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SUSTAINABLE WIRELESS SENSOR DEVICE FOR HEARTBEAT MONITORING
WITH ENERGY HARVESTER

SIN TONG KOK

A report submitted in partial fulfillment of the
requirements for the award of the degree of
Bachelor in Mechatronic Engineering

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2013

I declare that this report entitled "SUSTAINABLE WIRELESS SENSOR DEVICE FOR HEARTBEAT MONITORING WITH ENERGY HARVESTER" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Special dedicated to my beloved family and friends

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Lastly, thanks to my family who had given their greatest encouragement and support for all these years. Without their helps, there will be a problem for me to complete this project.

ABSTRACT

With the recent advance in technology, wireless sensors device are now used in medical healthcare application especially in detecting human heartbeat. This project is to design a sustainable wireless sensor device for sensing heartbeat. The device can sense heartbeat rate from fingertips. An Android application was developed to receive the heartbeat rate for health monitoring. The heartbeat rate can be viewed in tables or graphs and can be stored in Google Fusion Table as online database. The user can generate energy using piezoelectric element to operate the device without external source. The energy will be harvested and stored into super capacitor to power the device.

ABSTRAK

Dengan kemajuan teknologi terkini, peranti sensor tanpa wayar digunakan dalam aplikasi penjagaan kesihatan perubatan terutama dalam mengesan degupan jantung manusia. Projek ini adalah untuk mereka bentuk alat sensor tanpa wayar yang mampu untuk mengesan denyutan jantung. Peranti boleh mengesan kadar denyutan jantung dari hujung jari. Aplikasi Android telah direkakan untuk menerima kadar degupan jantung untuk pemantauan kesihatan. Kadar degupan jantung yang boleh dilihat dalam jadual atau graf dan boleh disimpan di dalam Jadual Fusion Google sebagai pangkalan data dalam talian. Pengguna boleh menjana tenaga menggunakan unsur piezoelektrik untuk mengendalikan peranti tanpa sumber luar. Tenaga akan dituai dan disimpan ke dalam super kapasitor untuk menghidupkan peranti.

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LIST OF ABBREVIATIONS

LabVIEW	-	Laboratory Virtual Instrument Engineering Workbench
ECG	-	Electrocardiogram
IR	-	Infrared
BCD	-	Binary Coded Decimal
BPM	-	Beats per Minute
MIT	-	Massachusetts Institute of Technology
LED	-	*Light-emitting Diode*
VR	-	Voltage Regulator

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The number of people suffering from chronic diseases has been increased dramatically because busy and unhealthy modern life style. High blood pressure patients in China had increase from 130 million in 2007 to 200 million in 2011. In a scale of almost one to ten adults in China suffer from diabetes outbreak currently[1]. The limitation of the traditional medical care is the main reason of this problem. The patient could not get the proper and continuous advice from the doctor. The patients does not realized about their diseases until they go to do body checkup and maybe it is too late. After the patients knew about their diseases, the doctor could not help them because they had no time to go to the doctor for blood pressure or any health monitoring. In these cases, doctors could not give patients advice when necessary.

Besides that, another major problem is the increasing of the elderly in the population which needs more valuable bed needed space to provide a long term health care services in hospital. In China, the demand for healthcare is increasing rapidly due to the ageing population resulting from the one-child policy since 1970s, in which only one child is allow in a family[1].

These problems become the obstacle to prevent the patient to receive the doctor consultant for symptom monitoring. To solve this problem, the popularity of mobile phones could make a contribution. Recent innovation technologies such as mobile computing devices can be increasingly integrated into the healthcare environment and work together to create a reliable and secure communication backbone to allow access to vital information anytime and anywhere[2].Wireless technology and mobile network offer a great potential such as high mobility, wider coverage range and better data collection. Networked mobile devices in healthcare industry help clinicians to connect to the patients and provide them more efficient, accurate and better quality care with fewer medical errors[2].

Some examples of available wireless mobile in healthcare are shown in Figure 1.1 (a) iHealth Smart GlucoMeter which is a blood glucose system that apply the smart device like smartphone or smartphone with an attached device to measure blood glucose levels and monitoring their health[3]. (b) Zeo Sleep Manager is a small and light wireless head band, bedside display and set of online tools that measure sleep patterns through the electrical signals naturally produced by the brain[4].

(a) iHealth Smart GlucoMeter

(b) Zeo Sleep Manager

Figure 1.1: Example of Wireless Devices in Healthcare

The energy harvesting technologies is suitable to power up wireless sensor device due to the limitation of power sources. The ambient power sources (such as vibrational, thermal, wind solar and so on) can convert into usable electrical energy which is stored and used for performing sensing or actuation. The advantages of energy harvesting are to reduce the dependency on battery power, reduce the maintenance cost and provide the long-term solutions[5].

In this project, the general concept of this wireless sensor device is used to detect the heartbeat rate and send the data rate obtained to the user's smartphone for data collection. For hardware design, it concentrates on development of self-sustained wireless sensor device with energy harvesting. It consists of microcontroller, heartbeat sensor, energy harvester, transceiver, and piezoelectric film. The ambient energy selected is using piezoelectric which is the energy generated by vibration and human motion. For software design, it concentrates on the data transmitting and processing. The microcontroller will be programmed to sense/send data to the user's smartphone for data collection. The android graphical user interface (GUI) is developed to store and display the data obtained.

1.2 Objectives

Based on the problem statement above, there are several objectives need to be achieved at the end of the project:

- To design self-sustained wireless sensor device
- To develop a wireless sensor device which able to measure heartbeat
- To collect the data and display it in statistical order on the end user GUI Android application in smartphone

1.3 Problem Statement

People nowadays have no health awareness. Besides that, the patients cannot update their health condition continuously to the doctor. This caused the increase of health problems. The wireless sensor devices available in the market usually need an external power supply to power it. The small volumetric devices are limited in amount of energy that can be stored. Hence the batteries in finite energy supply must be optimally used to perform the sensing and communication tasks. The batteries must be replaced regularly which is a costly. Besides, the hardware designed must have low power consumption. The energy harvested is can be stored in the power storage which is super capacitor and sufficient to supply the power to complete a cycle of data recording. A portable and wireless device was needed to replace the non-portable and large medical instrument to record and present the data.

1.4 Scope

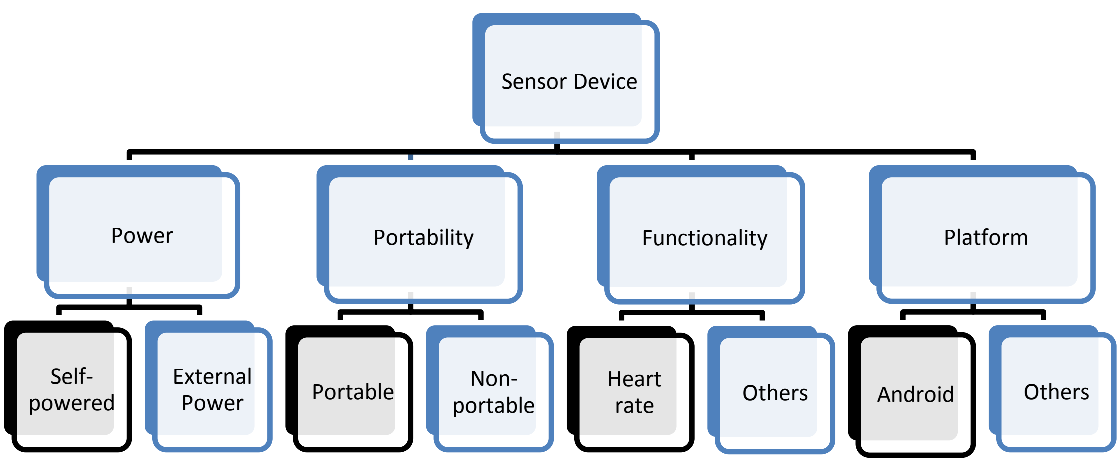

Figure 1.2: Scope of Project

There are four main elements need to be considered in this project as shown in Figure 1.2 which are in term of power, portability, functionality and platform using. Firstly, the power of the sensor device will focused on self-powered which are power by energy harvesting power supply without external power supply. Next, the device is portable and can be operate without any external wiring. The functionality of the device is to measure human's heart rate. Lastly, the application will be developed using Android platform which providing a graphical user interface to user for data collection and analysis.

1.5 Summary of Work

Work Schedule

1. 1st Semester, 2012/2013

Weeks	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
Project Proposal																
Finalized Proposal																
Background study																
Components purchasing																
Research on Android GUI Programming																
Start design & build the device																
Report/Thesis Writing																
Presentation																

Table 1.1: Gantt Chart for Final Year Project 1

2. 2nd Semester, 2012/2013

Weeks	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
Continue device building																
Coding on ATMega328																
Continue Android GUI Programming																
Debugging software and improve																
Preparation for demo/presentation																
Report/Thesis Writing																
Design Poster																
Presentation																
Thesis compilation																

Table 1.2: Gantt Chart for Final Year Project 2

CHAPTER 2

LITREATURE REVIEW

2.1 Chapter Overview

This chapter will discuss about the related project done by previous UTM students and online sources. These related works have been reviewed carefully in order to improve the quality and reliability of this project. Besides that, there are some useful ideas that can be implemented in this project from other similar projects.

2.2 Related Projects

2.2.1 EZ430-Chronos Watch as a Wireless Health Monitoring Device by Ili Najaa Binti Mohd Nordin (UTM 2011)[6]

This project built a wireless health monitoring system develop in Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) which is able to transmit and receive electrical signals from a patient's to an EZ430-Chronos sport watch.

The recommendation of the project is use PIC microcontroller instead of using computer as a transmitter station. It is very convenient from using a computer which is consumes a lot of power if compared with the PIC microcontroller. The hardware can packed into a small device to control the inputs and outputs. Hence, the device has high portability to carry around.

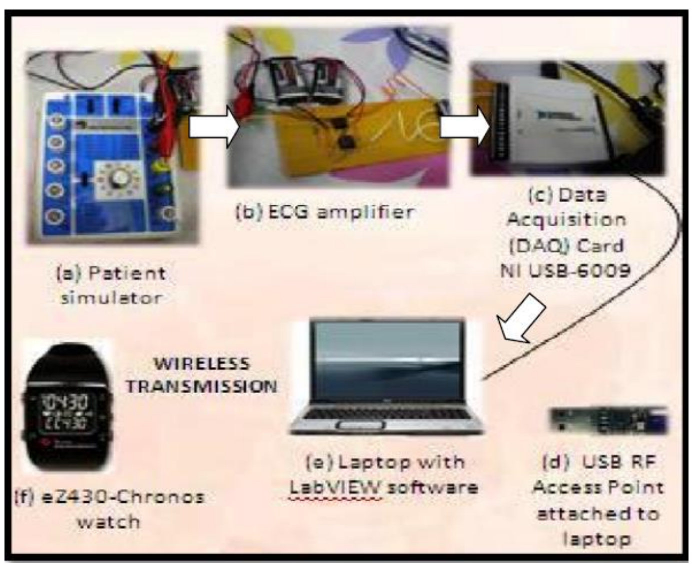

Figure 2.1: EZ430-Chronos Watch as a Wireless Health Monitoring Device

2.2.2 Development of Electrocardiogram (ECG) Wireless Sensors Board for Medical Healthcare Application by Nor Syahidatul Nadiah binti Ismail (UTM 2009)[7]

This project built an ECG Wireless Sensors Board for healthcare application which is able to transmit ECG signals using XBEE wireless transmission between the board and computer.

XBEE module used is limited to 100m range. If over this range, the signals might not be received. The board developed is large and hard to carry by the patient.

Figure 2.2: Development of ECG Wireless Sensors Board for Medical Healthcare Application

2.2.3 A Smartphone-Centric Platform for Personal Health Monitoring using Wireless Wearable Biosensors[8]

This project aimed to develop a platform in solving the issues associated with wearable sensors and mobile phone based monitoring. This platform is made by three main elements which are wearable biosensor, controller for the biosensor and the mobile monitoring unit. This platform can be operated in different phone operating system such as Linux and Symbian and can support different sensors. The wearable devices had a closed loop control features to reduce the power consumption based on real-time health condition.

The platform is applied to the older version of mobile phones. There is a more powerful platform can be replaced to perform the same task such as Android platform.

CHAPTER 3

METHODOLOGY AND APPROACHES

3.1 Introduction

The development of this project combines knowledge from various discipline of study, thus a systematic approach for the development process is crucial. This chapter describes the development methodology and guidelines in designing the device.

The design process start with hardware design, software design, hardware and software integration and lastly is testing and calibration. Once the objectives and application were identified, research had been carried out to determine the suitable component for the hardware design. The hardware and software were developed separately and will later be integrated together to form a complete system. Testing and calibration will be carried out to test and improve the complete system.

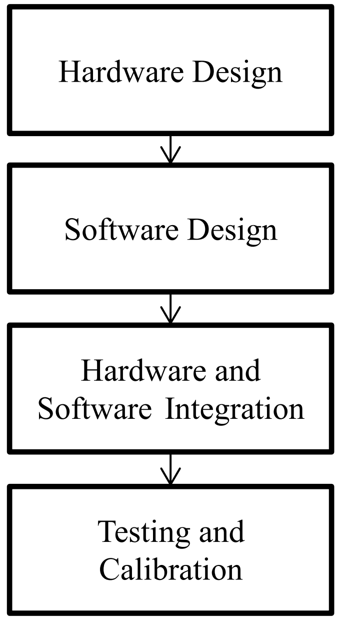

Figure 3.1: Design Process

3.2 Hardware

3.2.1 Processing Unit

PIC16F628 manufactured by Microchip has been chosen as the processing unit for wireless sensor device. This chip had been chosen based on several reasons. The main reason is this chip has a low voltage and current consumption which enable the device to be portable with small battery storage. Besides, it has a small size and has enough output ports for my application. It also supports serial interfacing.

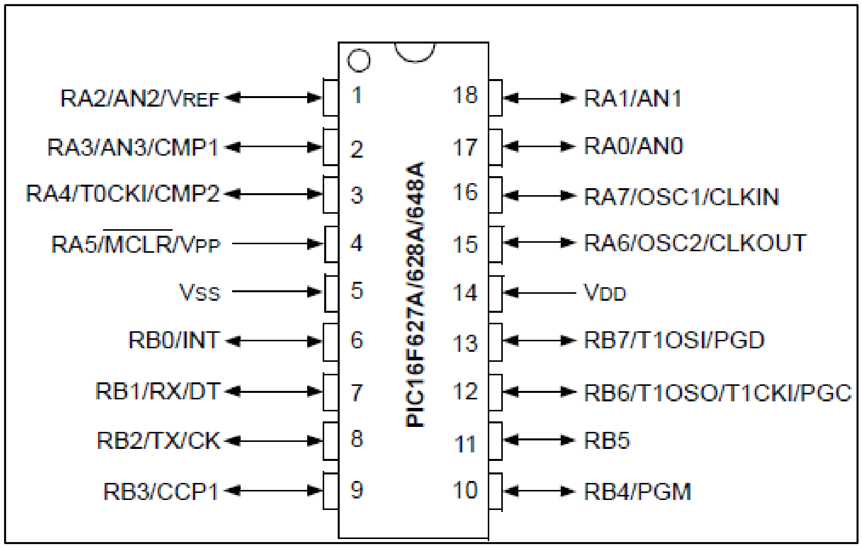

Figure 3.2: PIC16F628 Pin Diagram

3.2.2 Piezoelectric Harvesting Power Supply (LTC3588 Breakout)

Figure 3.3: Piezoelectric Harvesting Power Supply LTC3588 Breakout

The LTC3588 Breakout integrates a low-loss full-wave bridge rectifier with a high efficiency buck converter to form a complete energy harvesting solution optimized for high output impedance energy sources such as piezoelectric transducers.

Four output voltages, 1.8V, 2.5V, 3.3V and 3.6V, are pin selectable with up to 100mA of continuous output current; however, the output capacitor may be sized to service a higher output current burst. An input protective shunt set at 20V enables greater energy storage for a given amount of input capacitance.

This breakout board had been chosen because it works perfectly with low power devices. The energy harvested from the ambient environment such as vibration or human motion to power up the devices. This can eliminated the replacement of external power supply.

Features of LTC3588 Breakout

- 950nA Input Quiescent Current (Output in Regulation – No Load)
- 450nA Input Quiescent Current in UVLO
- 2.7V to 20V Input Operating Range
- Integrated Low-Loss Full-Wave Bridge Rectifier
- Up to 100mA of Output Current
- Selectable Output Voltage (1.8V, 2.5V, 3.3V, 3.6V)
- High Efficiency Integrated Hysteretic Buck DC/DC
- Input Protective Shunt – Up to 25mA Pull-Down ≥ 20V
- Wide Input Undervoltage Lockout (UVLO)
- Available in 10-Lead MSE and 3mmx3mm DFN Packages

3.2.3 Volture Piezoelectric Energy Harvester[9]

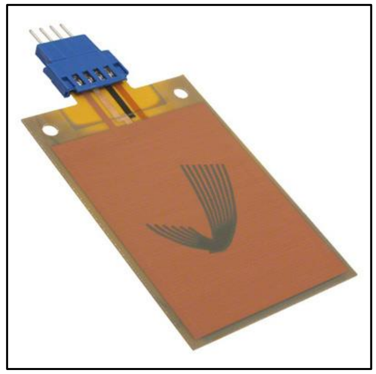

Figure 3.4: Volture Piezoelectric Energy Harvester (film)

Volture Piezoelectric Energy Harvester convert wasted energy from mechanical vibrations into usable electrical energy. This film can interface directly to LTC3588 Breakout. LTC3588 Breakout will rectify a voltage waveform and stored the harvested energy on an external capacitor. This combination forms a full energy harvesting solution.

3.2.4 Electric Double Layer Super Capacitor

Figure 3.5: 10F/2.5V Super Capacitor

Super capacitors have the highest available capacitance values per unit volume and the greatest energy density of all capacitors. In this project, super capacitor is used as temporary storage to store the harvested energy.

3.2.5 Cytron Bluebee Module

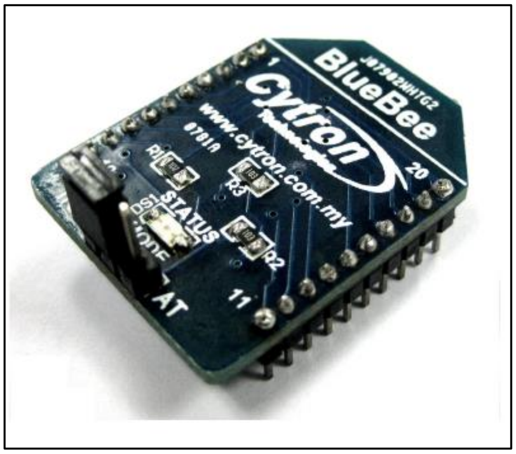

Figure 3.6: BlueBee Module

BlueBee module is used as a transceiver due to some reasons which are low in cost and suitable for low power wireless sensor application. Besides, this module is small which is suitable to use in portable device.

Pin	Name	Description
1	3V3	3.3V power supply for Bluebee
2	TXD	UART Data Output
3	RXD	UART Data Input
4	NA	NA
5	RESET	Reset for Bluebee
6	P9	Connection Indicator : High = Connected, Low = No Connection
7	NA	NA
8	P8	LED, Mode indicator, connected to BlueBee status LED
9	NA	NA
10	GND	Ground Port
11	NA	NA
12	CTS	UART clear to send, active low
13	NA	NA
14	NA	NA
15	NA	NA
16	RTS	UART request to send, active low
17	NA	NA
18	NA	NA
19	NA	NA
20	NA	NA

Table 3.2: Pin Function for BlueBee Module[10]

3.2.6 12W, 3.3/5V Input Wide Output Adjustable Boost Converter

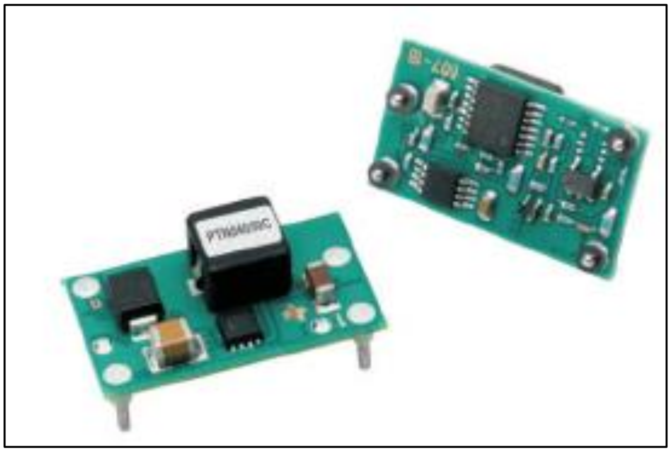

Figure 3.7: 12W, 3.3/5V Input Wide Output Adjustable Boost Converter (PTN04050C)

The PTN04050C is a 4-pin boost-voltage regulator product. The PTN04050C provides high-efficiency, step-up voltage conversion for loads of up to 12W in 2.95V to 5.5V input range. The output voltage is set using a single external resistor to set any value within the range, 5V to 15V. In this project, 5kOhm is selected to set the output voltage about 9.0V.

Features of PTN04050C

- Up to 12 W Output
- Wide Input Voltage Range and General-Purpose Applications (2.95 V to 5.5 V)
- Wide Output Voltage Adjust (5 V to 15 V)
- High Efficiency (Up to 90%)
- Operating Temperature: –40 ℃ to 85 ℃
- Surface Mount Package Available

3.2.7 Logic Converter 4 Channels (LC04A)

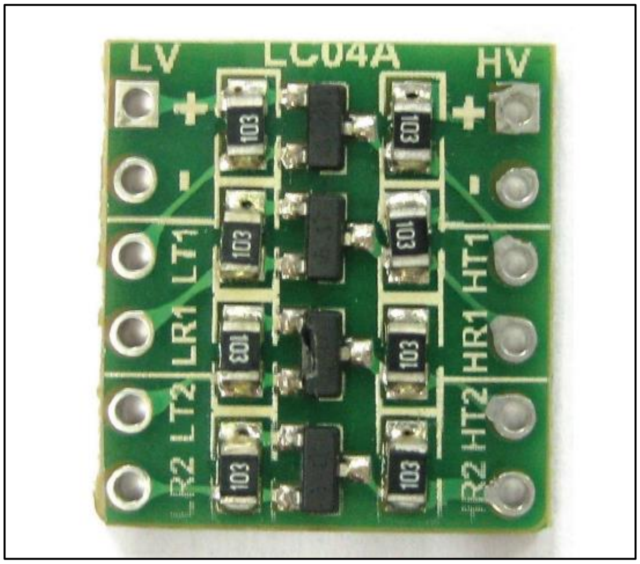

Figure 3.8: Logic Converter 4 Channels (LC04A)

LC04A is a logic converter which help user to steps down and step up 5V signals to 3.3V and 3.3V to 5V rapidly. It have four pin on high side to convert to four pin at the low side[11]. In this project, LC04A used to step down 5V from microcontroller to 3.3V of Bluebee module.

Features of LC04A

- Ways (bidirectional), logic zero will wins (dominant)
- LV must be lower voltage than HV
- LV can be as low as 1.8V, HV can go up to 5V.
- Channels, you can have TX, RX, CTS and RTS.
- UART, SPI, I2C, or simple sensor input that have different voltage level.
- Not analog converter nor amplifier.
- Dimension: 15mm x 16mm
-

3.2.8 Quad Operational Amplifier (LM324)

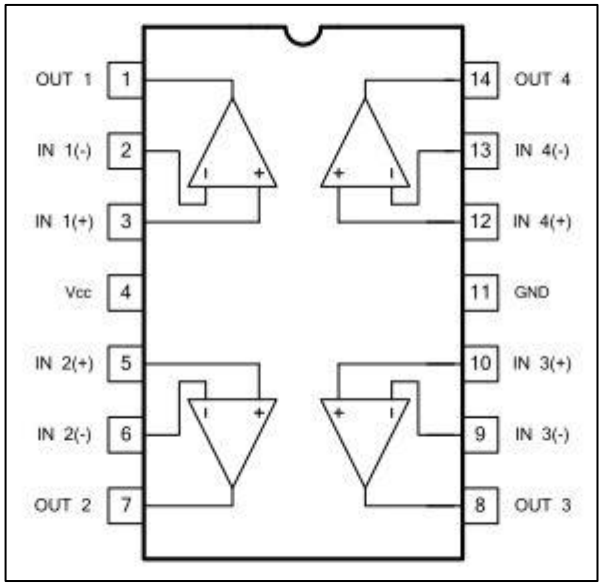

Figure 3.9: Quad Operational Amplifier (LM324) Pin Diagram

The LM324 consist of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply[12]. In this project, two operational amplifiers are needed to filter the noise and provide a gain to amplifier the weak signal pulse from the finger tip.

Features of LM324

- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain: 100dB
- Input Common Mode Voltage Range Includes Ground
- Large Output Voltage Swing: 0V to VCC -1.5V
- Power Drain Suitable for Battery Operation

3.2.9 IR Sensor with Socket

Figure 3.10: IR Sensor with Socket

The IR sensor set with socket consists of an IR transmitter and an IR receiver mounted side by side and is covered by a rectangular socket which also minimizes the influence from the environment. The IR transmitter transmits an infrared light into the fingertip placed on the sensor unit and the IR receiver senses the portion of the light that is reflected back. The blood volume inside the fingertip determines the intensity of reflected light. Therefore, heartbeat rate converted the reflected infrared light that can be detected by the photodiode. The amplitude of the reflected infrared light then converted to pulse with signal conditional circuit. The pulse then can be readable by the microcontroller and the heartbeat rate can be determined.

3.2.10 BCD to 7 Segment Decoder (74LS48)

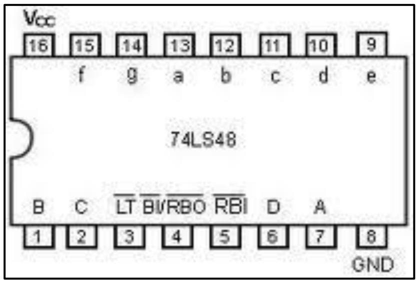

Figure 3.11: BCD to 7 Segment Decoder (74LS48) Pin Diagram

In order to reduce the number of pin used by 7 segment display, 74LS48 is used. Different BCD inputs from 0000-1001 apply to input terminal, the IC produces equivalent outputs from 0-9.

3.2.11 Voltage Regulator LM7805 and LM1117T

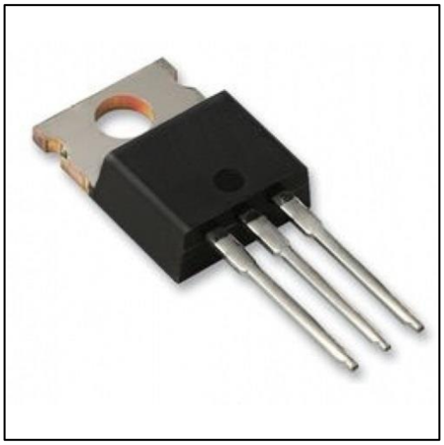

Figure 3.12: Voltage Regulator LM7805 and LM1117T

A voltage regulator is designed to automatically maintain a constant voltage level. In this project, two different voltage regulator 5.0V and 3.3V are used because all components are used 5.0V except Bluebee is used 3.3V.

3.2.12 3.7V 1100mAh Li-Ion Battery

Figure 3.13 3.7V 1100mAh Li-Ion Battery

This is a typical Lithium Ion rechargeable battery in cylindrical shaped that offer 1100mAh actual capacity. The size is small and suitable for portable project.

3.3 Circuitry Design

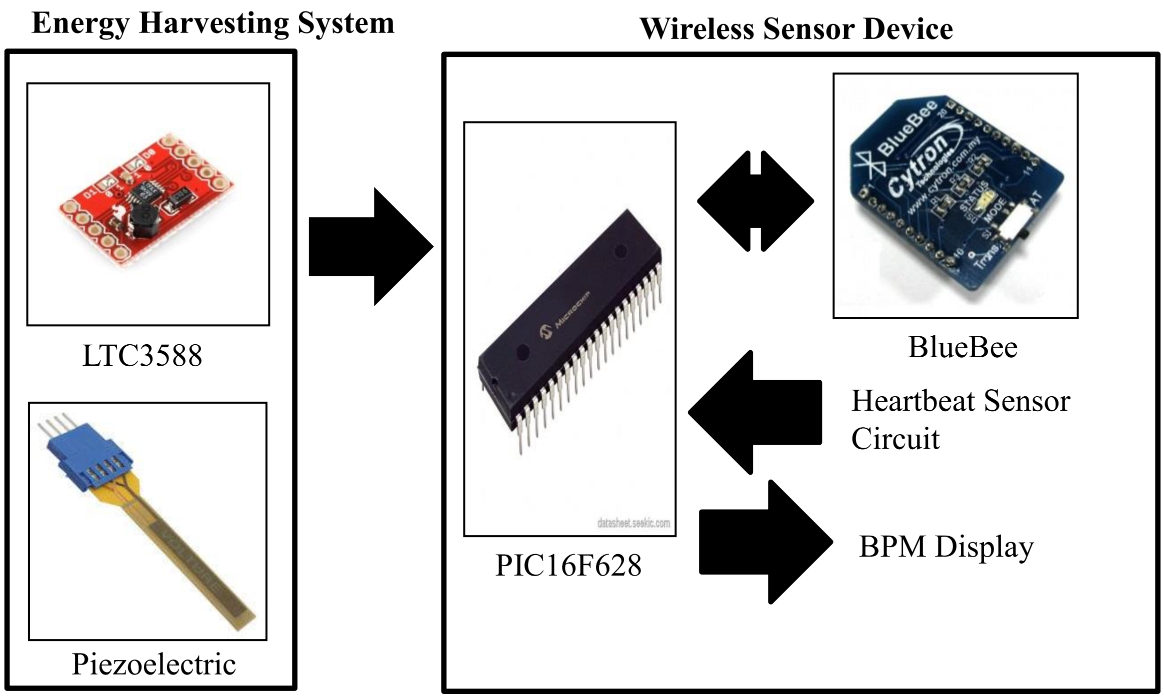

Figure 3.14: Wireless Sensor Device General Diagram

Figure 3.7 showed the wireless sensor device consist of these main components. PIC16F628 serves as a brain for the device. The sensor using is heartbeat sensor circuit to sense the heartbeat. The communication component using here is Bluebee and will connect to the smartphone. The power source is generate from the piezoelectric patch and LTC-3588 will collect and regulate the harvested energy and then the energy will use to power up the sensor device.

3.3.1 IR Sensor and Conditioning Circuit

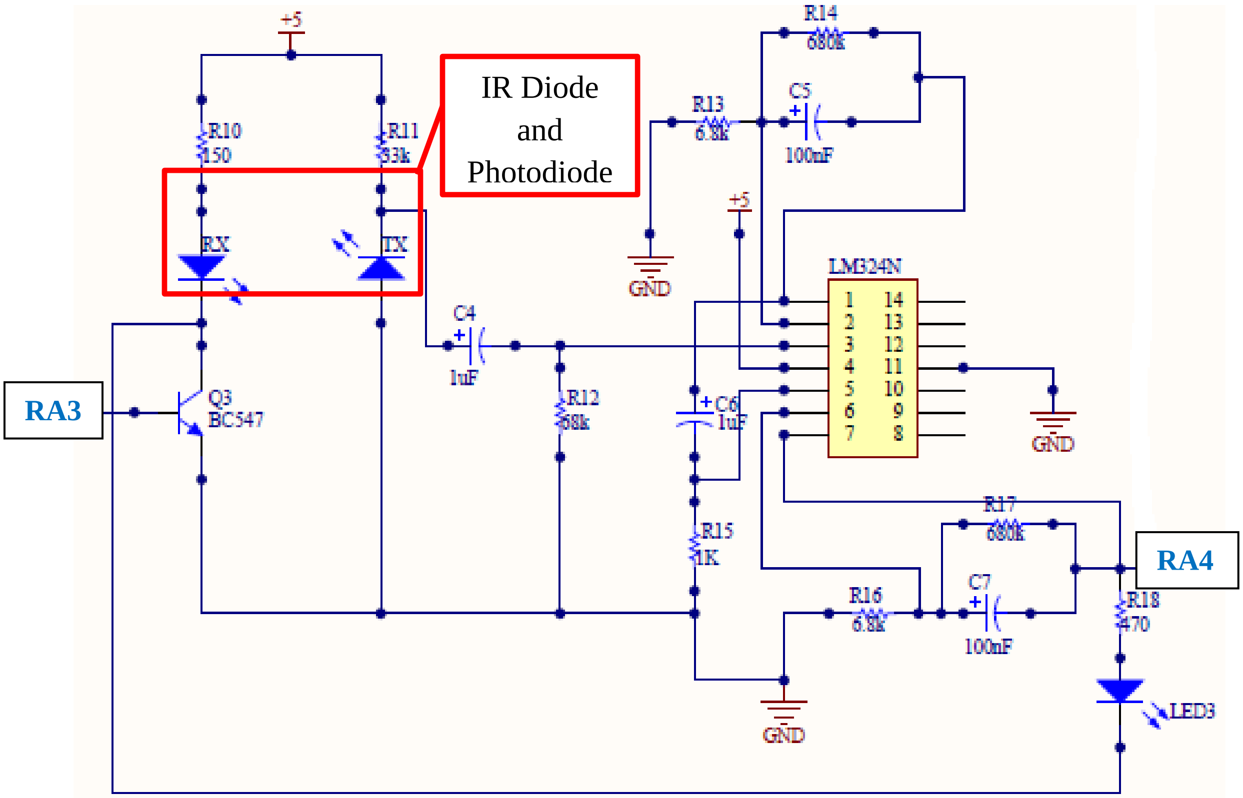

Figure 3.15: IR Sensor and Conditioning Circuit

The signal conditioning circuit consists of two identical active low pass filters. The circuit is designed to have 2.34 Hz cut-off frequency which is the maximum heart rate can be measured is 150 bpm. The operational amplifier IC used in this circuit is LM324N, a low power quad Op-Amp chip. The filtering is used to block any higher frequency noises present in the signal. The total amplification is 10201 which each gain of the filter stage is 101.

$$Gain\ of\ each\ stage = 1 + \frac{Rf}{Ri}$$

$$= 1 + \frac{680k}{6.8k}$$

$$= 101$$

$$Cut - off\ Frequency = \frac{1}{2\pi RfCf}$$
$$=2.34\text{Hz}$$

The dc component of the signal is block using a 1 uF capacitor at the input of each stage. From the equations above, the calculated results are 101 for gain for each stage and 2.34Hz for cut-off frequency. The weak signal generated from the photo sensor unit is boosted before converting into a pulse through a two stage amplifier/filter. Whenever a heartbeat is detected, the LED (RA3) blinks. The T0CK1 (RA4) input of PIC16F628A receives the output from the signal conditioner.

3.4 Software Implementation

Software implementation will be discussed in this section. In this project, there are two main software will be using include the MPLAB in C programming and MIT App Inventor. The MPLAB used to program the Microcontroller PIC16F628 to perform collect the data from the heart beat sensor circuit and send to user's smartphone through Bluetooth communication. The Android application used to develop a Graphical User Interface (GUI) for user to see and interact with. The GUI provides a control menu for user to select the option to perform a certain task.

3.4.1 MPLAB

MPLAB is free software which can be obtained from the internet. Both Assembly and C programming languages can be used with MPLAB. In this project, C programming language is used. There are three main parts for Microcontroller PIC16F628 which is BPM calculation, BPM display and the Bluetooth communication between sensor device and Android based smartphone.

3.4.1.1 MPLAB Program

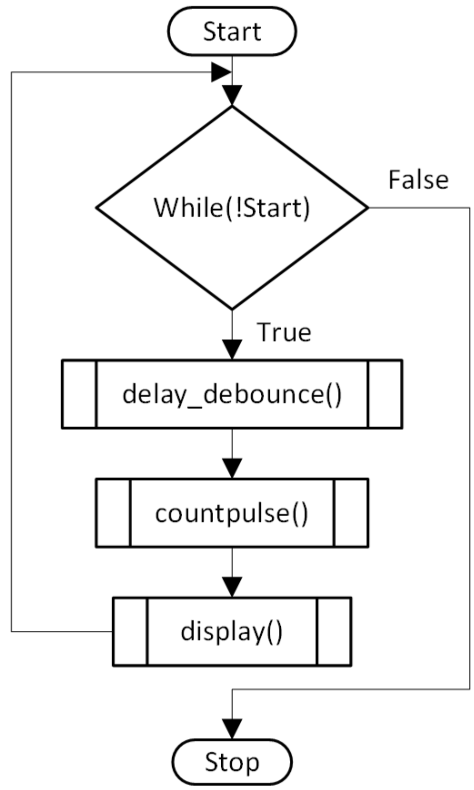

Figure 3.16: Flowchart of Main Program

This section will discussed some of the important subroutine of the program for Microcontroller PIC16F628. Figure 3.16 shows the flowchart of the main program. When start button is pressed, the program will start to operate.

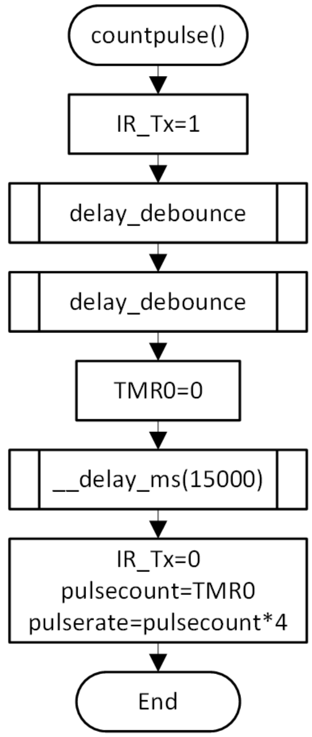

Figure 3.17: Flowchart of Countpulse() Function

```
//BPM Measurement Function
void countpulse()
{
        IR_Tx = 1;
        delay_debounce();
        delay_debounce();
        TMR0=0;
        __delay_ms(15000);  //Delay 15 Sec
        IR_Tx = 0;
        pulsecount=TMR0;
        pulserate=pulsecount*4;
}
```

Figure 3.17 shows the flowchart of Countpulse() function. This function is used to measure the BPM. When start button is pressed, the microcontroller activates the IR transmission in the sensor unit for 15 seconds. During this interval, the number of pulses collecting at the T0CKI input is counted. The actual heart rate would be 4 times the count value, and the resolution of measurement would be 4. IR transmission is controlled through RA3 pin of PIC16F628.

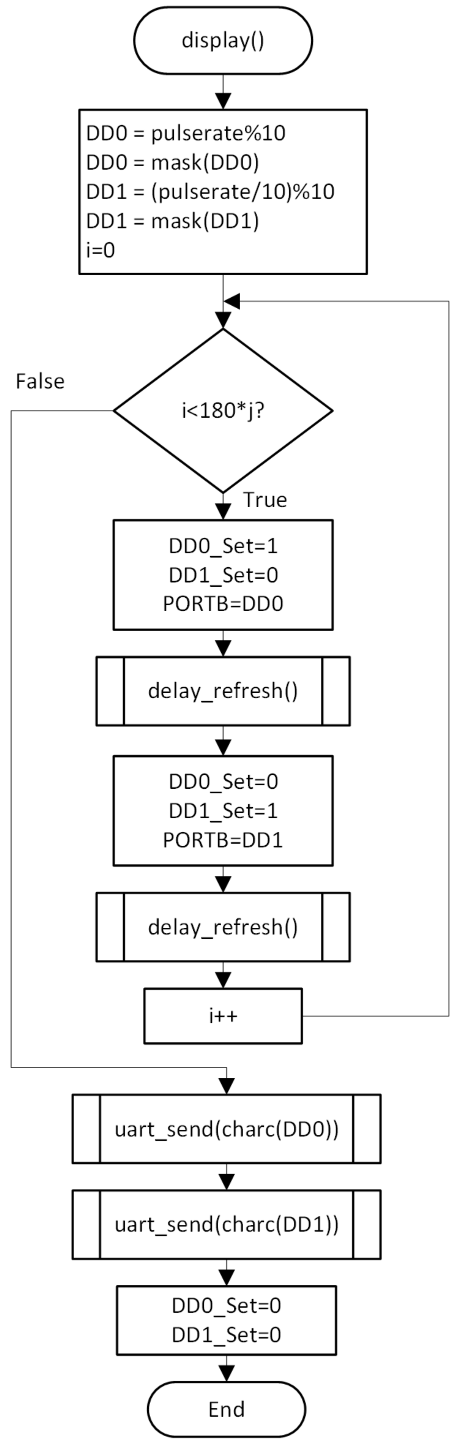

Figure 3.18: Flowchart of Display() Function

```
//BPM display in 7 Segment Display Function
void display()
{
 DD0 = pulserate%10;
 DD0 = mask(DD0);
 DD1 = (pulserate/10)%10;
 DD1 = mask(DD1);

//7 Segment Display Switching Loop
 for (i = 0; i<=180*j; i++)
{
        DD0_Set = 1;
        DD1_Set = 0;
        PORTB = DD0;
        delay_refresh();
        DD0_Set = 0;
        DD1_Set = 1;
        PORTB = DD1;
        delay_refresh();
  }
        uart_send (charc(DD0));
        uart_send (charc(DD1));
        DD0_Set = 0;
        DD1_Set = 0;
}
```

Figure 3.18 shows the flowchart of Display() function. This function is used to display the BPM in the 7 segment display. The pulserate is display using mask function to get the first digit and the second digit and store in DD0 and DD1. Next, DD0 and DD1 digits will display in two 7 segment display by on off the transistors in the for loop. After that, the BPM will sent byte by byte to Android based smartphone via Bluetooth

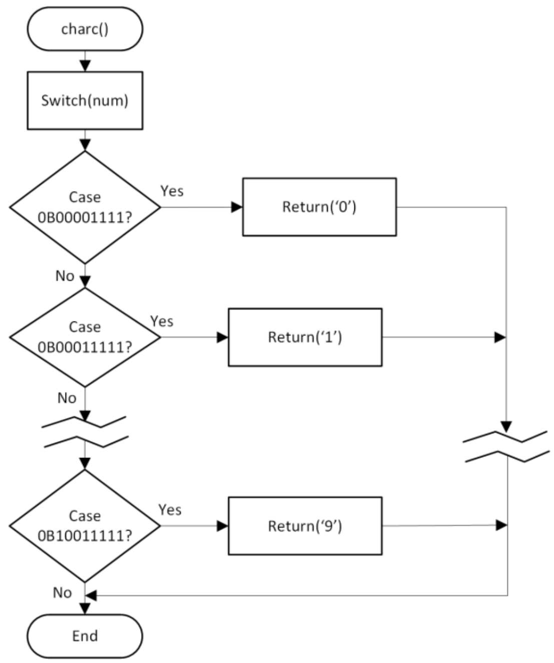

Figure 3.19: Flowchart of Mask() Function

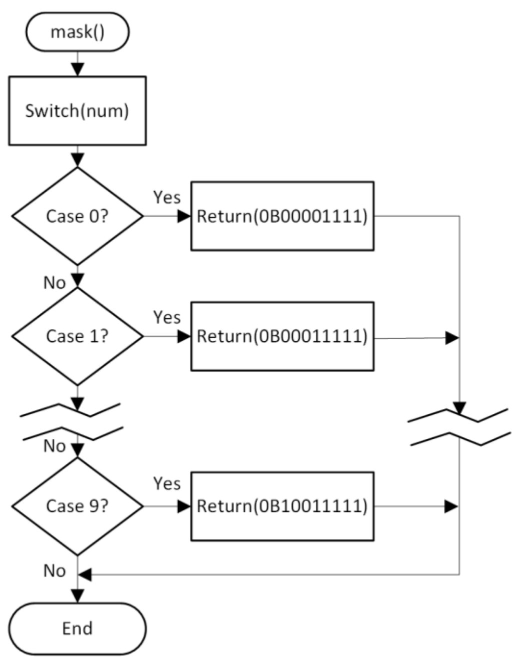

Figure 3.20: Flowchart of Charc() Function

Figure 3.19 and 3.20 shows the function of Mask() and Charc() functions. Both functions are used to switch cases from 0-9 and 0B00001111-0B10011111 for 7 display segment and Bluebee.

3.4.2 MIT App Inventor

MIT App Inventor is an application provided by Google and now maintained by the Massachusetts Institute of Technology (MIT). It allows user to drag-and-drop the visual objects to create an application that can run on the Android based smartphone.

Figure 3.21: Process Flow of Android App Development

MIT App Inventor allow user to develop applications for Android based smartphone using web browser. The application built can be tested using Android Emulator and Android based smartphone. From the figure above, Google App Inventor Server provide a platform which is App Inventor Designer where user can select the components for the application. Next, App Inventor Blocks Editor is where user can assemble the program blocks by drag-and drop. The application can be modified and tested in the Android Emulator and Android based smartphone at the same time.

There are three main parts for the Android application which is Bluetooth communication, BPM display and store in Google Fusion Table and lastly is display BPM in graph.

3.4.2.1 Android Application

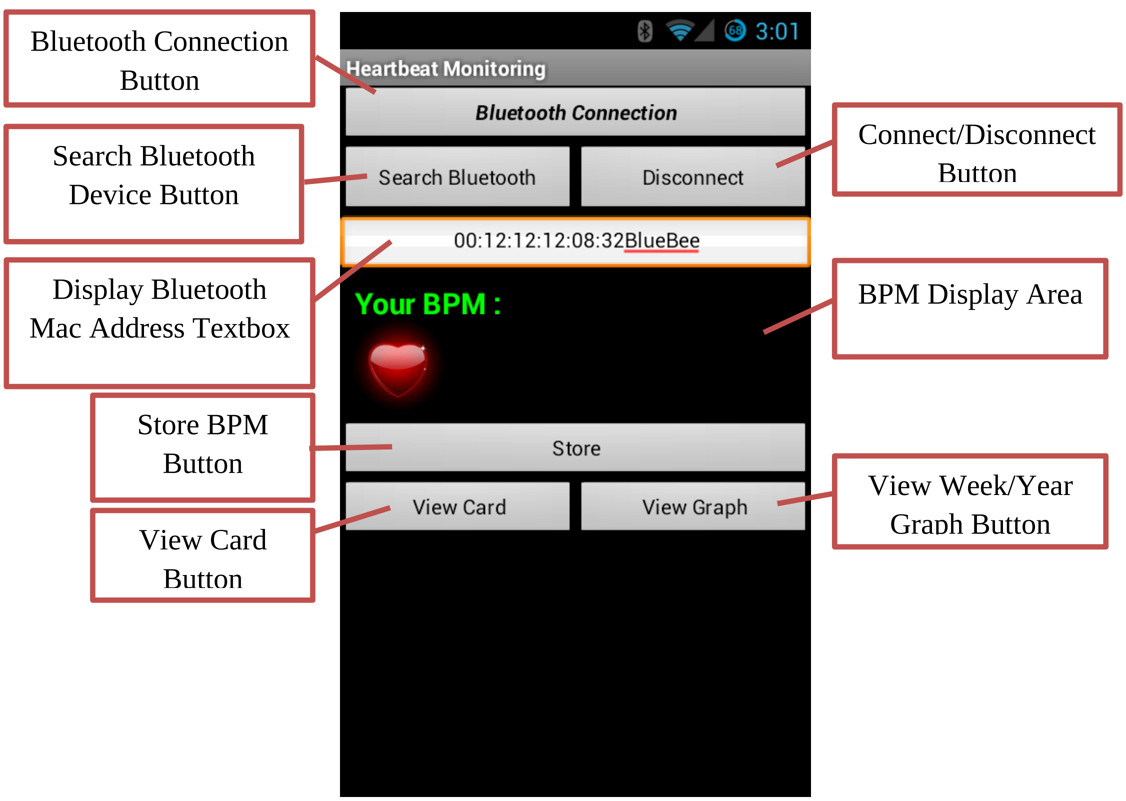

Figure 3.22: Android Application

No	Component	Function
1	Bluetooth Connection Button	Click to visible or hide Search Bluetooth and Connect/Disconnect button
2	Search Bluetooth Button	Click to search Bluetooth devices
3	Connect/Disconnect Button	Click to connect or disconnect Bluetooth connection
4	Bluetooth Mac Address Textbox	Display Bluetooth Mac Address
5	BPM Display Label	Display BPM data
6	Store Button	Click to store BPM data
7	View Card Button	Click to view BPM card
8	View Graph Button	Click to view week/year BPM Graph

Table 3.3: Component and Its Function in Android User Interface

3.4.2.2 Android Block Editor Program

This section will discussed some of the important parts of the visual blocks programming for the Android application.

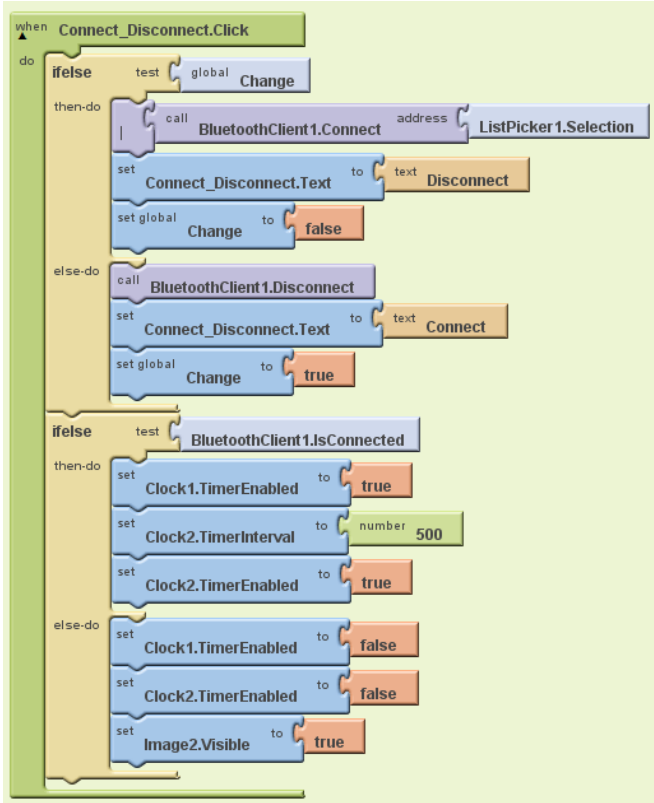

Figure 3.23: Connect/Disconnect Button Blocks

Figure 3.23 shows the function of Connect/Disconnect button. Change is a global Boolean variable. If Change is true, then the BluetoothClient1.Connect will connect to the selected Bluetooth device and at the same time the “Connect” text of the button will change to “Disconnect”. And then the Change will change from true to false. If Change is false, the BluetoothClient.Disconnect will disconnect from the connected Bluetooth device and at the same time the “Disconnect” will change to “Connect”. And then the Change will change from false to true. Next if else statement is used to enable Clock1 timer and Clock2 timer.

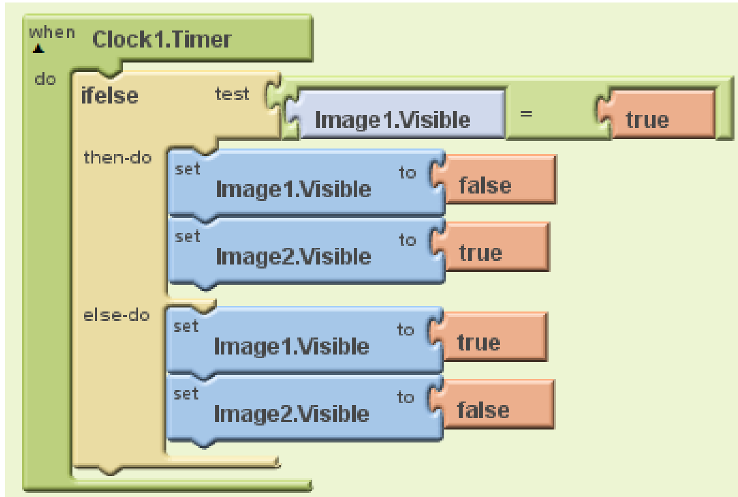

Figure 3.24: Clock1.Timer Blocks

Figure 3.24 shows the function of Clock1.Timer. Clock1.Timer is used to switch the heart shape image and a black image. This will caused blinking effect on the screen.

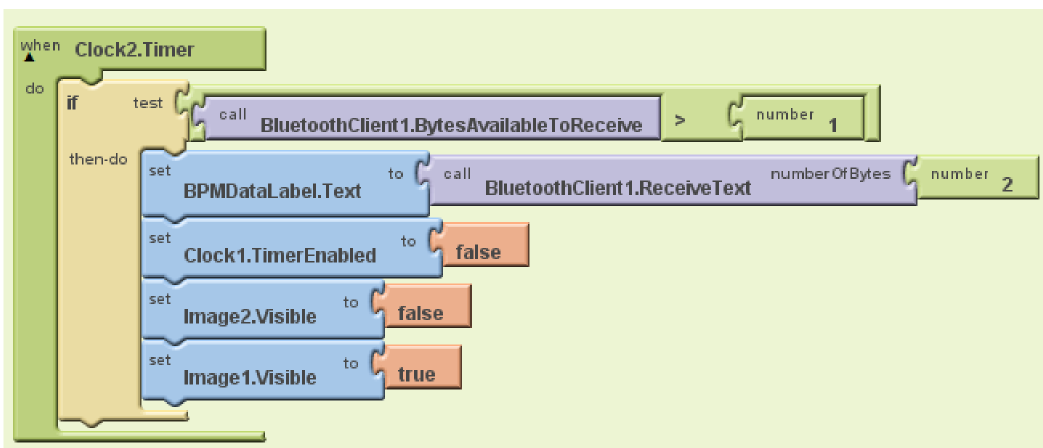

Figure 3.25: Clock2.Timer Blocks

Figure 3.25 shows the function of Clock2.Timer. Clock2.Timer is used to receive the BPM data from sensor device. The BPM data from the sensor device is sent byte by byte. For example, “6” and “0” sent by sensor device. If the byte received greater than 1 then the BPM data will display at BPMDataLabel.Text.

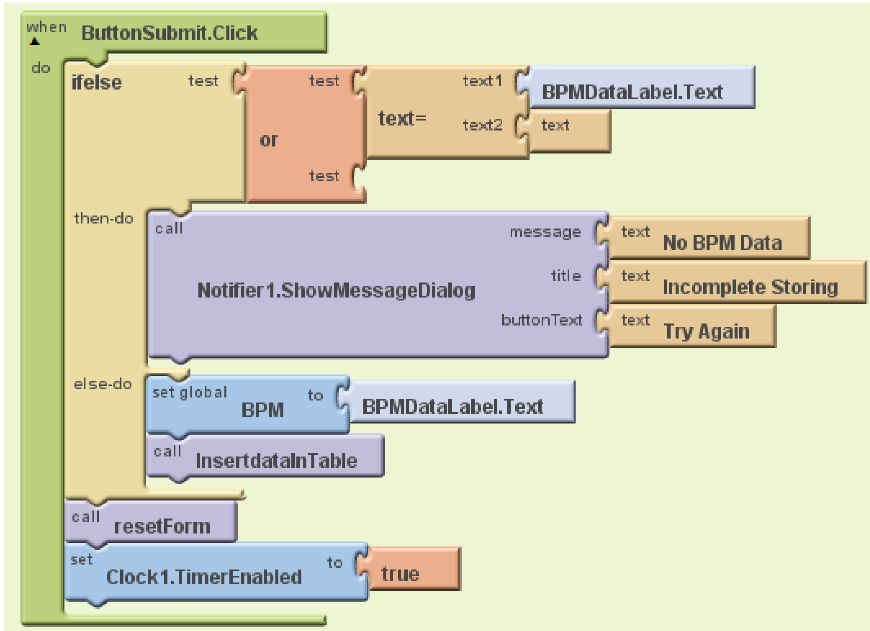

Figure 3.26: Store Button Blocks

Figure 3.26 shows the function of Store button. The if else statement here is used to store the BPM data to Fusion Table if BPMDataLabel.Text is not empty. If BPMDataLabel.Text is empty, Notifier1.ShowMessageDialog will pop out an Incomplete Storing dialog box as shown in Figure 3.27. After the BPM data stored, the application will reset to a default form.

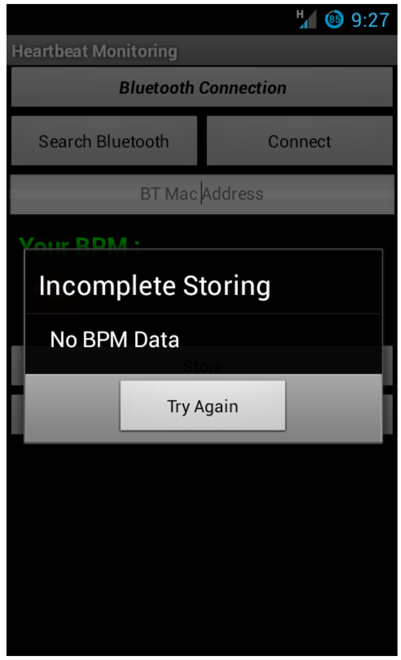

Figure 3.27: Incomplete Storing Dialog Box

In order to send the data to Fusion Table, FusiontablesControl component is used. This action will create a new row in the Fusion Table, setting the values of the various columns involved. The data inserted must follow the format of the insert query.

This procedure involves two steps:

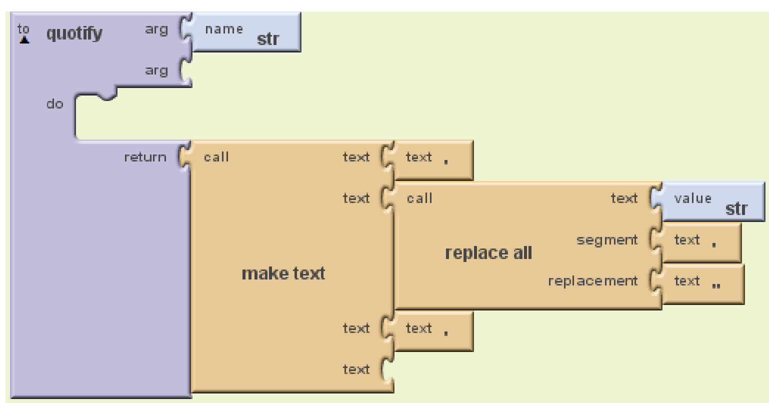

Figure 3.28: Step 1-Constructing the Insert Query

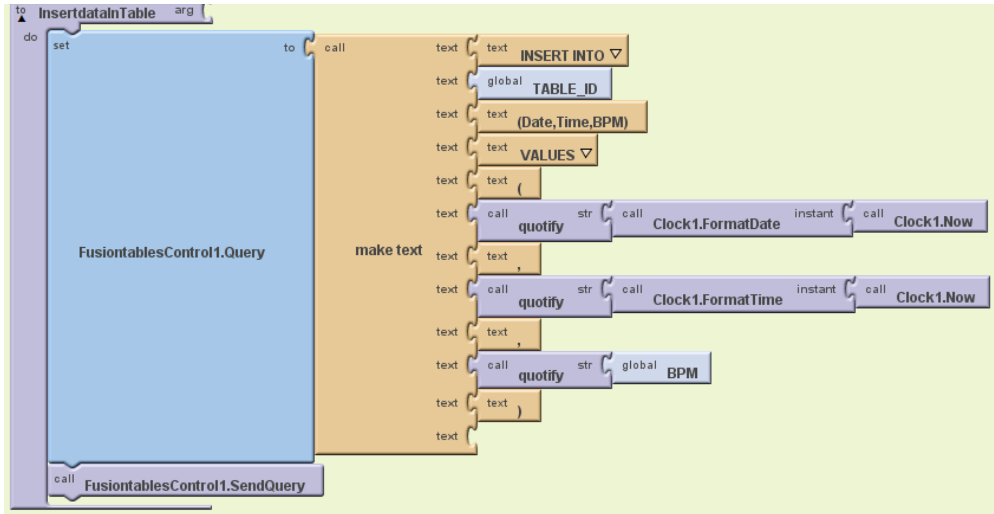

Figure 3.29: Step 2-Sending the query to Google's Fusion Table

An example of what this might look like is shown below. Notice that the values must be enclosed in single quotes:

INSERT INTO 191GHtZ_B2 (Date, Time, BPM) VALUES ('10/10/2012','7:30AM','60')

3.4.3 Solid works

Solid works is a 3D mechanism design tools that used to design the mechanical design in this project. The IR sensor socket and the mechanism for Volture Piezoelectric Energy Harvester are designed using this software.

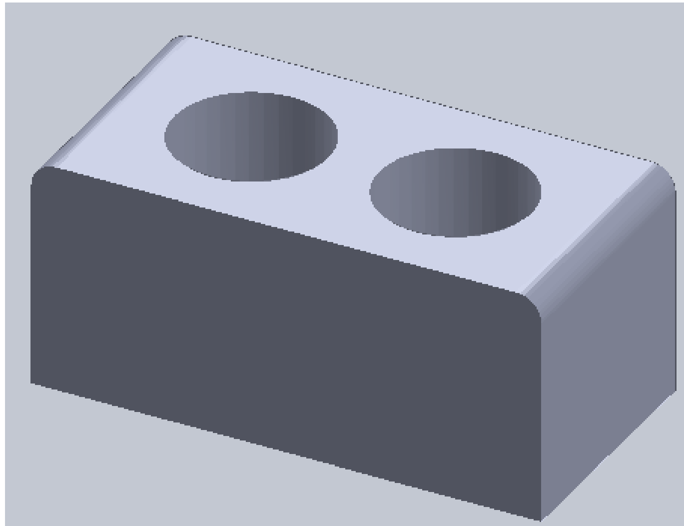

Figure 3.30: Solid works Drawing of IR Sensor Socket

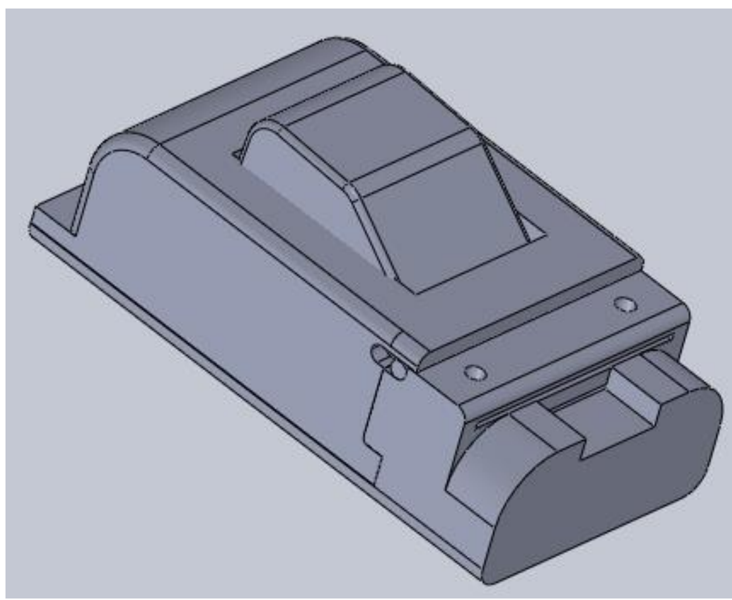

Figure 3.31: Solid works Drawing of Mechanism for Volture Piezoelectric Energy Harvester

CHAPTER 4

RESULT AND DISCUSSION

4.1 Hardware Result

4.1.1 Electronic Circuitry

In this project, there are three parts implemented for circuitry part, which are wireless sensor device, voltage regulator circuit and energy harvester power supply.

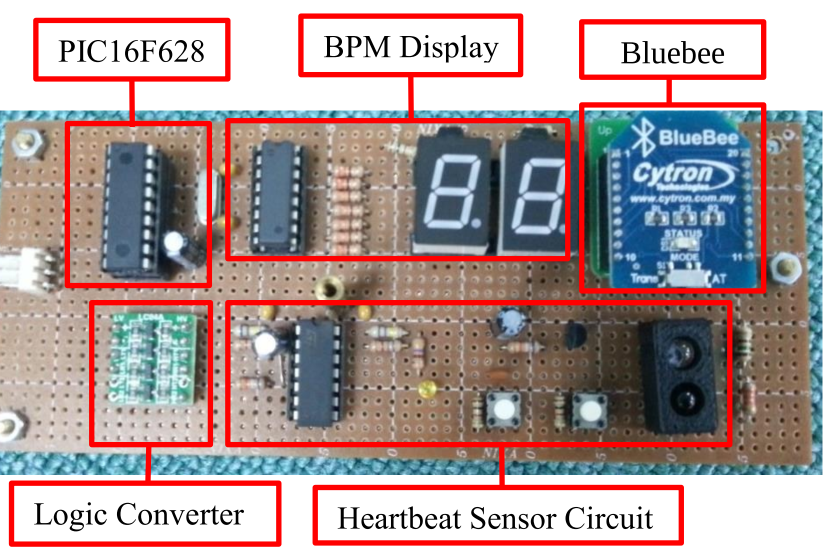

Figure 4.1: Wireless Sensor Device

Figure 4.1 shows the wireless sensor device which is the main board where Microcontroller PIC16F628, heartbeat sensor circuit, BPM display and Bluebee module are deployed.

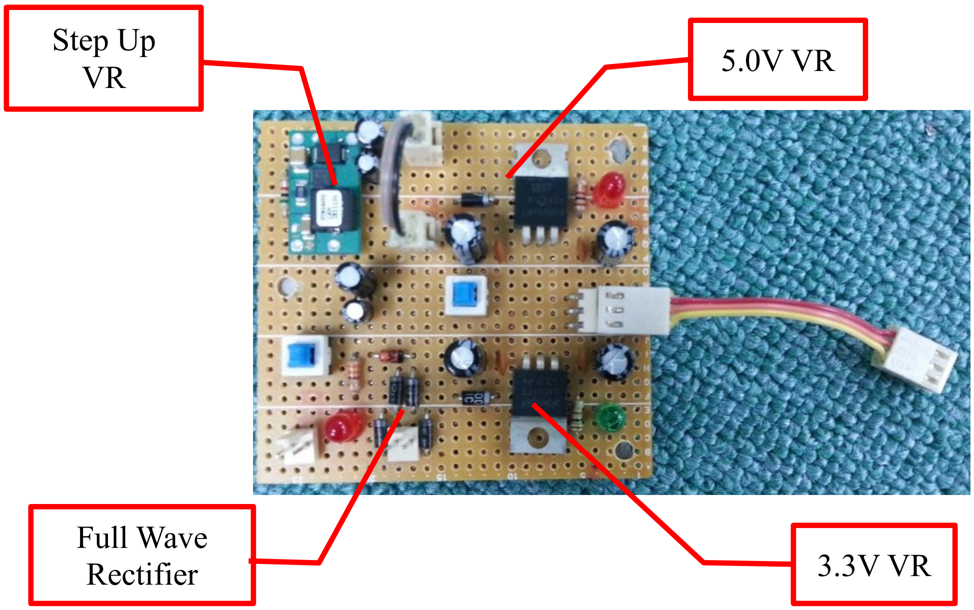

Figure 4.2: Voltage Regulator (VR) Circuit

Figure 4.2 shows the voltage regulator circuit which used to step up the voltage from 3.7V to 9.0V before supply to 5.0V and 3.3V voltage regulator. 3.3V is needed because Bluebee module is operating in this voltage. Logic converter is needed to step up and step down from 3.3V to 5.0V and 5.0V to 3.3V between Microcontroller PIC16F628 and Bluebee module.

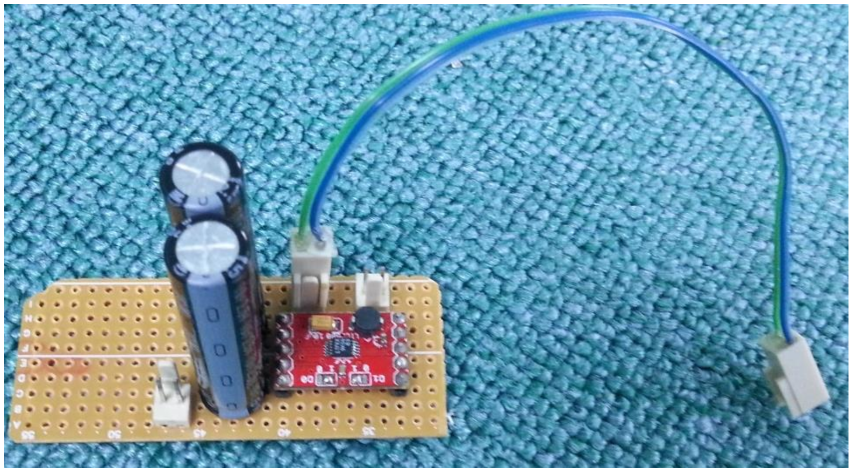

Figure 4.3: Energy Harvester Power Supply

Figure 4.3 shows the energy harvester power supply which used to collect the harvested energy from the piezoelectric film and store the harvested energy in super capacitor. But circuit is failed to harvest the energy and get the desired maximum output 3.6V which is more than enough to step up to 9.0V in the voltage regulator circuit. This problem is most probably because the 10F/2.5V super capacitor is hard to charge due to piezoelectric film had insufficient current to pump into the super capacitor.

The full wave rectifier in Figure 4.2 is the second trial to replace the energy harvester power supply to harvest the energy but the result is the same. However, using a single 3.7 rechargeable battery is sufficient to power up the whole sensor circuit.

Figure 4.4: Mechanism for Volture Piezoelectric Energy Harvester

Figure 4.4 shows the mechanism for Volture piezoelectric energy harvester which used to generate electric energy. The electric energy generated by pressing the button. The electric energy harvested is an AC power supply between -15V to +15V.

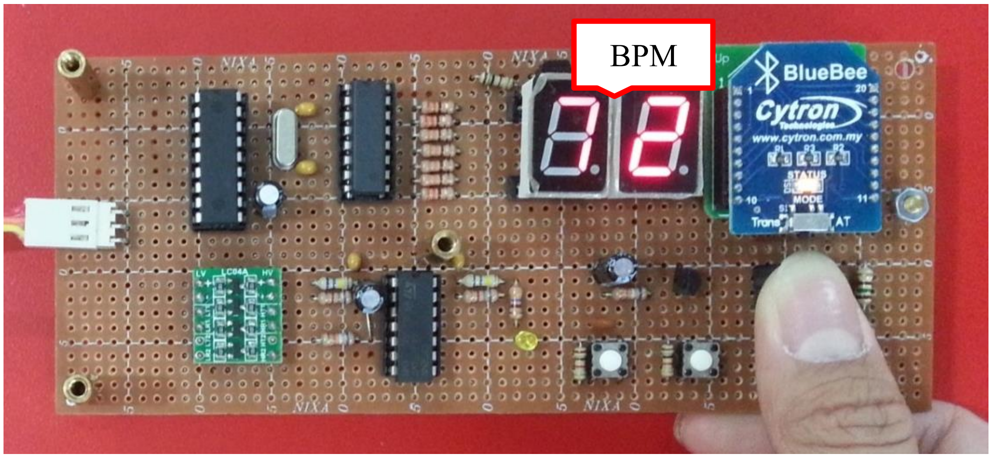

Figure 4.5: BPM Display on Wireless Sensor Device Result

The wireless sensor device has been tested. Firstly, the thumb is placed on the IR sensor socket and start button was pressed. The yellow LED is started to blink and indicated the BPM was started to measure. After 15 seconds, “72” is displayed on the 7 segment display about 2 seconds. Finally, the BPM data is sent to Android based smartphone.

4.2 Software Result

4.2.1 Android Application Result

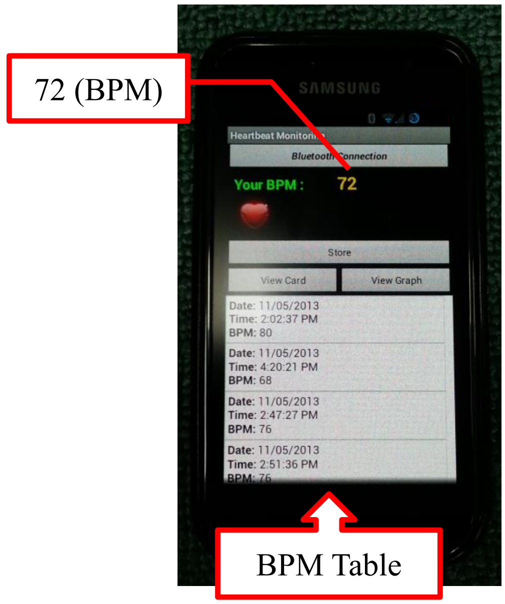

Figure 4.6: BPM Display on Android Application Result

The Android application is enabled to receive the BPM data from the wireless sensor device as shown in Figure 4.6. When store button is pressed, the BPM data is stored in the Google Fusion Table as shown in Figure 4.9. At the same time, the BPM table and graph can be viewed in Android application.

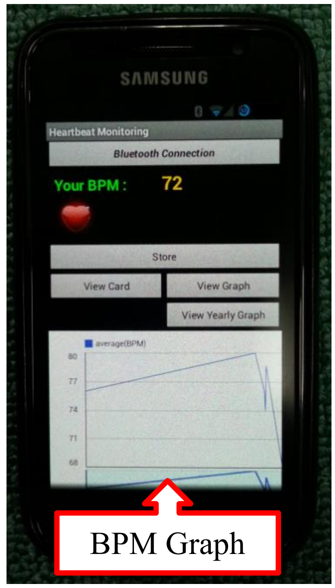

Figure 4.7: BPM Graph Display in Android Application Result

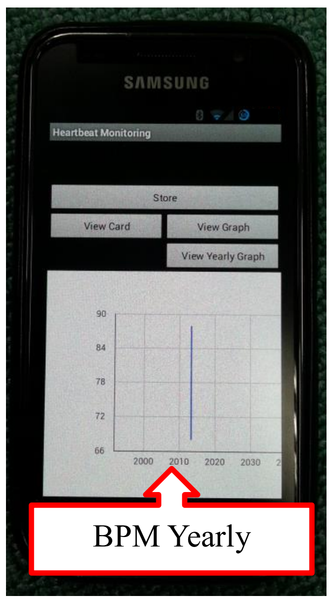

Figure 4.8: BPM Yearly Graph Display in Android Application Result

4.2.2 Fusion Table Result

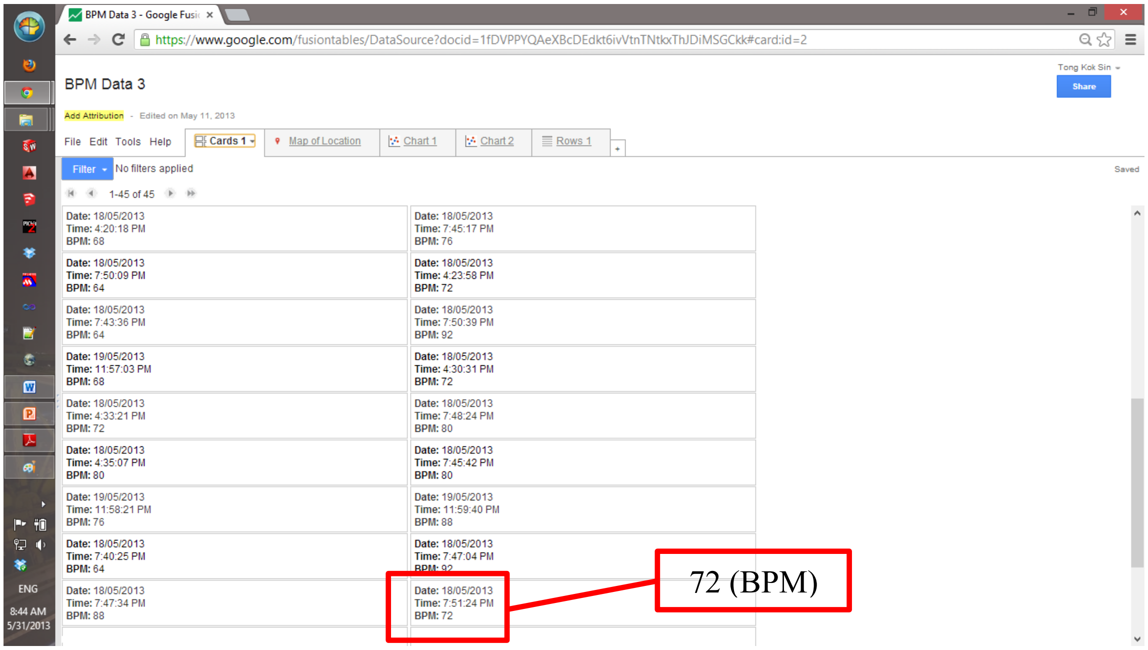

Figure 4.9: BPM Table in Google Fusion Table Result

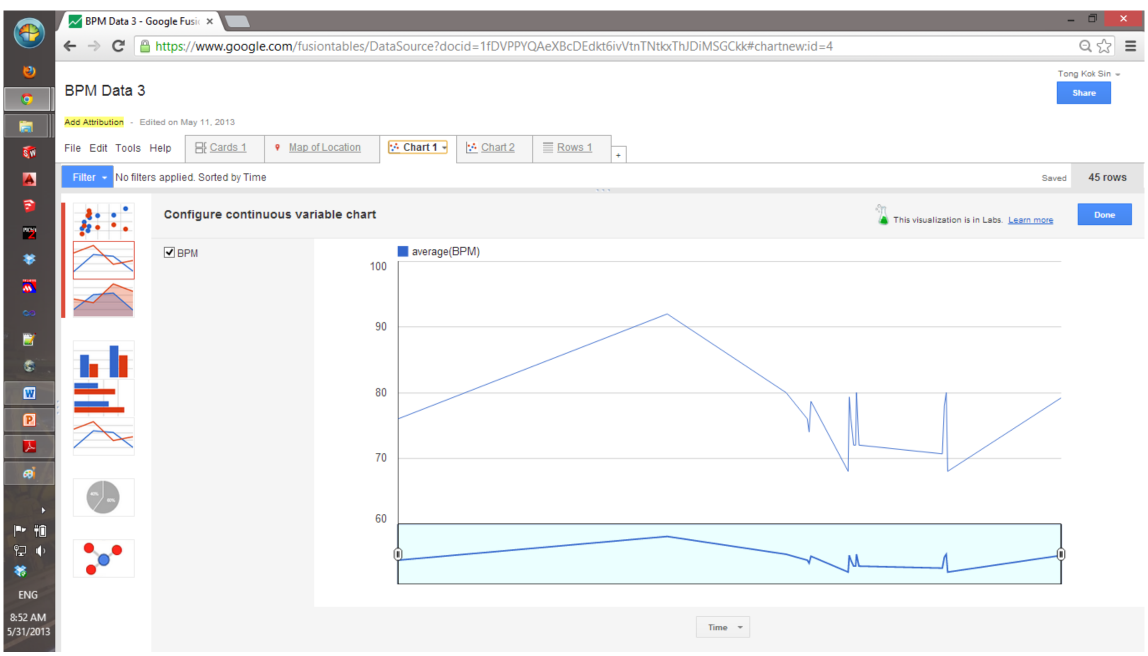

Figure 4.10: BPM Graph in Google Fusion Table Result

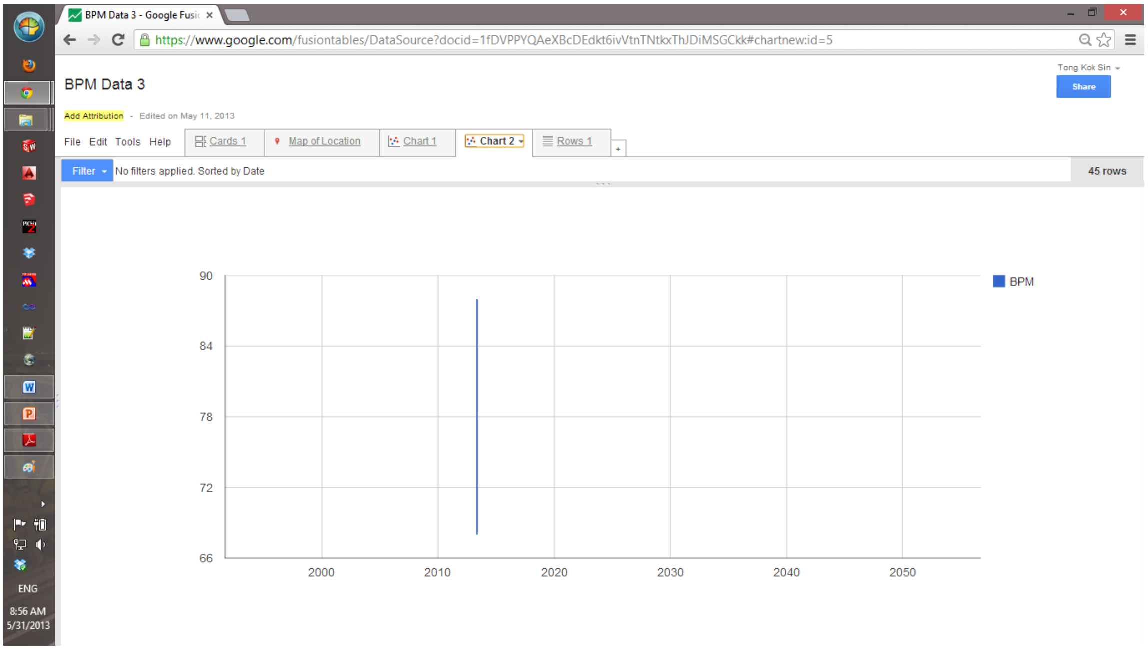

Figure 4.11: BPM Yearly Graph in Google Fusion Table Result

The BPM data can be visualized with line plot graph as shown in Figure 4.10 and Figure 4.11 provided by Google Web service.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Overall this project is partially successful, due to the failure to design a self-sustained wireless sensor device. But two of the objectives were fulfilled which the wireless sensor and the Android application is successfully developed.

Firstly, the wireless sensor device is able to measure heartbeat and display on the device. Secondly, the Android application is able to display and store the BPM data. The BPM data is well organized and visualized by using Google Fusion Table.

The energy harvester power supply is not working because the large super capacitor (10F/2.5V) used is too hard for the piezoelectric film to charge it up to the desired voltage.

5.2 Future Work

5.2.1 Recommendation

In this project, there is still lot more rooms for future improvement to produce a better project. Therefore, there is some recommendation is given below for further research:

i. A super capacitor with low Equivalent Series Resistance (ESR) is highly recommended to replace the super capacitor used in this project. Low ESR is also called low impedance. The current dissipated is higher than the normal super capacitor with lower voltage operation.

ii. The wireless sensor device size can be reduced to minimum the power consumption. The 7 segment display can be replaced with few LEDs because 7 segment display drawn a lot of current.

iii. The sensor used in this project is not so accurate because it easily influence by the noise. Wearable sensor is recommended.

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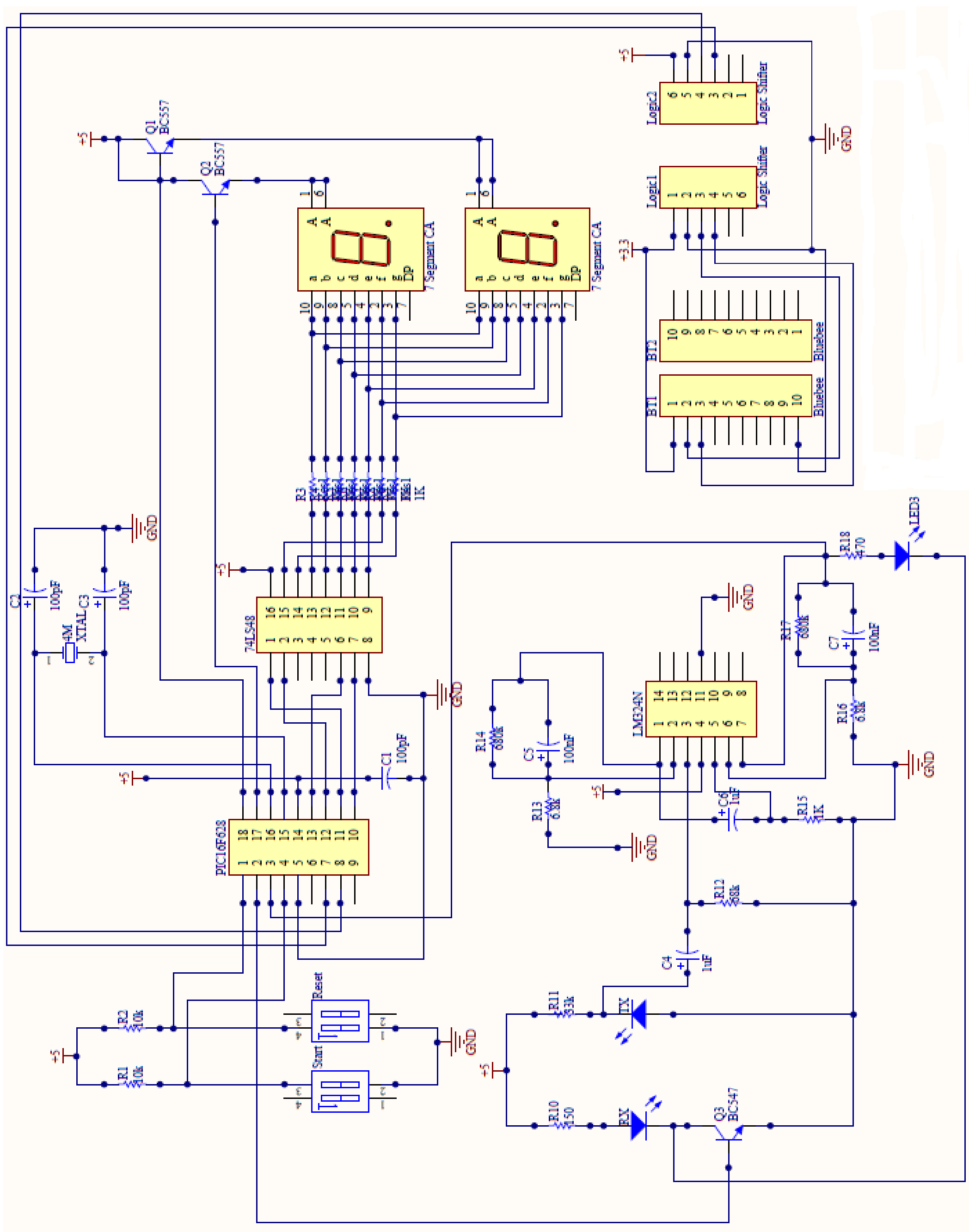
12. *LM324N Quad Operational Amplifier*. [cited 2013 February 22]; Available from: http://www.cytron.com.my/datasheet/IC/linear/LM324N.pdf.

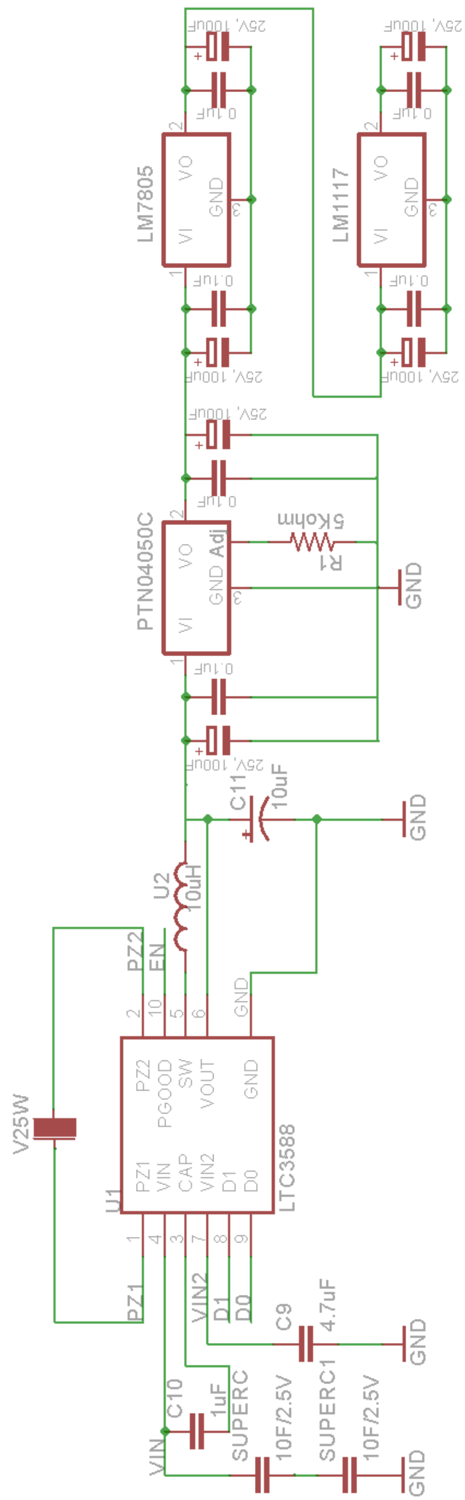
Appendix A

Wireless Sensor Device Schematic



Appendix B

Energy Harvester and Voltage Regulator Schematic



Appendix C

Microcontroller Source Code

```
#include<htc.h>
__CONFIG(0x3f0A);

//Crytal Declaration
#define _XTAL_FREQ 10e6

//Port Declaration
#define start RA2
#define reset RA5

#define IR_Tx RA3
#define X RA5
#define DD0_Set RA1
#define DD1_Set RA0

#define A RB4
#define B RB5
#define C RB6
#define D RB7

//Variable Declaration
unsigned short DD0, DD1;
unsigned short pulserate, pulsecount;
unsigned int i, j, k, y;

//Prototype Declaration
void uart_send (char data);
```

```
char uart_receive (void);

//Delay_debounce Function
void delay_debounce(){
 __delay_ms(300);
}

//Delay Function
void delay_refresh(){
 __delay_ms(5);
}

//Delay2 Function
void delay2 (int d)
{
                                        for (int i=0;i<d;i++)
                                        {;}
}

//BPM Measurement Function
void countpulse()
{
 IR_Tx = 1;
 delay_debounce();
 delay_debounce();
 TMR0=0;
 __delay_ms(15000);  // Delay 15 Sec
 IR_Tx = 0;
 pulsecount = TMR0;
 pulserate = pulsecount*4;
}
```

```
//Binary number 0-9 for 7 Segment Display Function
char mask(unsigned char num)
{
 switch (num)
{
 case 0 :
                                    {
                                    return 0B00001111;
                                    }
 case 1 :
                                    {
                                    return 0B00011111;
                                    }
 case 2 :
                                    {
                                    return 0B00101111;
                                    }
 case 3 :
                                    {
                                    return 0B00111111;
                                    }
 case 4 :
                                    {
                                    return 0B01001111;
                                    }
 case 5 :
                                    {
                                    return 0B01011111;
                                    }
 case 6 :
```

```
                    {
                    return 0B01101111;
                    }
 case 7 :
                    {
                    return 0B01111111;
                    }
 case 8 :
                    {
                    return 0B10001111;
                    }
 case 9 :
                    {
                    return 0B10011111;
                    }
 } //case end
}

//Character number 0-9 for Bluetooth Send Function
char charc(unsigned char num)
{
 switch (num)
{
 case 0B00001111 :
                    {
                    return '0';
                    }
 case 0B00011111 :
                    {
                    return '1';
                    }
```

```
case 0B00101111 :
                    {
                    return '2';
                    }
case 0B00111111 :
                    {
                    return '3';
                    }
case 0B01001111 :
                    {
                    return '4';
                    }
case 0B01011111 :
                    {
                    return '5';
                    }
case 0B01101111 :
                    {
                    return '6';
                    }
case 0B01111111 :
                    {
                    return '7';
                    }
case 0B10001111 :
                    {
                    return '8';
                    }
case 0B10011111 :
                    {
                    return '9';
```

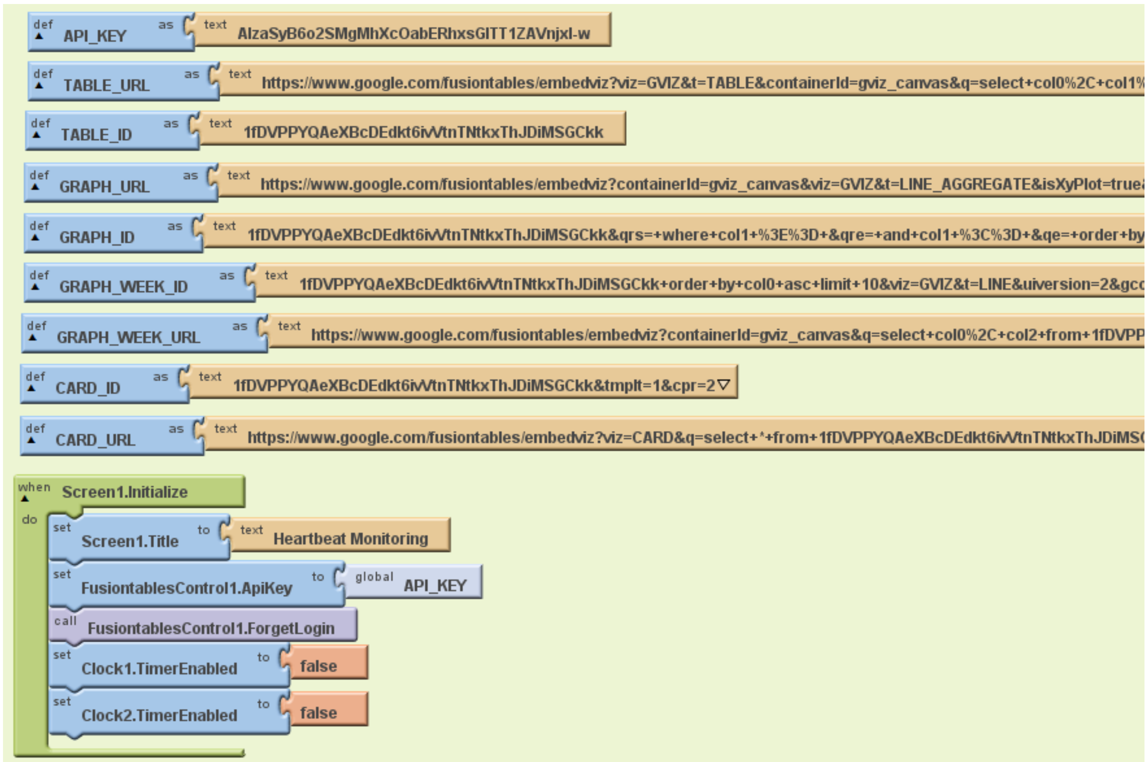
```
                                        }
 } //case end
}

//BPM display in 7 Segment Display Function
void display()
{
  DD0 = pulserate%10;
  DD0 = mask(DD0);
  DD1 = (pulserate/10)%10;
  DD1 = mask(DD1);

//7 Segment Display Switching Loop
  for (i = 0; i<=180*j; i++)
                                {
                                DD0_Set = 1;
                                DD1_Set = 0;
                                PORTB = DD0;
                                delay_refresh();
                                DD0_Set = 0;
                                DD1_Set = 1;
                                        PORTB = DD1;
                                delay_refresh();
   }
                                uart_send (charc(DD0));
                                uart_send (charc(DD1));
                                DD0_Set = 0;
                                DD1_Set = 0;
}

//UART sending subroutine
```

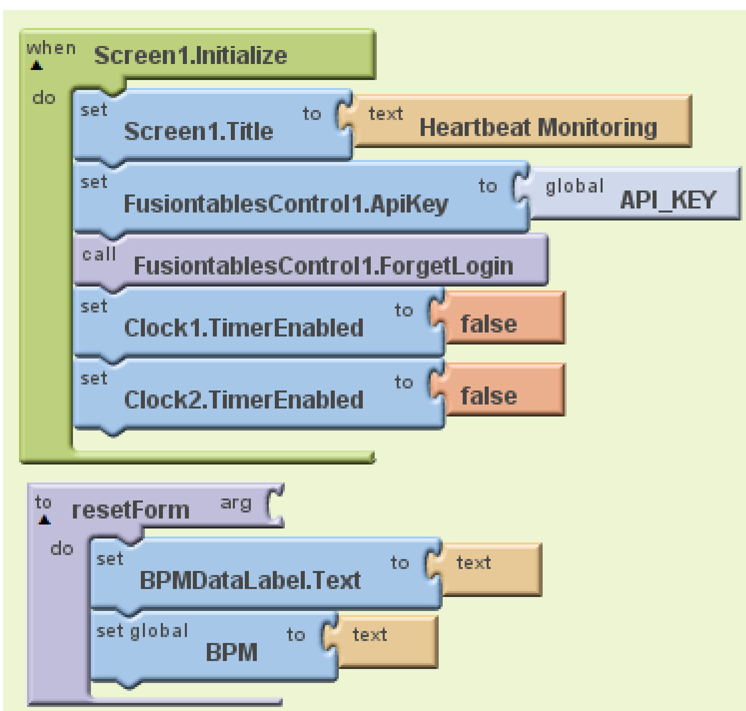
```
void uart_send (char data)
{
        while(!TXIF) continue;
        TXREG = data;
}

//UART receiving subroutine
char uart_receive (void)
{
        if(OERR == 1)
        {
            CREN = 0;
            CREN = 1;
        }
        while(!RCIF) continue;
        return RCREG;
}


void main()
{
        CMCON = 0x07;               // Disable Comparators
        TRISA = 0b00010100;         // RA4/T0CKI input, RA5 is
I/P only
        TRISB = 0b00000000;         // RB output
        OPTION = 0b00101000;        // Prescaler (1:1), TOCS =1
for counter mode
        pulserate = 0;              //Initialize pulserate

        TX9 = 0;                        // Bluetooth Setting
        RX9 = 0;
```

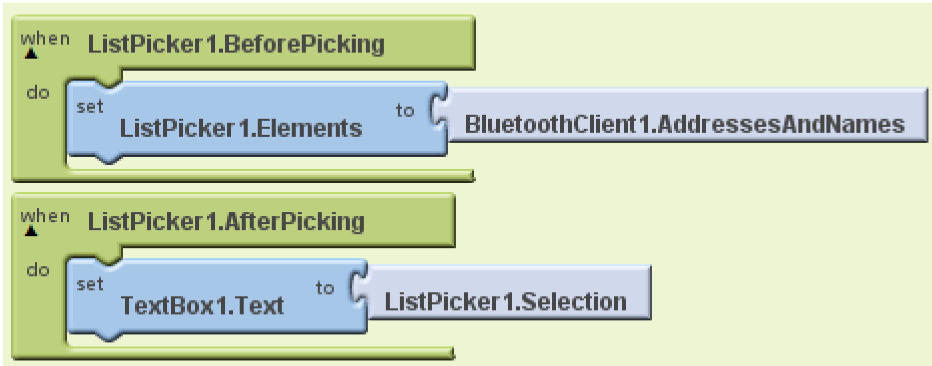
```
                                   SYNC = 0;
                                   BRGH = 1;
                                   ADEN = 0;
 SPBRG = 64;
                                   TXEN = 1;
                                   CREN = 1;
                                   SPEN = 1;

while(1) {
if(!start)
                                   {
                                        delay_debounce();
                                        countpulse();
                                        j= 3;
                                        display();
                                   }
}  // Infinite loop
}
```

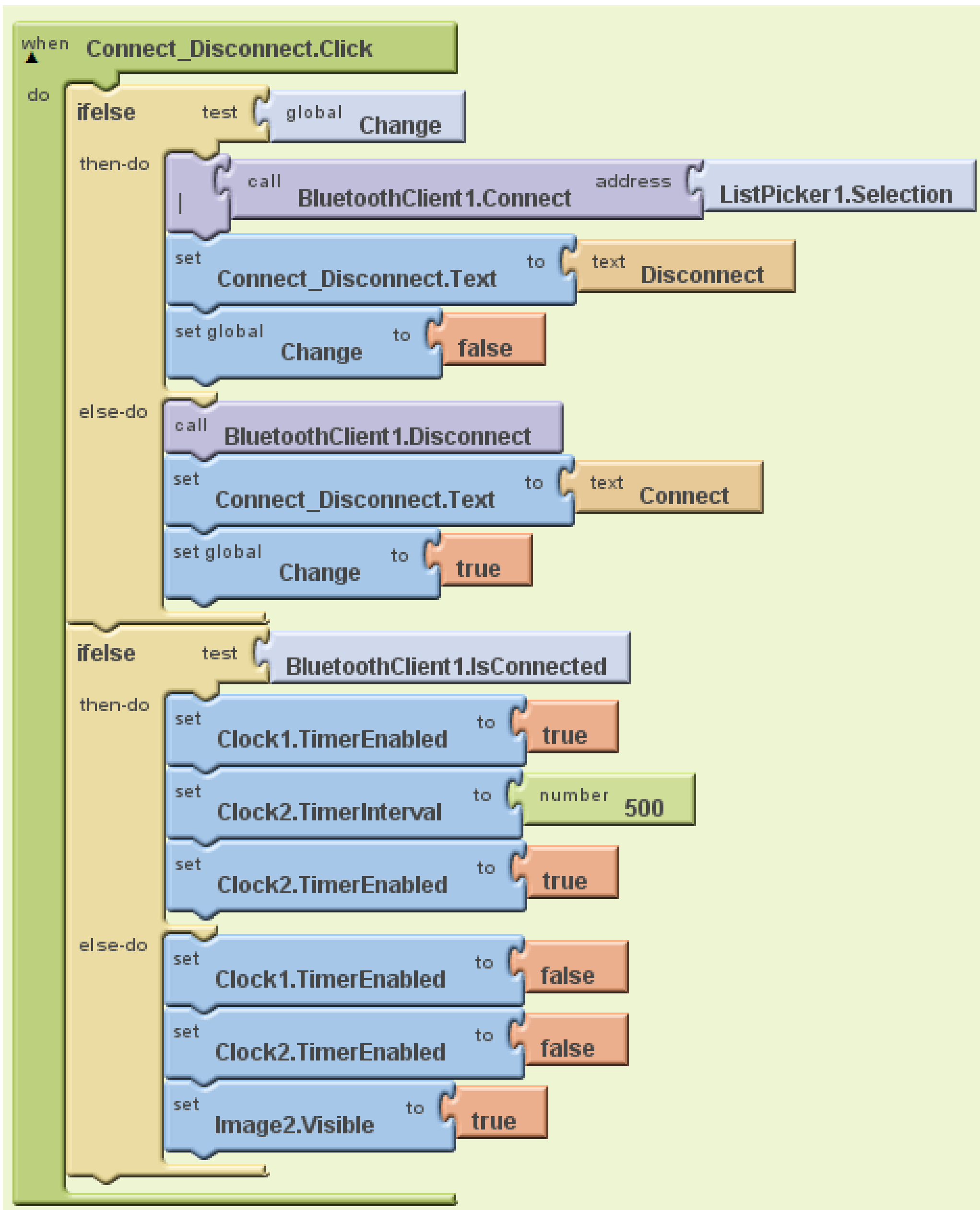
Appendix D

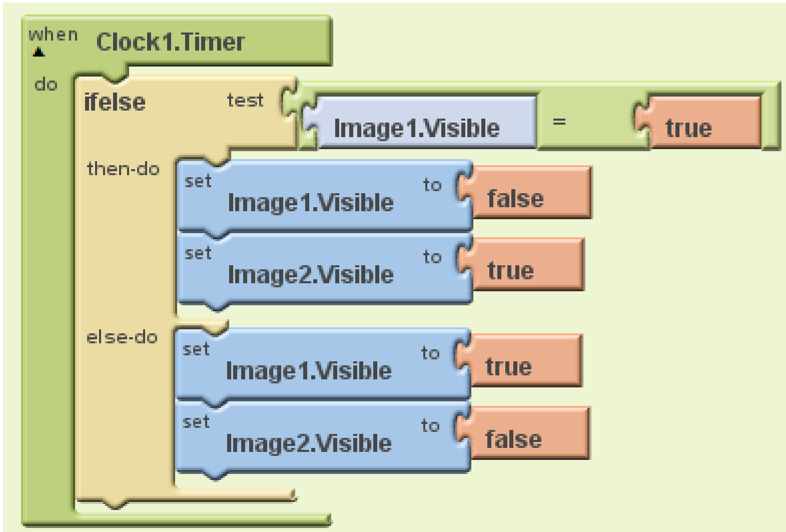
MIT App Inventor Graphical Programming

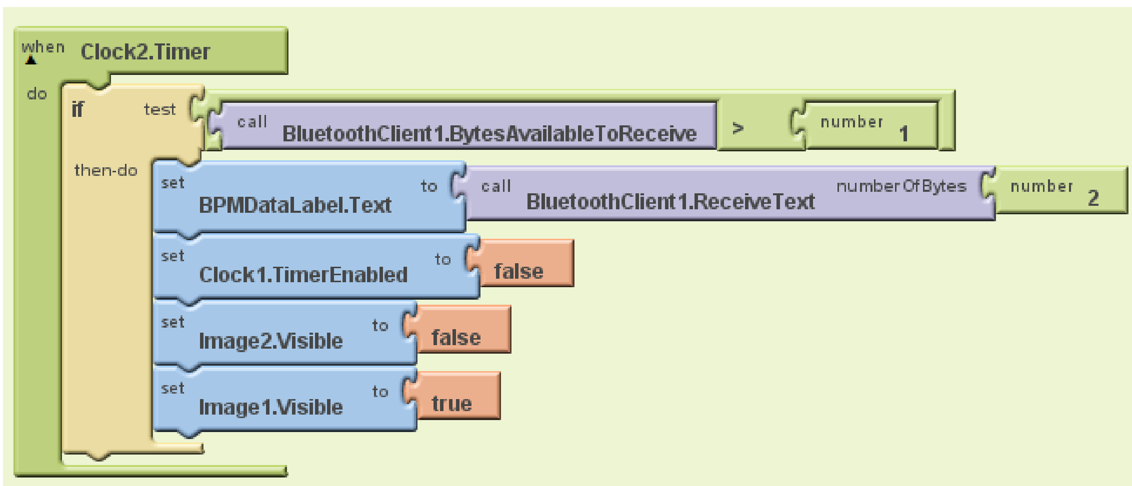


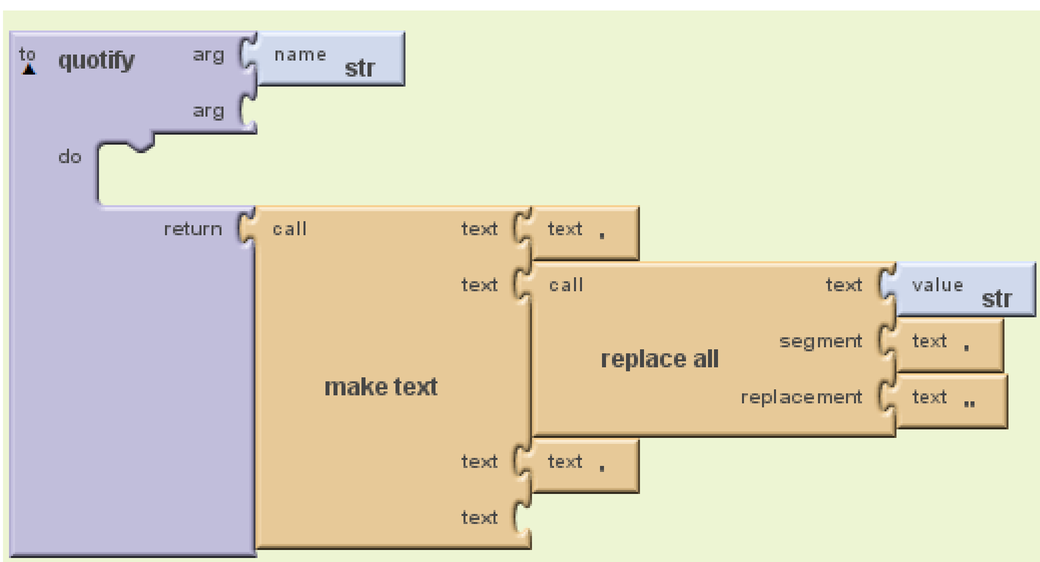


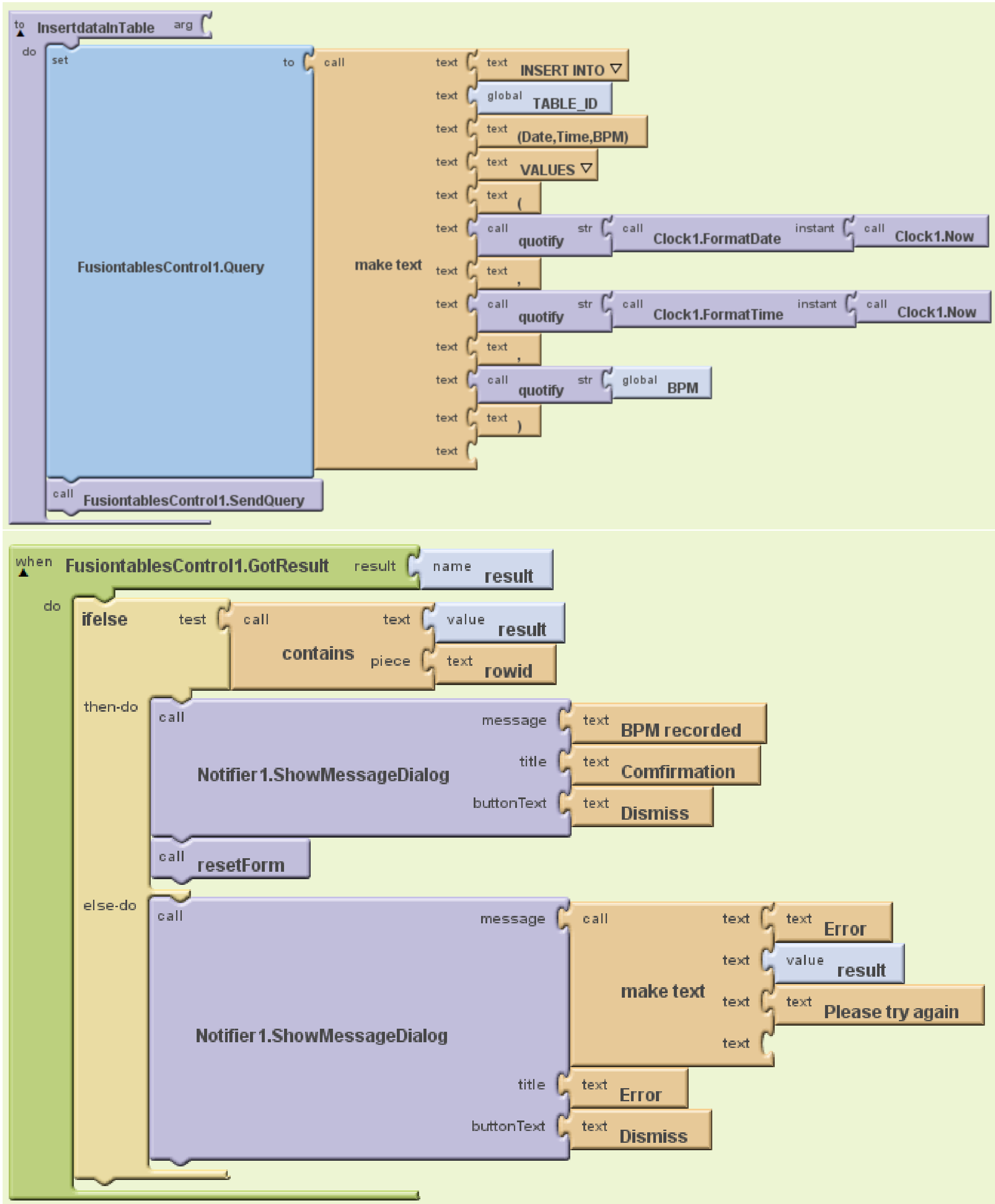

when ListPicker1.BeforePicking
do
set ListPicker1.Elements to BluetoothClient1.AddressesAndNames
when ListPicker1.AfterPicking
do
set TextBox1.Text to ListPicker1.Selection

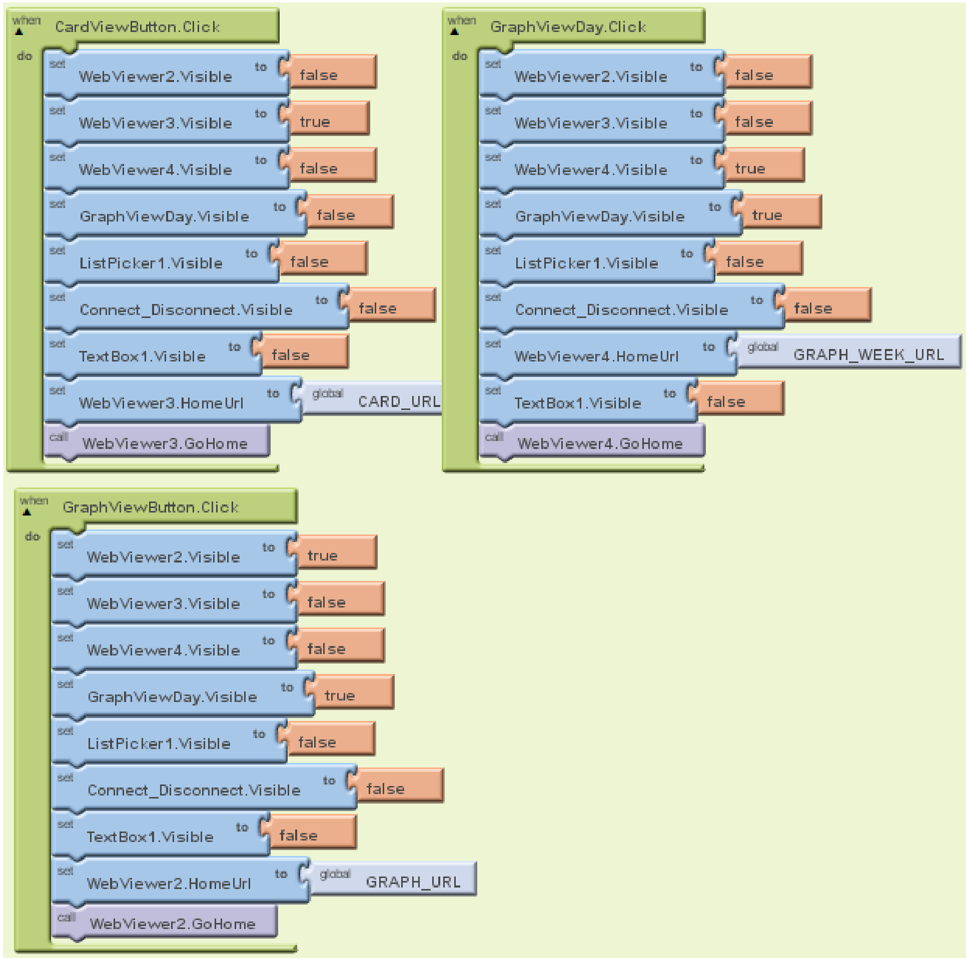

when Connect_Disconnect.Click
do
ifelse test global Change
then-do
call BluetoothClient1.Connect address ListPicker1.Selection
set Connect_Disconnect.Text to text Disconnect
set global Change to false
else-do
call BluetoothClient1.Disconnect
set Connect_Disconnect.Text to text Connect
set global Change to true
ifelse test BluetoothClient1.IsConnected
then-do
set Clock1.TimerEnabled to true
set Clock2.TimerInterval to number 500
set Clock2.TimerEnabled to true
else-do
set Clock1.TimerEnabled to false
set Clock2.TimerEnabled to false
set Image2.Visible to true

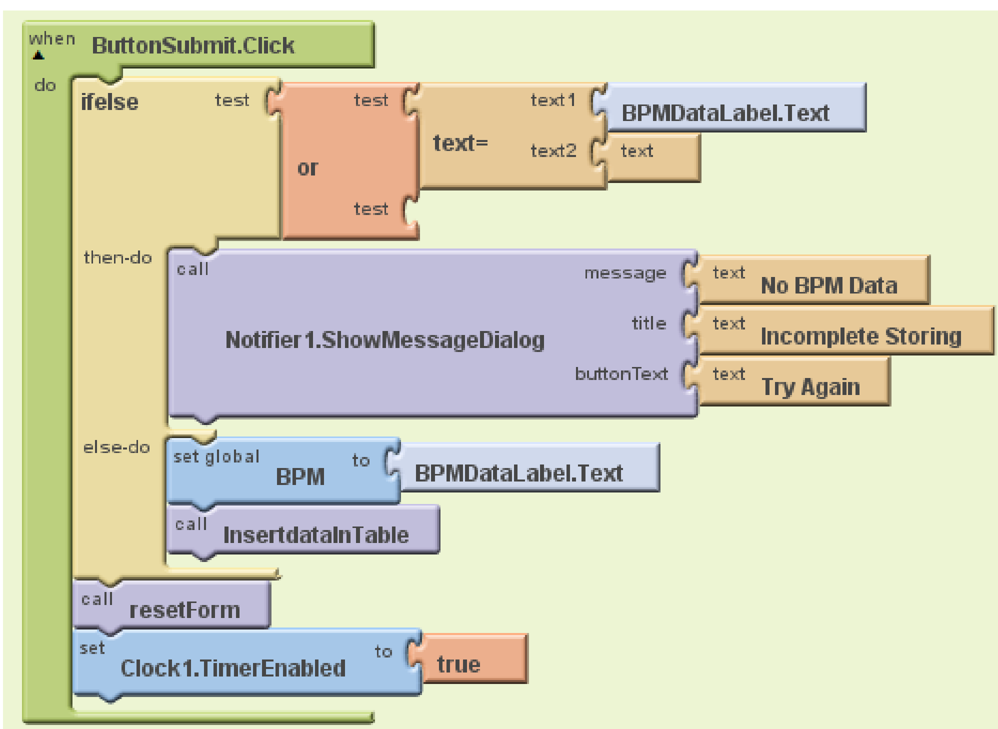

when
Clock1.Timer
do
ifelse
test
Image1.Visible
=
true
then-do
set
Image1.Visible
to
false
set
Image2.Visible
to
true
else-do
set
Image1.Visible
to
true
set
Image2.Visible
to
false


when
Clock2.Timer
do
if
test
call
BluetoothClient1.BytesAvailableToReceive
>
number 1
then-do
set
BPMDataLabel.Text
to
call
BluetoothClient1.ReceiveText
numberOfBytes
number 2
set
Clock1.TimerEnabled
to
false
set
Image2.Visible
to
false
set
Image1.Visible
to
true


to
quotify
arg
name str
arg
do
return
call
make text
text
text "
text
call
replace all
text
value str
segment
text "
replacement
text ""
text
text "
text


to InsertdataInTable arg
do
set FusiontablesControl1.Query to
call make text
text INSERT INTO
global TABLE_ID
text (Date,Time,BPM)
text VALUES
text (
call quotify str call Clock1.FormatDate instant call Clock1.Now
text ,
call quotify str call Clock1.FormatTime instant call Clock1.Now
text ,
call quotify str global BPM
text)
call FusiontablesControl1.SendQuery
when FusiontablesControl1.GotResult result name result
do
ifelse test call contains text value result piece text rowid
then-do
call Notifier1.ShowMessageDialog message text BPM recorded title text Comfirmation buttonText text Dismiss
call resetForm
else-do
call Notifier1.ShowMessageDialog message call make text text Error text value result text Please try again
title text Error
buttonText text Dismiss


when CardViewButton.Click
do
set WebViewer2.Visible to false
set WebViewer3.Visible to true
set WebViewer4.Visible to false
set GraphViewDay.Visible to false
set ListPicker1.Visible to false
set Connect_Disconnect.Visible to false
set TextBox1.Visible to false
set WebViewer3.HomeUrl to global CARD_URL
call WebViewer3.GoHome
when GraphViewDay.Click
do
set WebViewer2.Visible to false
set WebViewer3.Visible to false
set WebViewer4.Visible to true
set GraphViewDay.Visible to true
set ListPicker1.Visible to false
set Connect_Disconnect.Visible to false
set WebViewer4.HomeUrl to global GRAPH_WEEK_URL
set TextBox1.Visible to false
call WebViewer4.GoHome
when GraphViewButton.Click
do
set WebViewer2.Visible to true
set WebViewer3.Visible to false
set WebViewer4.Visible to false
set GraphViewDay.Visible to true
set ListPicker1.Visible to false
set Connect_Disconnect.Visible to false
set TextBox1.Visible to false
set WebViewer2.HomeUrl to global GRAPH_URL
call WebViewer2.GoHome


when ButtonSubmit.Click
do
ifelse test
or test
text= text1 BPMDataLabel.Text
text2 text
test
then-do
call Notifier1.ShowMessageDialog
message text No BPM Data
title text Incomplete Storing
buttonText text Try Again
else-do
set global BPM to BPMDataLabel.Text
call InsertdataInTable
call resetForm
set Clock1.TimerEnabled to true

Appendix E

Cost of the Project

	Parts/Components	QTY	Unit Price(RM)	Price(RM)
1	LTC-3588-1 Piezoelectric Energy Harvesting Power Supply	1	100.00	100.00
2	PIC16F628	1	20.00	20.00
3	Cytron Bluetooth Module	1	34.00	34.00
4	LM324N Op-amp	1	1.65	1.65
5	3.7 Rechargeable Battery	1	13.00	13.00
6	Piezoelectric Energy Harvester	1	250.00	250.00
7	10F/2.5V Supercapacitor	2	48.00	48.00
8	Miscellaneous (resistors, capacitors, connectors, wires, etc)	1	150.00	150.00
	Total			623.65