CERTIFICATION

As the candidate's supervisor, I have approved this project for submission.

Supervisor's name: ANDREW JOHN MSUMBA (PhD)

Signature ………………………………………………

Date ……………………………………………………

DECLARATION

I, BESTORY ANDERSON, B declare that the project presented here as partial fulfillment of bachelor of engineering in Electronics and Telecommunication is my origin work and has not been copied from anywhere or presented elsewhere except where explicitly indicated otherwise as all sources of knowledge have been acknowledged.

CANDIDATE NAME	**SIGNATURE**	**DATE**
ANDERSON Bestory, B	__________________	______________

ABSTRACT

Personal telehealth plays a crucial role in addressing global challenges of aging population and rising cost for health care. Remote monitoring of heart disease provides the means to keep patients under continuous supervision. In this project I introduce the design and implementation of a remote monitoring medical system for heart failure prediction and management.

The three-part system includes a patient-end for data collection, a medical data center as data storage and analysis, and a doctor-end to diagnosis and intervention. The system reads, stores and analyses the heart beat rate signals repetitively in real-time. The objective of this project is to design and implement a reliable, cheap, low powered, and accurate system that can be attached to the patient body on a regular basis and monitors the heart vital signs based on wireless technology.

Toward achievement of remote monitoring of heart disordered people system, the relevant data was collected, analyzed then was used to design the proposed system through proteus software, prototype was built then the system was tested using required test gears to verify the working of prototype in accordance with the objectives.

The built prototype is expected to solve the stated problem but internet reliability should be improved so that the designed system become reliable. This prototype can now be implemented as commercial system to overcome the prevailing problem stated in problem statement.

ACKNOWLEDGEMENT

Firstly, I would like to thank almighty God for his grace and mercy to give me good health, strength and comfort during the period of preparation of this project report.

I express my profound gratitude and indebtedness to my project supervisor Dr. JOHN ANDREW MSUMBA, Department of Electronics and Telecommunication Engineering, DIT for his inspiring intellectual guidance, constructive criticism and valuable suggestion throughout the preparation of this project report.

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LIST OF ABBREVIATION

2G	-	Second Generation
3G	-	Third Generation
ADC	-	Analog to Digital Converter
CD	-	Compact Disc
CH	-	Congenital Heart
CHF	-	Congenital Heart Failure
CRT	-	Cathode Ray Tube
CPU	-	Central Processing Unit
DC	-	Direct Current
DIT	-	Dar-Es-salaam Institute of Technology
DVD	-	Digital Versatile Disc
ECG	-	Electrocardiogram
GB	-	Gigabyte
GUI	-	Graphical User Interface
GPU	-	Graphics Processing Unit
GSM	-	Global Mobile System
HFDM	-	Heart Failure Disease Management
HFSAS	-	Heart Failure Somatic Awareness Scale
HSDPA	-	High Speed Downlink Packet Access
HSUPA	-	High Speed Uplink Packet Access

ICD	-	Implantable Cardioverter Defibrillators
IO	-	Input Output
MB	-	Megabyte
MODEM	-	Modulator and Demodulator
LED	-	Light Emitting Diode
PC	-	Personal Computer
PCB	-	Printed Circuit Board
PIC	-	Peripheral Interface Controller
RAM	-	Random Access Memory
SoC	-	System on Circuit
SPI	-	Serial to Parallel Interface
SQL	-	Structured Query Language
USB	-	Universal Serial Bus
Wi-Fi	-	Wireless Fidelity

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter introduce all information about what has captivated the idea of doing this project, it includes the background information, problem definition, objectives and the scope and limitation of this project.

1.1 Background Information

Heart failure (HF), often known as congestive or chronic heart failure (CHF), is a common condition that develops after the heart becomes damaged or weakened by heart disease such as myocardial infarction, coronary artery, and rheumatic heart diseases [1]. HF is a life-threatening disease and addressing it should be considered a global health priority [2]. At present, approximately 26 million people worldwide are living with HF according to the statistics reported by Ponikowski et al. [3]. In many countries, population-based HF studies have shown that about 1 to 2% of people have HF and even higher proportions have been reported in single center studies [4]. Although many advanced techniques have the test, electrocardiogram (ECG) [5], chest X-ray [6], echocardiogram [7], and coronary angiogram [8]. These methods require expertise from physicians, biologists, and clinicians. In this project, I will develop a portable, low cost and real-time monitoring system using 3G technology for heart beat monitoring. This application consists of 3G based network, Heart Beat sensors, data storage (server). It is mainly used to monitor Heart Beat of patients. The sensors are connected to Raspberry-Pi. Data is digitized and formatted by Raspberry-Pi and send to a computer by using 3G sheath through the internet where a software represent graphically shows the patients current status at receiver. Patient monitoring refers to the continuous or regular observation of repeating events of physiologic function to guide therapy or to monitor the effectiveness of interventions and is used primarily in the intensive care unit and operating room but now this will primarily be homed remote monitor.

1.2 Problem statement.

People suffering from heart diseases/disorders facies high cost due to regular attending to the hospitals for regular checkup and monitoring. It is also time consuming and tend even to raise the pain due to tiredness. Thus there is a need of collecting these measurements remotely from the patient even when the patient is at his/her home instead of having physical regular attendance to doctor for regular checkup and monitoring.

1.3 Project objectives.

The objectives are divided into two categories which are main objective and specific objectives

1.3.1 Main objective.

The main objective of the project is to design remote monitoring system which will enable data/measurements to be collected from the homed heart diseased person to doctor repository center at real time wireless for interpretation and intervention.

1.3.2 Specific objectives.

i. To design parameter specifications and design.

This is concerning with determining the required parameters with their specifications in each part so that to meet data flow as per requirements. Also this part deals with organizing the three major parts of the system to show how data will flow from the captured area to reach the required destination so as to meet general objective of the project

ii. To configure gateway to receive and transmit data.

Gateway will be programmed and configured to enable it to receive data and transmit received data to the internet.

iii. To design and constructing of database for storage

The data obtained from the patients to the doctor will be stored in this database

iv. To configure of server to handle the database.

At this part the database will be installed and configured to be run within the server.

v. To design and construction of Graphical User Interface (GUI)

The graphical User Interface will be constructed to provide doctor the access of data from the patient side.

vi. To implement and test the system.

1.4 Significance of the Project

The following advantages will be provided once the project is completed.

- Reducing cost due to regular travelling
- Time management
- Pain reduction
- Increasing efficiency of work for doctors.

1.5 Chapter conclusion

This chapter has discussed about introduction to heartbeat physiological activities, problem descriptions, objectives, significances, scope and limitation of the project. The problem addressed in this chapter is going to be solved after achieving the main objective. Methodological steps are the key procedures to be used in order to come up with the solution to the problem. The next chapter discuss these procedural steps towards achieving the main objectives of this project.

CHAPTER TWO

METHODOLOGY

2.0 Introduction

This chapter contains descriptions about different methods to be taken in order to accomplish the project. The following are the descriptions about methods which will be undertaken in order to fully address the objectives of this project.;

2.1 Literature review

It involves searching for knowledge and useful information that will be used to accomplish this project. Literature review is aimed to focus on reading and getting the knowledge from Books, World Wide Web and from other sources of knowledge. This involves the following:

2.2 Literature Review

In literature review different sources of information based on principles, technical, laws and all scientific verification are reviewed. These are printed books and online books, various technical reports, profession papers, journals, consultations and website from the internet.

2.3 Data Collection.

Both preliminary and technical data were collected. Preliminary data collected were having two parts, first part for verification of problem and need of the system. Second part was for specification requirements.

Technical data were also collected for each major component that will be used in the system. This technical data shows the features and technical specifications for each component. Data collection was done through questionnaires, reading books, surfing the internet and consulting some experts in cardiac diseases from Muhimbili national hospital and expert in biomedical equipment for more technical data as well as DIT staff for electronic and telecommunication equipment technical data.

2.4 Data Analysis

Data analysis will base on analyzing the collected data in relation to system requirement so that to obtain the suitable values of the components to be used. This will help in designing to meet main objective.

2.5 System Design

The design of the circuit will depend on the information from the data collected and analyzed in relation to the system requirements.

2.6 Circuit Simulation

The parts of this system as will be observed from the block diagram after design will be simulated in order to observe results of each part in the block diagram before implementing the complete the design.

2.7 Building Prototype and Testing

Circuit will be implemented in the board and tested if it is working properly. In case of any problem, then some corrections will be noted and done and then implementing the circuit on the circuit board.

2.8 Writing final report

The report will finally be written to explain what have been done from the start of the project to the end of it showing clearly what have been really achieved.

2.9 Chapter conclusion

This chapter has described the procedural steps which are undertaken in order to solve the existing problem. In order to develop a new system to solve the existing problem, a lot of information needs to be known in order to provide the awareness on how the previous system works. The next chapter digs deeper in finding and collecting information concerning this project.

CHAPTER THREE

LITERATURE REVIEW

3.0 Introduction.

This part describes the features, operation and limitations of the existing systems. It shows different technologies and approaches undertaken by different designers of the existing systems with drawbacks of these existing systems in relation to the proposed system. However, this part provides the necessary knowledge and information which help during design of the project.

3.1 Related Work

Currently, a number of studies have been proposed to patient's physiological parameter monitoring over wired and wireless transmission. Chaudhry et al. [9] established a large trial tele monitoring with1653 patients enrolled, where 826 were randomly assigned to undergo tele monitoring and 827 to receive usual care. Tele monitored patients were required to make daily calls for six months. During each call, the patients were asked a series of questions about their general health and HF symptoms. The results showed that the tele monitoring strategy on multicenter trial with a large database failed to provide a benefit over usual care and further strategies were needed to improve HF outcomes.

Suh et al. [10, 11] developed a system to remotely monitor patients with CHF, which had a three-tier architecture consisting of pervasive biosensors, a web server, and a back-end database. It acquired four health-related measures: weight, blood pressure, physical activity, and the Heart Failure Somatic Awareness Scale (HFSAS) [12] that reflect the most common signs and symptoms of CHF. Besides, their system can help the patients with guidance and feedback via text messages or emails.

A conceptual model for HF disease management (HFDM) was proposed in 2014 by Andrikopoulou et al. [13]. HFDM encompassed ongoing patient education and enhancement of self-care behavior, complemented by data derived from device diagnose base line risk; (1) monitoring of worsening signs and symptoms; and (2) encouragement of patient participation in their own care. This model has been proposed as a way to systematically identify the risk factor for HF and, accordingly, prevent associated mortality. Bui and Fonarow [14] reviewed some clinical trials and tested different HF monitoring strategies. They suggested several future challenges and opportunities in home-based hemodynamic monitoring such as evaluating HF monitoring in a broader population and in more diverse clinical settings, better defining optimal population for monitoring, studying long-term reliability and safety, and analyzing cost effectiveness of home-based monitoring. Similarly, Bhimaraj [15] made an evidence-based review of various home-based monitoring systems for HF patients, including monitoring with telephone, portable technology, wearable sensors, and implantable cardioverter defibrillators (ICD) or cardiac resynchronization therapy (CRT) devices. They mentioned that the explosion of social media and smart-phone applications is a potentially untapped resource in creating a patient centered system in the future.

Mohamed Fezari, et al. [16], describes the development of a heart rate monitor system based on a microcontroller. The implementation of an embedded system based on a microcontroller for real-time analysis of ECG signals has been investigated. The system has been tested successfully on simulated ECG signals for different heart diseases. The system is having ECG signal diagnosis capability, the real-time ECG processing, the remote control of a patient and the transportability. They have used PIC16F876.

S.Josephine Selvarani [17] has developed an on-line health monitoring of physiological signals of humans such as temperature and pulse using Zig-Bee by which the temperature and pulse of humans can be monitored from a distant location and some abnormalities can be easily indicated via SMS .The physiological measurements obtained from the Temperature Sensor and Heart Beat Sensor are transmitted to the programmed microcontroller to the PC through GSM. The PC collects the physiological measurements and also sends SMS, to the indicated mobile number through a GSM modem. The limitation of this paper is that if the signal of mobile is not present then the system will not work efficiently. It composed of the patient section and the server section, the communication unit, and the expert software. The graphical user interface programs on the PC are coded using Visual Basic Assembly level language is used for programming the microcontroller. Apart from the many current remote monitoring existing system for HF assessment, where some of them use invasive and implanted sensors and others monitor daily information to analyze HF via the Internet. My design, a three-part monitoring system not only builds on existing technologies but also introduces new functions that circumvent their shortfalls.

To monitor the health of a pregnant woman with preeclampsia a novel health monitoring system has been proposed in [18]. The system has been designed for the community based health care providers so that they can collect symptoms and perform clinical measurements at the patient's home. The clinical data are used to predict the risk level of a patient. Based on the risk level the system provides recommendations for treatment, referral, and reassessment. The proposed system also uses an Oximeter connected to a smartphone to measure oxygen saturation level of the patient in order to predict her risk level.

Remote healthcare system for monitoring electrocardiographic and temperature data has been presented in [19]. The system consists of three modules namely (i) a hardware module, (ii) Bluetooth module, and (iii) display module. The hardware module is used for data acquisition. The Bluetooth module is used for data transmission. Finally, the data are displayed by using the display module. The acquired clinical data are sent to a database server by using GPRS or WiFi. The performances of the system have been tested on different patients and it has been found that the proposed system is very helpful for the physicians. Mobile device based healthcare system for monitoring the patients with Alzheimer's disease has been developed and presented in [20]. The system is able to provide caregivers and medical professional with the ability to be in contact with the patients all the time. This system has been field tested by the Alzheimer's disease caregivers and the initial results show that the system is very effective for them.

A novel 6LoWPAN based ubiquitous healthcare system has been presented in [21]. The system integrates forwarding nodes and an edge router to provide real time monitoring of the ECG, temperature, and acceleration data of a patient. The user can send instructions to any node where the application running on it. The authors have used LabVIEW program to provide the connectivity. The whole system was tested by using an ECG simulator. The test results show that the received waveforms were found identical to those shown by a high resolution ECG signals.

An ambulatory system for monitoring the physical rehabilitation patients has been reported in [22]. The system consists of (i) a multi-sensor based monitoring device, (ii) a mobile phone with client application, (iii) a service-oriented-architecture based server solution, and (iv) an International Journal of Computer Networks & Communications (IJCNC) Vol.7, No.3, May 2015 17 application. The system has been tested in a controlled environments consisting of some healthy volunteers and some congestive heart failure patients. The test results show that the proposed system is able to detect and monitor congestive heart failure and it can send feedback to the nurses for patient follow-up.

Real time ubiquitous healthcare system for monitoring ECG signals by using mobile device has been presented in [23]. By using this system, the user can monitor his ECG signal. The authors have presented an algorithm for abnormal heartbeat detection and abnormal heartbeat check map (AHCM). The performance of the proposed system has been evaluated against the MIT-BIH normal arrhythmia database. It has been reported that the system is able to detect at an R-peak with a success rate of 97.8% and it is also able to detect abnormal heartbeat condition with a success rate of 78.9%.

A pervasive healthcare system enabling self-management for chronic patients has been introduced in [24]. The proposed system consists of (i) patient health monitoring system, (ii) status logging, and (iii) social sharing of the recorded information. The system has been implemented by (i) a mobile device, (ii) a wearable multi-sensing device, (iii) a service oriented architecture for communication, and (iv) microblogging services. The system has been tested on 16 patients. The test results show that the proposed system is very easy to learn and convenient to use by the chronic patients.

Wireless electrocardiogram (ECG) monitoring system based on Bluetooth Low Energy (BLE) technology has been reported in [25]. The system consists of (i) a single-chip ECG signal acquisition module, (ii) a Bluetooth module, and (iii) a smartphone. The system is able to acquire ECG signals through two-lead electrocardiogram (ECG) sensor. The system is also able to transmit the ECG data via the Bluetooth wireless link to a smartphone for further processing and displaying the ECG signals. The results show that the proposed system can be operated for a long period of time due to low power BLE technology.

3.2 Chapter conclusion

This chapter has described about the current knowledge including substantive findings, as well as theoretical and methodological contributions to this project. The literature review is expected to play a major role in the design of the proposed system as different ideas from previous works can be used to come up with a new and advanced system. The next chapter explains about the proposed system.

CHAPTER FOUR

PROPOSED SYSTEM

4.0 Introduction

This chapter explain the overall of system proposed. The proposed system details much on the parts constitute the system which are in the form of block diagram. The major part of the system is sensing system, signal pre-processing unit, sensing node and gateway, server and computer.

4.1 System Description

The proposed system consists of the following parts

- Sensing System block
- Signal Pre-processing Unit
- Sensing Node and Gateway
- Server
- Computer

The followings are the descriptions of the blocks of the proposed system.

4.1.1 Sensing System

This block includes ECG electrodes that convert physical signal to electrical signal. These sensors will be attached to the human body to get physical heartbeat performance and send acquired analog signal to the pre-processing and amplification unit after convention to electrical signal

4.1.2 Signal Pre-processing Unit

This includes an analog to digital converter (ADC). This part has the role of converting the analog signal coming from the ECG electrode to the digital form which is recognized by the next stage. At this stage filtering and amplification process are done.

4.1.3 Sensing node and Gateway

Sensing node is Pi node which receive digital signal from the amplifier and then transfer them to the gateway. In the gateway there is software responsible for converting the incoming data into text file format which is then transmitted to the server through internet

4.1.4 Server

This is hardware which will support processing software and database for data processing and storage of measured data respectively.

4.1.5 Computer

This will give interface to the doctor to get data from server (database) in standard format for interpretation and intervention. Not necessary to be a computer but any other devices can be used to access the data as long is connected to server.

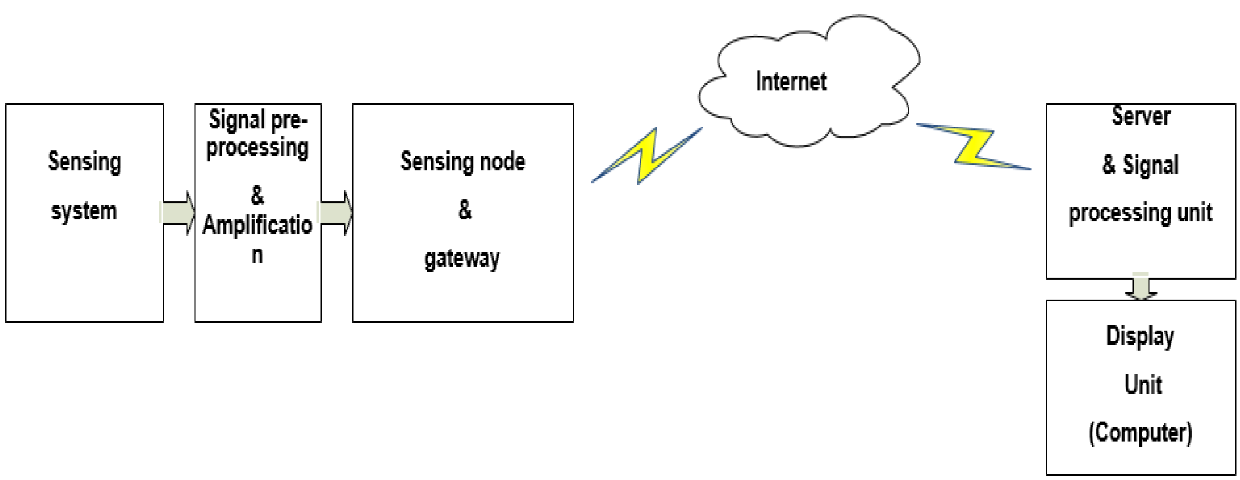


Figure 4.1 Block diagram of proposed system

CHAPTER FIVE

DATA COLLECTION

5.0 Introduction

This chapter explain data collected that concerning with the design of the proposed system. Two kinds of data were collected from different sources health related, these kinds of data are preliminary and technical data. Preliminary data are the data which justify the project and technical data are the data which illustrate the components that will help in the design. Preliminary data were collected from Muhimbili hospital. Data collected were obtained through interview and questionnaire methods. Data concerning general heart diseases effect status in Tanzania was collected. Technical data in details were collected through surfing internet and reading different sources of information.

5.1 Preliminary Data.

The following data were collected as preliminary information [26]

A descriptive cross sectional study was done from 1st July to 31st November 2007. During the five months' period, a total of 250 cardiac patients attending at cardiac clinic and those admitted in medical wards at Muhimbili National hospital were evaluated. Main outcome measure: Cardiac diagnosis Results: Of the 250 patients evaluated, 76 (48.7%) of cases were females. The median age of the study subjects was 32.5(±21.8) years. 66% were below 41 years of age. Rheumatic valvar heart disease was the predominant diagnosis detected in 115(46%) patients. There was female dominance with 76 (66.1%) being affected. Mitral valve stenosis was seen predominantly in females. Other diagnoses were: Hypertensive heart disease 53(21.3%), cardiomyopathies 28 (11.2%), Mitral valve prolapse 26(10.4%), pericardial disease15 (6.0%) and Congenital heart diseases 11 (4.4%). Ischemic heart disease 3 (1.2%) were the least diagnosed. Majority of patients attended were at advanced stages of heart failure, had low level of education and social economic status.

5.2 Technical Data

The following Technical data of the components suggested to be used were collected These data collected will be analyzed in the part of data analysis to help system and circuit design.

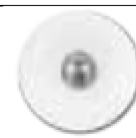
5.2.1 Sensing Unit (ECG Electrodes).

ECG Electrodes are the ones used to pick potentials generated from the heart (ECG) of the human body [27]. They change heart beat physical signal to electrical signal. Table 5.2.1shows different codes of ECG electrodes collected.

The collected electrodes were of two main types

- Dry ECG pads and
- Wet ECG pads

Table 5.1 Different codes of ECG electrodes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5.2.2 Preprocessing Unit

Different types of components were collected which collectively are used to design Preprocessing unit.

- Capacitors of different values
- Resistors of different values
- Instrumentation Amplifier
- Operation Amplifier

Table 5.2 Collected list of operational Amplifiers

Operational amplifiers

Part number	Description
LM158 LM258 LM358 LM2904	Low power, wide supply range dual op-amps
LM392	Low power dual op-amps and comparator
LM432	Dual op-amps with fixed 2.5 V reference
LM611	Op-amp with an adjustable voltage reference

5.2.3 Analogue to digital converter (ADC).

The following table 5.3 shows ADCs collected in data collections

Table 5.3 Different types of analogue to digital converter

Part No.	Description
MCP2030	MCP2030 3-Channel Analog Front-End
MCP3002	MCP3002 Dual 10-Bit A/D Convertor w/SPI
MCP3004	MCP3004 4-Channel 10-Bit A/D Convertor w/SPI
MCP3008	MCP3008 8-Channel 10-Bit A/D Convertor w/SPI
MCP3201	MCP3201 Single 12-Bit A/D Convertor w/SPI
MCP3202	MCP3202 Dual 12-Bit A/D Convertor w/SPI

5.2.4 Sensor node and gateway (control Unit)

The following list shows different controlling units collected in data collections that will act both as control unit and sensor node and gateway

- PIC12F1822
- PIC12LF1822

- PIC16F1823
- PIC16LF1823
- PIC16F1824
- Raspberry Pi
- Arduino
- Atmel AVR

5.2.5 Modem.

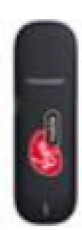
A modem is a network device that both modulates and demodulates analog carrier signals for encoding and decoding digital information for processing. Table 5.4 shows different models of Modem types

5.2.6 Server

A server is a computer program or a machine that waits for requests from other machines or software (clients) and responds to them. A server typically processes data. The purpose of a server is to share data or hardware and software resources among clients. Different types of servers collected are

- Database server
- Application server and
- Web server

Table 5.4 Different models of Modem [28]

Option Icon 	Huawei E220 	Huawei E169 	Huawei E1762 	Huawei E160e 
Huawei 153 	Huawei E173 	ZTE MF62 	Huawei E3131 	Huawei E5832 

CHAPTER SIX

DATA ANALYSIS AND SYSTEM DESIGN

6.0 Introduction

This chapter gives details about data analysis and design of the proposed systems. The analysis and designs are all based on the data collected in the previous chapter. The analysis involves both qualitative analysis and quantitative analysis. In the design of the proposed system, the use of the design equations wherever necessary has also been included in the chapter. Each block of the proposed system is analyzed and designed individually before being interfaced together to complete the overall design of the proposed system.

6.1 Sensing Unit

Biosignals are recorded as potentials, voltages, and electrical field strengths generated by nerves and muscles. The measurements involve voltages at very low levels, typically ranging between 1mV to 100mV and , with high source impedances [29]. Bio signals need to be amplified to make them compatible with devices such as displays, recorders, or A/D converters for computerized equipment.

6.1.1 Analyzing Electrode

Electrodes can work with an ECG machine to acquire and measure the electric potential on the skin. It comes in a few different varieties, such as contact or non-contact, wet or dry.

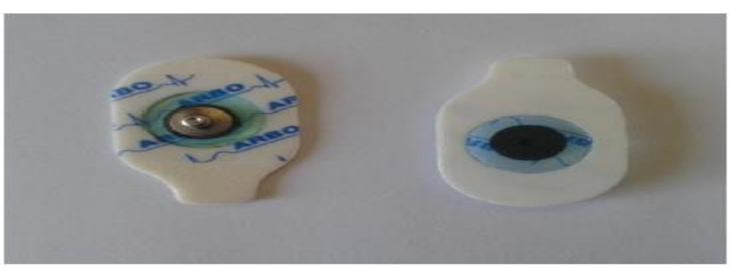


Figure 6.1 Ag/AgCl Electrodes

a) Wet Electrodes.

The standard commercial electrode is made of Ag/AgCl, shown in Figure 6.1 which consists of a metal pad coated with electrolytic gel to form a conductive interface between the skin and electrode. This type of electrode is commonly used at clinic and hospital. Although this wet electrode provides good signal quality it has the following disadvantages [30]

Disadvantage of Wet electrodes

1. Electrical conductivity could be lost when the gel becomes dry.
2 It is uncomfortable for long-term wearing and may cause skin irritation and skin allergic reaction.

b) Dry Electrodes

It is manufactured by printing and patterning metal ink on the paper substrate or the plastic substrate. This dry electrode can minimize allergic reaction caused by conductive gel of the wet electrodes. Furthermore, it can also provide continuous electrical conductivity for prolonged use. Hence, the use of the printed electrode fits for long-term ECG monitoring

6.1.2 Essential features of ECG signal are two:

- Small QRS amplitude and
- low frequency range.

QRS amplitude is quite variable from person to person [31], and is from 1mV to 100 mV. [32] The fundamental frequency for ECG ranges from DC level to few kilo Hertz.

6.2 Signal Pre-processing Unit

This unit includes amplifiers, filters as well as analogue to digital converter. The signal extracted from the subject by electrodes is in very small range not enough to be detected by ADC and then to processing unit. Therefore, it should be amplified to the detectable level. But before processing these signals at pre-processing stage some environmental factors should be analyzed.

6.2.1 Analysis and Design of Signal Pre-processing Unit

ECG signals may be corrupted by various kinds of noise. The main sources of noise are

- Power-line interference: 50–60 Hz pickup and harmonics from the power mains
- Electrode contact noise: variable contact between the electrode and the skin, causing baseline drift
- Motion artifacts: shifts in the baseline caused by changes in the electrode-skin impedance
- Muscle contraction: electromyogram-type signals (EMG) are generated and mixed with the ECG signals
- Respiration, causing drift in the baseline
- Electromagnetic interference from other electronic devices, with the electrode wires serving as antennas, and
- Noise coupled from other electronic devices, usually at high frequencies.

Typical lead III ECG with its P, QRS, Tand U segments is illustrated in fig.6.2. Three electrodes, two of them are picking up the biological signal and the third providing the reference potential. For meaningful and accurate detection, steps have to be taken to filter out or discard all the above unwanted contaminated signals.

The main challenge in ECG acquisition system is to detect the desired potential and attenuation of the amidst undesired bio potentials, noise and 50Hz electrical interference. The ECG acquisition system consisting of instrumentation amplifier amplifies the potentials and which is used to reject the common mode signals collected from electrodes with the gain of 364. This is followed by a Low pass filter (LPF), High pass filter (HPF) with the cut-off frequency of 220Hz and 0.16Hz respectively to attenuate the noise amidst from electrodes. Followed by the notch filter is used for attenuation of 50Hz line interference.

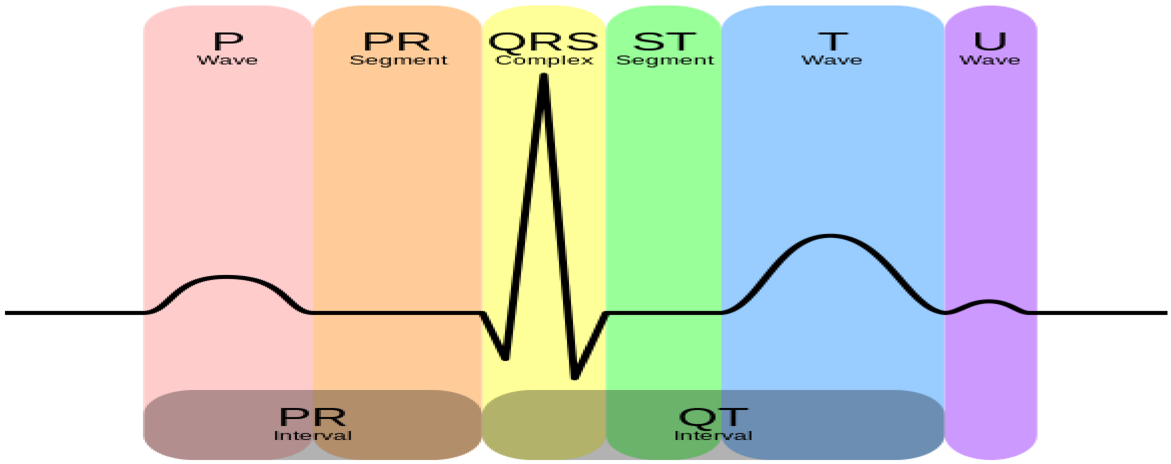


Figure 6.2 Normal rhythm of ECG. (www.sparkfun.com)

6.2.2 Design

A) Instrumentation amplifier (IA) and right leg driver (RLD).

Proper design of the amplifier provides rejection of large portion of the signal interferences. Main task of IA is to reject the line frequency interference that is electrostatically or magnetically coupled into the body. The desired bio potential appears as a voltage between the two inputs terminals of IA. Rejection of common mode signals is one of the most important characteristics of the IA [33]. AD620 is a low cost, and high accuracy IA having low noise, practically infinite input impedance used in ECG acquisition system that requires only one external resistor to set gain of 1 to 10,000. The common mode voltage on body is sensed and fed back to right leg. The right leg driver circuit as shown in figure.6.3 drives very small amount of current to right leg to equal the displacement current flowing in the body. This circuit also helps to patient's safety.

6.2.2.1 Gain Design of Instrumentation Amplifier;

From Instrumentation Amplifier Gain (G) formula;

$\mathrm{G} = 1 + \frac{49.4k}{R}$; Setting required gain to be G=364;

Then, R= 136ohms.

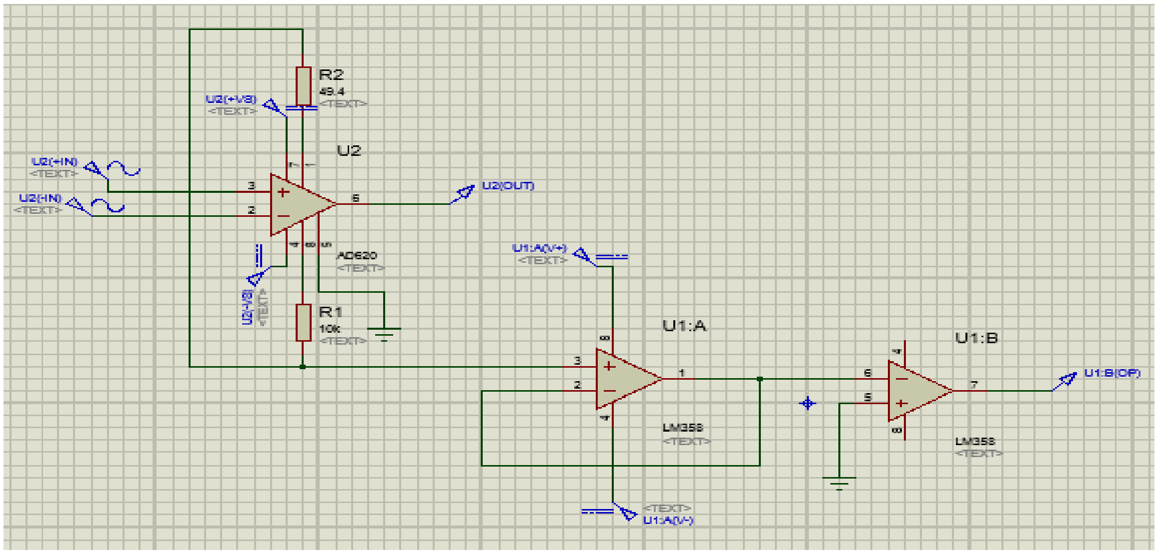


Figure 6.3 I A and RLD circuit

6.2.2.2 Filters Design

Sallen key topology is used for design of filters in ECG acquisition system and has been designed and tested. Filters uses a unity gain voltage amplifier with practically infinite input impedance and zero output impedance to design low pass, high pass and notch filter.

a) High pass filter

Cut off frequency design: Setting F_c=0.16Hz;

From the formula;

$$F_c = \frac{1}{2\pi\sqrt{R1\times R2\times C1\times C2}};$$

where R1=R2=R=990

Then, C1=C2=C=1uF.

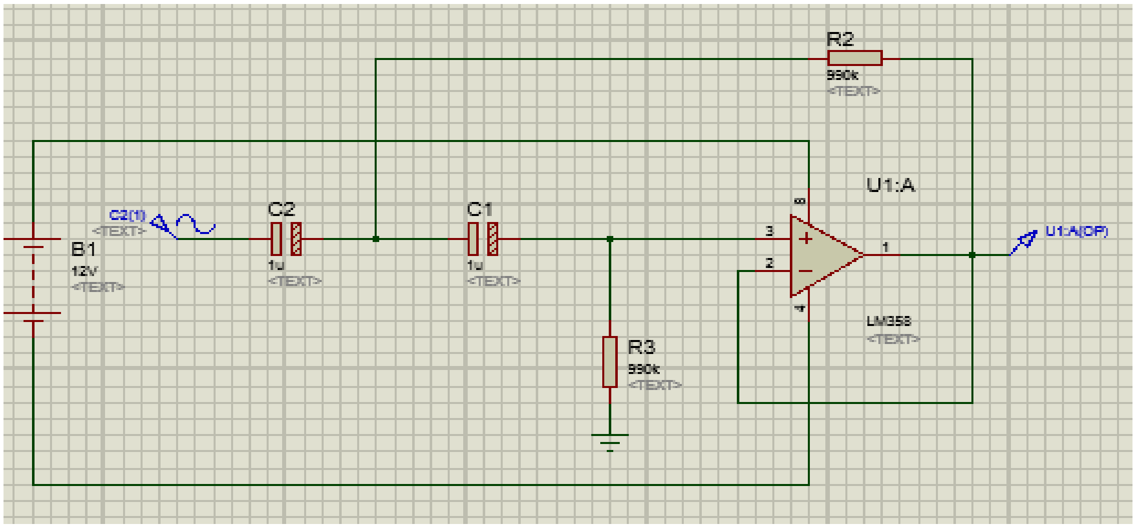


Figure 6.4 High Pass filter circuit.

b) Low Pass filter

Cut off frequency design: Setting F_c=219Hz;

From the formula;

$$F_c = \frac{1}{2\pi\sqrt{R1\times R2\times C1\times C2}};$$ where R1=R2=R=330k

Then, C1=C2=C=2.2nF

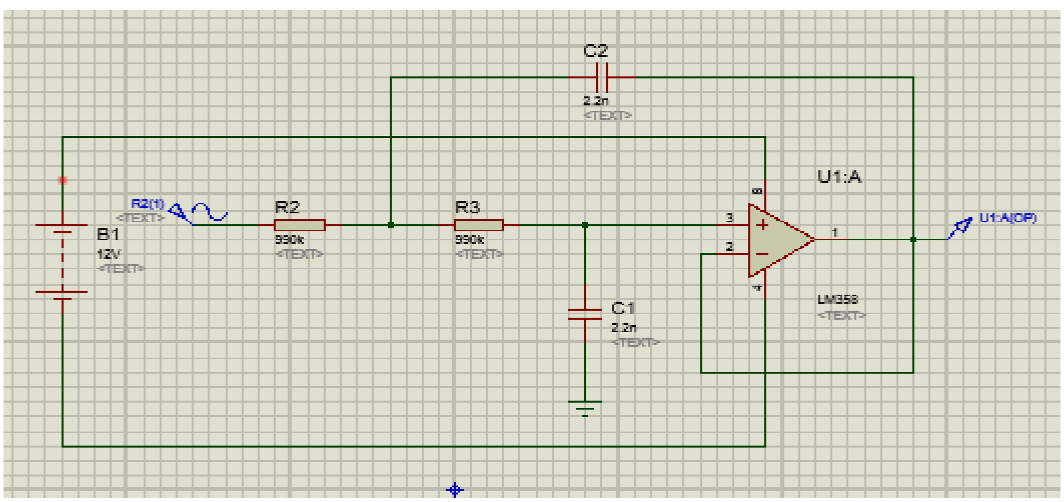


Figure 6.5 Low Pass filter circuit.

c) **Notch Filter.**

Cut off frequency design.

From the formula;

$F_c = \frac{1}{2\pi\sqrt{R1 \times R2 \times C1 \times C2}}$; where R1=R2=R=330

Setting F_c=48.2Hz;

Then, C1=C2=C=10n.

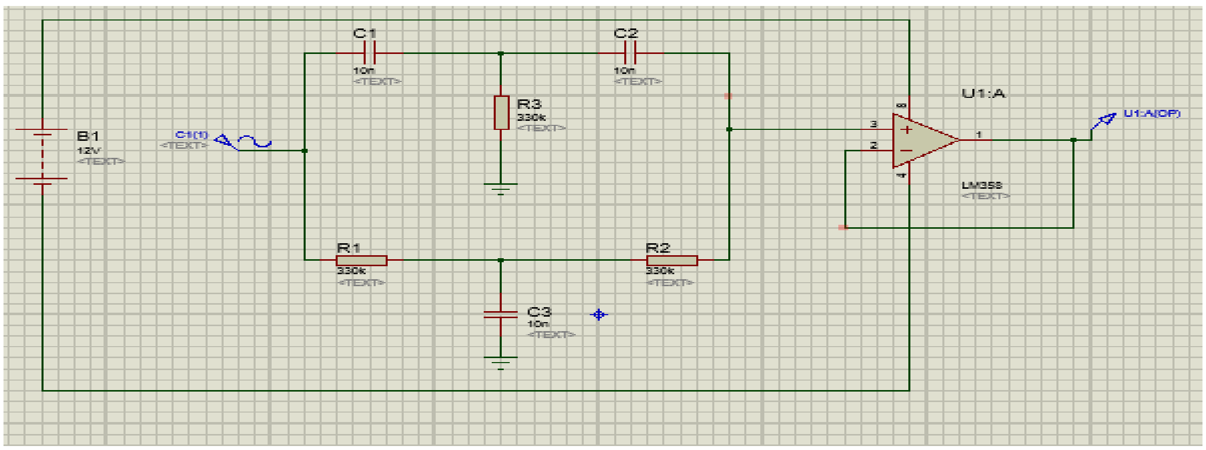


Figure 6.6 Notch filter circuit.

6.2.3 Circuit outline

The fig.6.7 shows entire circuit diagram of the ECG acquisition system. It consists of IA, active HPF, LPF and notch filter. Right arm (RA) and left arm (LA) electrodes have to be connected to connector which is input to the IA. Here perfect linearity is needed regardless of signal amplitude and instant output response regardless of the speed of the signal. Due to these two requirements we have used the AD620 (U1) as IA. And it is type of differential amplifier and that is connected with input buffer amplifiers. The differential amplifier amplifies difference between two potentials from electrodes but does not amplify the particular voltage. It has some important characteristics that are its very low DC offset, low drift, low noise, very high Common mode rejection ratio(CMRR) and input impedance and low output impedance. Gain of the IA can be adjusted by external resistances R10 andR11.

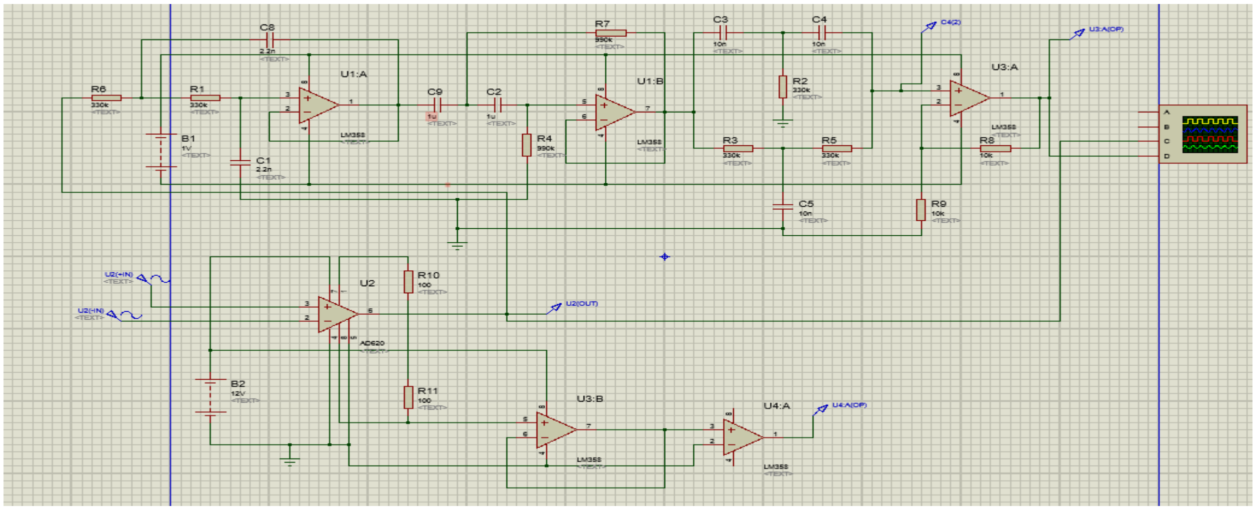


Figure 6.7 ECG acquisition system circuit.

6.2.4 Heart beat calculation

R-R interval as per the experimental result is 800ms

$$\frac{1}{800 \times 10^{-3}} \times 60 = 75\text{bpm}$$

Table 6.1 Heartbeat calculation

PQRST WAVE	NORMAL	ACTUAL OUTPUT
PWAVE	0.12 to 1.20sec	0.11sec
QRSWAVE	<=0.12sec	0.10sec
TWAVE	Not usually measured	0.218sec

6.3 Analogue to Digital converter analysis.

Without exception, all bio signals are analog signals. Processing of bio signals by computers therefore requires discretization (i.e., sampling and quantification). Selecting the most suitable A/D Converter (ADC) for the particular application is based on more than just the precision or bits. Different architectures are available, each exhibiting advantages and disadvantages in various data acquisition systems. The required accuracy or precision of the system puts in a category based on the number of bits required. For most bio signals a 6- to 12-bit ADC is sufficient.

When sampling a signal, we use an analog-to-digital converter (A-D converter or ADC). Samples are taken at a rate at least twice the rate of the highest-frequency component contained in the signal (i.e., the mixture of signal plus noise, unless the noise has been filtered out beforehand), and the samples are quantitated and expressed as numbers. The latter is always done with a limited accuracy and may, in principle, add so called quantization noise to the sampled signal. This quantization noise should generally not exceed the noise that is already present in the signal, or, as expressed in more general terms, discretization by the ADC should not increase the information entropy, syntactic and semantic signal properties should be left intact.

The degree of quantization can be expressed as the number of quantization steps for the range of possible amplitude values. If the signal amplitude spans a range of A volts (e.g., from $-A/2$ to $+A/2$) and the quantization step is Δq, then the number of quantization steps is $m = A/\Delta q$.

In practice, let m be a power of 2: $m = 2^n$,
So that the quantization of the ADC can be expressed in n bits.

For most bio signals a 6- to 12-bit ADC is sufficient; a 12-bit ADC implies a resolution of 1/4096 (less than 0.025%), related to a signal-to-noise ratio which is far superior to that attainable with most signal transducers.

Table 6.2 ADC Performance through 24-bit Converter

No of Bits	2^n	LSB (FS = 1V)	Resolution (%)	Resolution (ppm)	Resolution (dB)
8	256	3.91 mV	0.391	3910	48.16
10	1024	977 µV	0.0977	977	60.21
12	4096	244 µV	0.0244	244	72.25
14	16384	61 µV	0.0061	61	84.29
16	65536	15.3 µV	0.00153	15.3	96.33
18	262144	3.81 µV	0.000381	3.81	108.37
20	1048576	954 nV	9.54E-05	0.954	120.41
22	4194304	238 nV	2.38E-05	0.954	132.45
24	16777216	59.5 nV	5.95E-06	0.238	144.49

Table 6.3 ADC Product specification

Device	Resolution (bits)	Maximum Sampling Rate (samples/sec)	# of Input Channels	Input Type	Interface	Input Voltage Range (V)	Active Current Max. (µA)	Max. INL	Temperature Range (°C)	Packages
MCP3002	10	200	2	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	250	±1 LSB	-40 to +85	8 PDIP, MSOP, SOIC, TSSOP
MCP3004	10	200	4	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	14 PDIP, SOIC, TSSOP
MCP3008	10	200	8	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	16 PDIP, SOIC
MCP3202	12	100	2	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	550	±1 LSB	-40 to +85	8 PDIP, MSOP, SOIC, TSSOP
MCP3204	12	100	4	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	14 PDIP, SOIC, TSSOP
MCP3208	12	100	8	Single-ended or Pseudo-Differential	SPI	2.7 to 5.5	400	±1 LSB	-40 to +85	16 PDIP, SOIC

6.4 Sensor node and gateway (Raspberry Pi) analysis.

The raspberry pi board comprises a program memory (RAM), processor and graphics chip, CPU, GPU, Ethernet port, GPIO pins, Xbee socket, UART, power source connector. And various interfaces for other external devices. It also requires mass storage, for that we use an SD flash memory card. So that raspberry pi board will boot from this SD card similarly as a PC boots up into windows from its hard disk.

Essential hardware specifications of raspberry pi mainly include SD card containing Linux OS, US keyboard, monitor, power supply and video cable.

Table 6.4 Distinguishing features of different RPi models

	Number of USB ports	Minimum Current Drain (mA)	Ethernet	RAM (MB)	Number of GPIO Pins
Model A	1	500	No	256	26
Model A+	1	*	No	256	40
Model B	2	700	Yes	512	26
Model B+	4	600	Yes	512	40

6.4.1 Memory

The raspberry pi model Aboard is designed with 256MB of SDRAM and model B is designed with 512MB.Raspberry pi is a small size PC compare with other PCs. The normal PCs RAM memory is available in gigabytes. But in raspberry pi board, the RAM memory is available more than 256MB or 512MB

6.4.2 CPU (Central Processing Unit)

The Central processing unit is the brain of the raspberry pi board and that is responsible for carrying out the instructions of the computer through logical and mathematical operations. The raspberry pi uses ARM11 series processor, which has joined the ranks of the Samsung galaxy phone.

6.4.3 GPU (Graphics Processing Unit)

The GPU is a specialized chip in the raspberry pi board and that is designed to speed up the operation of image calculations. This board designed with a Broadcom video core IV and it supports OpenGL

6.4.4 Ethernet Port

The Ethernet port of the raspberry pi is the main gateway for communicating with additional devices. The raspberry pi Ethernet port is used to plug your home router to access the internet.

6.4.5 GPIO Pins

Contrary to the high-level ports, these general purpose input/output (GPIO) pins are not of the "plug and play" type and require caution when wiring to prevent damage to the RPi itself. The pins are exclusively tolerant to 3.3V logic levels which means anything higher than this value has a high risk of damaging the device. By definition, a GPIO is a generic pin on a chip whose behavior (including whether the pin is an input or output) can be programmed through software. Depending on the version, the RPi can either have 26 GPIO pins (A and B versions) or 40 (A+ and B+ versions). Most of the GPIO pins can be reconfigured to provide the alternate functions Serial Peripheral Interface (SPI), Inter-Integrated Circuit, Pulse Width Modulation and Universal Asynchronous Receiver/Transmitter, while the remaining few act as +5V, +3.3V and ground supply pins and can't be reprogrammed. The layout of the GPIO pin header for a RPI Model A can be studied in Figure 6.4.1

6.4.6 XBee Socket

The XBee socket is used in raspberry pi board for the wireless communication purpose.

6.4.7 Power Source Connector

The power source cable is a small switch, which is placed on side of the shield. The main purpose of the power source connector is to enable an external power source.

6.4.8 Display

The connection options of the raspberry pi board are two types such as HDMI and Composite. Many LCD and HD TV monitors can be attached using an HDMI male cable and with a low-cost adaptor. The versions of HDMI are 1.3 and 1.4 are supported and 1.4 version cable is recommended. The O/Ps of the Raspberry Pi audio and video through HMDI, but does not support HDMI I/p. Older TVs can be connected using composite video. When using a composite video connection, audio is available from the 3.5mm jack socket and can be sent to your TV. To send audio to your TV, you need a cable which adjusts from 3.5mm to double RCA connectors.

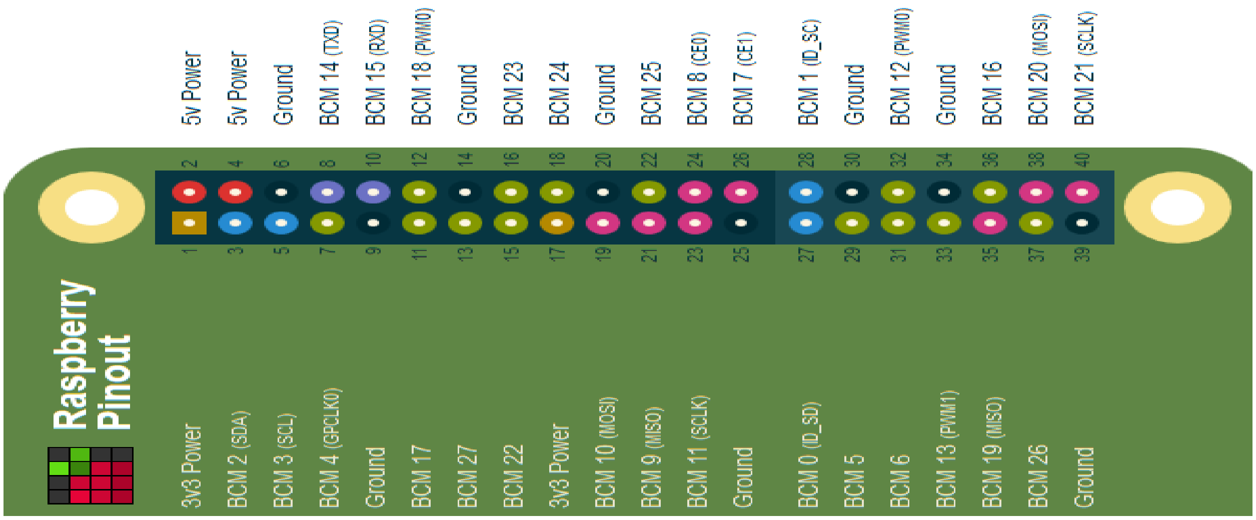


Figure 6.8 GPIO pinout for the RPi model B+

6.4.9 Raspberry Pi Clock Frequency

When the RPi was first considered for this work, there was a question of whether its GPIO capabilities were sufficient to handle the clock frequency of the proposed ADC. [34] conducted an experiment where he tested various libraries under several different programming languages, including Python, C and Perl, to observe what was the highest frequency square wave the RPi was capable of outputting. Not surprisingly, the three tested C libraries, wiringPi [35], BCM 2835 [36] and native library, were the ones with the best performance, most likely due to the low level nature of C. Although the BCM 2835 library was the one that performed the poorest among the three, with a maximum of 5.1MHz versus 7.1MHz and 22MHz for the wiringPi and native libraries, respectively, it was the one chosen for accessing the GPIO. Besides 5.1MHz being more than enough for what was required (2.5MHz) the library provided easier GPIO interfacing than the native library and offered a set of useful functions that were missing from the wiringPi library.

Figure 6.9 Diagram illustrating the different established connections between master and slave.

6.4.10 Acquisition algorithm

The ECG monitoring algorithm is executed in the following steps:

- ADC sampling
- Quantization
- Data transfer

Algorithm

1. Initialize the Raspberry-Pi.
2. Load OS on Raspberry-Pi.
3. Select the input parameter.
4. Read the equivalent digital data of the parameter selected.
5. Display the received data (Option).
6. Send the received data

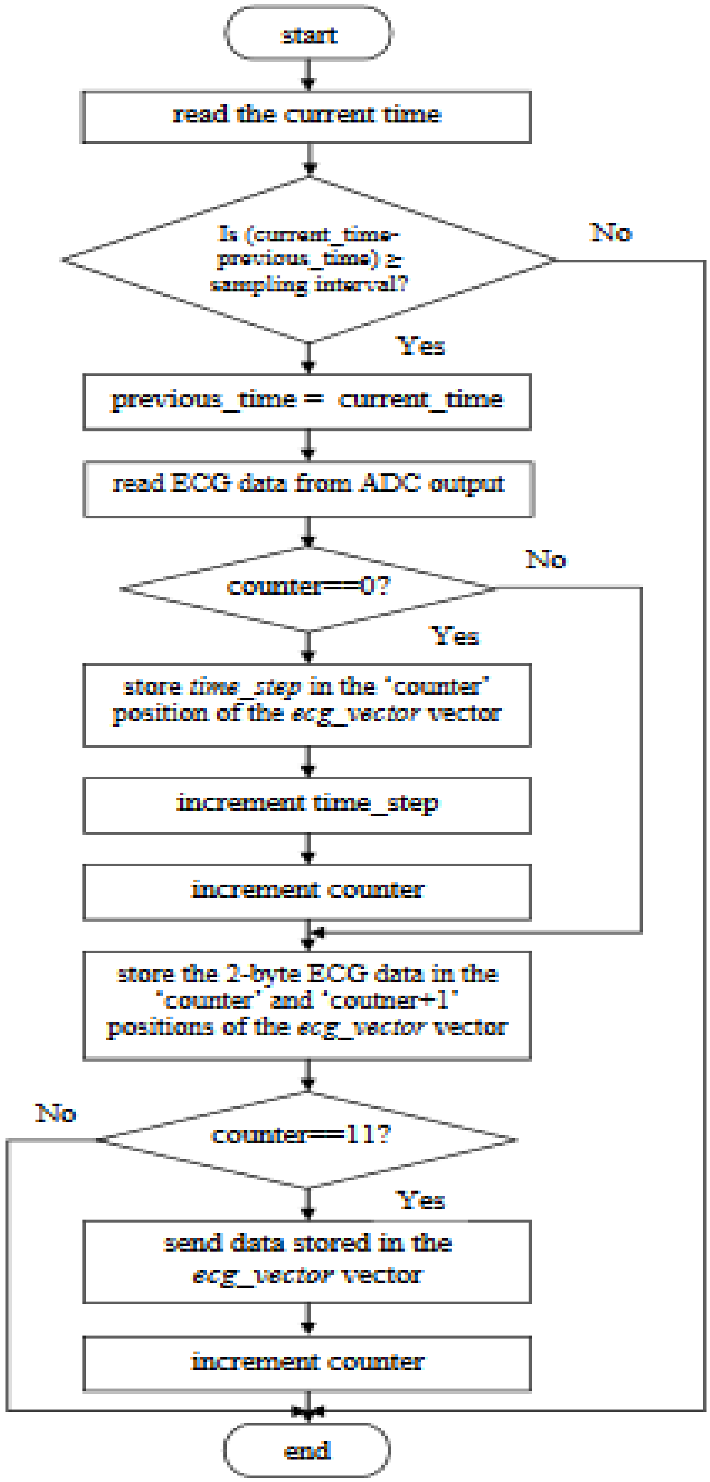


Figure 6.10 Flow chart of ECG monitoring algorithm

6.5 Server (Server Analysis)

A server is a computer program or a machine that waits for requests from other machines or software (clients) and responds to them. A server typically processes data

6.5.1 Database Server

Maintains and shares any form of database (organized collections of data with predefined properties that may be displayed in a table) over a network. Database server specifications are based on database sizes in use on the server. These specifications are based on a database server dedicated to running Plus2 [21]

6.5.2 Application Server

Application server specifications and the quantity of servers required are based on the number of users expected to be running Plus2 across the server farm. Farm resilience is maintained using an N+1 principle. Application server specifications and the quantity of servers required are based on the number of users expected to be running Plus2 across the server farm

6.5.3 Web Server

Web servers are computers that deliver (serves up) Web pages. Every Web server has an IP address and possibly a domain name for example, if you enter the URL. Any computer can be turned into a Web server by installing server software and connecting the machine to the Internet. There are many Web server software applications, including public domain software and commercial packages

Since the required server should provide services/access to the remote users it must support web services and must be capable of handling as many users as possible due to the type of services is to be provided. For these reasons LAMP server can be good choice.

6.5.3.1 LAMP server (web server).

System requirement for LAMP server.

- Linux environment
- Apache
- MySQL database
- PHP

6.5.3.2 LAMP Server (Linux, Apache, MySQL, PHP)

LAMP is an open source Web development platform that uses Linux as the operating system, Apache as the Web server, MySQL as the relational database management system and PHP as the object-oriented scripting language. The LAMP components are largely interchangeable and not limited to the original selection. As a solution stack, LAMP is suitable for building dynamic web sites and web applications.

6.5.3.3 Linux

Linux is a Unix-like computer operating system assembled under the model of free and open source software development and distribution. Most Linux distributions, as collections of software based around the Linux kernel and often around a package management system, provide complete LAMP setups through their packages. According to W3Techs in October 2013, 58.5% of web server market share was shared between Debian and Ubuntu, while RHEL, Fedora and CentOS together shared 37.3%. In this project I used Raspbian OS which is a flavor of Linux suitable for Raspberry Pi.

6.5.3.4 Apache

The role of LAMP's web server has been traditionally supplied by Apache, and has since included other web servers such as Nginx. The Apache HTTP Server has been the most popular web server on the public Internet. In June 2013, Netcraft estimated that Apache served 54.2% of all active websites and 53.3% of the top servers across all domains. Apache is developed and maintained by an open community of developers under the auspices of the Apache Software Foundation. Released under the Apache License, Apache is open-source software. A wide variety of features are supported, and many of them are implemented as compiled modules which extend the core functionality of Apache. These can range from server-side programming language support to authentication schemes.

6.5.3.5 MySQL Database Server

MySQL is an open-source relational database management system. MySQL is a popular choice of database for use in web applications, and is a central component of the widely used LAMP.

6.5.3.6 PHP

PHP is a server-side scripting language designed for web development but also used as a general-purpose programming language. PHP code may be embedded into HTML code, or it can be used in combination with various web template systems, web content management system and web frameworks. PHP code is usually processed by a PHP interpreter implemented as a module in the web server or as a Common Gateway Interface (CGI) executable. The web server combines the results of the interpreted and executed PHP code, which may be any type of data, including images, with the generated web page.

The standard PHP interpreter, powered by the Zend Engine, is free software released under the PHP License. PHP has been widely ported and can be deployed on most web servers on almost every operating system and platform, free of charge.

6.5.3.7 High Level overview of LAMP

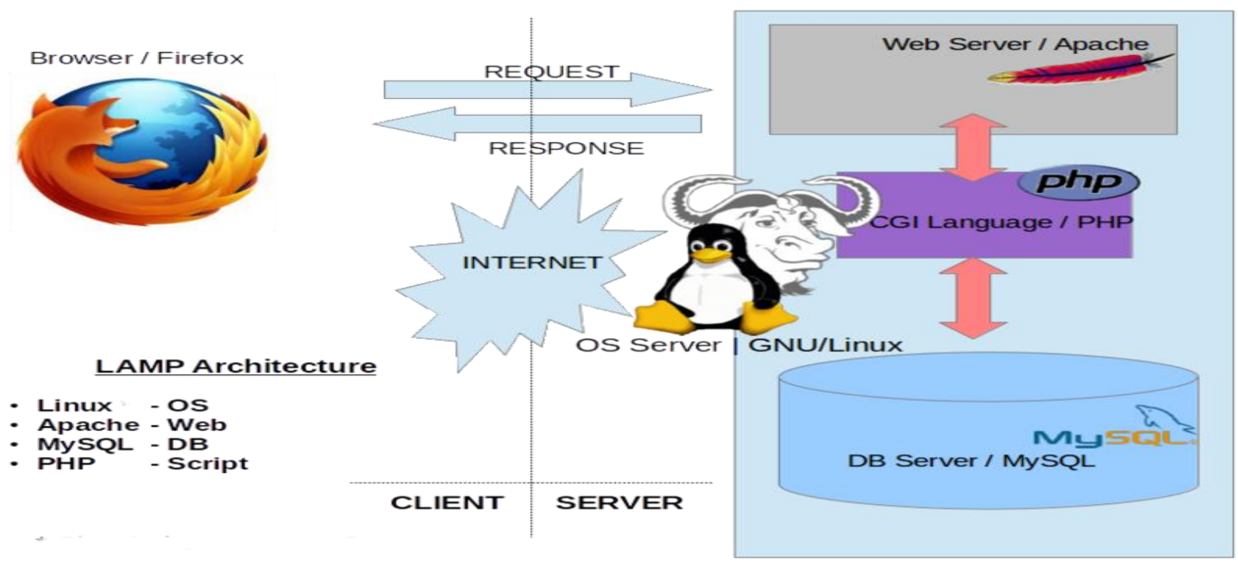


Figure 6.11 High level overview of LAMP

6.6 Graphical User Interface.

There are different approaches of constructing Graphical User Interface as were collected in data collections. Few being ecgML, LabVIEW, Mat lab etc.

6.6.1 ecgML

This is web browser for ECG viewing which is mostly likely to be used in my project because of the nature of my project which needs to have access from the internet. The following are the features of ecgML which distinguishing ecgML from other ECG user interfaces.

- ecgMLgenerator
- ECG parser and
- Ecg viewer

6.6.2 ecgMLgenerator

The ecgMLgenerator provides a user-friendly interface for automatically creating ecgML-based records. Working in conjunction with the Oracle XML Parser, Oracle Class Generator generates a set of Java classes (one class per XML element) based on either the ecgML DTD or XML Schema. The generated classes are then used to dynamically construct an ecgML-based representation, which is compliant to the DTD/XML Schema specified

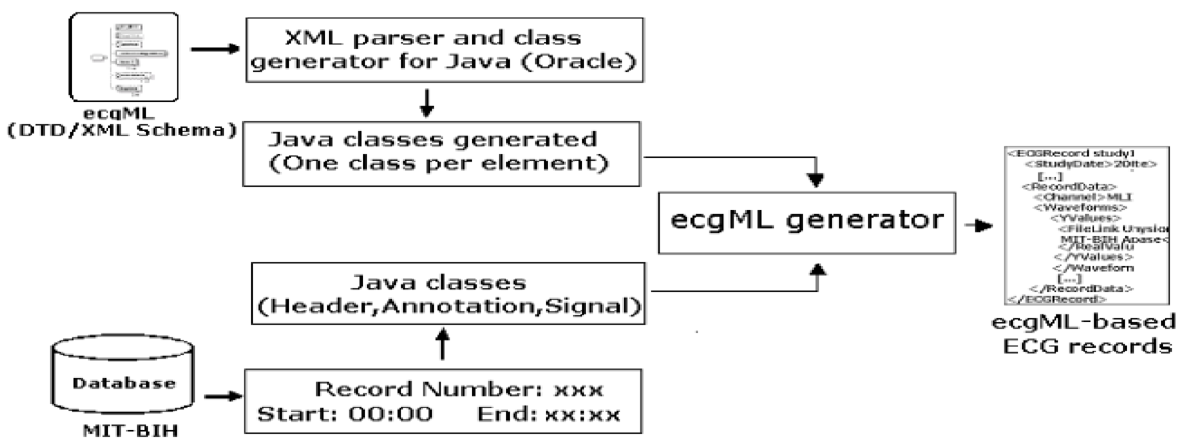


Figure 6.12 How the ecgMLgenerator constructs an ecgML record

6.6.3 The ecgML Model

I needed to harmonize the representation of digital ECG data originating from the full spectrum of devices along with annotations for events, and to include necessary associated information, such as patient identification, interpretation and other clinical data.

Each patient record starts with a root element ECGRecord, which is uniquely identified by its attribute studyID

The StudyDate and StudyTime elements represent the latest time record of the study of the ECG recording. Diagnosis contains a text version of the latest diagnostic interpretation of the ECG, while MedicalHistory is a description of the medical history of a patient's clinical problems and diagnoses. There are two main components for each record: one Patient Demographic element and one-or-more Record elements. The tree diagram of the ECGRecord element is given in Figure 6.13

6.6.4 Analyzing graphical User Interface basing on ecgML

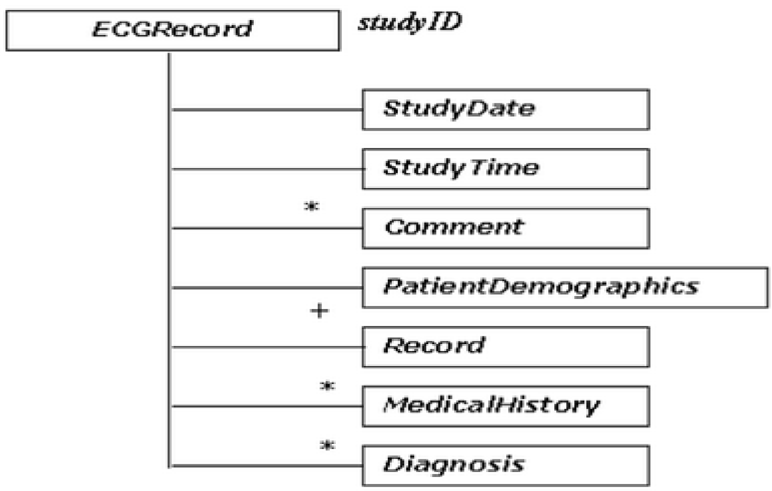


Figure 6.13 The tree diagram of ecgML element ECGRecord

PatientDemographics contains information of general interest concerning the person from whom the recording is obtained, such as demographic data (e.g. patientID, Name, etc.) and contact information (e.g. Address). This component was required in each record. Record, shown in Figure 6.14, represents the physical storage for the basic content of an ECG recording. The AcquisitionDate and AcquisitionTime elements specify date and time the record was taken. InvestigatorID and siteID were used to identify the responsible person and institution for the recording. There are three main components: zero-or-one RecordingDevice, zero-or-one ClinicalProtocol, and one-or-more RecordDate

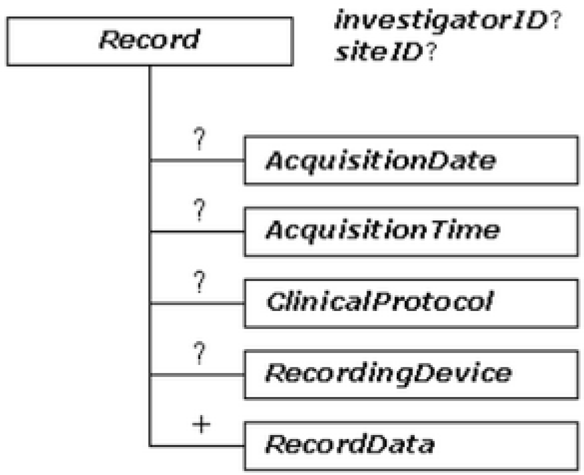


Figure 6.14 The tree diagram of ecgML element Record

RecordingDevice generated the data, while ClinicalProtocol included information relating to a patient's clinical report. RecordData is a key ecgML element. There were multiple RecordData elements within a file, which are identified by their Channel element names. The DICOM lead labelling format is recommended for this purpose [6]. RecordData includes three main sub-components: Waveforms, Annotations and Measurements. The corresponding tree diagrams are illustrated in Figure 6.16, Figure 6.17 and Figure 6.18

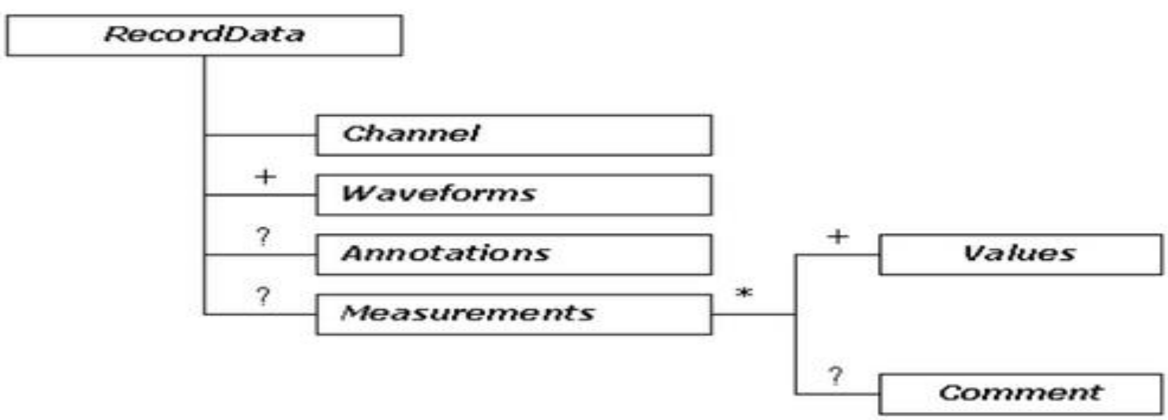


Figure 6.15 The tree diagram of ecgML element RecordData

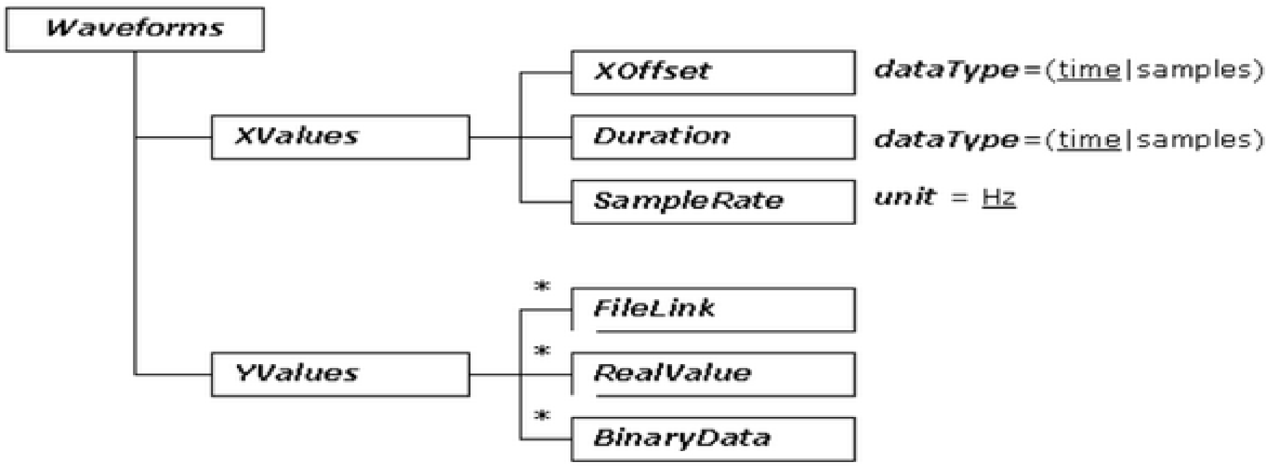


Figure 6.16 The tree diagram of ecgML element Waveform

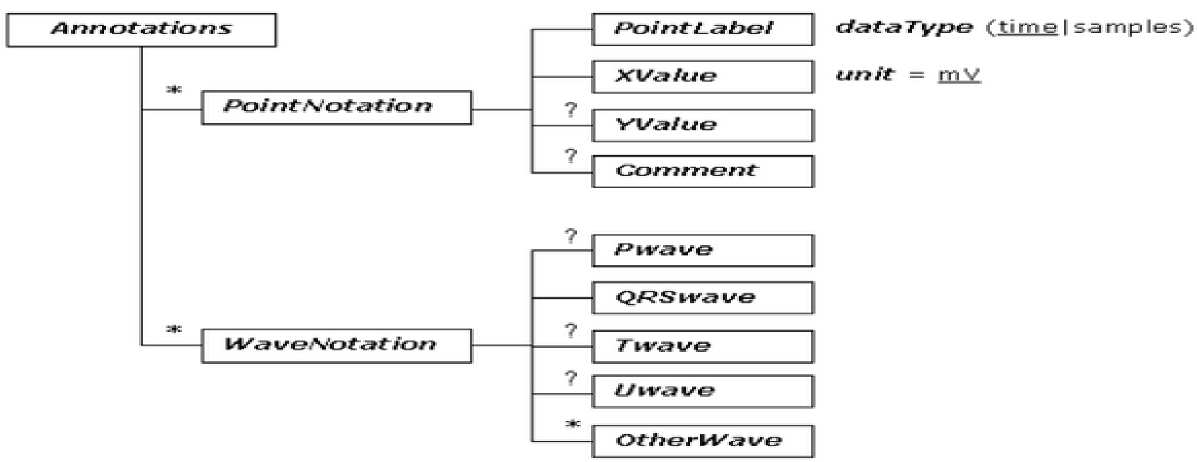


Figure 6.17 The tree diagram of ecgML element Annotations

6.7 Chapter Conclusion

This chapter has described about data analysis and system design. It has shown how the blocks of the proposed system have been opened and how component value have been calculated by using suitable design equations. It has also described about how different system parts have been designed and integrated to form overall system. The simulation of the designed system and its results are explained in the next chapter.

CHAPTER SEVEN

SIMULATION

7.0 Introduction

This chapter describes about the simulation of the designed system. It includes descriptions about simulation tools used, simulation constraints, performance testing parameters and simulation testing procedures. It also presents the results and their discussions.

7.1 Simulation software

The simulation software used for this project are proteus and Mat lab 2013a/Simulink.

The proteus simulation tool is chosen because of the following reasons

- It is rich in libraries of different types of electronic components and modules
- It performs well in different varieties of projects ranging from simple electronic circuit to complex ones
- In addition to simulation excellency, it offers a capability to prepare even the printed circuit board for actual realization of the prototypes of different designed systems.

Mat lab 2013a simulation tools was chosen because of many reasons but two reasons are the most;

- Mat lab has Simulink support packages for raspberry Pi hardware
- Allows modelling of components to meet simulation environment
- Also it provides real time simulation.

7.2 Simulation Constraints

The following are the simulation environment of the designed system.

- The rain ECG sensors were modelled by using voltage input probes because the ECG sensor was not available in the proteus.
- The sensor node and gateway was not simulated in proteus rather it was simulated in Mat lab software as it was not supported in proteus.

- The performance parameters are measured by using oscilloscope and Voltage probes available in the proteus software. Also in Mat lab oscilloscope termed as scope was used.

7.3 Performance testing parameters and procedures

In this simulation the following are the parameters to test in order to verify that the system is working as required or not.

7.3.1 Variation of output voltage waveform.

The output voltage waveform varies as different voltages from different values of voltage probes were applied

7.4 Results and discussion

By comparing the output voltage waveform obtained in fig 7.6 with that set as standard in fig 6.2 from data analysis and design, it is with full confidence to declare that the system performed as per specification in simulation environment.

7.5 Voltage waveform variation for different stages to obtain required ECG signal

The voltage signal from the sensors were passed through different stages as from Instrumentation Amplifier, High pass filter, low pass filter and notch filter in pre-processing unit. The output signal from each stage is shown below from the corresponding stage.

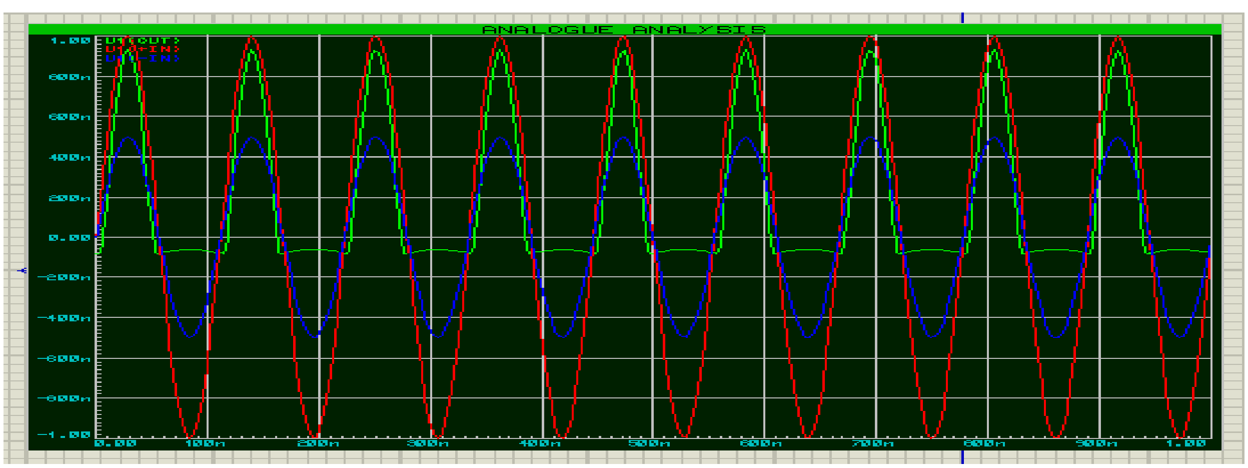


Figure 7.1 Analogy analysis of Instrumentational Amplifier (IN)

7.5.1 Analogy graph description for Instrumentation Amplifier;

The graph Fig 7.1 shows three signals. Red and blue colors represent input signals from the two electrodes as applied to the positive and negative terminals of the instrument Amplifier.

The green color represents amplified differential signal from the two red and blue input signals.

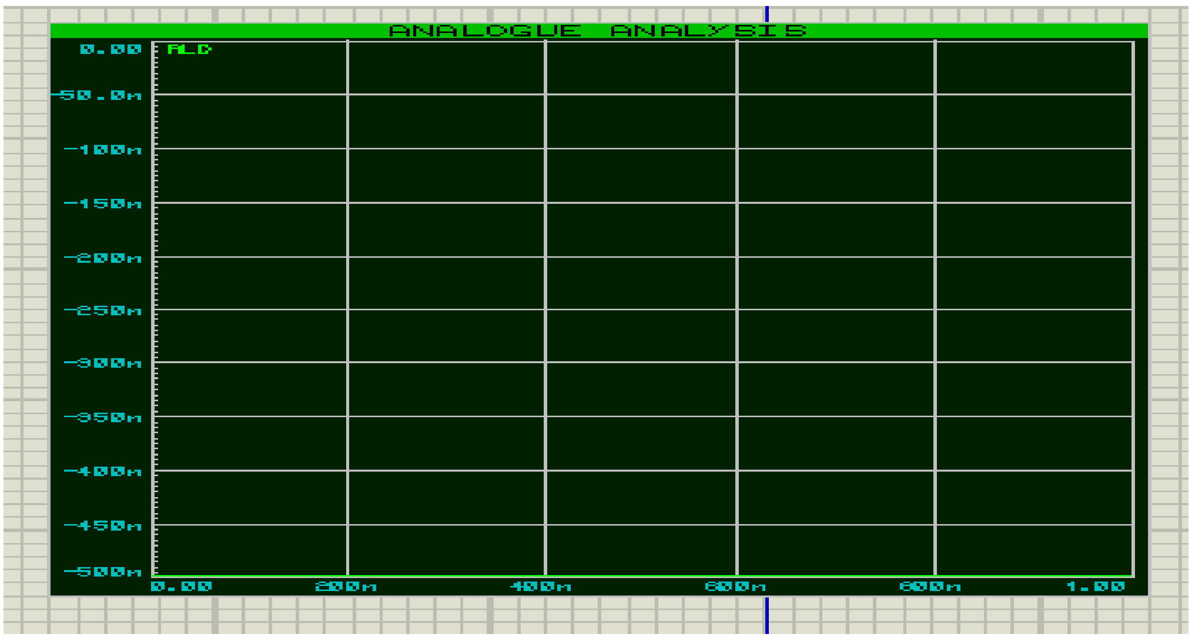


Figure 7.2 Analogy analysis of RLD.

7.5.2 Analogy graph description for RLD signal.

From the graph Fig 7.2 the signal is a DC signal. This signal should be DC signal because it is used as reference signal.

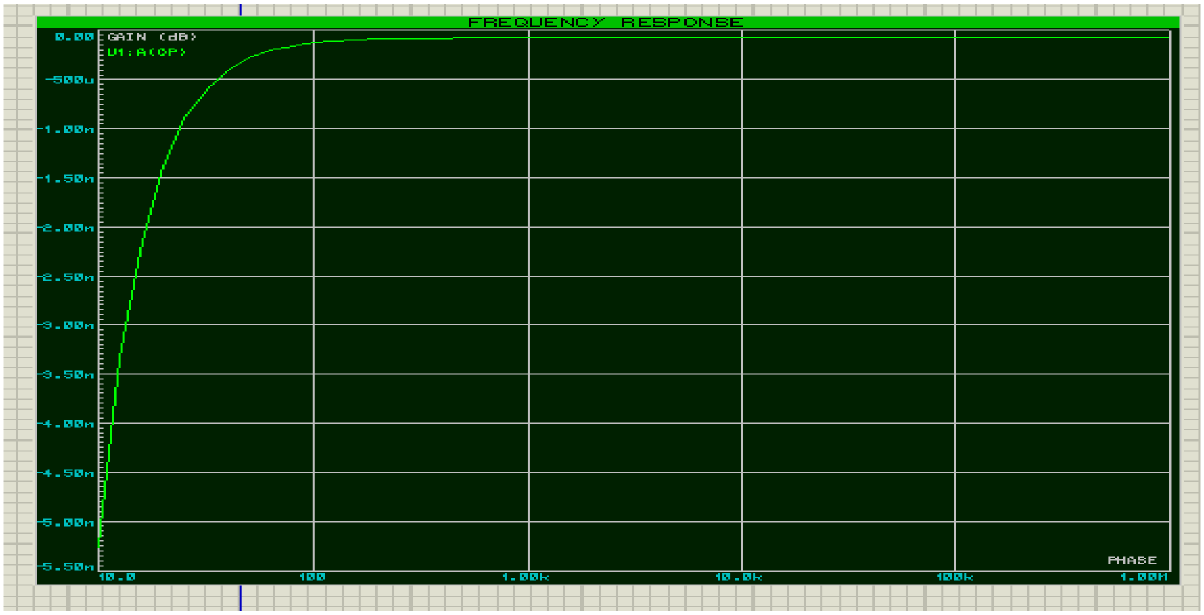


Figure 7.3 Frequency Response of High pass filter.

7.5.3 Frequency description for High pass filter.

The frequency response Fig 7.3 illustrates that the frequency above 0.16Hz will be allowed to pass through where by attenuating frequency below that which are from analysis caused by motion artifacts, electrode contact and respiration.

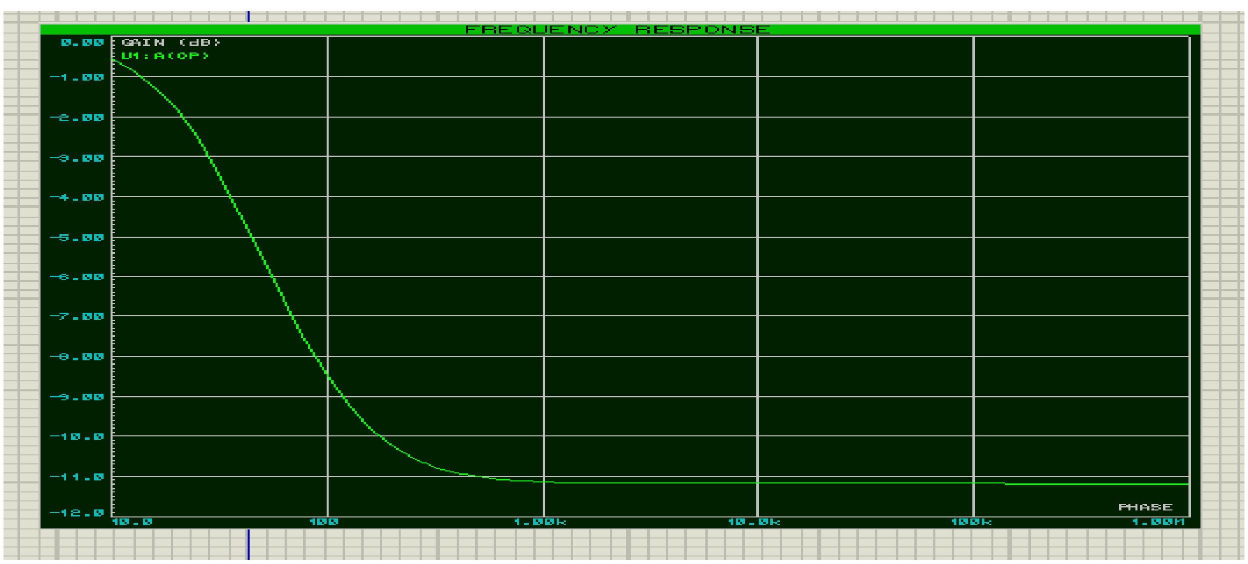


Figure 7.4 Frequency response of low pass filter

7.5.4 Frequency description for low pass filter.

The frequency response Fig 7.4 illustrates that the frequency below 219Hz will be allowed to pass through where by attenuating frequency above.

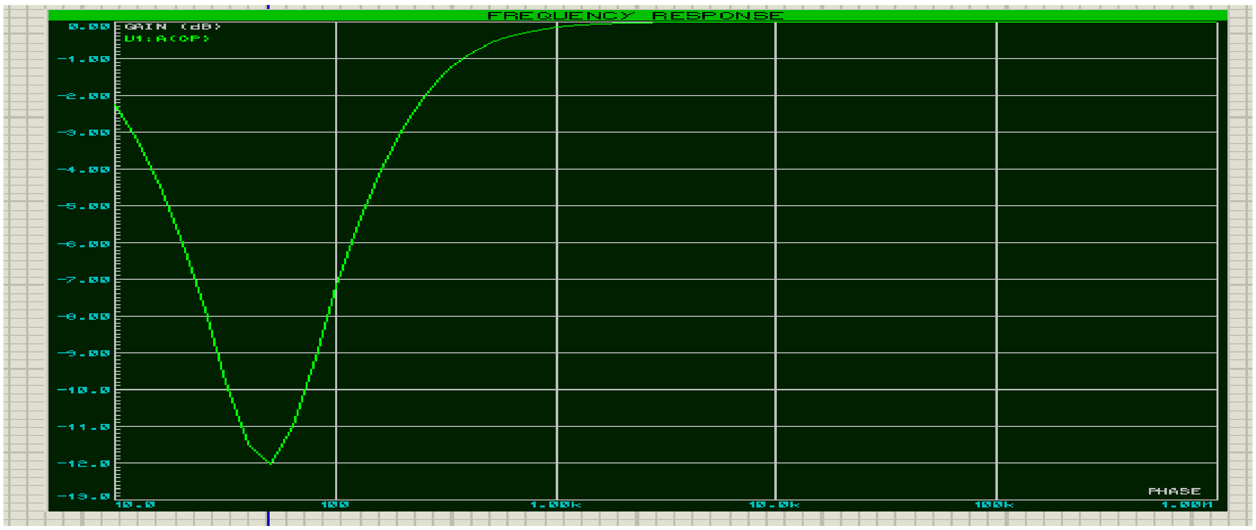


Figure 7.5 Frequency response of Notch filter.

7.5.5 Frequency analysis for Notch filter.

The frequency response Fig 7.5 illustrates that the frequency within 48Hz will not be allowed to pass through where by allowing frequency not within that frequency that which are from analysis caused by electrical interference

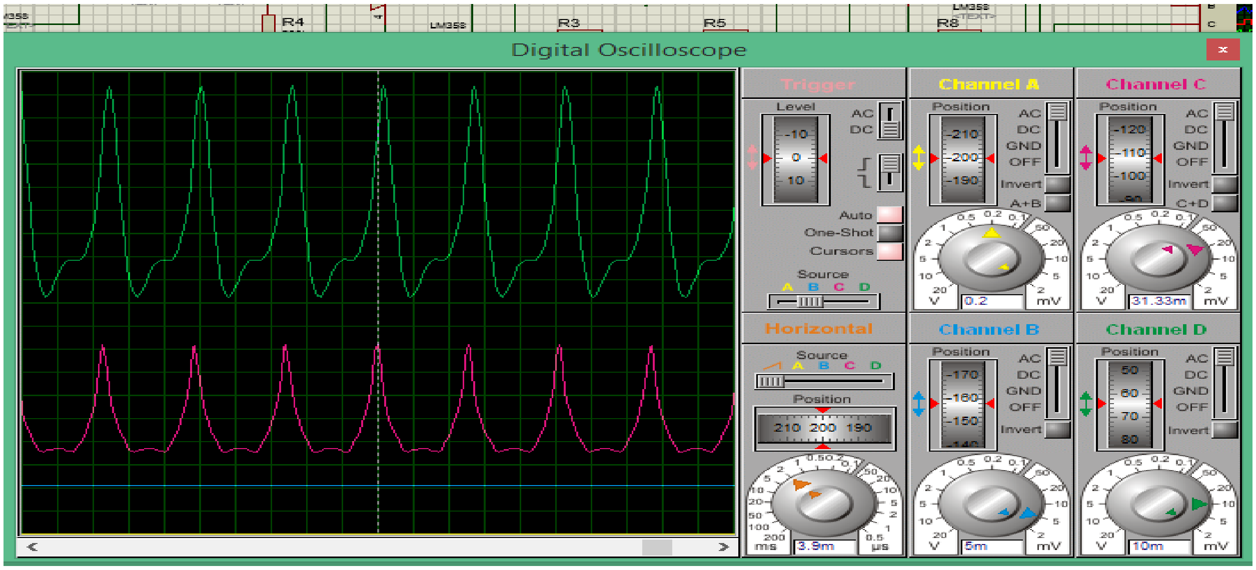


Figure 7.6 ECG signal as displayed by Oscilloscope

The overall signal waveform of the pre-processing unit was having variation waveform as shown above from Fig 7.6 of green color. With comparison from the standard ECG waveform the one declared from Fig 6.1 in data analysis, it can be concluded as met the required performance.

7.6 Communication

Under communication part Mat lab software was used to handle communication system.

There was sending part and receiving part in which UDP packets were sent.

7.6.1 Constraints under communication part:

There was no ECG signal generator. I modelled sine wave signal to be as my ECG signal to be transmitted.

7.6.2 Transmission part:

On the side of transmission system there were signal generator (sine wave generator) acting as ECG signal and UDP sender.

7.6.3 Receiving Part:

On this part there were UDP receiver, Scope and packet size counter.

7.7 Performance testing parameters and procedures

Under communication the test parameter were delay and signal distortion. Happy enough my system in simulation environment was real time oriented and error free observed from time of sending and receiving as well as comparing between waveform sent packages and received packages.

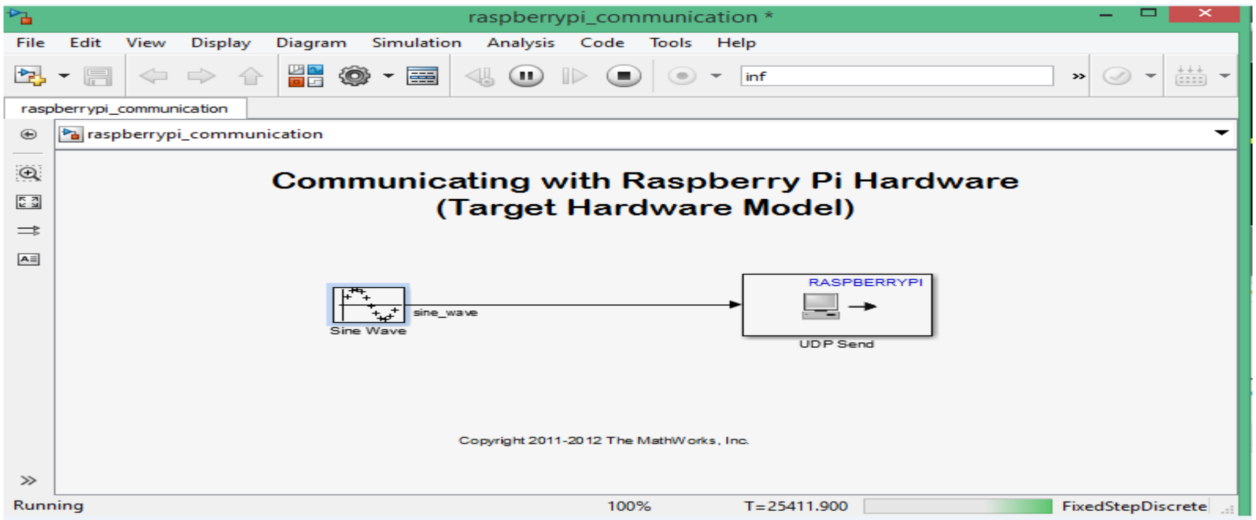


Figure 7.7 Transmission part.

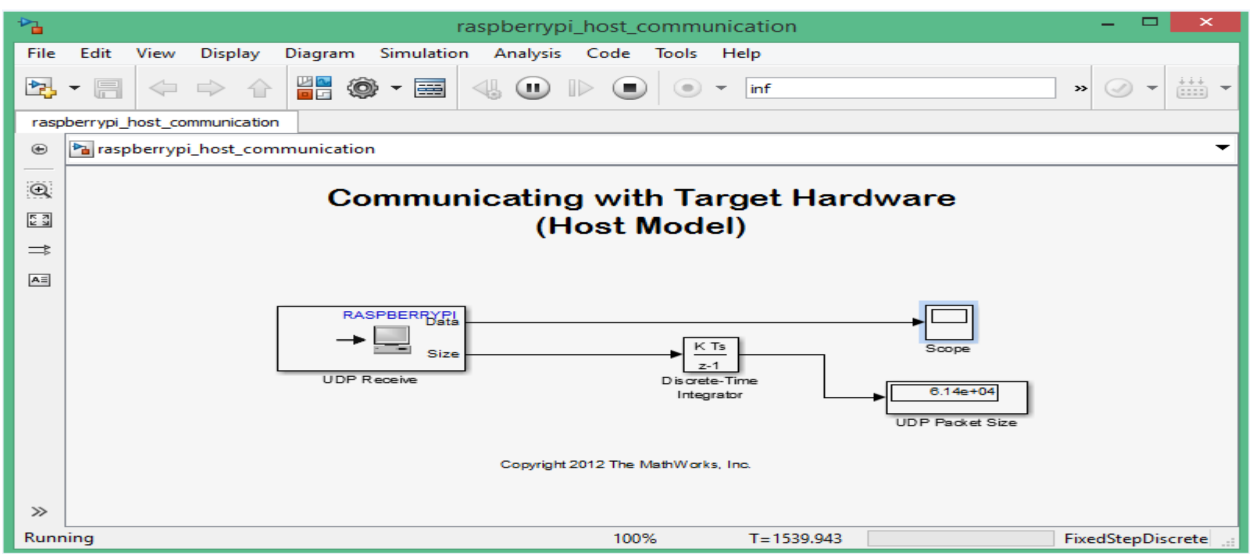


Figure 7.8 Reception part.

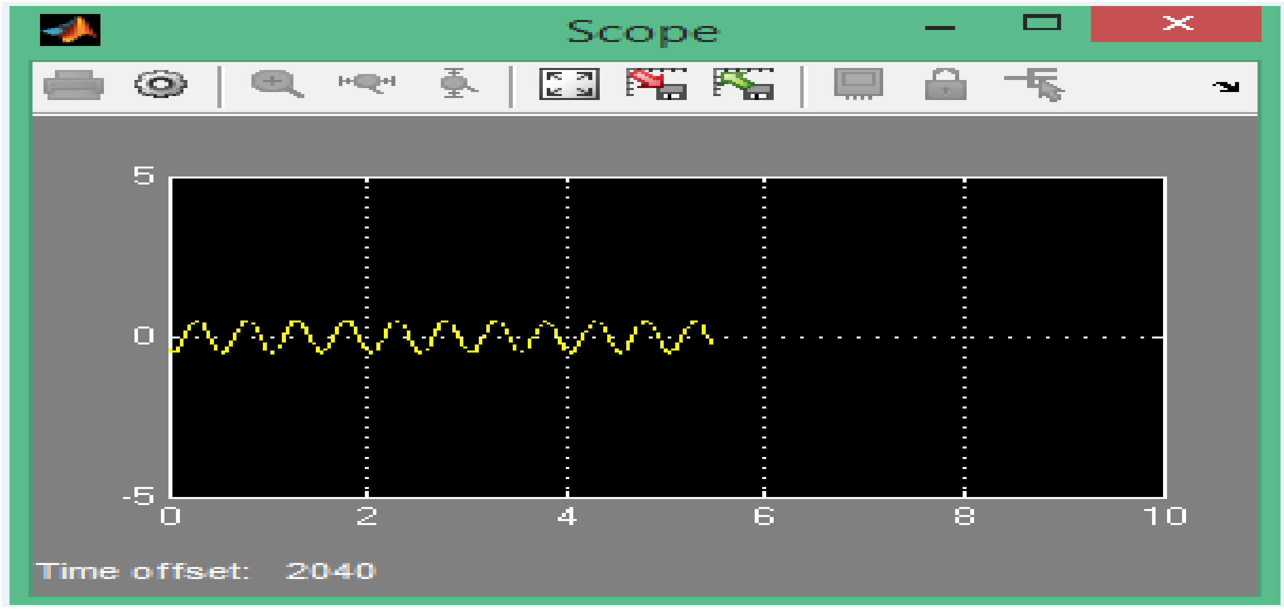


Figure 7.9 Matlab displaying system (User interface)

7.8 Chapter conclusion.

This chapter has described about the simulation of the designed system. This includes descriptions about simulation tools used, simulation constraints, performance testing parameters and performance testing procedures. It has also presented the results and their discussions. From the simulation results the prototype has to be built in order to see if the simulation results agree with the results from the actual working prototype. The next chapter gives the details on how the prototype is realized.

CHAPTER EIGHT

PROTOTYPE IMPLEMENTATION

8.0 Introduction

This chapter gives the details about the implementation from the design to realization of the prototype. It also describes about performance testing parameters, testing procedures, results and discussions of the overall performance of the prototype itself. In this project mains devices/tools used are heart beat sensor pads, heart beat preprocessing sensor unit, analogue to digital converter, raspberry pi, raspberry pi power adapter, two usb modems, and PC.

8.1 The setup of the project required the following

- Hardware tools and
- Software tools.

Hardware tools used were as follows:

- ECG electrode
- ECG sensor cable
- Analogue pre-amplifier AD8232
- Analogue to digital converter (MCP3202)
- Raspberry Pi B+ with all its peripherals
- HSPA USB Modem
- PC (server)

Software tools used were as follows;

- Raspbian (Raspberry Pi Os)
- Ubuntu
- MySQL database
- PHPMyadmin
- Apache Webserver
- ECG browser
- TightVNC
- Windows 8.1

8.2 ECG electrode pad;

As it is recommended to snap the sensor pads on the leads before application to the body. The closer to the heart the pads are, the better the measurement. The cables are color coded to help identify proper placement.

Table 8.1 Signal color code

Cable Color	Signal
Black	RA (Right Arm)
Blue	LA (Left Arm)
Red	RL (Right Leg)

Figure 8.1 ECG electrode pad connected to ECG cable.

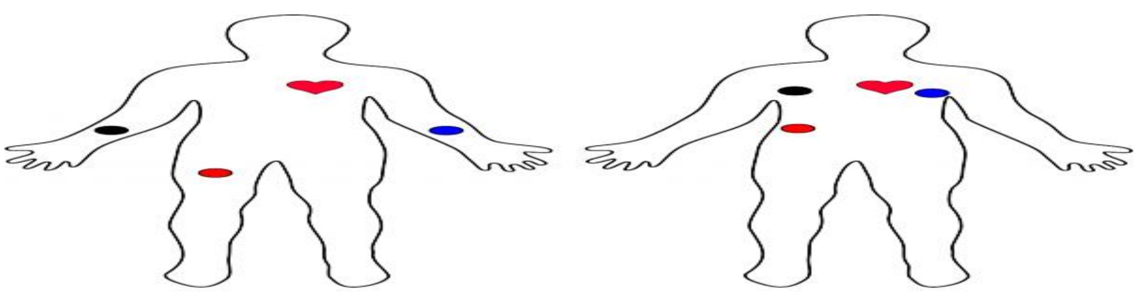


Figure 8.2 Typical Sensor Placements

8.3 Pin Connections to pre-processing device.

The AD8232 Heart Rate Monitor breaks out nine connections from the IC. Traditionally these connections are called "pins" because they come from the pins on the IC, but they are actually holes that I soldered wires or header pins to.

Figure 8.3 Headers installed

I connected five of the nine pins on the board to my Raspberry pi and MCP3202 converter. The five pins are labeled **GND**, **3.3v**, **OUTPUT**, **LO-**, and **LO+**.

Table 8.2 AD8232 Pinout.

Board Labe	Pin Function	Connection
GND	Ground	GND raspberry Pi
3.3v	3.3v power supply	3.3v Raspberry Pi
OUTPUT	Output Signal	A1 MCP3202
Lo-	Leads-off Detect -	Raspberry Pi
Lo+	Leads-off Detect +	Raspberry Pi
SDN	Shutdown	Not used

8.4 Analog to digital converter MCP3202

MCP3202 was used basing on data analysis and design. The MCP3202 is shown in figure 8.3

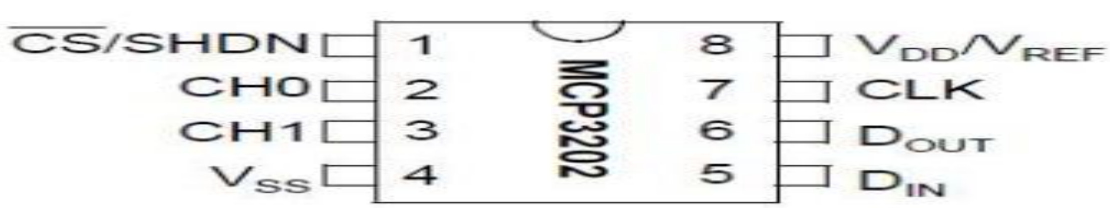


Figure 8.4 MCP3202

Table 8.3 MCP3202 Pins connection

Name	**Connection**	**Function**
CS/SHDN	To raspberry Pi	Chip Select/Shutdown Input
CH0	Not used	Channel0 Analog Input
CH1	From AD8232	Channel1Analog Input
VSS	To raspberry Pi	Ground
DIN	To raspberry Pi	Serial Data Input
DOUT	To raspberry Pi	Serial Data Out
CLK	To raspberry Pi	Serial Clock
VDD/VREF	To raspberry Pi	+2.7V to 5.5V Power Supply and Reference Voltage Input

8.5 Set up control Unit (Raspberry Pi)

- Download Raspbian Image
- Writing Raspbian to the SD Card
- Installing Raspbian
- Software Updates
- Setting up Static IP Address
- Remote access via TightVNC
    - On Windows
    - On the Raspberry Pi.
- Starting TightVNC at boot.
- Setting up an internet Network Connection

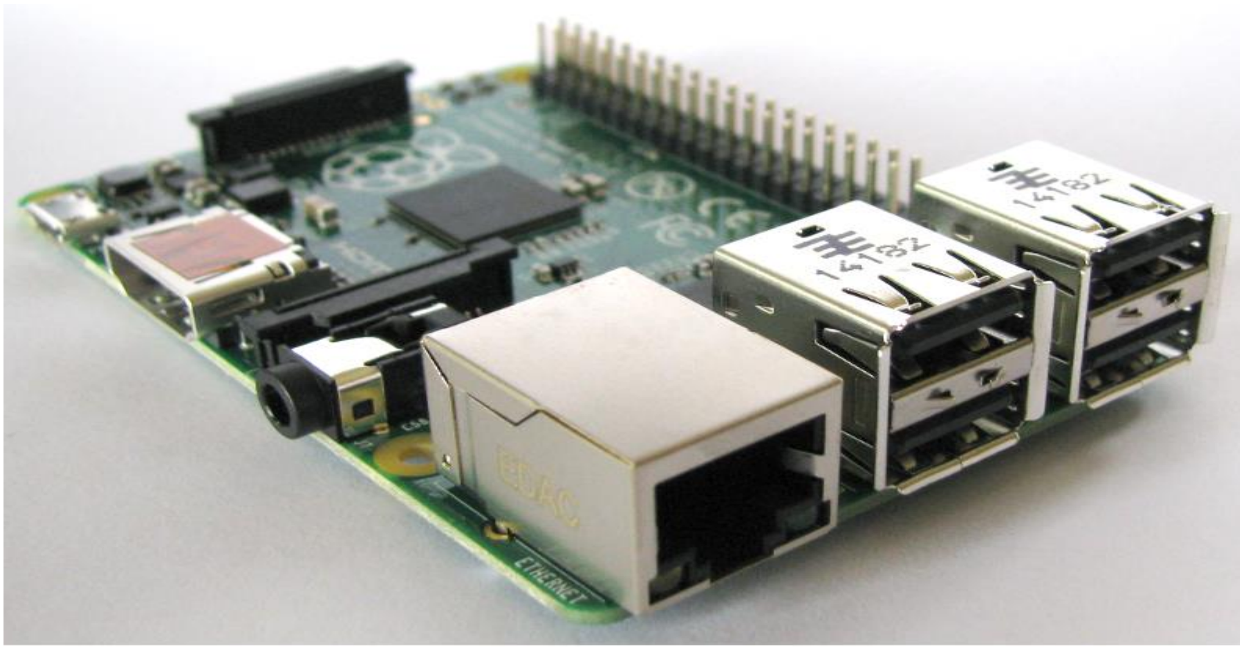


Figure 8.5 Raspberry Pi B+

8.5.1 SD Card

The Raspberry Pi needs to store the Operating System and working files on a micro SD card (actually a micro SD card for the B+ model, but a full size SD card if you're using a B model).

Figure 8.6 SD card

MicroSD Card

The microSD card receptacle is on the rear of the board and is of a 'push-push' type which means that you push the card in to insert it and then to remove it, give it a small push and it will spring out.

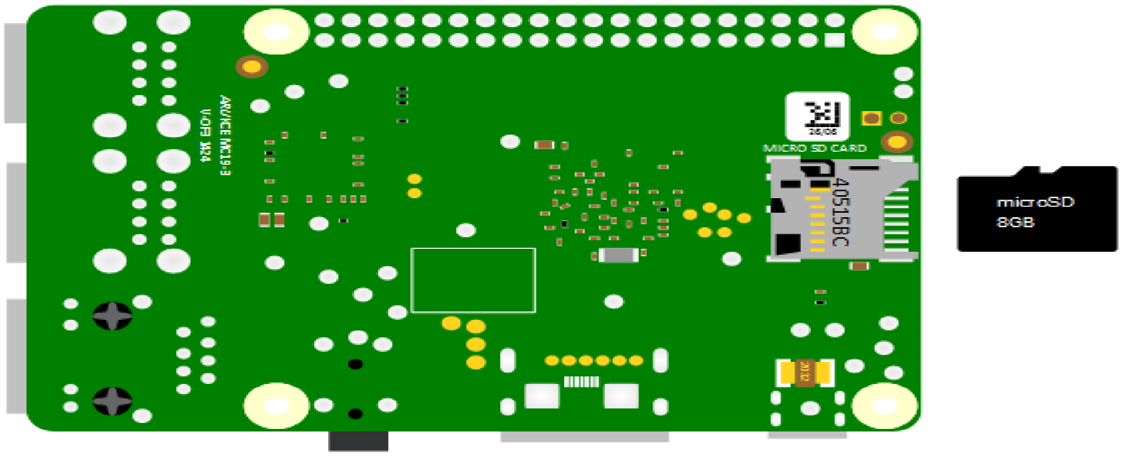


Figure 8.7 MicroSD Card Positioning

This is the equivalent of a hard drive for a regular computer, but I was going for a minimal effect. I used a minimum of an 8GB card (smaller is possible, but 8 is recommended). But it can be selected a higher speed card if possible (class 10 or similar) as it is anticipated that this should speed things up a bit.

8.5.2 Keyboard / Mouse

While I was making the effort to access the system via a remote computer, I needed need a keyboard and a mouse for the initial set-up. Because the B+ and B2 models of the Pi have 4 x USB ports, there was plenty of space for me to connect wired or wireless USB device

A wireless combination was also recognized without any problem and leads to an advantage of taking up a single USB port, but as l built towards a remote capacity for using the Pi, the nicety of a wireless connection is not strictly required.

8.5.3 Video/Screen

The Raspberry Pi comes with an HDMI port ready to go which means that any monitor or TV with an HDMI connection should be able to connect easily or using VGA monitor via HDMI to VGA adapter. Because this is kind of a hobby thing, someone might want to consider utilizing an older computer monitor with a DVI or 15 pin D connector. For this case someone need an adapter to convert the connection.

Figure 8.8 VGA to HDMI Adapter

8.5.4 Network

The B+ and B2 models of the Raspberry Pi have a standard RJ45 network connector on the board ready to go. In a domestic installation this is most likely easiest to connect into a home ADSL modem or router.

8.5.5 Power Supply Connection

The B+ model function adequately with a 700mA supply, but because of multiple devices that demanded power from the Pi, I considered a supply that is capable of an output up to 2A.

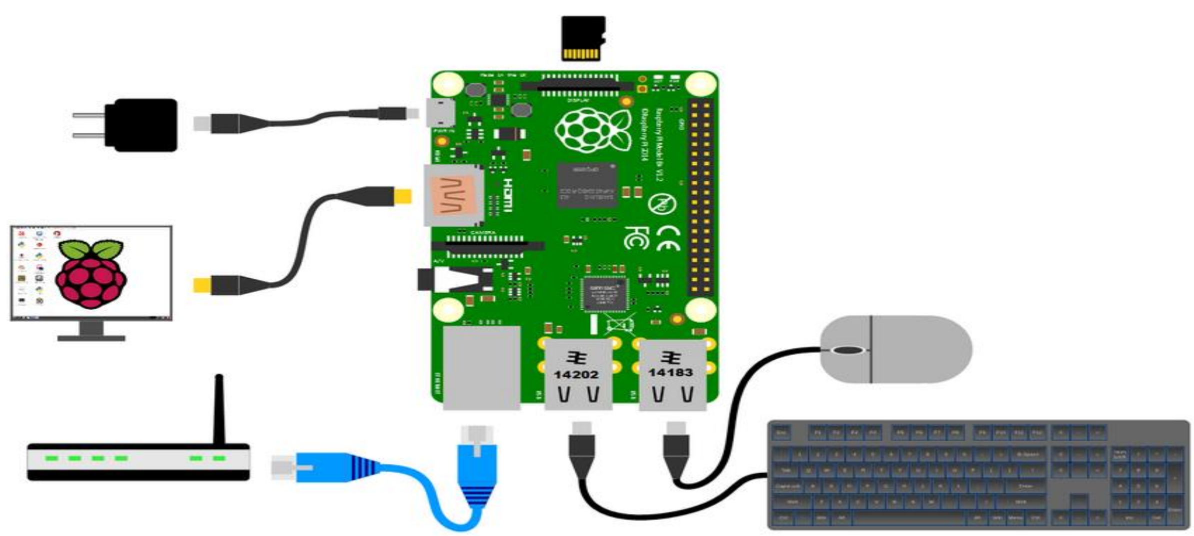


Figure 8.9 Hardware set up for raspberry Pi

8.5.6 Operating System

I used Linux based Operating system on Raspberry Pi specifically I installed a 'distribution' (version) of Linux called Raspbian. In our case we will be using a version of Linux that is assembled to run on the ARMv6 CPU used in the Raspberry Pi. A distribution intended to run as a server may omit all graphical desktop environments from the standard install, and instead include other software to set up and operate a solution stack such as LAMP (Linux, Apache, MySQL and PHP). Because Linux is freely re-distributable, anyone may create a distribution for any intended use.

8.5.6.1 Raspbian

The Raspbian Linux distribution is based on Debian Linux. You might well be asking if that matters a great deal. Well, it kind of does since Debian is such a widely used distribution that it allows Raspbian users to leverage a huge quantity of community based experience in using and configuring the software.

8.5.6.2 Sourcing and Setting Up

On my desktop machine I downloaded the Raspbian software and wrote it onto the SD card. This was then installed into the Raspberry Pi The best place to source the latest version of the Raspbian Operating System is to go to the raspberrypi.org page; http://www.raspberrypi.org/downloads/.

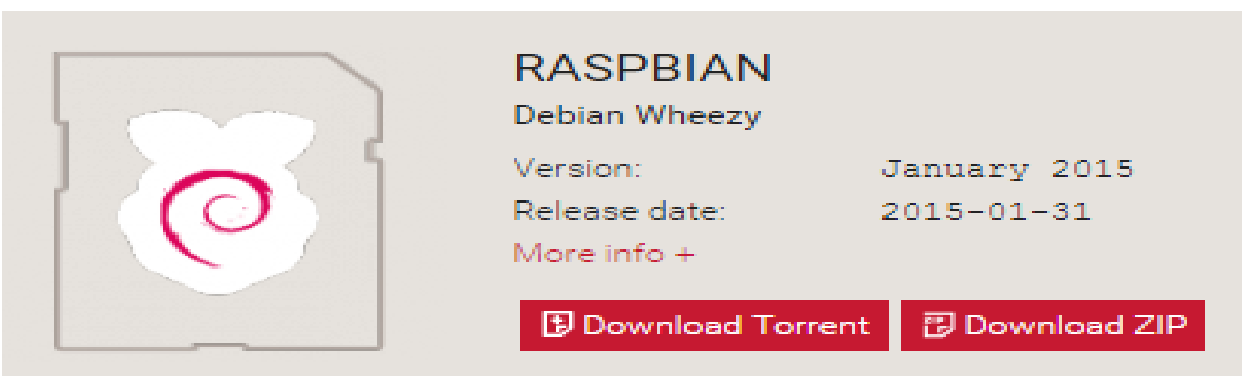


Figure 8.10 Raspbian Download

Figure 8.11 Debian Image

8.5.6.3 Installing Raspbian

After Raspbian disk image is written into a micro SD card. I Inserted the SD card into the slot on the Raspberry Pi and turned on the power. After turning on the power there were a range of information scrolling up the screen before eventually being presented with the Raspberry Pi Software Configuration Tool.

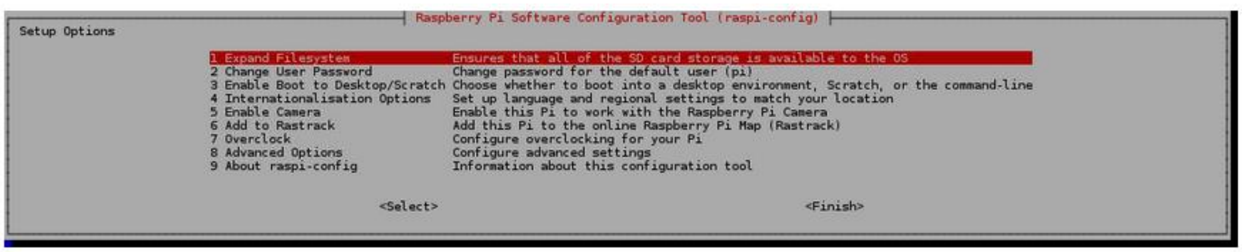


Figure 8.12 Raspberry Pi Software Configuration Tool

Using this tool, I configured the Raspberry Pi where I ensured all of the SD card storage is available to the Operating System. Once this completed I left the other settings where they are for the moment and selected finish. This allowed me to reboot the Pi and take advantage of the full capacity of the SD card.

Once the reboot is complete you will be presented with the console prompt to log on;

```
Raspbian GNU/Linux 7 raspberry tty1

raspberrypi login
```

I entered the default username and password as Pi and raspberry respectively.

8.5.6.4 Software Updates

The first thing I did was to make sure that I have the latest software for our system. This was a useful thing to do as it allowed any additional improvements to the software I was to use

Typing in the following line which are used to find the latest lists of available software;

```
sudo apt-get update
```

list of text scrolls up while the Pi is downloading the latest information were presented.

There after I wanted to upgrade my software to latest versions from those lists using;

```
sudo apt-get upgrade
```

8.5.6.5 GUI Desktop

At this point I found myself staring at a screen full of text and successfully logged on to your Raspberry Pi. The command `startx` launches the 'X' session, which is to say the basic framework for a GUI environment: drawing and moving windows on the display device and interacting with a mouse and keyboard. The Raspbian distribution I was using has a desktop already set up with a range of programs ready to go that can be accessed from the menu button.

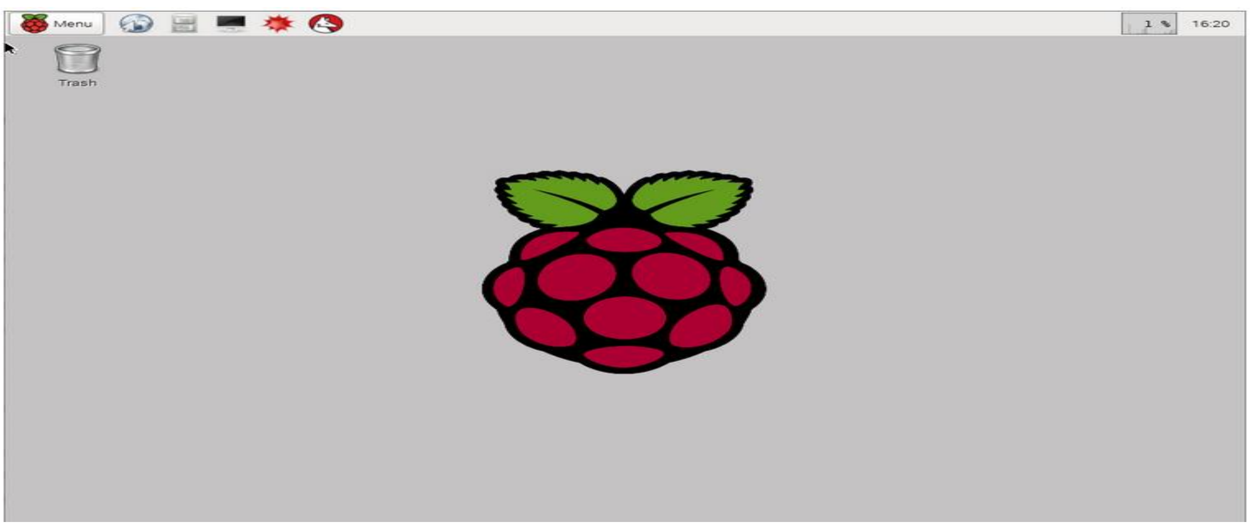


Figure 8.13 Raspbian Desktop

Running a GUI environment is a burden to the computer. It takes a certain degree of computing effort to maintain the graphical interface, so as a matter of course I only used the `startx` command when I wanted to interact with the computer via the desktop.

8.5.6.6 Remote access.

The following section describes how I configured Pi and our desktop Windows computer so that I remotely access the Raspberry Pi and it didn't require having a keyboard, mouse and video screen connected.

8.5.6.7 Static IP Address

Enabling remote access required that to assign Raspberry Pi a static IP address. Other reading says that the Raspberry Pi IP address should appear a few lines above the 'login' prompt when is firstly booted up as shown below but mine was not

```
My IP address is 10.1.1.25

Raspbian GNU/Linux 7 raspberrypi tty1

raspberrypi login:
```

Where IP address 10.1.1.25 belongs to the Raspberry Pi.

This address was 'dynamic' IP address and was changing each time the Pi was booted. For the purposes of using the Raspberry Pi as a web platform, database and with remote access I needed to set a fixed IP address.

8.5.6.8 The Netmask

At a higher level I was e able to set a 'netmask' which was doing the job for me. A netmask looks similar to an IP address, but it allows to specify the range of addresses for 'hosts' (in my case computers devices) that can be connected to the network. A very common netmask is 255.255.255.0 which means that the network in question can have any one of the combinations where the final number in the IP address varies. In other words, with a netmask of 255.255.255.0 the IP addresses available for devices on the network 10.1.1.x range from 10.1.1.0 to 10.1.1.255 or in other words any one of 256 unique addresses

For my projects I used the address 169.254.35.179

8.5.6.9 Setting a Static IP Address on the Raspberry Pi.

Before I started configuring firstly found out what the default gateway is for the network. A default gateway is an IP address that a device will use when it is asked to go to an address that it doesn't immediately recognize. This would most commonly occur when a computer on a home network wants to contact a computer on the Internet. The default gateway was therefore typically the address of the modem the network.

8.5.6.10 Default Gateway

I did this using command prompt by typing;

```
ipconfig
```

This presented a range of information including a section that looks a little like the following;

```
Ethernet adapter Local Area Connection:

  IPv4 Address. . . . . . . . . . . : 10.1.1.15
  Subnet Mask . . . . . . . . . . . : 255.255.255.0
  Default Gateway . . . . . . . . . : 10.1.1.1
```

The default gateway was therefore '10.1.1.1'.

8.5.6.11 Editing the `interfaces` file

On the Raspberry Pi at the command line I type following command to edit the file containing network interface information.

sudo nano /etc/network/interfaces

Once had finished I pressed ctrl-x to tell nano to prompt me to confirm saving the file and I then pressed 'y' to save the file (if it's correct). It then prompted me for the file-name to save the file as. I Pressed return to accept the default of the current name and I was done!

To allow the changes to become operative I typed in;

```
sudo reboot
```

8.5.6.12 Remote access

To allow me to work on our Raspberry Pi from my normal desktop I give myself the ability to connect to the Pi from another computer. This mean that I didn't need to have the keyboard / mouse or video connected to the Raspberry Pi and I could physically place it somewhere else and still work on it without problem.

To do this I needed to install an application on my windows desktop which was acting as a 'client' in the process and software on my Raspberry Pi to act as the 'server'. There is a couple of different ways that one can accomplish this task. One way I used was to give me access to the Pi GUI from a remote computer (so I could use the Raspberry Pi desktop in the same way that I did with the `startx` command earlier) using a program called TightVNC and the other way is to get access to the command line (where all I could do was to type in my commands (like when I first log into the Pi) via what's called SSH access. But I always used the first method.

8.5.6.13 Remote access via TightVNC

The software I installed was called TightVNC. It is free for personal and commercial use and implements a service called Virtual Network Computing. I needed to set up instances of it on the client (the Windows desktop machine) and the server (the Raspberry Pi).

8.5.6.14 Setting up the Client (Windows)

To install TightVNC for windows, I downloaded the TightVNC software and selected the appropriate version for your operating system. And worked through the installation process answering all the questions until you get to the screen asking what set-up type to choose.

8.5.6.15 Setting up the Server (Raspberry Pi)

I approached the process of installing the TightVNC server on the Raspberry Pi in two stages. In the first stage I installed the software, run it and tested it. In the second stage I configured it so that it starts automatically when the Raspberry Pi boots up which means that I could work remotely from that point.

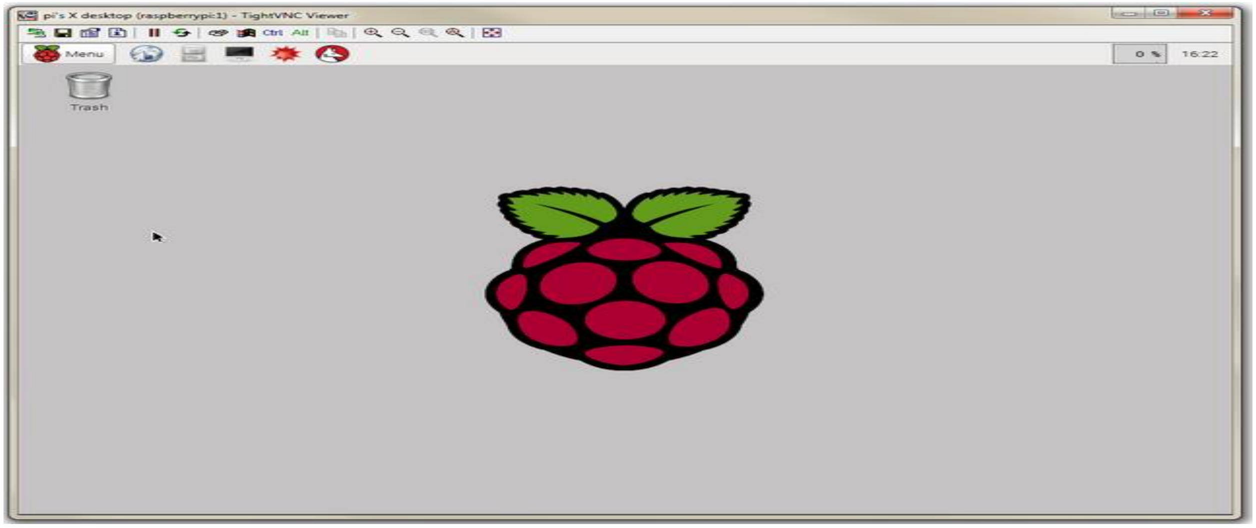


Figure 8.14 TightVNC Desktop

8.6 Server (LAMP server)

LAMP is abbreviation of Linux, Apache server, MySQL database and PHP.

8.6.1 Setting lamp server

LAMP is an open source Web development platform that uses Linux as the operating system, Apache as the Web server, MySQL as the relational database management system and PHP as the object-oriented scripting language. As a solution stack, LAMP is suitable for building dynamic web sites and web applications.

8.6.2 Installing Apache Web server and PHP on Raspbian

The Apache web server is currently the most popular web server in the world, which makes it a great default choice for hosting a website. Raspbian OS is based on Linux OS therefore I followed the steps below to install Apache and PHP.

I installed Apache easily using Linux package manager, apt. A package manager allowed me to install most software pain-free from a repository maintained by Linux.

At the Ubuntu terminal in my PC I ran the following command;

```
sudo apt-get install apache2 php5 libapache2-mod-php5
```

In this commands Specifically including apache2, php5 and libapache2-mod-php5.

'apache2' is the name of the web server and php5, libapache2-mod-php5 are for PHP.

Once completed I needed to restart our web server with the following command;

```
sudo service apache2 restart
```

I could thereafter test my web server from the Ubuntu desktop machine.

I opened up my web browser and type in the IP address of the machine into the URL bar at the top and I saw …

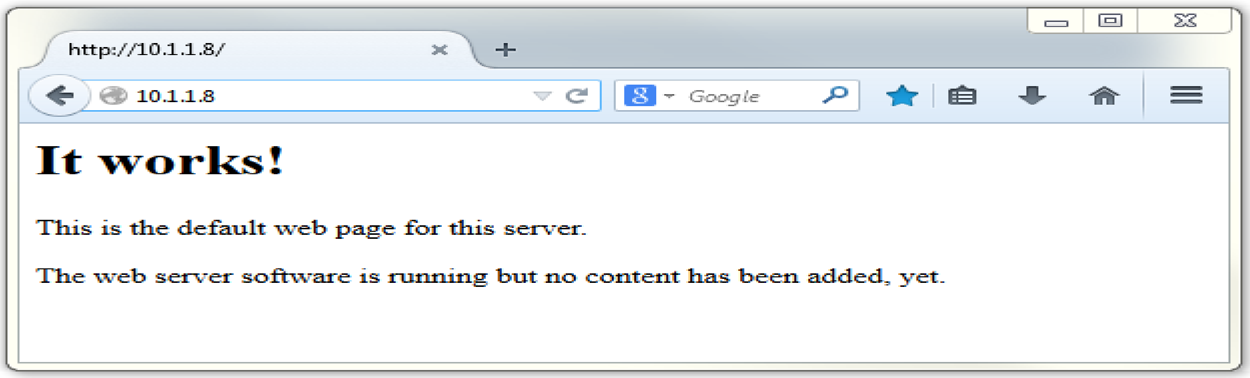


Figure 8.15 Testing the web server

8.6.3 Database

As mentioned earlier from data analysis in this book, I used a MySQL database to store the information that we collect. Installed MySQL in a couple of steps and then we will install the database administration tool phpMyAdmin to make our lives easier.

8.6.4 MySQL

From the command line I typed the following command to install Mysql-sever for database;

```
sudo apt-get install mysql-server
```

I was prompted (twice) to enter a root password for my database.

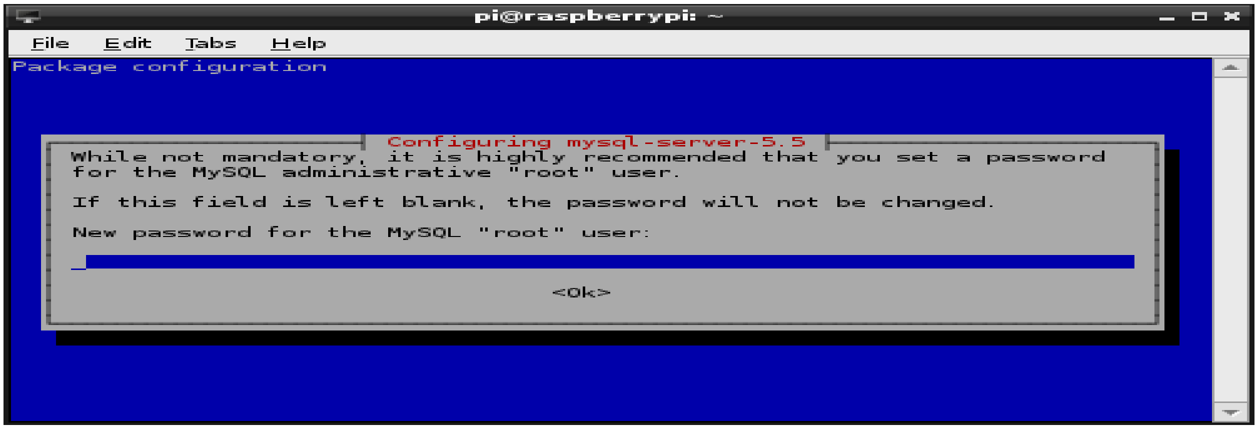


Figure 8.16 Configuration of MySQL-server.

I installed a couple more packages that I was to use in the future when I needed to integrate PHP and Python with MySQL. To do this I entered the following from the command line;

```
sudo apt-get install mysql-client php5-mysql python-mysqldb
```

MySQL server was installed. However, it’s not configured for use, so I installed phpMyAdmin to help out for this.

8.6.5 phpMyAdmin

phpMyAdmin is free software written in PHP to carry out administration of a MySQL database installation. To begin installation, I ran the following from the command line.

```
sudo apt-get install phpmyadmin
```

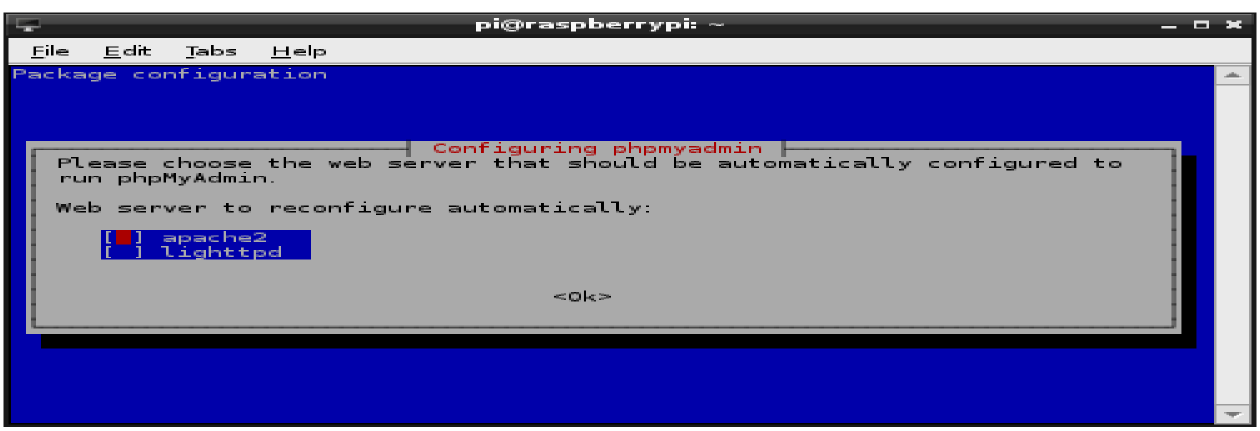


Figure 8.17 phpMyAdmin Installation

I Selected ‘apache2’ and tabbed to ‘Ok’ to continue. From this point I was prompted to configure the database for use with phpMyAdmin and Mysql database. Then I was to restart my apache2 by running the following command.

```
sudo service apache2 restart
```

Everything was running correctly.

8.6.6 Allow access to the database remotely

Since I wanted to allow access to the database remotely, this would appear to be part of the grand plan all along. But there are different types of access and in particular there may be a need for a remote computer to access the database directly. This direct access occurs when (for example) a web server on a different computer to sever wants to use the data. In this situation I was needed to request access to the database over the network by referencing the host computer that the database was on (in this case I specified that it is on the computer at the IP address 10.1.1.8).

8.6.7 Creating a database

When the data were sent from patient sensors to the server, were recorded in a database. MySQL is a database program, but I was still need to set up a database inside that program. In fact, in recording and explore my data I was dealing with a ‘table’ of data that existed inside a database. Here I created my database called ‘measurements’

Figure 8.18 phpMyAdmin New Database

8.6.8 Creating the MySQL Table

Using the phpMyAdmin web interface that I set up, log on using the administrator (root) account and selected the ‘measurements’ database that I created above as part of the initial set-up.

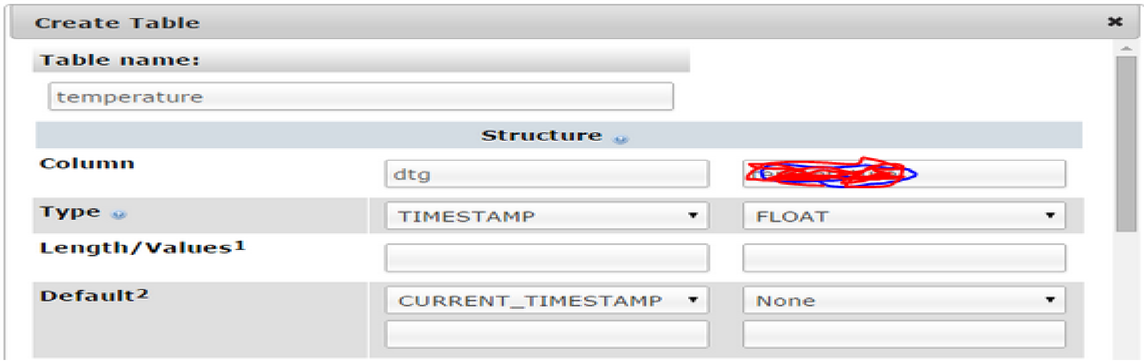


Figure 8.19 Configure the MySQL Table Columns

8.7 Graphical User Interface

Constructing ECG user interface required mainly the following tools;

- ecgMLgenerator
- ECG parser and
- Ecg viewer

8.7.1 The ecgML generator

Was automatically producing XML-based ECG records from existing ECG databases.

8.7.2 The ECG parser

Allows the user reading the ECG records and access their contents and structure

8.7.3 ECG viewer

Provided onscreen display of the corresponding waveform data, shown in Figure 8.20. It shows all annotation information of the individual waveform. The hierarchical structure of the XML-based ECG record, including every elements and attribute is displayed on the left hand side. It can be expanded and shrunk at any level. The right hand side shows an individual

part of the ECG waveform chosen from the ecgML structure. The viewer graphically locates boundaries (i.e. beginning, peak, and end) of the P, QRS and T waveforms for each selected QRS complex.

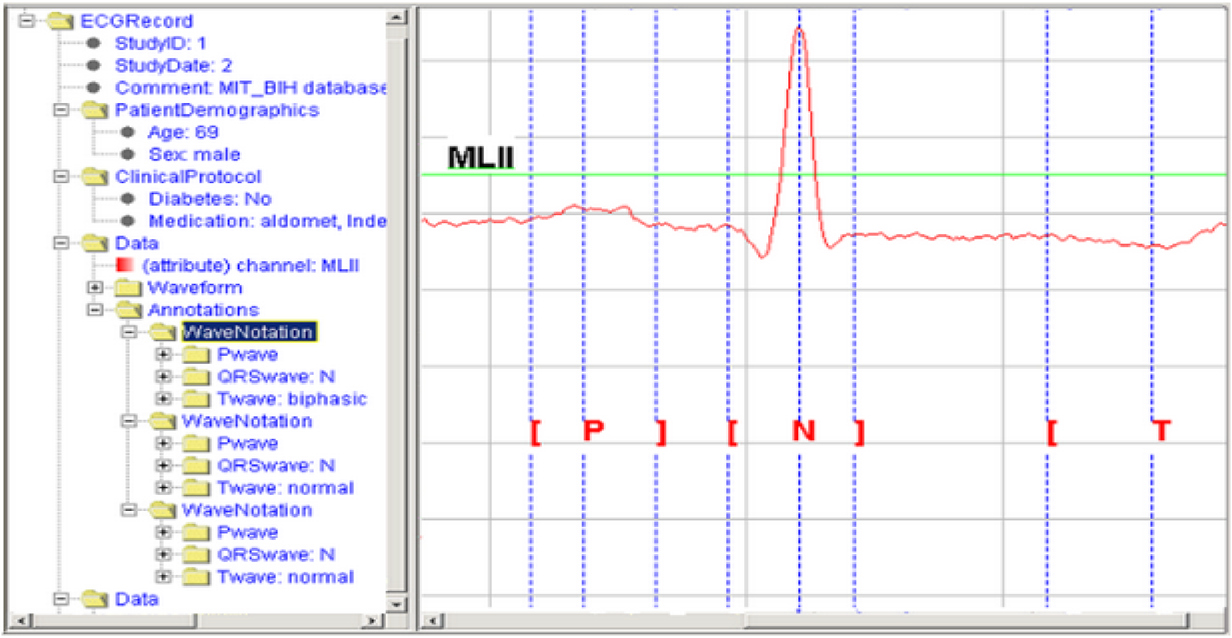


Figure 8.20 Screenshot of ECG viewer

8.8 Working prototype

Fig. Prototype.

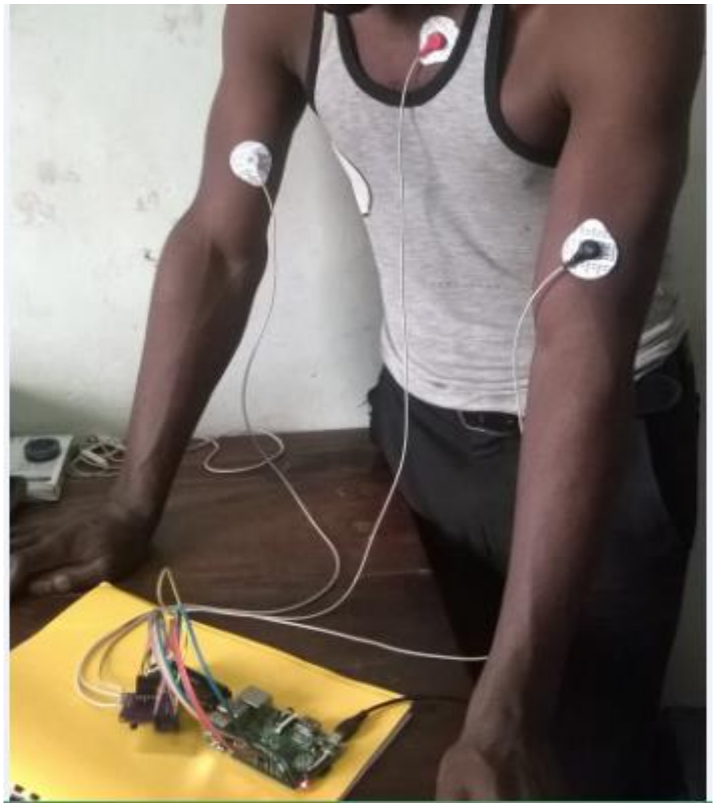


Figure 8.21 Working prototype

8.8.1 Prototype performance test

The following are the performance testing parameters of the prototype

8.8.2 Variation of output voltage waveform.

The output voltage waveform varies as different heartbeat rate were encountered by forcing different breathing rate from single person and heartbeat rate encountered from different people.

8.8.3 Delay and Distortion

Under communication the test parameter were delay and signal distortion. Happy enough my system encountered small delay which was actually caused by speed of internet and it was error free. Observation was made from time of sending and receiving as well as comparing between waveform sent packages and received packages.

8.8.4 Results and discussion

By comparing the output voltage waveform obtained in fig 8.20 with that set as standard in fig 6.2 from data analysis and design, it is with full confidence to declare that the system performed as per specification in simulation environment.

The system encountered small delay which was actually caused by speed of internet and it was error free. Observation was made from time of sending and receiving as well as comparing between waveform sent packages and received packages. Therefore, the system is declared as working as per specification.

8.9 Chapter conclusion

This chapter has explained the prototype implementation and testing. The results from prototype shows that all the specific objectives have been achieved and hence main objective of the project. This implies that the prototype implemented is performing well. The next chapter concludes the project, it gives the overall summary of what have been done and achieved throughout the project.

CHAPTER NINE

CONCLUSION AND RECOMMENDATION

9.0 Introduction

This is the last chapter in this report. It gives out the overall summary of the project done. It includes conclusion and recommendations about the project.

9.1 Conclusion

This report has provided all basic information concerning the existence of the problem and the procedures towards solving it. Using these procedures, the system has been designed and realized in hardware part and software part. Moreover, the system has been tested and appeared to give the expected results. Considering these results obtained after prototype testing, the overall performance of the designed system is good. Therefore, it can be concluded that the designed system is expected to solve the existing problem.

The designed system is expected to eliminate the problems such as wastage of time and unnecessary cost incurred in the time of illness. The achievement in the design of this system will now create a chance for other technician and engineers to improve the design and implement the new advanced remote heartbeat monitor.

9.2 Recommendations

The designed system has relied on the concept of Internet Of Things (IOT) as that is possible to connect number of devices and make them communicate. Connections issues in my prototype was not an issue, but reliability in communication was still a challenge. To assure good performance of the designed system internet reliability should be improved since the designed system depend much on internet connection.

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Appendix A

ECG Monitoring

```
void read_send_ECG(void) {
 int val = 0; bool handled = false;
uint8_t vref_v[VREF_NUM];
uint8_t sampling_rate_v[SAMPLING_RATE_NUM];
unsigned long current_sample_time = micros();
if (!is_connected)  return;
if (!is_sending_ecg) return;
if(!lib_aci_is_pipe_available(ecg_tx_pipe))  return;
if(!lib_aci_is_pipe_available(sampling_rate_pipe))  return;
if(!lib_aci_is_pipe_available(vref_pipe))  return;
if(check_DC_leadoff())  return; if((current_sample_time -previous_sample_time) <
ecg_sample_interval)
{  return;
 }else { previous_sample_time = current_sample_time; }
if(!is_send_vref) { is_send_vref = true; vref_v[0] = vref & 0xFF;
vref_v[1] = (vref & 0xFF00) >> 8;
if(IS_QUEUE_EMPTY(&tx_data_queue)){
// Since the queue is empty, the ECG data can be sent right Away
handled = lib_aci_send_data(vref_pipe, vref_v, VREF_NUM); }
if(!handled){59  // If queue is not empty or the earlier call to lib_aci_send_data failed
uint8_t queue_data[VREF_NUM + 1];
queue_data[0] = vref_pipe;
memcpy(&(queue_data[1]), vref_v, VREF_NUM);
handled = lib_queue_put(&tx_data_queue, queue_data, (VREF_NUM
+ 1)); } if(!handled){
// QUEUE ADD ERROR} return;}
```

```
if(!is_send_sampling_rate){is_send_sampling_rate = true;sampling_rate_v[0] = sampling_rate
& 0xFF; sampling_rate_v[1] = (sampling_rate & 0xFF00) >> 8;
if(IS_QUEUE_EMPTY(&tx_data_queue)){
// Since the queue is empty, the ECG data can be sent right away
handled = lib_aci_send_data(sampling_rate_pipe, sampling_rate_v,
SAMPLING_RATE_NUM);}
if(!handled){// If queue is not empty or the earlier call to lib_aci_send_data faileduint8_t
queue_data[SAMPLING_RATE_NUM+1]; queue_data[0] = sampling_rate_pipe;
memcpy(&(queue_data[1]), sampling_rate_v, SAMPLING_RATE_NUM); handled =
lib_queue_put(&tx_data_queue,
queue_data, (SAMPLING_RATE_NUM + 1));}
if(!handled}          // QUEUE ADD ERROR
}return;} val = analogRead(A4);
if(ecg_counter == 0) {
ecg_vector[ecg_counter++] = time_step;60
}ecg_vector[ecg_counter++] = val & 0xFF;ecg_vector[ecg_counter++] = (val & 0xFF00) >> 8;
if(ecg_counter == ECG_DATA_NUM) {ecg_counter = 0;time_step++;
if(IS_QUEUE_EMPTY(&tx_data_queue)){
// Since the queue is empty, the ECG data can be sent right away
handled = lib_aci_send_data(ecg_tx_pipe, ecg_vector, ECG_DATA_NUM);}
if(!handled){
// If queue is not empty or the earlier call to lib_aci_send_data failed
uint8_t queue_data[ECG_DATA_NUM+1];
queue_data[0] = ecg_tx_pipe;
memcpy(&(queue_data[1]), ecg_vector, ECG_DATA_NUM);
handled = lib_queue_put(&tx_data_queue, queue_d ata,
ECG_DATA_NUM+1);
} }
}
```

Appendix B

Total cost

Table 6.1 shows the total cost incurred during the project duration, the amount is in Tanzania Shillings (Tzs)

Table 9.1 Total cost incurred during the project duration

ITEM	QUANTITY	COST	Total cost
ECG electrode pads	20	-	15000
ECG electrode cables	3		12000
Printing services	17	5880	100000
Internet services	-	1500	25000
Electronic modules	-	-	115000
Transport fees	3	6000	18000
Others	-	-	35000
Overall Total cost			320000

Appendix C

Table 9.2 Senior Project 1-time frame

	PROJECT DURATION IN WEEKS														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**16**
A	■	■													
B	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
C			■	■											
D					■	■									
E						■	■								
F								■	■	■	■				
G												■	■	■	

KEY:

A. Selection of project title

B. Literature review

C. Project proposal writing

D. Defending the project

E. Data collection

F. writing Report

G. Report submission and assessment

Appendix D

Table 9.3 Senior Project 2-time frame

ACTIVITIES															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**16**
A															
B															
C															
D															
E															
F															
	DURATION OF PROJECT IN WEEKS														