User's Guide
SLAU832–June 2020

AFE4950 Evaluation Module Development Guide

This user guide describes the operation of the AFE4950 EVM demonstration kit. This demonstration kit is an evaluation module for the AFE4950 device. The AFE4950 is a fully- Integrated AFE for Wearable Optical Heart-Rate Monitoring, SpO2 and ECG. The EVM is intended for evaluation of the AFE features. This document also describes the steps for generating the AFE4950 register configuration files using the provided Excel tool for different operating conditions easily.

The following related documents are available on Texas Instruments web site at www.ti.com:

Device	Literature Number
AFE4950	SBASA36

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1 AFE4950 EVM Overview

1.1 Important Disclaimer Information

CAUTION

The AFE4950 EVM is intended for feasibility and evaluation testing only in laboratory and development environments. This product is not for diagnostic use. This product is not for use with a defibrillator.

Use the AFE4950 EVM with the following conditions:

- The AFE4950 EVM demonstration kit is intended only for electrical evaluation of the features of the AFE4950 devices in a laboratory, simulation, or development environment.
- The AFE4950 EVM demonstration kit is not intended for direct interface with a patient, or patient diagnostics.
- The AFE4950 EVM demonstration kit is intended for development purposes only. It is not intended to be used as all or part of an end-equipment application.
- The AFE4950 EVM demonstration kit should be used only by qualified engineers and technicians who are familiar with the risks associated with handling electrical and mechanical components, systems, and subsystems.

NOTE: Users are responsible for the safety of others as well as themselves when using or handling the AFE4950 EVM. Furthermore, users are responsible for the contact interface between a human body and electronics. Consequently, the user is responsible for preventing electrical hazards such as shock, electrostatic discharge, and electrical overstress of electric circuit components.

2 AFE4950 EVM Evaluation

All the latest software, firmware files will be uploaded to TI MSS folder. Use the latest software, firmware before starting the evaluation. Please visit www.ti.com/mysecuresoftware to access MSS folder. Files in the MSS folder are listed in Table 1.

Table 1. EVM software and other useful files in MSS folder

File	Description
Bio-Sensing_Installer_Vx.exe	Base Installer for GUI
AFE4950EVM_Installer_Vx.exe	Project specific installer for AFE9I30EVM
AFE4950_Register_Generation_Vx.zip	Contains latest Excel based register generation tool
BSL_Vx.zip	Contains latest compiled firmware as well as a utility to load the firmware into EVM
USB_Driver_Vx.zip	Latest USB driver for the EVM

2.1 AFE4950 EVM Kit Contents

AFE4950 EVM Kit contains the following components:

1. AFE4950 EVM Demonstration Kit
2. USB-to-micro USB cable
3. 10-pin to 10-pin sensor cable (Note: The sensor cable is provided as a convenience to enable measurements and cannot be used for any SNR measurements.)
4. AFE4950 PPG sensor board.
5. Cables for ECG connectors.

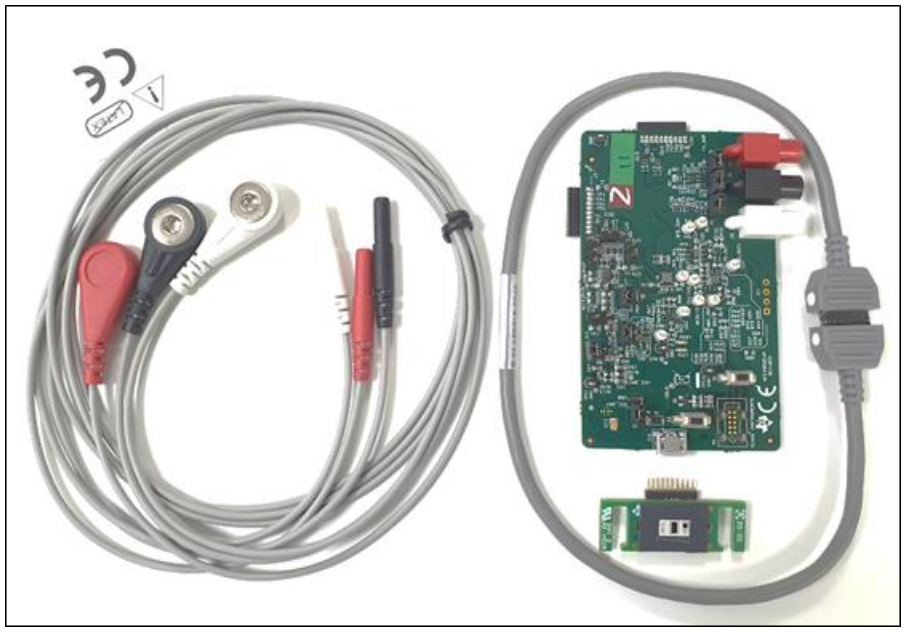


Figure 1. Contents of the AFE4950 EVM Demonstration Kit

2.2 Install the PC application EVM Software

There are two installers for AFE4950EVM's GUI as described below:

a. Bio-Sensing_Installer_Vx.exe: This installs the framework for the GUI. It is common for all the AFEs in the same family. If its latest version is already installed then, installation of this can be skipped.

b. AFE4950EVM_Installer_Vx.exe: This installs necessary components specific to AFE4950EVM.

Follow the below steps to install the PC application software:

1. Run the base installer (i.e. *Bio-Sensing_Installer_Vx.exe*) and follow the prompts to install the software. **This step can be skipped if latest version of this file is already installed in the PC.** The default installation directory will be: *C:\Program Files\Texas Instruments\Bio-Sensing*. Whereas the default location for all the project specific files will be C:\Users\..\Documents\Texas Instruments\Bio-Sensing.
2. Run the project specific installer (i.e. *AFE4950EVM_Installer_Vx.exe*) and follow the prompts to install the software

2.3 Install the USB driver

This step is required only if two USB COM ports are not detected when the EVM is connected to PC. If the PC already has EVM software installed for previous AFEs (i.e. EVM gets detected as "*AFE44xx EVM*"), its driver has to be un-installed and deleted (as shown below) before installing the new driver. **After deleting the old driver, if AFE4950EVM doesn't get detected as 2 USB COM ports then follow the step given below to install the new driver.**

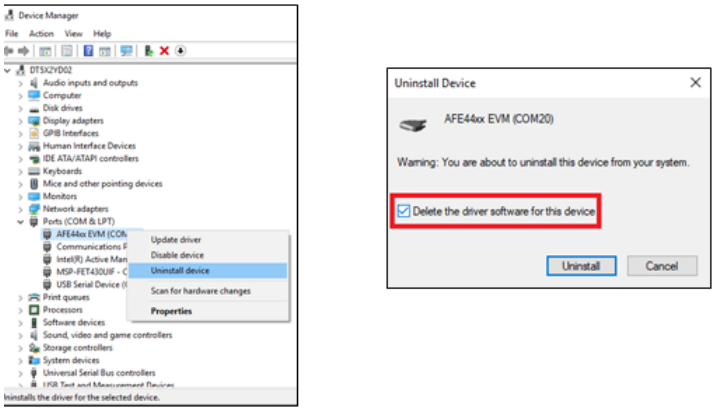


Figure 2. Uninstalling the Driver of Previous Generation AFE44xx/AFE49xx EVM

Follow the steps below to install the AFE4950EVM USB driver:

1. The communication interface between the AFE4950 EVM board and the PC is transmitted through the USB with a CDC profile. A one-time installation of the USB driver is required for communication between the AFE4950 EVM and PC application to function.
2. Plugin the USB-to-mini USB cable to J10 of AFE4950 EVM and the other end to the USB port on the PC.
3. Update the driver software from the Device Manager. The USB driver file **MSP430_CDC.inf** is located in the installation directory: *C:\Program Files\Texas Instruments\Bio-Sensing\AFE4950EVM\USB driver*

2.4 EVM Firmware Upgrade

Use the following steps to upgrade the AFE4950 EVM firmware:

1. Open the firmware loader application from the EVM software installation directory (i.e. *C:\Program Files\Texas Instruments\Bio-Sensing\AFE4950EVM\EVM Firmware*) by clicking the **BSL_USB_GUI.exe**
2. Click the **Browse** button and select the AFE4950 firmware. Figure 3 shows the firmware loader application with the appropriate firmware selected. The firmware is provided along with EVM software and will be at the location given below. Version number could differ.
   C:\Program Files\Texas Instruments\Bio-Sensing\AFE4950EVM\EVM Firmware\AFE4950 V1.1.0.txt
3. Press the **S1** switch on the EVM while plugging in the micro-USB interface cable (connected to PC) to the **J10** micro-USB connector on the EVM.
4. Release the **S1** switch when the application displays **Found 1 device** as shown in Figure 4. If the application does not detect the device and displays **No Device Connected**, then repeat step 3. Click on the **Upgrade Firmware** button when enabled.
5. The text box will display the status of the firmware programming. If programming is successful, **Done** message is displayed in the text box. Figure 5 shows the status of the successful programming.

Figure 3 to Figure 5 shows the utility to load the EVM firmware.

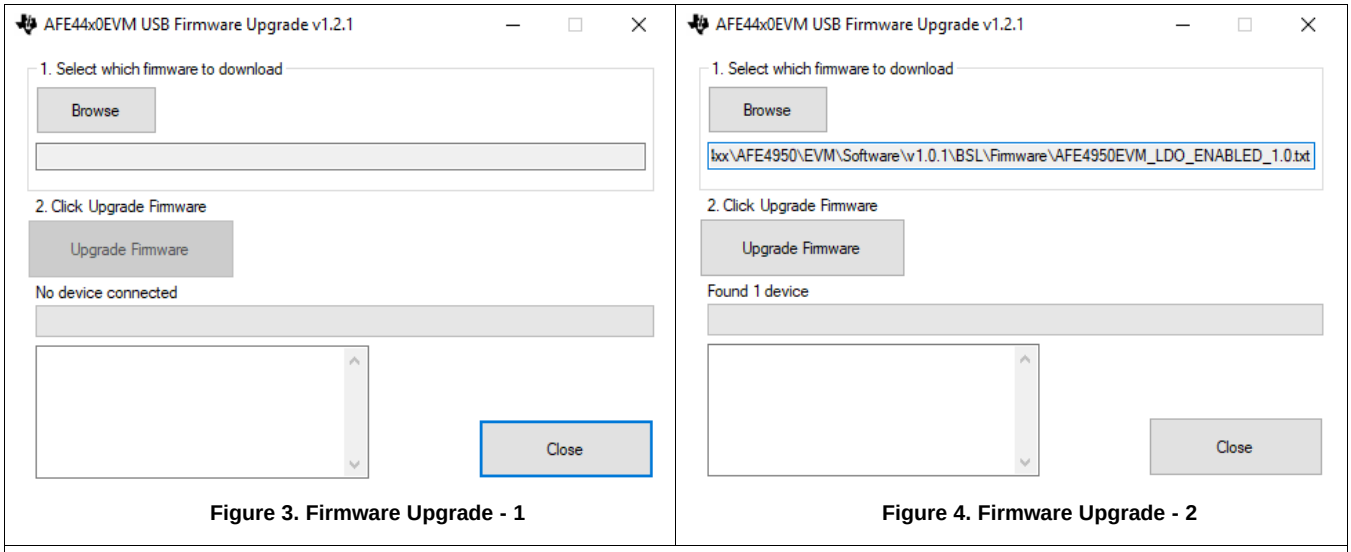


Figure 3. Firmware Upgrade - 1

Figure 4. Firmware Upgrade - 2

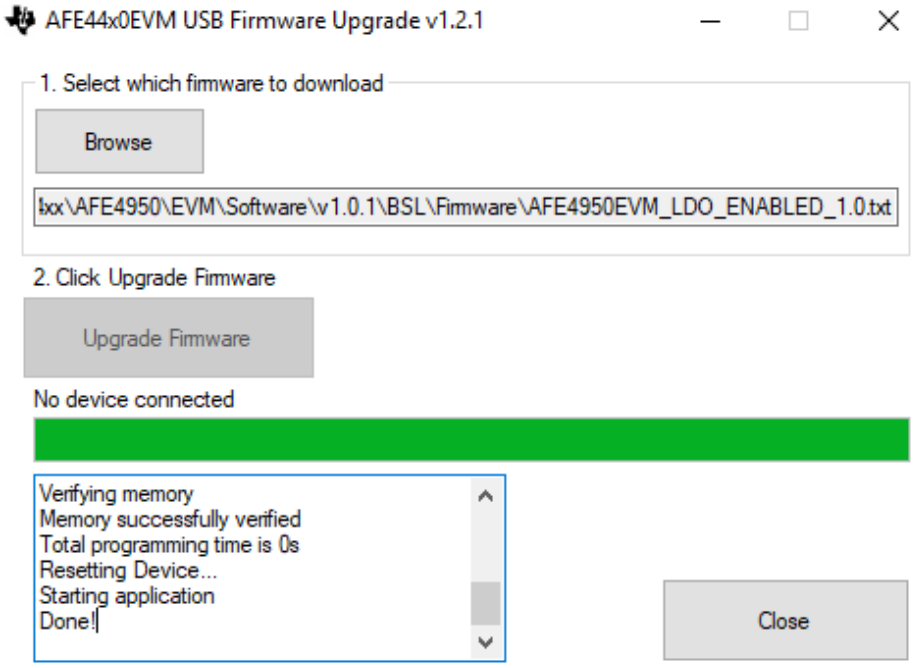


Figure 5. Firmware Upgrade - 3

2.5 Setup the Hardware

Prepare the EVM for signal acquisition as described below:

a. Connect the PPG sensor module to the EVM's **J1** connector using extension cable as shown in Figure 6. Make sure that the sensor module is connected in the correct orientation – pin #10 should line up with the marking (the *White Dot*) on the cable.

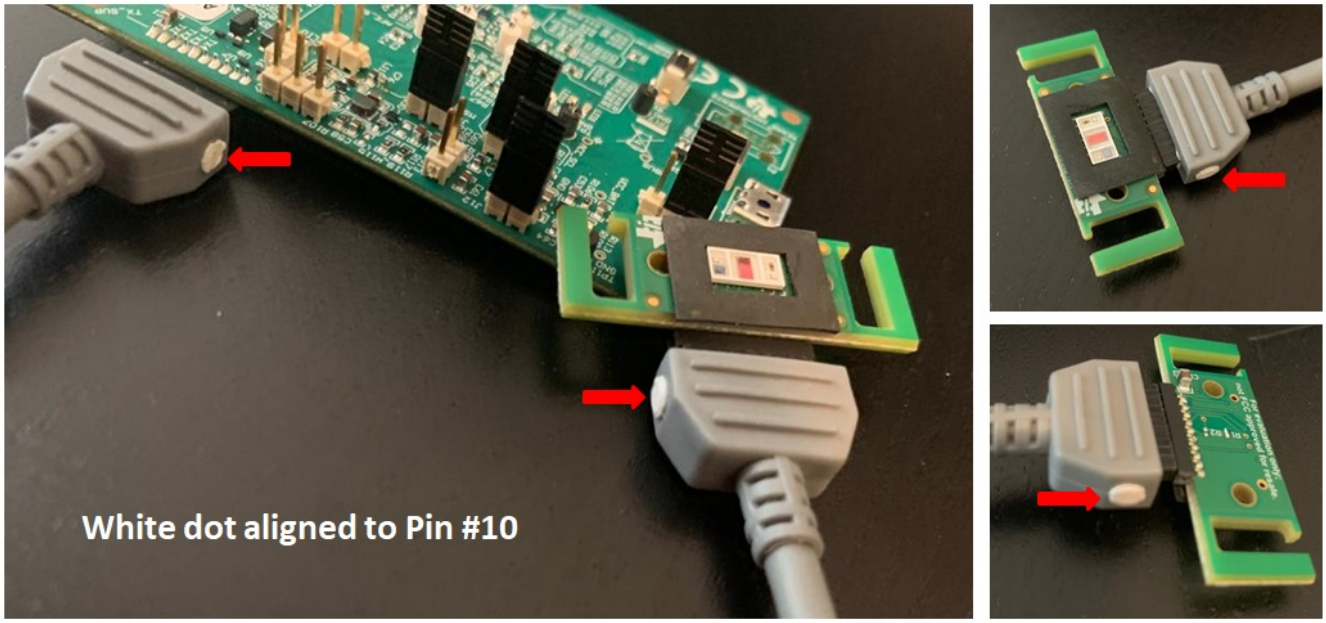


Figure 6. Connecting the PPG sensor board to the EVM

b. Based on the colors, connect the ECG cables to the ECG connectors of AFE4950EVM (i.e. **J4**, **J6** and **J9**) as shown in Figure 7.

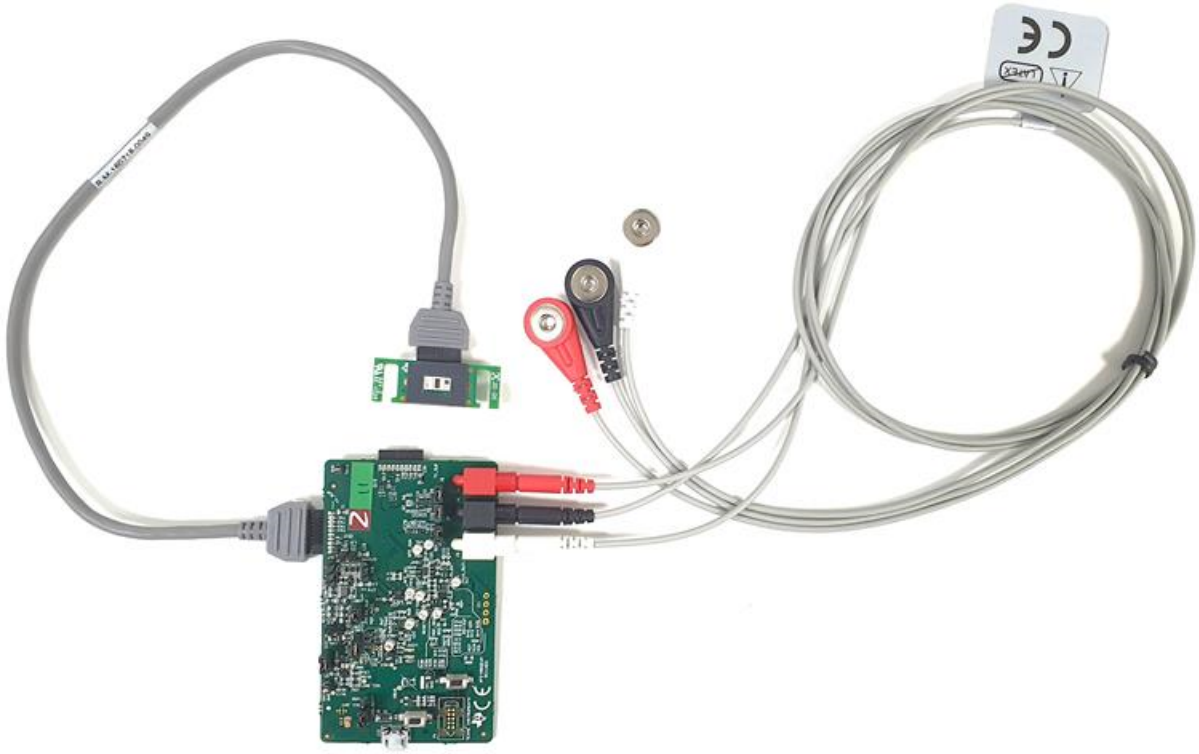


Figure 7. Connecting the ECG cables to the EVM

c. Place the sensor side of the PPG sensor board on the wrist and tie it snugly. Figure 8 shows the sensor board being held with a velcro strap.

d. Connect the ECG simulator to the EVM as described below.

i. White cable (i.e. connected to J13): Connects to RLD input of simulator.
ii. Red and Black cables connect to differential input pairs of simulator.

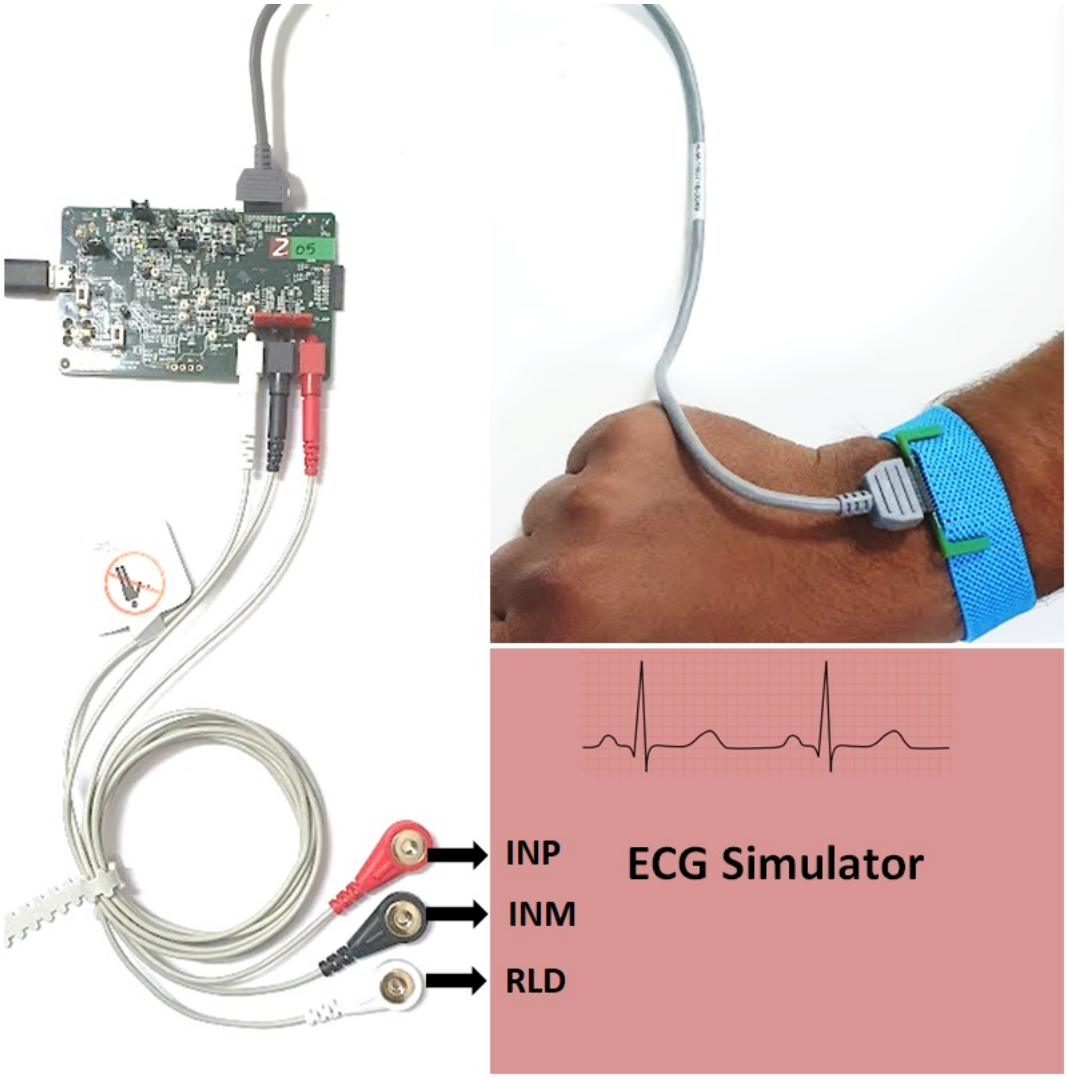


Figure 8. PPG sensor board and ECG cable interaction to the ECG Simulator for acquiring PPG and ECG signals

e. Open the EVM software by running **Bio-Sensing.exe**. From project specific profile (i.e. AFE4950EVM >> GUI) go to **devInit.py** script file and run (Short cut for running the script: **F5**) as shown in Figure 9, which loads the default EVM configuration. This will open a GUI window as shown in Figure 12, which has the capture controls. Click **Start Capture** to acquire the signal from the AFE as shown in Figure 16.

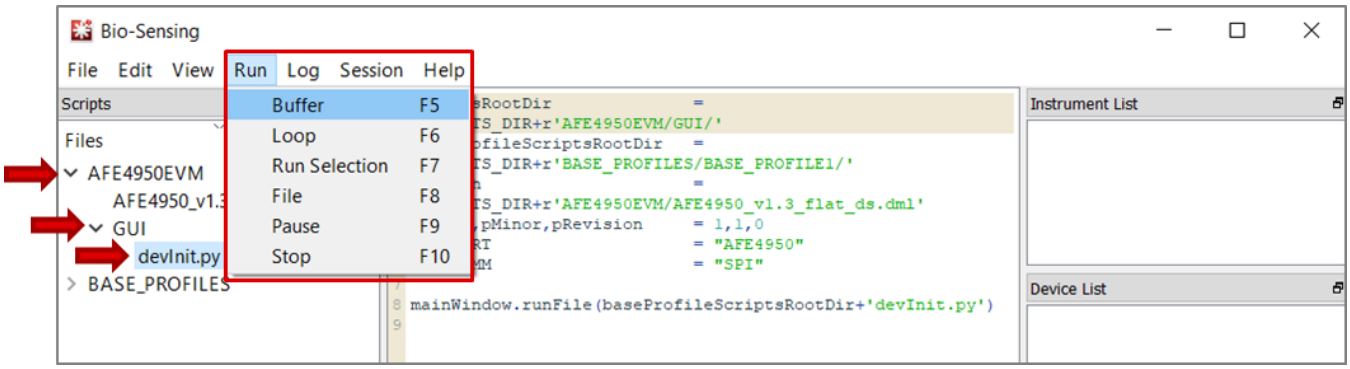


Figure 9. Running the EVM software

3 EVM Software

On opening the software (**Bio-Sensing.exe**), the window shown in Figure 10 will appear, different sections of the GUI window are explained in the image. **devInit.py** script initializes the device. Any python script can be executed by pressing **F5** key. Alternately, script can also be run from GUI as shown in Figure 11 (**Run > Buffer**).

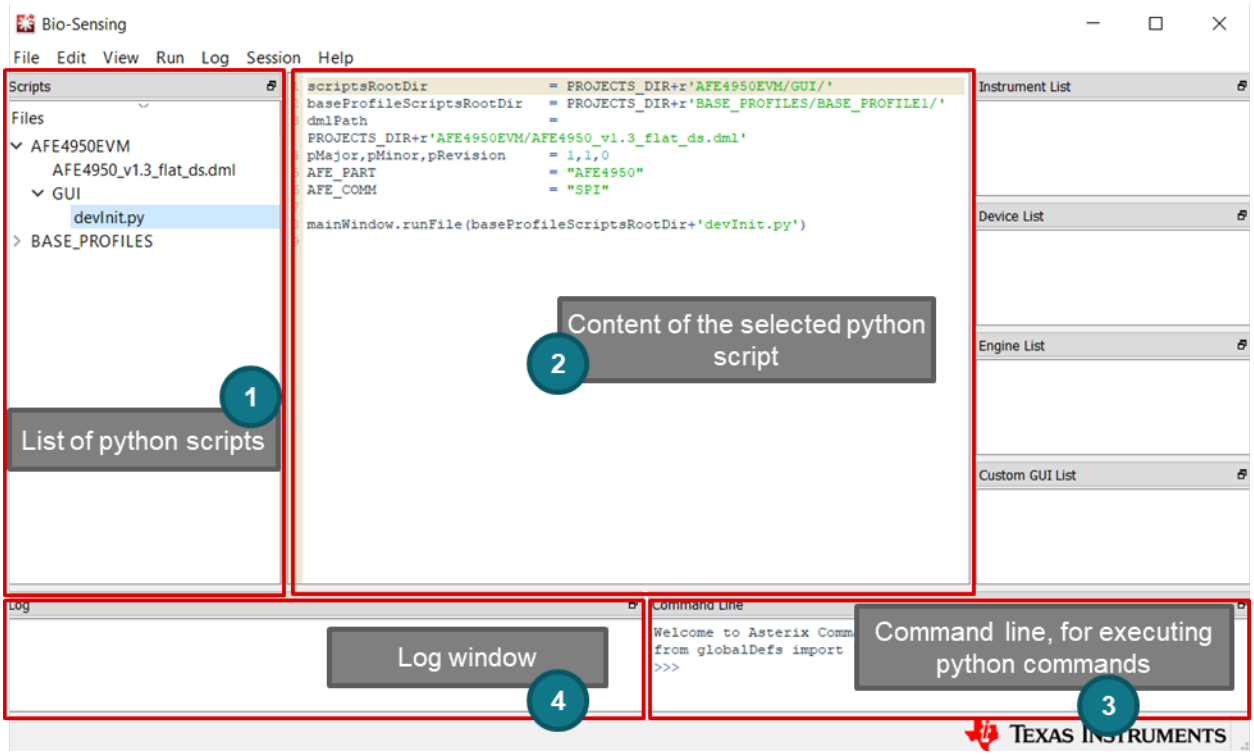


Figure 10. EVM software

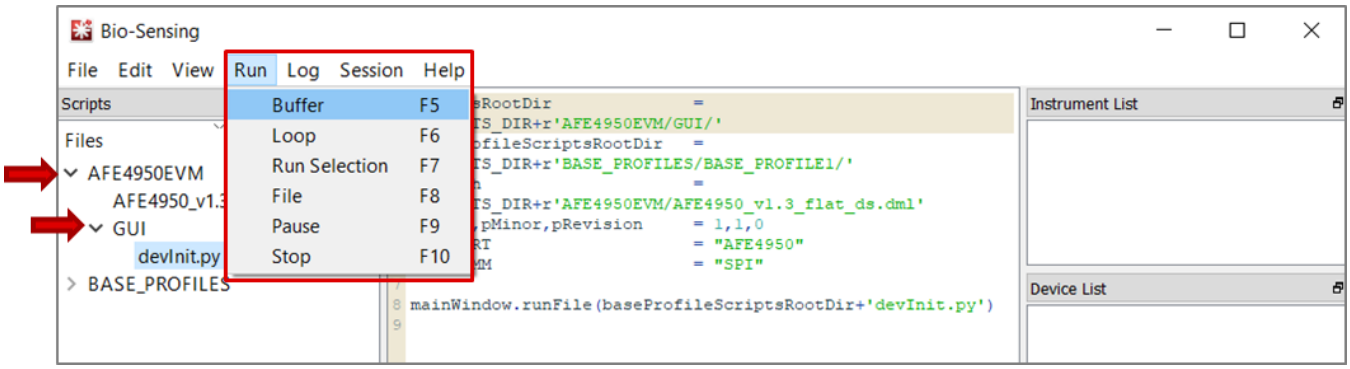


Figure 11. Running a Script from the EVM software

The EVM software will also open another EVM GUI window as shown in Figure 15. If this window is closed, it can be revoked by running **main.py** script. This window will have all the controls required for the EVM evaluation.

1. **GLOBAL SETTINGS**: This page has controls to import the register configuration. It also has controls to export the captured data, AFE configuration and raw register read/write options
2. **REGISTER SETTINGS**: This page has all AFE registers
3. **FILTER SETTINGS**: Software filters that can be applied to captured data before plotting.
4. **CAPTURE**: Initialize the capture of AFE data and plot. Plotting supports option to plot any captured data in to one of two plot windows.

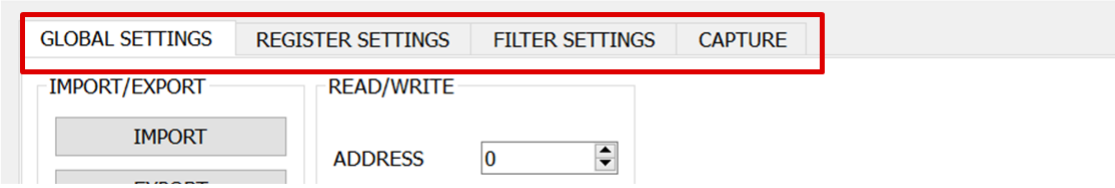


Figure 12. EVM GUI Window

3.1 Import AFE Register Configuration

AFE register configuration can be loaded to the AFE from **GLOBAL SETTINGS** page, using **IMPORT** button. On clicking **IMPORT**, a window pops-up to select the AFE configuration. The AFE configuration files are created using the excel register generation tool. Select **AFE4950_Settings.cfg** and click **Open** as shown in Figure 13 and Figure 14. Wait for the loading to complete and reach 100%. After loading is completed, navigate to **CAPTURE** page

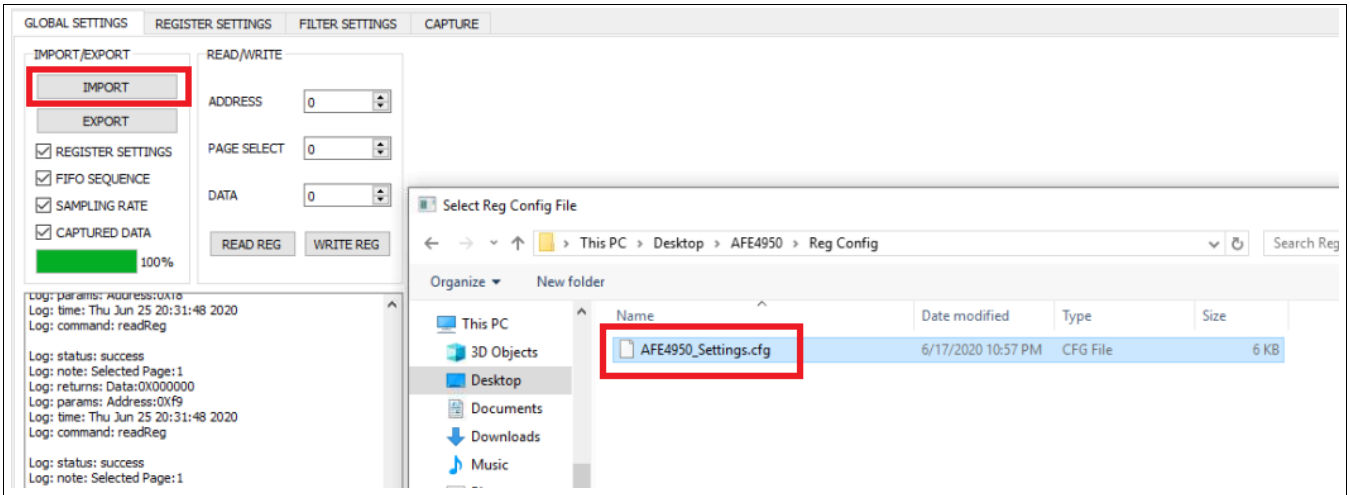


Figure 13. Importing the Register Configuration File - 1

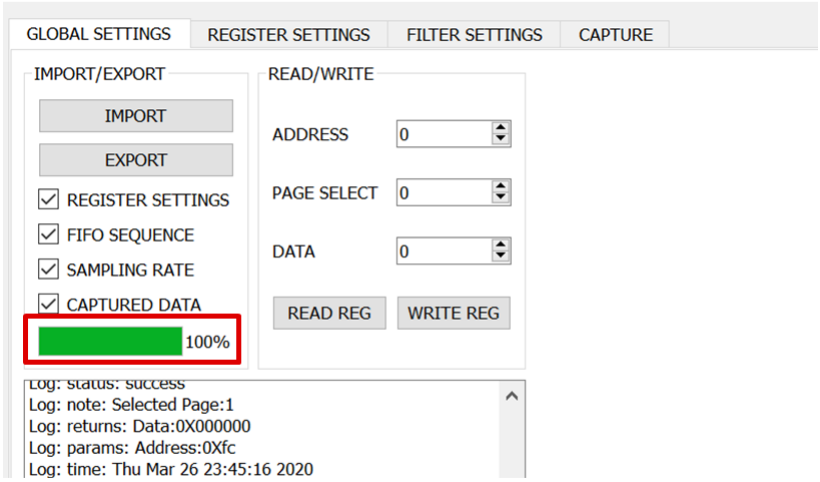


Figure 14. Importing the Register Configuration File -2

3.2 Capturing the AFE data and Plotting

The capture page window is shown in Figure 15. It has various controls listed below:

a. **Capture Controls**: Configure the capture settings here. Capture can be either made continuous or only for limited number of FIFO_RDY interrupts. The length of plot to be displayed in-terms of time (sec) can be adjusted here.

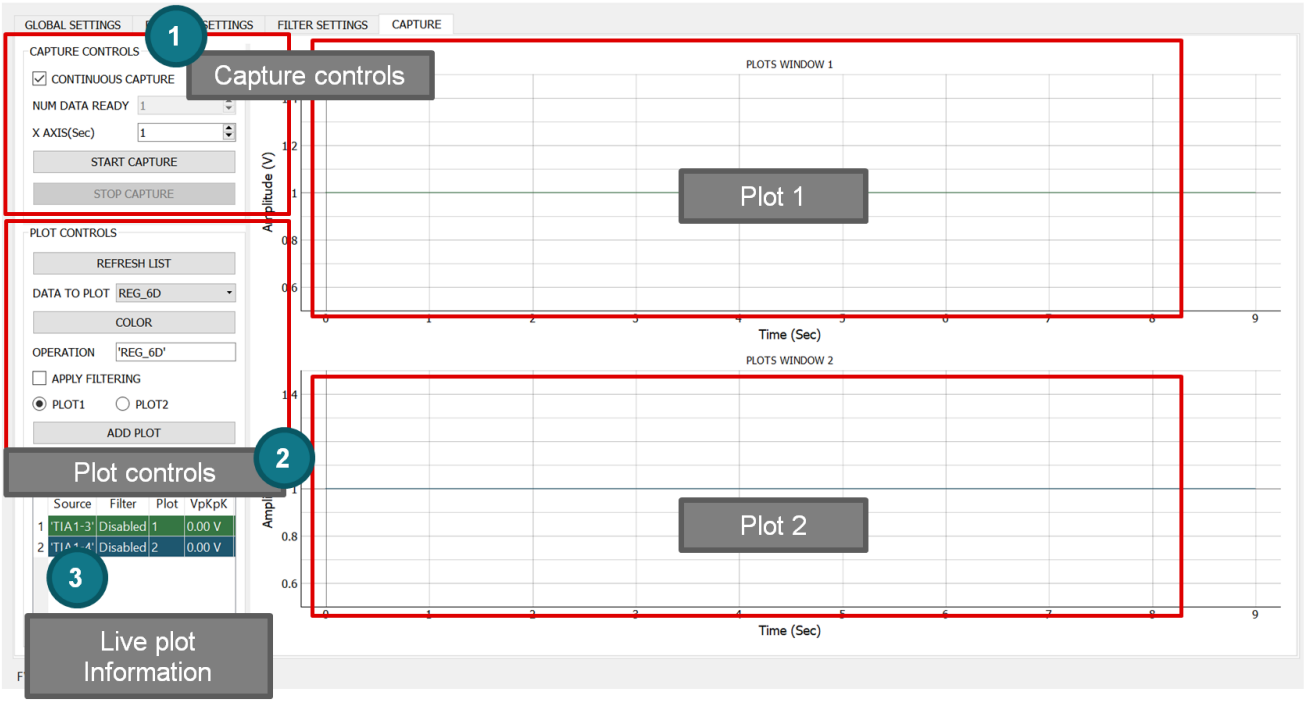


Figure 15. Capture page of EVM GUI

b. **Plot Controls**: Configure the data to be plotted. Follow the steps below, see Figure 16.
   - Click on the **Refresh List**.
   - The **Data to Plot** drop down will list all the different signals that are being stored in AFE's FIFO based on the current configuration.
   - When a signal is selected, it will appear in **Operation** tab. The signal name will be in single quotes.
   - Check "**APPLY FILTERING**" if signal needs to be filtered using software filters.
   - Select the **Plot1** or **Plot2** in which the signal is to be plotted. Click **Add Plot**.
   - Mathematical operations between signals can also be performed in the **Operation** tab and the result of it can be plotted. For example two PPG signals TIA1-1 and TIA1-2 can be subtracted with 'TIA1-1'-'TIA1-2'
   - To remove a signal from a plot, simply double click on the plot name in the **Live Data** tab.

c. **Plot Window**: Displays the live data for all the signals added to the respective plots using "Plot Controls". By default the time domain data is displayed in each plot, however frequency spectrum of signals can be plotted by right clicking a plot and selecting "**Plot Options >> Transforms >> Power Specturm (FFT)**". To change the plot from frequency domain to time domain, simply uncheck the "Power Spectrum (FFT)" . Adding a new plot, changes all the plots to time domain. Right click on plots also gives options regarding axis such as auto updation.

d. **Data Filtering**: There are two digital filters implemented in the GUI, one is Low Pass Filter (LPF) and other is Notch Filter. By default both the filter are disabled and can be enabled in "**FILTER SETTINGS**" tab of the GUI. Once enabled, all the plots which has "**APPLY FILTERING**" checked during plot configuration will be filtered and plotted in their respective plot window. Characterstics of each filter such as filter order and cutoff frequency can be tweaked in "**FILTER SETTINGS**" tab. Each filer can be individually enabled or disabled.

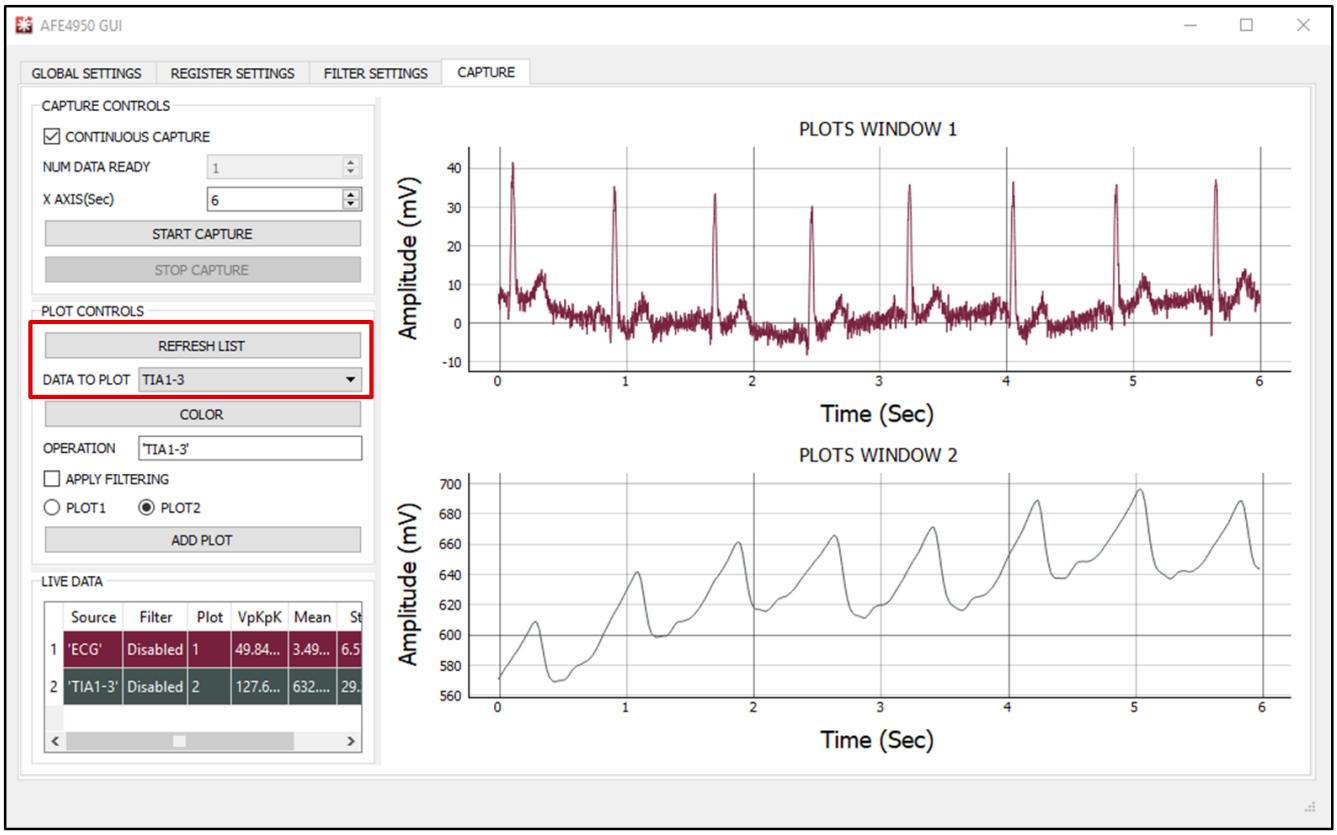


Figure 16. Plot controls

The captured data along with AFE's current register setting can be exported to a specified folder using the "EXPORT" option in "GLOBAL SETTINGS" tab of the GUI as shown below. There are options to select what information gets exported. Captured data gets exported in *.csv format whereas other information gets exported as *.cfg file. The exported configuration file can be later imported to configure the AFE into state same as prior to export.

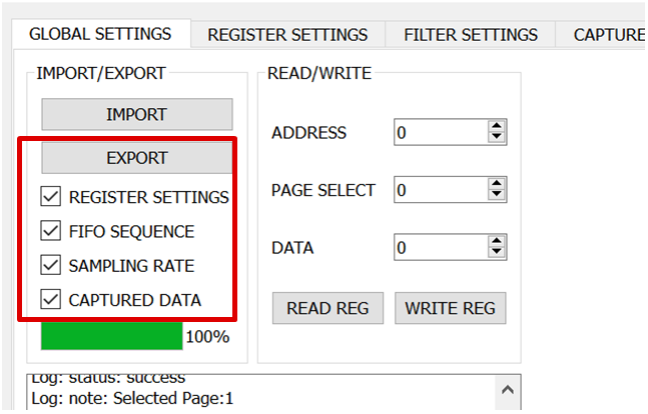


Figure 17. Exporting the data and AFE configuration

4 AFE4950 EVM Hardware

CAUTION

Many of the components on the AFE4950EVM are susceptible to damage by electrostatic discharge (ESD). Customers are advised to observe proper ESD handling precautions when unpacking and handling the EVM, including the use of a grounded wrist strap, bootstraps, or mats at an approved ESD workstation. Safety glasses should also be worn

The bill of materials (BOM) is provided in Section 7. The printed-circuit boards (PCB) are shown in Section 8.1 and Section 8.2, and the schematics are shown in Section 8.3. MSP430F5529 is the microcontroller used on the board.

For more details of the MSP430F5529, visit http://www.ti.com/product/MSP430F5529. The following sections explain the main hardware components available on the EVM. Figure 18 shows the functional block diagram for the EVM.

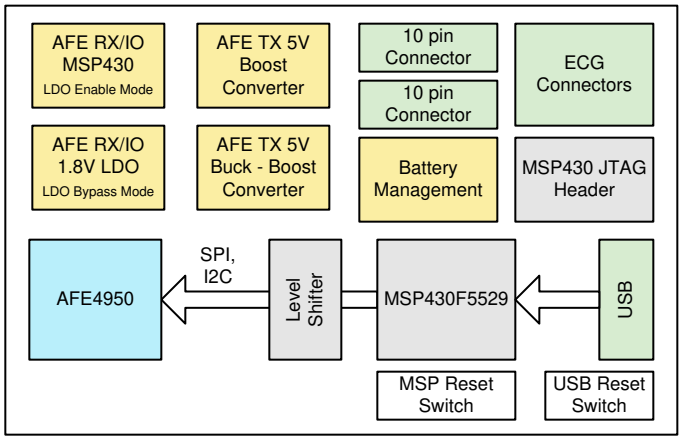


Figure 18. AFE4950EVM Block Diagram

4.1 Power Supply

By default, the EVM is configured to LDO enable mode with RX_SUP = IO_SUP = 3 V and TX_SUP = 5V. There is an option to configure the EVM in LDO Bypass mode where RX_SUP = IO_SUP = 1.8 V and TX_SUP = 5 V.

The power for the board is derived from the USB input (J9) through a forward-biased diode (D1) to avoid reverse current flow. The USB data bus is ESD protected using TI's ESD protection diode arrayTPD4E004DRYR (U11). The USB VBUS is fed to the integrated Li-Ion linear charger and system power path management module, BQ24032ARHLR (U9), which generates an output (VCC_BAT) that is greater than 4.2V. This output is fed to TI's highly efficient, low quiescent-current buck-boost converter, TPS63050YFFR (U1) for generating 5V for TX_SUP. TX_SUP can also be generated using TI's synchronous boost converter, TPS61099YFFR (U2). In the default configuration, 5V output of U1 is used as TX_SUP. The VCC_BAT is also fed to the ultralow-noise linear voltage regulatorTPS7A4901DGN (U10) for generating 3V for the MSP_DVCC, MSP_AVCC, RX_SUP (AFE in LDO enabled mode), and IO_SUP. For LDO Bypass mode VCC_BAT is fed to TPS72718YFFR (U3) for generating 1.8V for RX_SUP and IO_SUP.

LDO Enable Mode: Place shunts at J15 and J14 remove shunts from J16, J18 and J17.

LDO Bypass Mode: Place shunts at J18, J16 and J17 (pin #1 and 2), remove shunts from J14 and J15. This also requires change of EVM's firmware.

Series jumper resistors are provided to measure the supply voltages and confirm they are proper.

4.2 Clock

AFE4950 can be clocked using the internal oscillator (128 KHz) or through an external clock from the MSP430.

4.3 Accessing AFE4950 Digital Signals

The digital signals of the AFE that interface with the MSP430 can be accessed through the test points given in Table 2.

Table 2. AFE4950 Digital Signals

S.No	Signal	Description
1	SCLK	TP3
2	SDIN	TP4
3	ADC_RDY	TP1
4	RESETZ	TP2
5	GPIO2	TP7
6	LDO_BYP	TP9
7	SDOUT	TP5
8	SEN	TP6
9	I2C_SPI_SEL	TP8

4.4 Interfacing the MSP430 on the EVM to an AFE4950 on a Different Board

To interface the MSP430 using the I2C interface to an AFE4950 on a different board, do the following changes:

- Remove R46, R48, R50, R52, R63, R65, R27, R29, and R31.
- Connect the signals from the AFE4950 on a different board to the EVM as shown in Table 3.

Table 3. Signal from AFE4950 on another Board

Signal from external module	Connections on AFE4950EVM
SCLK	Pad of R52 that connects to U21
SDIN	Pad of R48 that connects to U21
SDOUT	Pad of R50 that connects to U21
SENZ	Pad of R46 that connects to U21
ADC_RDY	Pad of R27 that connects to U19
RESETZ	Pad of R31 that connects to U19
CLK	Pad of R29 that connects to U19
LDO_BYP	Pad of R63 that connects to U22
I2C_SPI_SEL	Pad of R65 that connects to U22

- Share the GND signal between the module and EVM. Ensure that the supplies on the external AFE4950 and the EVM are matched, or tap them from the EVM using the jumpers J15 (RX), J14 (IO) and J12 (TX).

4.5 To Interface an MCU on a Different Board with the AFE of EVM

To interface an MCU on a different board with the AFE of EVM in I2C interface:

- Remove R46, R48, R50, R52, R63, R65, R27, R29, and R31.
- Connect the signals from external MCU to the EVM as shown in Table 4

Table 4. Signal Mapping

S.No	Signal	Description
1	SCLK	TP3
2	SDIN	TP4
3	SDOUT	TP5
4	SENZ	TP6
5	ADC_RDY	TP1
6	RESETZ	TP2
7	CLK	Pad of R11 that is not connected to GND.
8	LDO_BYP	TP9
9	I2C_SPI_SEL	TP8
10	GPIO2	TP7

- Share the GND signal between the module and EVM
- IO level of external MCU should be of same level as AFE's IO supply
- In LDO bypass mode, LDO_BYP pin should be pulled high to RX_SUP of AFE. Whereas in LDO enable mode LDO_BYP pin should be pulled to GND.

4.6 USB Interface

The EVM has a micro-USB interface for PC application connectivity requiring a standard micro-USB to USB cable for connection.

4.7 On-Board Key Interface

The EVM has 2 switches. The function of the two switches is defined in Table 5

Table 5. AFE4950 EVM Switches

Switch Number	Description
S2	This switch is used to reset the MCU. The MCU resets and starts again with the firmware loaded.
S1	This switch is used to enable boot strap loader (BSL) MSP430 firmware.(1)

(1) To enable BSL, disconnect device and then reconnect while holding down S1. The device will appear as an HID device in the Device Manager.

4.8 Visual Indication

The green LED (LED3) indicates the USB power connection. The red LED (LED2) indicates that the microcontroller is busy servicing the requests from the PC application.

5 Connector Interface

The following connectors are used for external interface to the AFE4950 Evaluation Module:

- Micro-USB connector
- 10-pin connector

5.1 Micro-USB Connector

The USB micro connector J9 pin-outs are shown in Figure 19. The description of the pin-outs is provided in Table 6.

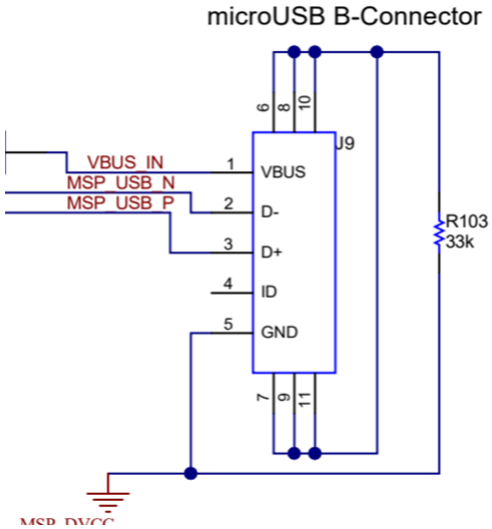


Figure 19. USB Micro Connector Pin Outs

Table 6. USB Micro Connector Pinout Descriptions

Pin Number	Pin Name	Pin Description
1	VBUS	USB power 5 V
2	D–	USB DM
3	D+	USB DP
4	ID	NC
5	GND	GND

5.2 10-Pin Connector

The 10-pin connector pin-outs are shown in Figure 20 and Figure 21 with description in Table 7 and Table 8. EVM uses two SFH7072 sensor boards. The connections of the sensor board to the AFE are also listed in Table 9 and Table 10.

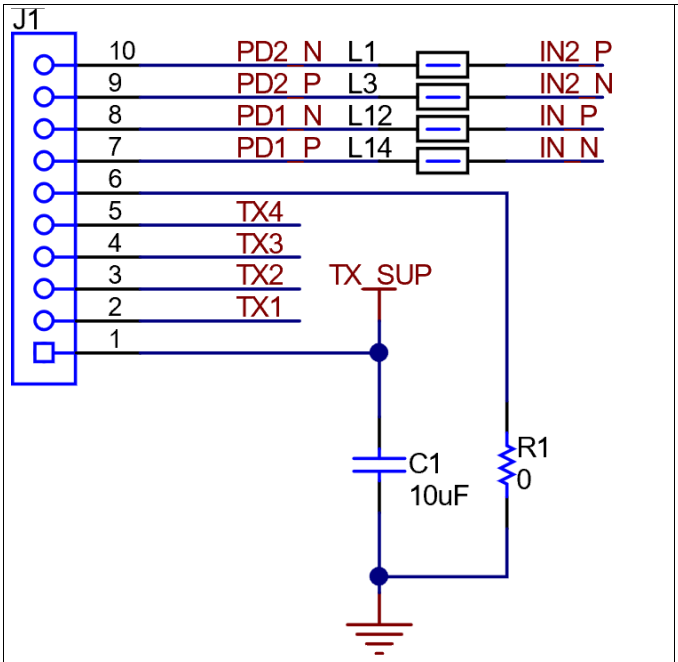


Figure 20. 10-Pin Connector – J1

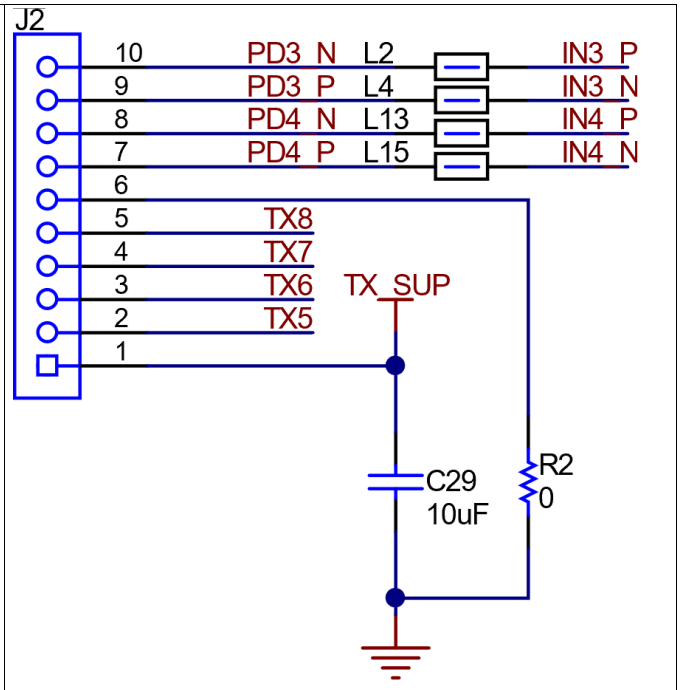


Figure 21. 10-Pin Connector – J2

Table 7. J1 connector, SFH7072 sensor board 1

Pin Number	Pin Name	Pin Description
1	TX_SUP	Power Supply for LEDs
2	TX1	Cathode of LED1
3	TX2	Cathode of LED2
4	TX3	Cathode of LED3
5	TX4	Cathode of LED4
6	GND	Ground
7	PD1_A	Photodiode1 anode
8	PD1_C	Photodiode1 cathode
9	PD2_A	Photodiode2 anode
10	PD2_C	Photodiode2 cathode

Table 8. J2 connector, SFH7072 sensor board 2

Pin Number	Pin Name	Pin Description
1	TX_SUP	Power Supply for LEDs
2	TX5	Cathode of LED5
3	TX6	Cathode of LED6
4	TX7	Cathode of LED7
5	TX8	Cathode of LED8
6	GND	Ground
7	PD4_A	Photodiode4 anode
8	PD4_C	Photodiode4 cathode
9	PD3_A	Photodiode3 anode
10	PD3_C	Photodiode3 cathode

Table 9. LED and PD association for J1

Green LED1	Green LED2	Red LED	IR LED
TX1	TX4	TX2	TX3
Green (IR Cut) PD		RED/IR (Broadband) PD	
PD1 (INP1-INM1)		PD2 (INP2-INM2)	

Table 10. LED and PD association for J2

Green LED1	Green LED2	Red LED	IR LED
TX5	TX8	TX6	TX7
Green (IR Cut) PD		RED/IR (Broadband) PD	
PD4 (INP4-INM4)		PD3 (INP3-INM3)	

6 AFE4950 Register Generation Excel

The AFE4950_Register_Generation_v*.xlsm will be given by TI. This configuration file will be in the EVM software installation directory.

Default file location: C:\Program Files\Texas Instruments\Latte\ Register Config\AFE4950_Register_Generation_v*.xlsm.

By default the EVM ships in LDO enable mode with following configuration.

- Clocking : Internal oscillator
- Acquisition Mode : Mix (that is PPG and ECG)
- PPG configuration
  - PPG output data rate: 50 Hz
  - 3 Phases are defined for PPG: AMB1, LED, AMB2
  - PPG Phases are sampled from Green PD of sensor board
  - TX1 (connected to Green LED on sensor board) is used to LED Phase.
  - TIA Gain (that is Rf): 250 kΩ
  - Sampling width: 117 uS
  - Noise reduction filter: 2.5 KHz
  - ANA AACM: Enabled to cancel ambient signal from all Phases
  - DIG AACM: Enabled to cancel the DC in LED Phase.
- ECG Configuration
  - ECG ouput data rate: 500 Hz
  - ECG INA Gain: 21
  - INA Digital Saturation Detection: Enabled

The register generation excel has different worksheets for configuring the AFE. The various worksheets in this file are described below.

a. Global
b. ECG MIX Config
c. PPG Config
d. PPG Phase Definition

6.1 Global Configuration

In the global configuration page configure the following.

a. Select the signal acquisition mode.
b. Select LDO mode and enter the RX_SUP voltage level for LDO Enable mode, in case of LDO Bypass mode RX_SUP is fixed to 1.8V . For the EVM, the default configuration is *LDO Enable* and the

RX_SUP is *3 V*.

c. Select the clocking configuration. For the EVM, the default configuration is *Internal* clocking configuration.

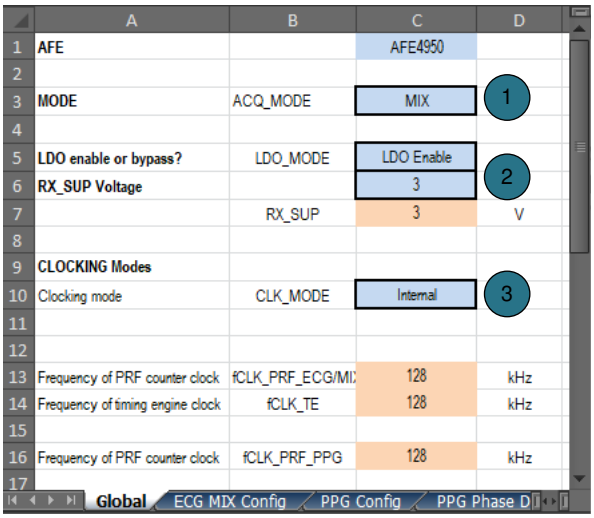


Figure 22. Global register configuration

6.2 ECG & Mixed Signal Acquisition Mode (ECG MIX Config)

This worksheet has configuration options for the ECG and MIX signal acquisition modes. For ECG only mode configuration, follow the steps below:

a. Enter the ECG output data rate.

b. Enable on-chip ECG decimation if required & select decimation factor.

Figure 23. ECG only Mode configuration

For MIX mode configuration, follow the steps below

a. Select the MIX_TIMING_CFG from drop down. This will define the PRF, ECG sample rate and PPG signal acquisition windows (PSAW)

b. Input the number of PPG signal acquisition windows (PSAW).

c. In the PSAW, select the starting PPG phase and ending PPG phase. If required number of PPG phases cannot be accommodated in one PSAW, select a config which has more number of PSAWs

and/or more time per PSAW.

1. For example: *ECG_500Hz_PRF_125Hz* has 4 PSAWs with a time width of 1.75 ms, 1.75 ms, 1.75 ms and 1.5 ms (for 128-kHz CLK), whereas *ECG_500Hz_PRF_500Hz* has only one PSAW with a duration of 1.5 ms.

d. Enable on-chip ECG decimation if required & select decimation factor.

e. Enter the PPG output data rate.

f. Enable PPG decimation and select the decimation factor to increase the PPG SNR if required.

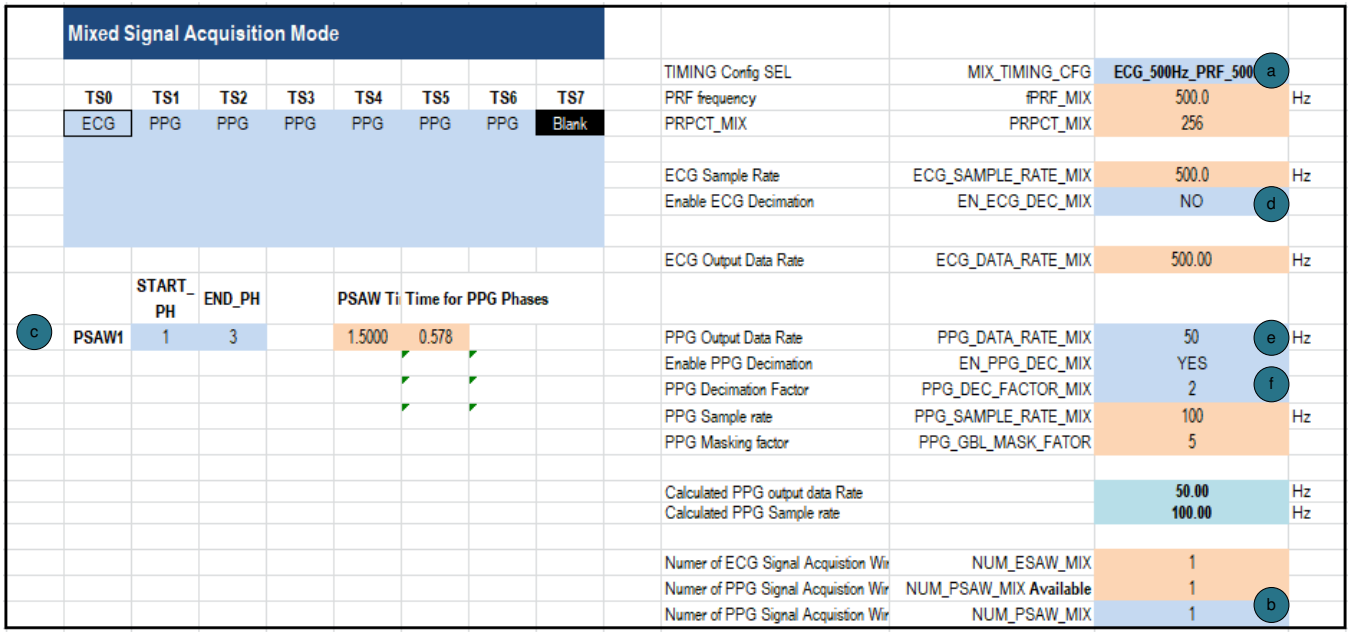
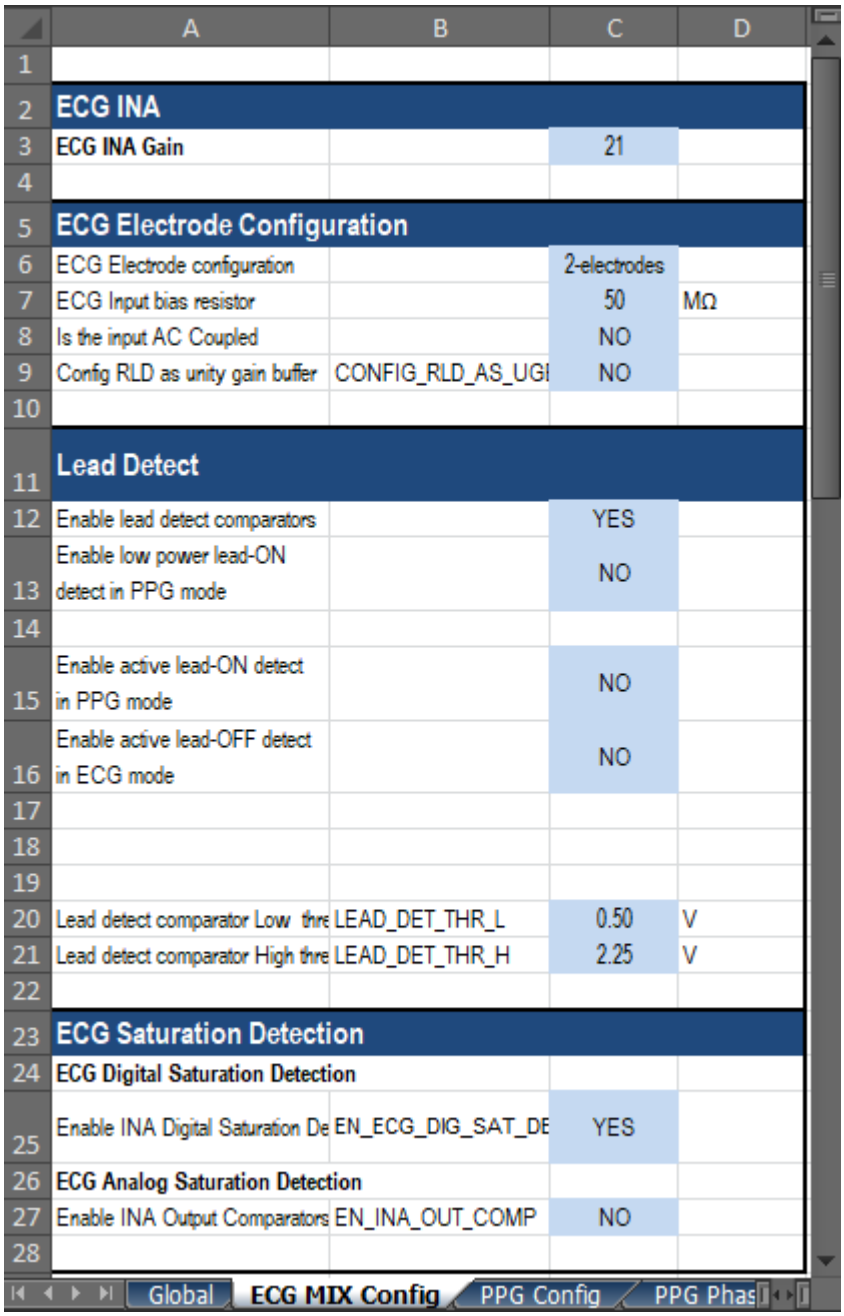


Figure 24. Mixed signal acquisition mode configuration

ECG electrode configuration, INA gain, lead detection and INA saturation detection can also be configured in the ECG MIX Config worksheet.



	A	B	C	D
1				
2	**ECG INA**			
3	ECG INA Gain		21	
4				
5	**ECG Electrode Configuration**			
6	ECG Electrode configuration		2-electrodes	
7	ECG Input bias resistor		50	MΩ
8	Is the input AC Coupled		NO	
9	Config RLD as unity gain buffer	CONFIG_RLD_AS_UGI	NO	
10				
11	**Lead Detect**			
12	Enable lead detect comparators		YES	
13	Enable low power lead-ON detect in PPG mode		NO	
14				
15	Enable active lead-ON detect in PPG mode		NO	
16	Enable active lead-OFF detect in ECG mode		NO	
17				
18				
19				
20	Lead detect comparator Low thre	LEAD_DET_THR_L	0.50	V
21	Lead detect comparator High thre	LEAD_DET_THR_H	2.25	V
22				
23	**ECG Saturation Detection**			
24	**ECG Digital Saturation Detection**			
25	Enable INA Digital Saturation De	EN_ECG_DIG_SAT_DE	YES	
26	**ECG Analog Saturation Detection**			
27	Enable INA Output Comparators	EN_INA_OUT_COMP	NO	
28				

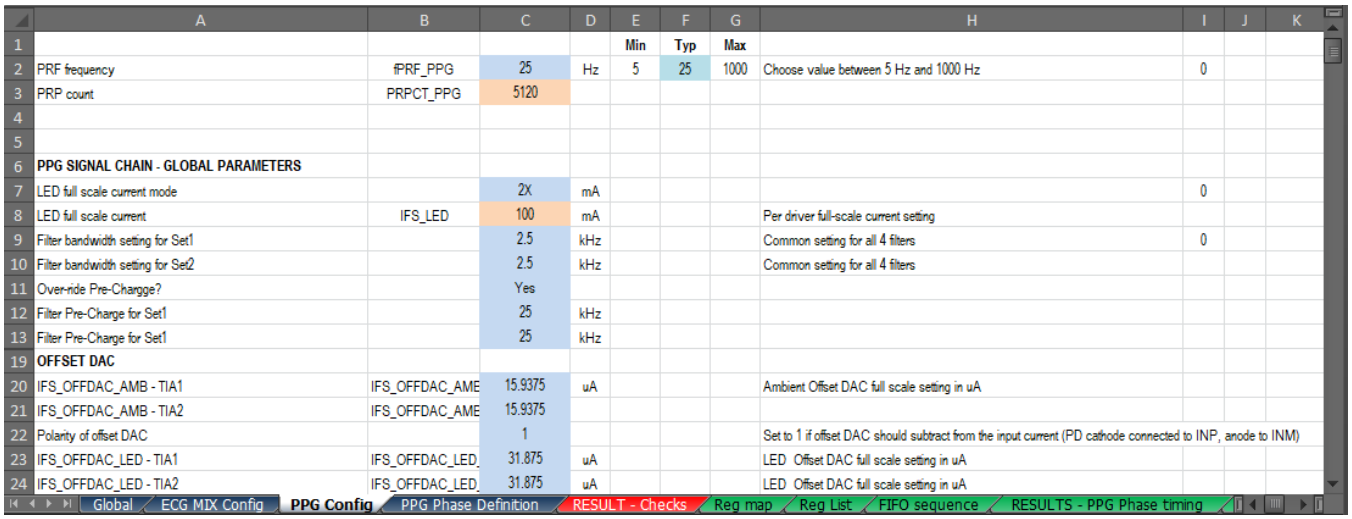
Global | ECG MIX Config | PPG Config | PPG Phas

Figure 25. ECG Gain, Electrode and Lead detect configuration

6.3 PPG Configuration

6.3.1 PPG Mode Configuration (PPG Config)

This sheet is used to specify the Global controls for the PPG. Fill the rows in sequence from top to bottom. Fill only the parameters that show up in the Blue boxes. Manually fill each cell using the drop down cells (do not cut and paste values across cells). Do not modify the any other colored cells. The light green boxes can be either left blank (to use the default values) or can be filled.



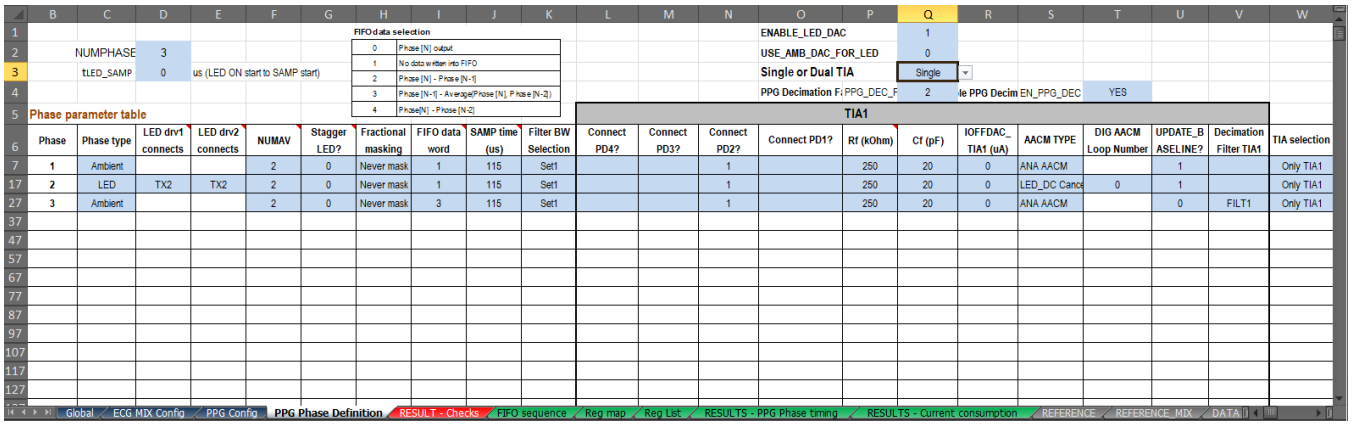
	A	B	C	D	E	F	G	H	I	J	K
1					Min	Typ	Max				
2	PRF frequency	fPRF_PPG	25	Hz	5	25	1000	Choose value between 5 Hz and 1000 Hz	0		
3	PRP count	PRPCT_PPG	5120								
4											
5											
6	PPG SIGNAL CHAIN - GLOBAL PARAMETERS										
7	LED full scale current mode		2X	mA					0		
8	LED full scale current	IFS_LED	100	mA				Per driver full-scale current setting			
9	Filter bandwidth setting for Set1		2.5	kHz				Common setting for all 4 filters	0		
10	Filter bandwidth setting for Set2		2.5	kHz				Common setting for all 4 filters			
11	Over-ride Pre-Chargge?		Yes								
12	Filter Pre-Charge for Set1		25	kHz							
13	Filter Pre-Charge for Set1		25	kHz							
19	OFFSET DAC										
20	IFS_OFFDAC_AMB - TIA1	IFS_OFFDAC_AME	15.9375	uA				Ambient Offset DAC full scale setting in uA			
21	IFS_OFFDAC_AMB - TIA2	IFS_OFFDAC_AME	15.9375								
22	Polarity of offset DAC		1					Set to 1 if offset DAC should subtract from the input current (PD cathode connected to INP, anode to INM)			
23	IFS_OFFDAC_LED - TIA1	IFS_OFFDAC_LED_	31.875	uA				LED Offset DAC full scale setting in uA			
24	IFS_OFFDAC_LED - TIA2	IFS_OFFDAC_LED_	31.875	uA				LED Offset DAC full scale setting in uA			

Global | ECG MIX Config | PPG Config | PPG Phase Definition | RESULT - Checks | Reg map | Reg List | FIFO sequence | RESULTS - PPG Phase timing

Figure 26. PPG global configuration

6.3.2 PPG Phase Definition

This sheet is used to specify number of phases, timing, signal chain parameters associated with each phase, and the LED/PD association for each phase. The phase type is selected from the drop down menu (Ambient and LED) and the appropriate parameters for the phase type are automatically shaded in blue. Specify only the parameters that show up in the Blue boxes. Manually fill each cell using the drop down boxes (do not cut and paste values across cells). Also, fill only the boxes that show up in blue. Do not modify the cream- colored boxes.



FIFO data selection

0	Phase [N] output
1	No data written into FIFO
2	Phase [N] - Phase [N-1]
3	Phase [N-1] - Average(Phase [N], Phase [N-2])
4	Phase[N] - Phase [N-2]

NUMPHASE 3 | tLED_SAMP 0 us (LED ON start to SAMP start)

ENABLE_LED_DAC 1 | USE_AMB_DAC_FOR_LED 0 | Single or Dual TIA Single | PPG Decimation F: PPG_DEC_F 2 | le PPG Decim EN_PPG_DEC YES

Phase parameter table

												TIA1											
6	Phase	Phase type	LED drv1 connects	LED drv2 connects	NUMAV	Stagger LED?	Fractional masking	FIFO data word	SAMP time (us)	Filter BW Selection	Connect PD4?	Connect PD3?	Connect PD2?	Connect PD1?	Rf (kOhm)	Cf (pF)	IOFFDAC_ TIA1 (uA)	AACM TYPE	DIG AACM Loop Number	UPDATE_B ASELINE?	Decimation Filter TIA1	TIA selection
7	1	Ambient			2	0	Never mask	1	115	Set1			1		250	20	0	ANA AACM		1		Only TIA1
17	2	LED	TX2	TX2	2	0	Never mask	1	115	Set1			1		250	20	0	LED_DC Cance	0	1		Only TIA1
27	3	Ambient			2	0	Never mask	3	115	Set1			1		250	20	0	ANA AACM		0	FILT1	Only TIA1

Global | ECG MIX Config | PPG Config | PPG Phase Definition | RESULT - Checks | FIFO sequence | Reg map | Reg List | RESULTS - PPG Phase timing | RESULTS - Current consumption | REFERENCE | REFERENCE_MIX | DATA

Figure 27. PPG per-phase configuration

Per phase parameters such as PD connection, Rf, Cf, OFFDAC and type of AACM should be independently configured for both the TIAs.

- Column ‘L’ through column ‘V’ for TIA1.
- Column ‘X’ through column ‘AH’ for TIA2

6.4 Generate the Output Files

In *Reg_List* worksheet click *save.*cfg File* to create the register configuration files, which can be used for evaluating the EVM as well as creating the required register configurations for customer platform and application. The output files generated using the excel will be in the same directory as the excel file.

- **AFE4950_Settings.cfg**: Register configuration in the format required for the EVM
- **AFE4950_Settings_mcu.cfg**: Register configuration in {address, data} format
- **AFE4950_FIFO_SEQ.cfg**: Data sequence in the FIFO
- **AFE4950_DATARATE.cfg**: Output data rate for each type of output data.

7 Bill of Materials

Table 11. AFE4950 Bill of Materials(1)

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference	Alternate PartNumber	Alternate Manufacturer
1	!PCB1	1		DC116	Any	Printed Circuit Board			
2	C1, C5, C6, C29, C54, C55, C56, C57, C59, C60, C61	11	10 uF	C1608X5R1E106M080AC	TDK	CAP, CERM, 10 uF, 25 V, ±20%, X5R, 0603	0603		
3	C2	1	10 uF	GRM155R60J106ME44D	MuRata	CAP, CERM, 10 uF, 6.3 V, ±20%, X5R, 0402	0402		
4	C3, C7, C64	3	1000 pF	C1005X7R1H102M050BE	TDK	CAP, CERM, 1000 pF, 50 V, ±20%, X7R, 0402	0402		
5	C4, C8, C9, C10, C14, C15, C17, C19, C20, C23, C24, C25, C26, C40, C43, C49, C50, C51	18	0.1 uF	0402YC104KAT2A	AVX	CAP, CERM, 0.1 uF, 16 V, ±10%, X7R, 0402	0402		
6	C13	1	22 uF	TLJN226M006R5400	AVX	CAP, TA, 22 uF, 6.3 V, ±20%, 5.4 ohm, SMD	2012-10		
7	C16, C65, C67, C68, C69, C70, C71	7	10 uF	EMK107BBJ106MA-T	Taiyo Yuden	CAP, CERM, 10 uF, 16 V, ±20%, X5R, 0603	0603		
8	C30, C33, C36	3	0.047 uF	C0603X5R1E473K030BB	TDK	CAP, CERM, 0.047 µF, 25 V,±10%, X5R, 0201	0201		
9	C37	1	2200 pF	GRM155R71H222KA01D	MuRata	CAP, CERM, 2200 pF, 50 V, ±10%, X7R, 0402	0402		
10	C38, C39, C46, C48	4	10 pF	500R07S100JV4T	Johanson Technology	CAP, CERM, 10 pF, 50 V, ±5%, C0G/NP0, 0402	0402		
11	C41	1	4.7 uF	C1005X5R1A475K050BC	TDK	CAP, CERM, 4.7 uF, 10 V, ±10%, X5R, 0402	0402		
12	C42	1	2.2 uF	C0603C225K8PACTU	Kemet	CAP, CERM, 2.2 uF, 10 V, ±10%, X5R, 0603	0603		
13	C44, C45	2	12 pF	CL05C120JB5NNNC	Samsung Electro-Mechanics	CAP, CERM, 12 pF, 50 V, ±5%, C0G/NP0, 0402	0402		
14	C47	1	0.47 uF	04026D474KAT2A	AVX	CAP, CERM, 0.47 uF, 6.3 V, ±10%, X5R, 0402	0402		
15	C52, C53	2	10 uF	GRM188R60J106ME47D	MuRata	CAP, CERM, 10 uF, 6.3 V, ±20%, X5R, 0603	0603		
16	C58, C74, C75	3	1 uF	TMK107BJ105KA-T	Taiyo Yuden	CAP, CERM, 1 µF, 25 V,±10%, X5R, 0603	0603		
17	C66, C72	2	0.0 1uF	GCM155R71H103KA55D	MuRata	CAP, CERM, 0.01 uF, 50 V, ±10%, C0G/NP0, 0402	0402		
18	C73, C76	2	10 uF	CC0402MRX5R5BB106	Yageo	CAP, CERM, 10 uF, 6.3 V,±20%, X5R, 0402	0402		
19	C78	1	100 pF	C0603C0G1E101J030BA	TDK	CAP, CERM, 100 pF, 25 V, ±5%, C0G/NP0, 0201	0201		
20	D1	1	40 V	SD103AW-7-F	Diodes Inc.	Diode, Schottky, 40 V, 0.35 A, SOD-123	SOD-123		
21	D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, D20	19		TPD1E04U04DPYR	Texas Instruments	1-Channel ESD Protection Diode With Low Dynamic Resistance for HDMI 2.0 and USB 3.0, DPY0002A (X1SON-2)	DPY0002A	TPD1E04U04DPYT	Texas Instruments
22	H1	1		402320148	Biometric	10 Pin to 10 Pin HRM Sensor Cable. "Kitting Item"			
23	H2	1		AK67421-0.3	Assman WSW	Cable, USB-A to micro USB-B, 0.3 m "Kitting Item"			

(1) Unless otherwise noted in the Alternate PartNumber and/or Alternate Manufacturer columns, all parts may be substituted with equivalents.

Table 11. AFE4950 Bill of Materials[(1)] (continued)

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference	Alternate PartNumber	Alternate Manufacturer
24	H3	1		ECG-PRO-3-WAY-CABLE	Olimex	3 WAY ECG CAbles "Kitting Item"			
25	J1, J2	2		851-43-010-20-001000	Mill-Max	Receptacle, 50mil, 10x1, Gold, R/A, TH	receptacle 10x1, 50mil		
26	J3, J17	2		TSW-103-07-T-S	Samtec	Header, 2.54 mm, 3x1, Tin, TH	Header, 2.54 mm, 3x1, TH		
27	J4, J6, J9	3		41828	PlasticsOne	Touchproof Jack, R/A, TH	Touchproof Jack, R/A, TH		
28	J5, J7, J8, J12, J13, J14, J15, J16, J18	9		TSW-102-07-T-S	Samtec	Header, 2.54 mm, 2x1, Tin, TH	Header, 2.54 mm, 2x1, TH		
29	J10	1		10118193-0001LF	FCI	Connector, Receptacle, USB Micro B, R/A, SMT	Connector, Receptacle, USB Micro B, R/A, SMT		
30	L1, L2, L3, L4, L12, L13, L14, L15	8		MMZ1005S182ET000	TDK	Inductor, Ferrite Bead, Ferrite, 0.2 A, 2.1 ohm, SMD	1x0.5mm		
31	L5	1	1.5 uH	1286AS-H-1R5M=P2	MuRata	Inductor, Wirewound, Powdered Iron, 1.5 µH, 1.8 A, 0.114 ohm, SMD	2.0x1.2x1.6mm		
32	L6	1	2.2 uH	74404024022	Wurth Elektronik	Inductor, Wirewound, Ferrite, 2.2 uH, 1.8 A, 0.08 ohm, SMD	SMD, 2.5x2mm		
33	L7, L9, L10, L11	4	120 ohm	BLM18AG121SN1D	MuRata	Ferrite Bead, 120 ohm @ 100 MHz, 0.5 A, 0603	0603		
34	L8	1	10 uH	LPS3010-103MRB	Coilcraft	Inductor, Shielded, Ferrite, 10 uH, 0.48 A, 0.54 ohm, SMD	LPS3010		
35	LBL1	1		THT-14-423-10	Brady	Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch		
36	LED1, LED3	2	Green	SML-LX0603GW-TR	Lumex	LED, Green, SMD	LED, GREEN, 0603		
37	LED2	1	Super Red	SML-LX0603SRW-TR	Lumex	LED, Super Red, SMD	LED, 1.6x.6x.8mm		
38	PCB2	1		MHR041A	Texas Instruments	AFE4410/AFE4420 Sensor Board	Used in PnP output and some BOM reports		
39	Q1	1	25 V	MMBT5089LT1G	ON Semiconductor	Transistor, NPN, 25 V, 0.05 A, SOT-23	SOT-23		
40	R1, R2, R27, R28, R29, R30, R31, R32, R46, R47, R48, R49, R50, R51, R52, R53, R62, R63, R64, R65, R66	21	0	ERJ-1GE0R00C	Panasonic	RES, 0, 5%, 0.05 W, AEC-Q200 Grade 1, 0201	0201		
41	R3, R8, R71, R73	4	0	CRCW02010000Z0ED	Vishay-Dale	RES, 0, 5%, 0.05 W, 0201	0201		
42	R4, R10, R70	3	49.9 k	RC0201FR-0749K9L	Yageo America	RES, 49.9 k, 1%, 0.05 W, 0201	0201		
43	R5, R12, R72	3	51.0 k	RC0201FR-0751KL	Yageo America	RES, 51.0 k, 1%, 0.05 W, 0201	0201		
44	R11, R35, R67	3	499 k	CRCW0402499KFKED	Vishay-Dale	RES, 499 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
45	R13, R83, R126	3	47k	CRCW040247K0JNED	Vishay-Dale	RES, 47 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
46	R14, R15, R16, R17, R19, R21, R22, R24, R25	9	10.0 k	ERJ-2RKF1002X	Panasonic	RES, 10.0 k, 1%, 0.1 W, 0402	0402		
47	R82, R90	2	100	CRCW0402100RFKED	Vishay-Dale	RES, 100, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
48	R84, R92, R93, R95, R97, R102, R103, R108, R111, R118, R130	11	0	CRCW04020000Z0ED	Vishay-Dale	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		

Table 11. AFE4950 Bill of Materials[(1)] (continued)

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference	Alternate PartNumber	Alternate Manufacturer
49	R85	1	1.40 k	CRCW04021K40FKED	Vishay-Dale	RES, 1.40 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
50	R86, R87	2	33	CRCW040233R0JNED	Vishay-Dale	RES, 33, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
51	R88	1	33 k	CRCW040233K0JNED	Vishay-Dale	RES, 33 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
52	R89, R110	2	1.00 Meg	CRCW04021M00FKED	Vishay-Dale	RES, 1.00 M, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
53	R91, R98, R99, R127	4	4.7 k	CRCW04024K70JNED	Vishay-Dale	RES, 4.7 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
54	R94	1	10.0 k	CRCW040210K0FKED	Vishay-Dale	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
55	R96, R100, R101	3	10.0	CRCW040210R0FKED	Vishay-Dale	RES, 10.0, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
56	R104	1	220	CRCW0402220RJNED	Vishay-Dale	RES, 220, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
57	R105	1	130	CRCW0402130RJNED	Vishay-Dale	RES, 130, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
58	R106, R120, R121, R122, R124, R125	6	0	CRCW06030000Z0EA	Vishay-Dale	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603		
59	R107, R128, R129	3	0	ERJ-3GEY0R00V	Panasonic	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603		
60	R109	1	953 k	CRCW0402953KFKED	Vishay-Dale	RES, 953 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
61	R112	1	47	CRCW060347R0JNEA	Vishay-Dale	RES, 47, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	0603		
62	R114	1	180 k	CRCW0402180KJNED	Vishay-Dale	RES, 180 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
63	R117	1	1.00 Meg	CRCW06031M00FKEA	Vishay-Dale	RES, 1.00 M, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603		
64	R119	1	255 k	CRCW0603255KFKEA	Vishay-Dale	RES, 255 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603		
65	R123	1	75.0 k	CRCW040275K0FKED	Vishay-Dale	RES, 75.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
66	S1, S2	2		RS-032G05A3-SM RT		Switch, Tactile, SPST-NO, 0.05A, 12V, SMD	SPST, 6x3.5mm		
67	SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J7, SH-J8	7		881545-2	TE Connectivity	Shunt, 100mil, Gold plated, Black	Shunt 2 pos. 100 mil		
68	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9	9		5002	Keystone	Test Point, Miniature, White, TH	White Miniature Testpoint		
69	TP10, TP11, TP12, TP13	4		5001	Keystone	Test Point, Miniature, Black, TH	Black Miniature Testpoint		
70	U1	1		AFE4950YGB	Texas Instruments	Ultra-Small, Integrated AFE for Wearable Optical Heart-Rate Monitoring, SpO2 and Electrical Bio-sensing, YBG0036-C01 (DSBGA-36)	YBG0036-C01		Texas Instruments

Table 11. AFE4950 Bill of Materials[(1)] (continued)

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference	Alternate PartNumber	Alternate Manufacturer
71	U18	1		BQ24032ARHLR	Texas Instruments	Dual Input Li-Ion Charger with Dynamic Power Path, Output regulated to 4.4 V, Vbat 4.2 V, 4.3 V, -40 to 85 degC, 20-pin QFN (RHL), Green (RoHS & no Sb/Br)	RHL0020A		
72	U19, U21	2		TXB0104YZTR	Texas Instruments	4-Bit Bidirectional Voltage-Level Shifter with Auto Direction Sensing and +/-15 kV ESD Protect, YZT0012ACAC (DSBGA-12)	YZT0012ACAC		Texas Instruments
73	U20	1		TXS0102YZPR	Texas Instruments	2-Bit Bidirectional Voltage-Level Shifter for Open-Drain and Push-Pull Application, YZP0008ADCD (DSBGA-8)	YZP0008ADCD		Texas Instruments
74	U22	1		TXB0102YZPR	Texas Instruments	2-Bit Bidirectional Voltage-Level Translator with Auto Direction Sensing and +/-15-kV ESD Protect, YZP0008ADAD, Large T and R	YZP0008ADAD		
75	U26	1		TPD4E004DRYR	Texas Instruments	ESD-Protection Array for High-Speed Data Interfaces, 4 Channels, -40 to +85 degC, 6-pin SON (DRY), Green (RoHS & no Sb/Br)	DRY0006A		
76	U27	1		TPS3825-33DBVR	Texas Instruments	Voltage Monitor with Manual Reset, DBV0005A (SOT-23-5)	DBV0005A	TPS3825-33DBVT	Texas Instruments
77	U28	1		MSP430F5529IPN	Texas Instruments	25 MHz Mixed Signal Microcontroller with 128 KB Flash, 8192 B SRAM and 63 GPIOs, -40 to 85 degC, 80-pin QFP (PN), Green (RoHS & no Sb/Br)	PN0080A		
78	U29	1		TPS63050YFFR	Texas Instruments	Tiny Single Inductor Buck Boost Converter, YFF0012AFAF (DSBGA-12)	YFF0012AFAF	TPS63050YFFT	Texas Instruments
79	U30	1		TPS61099YFFR	Texas Instruments	Synchronous Boost Converter with 800 nA Ultra-Low Quiescent Current, YFF0006AFAD (DSBGA-6)	YFF0006AFAD	TPS61099YFFT	Texas Instruments
80	U31	1		TPS7A4901DGNT	Texas Instruments	Single Output High PSRR LDO, 150 mA, Adjustable 1.2 to 33 V Output, 3 to 36 V Input, with Ultra-Low Noise, 8-pin MSOP (DGN), -40 to 125 degC, Green (RoHS & no Sb/Br)	DGN0008D		
81	U32	1		TPS72718YFFR	Texas Instruments	250-mA, Ultralow IQ, Fast Transient Response, RF Low-Dropout Linear Regulator, YFF0004AUAB_A1 (DSBGA-4)	YFF0004AUAB_A1	TPS72718YFFT	Texas Instruments
82	Y1	1		ABS07-32.768KHZ-T	Abracon Corporation	CRYSTAL, 32.768KHz, 12.5PF, SMD	3.2x0.9x1.5mm		
83	Y2	1		ABM3B-24.000MHZ-10-1-U-T	Abracon Corporation	Crystal, 24 MHz, 10 pF, SMD	Crystal, 3.2x1.1x5.x mm		
84	C11	0	10 uF	C0603C106M9PACTU	Kemet	CAP, CERM, 10 uF, 6.3 V, ±20%, X5R, 0603			
85	C12, C21, C22	0	0.1 uF	CC0402KRX7R6BB104	Yageo America	CAP, CERM, 0.1 uF, 10 V, ±10%, X7R, 0402			
86	C18	0	22 uF	TLJN226M006R5400	AVX	CAP, TA, 22 uF, 6.3 V, ±20%, 5.4 ohm, SMD			
87	C27	0	10 uF	GRM155R60J106ME44D	MuRata	CAP, CERM, 10 uF, 6.3 V, ±20%, X5R, 0402			
88	C31, C34, C77	0	10 pF	GJM0335C1E100JB01D	MuRata	CAP, CERM, 10 pF, 25 V, ±5%, C0G/NP0, 0201			
89	C32	0	100 pF	C0603C0G1E101J030BA	TDK	CAP, CERM, 100 pF, 25 V, ±5%, C0G/NP0, 0201			
90	C35	0	1000 pF	C0603X5R1E102K030BA	TDK	CAP, CERM, 1000 pF, 25 V, ±10%, X5R, 0201	0201		
91	C62	0	10 pF	GRM1555C1H100RA01D	MuRata	CAP, CERM, 10 pF, 50 V, ±4%, C0G/NP0, 0402	0402		
92	C63	0	20 pF	GRM1885C1H200JA01D	MuRata	CAP, CERM, 20 pF, 50 V, ±5%, C0G/NP0, 0603	0603		

Table 11. AFE4950 Bill of Materials[(1)] (continued)

Item #	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference	Alternate PartNumber	Alternate Manufacturer
93	FID1, FID2, FID3, FID4, FID5, FID6	0		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	N/A		
94	J11	0		TSW-104-07-G-S	Samtec	Header, 100mil, 4x1, Gold, TH	4x1 Header		
95	R6, R7	0	200 Meg	CRCW0603200MJPEAHR	Vishay-Dale	RES, 200 M, 5%, 0.1 W, 0603	0603		
96	R9	0	499	CRCW0402499RFKED	Vishay-Dale	RES, 499, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
97	R18, R20, R23, R26	0	10.0 k	ERJ-2RKF1002X	Panasonic	RES, 10.0 k, 1%, 0.1 W, 0402	0402		
98	R33, R34, R37, R40, R43, R44, R45	0	0	ERJ-1GE0R00C	Panasonic	RES, 0, 5%, 0.05 W, AEC-Q200 Grade 1, 0201	0201		
99	R36, R38, R39, R41, R56, R57, R58, R59, R60, R61, R68, R69, R113, R115, R116, R131	0	0	CRCW04020000Z0ED	Vishay-Dale	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
100	R42	0	499 k	CRCW0402499KFKED	Vishay-Dale	RES, 499 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
101	R54, R55	0	10.0 k	CRCW040210K0FKED	Vishay-Dale	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402		
102	R74	0	49.9 k	ERA-2AEB4992X	Panasonic	RES, 49.9 k, 0.1%, 0.063 W, 0402	0402		
103	SH-J6, SH-J9, SH-J10, SH-J11	0		881545-2	TE Connectivity	Shunt, 100mil, Gold plated, Black	Shunt 2 pos. 100 mil		

Table 12. Sensor Board Bill of Materials

Item	Designator	Quantity	Value	Part Number	Manufacturer	Description	Package Reference
1	PCB	1		MHR041	Any	Printed Circuit Board	
2	C1	1	33µF	C2012X5R1A336M125AC	TDK	CAP, CERM, 33 µF, 10 V, ±20%, X5R, 0805	0805
3	FID1, FID2, FID3, FID4, FID5, FID6	6		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	N/A
4	H1	1		SJ5832	3M	UC-Rubber Cover custom fitted to sensor: Post Build	Used in PnP output and some BOM reports
5	J1	1		850-10-010-20-001000	Mill-Max	Header, 50mil, 10x1, R/A, TH	Header, 10x1, 50mil, R/A
6	R2	1	0	CRCW04020000Z0EDHP	Vishay-Dale	RES, 0, 0%, 0.2 W, AEC-Q200 Grade 0, 0402	0402
7	U1	1		SFH7072	OSRAM	BioMon Sensor, SMD	7.5x3.9mm
8	R1	0	0	CRCW04020000Z0EDHP	Vishay-Dale	RES, 0, 0%, 0.2 W, AEC-Q200 Grade 0, 0402	0402

8 PCB Layouts and Schematics

8.1 AFE4950EVM PCB Layouts

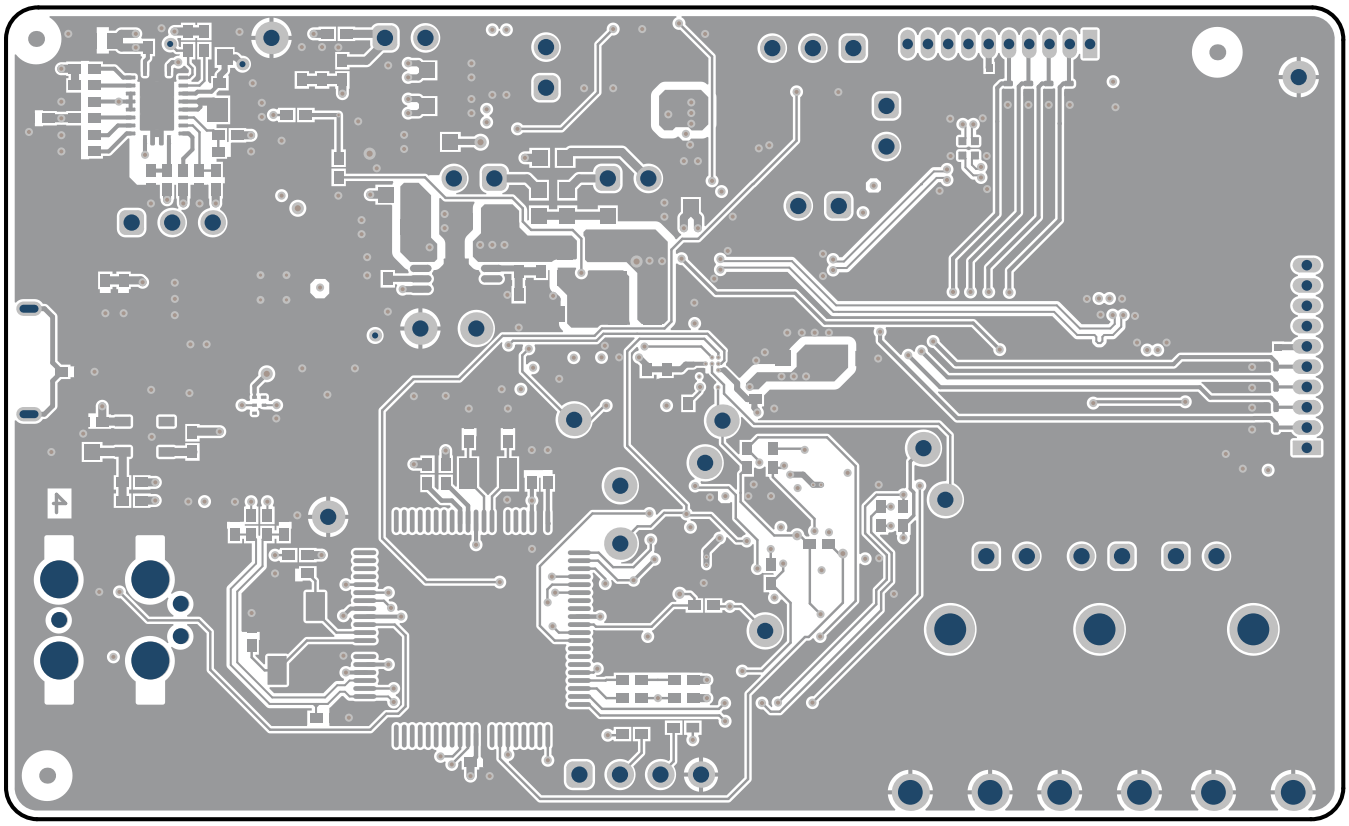


Figure 28. AFE4950EVM PCB Layout - Bottom Layer (1 of 6)

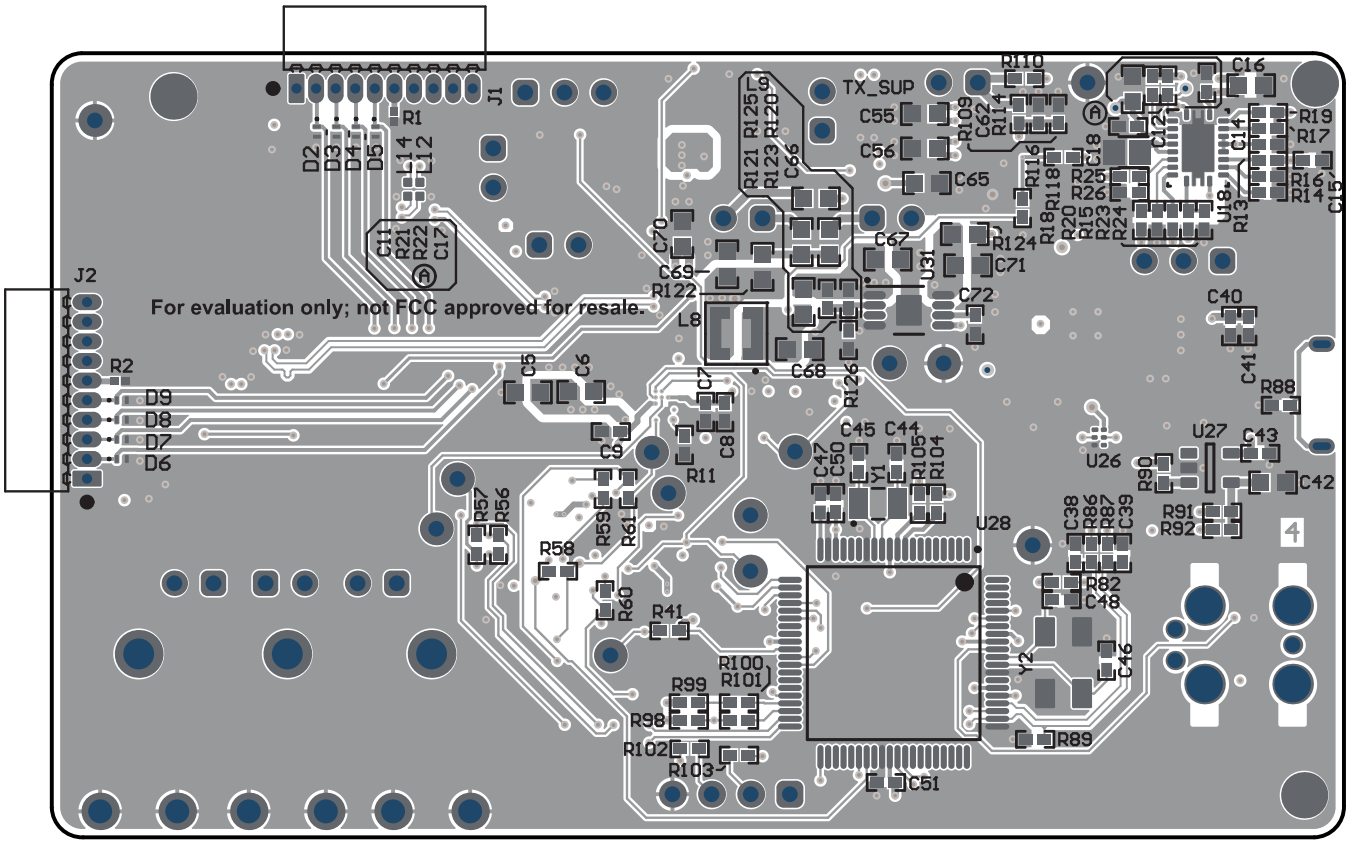


Figure 29. AFE4950EVM PCB Layout - Bottom Layer with Components (2 of 6)

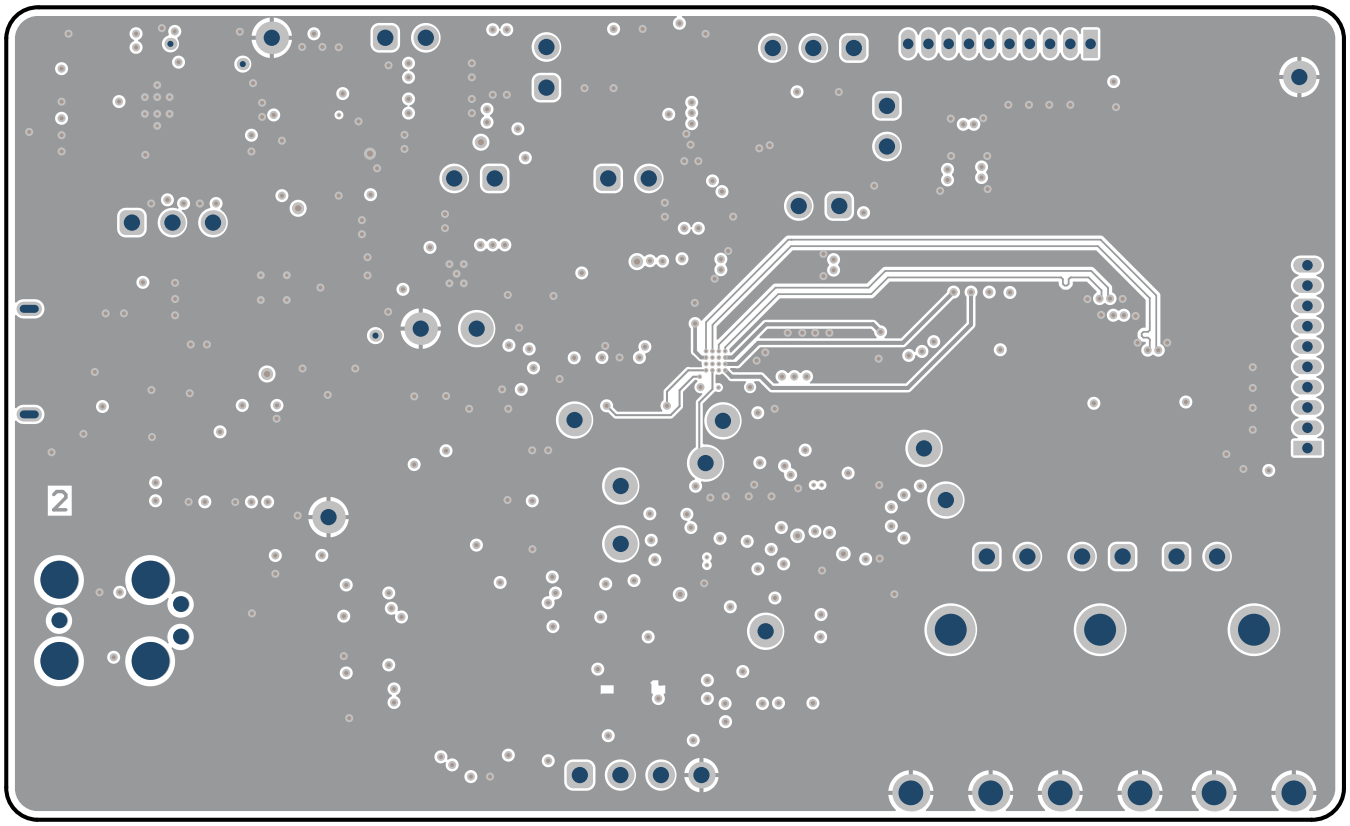


Figure 30. AFE4950EVM PCB Layout - Ground Plane (3 of 6)

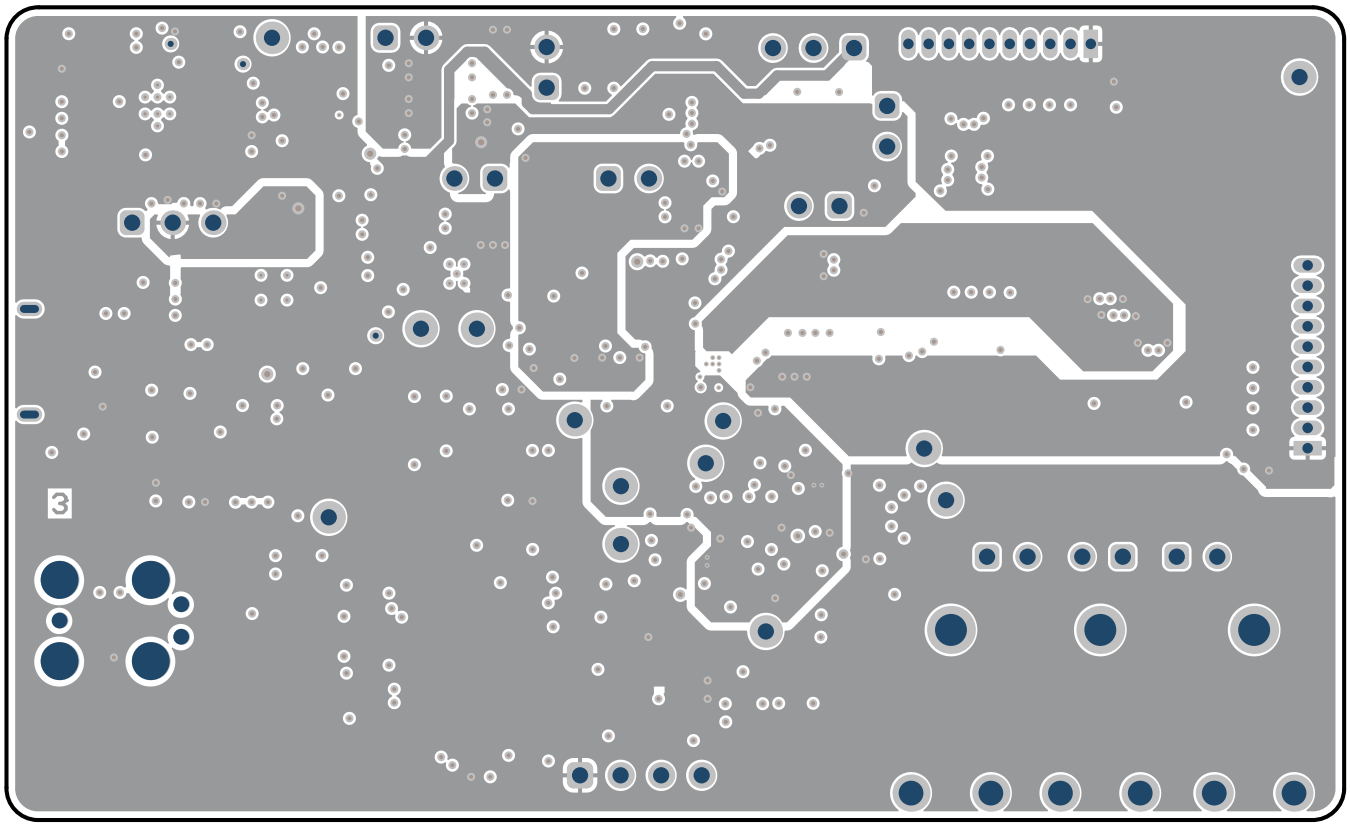


Figure 31. AFE4950EVM PCB Layout - Power Plane (4 of 6)

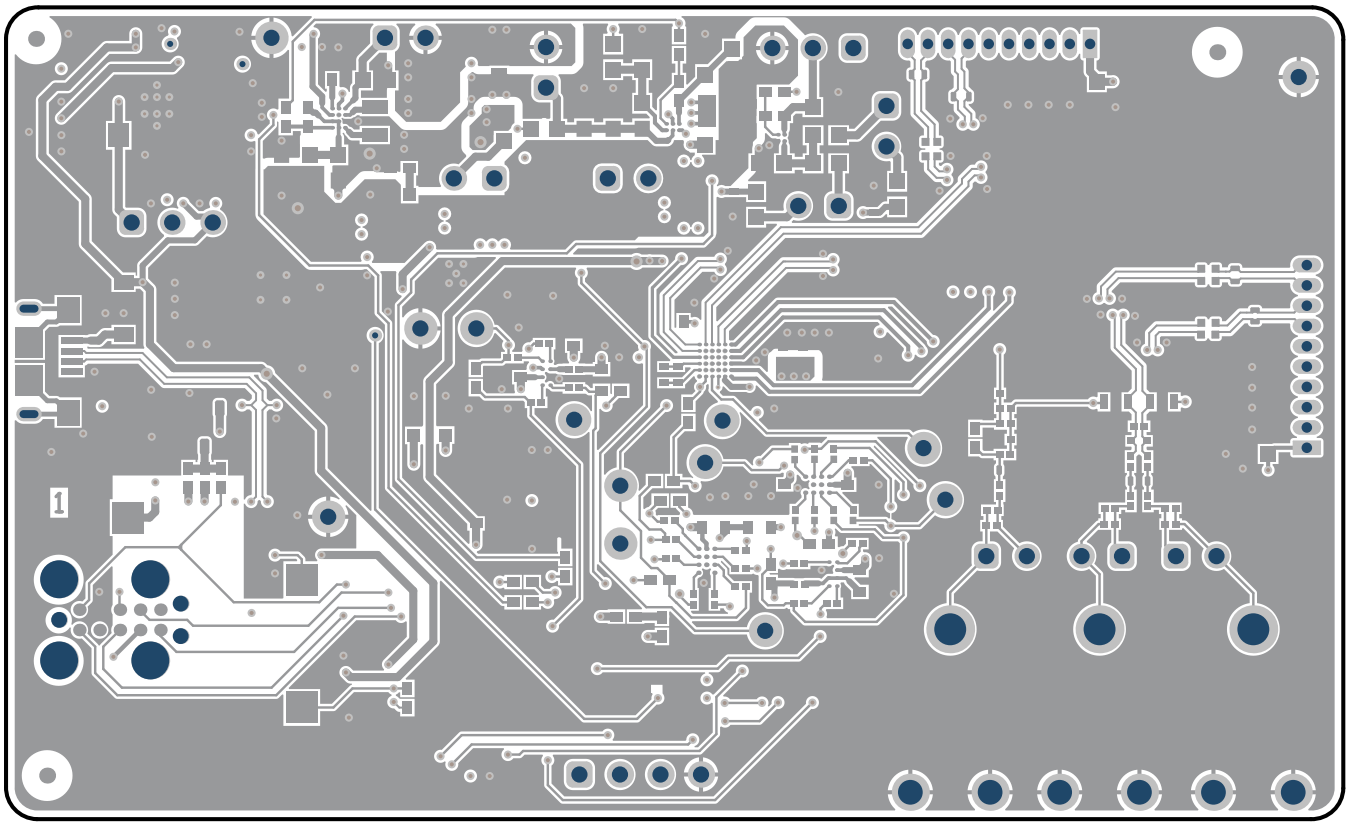


Figure 32. AFE4950EVM PCB Layout - Top Layer (5 of 6)

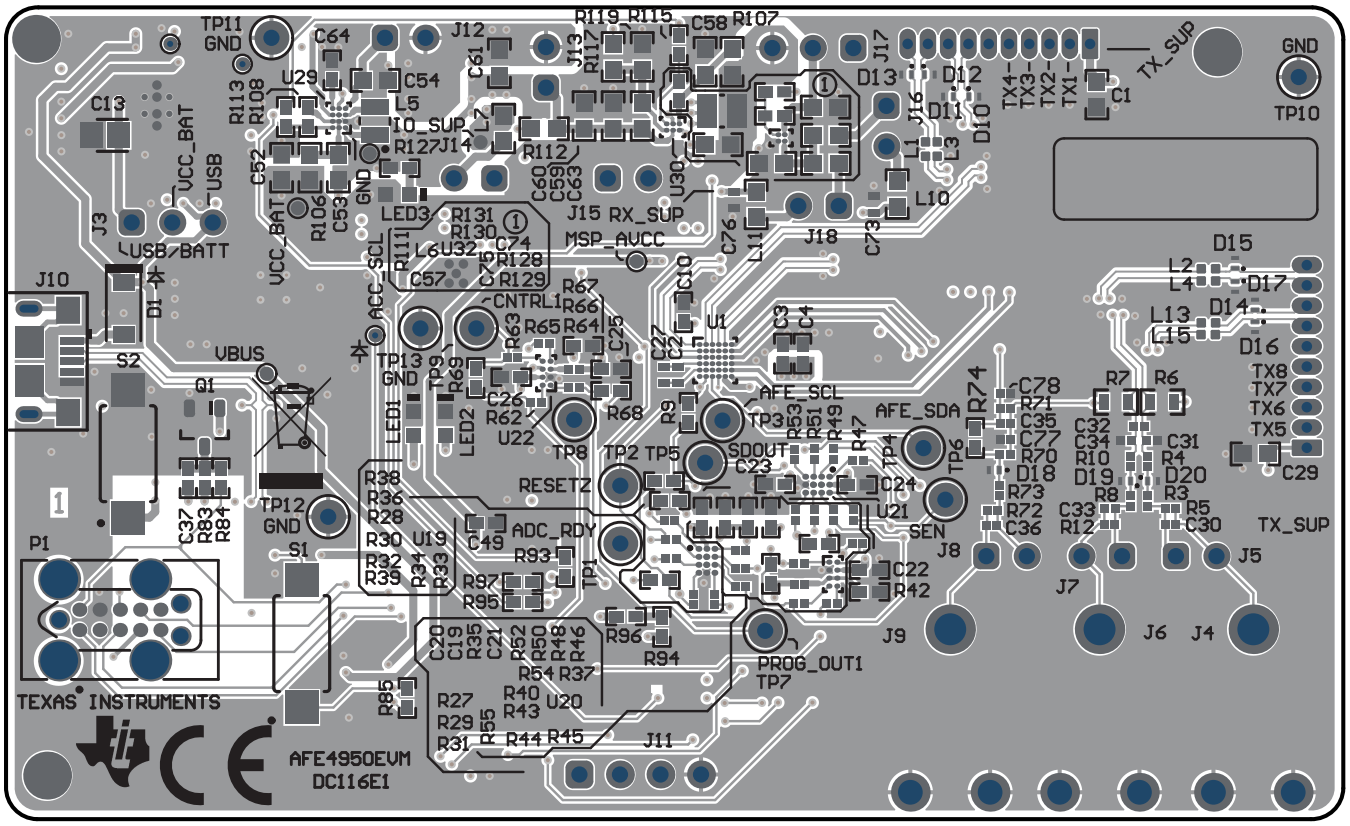


Figure 33. AFE4950EVM PCB Layout - Top Layer with components(6 of 6)

8.2 Sensor Board Layouts

Figure 34 through Figure 37 show the sensor board layouts.

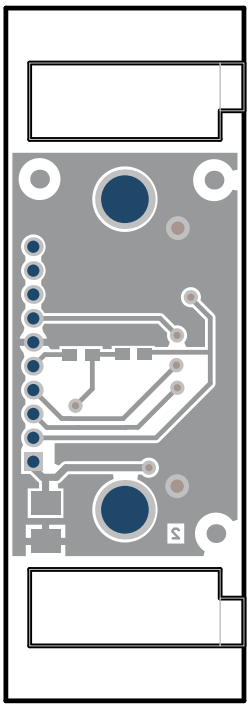


Figure 34. Bottom Layer

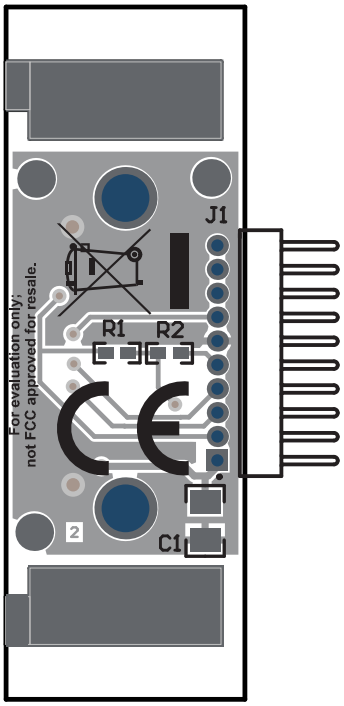


Figure 35. Bottom View Composite

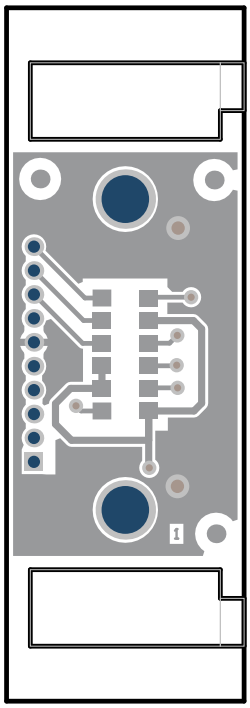


Figure 36. Top Layer

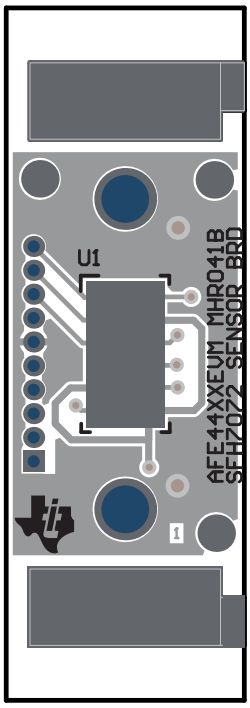


Figure 37. Top View Composite

8.3 AFE4950EVM Schematics

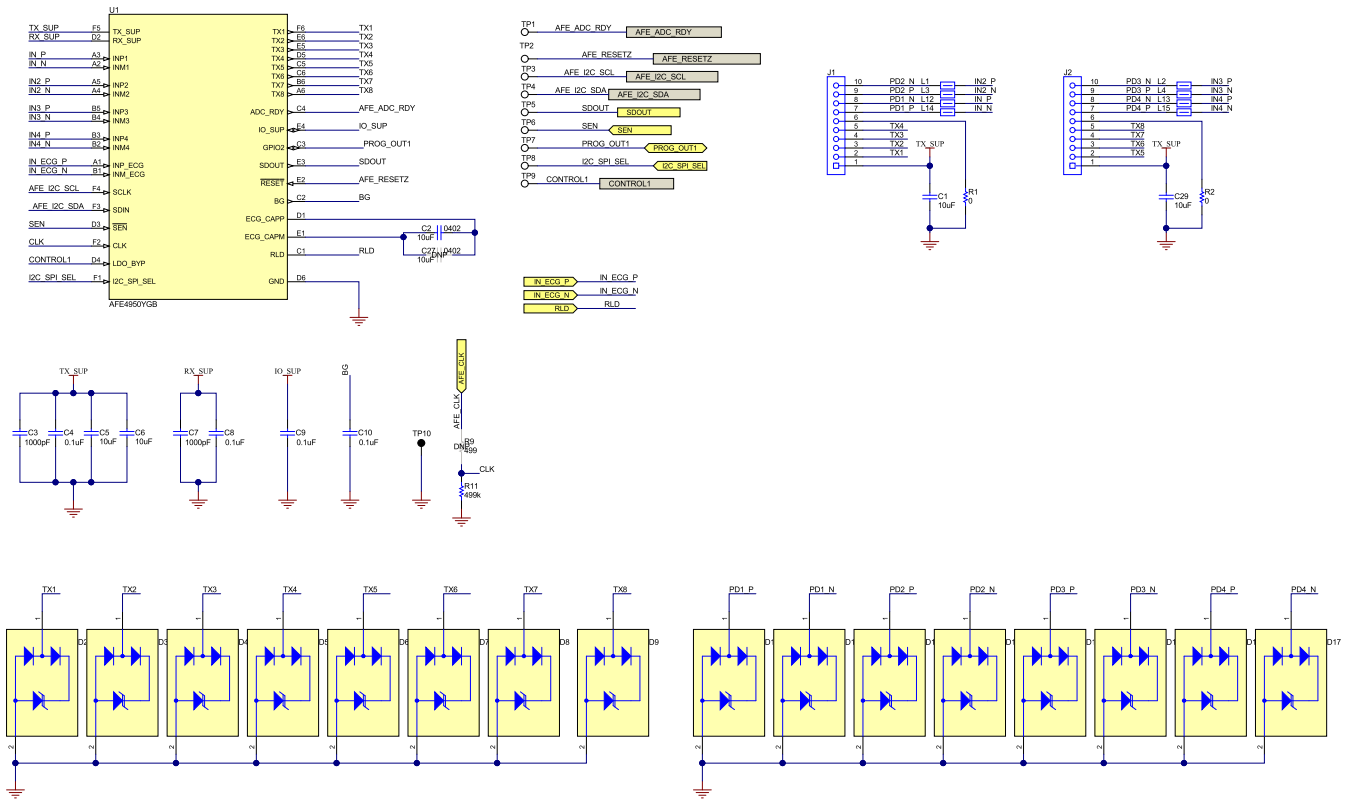


Figure 38. AFE4950EVM Schematic (1 of 6)

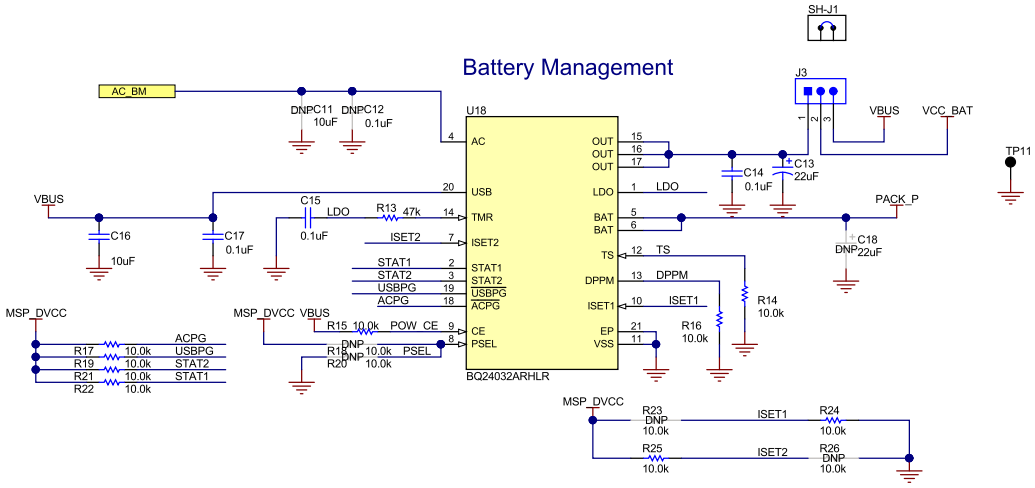


Figure 39. AFE4950EVM Schematic (2 of 6)

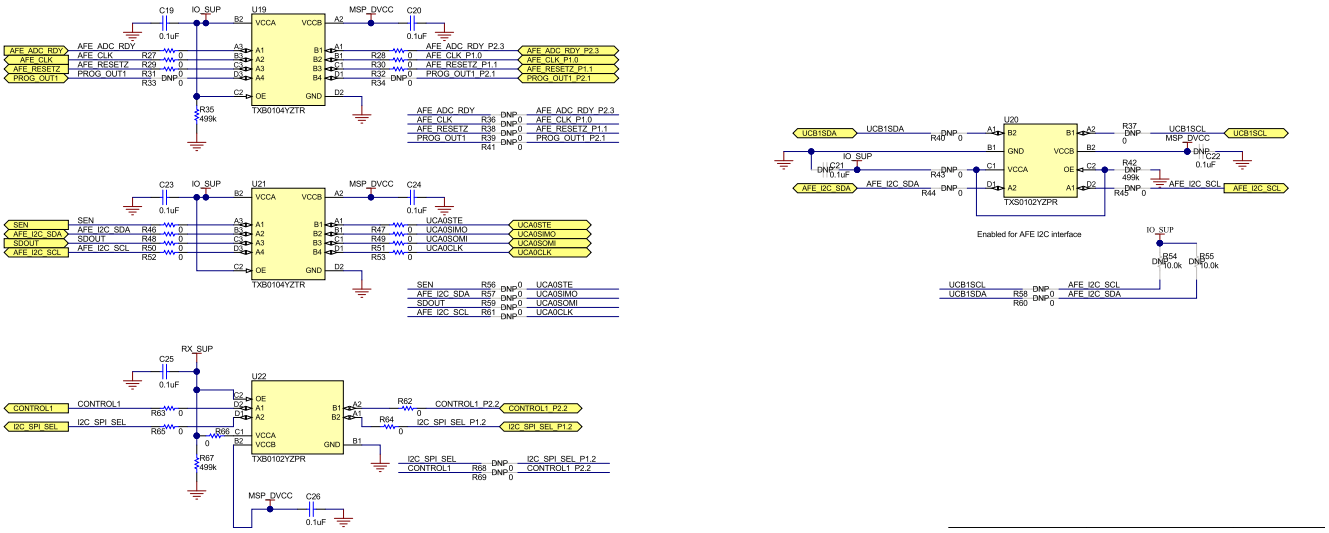


Figure 40. AFE4950EVM Schematic (3 of 6)

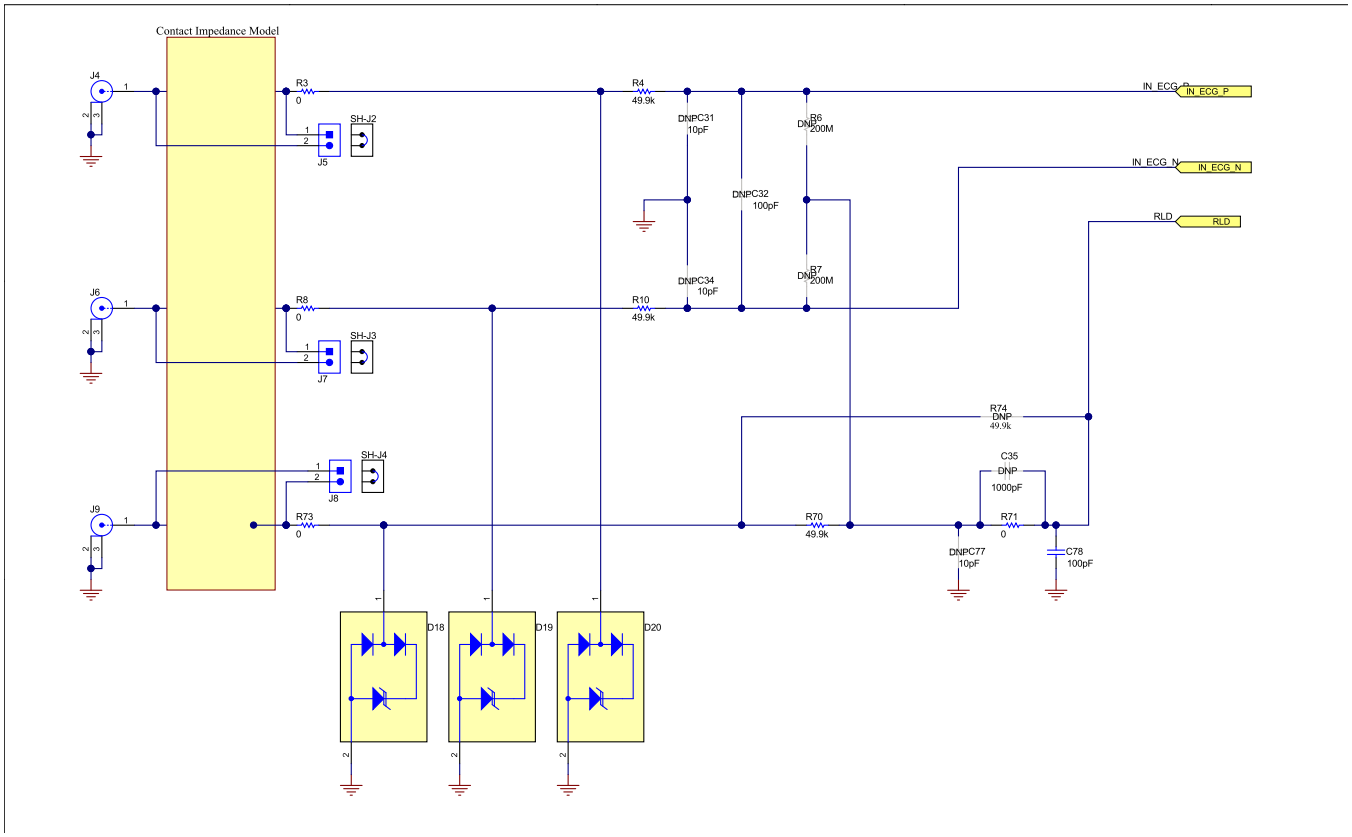


Figure 41. AFE4950EVM Schematic (4 of 6)

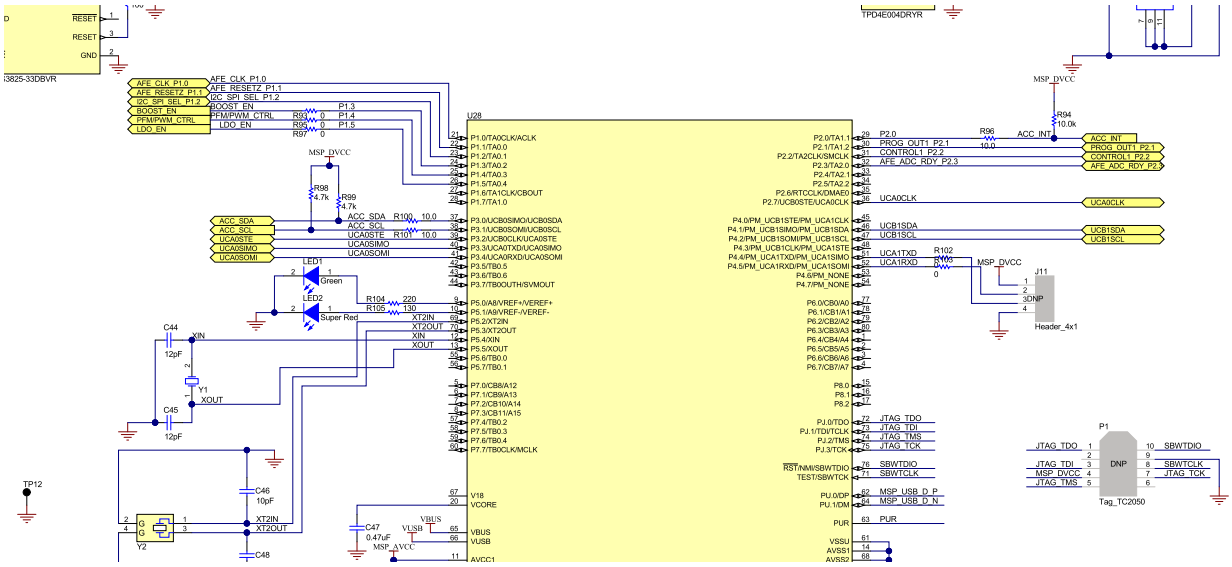


Figure 42. AFE4950EVM Schematic (5 of 6)

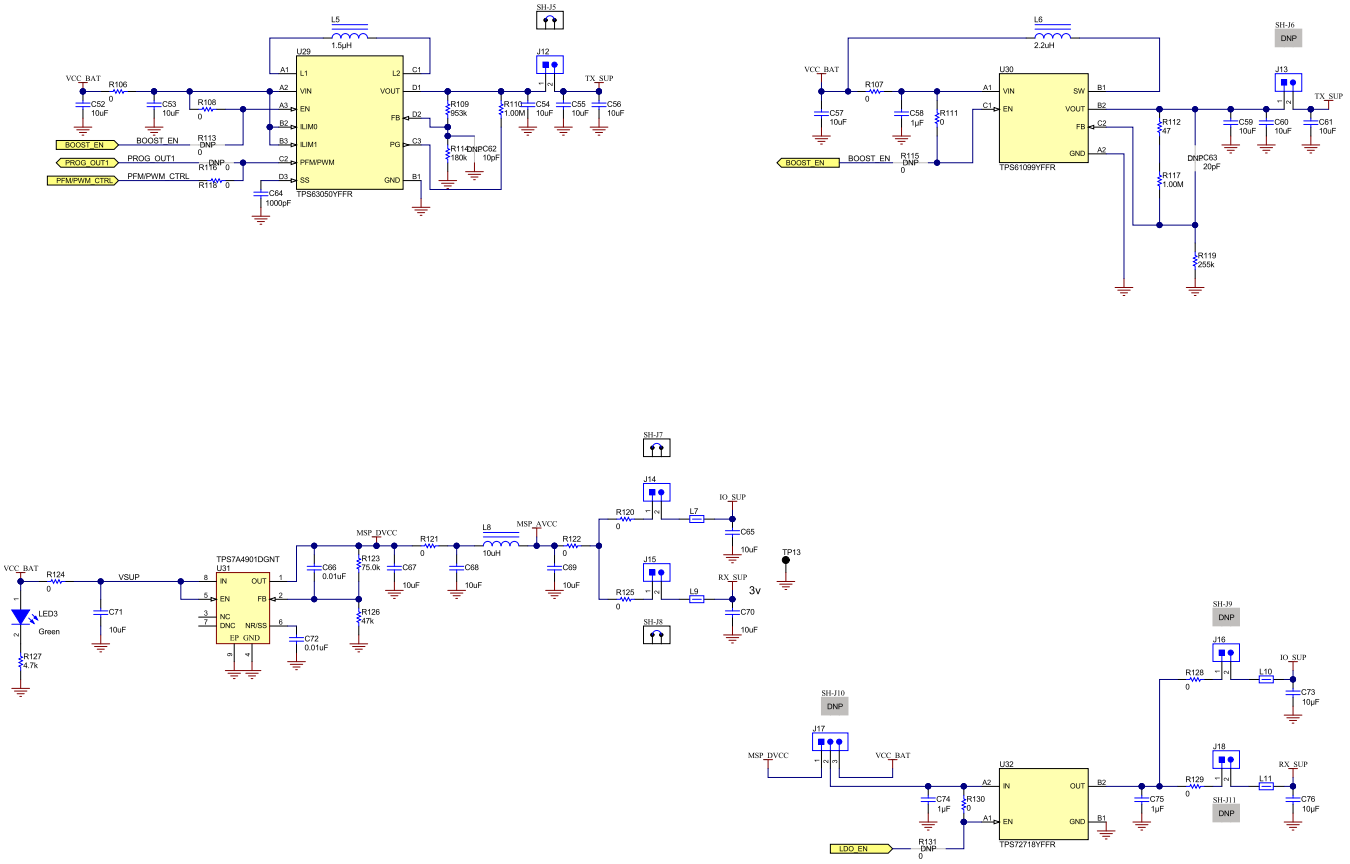


Figure 43. AFE4950EVM Schematic (6 of 6)

8.4 Sensor Board Schematic

Figure 44 illustrates the sensor board schematics.

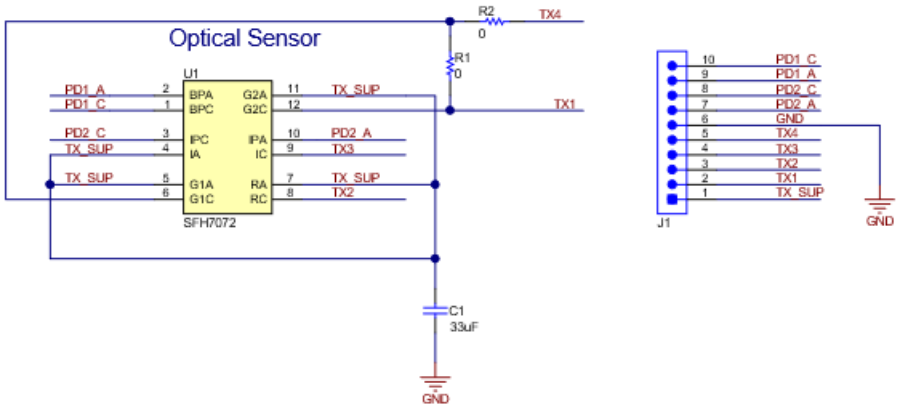


Figure 44. Sensor Board Schematic

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *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 not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: 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 his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: 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.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. 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.

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.

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.

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

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。
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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page
電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, 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 also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user 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, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM 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. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

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