



# Activity Monitor

## Design Reference Manual

### Devices Supported:

**MCF51MM256**

**MC34673**

**MC13202**

**MMA7660**

Document Number: DRM125

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# Chapter 1 Introduction

## 1.1 Purpose

The intent of this document is to specify the features of the Activity Monitor reference design. This fitness and health device is meant to monitor user's activity using different acquisition modules. Some necessary background information about activity monitoring will also be provided. The System Analysis, Software Model, Firmware, Schematics, and Bill of Materials details are described in this Activity Monitor Reference Manual.

## 1.2 Reference documents

The documents listed below should be referenced for more information regarding this reference design or the products featured within:

- MCF51MM256RM - Microcontroller Reference Manual in [www.freescale.com](http://www.freescale.com)
- MCF51MM256 - Microcontroller Data Sheet in [www.freescale.com](http://www.freescale.com)
- MC13202 - 2.4Ghz RF transceiver for ZigBee® applications Data Sheet in [www.freescale.com](http://www.freescale.com)
- MMA7660 - Three Axis Low-g Digital Output Accelerometer Data Sheet in [www.freescale.com](http://www.freescale.com)
- MC34673 - Li-Ion or Li-Polymer Battery Charger Data Sheet in [www.freescale.com](http://www.freescale.com)

## 1.3 Overview

An activity monitor is a small device that records information about user's physical activity patterns. The device should normally run continuously for long periods of time. Activity monitors can frequently interpret and summarize the recorded data. This instrument is a noninvasive acquisition system and the basic module that it must include is a pedometer, which measures vertical acceleration to count steps and accumulate total time spent at certain activity intensity. When positioned correctly, this device could record each step and can also measure common activities like going up and down the stairs, bending to tie your shoes, etc. They are normally worn on the user's hips or on the wrist.



**Figure 1-1. Pedometer**

Besides including a pedometer module an activity monitor can integrate several functionalities. This will help going further on with the body measurements, making the results even more accurate. This is the case of Freescale's Activity Monitor reference design, which besides the pedometer features a Heart-Rate detection module that helps monitoring physical activity intensity. Depending on which target zone a person's pulse rate is the intensity level of the physical activity can be calculated. An example of the different fitness zones is shown on the chart below.

<b>HEART RATE ZONES</b>					
<b>AGE</b>	<b>RECOVERY 50-60%</b>	<b>FAT BURN 60-70%</b>	<b>AEROBIC 70-80%</b>	<b>ANAEROBIC 80-90%</b>	<b>ATHLETE 90-100%</b>
<b>20-23</b>	100-120	120-140	140-160	160-180	180-200
<b>24-27</b>	98-118	118-138	138-157	157-177	177-196
<b>28-31</b>	96-116	116-135	135-154	154-173	173-192
<b>32-35</b>	94-113	113-132	132-151	151-170	170-188
<b>36-39</b>	92-111	111-129	129-148	148-166	166-184
<b>40-43</b>	90-108	108-126	126-144	144-162	162-180
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<b>52-55</b>	84-101	101-118	118-135	135-152	152-168

**Figure 1-2. Heart Rate Zones chart**

As normally expected, age is a key factor while measuring physical activity, and not only age but the user's height, weight, and gender are also very important elements when trying to be accurate. So, it is very convenient to include a personal data acquisition system in the activity monitors. This way all of the user's biometrics are variables incorporated in the physical activity algorithms. As an example, the *Journal of Sports Sciences* provided the following calorie expenditure formulas for each gender:

**Men:**

$$\text{Calories Burned} = [(\text{Age} \times 0.2017) - (\text{Weight} \times 0.09036) + (\text{Heart Rate} \times 0.6309) - 55.0969] \times \text{Time}/4.184$$

**Women:**

$$\text{Calories Burned} = [(\text{Age} \times 0.074) - (\text{Weight} \times 0.05741) + (\text{Heart Rate} \times 0.4472) - 20.4022] \times \text{Time}/4.184$$

All of these information collected help people get a real measurement of their physical activity. Whether they want to get fitter or even if they want to see improvement in their preferred sport the more you can know about your body, the better.

## Chapter 2 Activity Monitor Board (Key Features)

The Activity Monitor board is a highly integrated design compounded by several modules which include a TFT display, touch sensing interface, accelerometer, and USB connectivity, among other characteristics. [Figure 2-1](#) below shows a high-level block diagram of the system. The major features of the Activity Monitor include:

- Freescale's MCF51MM256 Flexis™ 32-bit ColdFire® V1 Microcontroller
- Freescale's MMA7660 Three-axis Low-g Digital Output Accelerometer
- Freescale's MC13202 2.4 GHz Low Power Transceiver for ZigBee® Applications
- Freescale's MC34673 Li-Ion or Li-Polymer Battery Charger (Through USB)
- Fingertip acquired Heart Rate detection module
- USB Connectivity (Freescale's CMX USB Stack)
- Touch Sensing Interface (Freescale's Xtrinsic Touch Sensing Software)
- 1.8" TFT Display - 128 x 160 pixels
- Micro SD card slot
- Magnetic Buzzer



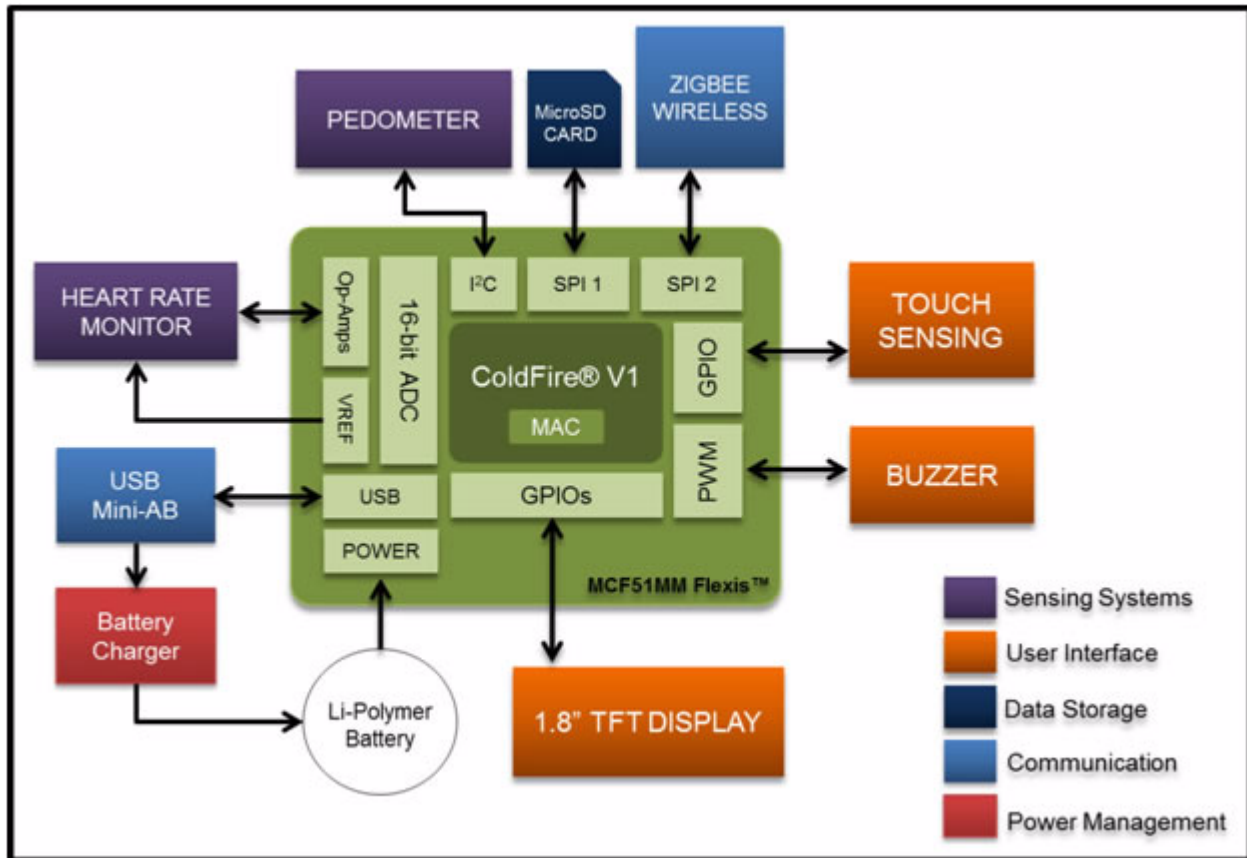


Figure 2-1. Activity Monitor block diagram

## 2.1 MCF51MM256 overview

The MCF51MM256 provides ultra–low-power operation, USB connectivity, graphic display support, and unparalleled measurement accuracy, all in a single 32-bit microcontroller, allowing device designers to create more fully featured products at a lower cost.

The MCF51MM256 is ideal for medical applications or any other application requiring a significant amount of precision analog such as instrumentation and industrial control.

The MCF51MM256 is part of the Freescale Flexis™ microcontroller series. The following is a summary of features of the MCF51MM256:

- Up to 50.33 MHz ColdFire V1 core speed and 25 MHz bus speed
- 256K flash
- 32K SRAM
- Two ultra–low-power stop modes
- Time of the Day (TOD)
- Two flexible operational amplifiers (OPAMP)
- Two trans-impedance amplifiers (TRIAMP)
- Multipurpose clock generator (MCG)

- Dual-role Full-speed USB On-The-Go (OTG) Controller and transceiver
- Two serial communications interfaces (SCI)
- Two serial peripheral interfaces (SPI)
- Analog comparators
- 16-bit Analog-to-digital converter (ADC)
- 12-bit Digital-to-Analog converter (DAC)
- Mini-Flex Bus
- Analog comparator with selectable interrupt (PRACMP)
- I2C interface
- Programmable delay block (PDB)
- Carrier modulation timer (CMT)
- Two timer modules (TPM)
- Voltage Reference Output (VREFO)
- Up to 68 GPIOs and 16 Rapid GPIOs

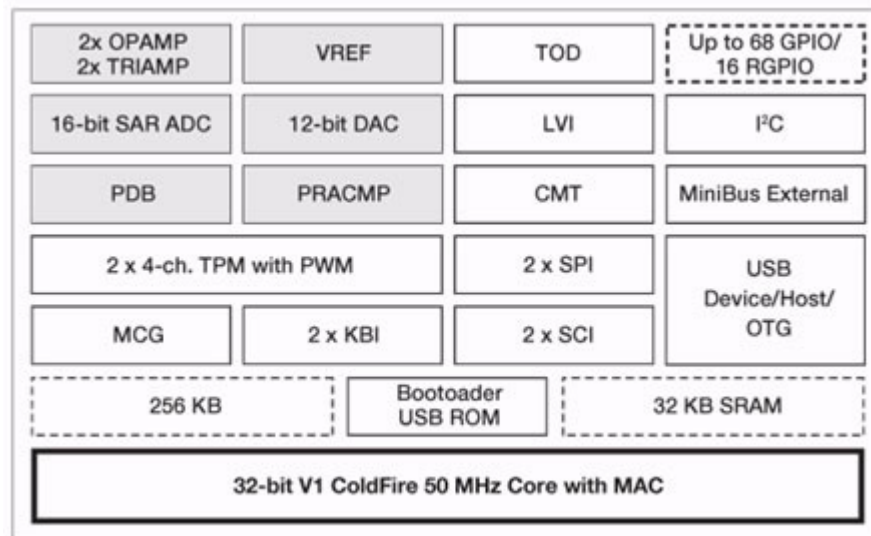


Figure 2-2. MCF51MM block diagram

## 2.2 MMA7760 overview

The MMA7660FC is a  $\pm 1.5$  g 3-Axis Accelerometer with Digital Output (I2C). It is a very low-power, low-profile capacitive MEMS sensor featuring a low pass filter, compensation for 0 g offset and gain errors, and conversion to 6-bit digital values at a user's configurable samples per second. The device can be used for sensor data changes, product orientation, and gesture detection through an interrupt pin (INT). The device is housed in a small 3mm x 3mm x 0.9mm DFN package.

**Features:**

- Digital Output (I2C)
- Low-Power Current Consumption:
  - Off Mode: 0.4  $\mu$ A,
  - Standby Mode: 2  $\mu$ A,
  - Active Mode: 47  $\mu$ A at 1 ODR
- Configurable Samples per Second from 1 to 120 samples a second
- Low Voltage Operation:
  - Analog Voltage: 2.4 – 3.6 V
  - Digital Voltage: 1.71 – 3.6 V
- Auto-Wake/Sleep Feature for Low Power Consumption
- Tilt Orientation Detection for Portrait/Landscape Capability
- Gesture Detection Including Shake Detection and Tap Detection
- Robust Design, High Shocks Survivability (10,000 g)
- Low Cost



## 2.3 MC13202 overview

The MC13202 is a short-range, low-power, 2.4 GHz Industrial, Scientific, and Medical (ISM) band transceivers. The MC13202 contains a complete 802.15.4 physical layer (PHY) modem designed for the IEEE<sup>®</sup> 802.15.4 Standard which supports peer-to-peer, star, and mesh networking.

The MC13202 includes the 802.15.4 PHY/MAC for use with the HCS08 Family of MCUs. The MC13202 can be used with Freescale's IEEE 802.15.4 MAC and BeeStack, which is Freescale's ZigBee<sup>®</sup> compliant protocol stack.

**Features:**

- Recommended power supply range: 2.0 – 3.4 V.
- Fully compliant 802.15.4 Standard transceiver.
- Supports 250 KB/s O-QPSK data in 5.0 MHz channels and full spread-spectrum encode.
- Operates on one of 16 selectable channels in the 2.4 GHz band.
- -1 to 0 dBm nominal output power, programmable from -27 dBm to +3 dBm typical.
- Receive sensitivity of <-92 dBm (typical) at 1% PER, 20-byte packet, much better than the 802.15.4 Standard of -85 dBm.
- Integrated transmit/receive switch.

- Dual PA output pairs which can be programmed for full differential single port or dual port operation that supports an external LNA and/or PA.
- Three power down modes for increased battery life
  - $< 1 \mu\text{A}$  Off current
  - $1.0 \mu\text{A}$  Typical Hibernate current
  - $35 \mu\text{A}$  Typical Doze current (no CLKO)
- Programmable frequency clock output (CLKO) for use by MCU.
- Onboard trim capability for 16 MHz crystal reference oscillator eliminates need for external variable capacitors and allows for automated production frequency calibration.
- Four internal timer comparators available to supplement MCU timer resources.
- Supports both Packet Mode and Streaming Mode data transfer.
- Buffered transmit and receive data packets for simplified use with low cost MCUs.
- Seven GPIO to supplement MCU GPIO.



## 2.4 MC34673 overview

The MC34673 is a cost-effective fully-integrated battery charger for Li-Ion or Li-Polymer batteries. The high input voltage, up to 28 V, eliminates the input over-voltage protection circuit required in handheld devices such as PDAs, cell phones, portable video game players, and digital still cameras.

### Features

- No external MOSFET, reverse-blocking diode, or current-sense resistor are required
- Guaranteed maximum 1.2 A programmable CC-mode current
- $\pm 0.7\%$  voltage accuracy over  $-20\text{ }^{\circ}\text{C}$  to  $70\text{ }^{\circ}\text{C}$
- $\pm 6\%$  current accuracy over  $-40\text{ }^{\circ}\text{C}$  to  $85\text{ }^{\circ}\text{C}$
- 28 V maximum voltage for the power input with 6.8 V over-voltage protection threshold
- 2.6 V minimum input operating voltage
- Trickle charge for fully discharged batteries
- Charge current monitor
- Charge current thermal foldback
- Pb-free packaging designated by suffix code EP



## Chapter 3 Setup Guide

The following steps provide a basic procedure to run the Activity Monitor properly. The first section explains the MCU's programming process and the next section describes the required steps for the Micro SD card to work correctly.

### 3.1 Loading Activity Monitor's software to MCU

The following procedure shows how to load the Activity Monitor's program into the MCU using the board's BDM module.

1. Make sure you have downloaded the latest revision of the "CW\_ActivityMonitor\_REV X.zip" file to your PC.
2. Open the "CW\_ActivityMonitor\_REV X.zip" file, and extract the files into a working folder on your desktop.
3. Prepare the board by plugging in a USB cable (Type A - mini B) from any USB port of your PC, to the Activity Monitor's USB socket.
4. Also connect the P&E Multilink to the J12 connector as shown in the [Figure 3-1](#). Then plug in the P&E Multilink programmer to your PC (if asked for the installation driver, set the next path: "...Program Files/Freescale/ CodeWarrior for Microcontrollers V6.3/Drivers").



**Figure 3-1. Board prepared for programming**

5. Now you are ready to open a CodeWarrior project "ActivityMonitor\_REV X.mcp". Make sure the debug mode is set to "P&E Multilink/Cyclon Pro" and that you have the same values for the options as shown in [Figure 3-2](#). Click on "Debug" under Project in the menu bar, or hit F5. The "P&E MCF51MMxx Connection Manager" window should appear.

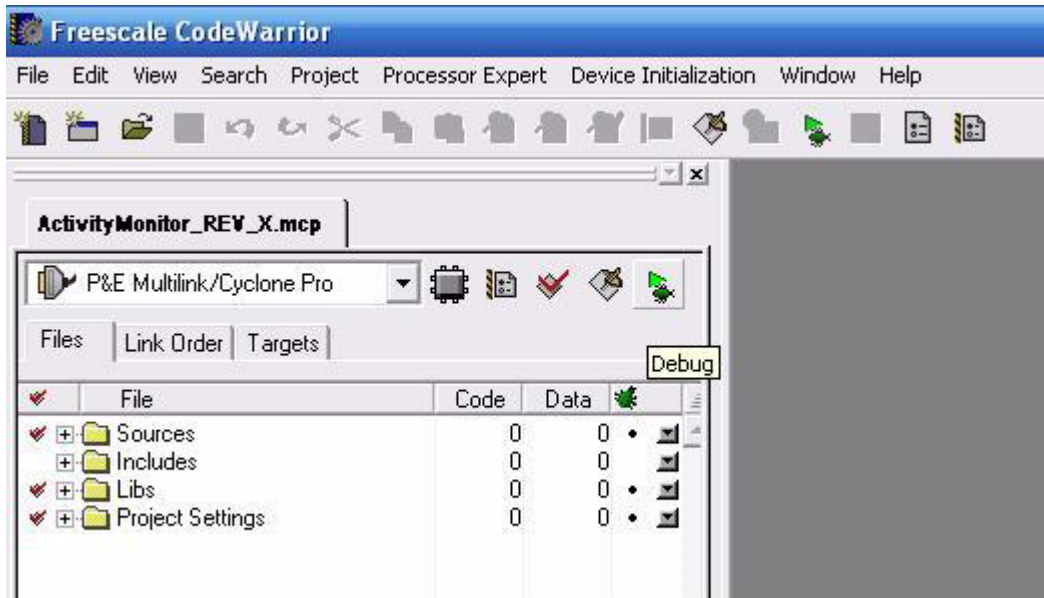


Figure 3-2. IDE configuration

- Finally click the "Connect (Reset)" button and if you are asked to "Erase and program flash" click "Yes". After that the MCU Flash will be programmed.

## 3.2 Preparing the MicroSD card

In order for the Micro SD card to work correctly, it must have all of the files required from the Activity Monitor. They should all be located on the Micro SD card root directory, if not please copy them from the "Micro SD Files" folder under the project files. The package should contain the following 23 items:

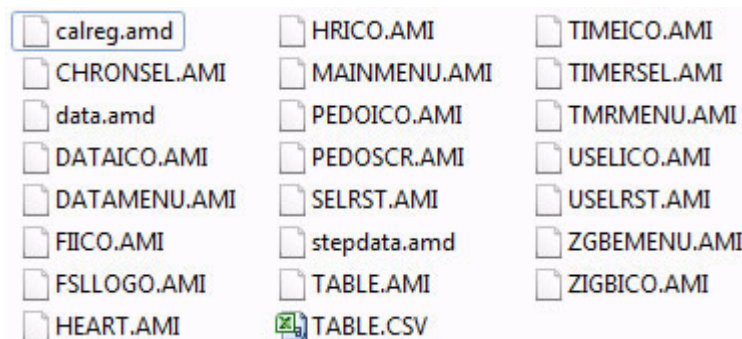


Figure 3-3. Files of the Micro SD card

Here is an explanation of each file extension of [Figure 3-3](#):

- \*.AMI – Activity Monitor Image
- \*.amd – Activity Monitor Data
- \*.CSV – Comma Separated Values

If you don't have all the files, please copy all of them from the "Micro SD Files" folder located in the Activity Monitor file package, to the Micro SD card root directory you are using.

**NOTE:** Besides having all the correct files on the Micro SD, it should be using FAT (FAT16) as the file system format. If you are not sure which format your card is using, insert the Micro SD card using a Micro SD to USB adapter, scroll over to "properties" and have a look where it says "Card format".

To format your Micro SD card using FAT16 file system follow the steps:

1. Insert the Micro SD card into your computer using any adapter required.
2. Open "My Computer" menu and right-click on the drive your card is inserted into.
3. Choose the "Format" option.
4. After the format menu appears, select FAT from the file system dropdown menu. See [Figure 3-4](#).
5. Click the "Start" button.

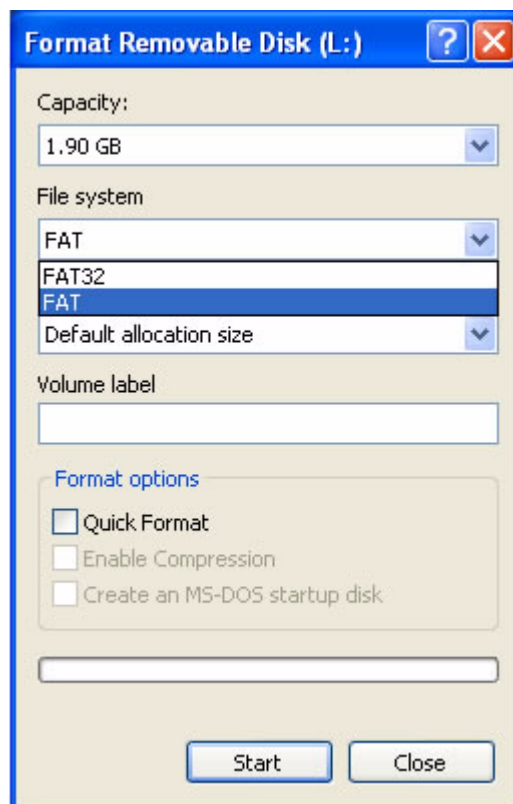


Figure 3-4. Format program



## Chapter 4 Application Overview

The activity monitor is meant to improve health performance, so users can have a better management of their fitness and health activities. It is meant to promote the use of low-power medical applications or any other application requiring precision analog instrumentation to develop highly-integrated portable devices that can assist users in taking care of their health.

The device measures user's burned calories in their daily activity, keeps record of the food and calories ingested during the day, and can monitor their heart rate which is a very useful tool while exercising. This device exhibits the features and potential of Freescale's MCF51MM Flexis™ 32-bit ColdFire® V1 Microcontroller.

### Heart Rate Monitor:

Watch your real time ECG and hearth rate by placing your fingertips on the sensors.

### Food Intake:

The user will select the amount of calories eaten from a common food data base.

### Power Supply:

A rechargeable battery module is included with the device providing portability for several hours.

### Data Storage:

A Micro SD Card Reader was integrated to save data and store user biometrics.



### Pedometer:

This application counts user's steps and calculates the burned calories during the day.

### Communication:

The device features a ZigBee® wireless interface and also USB communication.

### Full Color Display

The device has a TFT LCD (commonly used in mobile phones)

### Touch Sensing Interface

The user will have control of the device through a capacitive touch sensing film.

## 4.1 Device layout

Freescale's Activity Monitor is designed to look and feel like standard cellphones. [Figure 4-1](#) illustrates the appearance of an Activity Monitor and the location of its key buttons.

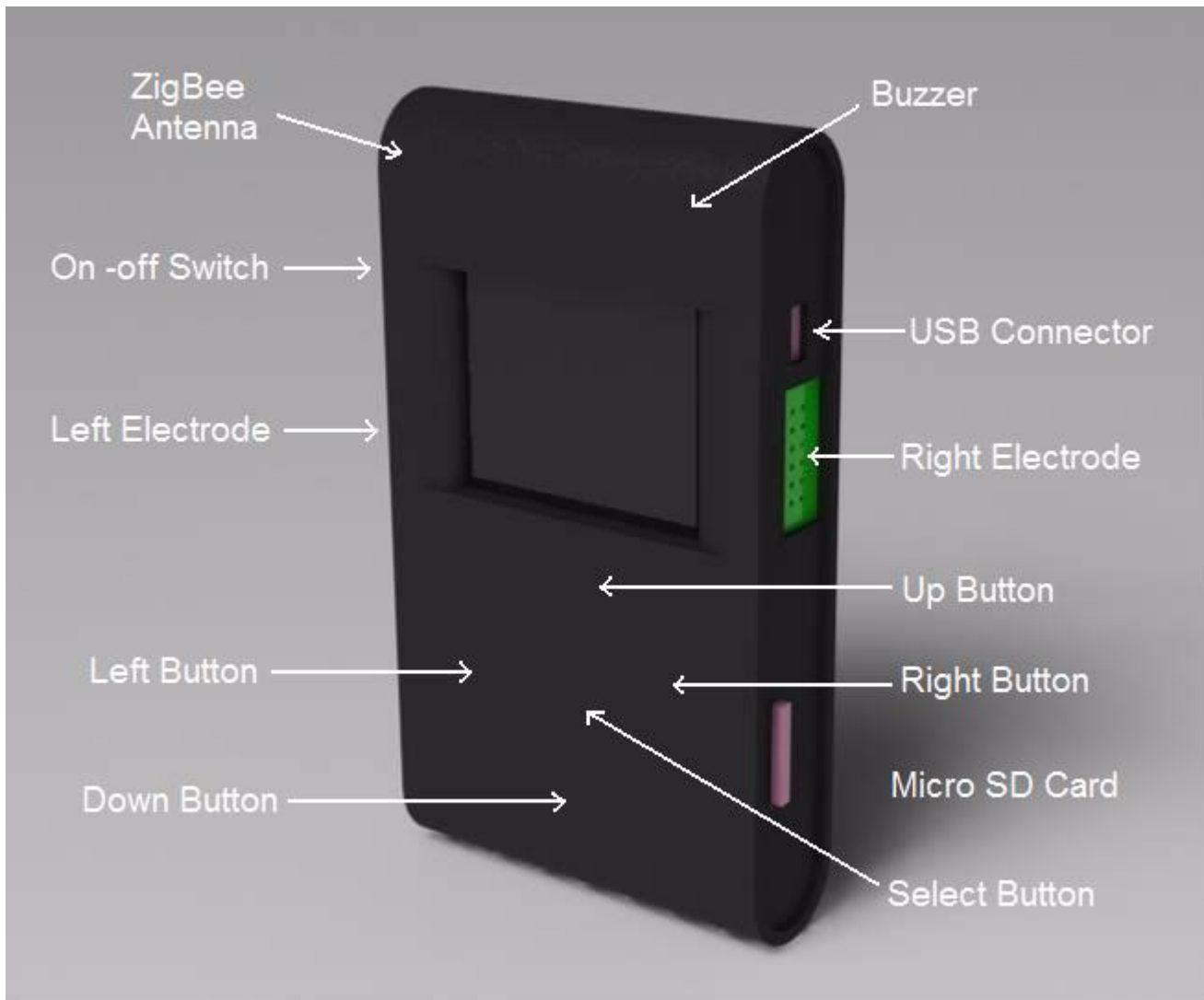


Figure 4-1. Activity Monitor's key buttons

### 4.1.1 Before using the Activity Monitor

The first thing user has to do is check if the Micro SD card with required files is within the Activity Monitor. If not, the device will not function properly and will ask for a restart. The Activity Monitor will automatically search for the user data in the SD Card. If there is no current data, the Personal Data application will start and the user will be able to plug in his or her personal data.

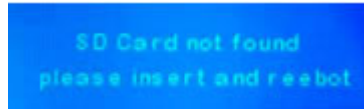


Figure 4-2. Micro SD card error message

## 4.2 Selecting the desired application

To enter any of the Activity Monitor applications such as: ECG Monitor, Food Intake, Pedometer, Time Tracker, Personal Data, or ZigBee®, please follow the correct steps:

1. Turn the Activity Monitor on by shifting the On-Off switch (Freescale's Logo will appear while the program is loading and shortly afterwards the Main Menu will be displayed).



Figure 4-3. Main menu

2. To toggle between the different options the user can use the left and right buttons. While shifting between different applications the selected icon will be highlighted. To enter the preferred application, use the select button. The applications at the Main Menu bar are the following:



Figure 4-4. Application icons

3. In order to exit any application the user must hold the Up button for two seconds. The application will exit and return to the Main Menu. To turn the Activity Monitor off the user can turn the On-Off switch from on to off.

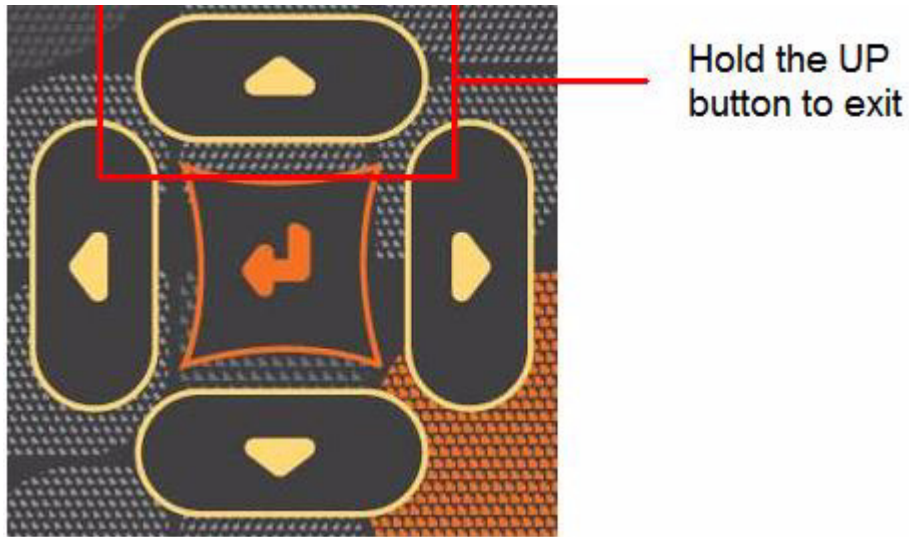

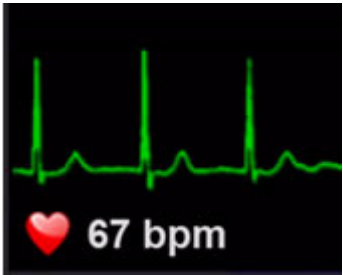


Figure 4-5. Exit button location



## 4.2.1 Applications description

The following is a description of how each of the applications works and to correctly interact with them. There are six different applications, you can choose from ECG, Food Intake, Pedometer, Time Tracker, Personal Data, and ZigBee®.



### 4.2.1.1 ECG and Heart Rate monitor

 <p><b>ECG</b></p> <p>The user will be able to use the ECG by placing his/her fingers on the electrodes. Soon, the device will show the user's real-time heart rate. The application also could display the user's Heart Rate Zone (Recovery, Fat Burning, Above).</p>	
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### 4.2.1.2 Pedometer

 <b>PEDOMETER</b> <p>The user will be able to use the pedometer right after selecting the application. While running the application, the device will count user's steps. Then the application calculates total calories burned. Beside this, some activities could be added to this total (e.g. Swimming for 30 min).</p>	
---	--



### 4.2.1.3 Food intake

 <b>FOOD INTAKE</b> <p>To keep track of total calories consumed every day, the user can select any food from the database. The application will add up the calories. The user is able to edit data and also add new elements in the database with a PC.</p>	 <table border="1"> <thead> <tr> <th>FOOD TYPE</th> <th>CAL</th> </tr> </thead> <tbody> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> </tbody> </table> <p>Calories: <span style="float: right;">x 100g</span></p>	FOOD TYPE	CAL																				
FOOD TYPE	CAL																						



### 4.2.1.4 Time tracker

 <b>TIME TRACKER</b> <p>Tracking time is a very helpful tool while exercising. The user can use a chronometer or a timer. Select the option you want to enter. Then use the touch buttons to configure the desired time of the application.</p>	
--	--

### 4.2.1.5 Personal data

 <p><b>PERSONAL DATA</b></p> <p>The data acquisition screen allows the user to enter the following parameters: name, age, gender, weight, and height. This allows the Activity Monitor to acquire the personal biometrics for correct calculations. All the parameters can be updated and the results will be recalculated.</p>	
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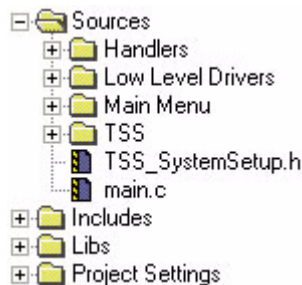
### 4.2.1.6 ZigBee®

 <p><b>ZIGBEE</b></p> <p>This connectivity module will allow users to connect with other devices by selecting any of the applications in the menu. The user will select the desired module and the device will find and connect with other Activity Monitors.</p>	
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## Chapter 5 Software Design

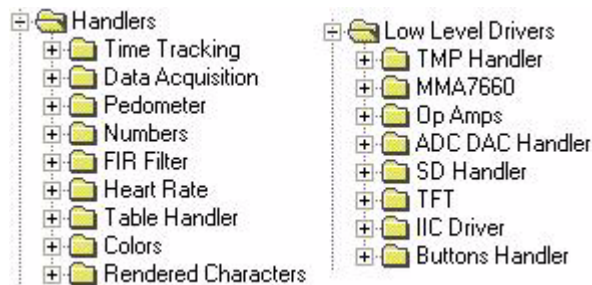
In this section, the main software functionalities and program flow will be explained.

The Project files were arranged in the next folder sequence for better understanding:



**Figure 5-1. Folder arrangement**

The folder "Handlers" contains all the configuration files for Activity Monitor's different applications. In this folder there are also routines of each task of these applications. Next is the "Low Level Drivers" folder that contains drivers or firmware that configures different MCU's modules to work properly as required by the project software. [Figure 5-2](#) shows the subfolders of each category.



**Figure 5-2. Subfolders**

- **TIME TRACKING:** Includes the routine and configuration parameters for the Time Tracking application.
- **DATA ACQUISITION:** Includes the routine and configuration parameters for the Personal data application.
- **PEDOMETER:** Includes the routine and configuration parameters for the Pedometer application.
- **NUMBERS:** Contains the data matrix to generate the numbers that are shown on the display.
- **FIR FILTER:** Includes the configuration parameters for the FIR filter used by the Heart Rate application.
- **HEART RATE:** Includes the routine and configuration parameters for the ECG application.

- TABLE HANDLER: Includes the routine and configuration parameters for the Food Intake application.
- COLORS: Defines data arrangements to generate colors used by the software.
- RENDERED CHARACTERS: Includes the algorithm to render or merge characters to the background.

Please refer to the CodeWarrior project "ActivityMonitor\_REV X.mcp" for further explanation.

## 5.1 Software flowcharts

Below are different flowcharts that explain Activity Monitor's step-by-step software process. The software runs a "Start-Up" sequence each time the device is turned on or rebooted. Once the main menu has appeared on screen a cycle for going in and out of any application is followed.

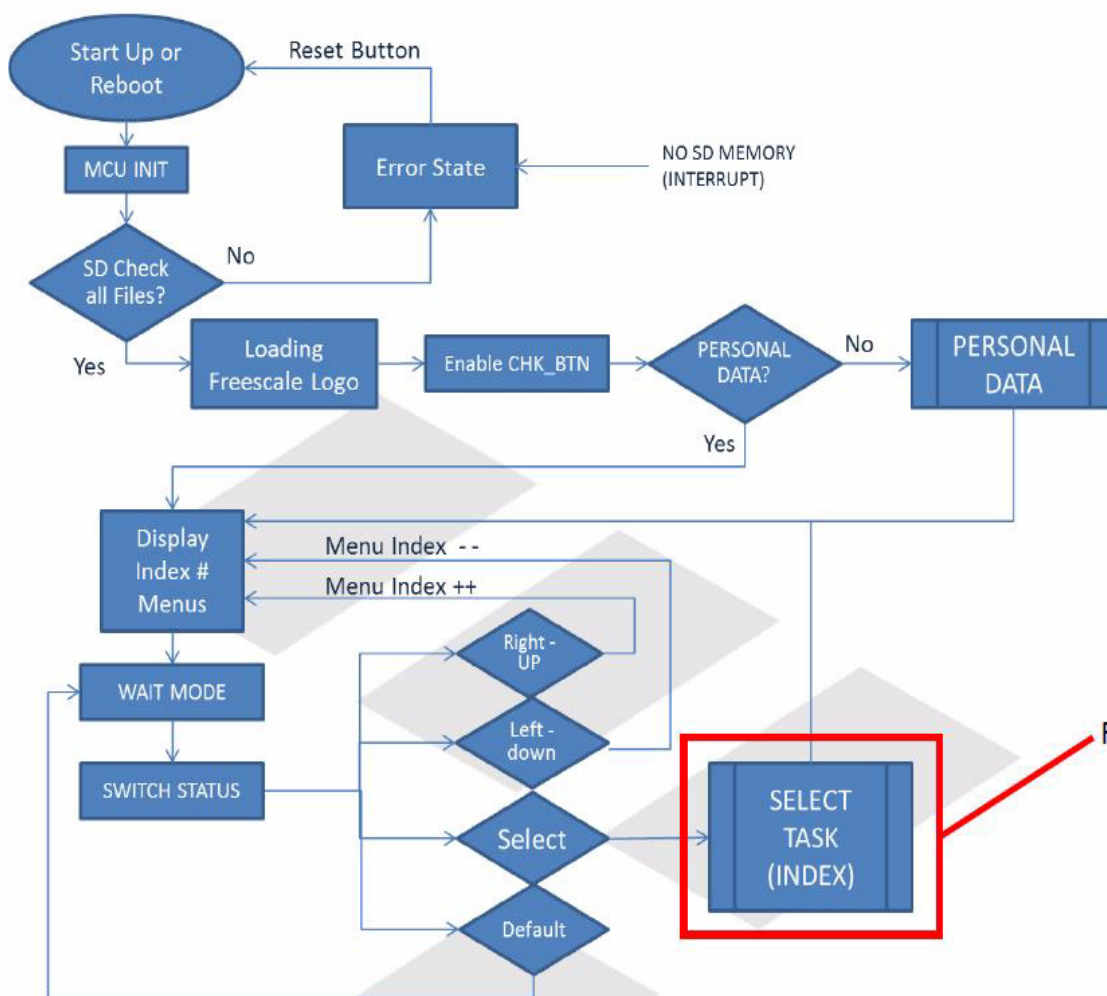
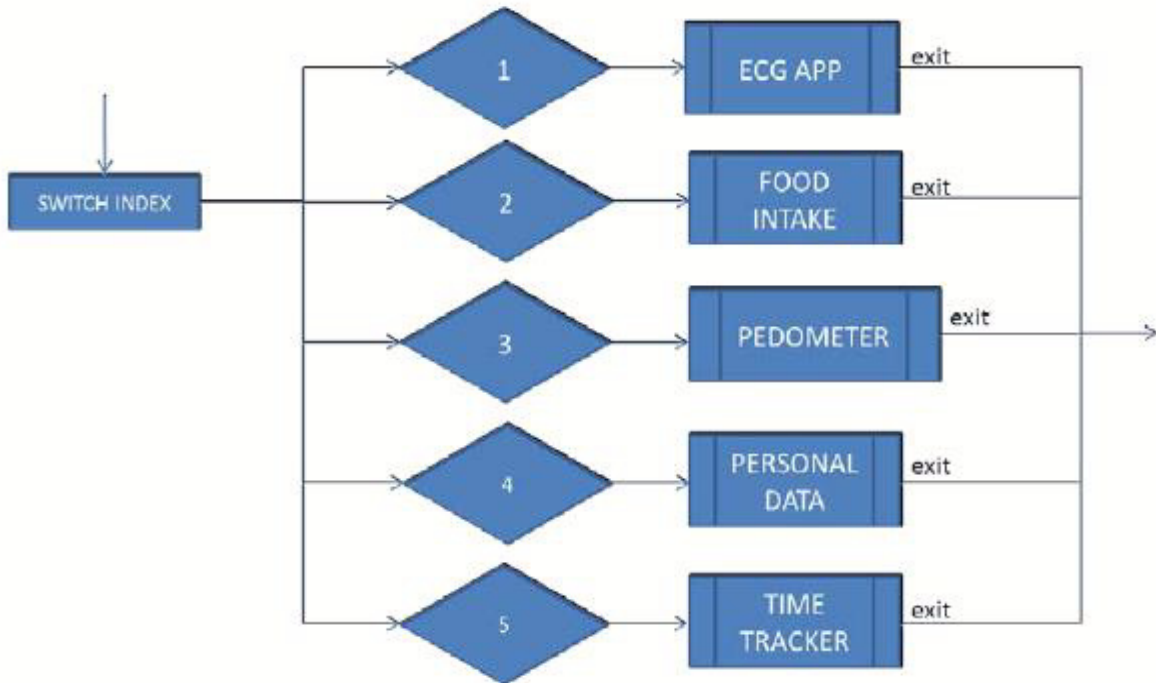


Figure 5-3. Initialization and main software flowchart

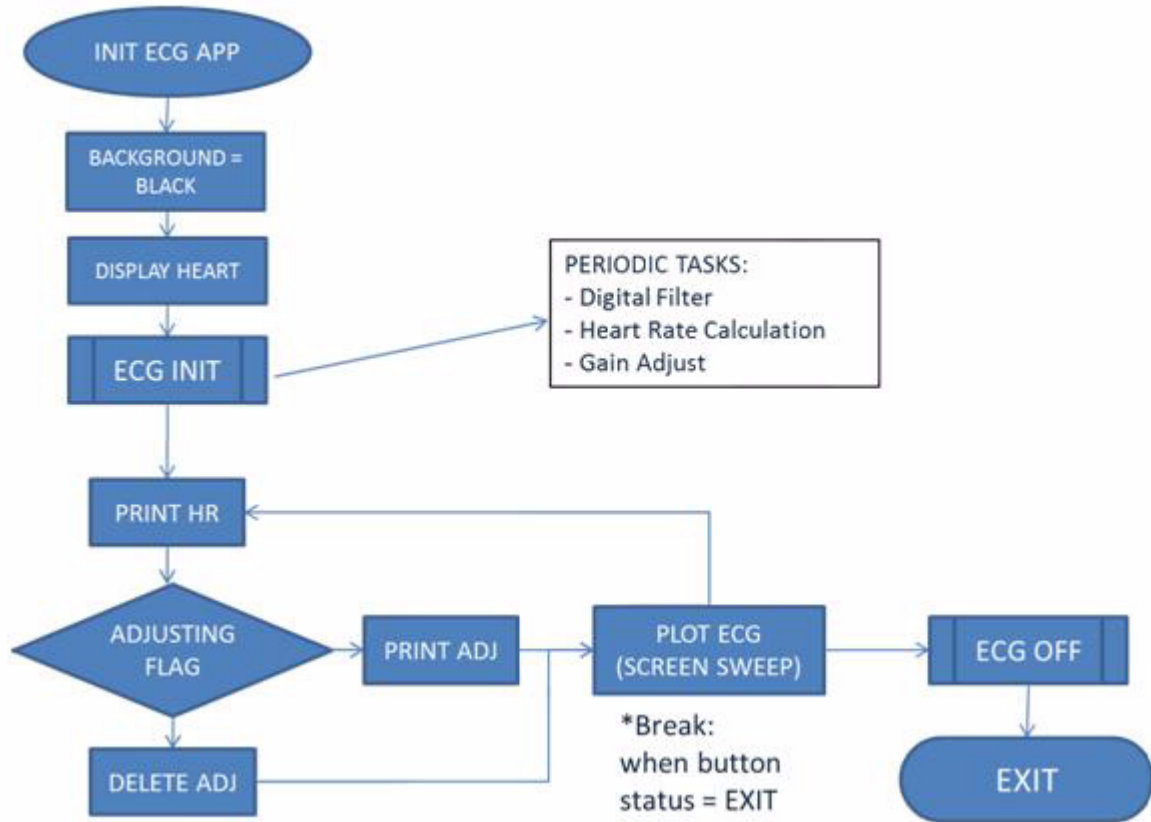


Figure 5-3 shows the booting sequence and cycling applications handler. When an application selection is detected on the main menu a small routine named SELECT TASK (INDEX) runs the correct application, as seen on Figure 5-4. Then each application unique routines are detailed on the next figures.



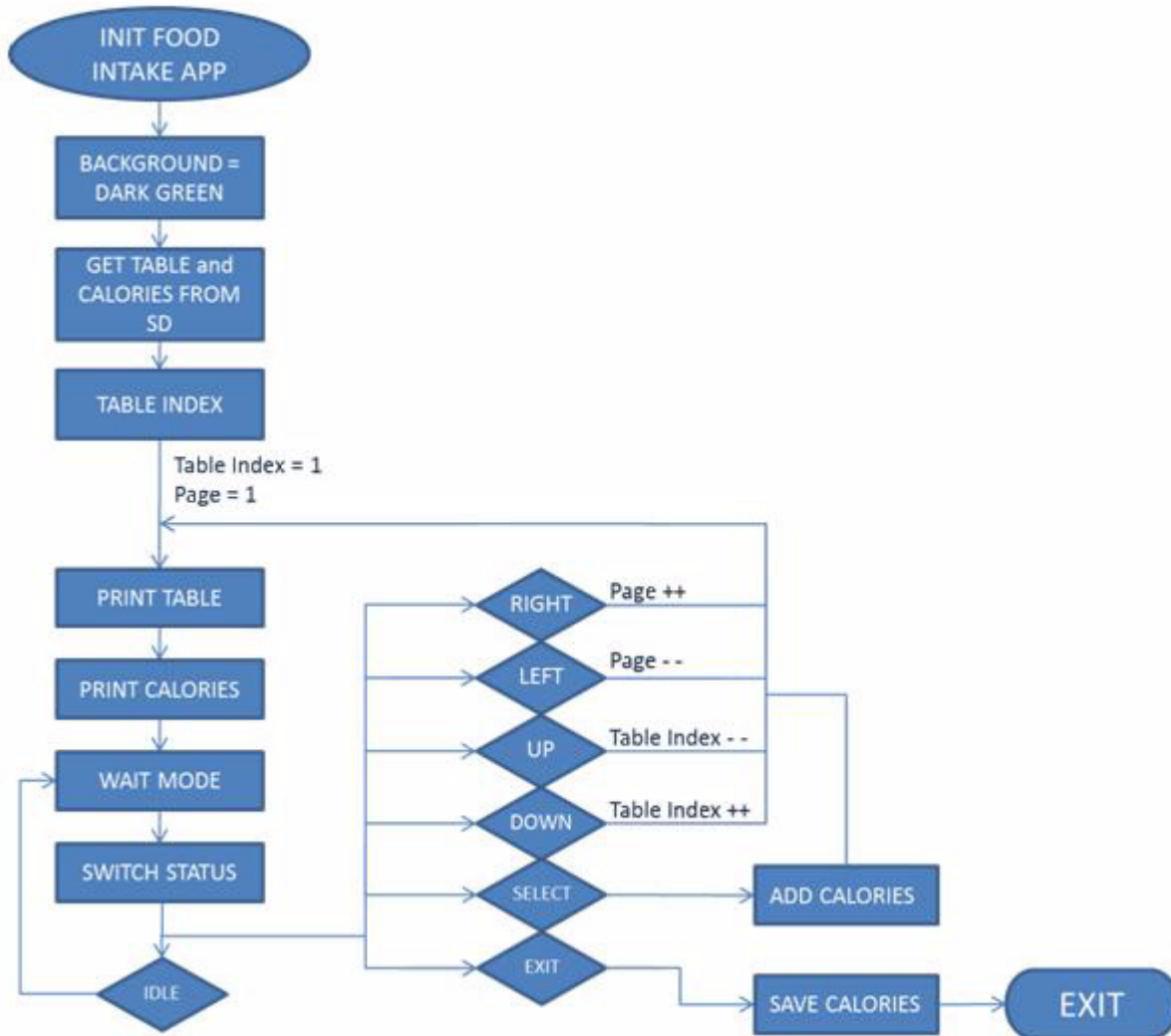
**Figure 5-4. Select-task (INDEX)**

Figure 5-4 shows the ECG application routine. ECG INIT flag is turned on indicating the ECG routine is running. The first task is the sampling and filtering the ECG analog signal, then is the Heart Beat detection with gain feedback, and finally the Heart Rate Calculation.



**Figure 5-5. ECG APP routine**

Figure 5-6 below illustrates the process followed by the Food Intake Application. The data is requested from the SD file, which can be modified anytime using a computer with Microsoft Excel. Once the first part of the list is printed, users can then go forward or backward and select any element of the foods displayed.



**Figure 5-6. FOOD INTAKE routine**

An important detail of these flowcharts is that it seems there is no touch-sensing routines for constantly monitoring the touch pad electrodes. This is because Freescale's Touch Sensing Software needs to be configured once at the beginning of the program and then it will run continuously using a MCU's designated timer. The command should look like this:

```

TSS_Config(); // Touch Sensing Configuration
TSS_Task(); // Touch Sensing Periodic Task
  
```

Figure 5-7 illustrates the general process of the time tracking routine; there are two other sub-routines, CHRONOMETER and TIMER which are explained in Figure 5-8 and Figure 5-9, respectively. The user can go in and out of both these routines as required.

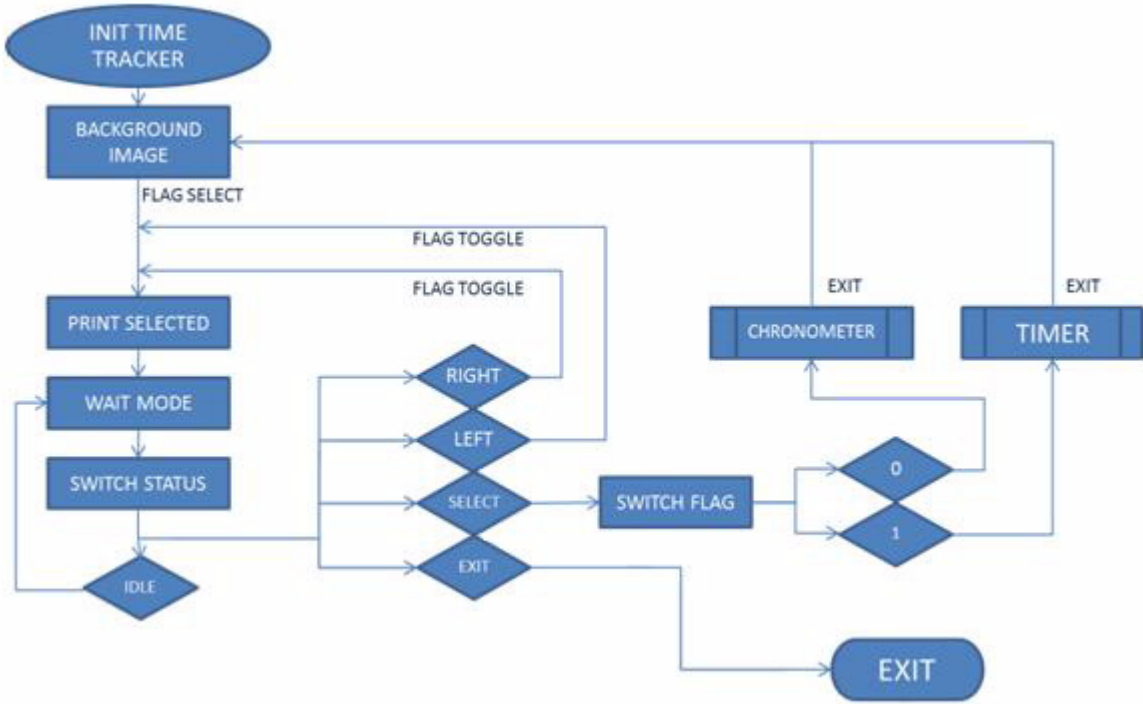


Figure 5-7. TIME TRACKER routine

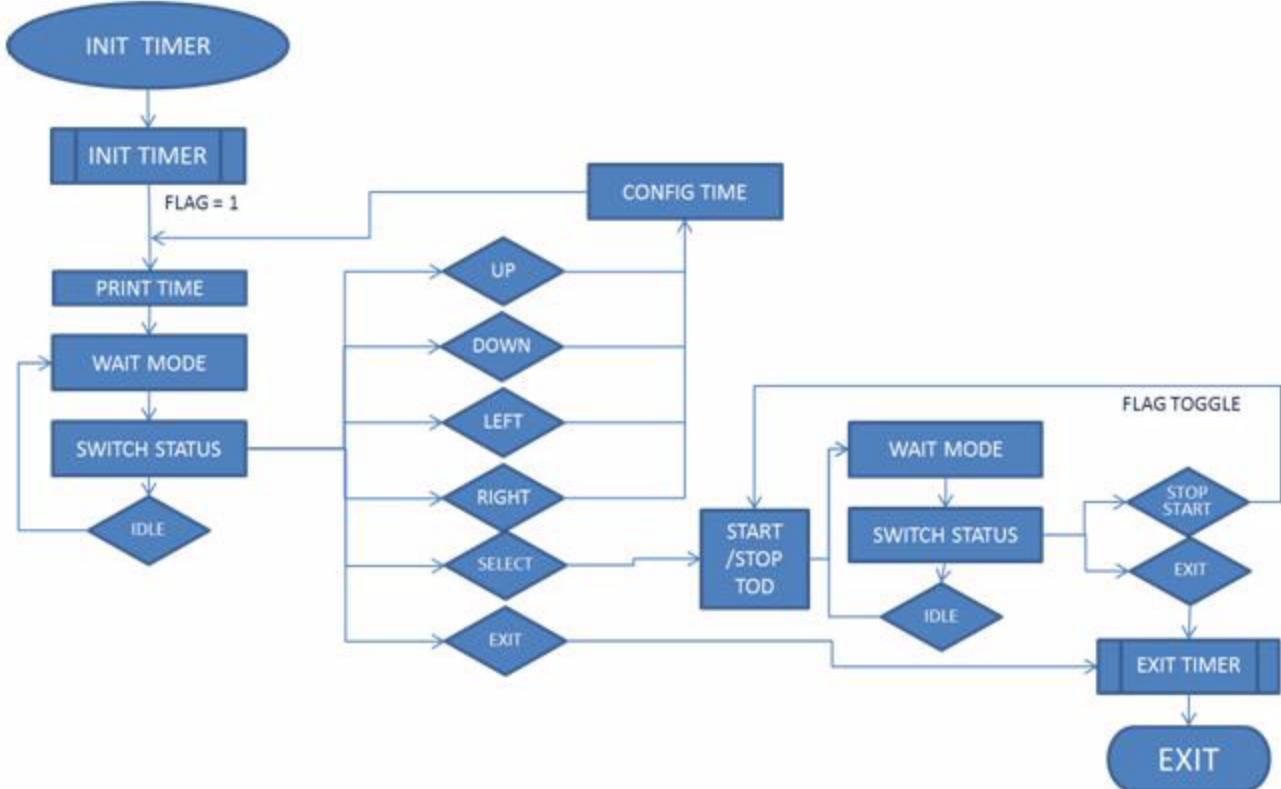


Figure 5-8. TIME TRACKER (TIMER) routine

Figure 5-8 is the Timer routine where user sets the amount of time desired, and hits the select button to start or stop the countdown. The timer used by this application is also used for the chronometer which is set to 1 ms interrupt.

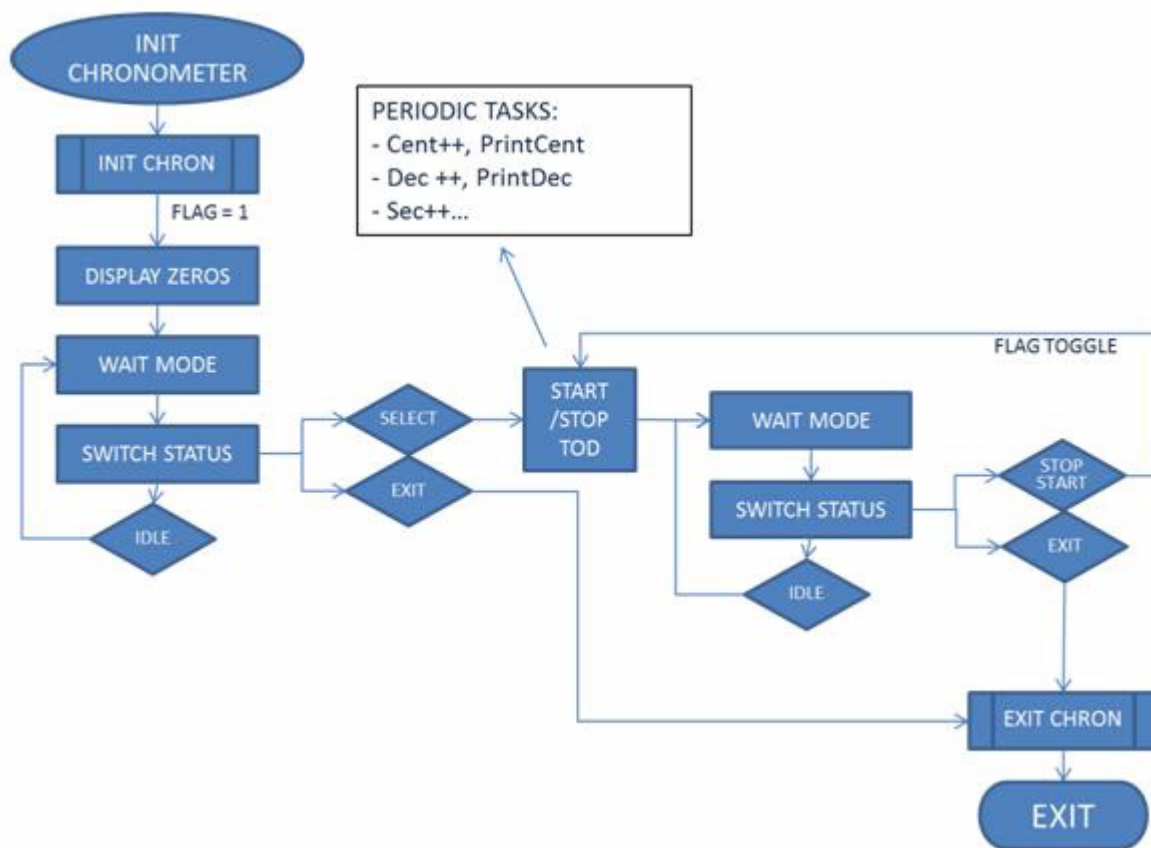


Figure 5-9. TIME TRACKER (CHRONOMETER) routine

Figure 5-9 explains the Chronometer routine where user can only start or stop the counting. Below is an example of how the time is calculated by the chronometer application.

```

/* SECOND HAS ELAPSED */
if(u8dSeconds>99) {
u8dSeconds=0;
u8Seconds++;

/* MINUTE HAS ELAPSED */
if(u8Seconds>59) {
u8Seconds=0;
u8Minutes++;

/* MAX MINUTES HAVE ELAPSED */
if(u8Minutes>99) {
u8Minutes=0
}}}

```

Figure 5-10 illustrates the PERSONAL DATA application flow. There are several configurable parameters such as NAME, AGE, GENDER, HEIGHT, WEIGHT, etc. The user has to hit the select button when the parameter to configure is highlighted in order to make modifications.

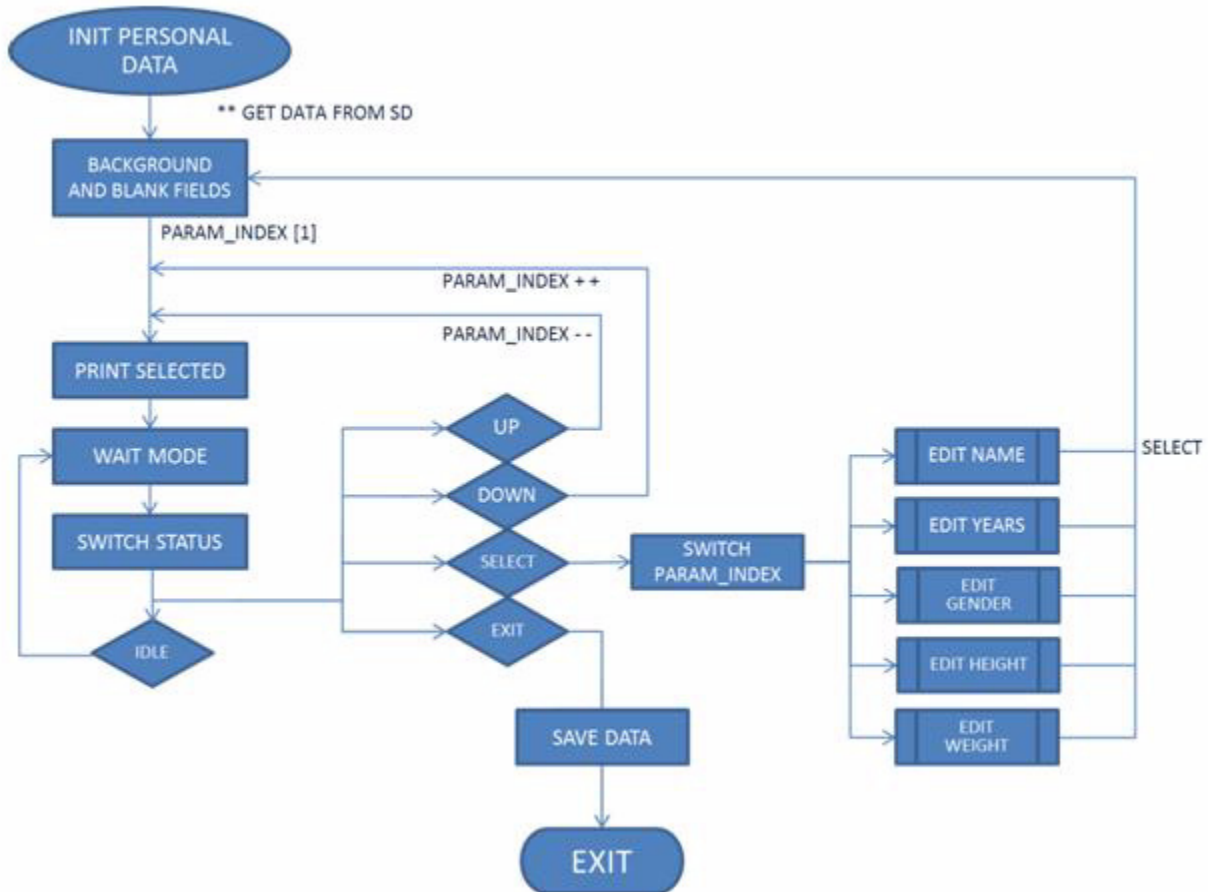


Figure 5-10. PERSONAL DATA routine

The PERSONAL DATA routine also extracts data from the Micro SD card, an example of this and the print background image functions usage is given below.

```

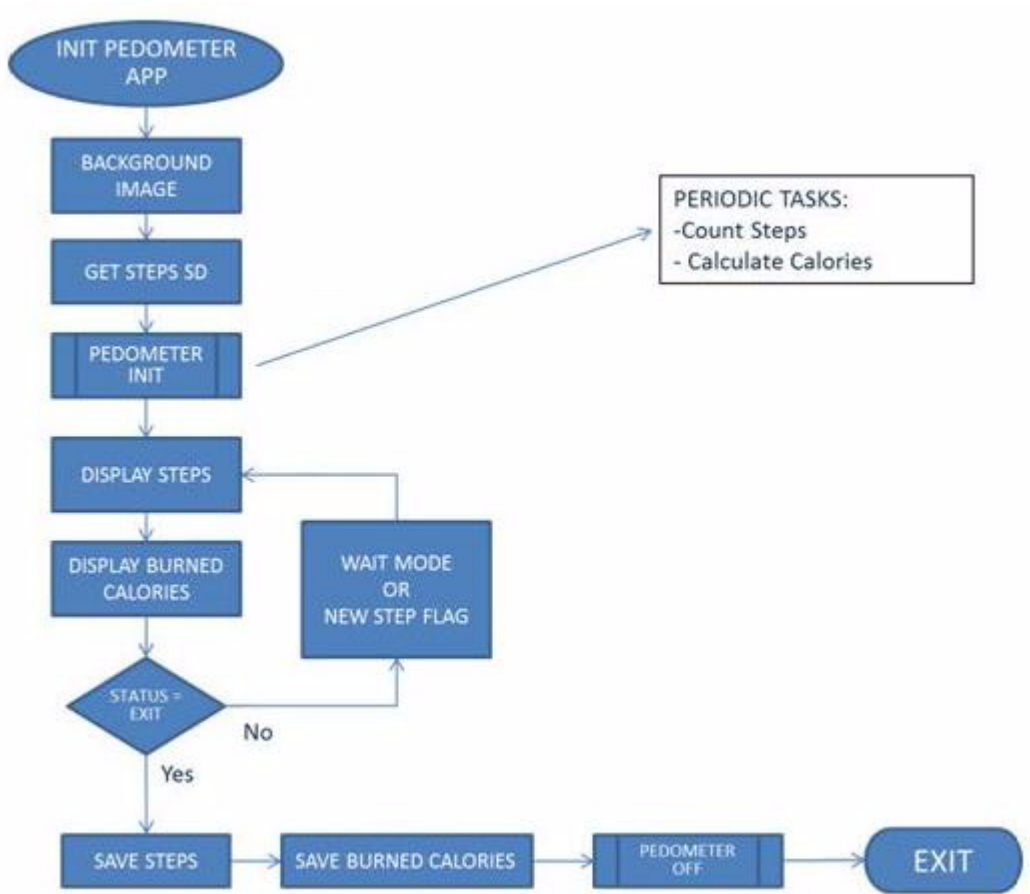
/* Get Personal Data from SD */
vfnGetSDPersonalData ();

/* Print Background */
vfnPrint_SD_Image ("DATAMENU.AMI", 0, 0);

/* Save Personal Data to SD */
u8SDFileStatus=FAT_FileOpen(DATA_FILE,OVERWRITE);
if(u8SDFileStatus==FILE_FOUND){
    FAT_FileWrite((UINT8*)au8SavingBuffer,21);
}
    
```

Figure 5-11 is the Pedometer Application routine. Like some of the routines explained before, this application requires data from the Micro SD; in this case it would be the number of steps saved. After the

information is obtained, the periodic task of the program starts. The accelerometer values are interpreted to detect user's steps.



**Figure 5-11. PEDOMETER routine**

The threshold of each accelerometer axis can be configured to obtain more accurate parameters for the step detection algorithm. These threshold parameters can be changed from the "pedometer.h" file:

```

#define X_THRESHOLD      -10  /**/
#define Y_THRESHOLD      15  //---> Comparison Tresholds
#define Z_THRESHOLD      5   /**/
  
```

## Chapter 6 Hardware Design

The Activity Monitor board is a specific design that features several modules which makes it a highly integrated device. It was designed to have the hardware elements necessary to demonstrate the capabilities of the MCF51MM256. The modules included are LCD Interface, ECG module, Mini-USB, Micro SD, Accelerometer, Touch Film, ZigBee<sup>®</sup>, Battery Charger, etc. This section will provide a quick explanation of the electrical design from schematics and also the Layout board considerations while designing the printed circuit board (PCB).

### 6.1 Schematics

In this segment the design schematics will be described below. Also a small description will be provided with each block of the entire hardware implementation.

#### 6.1.1 MCU

[Figure 6-1](#) shows the MCU (MCF51MM256) with the components around it. Most of the signal connecting to MCU are linked to other block of the schematics. [Figure 6-2](#) is the decoupling configuration for this particular design.



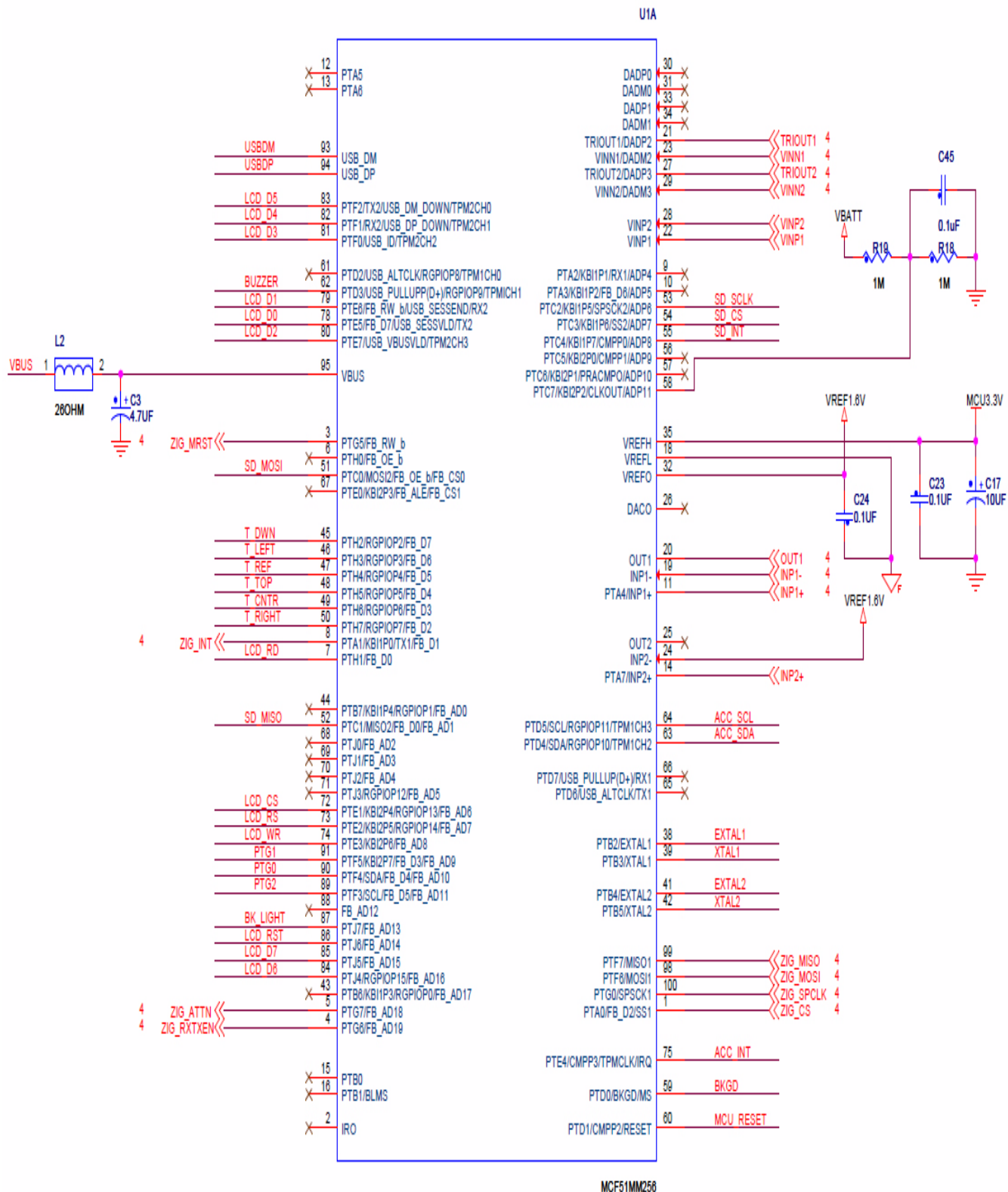


Figure 6-1. MCF51MM256 schematic

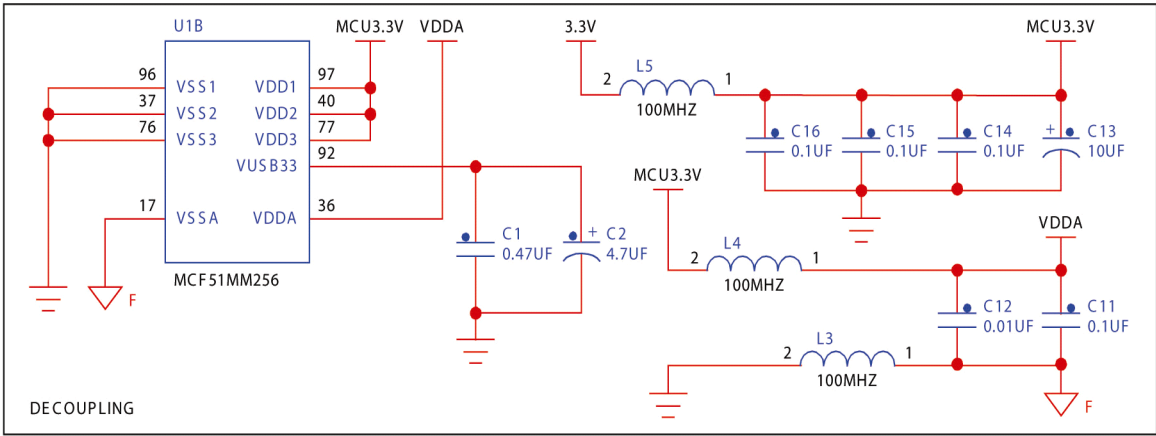


Figure 6-2. Decoupling schematic

### 6.1.2 BDM, reset, and clock

Figure 6-3 shows the BDM (Background Debug Mode), Reset, and Clock configuration. There are two different external clock sources, 32 KHz and 16 MHz. The main MCU's clock is generated from the 16 MHz oscillator, but the 32 KHz is required for the TOD (Time of day) module. The rest is basic and recommended configuration for BDM module that helps re-flash the program memory in case needed, and the Reset modules to restart or reboot the program when desired.

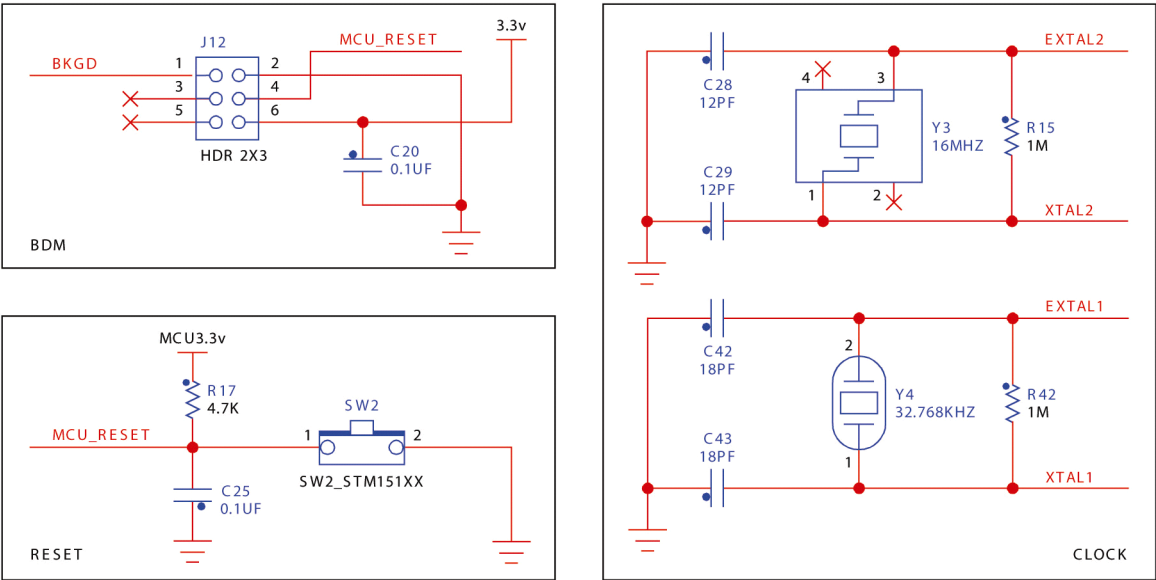


Figure 6-3. BDM, reset, clock schematic

### 6.1.3 MicroSD

Figure 6-4 explains the Micro SD connector configuration; there are some Pull-up resistors required but it is a minimal system. The Micro SD card uses SPI interface with the MCU, so you can see the four signals required, plus an SD\_INT signal that will tell if the Micro SD card is inside or not.

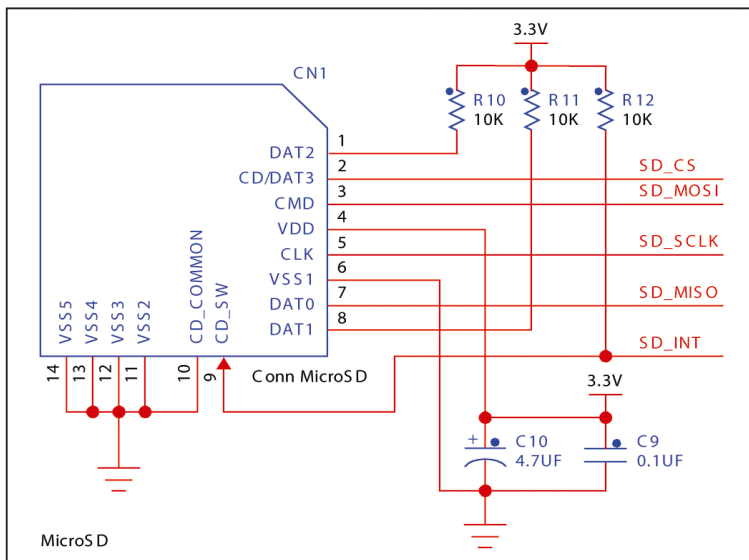


Figure 6-4. Micro SD schematic

### 6.1.4 Accelerometer

Figure 6-5 is the accelerometer's basic start-up system. It should have digital and analog power sources, very important to consider when designing the layout. The accelerometer uses IIC interface with the MCU so there are the two required signals SDA and SCL plus a configurable interruption signal.

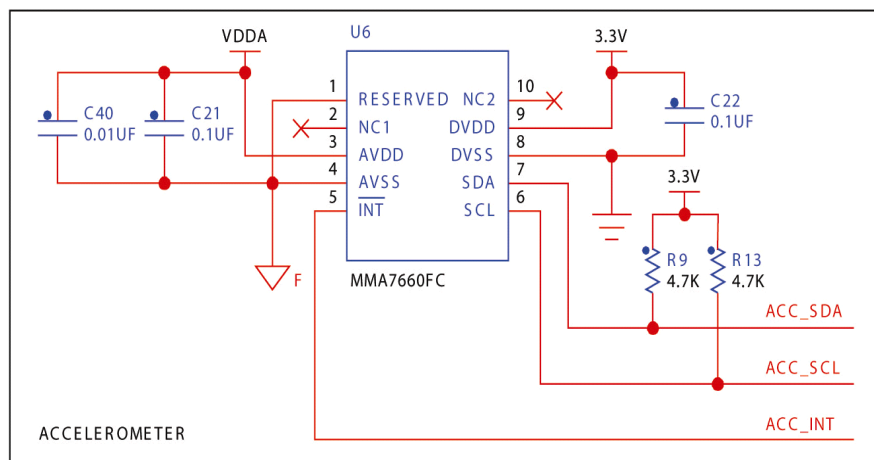


Figure 6-5. Accelerometer schematic

### 6.1.5 Battery charger

This is the Li-Polymer battery charger circuit. It has some monitor and control signals to the MCU to start/stop charging and a resistor R30 that configures the amount of current while charging the battery. Please refer to the IC's data sheet for further information. There is also the main power Switch (SW1) that will turn on/off the Activity Monitor. The battery is connected to the "Battery pads".

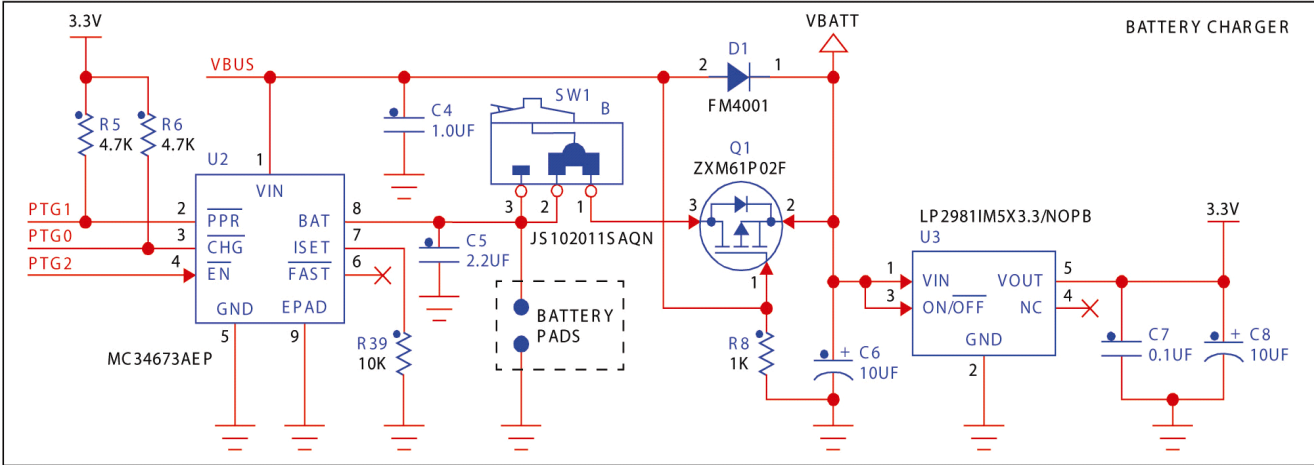


Figure 6-6. Battery charger schematic

### 6.1.6 LCD interface

Figure 6-7 shows the nets connecting the LCD to the MCU. Almost all signals go directly to the MCU's GPIOs, except the LCD BK\_Light signal that turns the LCD's back light on/off. This LCD uses an 8-pin port for data and 4 pins for instructions.

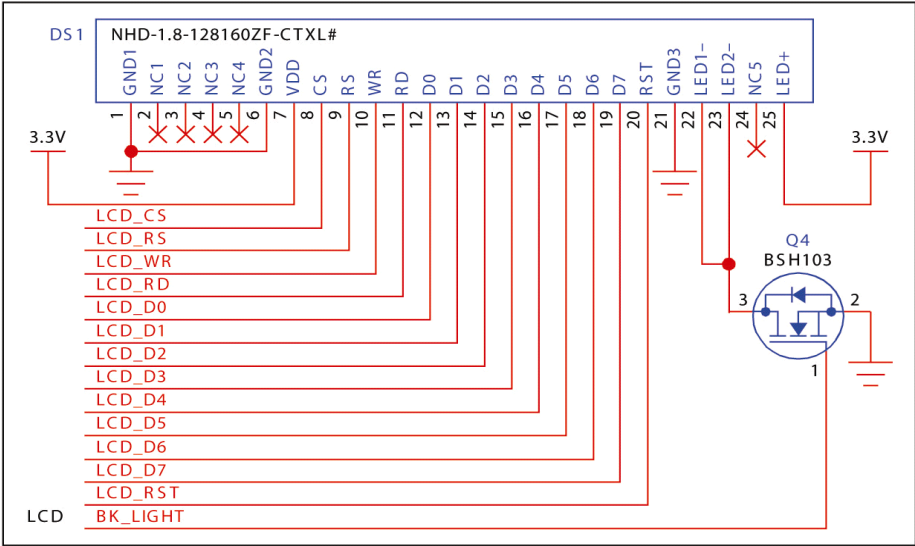


Figure 6-7. LCD interface schematic

### 6.1.7 ECG

Figure 6-8 and Figure 6-9 explain the required circuit for the ECG implementation used in the Activity Monitor. The MCF51MM256 has four integrated OpAmps, and this is why there are instrumentation signals going directly to MCU's pins. The first section of Figure 6-9 is an INA (Instrumentation Amplifier) then there is a band-pass passive filter, with an internally configured active amplifier at the end of INP2+. This circuit complemented with the digital filter implementation gives signal filtering necessary to get user's ECG.

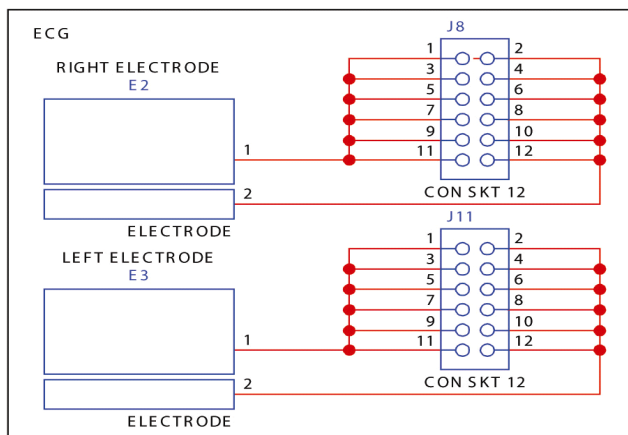


Figure 6-8. ECG electrodes schematic

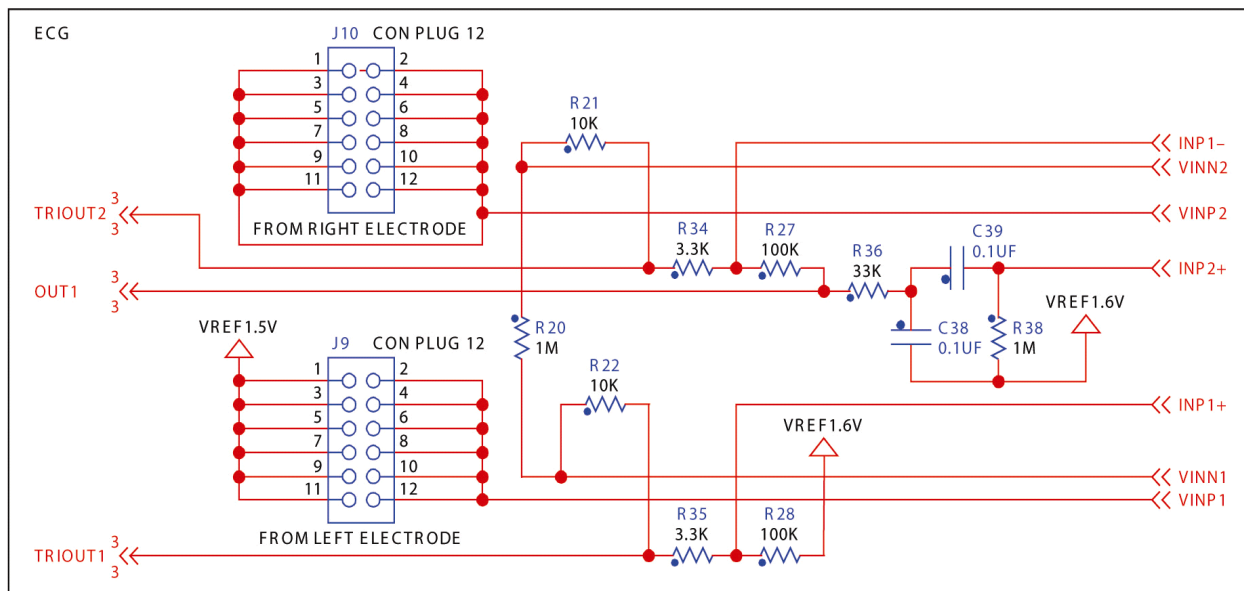


Figure 6-9. ECG instrumentation Schematic

### 6.1.8 USB interface

The next figure shows the USB circuit configured for device mode; it has its decoupling circuit as well to avoid electrical noise. The differential pair, USBDM and USBDP, is through where the data is transmitted and is very important to treat these signals accordingly while designing the layout to avoid any conflicts.

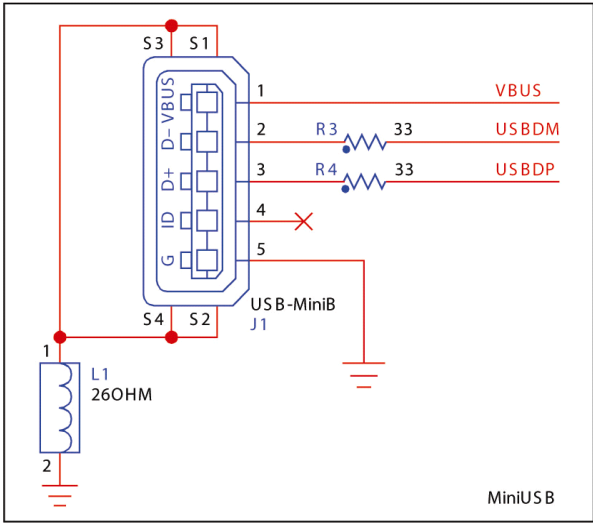


Figure 6-10. USB schematic

### 6.1.9 Buzzer

The Activity Monitor counts with an integrated Buzzer that is meant to activate the traditional sound when an ECG module detects a heart pulse. This module works through a MCU's PWM pin module.

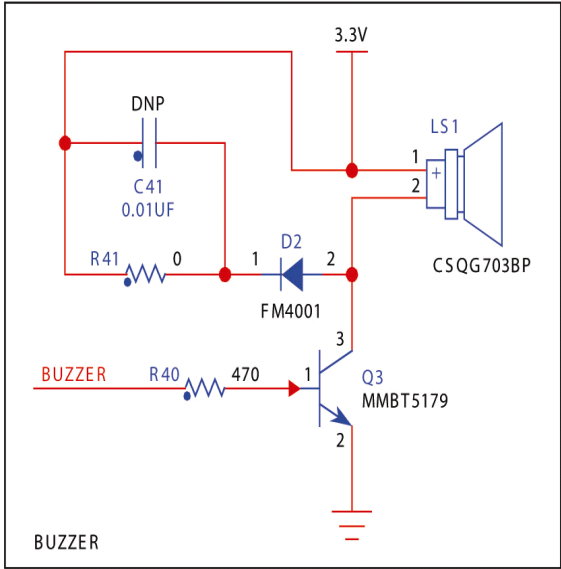


Figure 6-11. Buzzer schematic

### 6.1.10 Touch film

The circuit at [Figure 6-12](#) shows the correct implementation for a capacitive touch sensing interface. The Touch Film is plugged in the connector J3 and with the pull-up resistors the MCU is able to read if an electrode has been touched.

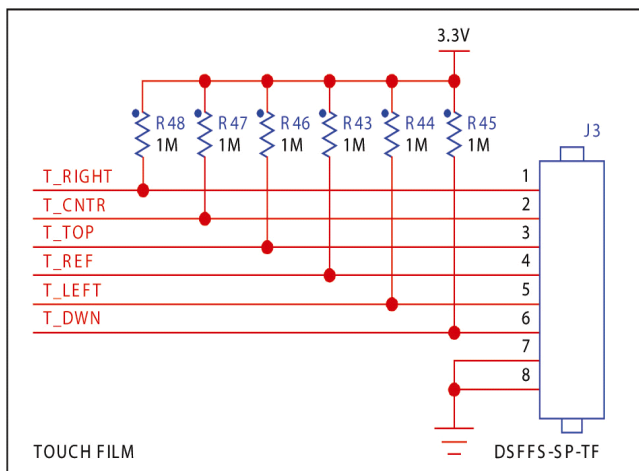


Figure 6-12. Touch film schematic

### 6.1.11 ZigBee®

Figure 6-13 shows the ZigBee® radio configuration circuit. It has its own 16 MHz oscillator, and it communicates with the MCU using SPI interface. A balun (Z1) transforms the 200 Ohms impedance from the radio to 50 Ohms impedance required for the antenna to work properly.

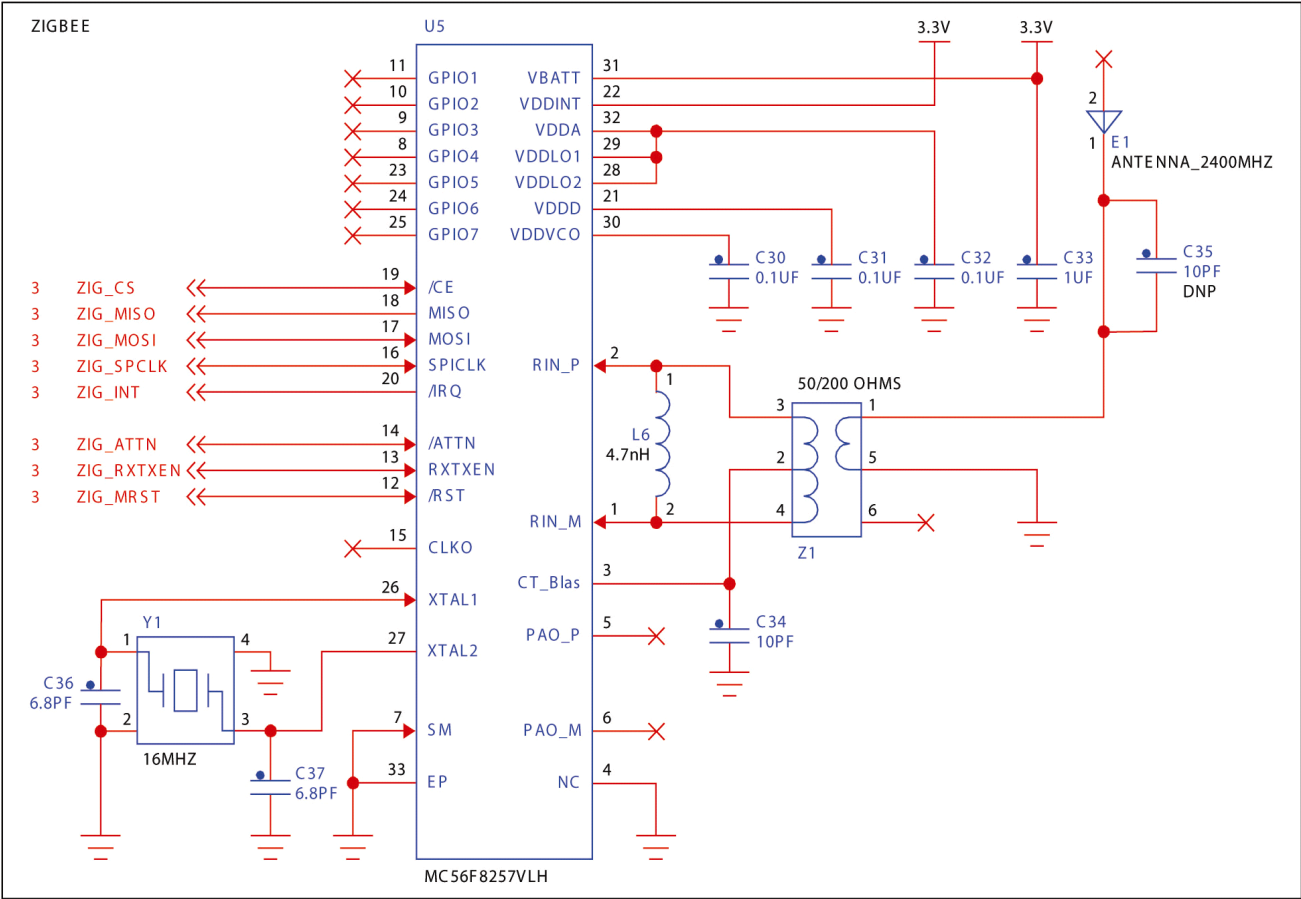


Figure 6-13. ZigBee® schematic

## 6.2 Layout design considerations

This section outlines the hardware design considerations for the PCB of the Activity Monitor reference design. It will also describe the stack up selected and will give a quick description of each layer and location of the principal modules.

### 6.2.1 Stack up

PCB stack up is a very important factor in determining the EMC performance of a device. A good stack up among other things is a very effective way of reducing radiation from the PCB. Figure 6-14 is the stack up selected for the activity monitor.



	Subclass Name	Type	Material	Thickness (MIL)
1		SURFACE	AIR	
2		DIELECTRIC	DRY_FILM_MASK	3
3	TOP	CONDUCTOR	COPPER	1.2
4		DIELECTRIC	FR-4	8
5	L2_GND_1	PLANE	COPPER	1.2
6		DIELECTRIC	FR-4	8
7	L3_PWR_1	PLANE	COPPER	1.2
8		DIELECTRIC	FR-4	8
9	L4_PWR_2	PLANE	COPPER	1.2
10		DIELECTRIC	FR-4	8
11	L5_GND_2	PLANE	COPPER	1.2
12		DIELECTRIC	FR-4	8
13	BOTTOM	CONDUCTOR	COPPER	1.2
14		DIELECTRIC	DRY_FILM_MASK	3
15		SURFACE	AIR	

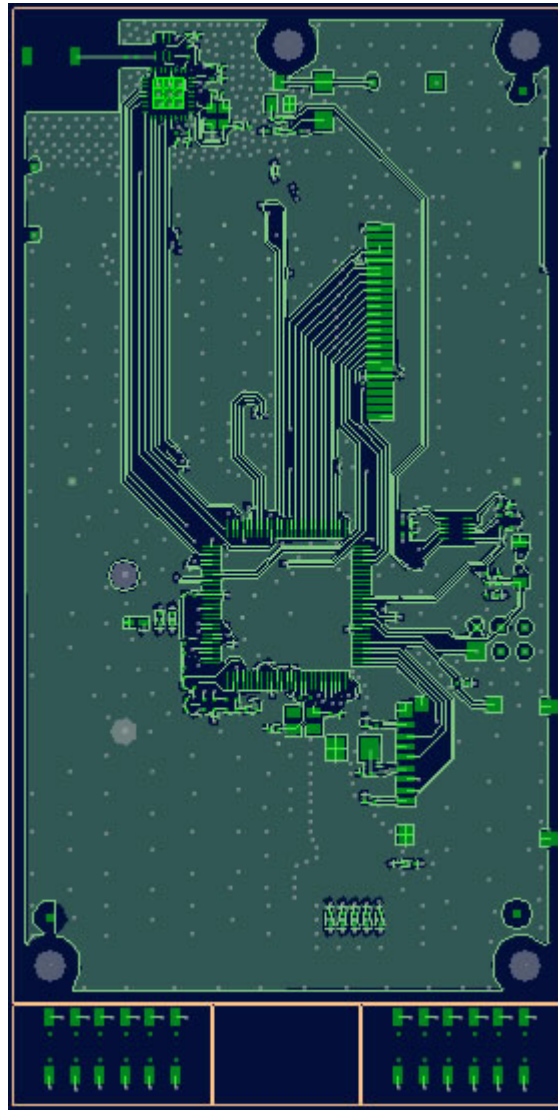
Figure 6-14. Stack up

## 6.2.2 Layers

In this section all the PCB layers will be shown with a quick explanation of each figure. This is the result of a very precise design. Not because there is analog and digital circuitry involved in the same module, but because it has a medical instrumentation module, which requires a lot of noise rejection, and a radiation module (ZigBee®) in the same board.

As seen in the previous section, the Activity Monitor board has a six layer stack up plus two other Silkscreen covers, TOP and BOTTOM. Figure 6-15 shows the Top Silkscreen with the components pin-out turned on, so that viewer can locate the different modules on the board.





**Figure 6-16. Layer 1 – Signal and GND pour**

The following [Figure 6-17](#) is a ground plane divided strategically to separate digital and analog grounds. It is referred to the next power layer (Layer 3) in order to match different powers with unique grounds. This is the ground layer to which the ZigBee<sup>®</sup> radio module is referenced.

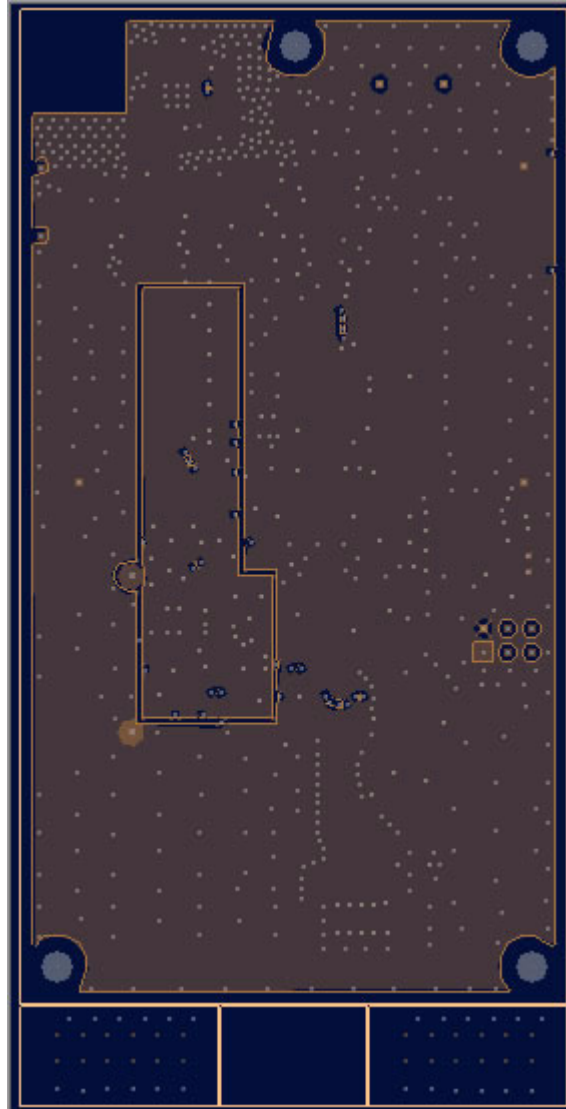
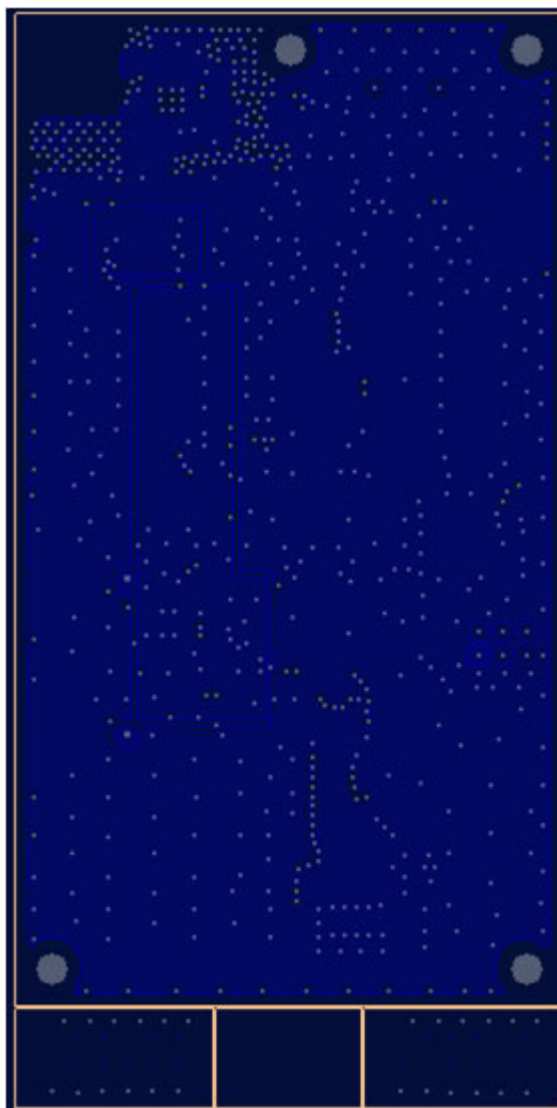


Figure 6-17. Layer 2 - GND and GND\_FIELD



**Figure 6-18. Layer 3 - MCU3.3V, Vref1.6V, and Vbatt**

At this power layer there are three different power sources. The most predominant one is the MCU3.3V that covers most of the layer, and then the one with an "L" shape is Vref1.6V needed for the ECG module instrumentation. Last, in the small rectangle is "Vbatt" which is the battery's voltage.

After the power layer number three, comes this other power at [Figure 6-19](#) (Layer 4). This layer contains the resting two other voltages: mainly the 3.3 V power source that powers all the digital devices in contrast to the VDDA power source that powers all the analog 3.3 V devices.

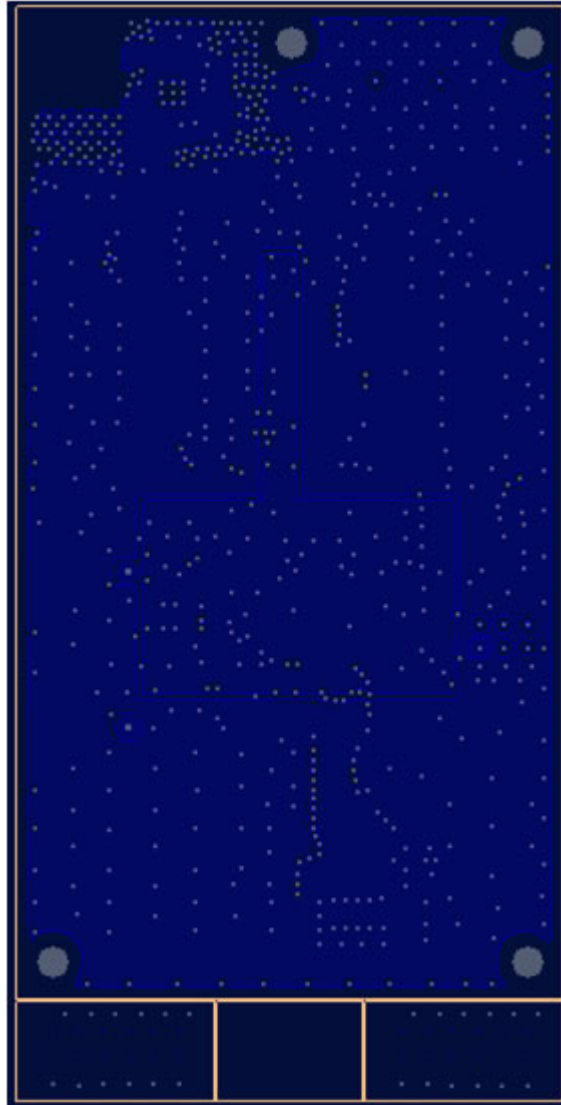
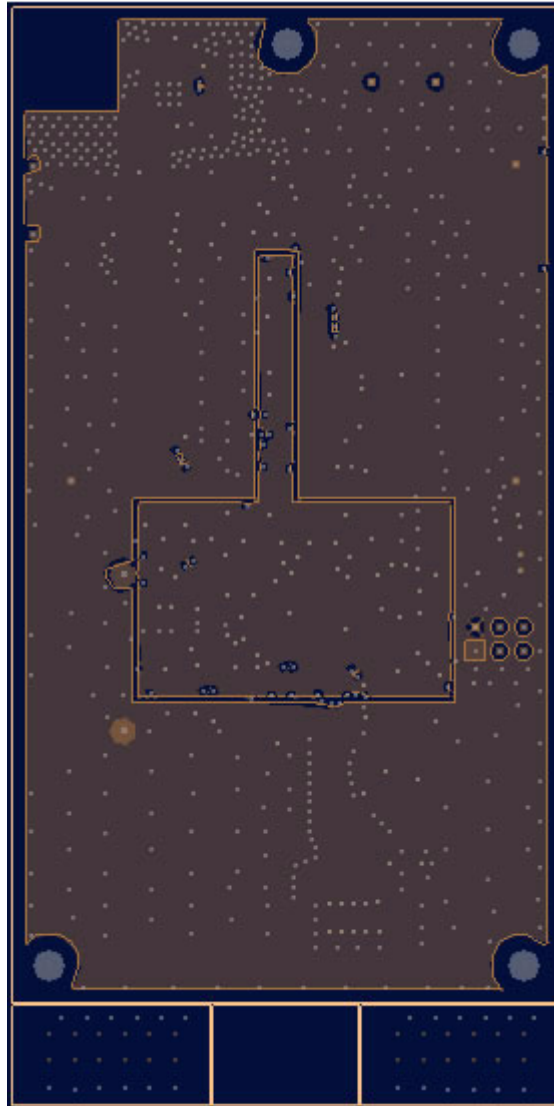


Figure 6-19. Layer 4 - 3.3V and VDDA



**Figure 6-20. Layer 5 - GND and GND\_FIELD**

The same as in Layer 3 the ground plane is referred to the previous power layer (Layer 4) to match the different powers with their own grounds. This is also a mix of digital and analog ground in the same layer.

This is the bottom layer at [Figure 6-21](#). It is also a signal layer with a ground pour. The USB differential pair circuit is on this layer. It also contains the power management module, the touch sensing connector, and the ECG acquisition electrodes, among other elements.

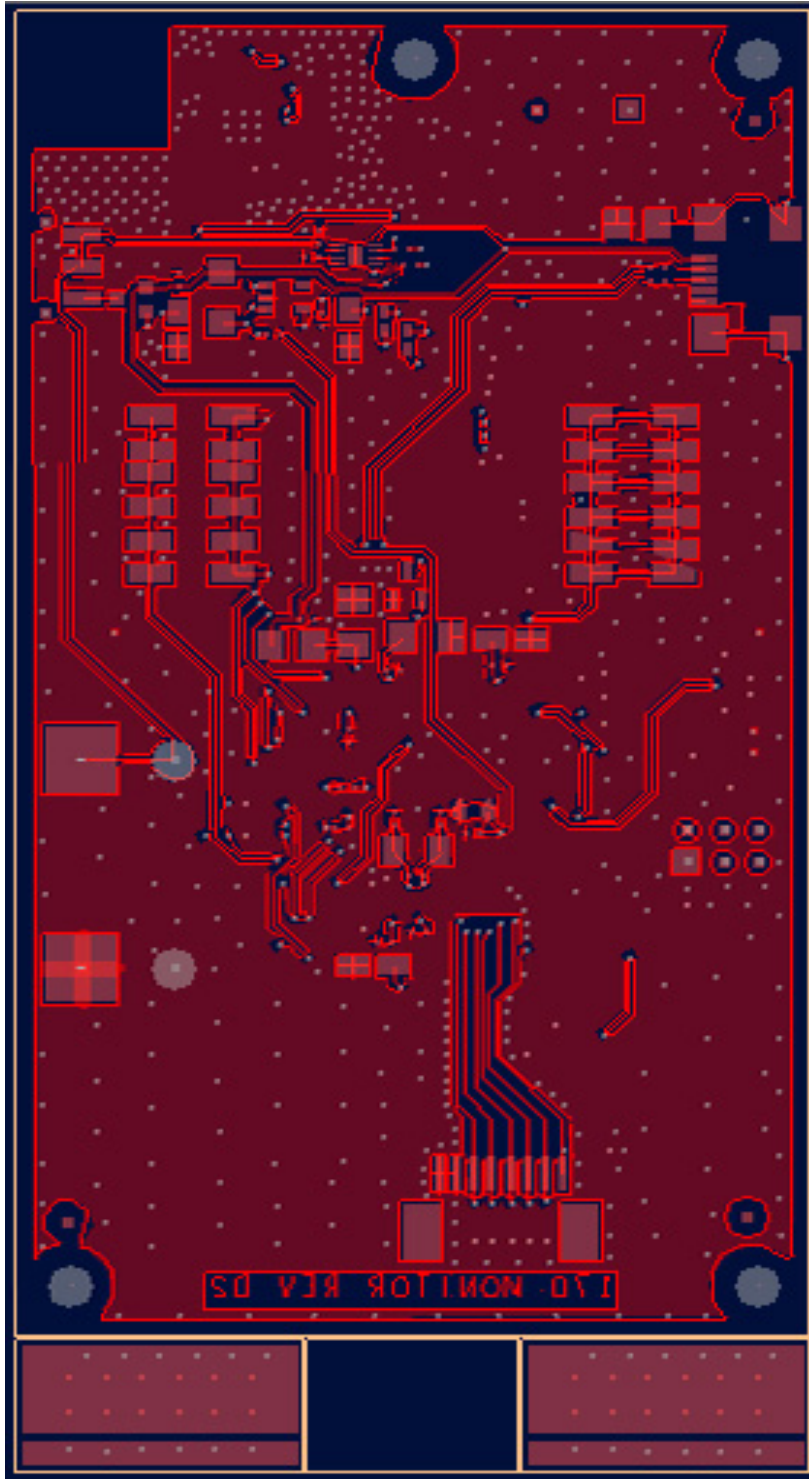


Figure 6-21. Layer 6 – Signal and GND pour



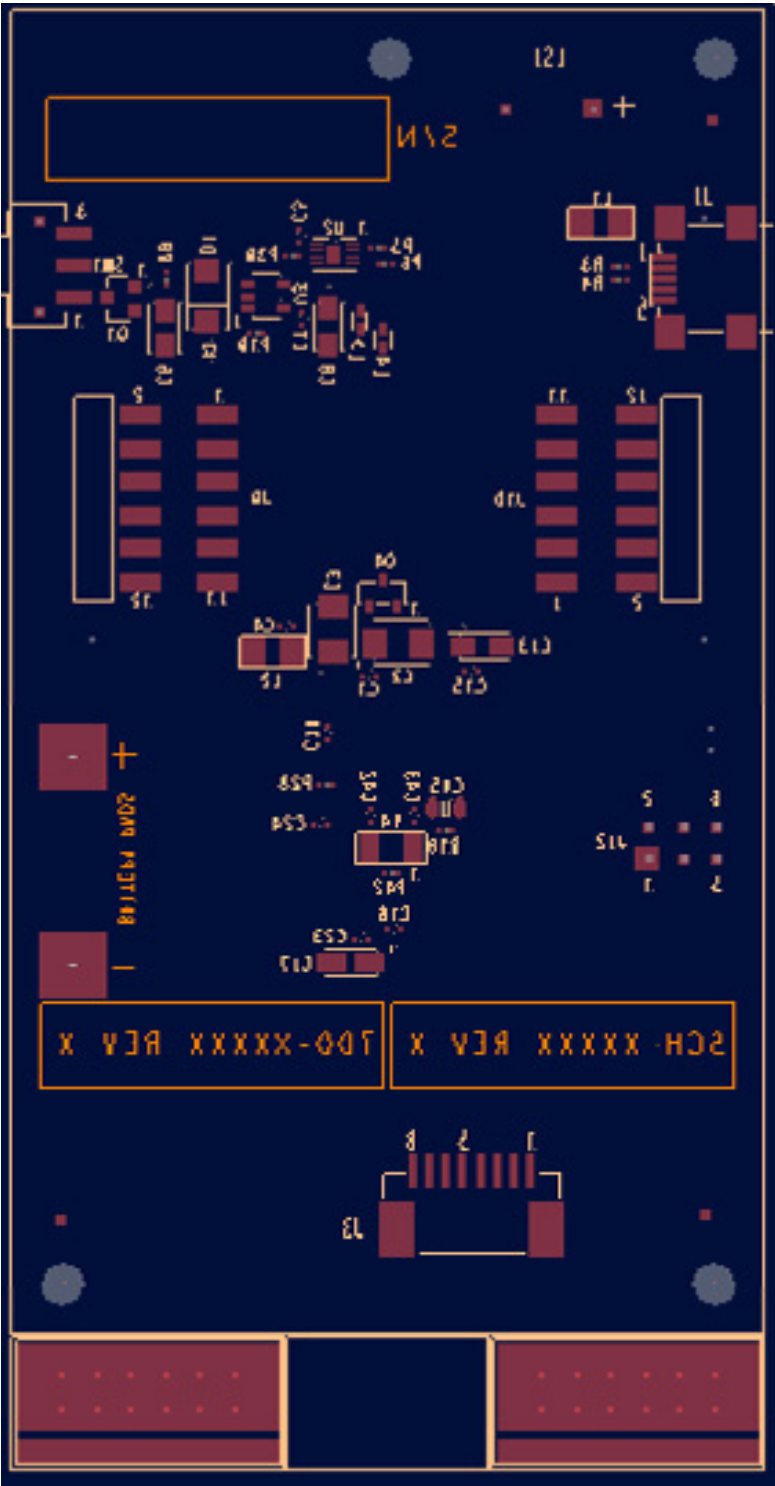


Figure 6-22. Bottom silkscreen

Figure 6-22 is the Bottom Silkscreen that helps us locate the bottom components. The figure seems to be mirrored, but this would be the correct representation of the bottom layers.

## 6.3 Board pictures

Figure 6-23 illustrates the Rev B assembled board pictures. This is the complete activity monitor board with all the corresponding components correctly assembled. To the left is the TOP view of the board; to the right is the BOTTOM view. The electrodes have been broken away from the rest of the board and placed correctly to each side.

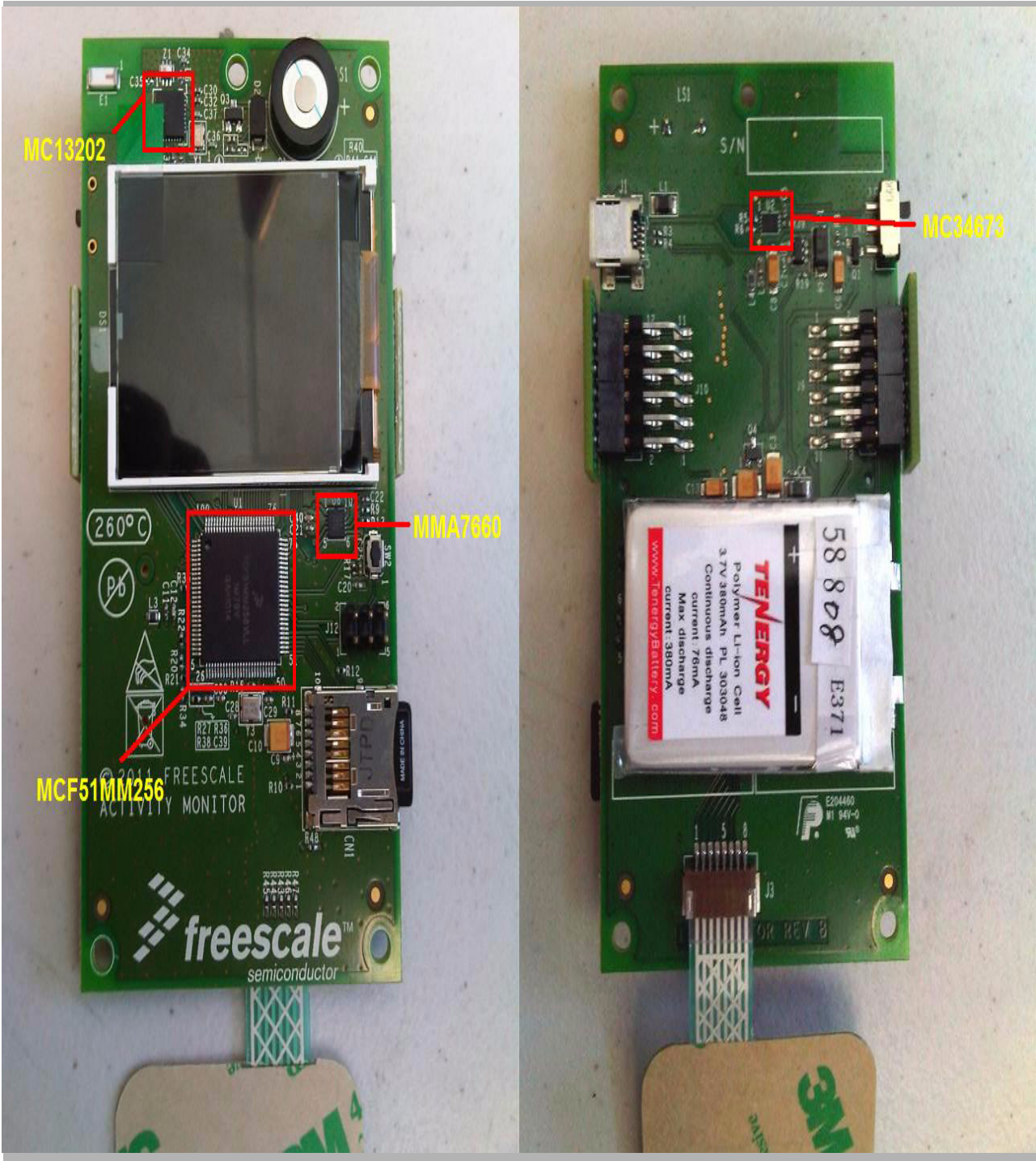


Figure 6-23. Rev B assembled board pictures

Figure 6-24 and Figure 6-25 illustrate the PCB before assembly process. They are panelized for a more efficient mounting job. In these pictures the electrodes are still part of the same board.

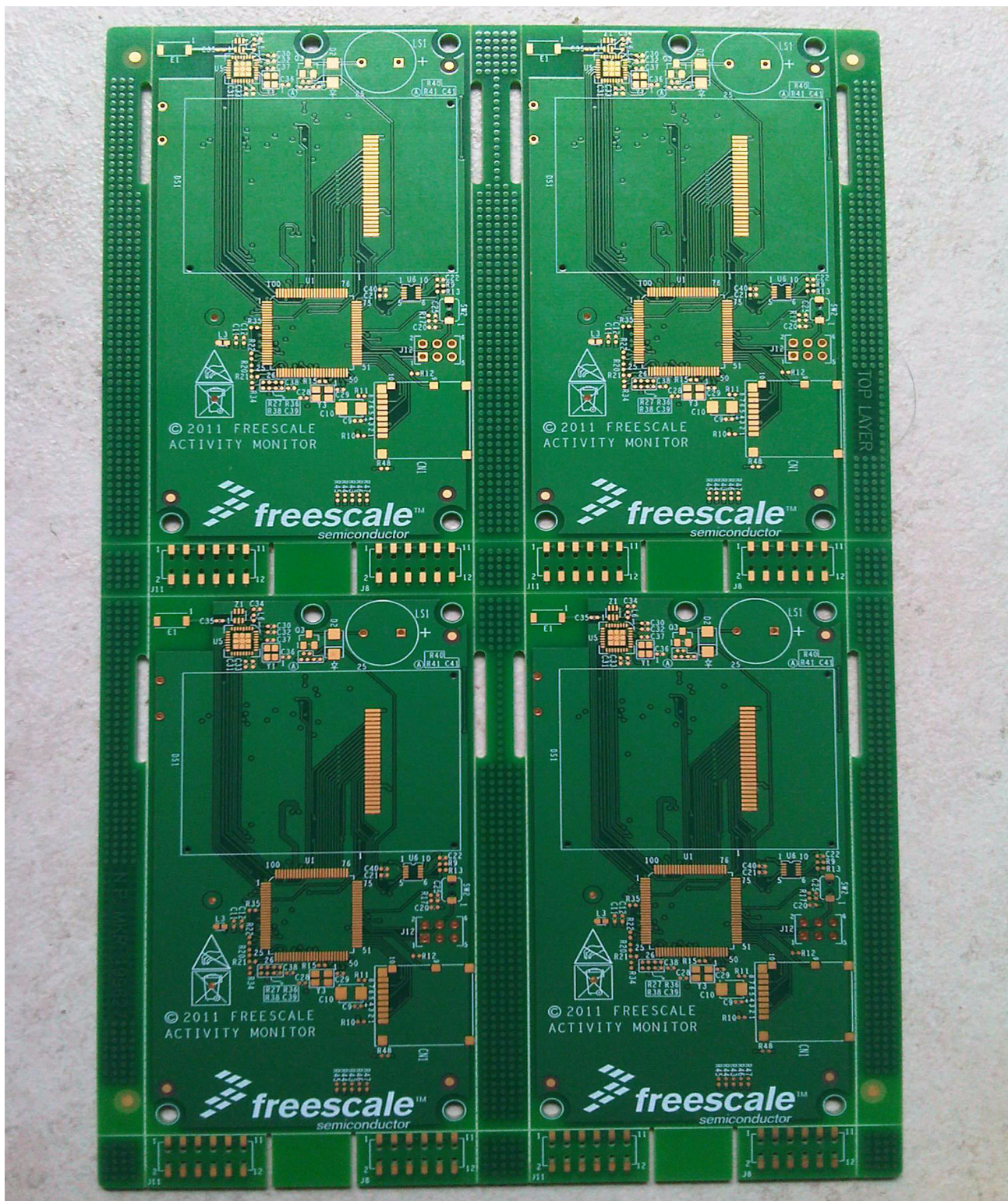


Figure 6-24. PCB top view

Activity Monitor, Rev. 1

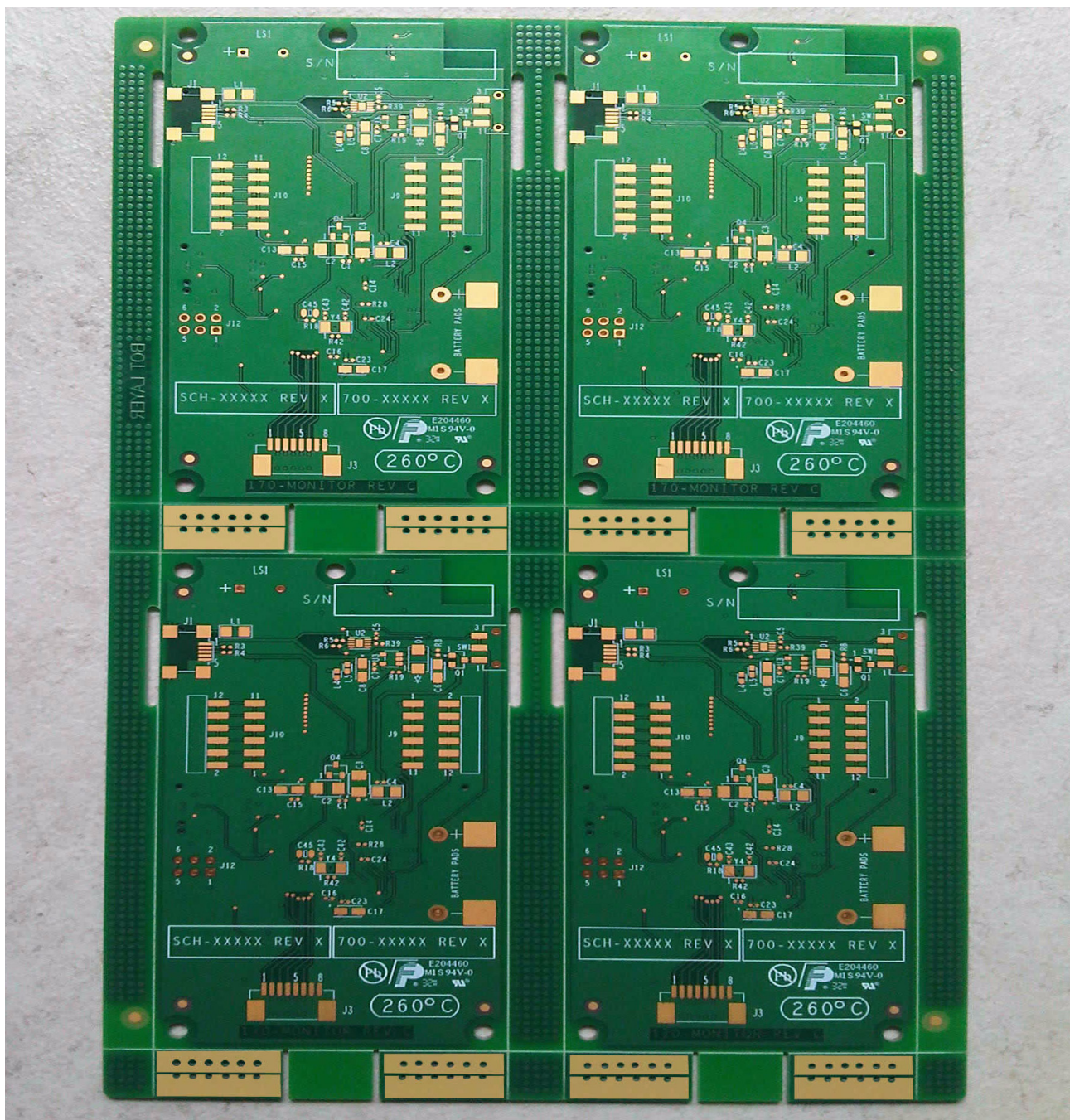


Figure 6-25. PCB bottom view

## 6.4 Bill of materials

Reference Designator	QTY	Manufacturer part#	Manufacturer's Name	Description
CN1	1	5027740891	Molex	CON MICRO_SD 1.1MM 1.8MM -- Reverse Mount
C1	1	GRM155R60J474KE19D	Murata	CAP CER 0.47UF 6.3V 10% X5R 0402
C2,C3,C10	3	T491B475M025AT	KEMET	CAP TANT 4.7UF 25V 20% -- 3528-21
C4	1	C1005X5R0J105M	TDK	CAP CER 1.0UF 6.3V 20% X5R 0402
C5	1	C0402C225M9PACTU	KEMET	CAP CER 2.2UF 6.3V 20% X5R 0402
C6,C8,C13,C17	4	TAJA106K006RNJ	AVX	CAP TANT 10UF 6.3V 10% -- 3216-18
C7,C9	2	MCCB104K0NRTF	SMEC	CAP CER 0.1UF 10V 10% X7R 0402
C11,C14,C15,C16,C20,C21,C22,C23,C24,C25,C45	11	C0402C104K8PAC	KEMET	CAP CER 0.1UF 10V 10% X5R 0402
C12	2	0402YC103MAT2A	AVX	CAP CER 0.01UF 16V 20% X7R 0402
C41	2	0402YC103MAT2A	AVX	CAP CER 0.01UF 16V 20% X7R 0402
C28,C29	2	GRM1555C1H120JZ01D	MURATA	CAP CER 12PF 50V 5% C0G 0402
C30,C31,C32	3	C1005X5R1C104K	TDK	CAP CER 0.1UF 16V 10% X5R 0402
C33	1	C0402C105K9PAC	KEMET	CAP CER 1UF 6.3V 10% X5R 0402
C34	1	CL05C100CB5NNNC	SAMSUNG	CAP CER 10PF 50V +/-0.25PF C0G 0402
C35	1	CL05C100CO5NNNC	SAMSUNG	CAP CER 10PF 16V 0.25PF C0G 0402
C36,C37	2	GRM1555C1H6R8DZ01J	MURATA	CAP CER 6.8PF 50V 0.5PF C0G 0402
C38,C39	2	CC0402KRX5R8BB104	YAGEO AMERICA	CAP CER 0.1UF 25V 10% X5R 0402
C40	1	0402ZC103MAT2A	AVX	CAP CER 0.01UF 10V 20% X7R 0402
C42,C43	2	0402G180F500SNT	CAPAX TECHNOLOGIES INC.	CAP CER 18PF 50V 1% C0G 0402
D1,D2	2	FM4001	RECTRON	DIODE RECT 1.0A 50V DO-214AC
E1	1	2450AT42A100	JOHANSON TECHNOLOGY	ANTENNA 2.4GHZ SMT 5.0X2.0X1.1
J1	1	UX60A-MB-5ST	HIROSE	CON 5 USB2.0 MINI-B RA SHLD SKT SMT 0.8MM SP AU
J2	1	961206-6404-AR	SAMTEC	HDR 2X3 TH 2.45MM CTR 217H AU 110L
J3	1	08FFS-SP-TF(LF)(SN)	JST MFG. CO	CON 1X8 FFS RA SMT 1.25MM SP 3.2MM -- TOP CONTACT
J8,J11	2	966212-2000-AR-PR	3M	CON 2X6 SKT SMT 2.54MM SP 254H AU
J9,J10	2	961212-5900-AR-PR	3M	CON 2X6 PLUG RA SMT 2.54MM SP 256H AU
LS1	1	CSQG703BP	CUI STACK	BUZZER MAG 2.0KHZ 3V 12MM TH
L1,L2	2	M11206K260R-10	LAIRD TECHNOLOGIES	IND FER BEAD 26 OHM@100MHZ 1.5A 25% 1206
L3,L4,L5	3	MPZ1608D101B	TDK	IND FER BEAD 100 OHM@100MHZ 1A 25% 0603
L6	1	LL1005-FHL4N7S	TOKO INC.	IND -- 0.0047UH@100MHZ 400MA +/-0.3NF 0402
Q1	1	ZXM61P02F	ZETEX INC	TRAN PMOS SW 20VDS SOT23
Q3	1	MMBT5179	Fairchild	TRAN NPN RF 12V 0.05A SOT23
Q4	1	BSH103	PHILIPS SEMICONDUCTOR	TRAN NMOS SW 30VDS SOT-23
R3,R4	2	RC73L2Z330JTF	SMEC	RES MF 33 OHM 1/16W 5% 0402
R5,R6,R9,R13,R17	5	RC0402JR-074K7L	YAGEO AMERICA	RES MF 4.7K 1/16W 5% 0402
R8	1	CRCW04021K00JNED	VISHAY INTERTECHNOLOGY	RES MF 1.0K 1/16W 5% 0402
R10,R11,R12,R21,R22,R39	6	CRCW040210K0JNED	VISHAY INTERTECHNOLOGY	RES MF 10K 1/16W 5% 0402
R15,R18,R19,R38	4	CRCW04021M00FKED	VISHAY INTERTECHNOLOGY	RES MF 1.0M 1/16W 1% 0402
R20,R42,R43,R44,R45,R46	8	ERJ-2GEJ105X	PANASONIC	RES MF 1.0M 1/10W 5% 0402
R27,R28	2	RK73H1ETTP1003F	KOA SPEER	RES MF 100K 1/16W 1% 0402
R34,R35	2	CRCW04023K30JNED	VISHAY INTERTECHNOLOGY	RES MF 3.3K 1/16W 5% 0402
R36	1	RC73L2Z333JTF	SMEC	RES MF 33K 1/16W 5% 0402
R40	1	CR0402JW471GLF	BOURNS	RES TF 470 1/16W 5% RC0402
R41	1	MCR01MZPJ000	ROHM	RES MF ZERO OHM 1/16W 5% 0402
SW1	1	JS102011SAQN	C&K COMPONENTS	SW SPDT RA SLD 6V 300MA SMT
SW2	1	TL1015BF160QG	E SWITCH	SW SPST MOM NO TACT 12V 50MA SMT
U1	1	MCF51MM256CLL	FREESCALE SEMICONDUCTOR	IC MCU 32BIT 256K FLASH 32K RAM 1.8-3.6V LQFP100
U2	1	MC34673AEP	FREESCALE SEMICONDUCTOR	IC CHARGER LI-ION/POLYMER BATT 1.2A 20V 8-UDFN
U3	1	LP2981IM5X-3.3/NOPB	NATIONAL SEMICONDUCTOR	IC VREG LDO MICROPOWER 3.3V 100MA 2.1-16V SOT23-5
U6	1	MMA7660FC	FREESCALE SEMICONDUCTOR	IC XCVR 2.4GHZ 2/3.4V QFN32
U5	1	MC13202FC	FREESCALE SEMICONDUCTOR	IC SENSOR ACCELEROMETER 2.4-3.6V DFN10
Y1	1	NX2520SA-16.000000MHz	NDK	XTAL 16MHZ -- 2520 SMD
Y3	1	NX3225SA-16.000000MHz	NDK	XTAL 16MHZ FIXED -- SMT 3.2X2.5MM
Y4	1	G73270001	SARONIX	XTAL 32.768KHZ -- -- SMD
Z1	1	2450BL15B200E	JOHANSON TECHNOLOGY	XFMR BALUN 2.45GHZ +/-50MHZ 50/200OHM 3W SMT
NA	1	NHD-1.8-128160ZF-CTXL#	NEWHEAVEN DISPLAY	TFT Liquid Crystal Display Module
NA	1	Custom Part	KEE GROUP	TOUCH FILM
NA	1	NA	SanDisk	MICRO SD CARD 256MB
NA	1	3021003-03	Qualtek	CBL USB A-MNI B CON 3' 28/28 AWG
NA	1	033048	TENERGY	LI-POLYMER BATTERY 3.7V 430mAh

Figure 6-26. PCB BOM

## Chapter 7 Troubleshooting

This section is a quick-reference troubleshooting guide for solving Activity Monitor problems that might be encountered while using it. A practical explanation and recommendations to help solve common problems with the device are presented in the following sections. Nevertheless, a particular problem might require a different solution from those proposed in this application note. For such cases, please contact Freescale's support to receive further help.

### 7.1 Charge your Activity Monitor's battery



Plug a USB cable (Type A - mini B) into the side of the Activity Monitor, as seen in [Figure 7-1](#). The software should start normally and the battery indicator at the main menu should be completely filled with a plain white bar (with no bars): 



Figure 7-1. USB connection

When the Activity Monitor's Battery is fully charged (about 2 hours), the battery indicator must have all the bars when disconnected: 

#### 7.1.1 The Activity Monitor does not start

If the device is having problems starting up, follow the steps given below until the problem is solved:

1. Make sure that main switch is in the "ON" position; this is towards the bottom of device.
2. Connect the Activity Monitor to a USB power source using a USB (Type A - mini B) cable.
3. Check if the device's battery is fully charged (see "[Section 7.1, 'Charge your Activity Monitor's battery'](#)").
4. If none of the above works, please contact Freescale's support to receive further help.

## 7.1.2 SD card or Files not found

If you get a "SD Card not found" message or if a certain file is not found by the system, follow the steps given below until the problem is solved:

1. Check if the device's battery is fully charged (see [Section 7.1, "Charge your Activity Monitor's battery"](#)).
2. Make sure the Micro SD card is correctly inserted (the SD card contact pins should be facing upwards).
3. Make sure the Micro SD card is compliant with the Activity Monitor (see [Section 3.2, "Preparing the MicroSD card"](#)).
4. If none of the above works, please contact Freescale's support to receive further help.

## 7.1.3 The Touch Sensing Interface is not working

If the device is having troubles with the touch sensing buttons, follow the steps given below until the problem is solved:

1. Restart the device using the ON/OFF switch (the touch sensing interface locked itself).
2. Check if the device's battery is fully charged (see [Section 7.1, "Charge your Activity Monitor's battery"](#)).
3. If none of the above works, please contact Freescale's support to receive further help.