User's Guide
SLAU572B–June 2014–Revised July 2014

AFE4403 Development Guide

This user's guide describes the characteristics, operation and use of the AFE4403EVM demonstration kit. This demonstration kit is an evaluation module for the AFE4403 device. The family of devices are fully-integrated AFE, ideally suited for Pulse Oximeter applications. The EVM is intended for prototyping and evaluation. This user's guide includes a complete circuit description, schematic diagram and bill of materials.

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

Device	Literature Number
AFE4403	SBAS650

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1 AFE4403EVM Overview

1.1 Important Disclaimer Information

CAUTION

The AFE4403EVM 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.

Only use the AFE4403EVM under the following conditions:

- The AFE4403EVM demonstration kit is intended only for electrical evaluation of the features of the AFE4403 devices in a laboratory, simulation, or development environment.
- The AFE4403EVM demonstration kit is not intended for direct interface with a patient, or patient diagnostics.
- The AFE4403EVM 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 AFE4403EVM 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.
- The user is responsible for the safety of themselves, fellow employees and contractors, and co-workers when using or handling the AFE4403EVM. Furthermore, the user is fully responsible for the contact interface between the 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.

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2 Overview

2.1 Introduction

The EVM is intended for evaluating AFE4403 device. The family of devices consist of a low-noise receive channel, the LED transmit section, and diagnostics for sensor and LED fault detection. The AFE4403 has a highly configurable timing controller, enabling complete control of the device's timing characteristics. The device also has an integrated oscillator working off from two clock sources: either an external crystal or the clock from an external host processor to ease clocking requirements and provide a low-jitter clock to the AFE4403 The device communicates to an external host processor using the Serial Peripheral Interface (SPI). The purpose of the EVM is to expedite evaluation and system development activities related to AFE4403 devices. The demonstration kit is shown in Figure 1.

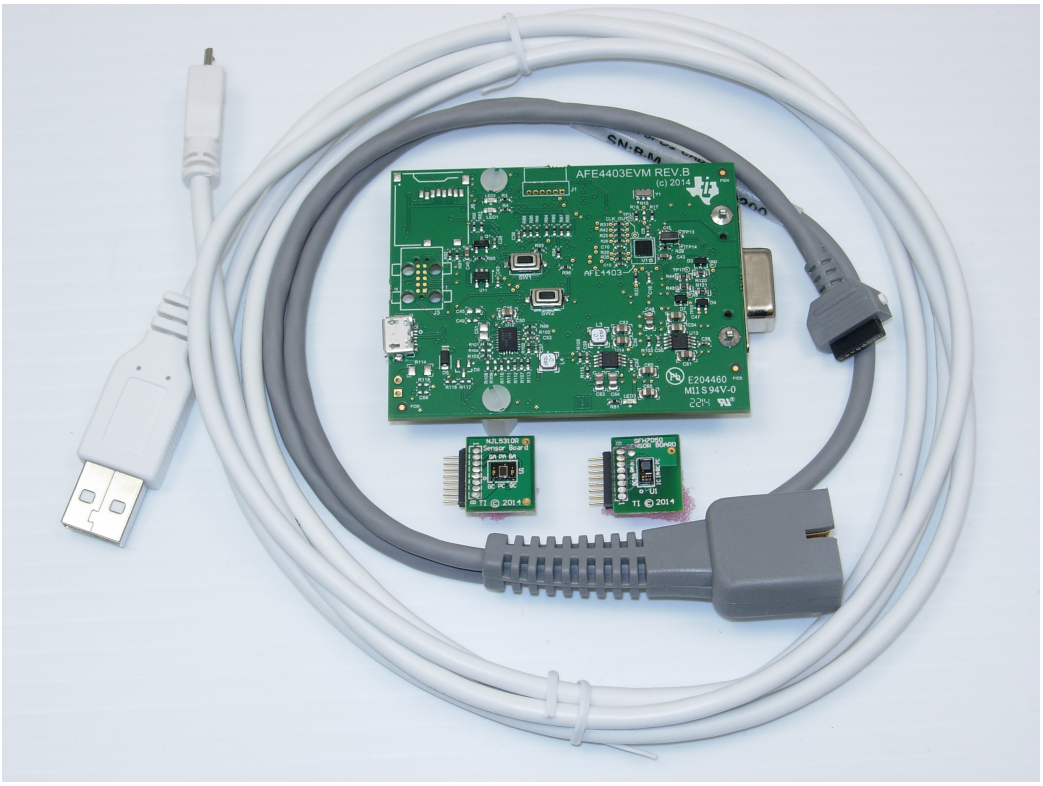


Figure 1. AFE4403 Demonstration Kit

Throughout the document, the term demonstration kit is synonymous with AFE4403EVM.

2.2 AFE4403EVM Kit Contents

- AFE4403EVM Demonstration Kit
- USB-to-micro USB cable
- DB9 to 8 pin header sensor cable
- NJRC NJL5310R sensor board
- OSRAM SFH7050 sensor board

2.3 Features Supported in this Version

1. DB9 pulse oximeter sensor cable support
2. Acquire data at up to 3000 Hz in evaluation mode
3. USB-based power and PC application connectivity
4. Access to all AFE4403 registers via an easy-to-use GUI

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5. Built-in time domain, histogram, and FFT on the PC application
6. USB-based firmware upgrade option

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3 Software Installation

The latest AFE4403EVM PC application software (GUI) is available from the TI website at www.ti.com. Download the zipped file to a temporary directory on the PC.

3.1 Minimum Requirements

Before installing the software, verify that your PC meets the minimum requirements outlined in this section.

3.1.1 Required Setup for AFE4403EVM Demo Software

- IBM PC-compatible computer
- Pentium® III/ Celeron® 866 MHz or equivalent processor
- Minimum 256MB of RAM (512MB or greater recommended)
- Hard disk drive with at least 200 MB free space
- Microsoft® Windows® XP SP2 operating system or Windows 7 operating system
- 1280 × 1024 or greater display screen resolution

3.2 Installing the Software (PC Application)

Before installing the software, make sure the AFE4403EVM is NOT connected to the PC. If using a machine with Windows 7 OS, we recommend having administrator rights to avoid problems during installation. Unzip the installer file, and then find and double click *setup.exe* to install the software. Unless otherwise specified during the install process, the software installs at the following location:

- On a Windows XP machine
  - *C:\Program Files\Texas Instruments\AFE4403EVM GUI*
- On a Windows 7 machine
  - *C:\Program Files(x86)\Texas Instruments\AFE4403EVM GUI*

It creates a program menu item, AFE4403EVM GUI under *Programs→Texas Instruments→AFE4403EVM GUI* to execute the software. The following steps ensure proper installation of the PC application.

Click *setup.exe* and follow the prompts to continue with the installation process.

Select the destination directory and click the **Next>>** button.

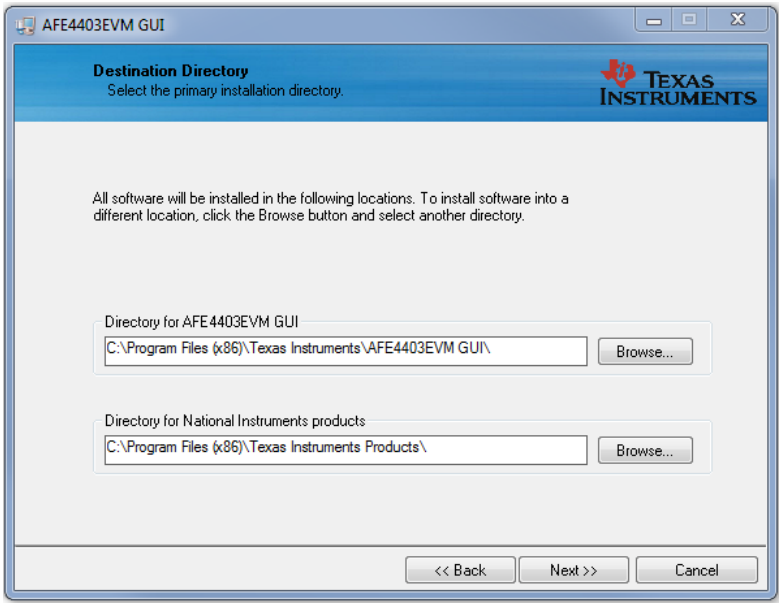


Figure 2. PC Application Installation - Screen 1

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Accept the NI Software License Agreement and click the **Next>>** button.

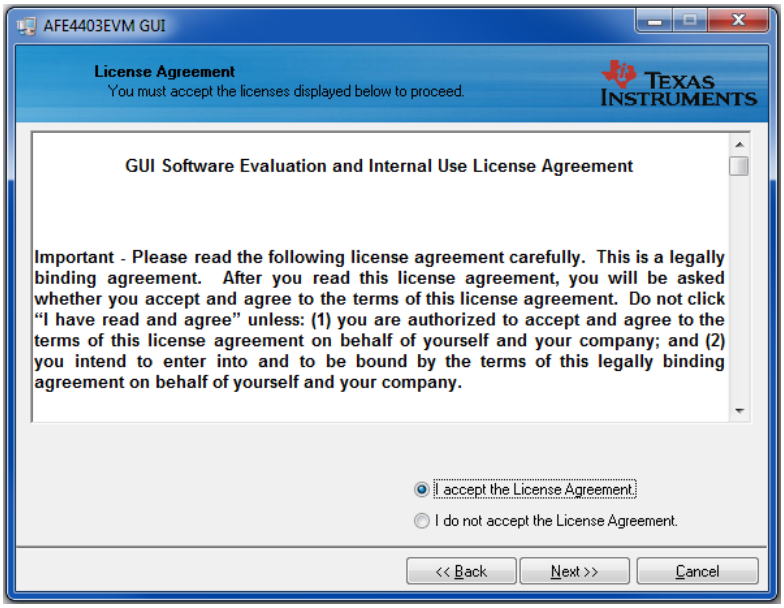


Figure 3. PC Application Installation - Screen 2

Accept the license agreement and click the **Next>>** button.

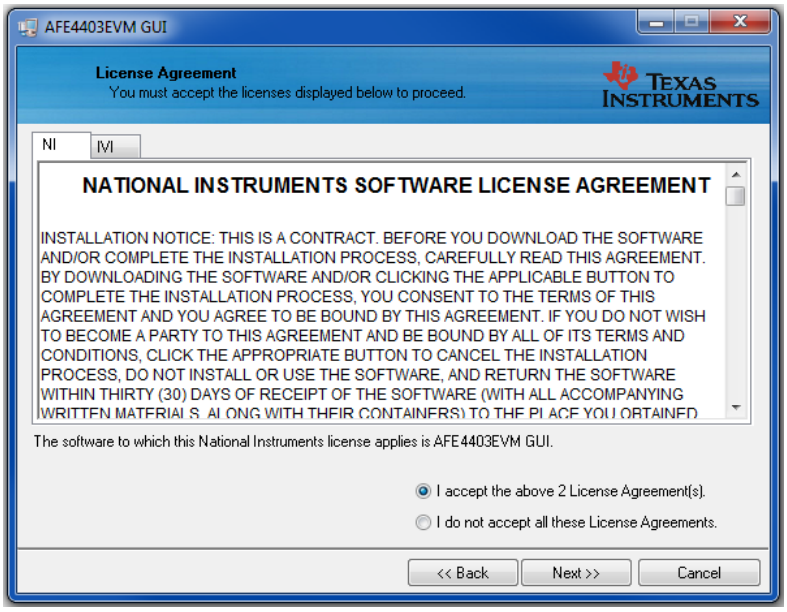


Figure 4. PC Application Installation - Screen 3

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Click the **Next>>** button to begin the installation.

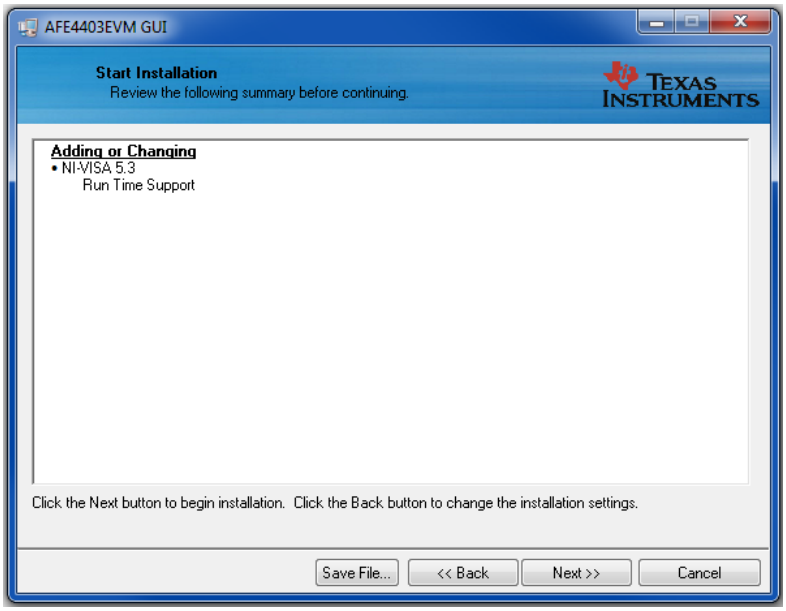


Figure 5. PC Application Installation - Screen 4

The application software is now installed. Once the installation is complete, click the **Next>>** button to continue with the installation of Python v2.7.

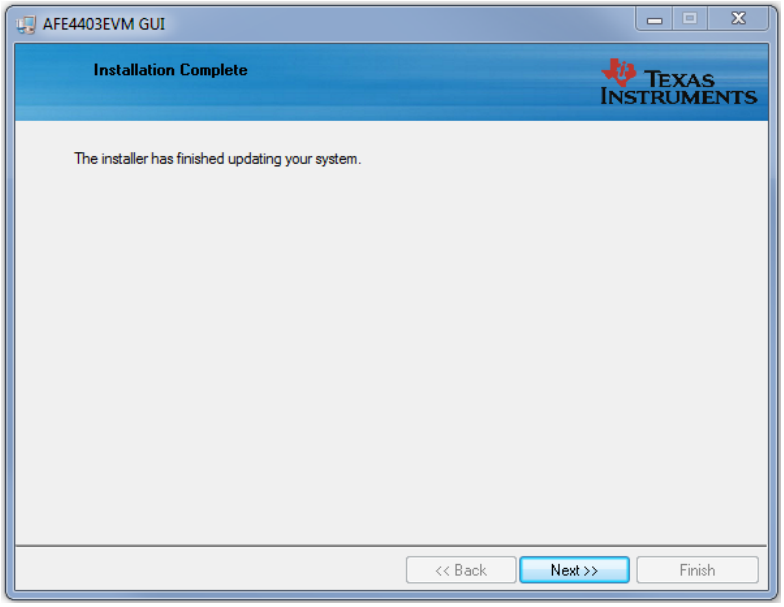


Figure 6. PC Application Installation - Screen 5

Once the Python v2.7 is installed, click the **OK** button. The PC application is now ready to use.

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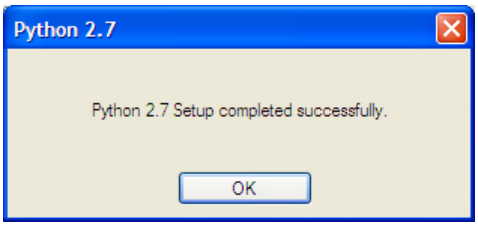


Figure 7. Python Installation

3.3 Installing the USB Drivers

The communication interface between the AFE4403EVM board and PC is through the USB, using the CDC profile. A one-time installation of the USB driver is required for the communication between the AFE4403EVM and PC application.

Following the steps below ensures proper installation of the USB drivers:

1. Plugin the USB-to-mini USB cable to J4 of AFE4403EVM and the other end to the USB port on the PC.
2. Win XP OS starts up the *New Hardware Wizard* to enable the user to install the USB driver for the new hardware. The Windows 7 OS attempts to find the driver for the *new hardware found* automatically and if the driver is not found, there is no pop-up message to indicate that the driver installation failed. In the Windows 7 OS, click on *Device Manager*, right click on *MSP430-USB* example under *Other devices* and click on *Update Driver Software* as shown in Figure 8. This step is not required for the Windows XP OS.

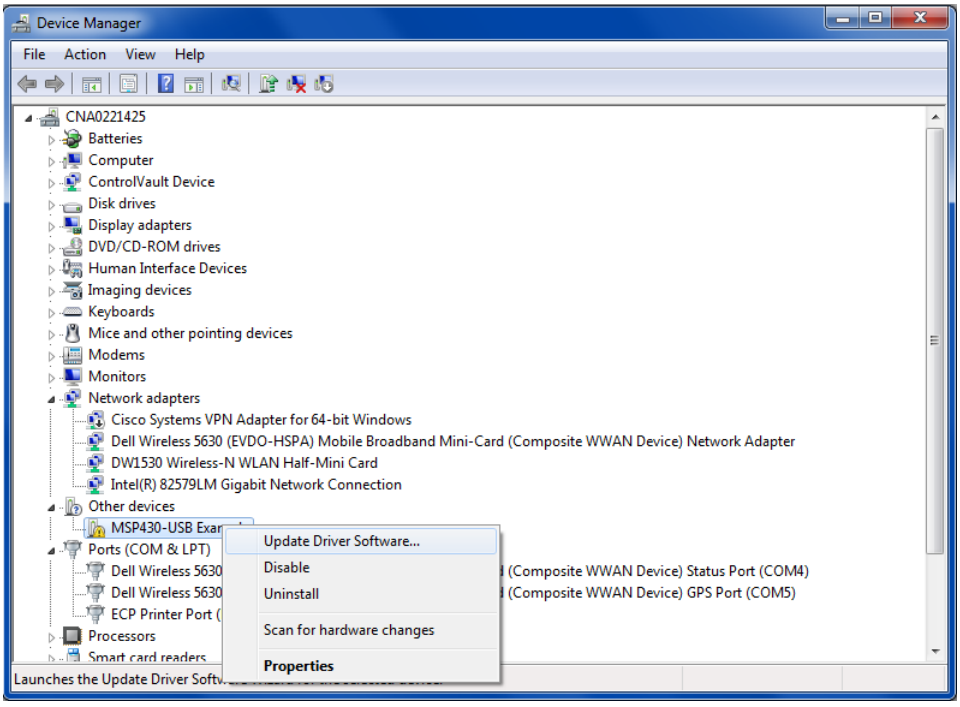


Figure 8. USB Driver Installation - Screen 1 (Windows 7 OS only)

3. Select the *Browse my computer for driver software* option

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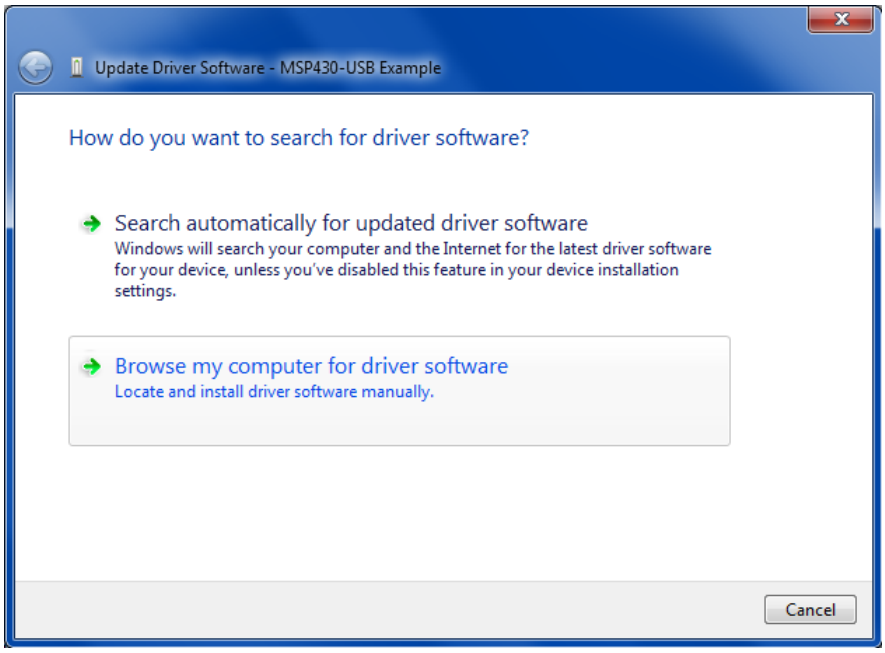


Figure 9. USB Driver Installation - Screen 2

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4. As shown in Figure 10, navigate to the directory where the *AFE44xx.inf* file is located by clicking the **Browse** button. The file is located at the following path:
   - On a Windows XP machine:
     - *C:\Program Files\Texas Instruments\AFE4403EVM GUI\USB Driver*
   - On a Windows 7 machine:
     - *C:\Program Files(x86)\Texas Instruments\AFE4403EVM GUI\USB Driver*

   Click the **Next** button to continue. The Driver file is copied to the system directory after clicking the **Next** button.

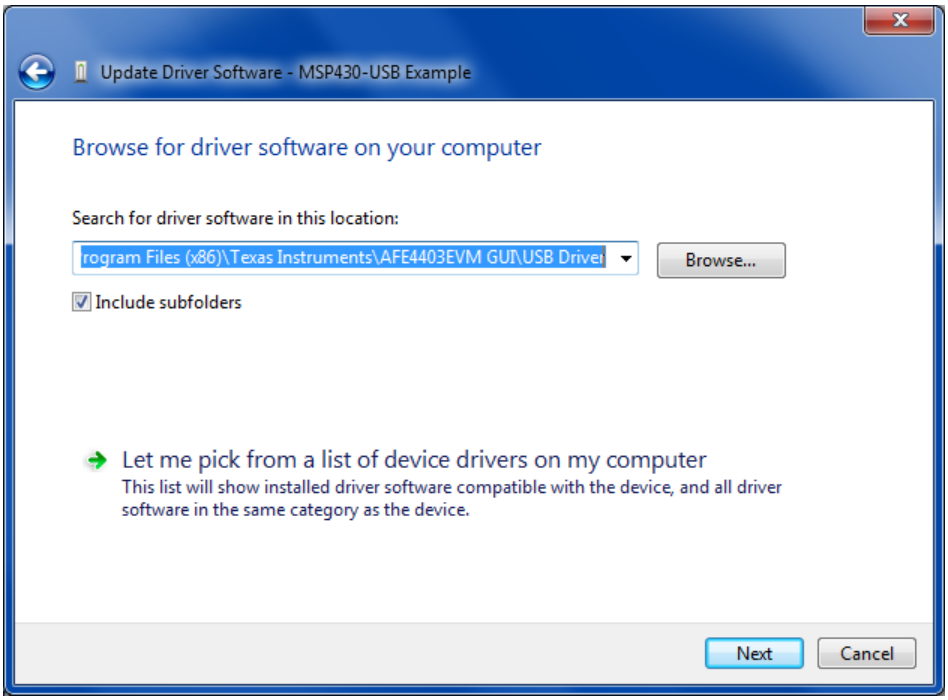


Figure 10. USB Driver Installation - Screen 3

5. There may be a warning that Windows can't verify the publisher of this driver software, as shown in Figure 11. Choose to install the driver software anyway to proceed.

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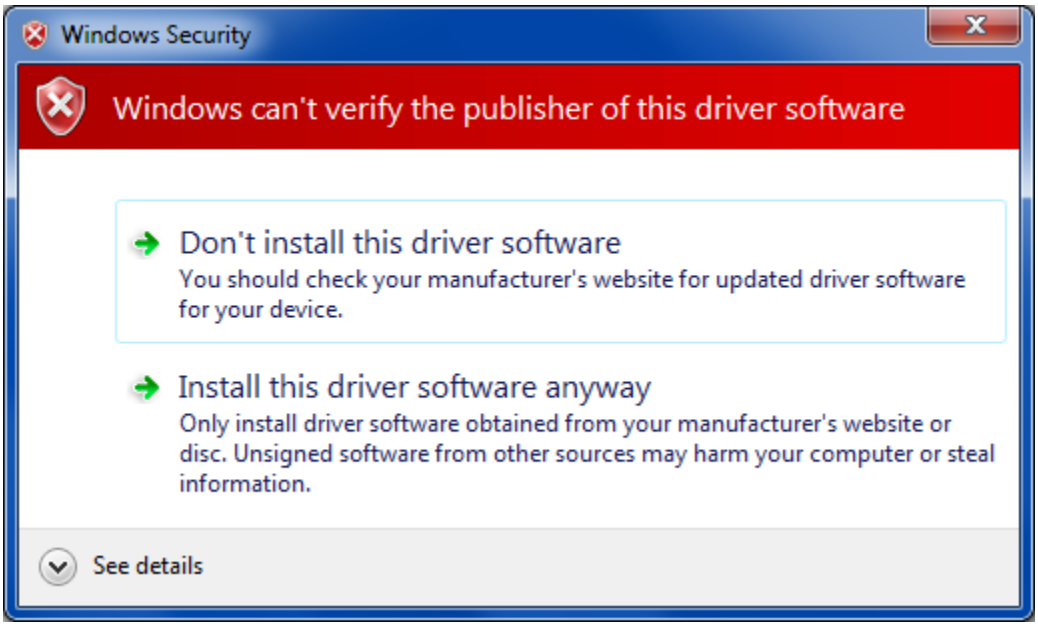


Figure 11. Windows Publisher Verification Warning

6. Click the **Close** button once the driver installation is complete (Figure 12).

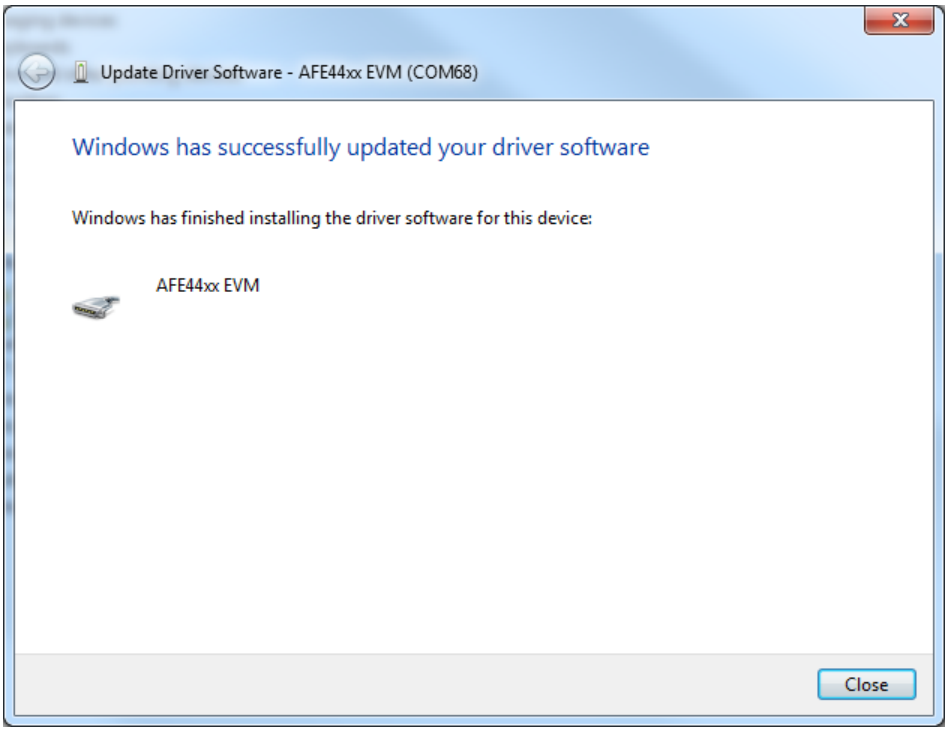


Figure 12. USB Driver Installation - Screen 4

7. The AFE4403EVM is now recognized as *Virtual COM Port* under the Device Manager as shown in Figure 13.

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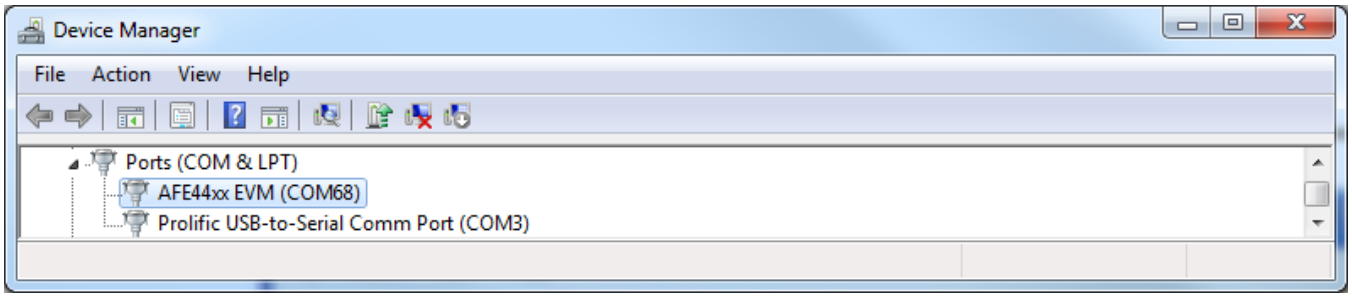


Figure 13. Device Manager Screen

The USB driver installation is now complete and the EVM is ready to use.

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3.3.1 Windows 8 Installing Unsigned Drivers

Perform an advanced startup sequence to let Windows 8 install unsigned drivers.

Move the cursor to the top right of the screen, click settings, then power, then HOLD SHIFT and click Restart as shown in Figure 14.

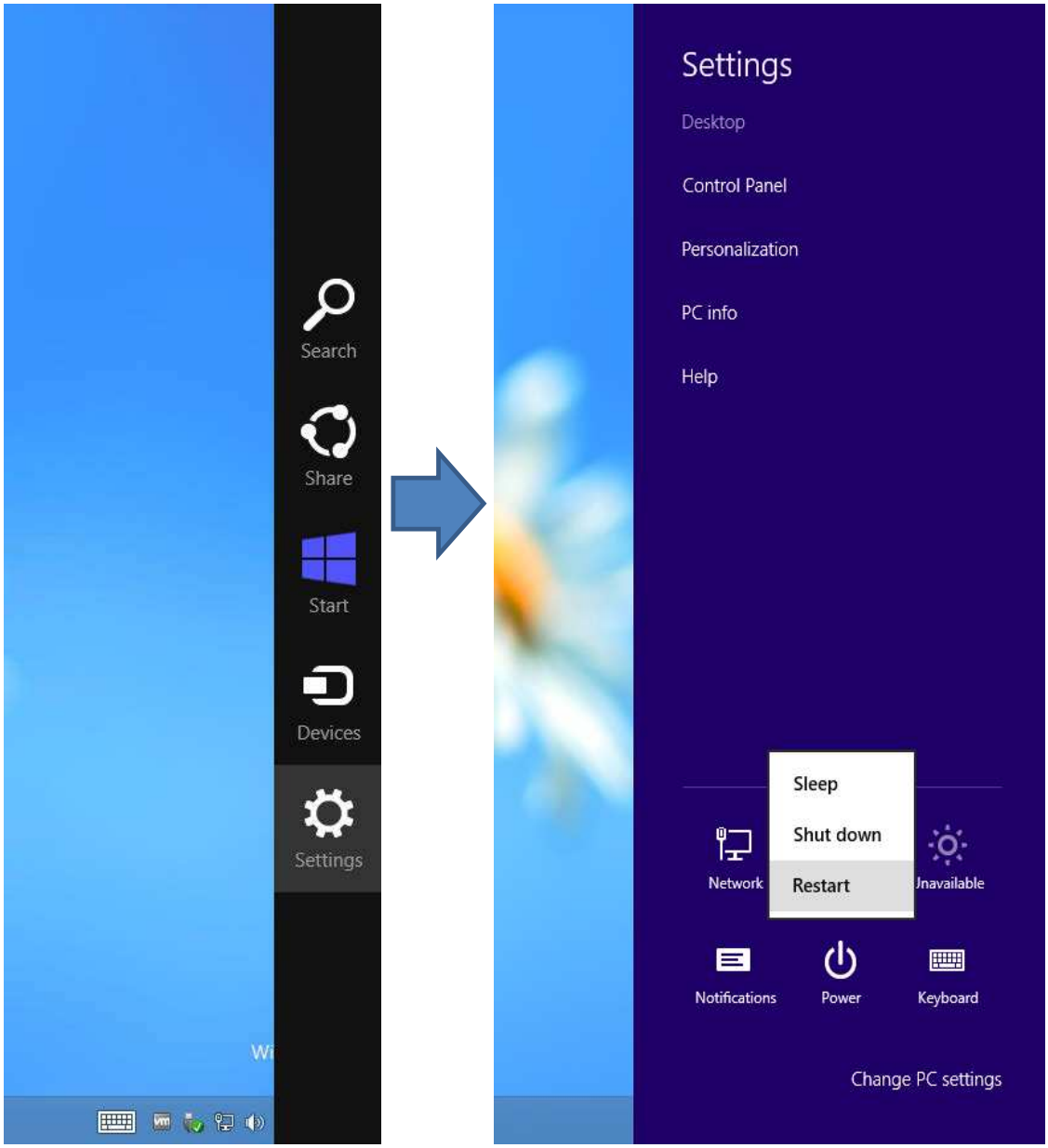


Figure 14. Windows 8 Installing Unsigned Drivers - Screen 1

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After a loading screen, three options appear. Choose Troubleshoot as shown in Figure 15.

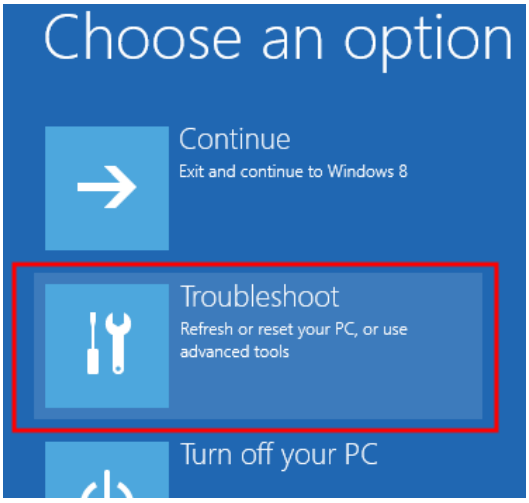


Figure 15. Windows 8 Installing Unsigned Drivers - Screen 2

Choose advanced options as shown in Figure 16.

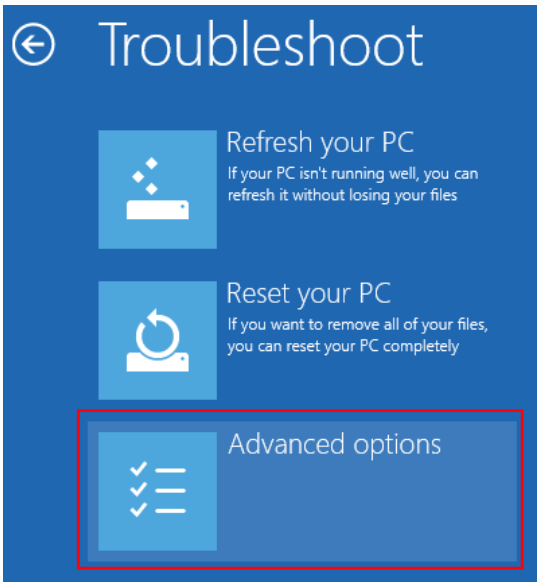


Figure 16. Windows 8 Installing Unsigned Drivers - Screen 3

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Choose startup Settings as shown in Figure 17.

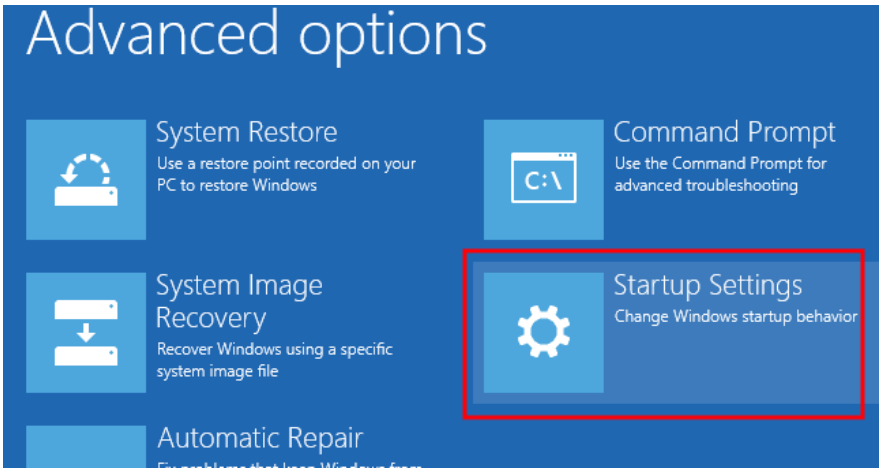


Figure 17. Windows 8 Installing Unsigned Drivers - Screen 4

Next a list of options displays. Click Restart at the bottom right as shown in Figure 18.

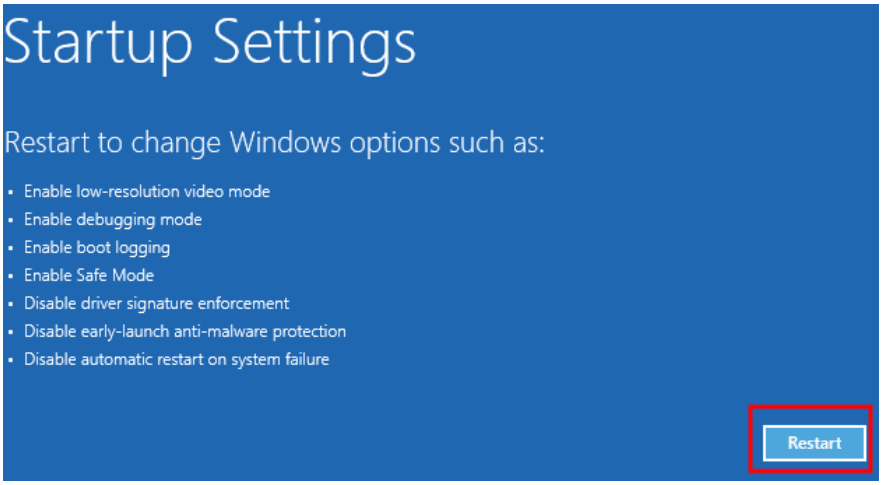


Figure 18. Windows 8 Installing Unsigned Drivers - Screen 5

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After the computer restarts, the following screen appears (see Figure 19). Press F7 to disable driver signature enforcement.

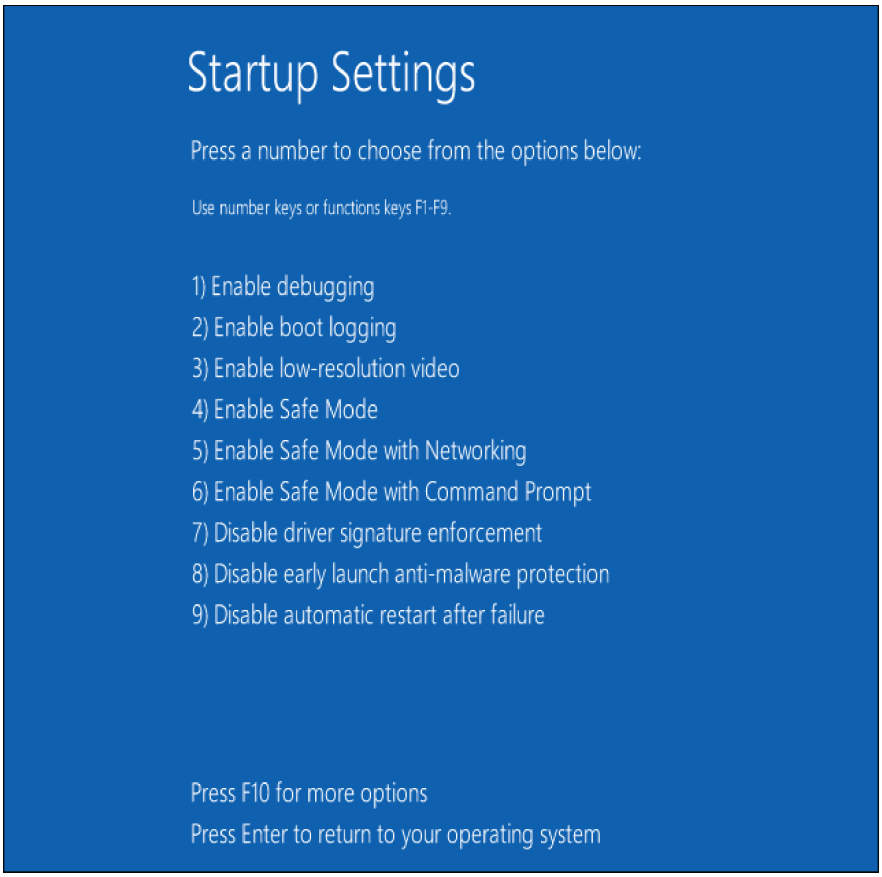


Figure 19. Windows 8 Installing Unsigned Drivers - Screen 6

Now, the user can install unsigned drivers. A warning may appear as shown in Figure 20; choose Install this driver software anyway.

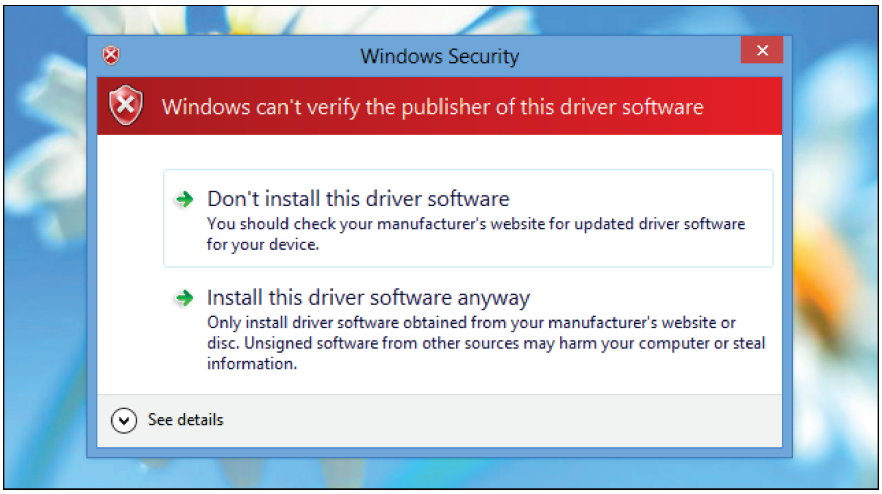


Figure 20. Windows 8 Installing Unsigned Drivers - Screen 7

Restart the computer again to re-enable driver signature enforcement after the installation is complete.

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4 Running the Software

Run the GUI software from the Start menu by selecting *All Programs→Texas Instruments→AFE4403EVM GUI*. Unless the hardware has been disconnected, observe messages that confirm the connection has been established and the program waits in idle mode for user input.

If the connection to the AFE4403EVM board is not established, the program prompts to continue to run the GUI in *Simulation* mode, or to Stop and Close the GUI and check if the AFE4403EVM is connected to the PC.



Figure 21. AFE4403EVM Not Connected Error Message

4.1 Overview of the Features

This section provides a quick overview of the various features and functions of the AFE4403EVM software GUI. The GUI allows the user to easily configure the various functions of the AFE, such as receiver gain, bandwidth settings, LED current settings, and timing/clocking control settings.

Operations in the GUI should only be performed after the status bar (located at the bottom of the GUI) displays **Ready For New Command**.

The main tabs consist of:

- *About* – Product Safety Warnings, Restrictions and Disclaimers (see Figure 22).
- *Device Configuration* – Configures all the AFE4403 user registers in a series of related subtabs.
  - *Global Settings*
  - *Tx Stage*
  - *Rx Stage*
  - *Timing Controls*
  - *Low Level Configuration*
- ADC Capture & Analysis – For viewing and analyzing the raw data.
- Save – For writing data samples and analysis results to a file.

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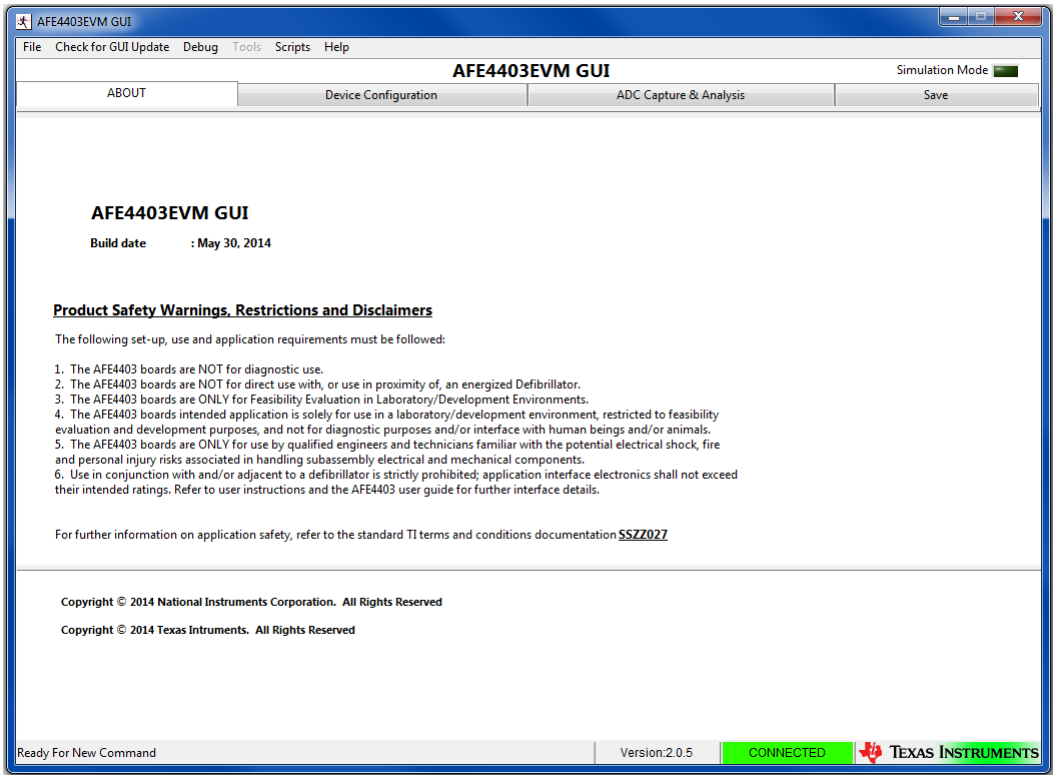


Figure 22. Product Safety Warnings, Restrictions and Disclaimers

4.1.1 Device Configuration Tab

The *Device Configuration* tab allows configuration of the various registers of the AFE4403 device. This subtab contains five subtabs: *Global Settings*, *Tx Stage*, *Rx Stage*, *Timing Controls* and *Low Level Configuration*.

4.1.1.1 Global Settings Subtab

The *Global Settings* subtab for the AFE4403 device shown in Figure 23 has the following features:

1. View the Device ID and Firmware Revision
2. **Device Reset** button that resets the device. (Please note that after a device reset is issued, the AFE4403 device registers must be programmed correctly for the PC application GUI to function properly. See **Reset to EVM Defaults** on how to issue a device reset and also program the AFE4403 registers to the EVM default register settings)
3. **Reset to EVM Defaults** button that resets the device and sets up the board to the EVM default register settings.
4. Enables the user to set or reset:
   (a) SPI Read
   (b) XTAL Disable
   (c) Powerdown AFE
   (d) Powerdown TX
   (e) Powerdown RX
   (f) Enable Slow Diag Clock
   (g) Four controls for dynamic powerdown
   (h) CLKOUT Output State

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(i) SOMI Output State

5. Enables the user to control the clock divider ratio settings. When the user enters an input clock, the GUI will automatically choose a divide by value so that the output clock is within 4–6 MHz
6. Click on *Diagnostic Enable* and view the *Alarm* status flags triggered through *Diagnostic Enable*.

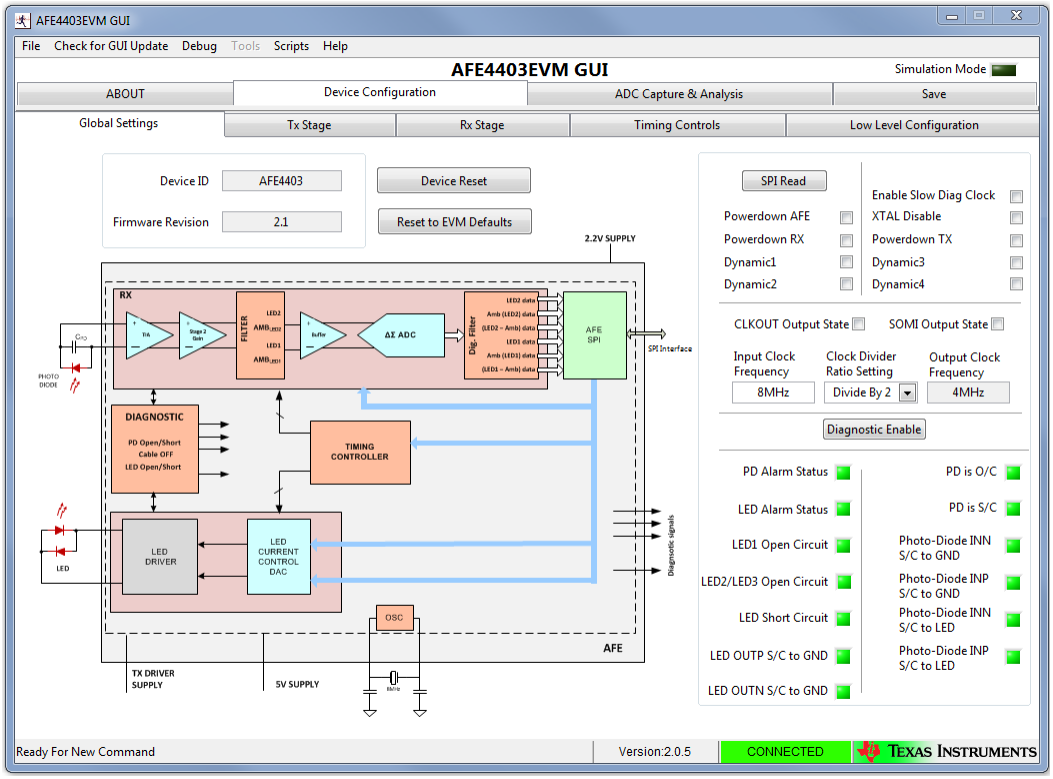


Figure 23. AFE4403: Device Configuration: Global Settings

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4.1.1.2 Tx Stage Subtab

Figure 24 shows the *Tx Stage* subtab under the *Device Configuration* tab consisting of the settings to:

1. Set LED1 and LED2/LED3 currents
2. Program LED current control DAC through a pull-down menu
3. Program the transmitter reference voltage through a pull-down menu
4. Select between H-bridge mode and Push-pull mode
5. Enable TX3 Mode

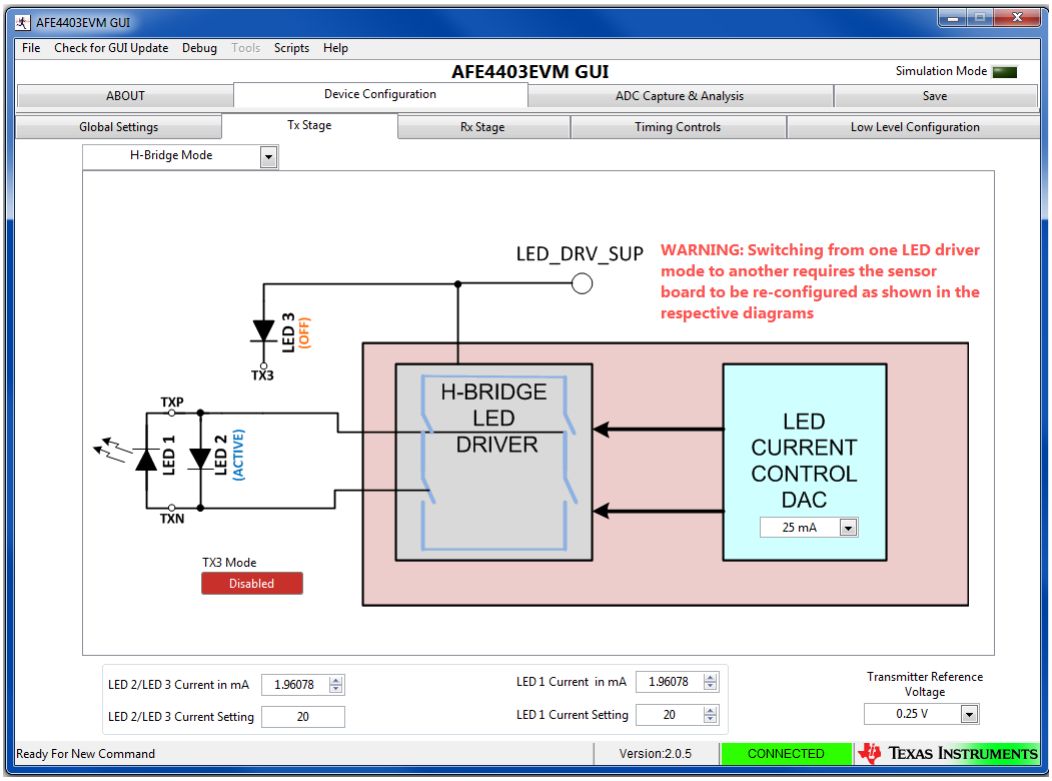


Figure 24. AFE4403: Device Configuration: Tx Stage

4.1.1.3 Rx Stage Subtab

Figure 25 shows the *Rx Stage* subtab under the *Device Configuration* tab consisting of the settings to:

1. Enable separate gain mode
2. Set feedback resistance and capacitance for the trans-impedance amplifier with separate gain mode disabled
3. Set feedback resistance and capacitance for the trans-impedance amplifier with separate gain mode enabled
4. Enable second-stage and set gain for the second-stage amplifier
5. Set ambient DAC current
6. Select filter corner frequency

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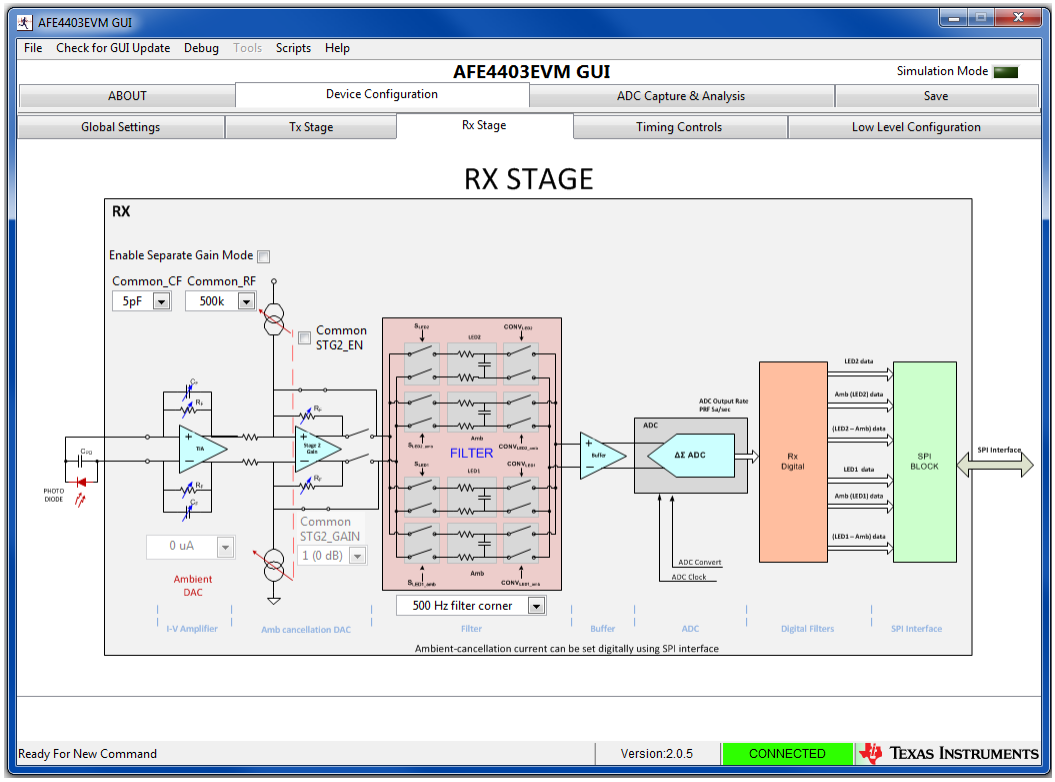


Figure 25. AFE4403: Device Configuration: Rx Stage

4.1.1.4 *Timing Controls Subtab*

The *Timing Controls* subtab under the *Device Configuration* tab, shown in Figure 26, consists of the following settings:

1. Enter the *Pulse Repetition Frequency*(PRF) and *Duty Cycle %* and click the **SET** button to automatically set the following:
   (a) LED1 and LED2/LED3 ON and OFF time,
   (b) Rx sample start and end time for 4 channels (LED1, LED1 Ambient, LED2/LED3, LED2/LED3 Ambient)
   (c) Rx convert start and end time for 4 channels (LED1, LED1 Ambient, LED2/LED3, LED2/LED3 Ambient)
2. Manually control timing settings for on time, sample time, conversion time, ADC reset time, and power down cycle time by changing the numbers on the left
3. Save the timing settings based on PRF and duty cycle to a configuration file
4. Load the timing settings based on PRF and duty cycle from a configuration file
5. Load a preset configuration file from a list of options in the drop down menu
6. *Timer Enable* selector
7. Timer Counter **RESET** button
8. Set Number of Averages

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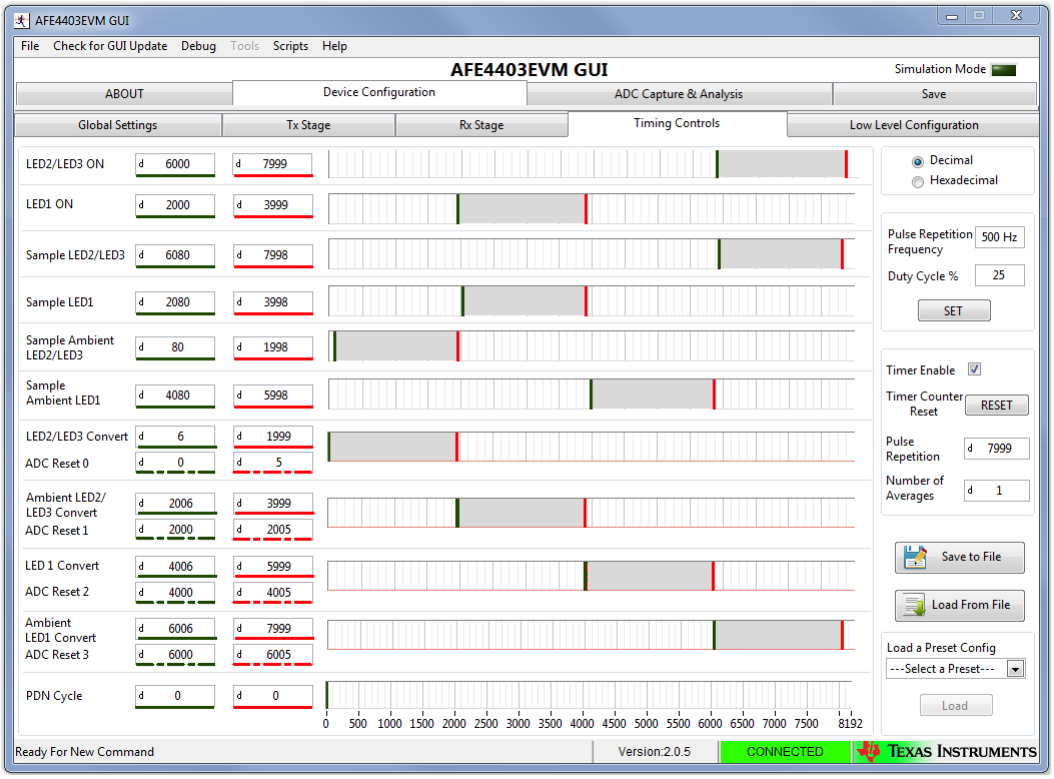


Figure 26. AFE4403: Device Configuration: Timing Controls

4.1.1.5 Low Level Configuration Subtab

The *Low Level Configuration* subtab under the *Device Configuration* tab is used to directly configure the various registers of the AFE4403 devices. Refer to the AFE4403 data sheet (SBAS650) for the register details of the chip.

Figure 27 shows the low-level configuration registers of the AFE4403 devices. The *Register Map* portion of the sub-tab shows the EVM default values of the registers after the GUI is loaded under the *EVM Default* column. The *LW** column shows the latest written values of the AFE4403 register and the *LR** column shows the latest read values of the AFE4403 registers. From the *Register Map* section, when any register is selected, the bit-level details about the register are explained in the *Register Description* section. The ability to read and write the register and modify the individual bits of the register are provided in the *Register Data* section. The values of all the registers are read by clicking the **Read All** button.

Click on *Transfer Read to Write* to copy the contents of the Read Data to Write Data. Then click on *Write Register* to write to the data to the register of the AFE4403.

By clicking on the **Save Config** button, the register configuration is saved to a configuration file. The register configuration is loaded from a configuration file by clicking the **Load Config** button.

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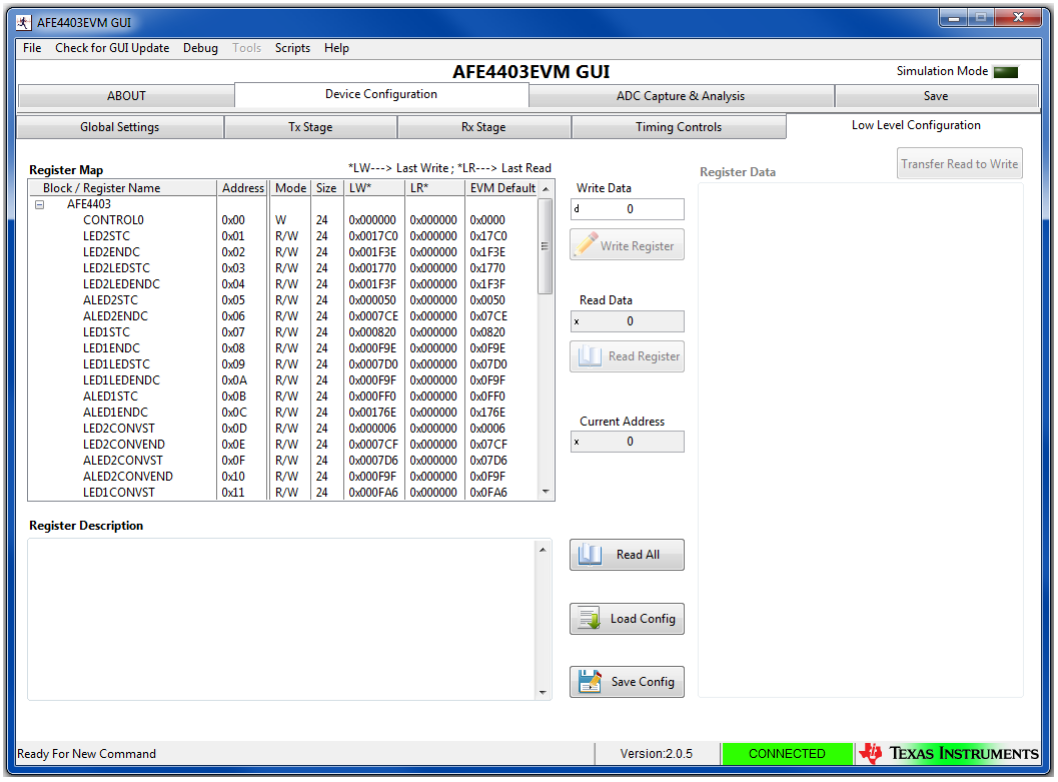


Figure 27. Device Configuration: Low Level Configuration

When a selection is made on any of the tabs on the GUI, multiple fields of various registers are modified. Click on the lower-left corner of the GUI to view the registers that are modified when a selection is made.

4.1.2 ADC Capture and Analysis

The *ADC Capture and Analysis* tab consists of various analysis routines and displays. This tab is used to:

- Set the capture mode to finite or continuous
- Set the number of samples (block size) in Finite Capture mode
- Set the display to volts or codes
- Set the filter type to None or Notch
- Set the Notch Freq to 50 or 60 Hz when the filter type is set to Notch
- Set Analysis Type to All Domain or Time Domain only
- Auto save after capture selector
- Acquire the data by clicking the **Capture** button
- When the user selects the auto save after capture selector under the *ADC Capture & Analysis* tab, the GUI uses the settings selected under *Analysis to Save*, *Channels to Save*, *Data to Save*, and *Save File Settings*. A *Results saved successfully!* notification is given after every capture.

The captured data can be analyzed in time domain and frequency domain; the data can also be displayed in a histogram format. The ADC Capture and Analysis tab is shown in Figure 28.

By selecting the Time Domain plot, the data are displayed in time domain format. The units can be converted from codes to volts using the drop-down window in the top-left corner of the GUI. For the time domain plot, the mean voltage, root mean square (RMS) voltage, and peak-to-peak voltage are displayed in the *Test Results* section, which is a pop-up window that opens when the **Scope Analysis** button is clicked. The Scope Analysis: Test Results section pop-up window is shown in Figure 29.

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By selecting the FFT plot, the data are displayed in the frequency domain by performing an FFT on the channel selected. Details of the FFT (including SNR, THD, and so on) are shown in the Test Results section located in the left side of the GUI.

Selecting the Histogram plot displays the data in a histogram format for the channel selected. The data are arranged in the total number of histogram bins set within the tab following acquisition. The histogram analysis (shown in the *Test Results* section of the GUI) is used to view the mean voltage, root mean square (RMS) voltage, and peak-to-peak voltage.

Four plot modes can be selected: Single Plot mode, Double Plot mode, Three Plot mode and Four Plot mode. In Single Plot mode, only one plot (Time, FFT, or Histogram) can be viewed and analyzed for post processing. In Double Plot mode, any two plots (Time, FFT or Histogram) can be viewed and analyzed. In Three Plot mode, any three plots and in Four Plot mode, any four plots (Time, FFT or Histogram) can be viewed and analyzed.

The following algorithms have been used to find the # of samples for FFT calculation:

(a) # of samples for FFT calc. which is power of 2 ≤ min ((Data rate (sps) × N where N is the value in the *Show data for the last N secs* column) , No. of samples)

(b) If ((# of samples for FFT calc. == No. of samples) && (Filter Type == “None”)) then # of samples for FFT calc. = No. of samples

(c) If ((# of samples for FFT calc. == No. of samples) && (Filter Type == “Notch”)) then # of samples for FFT calc. = No. of samples / 2. This is to allow for filter settling.

(d) If (# of samples for FFT calc. < 32 samples) then an error msg “Insufficient # of samples for FFT calculation” will be displayed.

Examples:

1. No. of samples = 3
   Data rate (sps) = 500
   Show data for the last 5 secs
   Then # of samples for FFT calc. which is power of 2 = 2048 ≤ min ((500 × 5) , 8192)
2. No. of samples = 8192
   Data rate (sps) = 500
   Show data for the last 8 secs
   Then # of samples for FFT calc. which is power of 2 = 2048 ≤ min ((500 x 8) , 8192)
3. No. of samples = 8192
   Data rate (sps) = 500
   Show data for the last 20 secs
   # of samples for FFT which is power of 2 = 8192 ≤ min ((500 x 20) , 8192)
   Since (# of samples for FFT calc. == No. of samples) and if (Filter Type = None) then # of samples for FFT which is power of 2 = 8192
   Since (# of samples for FFT calc. == No. of samples) and if (Filter Type = Notch) then # of samples for FFT which is power of 2 = 8192 / 2
4. No. of samples = 30
   Data rate (sps) = 500
   Show data for the last 1 secs
   Then display Error message “Insufficient # of samples for FFT calculation” since # of samples for FFT which is power of 2 = 16 ≤ min ((500 × 1) , 30)
5. No. of samples = 32
   Data rate (sps) = 500
   Show data for the last 2 secs
   # of samples for FFT which is power of 2 = 32 ≤ min ((500 × 2) , 32)
   Since (# of samples for FFT calc. == No. of samples) and If (Filter Type = None) then # of samples for FFT calc. which is power of 2 = 32
   Since (# of samples for FFT calc. == No. of samples) and If (Filter Type = Notch) then an error msg “Insufficient # of samples for FFT calculation” will be displayed since # of samples for FFT calc. which is power of 2 = (32 / 2) < 32 samples

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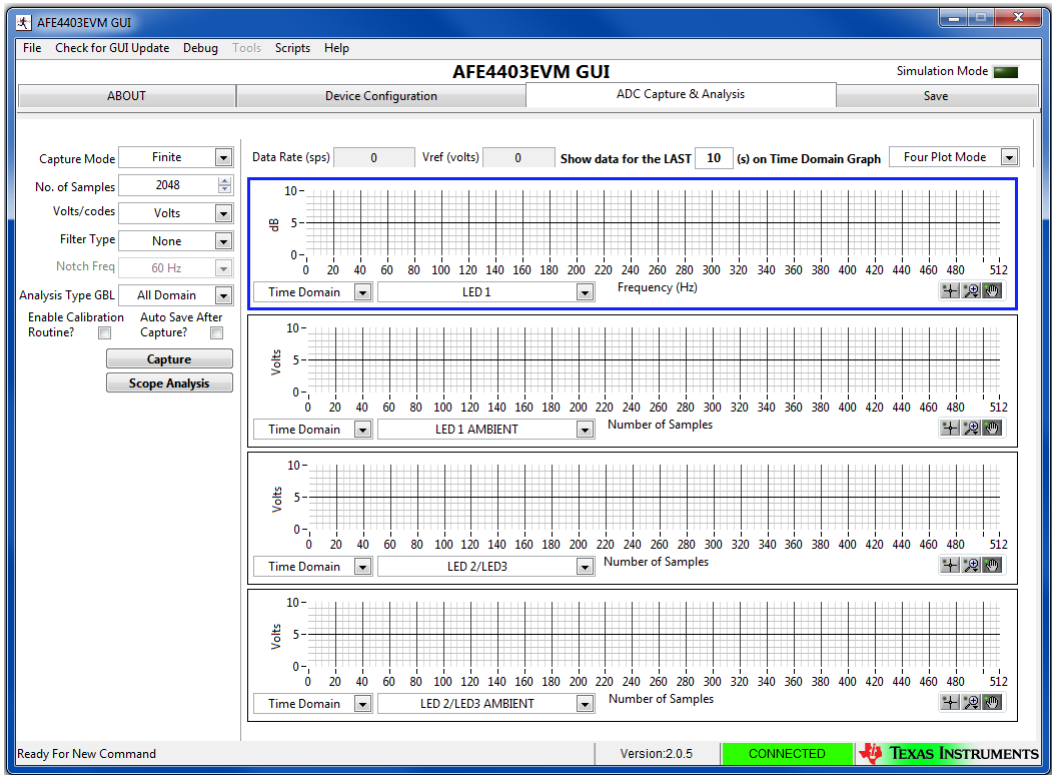
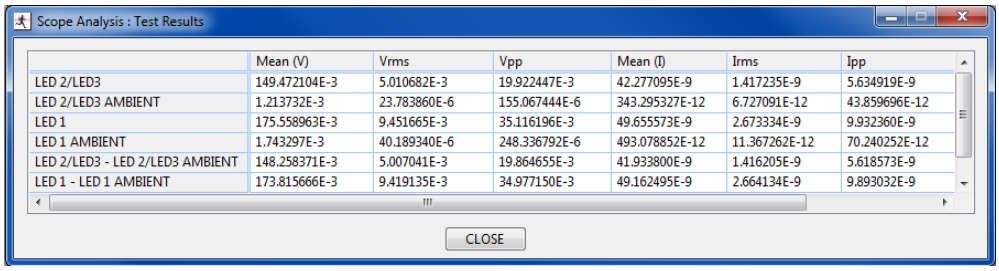


Figure 28. ADC Capture and Analysis Tab



	Mean (V)	Vrms	Vpp	Mean (I)	Irms	Ipp
LED 2/LED3	149.472104E-3	5.010682E-3	19.922447E-3	42.277095E-9	1.417235E-9	5.634919E-9
LED 2/LED3 AMBIENT	1.213732E-3	23.783860E-6	155.067444E-6	343.295327E-12	6.727091E-12	43.859696E-12
LED 1	175.558963E-3	9.451665E-3	35.116196E-3	49.655573E-9	2.673334E-9	9.932360E-9
LED 1 AMBIENT	1.743297E-3	40.189340E-6	248.336792E-6	493.078852E-12	11.367262E-12	70.240252E-12
LED 2/LED3 - LED 2/LED3 AMBIENT	148.258371E-3	5.007041E-3	19.864655E-3	41.933800E-9	1.416205E-9	5.618573E-9
LED 1 - LED 1 AMBIENT	173.815666E-3	9.419135E-3	34.977150E-3	49.162495E-9	2.664134E-9	9.893032E-9

Figure 29. Scope Analysis: Test Results

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4.1.3 Save Tab

The *Save* tab shown in Figure 30 provides provisions to save the analysis or data to a file. By default, the data are saved to the following location:

- On a Windows XP machine
  - *C:\Program Files\Texas Instruments\AFE4403EVM GUI\Log*
- On a Windows 7 machine
  - *C:\Program Files(x86)\Texas Instruments\AFE4403EVM GUI\Log*

Use the *Directory to Save Files* option to select the folder where data are to be saved. In the pop-up window, navigate to the folder where the data file is to be saved and select *Use Current Folder*. Then select *Save to File* to save the file.

When the user selects the auto save after capture selector under the *ADC Capture & Analysis* tab, the GUI uses the settings selected under *Analysis to Save*, *Channels to Save*, *Data to Save*, and *Save File Settings*. A *Results saved successfully!* notification is given after every capture.

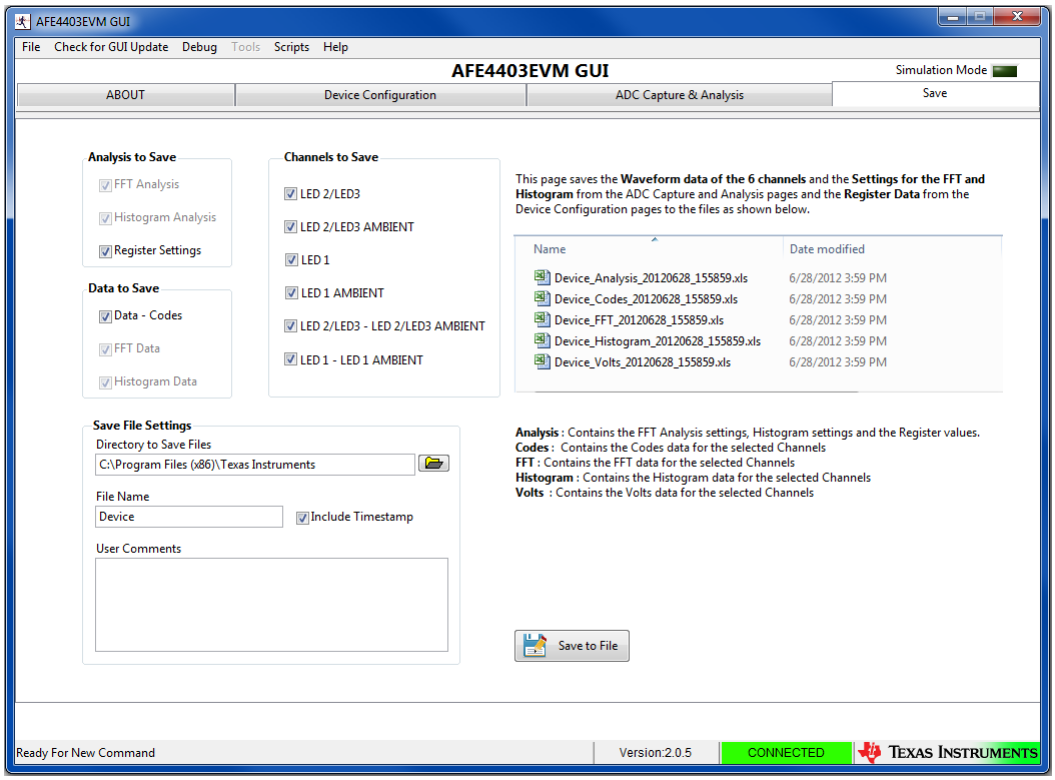


Figure 30. Save Tab

Table 1 contains the Save tab control descriptions.

Table 1. Save Tab Control Descriptions

Button/Control	Description
Scope Analysis	Saves the scope analysis result. The result is saved in the file *Device_<record number>_Analysis.xls*.
FFT Analysis	Saves the FFT analysis result. The result is saved in the file *Device_<record number>_Analysis.xls*.
Histogram Analysis	Saves the histogram analysis result. The result is saved in the file *Device_<record number>_Analysis.xls*.
Register Settings	All the current register values are read from the EVM and stored. The result is saved in the file *Device_<record number>_Analysis.xls*.
Data - Codes	Acquired data sample values are stored to the file *Device_ <record number>_Codes.xls*.

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Table 1. Save Tab Control Descriptions (continued)

Button/Control	Description
FFT Data	Acquired data sample's FFT values are stored to the file *Device_ <record number>_FFT.xls*.
Histogram Data	Acquired data sample's histogram values are stored to the file *Device_ <record number>_Histogram.xls*.

The *Record Number* saves files with the provided number in the file name. User notes can also be added to the file by typing the notes in the *User Comments* control.

5 AFE4403EVM Hardware

CAUTION

Many of the components on the AFE4403EVM 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 key features of the AFE4403 Analog Front End demonstration board are:

- Based on MSP430F5529
- DB9 pulse oximeter sensor cable support
- Acquire data at up to 3000 Hz in evaluation mode
- SPI Data interface

The AFE4403EVM board can be used as a demo board for pulse oximeter and heart rate applications. The BOM is provided in Section 11. The printed circuit board (PCB) and schematic are shown in Section 12.1 and Section 12.4, respectively.

MSP430F5529 (U2 – see Section 12.4) is the microcontroller used on the board. For more details of the MSP430F5529 please visit http://focus.ti.com/docs/prod/folders/print/msp430f5529.html

The following sections explain the main hardware components available on the EVM. Figure 31 shows the functional block diagram for the EVM.

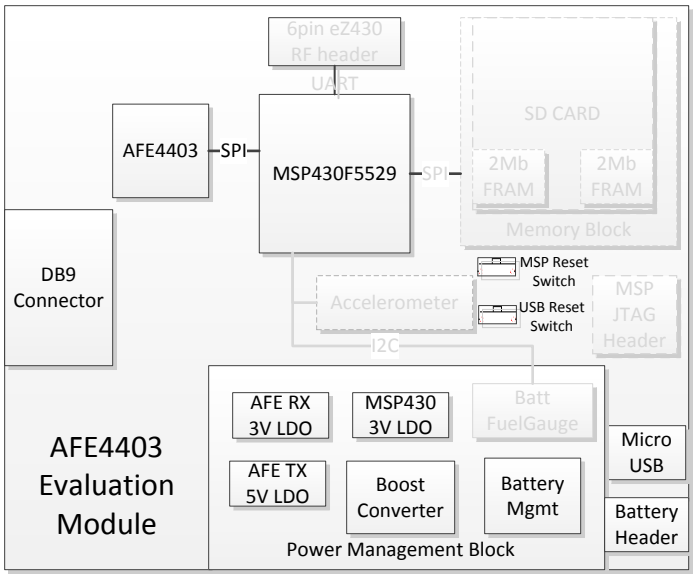


Figure 31. AFE4403EVM Block Diagram

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5.1 Power Supply

AFE4403 can operate from 2.0- to 3.6-V Rx analog supply (RX_ANA_SUP), 2.0- to 3.6-V Rx digital supply (RX_DIG_SUP), 3.0- to 5.25-V Tx Control supply (TX_CTRL_SUP) and LED driver supply (LED_DRV_SUP).

The power for the board is derived from the USB input (J4) through a forward-biased diode (D5) to avoid reverse current flow. The USB data bus is ESD protected using TI's ESD protection diode array TPD4E004DRYR (U7). The USB VBUS is fed to the integrated Li-ion linear charger and system power-path management module, BQ24032ARHLR (U12), which generates greater than 4.2-V output (VCC_BAT). This output is fed to TI's low-input boost converter with integrated power diode and input/output isolation, TPS61093 (U9), for generating a boosted voltage of 8.97 V. This output is fed to low-noise voltage regulator LP3878-ADJ (U8) for generating 5 V for the LED_DRV_SUP and TX_CTRL_SUP. The boost converter output is also fed to the ultralow-noise linear voltage regulator TPS7A4901DGN (U13) for generating 3 V for the RX_ANA_SUP and RX_DIG_SUP. The boost converter output is also fed to the ultralow-noise linear voltage regulator TPS7A4901DGN (U14) for generating 3 V for MSP_DVCC and MSP_AVCC.

Test point and series jumper resistors are provided to make sure the power supplies to the board are correct. The corresponding voltages on AFE4403EVM are given in Table 2.

Table 2. Test Points for Measuring Voltages on the AFE4403SPO2EVM

S. No.	Test Point	Description
1	TP36	5 V
2	R76	5 V
3	R65	5 V
4	R55	3 V
5	R54	3 V
6	L3, pin # 2	3 V

5.2 Clock

The EVM has the option to use the on-board 8-MHz crystal or the clock for the AFE4403 from the MSP430. The EVM is shipped to use the on-board 8-MHz crystal. The 4-MHz buffered output clock from the AFE4403 can be accessed through an accessible via labeled CLKOUT.

5.3 Accessing AFE4403 Digital Signals

AFE4403 SPI interface and other digital signals with MSP430 can be accessed through the series resistor jumpers given in Table 3.

Table 3. AFE4403 Digital Signals

S. No.	Signal	Jumper Resistor
1	STE	R29
2	SIMO	R31
3	SOMI	R33
4	SCLK	R35
5	ADC_RDY	R26
6	DIAG_END	R38
7	AFE_PDNZ	R42

5.4 USB Interface

The EVM has a micro-USB interface for PC application connectivity requiring a standard micro-USB to USB cable for connection. AFE4403EVM is designed to work in the slave mode.

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5.5 On-Board Key Interface

The EVM has 2 switches. The function of each switch is defined in Table 4

Table 4. AFE4403EVM Switches

Switch Number	Description
SW1	This switch is used for hard reset of the board. The board resets and starts again with the firmware loaded.
SW2	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 SW2. The device will appear as an HID device in the device manager.

5.6 Visual Indication

The blue LED (LED3) indicates the USB power connection. The blue LED (LED1) indicates that the microcontroller is busy servicing the requests from the PC application.

6 USB-Based Firmware Upgrade

The firmware on the AFE4403EVM can be changed from the PC application by selecting the *Firmware Upgrade* menu option on the PC application. At the end of the firmware upgrade, the system issues a reset command and reloads with new firmware. The firmware upgrade process steps are represented in the screen shots below:

- From the PC application, click on *File →Firmware Upgrade*
- A pop-up window opens as shown in Figure 32. Follow the instructions to continue to Firmware Upgrade or to cancel the operation.

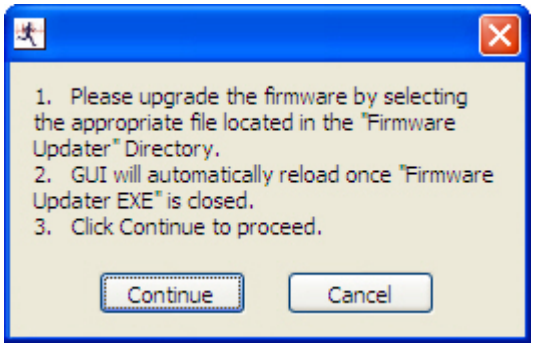


Figure 32. PC Application Firmware Upgrade – 1

- The firmware upgrade application detects the connected EVM. (Figure 33)

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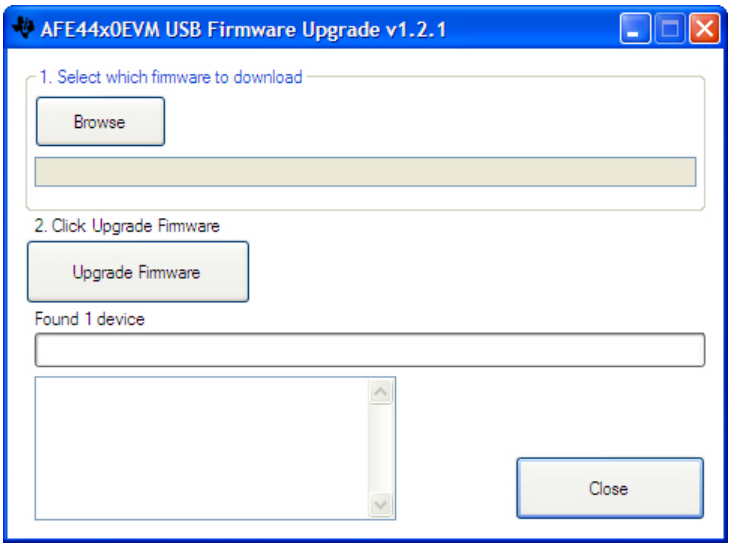


Figure 33. PC Application Firmware Upgrade – 2

- Browse and select the appropriate firmware binary file (example: AFE4403_EVM_FW_V2.1.txt file) and click *Upgrade Firmware* as shown in Figure 34. The default firmware is available from:
  - On a Windows XP machine:
    - *C:\Program Files\Texas Instruments\AFE4403EVM GUI\Firmware Updater*
  - On a Windows 7 machine:
    - *C:\Program Files(x86)\Texas Instruments\AFE4403EVM GUI\Firmware Updater*

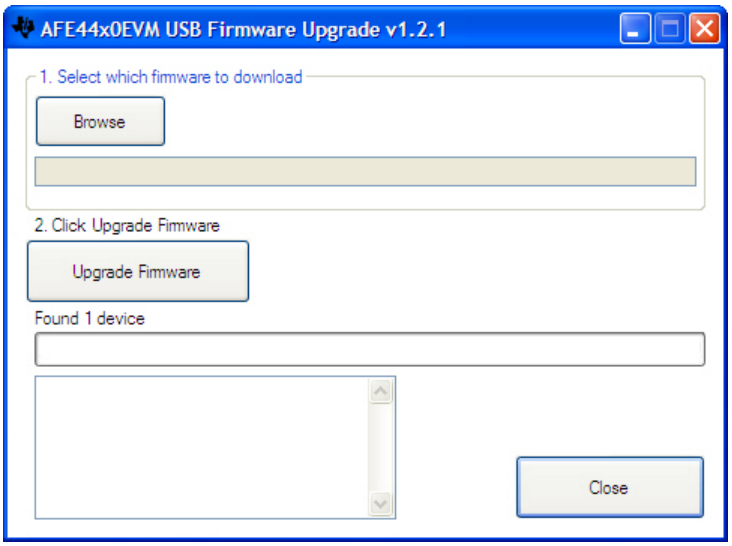


Figure 34. PC Application Firmware Upgrade – 3

- Once the device is programmed successfully, as shown in Figure 35, the device resets and reloads with the new firmware. Close the *Firmware Upgrade* application by clicking on the **Close** button and the PC GUI application automatically restarts the GUI after 4-5 seconds.

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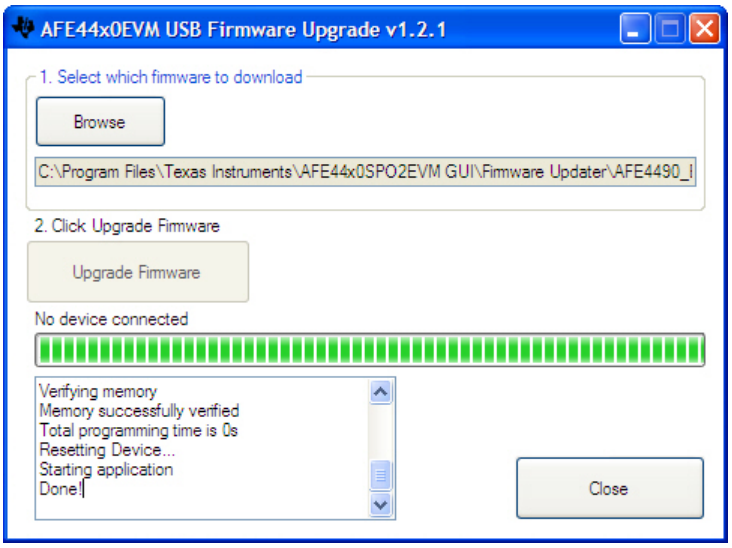


Figure 35. PC Application Firmware Upgrade – 4

7 AFE4403EVM Firmware Upgrade Without GUI

Use the following steps to upgrade the AFE4403EVM firmware without the GUI:

1. Open the firmware loader application by clicking the BSL_USB_GUI.exe located at the following location:
   - On a Windows 7 or Windows 8 operating system (OS): "*C:\Program Files(x86)\Texas Instruments\AFE4403EVM GUI\Firmware Updater*"
   - On a Windows XP OS: "*C:\Program Files\Texas Instruments\AFE4403EVM GUI\Firmware Updater*"
2. Click the **Browse** button and load the AFE4403 firmware. Figure 36 shows the firmware loader application with the appropriate firmware selected. The firmware is located in the "*C:\Program Files(x86)\Texas Instruments\AFE4403EVM GUI\Firmware Updater*" directory.

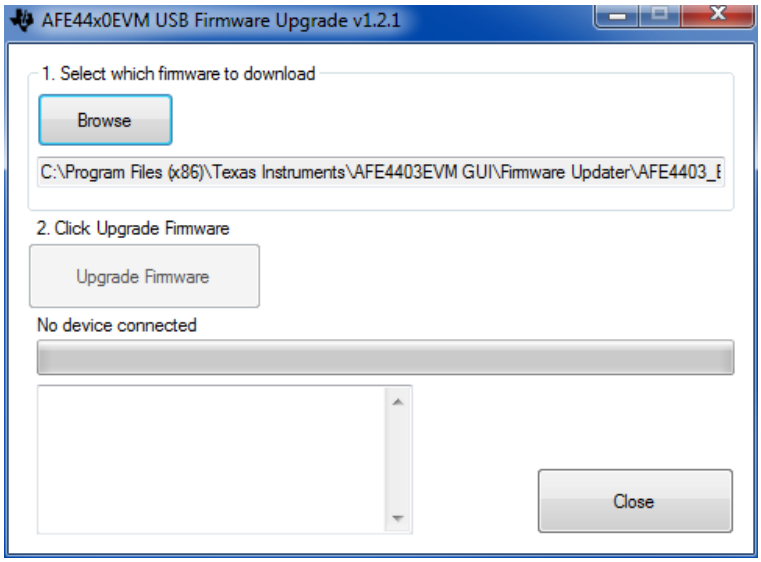


Figure 36. Firmware Loader Application: Select Firmware

3. Press SW2 switch on the EVM while plugging in the micro-USB interface cable to the J4 micro-USB connector on the EVM.

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4. Release the SW2 switch when the application displays *Found 1 device*. If the application does not detect the device and displays *No Device Connected*, then repeat step 3. Click on the *Upgrade Firmware* button. (see Figure 37)

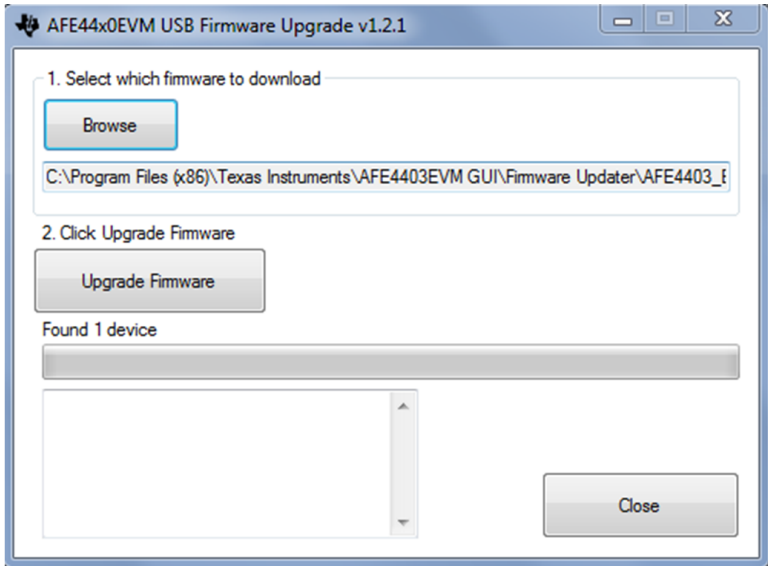


Figure 37. Firmware Loader Application: Found Device

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 38 shows the status of the successful programming.

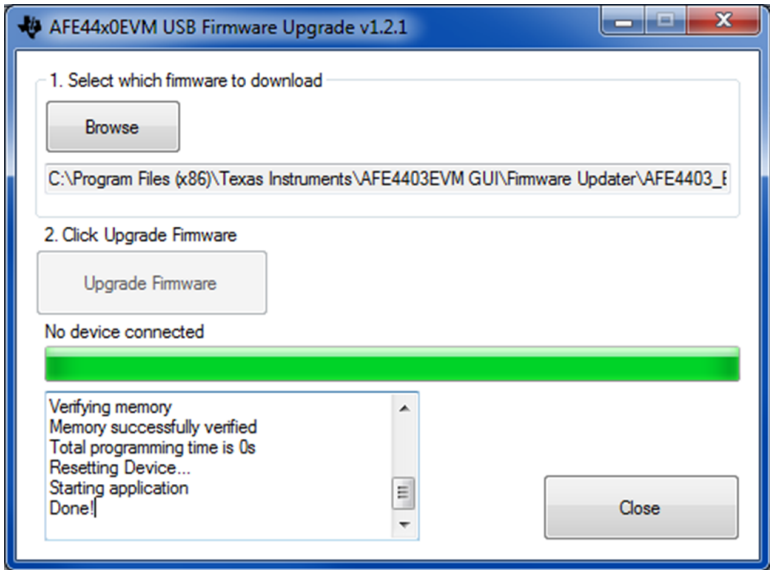


Figure 38. Firmware Loader Application: Programming Status

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8 Connector Interface

The following connectors are used for external interface to the AFE4403 Pulse Oximeter board.

- DB9
- Micro-USB connector

8.1 DB9 Pulse Oximeter Connector

The DB9 pulse oximeter connector pin-outs are shown in Figure 39. The description of the pin-outs is provided in Table 5

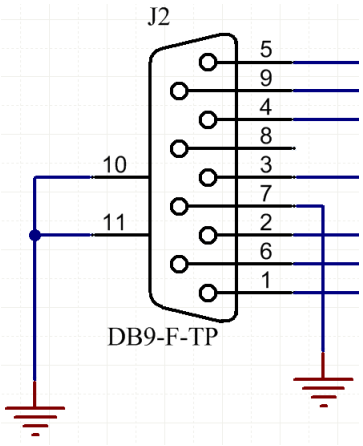


Figure 39. DB9 Pulse Oximeter Connector Pin Outs

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Table 5. DB9-based Pulse Oximeter Connector Pin Out Descriptions

Pin Number	Pin Name	Pin Description
1	TX_LED_3	Cathode of LED3(1)
2	TX_LED_P	Anode of LED1, cathode of LED2(1)
3	TX_LED_N	Cathode of LED1, anode of LED2(1)
4	VCM	Common-mode voltage output
5	DET_N	Photodiode anode
6	LED_DRV_SUP	LED driver supply pin. Connected to anode of LED3(1)
7	GND	Ground
9	DET_P	Photodiode cathode

(1) Anode and cathode connections are only applicable for default H-Bridge mode. For push-pull (common anode), the anodes of all three LEDs are connected to LED_DRV_SUP and the cathodes LED1, LED2, and LED3 are connected to TXN, TXP, and TX3, respectively.

8.2 Micro-USB Connector

The USB micro connector pin-outs are shown in Figure 40. The description of the pin-outs is provided in Table 6.

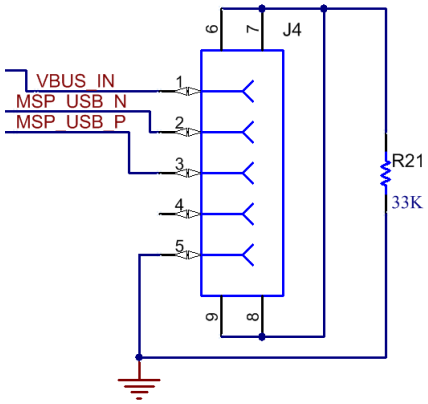


Figure 40. USB Micro Connector Pin Outs

Table 6. USB Micro Connector Pin Out 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

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8.3 8-Pin Connector

The 8-pin connector pin-outs are shown in Figure 41. The description is provided in Table 7.

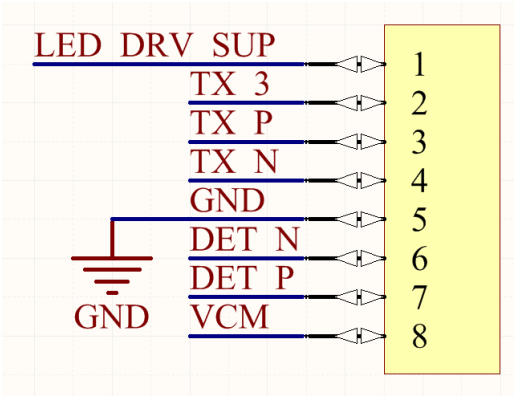


Figure 41. 8-Pin Connector

Table 7. 8-Pin Connector Pin Descriptions

Pin Number	Pin Name	Pin Description
1	LED_DRV_SUP	LED driver supply pin. Connected to anode of LED3(1)
2	TX_3	Cathode of LED3(1)
3	TX_P	Anode of LED1, cathode of LED2(1)
4	TX_N	Cathode of LED1, anode of LED2(1)
5	GND	Ground
6	DET_N	Photodiode anode
7	DET_P	Photodiode cathode
8	VCM	Common-mode voltage output

9 AFE4403EVM Reflective Sensing Quick Start Guide

Use the following steps as a quick start guide for AFE4403EVM reflective sensing:

1. Update the MSP430 firmware:
   (a) Download the *AFE4403EVM GUI* from the TI website, (http://www.ti.com/tool/AFE4403EVM)
   (b) Run *AFE4403EVM GUI* which is found in the chosen installation directory (by default this is ROOT:\Program Files (x86)\Texas Instruments\AFE4403SPO2EVM GUI).
   (c) Click on *File* at the top left of the window followed by *Firmware Upgrade*. A window pops up, click the **Continue** button.'
   (d) Click the **Browse** button and choose the desired hex file. This file should have a *.txt* extension (example: AFE4403_EVM_FW_V2.1.txt).
2. Test setup:
   (a) Each sensor board has two different configurations:
   - The NJRC NJL5310R sensor board has two green LEDs that can be connected in parallel or back to back. RA1 and RA2 connects them in parallel and RB1 and RB2 connects them back to back, as shown in Figure 42. Note that when in parallel, both LEDs represent LED2 and when back to back, one represents LED1 and the other LED2. This board does not support TX3 mode.

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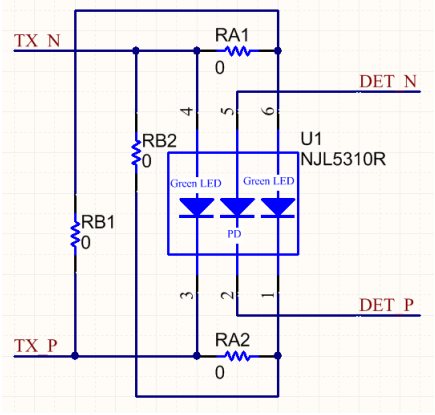


Figure 42. NJRC NJL5310R Sensor Board LED Connections

- The OSRAM SFH7050 sensor board has one infrared, one red, and one green LED. This board can be configured in H-Bridge mode with jumpers RHB1 and RHB2 or push-pull (common anode) mode with jumpers RCA1 and RCA2, shown in Figure 43. By default, the IR and red LEDs are on, and the third green LED can be enabled with TX3 mode in the *TX Stage* tab.

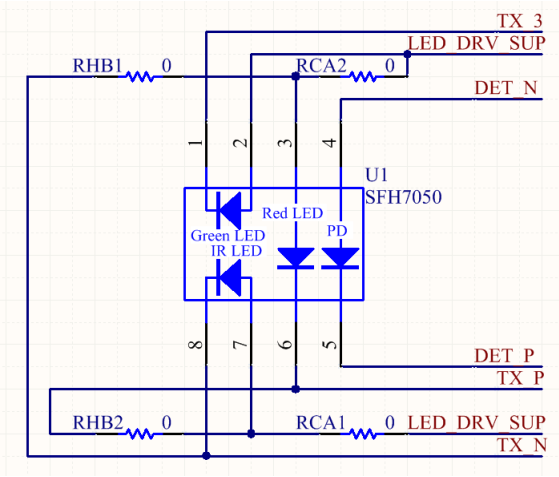


Figure 43. OSRAM SFH7050 Sensor Board LED Connections

(b) Connect the sensor module to the EVM DB-9 connector with the cable provided. Make sure that the sensor is connected in the correct orientation – pin 1 should line up with the marking on the cable, as shown on Figure 44.

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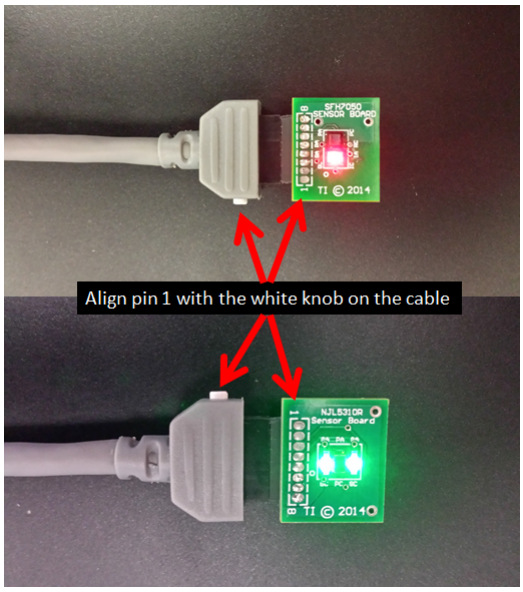


Figure 44. Sensor Board Cable Connections

(c) Place the sensor side of the sensor board on the wrist and tie it snugly. Figure 45 shows the sensor board being held with a velcro strap. Holding the sensor down with a finger is not recommended because a high level of motion noise is likely to occur due to small movements and changes in pressure.

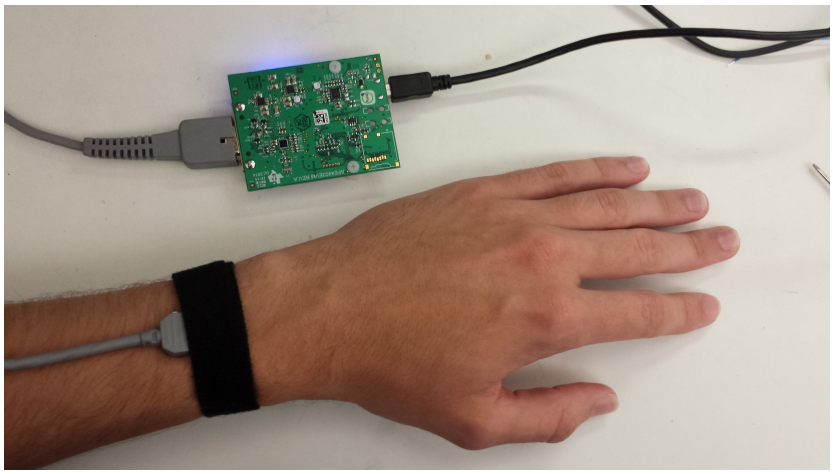


Figure 45. Setup for Obtaining Measurements from the Wrist

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3. Capturing Data
   (a) Run the *AFE4403EVM GUI* found in the installation directory.
   (b) Click on the *ADC Capture & Analysis* tab near the top of the window
   (c) Click the **Capture** button to begin capturing data. Figure 46 shows a sample waveform:

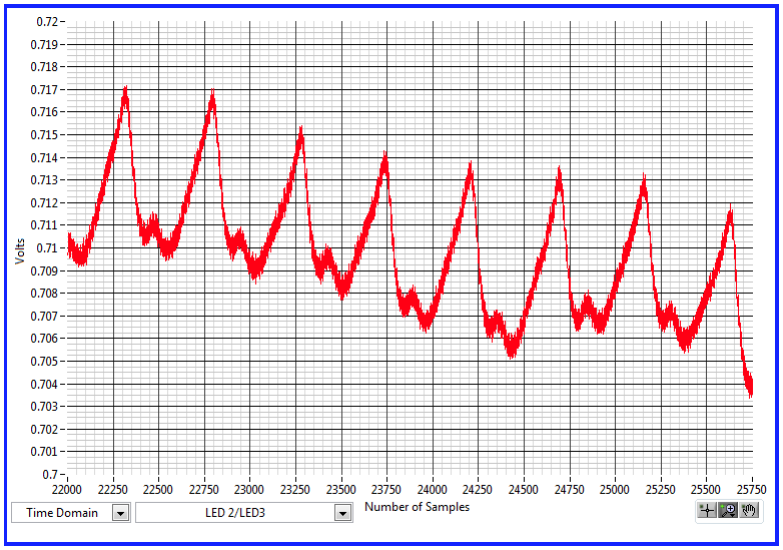


Figure 46. Sample Waveform of Green LED Captured on the Wrist with OSRAM SFH7050

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10 AFE4403EVM FAQs

10.1 EVM communicating with the PC application

A quick and simple check to verify serial register write operation is to put the AFE4403 in power-down mode. Follow the sequence to check if the GUI is communicating with the EVM.

- In *Device Configuration→Global Settings* tab, select *Powerdown_AFE*
- This powers down the AFE and the VCM output voltage of the AFE drops to 0 V
- VCM is measured at the VCM_AFE serial jumper resistor R28 on the board

10.2 ADC_RDY signal

After executing the GUI, observe the ADC_RDY waveform at series jumper resistor R26.This should be at the same frequency as the PRF. Figure 47 shows the ADC_RDY waveform at 500-Hz PRF.

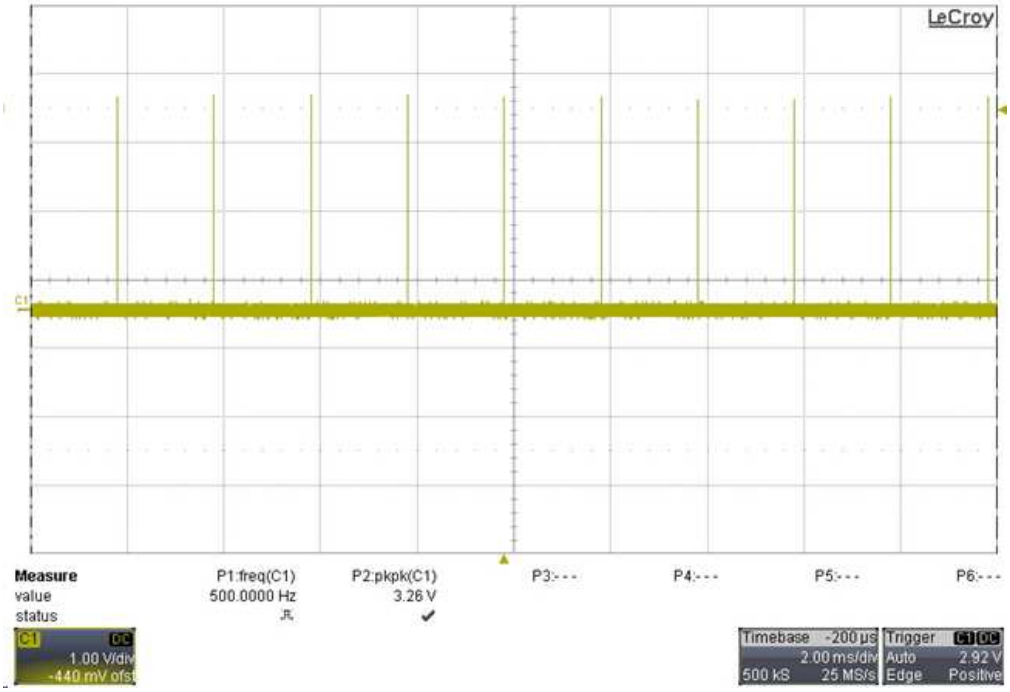


Figure 47. ADC_RDY Waveform at 500-Hz PRF

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10.3 Check TXP and TXN Waveforms

TXP and TXN waveforms are observed at TX_P (TP23) and TX_N (TP17). Figure 48 shows TXP and TXN waveforms without connecting the pulse oximeter cable. Figure 49 shows TXP and TXN waveforms after connecting the pulse oximeter cable.

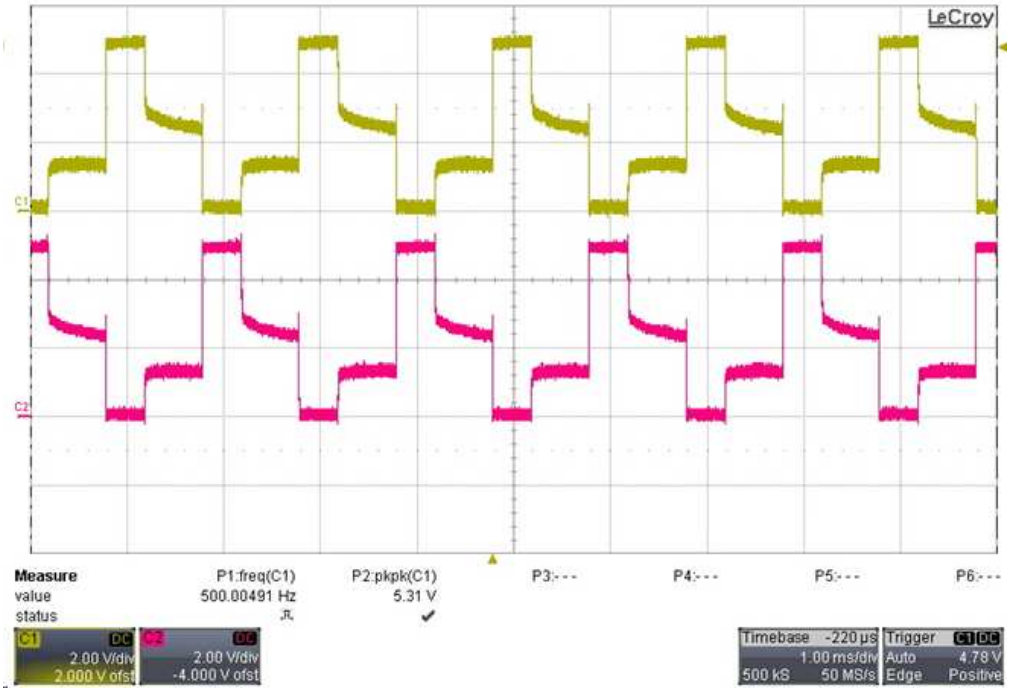


Figure 48. TXP and TXN Without Pulse Oximeter Cable

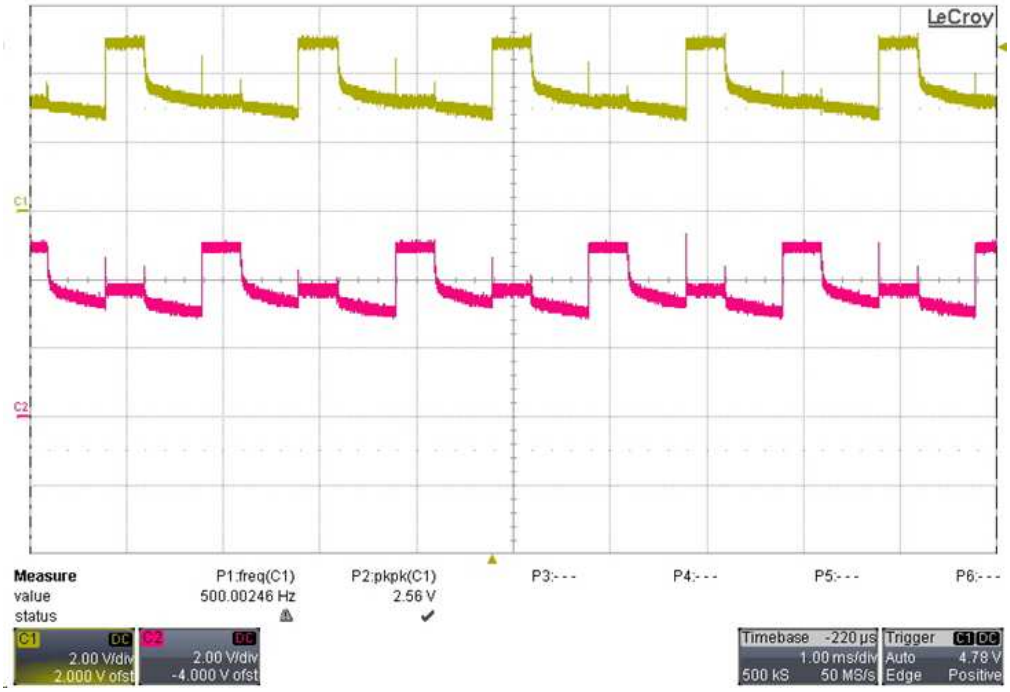


Figure 49. TXP and TXN After Connecting the Pulse Oximeter Cable

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10.4 Diagnostics

The device includes diagnostics to detect open or short conditions of the LED and photo-sensor, LED current profile feedback, and cable on or off detection. The EVM supports the diagnostic feature of the device.

The diagnostic feature is enabled from the *Global Settings* under the *Device Configuration* tab. Clicking the **Diagnostic Enable** button enables the diagnostic function and once the diagnostic function is completed, the status of the fault flags are updated on the *Global Settings* tab. Figure 50 shows the diagnostic mode fault flags when no sensor was connected to the EVM.

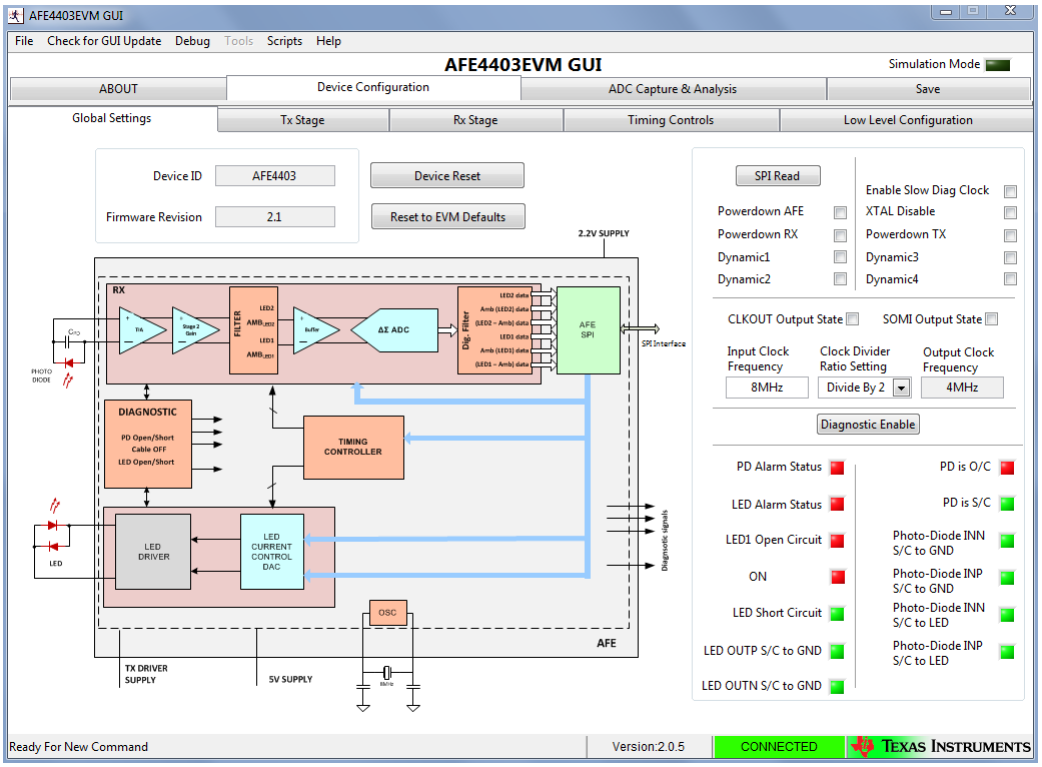


Figure 50. Diagnostic Feature Fault Flags with No Sensor Connected to the EVM

10.5 Automation of Register Read and Write Operations

Refer to the Scripting document located in the Documentation directory for detailed instruction on how to use automation functions for register read and write operations.

Documentation directory is located at the following location:

- On a Windows XP machine – C:\Program Files\Texas Instruments\AFE4403EVM GUI\Documentation
- On a Windows 7 machine – C:\Program Files(x86)\Texas Instruments\AFE4403EVM GUI\Documentation

10.6 Optimum Viewing Experience on Windows 7 OS

Change the size of text to Smaller - 100% for optimum viewing experience on Windows 7 operating system as shown in Figure 51.

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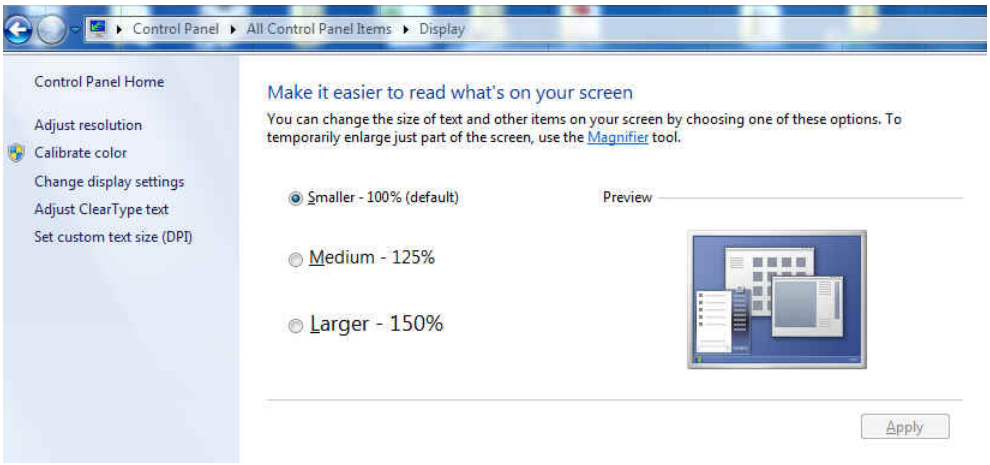


Figure 51. Setting Font Size on Windows 7 Operating System

10.7 Windows 8 Support for Device GUIs

At GUI Start up, sometimes the GUI might show a broken arrow as seen in Figure 52. One of the reasons for this issue may be due to a missing update of .NET FRAMEWORK 3.5 (includes .NET 2.0 and .NET 3.0).

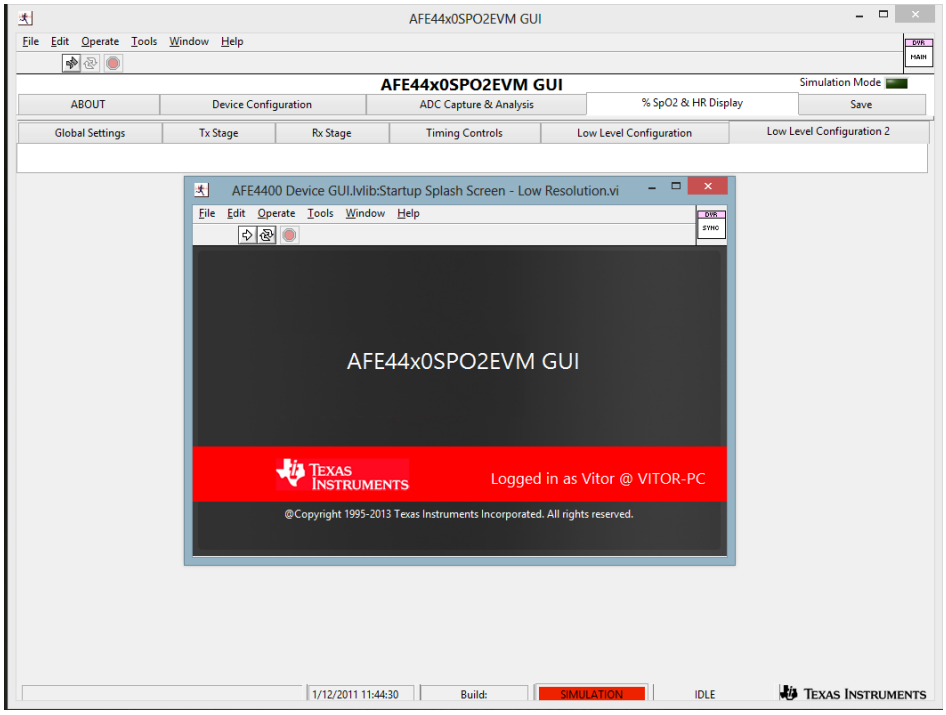


Figure 52. Broken Arrow Error

The .NET FRAMWORK 3.5 is needed for the GUI to:

- Check if Python is Installed
- Checking and setting environment variables needed for the scripting feature in the GUI

Points to Remember:

- There is no download for the .NET Framework 3.5 for Windows 8 or Windows 8.1. The user must enable the .NET Framework 3.5 in Control Panel by following the instructions provided in this article.

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- Use the .NET Framework 3.5 for apps built for versions 2.0 and 3.0 as well as 3.5.
- Installing a Windows language pack before installing the .NET Framework 3.5 will cause the .NET Framework 3.5 installation to fail. Install the .NET Framework 3.5 before installing any Windows language packs. (Source: http://msdn.microsoft.com/library/hh506443(v=VS.110).aspx)

There are two methods to resolve this.

10.7.1 Method 1 (Enabling the .NET Framework 3.5 in Control Panel)

In Control Panel, choose Programs and Features, choose Turn Windows features on or off, and then select the .NET Framework 3.5 (includes .NET 2.0 and 3.0) check box. This option requires an Internet connection. The user does not need to select the child items.

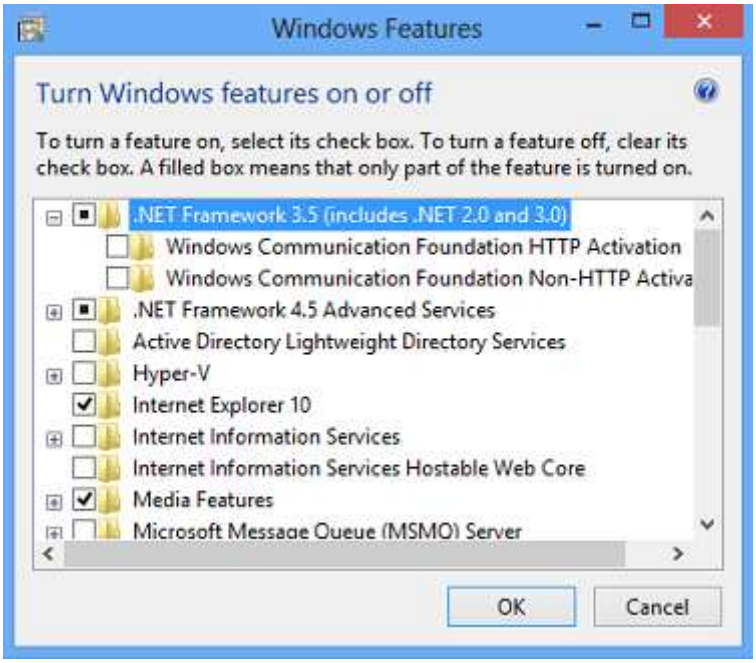


Figure 53. Method 1 (Screen 1)

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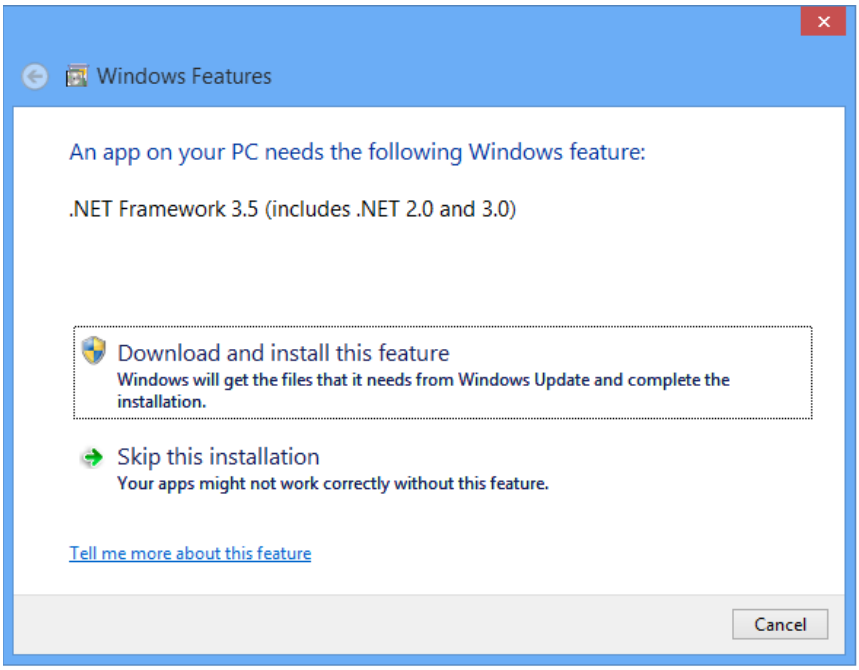


Figure 54. Method 1 (Screen 2)

Select Download and Install this feature.

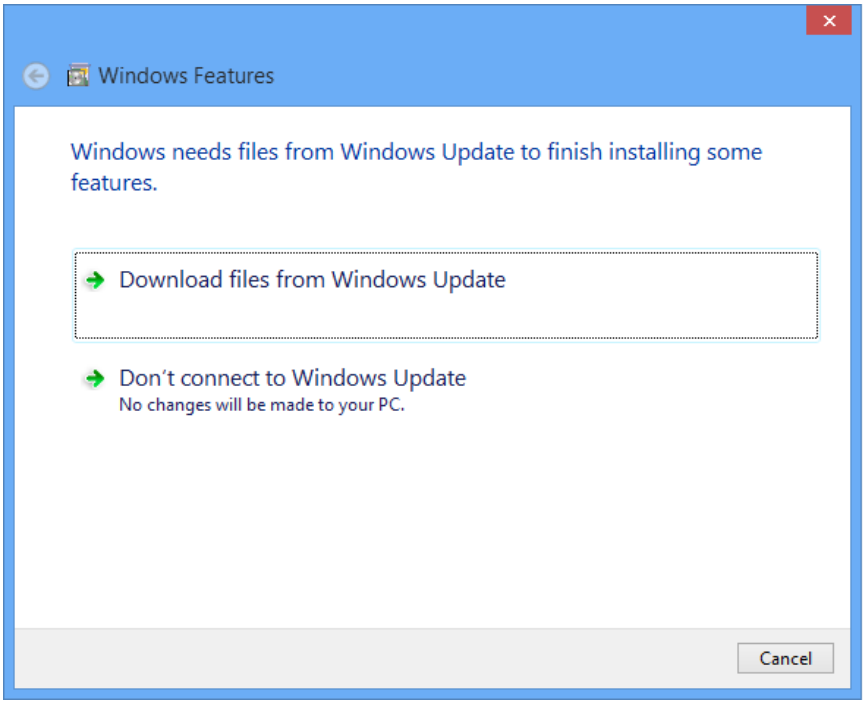


Figure 55. Method 1 (Screen 3)

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Select Download Files from Windows Update.

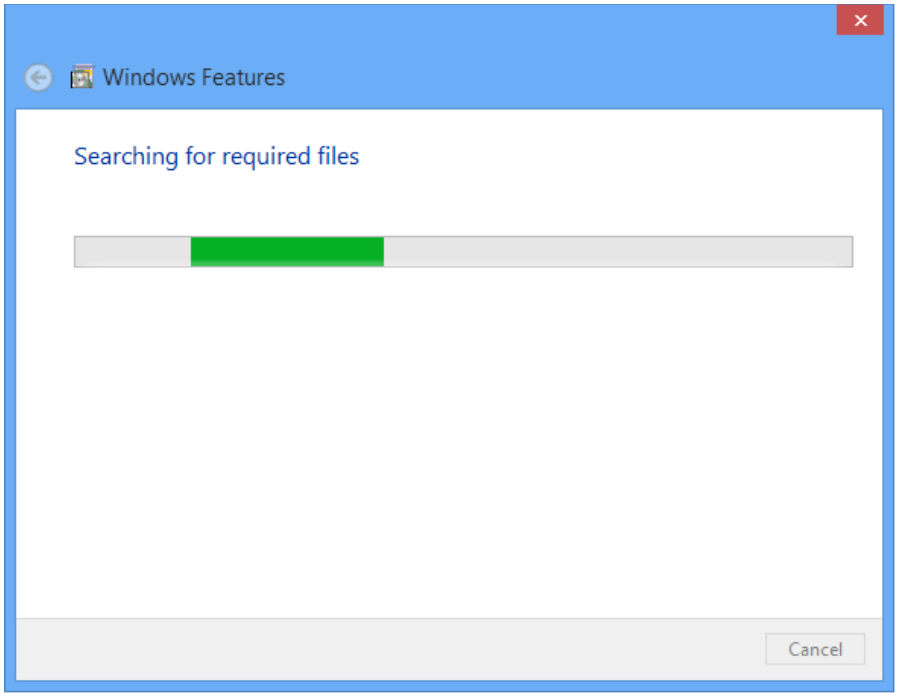


Figure 56. Method 1 (Screen 4)

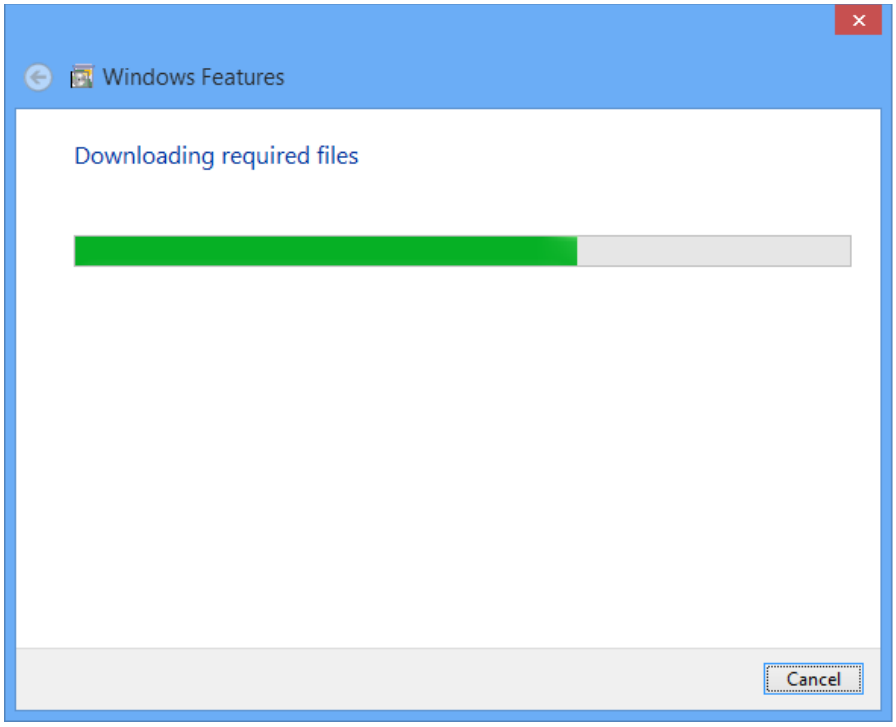


Figure 57. Method 1 (Screen 5)

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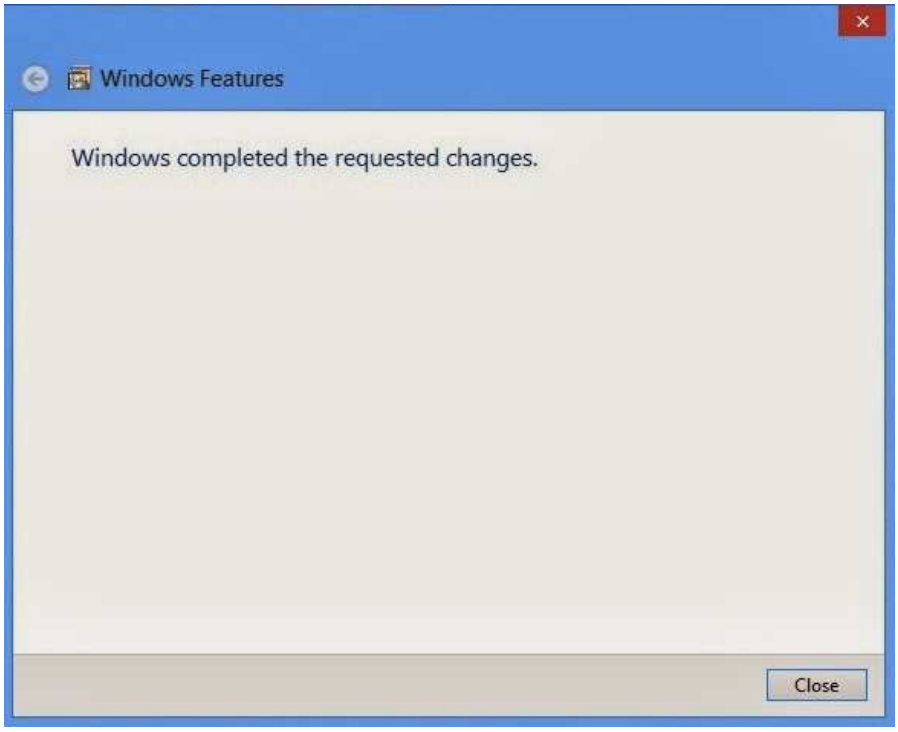


Figure 58. Method 1 (Screen 6)

10.7.2 Method 2 (Enabling .NET Framework 3.5 on Windows 8 in Offline Mode)

This is basically using Windows 8 CD to enable/install .NET FRAMEWORK 3.5 in the PC. This method does not require an internet connection.

Step 1: Insert Windows 8 DVD or mount ISO image. The source of this feature can be found in folder E:\sources\sxs. (In this case E: is the user's drive letter on which the user has loaded Windows 8 Media.)

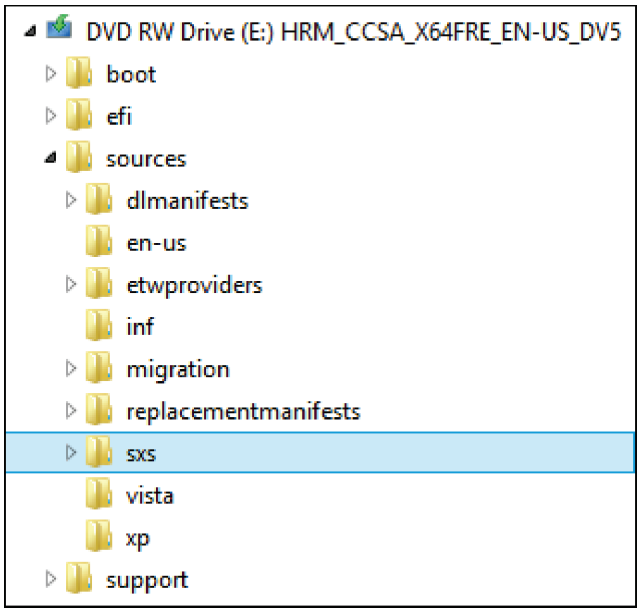


Figure 59. Method 2 (Screen 1)

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Step 2: Open Command prompt as administrator.

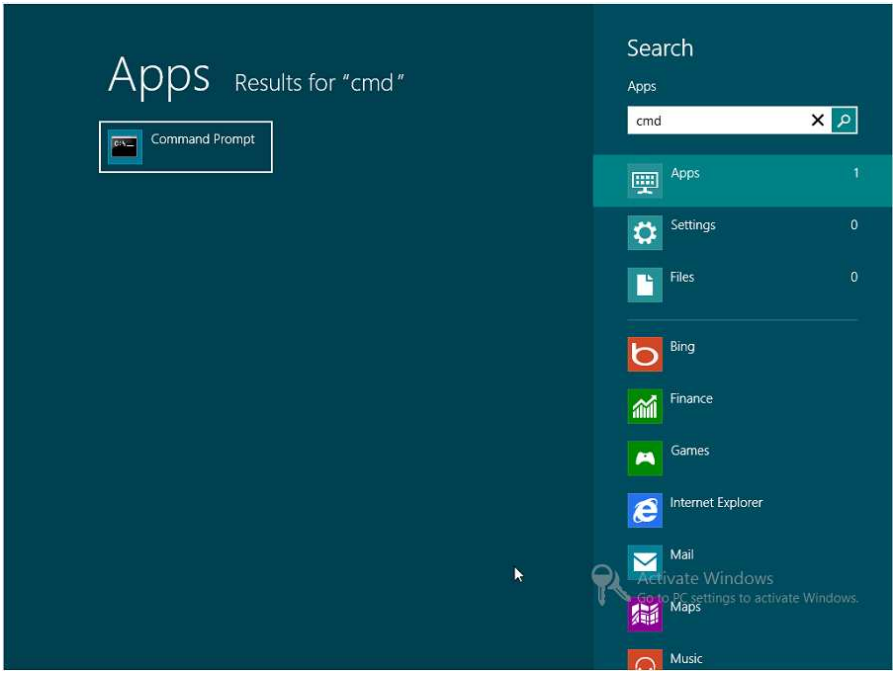


Figure 60. Method 2 (Screen 2)

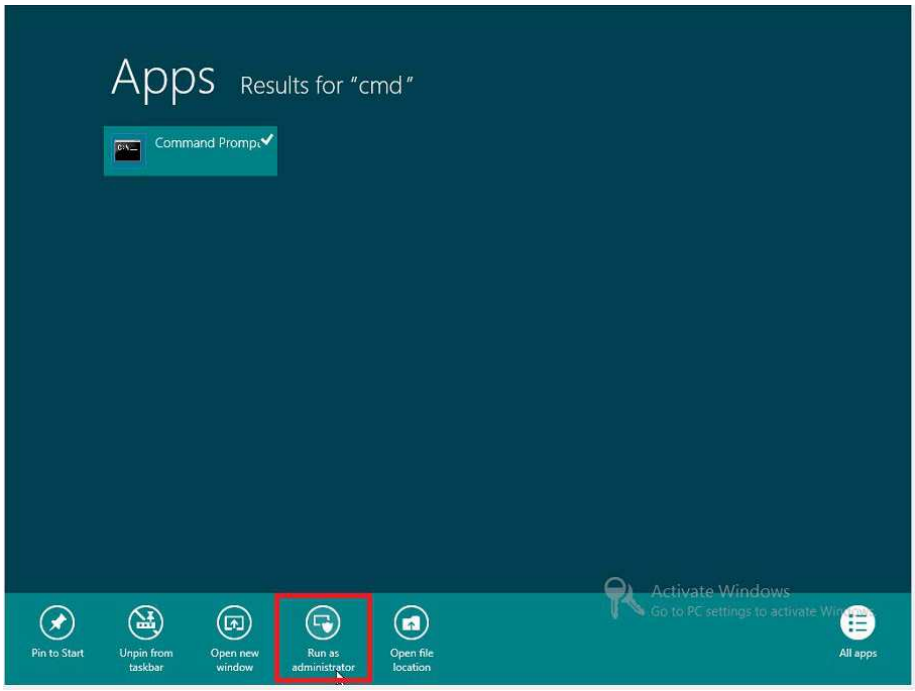


Figure 61. Method 2 (Screen 3)

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Step 3: Run the following command Dism.exe /online /enable-feature /featurename:NetFX3 /All /Source:E:\sources\sxs /LimitAccess, and hit Enter. Make sure to choose the appropriate drive letter (in this case it is E:\).

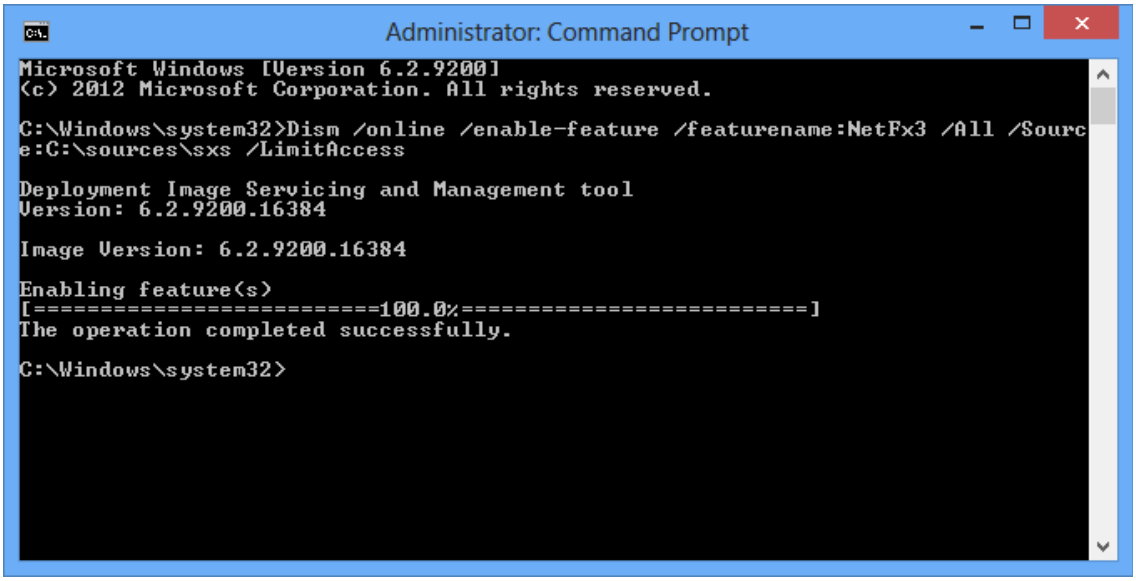


Figure 62. Method 2 (Screen 4)

Method 2 source: http://support.microsoft.com/kb/2785188

Table 8. Troubleshoot and Links

Description	Link
Installing the .NET Framework 3.5 on Windows 8 or 8.1	http://msdn.microsoft.com/library/hh506443(v=VS.110).aspx
Enable .NET Framework 3.5 on Windows 8 in Offline Mode	http://support.microsoft.com/kb/2785188
.NET Framework 3.5 installation error: 0x800F0906, 0x800F081F, 0x800F0907	http://support.microsoft.com/kb/2734782
Other helpful link	http://comps-tech-solution.blogspot.in/2013/09/how-to-install-net-framework-35-in.html

10.8 COM Port

It has been observed that on certain machines, the GUI will not work for lower COM ports. When the GUI and the USB drivers are installed correctly and the Device Manager shows the AFE44x0SPO2EVM recognized as a virtual COM port, but the GUI cannot establish communication to the AFE44x0SPO2EVM and shows the Device Communication Error, change the COM port to a higher number (greater than 25).

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11 Bill of Materials

Table 9 lists the bill of materials (landscaped for readability).

Table 9. AFE4403EVM Bill of Materials

Item	Designator	Description	RoHS	Manufacturer	PartNumber	Quantity	Required
1	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP25, TP26, TP27, TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP35, TP36, TP37, TP38, TP39, TP40, TP41, TP42, TP43, TP44, TP45	Test Point Pad, 10mil Hole, 20mil Pad	TBD	N/A	Pads Only - Non-BOM	0	0
2	C1, C3, C4, C30, C33, C34, C37, C49, C66	CAP, CERAMIC, 0.1uF, 16 V, 10%, X7R, 0402	Y	TDK	C1005X7R1C104K050BC	0	0
3	C20, C22	CAP, CERAMIC, 0.1uF, 16 V, 10%, X7R, 0402	Y	MURATA	GRM155R71C104KA88D	0	0
4	C23	CAP, CERAMIC, 10000 PF, 50V, 10%, X7R, 0402	Y	MURATA	GCM155R71H103KA55D	0	0
5	C2, C45	CAP, CERAMIC, 10uF, 6.3 V, 20%, X5R, 0603	Y	AVX	06036D106MAT2A	0	0
6	C19	CAP, CERAMIC, 2200pF, 50V, 10%, X7R, 0402	Y	MURATA	GRM155R71H222KA01D	0	0
7	C51	CAP, TANT, 22uF, 6.3V, 20%, 0805	Y	AVX	TLJN226M006R5400	0	0
8	J5	CONN, HEADER 2POS .100 VERT, TIN	Y	MOLEX	22-27-2021	0	0
9	J6	CONN, MEMORY CARD PUSH PUSH TYPE, SMT, 8-PIN	Y	MOLEX	473340001	0	0
10	D6	DIODE, ZENER DUAL, 5.6V, SOT23-3	Y	MICRO COMMERCIAL	AZ23C5V6-TP	0	0
11	J1	EZ RF HEADER	Y	MILL-MAX	850-40-006-20-001000	0	0
12	U3, U5	IC, FRAM 2MBIT, 40MHZ, 8-SOIC	Y	CYPRESS SEMICONDUCTOR	FM25V20-GTR	0	0
13	U10	IC, GAS GAUGE LI-ION/LIPOL, 10-SON	Y	TEXAS INSTRUMENTS	BQ27200DRKR	0	0
14	U6	IC, GYRO/ACCELEROMETER 9-AXIS, 24-LGA	Y	INVENSENSE	MPU9150	0	0
15	U4	IC, TVS DIODE, 10VC, 8-WSON	Y	TEXAS INSTRUMENTS	TPD8E003DQDR	0	0
16	R114	RESISTOR, METAL ELEMENT, 0.02 OHM, 1%, 0.25 W, SMT1206	Y	VISHAY	WSL1206R0200FEA	0	0
17	R8, R15, R18, R19, R20	RESISTOR, THICK FILM, 0 OHM, JUMPER, 0.063W, SMT0402	Y	VISHAY	CRCW04020000Z0ED	0	0
18	R58	RESISTOR, THICK FILM, 0 OHM, JUMPER, 0.1 W, SMT0603	Y	VISHAY	CRCW06030000Z0EA	0	0
19	R108, R109, R116, R117	RESISTOR, THICK FILM, 100 OHM, 5%, 0.0625 W, SMT0402	Y	VISHAY	CRCW0402100RJNED	0	0
20	R56	RESISTOR, THICK FILM, 10K OHM, 5%, 0.0625 W, SMT0402	Y	VISHAY	CRCW040210K0JNED	0	0
21	R10, R11, R12, R64, R78, R98, R104, R111	RESISTOR, THICK FILM, 10K OHM, 5%, 0.1W, SMT0402	Y	PANASONIC	ERJ-2GEJ103X	0	0
22	R70, R80, R118	RESISTOR, THICK FILM, 1K OHM, 5%, 0.1W, SMT0402	Y	PANASONIC	ERJ-2GEJ102X	0	0
23	R46, R47	RESISTOR, THICK FILM, 4.7K OHM, 5%, 0.1 W, SMT0603	Y	YAGEO	RC0603JR-104K7L	0	0
24	J3	TAG CONNECT	TBD	TAG-CONNECT	TC2050-IDC-FP	0	0
25	U1	BGA, 36 PINS	TBD	TEXAS INSTRUMENTS	AFE4403YZPR	1	1
26	C50, C53, C57	CAP, CERAMIC, 0.1uF, 16 V, 10%, X7R, 0402	Y	TDK	C1005X7R1C104K050BC	3	3
27	C8, C9, C10, C14, C16, C26, C31, C38, C43	CAP, CERAMIC, 0.1uF, 16 V, 10%, X7R, 0402	Y	MURATA	GRM155R71C104KA88D	9	9
28	C5	CAP, CERAMIC, 0.47uF, 6.3 V, 10%, X5R, 0402	Y	MURATA	GRM155R60J474KE19D	1	1
29	C36	CAP, CERAMIC, 1000 PF, 50V, 10%, X7R, 0402	Y	MURATA	GRM155R71H102KA01D	1	1

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Table 9. AFE4403EVM Bill of Materials (continued)

Item	Designator	Description	RoHS	Manufacturer	PartNumber	Quantity	Required
30	C12, C27, C55, C58, C59, C62	CAP, CERAMIC, 10000 PF, 50V, 10%, X7R, 0402	Y	MURATA	GCM155R71H103KA55D	6	6
31	C17, C18, C21, C24	CAP, CERAMIC, 10PF, 50V, 5%, NP0, 0402	Y	MURATA	GRM1555C1H100JA01D	4	4
32	C28, C29, C32, C46, C47, C48, C52, C54, C56, C60, C61, C63, C64, C65	CAP, CERAMIC, 10uF, 16V, 10%, X5R, 0805	Y	MURATA	GRM21BR61C106KE15L	14	14
33	C11, C13	CAP, CERAMIC, 12PF, 50V, 5%, NP0, 0402	Y	MURATA	GRM1555C1H120JA01D	2	2
34	C15	CAP, CERAMIC, 1uF, 10V, 10%, X5R, 0402	Y	MURATA	GRM155R61A105KE15D	1	1
35	C35	CAP, CERAMIC, 1uF, 6.3V, 10%, X6S, 0603	Y	MURATA	GRM185C80J105KE26D	1	1
36	C40, C41, C42	CAP, CERAMIC, 2.2uF, 6.3V, 10%, X5R, 0603	Y	MURATA	GRM188R60J225KE19D	3	3
37	C39	CAP, CERAMIC, 2200pF, 50V, 10%, X7R, 0402	Y	MURATA	GRM155R71H222KA01D	1	1
38	C25	CAP, CERAMIC, 4.7uF, 6.3 V, 20%, X5R, 0402	Y	TAIYO YUDEN	JMK105BBJ475MV-F	1	1
39	L1	CHOKE, COMMON MODE,90 OHM, 1206	Y	MURATA	DLW31SN900SQ2L	1	1
40	J2	CONN, D-SUB STANDARD CONNECTORS, SMT, D-9	Y	KYCON, INC	K202XHT-E9S-N	1	1
41	J4	CONNECTOR, MICRO-USB-AB, RECEPTACLE, RIGHT ANGLE, 5-PIN, SMT	Y	HIROSE	ZX62D-AB-5P8	1	1
42	Y3	CRYSTAL, 24MHZ, 10PF, SMD, 4-PIN	Y	ABRACON CORPORATION	ABM3B-24.000MHZ-10-1-U-T	1	1
43	Y2	CRYSTAL, 32.768KHZ, 12.5PF, SMD, 2-PIN	Y	ABRACON CORPORATION	ABS07-32.768KHZ-T	1	1
44	D1, D2, D3, D4, D7	DIODE, ARRAY, 75V, 150MA, SOT323	Y	DIODES INC	BAV99W-7-F	5	5
45	D5	DIODE, SCHOTTKY, 40V, 0.35A, SOD123	Y	DIODE INCORPORATED	SD103AW-7-F	1	1
46	U11	IC, 2.93V SUPPLY MONITOR, SOT23-5	Y	TEXAS INSTRUMENTS	TPS3825-33DBVT	1	1
47	U12	IC, LI-ON LINEAR CHRG MGMT, 20-QFN	Y	TEXAS INSTRUMENTS	BQ24032ARHLR	1	1
48	U2	IC, MCU 16BIT, 128KB FLASH, 80-LQFP	Y	TEXAS INSTRUMENTS	MSP430F5529IPN	1	1
49	U9	IC, REG BOOST ADJ, 1A, 10-SON	Y	TEXAS INSTRUMENTS	TPS61093DSK	1	1
50	U13, U14	IC, REG LDO ADJ, 0.15A, 8-MSOP	Y	TEXAS INSTRUMENTS	TPS7A4901DGN	2	2
51	U8	IC, REG LDO ADJ, 0.8A, 8-SOP	Y	TEXAS INSTRUMENTS	LP3878MR-ADJ/NOPB	1	1
52	U7	IC, TVS DIODE, 6-SON	Y	TEXAS INSTRUMENTS	TPD4E004DRY	1	1
53	L3, L4	Inductor, Shielded, 10uH, 640mA, 0.54 ohm, SMT	Y	Coilcraft	LPS3010-103MRB	2	2
54	LED2, LED3	LED, 470NM, BLUE CLEAR, 0603, SMT	Y	ROHM SEMICONDUCTOR	SMLE12BC7TT86	2	2
55	LED1	LED, 527NM, BLUISH GREEN, 0603, SMT	Y	ROHM SEMICONDUCTOR	SMLE12EC6TT86	1	1
56	Y1	OSC, CER RESONATOR, 8.00MHZ, SMD, 3-PIN	Y	MURATA	CSTCE8M00G55-R0	1	1
57	R2, R5, R16, R17, R68, R73, R82, R91, R124	RESISTOR, THICK FILM, 0 OHM, JUMPER, 0.063W, SMT0402	Y	VISHAY	CRCW04020000Z0ED	9	9
58	R44, R48, R54, R55, R60, R65, R66, R67, R69, R71, R76, R119, R120, R121, R122, R123	RESISTOR, THICK FILM, 0 OHM, JUMPER, 0.1W, 100PPM/K, SMT0603	Y	VISHAY	CRCW06030000Z0EA	16	16
59	R96	RESISTOR, THICK FILM, 1.4K OHM, 1%, 0.063W, 100PPM/K, SMT0402	Y	VISHAY	CRCW04021K40FKED	1	1
60	R1, R6, R7, R9, R13, R14, R25, R26, R29, R31, R33, R35, R38, R42, R84, R85, R86, R87, R88, R89, R90, R93, R94	RESISTOR, THICK FILM, 10 OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW040210R0JNED	23	23
61	R53, R95	RESISTOR, THICK FILM, 100 OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW0402100RJNED	2	2
62	R59, R62, R99, R100, R101, R105, R107, R110, R112, R113	RESISTOR, THICK FILM, 10K OHM, 5%, 0.1W, SMT0402	Y	PANASONIC	ERJ-2GEJ103X	10	10
63	R3	RESISTOR, THICK FILM, 130 OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW0402130RJNED	1	1

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Table 9. AFE4403EVM Bill of Materials (continued)

Item	Designator	Description	RoHS	Manufacturer	PartNumber	Quantity	Required
64	R74	RESISTOR, THICK FILM, 15.4K OHM, 1%, 0.1W, 100PPM/K, SMT0603	Y	VISHAY	CRCW060315K4FKEA	1	1
65	R28	RESISTOR, THICK FILM, 1K OHM, 1%, 0.063W, 100PPM/K, SMT0402	Y	VISHAY	CRCW04021K00FKED	1	1
66	R79	RESISTOR, THICK FILM, 1K OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW04021K00JNED	1	1
67	R52	RESISTOR, THICK FILM, 1MEG OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW04021M00JNED	1	1
68	R75	RESISTOR, THICK FILM, 200K OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW0402200KJNED	1	1
69	R4	RESISTOR, THICK FILM, 220 OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW0402220RJNED	1	1
70	R72	RESISTOR, THICK FILM, 261K OHM, 1%, 0.1W, 100PPM/K, SMT0603	Y	VISHAY	CRCW0603261KFKEA	1	1
71	R57, R61	RESISTOR, THICK FILM, 33 OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW040233R0JNED	2	2
72	R21	RESISTOR, THICK FILM, 33K, 5%, 0.1W, SMT0402	Y	PANASONIC	ERJ-2GEJ333X	1	1
73	R77	RESISTOR, THICK FILM, 4.02K OHM, 1%, 0.063W, 100PPM/K, SMT0402	Y	VISHAY	CRCW04024K02FKED	1	1
74	R81, R92	RESISTOR, THICK FILM, 4.7K OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW04024K70JNED	2	2
75	R83, R103, R115	RESISTOR, THICK FILM, 47K OHM, 5%, 0.063W, 200PPM/K, SMT0402	Y	VISHAY	CRCW040247K0JNED	3	3
76	R102	RESISTOR, THICK FILM, 47K OHM, 5%, 0.1W, SMT0402	Y	PANASONIC	ERJ-2GEJ473X	1	1
77	R63, R106	RESISTOR, THICK FILM, 75K OHM, 1%, 0.063W, 100PPM/K, SMT0402	Y	VISHAY	CRCW040275K0FKED	2	2
78	SW1, SW2	SWITCH, TACTILE SPST, 50 mA, 12 VDC, SMT-2 PIN	Y	C&K COMPONENTS	PTS635SL25SMT	2	2
79	Q1	TRANS, NPN, 25V, 50MA, SOT23	Y	ON SEMICONDUCTOR	MMBT5089LT1G	1	1

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Table 10. OSRAM SFH7050 Sensor Board Bill of Materials

Item	Designator	Description	RoHS	Manufacturer	PartNumber	Quantity	Required
1	P1	CONN, HEADER, 50 MIL PITCH, 8-PIN, RIGHT ANGLE, TH	Y	MILL-MAX	850-10-008-20-001000	1	1
2	RHB1, RHB2	RESISTOR, THICK FILM, 0 OHM, JUMPER, 0.1W, SMT0402	Y	PANASONIC	ERJ-2GE0R00X	2	2
3	U1	SENSOR, Multichip LED and photodiode package with a Green LED, Red LED, IR LED and a photodetector, 8-Lead	Y	OSRAM	SFH7050	1	1
4	RCA1, RCA2	RESISTOR, THICK FILM, 0 OHM, JUMPER, 0.1W, SMT0402	Y	PANASONIC	ERJ-2GE0R00X	0	0

Table 11. NJRC NJL5310R Sensor Board Bill of Materials

Item	Designator	Description	RoHS	Manufacturer	PartNumber	Quantity	Required
1	P1	CONN, HEADER, 50 MIL PITCH, 8-PIN, RIGHT ANGLE, TH	Y	MILL-MAX	850-10-008-20-001000	1	1
2	RA1, RA2	RESISTOR, THICK FILM, 0 OHM, JUMPER, 0.1W, SMT0402	Y	PANASONIC	ERJ-2GE0R00X	2	2
3	U1	SENSOR, LED, Multichip LED and photodiode package with two Green LEDs and a photodetector, 7-Lead	Y	NJRC	NJL5310R	1	1
4	RB1, RB2	RESISTOR, THICK FILM, 0 OHM, JUMPER, 0.1W, SMT0402	Y	PANASONIC	ERJ-2GE0R00X	0	0

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12 PCB Layouts and Schematics

12.1 AFE4403EVM PCB Layouts

Figure 63 through Figure 72 show the EVM PCB layouts.

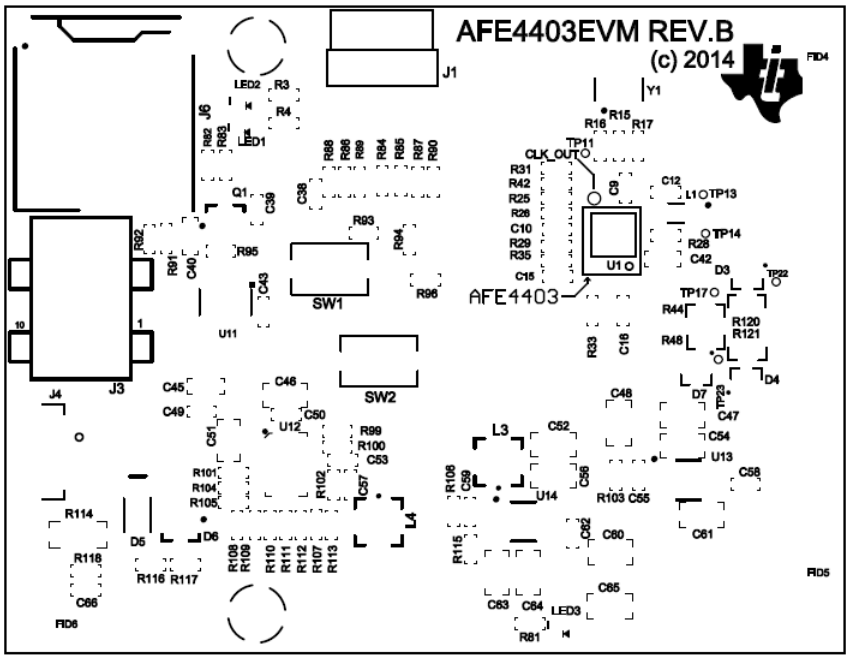


Figure 63. AFE4403EVM Top Overlay

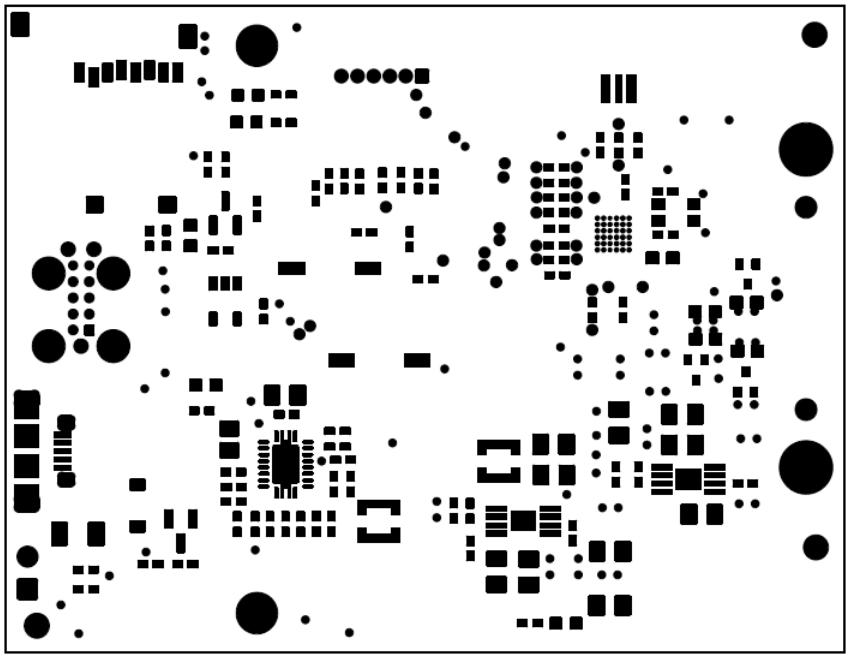


Figure 64. Top Solder

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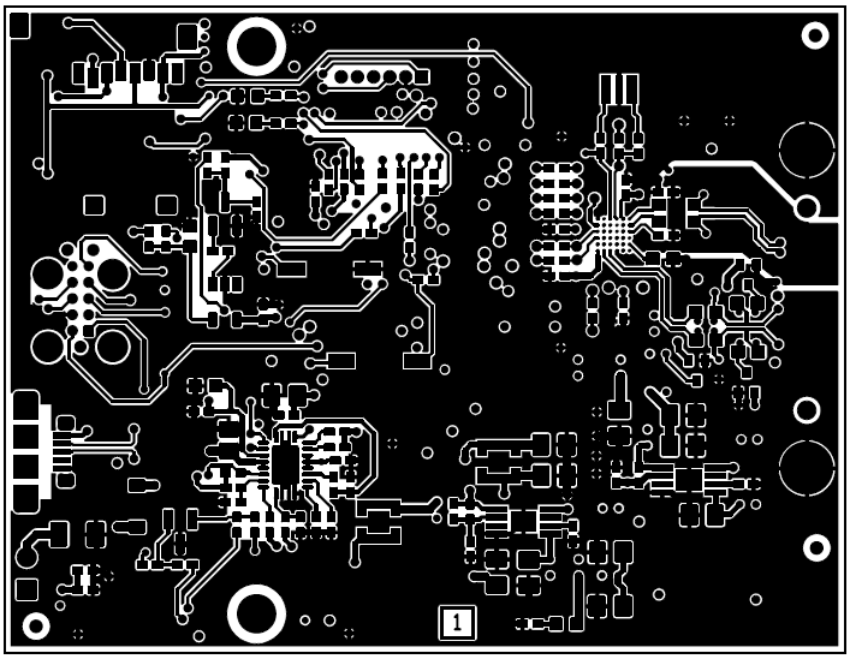


Figure 65. Top Copper (Layer 1)

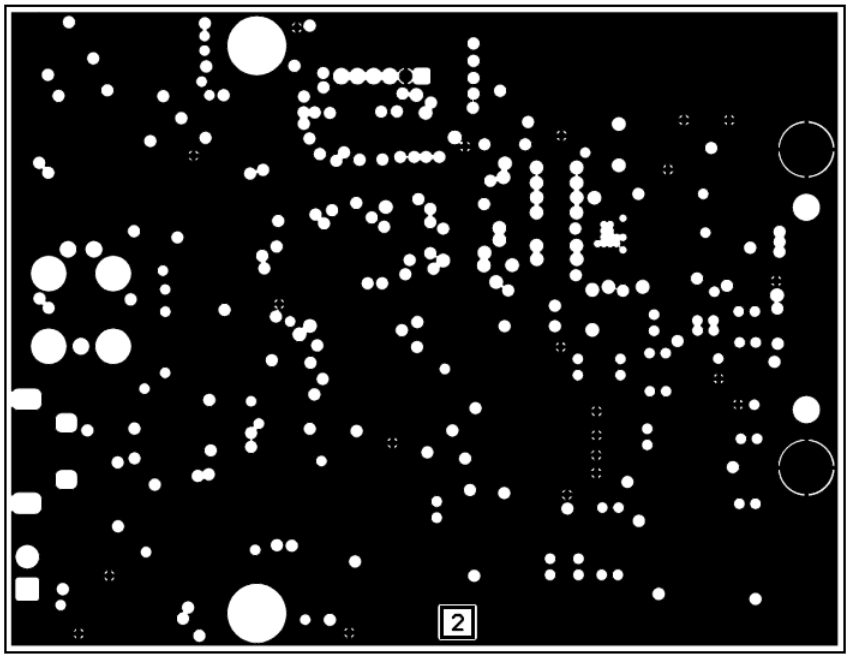


Figure 66. GND (Layer 2)

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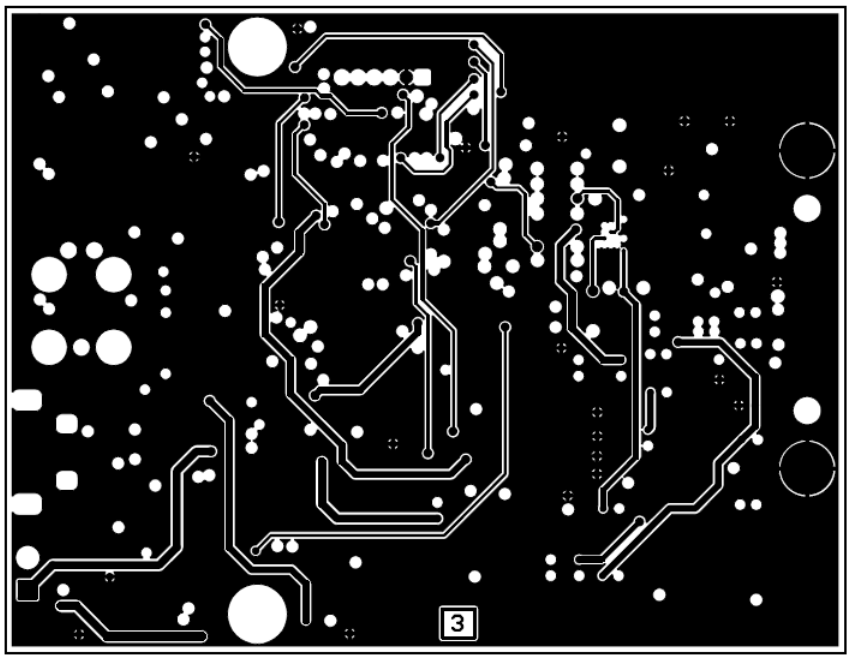


Figure 67. Signal 1 and GND (Layer 3)

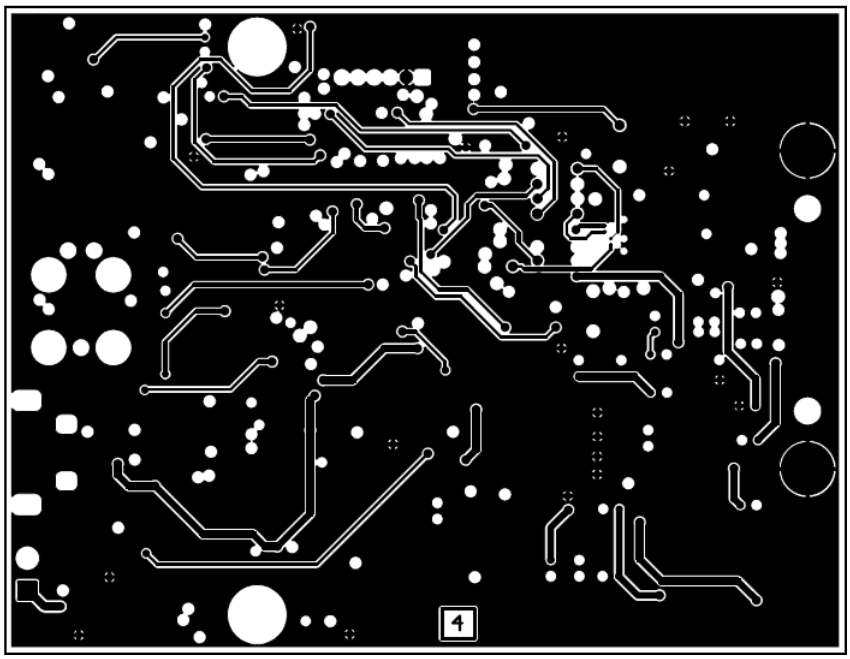


Figure 68. Signal 2 and GND (Layer 4)

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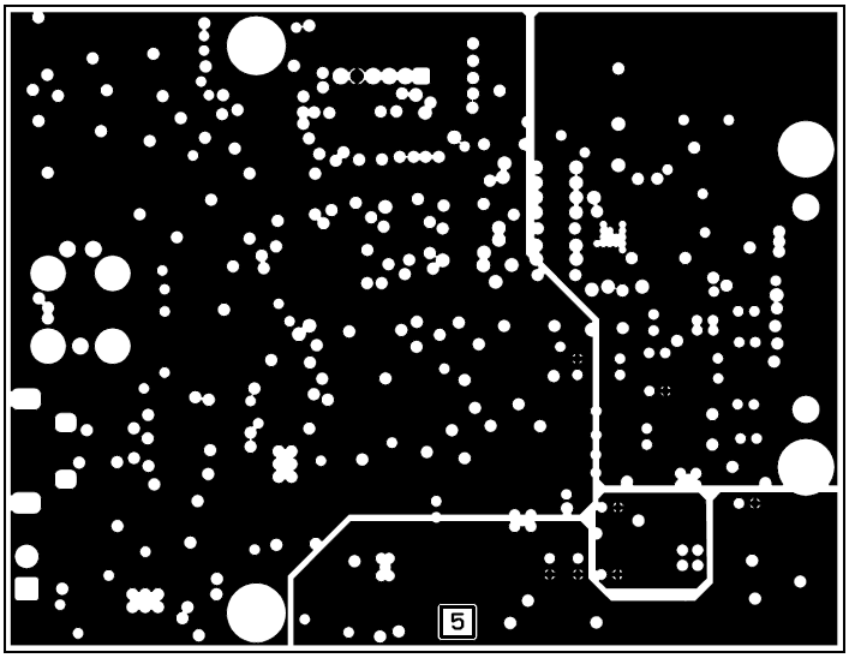


Figure 69. Power Plane (Layer 5)

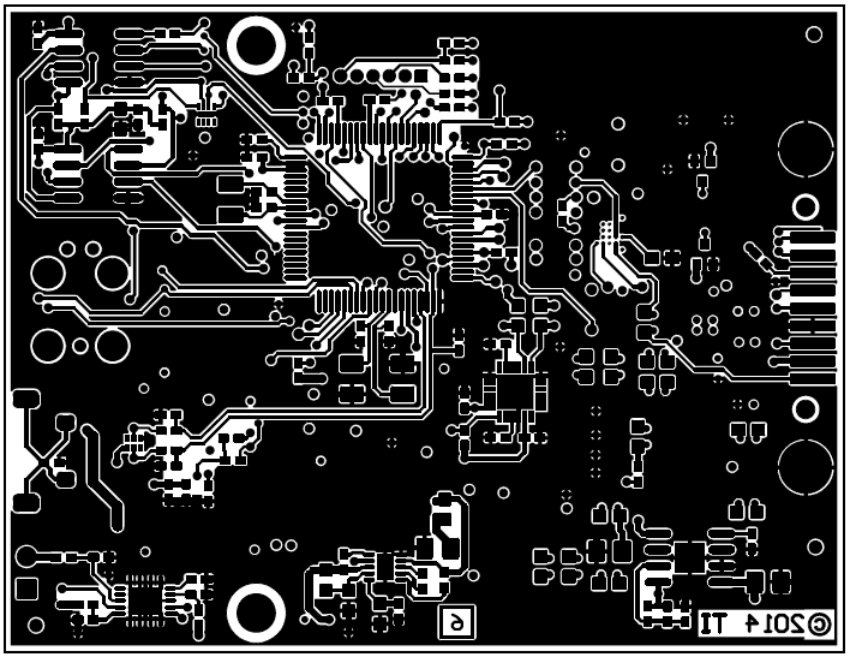


Figure 70. Bottom Copper (Layer 6)

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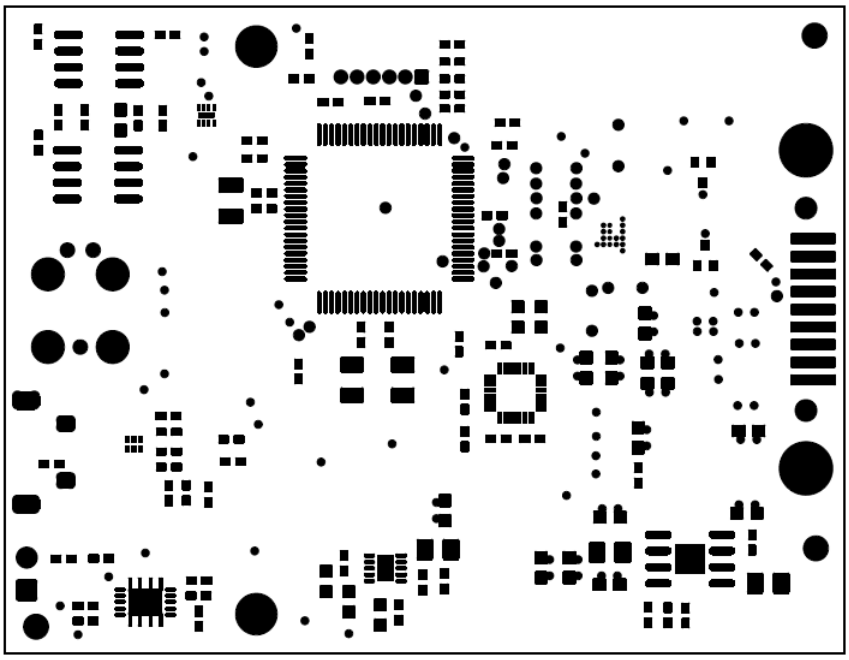


Figure 71. Bottom Solder

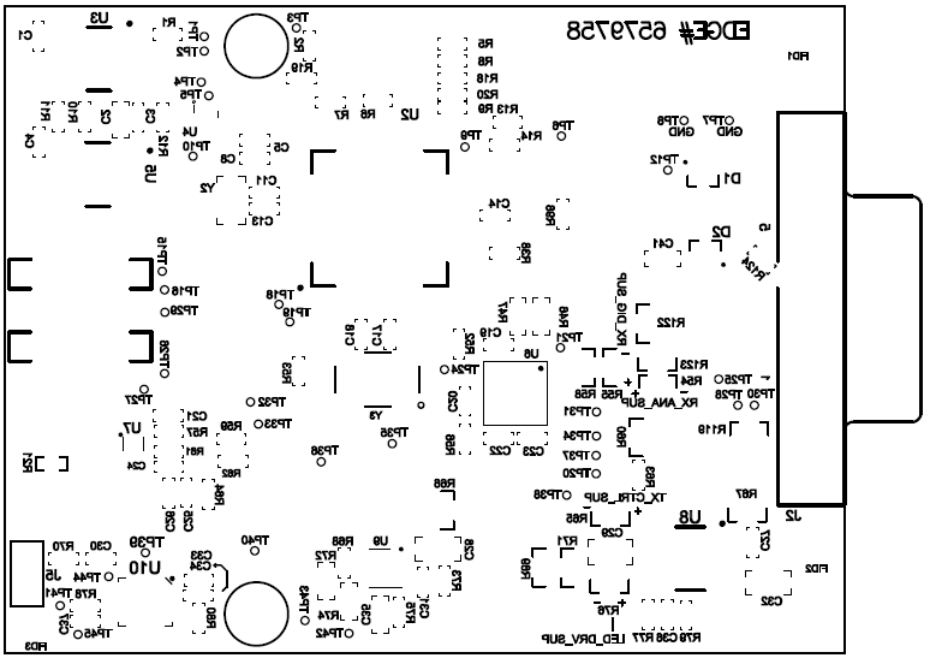


Figure 72. Bottom Overlay

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12.2 SFH7050 Sensor Board Layouts

Figure 73 through Figure 78 show the SFH7050 sensor board layouts.

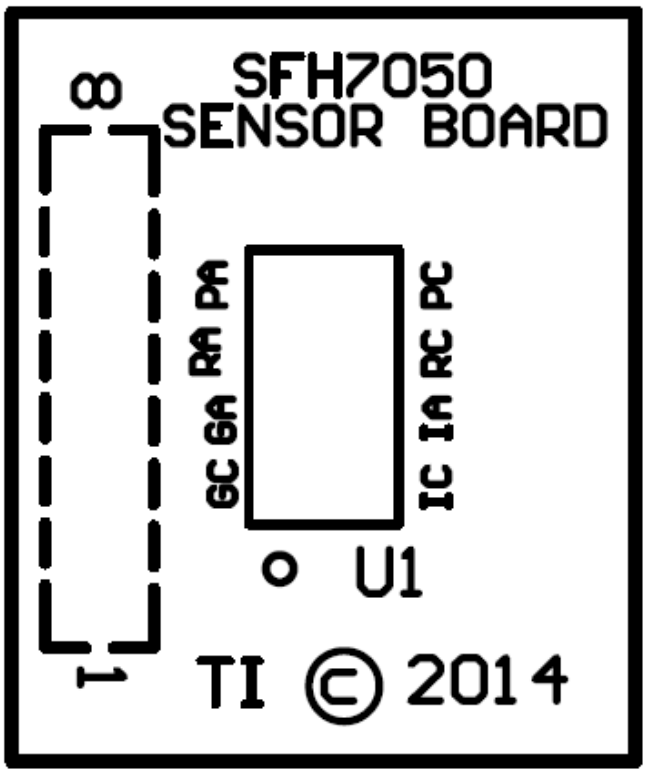


Figure 73. SFH7050 Sensor Board Top Silk Screen

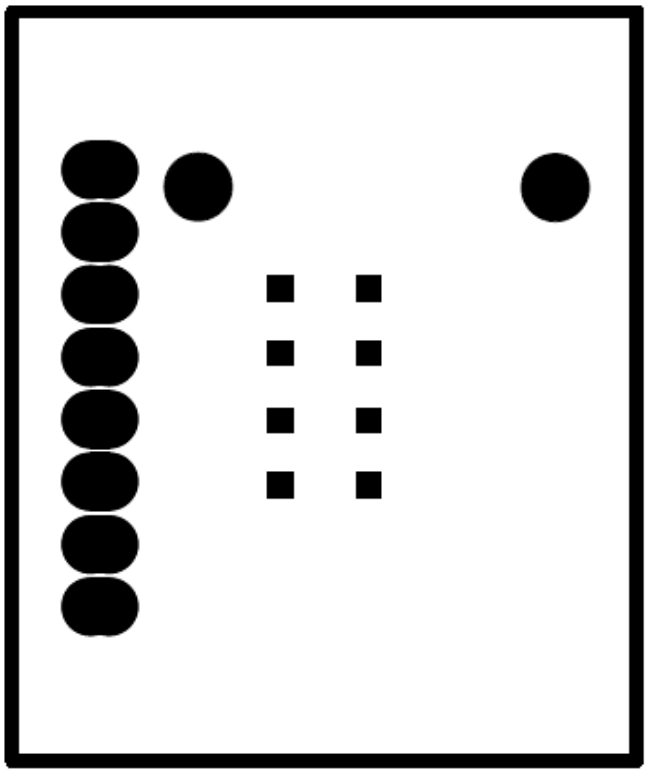


Figure 74. SFH7050 Sensor Board Top Solder Mask

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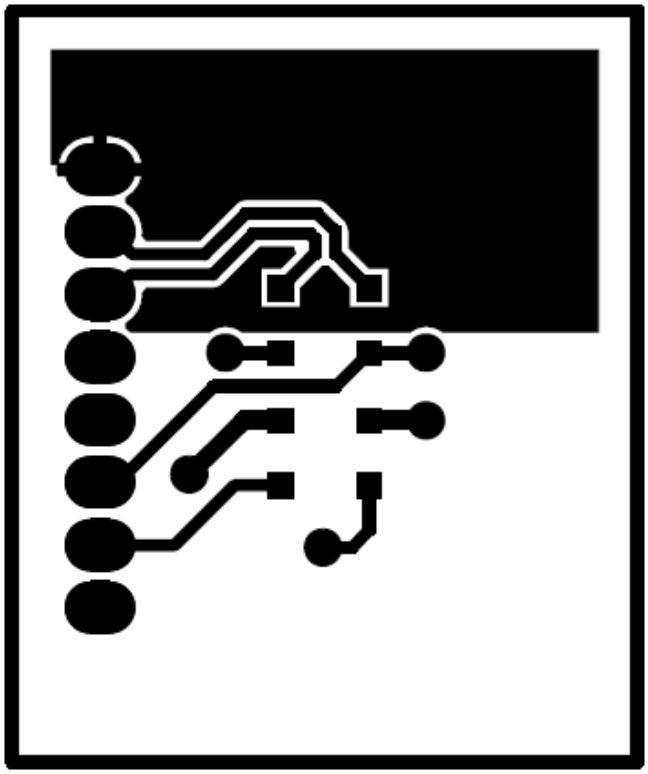


Figure 75. SFH7050 Sensor Board Top Copper

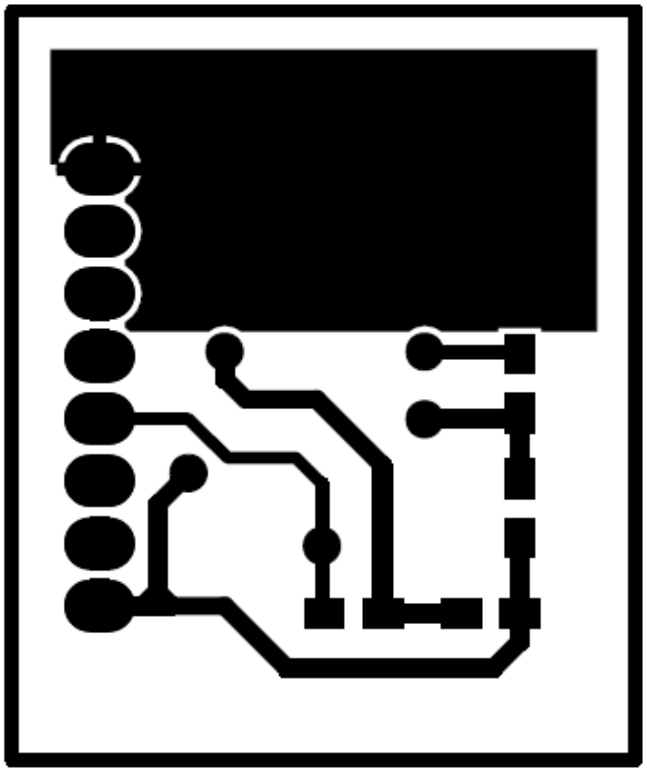


Figure 76. SFH7050 Sensor Board Bottom Copper

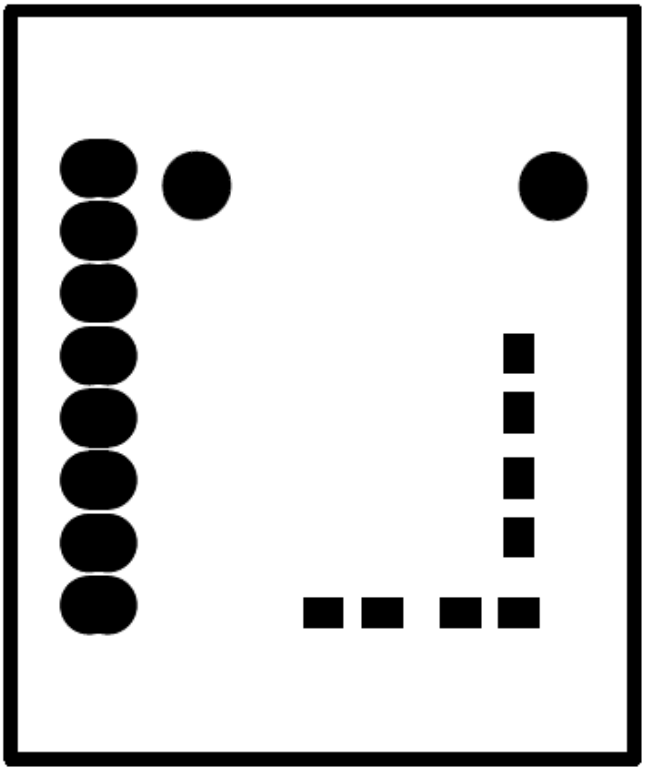


Figure 77. SFH7050 Sensor Board Bottom Solder Mask

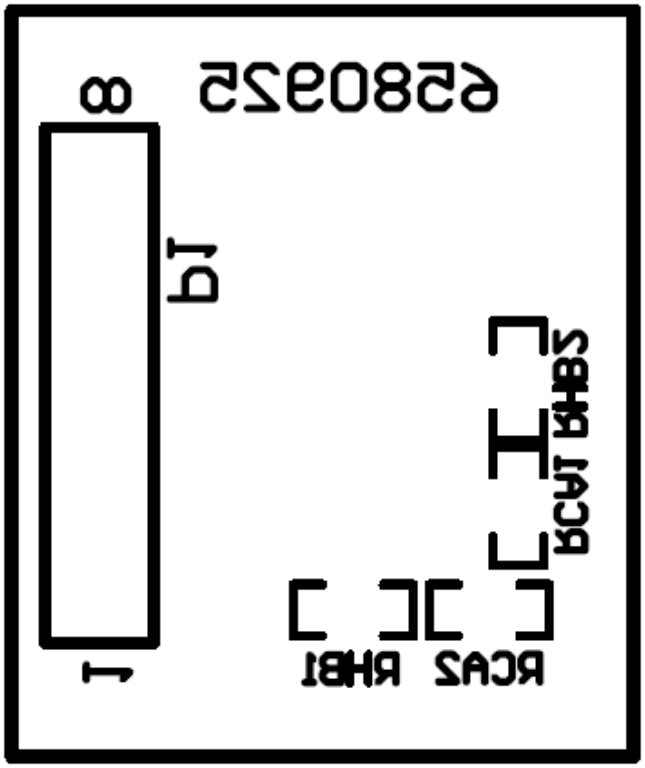


Figure 78. SFH7050 Sensor Board Bottom Silk Screen

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12.3 NJL5310R Sensor Board Layouts

Figure 79 through Figure 84 show the NJL5310R sensor board layouts.

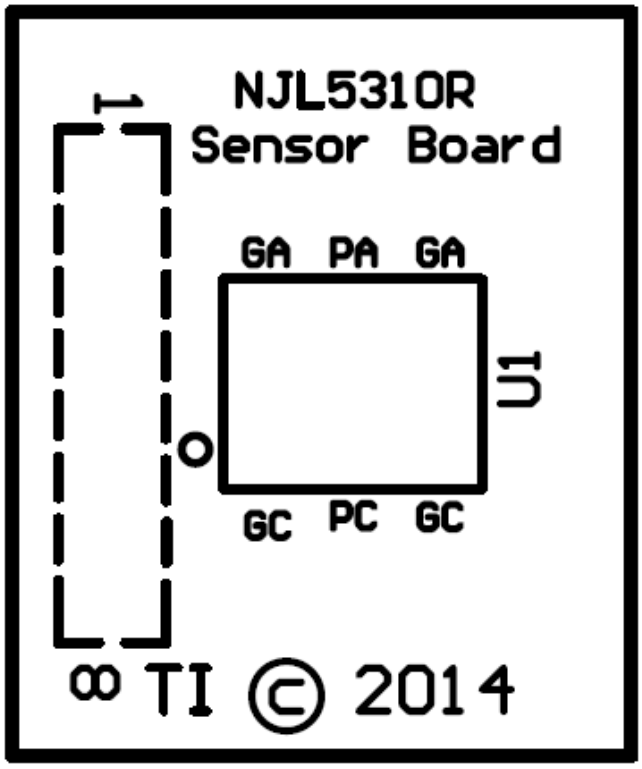


Figure 79. NJL5310R Sensor Board Top Silk Screen

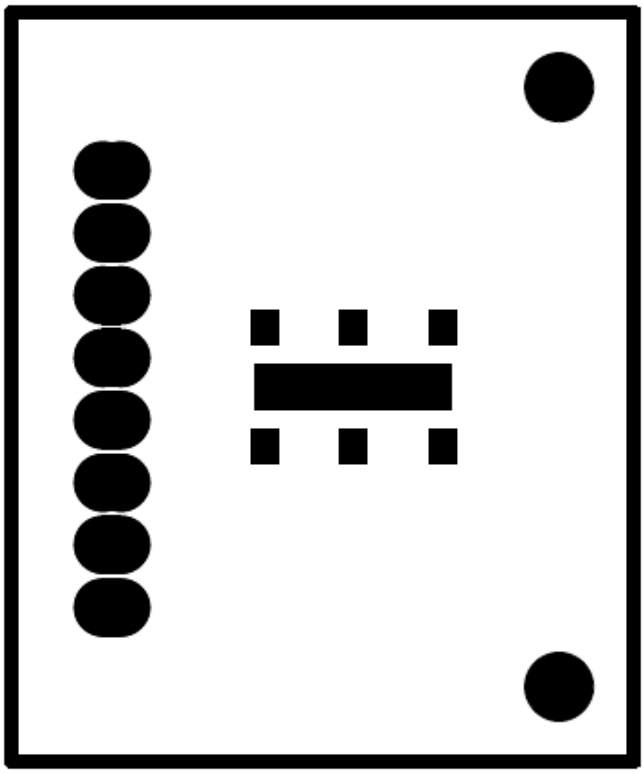


Figure 80. NJL5310R Sensor Board Top Solder Mask

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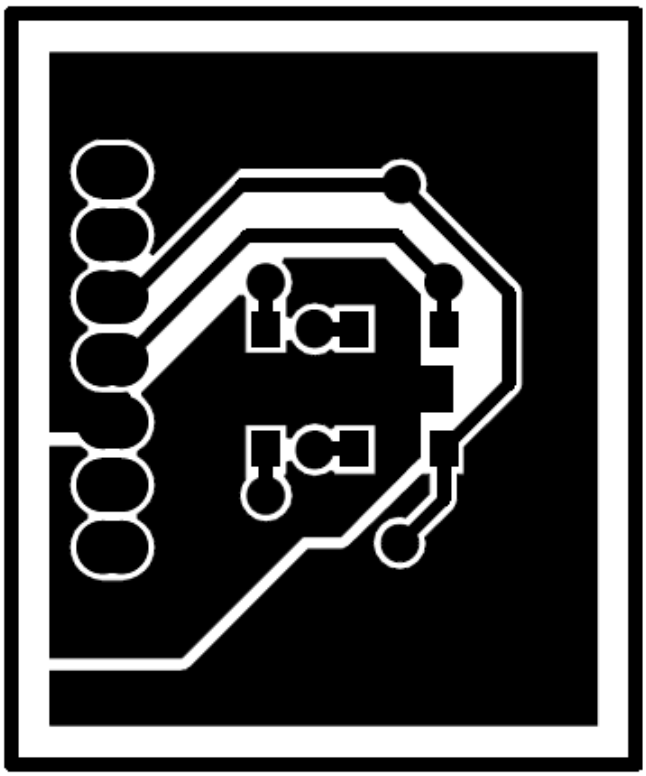


Figure 81. NJL5310R Sensor Board Top Copper

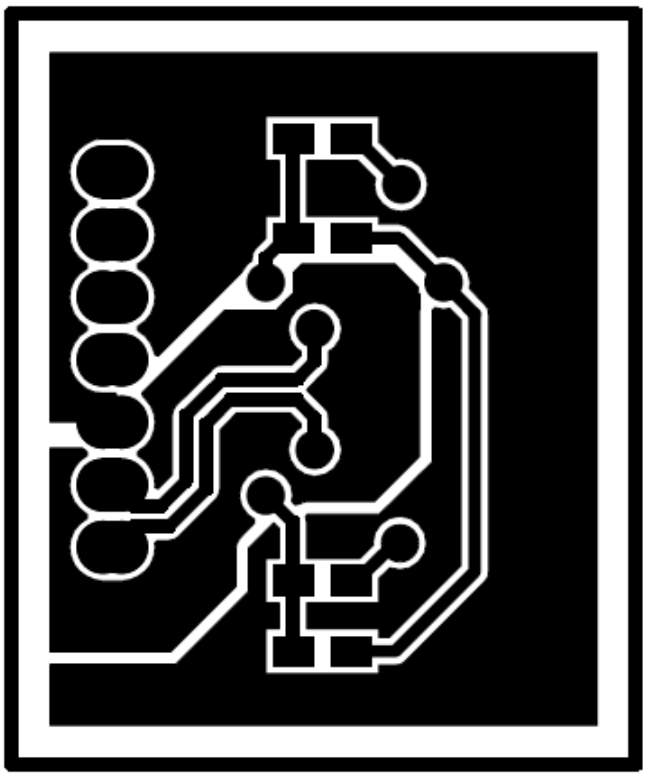


Figure 82. NJL5310R Sensor Board Bottom Copper

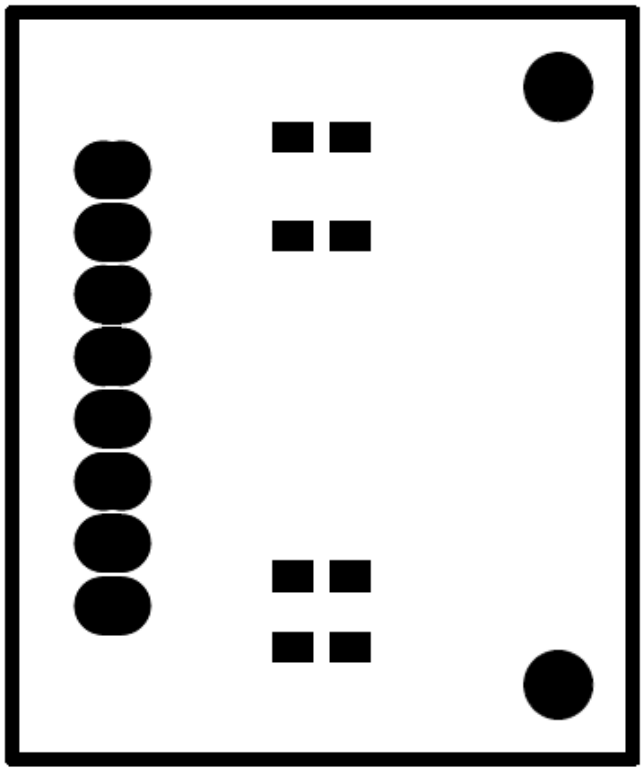


Figure 83. NJL5310R Sensor Board Bottom Solder Mask

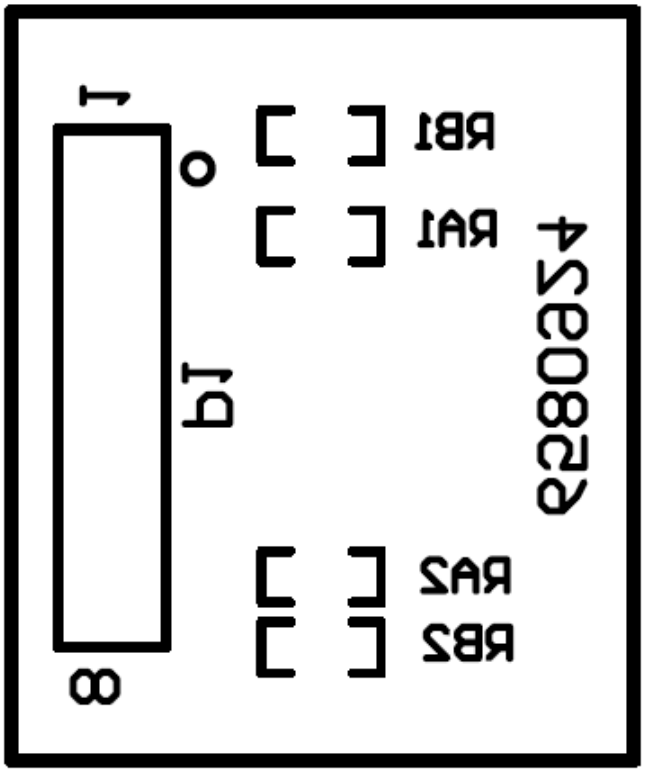


Figure 84. NJL5310R Sensor Board Bottom Silk Screen

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12.4 Schematics

This section includes the AFE4403EVM, SFH7050 sensor board, and NJL5310R sensor board schematics.

12.4.1 AFE4403EVM Schematics

Figure 85 through Figure 88 illustrate the AFE4403EVM schematics.

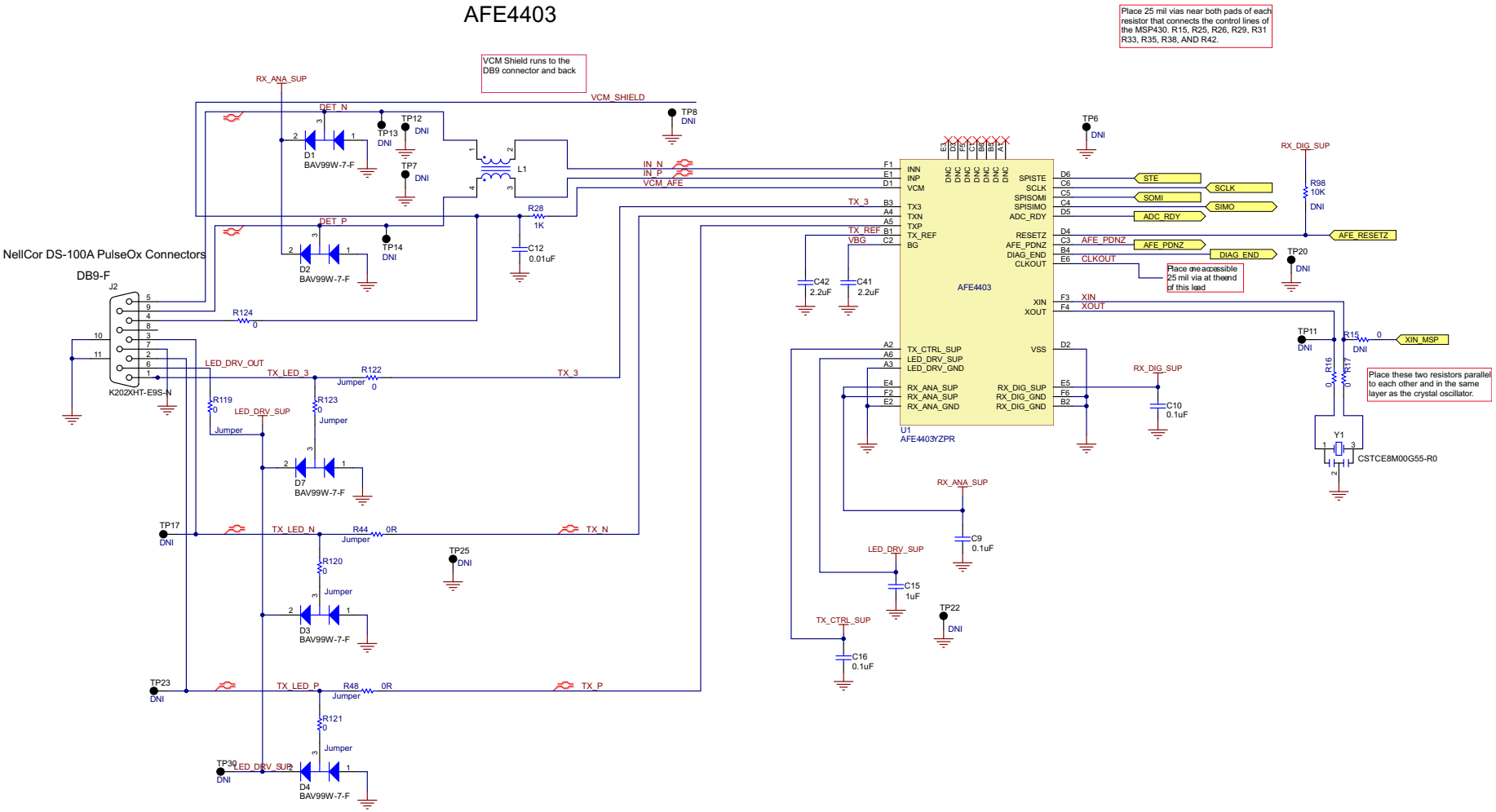


Figure 85. AFE4403EVM Schematics (1 of 4)

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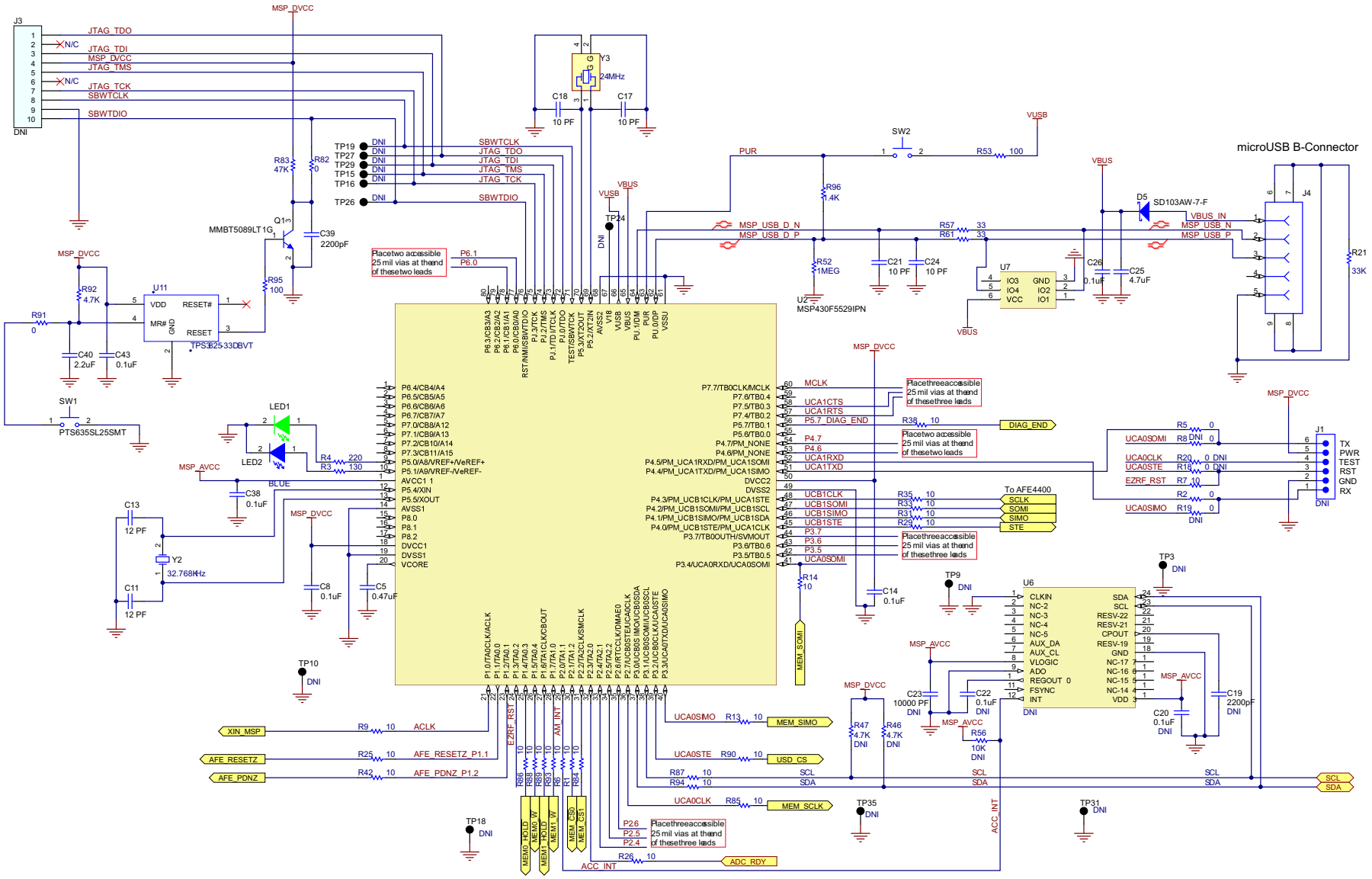


Figure 86. AFE4403EVM Schematics (2 of 4)

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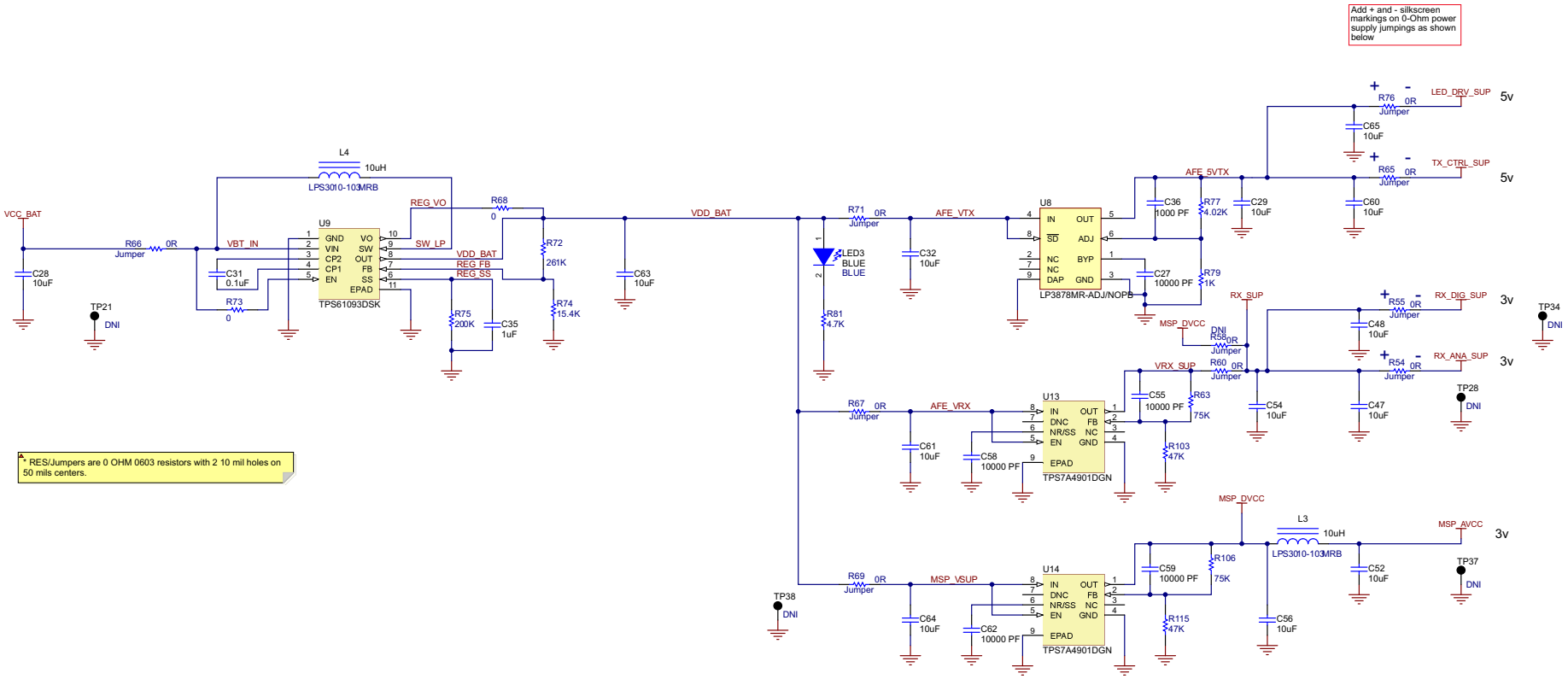


Figure 87. AFE4403EVM Schematics (3 of 4)

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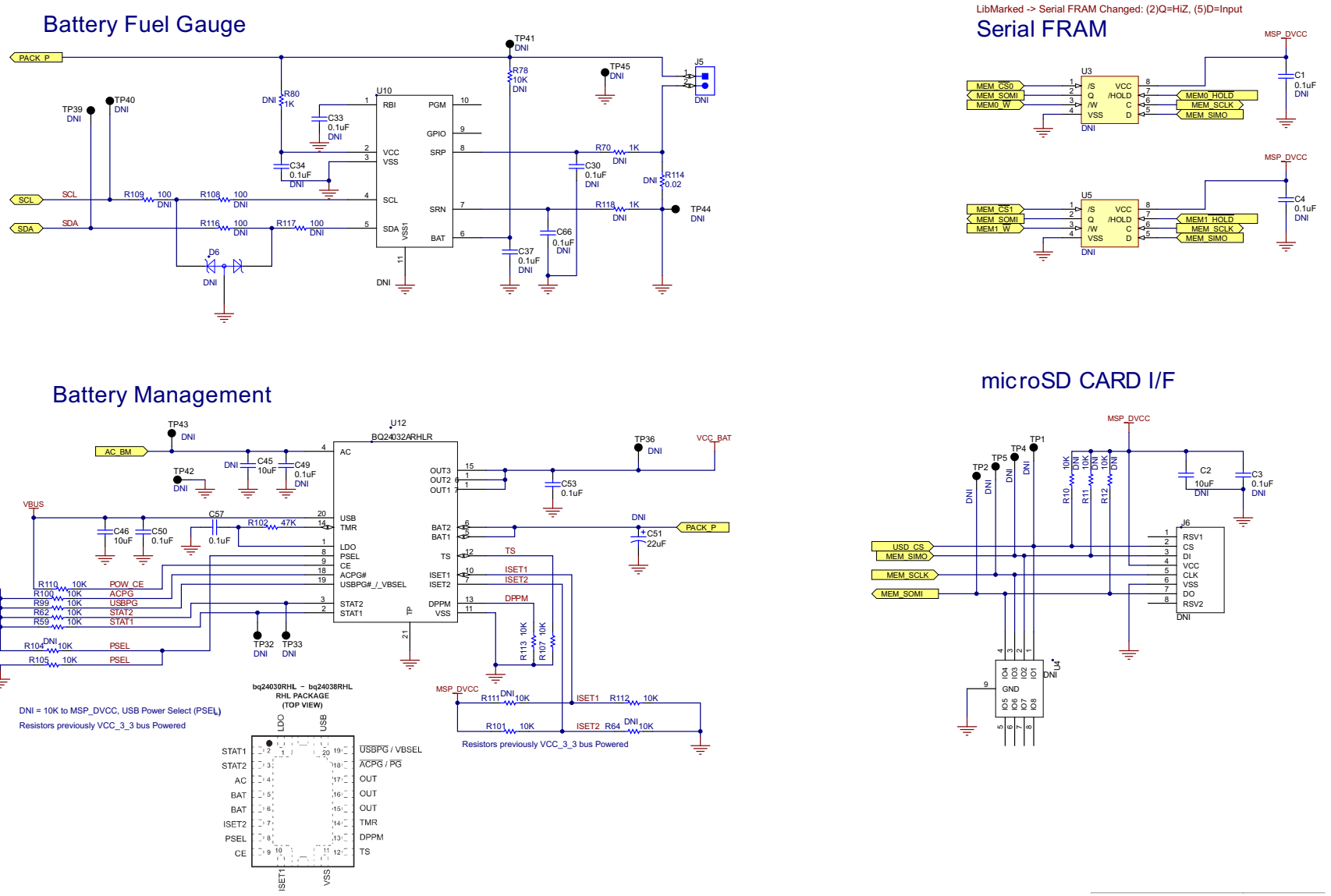


Figure 88. AFE4403EVM Schematics (4 of 4)

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12.4.2 SFH7050 Sensor Board Schematic

Figure 89 illustrates the SFH7050 sensor board schematic.

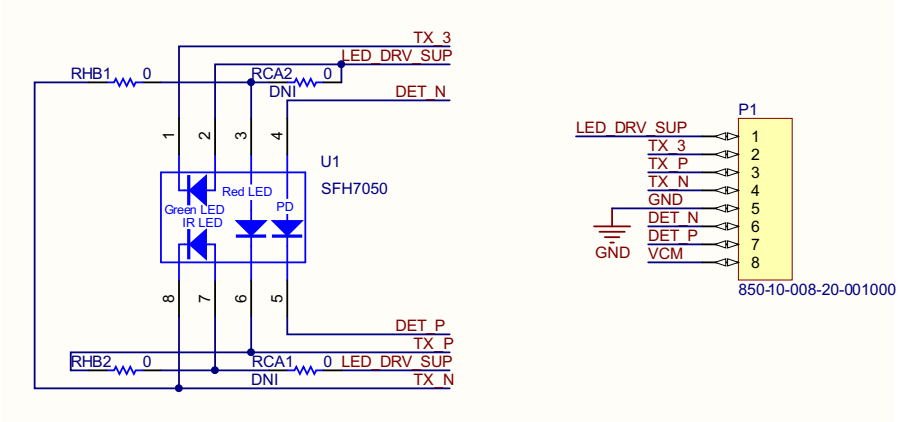


Figure 89. SFH7050 Sensor Board Schematic

12.5 NJL5310R Sensor Board Schematic

Figure 90 illustrates the NJL5310R sensor board schematic.

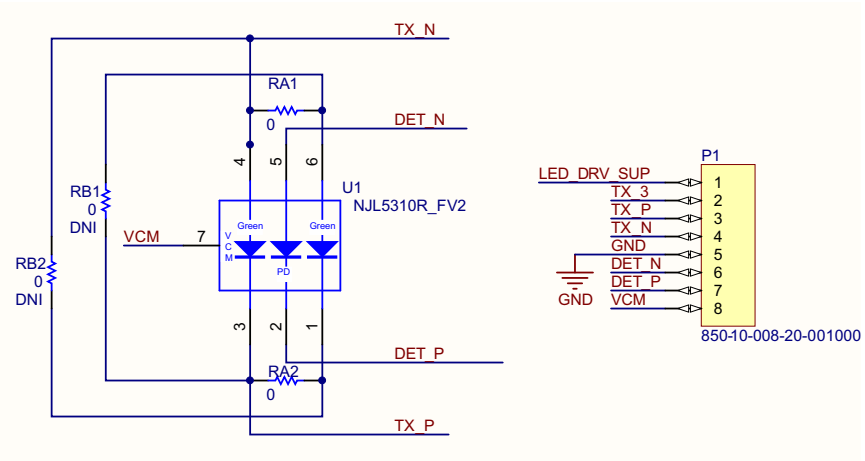


Figure 90. NJL5310R Sensor Board Schematic

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Revision History

Changes from Original (June 2014) to A Revision **Page**

- Changed JRC to NJRC globally, beginning in *AFE4403EVM Kit Contents* section. 5
- Changed TBD to 'Y' in RoHS column, row number 3 in the *OSRAM SFH7050 Sensor Board Bill of Materials* table. 54
- Changed the Description, RoHS, Manufacturer, and PartNumber columns in row 3 of the *NJRC NJL5310R Sensor Board Bill of Materials* table. 54

Revision History

Changes from A Revision (July 2014) to B Revision **Page**

- Changed AFE4403.inf to AFE44xx.inf, in step 4..... 12
- Changed *USB Driver Installation - Screen 4* image. 13
- Changed *Device Manager Screen* image..... 14

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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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.

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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 a special agreement specifically governing such use.

Only those TI components which 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 which have ***not*** been so designated is solely at the Buyer's risk, and that 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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