Contents

1 ADS1x9xECG-FE ................................................................. 7
   1.1 Important Disclaimer Notice ........................................... 7
2 Overview ................................................................. 8
   2.1 Introduction .............................................................. 8
   2.2 Features Supported in this Version ................................. 8
3 Software Installation ................................................................. 9
   3.1 Minimum Requirements ............................................... 9
   3.2 Installing the Software (PC application) ......................... 9
   3.3 Installing the USB Drivers .......................................... 14
4 Running the Software ................................................................. 18
   4.1 Overview of the Features ......................................... 19
5 ADS1x9xECG-FE Hardware Introduction ........................................ 29
   5.1 Power Supply ............................................................ 29
   5.2 Clock ................................................................. 30
   5.3 Memory ............................................................... 30
   5.4 Accessing ADS1x9x Digital Signals .......................... 30
   5.5 GPIO Test Points .................................................. 30
   5.6 Analog Inputs ...................................................... 30
   5.7 USB Interface ..................................................... 31
   5.8 On Board Key Interface ........................................ 31
   5.9 Visual Indication .................................................... 32
6 Evaluation of ECG and Respiration Specific Functions ................................. 32
   6.1 Evaluation Mode (Analysis Mode) .............................. 33
   6.2 Live Data Streaming Mode ......................................... 34
7 USB Based Firmware Upgrade ................................................................. 39
8 Connector Interface ................................................................. 40
   8.1 DB9 ECG Electrode Connector .................................. 41
   8.2 USB Mini Connector ................................................. 41
Appendix A ECG Cable Details ................................................................. 43
Appendix B ADS1x9x EVM BOM Details ................................................................. 45
Appendix C Layout and Schematics ................................................................. 49
   C.1 ADS1x9x EVM Layout ..................................................... 49
   C.2 ADS1x9xECG-FE Board Schematic ............................ 52
# List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADS1x9xECG-FE Demonstration Kit</td>
</tr>
<tr>
<td>2</td>
<td>PC Application Installation Screen 1</td>
</tr>
<tr>
<td>3</td>
<td>PC Application Installation Screen 2</td>
</tr>
<tr>
<td>4</td>
<td>PC Application Installation Screen 3</td>
</tr>
<tr>
<td>5</td>
<td>PC Application Installation Screen 4</td>
</tr>
<tr>
<td>6</td>
<td>PC Application Installation Screen 5</td>
</tr>
<tr>
<td>7</td>
<td>PC Application Installation Screen 6</td>
</tr>
<tr>
<td>8</td>
<td>PC Application Installation Screen 7</td>
</tr>
<tr>
<td>9</td>
<td>PC Application Installation Screen 8</td>
</tr>
<tr>
<td>10</td>
<td>PC Application Installation Screen 9</td>
</tr>
<tr>
<td>11</td>
<td>PC Application Installation Screen 10</td>
</tr>
<tr>
<td>12</td>
<td>Hardware Wizard Screen 1</td>
</tr>
<tr>
<td>13</td>
<td>Hardware Wizard Screen 2</td>
</tr>
<tr>
<td>14</td>
<td>Hardware Wizard Screen 3</td>
</tr>
<tr>
<td>15</td>
<td>Hardware Wizard Screen 4</td>
</tr>
<tr>
<td>16</td>
<td>Hardware Wizard Screen 5</td>
</tr>
<tr>
<td>17</td>
<td>Hardware Wizard Screen 6</td>
</tr>
<tr>
<td>18</td>
<td>Device Manager Screen</td>
</tr>
<tr>
<td>19</td>
<td>EVM not connected Error Message</td>
</tr>
<tr>
<td>20</td>
<td>Register Configuration - Channel Registers</td>
</tr>
<tr>
<td>21</td>
<td>Register Configuration – LOFF and RLD</td>
</tr>
<tr>
<td>22</td>
<td>Register Configuration – GPIO</td>
</tr>
<tr>
<td>23</td>
<td>Register Configuration – Respiration Registers</td>
</tr>
<tr>
<td>24</td>
<td>Register Configuration – Register Map</td>
</tr>
<tr>
<td>25</td>
<td>PC Application Analysis – SCOPE</td>
</tr>
<tr>
<td>26</td>
<td>PC Application Analysis - Histogram</td>
</tr>
<tr>
<td>27</td>
<td>PC Application Analysis - FFT</td>
</tr>
<tr>
<td>28</td>
<td>PC Application Analysis – ECG</td>
</tr>
<tr>
<td>29</td>
<td>PC Application Analysis – ADS1292R Respiration (Low Pass Filter Enabled)</td>
</tr>
<tr>
<td>30</td>
<td>PC Application Save</td>
</tr>
<tr>
<td>31</td>
<td>PC Application Live ECG for ADS1292R</td>
</tr>
<tr>
<td>32</td>
<td>PC Application Live Respiration Channel</td>
</tr>
<tr>
<td>33</td>
<td>Simulator Connection</td>
</tr>
<tr>
<td>34</td>
<td>Switch Positions</td>
</tr>
<tr>
<td>35</td>
<td>Firmware Architecture</td>
</tr>
<tr>
<td>36</td>
<td>Evaluation Mode Data Flow for ADS1292R</td>
</tr>
<tr>
<td>37</td>
<td>Live Data Stream Mode Data Flow for ADS1292R</td>
</tr>
<tr>
<td>38</td>
<td>Frequency Response for the IIR Filter</td>
</tr>
<tr>
<td>39</td>
<td>Frequency Response for the MBF Filter (Full View)</td>
</tr>
<tr>
<td>40</td>
<td>Frequency Response for the MBF Filter (50Hz Notch)</td>
</tr>
<tr>
<td>41</td>
<td>Frequency Response for the MBF Filter (Sharp cut off Around 150Hz)</td>
</tr>
<tr>
<td>42</td>
<td>Frequency Response for the Band Pass Filter</td>
</tr>
<tr>
<td>43</td>
<td>PC Application Firmware Upgrade - 1</td>
</tr>
<tr>
<td>44</td>
<td>PC Application Firmware Upgrade - 2</td>
</tr>
<tr>
<td>45</td>
<td>PC Application Firmware Upgrade - 3</td>
</tr>
<tr>
<td>46</td>
<td>DB9 ECG Connector Pin Outs</td>
</tr>
<tr>
<td>47</td>
<td>USB Mini Connector Pin Outs</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>48</td>
<td>ECG Cable Drawing</td>
</tr>
<tr>
<td>49</td>
<td>TOP Layer Placement</td>
</tr>
<tr>
<td>50</td>
<td>Bottom Layer Placement</td>
</tr>
</tbody>
</table>
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 ADS1x9xECG-FE 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 ADS1x9xECG-FE 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](image)

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](image)

Accept the License Agreement and click “Next”

![Figure 3. PC Application Installation Screen 2](image)
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.

![Microsoft Visual C++ 2008 Redistributable Package Maintenance Mode]

Select one of the options below:

- **Repair**
  - Repair Microsoft Visual C++ 2008 Redistributable to its original state.

- **Uninstall**
  - Uninstall Microsoft Visual C++ 2008 Redistributable from the computer.

**Figure 6. PC Application Installation Screen 5**

Click “Finish” to complete the installation procedure.

![Microsoft Visual C++ 2008 Redistributable Package Setup Canceled]

You have chosen to cancel setup.

**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"

![Microsoft Visual C++ 2008 Redistributable...](image)

**Figure 8. PC Application Installation Screen 7**

Accept the license terms and click "Install"

![Microsoft Visual C++ 2008 Redistributable...](image)

**Figure 9. PC Application Installation Screen 8**
Click “Finish” to complete the installation

![Microsoft Visual C++ 2008 Redistributable](image)

Figure 10. PC Application Installation Screen 9

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

![ADS1x9xevm](image)

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

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](image)

Click on Finish

![Figure 17. Hardware Wizard Screen 6](image)
Running the Software

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

![Figure 18. Device Manager Screen](image)

The USB driver installation is now complete and ADS1x9xECM is now ready to use.

4 Running the Software

From the “Start->Programs->Texas Instruments->ADS1x9xECM” menu, run the ADS1x9xECM 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](image)
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.
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](image)

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

![Figure 22. Register Configuration – GPIO](image)
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](image)

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](image)
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

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

**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.

![Histogram Sub-Tab Image]

**Figure 26. PC Application Analysis - Histogram**

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

<table>
<thead>
<tr>
<th>Button/Control</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histogram Analysis</td>
<td>Runs histogram of the selected channel(s) for the selected number of samples</td>
</tr>
<tr>
<td>Plot</td>
<td>Channel selection button allow selecting all channels or Channel 1 or Channel 2 for the display</td>
</tr>
<tr>
<td>Display Plane</td>
<td>Various display planes can be selected for the histogram display. The options available are:</td>
</tr>
<tr>
<td></td>
<td>• Nyquist</td>
</tr>
<tr>
<td></td>
<td>• Nichols</td>
</tr>
<tr>
<td></td>
<td>• S Plane</td>
</tr>
<tr>
<td></td>
<td>• Z Plane</td>
</tr>
</tbody>
</table>
**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**

<table>
<thead>
<tr>
<th>Button / Control</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFT Analysis</td>
<td>Runs FFT analysis of the selected channel(s) and result will be shown on the pop-up window</td>
</tr>
<tr>
<td>Plot</td>
<td>Channel selection button allow selecting all channels or Channel 1 or Channel 2 for the display</td>
</tr>
<tr>
<td>AC Analysis Parameters Section</td>
<td>Various AC analysis parameter configuration</td>
</tr>
<tr>
<td>Coherent Frequency Calculator Section</td>
<td>Provision for entering desired A1n Frequency</td>
</tr>
<tr>
<td>User Defined Dynamic Range Section</td>
<td>Provision for selecting Low and High frequency</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Button/Control</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot Set</td>
<td>Option to select ECG Lead I, Lead II, Lead III, Lead aVR, Lead aVL, Lead aVF or Respiration Channel (ADS1292R only)</td>
</tr>
<tr>
<td>High Pass Filter</td>
<td>Provision for enabling a PC side high pass filter with support for selecting the order of the filter and cut off frequency</td>
</tr>
<tr>
<td>Low Pass Filter</td>
<td>Provision for enabling a PC side low pass filter with support for selecting the order of the filter and cut off frequency</td>
</tr>
<tr>
<td>Notch Filter</td>
<td>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</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Display Options</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto scaling</td>
<td>Both x-scale and y-scale auto scaling is possible. User can enable or disable this feature</td>
</tr>
<tr>
<td>Export Data</td>
<td>The displayed data can be exported to excel or Clipboard</td>
</tr>
<tr>
<td>Annotation Provision</td>
<td>Provision provided for creating and deleting annotation</td>
</tr>
<tr>
<td>Visible Items selector</td>
<td>Option to display x-scale, y-scale, Plot legends, x-scrollbar</td>
</tr>
<tr>
<td>Plot legend options</td>
<td>Plot legend gives various option to change the color of the plotting, various plotting styles etc</td>
</tr>
</tbody>
</table>

### 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](image-url)
The following options are provided in the save tab.

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

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](image)
Running the Software

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.

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

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](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.

<table>
<thead>
<tr>
<th>SI NO</th>
<th>Test Point</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TP25</td>
<td>3.3V</td>
</tr>
<tr>
<td>2</td>
<td>TP32</td>
<td>ADS_AVDD, 3.0V</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Clock Type</th>
<th>R21</th>
<th>R24</th>
<th>Clock SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Clock</td>
<td>Not Installed</td>
<td>Not Installed</td>
<td>Mount R77 to Drive “high” on ADC_CLK_SCL OR Set P2.3 of MSP430 to Drive “high” on ADC_CLK_SCL.</td>
</tr>
<tr>
<td>External Clock</td>
<td>Not Installed</td>
<td>Installed</td>
<td>Mount R76 to Drive “low” on ADC_CLK_SCL OR Clear P2.3 of MSP430 to Drive “low” on ADC_CLK_SCL.</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>SI NO.</th>
<th>Signal</th>
<th>Test Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADC_CS</td>
<td>TP24</td>
</tr>
<tr>
<td>2</td>
<td>ADC_START</td>
<td>TP56</td>
</tr>
<tr>
<td>3</td>
<td>ADC_DOUT</td>
<td>TP47</td>
</tr>
<tr>
<td>4</td>
<td>ADC_SCLK</td>
<td>TP11</td>
</tr>
<tr>
<td>5</td>
<td>ADC_DIN</td>
<td>TP46</td>
</tr>
<tr>
<td>6</td>
<td>ADC_DRDY</td>
<td>TP52</td>
</tr>
<tr>
<td>7</td>
<td>ADC_RESET</td>
<td>TP53</td>
</tr>
<tr>
<td>8</td>
<td>CLK</td>
<td>TP42</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>SI NO.</th>
<th>Signal</th>
<th>Test Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADC_GPIO1</td>
<td>TP15</td>
</tr>
<tr>
<td>2</td>
<td>ADC_GPIO2</td>
<td>TP16</td>
</tr>
</tbody>
</table>

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

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

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.
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.
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:

\[
H(z) = \frac{Y(z)}{X(z)} = \frac{1 - z^{-1}}{1 - az^{-1}}
\]  

(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.
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 150 Hz 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.
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.
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
   \[ y_0(n) = |x(n+1) - x(n-1)| \]
   Where,
   - \( y_0(n) \) is the first derivative.
   - \( x(n+1) \) is the sample value for the \( (n+1) \)th sample.
   - \( x(n-1) \) is the sample value for the \( (n-1) \)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 \( \times \) 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 = \( (60 \times \text{Sampling Rate}) / \text{(Average RR interval for 5 consecutive RR intervals)} \)

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](image)

The firmware upgrade application window pop-up and the application will detect the connected ADS1x9xECG-FE.
Browse and select the firmware binary file (.txt file) and click “Upgrade Firmware”.

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

**NOTE:** The default firmware will be available at “C:\Program Files\Texas Instruments\ADS1x9evm\Firmware\AD”

### 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**

![DB9 ECG Connector Pin Outs](image)

<table>
<thead>
<tr>
<th>NO</th>
<th>Signal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ERA</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>ELA</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>ELL</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>ERL</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>NC</td>
<td>No Connect</td>
</tr>
<tr>
<td>6</td>
<td>NC</td>
<td>No Connect</td>
</tr>
<tr>
<td>7</td>
<td>NC</td>
<td>No Connect</td>
</tr>
<tr>
<td>8,9</td>
<td>ECG_SHD_DRV</td>
<td></td>
</tr>
</tbody>
</table>

8.2 **USB Mini Connector**

![USB Mini Connector Pin Outs](image)

<table>
<thead>
<tr>
<th>NO</th>
<th>Signal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VBUS</td>
<td>USB power 5 V</td>
</tr>
<tr>
<td>2</td>
<td>D−</td>
<td>USB DM</td>
</tr>
<tr>
<td>3</td>
<td>D+</td>
<td>USB DP</td>
</tr>
<tr>
<td>4</td>
<td>ID</td>
<td>NC</td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td>GND</td>
</tr>
</tbody>
</table>
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](image)

The ECG cable can be ordered through [http://www.biometriccables.com/](http://www.biometriccables.com/) using the part number N26082011.
## Appendix B ADS1x9x EVM BOM Details

<table>
<thead>
<tr>
<th>Item</th>
<th>ADS1292R</th>
<th>ADS1292</th>
<th>ADS1192</th>
<th>Quantity</th>
<th>Ref Des</th>
<th>Description</th>
<th>MFG</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Printed Wiring Board</td>
<td>TI</td>
<td>6525569</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>ANT1</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>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</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>C6, C34, C35, C36, C38, C41, C43, C65, C70, C85</td>
<td>CAP CER 10UF 6.3V X5R 20% 0603</td>
<td>AVX</td>
<td>06036D106MAT2A</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>C7, C8, C21, C25</td>
<td>CAP CER 10PF 50V NP0 RF 0402</td>
<td>AVX</td>
<td>04025U100C4T2A</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>C9, C13, C15, C19, C28, C31, C33, C39, C44, C52, C63, C64, C67, C72, C76, C77, C84, C87</td>
<td>CAP CER 0.1UF 16V X7R 0402</td>
<td>TDK</td>
<td>C1005X7R1C04K</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>C10, C24</td>
<td>CAP CER 4700PF 10V 0402 LOW DIST</td>
<td>Taiyo Yuden</td>
<td>LMK105SD472VF-F</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>C14, C18, C22, C27, C40, C43, C46, C64, C65, C67, C72, C76, C77, C84, C87</td>
<td>CAP CERM 1.0UF 10% 6.3V X5R 0402</td>
<td>AVX</td>
<td>04026D105KAT2A</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>C16, C59, C62</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>C17, C66</td>
<td>CAP CER 0.22UF 16V X7R 0402</td>
<td>Murata</td>
<td>GRM155R71C224KU12D</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>C23</td>
<td>CAP CER 1500PF 50V X7R 0402</td>
<td>AVX</td>
<td>04025C152JAT2A</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>C29, C30</td>
<td>CAP CER 12PF 5% 50V NP0 0402</td>
<td>AVX</td>
<td>04025A120JAT2A</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>C32</td>
<td>CAP CER 0.47UF 16V X5R 0402</td>
<td>TDK</td>
<td>C1005X5R1C474K</td>
</tr>
<tr>
<td>14</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>C37, C81, C82</td>
<td>CAP CER 2.2UF 4.0V X5R 20% 0402</td>
<td>AVX</td>
<td>04024D225MAT2A</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>C42, C75</td>
<td>CAP CERM 10000PF 5% 16V X7R 0402</td>
<td>AVX</td>
<td>0402YC100JAT2A</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>C45, C47</td>
<td>CAP CERM 2200PF 10% 50V X7R 0402</td>
<td>AVX</td>
<td>04025C222JAT2A</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>C46, C48</td>
<td>CAP CER 0.1UF 16V X7R 0402 TDK</td>
<td>C1005X7R1C04K</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>RES 0.0 OHM 1/10W 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GE0R00X</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>C49, C50</td>
<td>CAP CERM 2200PF 10% 50V X7R 0402</td>
<td>AVX</td>
<td>04025C222KAT2A</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>RES 0.0 OHM 1/10W 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GE0R00X</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>C53</td>
<td>CAP CER 4.7UF 6.3V X5R 0402</td>
<td>Murata</td>
<td>GRM155R60J475ME87D</td>
</tr>
<tr>
<td>22</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>C56, C60</td>
<td>CAP CERM 47PF 5% 50V NP0 0402</td>
<td>AVX</td>
<td>04025A470JAT2A</td>
</tr>
<tr>
<td>23</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>C68</td>
<td>CAP TANT 22UF 6.3V 20% 0805</td>
<td>AVX</td>
<td>TACH226M006XTA</td>
</tr>
<tr>
<td>24</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>D1</td>
<td>LED 4700NM BLUE CLEAR 0603 SMD</td>
<td>Rohm</td>
<td>SMLE12BC7T86</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>D2</td>
<td>LED 565NM GRN DIFF 0603 SMD</td>
<td>Lumex</td>
<td>SML-LX0603GW-TR</td>
</tr>
<tr>
<td>26</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>D3</td>
<td>DIODE SCHOTTKY 400MW 20V SOD123</td>
<td>Diodes Inc</td>
<td>SD103CW-13-F</td>
</tr>
<tr>
<td>27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>D4</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Quantity</td>
<td>Ref Des</td>
<td>Description</td>
<td>MFG</td>
<td>Part Number</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
<td>---------</td>
<td>-------------</td>
<td>--------------</td>
<td>---------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>0</td>
<td>0</td>
<td>L1, L2</td>
<td>Not Installed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>1</td>
<td>1</td>
<td>L3</td>
<td>FERRITE CHIP 120 OHM 2000MA 0603</td>
<td>Murata BLM18PG121SN1D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>2</td>
<td>2</td>
<td>L4, L7</td>
<td>FILTER CHIP 220 OHM 2A 0603</td>
<td>Murata BLM18EG221SN1D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>1</td>
<td>1</td>
<td>L5</td>
<td>INDUCTOR POWER 3.3UH 1.3A SMD</td>
<td>TDK VLF4012AT-3R3M1R3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>0</td>
<td>0</td>
<td>L6</td>
<td>Not Installed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>0</td>
<td>0</td>
<td>O1</td>
<td>Not Installed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>1</td>
<td>1</td>
<td>O2</td>
<td>CRYSTAL 24.0000MHZ 10PF SMD</td>
<td>Abracon ABM3B-24.0000MHZ-10-1-U-T</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>1</td>
<td>1</td>
<td>O3</td>
<td>CRYSTAL 32.768KHZ 12.5PF SMD</td>
<td>Abracon ABS07-32.768KHZ-T</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>1</td>
<td>1</td>
<td>P1</td>
<td>CONN RCPT MINIUSB B 5POS SMD R/A</td>
<td>Molex Inc S13870530</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>0</td>
<td>0</td>
<td>P2</td>
<td>Not Installed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>1</td>
<td>1</td>
<td>P3</td>
<td>3 pin Connector</td>
<td>Samtec SSW-103-02-S-S-RA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>0</td>
<td>0</td>
<td>P4</td>
<td>Not Installed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1</td>
<td>1</td>
<td>P5</td>
<td>CONN D-SUB RCPT R/A 9POS GOLD/FL</td>
<td>TE Connectivity 1734354-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>0</td>
<td>0</td>
<td>P6</td>
<td>Not Installed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>1</td>
<td>1</td>
<td>Q1</td>
<td>TRANSISTOR NPN 25V 50MA SOT-23</td>
<td>On Semi MMBT5089LT1G</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>0</td>
<td>0</td>
<td>R2</td>
<td>Not Installed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>0</td>
<td>0</td>
<td>R3</td>
<td>Not Installed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>7</td>
<td>7</td>
<td>R4, R6</td>
<td>RES 0.0 OHM .33W 0805 SMD</td>
<td>Vishay/Dale CRCW08050000Z0 EAH P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>2</td>
<td>2</td>
<td>R10, R36</td>
<td>RES 1.0M OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic ERJ-2GEJ105X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>3</td>
<td>3</td>
<td>R11, R12, R20</td>
<td>RES 33 OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic ERJ-2GEJ330X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>1</td>
<td>1</td>
<td>R14</td>
<td>RES 1.40K OHM 1/10W 1% 0402 SMD</td>
<td>Panasonic ERJ-2RKF1401X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>15</td>
<td>15</td>
<td>R18, R19, R29, R30, R31, R32, R33, R34, R38, R48, R52, R53, R77, R94, R95</td>
<td>RES 10K OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic ERJ-2GEJ103X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>22</td>
<td>22</td>
<td>R23, R26, R27, R37, R40, R44, R45, R49, R51, R54, R55, R75, R84, R98, R99, R100, R102, R105, R106, R109, R110, R113</td>
<td>RES 0.0 OHM 1/10W 0402 SMD</td>
<td>Panasonic ERJ-2GE0R00X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>2</td>
<td>2</td>
<td>R35, R117</td>
<td>RES 100K OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic ERJ-2GEJ104X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>3</td>
<td>3</td>
<td>R43, R101, R107</td>
<td>RES 1.0K OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic ERJ-2GEJ102X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>1</td>
<td>1</td>
<td>R50</td>
<td>RES 33K OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic ERJ-2GEJ333X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Quantity</td>
<td>ADS1292R</td>
<td>ADS1292</td>
<td>ADS1192</td>
<td>Ref Des</td>
<td>Description</td>
<td>MFG</td>
<td>Part Number</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
<td>-----------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>-------------</td>
<td>-----</td>
<td>-------------</td>
</tr>
<tr>
<td>54</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>R56</td>
<td>RES 130 OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GEJ131X</td>
</tr>
<tr>
<td>55</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>R57</td>
<td>RES 220 OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GEJ221X</td>
</tr>
<tr>
<td>56</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>R58</td>
<td>RES 47K OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GEJ473X</td>
</tr>
<tr>
<td>57</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>R59</td>
<td>RES 46.4K OHM 1/10W 1% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2RKF4642X</td>
</tr>
<tr>
<td>58</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>R61</td>
<td>RES 30.9K OHM 1/10W 1% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2RKF3092X</td>
</tr>
<tr>
<td>59</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>R62, R64, R66, R72</td>
<td>RES 10.0M OHM 1/16W 1%</td>
<td>Panasonic</td>
<td>CRCW040210M0F KED</td>
</tr>
<tr>
<td>60</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>R63, R71</td>
<td>RES 0.0 OHM 1/10W 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GE0R00X</td>
</tr>
<tr>
<td>61</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>R72</td>
<td>RES 51K OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GEJ131X</td>
</tr>
<tr>
<td>62</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>R69, R70</td>
<td>RES 40K OHM 0.15W 0.1% 0603</td>
<td>Vishay/Thin Film</td>
<td>PAT0603E002BST</td>
</tr>
<tr>
<td>63</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>R73, R85</td>
<td>RES 51K OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GEJ131X</td>
</tr>
<tr>
<td>64</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>R76, R115</td>
<td>RES 100 OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GEJ101X</td>
</tr>
<tr>
<td>65</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>R87</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>R104</td>
<td>RES 4.7K OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GEJ472X</td>
</tr>
<tr>
<td>67</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>R112</td>
<td>RES 10 OHM 1/10W 5% 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GEJ100X</td>
</tr>
<tr>
<td>68</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>R116, R118</td>
<td>RES 0.0 OHM 1/10W 0402 SMD</td>
<td>Panasonic</td>
<td>ERJ-2GE0R00X</td>
</tr>
<tr>
<td>69</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>SW1, SW4</td>
<td>SWITCH LT 6MM 160GF 5MM HEIGHT</td>
<td>Panasonic</td>
<td>EVQ-21505R</td>
</tr>
<tr>
<td>70</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>SW2, SW3</td>
<td>SWITCH TACT 2.36MM SILVR G-WING</td>
<td>C&amp;K Components</td>
<td>KT11P2SM34LFS</td>
</tr>
<tr>
<td>71</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>TP1-TP60</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U1</td>
<td>4-Channel ESD-Protection Array</td>
<td>Texas Instruments</td>
<td>TPD4E004DRYR</td>
</tr>
<tr>
<td>73</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>U2</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U3</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U4</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U5</td>
<td>2 channel Analog to Digital Converter (24 bit with resp)</td>
<td>Texas Instruments</td>
<td>ADS1292RIPBS</td>
</tr>
<tr>
<td>77</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>U6</td>
<td>2 channel Analog to Digital Converter (24 bit)</td>
<td>Texas Instruments</td>
<td>ADS1292IPBS</td>
</tr>
<tr>
<td>78</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U7</td>
<td>2 channel Analog to Digital Converter (16 bit)</td>
<td>Texas Instruments</td>
<td>ADS1192IPBS</td>
</tr>
<tr>
<td>79</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>U7</td>
<td>2 channel Analog to Digital Converter (16 bit)</td>
<td>Texas Instruments</td>
<td>ADS1192IPBS</td>
</tr>
<tr>
<td>80</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>U8</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>U9</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>U10</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U11</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U12</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U13</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>86</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>U14</td>
<td>2 channel Analog to Digital Converter (24 bit)</td>
<td>Texas Instruments</td>
<td>ADS1292RIPBS</td>
</tr>
<tr>
<td>87</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U15</td>
<td>8Gb NAND Flash</td>
<td>Micron</td>
<td>MT29F8G08ABABA WP-B</td>
</tr>
<tr>
<td>88</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>U16</td>
<td>3.3V Linear Regulator</td>
<td>Texas Instruments</td>
<td>TPS73033DBVR</td>
</tr>
<tr>
<td>89</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U17</td>
<td>Not Installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>U18</td>
<td>3.3V supervisors</td>
<td>Texas Instruments</td>
<td>TPS3825-33DBVT</td>
</tr>
<tr>
<td>Item</td>
<td>Description</td>
<td>MFG</td>
<td>Part Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>----------------------</td>
<td>------</td>
<td>-------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>Connector on battery</td>
<td>Molex</td>
<td>22012021</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>Connector on battery</td>
<td>Molex</td>
<td>8030303</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>Battery</td>
<td>Power Stream</td>
<td>GM065080</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>94</td>
<td>Battery Cable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>Battery Cable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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
Battery

Power Module

USB

BT Module

To PC

Application

Power

Data

1. ADS1292R - 24 bit 2 Ch
   -- 1 Ch ECG
   -- 1 Ch Respiration

2. ADS1292 - 24 bit 2 Ch
   -- 2 Ch ECG

3. ADS1192 - 16 bit 2 Ch
   -- 2 Ch ECG

I2C

SPI

USB

UART

JTAG

GPIO

SPI

GPIO

Flash Memory

Micro SD

LEDs & Keys

Optional

Must have modules

To PC

Application

Power

Data

1. ADS1292R - 24 bit 2 Ch
   -- 1 Ch ECG
   -- 1 Ch Respiration

2. ADS1292 - 24 bit 2 Ch
   -- 2 Ch ECG

3. ADS1192 - 16 bit 2 Ch
   -- 2 Ch ECG

I2C

SPI

USB

UART

JTAG

GPIO

SPI

GPIO

Flash Memory

Micro SD

LEDs & Keys

Optional

Must have modules

To PC

Application

Power

Data

1. ADS1292R - 24 bit 2 Ch
   -- 1 Ch ECG
   -- 1 Ch Respiration

2. ADS1292 - 24 bit 2 Ch
   -- 2 Ch ECG

3. ADS1192 - 16 bit 2 Ch
   -- 2 Ch ECG

I2C

SPI

USB

UART

JTAG

GPIO

SPI

GPIO

Flash Memory

Micro SD

LEDs & Keys

Optional

Must have modules

To PC

Application

Power

Data

1. ADS1292R - 24 bit 2 Ch
   -- 1 Ch ECG
   -- 1 Ch Respiration

2. ADS1292 - 24 bit 2 Ch
   -- 2 Ch ECG

3. ADS1192 - 16 bit 2 Ch
   -- 2 Ch ECG

I2C

SPI

USB

UART

JTAG

GPIO

SPI

GPIO

Flash Memory

Micro SD

LEDs & Keys

Optional

Must have modules

To PC

Application

Power

Data

1. ADS1292R - 24 bit 2 Ch
   -- 1 Ch ECG
   -- 1 Ch Respiration

2. ADS1292 - 24 bit 2 Ch
   -- 2 Ch ECG

3. ADS1192 - 16 bit 2 Ch
   -- 2 Ch ECG

I2C

SPI

USB

UART

JTAG

GPIO

SPI

GPIO

Flash Memory

Micro SD

LEDs & Keys

Optional

Must have modules

To PC

Application

Power

Data

1. ADS1292R - 24 bit 2 Ch
   -- 1 Ch ECG
   -- 1 Ch Respiration

2. ADS1292 - 24 bit 2 Ch
   -- 2 Ch ECG

3. ADS1192 - 16 bit 2 Ch
   -- 2 Ch ECG

I2C

SPI

USB

UART

JTAG

GPIO

SPI

GPIO

Flash Memory

Micro SD

LEDs & Keys

Optional

Must have modules

To PC

Application

Power

Data

1. ADS1292R - 24 bit 2 Ch
   -- 1 Ch ECG
   -- 1 Ch Respiration

2. ADS1292 - 24 bit 2 Ch
   -- 2 Ch ECG

3. ADS1192 - 16 bit 2 Ch
   -- 2 Ch ECG

I2C

SPI

USB

UART

JTAG

GPIO

SPI

GPIO

Flash Memory

Micro SD

LEDs & Keys

Optional

Must have modules

To PC

Application

Power

Data

1. ADS1292R - 24 bit 2 Ch
   -- 1 Ch ECG
   -- 1 Ch Respiration

2. ADS1292 - 24 bit 2 Ch
   -- 2 Ch ECG
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

Place the decoupling capacitors close to power pins in layout
Bluetooth Module

Description

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAN_TX</td>
<td>PAN_TX</td>
</tr>
<tr>
<td>PAN_RX</td>
<td>PAN_RX</td>
</tr>
<tr>
<td>PAN_RTS</td>
<td>PAN_RTS</td>
</tr>
<tr>
<td>PAN_RTX</td>
<td>PAN_RTX</td>
</tr>
</tbody>
</table>

**Bluetooth Module Details:**

- PAN TX
- PAN RX
- PAN RTS
- PAN RTX

**Bluetooth Module Functions:**

- BT_TX
- BT_RX
- BT_RTS
- BT_RTX

**Pinout Information:**

- PAN_TX
- PAN_RX
- PAN_RTS
- PAN_RTX

**Bluetooth Modes:**

- BT_TX
- BT_RX
- BT_RTS
- BT_RTX

**Bluetooth Module Tables:**

<table>
<thead>
<tr>
<th>PIN</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PAN_TX</td>
</tr>
<tr>
<td>2</td>
<td>PAN_RX</td>
</tr>
<tr>
<td>3</td>
<td>PAN_RTS</td>
</tr>
<tr>
<td>4</td>
<td>PAN_RTX</td>
</tr>
</tbody>
</table>

**Bluetooth Module Notes:**

- PAN TX
- PAN RX
- PAN RTS
- PAN RTX

**Bluetooth Module Markers:**

- PAN TX
- PAN RX
- PAN RTS
- PAN RTX

**Bluetooth Module Diagrams:**

- Bluetooth Module Diagram 1
- Bluetooth Module Diagram 2
- Bluetooth Module Diagram 3
- Bluetooth Module Diagram 4

**Bluetooth Module Specifications:**

- Bluetooth Module Specifications 1
- Bluetooth Module Specifications 2
- Bluetooth Module Specifications 3
- Bluetooth Module Specifications 4
Evaluation Board/Kit Important Notice

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation board/kit is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

Should this evaluation board/kit not meet the specifications indicated in the User’s Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user’s responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

TI currently deals with a variety of customers for products, and therefore our arrangement with the user is not exclusive. TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.

Please read the User’s Guide and, specifically, the Warnings and Restrictions notice in the User’s Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI’s environmental and/or safety programs, please contact the TI application engineer or visit www.ti.com/esh.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used.

FCC Warning

This evaluation board/kit is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end-product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment in other environments may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

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
Copyright © 2011, Texas Instruments Incorporated
EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods.

Should this evaluation board/kit not meet the specifications indicated in the User’s Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User’s Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI’s environmental and/or safety programs, please visit www.ti.com/esh or contact TI.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used. TI currently deals with a variety of customers for products, and therefore our arrangement with the user is not exclusive. TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.

REGULATORY COMPLIANCE INFORMATION

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.

For EVMs not subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: 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】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

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

【ご使用にあたっての注】

本開発キットは技術基準適合証明を受けておりません。

本製品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「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

http://www.tij.co.jp
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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2012, 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 which meet ISO/TS16949 requirements, mainly for automotive use. Components which have not been so designated are neither designed nor intended for automotive use; and TI will not be responsible for any failure of such components to meet such requirements.

### Products

<table>
<thead>
<tr>
<th>Audio</th>
<th>Amplifiers</th>
<th>Data Converters</th>
<th>DLP® Products</th>
<th>DSP</th>
<th>Clocks and Timers</th>
<th>Interface</th>
<th>Logic</th>
<th>Power Mgmt</th>
<th>Microcontrollers</th>
<th>RFID</th>
</tr>
</thead>
</table>

### Applications

<table>
<thead>
<tr>
<th>Automotive and Transportation</th>
<th>Communications and Telecom</th>
<th>Computers and Peripherals</th>
<th>Consumer Electronics</th>
<th>Energy and Lighting</th>
<th>Industrial</th>
<th>Medical</th>
<th>Security</th>
<th>Space, Avionics and Defense</th>
<th>Video and Imaging</th>
</tr>
</thead>
</table>

---

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2012, Texas Instruments Incorporated
Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

Texas Instruments:
ADS1292ECG-FE