ADS1x9xECG-FE Demonstration Kit

User's Guide

Literature Number: SLAU384
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Contents

List of Figures

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ADS1x9xECG-FE Demonstration Kit

This user's guide describes the characteristics, operation, and use of the ADS1x9xECG-FE. This demonstration kit models the ADS1192, ADS1292 and ADS1292R. The family of devices are two-channel, 16/24-bit, low-power, integrated analog front-end (AFE) designed for portable electrocardiogram (ECG) and respiration applications. The ADS1x9xECG-FE is intended for prototyping and evaluation. This user's guide includes a complete circuit description, schematic diagram, and Bill of Materials.

1 ADS1x9xECG-FE

1.1 Important Disclaimer Notice

NOTICE: The ADS1x9x demonstration kits are 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:

- The **ADS1x9xECG-FE** to be used only under these conditions:
  - The **ADS1x9xECG-FE** demonstration kit must not be used for diagnostic purposes.
  - The **ADS1x9xECG-FE demonstration kit** must not be used with a defibrillator or other equipment that produces high voltages in excess of the output supply provided by the battery provided with the EVM.
  - The **ADS1x9xECG-FE demonstration kit** is intended solely for evaluation and development purposes. It is not intended for use and may not be used as all or part of an end equipment product.
  - The **ADS1x9xECG-FE demonstration kit** should be used solely by qualified engineers and technicians who are familiar with the risks associated with handling electrical and mechanical components, systems and subsystems.
  - You are responsible for the safety of you and your employees and contractors when using or handling the **ADS1x9x** demonstration kit. Furthermore, you are fully responsible for the contact interface between the human body and electronics; consequently, you are responsible for preventing electrical hazards such as shock, electrostatic discharge, and electrical overstress of electric circuit components.

2 Overview

2.1 Introduction

NOTE: From here on unless otherwise noted, ADS1x9x refers to ADS1192, ADS1292 and ADS1292R based demonstration kits.

This user's guide describes ADS1x9x software and hardware. The appendix contains the Bill of Materials and schematic design. The demonstration board shown in Figure 1 is provided to speed up evaluation and system development activities related to ADS1x9x devices.

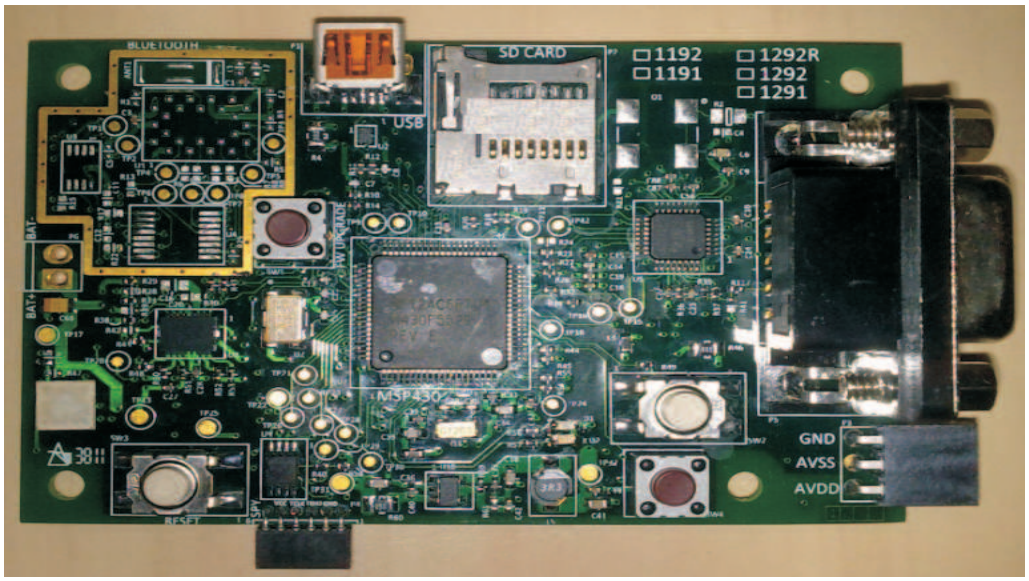


Figure 1. ADS1x9xECG-FE Demonstration Kit

The hardware is designed so all of the following ECG front end devices can be evaluated:

1. ADS1292 – 2 channels at 24 bits
2. ADS1292R – 2 channel at 24 bit with respiration
3. ADS1291 – 1 channel at 24 bit
4. ADS1191 – 1 channel at 16 bit
5. ADS1192 – 2 channel at 16 bit

The board can assembled with any one of these chips. ADS1292, ADS1292R and ADS1192 demonstration kits are available. The MSP430 firmware and PC application are designed to automatically detect the installed part and configure to accommodate the part.

Throughout this document, the term **demonstration kit** is synonymous with the **ADS1x9xECG-FE**.

2.2 Features Supported in this Version

1. Four electrode ECG cable support
2. View six ECG Leads: Lead I, Lead II, Lead III, Lead aVR, Lead aVL, Lead aVF and respiration channel (ADS1292R only) .
3. Two modes of operation: Evaluation and Live ECG / Respiration
4. Acquire data at up to 8 kHz in Evaluation mode
5. Current based Lead off detection
6. USB based power and PC application connectivity
7. Access to all ADS1x9x registers via an easy to use GUI.

8. Built-in time domain, histogram, FFT and ECG / Resp related analysis on the PC application
9. Live ECG with heart rate calculation.
10. Live Respiration wave with respiration rate calculation
11. USB based firmware upgrade option
12. MSP430 Firmware debugging using ez430 USB emulator

3 Software Installation

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 ADS1x9xECG-FE Demo Software

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

3.1.2 Additional Requirements for use with Hardware

- ADS1x9xECG-FE Demonstration Kit
- USB to mini USB cable
- DB9 ECG Cable

3.2 Installing the Software (PC application)

Before installing the software make sure the ADS1x9xECG-FE is NOT connected to the PC. Unzip the installer file, find and double click “setup.exe” to install the software. Unless otherwise specified during the install process, the software will install at C:\Program Files\Texas Instruments\ADS1x9xEVM. It will create a program menu item ADS1x9xEVM under “Programs → Texas Instruments → ADS1x9xevm” to execute the software. The following steps will endure proper installation of the PC application.

Click on “setup.exe” the following screen will appear. Click “Next”

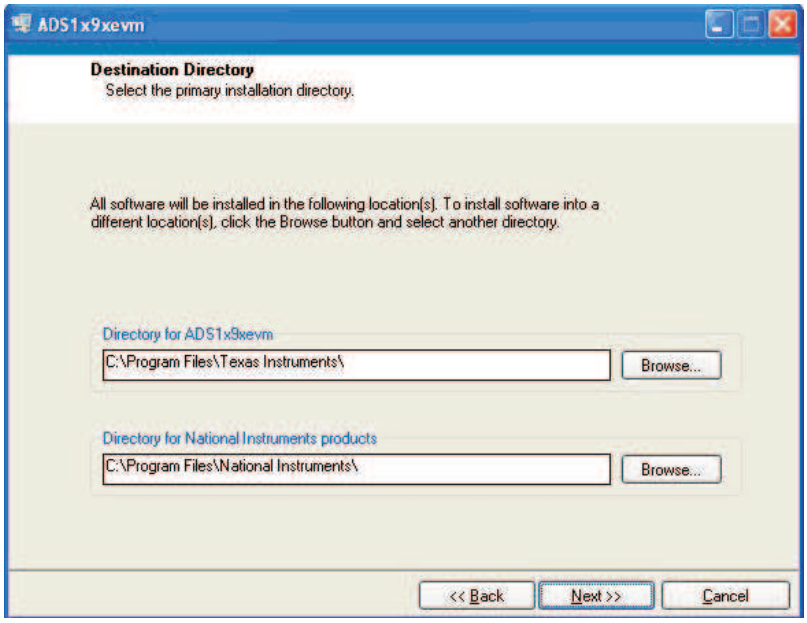


Figure 2. PC Application Installation Screen 1

Accept the License Agreement and click “Next”

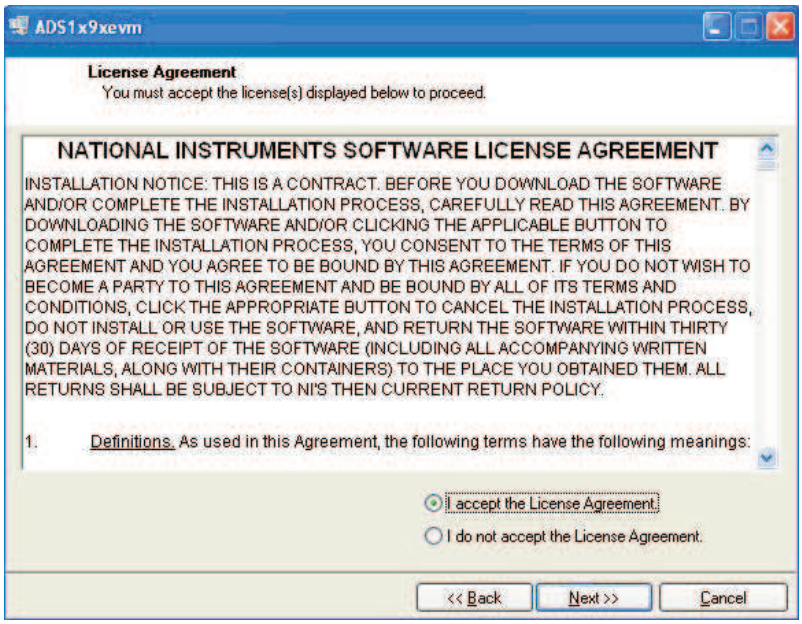


Figure 3. PC Application Installation Screen 2

Accept the License Agreement and click “Next”

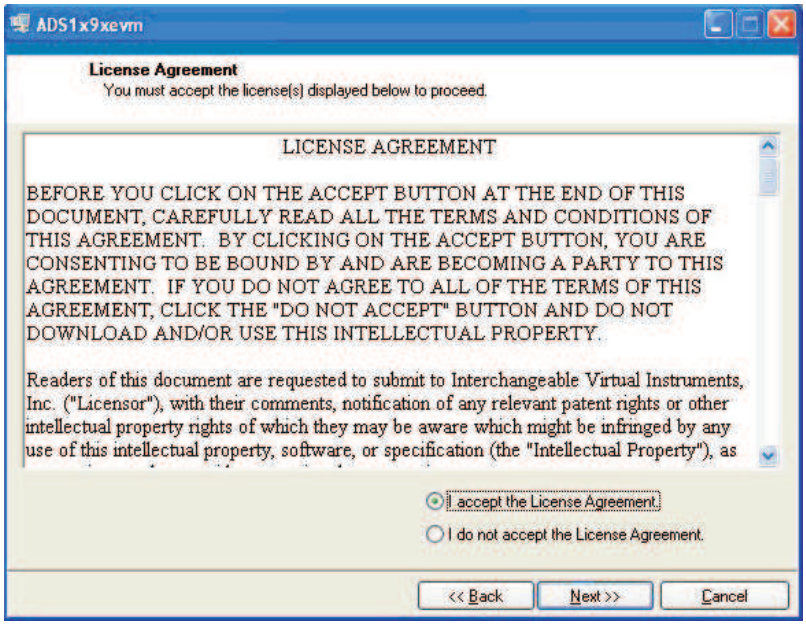


Figure 4. PC Application Installation Screen 3

The LabVIEW application part is installed now. Click “Next” to install the Microsoft C++ 2008 Redistributable Package (x86)

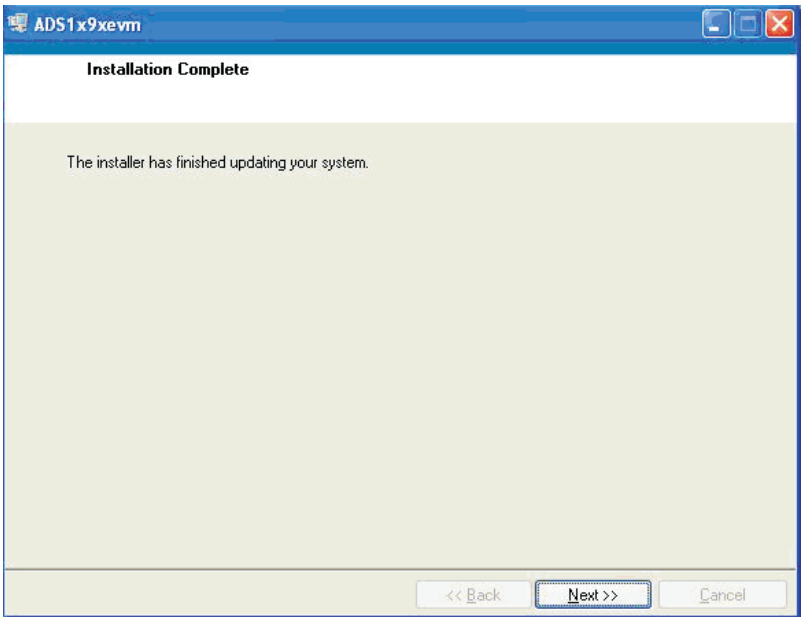


Figure 5. PC Application Installation Screen 4

If your system is already installed with Microsoft C++ 2008 Redistributable Package (x86) then the following screen appears. Click “Cancel” to proceed.

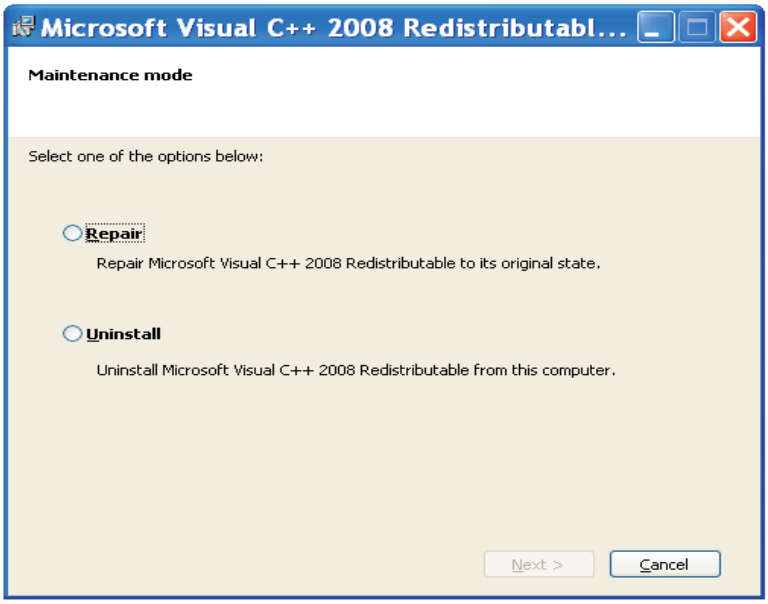


Figure 6. PC Application Installation Screen 5

Click “Finish” to complete the installation procedure.

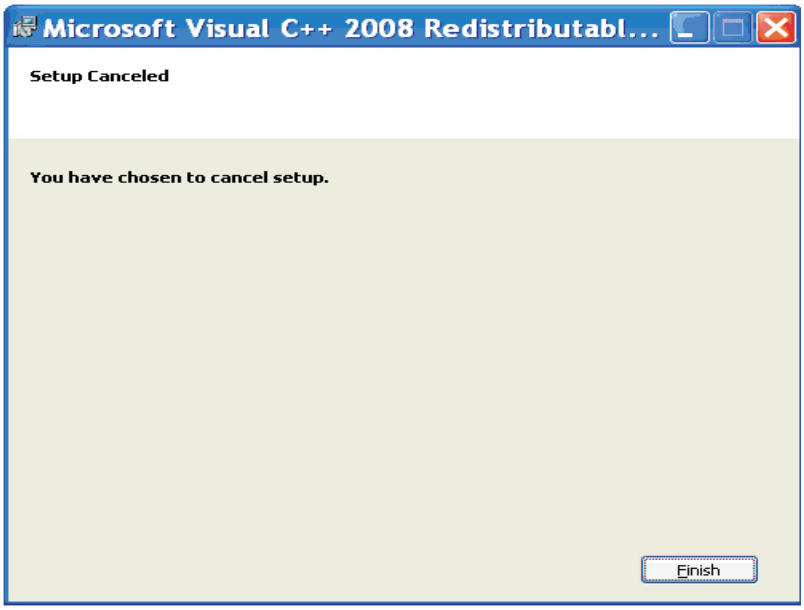


Figure 7. PC Application Installation Screen 6

If your system is not installed with Microsoft C++ 2008 Redistributable Package (x86) then the following screen appears. Click “Next”

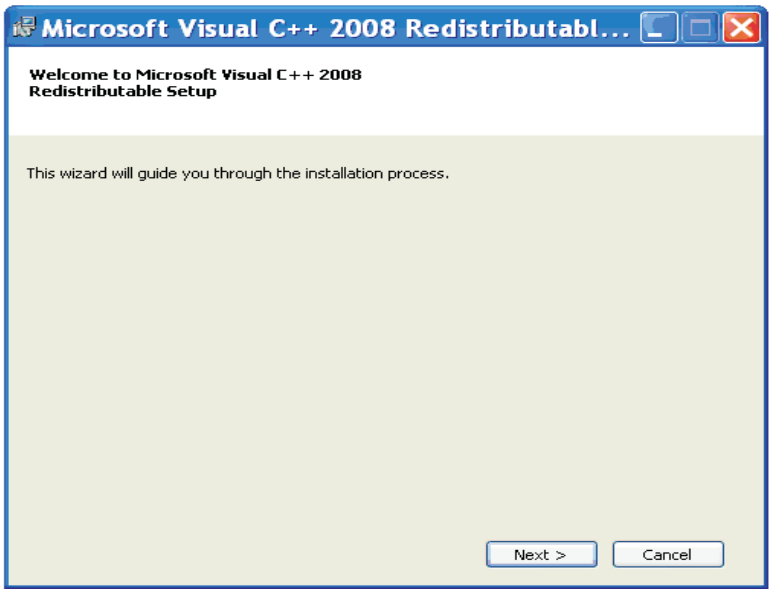


Figure 8. PC Application Installation Screen 7

Accept the license terms and click “Install”

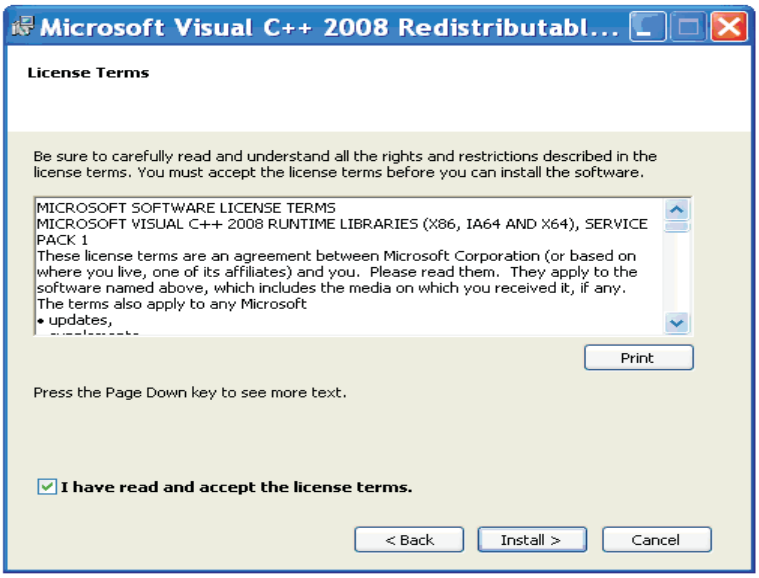


Figure 9. PC Application Installation Screen 8

Click “Finish” to complete the installation

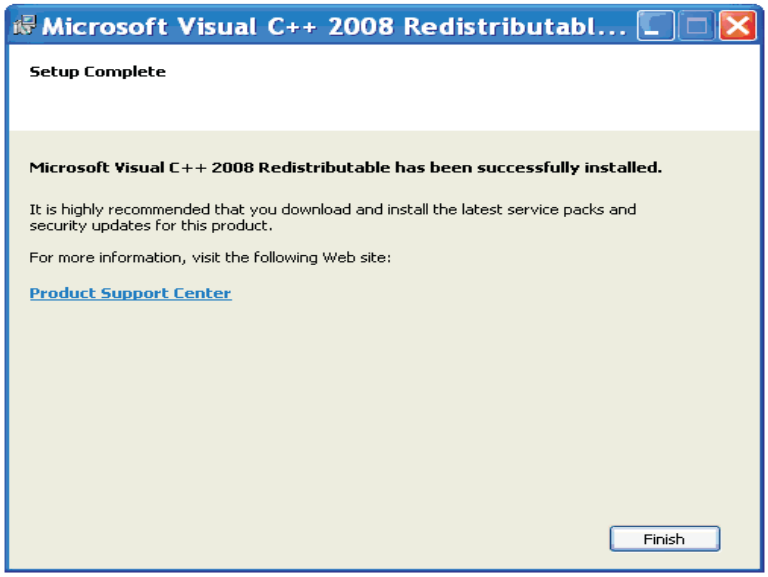


Figure 10. PC Application Installation Screen 9

The following screen might appear for the first time installation. Restart the machine

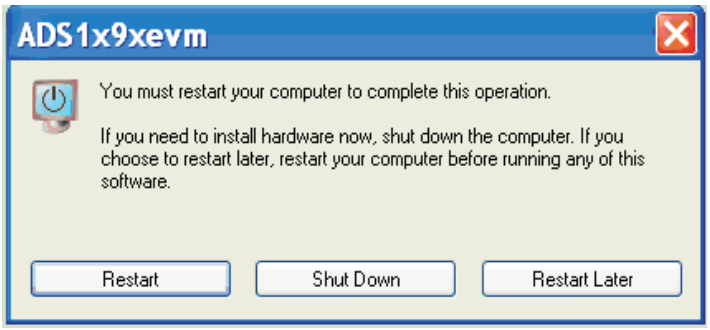


Figure 11. PC Application Installation Screen 10

The PC application is now ready to use.

3.3 Installing the USB Drivers

The communication interface between the ADS1x9xECG-FE board and PC is through USB using CDC profile. A onetime installation of the USB driver is required for the communication between ADS1x9xECG-FE and PC application.

The following steps will ensure proper installation of the USB drivers.

1. Plug-in USB to mini USB cable to P1 of ADS1x9xECG-FE and the other end to the USB port on the PC.
2. The operating system will prompt for USB driver for the “**ADS1x9x - ECG Recorder**” device. When the wizard comes up, select the options “**No, not this time**” as shown in Figure 12. Click “Next”

Figure 12. Hardware Wizard Screen 1

Select the option “Install from a list or specific locations (Advanced)” and click “Next”

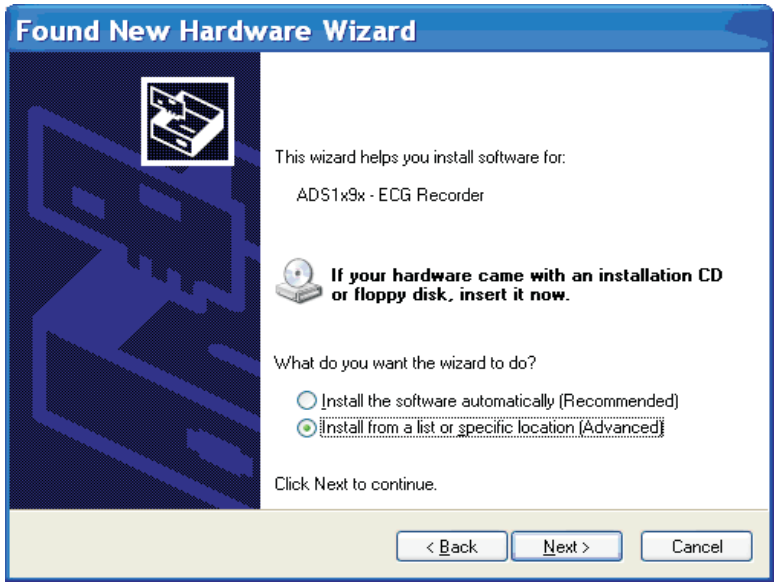


Figure 13. Hardware Wizard Screen 2

As shown in Figure 14 navigate to the directory in which “MSP430-CDC.inf” file is located (C:\Program Files\Texas Instruments\ADS1x9xevm\USB Drivers). This file will be copied to the directory while installing the PC application.

Click “Next”

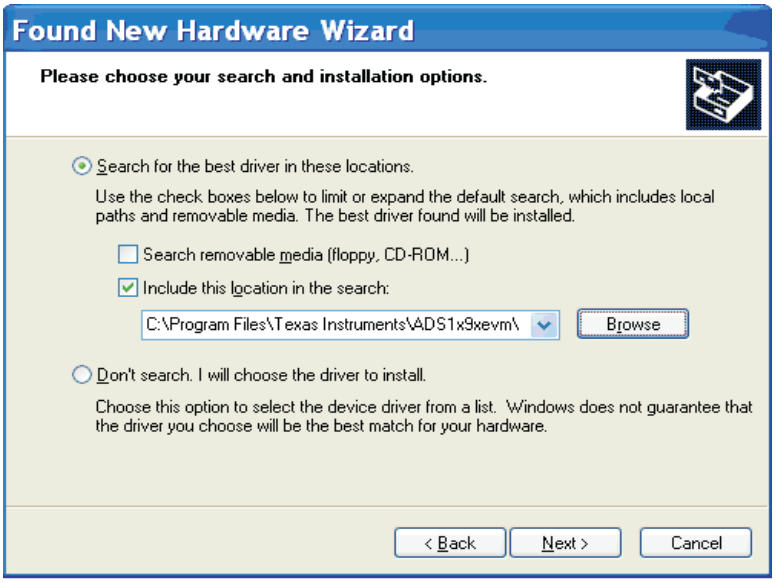


Figure 14. Hardware Wizard Screen 3

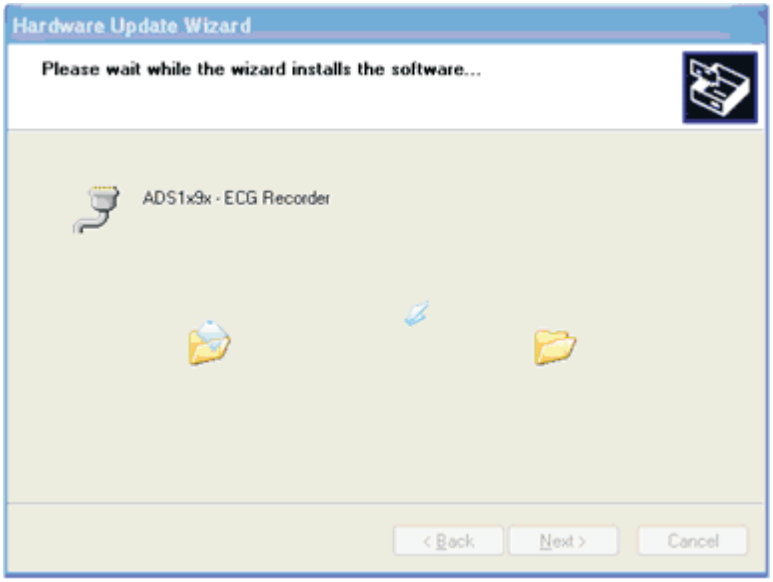


Figure 15. Hardware Wizard Screen 4

For the following warning message click on “Continue Anyway”

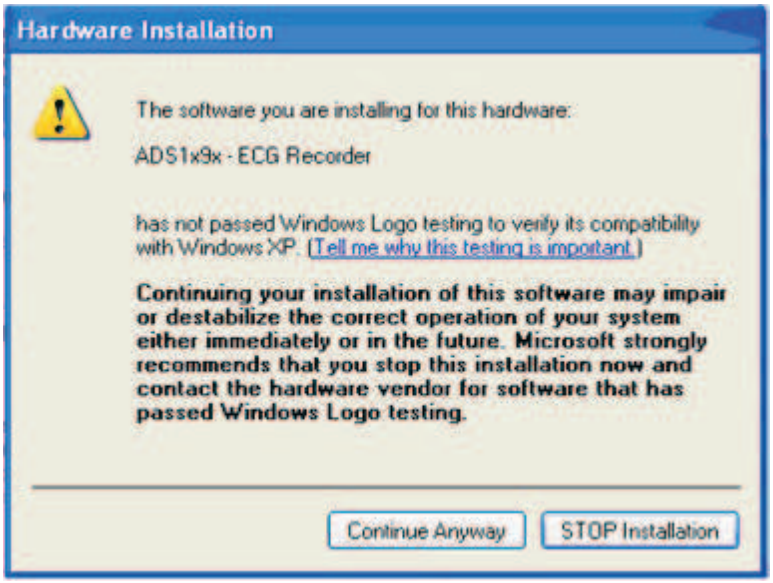


Figure 16. Hardware Wizard Screen 5

Click on Finish

Figure 17. Hardware Wizard Screen 6

The ADS1x9xECG-FE now will get recognized as virtual COM port under Device Manager as shown in Figure 18.

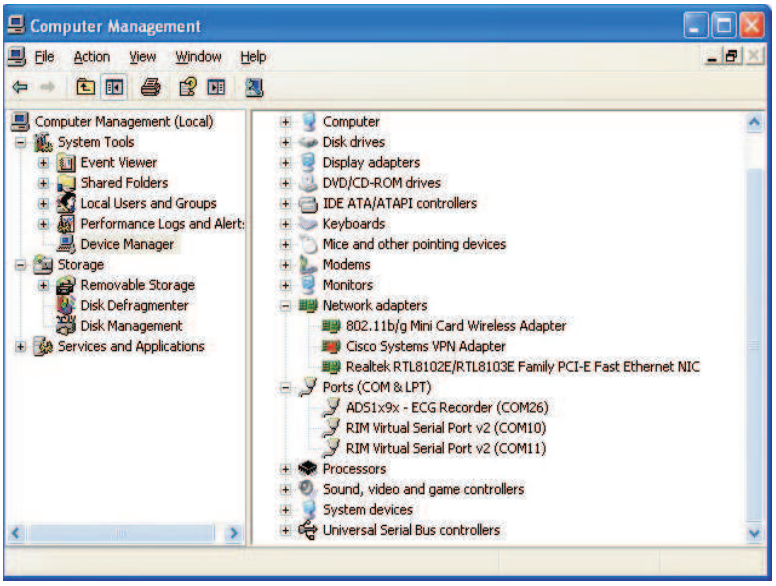


Figure 18. Device Manager Screen

The USB driver installation is now complete and ADS1x9xEVM is now ready to use.

4 Running the Software

From the “Start->Programs->Texas Instruments->ADS1x9xevm” menu, run the ADS1x9xEVM software. Unless the hardware has been disconnected the user will observe messages that confirm that the connection has been established and the program will wait in idle mode waiting for user input.

If the connection to the ADS1x9xECG-FE board is not established then the program will prompt the user to check the connection between the PC and ADS1x9xECG-FE and retry.

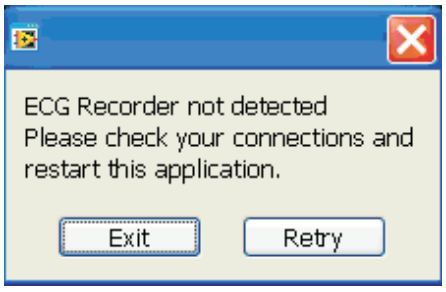


Figure 19. EVM not connected Error Message

4.1 Overview of the Features

This section provides a quick overview of the various features and functions of the ADS1x9xECG-FE software package.

The tabs down the left side of the screen consist of “About”, “ADC Register”, “Analysis”, “Save” and “Live ECG\RESP Display”.

”ADC Register” tab allows the user to configure all the ADS1x9x user registers. “Analysis” tab allows the user to view and analyze the raw data. The “Analysis” tab includes the oscilloscope for time domain analysis, Histogram plot, FFT plot for frequency domain analysis and a tab for block size ECG\Resp analysis. The save tab allows the user to write data samples and analysis results to a file. For demonstration purposes, a "Live ECG\RESP Display" tab is provided. In this tab, live streaming of ECG signals along with heart rate, lead off information and live streaming of respiration waveform with respiration rate are available.

4.1.1 ADC Registers Tab

The ADC register tab allows the user to configure the various registers of the ADS1x9x. Please see ADS1x9x datasheet for details of the various registers available with the chip. The ADS1x9xECG-FE GUI only supports "Continuous Conversion Mode". "Single Shot Mode" is not supported.

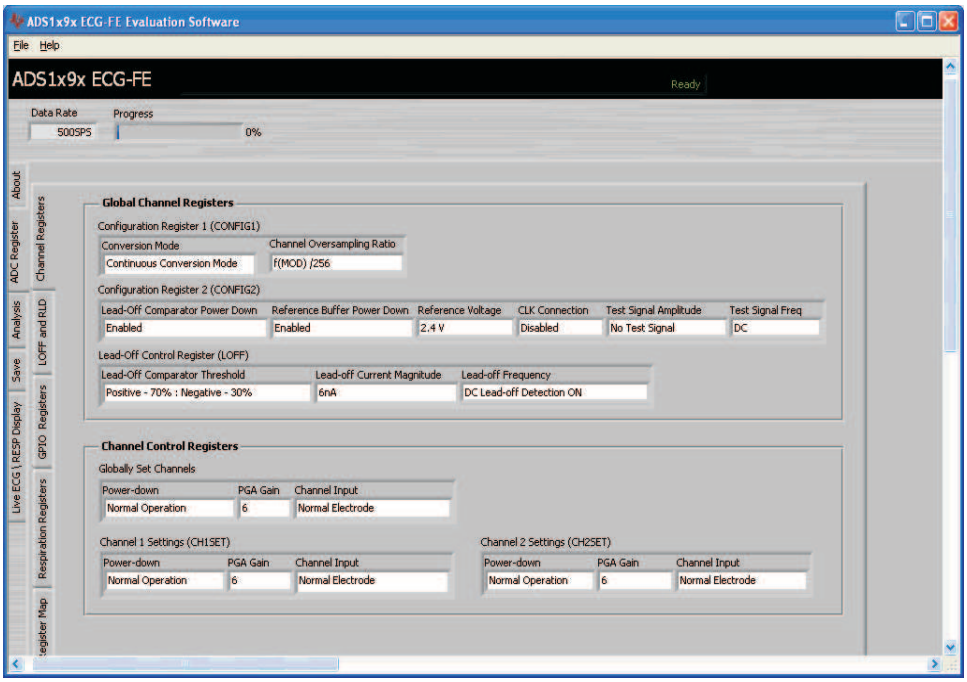


Figure 20. Register Configuration - Channel Registers

The **LOFF** and **RLD tab** consists of the settings for activating the lead off, selecting the channels for lead off detection and displays the status of the lead off.

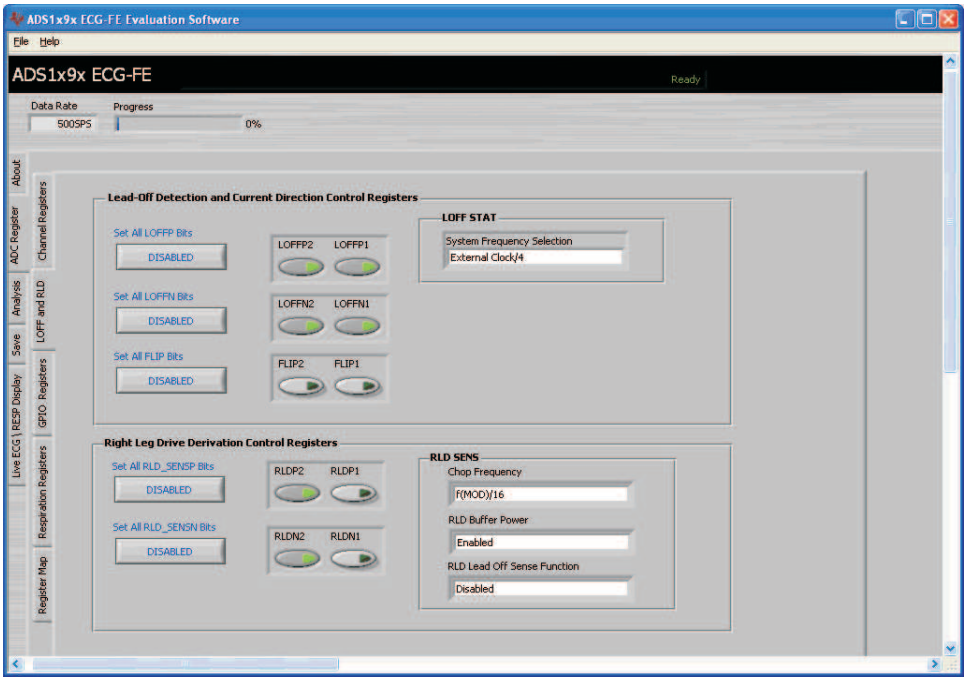


Figure 21. Register Configuration – LOFF and RLD

The **GPIO Registers tab** consists of the settings for GPIO

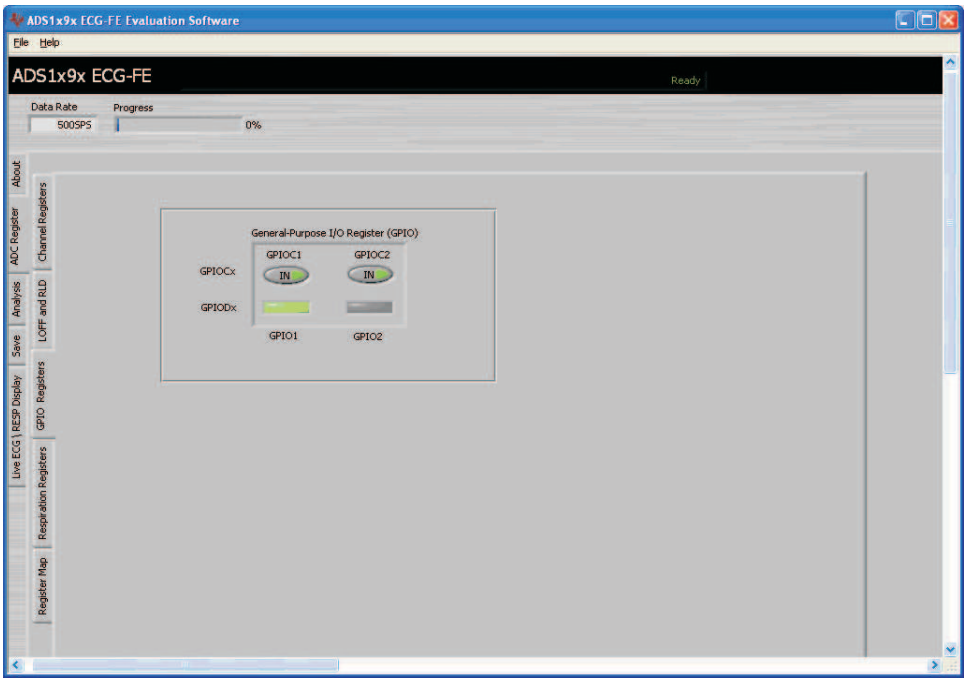


Figure 22. Register Configuration – GPIO

The **Respiration Registers tab** consists of the settings needed for the respiration and RLD reference signal. The respiration controls are specific to the ADS1292R, they are not applicable for the ADS1192 and ADS1292.

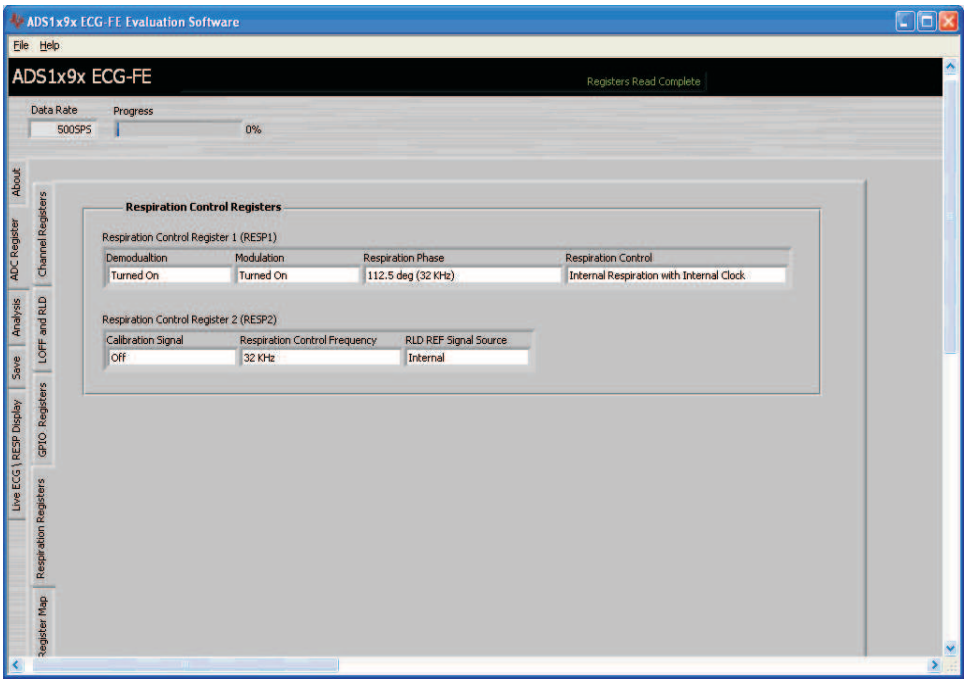


Figure 23. Register Configuration – Respiration Registers

The **Registers Map tab** reads back the register bit values from the ADS1x9xECG-FE. The “Refresh Registers” button provided in this tab read back the register values from the ADS1x9xECG-FE at any time.

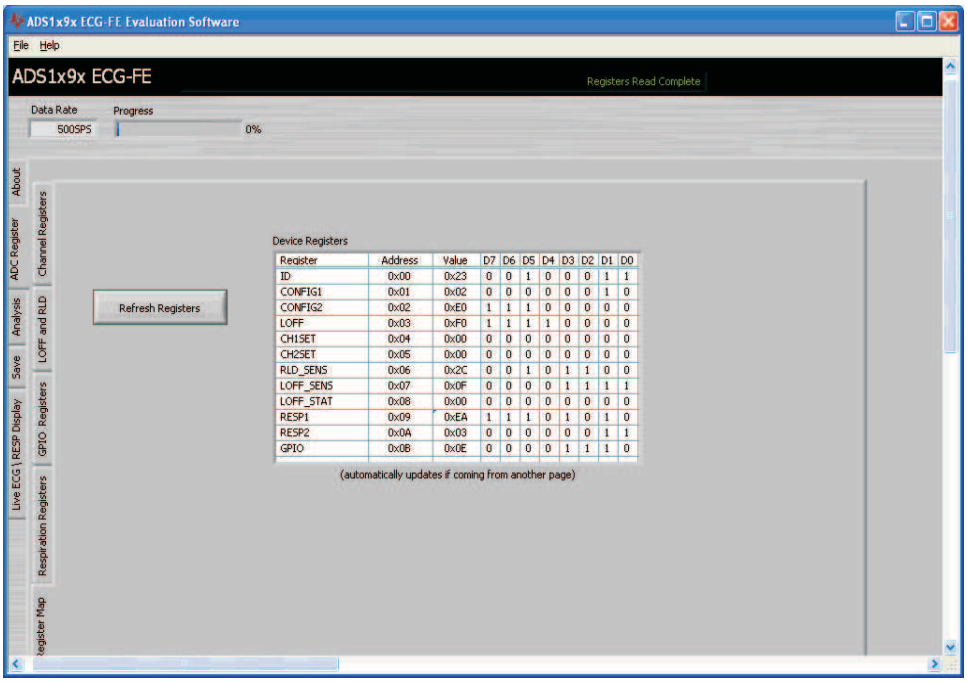


Figure 24. Register Configuration – Register Map

4.1.2 Analysis Tab

The analysis tab consists of various analysis routines and displays. The following sub tabs are available for the Analysis tab

- Scope
- Histogram
- FFT
- ECG\Resp Display

The data can be acquired from the EVM by clicking “ACQUIRE” button. The number of samples to be acquired can also be given at the space provided. The “CONTINUOUS” button acquires the data from the EVM continuously.

Scope Sub-Tab

The Scope sub-tab displays all channels in Volts, referenced to the voltage reference value set previously in the "ADC Register" tab. Note that all the voltage values in the y-axis can be input referred values (output divided by the PGA gain Setting) dependant on the status of the "Analysis Data is input referred" check box. The 'Scope Analysis" button activates a pop up that displays the mean voltage, root mean square (RMS) voltage and peak to peak voltage for noise analysis.

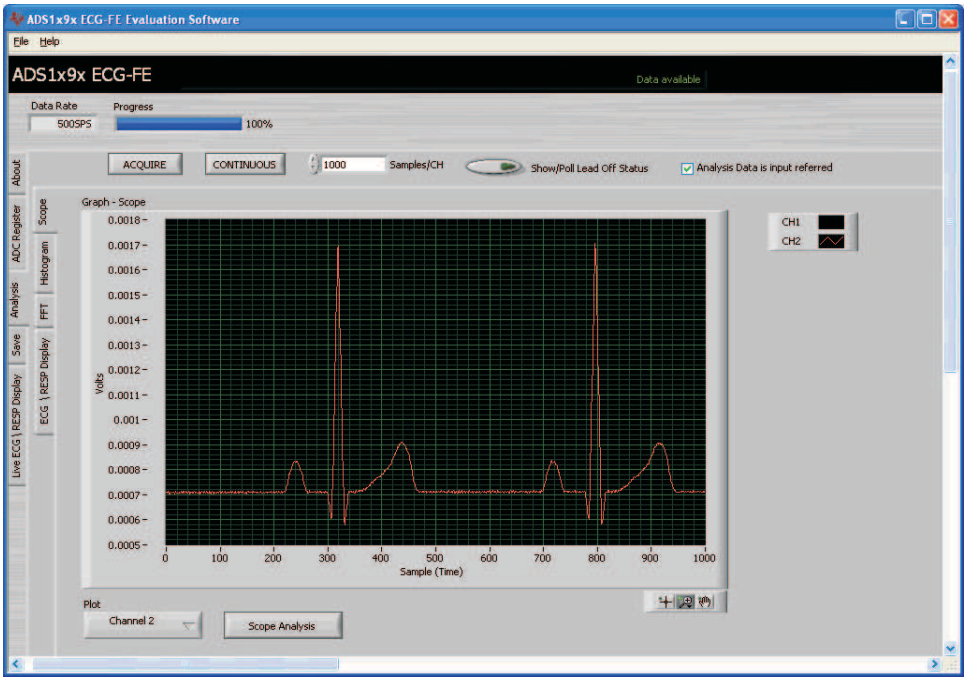


Figure 25. PC Application Analysis – SCOPE

The following main buttons/Controls are available in this sub-tab

Button/Control	Description
Scope Analysis	Displays the mean, root mean square(RMS) value and peak to peak for noise analysis of the acquired data
Plot	Channel selection button allow selecting all channels or Channel 1 or Channel 2 for the display

Histogram Sub-Tab

The Histogram sub-tab displays the data in a histogram format for the two channels. The data will be shown following an acquisition cycle. The "Histogram Analysis" button can be used to view the mean voltage, root mean square (RMS) voltage and peak to peak voltage for analysis.

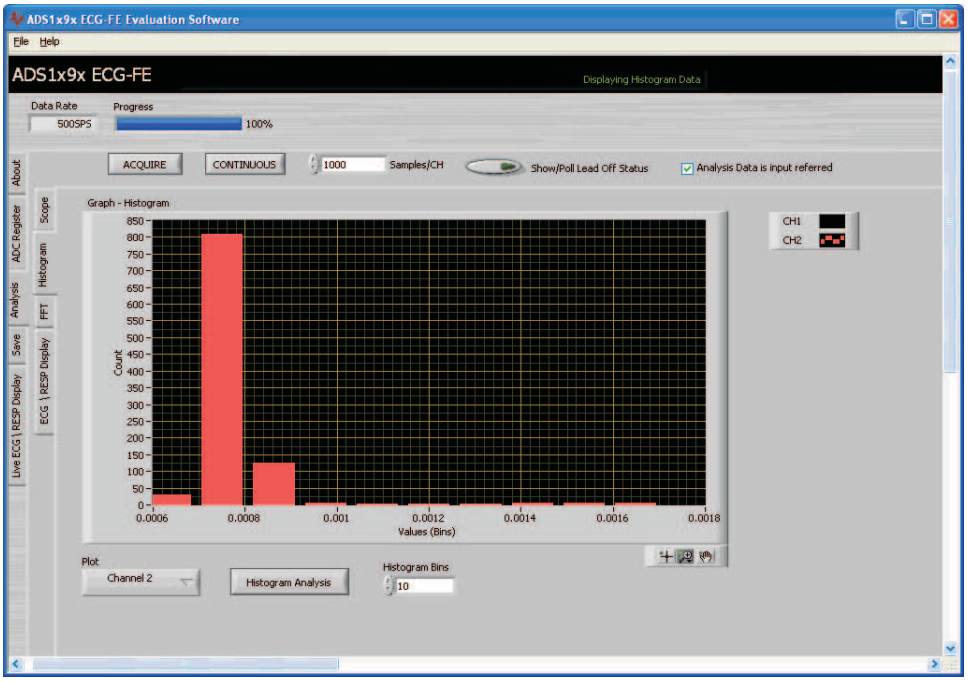


Figure 26. PC Application Analysis - Histogram

The following buttons/Controls are available in this sub-tab

Button/Control	Description
Histogram Analysis	Runs histogram of the selected channel(s) for the selected number of samples
Plot	Channel selection button allow selecting all channels or Channel 1 or Channel 2 for the display
Display Plane(Right click on the display area and then select “Optional Plane” menu item)	Various display planes can be selected for the histogram display. The options available are: • Nyquist • Nichols • S Plane • Z Plane

FFT Sub-Tab

The FFT sub-tab displays the data in the frequency domain by performing a FFT on the two channels. Details of the FFT, including SNR, THD, etc. can be viewed using the "FFT Analysis" button located in the bottom left corner of the display.

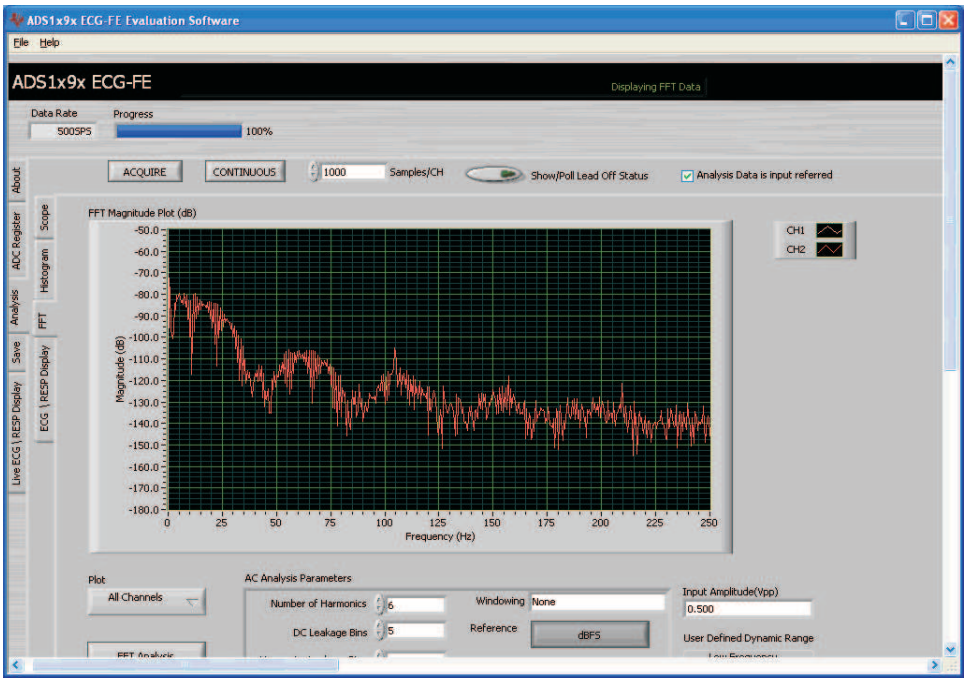


Figure 27. PC Application Analysis - FFT

Button / Control	Description
FFT Analysis	Runs FFT analysis of the selected channel(s) and result will be shown on the pop-up window
Plot	Channel selection button allow selecting all channels or Channel 1 or Channel 2 for the display
AC Analysis Parameters Section	Various AC analysis parameter configuration
Coherent Frequency Calculator Section	Provision for entering desired Ain Frequency
User Defined Dynamic Range Section	Provision for selecting Low and High frequency

ECG\RESP Sub-Tab

The ECG\RESP Display sub-tab can display ECG data for Lead I, Lead II, Lead III, Lead aVR, Lead aVL, or Lead aVF for the ADS1192 and ADS1292. The ADS1292R can only display Lead II or Respiration data.

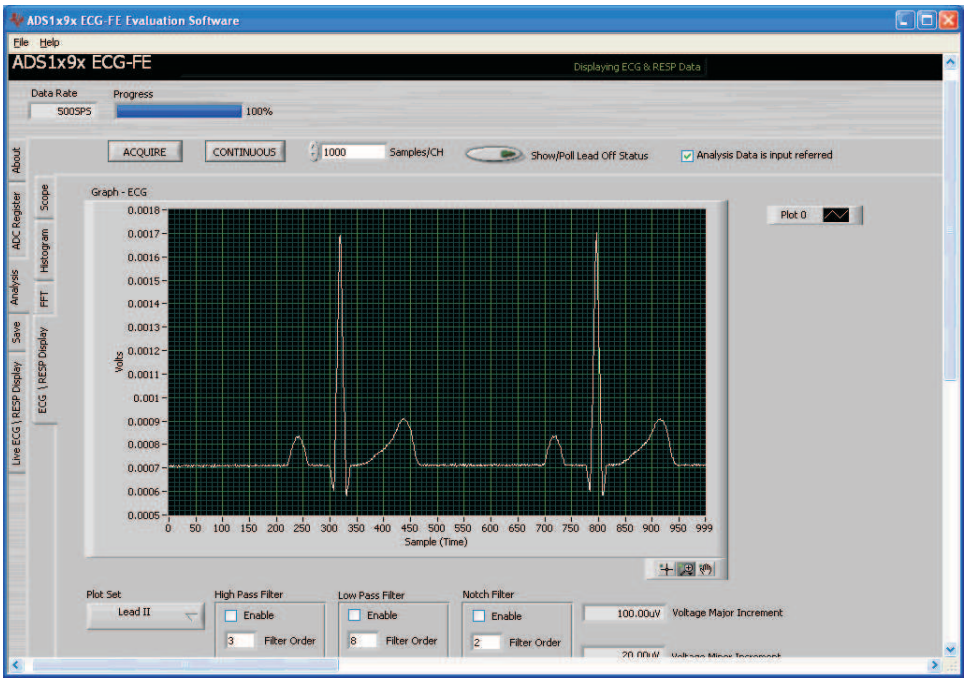


Figure 28. PC Application Analysis – ECG

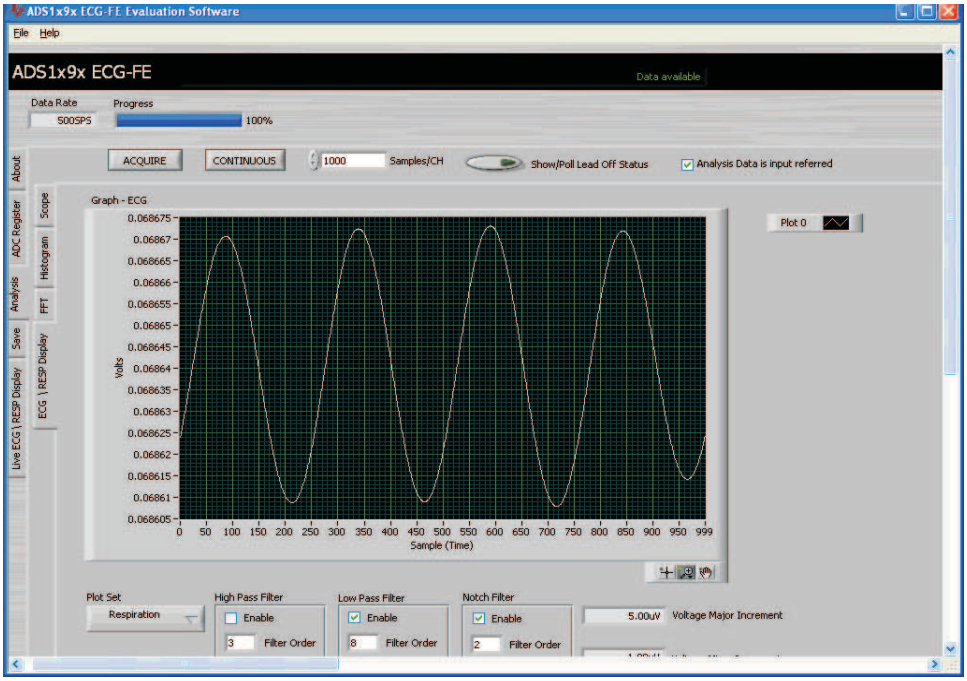


Figure 29. PC Application Analysis – ADS1292R Respiration (Low Pass Filter Enabled)

The following buttons/Controls are available in this sub-tab

Button/Control	Description
Plot Set	Option to select ECG Lead I, Lead II, Lead III, Lead aVR, Lead aVL, Lead aVF or Respiration Channel (ADS1292R only)
High Pass Filter	Provision for enabling a PC side high pass filter with support for selecting the order of the filter and cut off frequency
Low Pass Filter	Provision for enabling a PC side low pass filter with support for selecting the order of the filter and cut off frequency
Notch Filter	Provision for enabling a PC side notch filter for 50Hz or 60Hz with support for selecting the order of the filter. This filter will be applied on the acquired data for the sampling rate of 500SPS

Note: Apart from the above specific buttons / Control on each sub-tabs. The application also provides various display options. The main display options available on the GUI are

Display Options	Description
Auto scaling (Right click on the display area)	Both x-scale and y-scale auto scaling is possible. User can enable or disable this feature
Export Data (Right click on the display area)	The displayed data can be exported to excel or Clipboard
Annotation Provision (Right click on the display area)	Provision provided for creating and deleting annotation
Visible Items selector (Right click on the display area)	Option to display x-scale, y-scale, Plot legends, x-scrollbar
Plot legend options (Right click on the plot legend)	Plot legend gives various option to change the color of the plotting, various plotting styles etc

4.1.3 Save Tab

The save tab provides provision to save the analysis or data to the file. By default the data will be saved to the directory “C:\Program Files\Texas Instruments\ADS1x9xevm\saved”. Use the "Directory to Save Files" option to select the folder where data is to be saved. In the pop up window navigate to folder where file is to be saved and select "Use Current Folder". Then select "Save to File" to save the file.

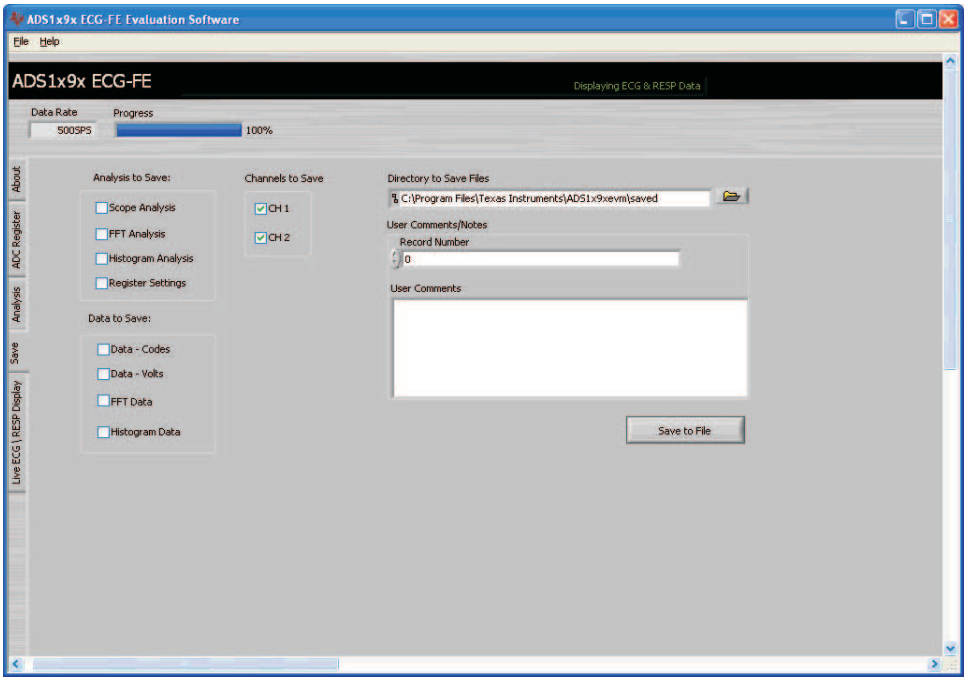


Figure 30. PC Application Save

The following options are provided in the save tab.

Button/Control	Description
Scope Analysis	For saving scope analysis result. The result will be saved in the file “Device_<record number>_Analysis.xls”.
FFT Analysis	For saving FFT analysis result. The result will be saved in the file “Device_<record number>_Analysis.xls”.
Histogram Analysis	For saving histogram analysis result. The result will be saved in the file “Device_<record number>_Analysis.xls”.
Register Setting	All the current register values will be read from the EVM and stored. The result will be saved in the file “Device_<record number>_Analysis.xls”.
Data - Codes	Acquired data sample values will be stored to the file “Device_ <record number>_Codes.xls”
Data - Volts	Acquired data sample’s voltage values will be stored to the file “Device_ <record number>_Volts.xls”
FFT Data	Acquired data sample’s FFT values will be stored to the file “Device_ <record number>_FFT.xls”
Histogram Data	Acquired data sample’s histogram values will be stored to the file “Device_ record number>_Histogram.xls”

The record number can be given by the user and saved files will use this record number in the file name. There are options to select Channel 1 and Channel 2 while saving the corresponding data to the file.

User notes also can be added to the file by typing the notes in the GUI area “User Comments”.

4.1.4 Live ECG / RESP Display Tab

Live ECG and Live respiration channel display are available in the “Live ECG/RESP Display” tab. This tab also shows the heart rate, respiration rate and lead-off information.

Figure 31. PC Application Live ECG for ADS1292R

Figure 32. PC Application Live Respiration Channel

Live ECG display or Live Respiration display can be started by clicking on the “Start Data Streaming” and the same can be stopped by clicking on “Stop Data Streaming”.

The following buttons/Controls are available in this sub-tab.

Buttons/Control	Description
Lead Selection	The following can be selected for the live display • ECG Lead I • ECG Lead II
	• ECG Lead III
	• ECG Lead aVR
	• ECG Lead aVL
	• ECG Lead aVF
	• Respiration Channel (ADS1292R only)
Signal BW	Signal bandwidth can be selected to either 40Hz or 150 Hz. The filter on the EVM board will automatically get enabled based on the selection made
Notch Filter	Provision for selecting either 50Hz or 60Hz notch filter. The filter on the EVM board will automatically get enabled based on the selection made
Auto scaling (Right click on the display area)	Both x-scale and y-scale auto scaling is possible. User can enable or disable this feature
Export Data (Right click on the display area)	The displayed data can be exported to excel or Clipboard
Visible Items selector (Right click on the display area)	Option to display x-scale, y-scale, Plot legends, x-scrollbar
Plot legend options (Right click on the plot legend)	Plot legend gives various option to change the color of the plot, various plotting styles etc...

Lead-off status will be displayed on the GUI. The lead-off display can be interpreted as shown in the table below

Leads	Lead Off Status
LL off	IN2P is red
RA off	IN2N and IN1N are red
LA off	IN1P is red

The lead-off information is also available on the pop-up window “Lead-Off Status Registers”. The pop-up window can be selected by clicking on the “Show/Poll Lead Off Status” on the “Analysis” main tab.

5 ADS1x9xECG-FE Hardware Introduction

The key features of the ADS1x9x analog front end demonstration board are:

- Based on MSP430F5529
- ADS1192 and ADS1292 suitable for six leads of ECG: Lead I, Lead II, Lead III, Lead aVR, Lead aVL, or Lead aVF
- ADS1292R suitable for one lead of ECG (Lead II) and respiration channel
- Low power consumption (350 Micro Watt/channel)
- Data Rates of 125 SPS to 8 kSPS
- Unipolar Operation
- Lead off detection circuitry
- On chip oscillator and reference
- On chip RLD amplifier
- SPI data interface
- 8Gb NAND Flash support

The ADS1x9xECG-FE can be used as a demo board for standard six lead ECG and respiration channel using 4 electrodes input. Defibrillator protection and patient protection circuitry are not provided. The ADS1x9xECG-FE board is made with a 4-layer PCB board. The board layout and Schematic are shown in Appendix C.

MSP430F5529 (U7) is the microcontroller used on the board. For more details of the MSP430F5529 please visit http://focus.ti.com/docs/prod/folders/print/msp430f5529.html

The following sections explain the main hardware components available on the ADS1x9xECG-FE.

5.1 Power Supply

ADS1x9x can operate from 2.7V to 5.25V analog supply (AVDD/AVSS) and 1.65 to 3.6V (DVDD) digital supply. In this design the ADS1x9x is operated at 3V analog and 3.3V digital.

The power for the board is derived from the USB input (P1) through a forward biased diode (D3) to avoid reverse current flow. The USB data bus is ESD protected using TI’s ESD protection diode array TPD4E004DRYR (U2). The USB VBUS is fed to the integrated Li-ion linear charger and system power-path management module, BQ24032ARHLR (U8), which generates greater than 4.2V output (VCC_BAT). This output is then fed to TI’s low-power linear voltage regulator, TPS73033 (U16), for generating regulated 3.3V for digital section of the board. The 3V supply for the analog section is derived from VCC_BAT using TI’s low dropout voltage regulator TPS73201 (U10).

The inductors L3, L4, L5 and L7 are used to minimize the power supply noise induced by the power supply regulators.

The test points TP25, TP32 are provided to make sure the power supplied to the board is correct. The corresponding voltages are given in the table below. The analog power supply (ADS_AVDD) is also brought out on connector P3.

Sl NO	Test Point	Description
1	TP25	3.3V
2	TP32	ADS_AVDD, 3.0V

5.2 Clock

ADS1x9x has internal on chip circuit which generates 512 KHz clock nominally. This clock can vary by ±2% over temperature. For application requiring higher accuracy the ADS1x9x can also use an external clock signal. The demonstration kit provides the firmware option to select either an internal or external clock for testing. The demonstration kit also provides the option to generate an external clock for the ADC from the MSP430 or on board oscillator.

Oscillators O2 (24MHz) and O3 (32.768 KHz) are used by the microcontroller.

Clock Type	R21	R24	Clock SEL
Internal Clock	Not Installed	Not Installed	Mount R77 to Drive “high” on ADC_CLK_SCL OR Set P2.3 of MSP430 to Drive “high” on ADC_CLK_SCL.
External Clock	Not Installed	Installed	Mount R76 to Drive “low” on ADC_CLK_SCL OR Clear P2.3 of MSP430 to Drive “low” on ADC_CLK_SCL.

5.3 Memory

ADS1x9xECG-FE supports a 1GB NAND Flash memory (U14). The NAND flash is interfaced with the MSP430 through a GPIO interface. Although installed, firmware support for storing ECG and respiration data to the NAND flash memory is not available in this version.

5.4 Accessing ADS1x9x Digital Signals

ADS1x9x SPI interface with MSP430 can be accessed through the test points given in the table below:

Sl NO.	Signal	Test Points
1	ADC_CS	TP24
2	ADC_START	TP56
3	ADC_DOUT	TP47
4	ADC_SCLK	TP11
5	ADC_DIN	TP46
6	ADC_DRDY	TP52
7	ADC_RESET	TP53
8	CLK	TP42

5.5 GPIO Test Points

There are 2 GPIO connections between the ADS1x9x and the MSP430 micro-controller, which are accessible through the test points given in the table below:

Sl NO.	Signal	Test Points
1	ADC_GPIO1	TP15
2	ADC_GPIO2	TP16

5.6 Analog Inputs

The ADS1x9xECG-FE gives the user the option to feed in the standard ECG/Respiration signals from a patient simulator to the DB9 connector (P5).

The output from any typical patient simulator can be directly fed into the DB9 connector. For all measurements in this user guide a Fluke medSim 300B simulator was used as shown in Figure 33.

Figure 33. Simulator Connection

5.7 USB Interface

The ADS1x9xECG-FE has a mini USB interface for PC application connectivity. Standard mini USB to USB cable can be used for the connection. ADS1x9xECG-FE is designed to work in the slave mode.

5.8 On Board Key Interface

The ADS1x9xECG-FE board has four switches. Figure 34 details the position of each switch.

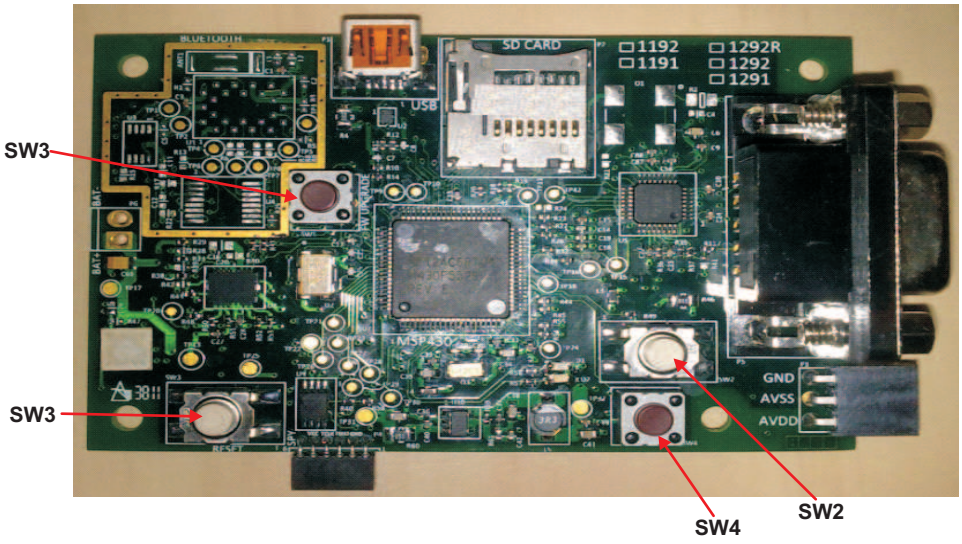


Figure 34. Switch Positions

The function of each switch is defined in the following table:

Switch Number	Description
SW1	This switch is used to enable boot strap loader (BSL) MSP430 firmware. Refer to for the usage
SW2	Unused
SW3	This switch is used for hard reset of the board. The board will reset and start again with the firmware loaded.
SW4	Unused

5.9 Visual Indication

The demonstration kit has two LEDs to indicate various operating states. The flashing green LED (D2) indicates the ADS1x9xECG-FE is in the idle state and steady blue LED (D1) indicates the micro-controller is busy in servicing requests from the PC application.

6 Evaluation of ECG and Respiration Specific Functions

The micro-controller receives the 2 channel data from ADC through the SPI interface to send to the PC. The software is designed to handle the following activities:

- Data acquisition
- ADC Lead off detection
- DC signal removal
- Multi band pass filtering
- ECG lead formation
- QRS (HR) detection
- RR Detection
- USB communication
- Firmware upgrade through USB

An example of the high level architecture of the firmware implementation for the ADS1292R is given below:

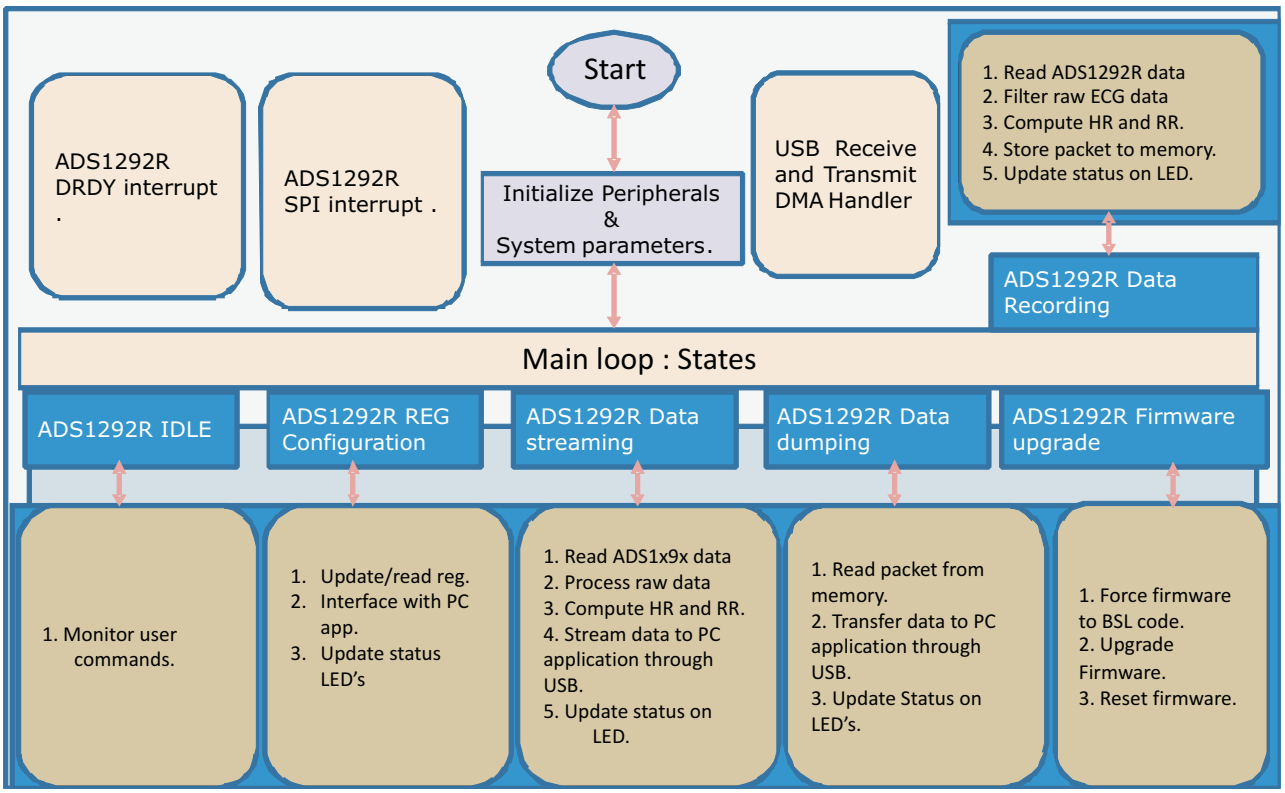


Figure 35. Firmware Architecture

The PC side of the application consists of labview front end GUI with back end DLL written using C++. The DLL interfaces with the Windows USB driver and communicates to the demonstration kit. The labview front end GUI uses function calls to communicate with the demonstration kit through the DLL.

There are two general operating modes available in the system.

1. Evaluation Mode (Analysis Mode)
2. Live Data Streaming Mode

6.1 Evaluation Mode (Analysis Mode)

The Analysis Mode is used for the following requests:

1. Register setting
2. Register read
3. Data acquire

Firmware configures the ADC registers with default values during power on. Users can change the register settings through the PC application GUI. The register setting request from the PC will be processed by the firmware and the appropriate register set command will be sent to the ADC.

During the data acquire request, the firmware will process the number of samples to be acquired as set in the GUI. The firmware will instruct the ADC to start the data conversion in continuous mode. Based on the sampling rate configured, the ADC will generate data ready pulses (DRDY) which are used by the micro-controller to indicate when to read data back. The data is stored and later sent to the PC application in individual packets. Each packet contains 8 samples which are 24bits in length.

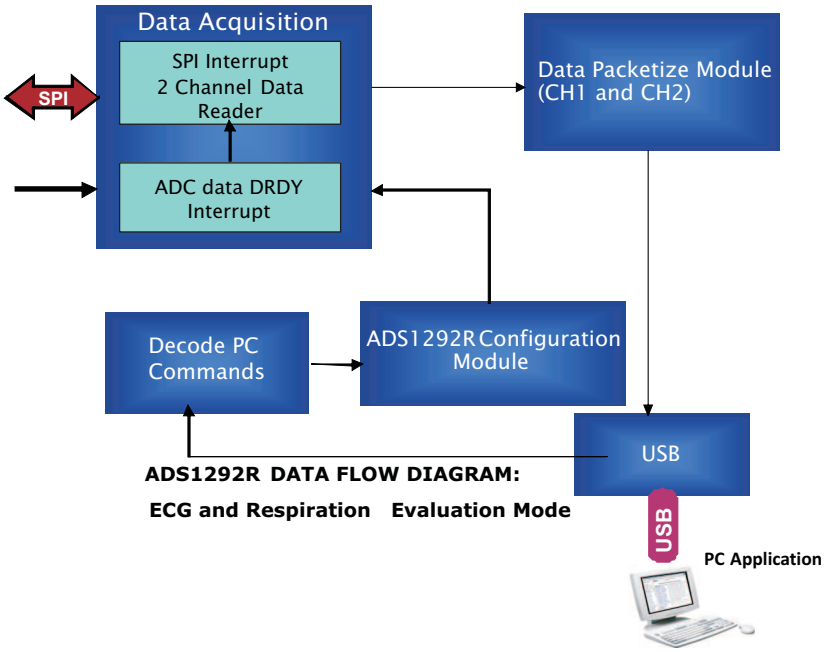


Figure 36. Evaluation Mode Data Flow for ADS1292R

6.2 Live Data Streaming Mode

The Live ECG / Live Respiration data streaming can be started from the PC application tab “Live ECG \ RESP Display” by clicking “Start Data Streaming”. The PC application will set the sampling rate to 500SPS before requesting the firmware to start the live data streaming.

The firmware will instruct the ADC to start the data conversion in continuous mode at 500SPS. The ADC will generate data ready interrupt (DRDY). Based on the interrupt, the firmware reads the data from the ADC.

The firmware will apply the following filters on the data read:

1. DC removal IIR filter
2. Multiband pass FIR filter with 50/60 Hz notch (user selectable) OR band pass filter

The filtered signal is used for detecting the heart rate, respiration rate and deriving ECG leads. Filters are applied only for live data streaming mode.

The system data flow diagram for live data stream mode is given in Figure 37.

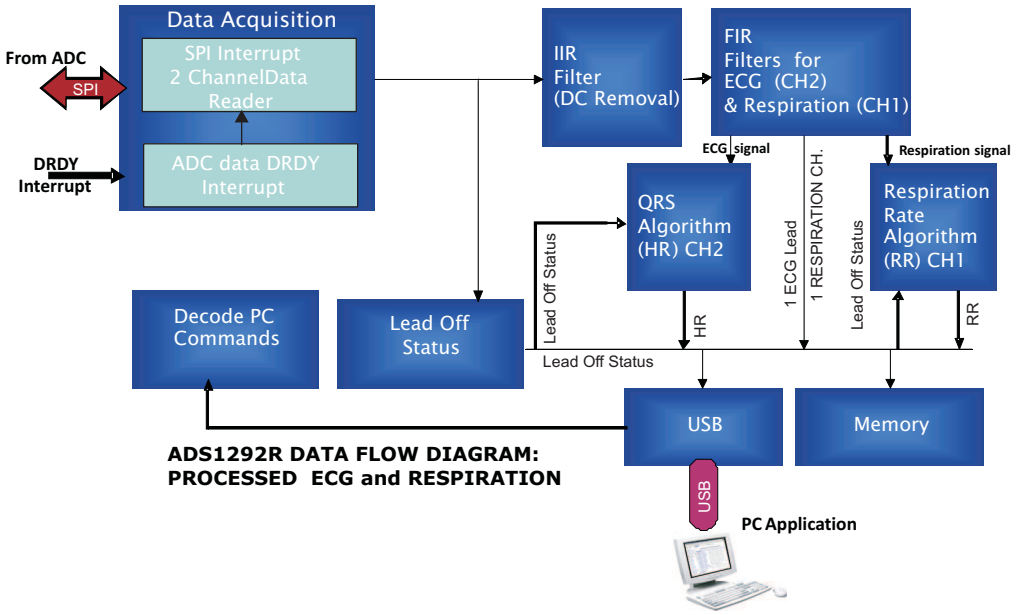


Figure 37. Live Data Stream Mode Data Flow for ADS1292R

6.2.1 Filters

IIR Filter - DC signal removal

1st Order IIR filter is used to remove the DC component from the acquired data. The following transfer function is used for the filter:

$$H(z) = \frac{Y(z)}{X(z)} = \frac{1 - z^{-1}}{1 - az^{-1}} \quad (1)$$

To provide DC attenuation at 22dB, the value of alpha is chosen as 0.992. The IIR filter output is down scaled to 16-bit and then provided to the FIR filter. The frequency response for the IIR filter is shown in Figure 38.

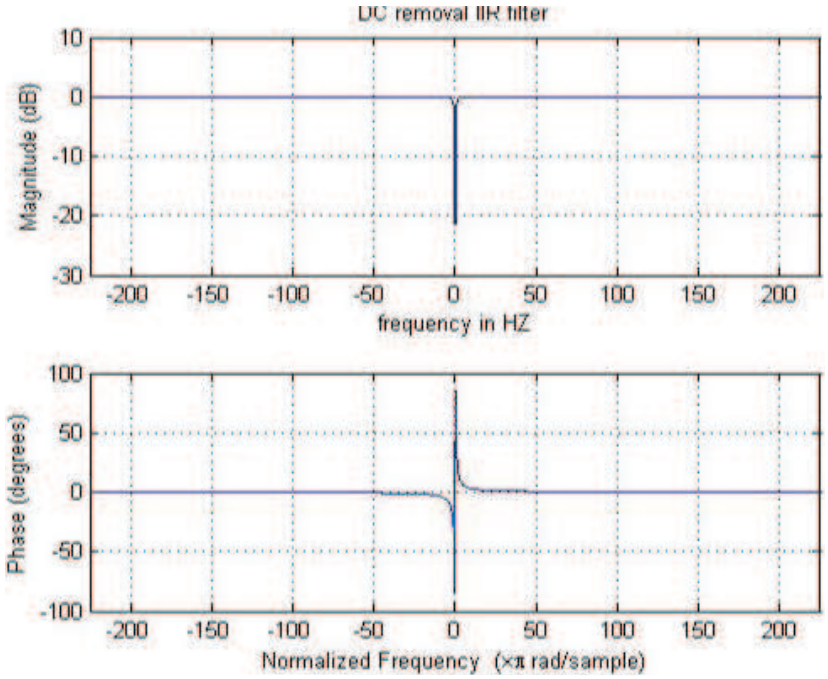


Figure 38. Frequency Response for the IIR Filter

Multi Band Pass Filter

Multi band pass filter (MBF) is used for removing unwanted signals and power line noise from the live data.

The MBF digital filter is a 161 order FIR filter with Hamming window having cut-off at 150Hz and notch at 50/60 Hz. The notch frequency is selectable from the PC application. This filter provides a very sharp cut-off around 150 Hz with attenuation more than 30 dB at the stop band. The notch at 50/60 Hz provides attenuation of more than 30 dB. Sampling frequency is 500 samples/ second.

The frequency response of the filter with a 50 Hz notch is shown in Figure 39, Figure 40, and Figure 41.

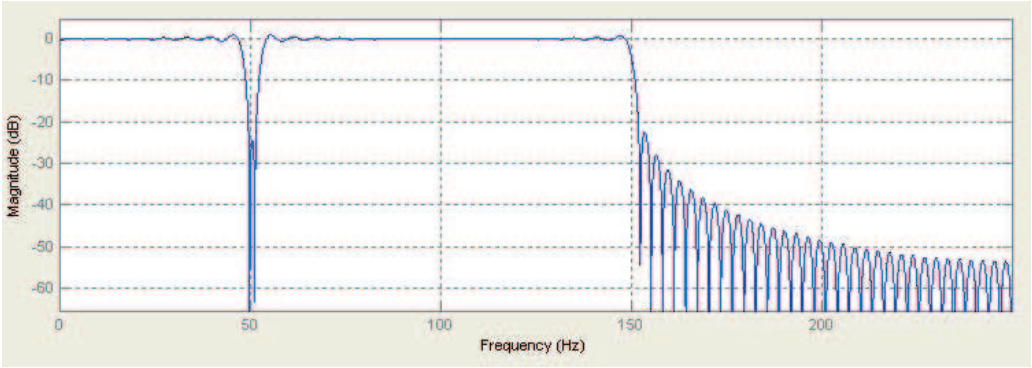


Figure 39. Frequency Response for the MBF Filter (Full View)

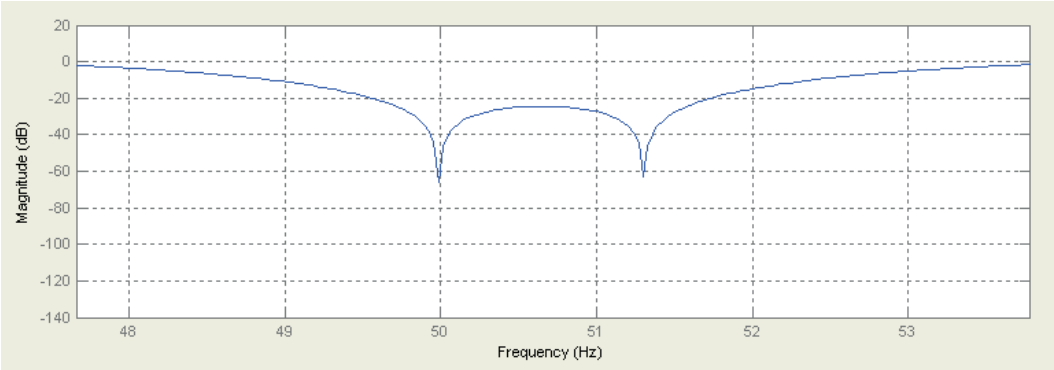


Figure 40. Frequency Response for the MBF Filter (50Hz Notch)

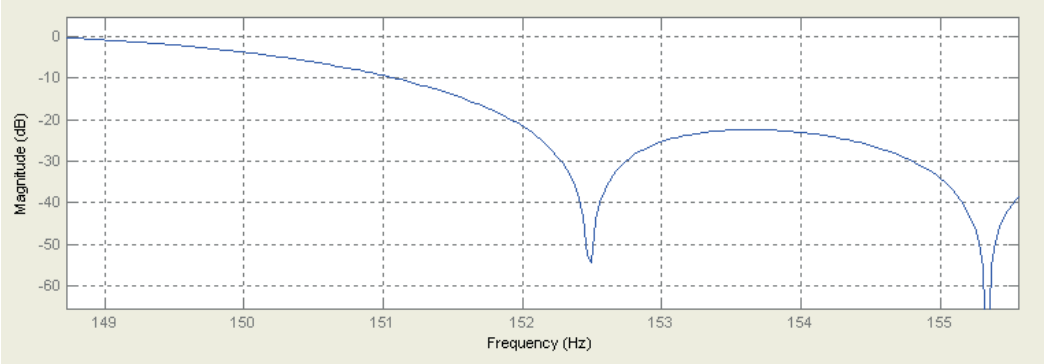


Figure 41. Frequency Response for the MBF Filter (Sharp cut off Around 150Hz)

Band Pass Filter

PC application also provides the provision for selecting 161 order muscle artefact filter which has the pass band of 0.67 Hz to 40 Hz. This filter provides a sharp cut-off at 40 Hz with attenuation of 30 dB at the stop band. The frequency response for the filter is shown in Figure 42.

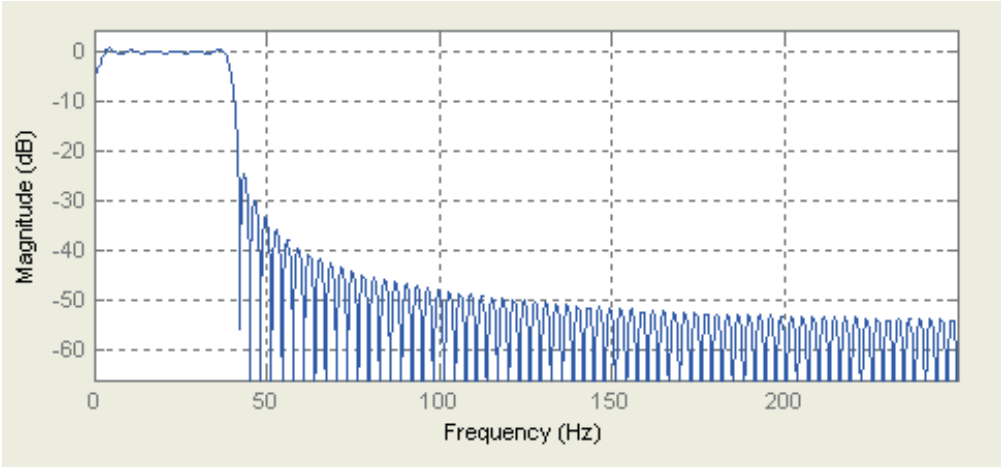


Figure 42. Frequency Response for the Band Pass Filter

6.2.2 Lead Derivation

The demonstration kit is configured to generate two ECG leads (Lead I and Lead II) from the four electrodes using two channels of the ADS1192 and ADS1292 data. The other four ECG leads are computed from Lead I and Lead II using the following equations:

Lead III = Lead II - Lead I

Lead aVR = - Lead II + 0.5 * Lead III

Lead aVL = Lead I - 0.5 * Lead II

Lead aVF = Lead III + 0.5 * Lead

The ADS1292R demonstration kit is configured to generate one ECG lead (Lead II) and one respiration channel from the four electrodes using the two channels.

6.2.3 QRS and Respiration Rate Detection

QRS detection is based on first derivative of the Lead II ECG signal and threshold. Once five consecutive QRS are detected the heart rate is calculated by taking average of the five RR intervals.

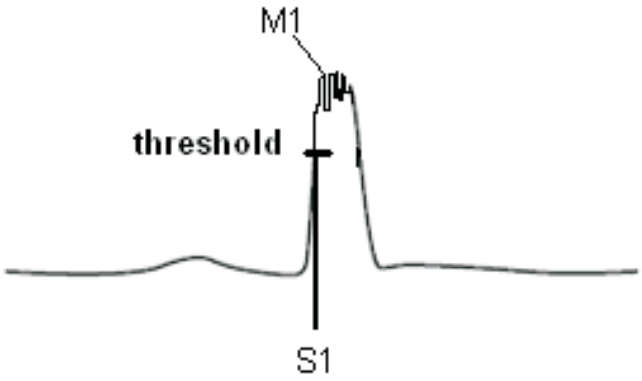
The following steps are involved for calculating heart rate:

1. Calculate first derivative of the Lead II ECG signal samples. The first derivative for any sample is calculated as

   $y0(n) = |x(n+1) – x(–1)|$

   Where,

   y0(n) is the first derivative.
   x (n+1) is the sample value for (n + 1) th sample.
   x (n – 1) is the sample value for (n – 1) th sample.
2. Initial two seconds of the first derivative is stored in a buffer and the maximum value (P) in this buffer is obtained.
3. Calculate the threshold as 0.7 x P.
4. Whenever a derivative crosses the threshold, the ECG sample index (S1) of that particular sample is marked.
5. The QRS peak is detected by scanning the next 40 derivatives (MAXIMA_SEARCH_WINDOW = 40) and obtaining the maxima (M1) .This maxima (M1) value is stored in another buffer.



6. After detecting a QRS peak, the next 50 samples (SKIP_WINDOW = 50) are skipped to take care of the minimum RR interval that can occur in the case of maximum detectable heart rate (i.e. 240 BPM).
7. Next five QRS peaks are detected by repeating steps 4 to 7.
8. RR interval is calculated as the number of samples between two consecutive QRS peaks.
9. Heart rate is calculated using the below formula HR per Minute = (60 * Sampling Rate)/ (Average RR interval for 5 consecutive RR intervals)
10. Threshold also gets recalculated from the QRS peak values detected.

Respiration rate for boards with the ADS1292R installed is calculated from the respiration waveform using the similar algorithm mentioned above.

USB Receive and transmit module

The processed ECG data and Respiration data along with heart rate, lead-off status and respiration rate is communicated to the PC application packet by packet. Each packet of data will have 14 samples of data along with heart rate, respiration rate and lead off status. Each sample is 16bit. The communication happens through USB interface.

7 USB Based Firmware Upgrade

The firmware on the ADS1x9xECG-FE can be changed from the PC application by selecting the Firmware Upgrade option on the PC application.

The firmware upgrade command can be initiated by the PC application. The state machine implemented in the firmware enters into a firmware upgrade mode. At the end of the firmware upgrade, the system issues a reset command and will reload with new firmware. The firmware upgrade process steps are represented in the below screen shots:

Select PC application Menu File->Load Firmware

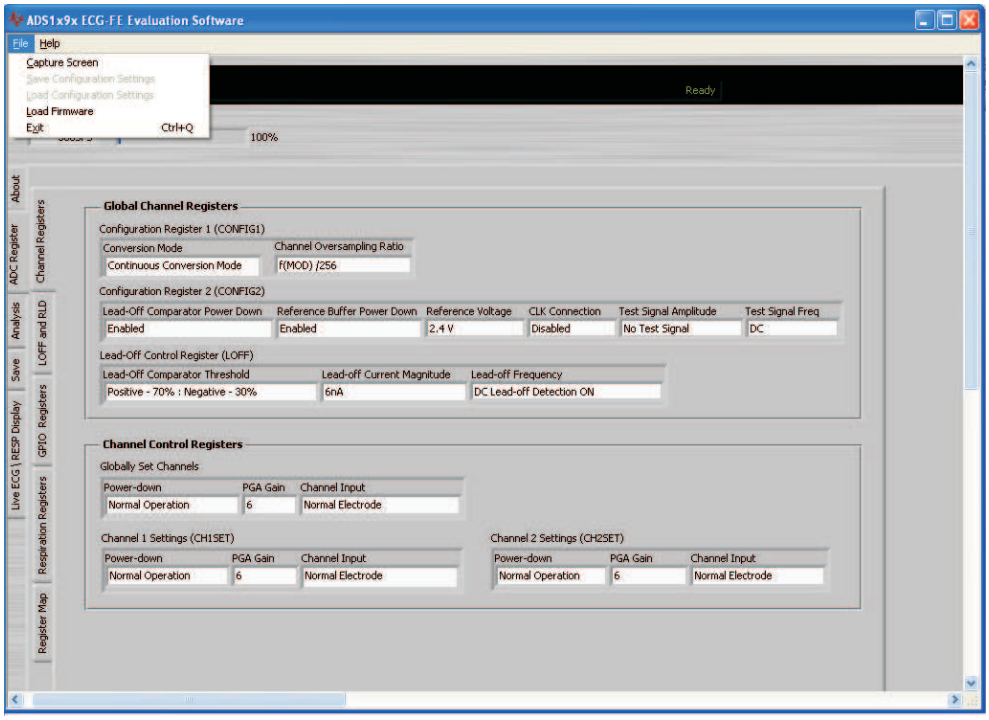


Figure 43. PC Application Firmware Upgrade - 1

The firmware upgrade application window pop-up and the application will detect the connected ADS1x9xECG-FE.

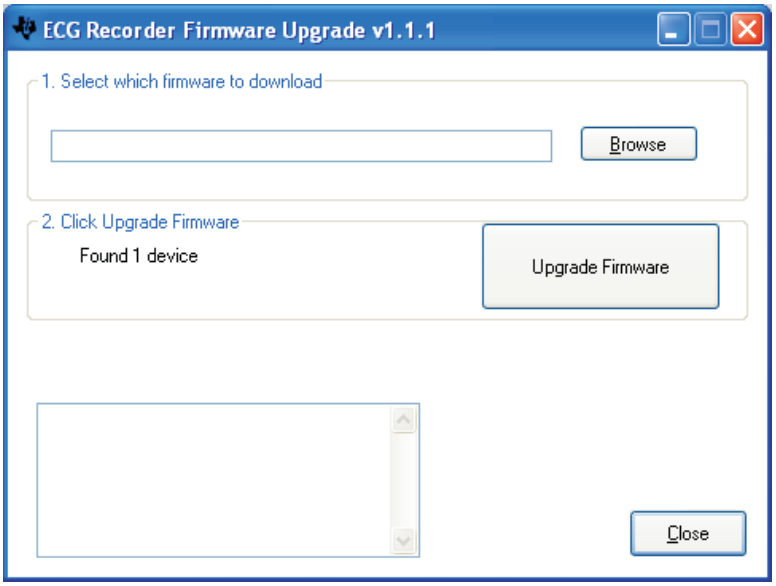


Figure 44. PC Application Firmware Upgrade - 2

Browse and select the firmware binary file (.txt file) and click “Upgrade Firmware”

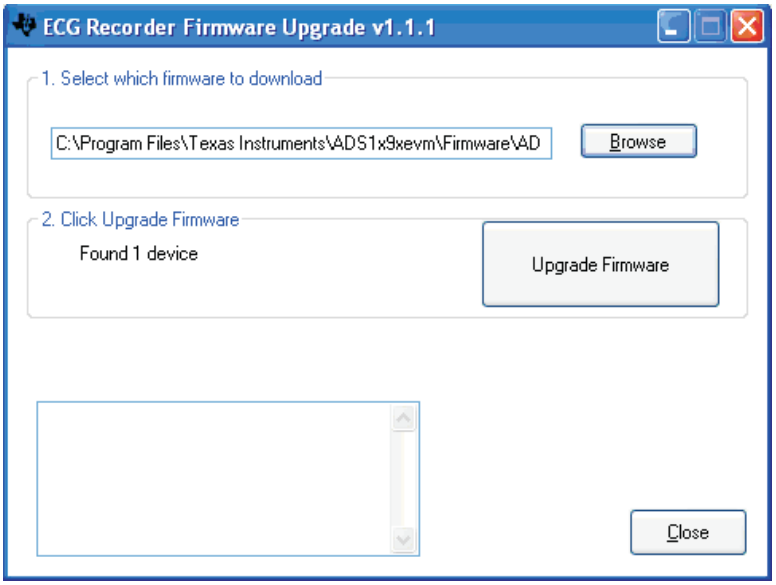


Figure 45. PC Application Firmware Upgrade - 3

Device will reset and come up with new firmware with itself.

NOTE: The default firmware will be available at “C:\Program Files\Texas Instruments\ADS1x9xevm\Firmware”

8 Connector Interface

The following connectors used for external interface to ADS1x9x ECG recorder board.

- DB9

- USB mini connector

8.1 DB9 ECG Electrode Connector

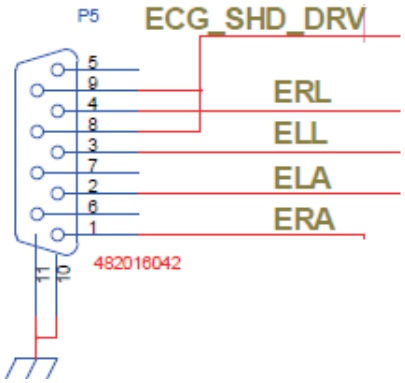


Figure 46. DB9 ECG Connector Pin Outs

NO	Signal	Description
1	ERA	
2	ELA	
3	ELL	
4	ERL	
5	NC	No Connect
6	NC	No Connect
7	NC	No Connect
8,9	ECG_SHD_DRV	

8.2 USB Mini Connector

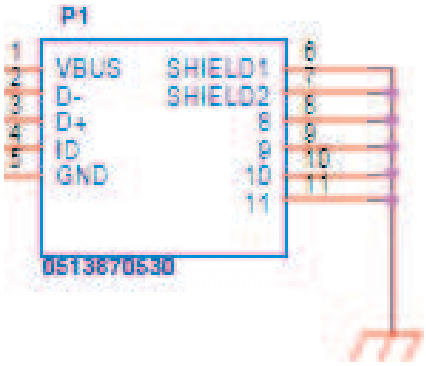


Figure 47. USB Mini Connector Pin Outs

NO	Signal	Description
1	VBUS	USB power 5 V
2	D–	USB DM
3	D+	USB DP
4	ID	NC
5	GND	GND

Appendix A ECG Cable Details

The DB9 ECG connector uses the following pin out.

Pin 1: RA
Pin 2: LA
Pin 3: LL
Pin 4: RL
Pin 8: Shield
Pin 9: Shield
All others pins are open.

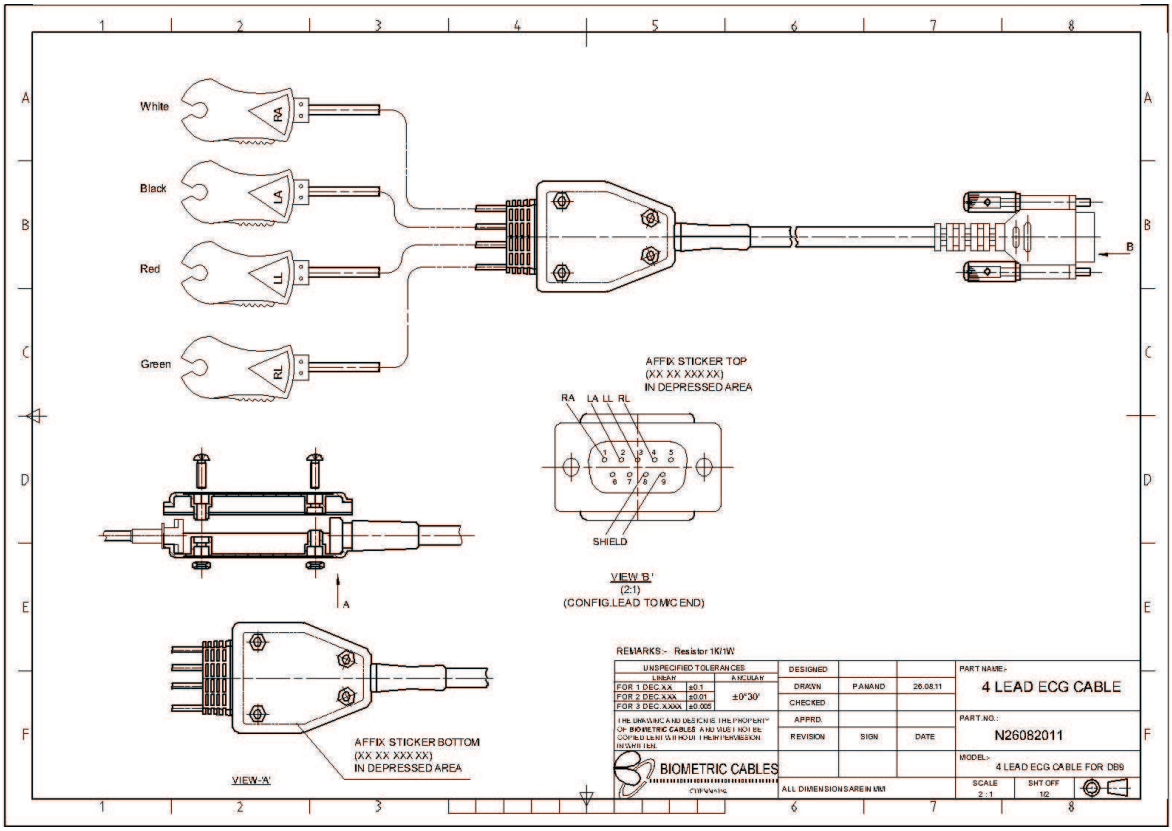


Figure 48. ECG Cable Drawing

The ECG cable can be ordered through http://www.biometriccables.com/ using the part number N26082011.

Appendix B ADS1x9x EVM BOM Details

Quantity				Ref Des	Description	MFG	Part Number
Item	ADS1292R	ADS1292	ADS1192				
1	1	1	1		Printed Wiring Board	TI	6525569
2	0	0	0	ANT1	Not Installed		
3	0	0	0	C1 ,C2, C3, C4, C5, C11, C12, C20, C26, C51, C54, C55, C57, C61, C69, C71, C73, C74, C78, C79, C80, C83, C89, C90, C91, C92	Not Installed		
4	10	10	10	C6, C34, C35, C36, C38, C41, C43, C65, C70, C85	CAP CER 10UF 6.3V X5R 20% 0603	AVX	06036D106MAT2A
5	4	4	4	C7, C8, C21, C25	CAP CER 10PF 50V NP0 RF 0402	AVX	04025U100CAT2A
6	18	18	18	C9, C13, C15, C19, C28, C31, C33, C39, C44, C52, C63, C64,C67, C72, C76, C77, C84, C87	CAP CER 0.1UF 16V X7R 0402	TDK	C1005X7R1C104K
7	2	2	2	C10, C24	CAP CER 4700PF 10V 0402 LOW DIST	Taiyo Yuden	LMK105SD472KV-F
8	8	8	8	C14, C18, C22, C27, C40, C58, C86, C88	CAP CERM 1.0UF 10% 6.3V X5R 0402	AVX	04026D105KAT2A
9	0	0	0	C16,C59,C62	Not Installed		
10	2	2	2	C17, C66	CAP CER 0.22UF 16V X7R 0402	Murata	GRM155R71C224KA12D
11	1	1	1	C23	CAP CER 1500PF 50V X7R 0402	AVX	04025C152JAT2A
12	2	2	2	C29, C30	CAP CER 12PF 5% 50V NP0 0402	AVX	04025A120JAT2A
13	1	1	1	C32	CAP CER 0.47UF 16V X5R 0402	TDK	C1005X5R1C474K
14	3	3	3	C37, C81, C82	CAP CER 2.2UF 4.0V X5R 20% 0402	AVX	04024D225MAT2A
15	2	2	2	C42, C75	CAP CERM 10000PF 5% 16V X7R 0402	AVX	0402YC103JAT2A
16	2	0	0	C45, C47	CAP CERM 2200PF 10% 50V X7R 0402	AVX	04025C222KAT2A
17	2	0	0	C46,C48	CAP CER 0.1UF 16V X7R 0402	TDK	C1005X7R1C104K
18	0	2	2		RES 0.0 OHM 1/10W 0402 SMD	Panasonic	ERJ-2GE0R00X
19	2	0	0	C49, C50	CAP CERM 2200PF 10% 50V X7R 0402	AVX	04025C222KAT2A
20	0	2	2		RES 0.0 OHM 1/10W 0402 SMD	Panasonic	ERJ-2GE0R00X
21	1	1	1	C53	CAP CER 4.7UF 6.3V X5R 0402	Murata	GRM155R60J475ME87D
22	2	2	2	C56, C60	CAP CERM 47PF 5% 50V NP0 0402	AVX	04025A470JAT2A
23	1	1	1	C68	CAP TANT 22UF 6.3V 20% 0805	AVX	TACH226M006XTA
24	1	1	1	D1	LED 470NM BLUE CLEAR 0603 SMD	Rohm	SMLE12BC7TT86
25	1	1	1	D2	LED 565NM GRN DIFF 0603 SMD	Lumex	SML-LX0603GW-TR
26	1	1	1	D3	DIODE SCHOTTKY 400MW 20V SOD123	Diodes Inc	SD103CW-13-F
27	0	0	0	D4	Not Installed		

Quantity				Ref Des	Description	MFG	Part Number
Item	ADS1292R	ADS1292	ADS1192				
28	0	0	0	L1, L2	Not Installed		
29	1	1	1	L3	FERRITE CHIP 120 OHM 2000MA 0603	Murata	BLM18PG121SN1D
30	2	2	2	L4,L7	FILTER CHIP 220 OHM 2A 0603	Murata	BLM18EG221SN1D
31	1	1	1	L5	INDUCTOR POWER 3.3UH 1.3A SMD	TDK	VLF4012AT-3R3M1R3
32	0	0	0	L6	Not Installed		
33	0	0	0	O1	Not Installed		
34	1	1	1	O2	CRYSTAL 24.0000MHZ 10PF SMD	Abracon	ABM3B-24.000MHZ-10-1-U-T
35	1	1	1	O3	CRYSTAL 32.768KHZ 12.5PF SMD	Abracon	ABS07-32.768KHZ-T
36	1	1	1	P1	CONN RCPT MINIUSB B 5POS SMD R/A	Molex Inc	513870530
37	0	0	0	P2	Not Installed		
38	1	1	1	P3	3 pin Connector	Samtec	SSW-103-02-S-S-RA
39	0	0	0	P4	Not Installed		
40	1	1	1	P5	CONN D-SUB RCPT R/A 9POS GOLD/FL	TE Connectivity	1734354-1
41	0	0	0	P6	Not Installed		
42	1	1	1	Q1	TRANSISTOR NPN 25V 50MA SOT-23	On Semi	MMBT5089LT1G
43	0	0	0	R1, R3, R5, R6, R7, R8, R9, R13, R15, R16, R17, R21, R22, R24, R25, R28, R39, R41, R42, R47, R65, R67, R68, R74, R76, R78, R79, R80, R81, R83, R86, R88, R89, R90, R91, R92, R93, R96, R103	Not Installed		
44	0	0	0	R2	Not Installed		
45	7	7	7	R4, R46, R60, R97, R108, R111, R114	RES 0.0 OHM .33W 0805 SMD	Vishay/Dale	CRCW08050000Z0EAHP
46	2	2	2	R10, R36	RES 1.0M OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ105X
47	3	3	3	R11, R12, R20	RES 33 OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ330X
48	1	1	1	R14	RES 1.40K OHM 1/10W 1% 0402 SMD	Panasonic	ERJ-2RKF1401X
49	15	15	15	R18, R19, R29, R30, R31, R32, R33, R34, R38, R48, R52, R53, R77, R94, R95	RES 10K OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ103X
50	22	22	22	R23, R26, R27, R37, R40, R44, R45, R49, R51, R54, R55, R75, R84, R98, R99, R100, R102, R105, R106, R109, R110, R113	RES 0.0 OHM 1/10W 0402 SMD	Panasonic	ERJ-2GE0R00X
51	2	2	2	R35, R117	RES 100K OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ104X
52	3	3	3	R43, R101,R107	RES 1.0K OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ102X
53	1	1	1	R50	RES 33K OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ333X

Quantity				Ref Des	Description	MFG	Part Number
Item	ADS1292R	ADS1292	ADS1192				
54	1	1	1	R56	RES 130 OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ131X
55	1	1	1	R57	RES 220 OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ221X
56	1	1	1	R58	RES 47K OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ473X
57	1	1	1	R59	RES 46.4K OHM 1/10W 1% 0402 SMD	Panasonic	ERJ-2RKF4642X
58	1	1	1	R61	RES 30.9K OHM 1/10W 1% 0402 SMD	Panasonic	ERJ-2RKF3092X
59	4	0	0	R62, R64, R66, R72	RES 10.0M OHM 1/16W 1% 0402 SMD	Panasonic	CRCW040210M0FKED
60	2	0	0	R63, R71	RES 0.0 OHM 1/10W 0402 SMD	Panasonic	ERJ-2GE0R00X
61	0	2	2		RES 51K OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ513X
62	2	0	0	R69, R70	RES 40K OHM 0.15W 0.1% 0603	Vishay/Thin Film	PAT0603E4002BST1
63	2	2	2	R73, R85	RES 51K OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ513X
64	2	2	2	R82, R115	RES 100 OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ101X
65	0	0	0	R87	Not Installed		
66	1	1	1	R104	RES 4.7K OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ472X
67	1	1	1	R112	RES 10 OHM 1/10W 5% 0402 SMD	Panasonic	ERJ-2GEJ100X
68	2	2	2	R116, R118	RES 0.0 OHM 1/10W 0402 SMD	Panasonic	ERJ-2GE0R00X
69	2	2	2	SW1,SW4	SWITCH LT 6MM 160GF 5MM HEIGHT	Panasonic	EVQ-21505R
70	2	2	2	SW2,SW3	SWITCH TACT 2.36MM SILVR G-WING	C&K Components	KT11P2SM34LFS
71	0	0	0	TP1-TP60			
72	0	0	0	U1	Not Installed		
73	1	1	1	U2	4-Channel ESD-Protection Array	Texas Instruments	TPD4E004DRYR
74	0	0	0	U3	Not Installed		
75	0	0	0	U4	Not Installed		
76	1	0	0	U5	2 channel Analog to Digital Converter (24 bit with resp)	Texas Instruments	ADS1292RIPBS
77	0	1	0		2 channel Analog to Digital Converter (24 bit)	Texas Instruments	ADS1292IPBS
78	0	0	1		2 channel Analog to Digital Converter (16 bit)	Texas Instruments	ADS1192IPBS
79	1	1	1	U7	MSP Microcontroller	Texas Instruments	MSP430F5529IPNR
80	1	1	1	U8	Power-Path Management IC	Texas Instruments	BQ24032ARHLR
81	1	1	1	U9	2 bit Voltage Level Shfter	Texas Instruments	TXS0102DCTR
82	1	1	1	U10	3V Low-Dropout Regulator	Texas Instruments	TPS73201DBVT
83	0	0	0	U11	Not Installed		
84	0	0	0	U12	Not Installed		
85	0	0	0	U13	Not Installed		
86	1	1	1	U14	8Gb NAND Flash	Micron	MT29F8G08ABABAWP:B
87	0	0	0	U15	Not Installed		
88	1	1	1	U16	3.3V Linear Regulator	Texas Instruments	TPS73033DBVR
89	0	0	0	U17	Not Installed		
90	1	1	1	U18	3.3V supervisors	Texas Instruments	TPS3825-33DBVT

Quantity				Ref Des	Description	MFG	Part Number
Item	ADS1292R	ADS1292	ADS1192				
Battery Assembly							
91	0	0	0	Connector on battery	2.54mm (.100") Pitch KK® Crimp Terminal Housing	Molex	22012021
92	0	0	0	Connector on battery	KK® Crimp Terminal 4366	Molex	8030303
93	0	0	0	Battery	4.2V Li Ion Battery	Power Stream	GM065080
94	0	0	0	Battery Cable	22 AWG red color cable		
95	0	0	0	Battery Cable	22 AWG black color cable		

Appendix C Layout and Schematics

C.1 ADS1x9x EVM Layout

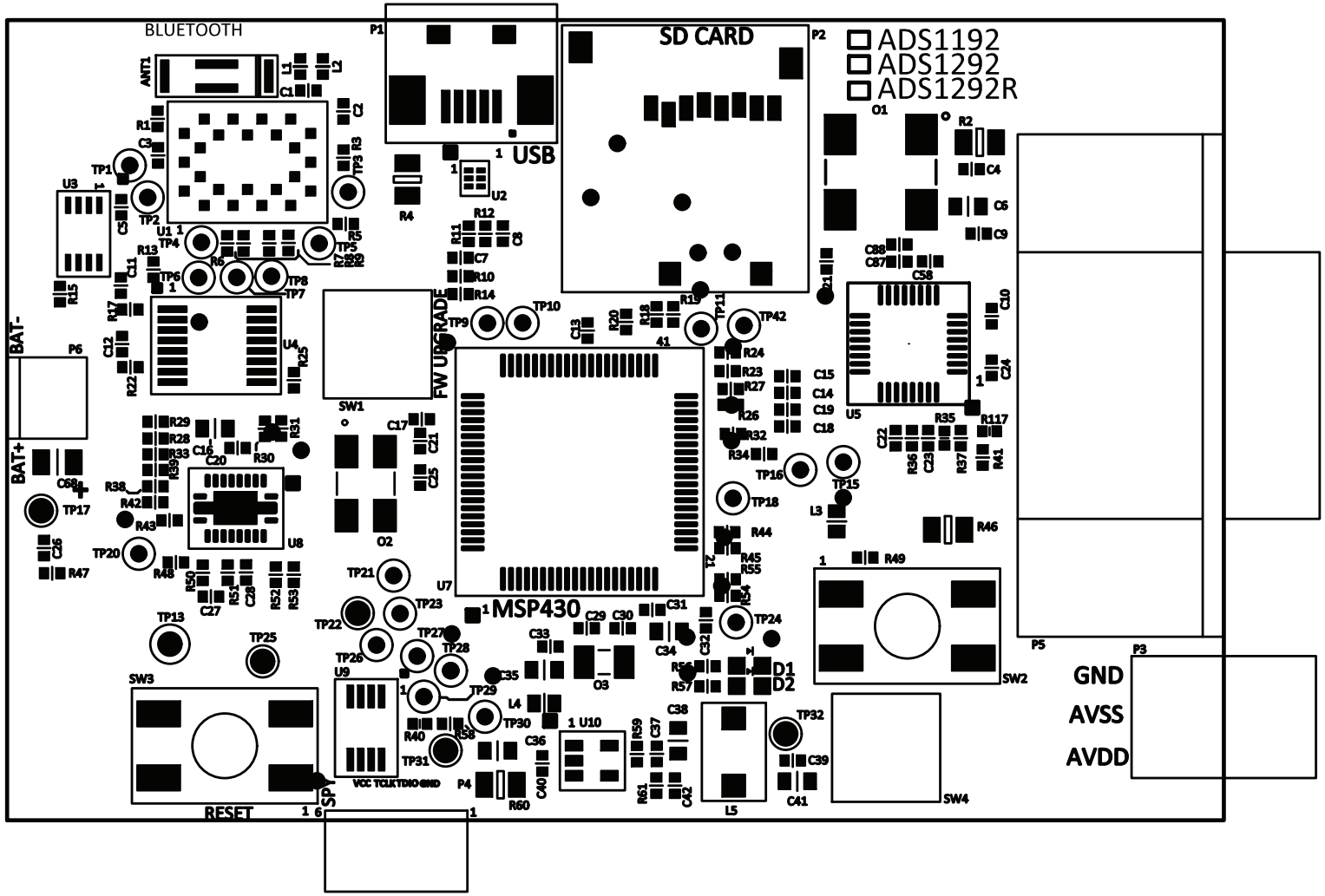


Figure 49. TOP Layer Placement

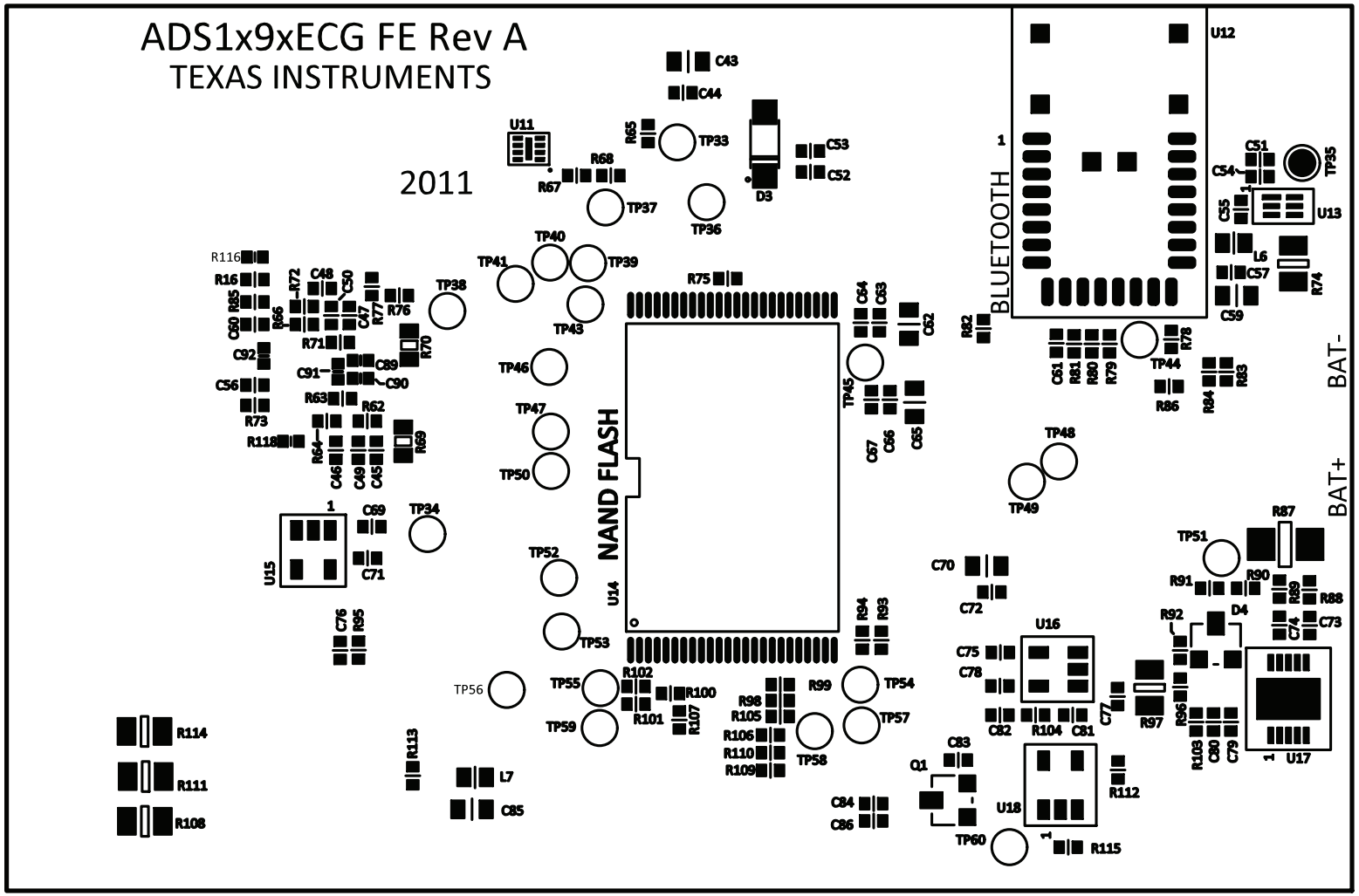
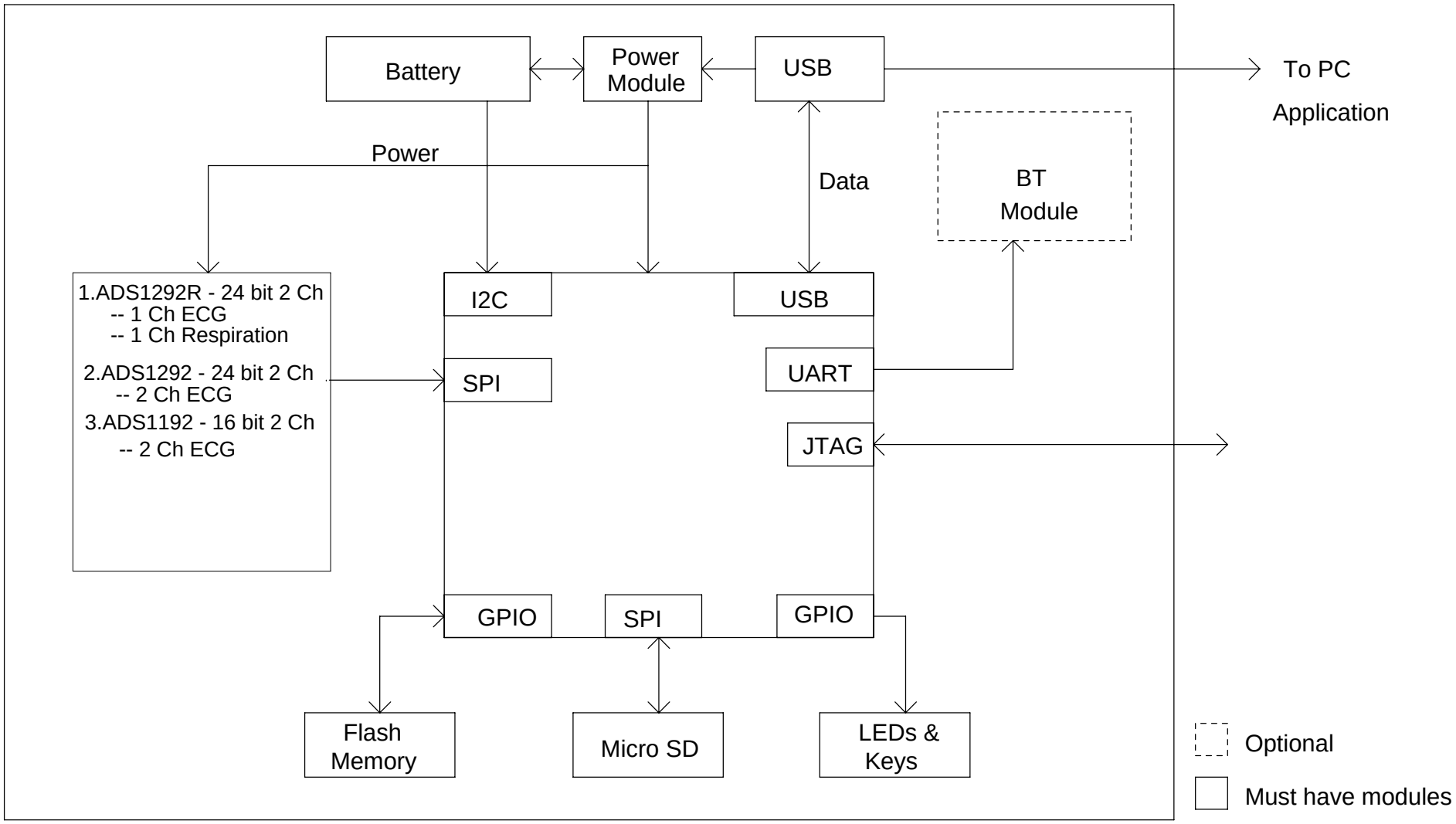
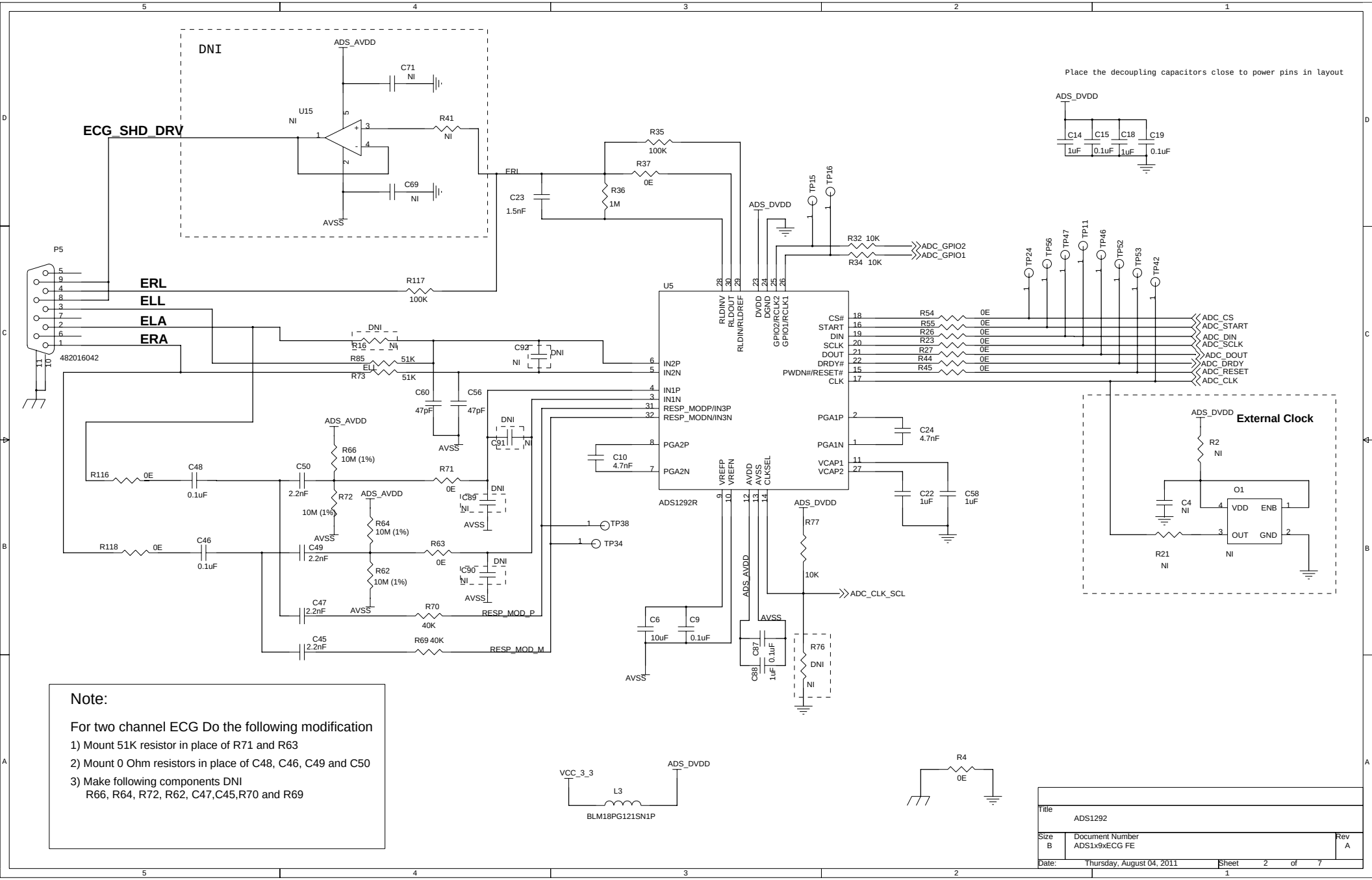


Figure 50. Bottom Layer Placement

C.2 ADS1x9xECG-FE Board Schematic



Title: Block Diagram		
Size: B	Document Number: ADS1x9xECG FE	Rev: A
Date: Thursday, August 04, 2011	Sheet 1 of 7	

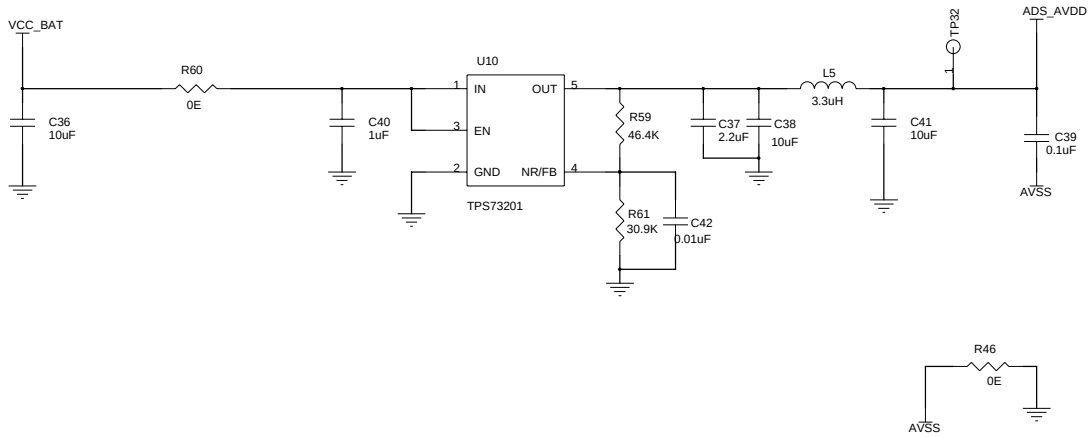


Note:

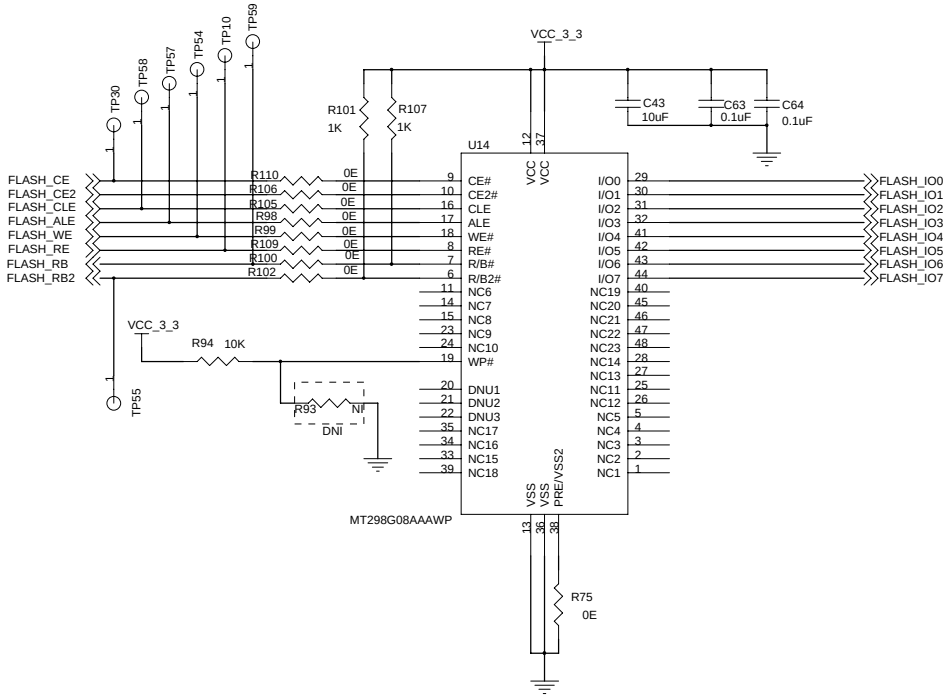
For two channel ECG Do the following modification

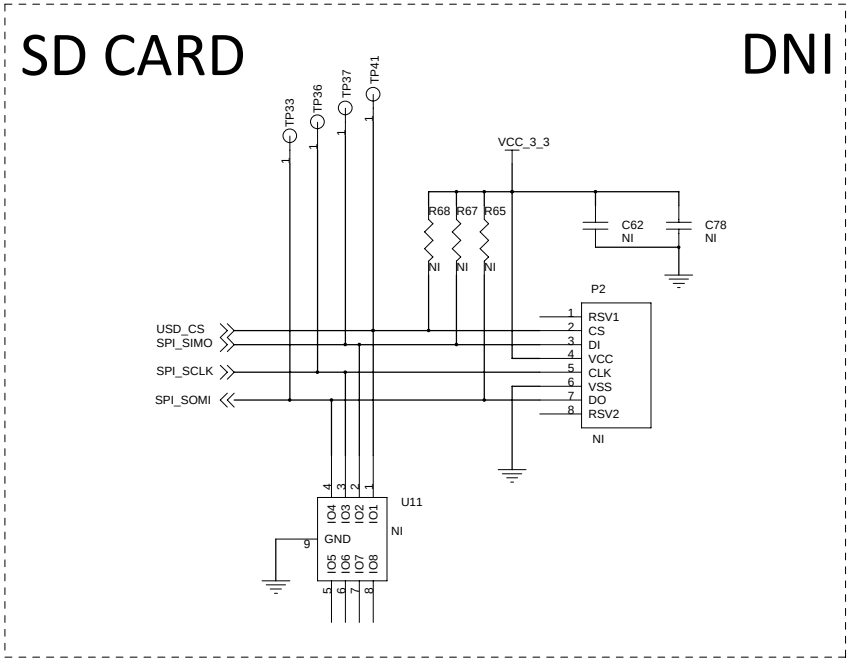
1) Mount 51K resistor in place of R71 and R63
2) Mount 0 Ohm resistors in place of C48, C46, C49 and C50
3) Make following components DNI
   R66, R64, R72, R62, C47,C45,R70 and R69

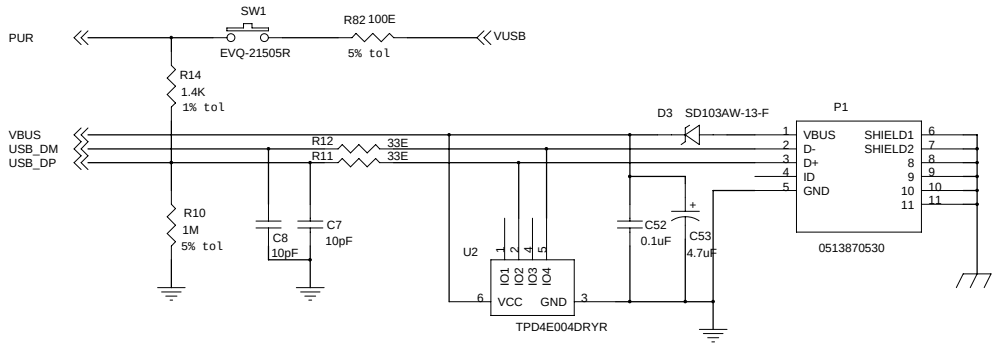
Title	ADS1292	
Size B	Document Number ADS1x9xECG FE	Rev A
Date: Thursday, August 04, 2011	Sheet 2 of 7	



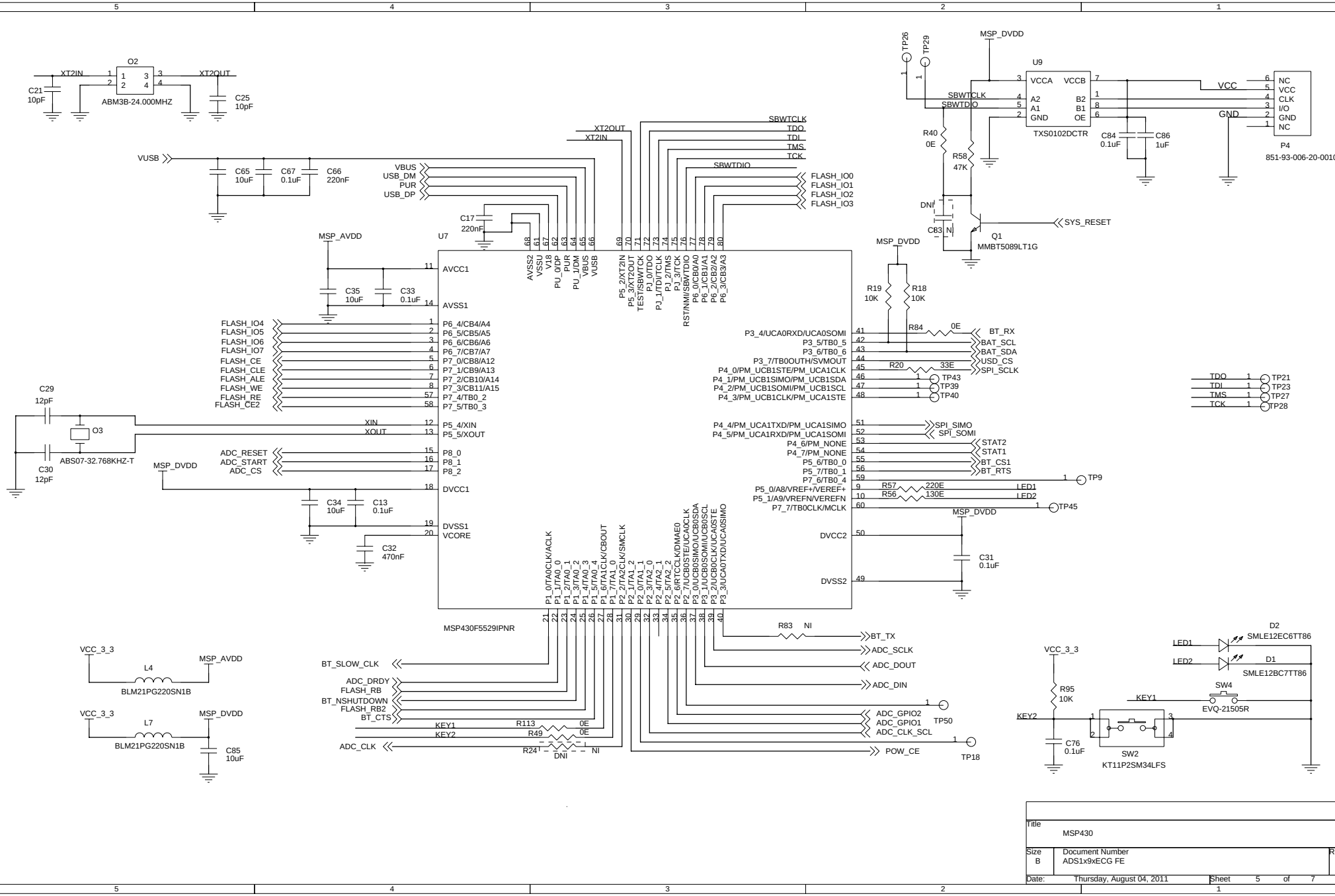
Title	ADS1292 Power Supply	
Size B	Document Number ADS1x9xECG FE	Rev A
Date: Thursday, August 04, 2011	Sheet 3 of 7	



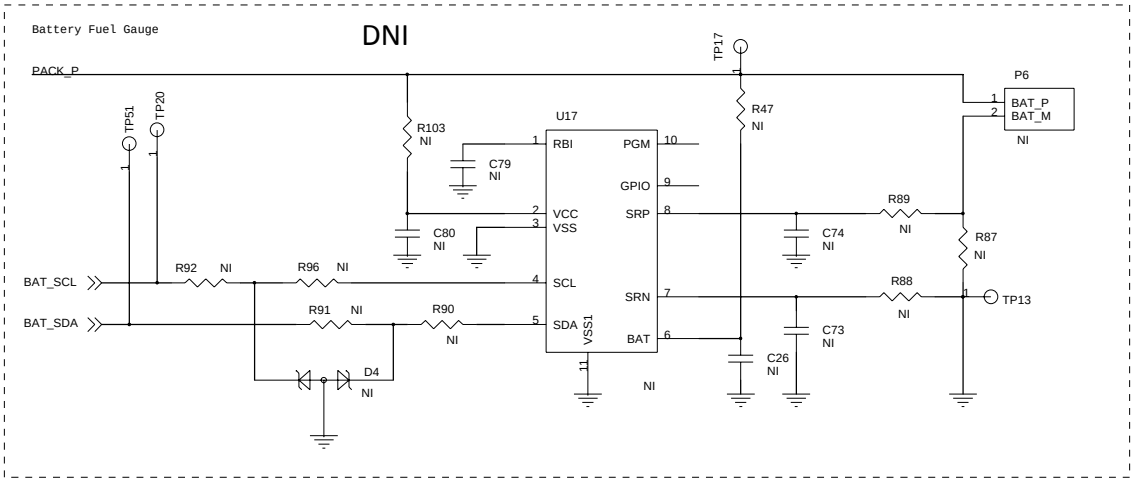


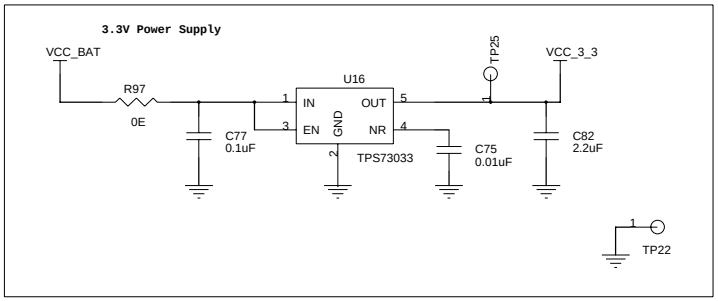


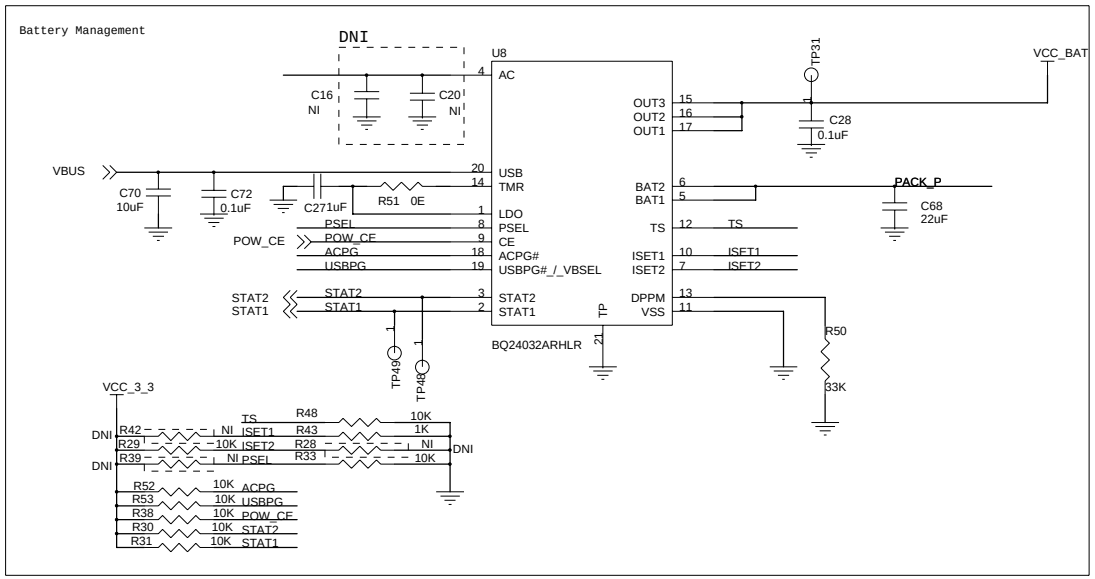
Title	USB, Micro SD, USB Interfaces	
Size B	Document Number ADS1x9xECG FE	Rev A
Date: Thursday, August 04, 2011	Sheet 4 of 7	

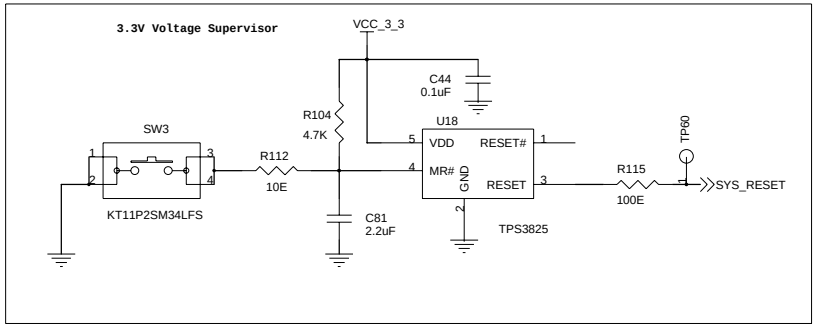


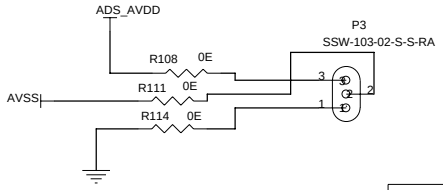
Title	MSP430	
Size B	Document Number ADS1x9xECG FE	Rev A
Date: Thursday, August 04, 2011	Sheet 5 of 7	





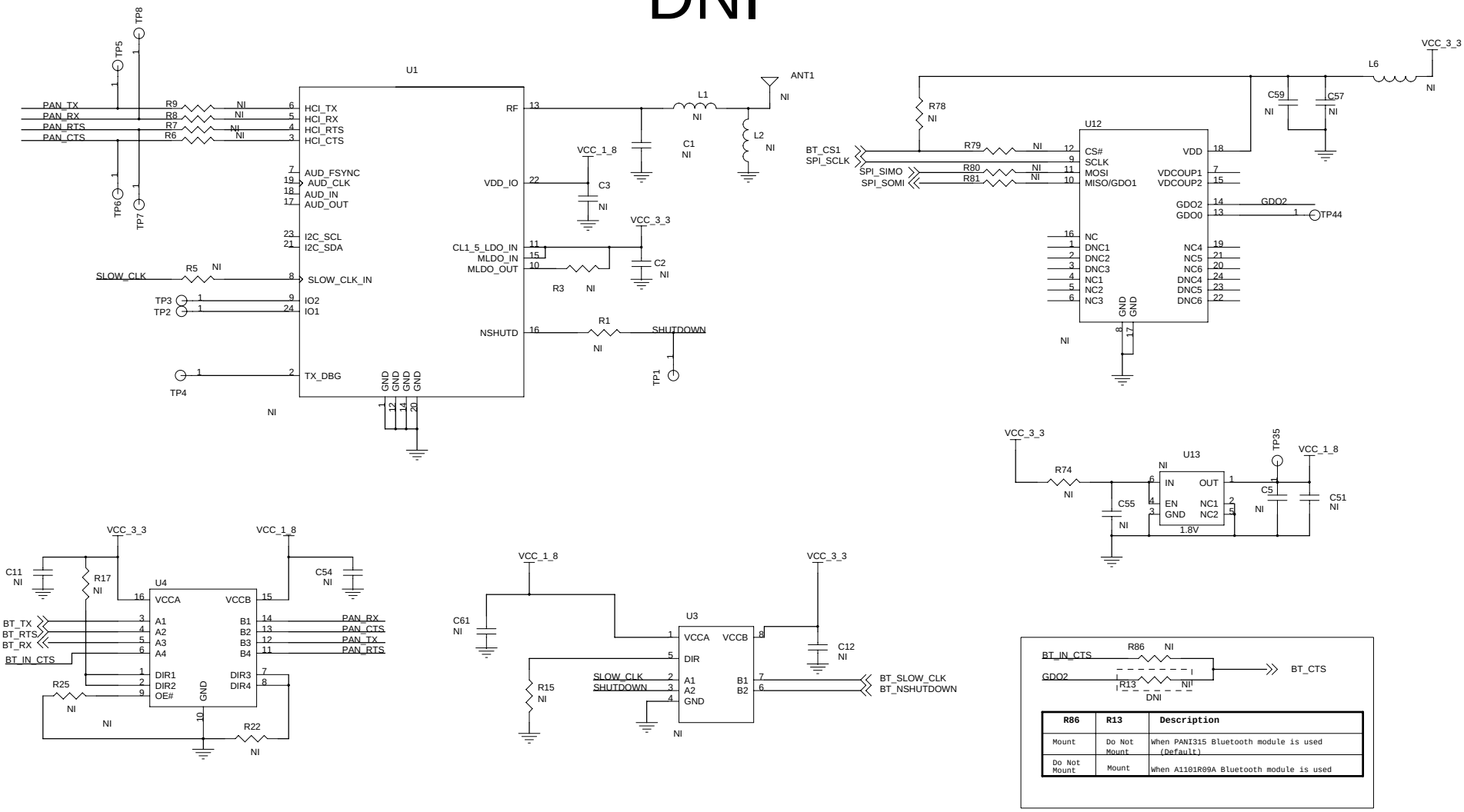






Title	Power Supply	
Size B	Document Number ADS1x9xECG FE	Rev A
Date: Thursday, August 04, 2011	Sheet 6 of 7	

DNI



R86	R13	Description
Mount	Do Not Mount	When PANI315 Bluetooth module is used (Default)
Do Not Mount	Mount	When A1101R09A Bluetooth module is used

Title	Bluetooth Module	
Size: B	Document Number: ADS1x9xECG FE	Rev: A
Date: Thursday, August 04, 2011	Sheet 7 of 7	

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 0 V to 5 V and the output voltage range of 0 V to 5 V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 30° C. The EVM is designed to operate properly with certain components above 30° C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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

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As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

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General Statement for EVMs including a radio

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

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

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

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

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

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

Concerning EVMs including radio transmitters

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

Concerning EVMs including detachable antennas

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

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

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

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

Concernant les EVMs avec appareils radio

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

Concernant les EVMs avec antennes détachables

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

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

【Important Notice for Users of this Product in Japan】

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If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

Texas Instruments Japan Limited
(address) 24-1, Nishi-Shinjuku 6 chome, Shinjuku-ku, Tokyo, Japan

http://www.tij.co.jp

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EVALUATION BOARD/KIT/MODULE (EVM)
WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

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

Agreement to Defend, Indemnify and Hold Harmless. You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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