

AFE4404 Development Guide

This user's guide describes the characteristics, operation, and use of the AFE4404 EVM demonstration kit. This demonstration kit is an evaluation module for the AFE4404 device. The family of devices are fully-integrated AFE, ideally suited for Optical Heart Rate monitoring and 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
AFE4404	SBAS689

Contents

1	AFE4404 EVM Overview	4
1.1	Important Disclaimer Information	4
2	Overview	4
2.1	Introduction	4
2.2	AFE4404 EVM Kit Contents	5
2.3	Features Supported in This Version.....	5
2.4	AFE4404 EVM Evaluation	5
3	Software Installation	10
3.1	Minimum Requirements	10
3.2	Installing the Software (PC Application).....	11
3.3	Installing the USB Drivers	16
4	Running the Software.....	26
4.1	Overview of the Features	27
5	AFE4404 EVM Hardware	37
5.1	Power Supply	38
5.2	Clock	39
5.3	Accessing AFE4404 Digital Signals	39
5.4	USB Interface	39
5.5	On-Board Key Interface	39
5.6	Visual Indication	39
6	USB-Based Firmware Upgrade	39
7	AFE4404 EVM Firmware Upgrade Without GUI	42
8	Connector Interface	45
8.1	Micro-USB Connector	45
8.2	10-Pin Connector.....	46
9	AFE4404 EVM FAQs	47
9.1	ADC_RDY Signal.....	47
9.2	Automation of Register Read and Write Operations.....	47
9.3	Optimum Viewing Experience on Windows 7 OS.....	47
9.4	Windows 8 Support for Device GUIs	48
9.5	COM Port.....	59
10	Bill of Materials	60
11	PCB Layouts and Schematics	64

Pentium, Celeron are registered trademarks of Intel Corporation.
Microsoft, Windows are registered trademarks of Microsoft Corporation.

11.1	AFE4404 EVM PCB Layouts	64
11.2	Sensor Board Layouts	67
11.3	Schematics.....	69
11.4	Sensor Board Schematic.....	73

List of Figures

1	AFE4404 Demonstration Kit.....	5
2	NJRC NJL5513R Sensor Board LED Connections	6
3	Setup for Obtaining Measurements from the Wrist.....	7
4	Pin 1 Connections	8
5	Connections	8
6	Sensor On with Black Electrical Tape.....	9
7	Setting Sensor Board on the wrist.....	9
8	Sample Waveform of Green LED Captured on the Wrist With NJRC NJL5513R	10
9	PC Application Installation – Installation Directory.....	11
10	PC Application Installation – Installation Directory.....	12
11	PC Application Installation – License Agreement.....	13
12	Adding or Changing.....	14
13	PC Application Installation – Installation Complete	15
14	PC Application Installation – Installation complete.....	16
15	USB Driver Installation - Screen 1 (Windows 7 OS only).....	17
16	USB Driver Installation - Screen 2	18
17	USB Driver Installation - Screen 3	19
18	Windows Publisher Verification Warning.....	20
19	USB Driver Installation - Screen 4	21
20	Device Manager Screen.....	21
21	Windows 8 Installing Unsigned Drivers - Screen 1	22
22	Windows 8 Installing Unsigned Drivers - Screen 2	23
23	Windows 8 Installing Unsigned Drivers - Screen 3	23
24	Windows 8 Installing Unsigned Drivers - Screen 4	24
25	Windows 8 Installing Unsigned Drivers - Screen 5	24
26	Windows 8 Installing Unsigned Drivers - Screen 6	25
27	Windows 8 Installing Unsigned Drivers - Screen 7	26
28	AFE4404 EVM Not Connected Error Message	26
29	Product Safety Warnings, Restrictions, and Disclaimers	27
30	AFE4404: Device Configuration: Global Settings	29
31	AFE4404: Device Configuration: Tx Stage	30
32	AFE4404: Device Configuration: Rx Stage	31
33	AFE4404: Device Configuration: Timing Controls	32
34	Device Configuration: Low Level Configuration	33
35	ADC Capture and Analysis Tab	35
36	Scope Analysis: Test Results.....	35
37	Save Tab	36
38	AFE4404 EVM Block Diagram	38
39	PC Application Firmware Upgrade – 1	40
40	PC Application Firmware Upgrade – 2	40
41	PC Application Firmware Upgrade – 3	41
42	PC Application Firmware Upgrade – 4	42
43	Firmware Loader Application: Select Firmware	43

44	Firmware Loader Application: Found Device	43
45	Firmware Loader Application: Programming Status	44
46	USB Micro Connector Pin Outs	45
47	10-Pin Connector	46
48	ADC_RDY Waveform at 100-Hz PRF	47
49	Setting Font Size on Windows 7 Operating System.....	48
50	Broken Arrow Error.....	49
51	Method 1 (Screen 1)	50
52	Method 1 (Screen 2)	51
53	Method 1 (Screen 3)	52
54	Method 1 (Screen 4)	53
55	Method 1 (Screen 5)	54
56	Method 1 (Screen 6)	55
57	Method 2 (Screen 1)	56
58	Method 2 (Screen 2)	57
59	Method 2 (Screen 3)	58
60	Method 2 (Screen 4)	59
61	AFE4404 EVM Top Overlay	64
62	Top Solder.....	64
63	Top Copper (Layer 1).....	65
64	Bottom Copper (Layer 4)	65
65	Bottom Solder.....	66
66	Bottom Overlay	66
67	Sensor Board Top Silk Screen	67
68	Sensor Board Top Solder Mask	67
69	Sensor Board Top Copper	67
70	Sensor Board Bottom Copper	67
71	Sensor Board Bottom Solder Mask	67
72	Sensor Board Bottom Silk Screen	67
73	AFE4404 EVM Schematics (1 of 4).....	69
74	AFE4404 EVM Schematics (2 of 4).....	70
75	AFE4404 EVM Schematics (3 of 4).....	71
76	AFE4404 EVM Schematics (4 of 4).....	72
77	Sensor Board Schematic	73

List of Tables

1	Save Tab Control Descriptions	37
2	AFE4404 Digital Signals.....	39
3	AFE4404 EVM Switches	39
4	USB Micro Connector Pin Out Descriptions	45
5	10-Pin Connector Pin Descriptions	46
6	Troubleshoot and Links.....	59
7	AFE4404 EVM Bill of Materials	60
8	Sensor Board Bill of Materials	63

1 AFE4404 EVM Overview

1.1 Important Disclaimer Information

CAUTION

The AFE4404 EVM is intended for feasibility and evaluation testing only in laboratory and development environments. This product is not for diagnostic use. This product is not for use with a defibrillator.

Only use the AFE4404 EVM under the following conditions:

- The AFE4404 EVM demonstration kit is intended only for electrical evaluation of the features of the AFE4404 devices in a laboratory, simulation, or development environment.
- The AFE4404 EVM demonstration kit is not intended for direct interface with a patient, or patient diagnostics.
- The AFE4404 EVM demonstration kit is intended for development purposes **only**. It is not intended to be used as all or part of an end-equipment application.
- The AFE4404 EVM demonstration kit should be used only by qualified engineers and technicians who are familiar with the risks associated with handling electrical and mechanical components, systems, and subsystems.
- The user is responsible for the safety of themselves, fellow employees and contractors, and co-workers when using or handling the AFE4404 EVM. 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.

2 Overview

2.1 Introduction

The EVM is intended for evaluating AFE4404 device. The family of devices consist of a low-noise receive channel, the LED transmit section, and diagnostics for photodiode short fault detection. The AFE4404 supports three LEDs and a single photodiode. The AFE4404 has a highly-configurable timing controller, enabling complete control of the device's timing characteristics. The device can be clocked by an external clock or by internal oscillator. The device communicates to an external host processor using the I²C interface. The purpose of the EVM is to expedite evaluation and system development activities related to AFE4404 devices. The demonstration kit is shown in [Figure 1](#).

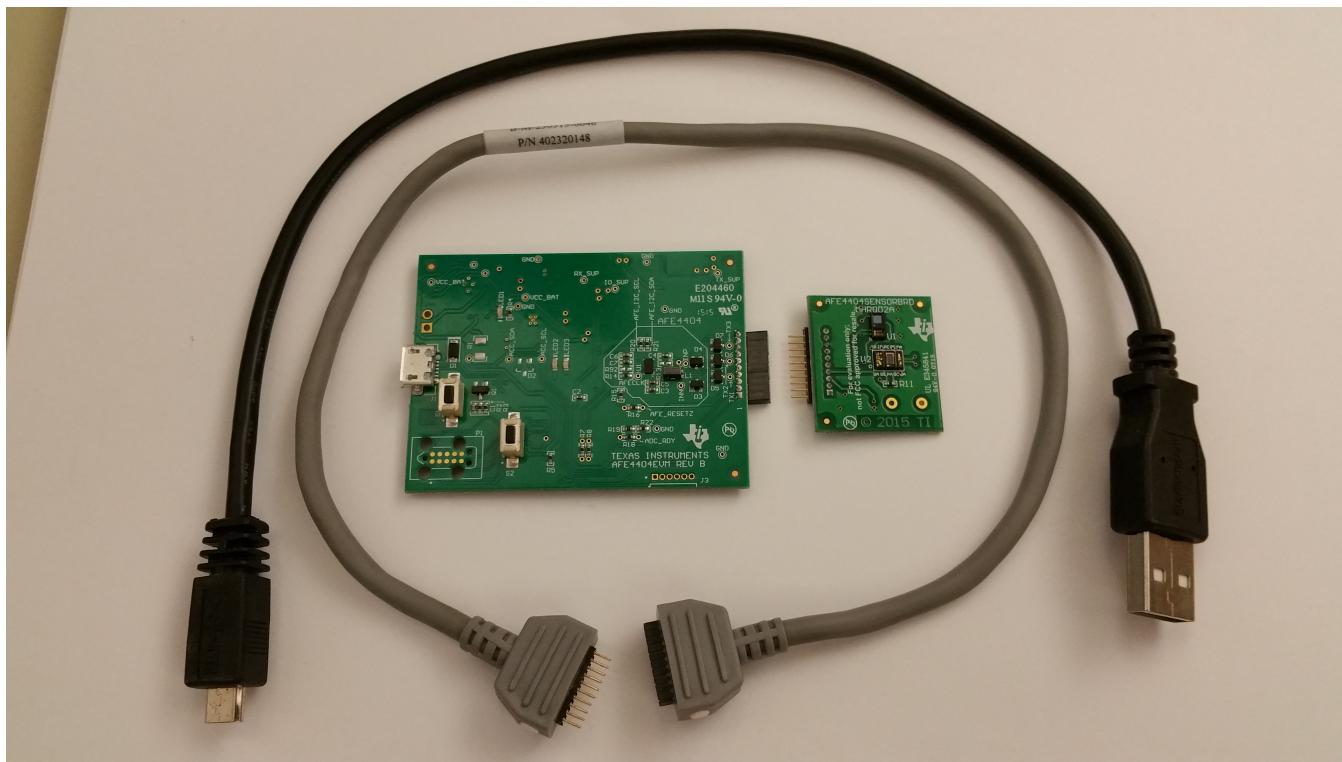


Figure 1. AFE4404 Demonstration Kit

Throughout the document, the term demonstration kit is synonymous with AFE4404 EVM.

2.2 **AFE4404 EVM Kit Contents**

- AFE4404 EVM Demonstration Kit
- USB-to-micro USB cable
- 10 pin to 10 pin sensor cable
- AFE4404 sensor board

2.3 **Features Supported in This Version**

1. Acquire data at up to 1000 sps in evaluation mode
2. USB-based power and PC application connectivity
3. Access to all AFE4404 registers via an easy-to-use GUI
4. Built-in time domain, histogram, and FFT on the PC application
5. USB-based firmware upgrade option

2.4 **AFE4404 EVM Evaluation**

Use the following steps as a quick start guide for AFE4404 EVM reflective sensing:

1. Install the PC application software
 - (a) Before installing the software, make sure the AFE4404 EVM is **not** connected to the PC.
 - (b) Run the executable and follow the prompts to install the software.
 - (c) The default installation directory will be:
 - On a Microsoft® Windows® XP machine – C:\Program Files\Texas Instruments\AFE4404 EVM GUI
 - On a Windows 7 machine – C:\Program Files(x86)\Texas Instruments\AFE4404 EVM GUI

- (d) The detailed steps for installing the USB drivers are outlined in [Section 3.3](#).
2. Install the USB driver
 - (a) The communication interface between the AFE4404 EVM 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 AFE4404 EVM and PC application.
 - (b) Plugin the USB-to-mini USB cable to J1 of AFE4404 EVM and the other end to the USB port on the PC.
 - (c) Update the driver software from the Device Manager. The USB driver file AFE44xx.inf is located in the following directory:
 - On a Windows XP machine – C:\Program Files\Texas Instruments\AFE4404 EVM GUI\USB Driver
 - On a Windows 7 machine – C:\Program Files(x86)\Texas Instruments\AFE4404 EVM GUI\USB Driver
 - (d) The detailed steps for installing the USB drivers are outlined in [Section 3.3](#).
 3. Update the MSP430 firmware:
 - (a) Run AFE4404 EVM GUI.exe which is found in the chosen installation directory
 - On a Windows XP machine – C:\Program Files\Texas Instruments\AFE4404 EVM GUI
 - On a Windows 7 machine – C:\Program Files(x86)\Texas Instruments\AFE4404 EVM GUI
 - (b) Click on File at the top left of the window followed by *Firmware Upgrade*. A window pops up, click the **Continue** button.
 - (c) Click the **Browse** button and choose the desired hex file. This file should have a .txt extension (example: AFE4404_EVM_FW_V1.0.txt).
 - On a Windows XP machine – C:\Program Files\Texas Instruments\AFE4404 EVM GUI\Firmware Updater
 - On a Windows 7 machine – C:\Program Files(x86)\Texas Instruments\AFE4404 EVM GUI\Firmware Updater
 4. Test setup:
 - (a) The AFE4404 sensor board has two optical sensor modules: NJRC NJL5513R and OSRAM SFH7050. The NJRC sensor has two green LEDs and 1 red LED that are connected in parallel. Note that when in parallel, both LEDs represent LED1 and the red LED represents LED2. The OSRAM sensor has one infrared, one red, and one green LED. This sensor is configured in push-pull (common anode) mode. If the NJRC sensor is to be used, then make sure resistors R2, R4, R6, R8, and R10 are installed. If the OSRAM sensor is to be used, then make sure resistors R1, R3, R5, R7, and R9 are installed. By default, the NJRC sensor is used as shown in [Figure 2](#). The sensor board also has an option to use the BMA280, which is an accelerometer. This is uninstalled by default.

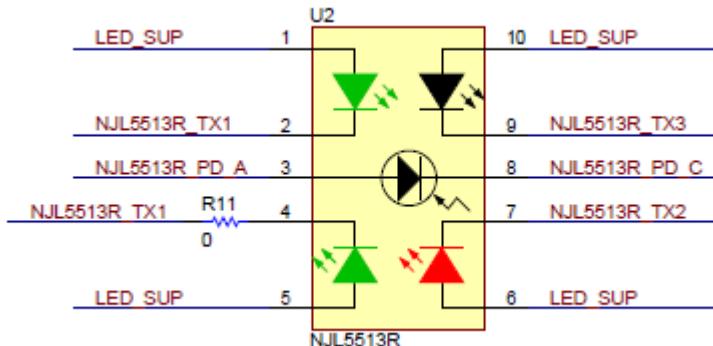


Figure 2. NJRC NJL5513R Sensor Board LED Connections

- (b) Connect the sensor module to the EVM. Make sure that the sensor is connected in the correct orientation – pin 1 should line up with the marking on the cable.

- (c) Place the sensor side of the sensor board on the wrist and tie it snugly. [Figure 3](#) 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.

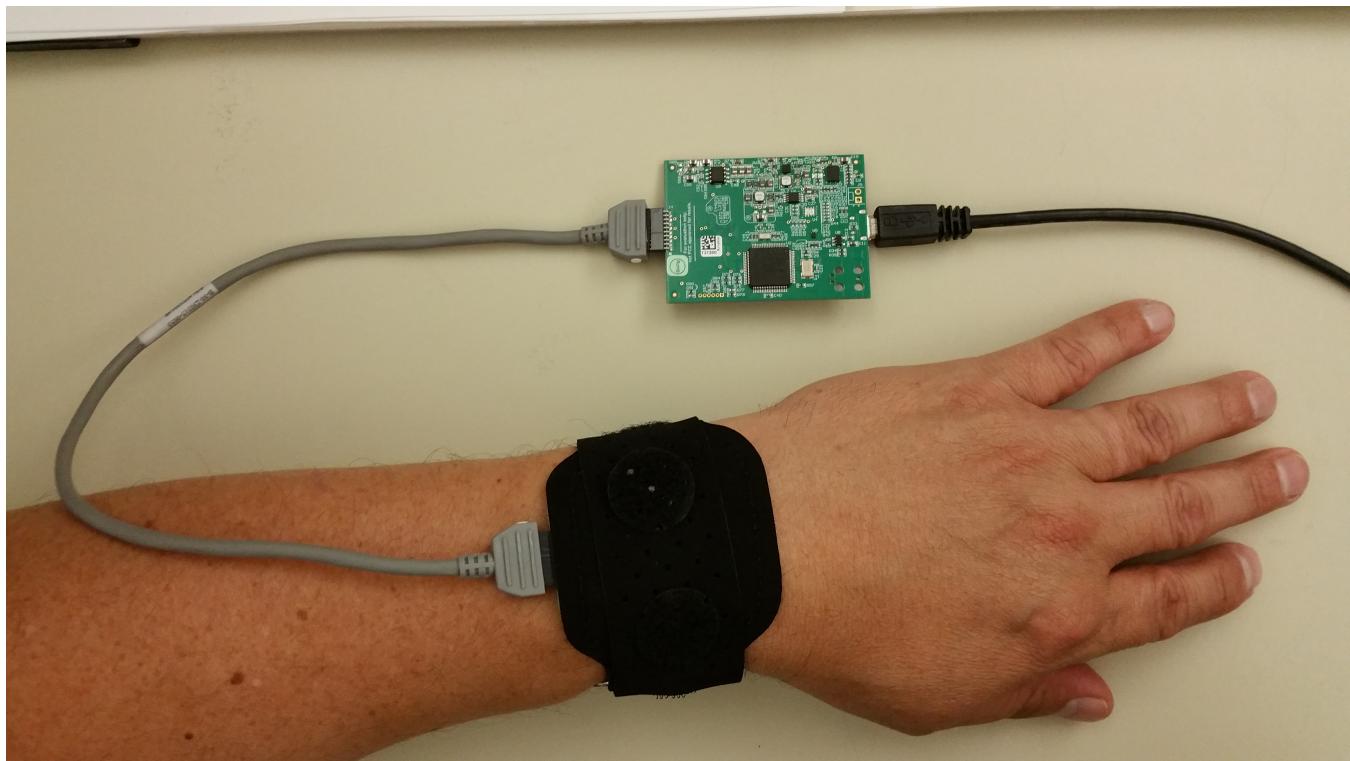


Figure 3. Setup for Obtaining Measurements from the Wrist

Note: [Figure 4](#) through [Figure 7](#) help get to [Figure 3](#).

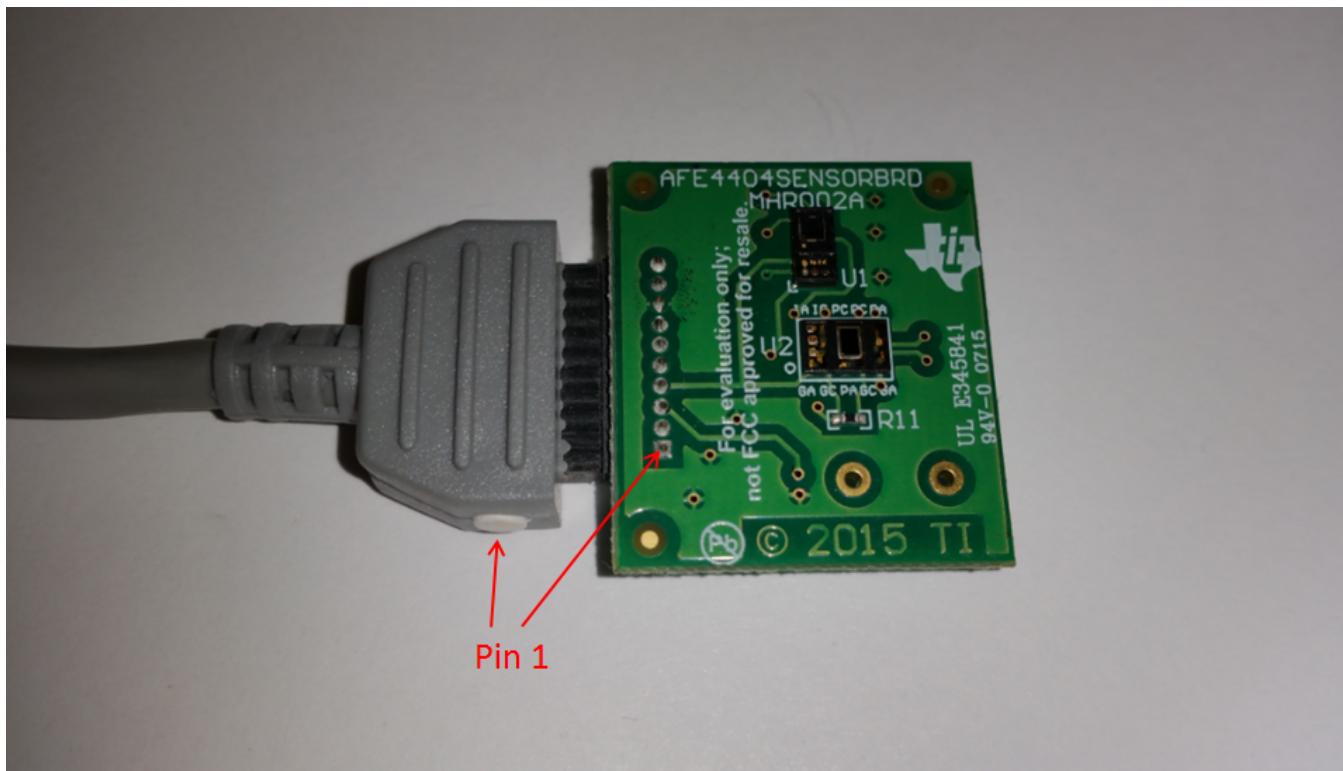


Figure 4. Pin 1 Connections

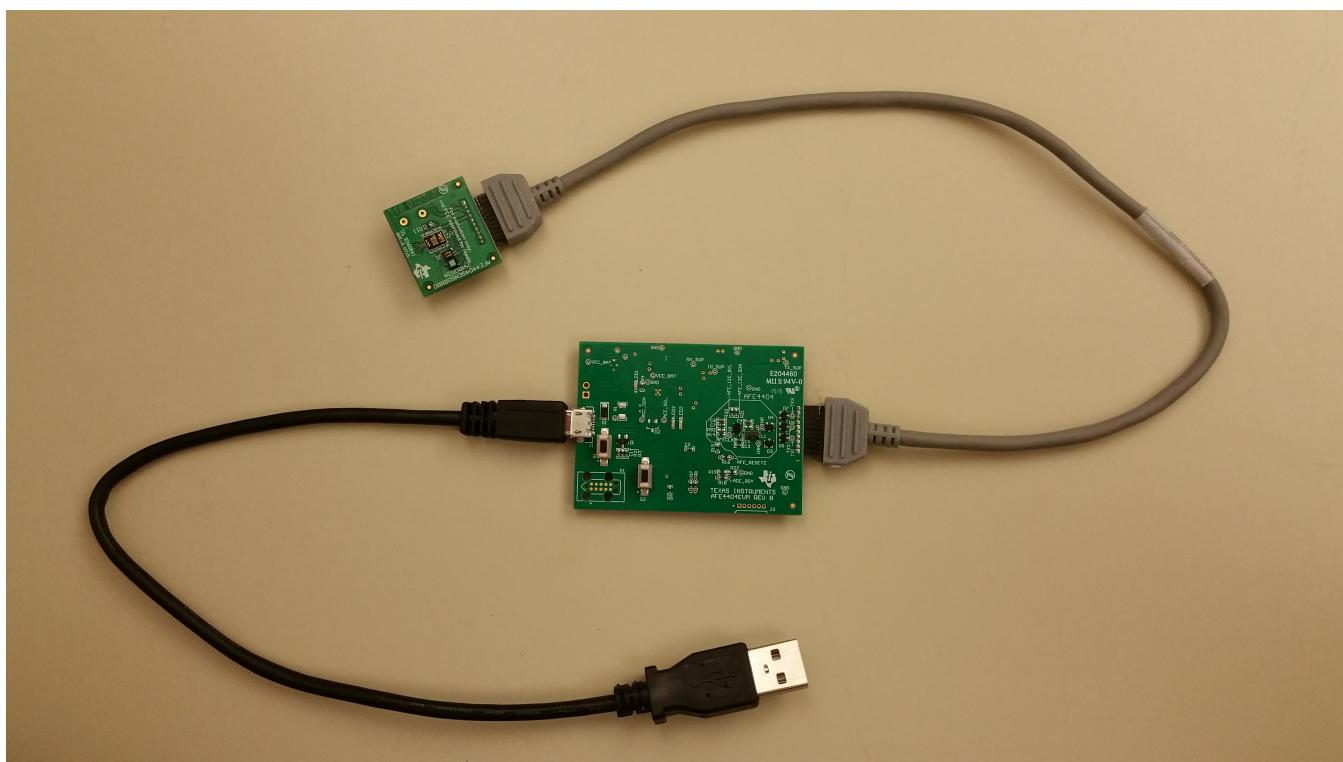


Figure 5. Connections

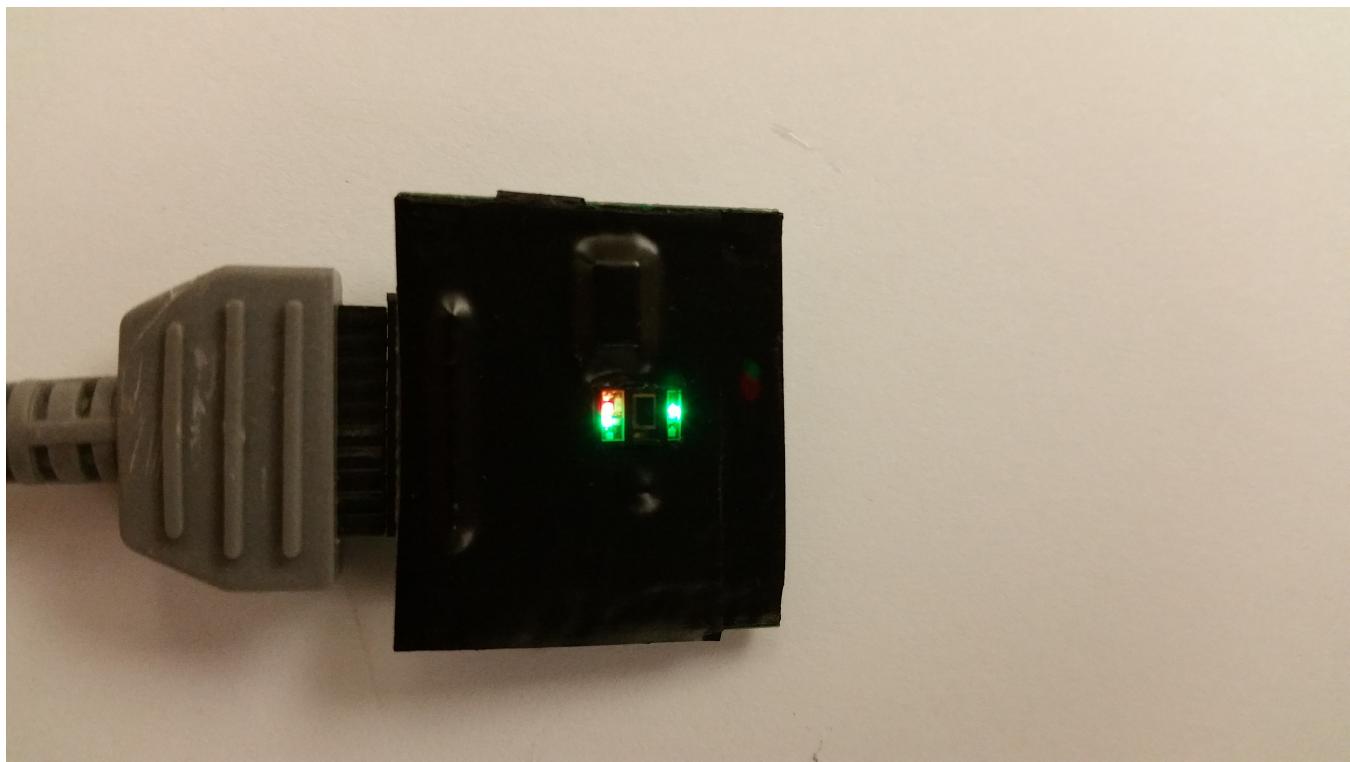


Figure 6. Sensor On with Black Electrical Tape

Note: Black tape is used to provide ground isolation.

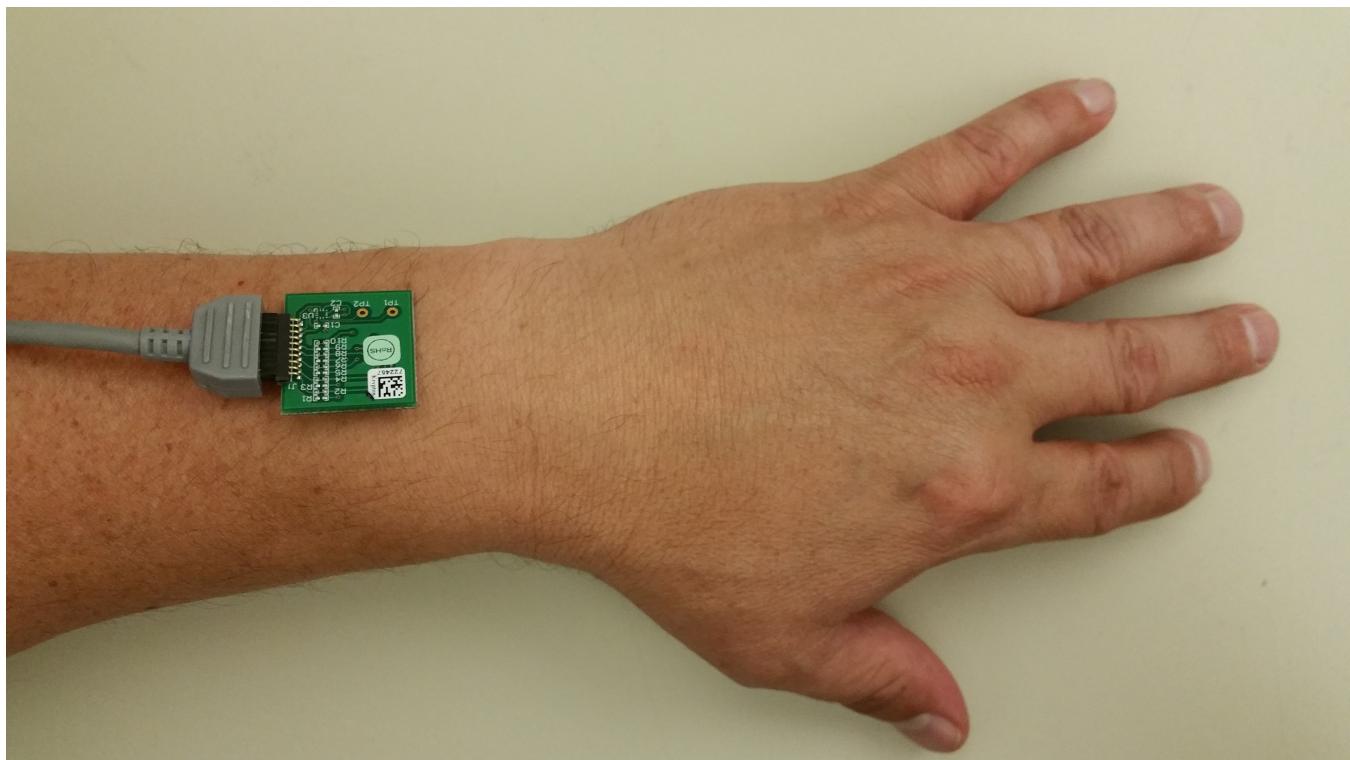


Figure 7. Setting Sensor Board on the wrist

5. Capturing data

- Run the *AFE4404 EVM GUI* found in the installation directory
- Click on the *ADC Capture & Analysis* tab near the top of the window
- Click the **Capture** button to begin capturing data. **Figure 8** shows a sample waveform:

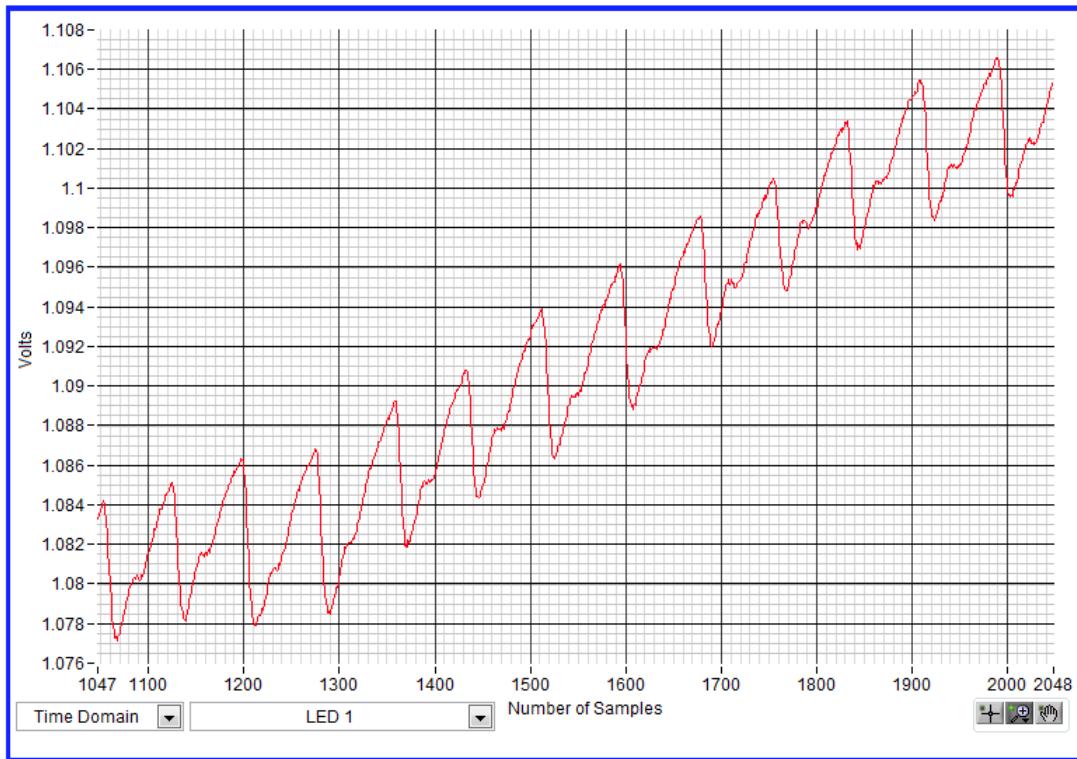


Figure 8. Sample Waveform of Green LED Captured on the Wrist With NJRC NJL5513R

3 Software Installation

The latest AFE4404 EVM PC application software (GUI) is available at www.ti.com. Download the latest file.

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 AFE4404 EVM 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 200MB 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 AFE4404 EVM is **not** connected to the PC. If using a machine with Windows 7 OS, TI recommends having administrator rights to avoid problems during installation. Double click the executable 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\AFE4404 EVM GUI
- On a Windows 7 machine – C:\Program Files(x86)\Texas Instruments\AFE4404 EVM GUI

The following steps ensure proper installation of the PC application.

1. Double click the executable from the Volume directory and follow the prompts to continue with the installation process.
2. Choose whether or not to create a Desktop Icon and click **Install**

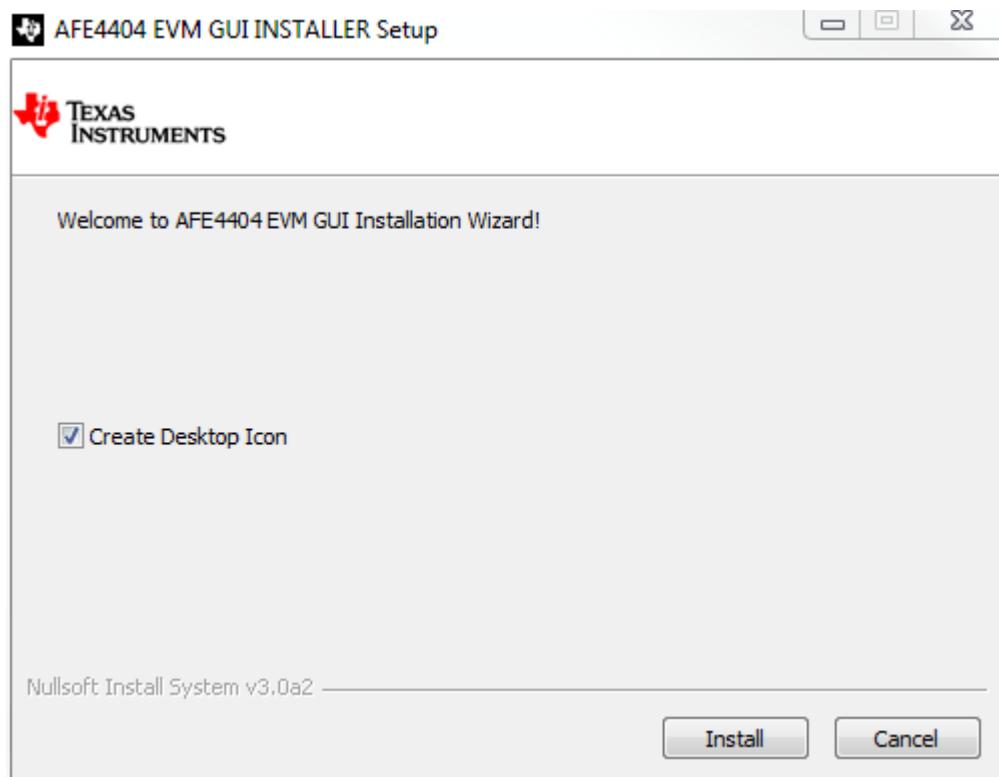


Figure 9. PC Application Installation – Installation Directory

Select the destination directory and click the **Next >>** button to begin the installation.

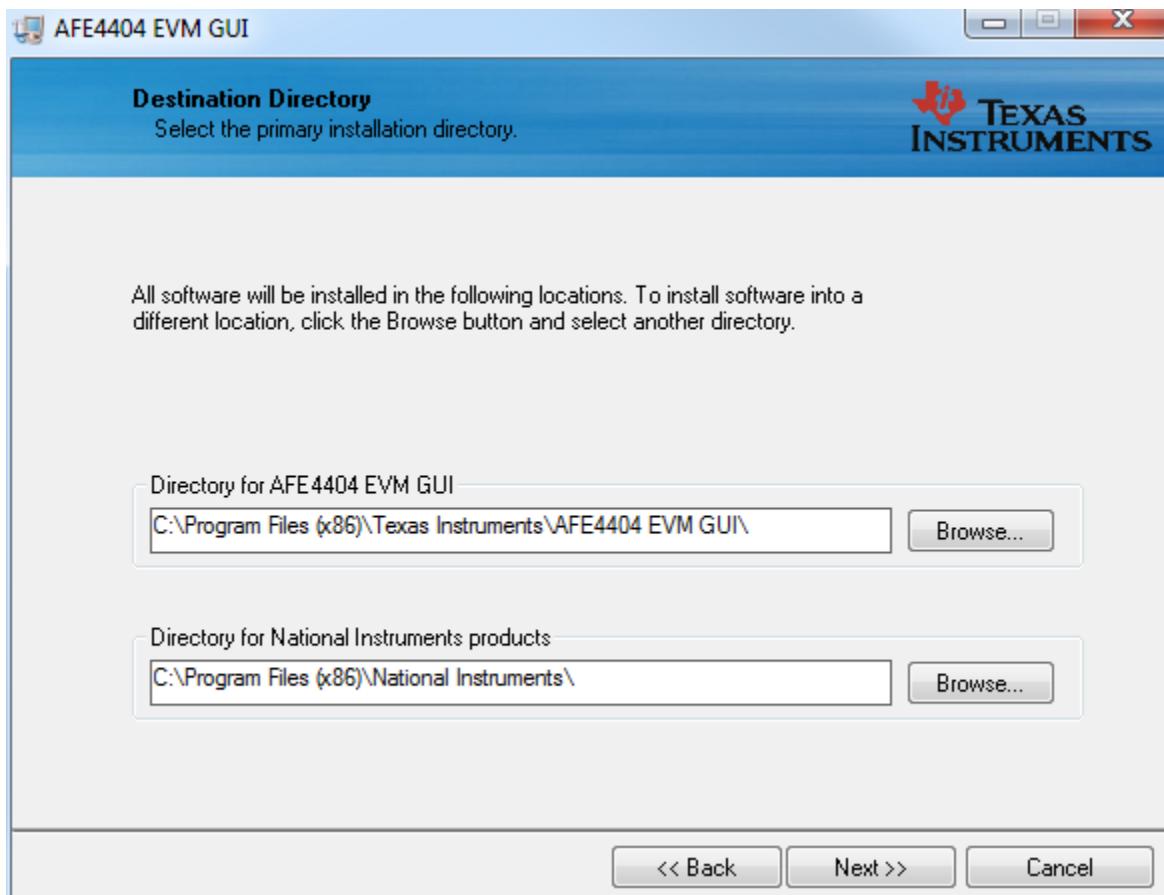


Figure 10. PC Application Installation – Installation Directory

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

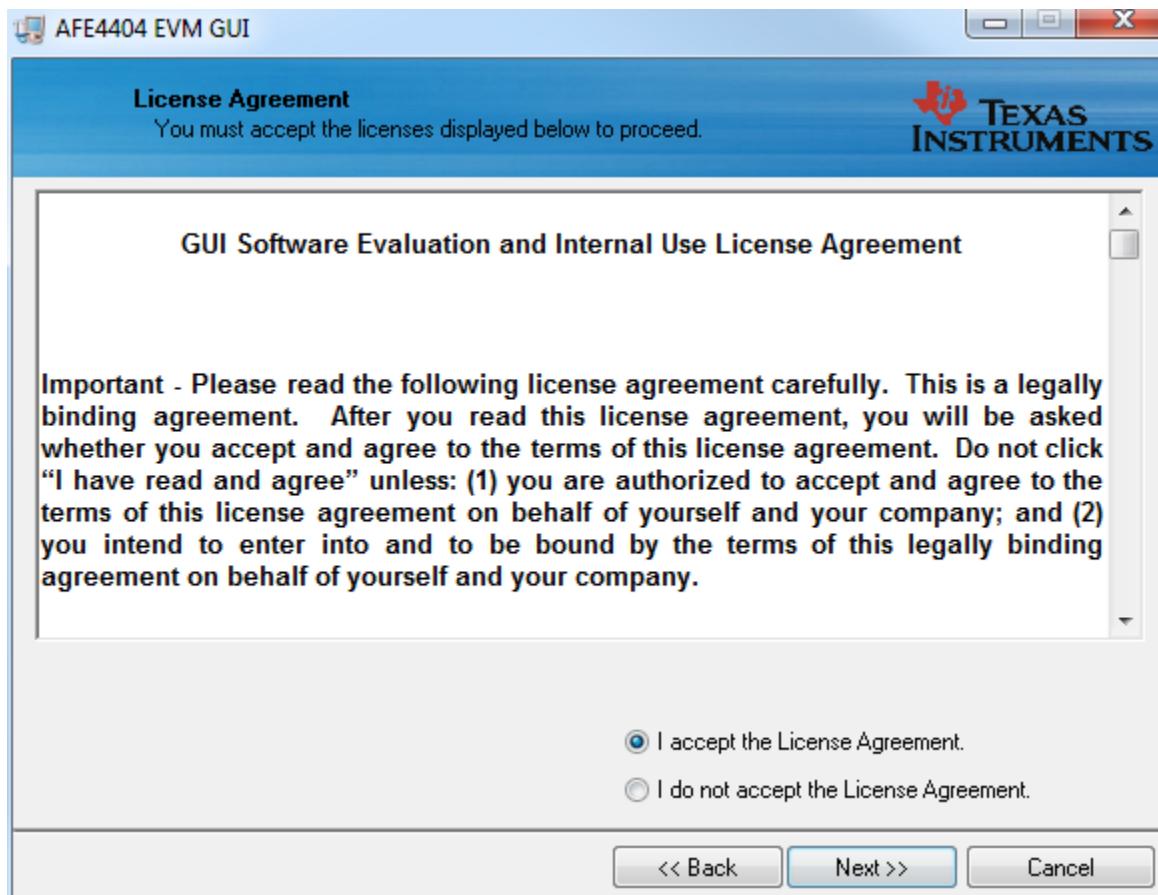


Figure 11. PC Application Installation – License Agreement

4. Click **Next>>** button to continue

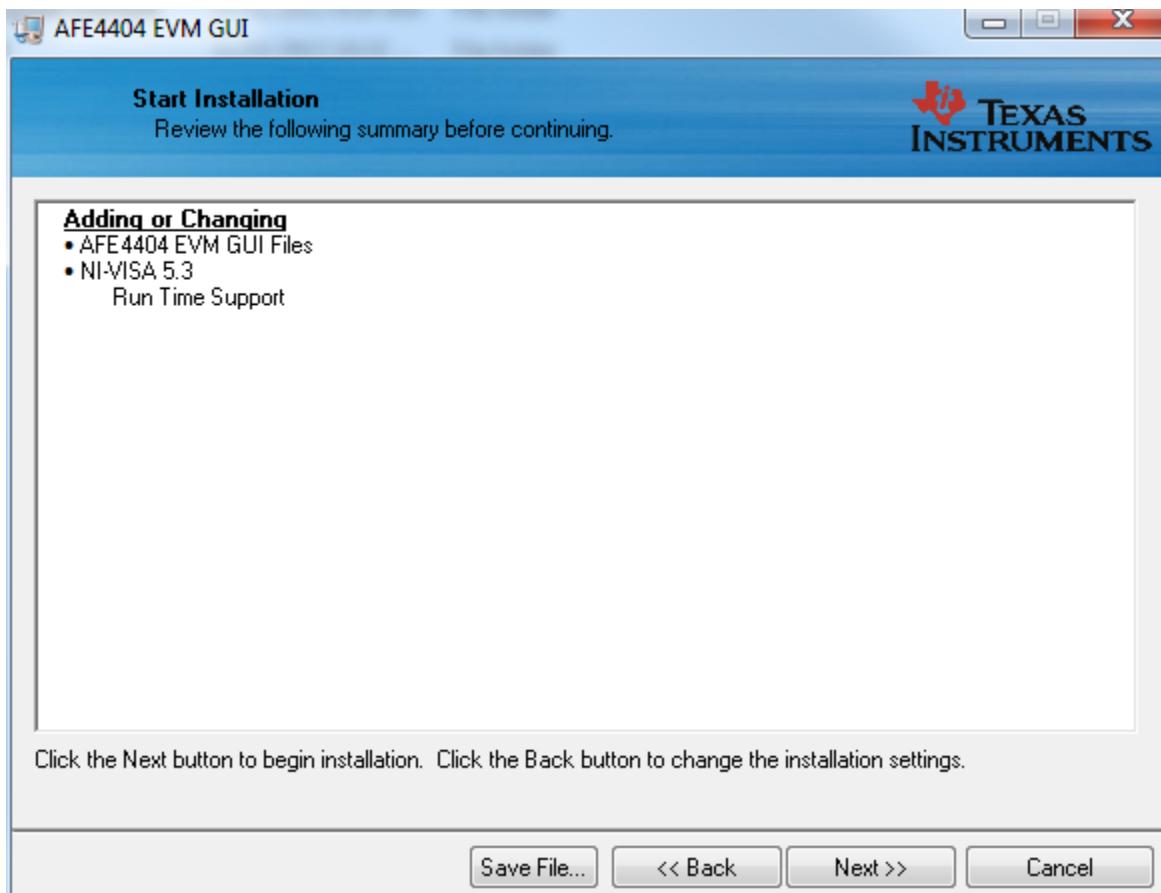


Figure 12. Adding or Changing

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

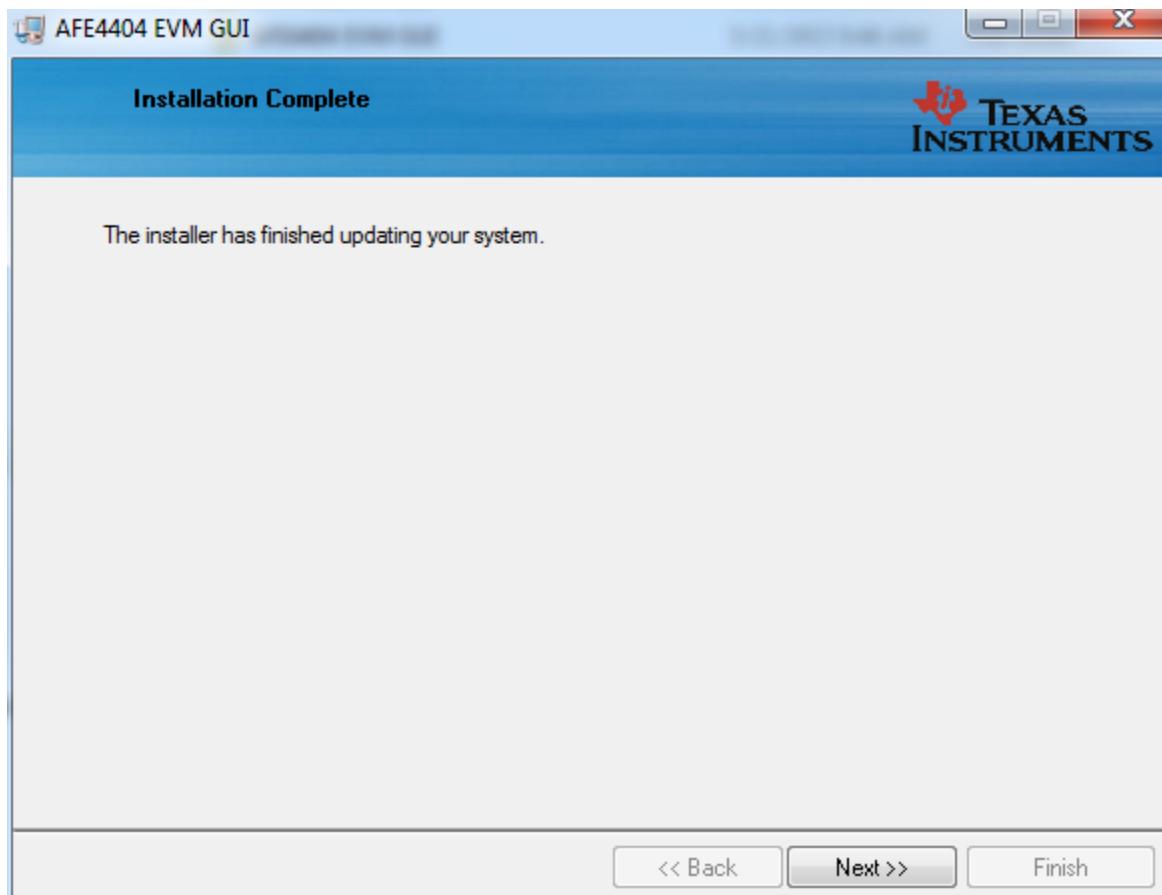


Figure 13. PC Application Installation – Installation Complete

Click **Close**. The PC application is now ready to use.

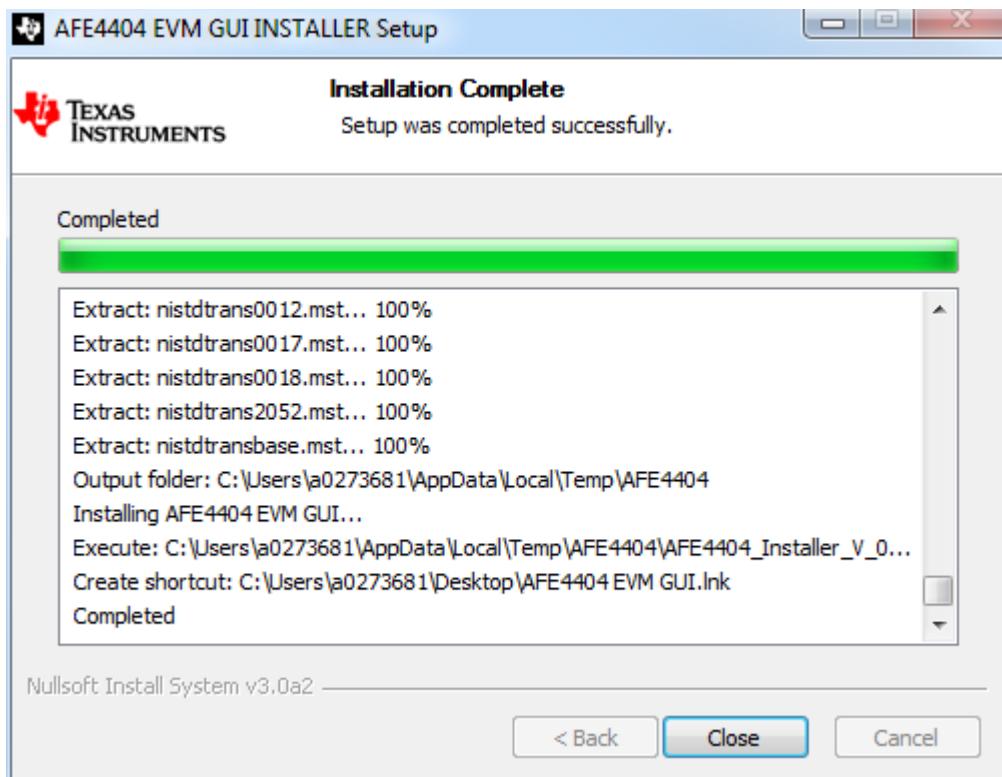


Figure 14. PC Application Installation – Installation complete

3.3 *Installing the USB Drivers*

The communication interface between the AFE4404 EVM 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 AFE4404 EVM and PC application.

Using the following steps ensures proper installation of the USB drivers:

1. Plugin the USB-to-mini USB cable to J1 of AFE4404 EVM and the other end to the USB port on the PC.
2. Windows 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 15](#). This step is not required for the Windows XP OS.

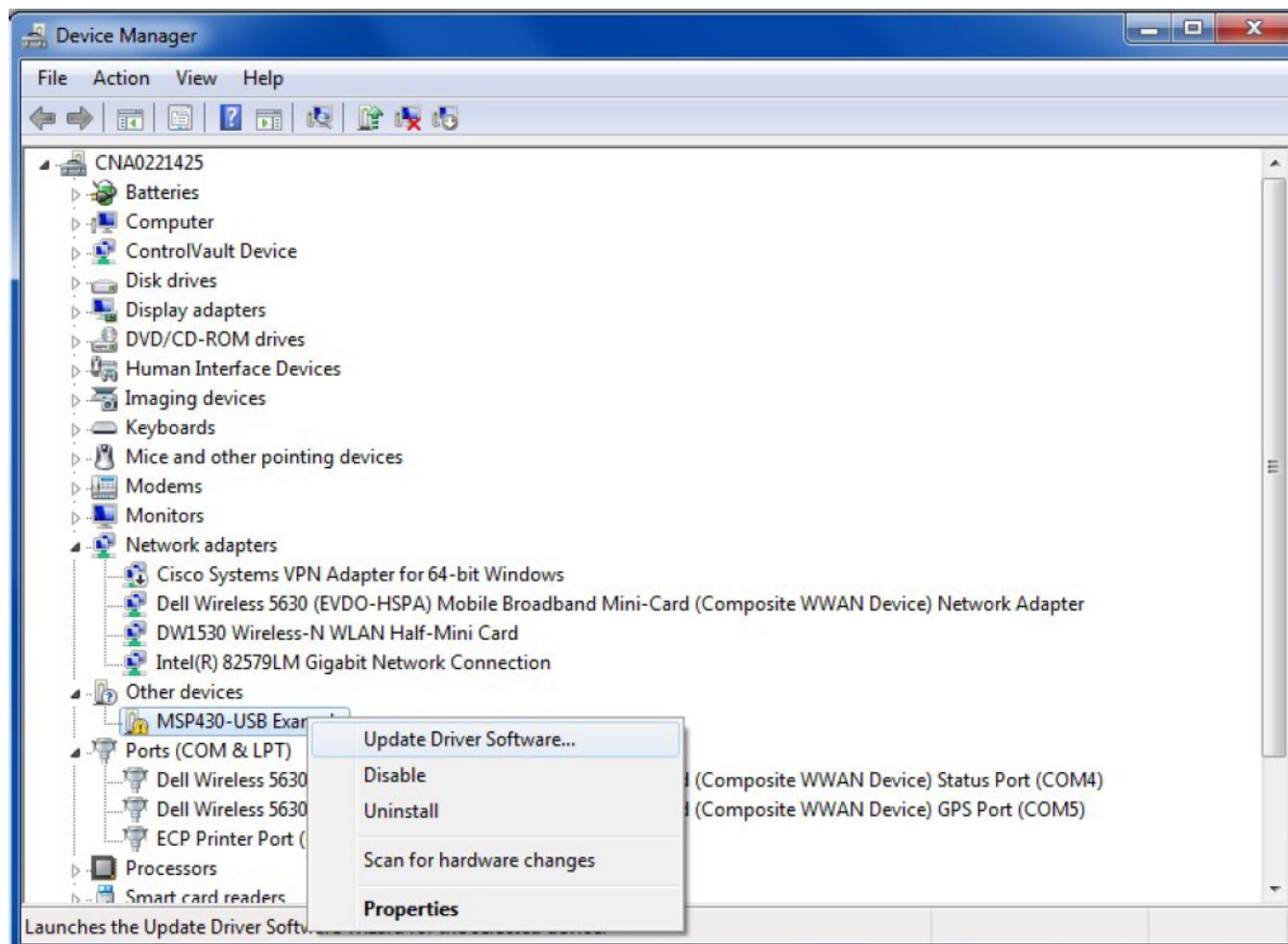


Figure 15. USB Driver Installation - Screen 1 (Windows 7 OS only)

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

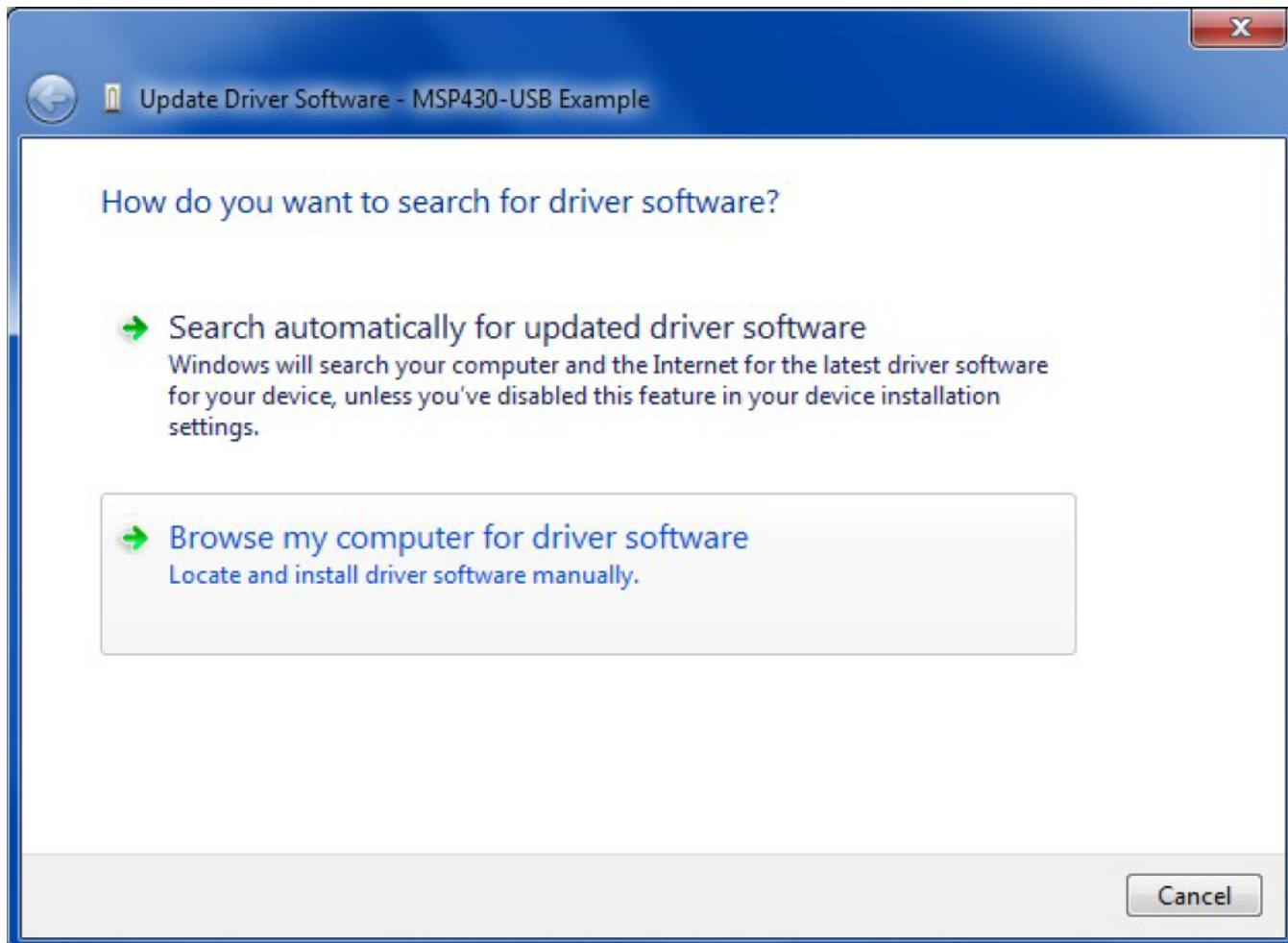


Figure 16. USB Driver Installation - Screen 2

4. As shown in [Figure 17](#), 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\AFE4404 EVM GUI\USB Driver*
 - On a Windows 7 machine – *C:\Program Files(x86)\Texas Instruments\AFE4404 EVM GUI\USB Driver*Click the **Next** button to continue. The Driver file is copied to the system directory after clicking the **Next** button.

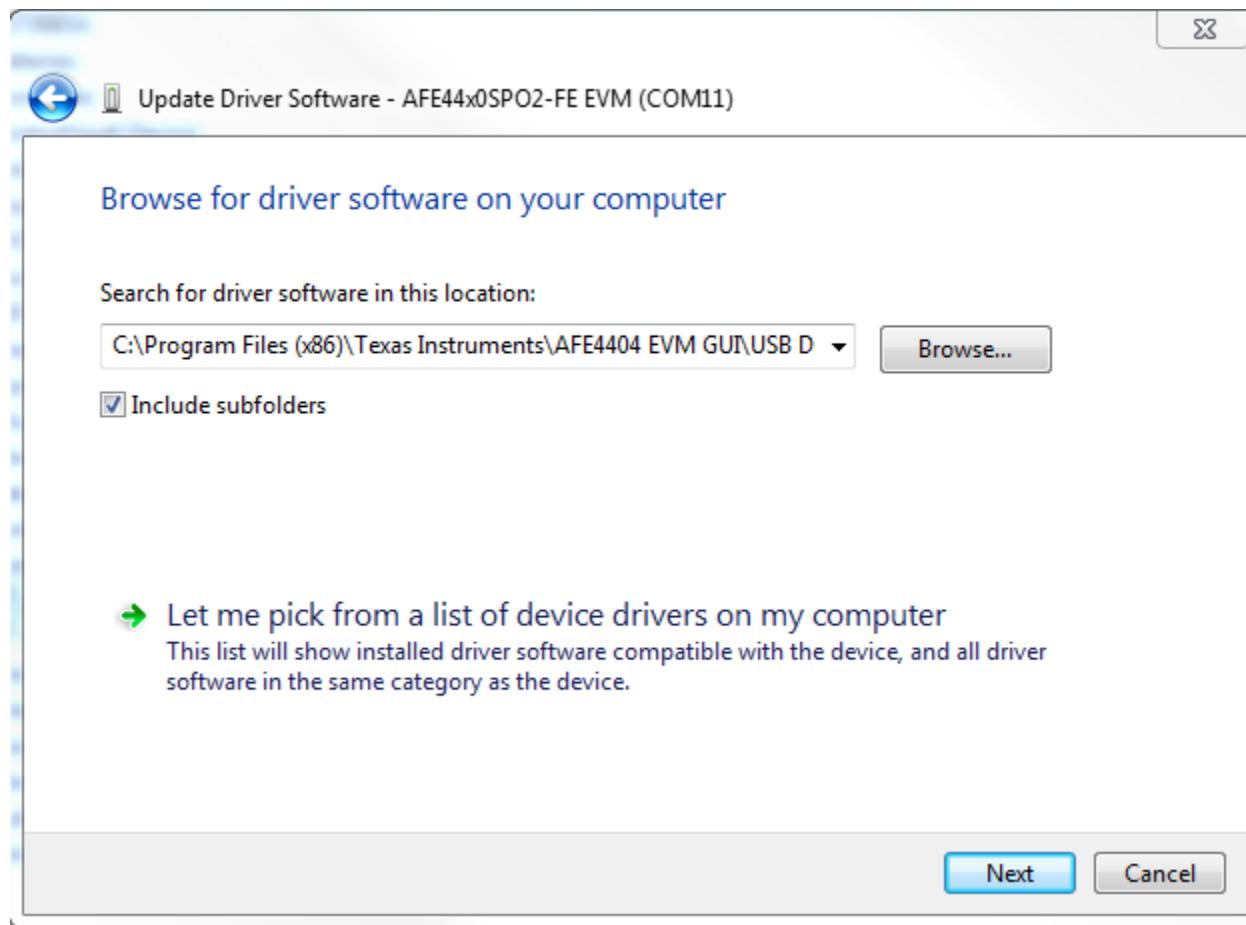


Figure 17. USB Driver Installation - Screen 3

5. There may be a warning that Windows cannot verify the publisher of this driver software, as shown in [Figure 18](#). Choose to install the driver software anyway to proceed.

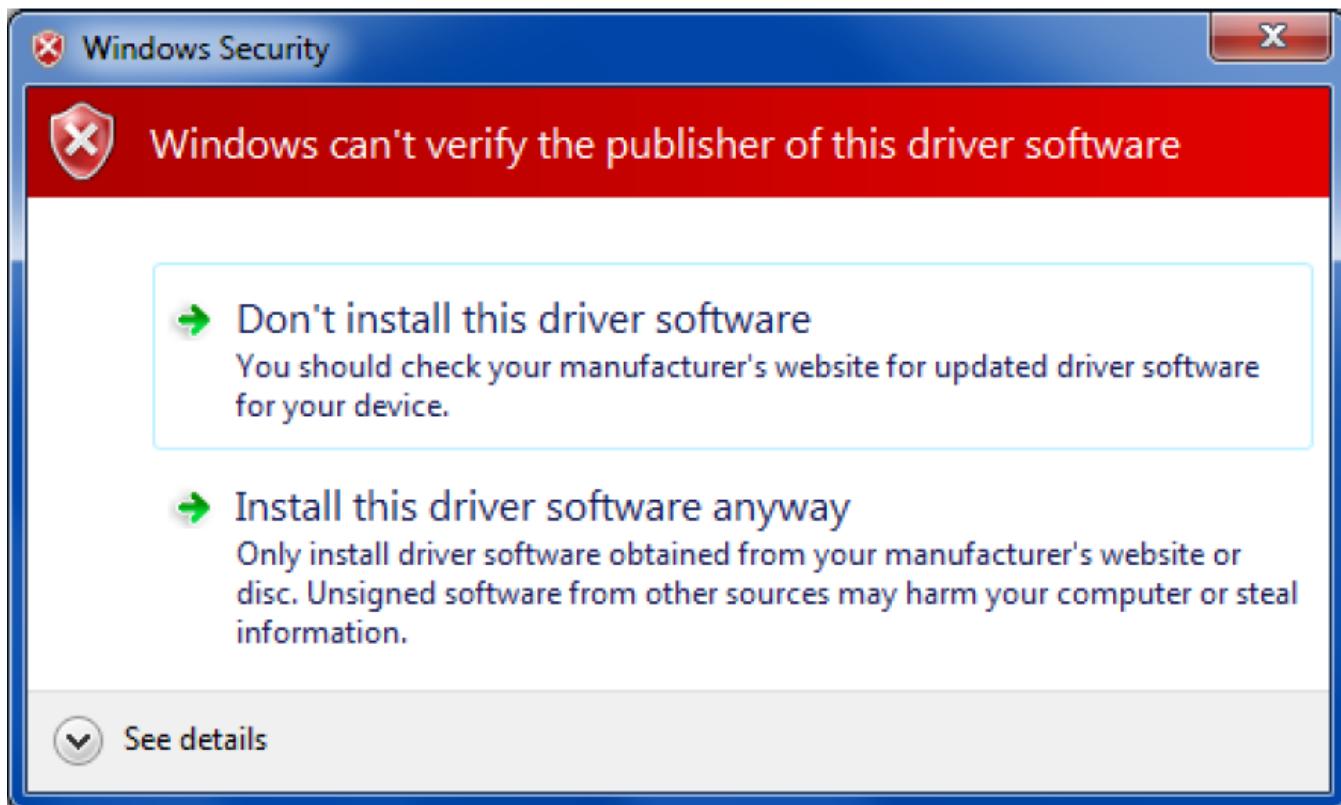


Figure 18. Windows Publisher Verification Warning

6. Click the **Close** button once the driver installation is complete ([Figure 19](#)).

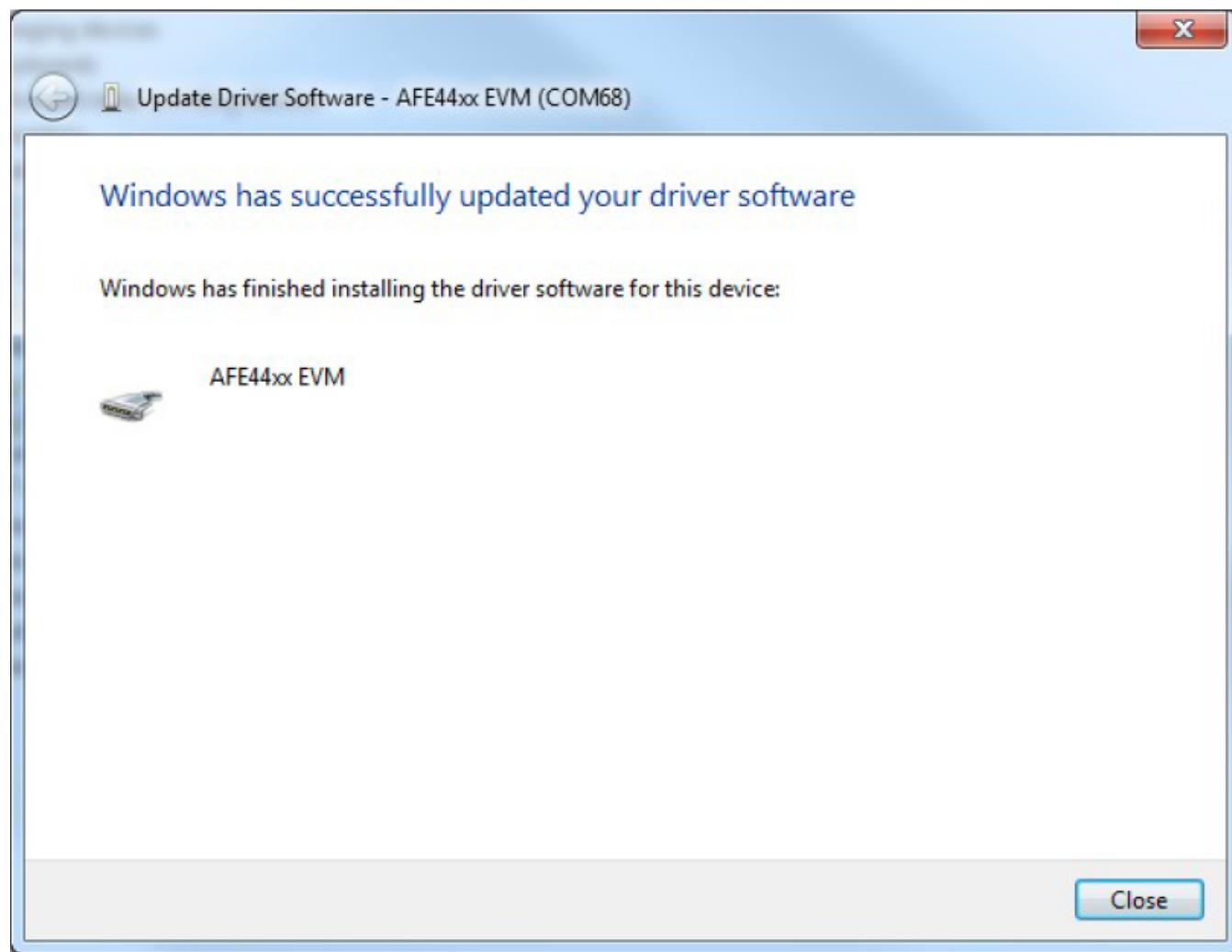


Figure 19. USB Driver Installation - Screen 4

7. The AFE4404 EVM is now recognized as Virtual COM Port under the Device Manager as shown in [Figure 20](#).

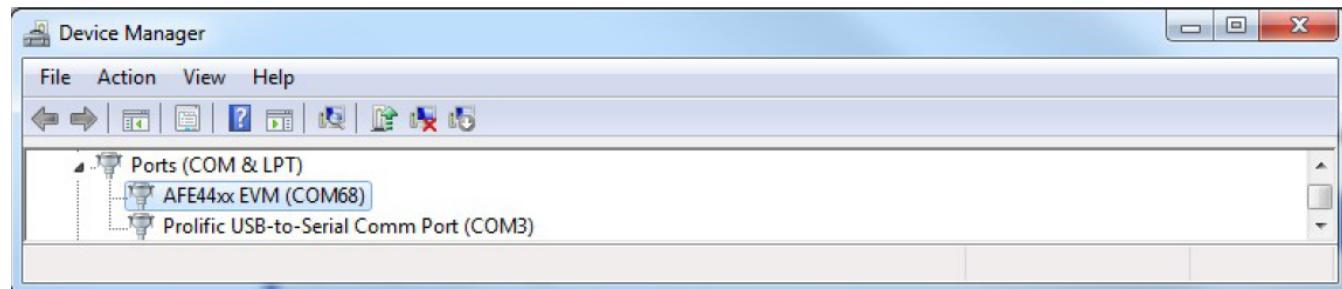


Figure 20. Device Manager Screen

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

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 21](#).

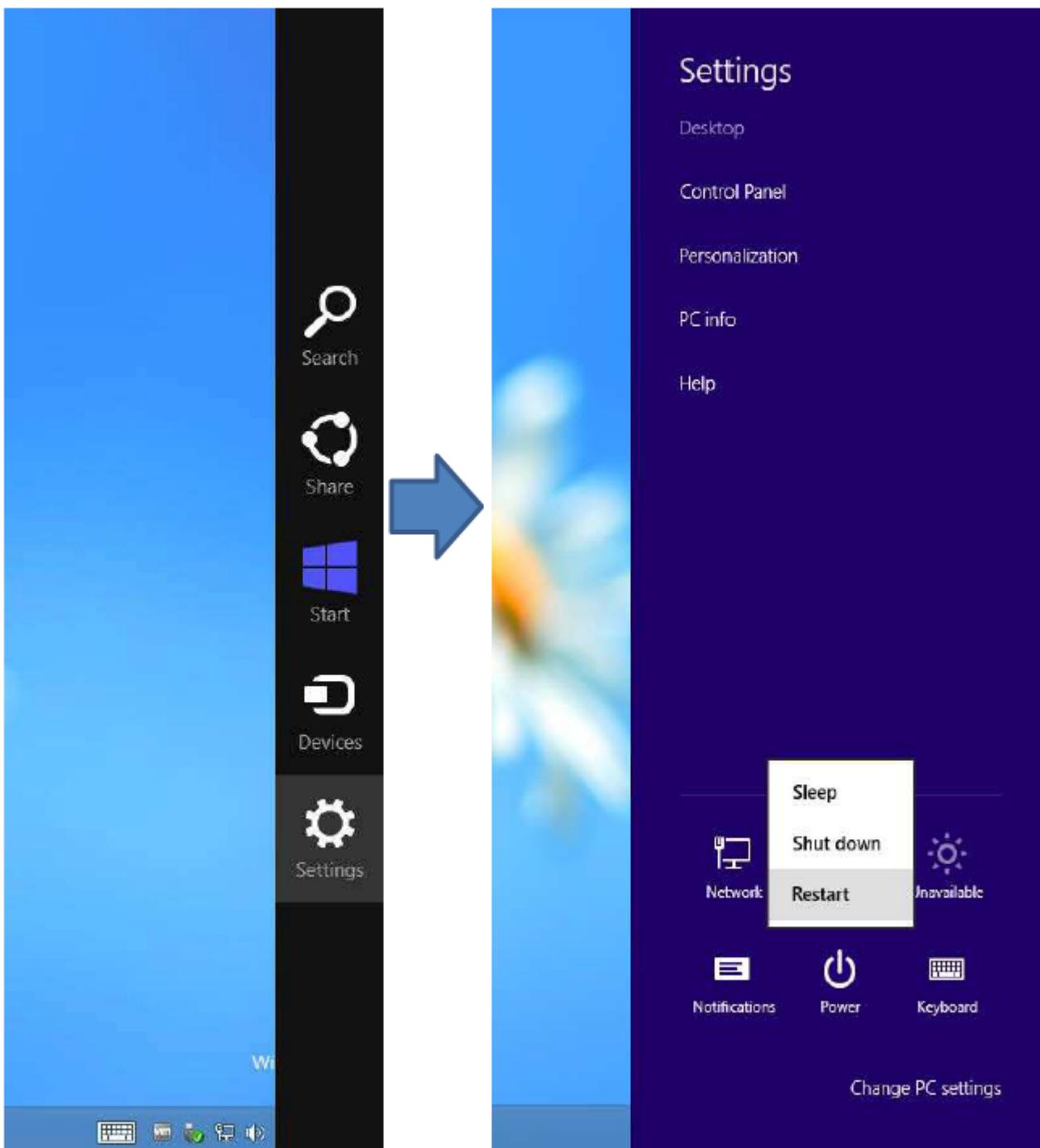


Figure 21. Windows 8 Installing Unsigned Drivers - Screen 1

After a loading screen, three options appear. Choose Troubleshoot as shown in [Figure 22](#).

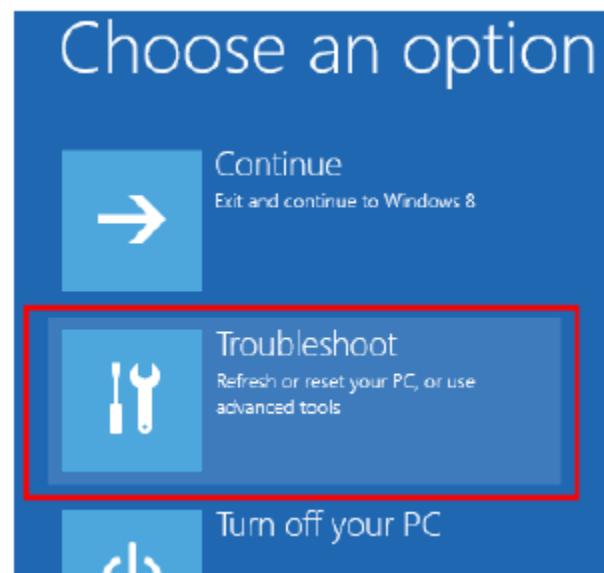


Figure 22. Windows 8 Installing Unsigned Drivers - Screen 2

Choose advanced options as shown in Figure 23.



Figure 23. Windows 8 Installing Unsigned Drivers - Screen 3

Choose startup Settings as shown in [Figure 24](#).

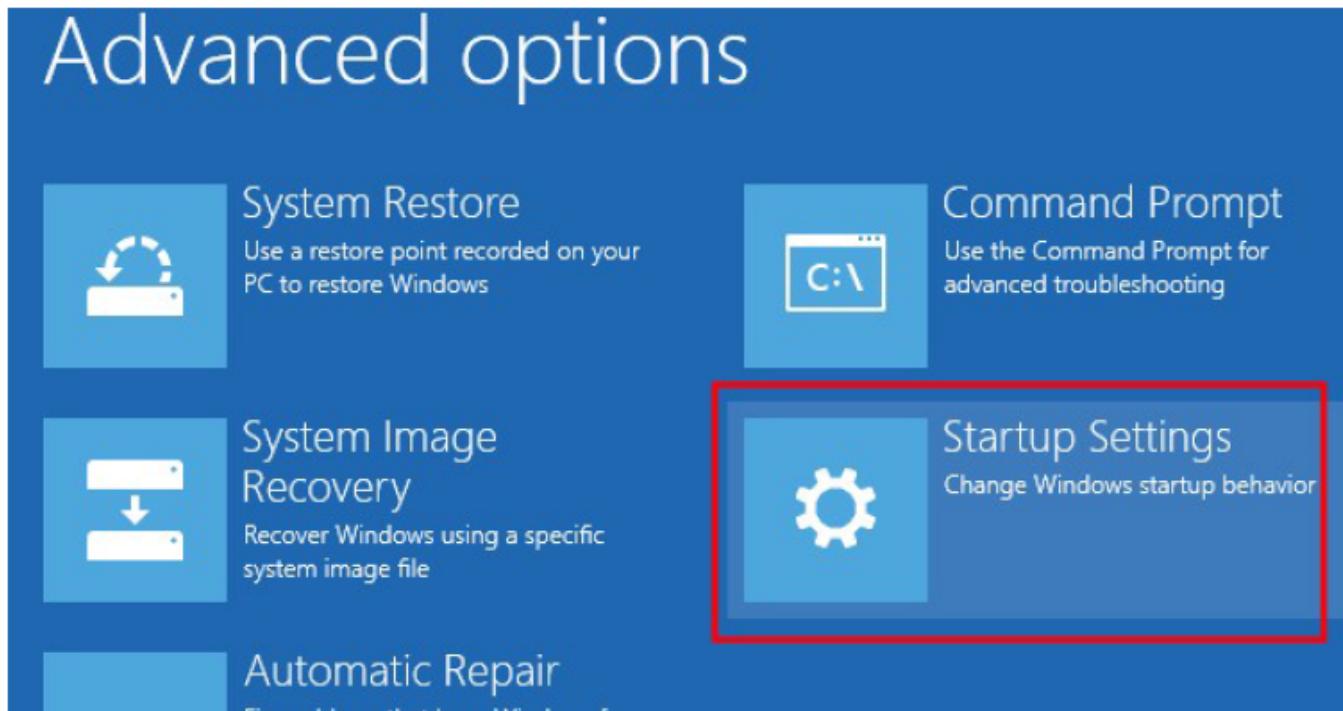


Figure 24. Windows 8 Installing Unsigned Drivers - Screen 4

Next a list of options displays. Click Restart at the bottom right as shown in [Figure 25](#).

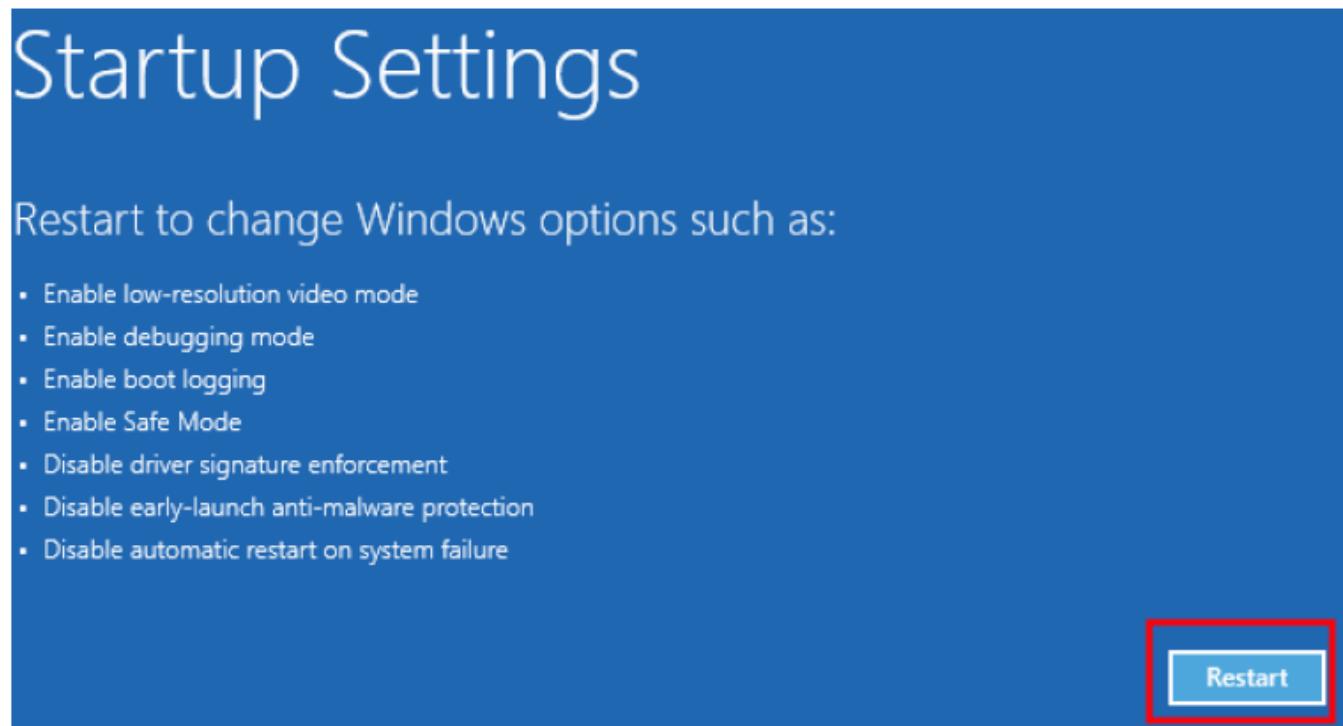


Figure 25. Windows 8 Installing Unsigned Drivers - Screen 5

After the computer restarts, the following screen appears (see [Figure 26](#)). Press F7 to disable driver signature enforcement.

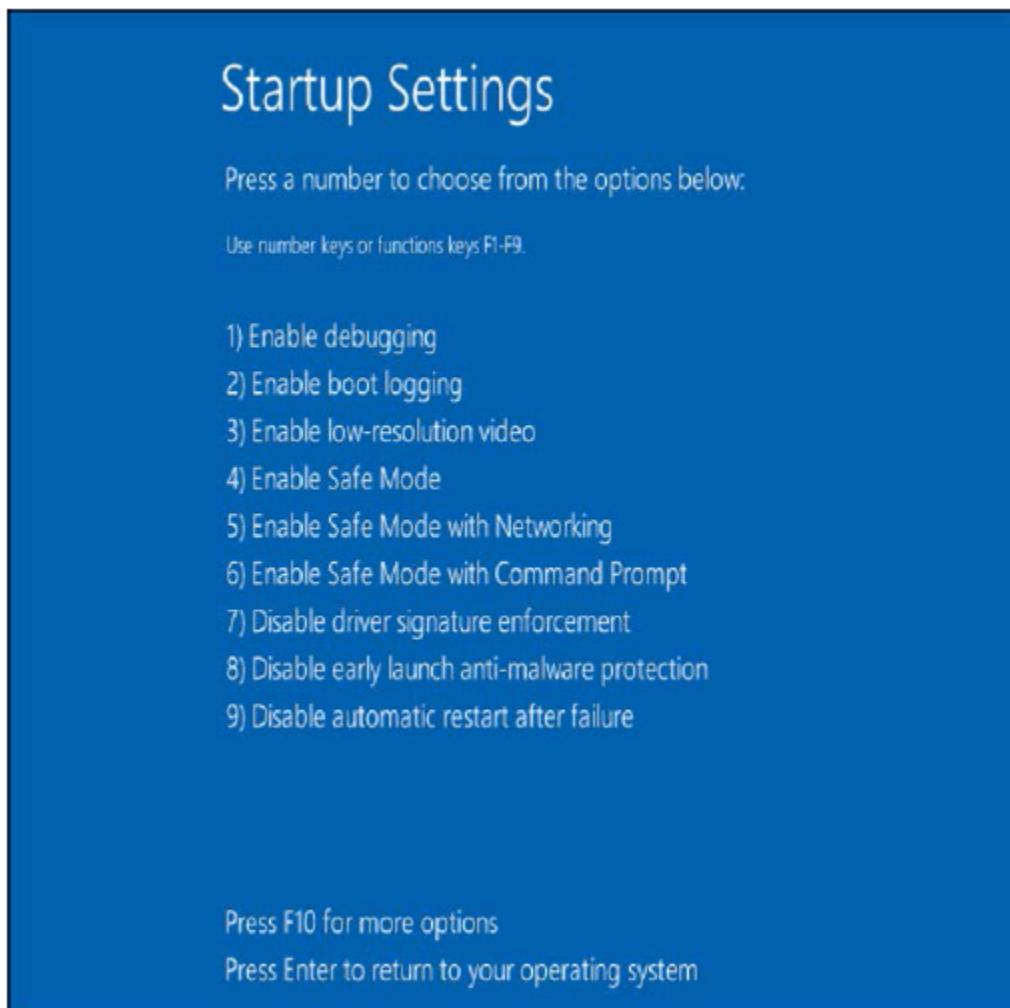


Figure 26. Windows 8 Installing Unsigned Drivers - Screen 6

Now, the user can install unsigned drivers. A warning may appear as shown in [Figure 27](#); choose *Install this driver software anyway*.



Figure 27. Windows 8 Installing Unsigned Drivers - Screen 7

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

4 Running the Software

Run the AFE4404 EVM GUI software by selecting the *AFE4404 EVM GUI.exe* which is found in the chosen installation directory (by default this is *C:\Program Files(x86)\Texas Instruments\AFE4404 EVM 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 AFE4404 EVM 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 AFE4404 EVM is connected to the PC.



Figure 28. AFE4404 EVM Not Connected Error Message

4.1 Overview of the Features

This section provides a quick overview of the various features and functions of the AFE4404 EVM 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:

- *Product Safety Warnings* – Product Safety Warnings, Restrictions and Disclaimers (see [Figure 29](#)).
- *Device Configuration* – Configures all the AFE4404 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.

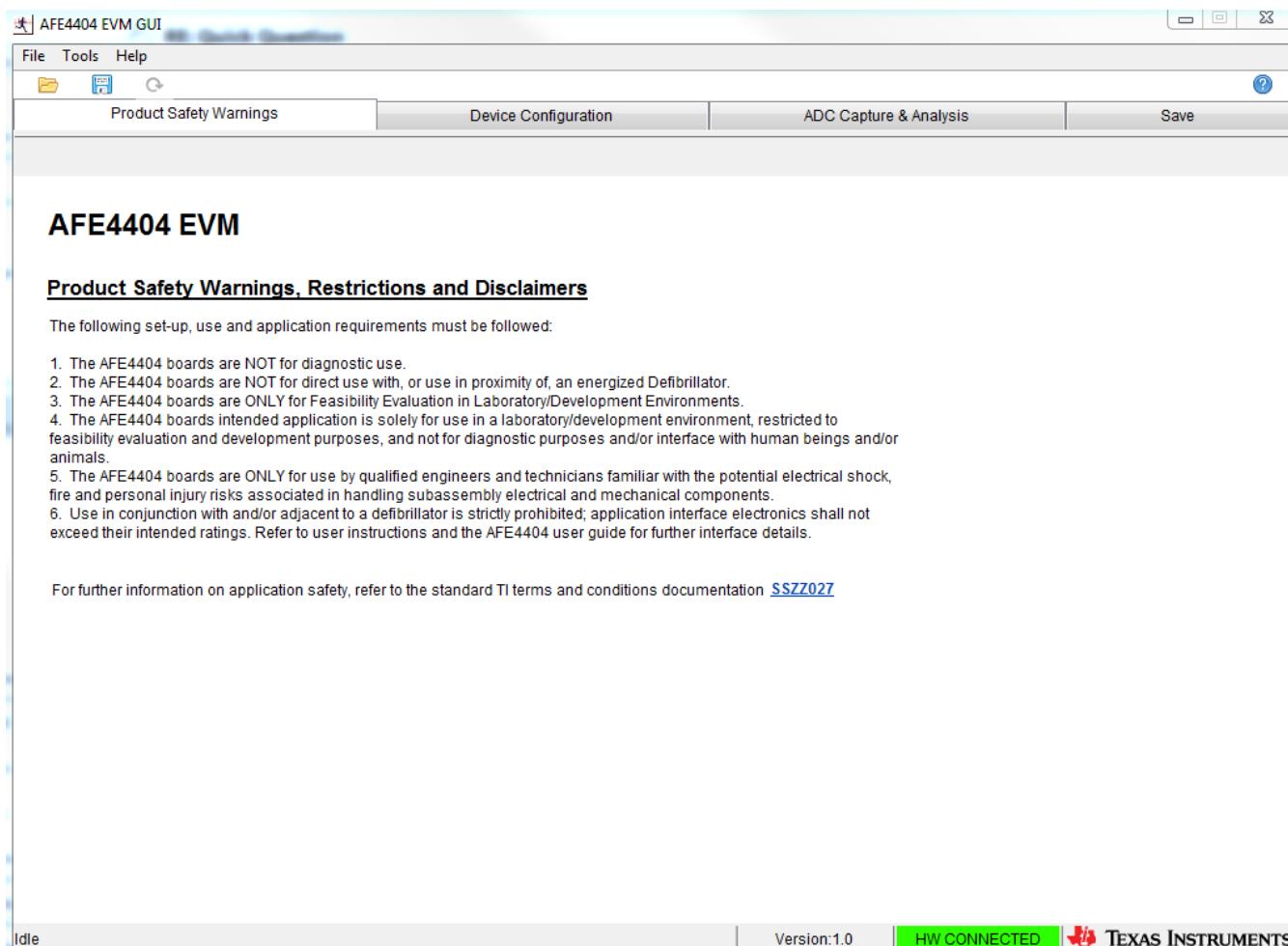


Figure 29. Product Safety Warnings, Restrictions, and Disclaimers

4.1.1 Device Configuration Tab

The *Device Configuration* tab allows configuration of the various registers of the AFE4404 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 AFE4404 device shown in [Figure 30](#) 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 AFE4404 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 AFE4404 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) Powerdown AFE
 - (b) Powerdown RX
 - (c) Four controls for dynamic powerdown
 - (d) Enable CLKOUT Generation
 - (e) Clock Mode
 - (f) Clock divider ratio for external CLK, PRF, and CLK output
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

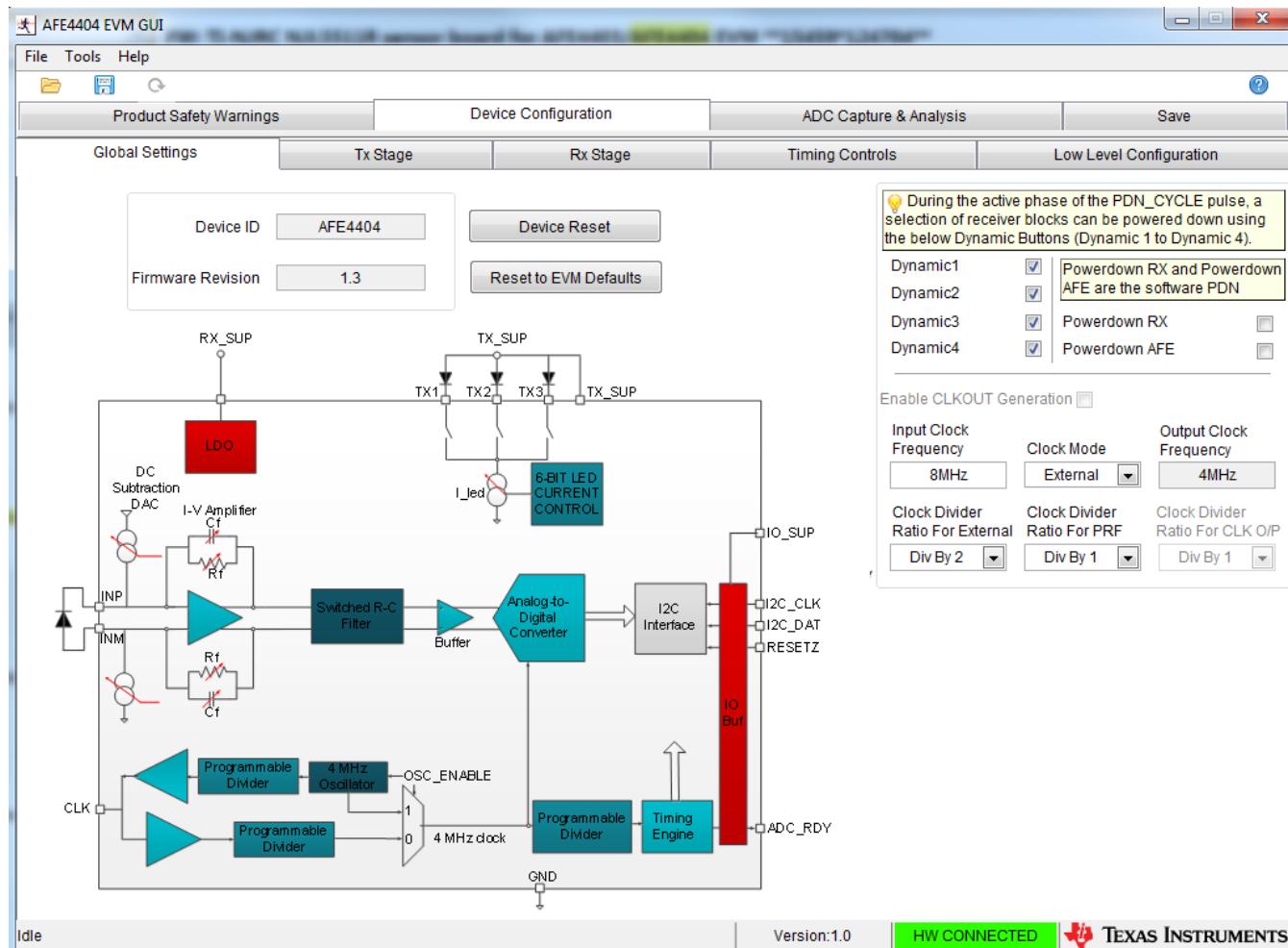


Figure 30. AFE4404: Device Configuration: Global Settings

4.1.1.2 Tx Stage Subtab

Figure 31 shows the *Tx Stage* subtab under the *Device Configuration* tab consisting of the settings to:

1. Set LED1, LED2, and LED3 currents in mA or current settings in codes (6-bit)

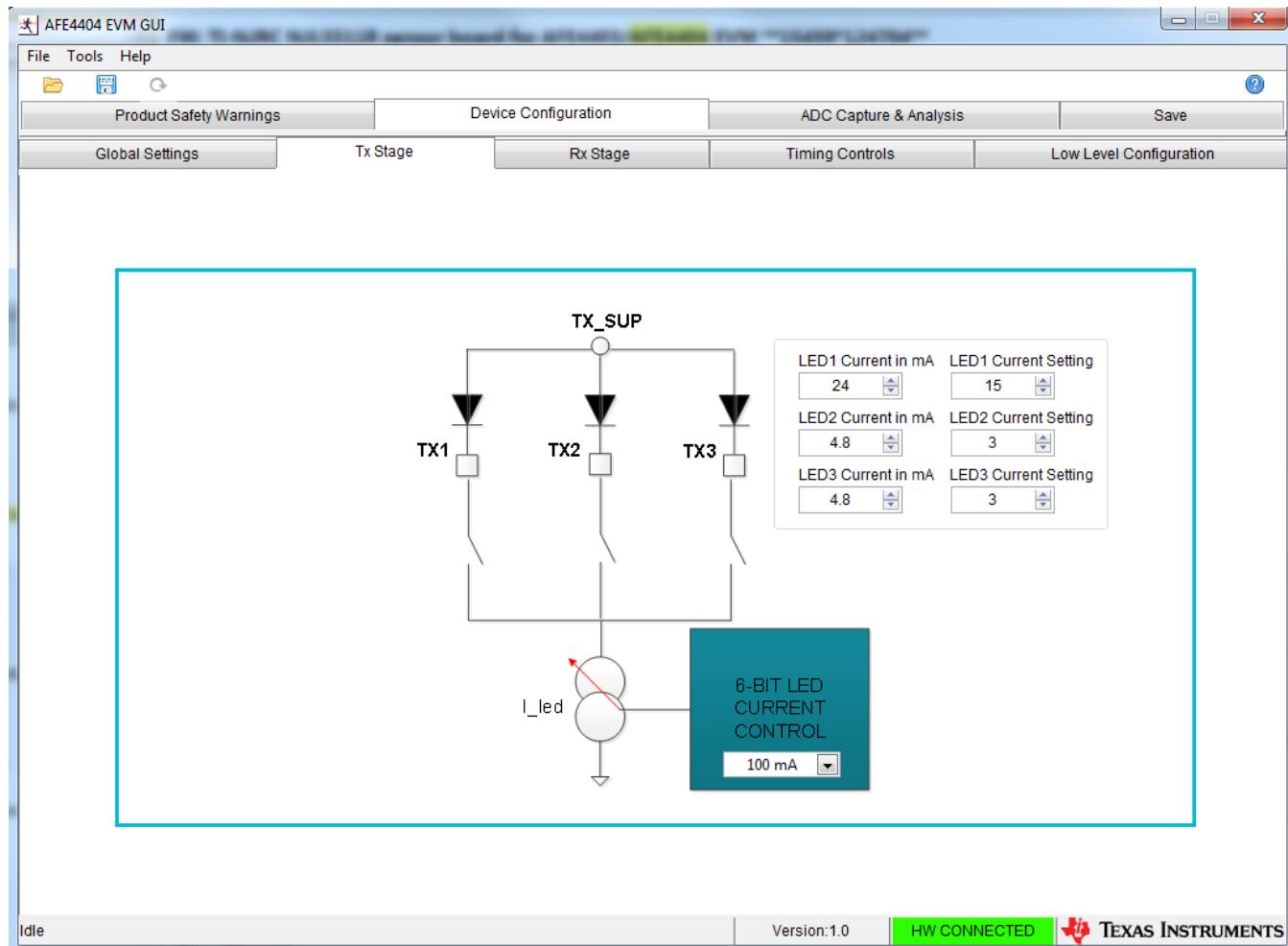


Figure 31. AFE4404: Device Configuration: Tx Stage

4.1.1.3 Rx Stage Subtab

Figure 32 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. Set ambient DAC current and polarity for LED2, LED3 (LED2 Ambient for dual LED), LED1 Ambient, and LED1.

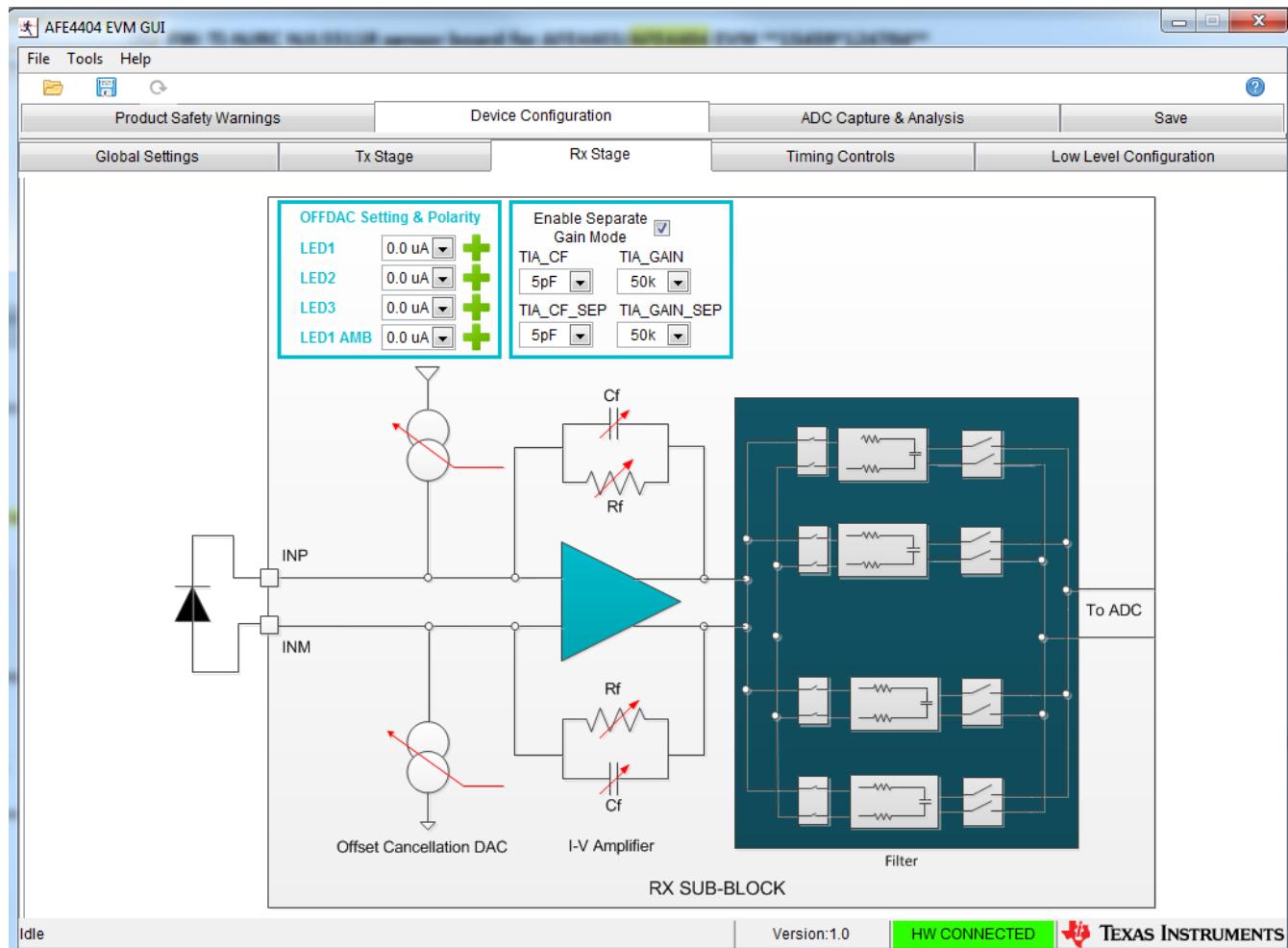


Figure 32. AFE4404: Device Configuration: Rx Stage

4.1.1.4 Timing Controls Subtab

The *Timing Controls* subtab under the *Device Configuration* tab, shown in [Figure 33](#), consists of the following settings:

1. Enter the *Pulse Repetition Frequency* (PRF) to find the Pulse Repetition Count
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



Figure 33. AFE4404: 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 AFE4404 devices. Refer to the AFE4404 data sheet ([SBAS689](#)) for the register details of the chip.

Figure 34 shows the low-level configuration registers of the AFE4404 devices. The *Register Map* portion of the sub-tab shows the EVM default values of the registers after the GUI is loaded. 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 changed by clicking on the desired bit. The values of all the registers are read by clicking the **Read All** button.

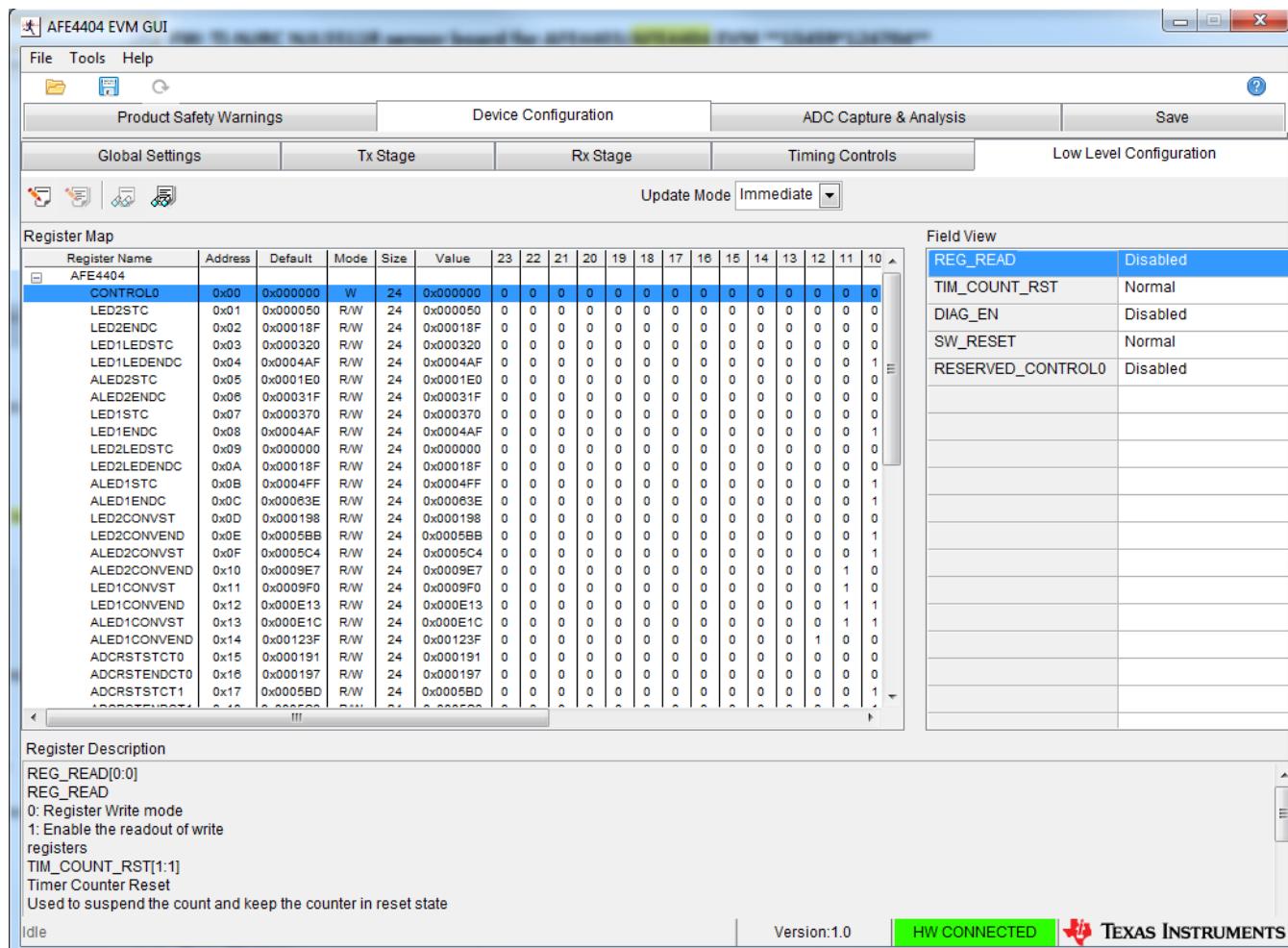


Figure 34. Device Configuration: Low Level Configuration

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 35](#).

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 36](#).

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:

- # of samples for FFT calc. which is power of 2 $\leq \min((\text{Data rate (sps)} \times N \text{ where } N \text{ is the value in the Show data for the last } N \text{ secs column}), \text{No. of samples})$
- If ($(\# \text{ of samples for FFT calc.} == \text{No. of samples}) \&\& (\text{Filter Type} == \text{"None"})$) then # of samples for FFT calc. = No. of samples
- If ($(\# \text{ of samples for FFT calc.} == \text{No. of samples}) \&\& (\text{Filter Type} == \text{"Notch"})$) then # of samples for FFT calc. = No. of samples / 2. This is to allow for filter settling.
- If ($(\# \text{ of samples for FFT calc.} < 32 \text{ samples})$) then an error msg "Insufficient # of samples for FFT calculation" will be displayed.

Examples:

- 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 = $2048 \leq \min(500 \times 5, 8192)$
- 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 = $2048 \leq \min(500 \times 8, 8192)$
- No. of samples = 8192
Data rate (sps) = 500
Show data for the last 20 secs
of samples for FFT which is power of 2 = $8192 \leq \min(500 \times 20, 8192)$
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
- 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 = $16 \leq \min(500 \times 1, 30)$
- No. of samples = 32
Data rate (sps) = 500
Show data for the last 2 secs
of samples for FFT which is power of 2 = $32 \leq \min(500 \times 2, 32)$
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.

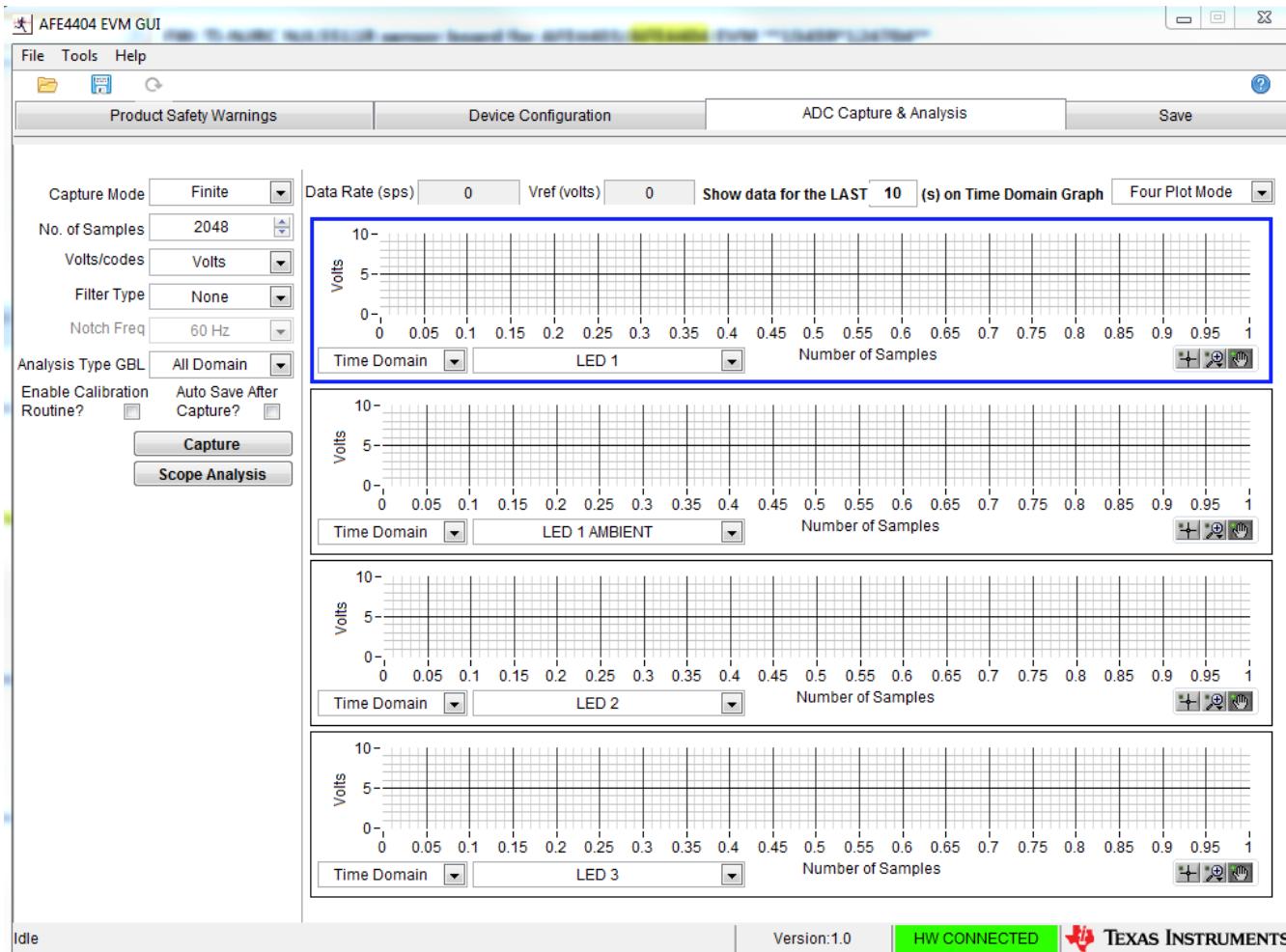


Figure 35. ADC Capture and Analysis Tab

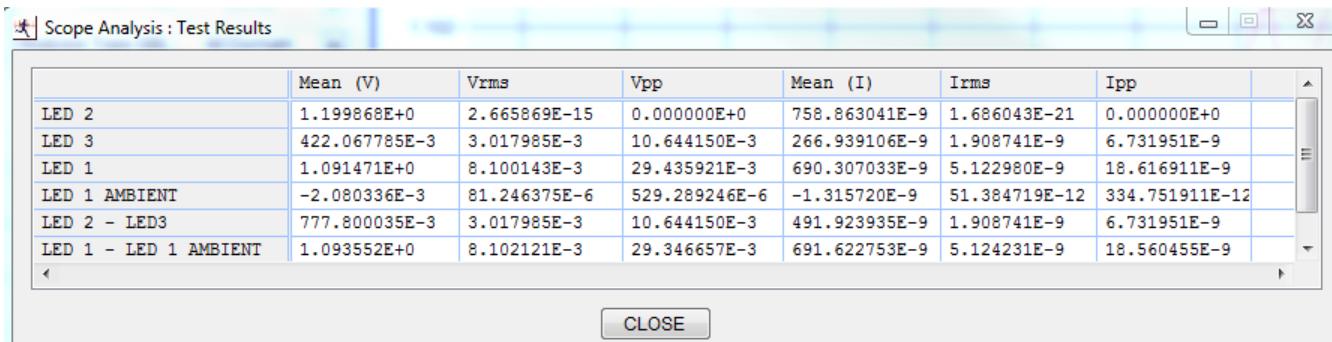


Figure 36. Scope Analysis: Test Results

4.1.3 Save Tab

The Save tab shown in [Figure 37](#) 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\AFE4404 EVM GUI\Log
- On a Windows 7 machine – C:\Program Files(x86)\Texas Instruments\AFE4404 EVM 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.

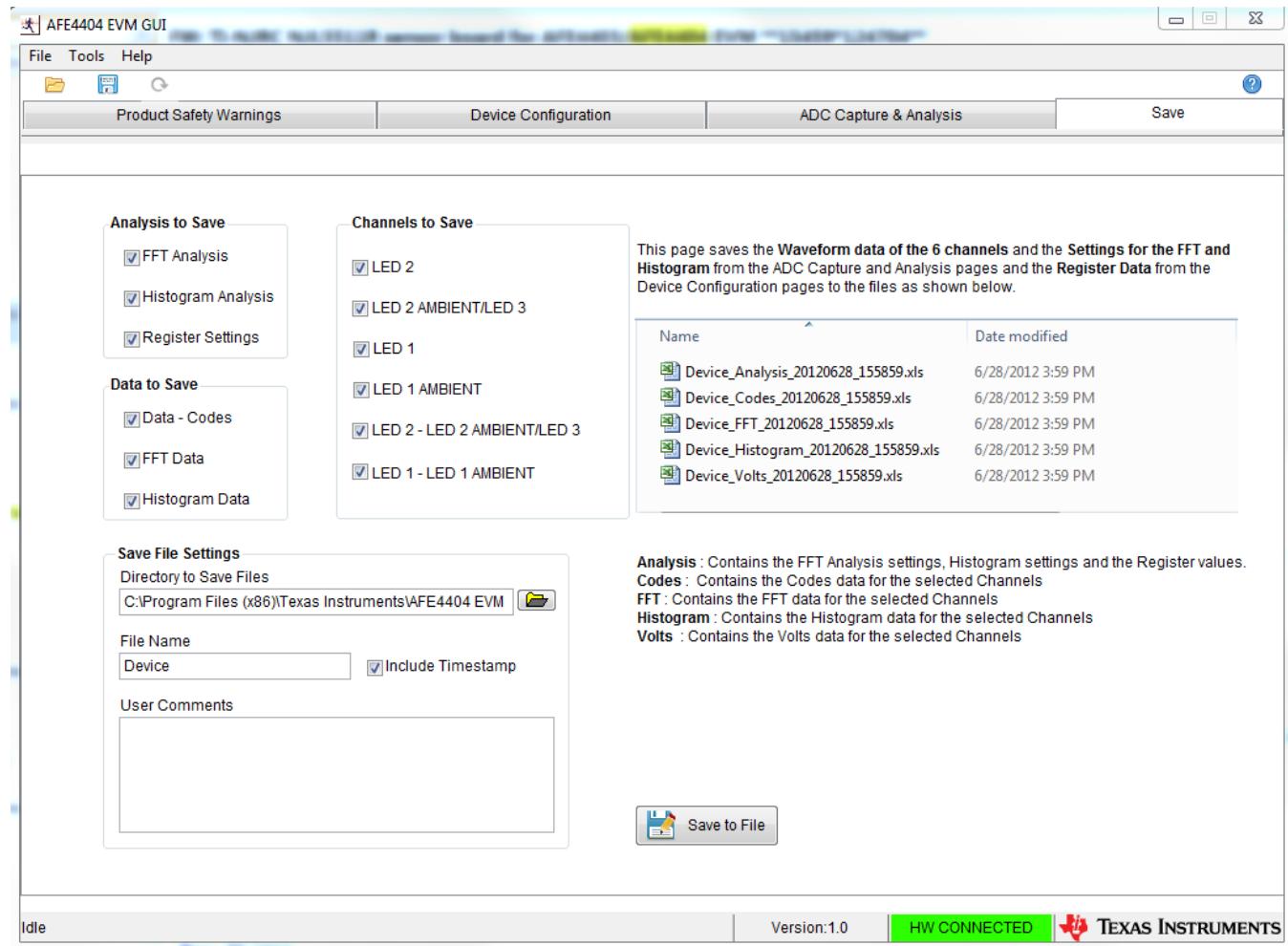


Figure 37. Save Tab

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 <i>Device_<record number>_Analysis.xls</i> .
FFT Analysis	Saves the FFT analysis result. The result is saved in the file <i>Device_<record number>_Analysis.xls</i> .
Histogram Analysis	Saves the histogram analysis result. The result is saved in the file <i>Device_<record number>_Analysis.xls</i> .
Register Settings	All the current register values are read from the EVM and stored. The result is saved in the file <i>Device_<record number>_Analysis.xls</i> .
Data - Codes	Acquired data sample values are stored to the file <i>Device_<record number>_Codes.xls</i> .
FFT Data	Acquired data sample's FFT values are stored to the file <i>Device_<record number>_FFT.xls</i> .
Histogram Data	Acquired data sample's histogram values are stored to the file <i>Device_<record number>_Histogram.xls</i> .

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 AFE4404 EVM Hardware

CAUTION

Many of the components on the AFE4404 EVM 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 AFE4404 Analog Front End demonstration board are:

- Based on MSP430F5529
- Acquire data at up to 1000 Hz in evaluation mode
- I2C Data interface

The AFE4404 EVM board can be used as a demo board for pulse oximeter and heart rate applications. The bill of materials (BOM) is provided in [Section 10](#). The printed-circuit boards (PCB) are shown in [Section 11.1](#), [Section 11.2](#), and the schematics are shown in [Section 11.3](#).

MSP430F5529 is the microcontroller used on the board. For more details of the MSP430F5529 visit <http://focus.ti.com/docs/prod/folders/print/msp430f5529.html>.

The following sections explain the main hardware components available on the EVM. [Figure 38](#) shows the functional block diagram for the EVM.

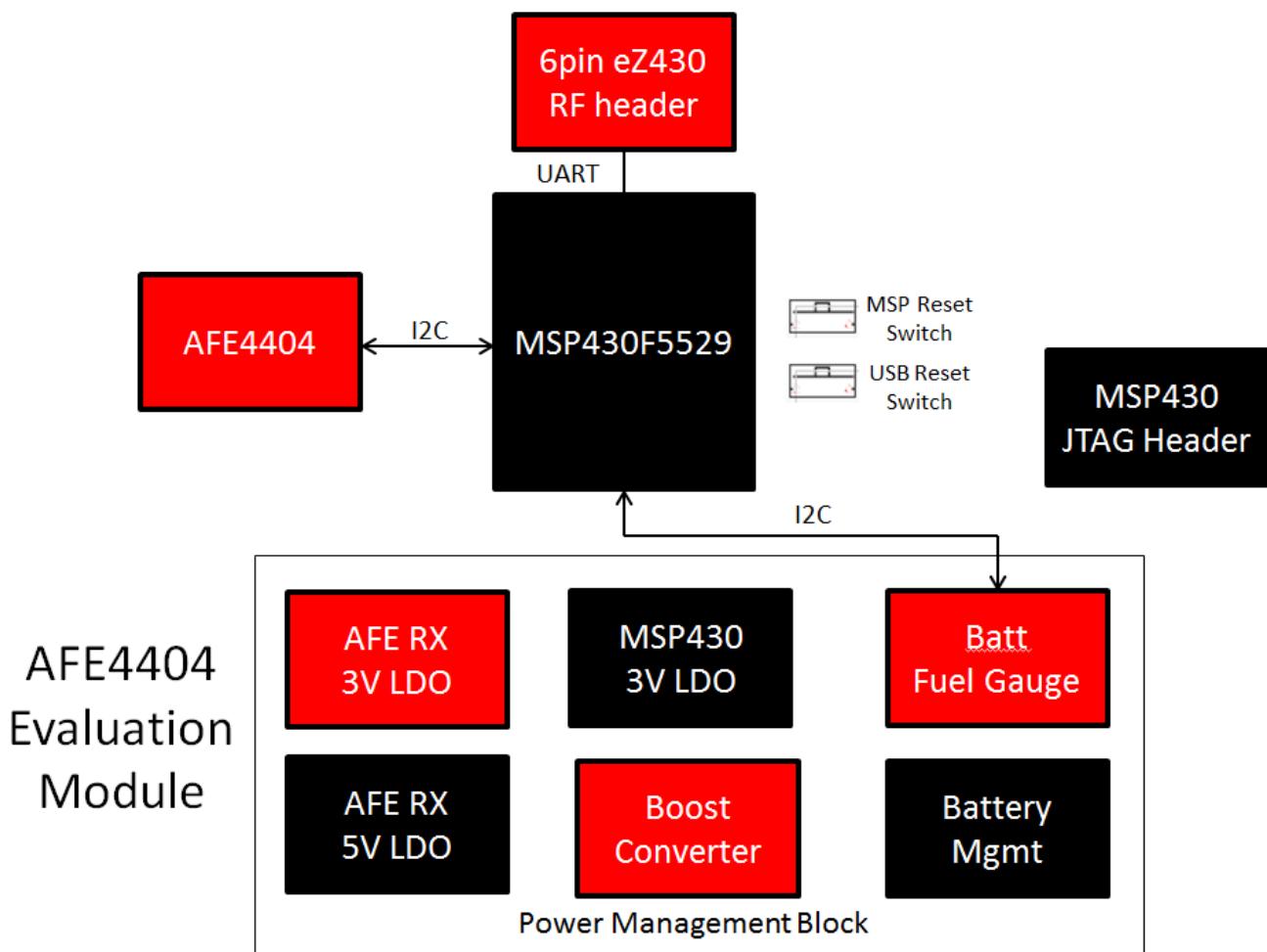


Figure 38. AFE4404 EVM Block Diagram

5.1 Power Supply

AFE4404 can operate from 2.0-V to 3.6-V Rx analog supply (RX_SUP), 1.8-V to 3.6-V IO digital supply (IO_SUP), and 3.0-V to 5.25-V Tx Control supply (TX_SUP).

The power for the board is derived from the USB input (J1) through a forward-biased diode (D1) to avoid reverse current flow. The USB data bus is ESD protected using TI's ESD protection diode array TPD4E004DRYR (U5). The USB VBUS is fed to the integrated Li-Ion linear charger and system power-path management module, bq24032ARHLR (U3), 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 (U7), for generating a boosted voltage of 8.97 V. This output is fed to low-noise voltage regulator LP3878-ADJ (U9) for generating 5 V for TX_SUP. The VCC_BAT is also fed to the ultralow-noise linear voltage regulator TPS7A4901DGN (U6) for generating 3 V for the MSP_DVCC, MSP_AVCC, RX_SUP and IO_SUP.

Series jumper resistors are provided to make sure the power supplies to the board are correct.

5.2 Clock

The EVM has the option to use the internal clocking using the on-chip 4-MHz oscillator (EVM default) or the clock for the AFE4404 from the MSP430 (Device default). In oscillator mode, the internally generated clock from the AFE4404 can be accessed through an accessible via labeled CLKOUT. The frequency of the output clock can be set using a programmable divider.

5.3 Accessing AFE4404 Digital Signals

AFE4404 I²C interface and other digital signals with MSP430 can be accessed through the series resistor jumpers given in [Table 2](#).

Table 2. AFE4404 Digital Signals

S. No.	Signal	Description
1	I ² C_SCL	R7
2	I ² C_SDA	R8
3	ADC_RDY	R18

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. The AFE4404 EVM is designed to work in the slave mode.

5.5 On-Board Key Interface

The EVM has 2 switches. The function of each switch is defined in [Table 3](#).

Table 3. AFE4404 EVM 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 (LED1) indicates the USB power connection. The blue LED (LED3) indicates that the microcontroller is busy servicing the requests from the PC application.

6 USB-Based Firmware Upgrade

The firmware on the AFE4404 EVM 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 following screen shots:

- From the PC application, click on *File → Firmware Upgrade*
- A pop-up window opens as shown in [Figure 39](#). Follow the instructions to continue to Firmware Upgrade or to cancel the operation.

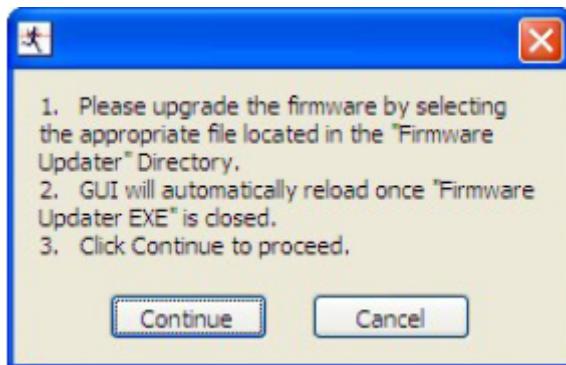


Figure 39. PC Application Firmware Upgrade – 1

- The firmware upgrade application detects the connected EVM (Figure 40).

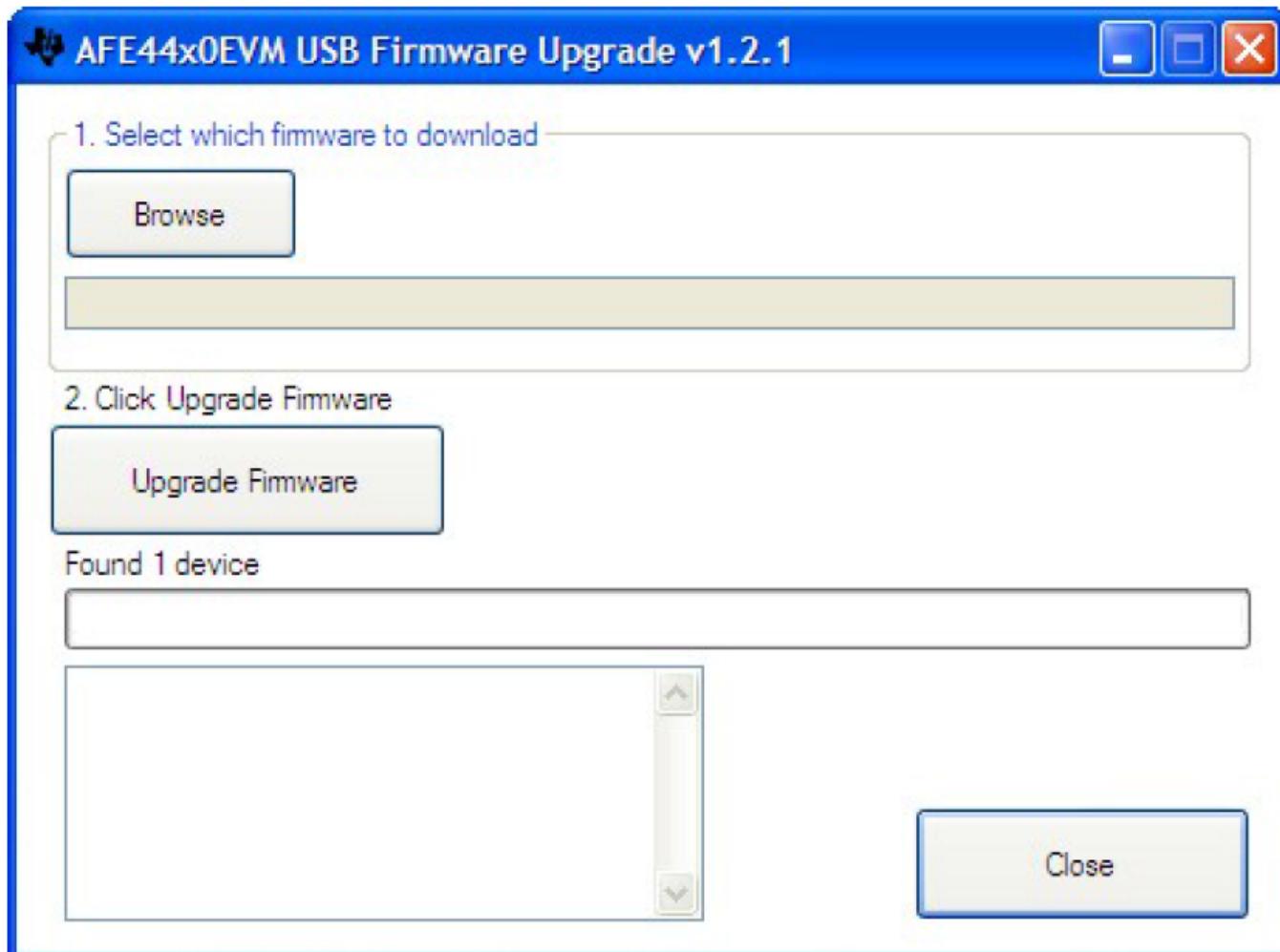


Figure 40. PC Application Firmware Upgrade – 2

- Browse and select the appropriate firmware binary file (example: AFE4404_EVM_FW_V1.0.txt file) and click *Upgrade Firmware* as shown in Figure 41. The default firmware is available from:
 - On a Windows XP machine:
 - C:\Program Files\Texas Instruments\AFE4404 EVM GUI\Firmware Updater
 - On a Windows 7 machine:

- C:\Program Files(x86)\Texas Instruments\AFE4404 EVM GUI\Firmware Updater

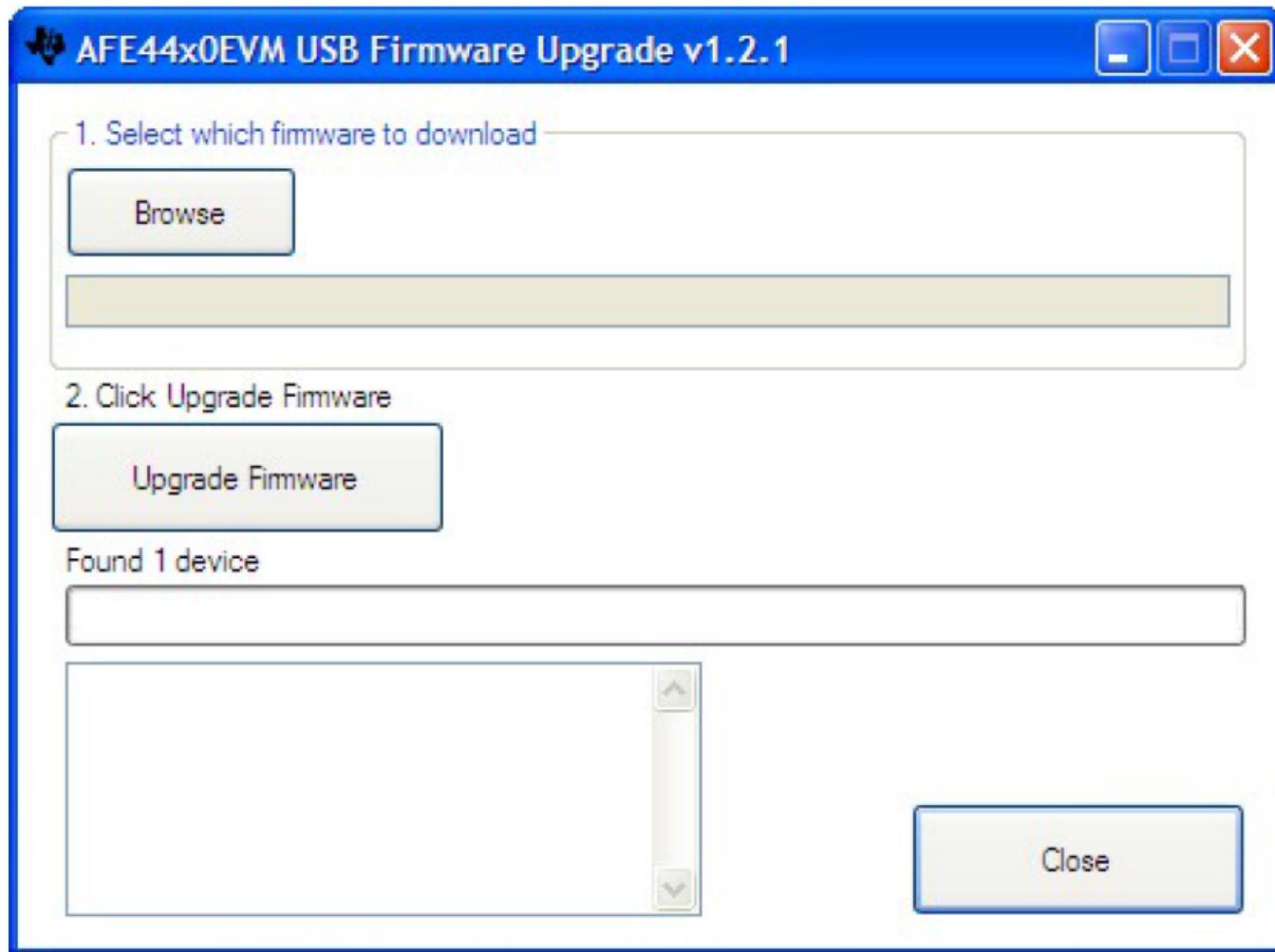


Figure 41. PC Application Firmware Upgrade – 3

- Once the device is programmed successfully, as shown in [Figure 42](#), 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.

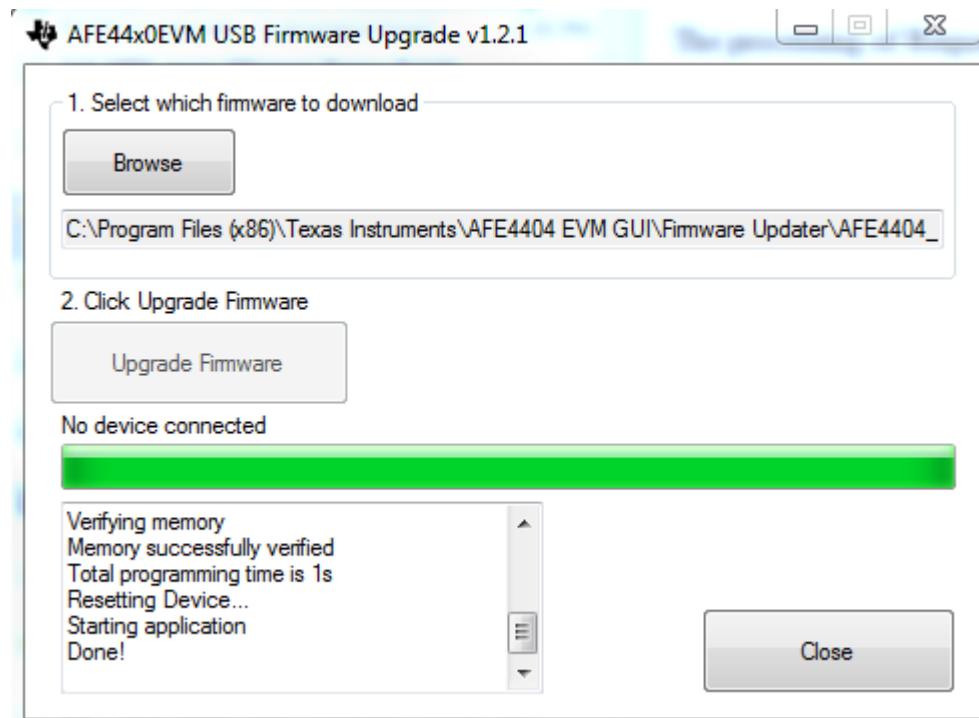


Figure 42. PC Application Firmware Upgrade – 4

7 AFE4404 EVM Firmware Upgrade Without GUI

Use the following steps to upgrade the AFE4404 EVM 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\AFE4404 EVM GUI\Firmware Updater"
 - On a Windows XP OS: "C:\Program Files\Texas Instruments\AFE4404 EVM GUI\Firmware Updater"
2. Click the **Browse** button and load the AFE4404 firmware. [Figure 43](#) shows the firmware loader application with the appropriate firmware selected. The firmware is located in the "C:\Program Files\Texas Instruments\AFE4404 EVM GUI\Firmware Updater" directory.

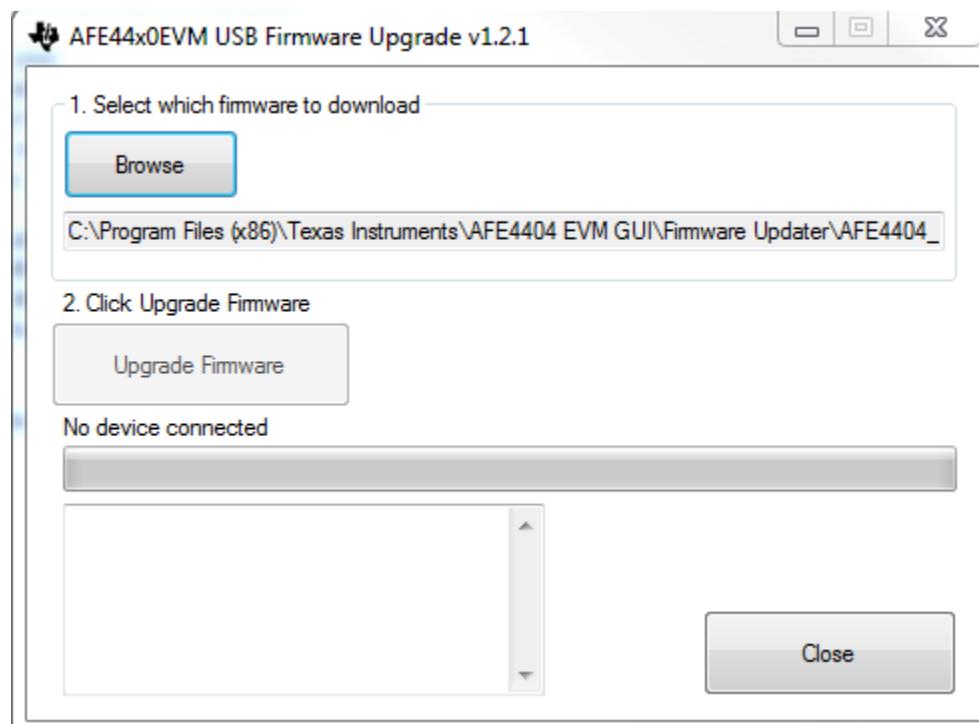


Figure 43. Firmware Loader Application: Select Firmware

3. Press the SW2 switch on the EVM while plugging in the micro-USB interface cable to the J1 micro-USB connector on the EVM.
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 44](#)).

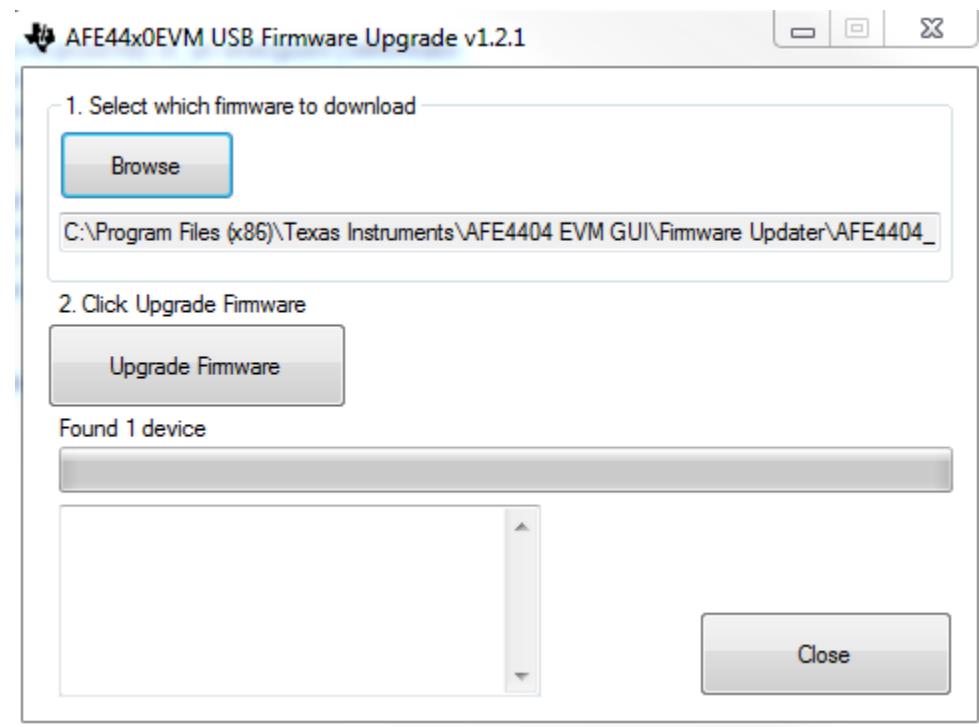


Figure 44. Firmware Loader Application: Found Device

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 45](#) shows the status of the successful programming

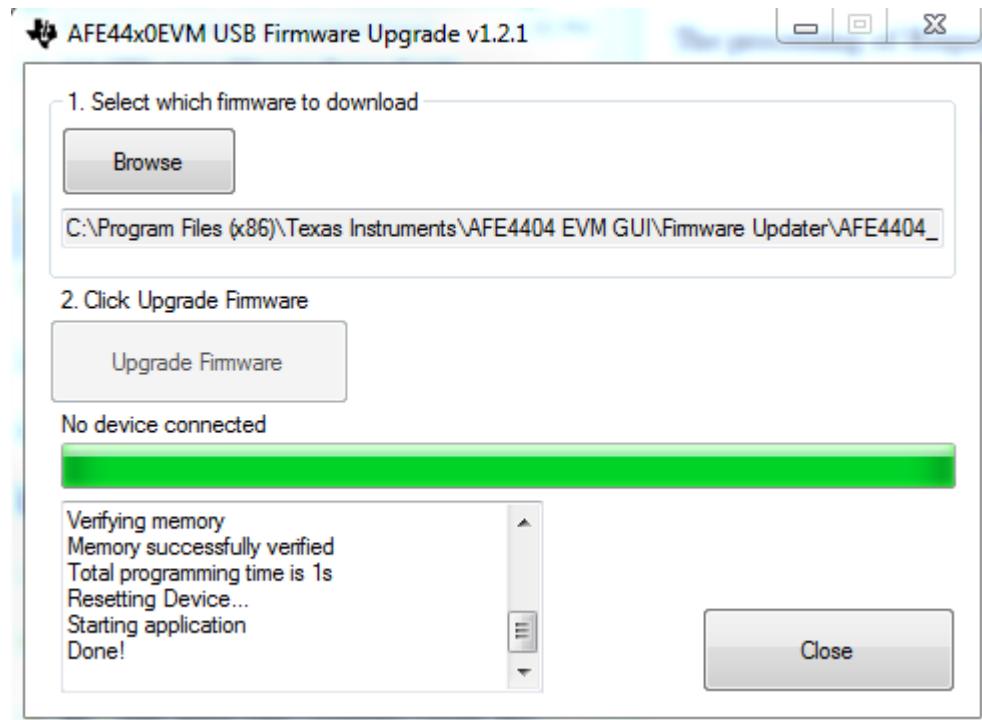


Figure 45. Firmware Loader Application: Programming Status

8 Connector Interface

The following connectors are used for external interface to the AFE4404 Evaluation Module.

- Micro-USB connector
- 10-pin connector

8.1 Micro-USB Connector

The USB micro connector J1 pin-outs are shown in [Figure 46](#). The description of the pin-outs is provided in [Table 4](#).

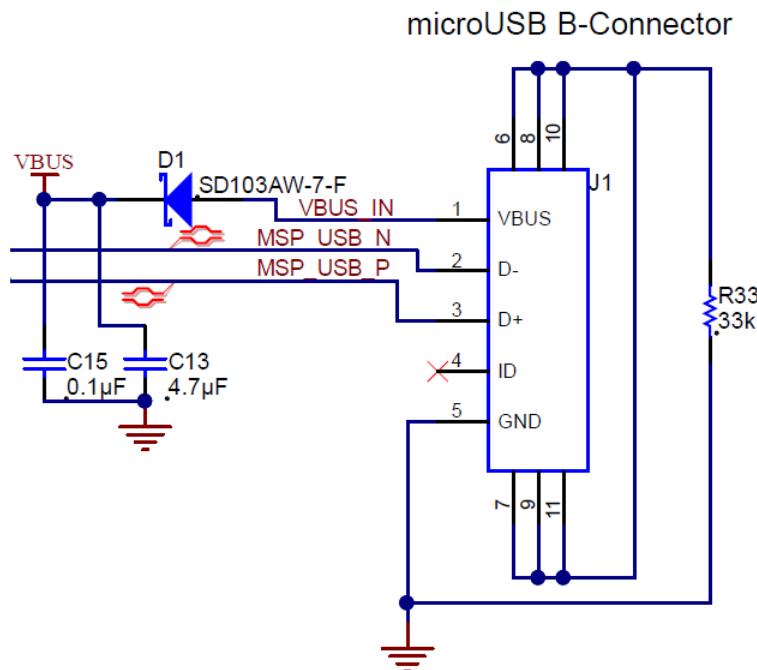


Figure 46. USB Micro Connector Pin Outs

Table 4. 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

8.2 10-Pin Connector

The 10-pin connector pin-outs are shown in [Figure 47](#). The description is provided in [Table 5](#).

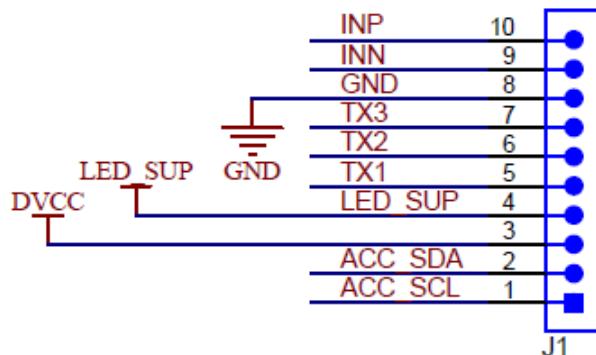


Figure 47. 10-Pin Connector

Table 5. 10-Pin Connector Pin Descriptions

Pin Number	Pin Name	Pin Description
1	ACC_SCL	CLK pin for BMA280
2	ACC_SDA	Data pin for BMA280
3	DVCC	Power for BMA280
4	LED_SUP	Power Supply for LEDs
5	TX1	Cathode of LED1
6	TX2	Cathode of LED2
7	TX3	Cathode of LED3
8	GND	Ground
9	INN	Photodiode anode
10	INP	Photodiode cathode

9 AFE4404 EVM FAQs

9.1 ADC_RDY Signal

After executing the GUI, observe the ADC_RDY waveform at series jumper resistor R18. This should be at the same frequency as the PRF. [Figure 48](#) shows the ADC_RDY waveform at 100-Hz PRF.

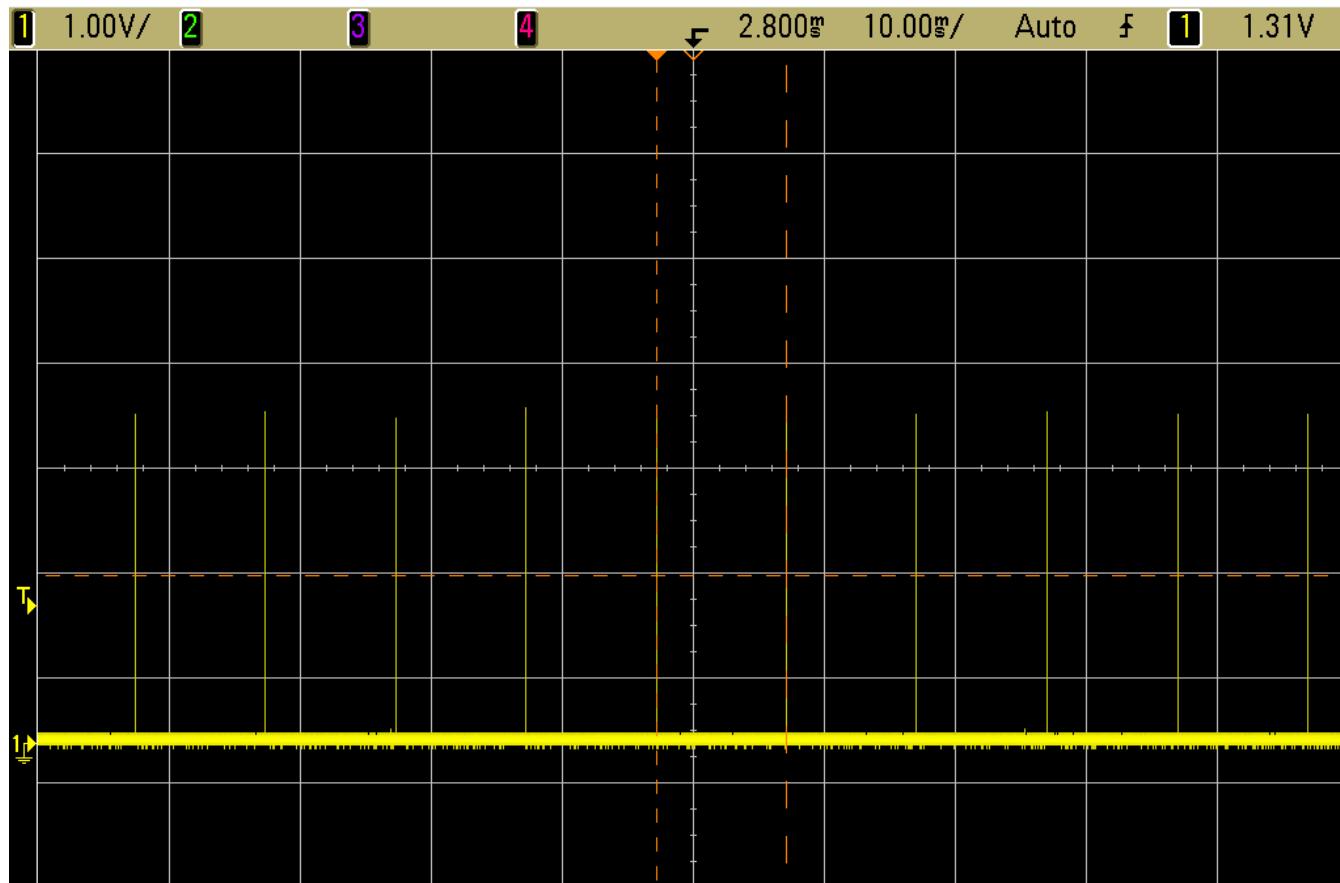


Figure 48. ADC_RDY Waveform at 100-Hz PRF

9.2 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\AFE4404 EVM GUI\Documentation
- On a Windows 7 machine – C:\Program Files(x86)\Texas Instruments\AFE4404 EVM GUI\Documentation

9.3 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 49](#).

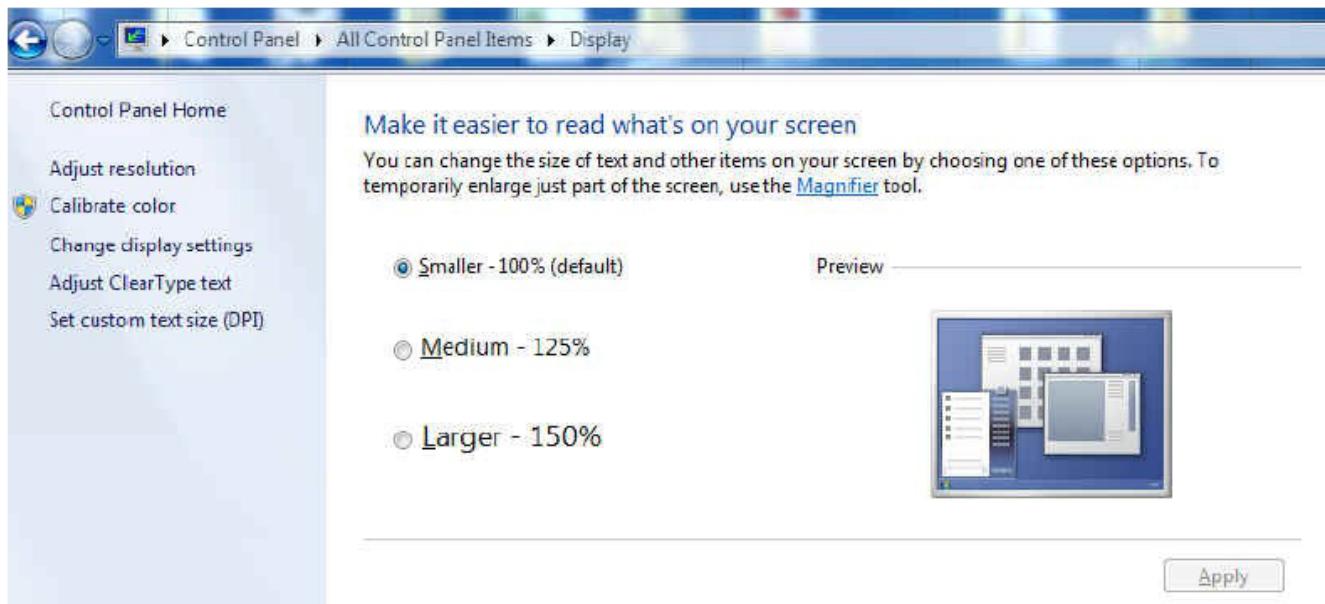


Figure 49. Setting Font Size on Windows 7 Operating System

9.4 Windows 8 Support for Device GUIs

At GUI Start up, sometimes the GUI might show a broken arrow as seen in Figure 50. One of the reasons for this issue may be due to a missing update of Microsoft .NET Framework 3.5 (includes .NET 2.0 and .NET 3.0).

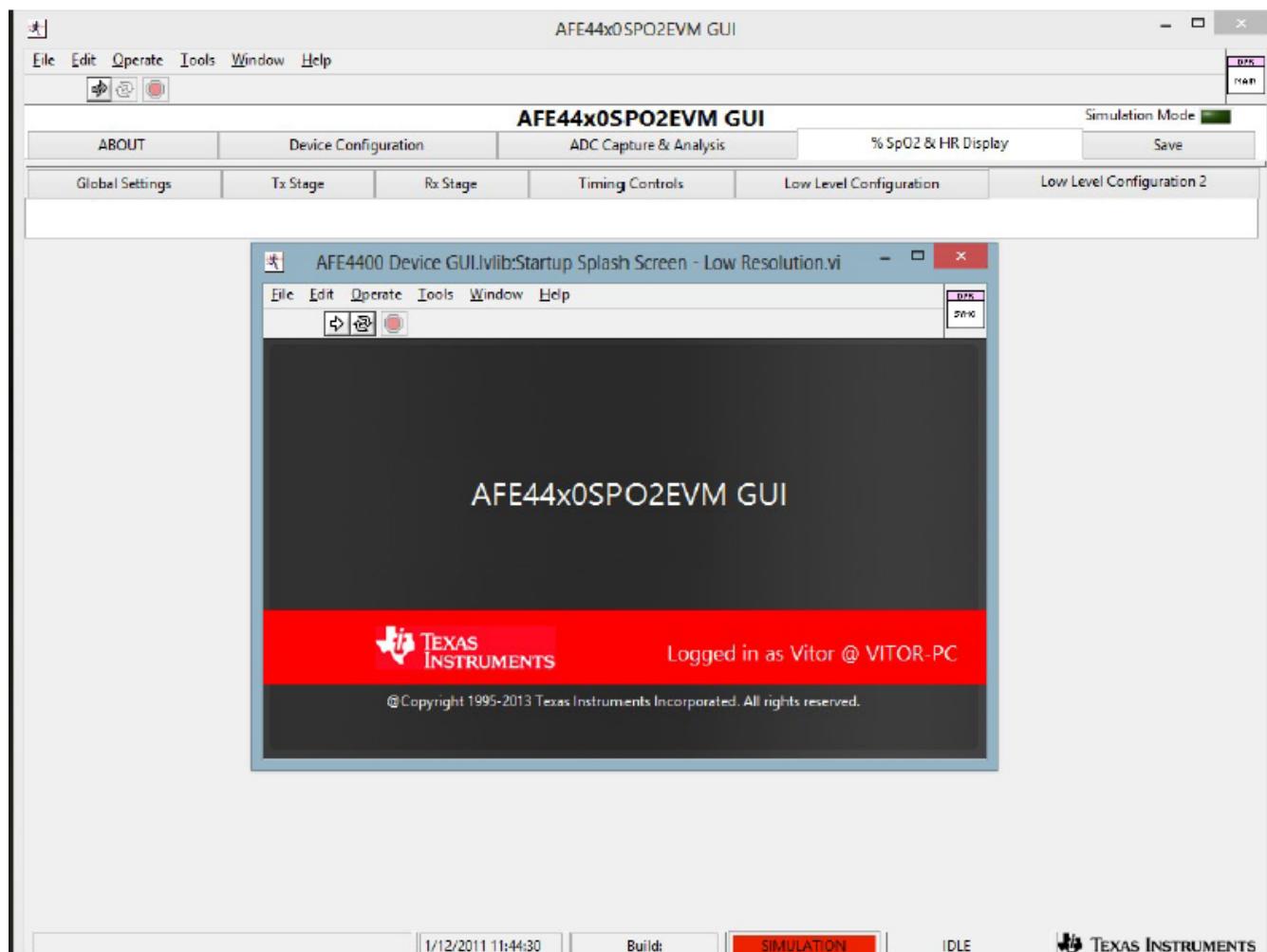


Figure 50. Broken Arrow Error

The .NET Framework 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.
- 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](http://msdn.microsoft.com/library/hh506443(v=VS.110).aspx)).

There are two methods to resolve this.

9.4.1 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.

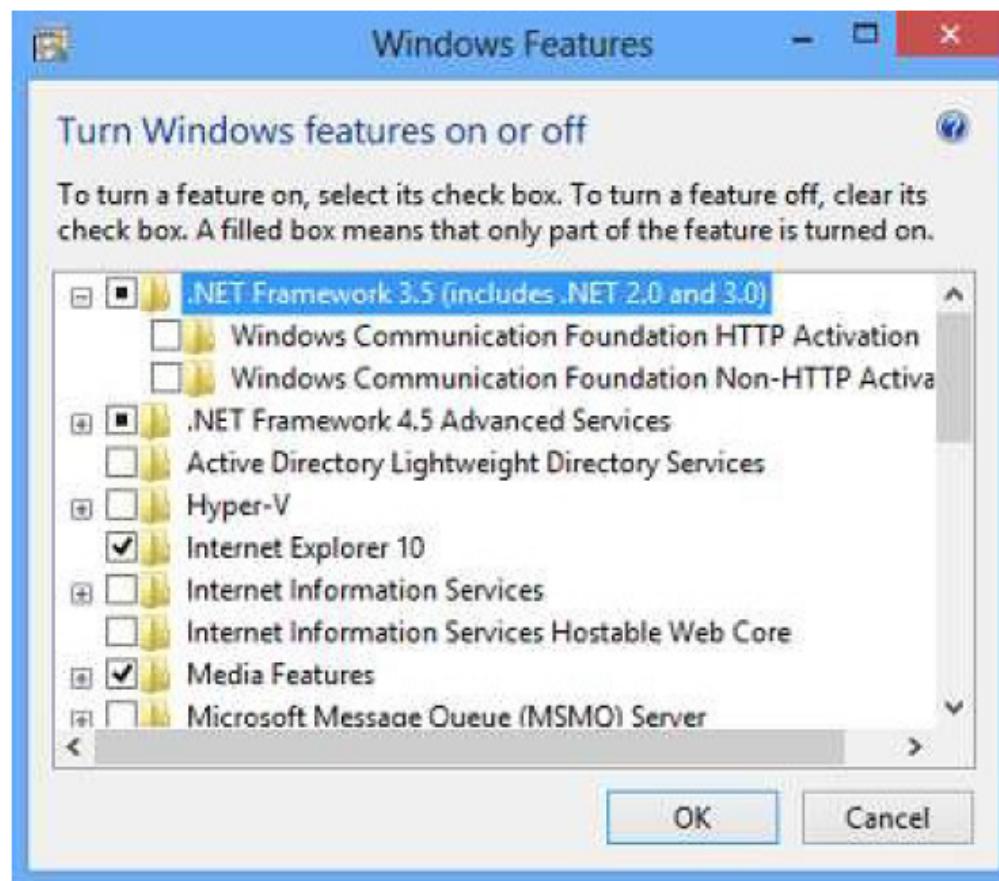


Figure 51. Method 1 (Screen 1)

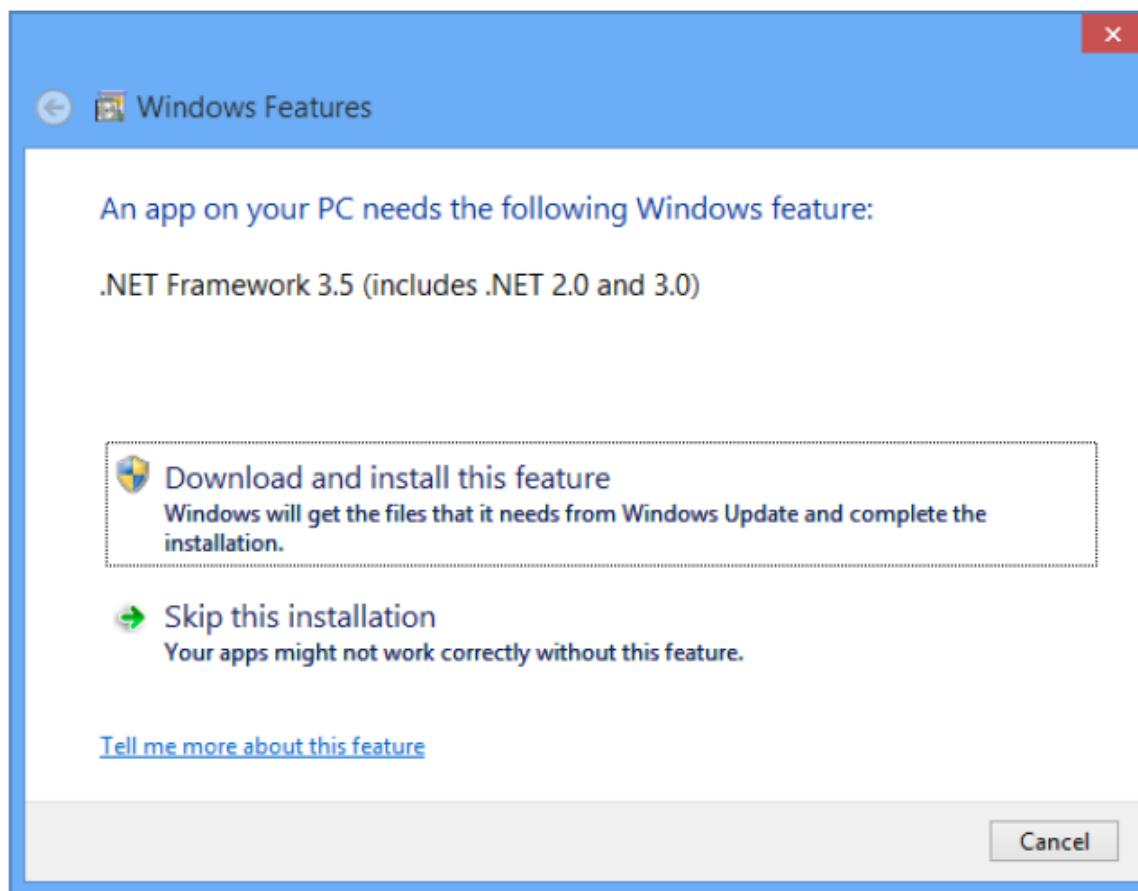


Figure 52. Method 1 (Screen 2)

Select Download and Install this feature.

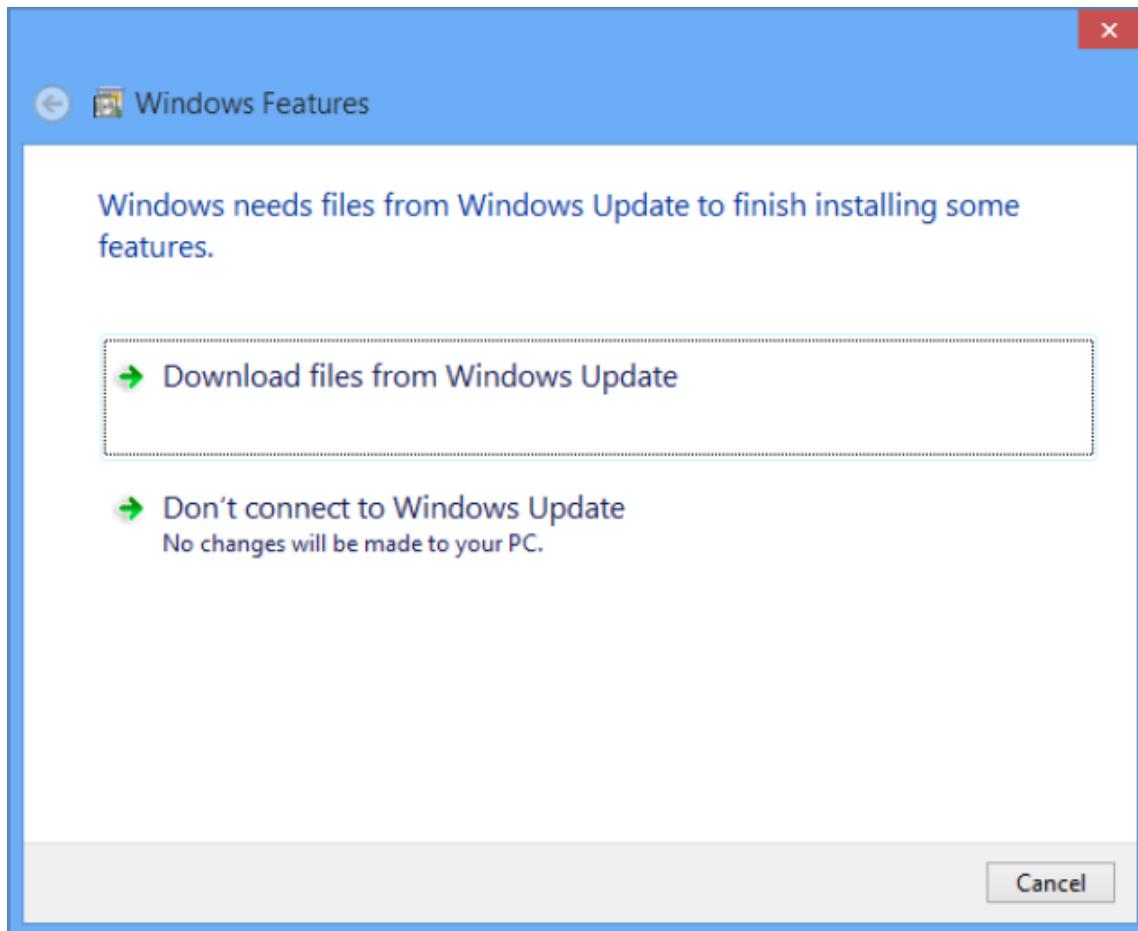


Figure 53. Method 1 (Screen 3)

Select Download Files from Windows Update.

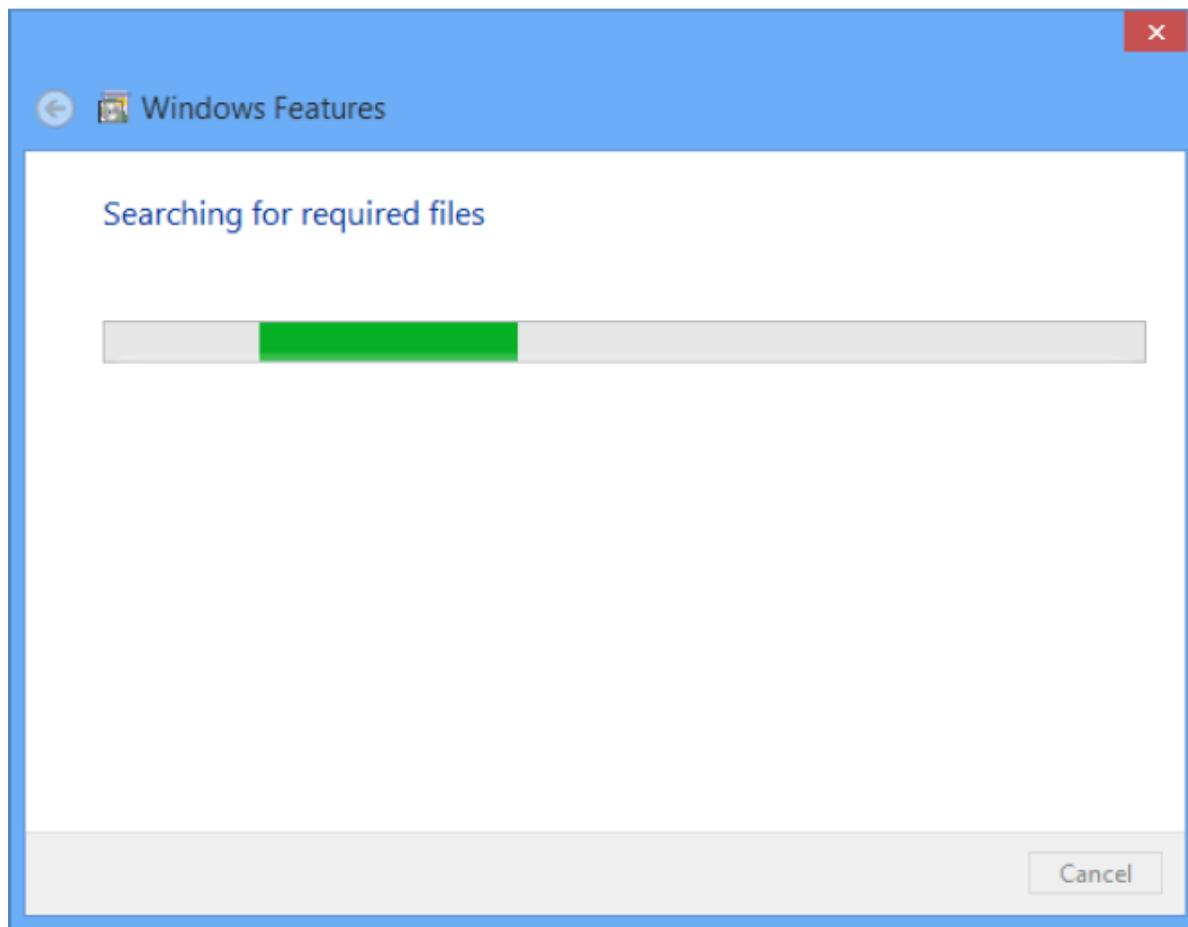


Figure 54. Method 1 (Screen 4)

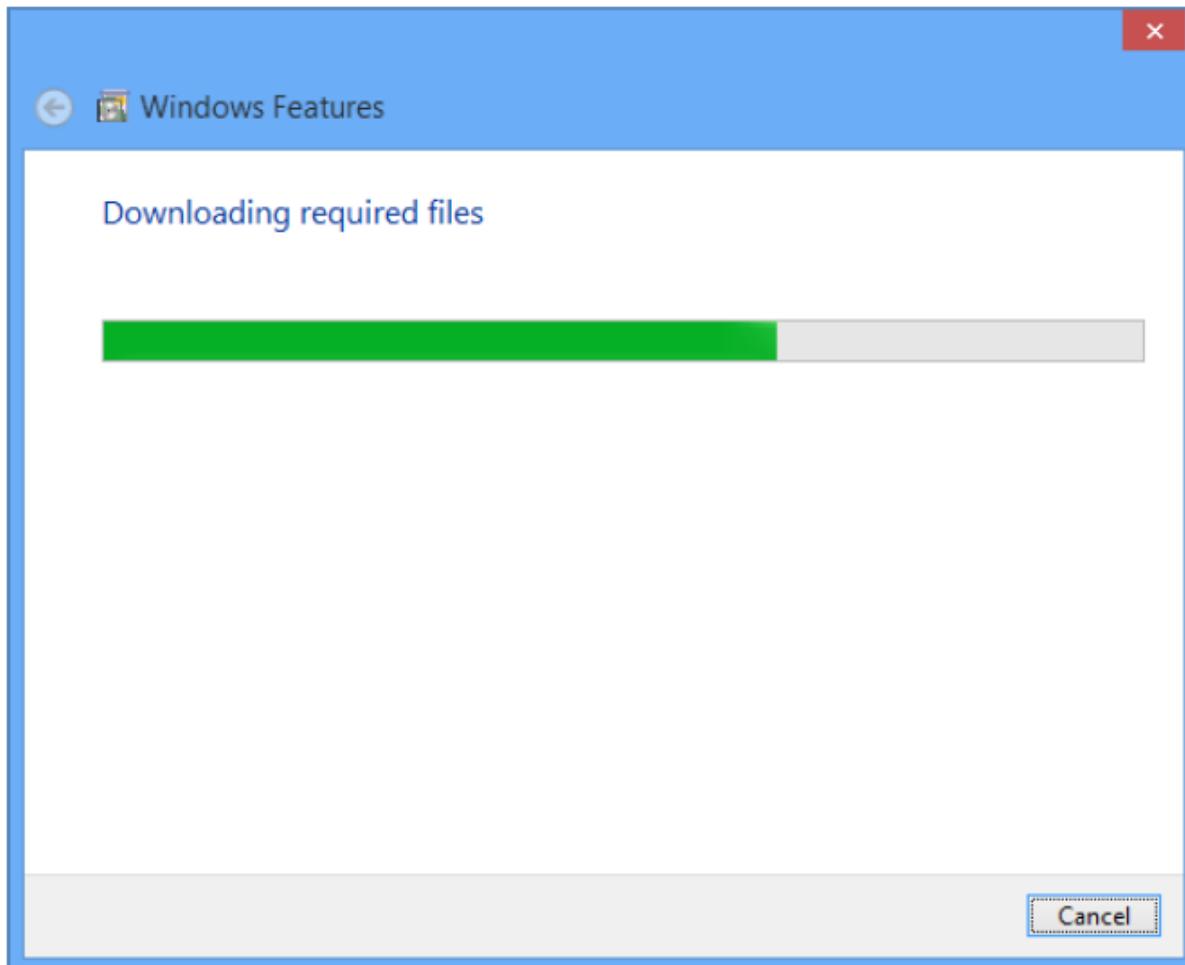


Figure 55. Method 1 (Screen 5)

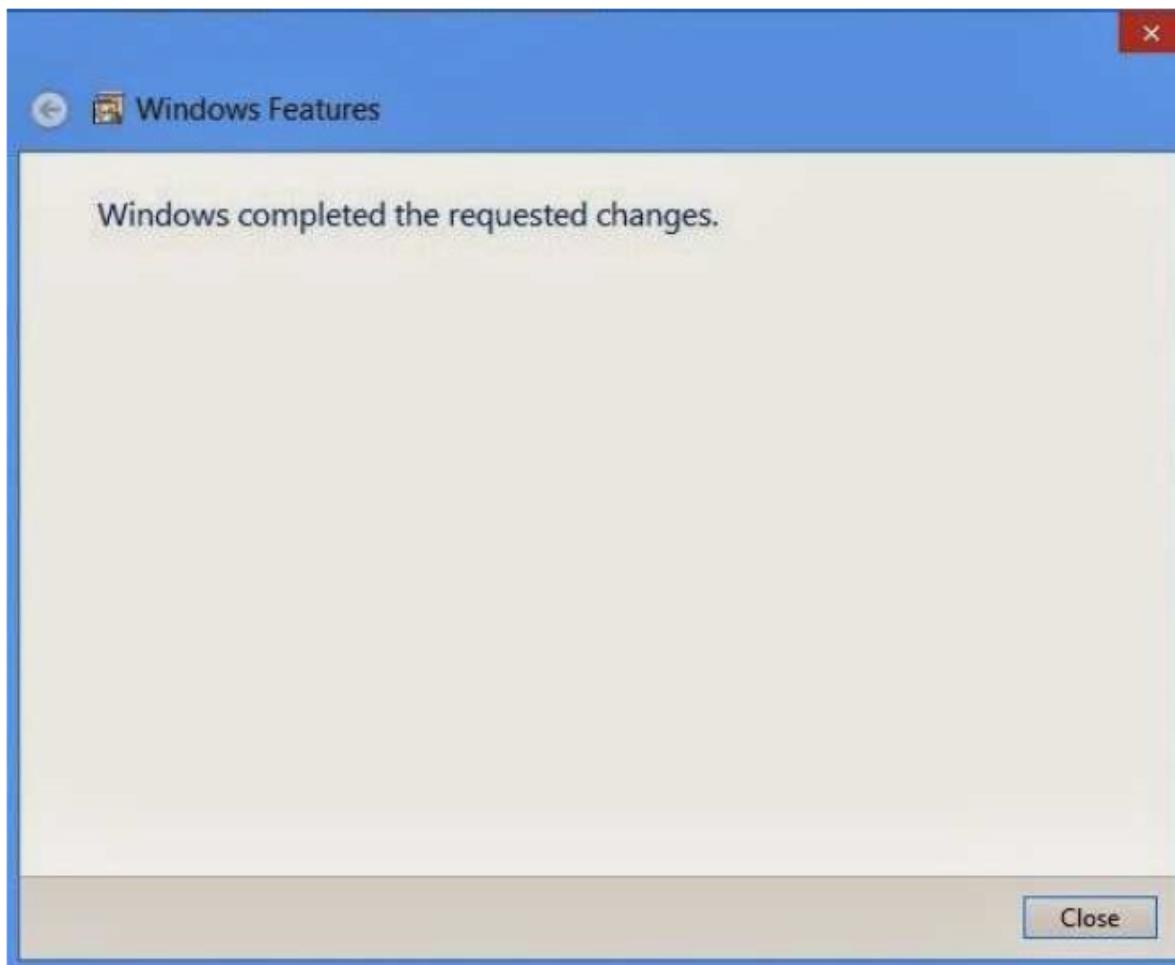


Figure 56. Method 1 (Screen 6)

9.4.2 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.)

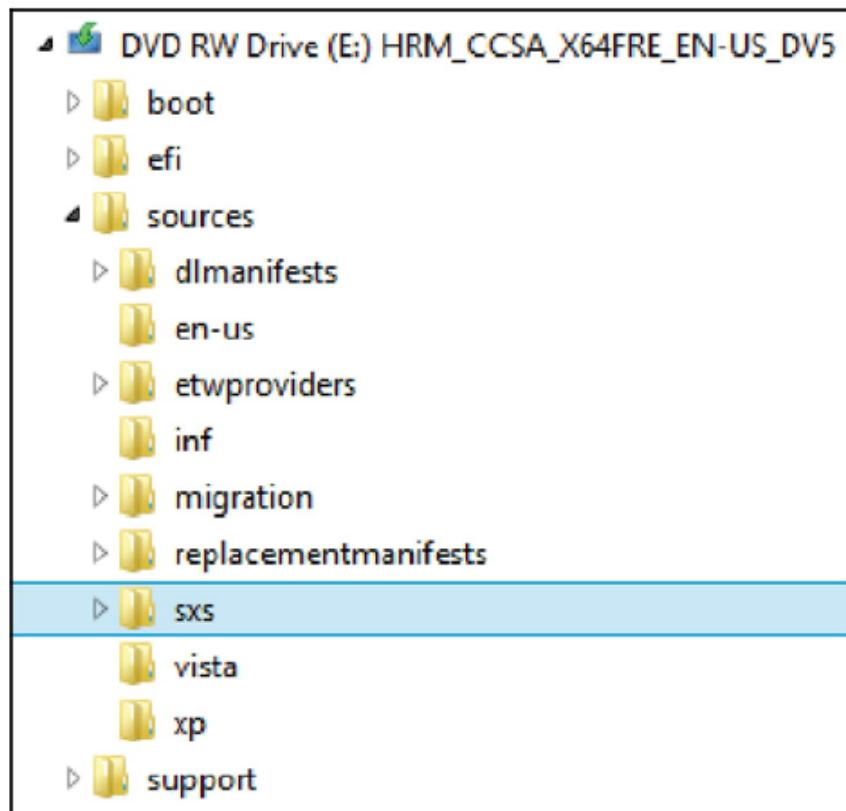


Figure 57. Method 2 (Screen 1)

Step 2. Open Command prompt as administrator.

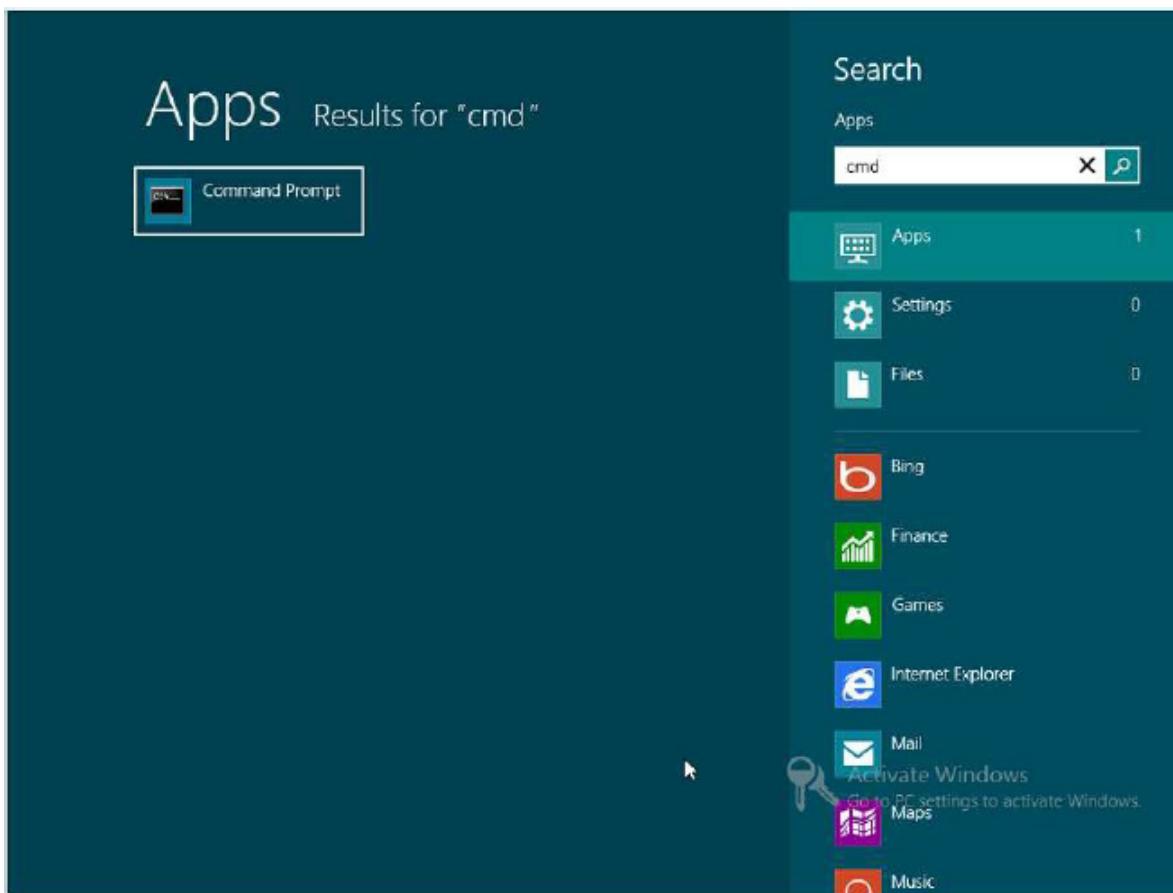


Figure 58. Method 2 (Screen 2)

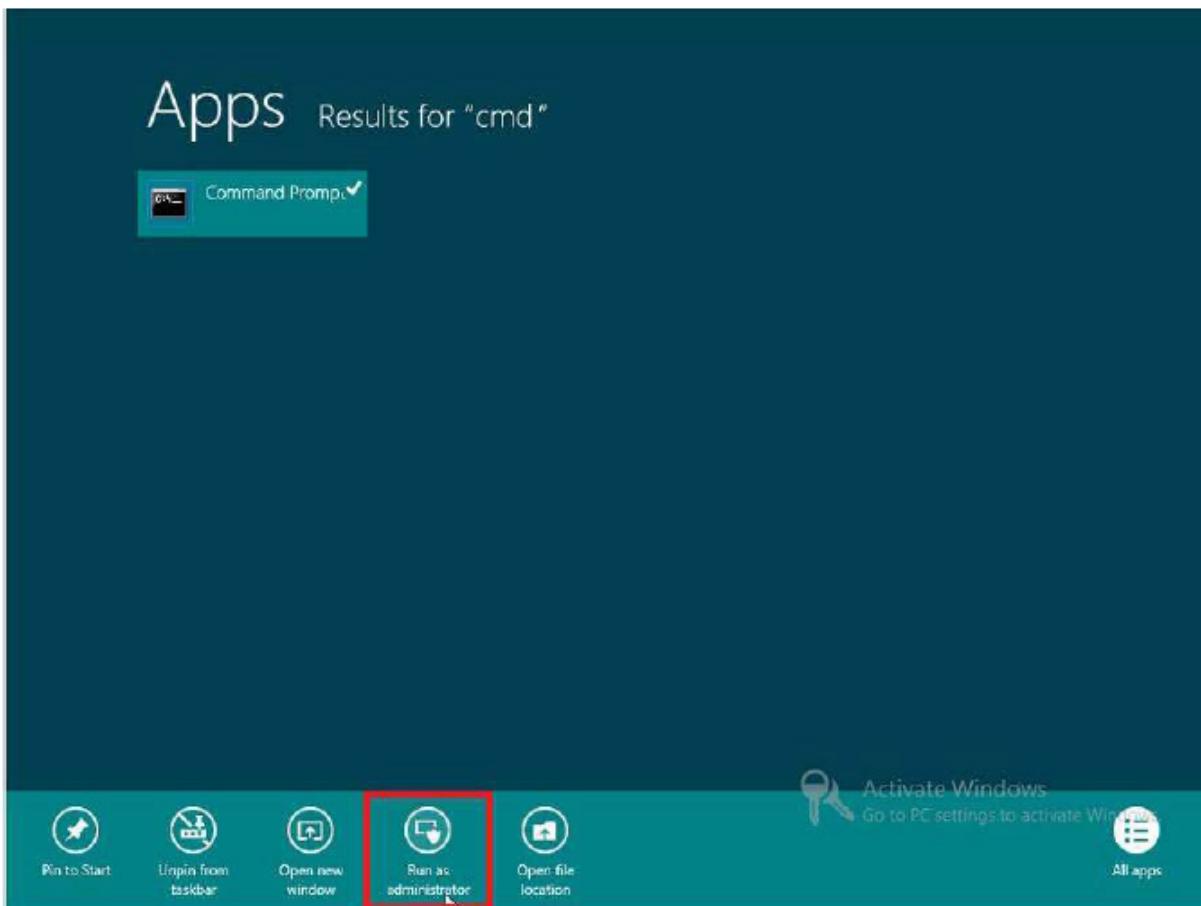
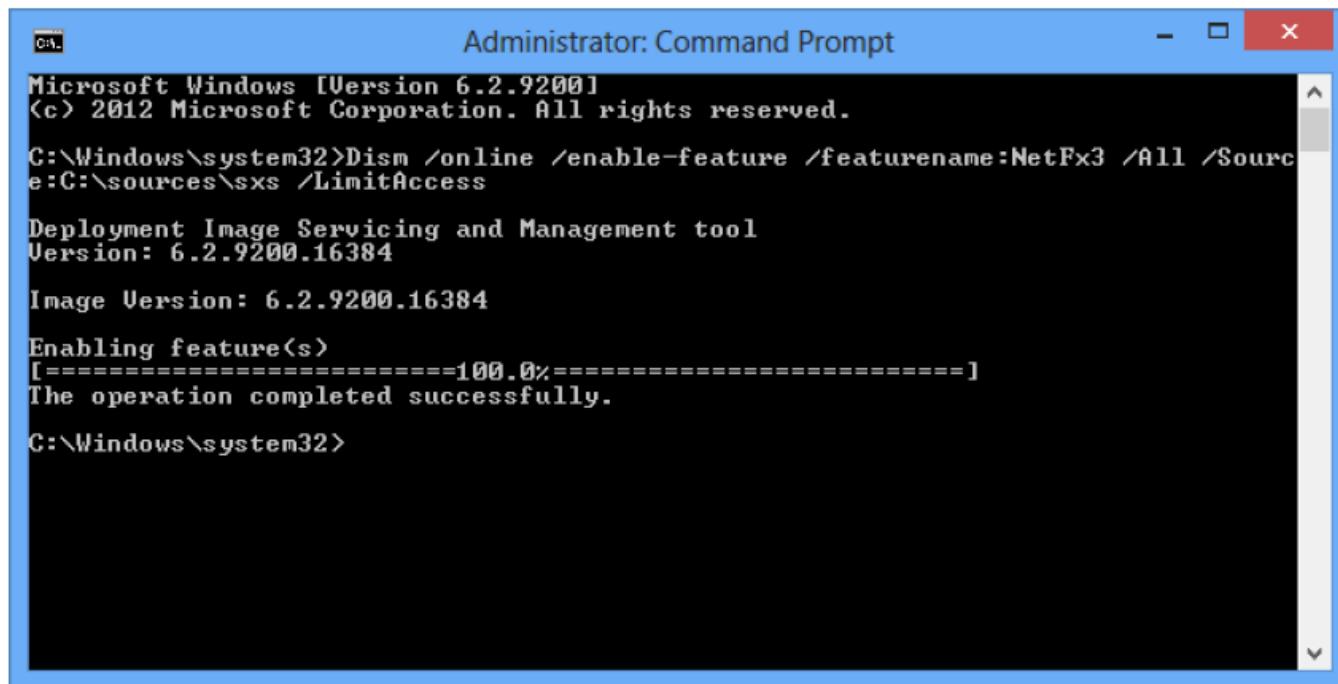


Figure 59. Method 2 (Screen 3)

- 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:\).



```

Administrator: Command Prompt

Microsoft Windows [Version 6.2.9200]
(c) 2012 Microsoft Corporation. All rights reserved.

C:\Windows\system32>Dism /online /enable-feature /featurename:NetFx3 /All /Source
e:C:\sources\sxs /LimitAccess

Deployment Image Servicing and Management tool
Version: 6.2.9200.16384

Image Version: 6.2.9200.16384

Enabling feature(s)
[=====100.0%=====]
The operation completed successfully.

C:\Windows\system32>

```

Figure 60. Method 2 (Screen 4)

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

Table 6. 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

9.5 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).

10 Bill of Materials

[Table 7](#) lists the bill of materials.

Table 7. AFE4404 EVM Bill of Materials⁽¹⁾

Designator	QTY	Description	Manufacturer	PartNumber	Alternate Manufacturer	Alternate Part Number
!PCB	1	Printed Circuit Board	Any	MHR001	-	-
C1	1	CAP, CERM, 2200 pF, 50 V, +/- 10%, X7R, 0402	Murata	GRM155R71H222KA01D		
C2, C3, C4, C6, C8, C9, C12, C14, C15, C24, C32, C40, C42	13	CAP, CERM, 0.1 µF, 16 V, +/- 10%, X7R, 0402	Murata	GRM155R71C104KA88D		
C5, C7	2	CAP, CERM, 1 µF, 16 V, +/- 10%, X5R, 0402	TDK	C1005X5R1C105K050BC		
C10, C25, C26, C35, C36, C37, C38, C43, C44, C46, C47, C49, C51, C55	14	CAP, CERM, 10 µF, 16 V, +/- 10%, X5R, 0805	Murata	GRM21BR61C106KE15L		
C11	1	CAP, CERM, 2.2 µF, 10 V, +/- 10%, X5R, 0603	Kemet	C0603C225K8PACTU		
C13	1	CAP, CERM, 4.7 µF, 10 V, +/- 10%, X5R, 0402	TDK	C1005X5R1A475K050BC		
C22, C23, C28, C29	4	CAP, CERM, 10 pF, 50 V, +/- 5%, C0G/NP0, 0402	Murata	GRM1555C1H100JA01D		
C27, C33, C48	3	CAP, CERM, 0.01 µF, 50 V, +/- 10%, C0G/NP0, 0402	Murata	GCM155R71H103KA55D		
C34	1	CAP, CERM, 1 µF, 6.3 V, +/- 10%, X6S, 0603	Murata	GRM185C80J105KE26D		
C39, C41	2	CAP, CERM, 12 pF, 50 V, +/- 5%, C0G/NP0, 0402	Murata	GRM1555C1H120JA01D		
C45	1	CAP, CERM, 0.47 µF, 10 V, +/- 10%, X5R, 0402	Murata	GRM155R61A474KE15D		
C52	1	CAP, CERM, 1000 pF, 50 V, +/- 10%, X7R, 0402	Murata	GRM155R71H102KA01D		
D1	1	Diode, Schottky, 40 V, 0.35 A, SOD-123	Diodes Inc.	SD103AW-7-F		
D3, D4, D5, D6, D7	5	Diode, Switching, 75 V, 0.15 A, SOT-323	Diodes Inc.	BAV99W-7-F		
H1	1	MHR002 - AFE4404EVM Sensor Board	Texas Instruments	MHR002	-	-
H2	1	UC-SPO2-118 - Custom cable to connect AFE4404EVM (MHR001) and AFE4404EVM Sensor board (MHR002)	Biometric Cables	UC-SPO2-118	-	-
J1	1	Connector, Receptacle, Micro-USB Type AB, R/A, Bottom Mount SMT	Hirose Electric Co. Ltd.	ZX62D-AB-5P8		
J4	1	Receptacle, 50mil, 10x1, Gold, R/A, TH	Mill-Max	851-43-010-20-001000		
L1	1	Coupled inductor, 0.37 A, 0.3 ohm, SMD	Murata	DLW31SN900SQ2L		
L2, L3	2	Inductor, Shielded, Ferrite, 10 µH, 0.48 A, 0.54 ohm, SMD	Coilcraft	LPS3010-103MRB		
LED1, LED2	2	LED, Green, SMD	Lumex	SML-LX0603GW-TR		
LED3	1	LED, Super Red, SMD	Lumex	SML-LX0603SRW-TR		
Q1	1	Transistor, NPN, 25 V, 0.05 A, SOT-23	ON Semiconductor	MMBT5089LT1G		
R2, R32, R62	3	RES, 47 k, 5%, 0.063 W, 0402	Vishay-Dale	CRCW040247K0JNED		

⁽¹⁾ Substitutions made according to Alternate Part Number must meet datasheet parameters, not just the Description specified.

Table 7. AFE4404 EVM Bill of Materials⁽¹⁾ (continued)

Designator	QTY	Description	Manufacturer	PartNumber	Alternate Manufacturer	Alternate Part Number
R3, R35, R52, R78, R90	5	RES, 0, 5%, 0.063 W, 0402	Vishay-Dale	CRCW04020000Z0ED		
R4, R34, R79, R80	4	RES, 4.7 k, 5%, 0.063 W, 0402	Vishay-Dale	CRCW04024K70JNED		
R5	1	RES, 1.40 k, 1%, 0.063 W, 0402	Vishay-Dale	CRCW04021K40FKED		
R7, R8, R15, R16, R18, R19, R75, R76, R84	9	RES, 10.0, 1%, 0.063 W, 0402	Vishay-Dale	CRCW040210R0FKED		
R14	1	RES, 499, 1%, 0.063 W, 0402	Vishay-Dale	CRCW0402499RFKED		
R20, R21, R22	3	RES, 10.0 k, 1%, 0.063 W, 0402	Vishay-Dale	CRCW040210K0FKED		
R28, R29, R30, R31, R36, R37, R38, R40, R41, R46	10	RES, 10.0 k, 1%, 0.1 W, 0402	Panasonic	ERJ-2RKF1002X		
R33	1	RES, 33 k, 5%, 0.063 W, 0402	Vishay-Dale	CRCW040233K0JNED		
R45, R56	2	RES, 100, 1%, 0.063 W, 0402	Vishay-Dale	CRCW0402100RFKED		
R48, R53, R65, R71, R73, R74, R88	7	RES, 0, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06030000Z0EA		
R50, R51	2	RES, 33, 5%, 0.063 W, 0402	Vishay-Dale	CRCW040233R0JNED		
R57	1	RES, 1.00 M, 1%, 0.063 W, 0402	Vishay-Dale	CRCW04021M00FKED		
R61	1	RES, 200 k, 5%, 0.063 W, 0402	Vishay-Dale	CRCW0402200KJNED		
R63	1	RES, 261 k, 1%, 0.1 W, 0603	Vishay-Dale	CRCW0603261KFKEA		
R64	1	RES, 75.0 k, 1%, 0.063 W, 0402	Vishay-Dale	CRCW040275K0FKED		
R67	1	RES, 130, 5%, 0.063 W, 0402	Vishay-Dale	CRCW0402130RJNED		
R68	1	RES, 220, 5%, 0.063 W, 0402	Vishay-Dale	CRCW0402220RJNED		
R69	1	RES, 15.4 k, 1%, 0.1 W, 0603	Vishay-Dale	CRCW060315K4FKEA		
R85	1	RES, 4.02 k, 1%, 0.063 W, 0402	Vishay-Dale	CRCW04024K02FKED		
R86	1	RES, 1.0 k, 5%, 0.063 W, 0402	Vishay-Dale	CRCW04021K00JNED		
S1, S2	2	Switch, Tactile, SPST-NO, 0.05A, 12V, SMD	C&K Components	RS-032G05A3-SM RT		
U1	1	Ultra-small, Integrated AFE for Heart Rate Monitors and Pulse Oximeters, YZP0015ALAL	Texas Instruments	AFE4404YZP	Texas Instruments	
U2	1	25 MHz Mixed Signal Microcontroller with 128 KB Flash, 8192 B SRAM and 63 GPIOs, -40 to 85 degC, 80-pin QFP (PN), Green (RoHS & no Sb/Br)	Texas Instruments	MSP430F5529IPN	Texas Instruments	Equivalent
U3	1	Dual Input Li-Ion Charger with Dynamic Power Path, Output regulated to 4.4 V, Vbat 4.2 V, 4.3 V, -40 to 85 degC, 20-pin QFN (RHL), Green (RoHS & no Sb/Br)	Texas Instruments	BQ24032ARHLR	None	Equivalent
U5	1	ESD-Protection Array for High-Speed Data Interfaces, 4 Channels, -40 to +85 degC, 6-pin SON (DRY), Green (RoHS & no Sb/Br)	Texas Instruments	TPD4E004DRYR	None	Equivalent

Table 7. AFE4404 EVM Bill of Materials⁽¹⁾ (continued)

Designator	QTY	Description	Manufacturer	PartNumber	Alternate Manufacturer	Alternate Part Number
U6	1	Single Output High PSRR LDO, 150 mA, Adjustable 1.2 to 33 V Output, 3 to 36 V Input, with Ultra-Low Noise, 8-pin MSOP (DGN), -40 to 125 degC, Green (RoHS & no Sb/Br)	Texas Instruments	TPS7A4901DGNT	None	Equivalent
U7	1	LOW INPUT BOOST CONVERTER WITH INTEGRATED POWER DIODE AND INPUT/OUTPUT ISOLATION, DSK0010A	Texas Instruments	TPS61093DSKR	Texas Instruments	
U8	1	Processor Supervisory Circuits, DBV0005A	Texas Instruments	TPS3825-33DBVR	Texas Instruments	TPS3825-33DBVT
U9	1	Micropower 800mA Low Noise "Ceramic Stable" Adjustable Voltage Regulator for 1V to 5V Applications, 8-pin PSOP, Pb-Free	Texas Instruments	LP3878MR-ADJ/NOPB		
Y1	1	Crystal, 24 MHz, 10 pF, SMD	Abracan Corporation	ABM3B-24.000MHZ-10-1-U-T		
Y2	1	CRYSTAL, 32.768KHZ, 12.5PF, SMD	Abracan Corporation	ABS07-32.768KHZ-T		
C16, C17, C18, C20, C30, C31	0	CAP, CERM, 0.1 µF, 16 V, +/- 10%, X7R, 0402	Murata	GRM155R71C104KA88D		
C19	0	CAP, CERM, 10 µF, 6.3 V, +/- 20%, X5R, 0603	Kemet	C0603C106M9PACTU		
C21	0	CAP, TA, 22 µF, 6.3 V, +/- 20%, 5.4 ohm, SMD	AVX	TLJN226M006R5400		
D2	0	Diode, Zener, 5.6 V, 300 mW, SOT-23	Micro Commercial Components	AZ23C5V6-TP		
FID1, FID2, FID3, FID4, FID5, FID6	0	Fiducial mark. There is nothing to buy or mount.	N/A	N/A		
J3	0	Header, 1.27 mm, 6x1, Tin, R/A, TH	Mill-Max	850-40-006-20-001000		
J5	0	Header (friction lock), 100mil, 2x1, Tin, TH	Molex	22-27-2021		
P1	0	Footprint for TC2050-IDC	Tag-Connect	TC2050-IDC-FP		
R1	0	RES, 0.02, 1%, 0.5 W, 1206	Stackpole Electronics Inc	CSR1206FK20L0		
R13	0	RES, 10.0 k, 1%, 0.063 W, 0402	Vishay-Dale	CRCW040210K0FKED		
R39, R43, R58	0	RES, 1.00 k, 1%, 0.1 W, 0402	Panasonic	ERJ-2RKF1001X		
R42, R44, R47, R49	0	RES, 10.0 k, 1%, 0.1 W, 0402	Panasonic	ERJ-2RKF1002X		
R54, R55, R59, R60	0	RES, 100, 1%, 0.063 W, 0402	Vishay-Dale	CRCW0402100RFKED		
R66, R72, R89	0	RES, 0, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06030000Z0EA		
R70, R77, R81, R87, R91	0	RES, 0, 5%, 0.063 W, 0402	Vishay-Dale	CRCW04020000Z0ED		
R92	0	RES, 499 k, 1%, 0.063 W, 0402	Vishay-Dale	CRCW0402499KFKED		
U4	0	Single-Cell Li-Ion and Li-Po Battery Gas Gauge IC with I2C Interface, -20 to 70 degC, 10-pin VSON (DRK), Green (RoHS & no Sb/Br)	Texas Instruments	BQ27200DRKR	None	Equivalent

Table 8. Sensor Board Bill of Materials

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
!PCB	1		Printed Circuit Board		MHR002	Any
J1	1		Header, 50mil, 10x1, R/A, TH	Header, 10x1, 50mil, R/A	850-10-010-20-001000	Mill-Max
R2, R4, R6, R8, R10, R11	6	0	RES, 0, 5%, 0.063 W, 0402	0402	ERJ-2GE0R00X	Panasonic
U1	1		BioMon Sensor, SFH7050	SMD, 4.7x2.5mm	SFH7050	OSRAM
U2	1		COBP PHOTO SENSOR with Red & IR & Two Green LED, SMD	5x3.2mm	NJL5513R	New Japan Radio
C1, C2	0	0.1uF	CAP, CERM, 0.1 μ F, 16 V, +/- 10%, X7R, 0402	0402	GRM155R71C104KA88D	Murata
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A
R1, R3, R5, R7, R9	0	0	RES, 0, 5%, 0.063 W, 0402	0402	ERJ-2GE0R00X	Panasonic
U3	0		14 Bit, Digital, Triaxial Acceleration Sensor with Intelligent On-Chip Motion-Triggered Interrupt Controller, 12LGA	LGA, 12-Leads, Body 2x2mm, Pitch 0.5mm	BMA280	Bosch Solar Energy

11 PCB Layouts and Schematics

11.1 AFE4404 EVM PCB Layouts

Figure 61 through Figure 66 show the EVM PCB layouts.

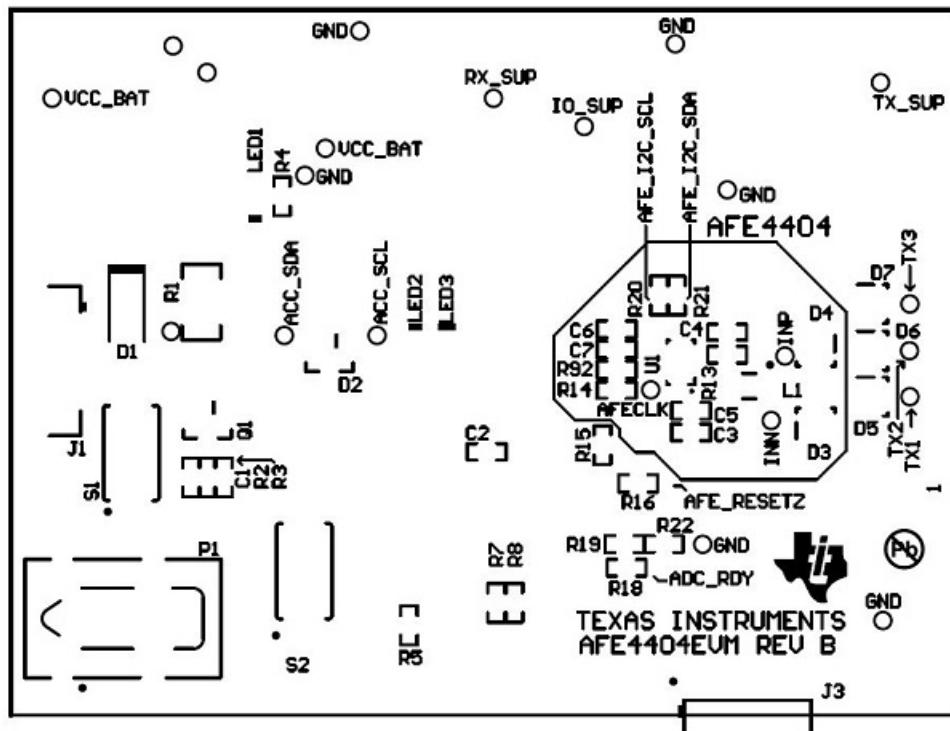


Figure 61. AFE4404 EVM Top Overlay

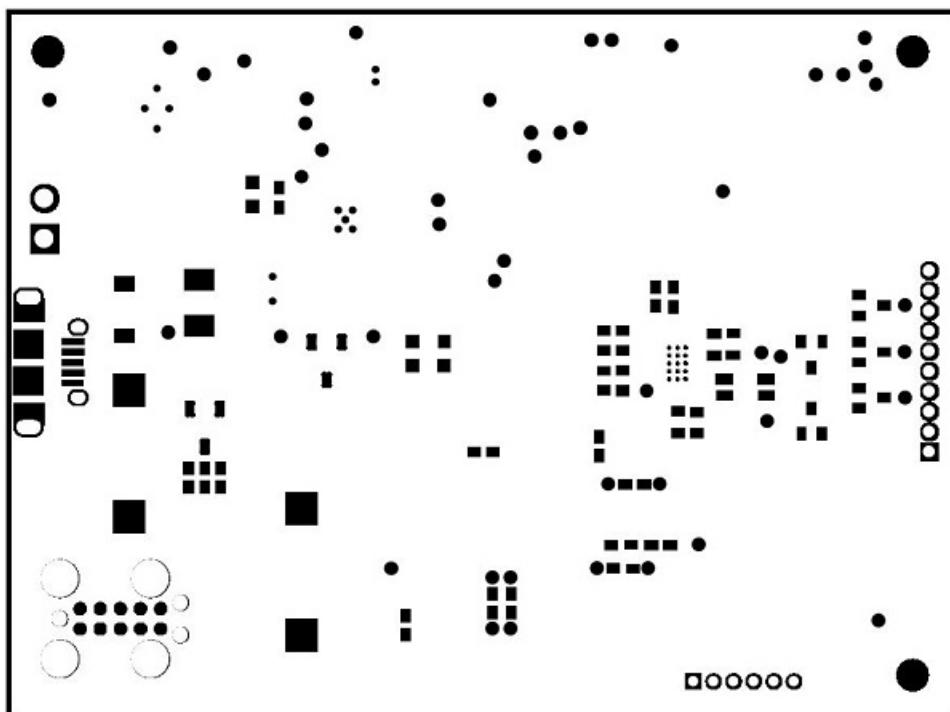


Figure 62. Top Solder

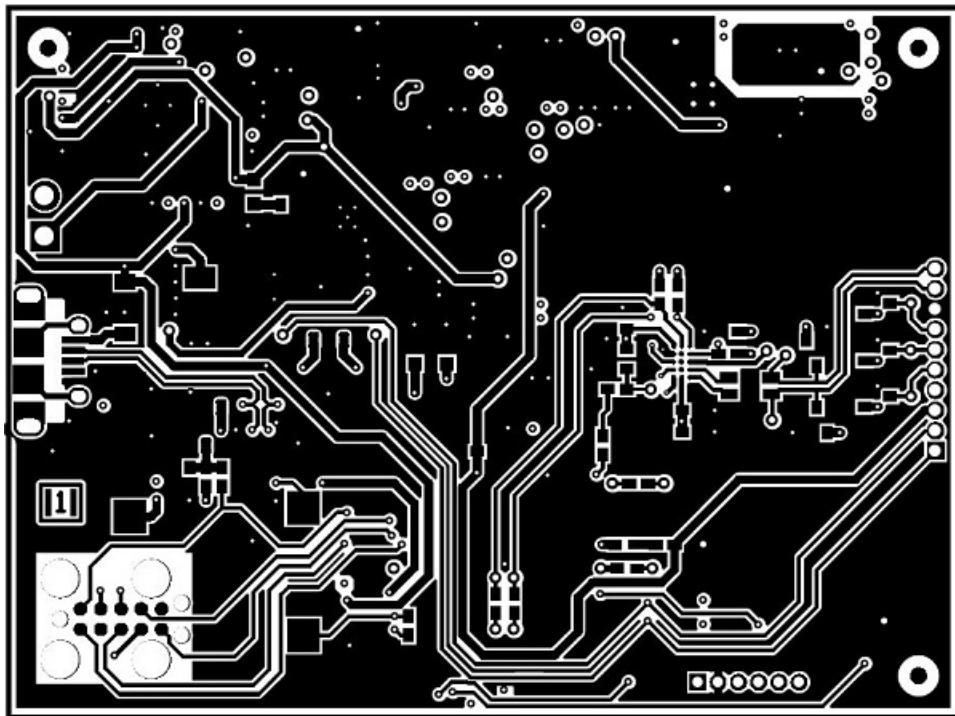


Figure 63. Top Copper (Layer 1)

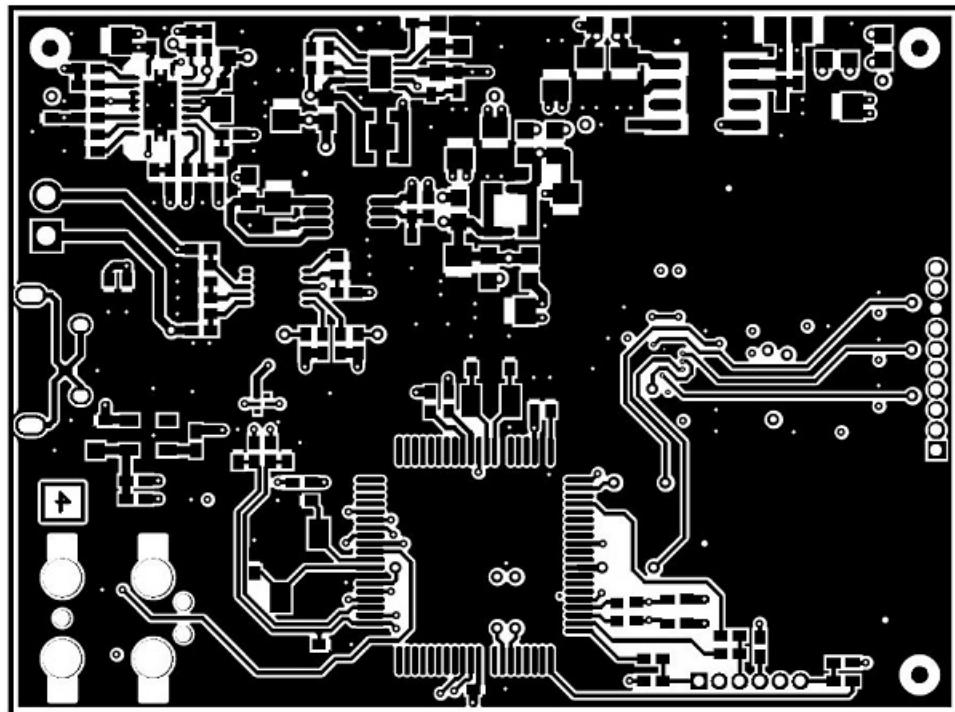


Figure 64. Bottom Copper (Layer 4)

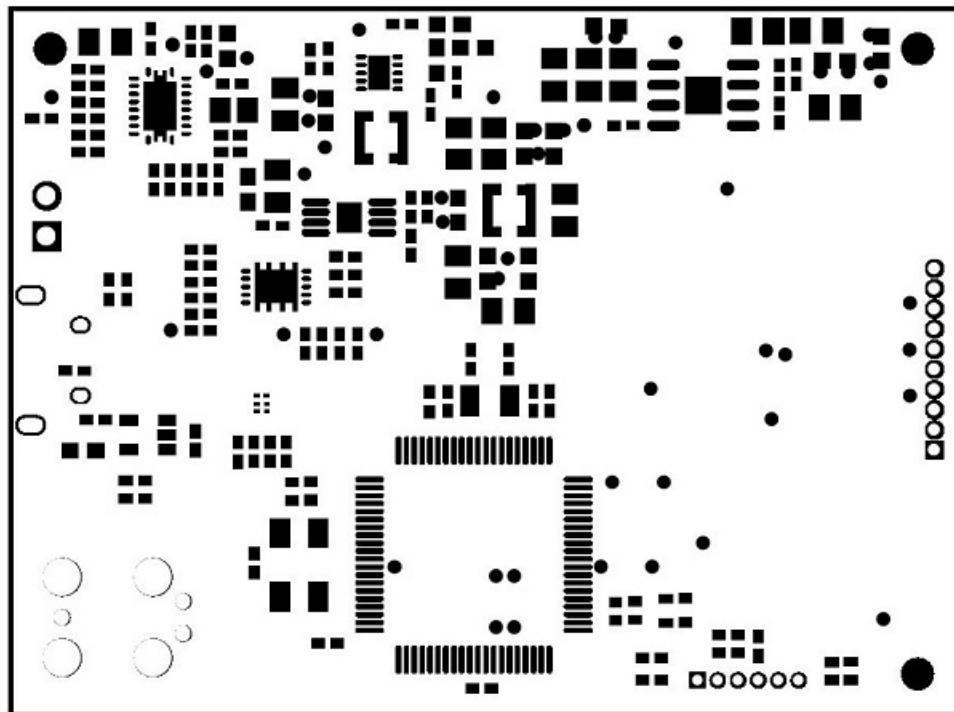


Figure 65. Bottom Solder

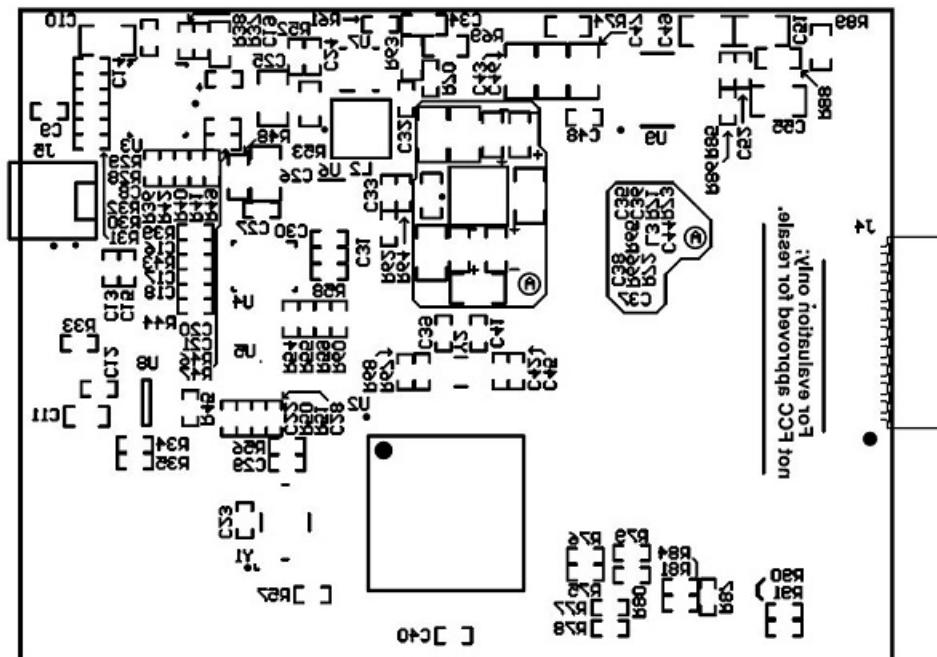


Figure 66. Bottom Overlay

11.2 Sensor Board Layouts

Figure 67 through Figure 72 show the sensor board layouts.

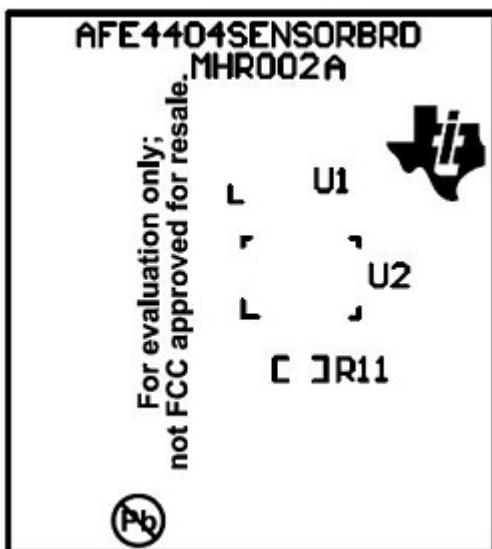


Figure 67. Sensor Board Top Silk Screen

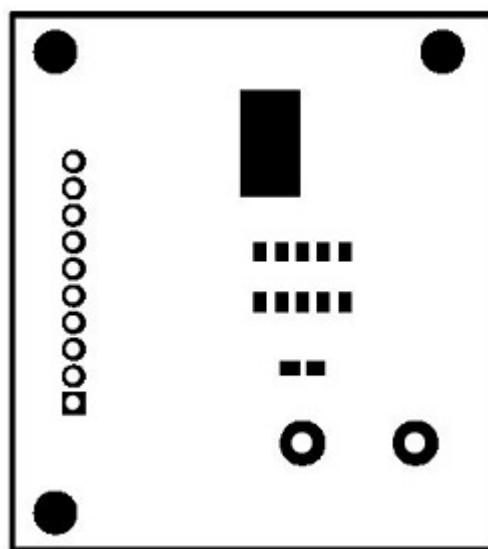


Figure 68. Sensor Board Top Solder Mask

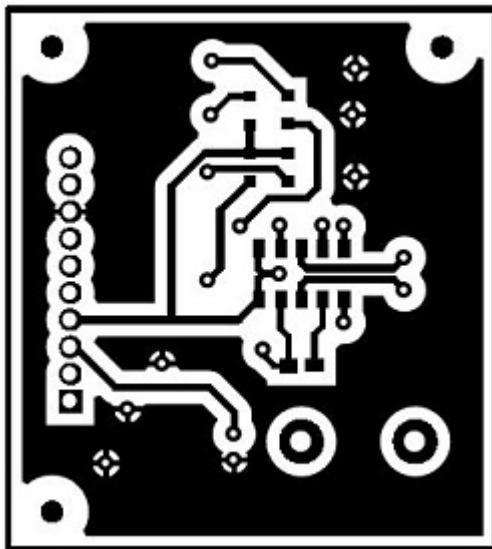


Figure 69. Sensor Board Top Copper

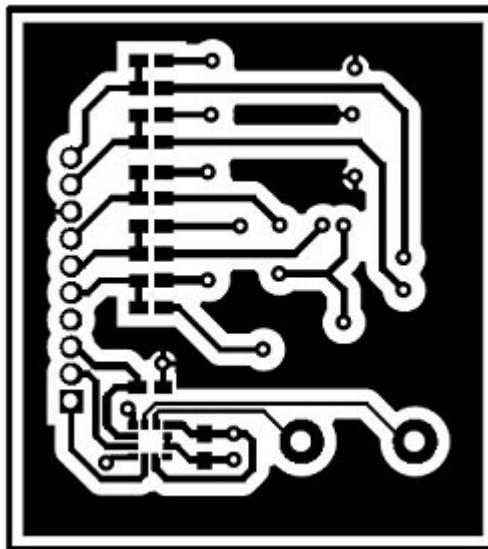


Figure 70. Sensor Board Bottom Copper

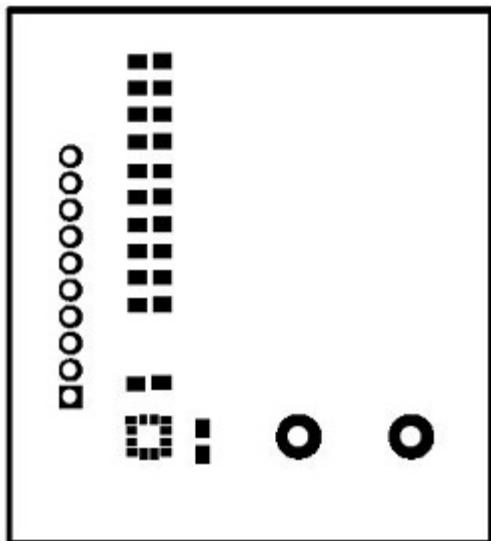


Figure 71. Sensor Board Bottom Solder Mask

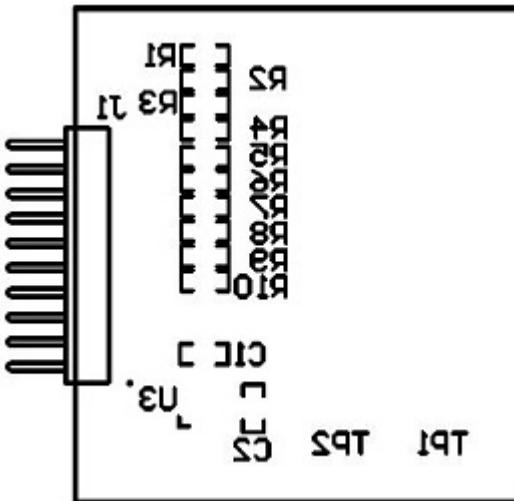


Figure 72. Sensor Board Bottom Silk Screen

11.3 Schematics

This section includes the AFE4404 EVM and sensor board schematics.

11.3.1 AFE4404 EVM Schematics

[Figure 73](#) through [Figure 76](#) illustrate the AFE4404 EVM schematics.

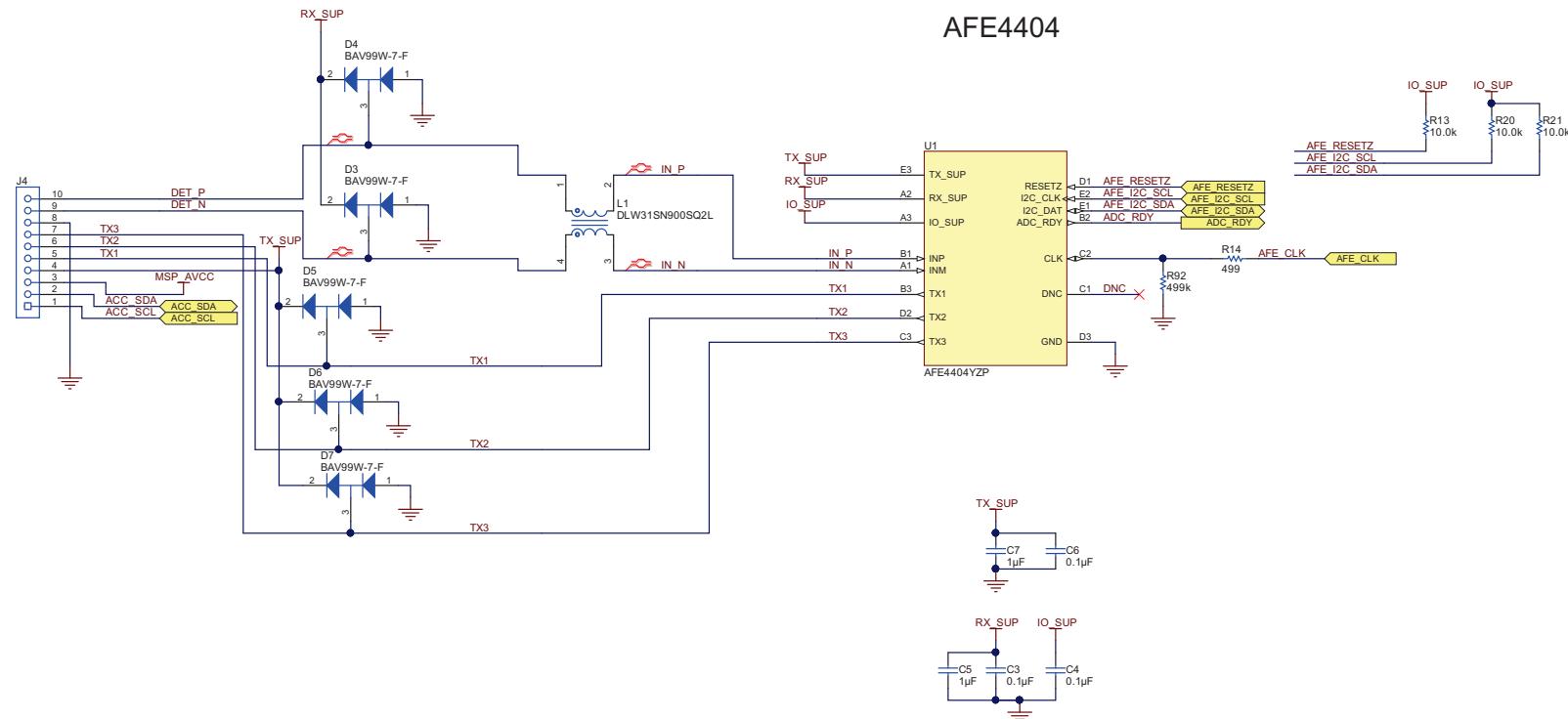


Figure 73. AFE4404 EVM Schematics (1 of 4)

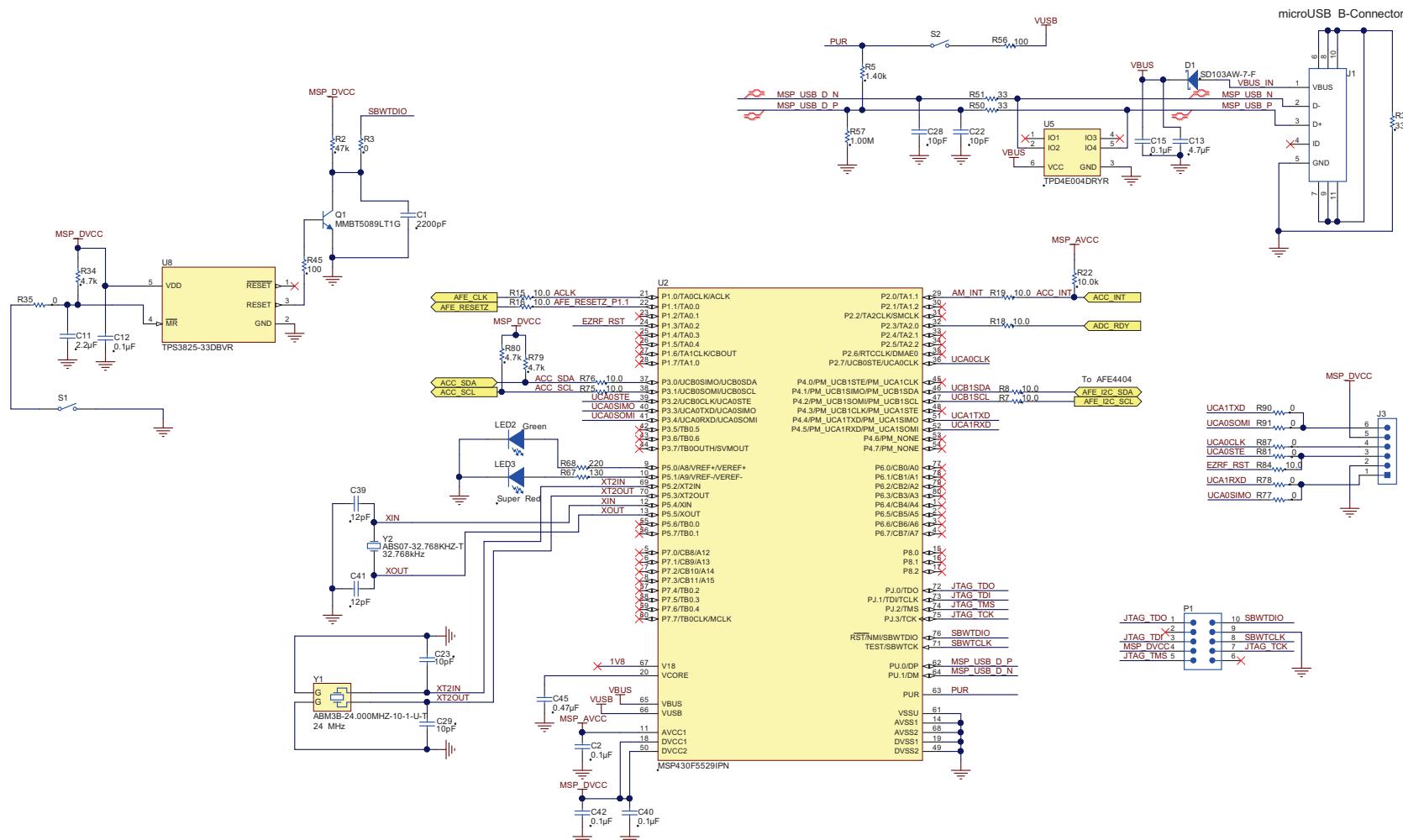


Figure 74. AFE4404 EVM Schematics (2 of 4)

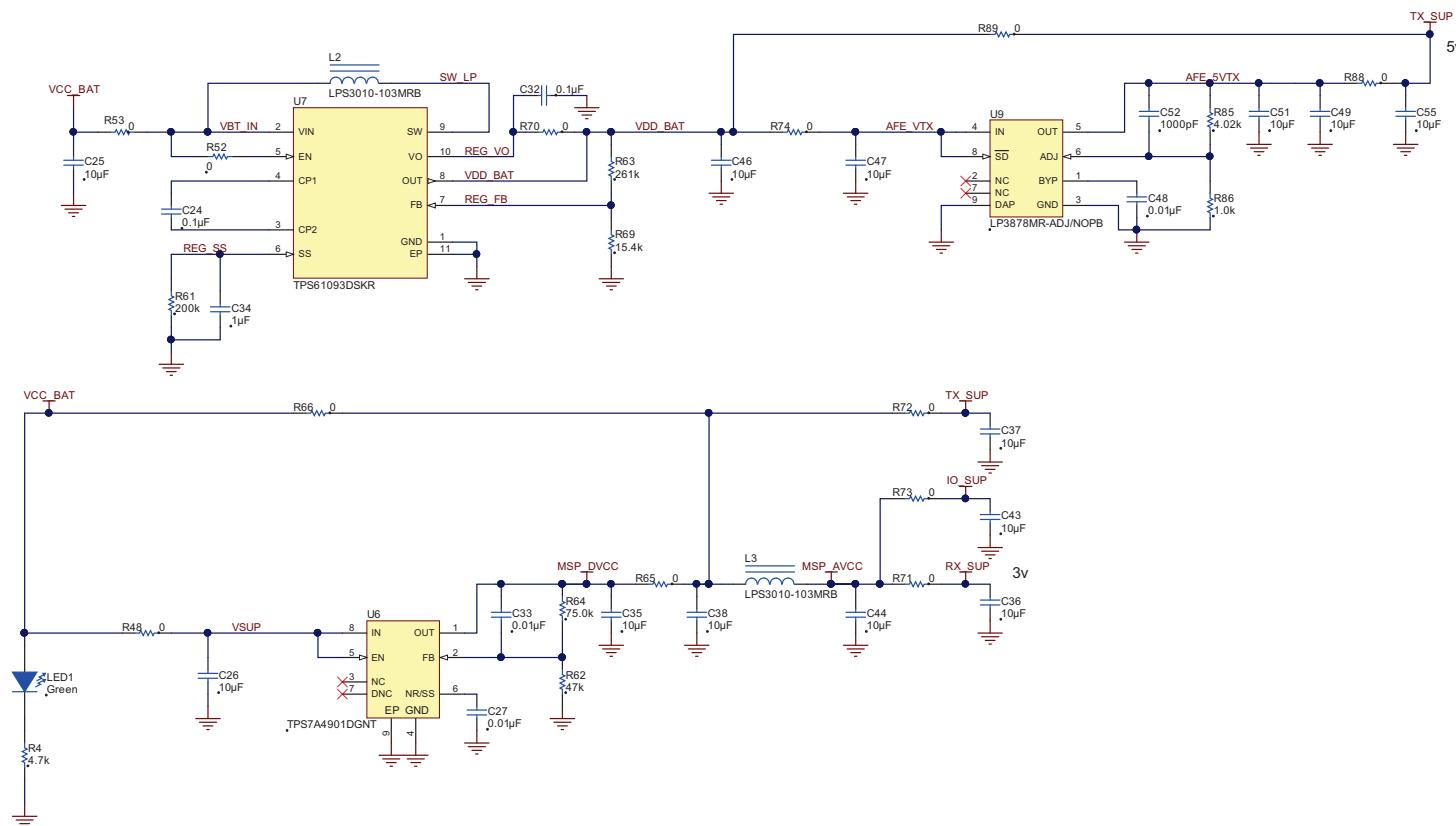


Figure 75. AFE4404 EVM Schematics (3 of 4)

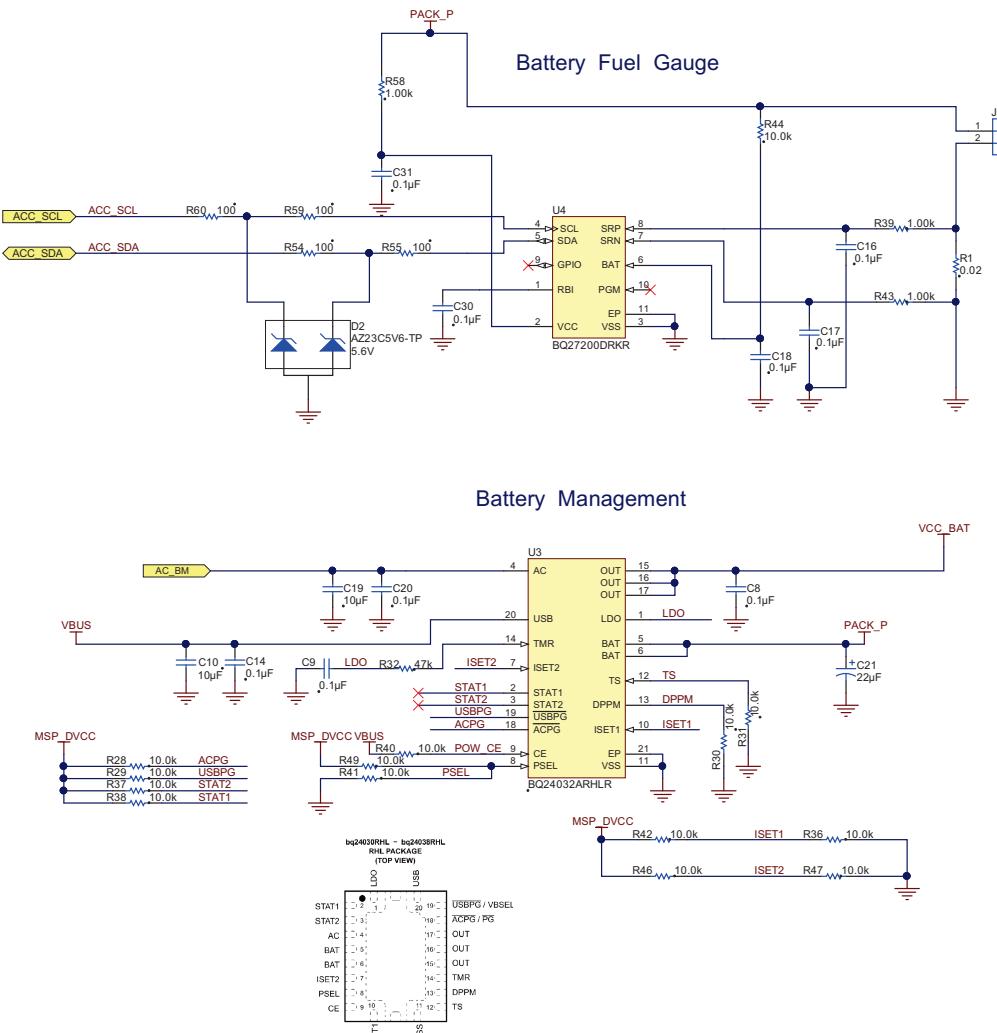


Figure 76. AFE4404 EVM Schematics (4 of 4)

11.4 Sensor Board Schematic

Figure 77 illustrates the sensor board schematic.

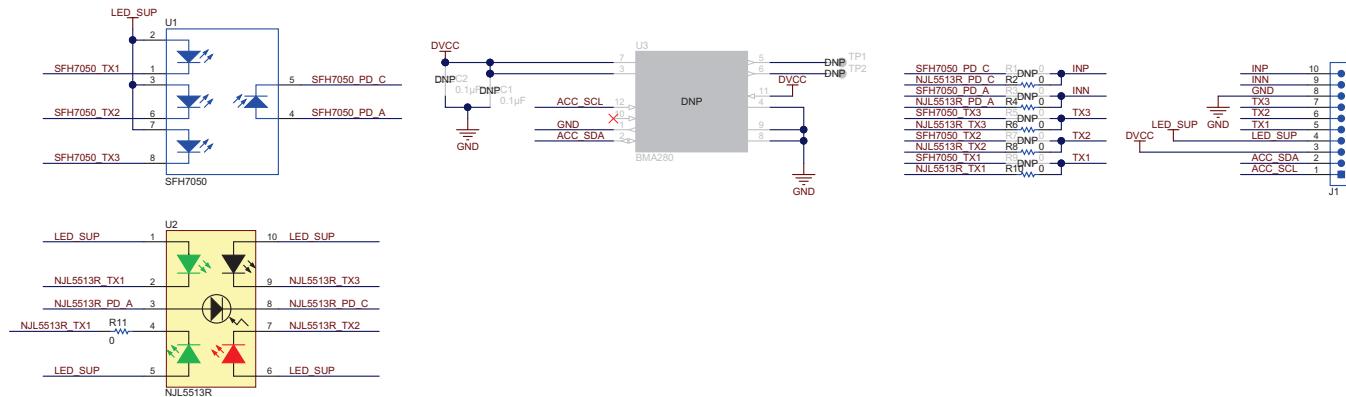


Figure 77. Sensor Board Schematic

Revision History

Changes from Original (May 2015) to A Revision

Page

- This revision contains fixes to typographical errors. 1

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

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.
 - 1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms and conditions that accompany such Software.
 - 1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.
- 2 *Limited Warranty and Related Remedies/Disclaimers:*
 - 2.1 These terms and conditions do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.
 - 2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.
 - 2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

- 3 *Regulatory Notices:*

- 3.1 *United States*

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

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

- 3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 Canada

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

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-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.

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

3.3 Japan

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

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

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required 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.

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

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

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿6丁目24番1号

西新宿三井ビル

- 3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsts/ti_ja/general/eStore/notice_02.page
電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsts/ti_ja/general/eStore/notice_02.page

4 EVM Use Restrictions and Warnings:

- 4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.
 - 4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.
 - 4.3 Safety-Related Warnings and Restrictions:
 - 4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.
 - 4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.
 - 4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.
5. Accuracy of Information: To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*
 - 6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY WRITTEN DESIGN MATERIALS PROVIDED WITH THE EVM (AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.
 - 6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS AND CONDITIONS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT MADE, CONCEIVED OR ACQUIRED PRIOR TO OR AFTER DELIVERY OF THE EVM.
7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS 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 OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS AND CONDITIONS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.
8. *Limitations on Damages and Liability:*
 - 8.1 *General Limitations.* IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS AND CONDITIONS OR THE USE OF THE EVMS PROVIDED HEREUNDER, REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN ONE YEAR AFTER THE RELATED CAUSE OF ACTION HAS OCCURRED.
 - 8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY WARRANTY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS AND CONDITIONS, OR ANY USE OF ANY TI EVM PROVIDED HEREUNDER, EXCEED THE TOTAL AMOUNT PAID TO TI FOR THE PARTICULAR UNITS SOLD UNDER THESE TERMS AND CONDITIONS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM AGAINST THE PARTICULAR UNITS SOLD TO USER UNDER THESE TERMS AND CONDITIONS SHALL NOT ENLARGE OR EXTEND THIS LIMIT.
9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.
10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2015, Texas Instruments Incorporated

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

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.

Products	Applications		
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com	TI E2E Community	
OMAP Applications Processors	www.ti.com/omap	e2e.ti.com	
Wireless Connectivity	www.ti.com/wirelessconnectivity		