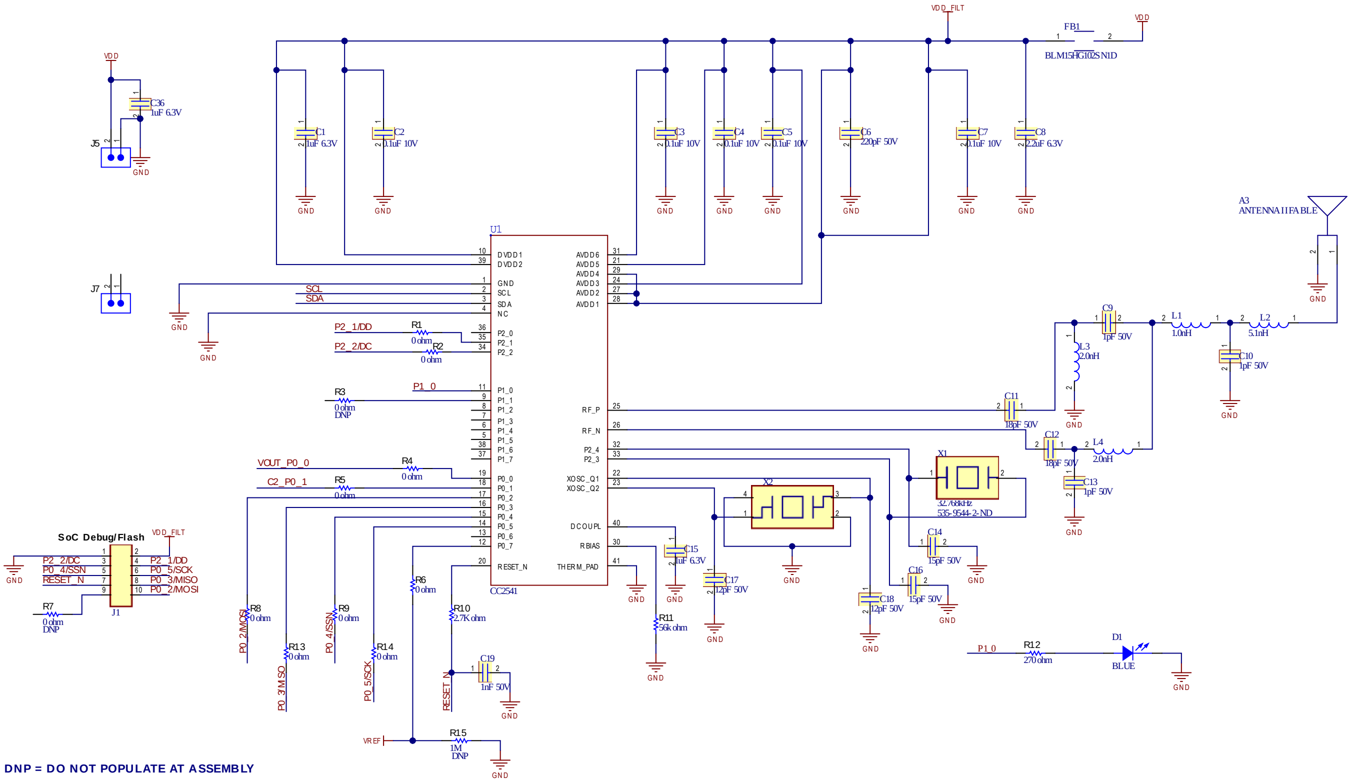
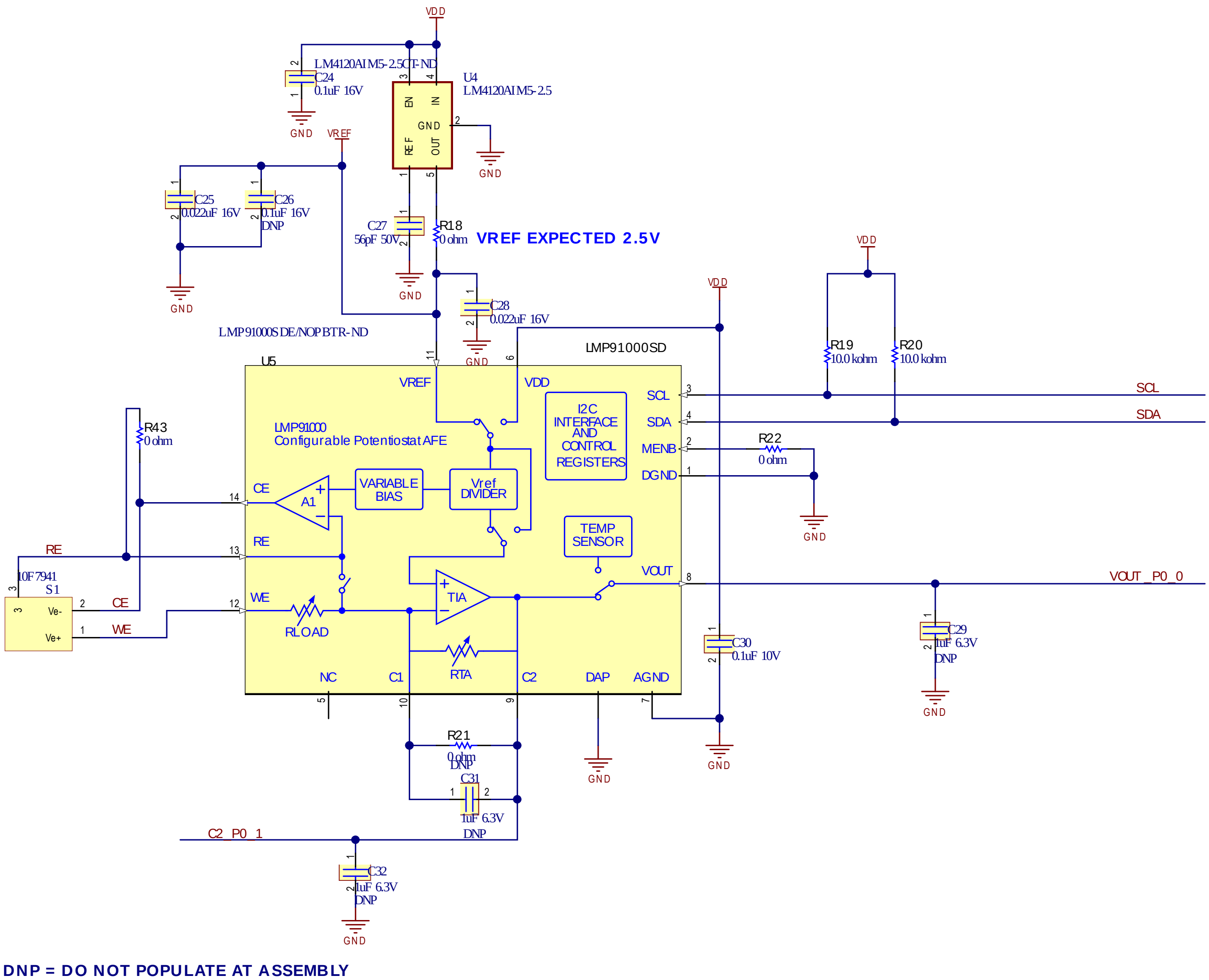


Figure 23. BLE Section




DNP = DO NOT POPULATE AT ASSEMBLY

**Figure 24. AFE Section**

## Table 3. BLE Section BOM

| Comment | Description | Designator | Footprint | LibRef | Qty | ASSY_Option | Manufacturer | Part No. | Supplier | Part No. |
|---|---|---|---|---|---|---|---|---|---|---|
| ANTENNA IIFA BLE | Antenna IIFA BLE | A3 | Antenna_IIFA _BLE | Antenna | 1 | No part to order or place at ASSY | | | | |
| GRM155R60J105KE19D | Cap Cer 1 µF 6.3 V 10% X5R | C1, C15, C36 | C402-25RD | GRM155R60J105KE19D | 3 | | | GRM155R60J105KE19D | Digi-Key | 490-1320-2-ND |
| GRM155R71A104KA01D | Cap Cer 0.1 µF 10 V 10% X7R | C2, C3, C4, C5, C7, C30 | C402-25RD | GRM155R71A104KA01D | 6 | | | GRM155R71A104KA01D | Digi-Key | GRM155R71A104KA01D -ND |
| GRM1555C1H221JA01D | Cap Cer 220 pF 50 V 5% NP0 | C6 | C402-25RD | GRM1555C1H221JA01D | 1 | | | GRM1555C1H221JA01D | Digi-Key | 490-1293-2-ND |
| GRM155R60J225ME15D | Cap Cer 2.2 µF 6.3 V 20% X5R | C8 | C402-25RD | GRM155R60J225ME15D | 1 | | | GRM155R60J225ME15D | Digi-Key | 490-4519-1-ND |
| GRM1555C1H1R0CA01D | Cap Cer 1 pF 50 V NP0 | C9, C10, C13 | C402-25RD | GRM1555C1H1R0CA01D | 3 | | | GRM1555C1H1ROCA01D | Digi-Key | 490-3199-2-ND |
| GRM1555C1H180JZ01D | Cap Cer 18 pF 50 V 5% NP0 | C11, C12 | C402-25RD | GRM1555C1H180JZ01D | 2 | | | GRM1555C1H180JZ01D | Digi-Key | 490-1281-2-ND |
| GRM1555C1H150JA01D | Cap Cer 15 pF 50 V 5% NP0 | C14, C16 | C402-25RD | GRM1555C1H150JA01D | 2 | | | GRM1555C1H150JA01D | Digi-Key | 490-5888-2-ND |
| GRM1555C1H120JA01D | Cap, 0402, C0G, 50 V, 12 pF | C17, C18 | C402-25RD | GRM1555C1H120JA01D | 2 | | | GRM1555C1H120JA01D | Newark | 14T3292 |
| GRM1555C1H102JA01D | Cap Cer 1000 pF 50 V 5% NP0 | C19 | C402-25RD | GRM1555C1H102JA01D | 1 | | | GRM1555C1H102JA01D | Digi-Key | 490-324-2-ND |
| C0402C104K4RAC7411 | Cap Cer 0.1 µF 16 V 10% X7R | C24 | C402-25RD | C0402C104K4RAC7411 | 1 | | | C0402C104K4RAC7411 | Digi-Key | 399-7352-2-ND |
| GRM155R71C223KA01J | Cap Cer 0.022 µF 16 V 10% X7R | C25, C28 | C402-25RD | GRM155R71C223KA01J | 2 | | Johanson Dielectrics Inc. | GRM155R71C223KA01J | Digi-Key | 709-1128-2-ND |
| C0402C104K4RAC7411 | Cap Cer 0.1 µF 16 V 10% X7R | C26 | C402-25RD | C0402C104K4RAC7411 | 1 | DNP | | C0402C104K4RAC7411 | Digi-Key | 399-7352-2-ND |
| VJ0402D560JXAAJ | Cap Cer 56 pF 50 V 5% NP0 | C27 | C402-25RD | VJ0402D560JXAAJ | 1 | | | VJ0402D560JXAAJ | Digi-Key | 720-1293-2-ND |
| GRM155R60J105KE19D | Cap Cer 1 µF 6.3 V 10% X5R | C29, C31, C32 | C402-25RD | GRM155R60J105KE19D | 3 | DNP | | GRM155R60J105KE19D | Digi-Key | 490-1320-2-ND |
| LED 0402 BLUE 465NM TRANSPARENT | | D1 | LED-SML-31SQ | LED 0402 BLUE465NM TRANSPARENT | 1 | | | | Digi-Key | 511-1615-1-ND |
| BLM15HG102SN1D | Filter Chip 1000 Ω 250 mA | FB1 | I402-25 | BLM15HG102SN1D | 1 | | | BLM15HG102N1D | Digi-Key | 490-3999-2-ND |
| FTSH-105-01-FDH | | J1 | FTSH2X5-110X29 | FTSH-105-01-FDH | 1 | | | | Arrow | 2745567S5787043N1004 |
| TBSTC-501-D- 200-22-G-300-LF | Major League Elec .050x.050 cl Thicker Brd Stacker Term Strips - Custom | J5, J7 | JUMP1X2-3826-50CTR | TBSTC-501-D- 200-22-G-300- LF | 2 | | Major League Elec | TBSTC-501-D-200-22-G-300-LF | | |
| LQG15HS1N0S02D | 1 nH, I0402-25 | L1 | I402-25 | LQG15HS1N0S02D | 1 | | Murata Elec | LQG15HS1N0S02D | Digi-Key | 490-2610-2-ND |
| LQG15HH5N1S02D | 5.1 nH ±0.3 nH, I0402-25 | L2 | I402-25 | LQG15HH5N1S02D | 1 | | Murata Elec | LQG15HH5N1S02D | Mouser | 81-LQG15HH5N1S02D |
| LQG15HS2N0S02D | 2.0 nH, I0402-25 | L3, L$ | I402-25 | LQG15HS2N0S02D | 2 | | Murata | LQG15HS2N0S02D | Mouser | 81-LQG15HS2N0S02D |

## Table 3. BLE Section BOM (continued)

| Comment | Description | Designator | Footprint | LibRef | Qty | ASSY_Option | Manufacturer | Part No. | Supplier | Part No. |
|---|---|---|---|---|---|---|---|---|---|---|
| ERJ-2GE0R00X | Res 0 Ω 1/10W | R1, R2, R4, R5, R6, R8, R9, R13, R14, R18, R22, R43 | R402-25RD | ERJ-2GE0R00X | 12 | | | | Digi-Key | P0.0JTR-ND |
| ERJ-2GE0R00X | Res 0 Ω 1/10W | R3, R21 | R402-25RD | ERJ-2GE0R00X | 2 | DNP | | | Digi-Key | P0.0JTR-ND |
| CR0402-J/-000G | Resistor Chip, Jumper, 0 Ω, 1% | R7 | R402-25RD | CR0402-J/-000G | 1 | DNP | | | Newark | 02J1955 |
| CRCW04022K70FKED | Res 2.70 kΩ 1/16W 1% | R10 | R402-25RD | CRCW04022K70FKED | 1 | | | | Digi-Key | 541-2.70KLCT-ND |
| CRCW040256K0FKED | Res 56 kΩ 1/16W 1% | R11 | R402-25RD | CRCW040256K0FKED | 1 | | | | Digi-Key | 541-56.0KLCT-ND |
| CRCW0402270RFKED | Res 270 Ω 1/16W 1% | R12 | R402-25RD | CRCW0402270RFKED | 1 | | | | Digi-Key | 541-270LCT-ND |
| CRCW04021M00JNED | Res 1 mΩ 1/16W 5% | R15 | R402-25RD | CRCW04021M00JNED | 1 | DNP | | | Digi-Key | 541-1.0MJCT-ND |
| CRCW040210K0FKED | Res 10 KΩ 1/16W 1% | R19, R20 | R402-25RD | CRCW040210K0FKED | 2 | | | | Digi-Key | 541-10.0KLCT-ND |
| Socket and Oxygen-Sensor | | S1 | SKT_O2-A1 | Socket and Oxygen-Sensor | 1 | | Alphasense (Sensor) | 02-A1 | Newark | 10F7941 |
| | | | | | | | Cambion (Socket) | 450-3326-01-03-00 | | |
| CC2541 | Single-Chip BLE | U1 | | CC2541 | 1 | | TI | CC2541F256RHAR | | |
| LM4120AIM5- 2.5/NOPB | IC VREF Series Prec 2.5 V | U4 | SOT23-27X39-5 | LM4120AIM5-2.5/NOPB | 1 | | | | Digi-Key | LM4120AIM5-2.5CT-ND |
| LMP91000SD | Configurable AFE Potentiostat for Low-Power Chemical Sensing | U5 | NHL0014B-WSON | LMP91000SD | 1 | | TI | | Digi-Key | LMP91000SDE/NOPBTR-ND |
| ABS07- 32.768kHz-9 | Oscillator | X1 | XTAL2-ABS07 | ABS07-32.768kHz-9 | 1 | | | | Digi-Key | 535-9544-2-ND |
| FA128 | Oscillator | X2 | XTAL4-37X34-FA128 | FA128 | 1 | | Epson | Q22FA1280009200 | | |

**NOTE:** Capacitors C29 and C32 on SAT0010 provide low-pass filtering to the analog output signals (VOUT and C2) from LMP91000. In the schematic, they are placed as placeholders and shown as DNP (do not populate). During testing of this platform it was noted that a value of .01 µF was most optimized for C29 and C32 for this particular platform. Customers can fine-tune this selection based on their system design.

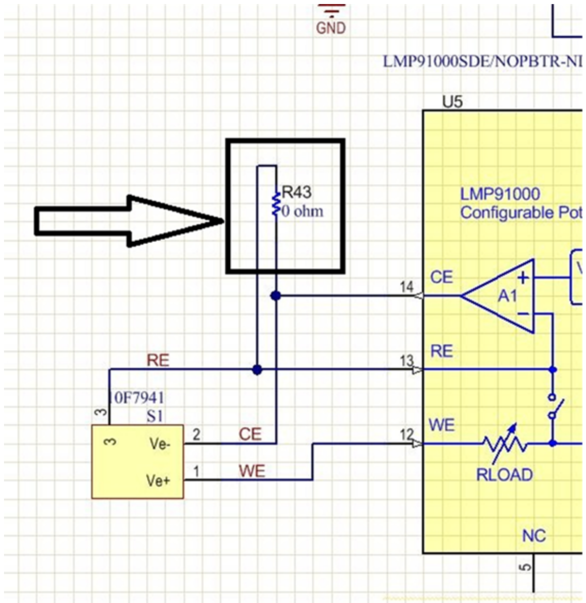



**Figure 25. CO and $O_2$**

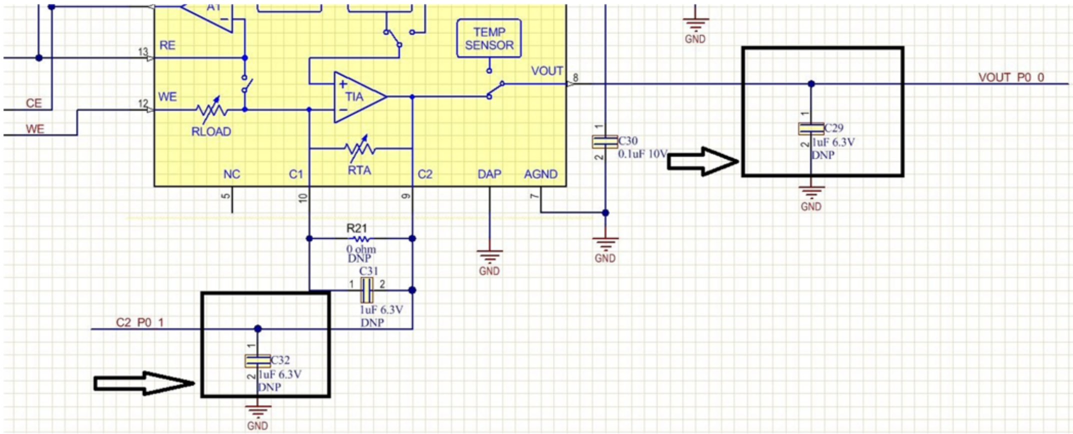



**Figure 26. Filter**

# 6 Layout

## 6.1 SAT Gas Sensor Platform With BLE

### 6.1.1 SAT0009 (Power Board) Layer Plots

See SNVC102 for additional layer plots of the SAT0009 (power board, Figure 27).

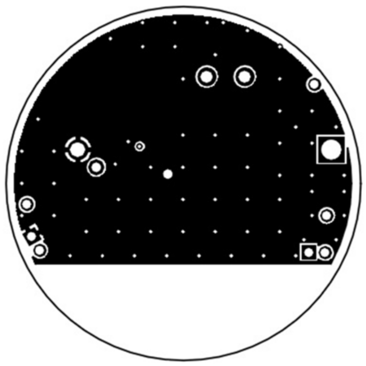



**Figure 27. Power Board**

### 6.1.2 SAT0010 (AFE and BLE Board) Layer Plots

See SNVC102 for additional layer plots of the SAT0010 (AFE and BLE board, Figure 28).

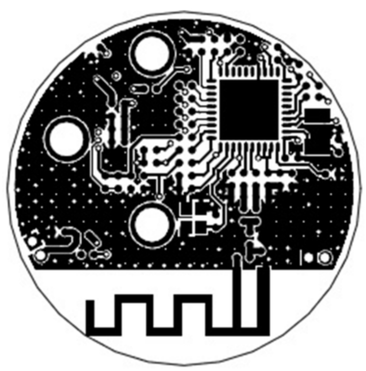



**Figure 28. AFE and BLE Board**

# 7 Practical Applications

## 7.1 iOS Application

Figure 29, Figure 30, Figure 31, Figure 32, and Figure 33 show the TI BLE Sensor application as used with an iPad.

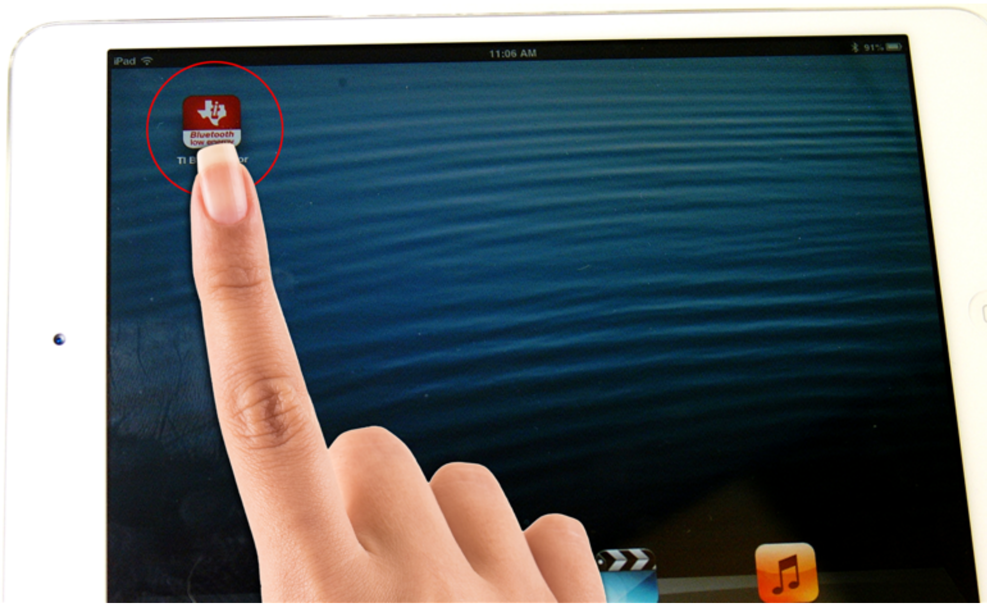


Figure 29. Application Icon


**Figure 30. Locating the Sensors**

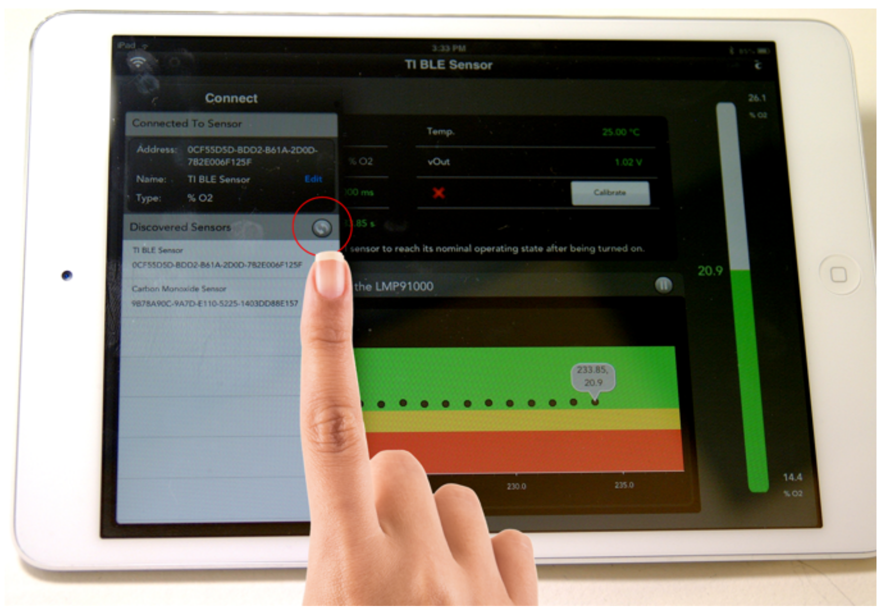



**Figure 31. Updating the Sensors**

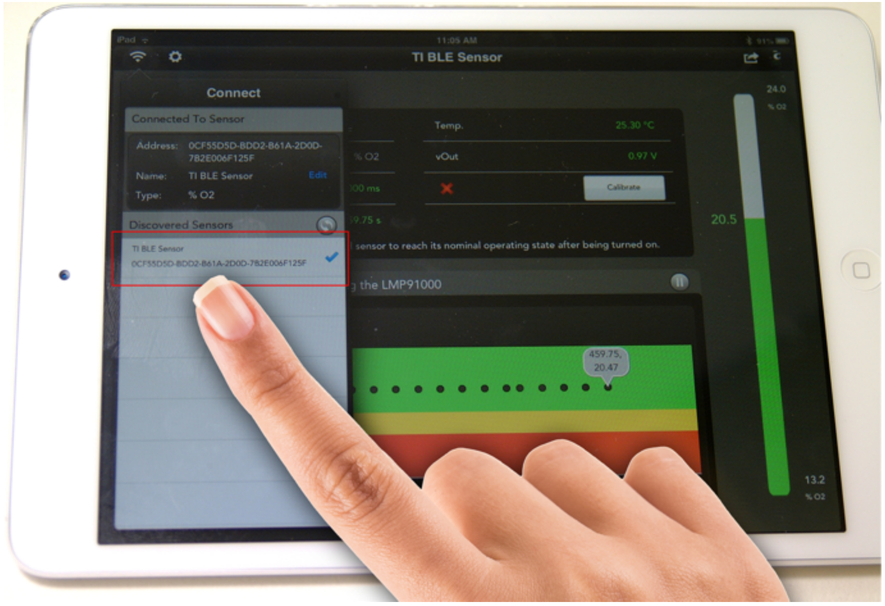



**Figure 32. Connecting to a Sensor**


**Figure 33. Main Menu**

### 7.2 Firmware Section

One of the development platforms for the CC2451 8051 microcontroller is the IAR development platform. For information on this platform, see http://www.iar.com/.

To communicate to the development platform through IAR, the CC DEBUGGER is required. See Section 3.1.

The CC DEBUGGER must be connected to the 10-pin header on the SAT0010 board. Make sure that the notch on the cable that connects to the 10-pin header is facing away from the sensor or toward the outside. If connected properly, the LED on the CC DEBUGGER turns green.


**Figure 34. CC DEBUGGER**

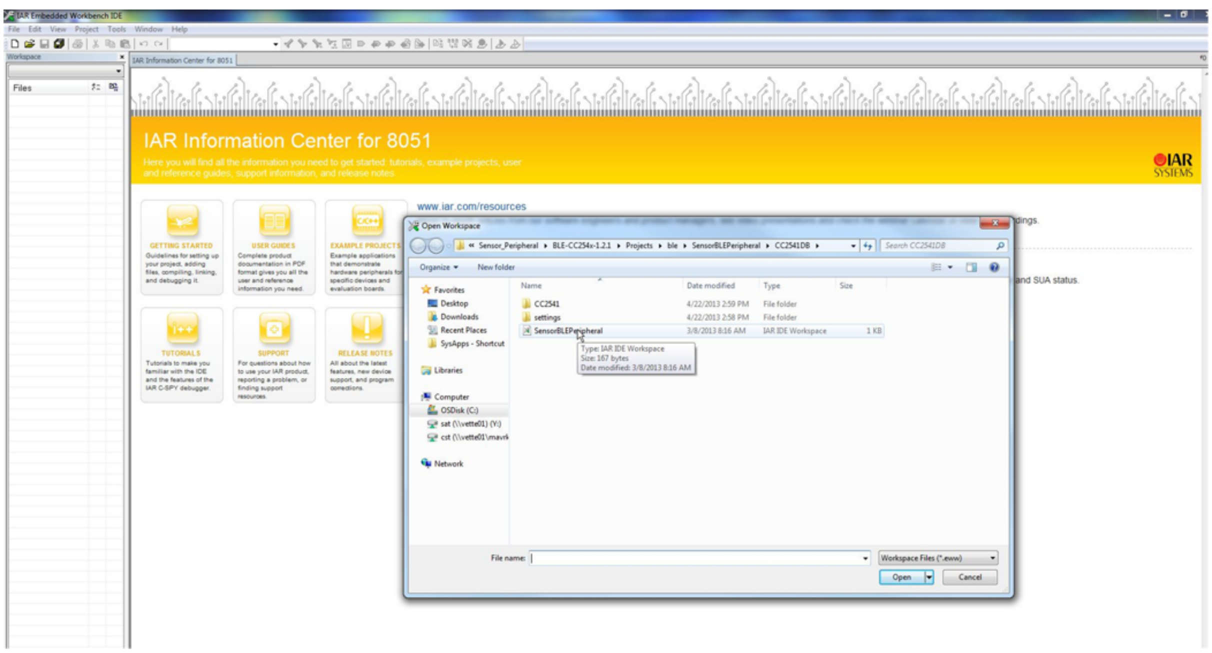



**Figure 35. Launching IAR**

Launch the project file as shown in Figure 35.

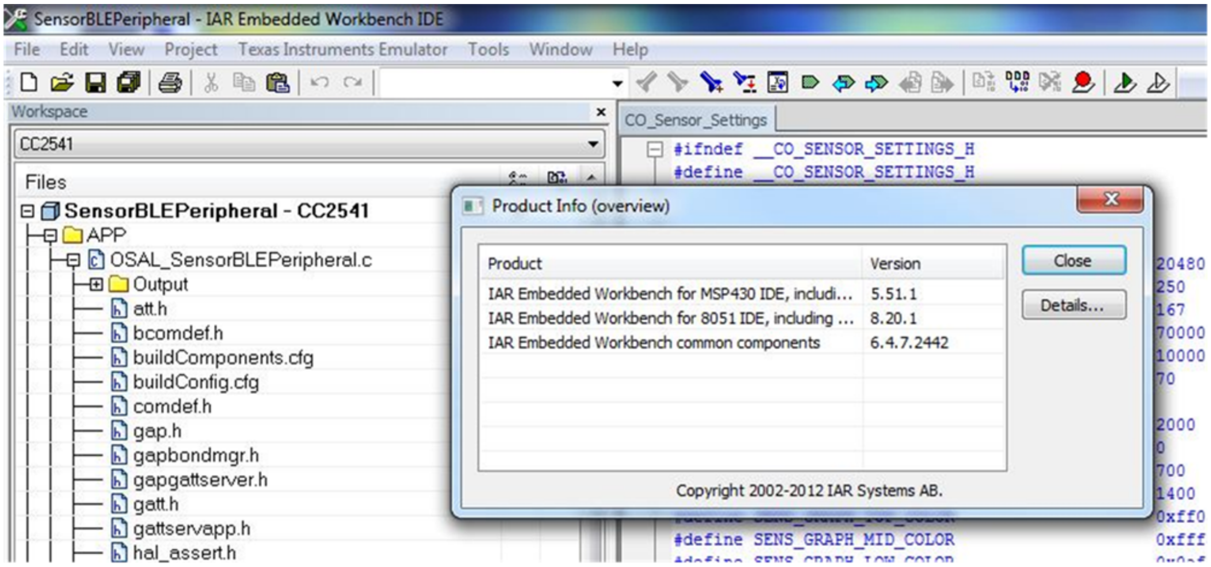



**Figure 36. IAR Version in Use**

Ensure that you are using the version used in Figure 36 or a newer version.

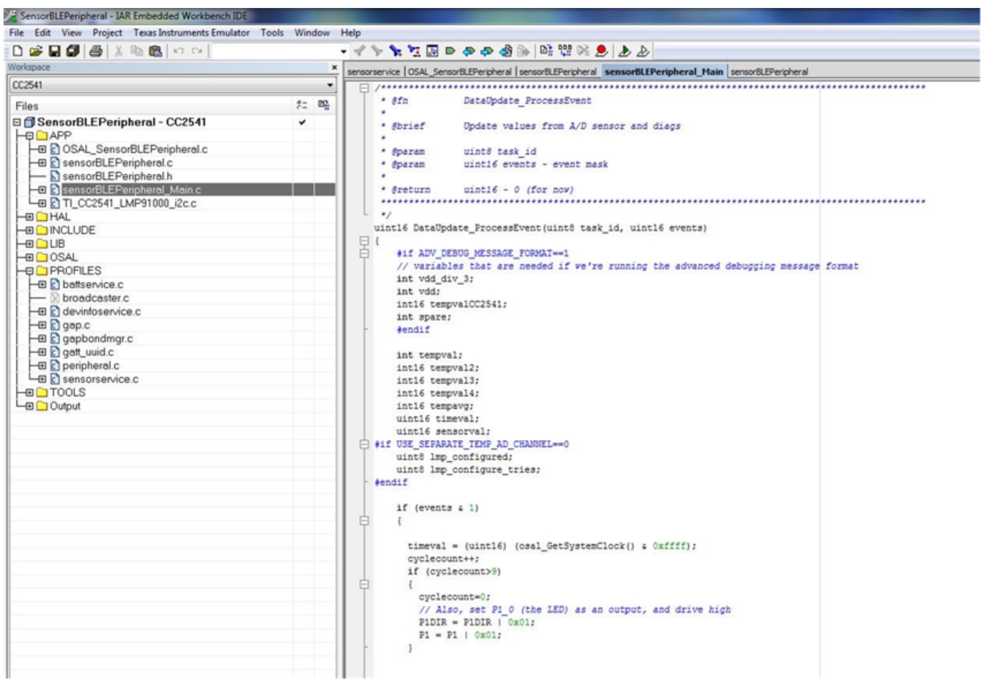


**Figure 37. Main Loop**

Highlight Main.c, as shown in Figure 37.

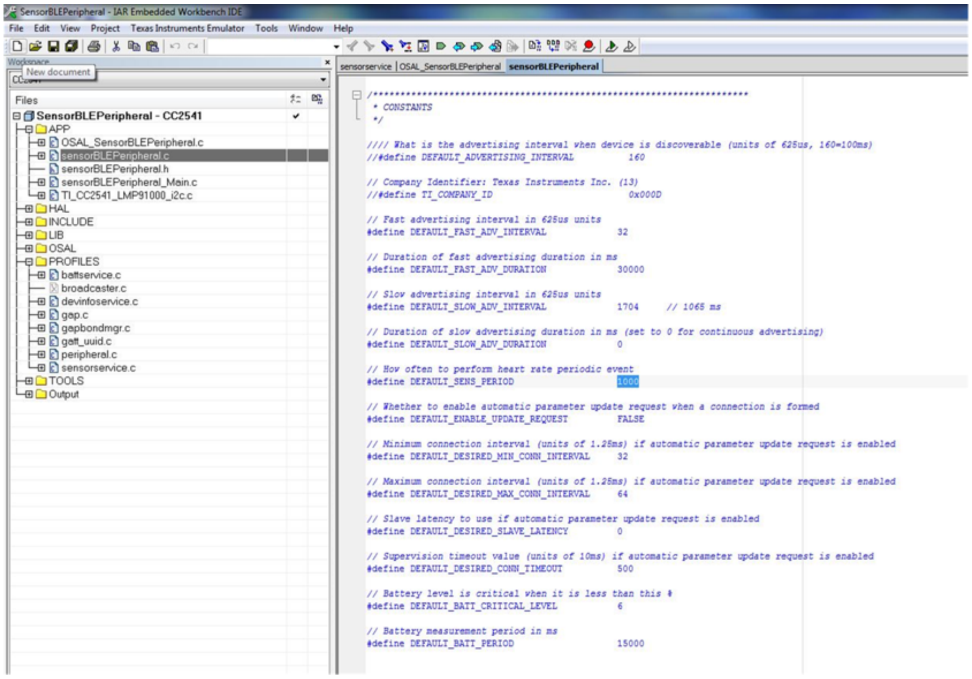



**Figure 38. Communication Settings**

The number of times the *Bluetooth* radio communicates with the iOS application can be easily changed by using the highlighted variable shown in Figure 38.

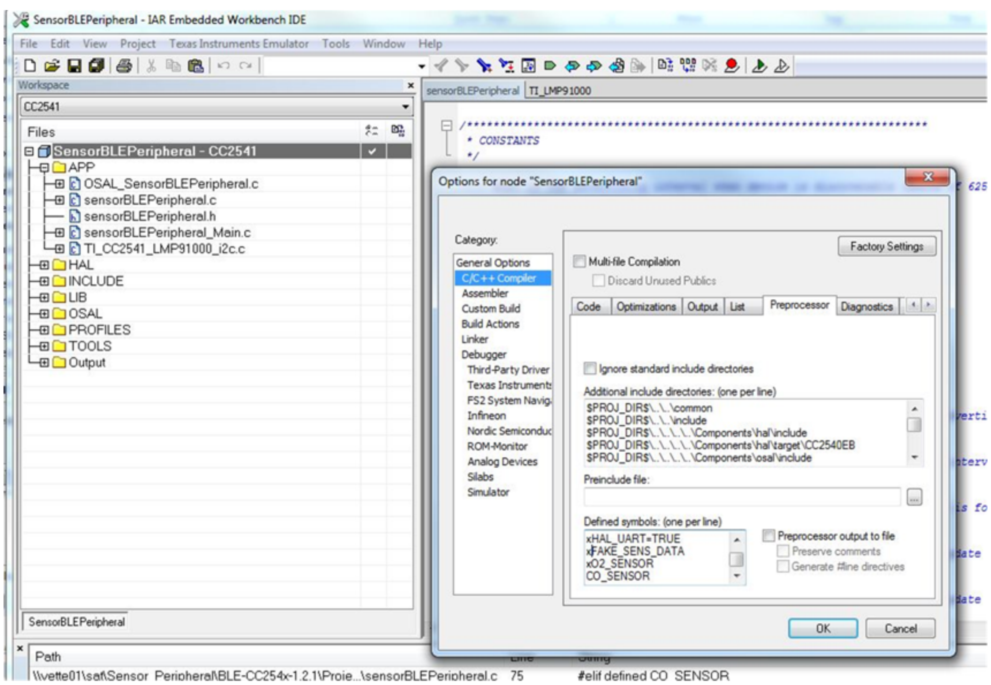



**Figure 39. Sensor Section**

The firmware has a case statement to easily change from a CO sensor to an $O_2$ sensor, as shown in Figure 39. Note the x in front of the CO option.

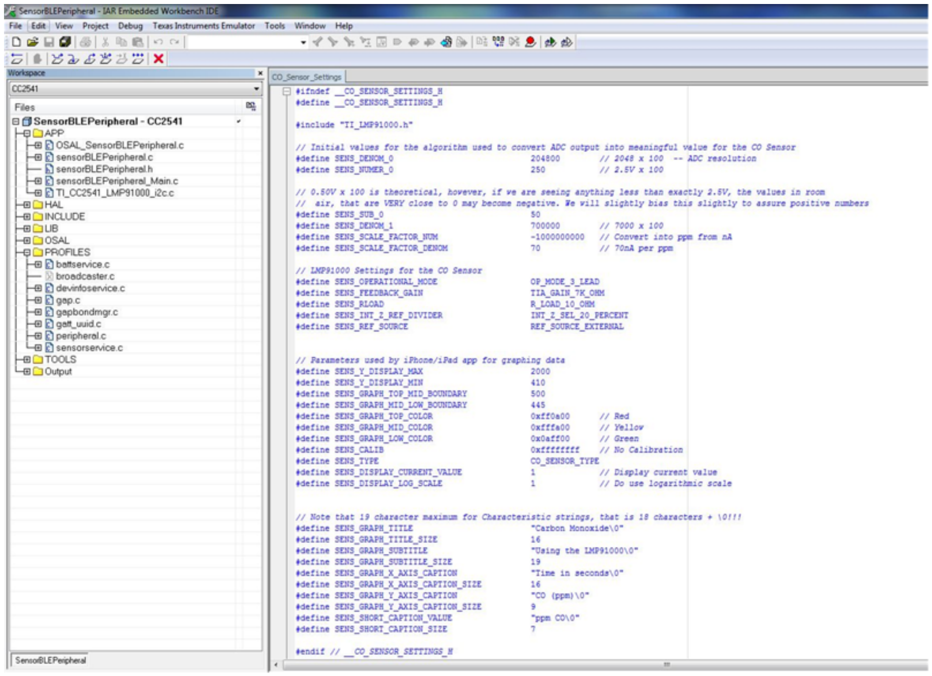


**Figure 40. CO Settings**

All the key configuration settings for LMP91000 have been co-located for easy update to the firmware (see Figure 40).

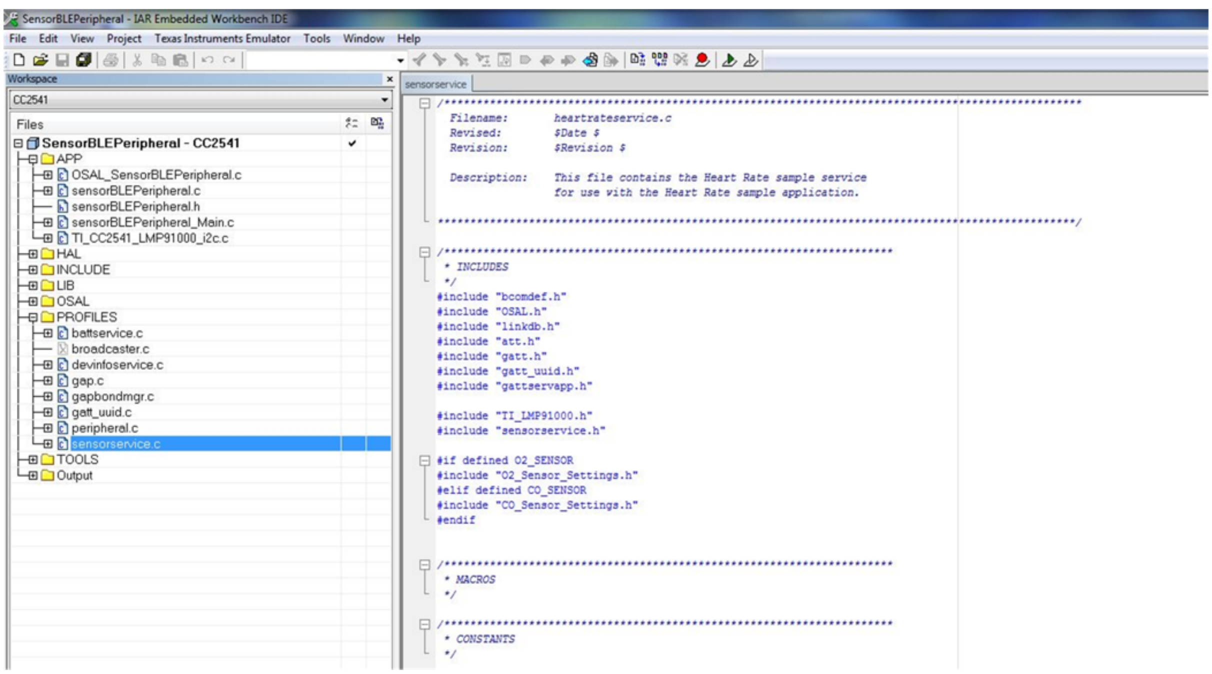



**Figure 41. Adding New Sensor**

New sensor services can be added to the firmware, as shown in Figure 41.

## Appendix A SAT0009 Power Board Files

### A.1 Gerber Files

See SNVC106 for the Gerber files for the SAT0009 power board and the SAT0010 AFE and BLE board.

### A.2 Altium Project Files

See SNVC100 for the Altium Project files of the SAT0009 power board (see Figure 42).

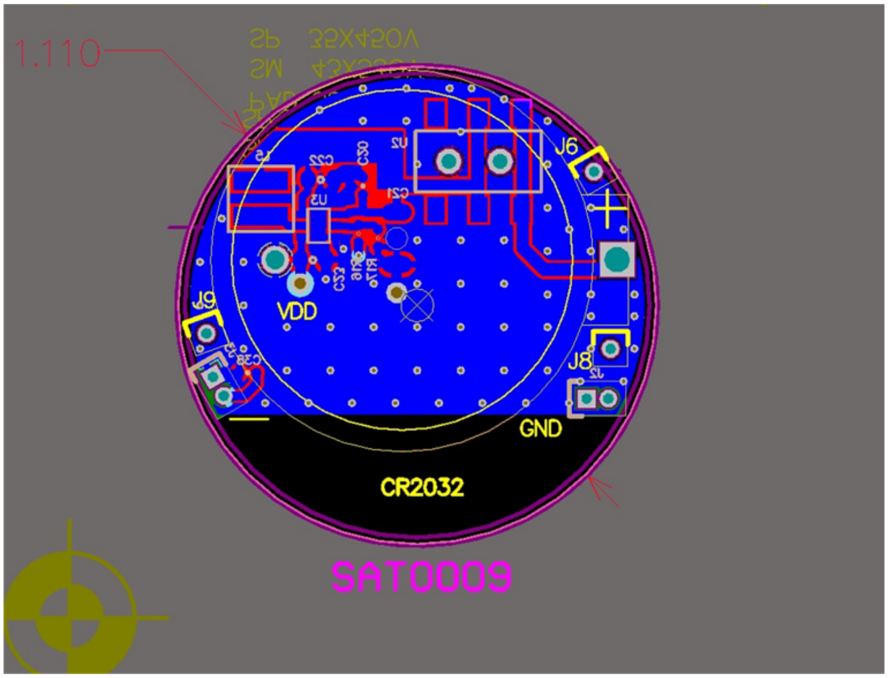



**Figure 42. Power Board**

See SNVC100 for the Altium Project files of the SAT0010 AFE and BLE board (see Figure 43).

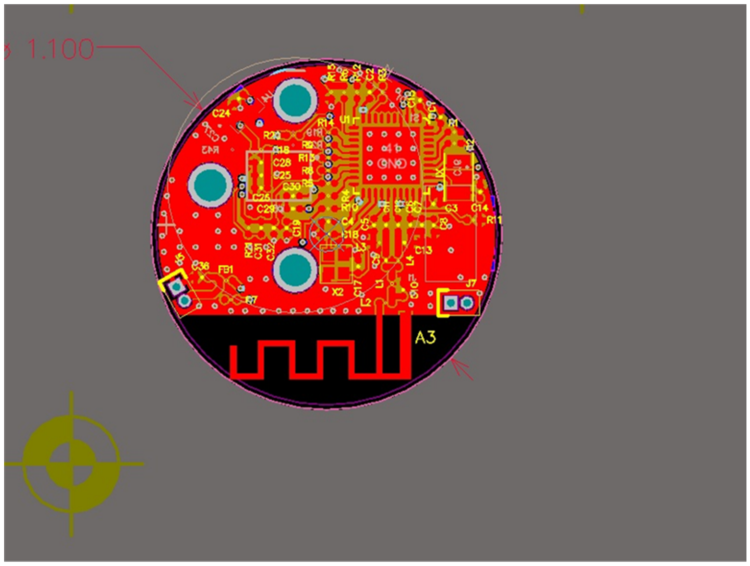


Figure 43. AFE and BLE Board

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6. User assumes all responsibility, obligation, and any corresponding liability for proper and safe handling and use of EVMs.
7. Should any EVM not meet the specifications indicated in the user’s guide or other documentation accompanying such EVM, the EVM may be returned to TI within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY TI TO USER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. TI SHALL NOT BE LIABLE TO USER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES RELATED TO THE HANDLING OR USE OF ANY EVM.
8. No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which EVMs might be or are used. TI currently deals with a variety of customers, and therefore TI’s arrangement with the user is not exclusive. TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services with respect to the handling or use of EVMs.
9. User assumes sole responsibility to determine whether EVMs may be subject to any applicable federal, state, or local laws and regulatory requirements (including but not limited to U.S. Food and Drug Administration regulations, if applicable) related to its handling and use of EVMs and, if applicable, compliance in all respects with such laws and regulations.
10. User has sole responsibility to ensure the safety of any activities to be conducted by it and its employees, affiliates, contractors or designees, with respect to handling and using EVMs. Further, user is responsible to ensure that any interfaces (electronic and/or mechanical) between EVMs and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
11. User shall employ reasonable safeguards to ensure that user’s use of EVMs will not result in any property damage, injury or death, even if EVMs should fail to perform as described or expected.
12. User shall be solely responsible for proper disposal and recycling of EVMs consistent with all applicable federal, state, and local requirements.

**Certain Instructions.** User shall operate EVMs within TI’s recommended specifications and environmental considerations per the user’s guide, accompanying documentation, and any other applicable requirements. Exceeding the specified ratings (including but not limited to input and output voltage, current, power, and environmental ranges) for EVMs may cause property damage, personal injury or death. If there are questions concerning these ratings, user should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the applicable EVM user's guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using EVMs’ schematics located in the applicable EVM user's guide. When placing measurement probes near EVMs during normal operation, please be aware that EVMs may become very warm. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use EVMs.

**Agreement to Defend, Indemnify and Hold Harmless.** User agrees to defend, indemnify, and hold TI, its directors, officers, employees, agents, representatives, affiliates, licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of, or in connection with, any handling and/or use of EVMs. User’s indemnity shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if EVMs fail to perform as described or expected.

**Safety-Critical or Life-Critical Applications.** If user intends to use EVMs in evaluations of safety critical applications (such as life support), and a failure of a TI product considered for purchase by user for use in user’s product would reasonably be expected to cause severe personal injury or death such as devices which are classified as FDA Class III or similar classification, then user must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

# RADIO FREQUENCY REGULATORY COMPLIANCE INFORMATION FOR EVALUATION MODULES

Texas Instruments Incorporated (TI) evaluation boards, kits, and/or modules (EVMs) and/or accompanying hardware that is marketed, sold, or loaned to users may or may not be subject to radio frequency regulations in specific countries.

**General Statement for EVMs Not Including a Radio**

For EVMs not including a radio and not subject to the U.S. Federal Communications Commission (FCC) or Industry Canada (IC) regulations, TI intends EVMs to be used only for engineering development, demonstration, or evaluation purposes. EVMs are not finished products typically fit for general consumer use. EVMs may nonetheless generate, use, or radiate radio frequency energy, but have not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or the ICES-003 rules. Operation of such EVMs may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

**General Statement for EVMs including a radio**

*User Power/Frequency Use Obligations*: For EVMs including a radio, the radio included in such EVMs is intended for development and/or professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability in such EVMs and their development application(s) must comply with local laws governing radio spectrum allocation and power limits for such EVMs. It is the user’s sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by TI unless user has obtained appropriate experimental and/or development licenses from local regulatory authorities, which is the sole responsibility of the user, including its acceptable authorization.

**U.S. Federal Communications Commission Compliance**

**For EVMs Annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant**

**Caution**

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications could void the user's authority to operate the equipment.

**FCC Interference Statement for Class A EVM devices**

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at its own expense.

**FCC Interference Statement for Class B EVM devices**

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

**Industry Canada Compliance (English)**

**For EVMs Annotated as IC – INDUSTRY CANADA Compliant:**

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

**Concerning EVMs Including Radio Transmitters**

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

**Concerning EVMs Including Detachable Antennas**

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

**Canada Industry Canada Compliance (French)**

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

**Concernant les EVMs avec appareils radio**

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

**Concernant les EVMs avec antennes détachables**

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d’usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265


## Important Notice for Users of EVMs Considered “Radio Frequency Products” in Japan

**EVMs entering Japan are NOT certified by TI as conforming to Technical Regulations of Radio Law of Japan.**

If user uses EVMs in Japan, user is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry’s Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after user obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after user obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless user gives the same notice above to the transferee. Please note that if user does not follow the instructions above, user will be subject to penalties of Radio Law of Japan.

http://www.tij.co.jp

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In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed an agreement specifically governing such use.

Only those TI components that TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components that have ***not*** been so designated is solely at Buyer's risk, and Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

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