Department of Electrical and Computer Engineering
North South University

Senior Design Project

A Portable ECG Machine

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Spring, 2018

CSE 499
Senior Design Project

A Portable ECG Machine

Submitted To:

Faculty Advisor:

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Department of Electrical and Computer Engineering
North South University
Spring, 2018

LETTER OF TRANSMITAL

July, 2018

To

Dr. Shazzad Hossain

Chairman,

Department of Electrical and Computer Engineering

North South University, Dhaka

Subject: **Submission of thesis paper on "A portable ECG machine"**

Dear Sir,

With due respect, we would like to submit our **Capstone Project Report** on **"A Portable ECG Machine"** as a part of our BSC program. The report deals with acquiring ECG data from a person. The project was really challenging and helpful to us because it helped us to gain experience and overcome the issues we faced during the development period. We tried to the maximum competence to meet all the dimensions required from this report.

We will be highly obliged if you kindly receive this report and provide your valuable judgment. It would be our immense pleasure if you find this report useful and informative to have an apparent perspective on the issue.

Sincerely Yours,

.....
Sabuj Golder
ECE Department
North South University, Bangladesh

.....
MD Fatin Rahman Behon
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.....
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APPROVAL

Sabuj Golder (ID # 1330061042), MD Fatin Rahman Behon (ID # 1320907042) Nasik Monowar (ID # 1320164042) from Electrical and Computer Engineering Department of North South University, have worked on the Senior Design Project titled "A Portable ECG Machine" under the supervision of Dr. Tanzilur Rahman partial fulfillment of the requirement for the degree of Bachelors of Science in Engineering and has been accepted as satisfactory.

Supervisor's Signature

……

Dr. Tanzilur Rahman

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Chairman's Signature

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Dr. Shazzad Hossain

Associate Professor

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DECLARATION

This is to certify that this Project is our original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

Students' names & Signatures

1. Sabuj Golder

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2. MD Fatin Rahman Behon

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3. Nasik Monowar

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ACKNOWLEDGEMENT

By kindness of the Almighty we have successfully completed our senior design project entitled “A Portable ECG Machine”.

Our deep gratitude goes first to my faculty advisor Dr. Tanzilur Rahman, who expertly guided us in our senior design project throughout the whole CSE499A and CSE499B. His guidance helped us in all type of research, writings and completing the project.

Our sincere thanks also goes to North South University, Dhaka, Bangladesh for giving us such a platform where we can have an industrial level experience as a part of our academics.

Last but not the least, we would like to thank our family as their inspiration and guidance kept us focused and motivated.

ABSTRACT

Electrocardiography commonly known as ECG is the process of recording electric signals generated from the heart's rhythm. The accurate Electrocardiogram (ECG) and pulse rate information is one of the most important aspects for the various sorts of heart functioning disorder identification. The paper briefly shows how the project was carried towards the aim and demonstrates a solution for acquiring ECG signals in a portable way. The goal was to make a prototype of a portable ECG-monitoring device is for clinical and non-clinical environments as part of a telemedicine system to provide remote and continuous surveillance of patients. The aim was to make a smart, easy to use, less costly, portable device to observe the heart beat signal from anywhere in any emergency case.

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Overview

1.1 Introduction

According to the latest WHO data published in 2017 Coronary Heart Disease Deaths in Bangladesh reached 112,791 or 14.31% of total deaths. There are several reasons which are related to this high death rate in heart diseases such as improper diet, obesity, irregularity in exercises, not realizing the symptoms of cardiovascular diseases etc. Even many people do not have idea about the symptoms of heart related disease and they don't realize if it's a cardiac arrest or normal heart pain which causes unwanted death. Getting an ECG report is always a hassle for the people who are living away in remote parts of a country. Most of the existing ECG machines in out county do not offer portability so the people need to go hospitals or clinics for getting an ECG report which is not convenient for the old aged people or pregnant woman. If a system could be developed which will be recording the ECG of subject as well as it will analyze it in real time whether the subject's heart is in proper heart rate condition.

1.2 What is ECG:

Electrocardiogram, ECG in short is a heart's signal recording and observing system in real time and the system which provides these functionalities is known as an ECG machine. The recorded data formulates an ECG report which is later used for post analysis. An ECG report plays a vital role in case of deciding any type of heart malfunctioning such

as cardiovascular diseases, arrhythmia, atrial fibrillation, cardiac arrest etc. ECG data formulates an ECG report which is later used for post analysis.

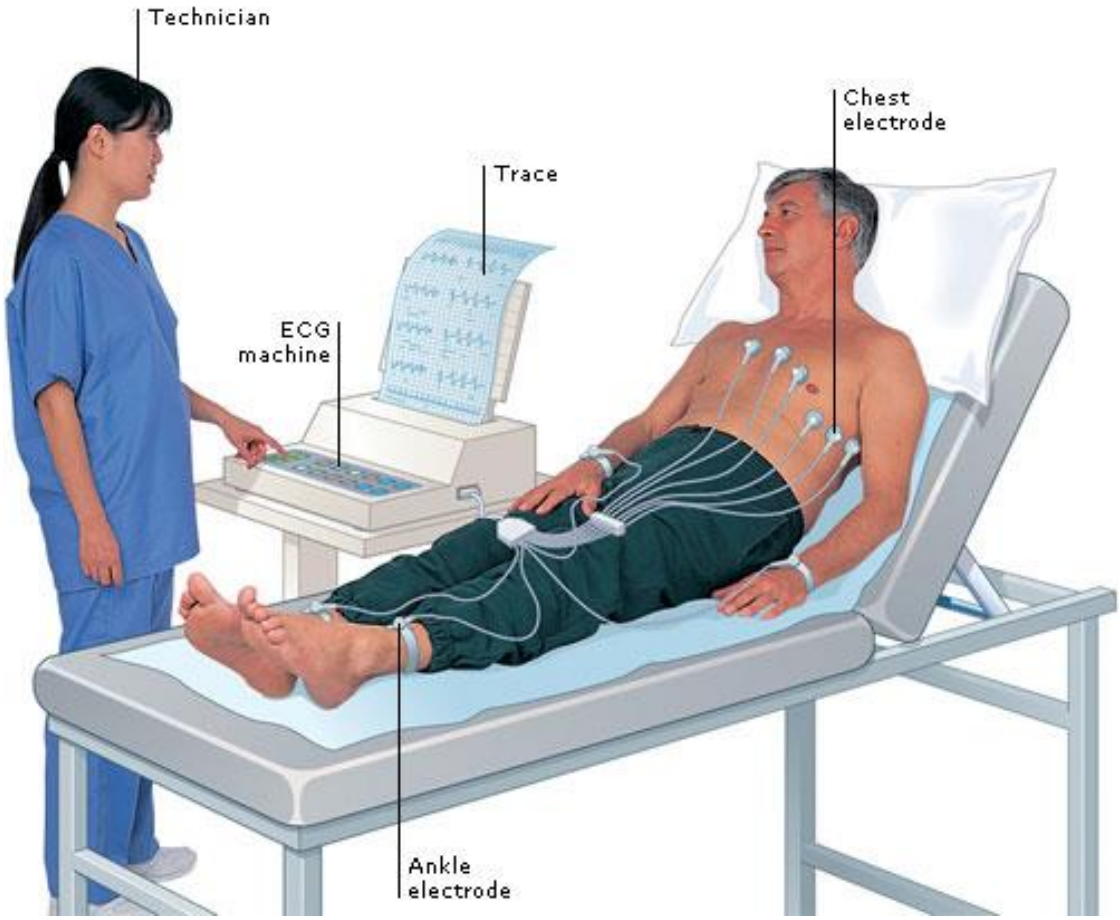

Figure 1.1: ECG Data Acquisition

Source:http://www.medicalequipmentmsl.com/upload/img/20180404/201804041522375722.jpg"

1.3 History and brief on ECG

The term electrocardiogram was introduced by Willem Einthoven in 1893 at a meeting of the Dutch Medical Society. In 1924, physiologist received the Nobel Prize for his life's work developing the ECG.

The electrocardiogram has evolved over the years.

1. The 12-lead ecg that is being used throughout the world was introduced In 1942.

2. It is known as a twelve-lead cardiogram as a result of it examines the electrical activity of the heart from 12 different points of human body by placing 12 electrodes.

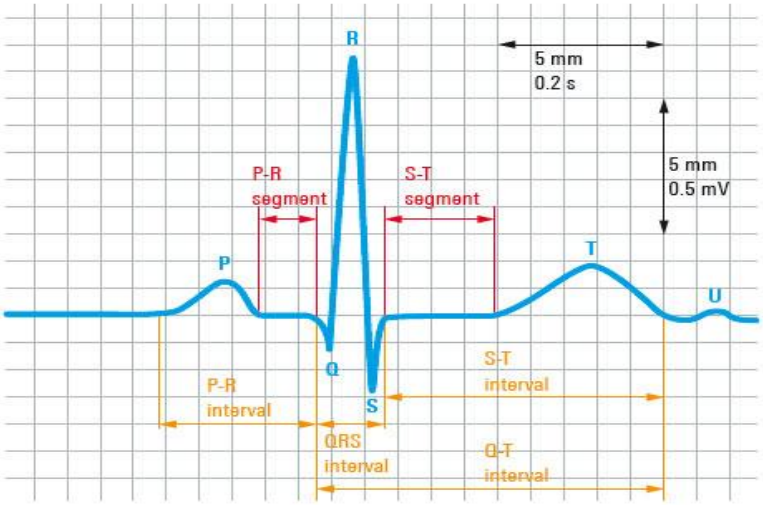

Figure 1.2: Real time heart rate functioning signal (ECG)

Source:"https://www.rohde-schwarz.com/us/applications/capturing-small-ecg-signals-in-medical-applications-application-card_56279-152385.html"

3. ECG is necessary because it provides an entire image of what's occurring.

4. To fully perceive however Associate in Nursing cardiogram reveals helpful info concerning the condition of your heart needs a basic understanding of the anatomy (that is, the structure) and physiology(that is, the function) of the guts.

ECG signal is achieved in form of curves or graphs along with x and y axis. The recorded graph signals are terribly week signals having terribly low frequency thus it needs signal processing before progressing to display unit.

Figure 1.2 is normal sinus rhythm of a subject. The waves lie between these ranges:

1. P wave must be above the reference duration changes 0.8-0.11 seconds
2. PR interval duration changes 0.12-0.20 seconds 3
3. PR segment duration changes 50 to 120 ms
4. QRS complex duration changes 0.8-0.12 seconds
5. ST segment duration changes 80 to 120 ms6
6 .T wave duration changes 150-160ms .
7. ST internal duration changes 300-320ms
8. QT internal duration changes up to 420ms in heart rate of 60bpm

The real time graph signal process and observance is incredibly important for ill patient like paralytic folks, aged folks, patient below comma and plenty of different patients those

are below operation or being ill on the ventilator for long times. The continual recorded signals are often stored for the long run application.

The positive peak within the plot is thought because the R-peak equally the center functioning graph wave is split into totally different interval like P-wave interval, PQR-wave interval, T-wave interval and then on. The all graph wave interval has fastened time dimension, therefore even a little variation in any wave interval represent a particular deficiency or illness in heart functioning. As an example, R-to-R interval provides the center rate in beats per minutes.

$$\text{Heart Rate (HR)} = 60bpm/(\text{R–to–R})interval \quad \ldots(1)$$

Equation (1) is illustrated that if there is even a slight variation in R-to-R interval that can come out with massive variation in pulse rate (HR) which variation is nothing however a form of sickness or disorder. The conventional pulse rate of the person is 72bpm and if the heart rate goes below the 60bpm, it will be known as bradycardia and if it goes on top of the 100bpm, it'll known as tachycardia.

ECG signal acquisition is incredibly necessary for deadly diseases identification like heart functioning, flow rate etc. A several researches are going all over the world for ECG signal process. AC interface, muscles tremor, wandering base line are some common noises (artifacts) that are typically created in ECG signal acquisition technique. AC interface is due to power supply frequency, wandering base line interference happens for conductor loss connections and muscles tremor is extremely effective as a it comes from muscles uncontrolled perform. The muscles tremor can't take away fully as it has involuntary activity.

In this advanced analysis age, a several analysis goes to implement a unique reasonably ECG information acquisition circuit which might scale back all potential artifacts up to the zero level.

Bio electrical impedance, strain gage, surface conductor and lots of alternative techniques are victimization for precise info sweetening. There are many techniques obtainable for ECG signal acquisition. However no technique is totally noise free, all the techniques would like signal process before creating any call concerning about the acquired ECG signal.

1.4 Unusual ECG Signal

The signal indicates weather the subject is alive or dead, once the graph pulse disappear the topic might declare dead and there is no would like of the other parameter measuring.

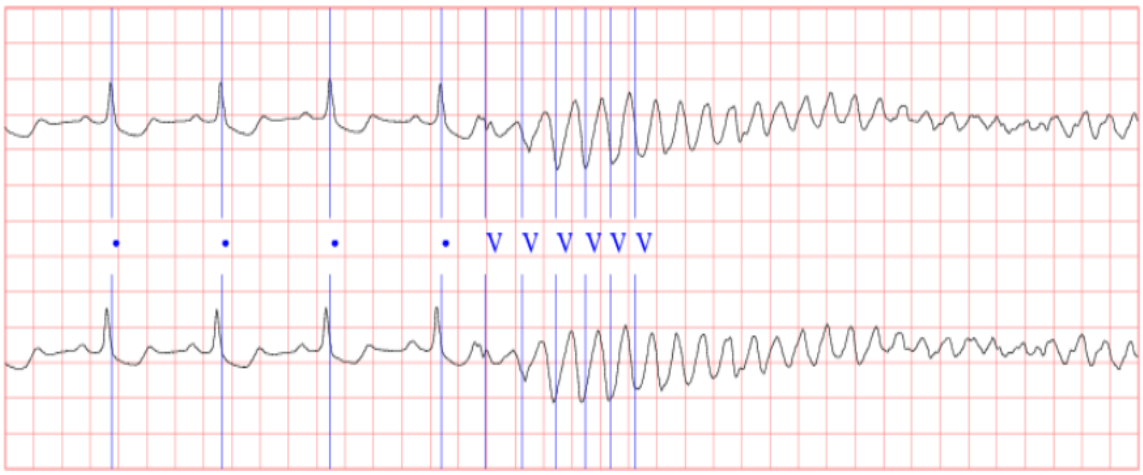

Figure 1.3 : Sudden Cardiac Death
Source: https://physionet.org/pn3/sddb/

The **figure 1.3** above shows how the curve becomes flat slowly by losing its original shape.

1.5 A little brief on hearts functionality

Our heart is a 4-chambered muscle whose functionality is to pump blood to all over the body. Basically heart is two "half hearts," the correct heart and also the left heart, that beat at the same time. Each of those two sides has two chambers: a smaller higher chamber referred to as the atrium (together, the two are referred to as atria), and a bigger lower chamber referred to as the ventricle.

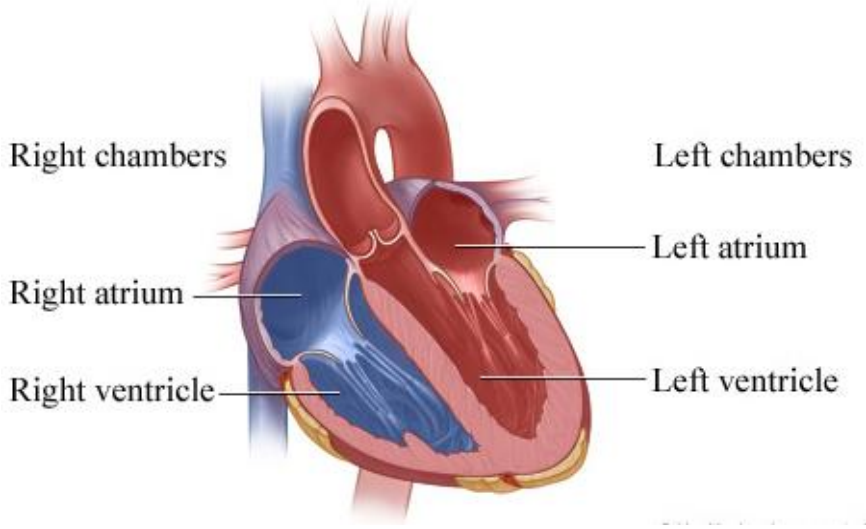

Figure 1.4: Heart's chambers

Source:https://myhealth.alberta.ca/health/medications/Pages/conditions.aspx?hwid=tp10241

The four chambers of the center are known as the right atrium, right ventricle, left atrium and heart ventricle. This sequence jointly represents the direction of blood flow through the center. The right atrium takes blood in that has completed a journey throughout the

body and is in short of O and alternative nutrients. This blood returns via two giant veins: the superior venous blood vessel returning blood from the pinnacle, neck, arms, and higher parts of the chest, and also the inferior venous blood vessel returning blood from the rest of the body. The right atrium pushes this blood into the ventricle, which, a fraction of a second later, pumps the blood into the blood vessels of the lungs. The lungs serve two functions: to treat the blood by exposing it to the air you inhale and to eliminate the Carbon dioxide gone through the lungs, the blood enters the atrium that pumps it into the heart ventricle. The heart ventricle then pumps the blood back to the cardiovascular system of blood vessels (arteries and veins). The blood leaves the heart ventricle via the artery, the most important artery within the body. As a result of the heart ventricle needs to exert enough pressure to stay the blood moving throughout all the blood vessels of the body, it's a strong pump. This pressure is generated by the heart ventricle that gets measured once you have your pressure checked. The heart, like all tissues within the body, needs O to perform. Thus, the center has reserved for itself its own blood offer. This blood flows to the center muscle through a bunch of arteries that begins but simple fraction in from wherever the artery begins. These are called the coronary arteries.

These arteries deliver O to each the center muscle and also the nerves of the center. When one thing happens so the flow of blood through artery gets interrupted, then a part of the center muscle equipped by that artery begins to die. This is often referred to as coronary cardiopathy, or artery malady. If this condition isn't stopped, the center itself starts to lose its strength to pump blood, a condition called cardiopathy. When the

interruption of coronary blood flow lasts solely many minutes, the symptoms are referred to as angina, and there's no permanent injury to the center.

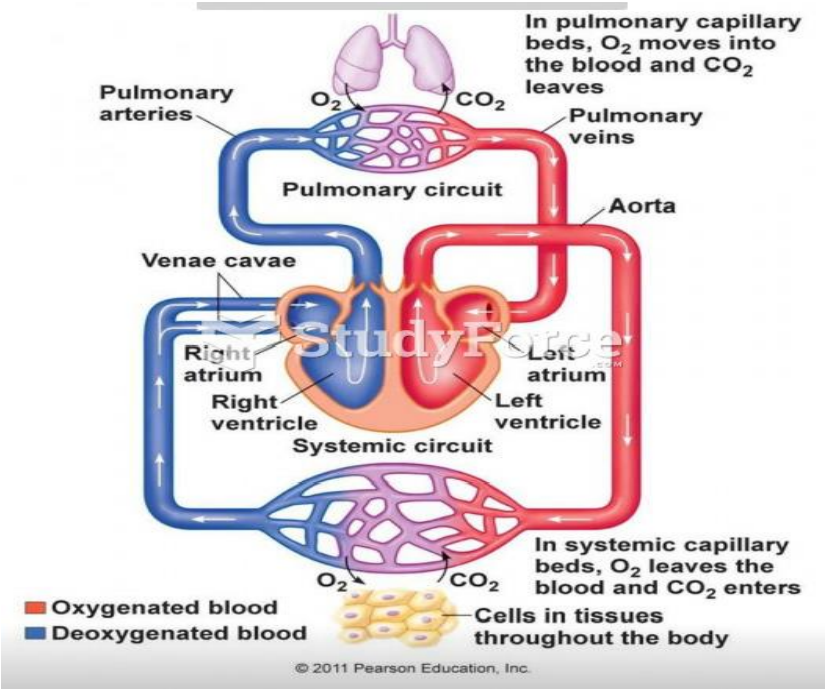

Figure1.5: Blood flow through the heart.

Source: "https://biologyforums.com/index.php?PHPSESSID=t9is9mtnjo2ibc8rh6niojh9a7;action=gallery;sa=view;id=18271"

When the interruption lasts longer, that a part of the center muscle dies. This is often observed as an attack (myocardial infarction). Nerves of the heart: The heart's performance is thus vital to the body that it's its own electrical system to stay it running severally of the remainder of the body's system. Even in cases of severe brain injury, the

center usually beats ordinarily. A combinational network of nerves runs throughout all four chambers of the center. Electrical impulses course through these nerves to trigger the chambers to contract with utterly synchronic temporal arrangement very like the distributor Associate in Nursing spark plugs of a automotive confirm that an engine's pistons fireplace within the right sequence. The electrical activities are recorded using the ECG graph. The shapes and frequencies of those tracings reveal abnormalities within the heart's anatomy or perform. The blood flow system through the heart is shown in **figure 1.5**.

1.6 Motivation

Day by more people are getting affected in cardiovascular diseases which is increasing the death rate in our country according to WHO's report. The reason of death is related to many different issues such as artery block, diabetes, high blood pressure, smoking, Stress, coronary artery diseases etc. On the other hand the mass people go through a lot to get an ECG report due to the fact that ECG machines are only available in high end hospitals or clinics. That means they suffer to travel from rural areas or places away from those clinics. It becomes more difficult for the aged people or pregnant women because of risk of sensitive movement. If an example is considered like a person who can't move easily and suffers from both ulcer pain and cardiovascular disease has a very high risk of suffering a cardiac attack can create misconception of having the ulcer pain. But in reality it could a minor or major heart attack which could lead them to death. These type of misconceptions can be prevented if a portable ECG measuring device could be used. If features like saving the data, transmitting to server could be added then it would become more realistic and useful in medical sector. Though it's hard to completely eradicate the death due to heart diseases, it can be controlled by such portable device which will always accompany the user for all the time and will give real time reading of his heart's Signal.

Our project have plenty of choices for creating it a lot of versatile and straight forward to use like activity and showing the signal on the display, detection of irregular heartbeat, battery longevity, showing the info on computer monitor or any display, portability, less complexity, etc. Our primary goal was to develop the device which will take patient's body signals through some conductor pads and therefore the instrumentation amplifier will convert the signals to analog to digital signals that we are able to see through a LCD display or in Arduino IDE plotter for graphical shape. This device is especially designed for the remote area people who can't get proper treatment facilities and not concern about the heart diseases.

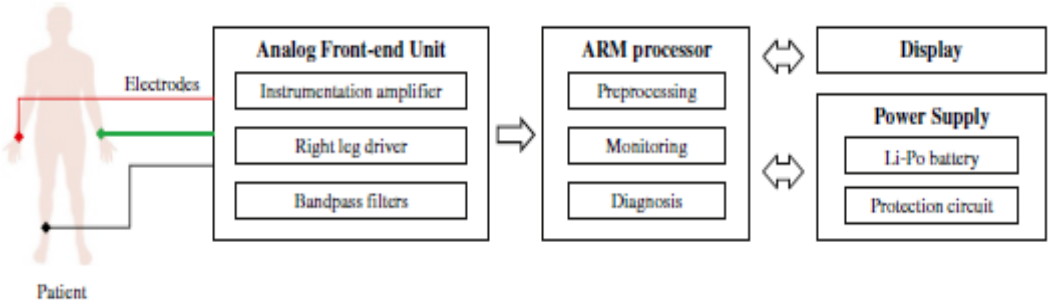

Fig 1.6: Overall framework configuration of the proposed portable ECG device.

Source: Implementation of a portable device for real-time ECG signal analysis (Taegyun Jeon1, Byoungho Kim3, Moongu Jeon1 and Byung-Geun Lee2*)

CHAPTER 2

Background

2.1 Introduction

A lot of works have been done before to construct an ECG machine which will be functional as a normal ECG machine but it will also be easy to carry. In this section a few works very much related to our work which have been done before will be explained with the system block diagrams and components used for those projects.

This paper introduces with a portable ECG Monitoring System with USB host interface.

USED EQUIPMENTS: (Hardware Part)

- Microprocessor C8051F021.
- SL811HS as USB host Interface chip.
- Acquisition Circuit
- Lead switchover circuit.
- Band Pass filter.
- Operational Amplifier.
- 35HZ double t notch filter.
- 50HZ double t notch filter.

Some block diagrams are being placed below which shows a complete overview of the system and how components are connected sequentially. From the figure it's observable that the input from a subject goes to lead switchover circuit which is later passed to amplifying and filter circuit. The amplifying and filter circuit consists of head amplifier,

band pass filter, wave trap and post amplifier.

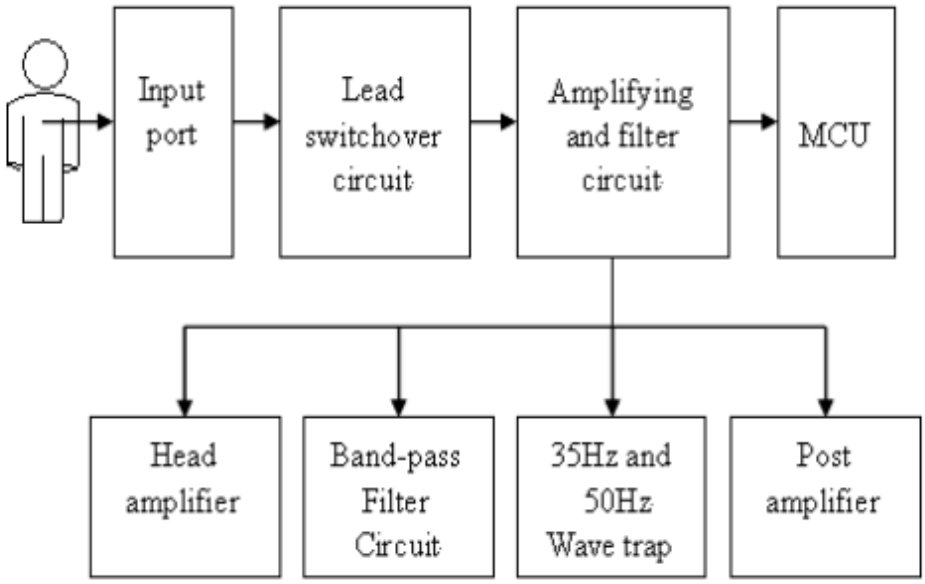

Figure 2.1: Acquisition system structure (Hardware)

Source: (The research of portable ECG monitoring system with USB Host Interface)

Used Equipment: (Software Part)

- C8051F021 and the SL811HS. (Layer One)
- USB Host and the USB Slave. (Layer Two)
- USB Specification standard request. (Layer Three)
- Achievement of the USB Host. (layer Four)

Flow diagram of the system structure show the connections the system and harware components.

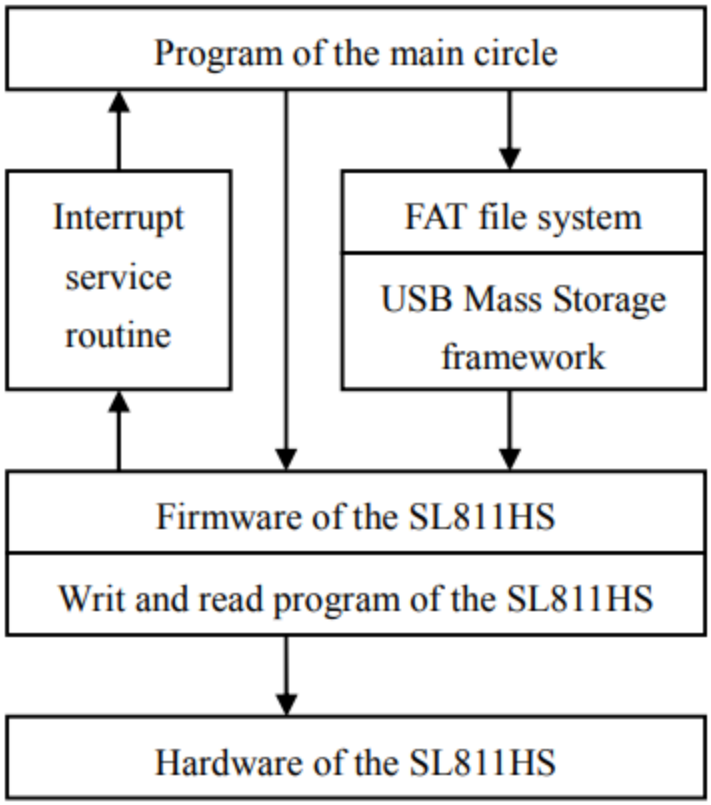

Figure 2.2: USB Host System Structure.

Source: (The Research of portable ECG monitoring system with USB host interface)

Methodology: This system uses a Microprocessor (C8051F021) as its controlling unit, and SL811HS as USB host Interface chip. The program of the main circle delivers the data to storage panel and then the data is passed to the firmware of USB host controller which is known as SL811HS.Later it's forwarded to the hardware. The firmware retrieves data to interrupt service routine and then it's cycled to program of the main circle.

This section describes about a previous work which uses conventional frontend but additional features like memory storage. It used a microprocessor to control the whole system. The amplifying and filter circuit unit consisted of head amplifier, Band pass filter, wave trap and post amplifier. This project has a lot of similarities to our proposed design that's why it's been chosen to be included in this paper.

This explanation and working procedure was collected from the paper “The Design of Portable ECG Health Monitoring System”.

Used Equipment:

- STM32F103VE chip. (Microprocessor).
- BMD101 chip. (For signal acquisition).
- ADuM5010 (Power isolation chip).
- LCD screen.
- Multi-connection Interface.
- Data Acquisition Model
- Physiological Information Sensor.
- In-Circuit Debugger.
- Micro wireless ECG electro cardio sensor

Methodology: This system works when the electrodes are touched with two fingers which is very much convenient for portable use. Then the microprocessor extracts the data and displays them on OLED screen. The data can be sent to a led for displaying as well as it can be stored for further process.

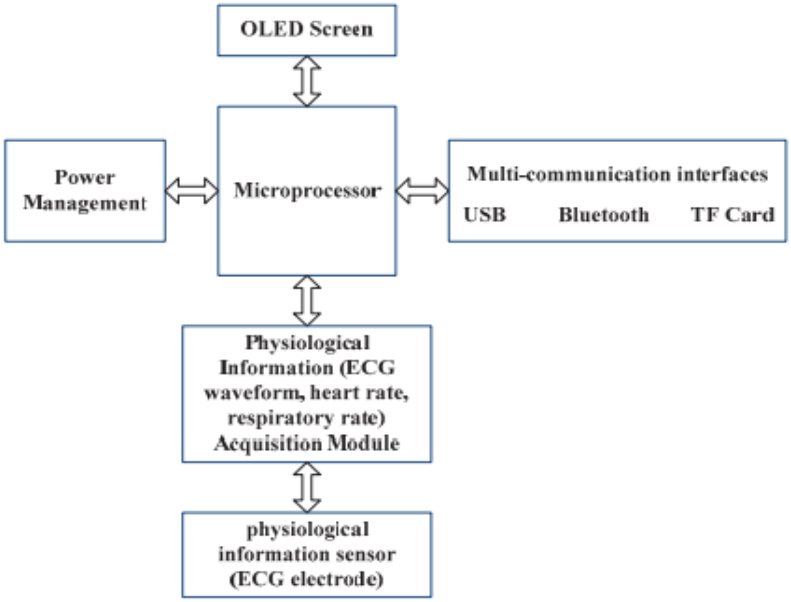

Figure 2.3: Block diagram of whole system.

Source: (The Design of Portable ECG Health Monitoring System)

Data Acquisition Module:

This module receives the low frequency ECG signal which has the value in between 0.05mV and 5mV (for general cases) and the frequency of ECG signal is between 0.05Hz and 100Hz.It consists of ADaM5010, BMD101.

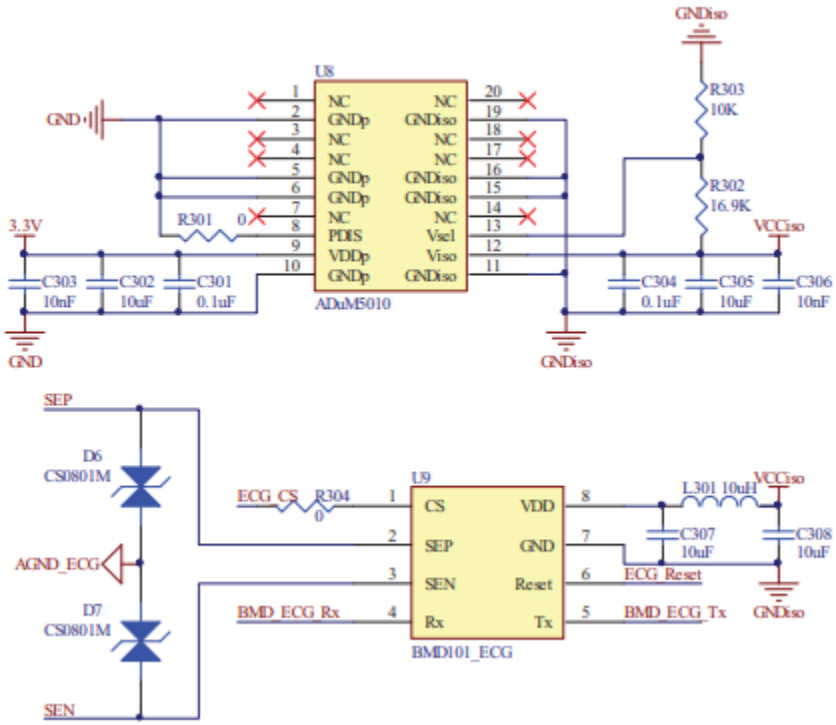

Figure 2.4: Block diagram of data acquisition system

Source: (The Design of Portable ECG Health Monitoring System)

Here BMD101 is a readymade micro wireless ECG electro cardio sensor module w/Bluetooth transmission.

Power Management Module: The system uses MICROUSB for charging the built-in battery which can supply up to 3A with 3.9-6.2 USB input. The procedure is same as smartphone charging and the power management module uses TI's BQ24295 chip to manage the system power.

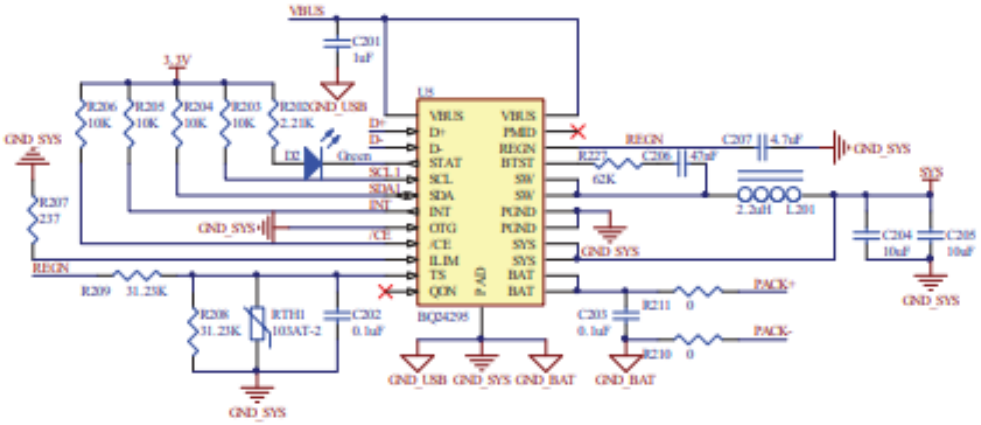

Figure 2.5: Block diagram of whole system

Source: "The Design of Portable ECG Health Monitoring System"

Another work having impressive features like LCD display, bluetooth file transfer system, storage unit etc. It has two separate modules, one for the power management and another one for data acquisition. It has a very unique kind of feature which is it can acquire data only by two fingertips of two hands instead of three, five or twelve electrode ECG system. This feature makes it very unique and convenient.

This section focuses another work collected from the paper "A Simple Portable ECG Monitor with IOT". It discusses about how data is collected and sent to remote server by using GSM/GPRS and then fetched from mobile phones or any related medical environment.

Equipment:

- Instrumentation Amplifier
- GSM
- Low pass filter
- Server
- High pass filter
- Phone
- Notch filter
- Buzzer

Methodology:

Received electrical signals are filtered out and amplified using instrumentation amplifier AD620. A notch filter is used to eliminate the 50 HZ supply noise picked up by the body. Then ADC (analog to digital converter) converts the amplified signal into digital samples. The ARM CORTEX M3 LPC1768 takes care of acquiring the samples and storing them in memory.

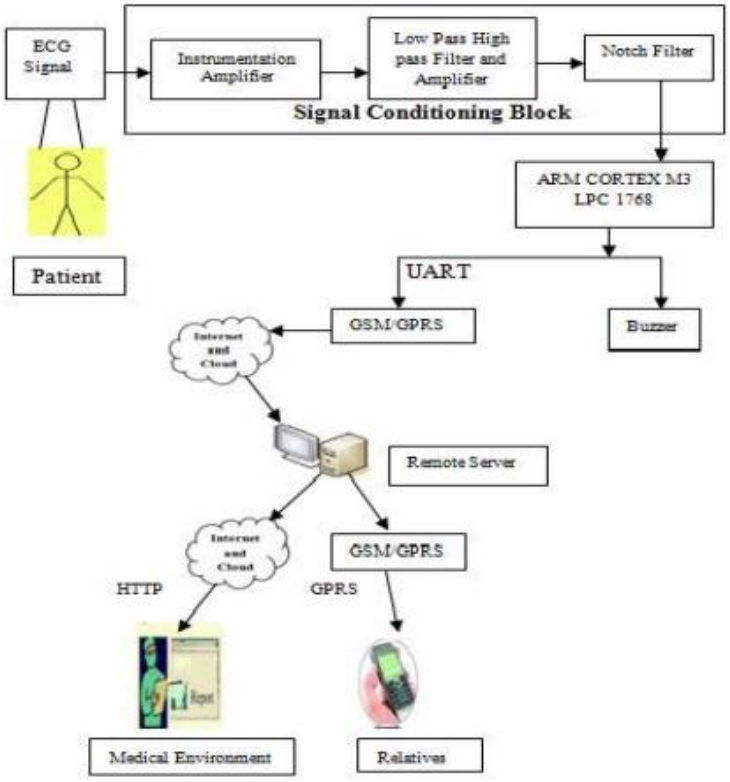

Figure 2.6: Overall scenario of total system.

Source: "A Simple Portable ECG Monitor with IOT"

The working procedure of the analog font end has been discussed later briefly but the other blocks are being discussed here. After acquiring the data, It's passed to ARM CORTEX M3 which is a single board computer. Then the data is forwarded to a buzzer and GPRS/GSM.The data acquired from memory is converted into serial data. The SIM900A uses RXD / TXD to transmit the acquired data on remote server and communication protocol between SIM900A and server is HTTP. It used HTTP post method for sending ECG data to Server or Cloud and the data is represented in graphical format on computer.

This project has most interesting features among the all described projects in this paper. It has impressive and useful options like GSM/GPRS, buzzer, remote server, phone alert to relatives etc. It maintains separate signal conditioning block just for data receiving. All other features interact with the arm cortex single board computer. This is another relatable project to ours.

Project discussed below is another relatable work to us which has been collected from the paper**:** "Low-Cost Prototype Design of a Portable ECG Signal Recorder". It was done by a few students of National Sun Yat-sen University and Nan Hua University Chiayi.

EQUIPMENT:

- Front end circuit(in amp, lpf, hpf, iso amp)
- Arduino.
- Monitor.

Methodology: It is a prototype of an ECG data acquisition system having an Arduino Nano and commercial ICs. The proposed front-end readout circuits as shown in Fig. 1 includes an instrumentation amplifier (IA), isolation amplifier, gain stage, clamp circuit, and a band-pass filter.

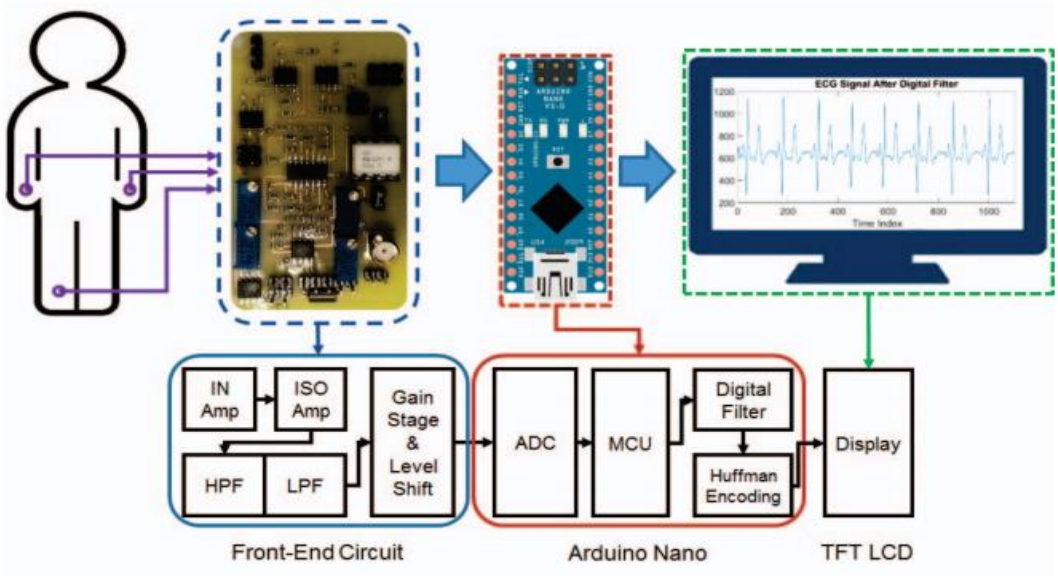

Figure 2.7: ECG acquisition System

Source: "Low-Cost Prototype Design of a Portable ECG Signal Recorder"

This project is based on arduino which directly shows the output from the front-end to the LCD. This one doesn't have any storage or transmitting feature. It is like other ECG data acquiring device which can replace the regular ECG machines. It uses three electrode ECG data acquisition structure.

Equipment:

- Electrodes
- Hpf, Lpf, Instrumentation Amplifier
- Voltage Level Shifter

Methodology:

This project was done for chronic heart disease patients. It was a portable design for those kind of patients and it could record and monitor the data at a same time. It can also transmit to medical services by text messages.

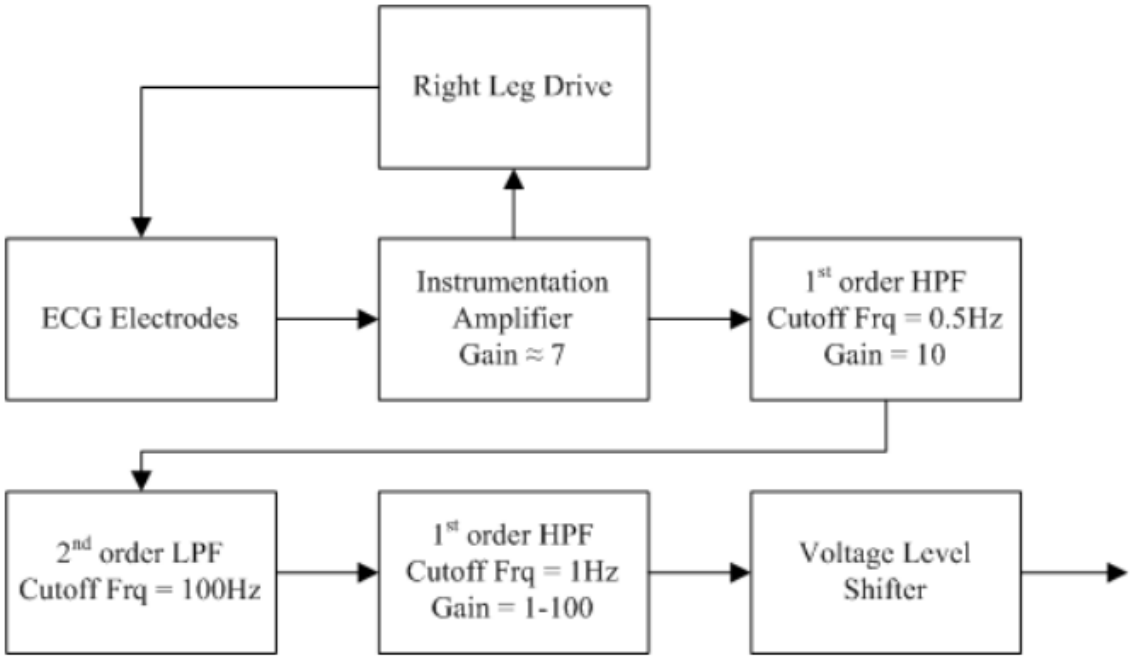

Figure 2.8: Block diagram of the system hardware.

This could help the clinician to diagnose heart failure. The signal is measured by three AG/AGCI through the second lead. It uses ad620 as instrumentation op-amp and protects

the input current by two zener diode. Then high and low pass was used to pass the signal in between 1 to 100hz.

2.2 Summary

In this section a few previous works have been explained for making the concept more understandable. The system block diagram of each work has been discussed to make sure that our work also follows the nearby path to them. It has been observed that every discussed project has a lot of similarity in terms of components, data acquisition approach, data processing approach and post processing approach.

CHAPTER 3

Proposed Design

3.1 System Description

As it's been said earlier that the aim was to build an ECG machine which will be able to take the data from the subject's body as well as it will process the data for alarming the patient and simulating data on phone in real time. It was also proposed that the data will be shown on a display and a memory will store data. The block diagram below shows our complete proposal.

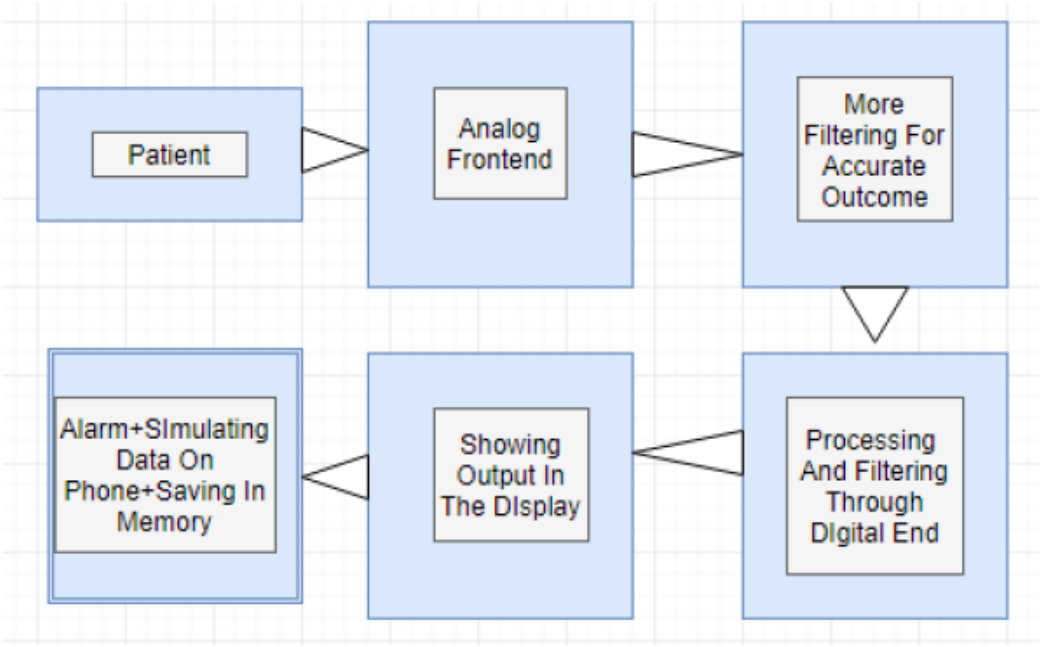

Figure 3.1: Proposed block diagram.

First of all it takes input from the subject then filters out the unnecessary portion such as unwanted frequencies from the signal and amplifies it for better post processing. Then the data is sent to display, alarm, memory and phone. The block diagram contains several

blocks which gives the complete overview of the total system. Each and every part of the block diagram will be explained.

Subject

The term patient can also be referred as subject because the machine will be able to collect signals from people if the electrodes are properly placed on the subject's body. The proposed circuit has a three electrode system for collecting the signal.

3.2 Electrode System

The number of electrodes varies depending on different electrode system. There are several electrode systems such as

Three electrode

It uses three electrodes placed on right arm (RA), left arm (LA) and left leg (LL) to collect the signal.

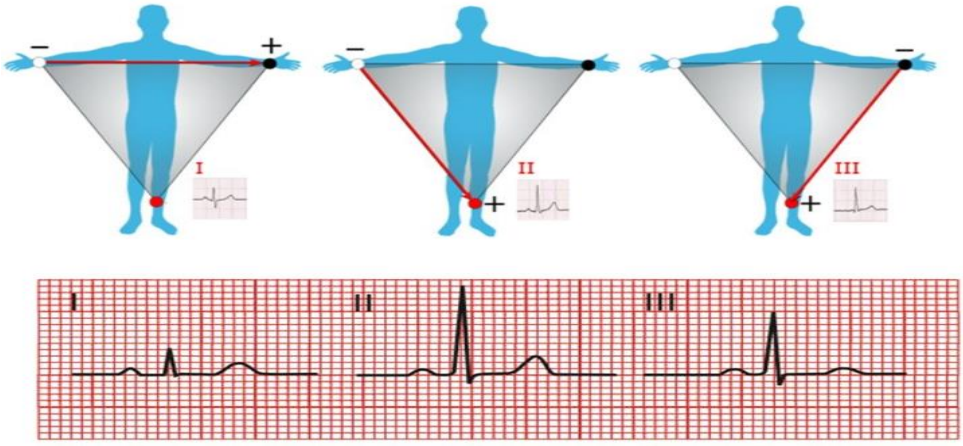

Figure 3.2: Three Electrode ECG.

Source:"https://www.quora.com/How-are-4-lead-ECG-different-from-12-lead"

The monitor displays the bipolar leads (I, II and III). But placement of electrodes may vary and that may produce slight change in the output.

Three electrodes can also be placed on left and right side of chest and below cartilage.

Five electrode

It uses five electrodes placed on right arm(RA),left arm(LA)right leg(RL),left leg(LL) and chest. Monitor displays the bipolar leads (I, II and III) and a single unipolar lead

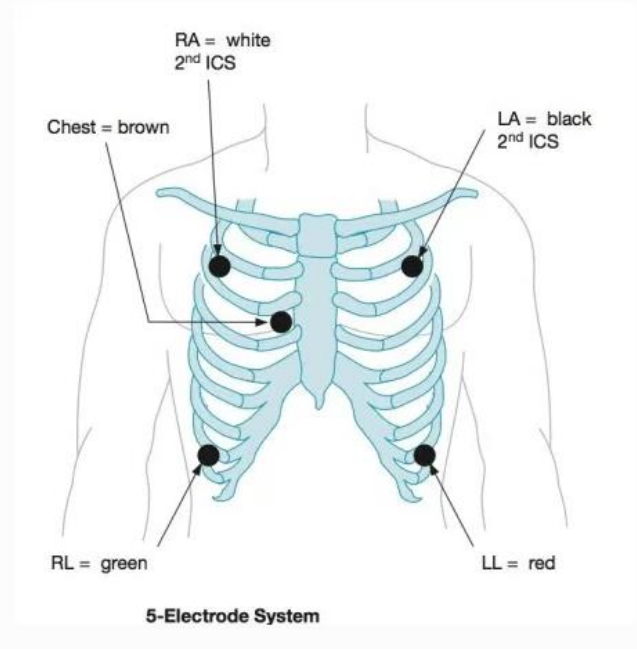

Figure 3.3: Five electrode ECG.

Source: "https://lifeinthefastlane.com/ecg-library/basics/lead-positioning/"

Twelve lead

This system uses 4 Electrodes on all 4 limbs (RA, LL, LA, RL) 6 Electrodes on precordium (V1–6).Monitors 12 leads (V1–6), (I, II, III) and (aVR, aVF, aVL).

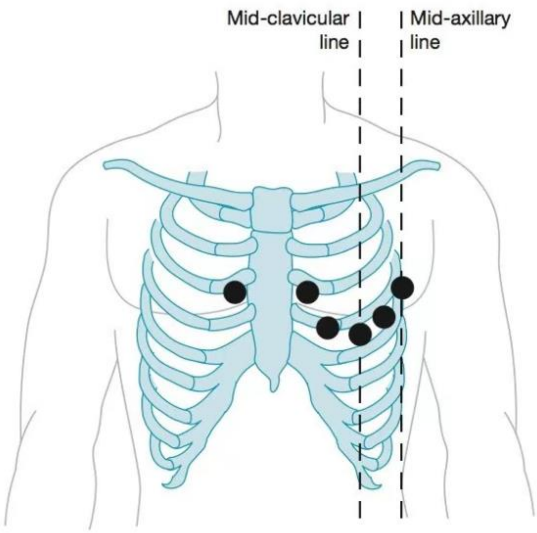

Figure 3.4: Twelve electrode ECG.

Source: "https://lifeinthefastlane.com/ecg-library/basics/lead-positioning/"

Brief on three electrode system

3 lead system is simple to use and can work with less sensitive machine. Moreover it has less complexity in terms of placement and it is capable of picking up the specific electrical rhythm, or lack of, in the heart. The final result of a three lead ECG doesn't have too much difference if compared to a 12 lead system.

3 lead ECG does not provide a clear view of the entire heart but it provides a basic view of the electrical pathway of the heart triangulated between the 3 leads. The electrodes forms a Einthoven's Triangle

A red lead is placed on the right wrist or shoulder- known as AVr.A yellow lead is placed on left wrist or shoulder- known as AVl.A green lead is placed on the ankle or left lower abdomen- known as AVf

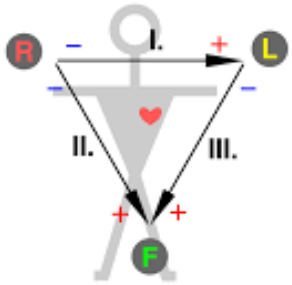

Figure 3.5: Three electrode ECG.

Source: "http://www.cfrhq.co.uk/3-lead-ecg/"

a) Data between AVr and AVl is known as lead l.

b) Data between AVr and AVf is known as lead ll

c) Data between AVl and AVf is known as lead lll

3.3 Analog Frontend

The signals collected from the body are supposed to be passed to operational amplifiers, filters, display, memory, digital post processing, alarm etc. Mainly the analog frontend consists of amplifiers and filters such as

- Band pass filter
- Notch filter
- High pass filter
- Low pass filter
- Instrumentation amplifier
- Operational amplifier etc.

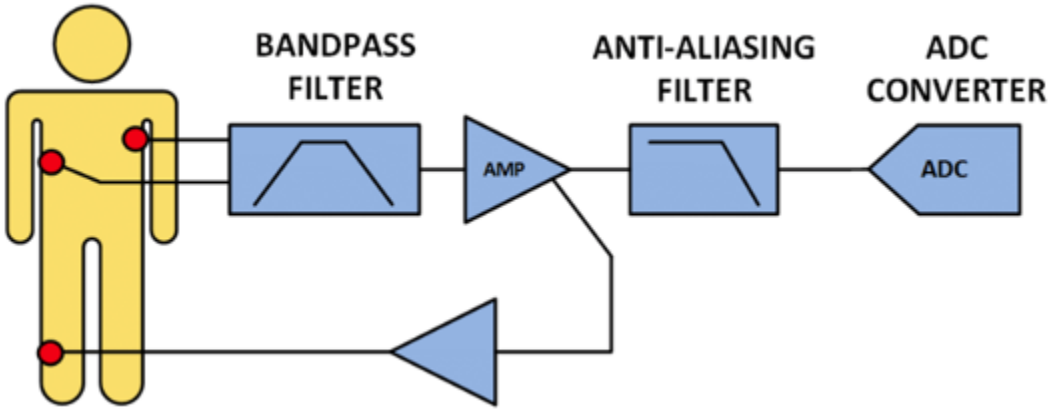

Figure 3.6: Analog Front End

Source: https://www.researchgate.net/figure/Typical-ECG-Analog-Front-End_fig3_302631407

3.3.1 Instrumentation Amplifier

Instrumentation are commonly used in industrial test and measurement application. An instrumentation amplifier has buffer circuit and difference amplifier .The formula for calculating gain is G=(1+(49.4kΩ/Rgain)).So the gain can be adjusted by changing the value of Rgain. Suppose we want gain approximately 90 then the Rg value should be 560 ohm

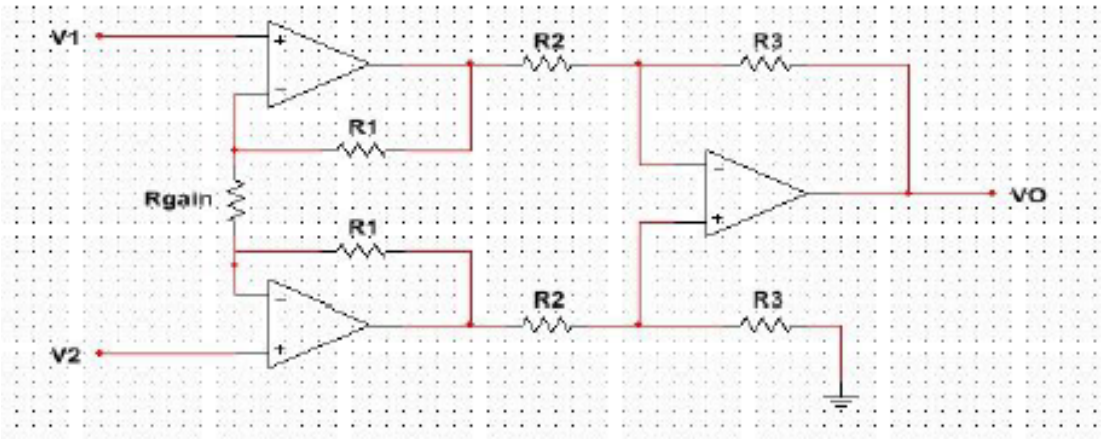

Figure 3.7: Instrumentation Amplifier

Source: "http://www.circuitstoday.com/instrumentation-amplifier"

The circuit diagram of a typical instrumentation amplifier using op-amp.A practical instrumentation amplifier circuit designed based on uA 741 op amp. Instrumentation amplifiers are generally used in situations where high sensitivity, accuracy and stability are required.

An instrumentation amplifier has

- Low DC offset.
- Low Drift.
- Low Noise.
- Very High Open Loop Gain.
- Very high common mode relation ratio.
- Very high input Impedance.

3.3.2 Operation Amplifier

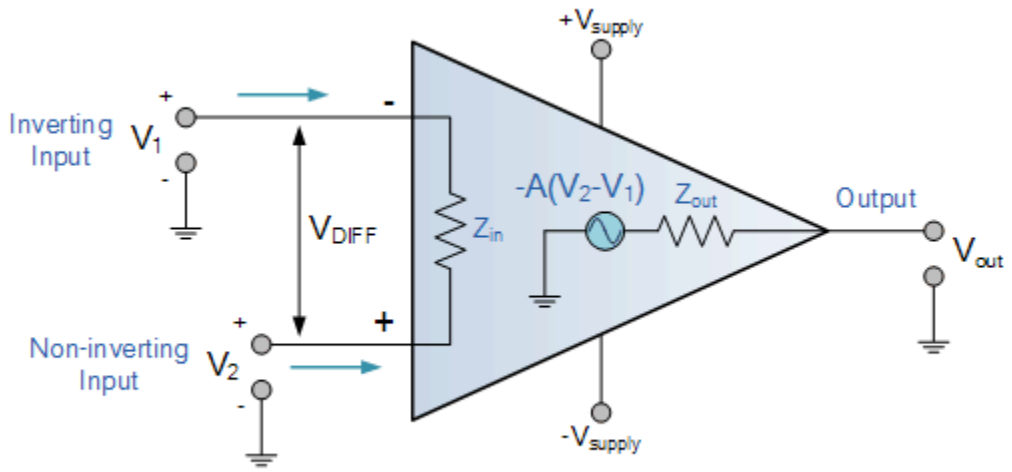

Figure 3.8: operation amplifier

Source: "https://www.electronics-tutorials.ws/opamp/opamp_1.html"

An Operational Amplifier is basically a three-terminal device which consists of two high impedance inputs. One of the inputs is called the Inverting Input, marked with a negative

or “minus” sign, (–). The other input is called the Non-inverting Input, marked with a positive or “plus” sign (+).

Op-amp is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals. We can connect external resistors or capacitors to the op-amp in a number of different ways to form basic “building Block” circuits such as, Inverting, Non-Inverting, Voltage Follower, Summing, Differential, Integrator and Differentiator type amplifiers.

3.4 FILTERS

A signal acquired from any subject contains a lot of unwanted frequencies which are listed below. This additional frequencies makes the original ECG signal distorted and the processing of the signal becomes harder for post processing. So it is a mandatory and vital step to remove the noises from the signal. Some basic noises can be removed in the circuit part and rest of the noises require digital processing in software like matlab. The noise removal part of the circuit will be described after the list of the noise sources.

Source of noises:

- Electrode contact noise and motion artefacts
- Muscle Noise: 5 – 50 Hz.
- Respiratory Noise: 0.12 – 0.5 Hz.
- Power-line interference: (50 – 60hz)- Produced By Power line.

- Electromyography noise: EMG noise is caused by the contraction of other muscles besides the heart.
- Burst noises - white Gaussian noise which appears on a subset of leads for a very short duration, such as: electrode pop noise, electrode motion artefact, electrosurgical noise, instrumentation noise.

Low Pass Filter

A low pass filter passes signal frequency lower than a certain cutoff frequency.It helps to obtain a desired signal below a range. It is also known as high cut filter or treble cut filter. The frequency response can be varied by varying the filter design.

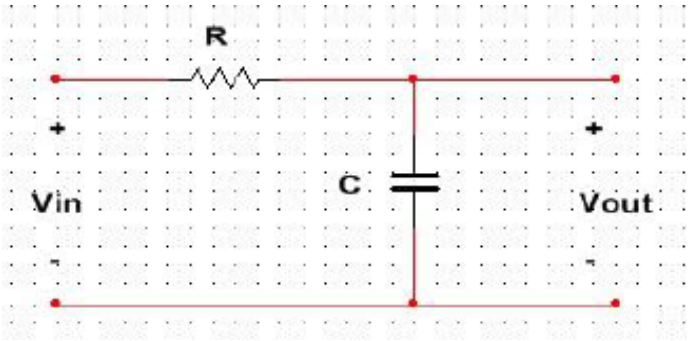

Figure 3.9: Low pass filter

Source: "https://en.wikipedia.org/wiki/Low-pass_filter"

First-order passive filters (1st order) can be made by connecting together a single resistor and a single capacitor in series across an input signal, (V_{IN}) with the output of the filter, (V_{OUT}) taken from the junction of these two components.

High Pass Filter

A high pass filter does the opposite of what a low pass filter does. It passes all the frequencies higher than a certain cutoff frequency. The value of certain cut off can be varied by changing the value of resistor and capacitor.

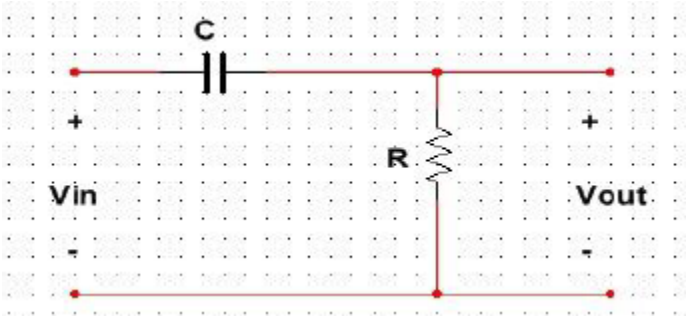

Figure 3.10: High pass filter

Source: "https://en.wikipedia.org/wiki/High-pass_filter"

Notch Filter

The figure below shows a T twin notch filter. The main purpose of using this filter is to prevent the noises from the electrical devices. It consists of passive RC high pass and low pass filters. The fc can be calculated by using the formula fc=1/2(pi)*r*c. If the value of R is chosen 100k and the capacitor value is chosen 34 nf then the circuit will be able to eliminate 50hz noise. This 50hz noise can be considered as the power line interference which is common for every electrical components.

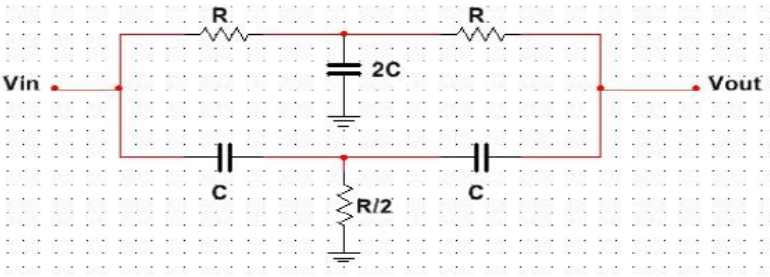

Figure 3.11: Notch Filter

Source: "Electrocardiogram measurement circuit design by Mert Kemal Tan"

Band Pass Filter

A band pass filter is an electronic device or circuit that allows signals between two specific frequencies to pass, but that discriminates against signals at other frequencies. Basically it is a combination of a low pass and high pass filter. Some band pass filters require an external source of power and employ active components such as transistors and integrated circuits; these are known as active band pass filters. Other band pass filters use no external source of power and consist only of passive components such as capacitors and inductors; these are called passive band pass filters.

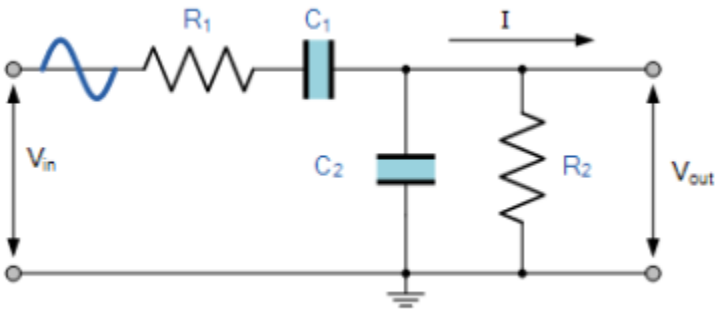

Figure 3.12: Band pass filter

Source: https://www.electronics-tutorials.ws/filter/filter_4.html

3.5 Processing Data Through The Digital End

It was mentioned earlier that ecg data can be processed in the analog end and the digital end. The analog end consists of circuits and filters where the digital end belongs to arduino, matlab and programming. This section shows how it was proposed to filter out the odds and detect the uneven rhythms.

Removing the noises includes >

- Fixing the baseline trend.
- Removing the power line interference.
- Applying filters like fir, iir, wavelet etc to make the signal smooth for detection of uneven rhythms.

Fixing the baseline trend

The baseline trend is the uneven distribution of the signal and shifting the baseline. If data is analyzed without removing those trends then the data loses important information and values of the signal. So the data needs to be detrended that means all the highest peaks should be in the same level and the signal should remain distribute evenly. The figure below shows two signals before and after baseline correction.

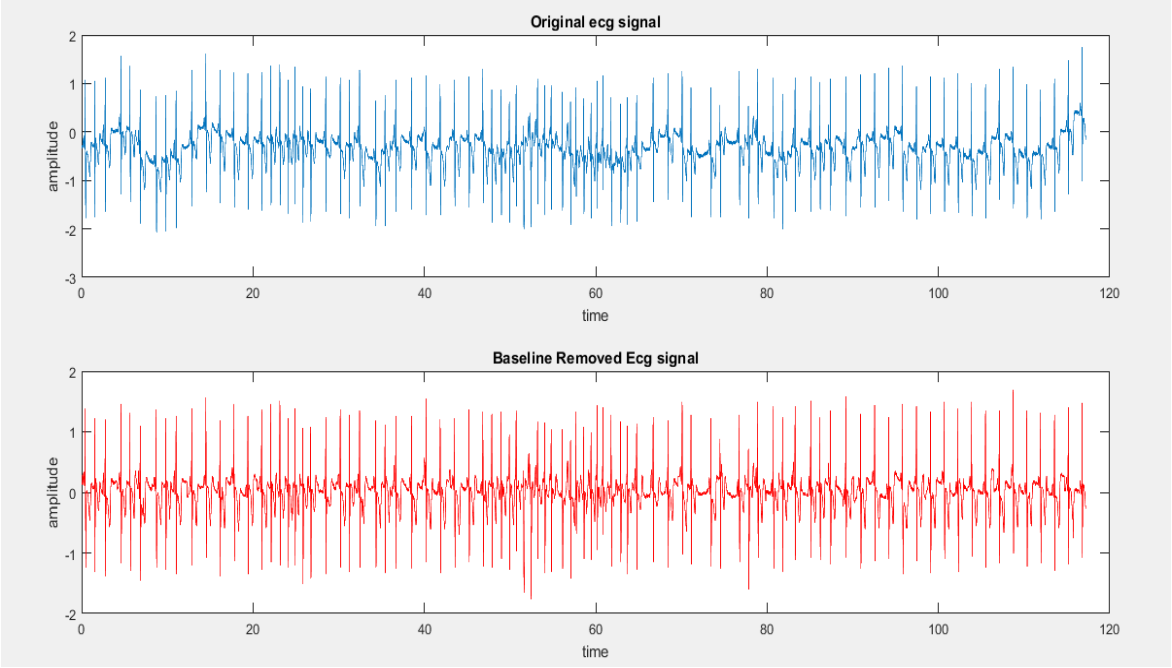

Figure 3.13: Baseline Trend Removal

High Pass Filtering

The high pass or low pass filtering can be done using the circuit or through the digital end. Both circuits were shown before. The figure below shows a high passed signal. These high pass model was prepared using matlab.

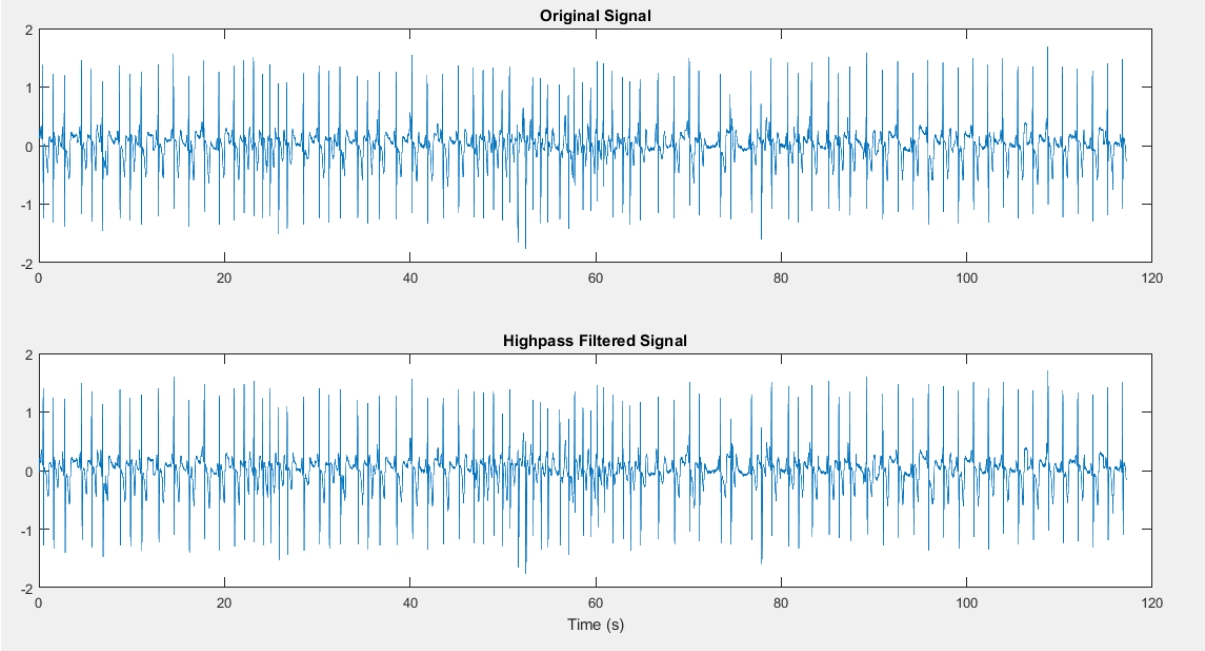

Figure 3.14: High Pass Filtering

Applying Wavelet

A wavelet is a mathematical function used in digital signal processing. The function waves above and below x axis by varying frequency, limited duration and zero average value. There are various types of wavelets such as

- Haar
- Morlet
- Daubechies (It has a wide variation starting drom DB1)

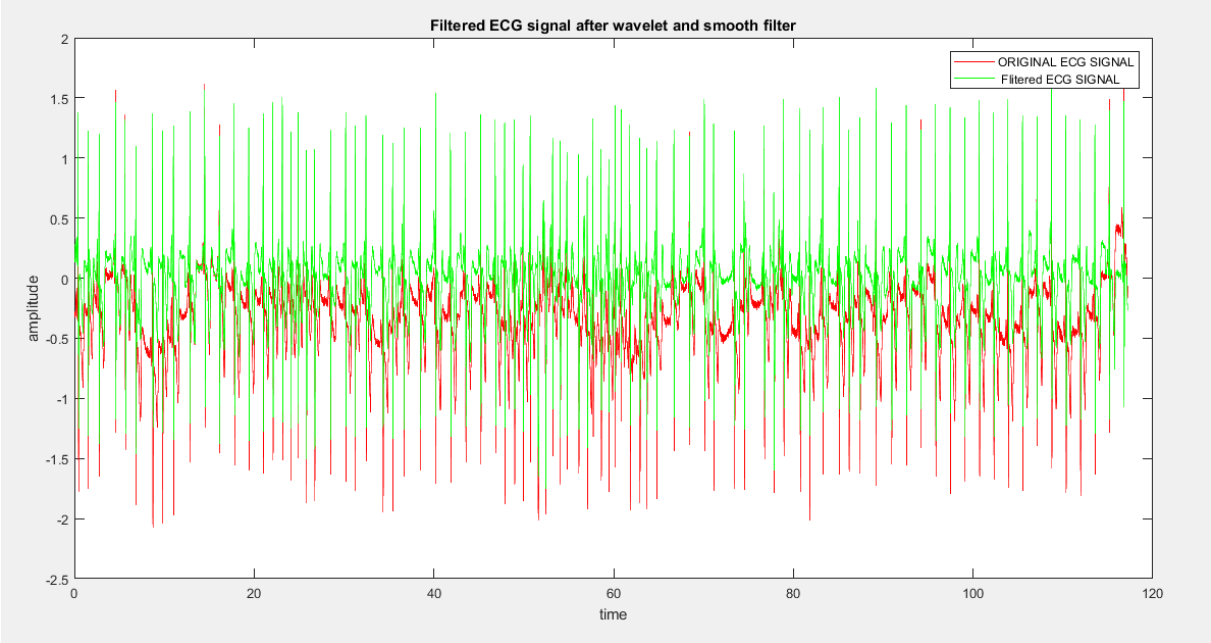

Figure 3.15: Applying Wavelet

The figure above shows two different colored signal blue and red.The blue one is the signal after applying a DB family wavelet and the red one is the original signal. It's

clearly visible that the signal after applying DB wavelet is lot more arranged and a bit shorter than previous one. These are only visible change but there are more changes which can't be observed.

3.6 Summary

Our project have plenty of choices for creating it a lot of versatile and straight forward to use like activity and showing the signal on the display, detection of irregular heartbeat, battery longevity, showing the info on computer monitor or any display, portability, less complexity, etc. Our primary goal was to develop the device which will take patient's body signals through some conductor pads and therefore the instrumentation amplifier will convert the signals to analog to digital signals that we are able to see through a LCD display or in Arduino IDE plotter for graphical shape. This device is specially designed for the remote area people who can't get proper treatment facilities and not concern about the heart diseases.

CHAPTER 4
Approaches

Throughout the development cycle of the project several modifications were done. Approaches were changed, part of circuits were removed and added for achieving the proper result a few times. All the steps and modifications are being described below.

4.1 Approach 1

The figure below show the simulation of the chosen circuit. For simulating the circuit all the components were placed in multisim and input was provided for verifying that the circuit is okay to proceed with. The circuit consists of an instrumentation amplifier an operation amplifier, a high pass, a low pass and a notch. Purposes of all the parts mentioned were explained before in proposed methodology section.

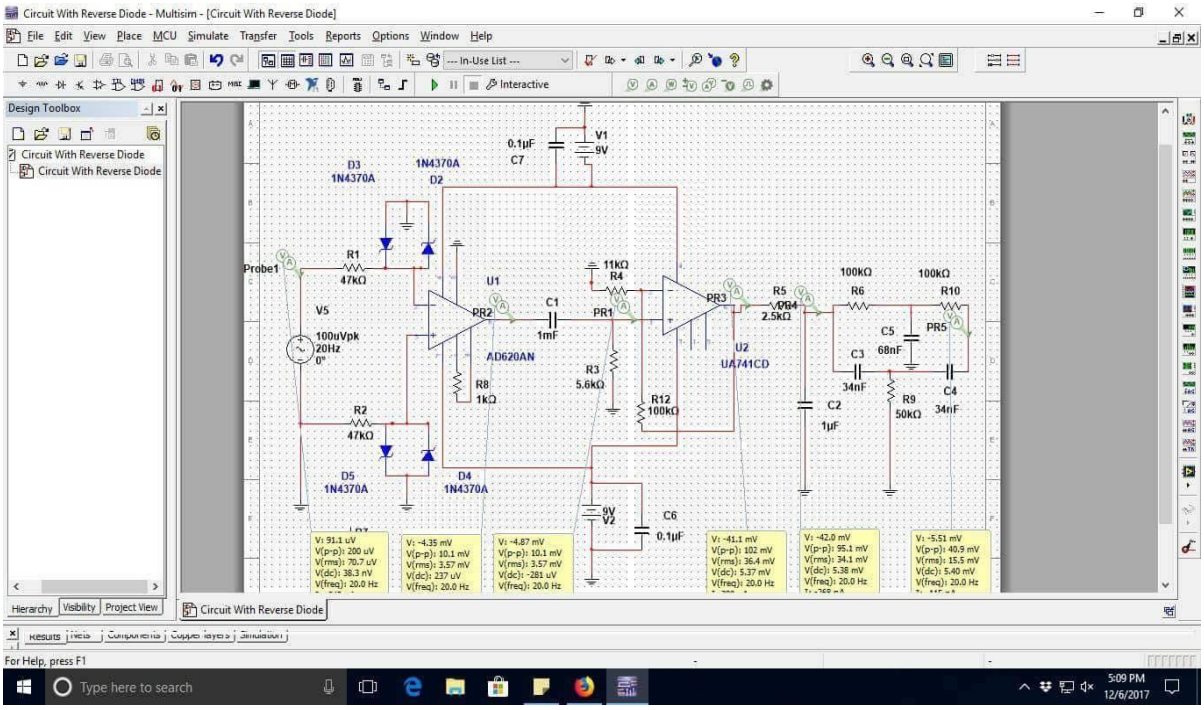

Figure 4.1 : Simulation of the circuit

Source: Dr. Tanzilur Rahman

The components were connected as per the multsim simulation file. The figure below shows all the parts as a single vero-board circuit. The circuit has three inputs and two voltage sources which provides +5v and -5v.

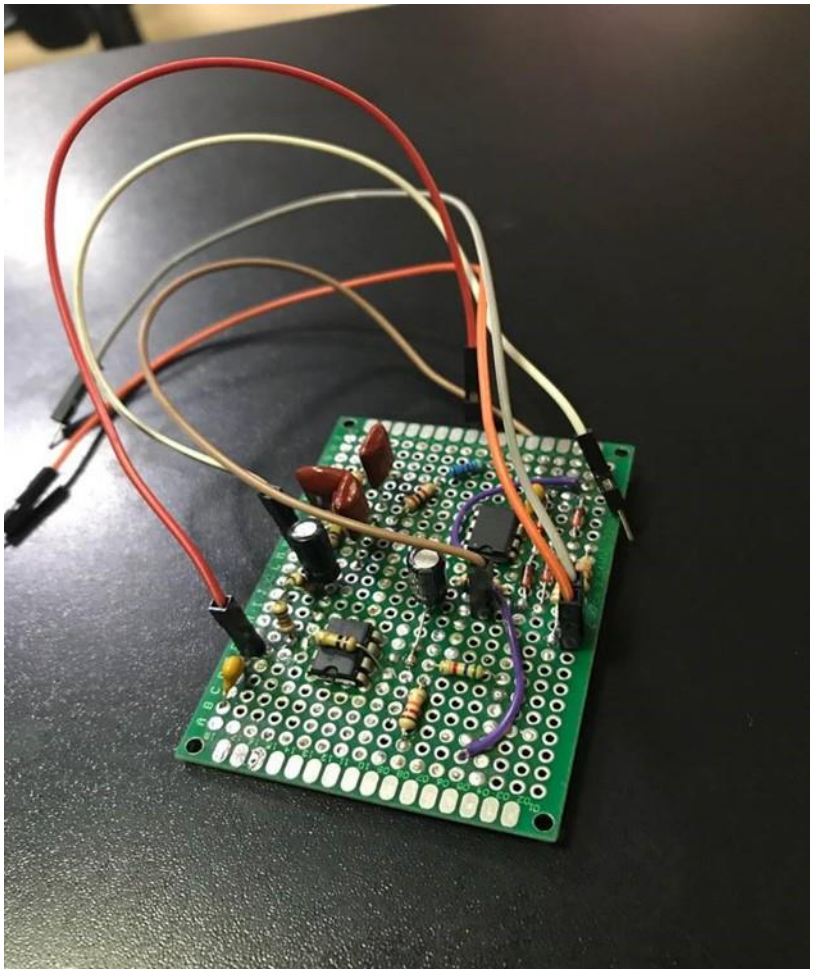

Figure 4.2: Hardware part (First Assembly)

4.2 Approach 2

The previous assembly did not work correctly so it was assembled again. This has the exactly same components as the one which was made before.

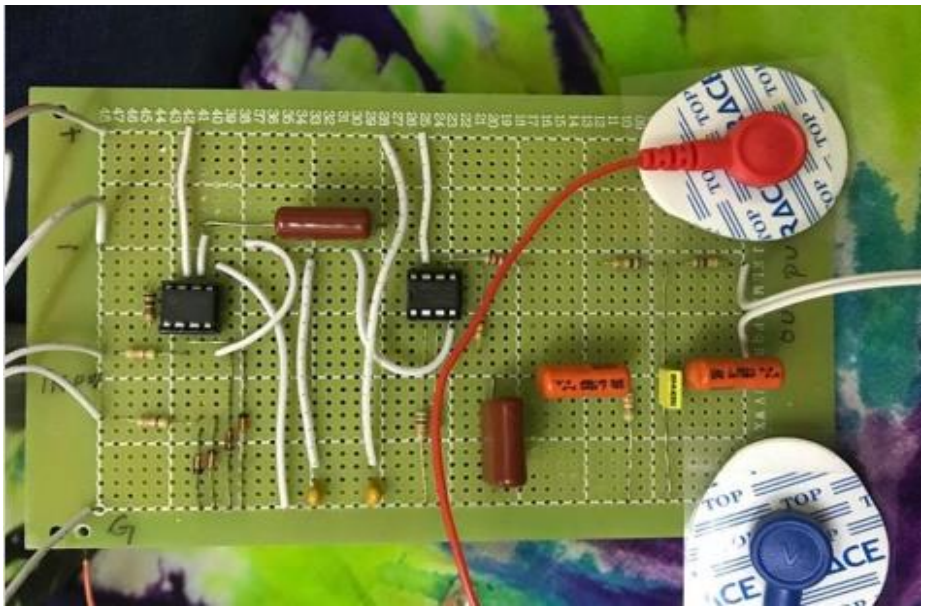

Figure 4.3: Second assembly

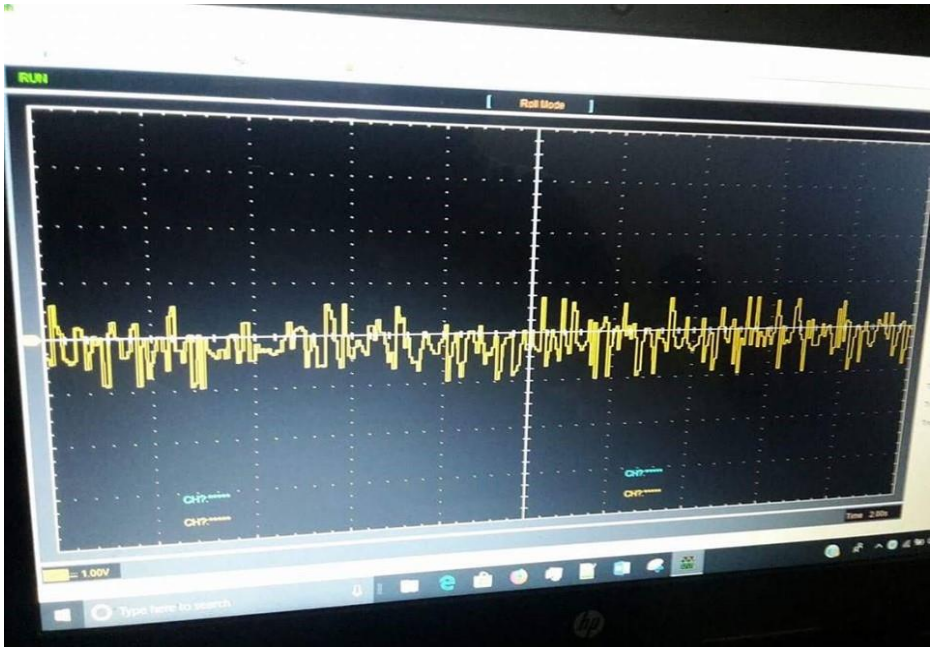

Figure 4.4: Output of second assembly

The **figure 3.4** was the output observed in a digital oscilloscope. The figure doesn't show expected curves. As an ECG signal must contain p, q, r, s, t waves, it was concluded that more modification was necessary for making the circuit workable.

4.3 Approach 3:

After all the failure it was decided to replace the notch with a variable resister and remove the protection diode.

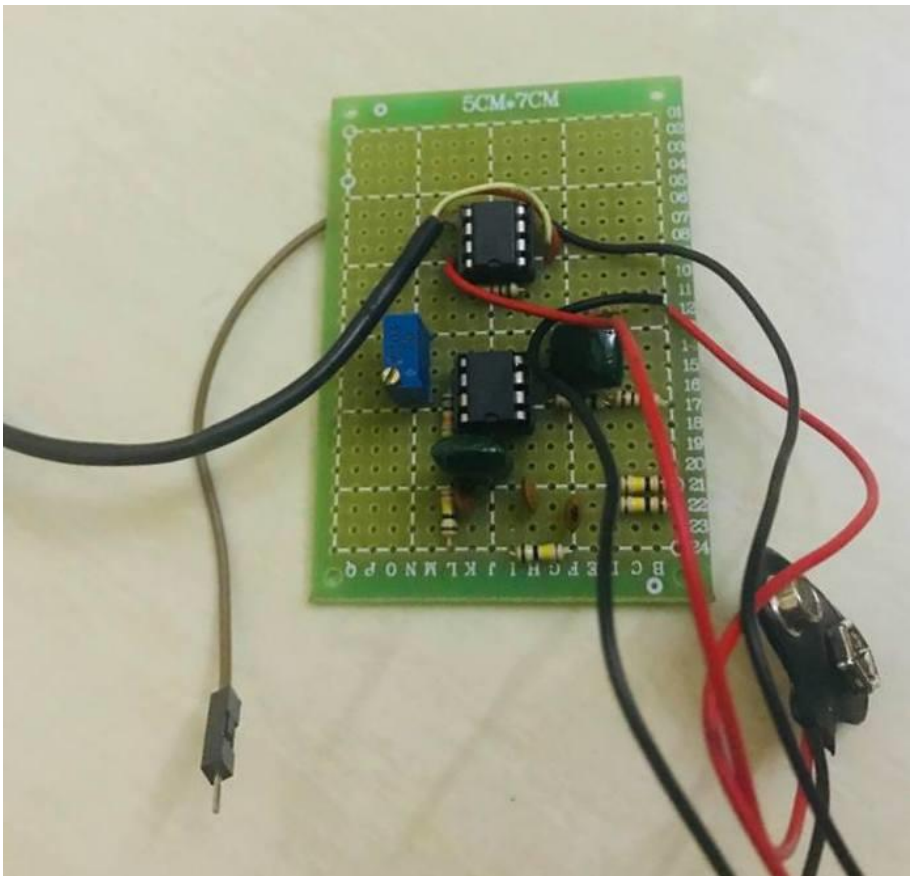

Figure 4.5: Third assembly

4.4 Summary

A lot of approaches were taken to carry out the project till the end. Different approaches did cost several instrument damage and that resulted to assemble the circuit again. Reassembly did not produce the expected result and because of that new decision was taken like modification in the circuit, addition or removal of parts from simulated circuit. This section showed how all these were done and shows the final circuit. It also contains several output.

CHAPTER 5
Results

5.1 Introduction

In this section the output of the final modified circuit will be displayed and explained. It will also explain how the result was obtained and how the result can be improved for future.

5.2 Result and Analysis

From the very beginning of the project we completed the circuit first then we tried to get the output using oscilloscope or from direct arduino direct input pin. A few efforts went in vain but finally the modified circuit provided the output.

Method: As like all other ECG machines our device also works following the ECG pad connecting method. Our system has a three electrode system and the explanation of a three electrode system has been done before in a brief manner. As per the theory the pads were connected to right and left side of the chest and down below to the end of the ribcage. And after that the output cable was connected directly to the oscilloscope. The figures below will show the screen shots of different stages which was recorded using a mobile phone.

This **figure 5.1** shows the direct output captured from the oscilloscope. The figure shows the presence of peaks. P, Q , R, S are visible but not well shaped though.

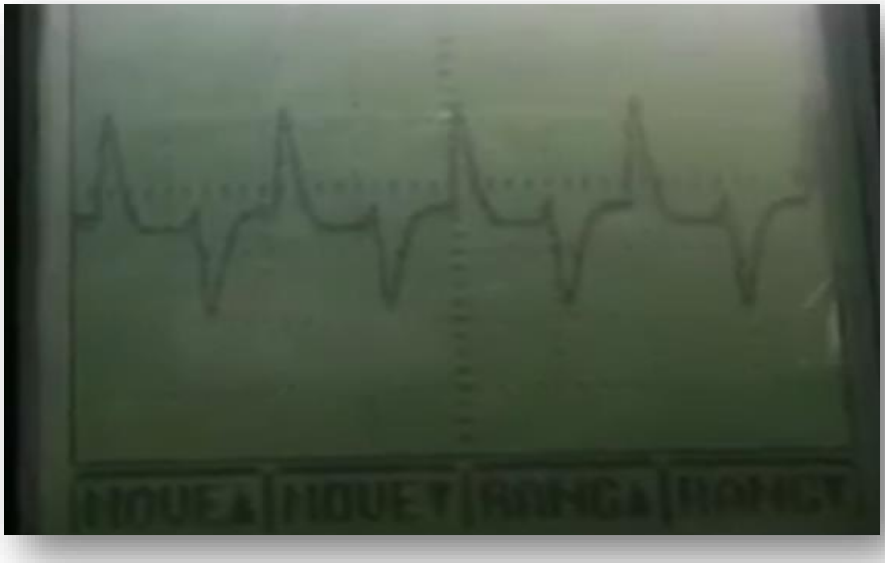

Figure 5.1: Direct output to oscilloscope

The figure below has all the mentioned peaks marked.

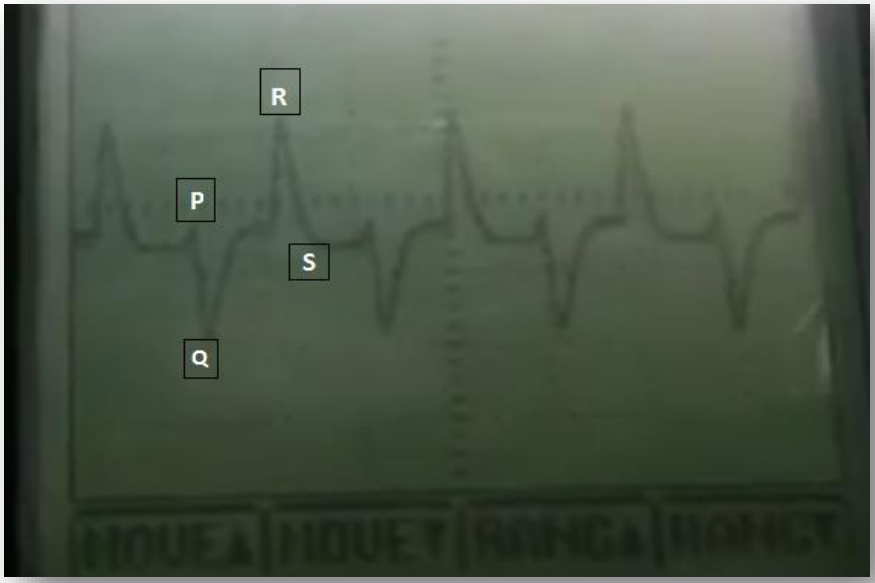

Figure 5.2: Marked Peaks

The figure below is the shows the condition of the oscilloscope when the output cable is connected to the oscilloscope. The top left corner of the display shows 0.05 v with 54.05 frequency value.

Figure 5.3: Output with data reading on the top

5.3 Impacts

The impact of the project on the people of the society, the patients and the conventional system will be discussed in this section. It will also discuss how it may make changes to the regular thinking of person, how it will benefit them and the fears they can get rid of if they get used to it. Though our project can be made a lot better by adding our proposed features but still it's useable. If the system can be modified a bit and spread to the people having heart issues then then a huge number of people will be benefited. They will never

have to be worried about what they always fear about. It will release their pressure of thinking about if he is okay. Not only the people but also the patients who frequently rushes to the hospitals won't have to there because of the system which will save their money and time. The patients who have issue about moving from one place to another will be very much relieved because they won't have to move.

5.4 Future Work

Our proposal included many other things which we could not finish such as recording the data, analyzing in real time, transmitting and saving to remote server etc. This features would make the project much more efficient.

CHAPTER 5
Cost of implementation

5.1 Introduction

This section will contain the costing of the instruments which was used for the project. At first we had a plan and budget for the total project but the budget had to be changed because of unsuccessful attempts and addition of instruments. Many components were faulty which resulted to buy new components.

5.2 Costing

Component Name	**Cost**
Resistors	60 tk
Diode 1N43704	20 tk
Capacitor	150 tk
Arduino Mega	1100 tk
Electrode Pads connector Cable	1000 tk
Electrode Pads	700 tk
Vero Board	100 tk
Batteries 9V	80 tk
Battery Connector	40 tk
Wires	30tk
Total	**3130 TK**

Chapter 6
Conclusion

It’s been a long way for us to carry out project to here but now it’s proven that a low cost portable ECG machine is possible to make which will be able as useful as like conventional ECG machines. Now we can successfully take data from the subject and we will be able to process that data for future if a few features are added.

At first we started with plan of making a ECG machine which will not only take input but also process the data but in the end we could just finish the data taking part. Our initial circuit could not produce the desired output so the circuit had to be modified. But now we have a successfully working machine which can make changes to people’s life.

The death rate because of heart issues are increasing drastically because of unawareness of people. Sudden death rate is also increasing because of lack of knowledge about heart failure .This device will be the solution for them. It was also mentioned earlier that not only the normal patients but also pregnant women, disabled people, rural people can stay at their place at get the benefit of a clinical ECG machine. This will change their fear of movement, reduce their money loss. The existing conventional concept can be changed by implementing our project. It would be our pleasure even if a single person is benefited from our project.

Bibliography

[1] Wireless ECG Monitoring System Project Report by Prof. Marom Bikson Prof. Luis Cardoso.

[2] Accurate ECG Signal Processing By Ajay Bharadwaj, Applications Engineer Sr, and Umanath Kamath.

[3] ELECTROCARDIOGRAM (ECG) MEASUREMENT CIRCUIT DESIGN MERT KEMAL TAN.

[4] Performance Comparison of Low-cost Hardware Platforms Targeting Physiological Computing Applications by Jos´e Guerreiroa,b, Andr´e Lourenc¸oa,b, Hugo Silver, Ana Fredb.

[5] DESIGNING OF PORTABLE AND LOW COST ECG SIGNAL ACQUISITION SYSTEM by Uma Shanker Yadav1*, Utkarsh Pancholi2, Aman Tugnawat3, Ranjana Patnaik4

[6] Implementation of a portable device for real-time ECG signal analysis by Taegyun Jeon, Byoungho Kim, Moongu Jeon1 and Byung-Geun Lee.

[7] DESIGN AND DEVELOPMENT OF A LOW COST PERSONAL COMPUTER BASED ECG MONITOR K Siddique-e Rabbani, A Raihan Abir, A K M Bodiuzzaman.

[8] A Low Cost Quadratic Level ECG Compression Algorithm and Its Hardware Optimization for Body Sensor Network System by Hyejung Kim, Yongsang Kim, Student Member, IEEE, and Hoi-Jun Yoo, Fellow, IEEE

[9] A Low-Cost Internet of Things (IOT) System for Multi-Patient ECG's Monitoring by M. Ryan Fajar Nurdin and Achmad Rizal.

[10] Implementation of a portable device for real-time ECG signal analysis (Taegyun Jeon1, Byoungho Kim3, Moongu Jeon1 and Byung-Geun Lee2*)

[11] The Research Of Portable ECG Monitoring System With USB Host Interface Xin Guo, Weijie Chen, Xiaoyun Xu, He Li.

[12] The Design of Portable ECG Health Monitoring System by aBo LIU1, Gang SHI2, Wei ZHAO3.