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March 11th, 2013

Dr. Andrew Rawicz
School of Engineering Science
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Design Specifications for Personal Electronic Stethoscope

Dear Dr. Rawicz,

Attached to this letter is our team's design specification for a Personal Electronic Stethoscope (PES), as per our class: Engineering Science 440. This device is designed for users to monitor the condition of their heart by connecting to a smart phone directly. Any abnormal behavior detected, an automatic instantaneous message will be sent to the individual's pediatrician. At Better Life Technologies, we believe this device can save numbers of people who have hidden heart disease.

In our design specification, we outline all of the necessary information and specification for our proposed Personal Electronic Stethoscope (PES). We also provide the detailed design requirements that need to be achieved at the end of the proof-of-concept phase for PES. The test plans and future design consideration is also mentioned in this documentation.

Better Lift Technology consists with five-member team who are confident, skilled and motivated. Real Yuen, Guntae Park, Jungioo Lee, Seven Yao, and Jesse Yang are all fifth-year engineering students majoring in electronics or systems engineering. Should you have any concerns or question about our proposal, please feel free to contact me by phone (604) 773-3766 or by email at yky1@sfu.ca.

Sincerely,

Real Yuen
President and CEO
Better Life Technology

Enclosure: *PES – Design Specification for Personal Electronic Stethoscope*

Design Spec.

- Personal Electronic Stethoscope

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Issued date: March 11, 2013

Revision: 1.2

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Executive Summary

At Better Life Technology, we aim to develop a Personal Electronic Stethoscope (PES) for patients who have heart diseases or any people who want to diagnose their heart condition whenever they want with their smart phones. This product will help to decrease death rates due to heart attacks or heart diseases and to prevent death or emergency situations. The main purposes of our device are making it cheaper and portable and making it for patients, not for doctors, and any person who wants. There are other methods to detect heart beats such as electrocardiography (ECG) which is very popular. Therefore, our device is aiming for patients and people who want to check their heart beat easily.

Our device will be made of a hardware part and a software part using smart phone; hardware will generate sound signal of heart beat and software will demonstrate the result of the condition in graph and number. The hardware part will be made of two subsections which are PCB design and hardware packaging. Hardware of the PES is designed to use preamplifier, active low-pass filter, and power amplifier to generate larger sound at output because output signal which is audio signal will become input signal at smart phone to demonstrate the data. MIC that is the input of PCB (Printed Circuit Board) hardware and this will absorb the heart beat sound. Thus, this part is also very important because mechanical design is needed for collecting heart beat sound from chest. Mobile OS will be used for software part because it can provide portability and easiness of usage that we are aiming for. Hardware packing will include cover case for PCB and MIC. Rubber sleeve and stethoscope head cover for MIC and water-proof plastic cover for PCB will be used.

In conclusion, Better Life Technology aims to use PES as a patient’s self-detector of heart beat rate to save more lives and manage the health. When compared to current products in the market, our PES is uniquely designed for patients and people who want to or need to use it. This document will describe and justify the design choices and options for the three major parts of our device. The design, implementation, and debugging of our product will be done by April 12, 2013.

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Glossary

CSA	Canadian Electrical Standards
ECG	Electrocardiography
EMC	Electromagnetic Compatibility
FCC	Federal Communications Commission
ICES	Information Technology Equipments
iOS	Apple's mobile operating system
MIC	Microphone
PCB	Printed Circuit Board
PES	Personal Electronic Stethoscope
SMD	Surface Mount Device
UI	User Interface

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1. Introduction

Nowadays, people are busy with their work, relationships, and other activities. People rarely realize or pay attention to physical warnings. From these reasons, Better Life Technology is going to create the device – PES, so people can monitor their heart conditions by themselves. Once there are any abnormal activities happening on the user's heart, a message will be sent to the user's phone and provide advices. The design of our product has been broken into three modules, the hardware stethoscope, the hardware packaging, and the software processing. For each module, a design was chosen and this document will explain out design choices and provide concise explanations for each choice.

1.1 Scope

This document will expand on our reasoning behind our design choices and will lay out the hardware and software design blocks for the Personal Electronic Stethoscope. All requirements are fully described for both proof-of-concept device and production device. Furthermore, test plans for the device are provided at the end of the specification to help guide and evaluate the function of our prototype device.

1.2 Intended Audience

The design specification document is intended to be used by the members of the Better Life Technology team throughout the development stages to ensure the testing engineers will test the proof-of-concept. The President and CEO, Real Yuen, will use this as a measure of compliance and progress of our project and direct future tasks. This document will also serve as a template against which the final product is evaluated.

2. System Specifications

Heart disease or heart attack is the number one killer in the world [1]. However, not everyone can afford or have time for a body check every year. According to these reason, Better Life Technology is going to create a device that the users are able to monitor their heart condition without any guide from doctor or specialist. Below has shown the basic block diagram of functions of the product we are aiming for.

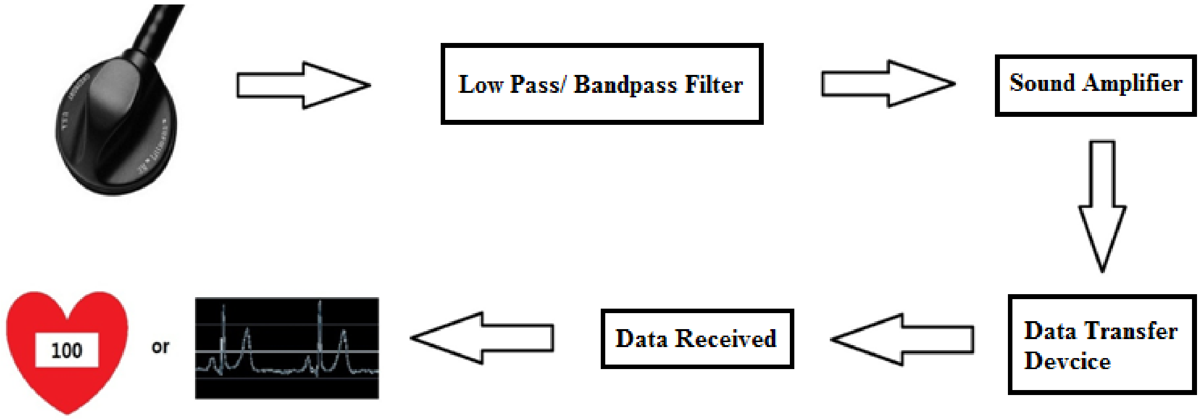

Figure1: Block diagram of functions for PES

The project design consists of three different systems: the electronic stethoscope, a data transfer device to the mobile and a mobile user interface. Although the electronic stethoscope already exists on the market, they are made for doctor or any other specialists also they are not able to transfer data. To implement this device, Better Life Technologies are going to apply the software and hardware techniques so that the electronic stethoscope will be able to capture data from the user and transfer the signal to the user's mobile.

The circuit part of the electronic stethoscope will contain a low pass or bandpass filter to reduce the noise from the surroundings. The filter is designed to capture signal within 20Hz to 2k Hz range (Which is the heart beat frequency) [2]. Then the filtered signal will be amplified and ready to transfer via the data transfer device.

The data transfer device will convert the captured signal into digital form, and then analyze the signal and process to the mobile interface.

The mobile user interface will provide the heart condition and a beating graph to the user. If there is any abnormal behaviour, a message will be sent to the user.

3. Overall System Design

This section of the document provides a general overview of our PES system and its components. Design details of perspective parts are outlined in next few subsections along with the design details and mechanism specification of individual parts correspondingly.

3.1 Portability, Time Consuming and User Friendly

There are some electronic stethoscopes in the market now to diagnose heart beat condition, but these electronic stethoscopes are for hospital purposes and only comprehensible by doctors. What makes our product at Better Life Technology so valuable, however, are portability, time consuming and user friendly. To achieve this target, this device must meet the following requirements:

- Weight less than one kilogram.
- Take less than a minute for the system to respond.
- Clear and straight instruction to follow.

To begin with the project, we build the electronics stethoscope circuit by Audioguru, Figure.2.

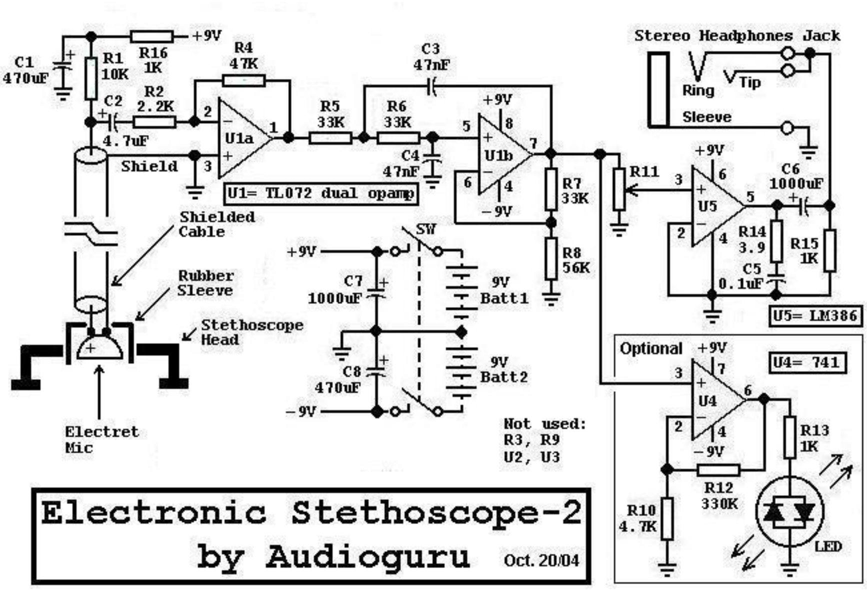

Figure2: Electronics Stethoscope Circuits Diagram

We built the circuit on the breadboard for test purpose, the values for the components is shown on Appendix A. From Figure.3, we can see the early stage of the prototype.

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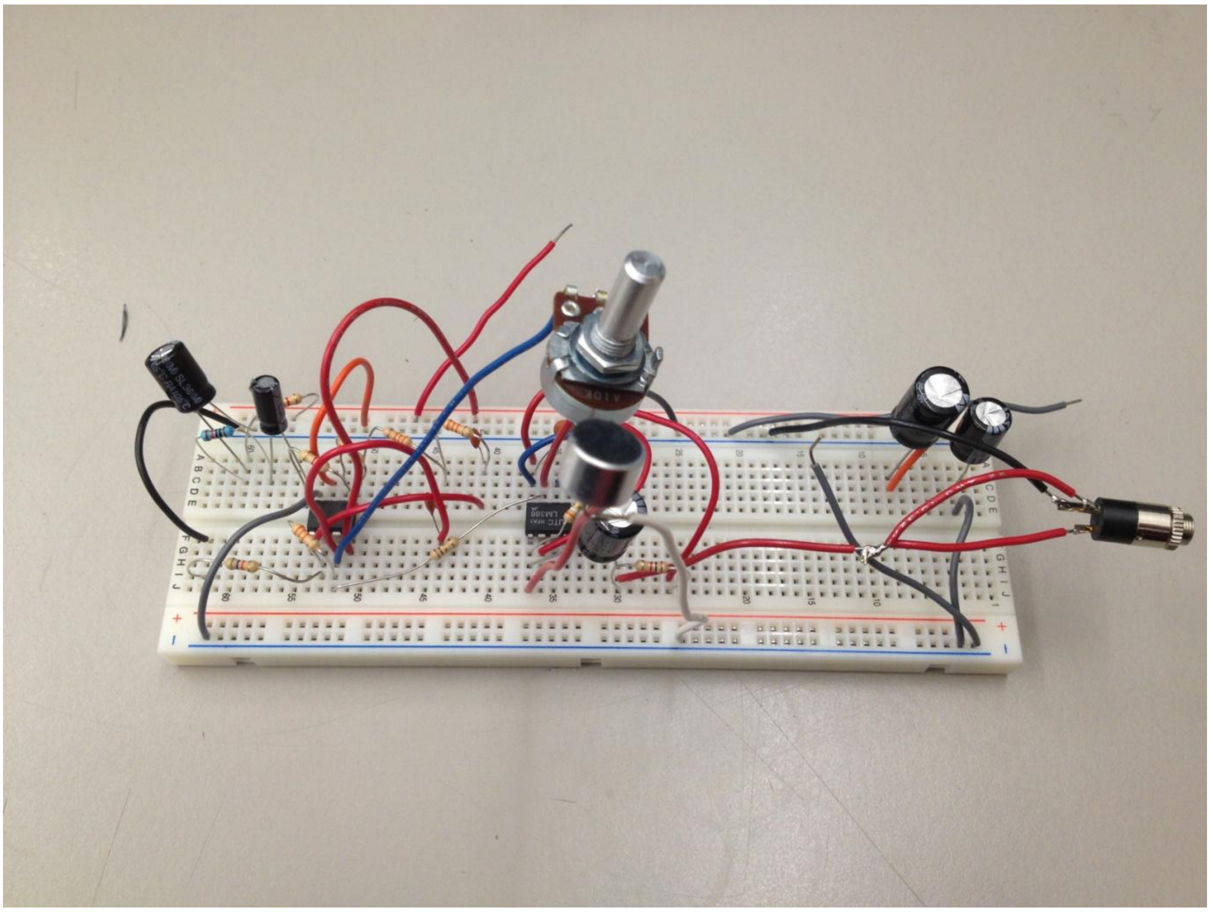

Figure3: Original Circuit Prototype

The main reason that we set up the weight restriction for the device is because we wish this device is easy to carry. Therefore the user can monitor their heart condition anytime they wanted. From the original prototype, we notice that if we apply the through-hole technique for this circuit board, the size will be very inconvenience for the user. Therefore, we come to a decision to build the circuit board on PCB with surface mount device technique. This technique can reduce the prototype size by 70%. Furthermore; we get rid of the LED part and decide to use a 3V battery with a voltage regulator to supply the necessary voltage for the OPAMP, which is 6V.

The software group from Better Life Technology will implement a program for the smart phone that captures the data from the output of the circuit. Then analyze the data and finally display the information for the user.

This product is aimed for all generation. As a result, we have to make sure the device is user friendly. Step by step instruction should provide for the user.

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3.2 Electronic Stethoscope Theory

The electronic stethoscope in market is not portable. Figure.4 shows the description of electronic stethoscope schematic diagram and how it works for each part.

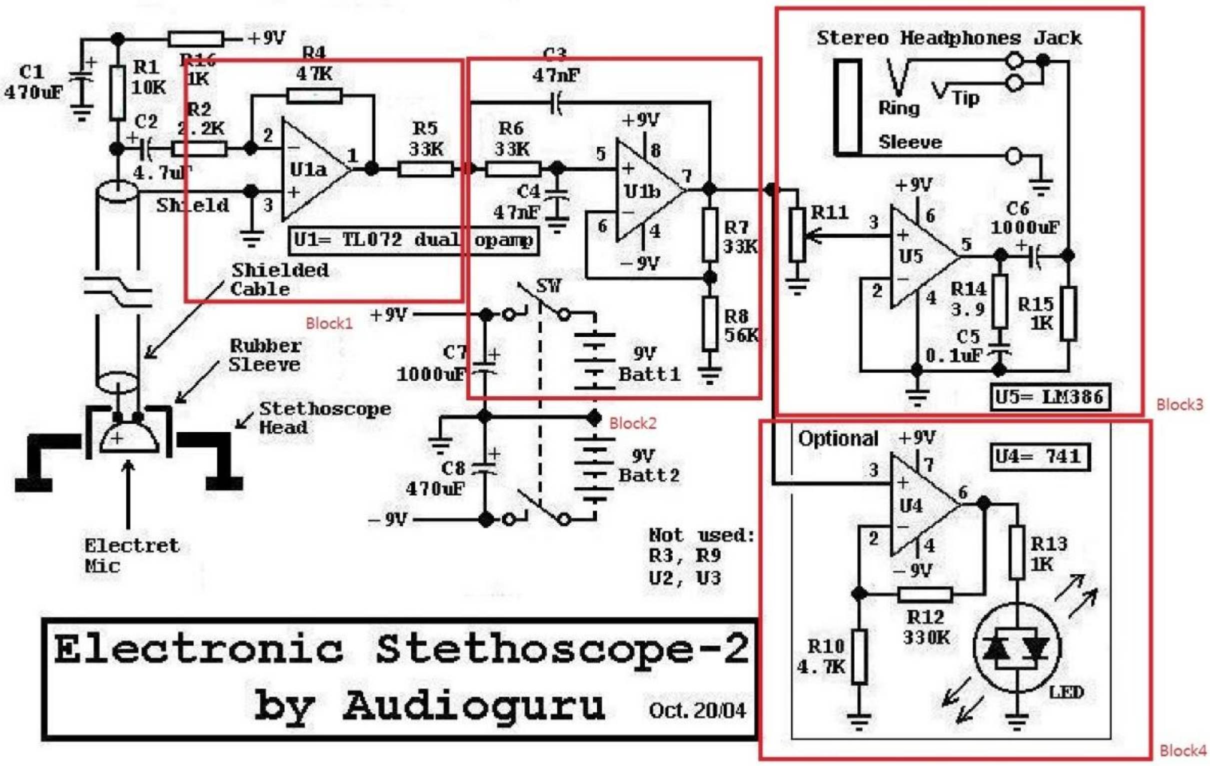

Figure4: Circuit diagram of Electronic Stethoscope in Blocks

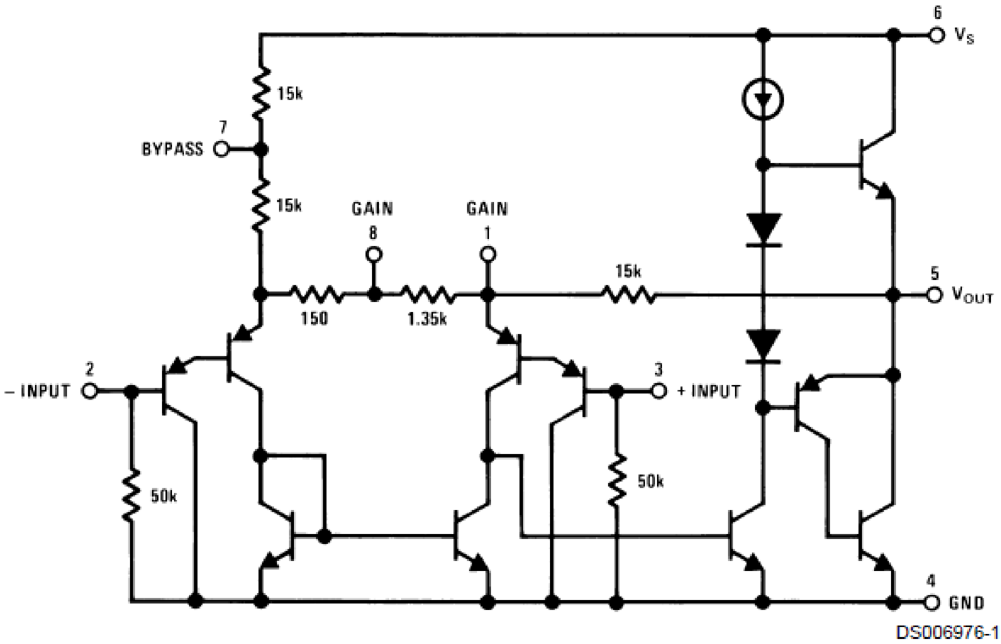

Figure5: Schematic diagram of LM386 (Power amplifier)

This diagram is separated by four blocks to describe what they are doing. First of all, Block1 shows the op-amp (TL072). This operates as a low-noise microphone pre-amp [3]. Its gain is only about 3.9 because the high output impedance of the drain of the FET inside the electrets microphone causes effective input resistor to be about 12.2k [3]. 4.7µF C2 capacitor has a fairly high value in order to pass very low frequency (about 20 to 30Hz) heartbeat sounds [3]. Block2 operates as a low-noise Sallen and Key, Butterworth low-pass-filer with a cut-off frequency of about 103Hz [3]. Resistors at output and feedback line, R7 and R8, provide a gain of about 1.6 and allow the use of equal values for C3 and C4 but still producing a sharp Butterworth response. The roll-off is 12dB/octave [3]. Block3 is a power amplifier IC with built –in biasing and inputs that are referred to ground [3]. It has a gain of 20, and it can drive any type of headphones including low impedance (8 ohms) ones [3]. Figure.5 shows the schematic diagram of Block3 op-amp, LM386 low voltage power amplifier and it show the explanation of built-in biasing and inputs that are referred to ground.

4. Hardware Design

PCB design used in Better Life Technology's electronic stethoscope device is developed from open-source circuit and we modified inside with PCB version components, voltage regulator, and a spike protection component. Open-source circuit used through-hole components and this circuit diagram made by Audioguru (nick name) provides all necessary schematics and theoretical details except a voltage regulator and a spike protection. Once we change through-hole components to SMD components, we had problems to find exactly same values and materials of components with the same performance. We will make a sample in PCB and figure it out. In this case, we decide to use 3V CR2032 coin battery because this battery is small enough and easier to use. But we notice that the SMD op-amp chips we found are not in operation with 3V power. Therefore, voltage regulator will be used and also spike protection will be used. In addition, potentiometer is used to volume control in original stethoscope circuit we provided above in Figure3, but we are not using potentiometer here because we don't need volume control in our hardware part.

4.1 Power Supply using Voltage Regulator

In open-source circuit diagram Figure.4, they used 9V and -9V voltage for input power source of circuit. The optional diagram from this has 741 op-amp but we will not use this in our device because we won't need LED for power notification. 6V and -6V of input power will be used in this product. With 3V coin battery, the input power is not 6V and -6V using Maxim680 voltage regulator. TL072 and LM386 op-amps we are using for SMD are required 4V to 10V supply voltage. Therefore, 6V of supply voltage is enough for the circuit, and we tested with 6V already and it worked properly. The following diagram shows the application diagram of Maxim680 voltage regulator and how this generates 6V and -6V. We also tested the device with 4V just in case, and as we expected, it worked because minimum supply voltage for both op-amp is 4V.

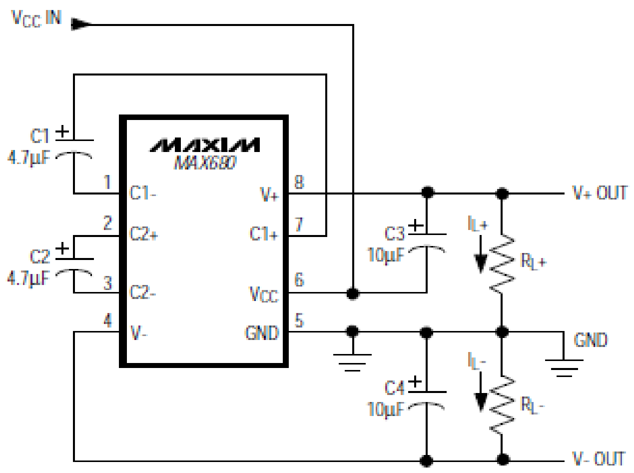

Figure6: Maxim680 voltage regulator diagram

4.2 Hardware Components and Description

Below, Figure.7 shows a simplified block diagram of the electronic stethoscope. Figure.8 shows the detail of this block diagram with all the components including a voltage regulator and spike protection.

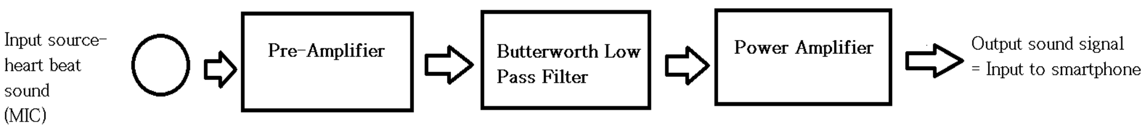

Figure7: Block diagram of hardware function

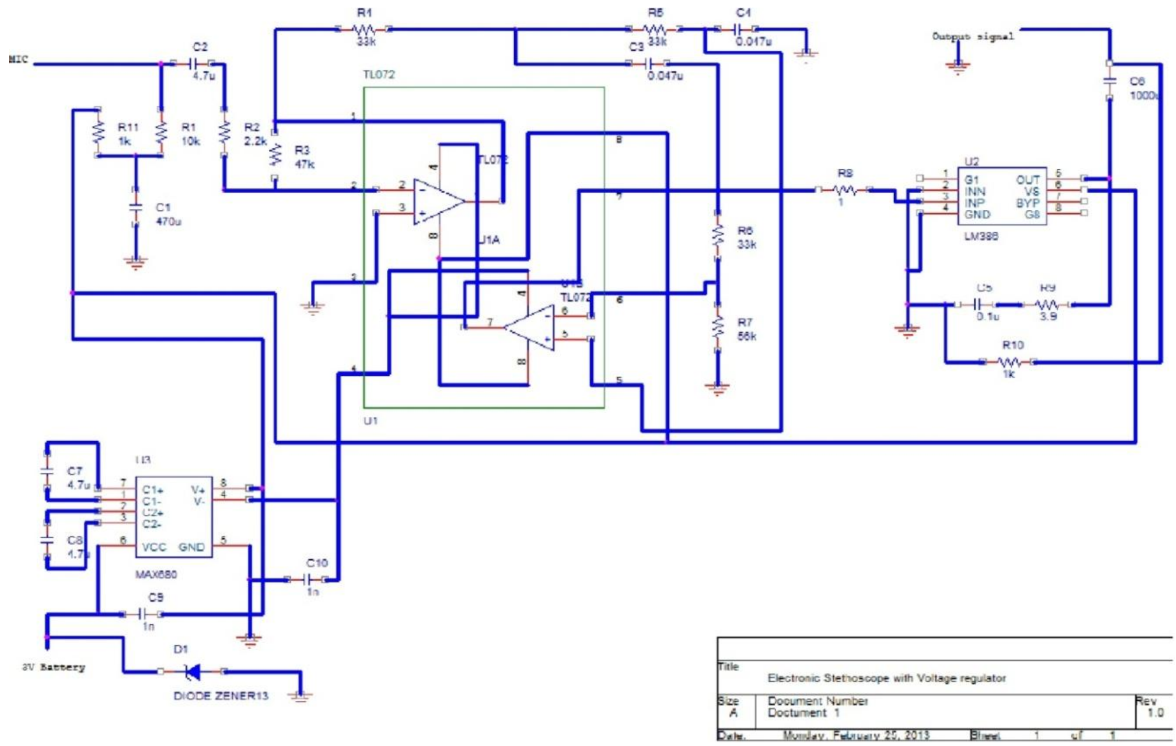

Figure8: Schematic diagram of PES

From the CR2032 3V battery, power is supplied and it goes though the Maxim680 voltage regulator. 6V and -6V are generated from this and these voltages are applied into input voltage of whole circuit and supply power for op-amps. 5V zener-diode (reverse voltage) is used for spike protection because the limit of supply voltage of this voltage regulator is 5V and it generates 10V. For example, if there is a spike from battery supply voltage and if it is higher than 5V, all the voltage will go to ground, so there are no any damages or effects in this circuit. As you can see in comparison between Figure3 and Figure.8, we replaced potentiometer with 1 ohm resistor because volume control is no longer needed. Therefore, the minimum resistor which can generate largest volume is used, and it worked in out prototype. However, we may use 2.2KΩ resistor because this might be enough at output volume. Next, after voltage regulator, pre-amplifier is performed using TL072, and Butterworth low-pass filter is performed using TL072 with different capacitors and resistors as well. Finally, power amplifier is performed using LM386 in U2. This power amplifier is for amplifying the heart beat sound at output.

4.3 Noise Considerations

Butterworth low-pass filter is used in this device and it reduces noise a lot. MIC head and rubber sleeve are also used here to collect heart beat sound and to reduce noise of other effects.

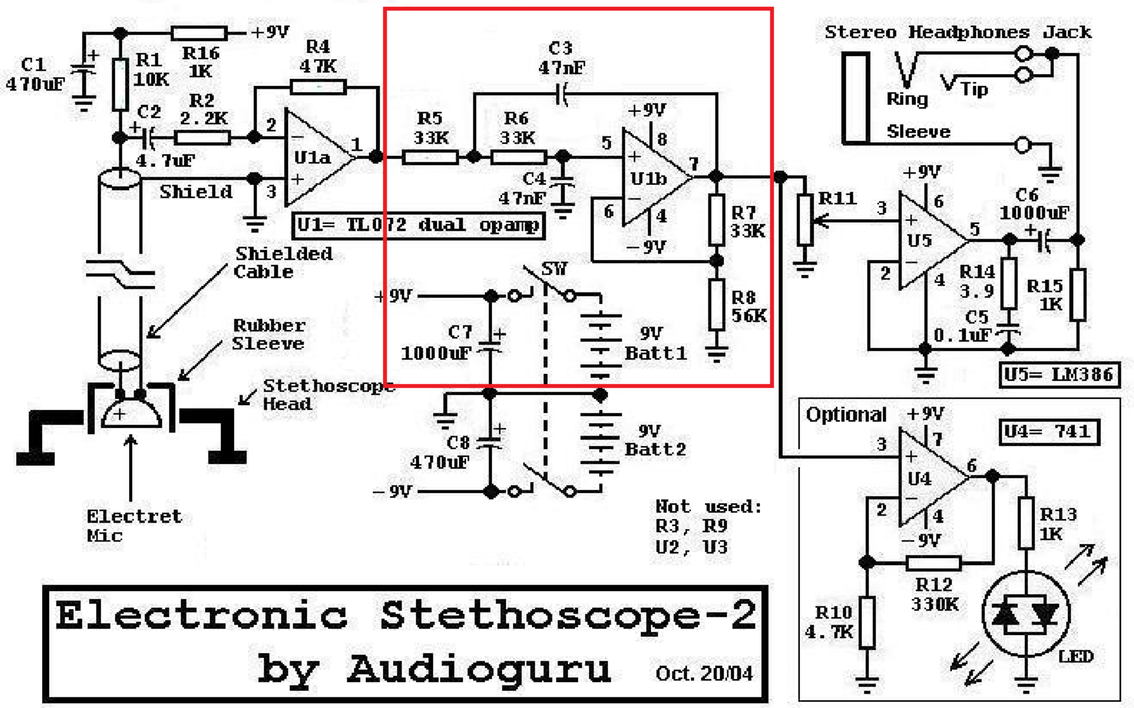

Figure9: Low-Pass filter for noise reduction

In figure.9, red block shows the Butterworth low-pass filter and it filters out very well. Thus, when output sound is heard by using an earphone, the sound was clear enough but it catches a little noise due to environment. However, we can figure this out by using rubber sleeve and stethoscope head in physical solution.

4.4 Safety Considerations

To protect electronic components from damage and prevent harm to developers and users, voltage spike protection is used by using zener-diode and the range of temperature for all the components is from -5℃ to 70℃ followed by datasheets of all components.

- Use of zener diode for spike protection
- Use hard case to protect from drop
- Proper insulation of wires
- Strong wiring connection for MIC connected in PCB

Rubber sleeve may not be maintained with high temperature; however it will be covered by head. Therefore, it will not be affected by direct damage.

4.5 Connector between Output Signal generated and Input Signal into smart phone

Our device will send a sound signal to input part of smart phone. At this time, audio signal wires from output of the device need to be transferred to a MIC wire of audio cable. The following figure shows how they will be connected.

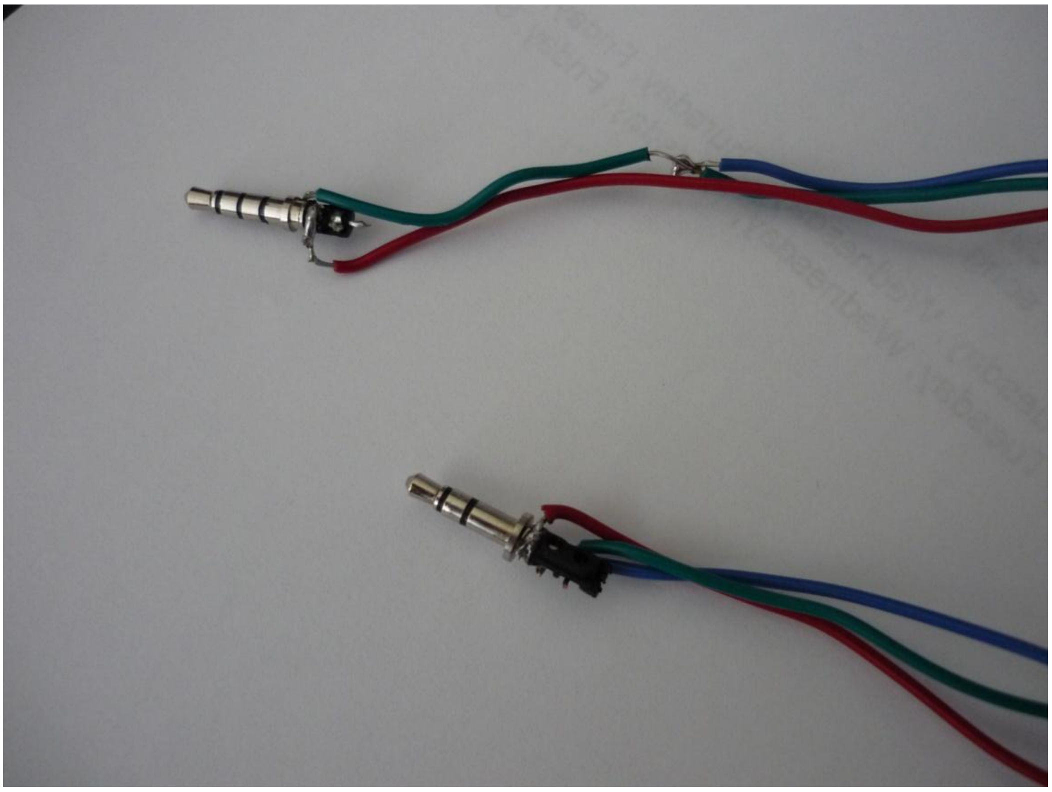

Figure10: Two connectors (4pin and 3pin audio cables)

3pin cable is connected to the output of PES hardware, and 4pin cable is connected to smart phone input. Ground sides are connected each other, and the stereo wires of 3pin cable are connected to MIC wire of 4pin cable. If we use 4pin cables for both sides, this would be better because consumer can switch either side of it for output of the device and input of smart phone.

5. Hardware Packaging

The packaging of Better Life Technology Personal Electronic Stethoscope is necessary for protecting the PCB. All of the Stethoscope hardware must be contained within the interior of the case. As for the physical requirement, the case must be small enough so the whole device is easy to carry. This section will outline the basic design of a proof-of-concept model.

5.1 Physical Design

The most fundamental criteria taken into consideration during the design process of the case was the need to be lightweight. Nevertheless, there is always a trade-off between a lightweight design and one that could withstand harsh environment abuse. After considering different options, we chose polypropylene. Polypropylene is a plastic polymer with the chemical formula C_3H_6. It is used in many different settings, both in industry and in consumer goods, and it can be used both as a structural plastic and as a fiber. This plastic is often used for food containers, particularly those that need to be dishwasher safe [4]. We choose polypropylene because of the price and the resistance to heat.

After the material is chosen, the next thing we are concerned about is the size of the box. We believe the size of the case will be around 90mm x 25mm x 25mm.

A rubber sleeve and the head of a stethoscope will be designed because we will use the electric microphone to hear heart beat. If the microphone is attached to human skin directly, the circuit is shorted. Therefore, we need a cover for the microphone and we decided to use rubber material to cover up the microphone and metal or aluminum material for the head.

5.2 Hardware Case

While we are designing the hardware case, we wish to minimize the size as much as possible. At the same time we have to be concerned about the heat coming from the PCB board. Furthermore, we have to consider the placement of the battery. Finally, Better Life Technology has come up with a 90mm x 25mm x 25mm box. The size of the box is based on the dimension from all the SMD components. As a result, the PCB board can perfectly fit into the hardware case. A detail drawing is shown on Appendix B.

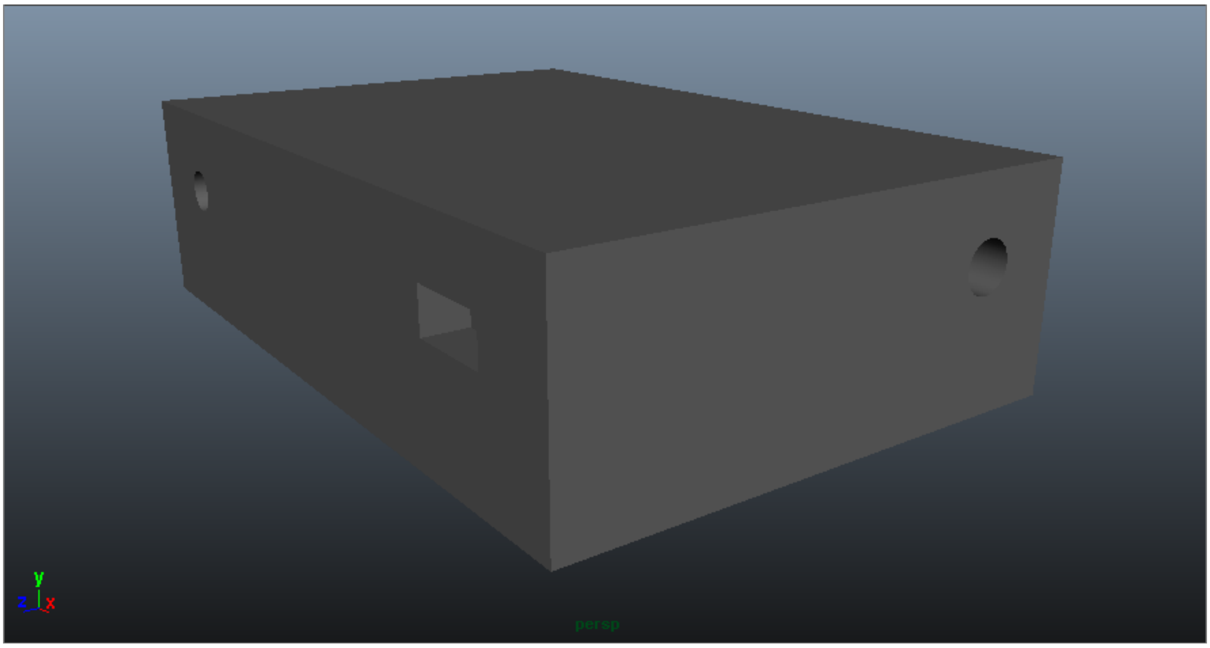

Figure11: Overall hardware case design

6. Software Design

The following section describes how the software part is developed. It will also mention the features and function of the product

6.1 Smart Phone Platform and Interface design

We chose to implement the display component on the iOS platform, which will allow the user to evaluate and analyze his or her heartbeat. MobileOne and Javascript will be used to design the software in the form of an iPhone App, and to compile the specific correlated functions in processing the received heartbeat data.

6.2 Features

Other than serving the purpose of a usable user interface, the app will also serve functions in measuring, parsing, and analyzing the received heartbeat data fed from the sensors. The specific functionalities include measurement of heart rate, beat sound characteristics, and presenting the data in a useful and conclusive form to the user. This will be accomplished by incorporating a preexisting user profile, which will include various physical data such as sex, age, body and name, and character specific feedback in health safety will be provided according to this profile. Additional information for an emergency contact person will also be recorded, which will include the person's phone number and name. This will allow descriptive messages relating to the user's health status to be sent to the user's contact in an emergency situation. The medical history of the user will be recorded as well, and can be checked by the user and the contact person at any time. The data that will be recorded by the app is displayed and explained in the table below.

Table1: Feature of software functions

Feature	Description
Heart beat rate measure	Display the number of heartbeat rate per minute
Heartbeat sound characteristic	Display characteristic of heartbeat sound, include Primary heart sounds strength heart murmurs, adventitious sounds, and gallop rhythms S3 and S4
Heartbeat sound analyze	Analyze heart sound compare with abnormal sample tell user potential disease or % of likely illness
Location of user	Detect location of user, send to contact when emergence happen
Test History record	Record user previous test history allow user to review.
Safe rage of determined	According to different age and gender of user app will choice different safe rage
Generate emergence SMS	When emergence happen will generate SMS send to pre-setting contact person. Tell them the situation and user location.

6.3 User Interface Design

The app will present usable data to the user in a clean and concise manner. The display structure is parsed into four sections; Startup, Test Page, Setting Page, and About Page, each serving different purposes in the user interface. The layout is show in the following figure in detail, and will be elaborated in this section.

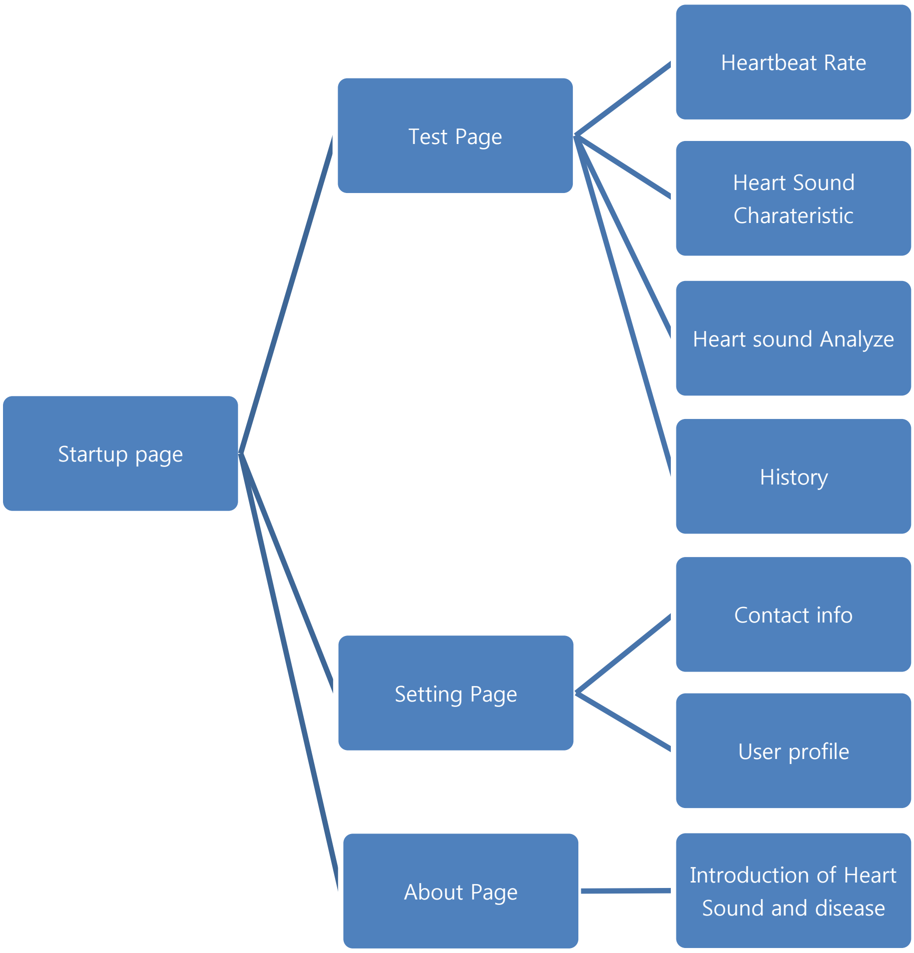

Figure12: User Interface Diagram

6.4 Startup Page

This page is the primary screen that will be displayed upon startup and initialization of the app. The user will be able to access the Test, Settings, and About pages from this stage via touch functionality on his or her iPhone. The display is shown in the figure below.

Figure13: Start-up page example

6.5 Test Page

The testing functions will be accessible through this window, which allows the user to perform analysis on his or her heartbeat status. The initial display will be a list of previously recorded heart rates, and can be accessed at any time. A new test can be initialized by clicking on an empty category, and the user will be brought to a new screen with data of current heart rate, sound characteristics, analysis, and the history. The designed app layouts are shown in the figures below.

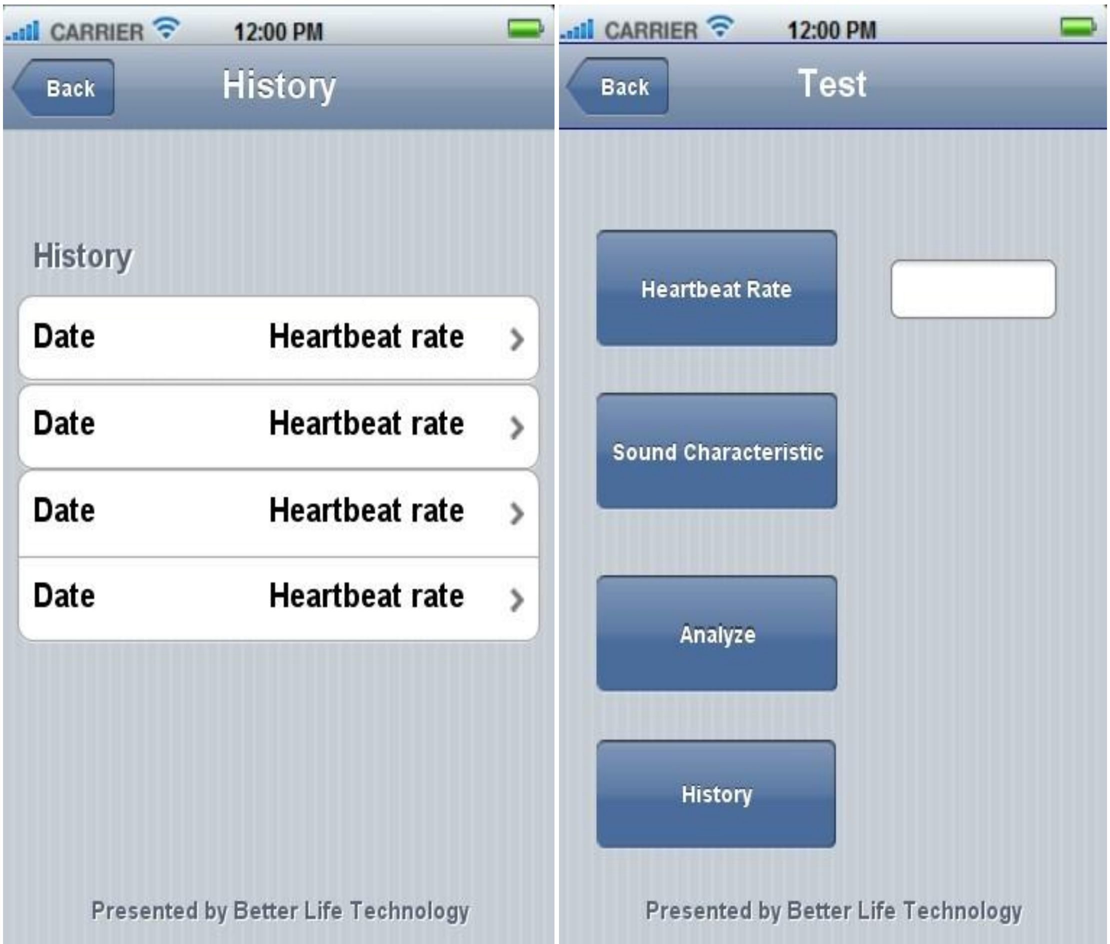

Figure14: Test page example

6.6 Setting Page

In this section, the user will be able to create a user profile, and for the contact person's. The information will include names and phone numbers for contacts, the user's name, age, and gender for the personal profile. The designed layouts are shown in the figures below.

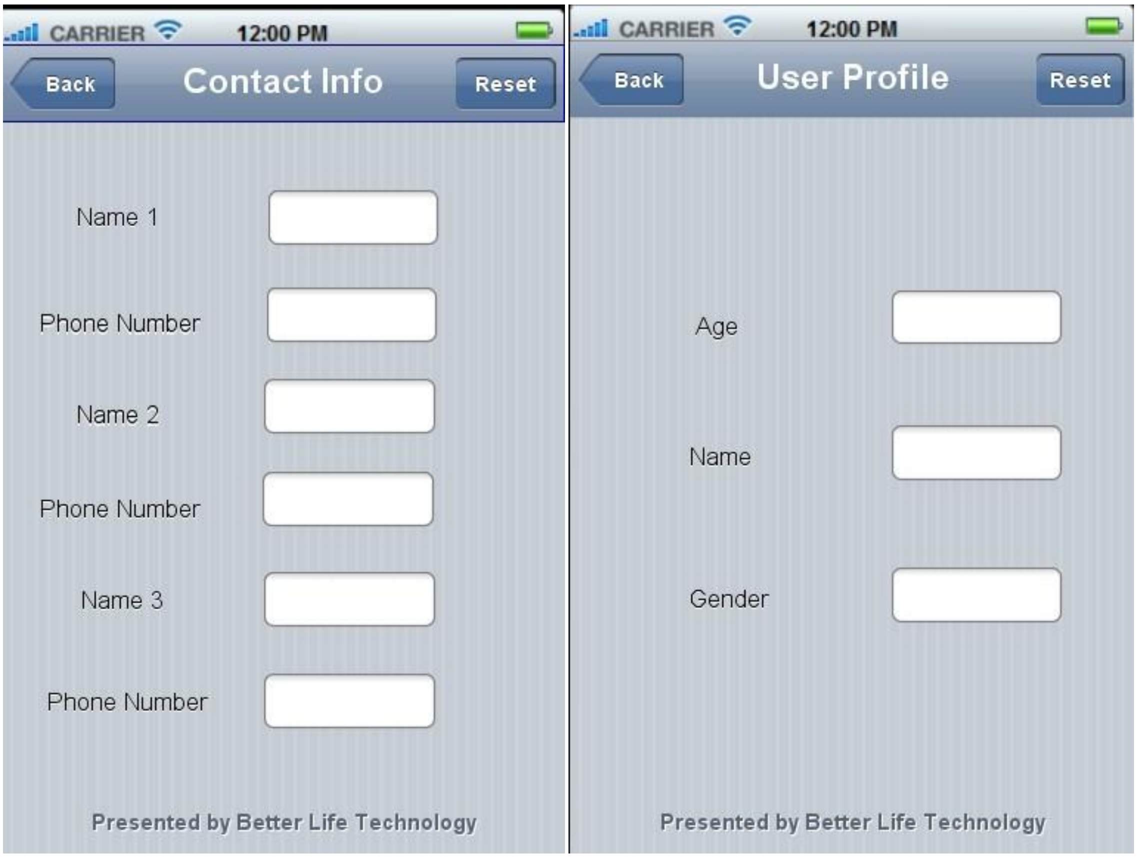

Figure15: Setting page example

6.7 About Page

This page is for informative purposes, and will display detailed information on heart beat noises and heart diseases. The "more" button will display background details regarding Better Life Technology. The display windows are shown in the figures below.

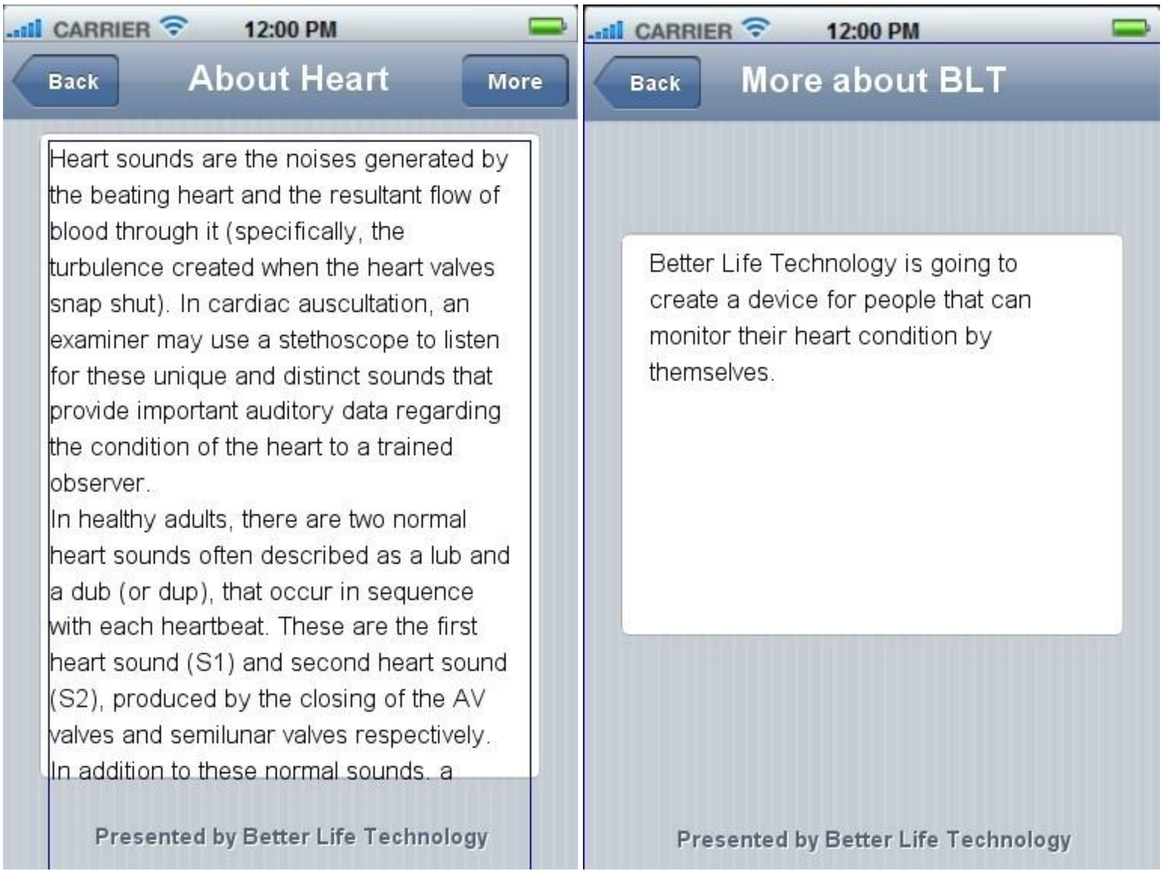

Figure16: About page example

Each accessible page is displayed in a flow chart below, which show the routes to access the functionalities.

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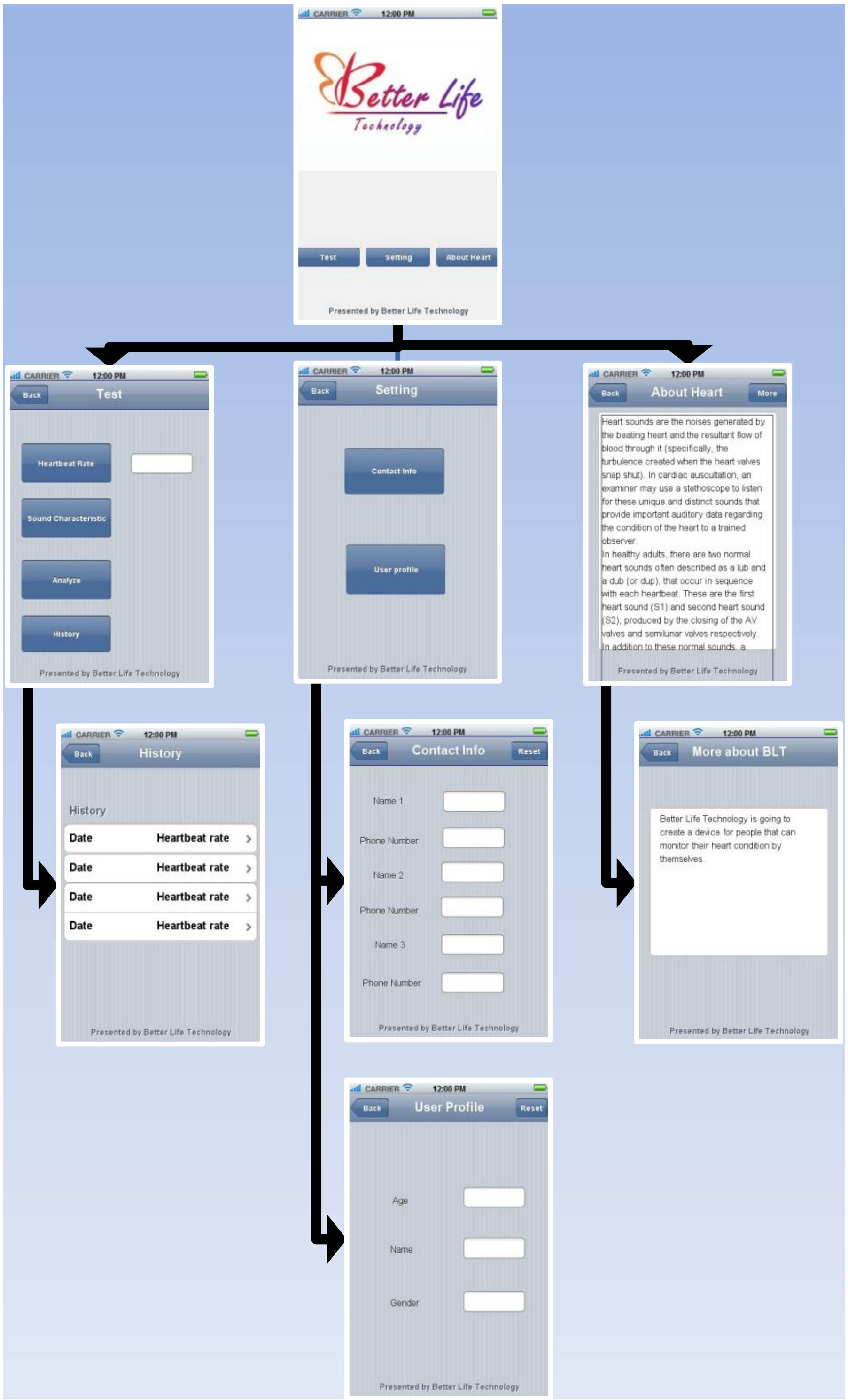


Figure17: Flow chart of software functions

7. System Test Plan

We divided our test into two section, hardware and software. For the hardware part, we have to ensure that the audio signal from the circuit is providing correctly. On the other hand, the result from the software needs to be accurate. The section below will explain the testing process to ensure all the parts of our product is working properly.

7.1 Hardware Tests

Unit Test 1: Correct audio output in a quiet area
User Input: A healthy heart beat

Conditions: Two channel oscilloscopes are used to capture the input and output. Compare the result.

Expected Observations: From the Oscilloscopes, the output should look exactly same as the input but with scaling.

Unit Test 2: Correct audio output in a noisy area
User Input: A healthy heart beat

Conditions: Two channel oscilloscopes are used to capture the input and output. Compare the result.

Expected Observations: From the Oscilloscopes, the result from the output will contain some noise, but should still look alike compared to the input.

Unit Test3: Output sound signal is going into smart phone as input signal.
4pin audio cable will be used and this cable will be made by two 4pin earphones.

Unit Test4: Drop test with specific condition.
The device with hard case will be dropped from 70 height on concrete covered by carpet.

Unit Test 5: EMC (Electromagnetic Compatibility)
See if the product will interface with other electronic product.

7.2 Software Test

Unit Test6: Feature the sound input data from a makeshift sensor in the form of an apple microphone.
Sound will be fed into the microphone to provide sound data to the app, in place of the actual heartbeat sensor. The app should be able to display information corresponding to the heart rate and the sound amplitude, and display the data in the Test Page, and provided a conclusive result regarding the health status of the user. The vocal input from the microphone will intentially go over the acceptable amplitude limit, which will display the corresponding warnings and send out an emergency message to the user's emergency contacts.

8. Conclusion

This document explains the design specification of the Personal Electronic Stethoscope (PES). The proof of concept device is well under development and we are confident in the completion of the final product by mid-April 2013. In addition to design solutions, a test plan is also outlined to ensure that Better Life Technology fulfill the requirements in the functional specification

9. Reference

[1] Hidden heart disease, not sports, behind sudden cardiac arrest. (2012, October) Percentage of people who have heart disease. [Online] http://www.thehindu.com/health/medicine-and-research/hidden-heart-disease-not-sports-behind-sudden-cardiac-arrest/article4043954.ece

[2] D.Balasubramanuam and D. Nedumaran (2010, August) Efficient Computation of Phonocardiographic Signal Analysis in Digital Signal Processor Based System. [Online] http://www.ijcte.org/papers/219-H304.pdf

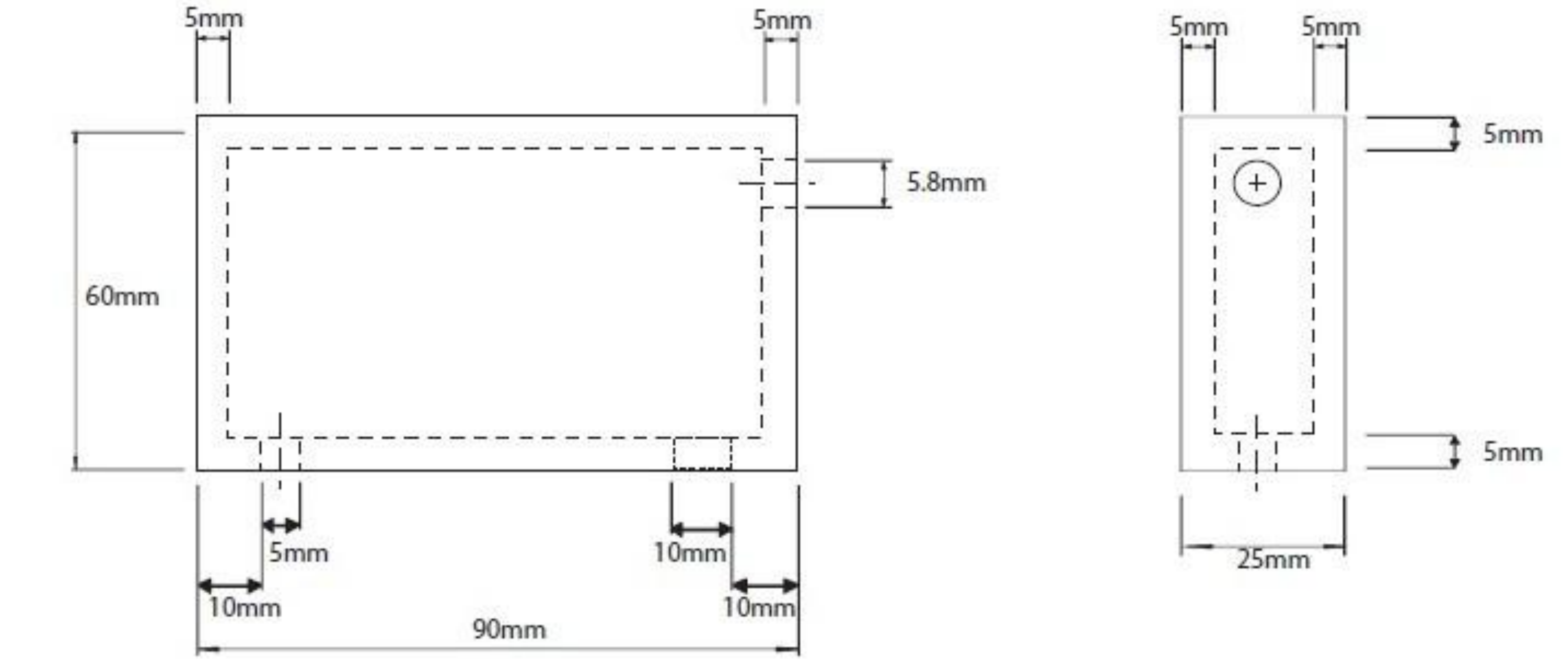
[3] Audioguru (2004. Oct). *Electronic Stethoscope* [Online] http://electronics-lab.com/projects/science/003/

[4] Brendan McGuigan (2013, February) What is Polypropylene? [Online] http://www.wisegeek.org/what-is-polypropylene.htm

Appendix A

Name	Components	Quantity
R1	10K 1/4W Resistor	1
R2	2.2K 1/4W Resistor	1
R4	47K 1/4W Resistor	1
R5,R6,R7	33K 1/W Resistor	3
R8	56K 1/4W Resistor	1
R10	4.7K 1/4W Resistor	1
R11	2.2K to 10K audio-taper (logarithmic) Volume Control	1
R12	330K 1/4W Resistor	1
R13,R15,R16	1K 1/4W Resistor	3
R14	3.9 Ohm 1/4W Resistor	1
C1,C8	470uF/16V Electrolytic Capacitor	2
C2	4.7uF/16V Electrolytic Capacitor	1
C3,C4	0.047uF/50V Metalized Plastic-film Capacitor	3
C5	0.1uF/50V Ceramic disc Capacitor	1
C6,C7	1000uF/16V Electrolytic Capacitor	2
U1	TL072 Low-noise, dual OPAMP	1
U4	741 OPAMP	1
U5	LM386 1/4W power amp	1
MIC	Two wire Electrets Microphone	1
J1	1/8” Stereo Headphones Jack	1
Batt1, Batt2	9V Alkaline Battery	2
SW	2-pole, single throw Power switch	1
Misc	Stethoscope head or jar lid, Rubber Sleeve for microphone	1

Appendix B



NOTES

This is the early stage of the prototype for the hardware packaging. It is designed to protect the PCB board. Further testing and revisions are required.

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Class ID: Prototype 1 / **Project No:** 0000-01	**Artist Name:** Real Yuen
Project Name: Personal Electronic Stethoscope	**Date Completed:** March 9, 2013
Approval: ☐ Not Approved, New Proof Required ☒ Approved	Approval Signature:

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