Heart Monitoring System

Project report submitted in partial fulfilment of the requirement for the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

By

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TABLE OF CONTENTS

DECLARATION

I hereby declare that the work reported in the B-Tech project entitled **"Health Monitoring System"** submitted at **Jaypee University of Information Technology, Waknaghat, India** is an authentic record of my work carried out under the supervision of **Dr. Emjee Puthooran**. I have not submitted this work elsewhere for any other degree or diploma.

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Heart Monitoring System "** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Electronics and Communication Engineering and submitted to the Department of Electronics and Communication Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Akshit Chandel (151095), Rishabh Kanwar(151098), Sandeep Sharma (151110)** during a period from July 2017 to May 2018 under the supervision of **Dr. Emjee Puthooran (Assistant Professor - Senior Grade)**, Department of Electronics and Communication Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: ………………

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ACKNOWLEDGMENT

We would like to express our gratitude to our supervisor Dr. Emjee Puthooran, Assistant Professor for his dedication and guidance through this journey. Without his active guidance, help, cooperation and encouragement, we would not have made headway in the project.

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The project was successful largely due to the guidance of many wonderful people who have given valuable advice to make the project a success.

On the very outset of this project, we would like to extend our sincere and heartfelt obligation towards all the personages who have helped us in this endeavour.

At last but not least gratitude goes to all our friends who directly or indirectly helped us to complete this project report.

LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYM	**MEANING**
ECG	Electro Cardio Graph
HR	Heart Rate
IRD	Infra-Red Devices
SL	Saline Level
Op-Amp	Operational Amplifier
RLD	Right Leg Driven
ADC	Analog to Digital
CVD	Cardiovascular Diseases
DC	Direct Current
GND	Ground
IC	Integrated Circuit
IDE	Integrated Development Environment
MCU	Micro-controller Unit
OS	Operating System
PCB	Printed Circuit Board
UART	Universal Asynchronous Receiver-Transmitter
USB	Universal Serial Bus
PPG	Photoplethysmogram
LA	Left Arm
RA	Right Arm
LL	Left Leg

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

We live in a generation where diseases have reached to very high surmounting levels. With our life being eased out by the technology, we have become more and more dependent and rely more on technology for the smallest of the tasks, which eventually has led to increase in a number of diseases and the most worrying of these are cardiovascular diseases. Lifestyle diseases such as cardiac ailments and blood pressure are becoming more prevalent in the society. Cardiovascular diseases are one of the leading causes of deaths in world. Heart rate, blood pressure, the body temperature and the ECG readings are by far the best parameters that could promote early detection of cardiac events. With the help the components used in this system, we can measure the heart rate and obtain the ECG (Electrocardiograph) of a subject.

The health care equipment plays a very vital role in the hospitals. Presently, the measuring of the body temperature and blood pressure, can be done using thermometer and sphygmomanometer respectively, and are by far easily available and quite efficient in their accuracy of measurement and results.

We have implemented this project to reduce the burden on healthcare professionals in terms of measuring and calculating some of the important parameters such as the heart rate and the ECG. It could also be used to monitor the aged and the sick at home especially in the absence of a family member or a guardian. This project is specifically designed to measure the ECG and the Heart Rate using appropriate biomedical sensors in synchronisation with the micro-controller unit. These parameters can be a great pointer to the status of the health of the heart of a patient or any person. Although, the ECG can only be interpreted better by a doctor or a professional.

The abnormality in the ECG wave can be a symptom and indicator of many cardiac ailments. Abnormality in heart rate is equally a pointer to many complications.

The function of this system is thus to measure the Heart Rate and the ECG of the Patient using appropriate sensors and modules, process it using the micro-controller and then transmit the data to the IDE interface which then displays the measures Heart rate and the ECG of the subject.

CHAPTER 1

INTRODUCTION

1.1 Motivation

In the present era, with the rise in technological and scientific advancements in all the spheres of life, all the daily chores and requirements have become quite easy to access. But technology is certainly a necessary evil. With the rise in such advancements the health of the people has been an ever growing cause of worry. Out of all these health conditions cardiovascular diseases are the most dangerous and are one of the leading cause of death in many countries. It accounts for more than 15 million deaths worldwide every year. Also in addition to that, several million people are disabled by the effects of cardiovascular diseases. Many research and scientific data is evident of the fact that the delay between the first symptom of any cardiac ailment and the call for medical assistance has a large variation among different patients and can result in fatal consequences if not treated in time.

Conclusion owing to these epidemiological i.e, medical and scientific research data states that if the resources are used wisely and in time for the early detection and treatment of these diseases, it has a very high and probably more potential of reducing the fatalities that are related to cardiac diseases.

Therefore, we need new strategies, equipments and research in order to reduce the time between the detection and treatment of a patient suffering from these diseases. Continuous monitoring of patients suffering from heart conditions is one such possible solution.

This project can be of great help to the patients who need continuous or time-to-time monitoring , or for those people who need to travel from place to place and have a heart condition.

Since the system continuously monitors the patient it can be a great indicator about the health of his heart and in case of any abnormality in the heart rate or the pulse rate and the ECG of the patient, the data can be immediately sent to the concerned doctors for further evaluation and to determine if the patient needs to undergo further evaluation or not, or if the patient needs to be admitted.

1.2 Objectives

In this project, we have designed a low-cost device which measures the heart rate i.e the beats per minute, and shows the Electro Cardio Graph (ECG) of the subject by using sensors on the shoulders and the pubis for the ECG and an optical sensor on the tip of the finger for the Heart Rate and then displaying the result on an IDE application interface. It is a portable heart rate monitor system based on a micro-controller embedded on the Arduino board. It offers the advantage of portability over the commonly used heart monitoring and ECG systems. The project explains how a single chip micro-controller can be used with the help of other biomedical sensors to measure and analyse the heart rate and the ECG signals in realtime. The Hardware and software design are oriented towards a single chip micro-controller based system, hence minimising the size.

1.3 Scope

This project includes the hardware and the software parts. The hardware part includes the ECG circuits that has been implemented in order to interpret data from the ECG module, the heart rate monitor to accurately measure the Heart Rate of the person, which it obtains and measures from the subject. Both of these modules use a non invasive method to measure these parameters. These systems are controlled by a micro-controller unit embedded in the Arduino board, which is connected to the system and is configured using IDE. In the software part, Arduino IDE, Processing IDE software is used.

1.4 Layout

This project report comprises of four main chapters :

- Chapter One: It provides an overview of this project as a whole, i.e it contains the background about the project, objectives, motivation, scope of the project and finally the Project layout.
- Chapter Two: Here, we have discussed about the introduction the human heart, how it generates the biopotential signals, which muscles act during this process. It also contains a brief introduction about the heart rate and what causes variation in that, the ECG as well as a brief literature review discussion about heart monitoring systems.
- Chapter Three: It specifies about the design methods that are used, system operations, and a description on the components used.
- Chapter Four: Presents the system implementation, methodology, interface between different components of the system and the codes used in the implementation of the system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The health of a patient's heart is a great indicator of the health of the entire body. The Heart Rate, the ECG and the body temperature can tell a lot about the current condition of the heart. Any deviation in these three measurements can indicate a possible change in the health of the heart. In the further section of this chapter we have individually described how each of these parameters can be of great help in detecting any abnormality in the heart. A large number of medical ailments can be detected from the variations measured in one or more of these parameters. Most of the specialised devices used for the measurement of these vital parameters are not portable and can be found only in the hospitals. Therefore, in this project, the concept of using a portable Heart rate sensor and the ECG obtained can be used as a diagnosing tool. [1]

2.2 Heart

The heart is one of the most important organs within the human body, which is responsible for the circulation and pumping of blood throughout the body. It is located in the middle of the thorax, slightly tilted to the left and surrounded by the lungs.

The anatomy of the heart is such that it is made up of two separate pumps: a right heart, in which the unoxygenated blood enters via the vena cava, then it enters the right atrium passing through a valve and then to the right ventricle and then to the lungs where it gets cleaned and oxygenated. This oxygenated blood then enters from the left atrium through the aorta and then enters the lest ventricle that pumps the blood throughout the body.

The human heart also is made up of three major types of cardiac muscle: ventricular muscle, atrial muscle, and specialised conductive and excitatory muscle fibres. The ventricular and atrial types of muscles differs from the specialised excitatory muscles in the method of contraction. The latter muscles exhibit either automatic rhythmical electrical discharge or conduction of the action potentials through the heart, providing an excitatory system that controls the rhythmical beating of the heart. This excitatory system generates a bio-potential which is used to plot the ECG.

An electrical impulse is also generated in the upper chambers of the heart i.e the atria.

Sino-atrial (SA) node, that is located in the right atrium acts as an automatic pacemaker. It acts independently of the brain to generate electricity for the heart to beat. It is a specialised group of cardiac muscles that do not contract.

Atrio-ventricular (AV) node, located between the auricles and the ventricles, also automatically generates impulses. These impulses are passed on to the Purkinje fibers that are a part of the specialised excitatory muscles, which in turn passes these impulses to the entire heart. These impulses are generated because of the ions rushing in and out.

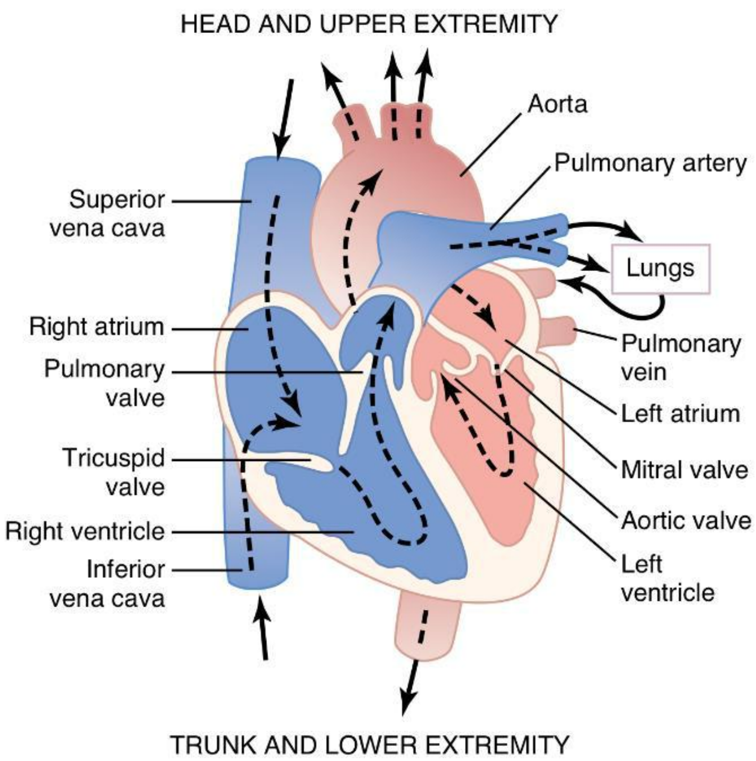

Figure 1. The Human Heart

2.2.1 Heart Rate

It is the rate at which the heart beats, also known as beats per minute and is affected by the expansion of the arterial wall with every beat. Majorly, it is because of the contraction and the relaxation of the ventricles i.e, systole and diastole respectively. Heart rate can be defined as the number of contractions per minute. The most prominent areas to measure the pulses generated by the heart are wrist (Radial artery), neck (Carotid-artery), inside of the elbow (Brachial artery), behind the knee (Popliteal artery) and ankle joint (Posterior artery).

The heart rate of an individual changes according to the age, the physical surroundings and its impacts on the body and also the psychological impacts on the body such as excitement, anger, anxiety, emotions, and heart disorders which are generally indicated by higher pulse rates than usual, which indicate the presence of abnormality in the body. The heart rate of a subject can be of great help in determining the various problems within the body, but it solely cannot be used to diagnose an abnormality. [2], [3]

The average heart rate of an adolescent male is about 72 bpm and for female it is 80 bpm.

Table 1. Variation in Heart Rate with Age

AGE	HEART RATE (BPM)
1-3 years	80-130
3-5 years	80-120
6-10 years	70-110
11-14 years	60-105
14+ years	60-100

2.2.2 Effect of Temperature on Heart Rate

Body temperature of a person can also cause great variations in the heart rate in a proportional kind of relationship. A rise in body temperature can cause the HR to rise and a fall in body temperature can cause the HR to fall as low as a few beats per minute. When a person is near to death, then the body temperature is in a range of 60° to 70°F. These effects assure the fact that a sudden rise or fall in the body temperature when calibrated and compared to the heart rate can be of great help and can help to deduce the situation of the heart. A normal thermometer gives almost accurate body temperature i.e, why we are not using any additional sensors to calculate the body temperature.

2.3 Electrocardiograph

Electrocardiograph or ECG is a test that records the electrical activity of the heart. It can also be used to test for irregularities and how the heart functions. The three limb electrodes, which use a non invasive method detect the electrical activity of the heart.

The important parts of an ECG wave are P wave, generated because of the depolarisation of the auricles, QRS complex, generated due to the depolarisation of the ventricles, T wave, due to the depolarisation of the ventricles and a U wave though not always noticeable, is because of the depolarisation of Purkinje Fibers. The analysis of these waves by a doctor can be of great help in determining the present condition of the heart. The waves generated by the depolarisation and the depolarisation of the ventricles is much more spiked and larger than those because of the atria and which owes to the fact that the atria is comparatively smaller than the ventricles.

The rhythms that originate in the SA node commonly known as Sinus rhythms can tell about the regular or irregular activity of the heart. The most general observations to detect irregular heart function are:

1. RR Interval

Measures the interval between two consecutive RR waves. If the interval is less than 0.6 seconds then it is regular otherwise irregular.

2. PR Interval

It is the time interval from the onset of the atrial contractions to the onset of ventricular contractions. For a healthy heart it lies in the range of 0.12 to 0.20 seconds.

3. QRS Complex

For a healthy heart, it lies in the range of 0.06 to 0.12 seconds.

Another important parameter to look for in an ECG is Heart Rate Variability (HRV), which is the variation in the time interval between heart beats also known as RR variability. This parameter is used objectively to monitor psychological stress. [4]

A normal electrocardiogram is shown in Figure 2.

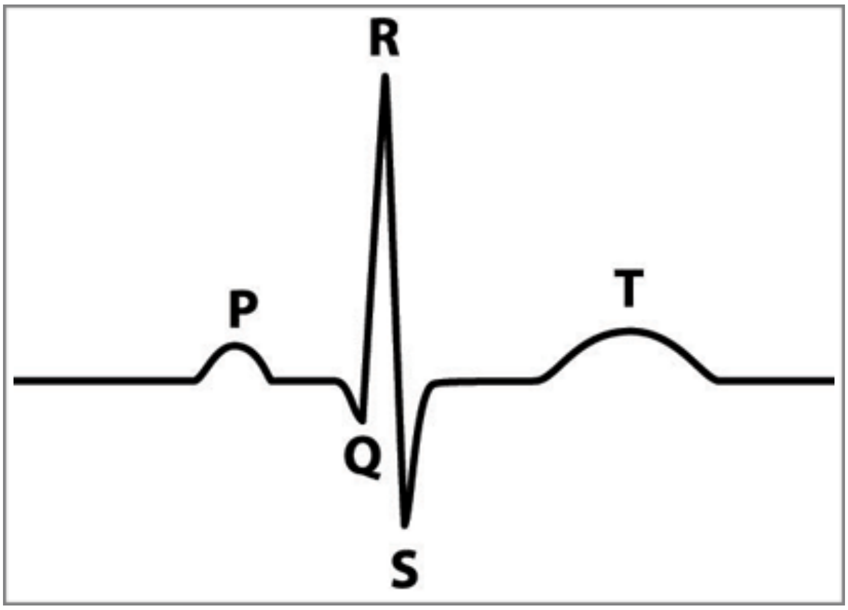

Figure 2. Parts of an ECG wave

2.4 Einthoven's Triangle

It was given by Willem Einthoven. It is a combination of three leads particularly known as the limb leads which are used in the process of electrocardiography which is used to check for any abnormality in the activity of the heart. The formation of these three limb leads is in such a way that two of the leads go on the shoulders and one in the pubis region. The formation of these leads is in the form of an inverted equilateral triangle that has the heart in the middle of it and it produces a zero potential when the voltages are summed up at the middle. [7], [8]

The formation of these three leads is by following the measuring and calculation of these voltage vectors.

LEAD 1:

I = LA - RA

LEAD 2:

II = LL(GND) - RA

LEAD 3:

III = LL(GND) - LA

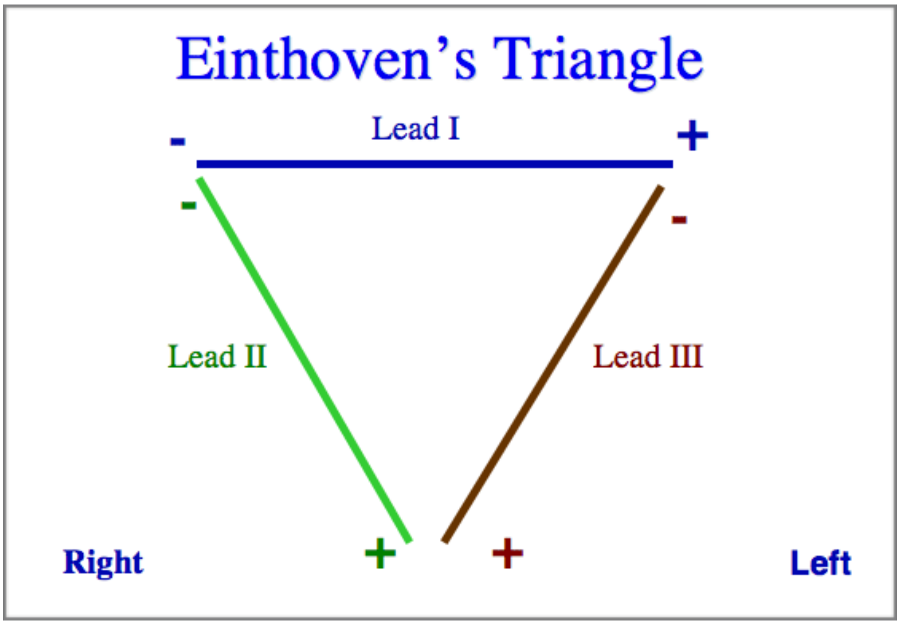

Figure 3. Einthoven's Triangle

The electrodes can be placed distally or proximally on the limb without affecting the recording, but to be assured that the wave obtained is most accurate then they should be placed proximally i.e, close to the heart. The function of the third electrode i.e, the ground or also known as the right-leg electrode is to reduce the interference caused due to common-mode signals of the other two limb leads and it can be placed anywhere in the pubis region i.e either on the left leg side or the right leg side without any effect on the ECG results, but to go with the nomenclature we have chosen the right leg side of the pubis region.

Each lead is used to measure the electric field created by the heart during the repolarisation and depolarisation of the auricles and the ventricles. This electric field can be represented in the form of a vector that changes continuously and is measured by recording the voltage difference between electrodes by the ECG module. [9]

2.5 Related Works

This section outlines what has been so far done or researched by others on this project.

Much has been done in this field. Among the researches and proposals, notable researches in this area include the following.

Lauren Akoth shows the simulation and processing of ECG data using Matlab. This research primary works on the simulation of heart rate of the subject. [10]

Purnima Puneet Singh has used Zigbee and GSM protocols to transmit the data obtained from a patient. GSM module is used for the purpose of mobile connection and zigbee is used to create a Personal Area Network (PAN) using their computer system. [11]

Bandana Mallick and Ajit Kumar have used a typical pulse sensor to measure and process the heart rate of a patient using Arduino as a micro-controller. [12]

Shrenik Suresh Sarade et. al proposed a project that enables the user to check his heart rate as well as body temperature and displays information on an LCD display. The heart rate of the user is measured using Infra-Red Device (IRD) sensors. [13]

CHAPTER 3

THEORETICAL BACKGROUND

3.1 Pulse Sensor

Pulse Sensor is a module used in this project that connects to the Arduino and uses a simple algorithm to work. It can be used to generate the beats per minute that is the heart rate of the subject and it can also be used to generate pulse because of the activity of the heart which can be further counted for a minute and the number of pulse generated in a minute can be termed as the beats per minute . This sensor can be clipped onto a fingertip or an earlobe and is plugged into the Arduino with the help of some jumper cables. This pulse sensor also has an open-source monitoring app that graphs your pulse rate in real time and measuring that gives your heart rate.

The front side of the sensor is the one with the heart logo. This side makes the contact with the skin. On the front end there is a small round hole, the light emitting detector is placed in this hole, and it acts like a photo diode. The LED shines through from the back of the module. There is also a little square just under the LED which is an ambient light sensor which adjusts the brightness of light of the photodiode or the LED according to the surrounding light conditions and the amount of light that is being absorbed by the capillary tissues. The light illuminated by the LED can be either reflected (if used on a finger tissue) or it could be transmitted (if used on the earlobe). It acts as an optoelectronic device. The back of the sensor is where the rest of the parts are mounted. The LED used in the sensor is a reverse mount LED. Furthermore, heart rate can be measured based on the optical power variation of light that gets scattered or absorbed during its path through the blood as there is variation in the heart beat. This sensor is basically based on the principle of photoplethysmoghraphy which again uses two principle that are transmittance i.e, light is transmitted through the vascular regions of the body such as the earlobe and received by a detector and reflection i.e, light from LED is reflected by the regions such as the capillary tissues in the fingers. [5]

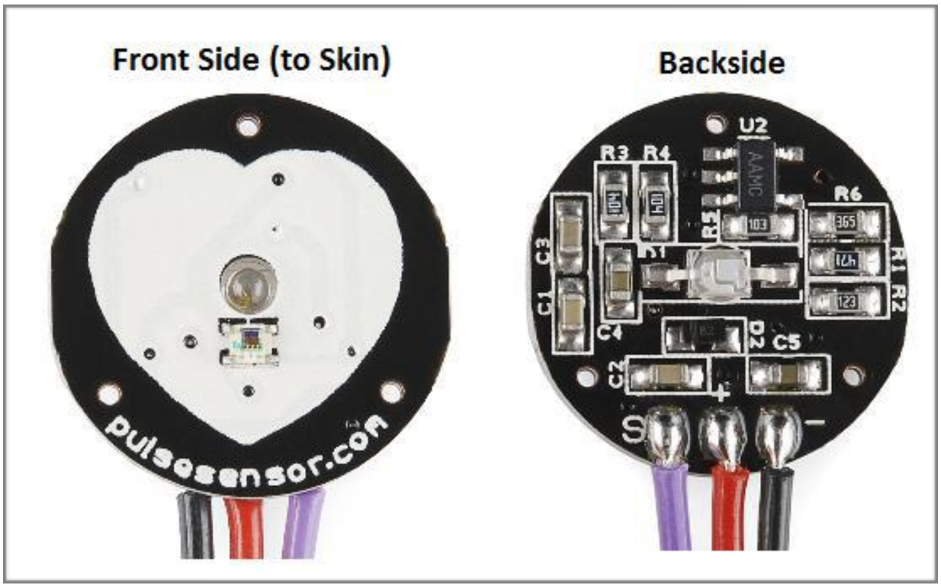

Figure 4. Front and Backside of a Typical Pulse Sensor

3.2 ECG Module

Electrocardiograph is one of the most important machines in the hospitals today. It keeps doctors and nurses updated on important status of patients. ECG measures and transmits biopotential signals generated by the electric activity of the heart . These signals are obtained by placing the electrodes on different specified parts of the human body.

An ECG module is used to replace the ECG machine. This module comes with three electrodes that measure the signal, pass it through the microcontroller unit and finally present the calculated ECG wave.

The **AD8232** is an integrated signal conditioning block for ECG and other biopotential measurement applications. This module is designed keeping in mind the biopotential signals, so it is capable to extract the minute signals, then amplifies them and then with the help of integrated filters removes any noise that might be present. The noise can be generated because of motion of the patient or subject to whom the electrodes have been attached or because of wrong electrode placement. The thing to be noted here is that the filters in this module can filter out any noise added because of rhythmical activity of the heart but the distortions caused by wrong electrode placement or because of the movement of the individual can cause drastic distortions in the ECG produced and therefore, can produce a wrong result. The design of this module is such that it allows the conversion of analog to digital signals quite easily and there is no need for separate calculation using the micro-controller unit. [6]

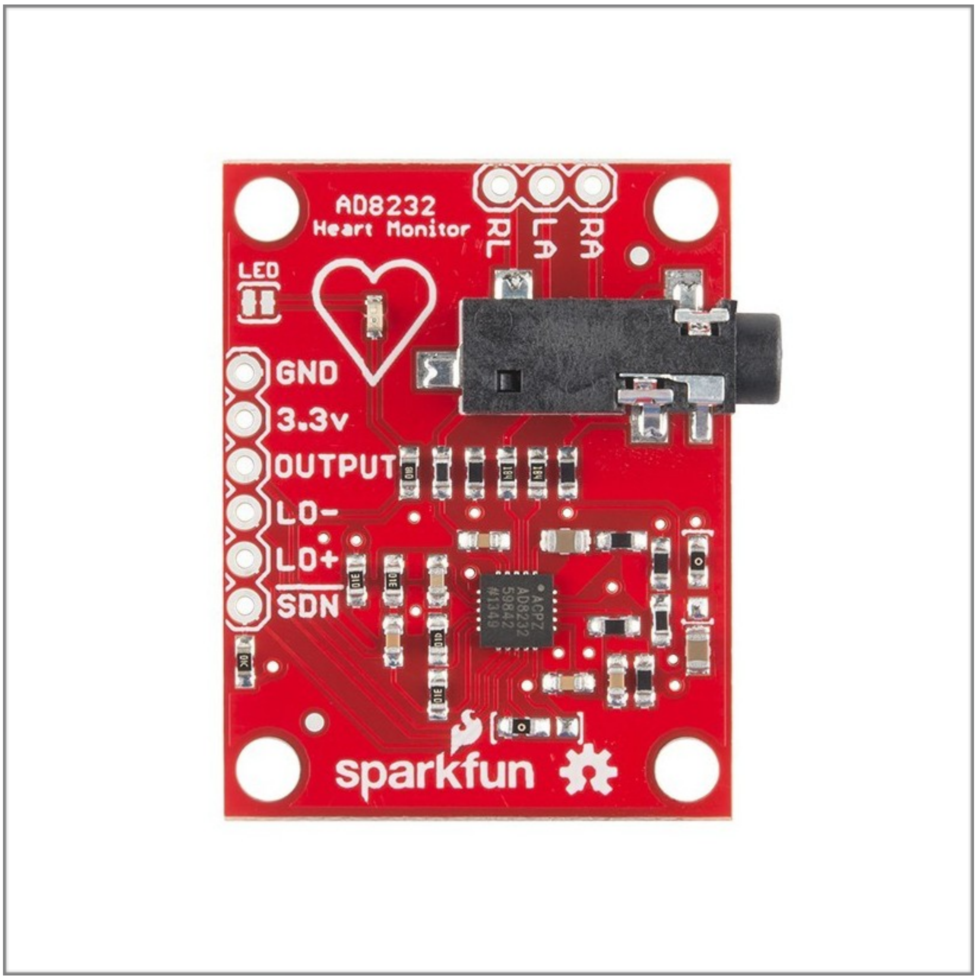

Figure 5. AD8232(ECG Module)

Architecture overview:

1.Instrumentation Amplifier (IA)

This amplifier is similar to an Op-Amp but it can also be used as a negative feedback amplifier. In this design it consists of two transconductance amplifiers. It is a kind of a differential amplifier. It is designed in such a way that it can apply gain as well as filter to the DC signal obtained from the electrodes simultaneously. It allows to amplify the very small ECG signal by a factor of hundred and yet reject the electrode noise.

2.Operational Amplifier (Op-Amp)

It is used here for low pass filtering of the signal and to add additional gain to it.

Right-Leg Drive (RLD) Amplifier:

It has the basic architecture of an Op-Amp but with a resistor at output to limit the current. It inverts the common-mode signal that is present at IA inputs. When RLD output current is injected into the subject, it contacts common-mode voltage variations, thus improving the common-mode rejection of the system.

3.Reference Buffer

It creates a virtual ground between the supply and the system ground.

4.Leads Off Detection (LOD)

It features detection modes optimised for 3- electrode configuration. It works by checking each input from the electrodes individually, so it is easily possible to indicate which of the electrode is disconnected.

5. Driven Electrode

The electrode that is connected to pubis (ground) is also know as the driven electrode and is used to minimise the effects of common-mode voltages that are induced because of the supply and other interferences.

The AD8232 extracts the common-mode voltage from the IA inputs and then passes it through the RLD amplifier to introduce an opposing signal into the patient. It helps in maintaining a constant voltage between the patient and the module, hence improving the Common-Mode Rejection Ratio (CMRR). [16]

3.3 Arduino Uno

In this project, we have chosen the Arduino Uno board because of its minimalistic design, easy configuration with all the operating systems whether it is Linux or Unix based. The micro-controller used in Arduino Uno is Atmega328p. It has 14 digital input/ output pins, of which 6 can be used as PWM(Pulse Width Modulation outputs that is used to convert the digital signal into an analog signal by varying the width of the pulse, 6 analog input pins which are used to take analog input from the sensors that are being used, a 16 MHz quartz crystal for oscillations and clock purposes, a USB connection to power the Arduino and to transmit the data to Arduino IDE, a power jack to ensure voltage supply to the board and all the components that are being used, an ICSP(In-Circuit Serial Programming) header which is a protocol used to programme the microcontroller and this pin is used for programming the Arduino Board or connecting the board to a computer for uploading a sketch and a reset button to erase all the temporary memory of the microcontroller. The connections made with the computer system are rather simple, we simply have to connect the board to the USB port of the system which powers it and acts as a reliable power supply.

It provides remote or mobile feature for this entire project, since the microcontroller is the core of this project and because of its small size. [14]

Advantages of Arduino Uno:

I. It is inexpensive as compared to other micro-controllers.

II. The Arduino is capable of working on cross-platform and the Arduino IDE runs on Windows, Macintosh OSX, and Linux operating systems. Most micro-controller systems available are compatible only with Windows.

III. The Arduino Software (IDE) is very simple to use and most of the algorithms are open source and easy to follow and modify whenever necessary. Also, the flexibility provided by the Arduino is unmatched.

IV. The micro-micro-controller unit i.e ATmega328p comes with a preprogrammed boot -loader that enables to upload a new code without the need of any external hardware.

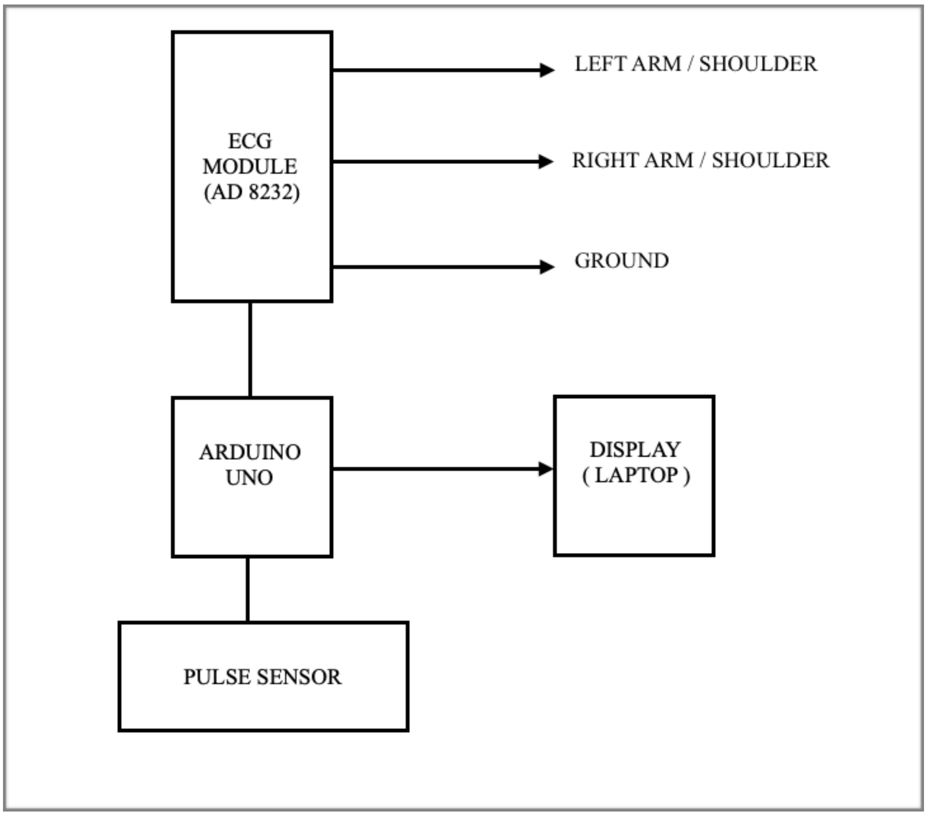

Figure 6 . Implementation Diagram

CHAPTER 4

METHODOLOGY

4.1 Introduction

This chapter describes the method used to implement this project. It is divided into two main parts, which are hardware design and software design. For hardware design, the main micro-controller hardware has been focused on the Arduino Uno board, which connects to the pulse sensor and the ECG module. Meanwhile, Arduino IDE and Processing IDE are used for software design.

4.2 Hardware Design

4.2.1 Arduino Uno Board

Arduino Uno Board is the main processing system in this project because it reads and interprets data from ECG module and pulse sensor output. Arduino software is downloaded directly from the Arduino main page via internet to create a specific program. Arduino requires a USB cable to power the board in 5V, or in this case we are using the laptop itself to give power to the board. Additional power can cause irreparable damage to the Arduino board.

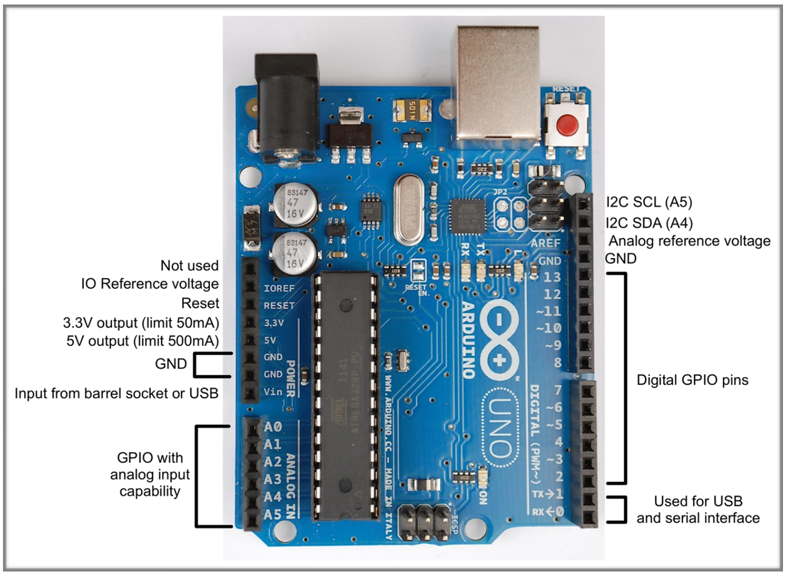

Figure 7. Arduino Uno

4.2.2 Pulse Sensor Circuit

Pulse sensor circuit is to measure the pulse or the heart rate of the patient. The normal heart rate for humans is 72 beats per minute. The pulse sensor embodies three pins into its architecture which are connected directly to the Arduino Uno board. These pins are 5V, GND and analog output pin. The heart rate of the subject can also be measured using the ECG that is obtained using the ECG Module by counting the number of QRS complexes in a 6 second interval and then multiplying it by a factor of 10. But it can be a tiresome task for the subject and there is also the factor of human error, that is why we have incorporated a pulse sensor to generate accurate results. The Pulse Sensor is an integrated circuit sensor.

This pulse sensor is an open source heart rate monitoring system that gives the beats per minute (bpm). It is used to obtain the PPG (Photoplethysmogram) which is used to detect the blood volume changes in the tissues. It comprises of a pulse oximeter that uses an LED which illuminates the skin and measures the changes in the absorption of the light to monitor the non-invasive heart rate. It measures the real-time beats per minute that is the heart rate of the subject with the help of Arduino enabled algorithms.

This sensor has two sides, the front side which has a heart shape is the side that is to be attached to the skin. The pins of the pulse sensors are three as shown in Figure 8. below.

On the front side, the left most pin is the Ground pin (GND) while the middle one is the input voltage pin which can be connected to the +5v of the Arduino. The right most pin is used as as an output pin that generates the measured signal and transfers it to Arduino and is connected to any of the analog inputs on the Arduino Board.

The Pulse sensor converts the physically obtained PPG into electrical signals. The sensor outputs a raw signal of analog voltage fluctuations, amplifies it and normalises the wave.

Every time when the heart beats, a pulse wave is generated that travels through all the arteries and to the tissues where the Pulse Sensor is attached.

For accurate readings, the sensor’s package is required to be in contact directly with the patient’s arm tissues or with the index finger of the patient.

Some important features of the pulse sensor, that is used are:

1. It is suitable to work in a wide temperature range (-55 to +150 C).
2. It ensures a guaranteed accuracy at +25 C.
3. It is suitable for remote and mobile applications.
4. It operates in the voltage range of 4 to 30 V.
5. It has a very low self heating.

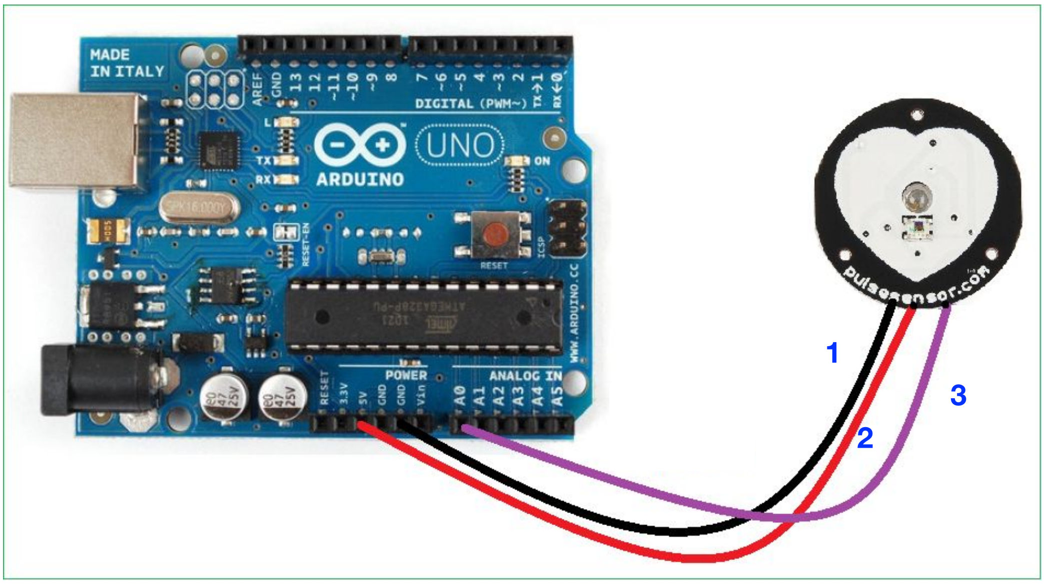

Figure 8. Interface between Arduino Uno and Pulse Sensor

Table 2. Arduino Uno and Pulse Sensor Pin Connection

Wire	Pin Function
1	GND
2	5V
3	Output Signal

4.2.3 ECG Module Interface

This reads the biopotential signals of the heart when the respective electrodes are connected on the left shoulder, right shoulder and the pubis (that is ground) that are included in the module, as given in the Einthoven's Triangle and read the heart pulse signals which are then processed by the processor and displayed on the computer display window after being passed through the microcontroller.

We have selected AD8232 for this purpose.

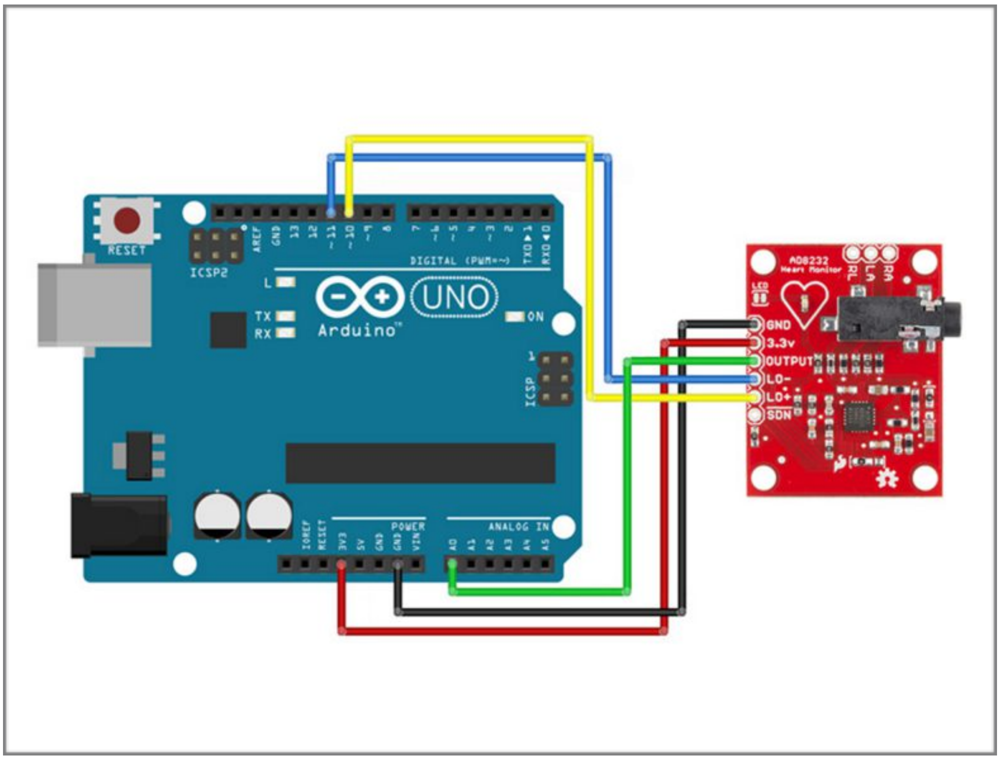

Figure 9. Interface between Arduino Uno and AD8232

Table 3. Arduino Uno and AD8232 Pin Connection

Board Label	Pin Function	Arduino Connection
3.3V	3.3 V Power supply	3.3 V
GND	Ground	GND
OUTPUT	Output Signal	A0
LO+	Leads-off Detect(+)	10
LO-	Leads-off Detect(-)	11
SDN	Shutdown	Not Used

4.2.4 Micro-controller Unit (MCU)

The arduino uno board which has the micro-controller named ATmega328p embedded on it provides for the filtration of the measured biopotential signals through the analog input, applying calculations on it and preparing these signals to be transmitted to the next unit i.e, the Arduino IDE for analysis.

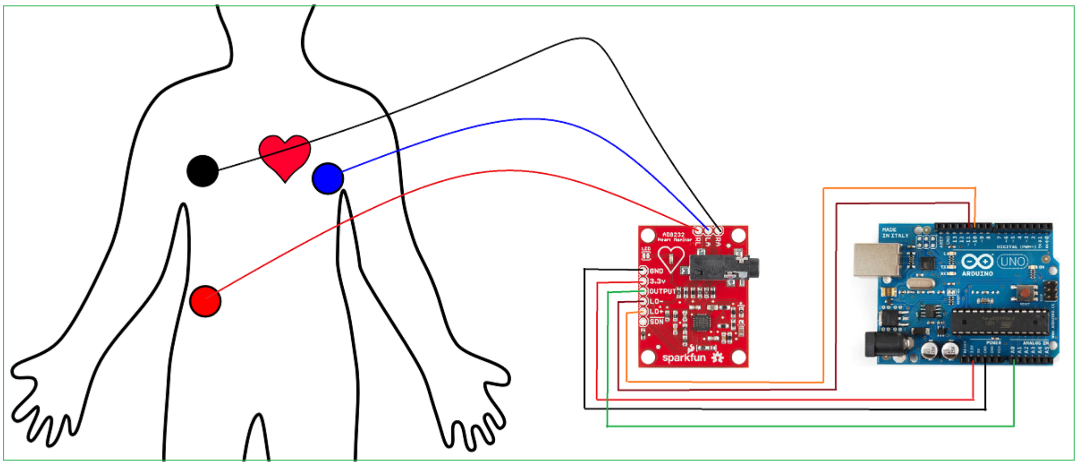

Figure 10. AD8232 Interface with Arduino and electrode placement

4.2.5 Power Supply

In this system we have used the USB port of the laptop or PC as the power supply for the Arduino Uno board, which in turn powers the ECG module as well as the Pulse Sensor. For safety and short circuit protection, a voltage regulator LM7805 is used. Rest of the components that is the Arduino board derives the power from the computer with which it is attached via an USB cable. The ECG module derives its power from the 3.3 V port of the Arduino Board and no separate power supply is required. The pulse sensor also derives its power from the 3.3V or 5V port from the Arduino board and no separate power supply is required. The only precaution that needs to be taken is to not to connect the Arduino board with the system while it is being connected to the power supply as it increases the power line interference drastically and may also burn the components and can also harm the subject.

4.2.6 Software Design

Primarily we have used two software tools for the development of algorithms in this project in order to program the Arduino which acts as the central processing system of this project. The algorithms for the Pulse Sensor as well as the ECG module have been taken from the open source websites and developed accordingly to the need of the project.

Arduino IDE :

It is the necessary software environment that enables to program the Arduino by writing a code, compiling it and then uploading it to the Arduino itself. It is also used to display the resulting ECG of the subject using Serial Monitor and Serial Plotter. The serial monitor tool is used to measure the beats per minute that is the heart rate and the serial plotter is used to display the obtained ECG of the subject. The version that is used in this project is 1.8.8 and supports both Serial Monitor for the hear rate values and Serial Plotter for the ECG wave.
The Arduino IDE is used to implement the codes of two major functions onto the Arduino board. These functions are : Measuring Heart Rate and plotting the ECG of the subject.

Processing IDE :

The Processing software is a java-based Development Environment (PDE) that makes it easy to write Processing programs for graphical programming that is not available in the Arduino IDE. It is an open source graphical library made for projects with visual context. The program is written in the provided Text Editor tool and compiled by pressing the Run button. A computer program in the processing programming is called a *sketch*. Sketches are stored in a folder named *Sketchbook,* and can be later modified.

Sketches can be used to draw a two or three dimensional graphics. The default mode available is for drawing two-dimensional graphics and the ECG wave is also plotted in two-dimensions only.

Observations:

I. Using a practical ECG in a hospital

Here, we have used the picture of an ECG taken by a student at a hospital using the twelve lead placements. These 12 leads are standard limb leads (I, II, III), the augmented limb leads (aVR, aVF and aVL) and the six precordial leads (V1,V2,V3,V4,V5,V6). But we have displayed the picture of only the standard limb leads (I, II, III) since our measured ECG is the average of these three recordings and also the recordings of other limb leads are used to narrow down any anomalies to one specific area, since each lead represents a known space on the muscle of the heart.

Figure 11. ECG observed at a hospital

From this ECG, it was interpreted that:

HR=80 bpm

RR=744 ms

QRS=116 ms

Which implies that all of these measurements lie in the standard region and that there are no irregularities noted.

II. Using our ECG module

Figure 12. ECG observed using AD8232

From this ECG, it was interpreted that:

HR= 77 bpm

RR= 0.78 seconds

QRS= 0.09 seconds

There was a very minor deviation from the twelve lead ECG. But all the measurements recorded lie in the standard region and that there are no irregularities noted in the ECG.

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