



**Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE)**

**DESIGN AND DEVELOPMENT OF A HEALTH MONITORING  
SYSTEM TO LINK CHRONIC DISEASE PATIENTS WITH  
DOCTORS AT HOME: CASE OF HYPERTENSION.**

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A Dissertation Submitted to the Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE), University of Rwanda as partial fulfilment of the requirements for the Master's Degree in Biomedical Engineering.

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## **DECLARATION**

I, NYIRABIKARI Drocelle, declare that this dissertation entitled Design and Development of a Health Monitoring System to Link Chronic Disease Patients with Doctors at home: The case study of hypertension is my original work based on research and prototype and has not been submitted for any other degree or professional qualification.

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Date: 09/08/2024

## **CERTIFICATE**

This is to certify that the project entitled Design and Development of a Health Monitoring System to Link Chronic Disease Patients with Doctors at home: Case study of hypertension is original work done by **NYIRABIKARI Drocelle** (Reference number: **222001242**), a MSc. Degree student in Biomedical Engineering.

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## **ABSTRACT**

Heart health is one of the parameters of one's health condition. Besides using the ECG machine, heart conditions can be determined through blood pressure, and heart beat rate measurements. In order to so provide efficient medical services at appropriate time, patient's health status should continuously be monitored and this requires that the blood pressure and heart beat rate measurements are continuously recorded and checked. Based on last decade statistics of medical records, death rates due to hypertensive heart disease shows that the blood pressure is a crucial risk factor for atherosclerosis and heart diseases, thus, preventive measures should be taken against high blood pressure which provide the ability to track, trace and save patient's life at the right time. For this, we designed and developed a health monitoring system that can be used to take health status measurements and send the data to the doctor in real time, the data can be analyzed and immediate action or measure to save patient's life can be taken with less cost and without a delay. We focused on monitoring the patient's blood pressure, heart beat rate, location and his/her body temperature and where the data are recorded using this system automatically transmit the measurements via Short Message Service (SMS) to the doctor or the medical expert. The objective of this work is providing an effective application for Real Time Health Monitoring and Tracking. The system will track, trace, monitor patients and facilitate taking care of their health so efficient medical services could be provided at appropriate time. By using prototyping method and specific sensors, data have been captured and compared with a configurable threshold defined by a specialized doctor who follows the patient via microcontroller. We used heart beat sensor to collect data and microcontroller to condition and process data, we also used key for user input, LCD to display data to the user and GSM module to send data to doctor. In any case of emergency, a short message service (SMS) will be sent to the Doctor's mobile number along with the measured values through GSM module. Furthermore, the GPS provides the position information of the monitored person who is under surveillance all the time. If we consider the terms of cost, settings and time, this system will be the most effective due it low cost compared to existing, more patient can afford this system and the ability to capture and transmit real-time health status make it superior to existing systems and device data are reliable than any other system currently available at local market.

**Keywords: Health monitoring systems, hypertension, chronic disease, Blood pressure.**

## LIST OF ACRONYMS

<b>AI:</b>	Artificial Intelligence
<b>BP:</b>	Blood pressure
<b>CAD:</b>	Computer-aided design
<b>CAE:</b>	Computer-aided engineering
<b>CDMS:</b>	Chronic Disease Monitoring System
<b>CEBE:</b>	Center of Excellence in Biomedical Engineering and E-Health
<b>DC:</b>	Direct current
<b>ECG:</b>	Electrocardiogram
<b>GPS:</b>	Global Positioning System
<b>GSM:</b>	Global system for mobile communication
<b>HMS:</b>	Health Monitoring System
<b>I2C:</b>	Inter-Integrated Circuit
<b>ICSP:</b>	In-Circuit Serial Programming
<b>IDE:</b>	Integrated development environment
<b>IoT:</b>	Internet of Things
<b>LCD:</b>	liquid-crystal display
<b>LED:</b>	light-emitting diode
<b>MAP:</b>	Mean Artery Pressure
<b>mm Hg:</b>	millimeters of mercury
<b>PIC:</b>	Peripheral Interface Controller
<b>PTT:</b>	Pulse Transit Time technique
<b>PWM:</b>	Pulse-width modulation
<b>RPM:</b>	Remote Patient Monitoring
<b>SMS:</b>	Short Message Service
<b>SPST:</b>	single-pole, single-throw
<b>UI:</b>	User Interface
<b>USB:</b>	Universal Serial Bus

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# CHAPTER 1. GENERAL INTRODUCTION

## 1.1 Introduction

The heart, a crucial organ in the human body, requires much attention to keep it healthy. Unfortunately, the heart disease has emerged as a leading global cause of mortality, with many individuals unaware of the critical importance of cardiac well-being[1]. Among the factors contributing to heart disease is hypertension, wherein blood pressure exceeds normal levels.

Blood pressure is the force of blood pushing against the artery walls. It's measured in millimeters of mercury (mm Hg)[2]. Some patients with hypertension require an intensive care and monitoring to avoid a heart attack [3]. Hypertension is influenced by a number of psychological conditions and stress levels causing the blood pressure change suddenly. Hypertension, or high blood pressure, is a major cause of disability and the leading risk factor for death around the world[4]. Ongoing surveillance is necessary to monitor and assess the population burden of hypertension [5]. Raised BP remains the leading cause of death globally. The category of high blood pressure is  $>140$ mmHg systolic pressure, or  $\geq 90$  mm Hg diastolic pressure [6]. Regular blood pressure checks and consultations with medical professionals is very important for patients. However, due to various constraints, such as busy schedules of doctors, limited healthcare facilities, long queue of patient at hospital and transport cost make it difficult for patient to be checked at time regularly. At times, when hospitals experience long queues, patients are often rescheduled for another appointment. This practice can lead to unnecessary financial burdens, as not all individuals seeking checkups require immediate treatment[7][8]. One of communication media for telemonitoring application is SMS services via the GSM network and it can be widely accessed[9]. From the description above we found that there is need of a health monitoring system that will be used by patients with high blood pressure. This dissertation aims to discuss on design and development of a health monitoring System to link patients with doctors at home. The system is integrated with GSM network for monitoring a patient's blood pressure in real time. The patient can do the measurements by himself/herself and the device will automatically send the systole and diastole data to medical experts via SMS. In our research, we designed and developed Health Monitoring System to Link Chronic Disease Patients with Doctors at home based on E-Health module. E-Health module was integrated with the Arduino to read the measurement data and then to be sent via short message service using the SIM 900 module[10]. This environment will help patient particularly outpatients to be able to communicate with the medical expert periodically and doctor can provide early treatment if something happens to the patient.



*Figure 1. Long queue of patient at hospital*

When we feel ill, we go to doctors which may be time consuming, expensive and may not be easily accessible especially for people live in rural areas [11]. In a developing country like our country, the only way to communicate with the doctor efficiently and effectively is to visit them in hospital or other health organization. The patient visits the doctor then he gets few vital data and prescribes based on it or asks to run some tests if needed for his health status. But going by specialist indeed for a basic matter is lovely, time devouring and some of the time it isn't simple to urge his appointment. At that point once more, the specialist might have to be screen his normal persistent from a farther region and it sounds costly as those with chronic diseases spend much money on tickets by doing unnecessary visit to the doctor, also they spend time and money in their every daily life movement going to hospitals and the caretakers frequently having fear of their healthy status and the long queue take much times to be consulted with doctors.

## **1.2 Problem statement**

Hypertension one of the chronic diseases pose a significant burden on healthcare systems worldwide, requiring continuous monitoring and management to prevent complications and improve patient outcomes[5]. However, traditional healthcare delivery models often fail to provide adequate support for chronic disease patients, particularly those who are homebound or have limited access to healthcare facilities in addition to busy schedules of doctors, long queue of patient at hospital and transport cost make it difficult for patient to be checked at time regularly. Nowadays, in most of the hospitals and clinics in our country, there are many patients who need medical services. Many of them have chronic diseases with vital signs of blood pressure, blood glucose, heart beat and body temperature[5]. Those may require regular monitoring/checking and care, so they do unnecessary visits to medical facilities or consult superfluously with doctors, and they spend much time there, even if they will be given another appointment which causes a long queue at the hospital. The lack of real-time monitoring and communication channels between patients and doctors can lead to delays in detecting health issues, suboptimal management of hypertension conditions which can result into increased healthcare costs or loss of life[4][5].

Therefore, designed and developed a Health Monitoring System (HMS) to link hypertensive patients with doctors at home in response to challenges described above. The system will help doctors continuously monitor hypertension conditions of a patient and provides real-time communication and exchange of data between patients and doctors. The system is integrated with GSM network for monitoring a patient's blood pressure in real time. The patient can do the measurements by himself/herself and the device will automatically send the systole and diastole data to medical experts via SMS he/she can also make a call to a doctor in case of emergence[12]. Hence the HMS will help to improve healthcare accessibility, enhance patient outcomes, and reduce healthcare costs through remote healthcare delivery for hypertensive patient.

### **1.3 Research Questions**

The following 4 questions are the baselines which guided this study:

1. Does regular monitoring through the system lead to better health outcomes and reduced hospitalizations for hypertensive patients?
2. Is a remote health monitoring system more effective than traditional in-person monitoring for managing chronic diseases?
3. How accurate and reliable are the health data collected by the monitoring system
4. Can the health monitoring system be designed to accommodate users with varying levels of technological literacy and access to internet connectivity?

### **1.4 Objectives**

#### **1.4.1 General Objective**

The objective of this study is to design and develop a health monitoring system that will help the hypertensive patients to check their vital signs at home and deliver the information to the doctors via SMS and make a call to a doctor in case of emergence.

#### **1.4.2 Specific Objectives**

To achieve the general objective of this project, the following specific objectives are used as guiding points (realizable; most of the time, publishable):

1. To identify and evaluate gaps present within the previous systems used to take care of hypertensive patients.
2. To design a health monitoring system that will help patients with hypertension to communicate with doctors at hospital without going there. This may include checking vital sign like: blood pressure and heartbeat.
3. To analyze the collected vital sign data from specific sensors This analysis can help to identify trends, abnormalities, and potential health risks and the data interpretation process to provide personalized recommendations to patients.
4. To test and implement a Healthy Monitoring system that alerts or calls doctor or patient/caregivers in case of critical or abnormal vital sign readings. This enables timely intervention and necessary medical assistance.

## **1.4 Study Scope**

This study focused on Design and development of a health monitoring system for the hypertensive patients in their local places. the monitoring will cover chronic disease patients with high blood pressure in rural and urban area and the doctor to whom treat the patients' conditions.

## **1.5 Significance of the Study**

The study holds significant importance in advancing healthcare accessibility by providing remote monitoring solutions for hypertensive patients. This is particularly beneficial for individuals living in rural or underserved areas, who may face challenges accessing healthcare facilities regularly. The implementation of an effective health monitoring system has the potential to reduce healthcare costs associated with chronic disease management. By preventing disease exacerbations, hospitalizations, and emergency room visits, the study can contribute to significant cost savings for both patients and healthcare systems and this is done by designing and developing of the innovative health monitoring systems.

## **1.6 Organization**

Chapter one gives the introduction to the design of a health monitoring system for chronic disease monitoring, Chapter two discusses the literature review conducted for the design of the health monitoring system and in this chapter your will get a comprehensive understanding of existing research, technologies, and best practices in remote health monitoring and chronic disease management. In chapter three discusses about methodology used while conducting this work. The data collection method such as documentation and internet has led us to gather and identify requirements for the best of designing and implementing a Healthy Monitoring System. Chapter four talks about design of Real Time Health Monitoring System using Arduino and with the help of GSM, blood pressure and pulse rate sensor, discusses the results and findings of the study and finally chapter five discusses challenges, recommendations and conclusions from the research study.

This chapter introduce the design of a health monitoring system for chronic disease monitoring serves as an entry point into the project, laying out the groundwork for the development process. It begins by highlighting the increasing prevalence of chronic diseases and the challenges they pose to healthcare systems worldwide. This section emphasizes the need for innovative solutions to enhance patient care and improve health outcomes. The introduction outlines the overarching

goal of the project, which is to design a robust health monitoring system that facilitates remote healthcare delivery, enabling chronic disease patients to receive timely and personalized care from healthcare providers. It also underscores the importance of user-centric design principles in ensuring that the system meets the diverse needs and preferences of its users. Moreover, the introduction briefly discusses the significance of the project in the context of advancing healthcare accessibility, efficiency, and patient empowerment.

## **CHAPTER 2. STATE OF THE ART**

### **2.1 Literature Review**

This literature review and theory chapter is divided into two sections. It is better if we understand the theory of blood pressure measurement and wireless technology first. Hence, the first part will be the theory and background study. The second part is the discussion on literature review of relevance papers.

### **2.2 Theory and Background Study**

In this theory and background study section, it is divided into 4 subsections. The first subsection is about the description of blood pressure. The second subsection is describing on how the blood pressure is measured. Next, it is the explanation about the methods or techniques used for measuring blood pressure electronically, the last subsection is explaining how health monitoring system is designed and possible ways on integrating blood pressure sensors with Arduino.

#### **2.2.1 What is Blood Pressure?**

Blood pressure is a pressure that exerted on arteries where the blood flows through it and spread to the whole body. Due to this fact, blood pressure also called as arterial pressure [13] . The early medical practitioners found that the heartbeat is related to measurement of blood pressure. Blood pressure is measured by determining the systolic pressure and diastolic pressure[2]. Systolic pressure is determined when the heart beating and diastolic pressure, it is determined when the heart relaxing [14]. Pressure is the result of blood pushing against artery walls in the body; this pressure typically changes throughout the day. Blood pressure that is continuously greater than what is regarded as normal is referred to as high blood pressure, or hypertension[15]. Hypertension is referred to as a “silent killer disease” because no noticeable symptoms can be seen until major complications and consequences arise. Arterial hypertension is a major cause of morbidity and mortality because of its association with coronary heart disease, cerebrovascular disease and renal disease. The extent of target organ involvement (i.e. heart, brain and kidneys) determines outcome[16]. Risk factors for hypertension include smoking, passive smoking exposure, diabetes, obesity, high cholesterol, unhealthy diets, and physical inactivity[14][17]. To be specific, the heartbeat mechanism is a cyclic mechanism. It is started from ventricle contraction (both right and left simultaneously) and immediately followed by atrium contraction (both right and left simultaneously). At ventricle contraction stage, the systolic pressure is

determined. Then, it is followed by relaxing stage where the diastolic pressure is determined. After that, the cycle resumes with ventricle contraction again and so on.

*Table 1. Estimated Blood Pressure Ranges (mm Hg)*

AGE OF PERSON	SYSTOLIC RANGE	DIASTOLIC RANGE
New born to 6 months	45-90	30-65
6 months to 2 years	80-100	40-70
Children (2-13 years)	80-120	40-80
Adolescent (14-18 years)	90-120	50-80
Adult (19-40 years)	95-135	60-80
Adult (41-60 years)	60-145	70-90
Older adult (61 and older)	95-145	75-90

Healthy blood pressure levels are various from a person to persons. According to InternationalDrugMart.com, many factors affect the healthy blood pressure level such as age, gender, and physical size [5].

*Table 2. Average Heart Beat Rate*

AGE OF PERSON	RANGE OF HEART RATE	AVERAGE RATE
0-1 Month	100-180	140
2-3 Month	110-180	145
4-12 Month	80-180	130
1-3 Years	80-160	120
4-5 Years	80-120	100
6-8 Years	70-115	92.5
9-11 Years	60-110	85
12-16 Years	60-110	85
Above 16 Years	60-100	80

### **2.2.2 How blood pressure is measured?**

A patient needs to go to the Hospital and Blood pressure is typically measured using a device called a sphygmomanometer, which consists of an inflatable cuff, a pressure gauge, and a stethoscope. To measure an individual's blood pressure, the deflated cuff is placed around the arm and inflated sufficiently to occlude arterial flow. At this point, the pressure of the cuff exceeds the systolic pressure, and auscultation over the brachial artery reveals no sound due to complete obstruction of flow [18] Here's a general overview of how blood pressure is measured using this device:

**Preparation:** The individual undergoing the blood pressure measurement is typically seated comfortably and relaxed.

**Placement of the Cuff:** The cuff of the sphygmomanometer is wrapped snugly around the upper arm, just above the elbow. The cuff should be positioned with the bottom edge about an inch above the elbow crease.

**Palpation of the Radial Artery:** Before inflating the cuff, the healthcare provider or individual performing the measurement may palpate the radial artery (located on the inner wrist below the thumb) to estimate the approximate systolic pressure.

**Inflation of the Cuff:** The cuff is inflated by squeezing the rubber bulb or pressing a button on the electronic device. As the cuff inflates, it temporarily stops blood flow through the brachial artery in the arm.

**Detection of Blood Pressure Sounds:** Using a stethoscope, the healthcare provider listens for the return of blood flow in the brachial artery. This is indicated by the appearance of tapping or thumping sounds known as Korotkoff sounds.

**Measurement of Systolic Pressure:** The pressure in the cuff is gradually released while the healthcare provider listens for the onset of Korotkoff sounds. The first appearance of these sounds corresponds to the systolic blood pressure, which represents the pressure in the arteries when the heart beats and pumps blood into the circulation.

**Measurement of Diastolic Pressure:** The pressure in the cuff is further released until the Korotkoff sounds disappear completely. The point at which the sounds disappear corresponds to the diastolic blood pressure, which represents the pressure in the arteries when the heart is at rest between beats.

**Recording the Blood Pressure:** Once both systolic and diastolic pressures have been measured, they are recorded as two numbers, with systolic pressure written over diastolic pressure (e.g., 120/80 mmHg).

It's important to note that blood pressure measurements can vary based on factors such as stress, physical activity, caffeine intake, and the technique used for measurement. For accurate and consistent results, blood pressure measurements should be taken under standardized conditions and using proper technique[19]. Additionally, multiple measurements may be taken over time to establish a baseline and monitor changes in blood pressure.

### **2.2.3 How existing Electronic Blood Pressure Monitor works?**

Electronic blood pressure monitors typically operate using an oscillometric method to measure blood pressure. When the cuff is inflated, it temporarily cuts off blood flow in the arm. As the cuff deflates, the monitor detects the pressure fluctuations in the cuff caused by the pulsations of blood flow through the brachial artery. The monitor then converts these pressure fluctuations into digital readings, displaying both systolic and diastolic blood pressure values on its screen[3].

Recent years, many electronic bloods pressure monitor marketed as hospital and home usage. Most of them are based on non-invasive sociometric technique. It is difficult to trace the origin or history related to this technique or time began where this technique is beginning to grow in one of the techniques to measure blood pressure. From the references collected, it seems that this technique quite related to kymograph by Carl Ludwig in 1847. The kymograph records the oscillation of the artery pulsation. Later, it has been improved by Vierordt (in 1855) and Marey (in 1860). Similar to oscillometric technique, this method exploits the pulsation of the pressured artery[20].

Usually, oscillometric devices consist of inflatable cuff and pressure sensor. The devices use the pressure sensor to measure pressure and read the pulsation of the pressured artery[21].

The working principal of the oscillometric technique is beginning with wearing inflatable cuff on a subject. Then, the cuff is inflated exceeding the systolic pressure range. After that, the cuff is deflated slowly. The systolic pressure is determined when a significant oscillation appeared. Throughout the deflation, there will be a maximum magnitude of oscillation, at this point it is the Mean Artery Pressure (MAP). Lastly, the diastolic pressure is determined when the last significant oscillation detected before the cuff is deflated completely. A health monitoring system is the subject of this research project. People living in both rural and city areas who suffer from chronic diseases like high blood pressure or diabetes lack immediate access to health or emergency clinics where they can undergo tests. Sending data via SMS, the device measures body temperature, blood glucose level, and heart rate in order to provide information to a mobile phone[22]

The delivery of healthcare services for patients with chronic diseases require more effective coordination between professionals and patients along the care pathway. This health monitoring system can improve patient follow-up and have a positive impact on the quality of care (reducing toxic effects, improving treatment compliance, limiting adverse events) and health-related costs, reducing the duplication of prescriptions and hospital readmissions [1]

The other technique to measure blood pressure electronically is Pulse Transit Time technique (PTT). This technique is introduced to design a cuff-less blood pressure monitor. Two types of pulse wave are usually paired and PTT is extracted from the both types. PTT is the time between two pulse waves propagating on the same cardiac cycle from two separate arterial sites. This technique is able to determine the systolic and diastolic pressure continuously too [23]. the drawback of existing system is that they are expensive, not every patient can afford it and there no functionality to allow a patient to communicate remotely with a doctor[24]. There is no way to monitor remotely a patient for existing system.

This chapter talked what is blood pressure and how blood pressure measurement is made. This chapter also discussed about how existing electronic blood pressure monitor works, how health monitoring system are designed and the gap within existing system

## CHAPTER 3. RESEARCH METHODOLOGY

### 3.1 Introduction

This chapter discusses about methodology used while conducting this work. The data collection method such as documentation and internet has led us to gather and identify requirements for the best of designing and developing a Healthy Monitoring System.

The prototyping method used to design and develop an Arduino-based Health Monitoring System to link hypertension patients with doctors at home involves several key steps aimed at creating a functional prototype that addresses the specific needs of the target users.

- **Identifying Requirements:** The first step was to gather requirements understanding the needs of hypertension patients and doctors for remote monitoring and communication, as well as identifying the necessary features and functionalities of the system.
- **Conceptual Design:** Based on the requirements gathered, a conceptual design of the health monitoring system was created. This included defining the system architecture, selecting appropriate sensors for measuring blood pressure and outlining the communication protocols for transmitting data between the patient to doctor.
- **Hardware Selection:** The next step is to select the hardware components needed to build the prototype which included an Arduino microcontroller, heartbeat sensor, GSM module for communication, LCD, keypad sound sensor and speaker, power supply and switch
- **Prototyping:** With the hardware components selected, the prototype was developed using rapid prototyping techniques. This involved assembling the hardware components, connecting them to the Arduino microcontroller, and writing code to interface with the sensors, collect data, and transmit it to the doctor via the GSM module.
- **Testing:** After the prototype was assembled, we tested the system to ensure that it meets the requirements and functions as intended. This involved testing the accuracy of the blood pressure readings, evaluating the reliability of the GSM communication, and assessing the usability of the patient and doctor interfaces.

### 3.2 Research Process

The research process used while designing a Health Monitoring System to Link Chronic Disease Patients with Doctors Remotely involves several key steps taken to ensure the system effectively meets the needs of both patients and healthcare providers.

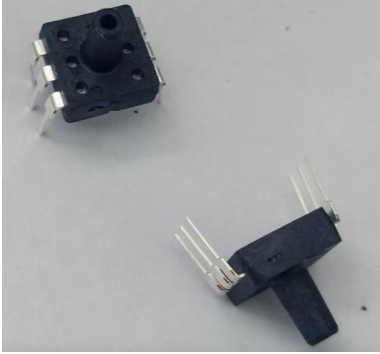

- Firstly, we conducted extensive literature review to explore existing research, technologies, and design previously used in remote health monitoring and chronic disease management. This provided valuable insights into successful approaches and potential challenges.
- Next, we conducted research through interviews and surveys with chronic disease patients, caregivers, and healthcare professionals to understand their specific needs, preferences, and pain points in remote healthcare delivery.
- Next, assessed existing technology to evaluate available technologies for remote health monitoring, considering factors such as reliability, security, and scalability.
- Next, we started design, develop and refine prototypes of the health monitoring system, incorporating user feedback and usability testing to ensure intuitive interface design and functionality. Integration with existing healthcare systems and adherence to security and privacy regulations will be prioritized throughout the design process.
- Final step was testing and evaluation in real-world settings to validate the system's performance, usability, and effectiveness before deployment.




### 3.3 Identifying requirements




#### 3.3.1 Hardware components



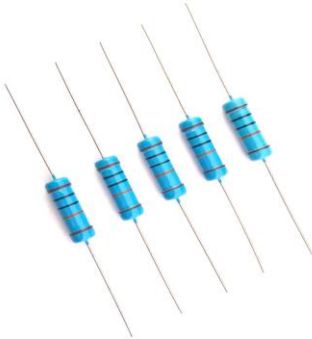
**Table 3:Hardware components**




No	Name,	Description	Function
1	MPS20N0040D Blood pressure sensor	The MPS20N0040D is a gauge pressure transducer that approximates the pressure.	Pressure Sensor in this project used as a component that will detect air pressure passing thru it. The sensor will be used to Blood pressure sensor of a patient and send the

	 <p><i>Figure 2. Blood pressure sensor</i></p>		<p>collected data to microcontroller to be processed</p>
<p>2</p>	<p>Microcontroller ATmega328</p>  <p><i>Figure 3. Arduino board with Atmega328</i></p>	<p>The ATmega328 is commonly found in Arduino development boards, including the Arduino Uno, where it serves as the main microcontroller responsible for executing user-written code and interfacing with various sensors, actuators, and other peripherals. ATmega328 microcontroller, which has a set of 14 input/output digital pins, where 6 out of 14 can be used as a PWM output pins, also, the microcontroller board has 6 analog inputs, a ceramic resonant of 16 MHz, an USB interface, a DC power jack, a reset button, and ICSP header. The USB interface, simplifies the connection of the microcontroller with the computer, also the USB can be a power supplier for the microcontroller board [25]</p>	<p>Health Monitoring System design. It acts as the brain of the whole system. It receives input data from connected sensors and keypad, and GSM module, conditions and process the data and send the response data to LCD and GSM module.</p>
<p>3</p>	<p>Liquid crystal display</p>	<p>Liquid Crystal Display (LCD) is</p>	<p>This display was used to</p>

	 <p><i>Figure 4. LCD</i></p>	<p>a flat-panel display technology that uses liquid crystals to produce visual output. LCDs are commonly used in electronic devices such as computer monitors, television screens, smartphones, tablets, and digital watches[26][27].</p>	<p>display notification and measurement to a patient while using health monitoring system</p>
4	 <p><i>Figure 5. GSM Module</i></p>	<p>A GSM (Global System for Mobile Communications) module is a type of hardware component that enables communication between a device and the GSM cellular network[28][29]. It allows devices to send and receive data, make voice calls, and send text messages (SMS) over the GSM network.</p>	<p>This module provide was used to allow patient to make calls and send SMS data to the doctor.</p>
5	 <p><i>Figure 6. keypad</i></p>	<p>A 4x4 keypad is a type of input device that consists of a matrix of buttons arranged in a grid format, typically with four rows and four columns. Each button represents a unique key, and pressing a button generates an electrical signal that corresponds to the key's position in the matrix[30].</p>	<p>This keypad on health monitoring system, will be used by a patient to make calls and send SMS data to the doctor.</p>
6	<p>3.7V 6000mAH 26650 Lithium rechargeable Battery</p>	<p>3.7V 6000mAh 26650 Lithium rechargeable Battery is a high-capacity lithium-ion battery suitable for powering a wide</p>	<p>This battery was used to power health monitoring system</p>

	 <p><i>Figure 7. 3.7V Rechargeable battery</i></p>	<p>range of electronic devices and applications, including flashlights, portable power banks, electric tools, and other devices that require a reliable and long-lasting power source[31].</p>	
7	<p>TP4056 1A Rechargeable Charging Board Charger Module for Lithium</p>  <p><i>Figure 8. 3.7V Charging Board Charger</i></p>	<p>This module can charge for single-cell lithium battery of 3.7V or multi-section paralleled lithium batteries, can be powered by USB ports 5v, With LED indicators showing the charging status. Red for charging, Green/Blue for fully charged.</p>	<p>This module was used to charge 3.7v battery of the health monitoring system</p>
8	<p>DC-DC Adjustable Step-up Module</p>  <p><i>Figure 9. DC step-up module</i></p>	<p>A DC-DC adjustable step-up module is an electronic device used to increase the voltage of a direct current (DC) power source to a higher level. these modules are commonly used in electronics, especially in situations where a higher voltage is required than what the input power source provides.</p>	<p>In HMS DC-DC Adjustable Step-up Module was used to boost battery voltage from 3.7V to 5v which is the operating voltage of the system.</p>
9	<p>Power Cable Plug DC Barrel Jack</p>	<p>A Power Cable Plug DC Barrel Jack Connector, also known simply as a DC barrel jack connector, is a type of electrical connector commonly used to supply power to electronic</p>	<p>The DC plug and the jack were used as power supply port for HMS</p>

	 <p><i>Figure 10. Jack and Plug</i></p>	<p>devices. It consists of two main parts: the plug and the jack. The plug is the male connector while the jack is the female connector</p>	
10	<p>Switch</p>  <p><i>Figure 11.Switch</i></p>	<p>A switch is an electrical component that is used to control the flow of electric current within a circuit. It is designed to open or close the circuit, thereby allowing or preventing the flow of electricity to devices or components connected to the circuit.</p>	<p>It is used to turn on and off the Health Monitoring System</p>
11	<p>Resistor</p>  <p><i>Figure 12.Resistor</i></p>	<p>A resistor is a passive two-terminal passive electronic component that restricts the flow of electric current. It is commonly used in electrical circuits to control the amount of current or voltage in the circuit. It limits current flow, divide voltages, and adjust signal levels.</p>	<p>The resistors were as protection for LEDs</p>
12	<p>LED</p>	<p>An LED, or Light Emitting Diode, is a semiconductor device that emits light when an electric current passes through it. LEDs are widely used in various applications for illumination,</p>	<p>The LEDs were used as power status indicator for Health Monitoring System</p>

	 <p><i>Figure 13.LED</i></p>	<p>indication, and display purposes due to their energy efficiency, long lifespan, compact size, and durability.</p>	
<p>13</p>	<p>Speaker</p>  <p><i>Figure 14.Speaker</i></p>	<p>A speaker is a transducer that converts electrical signals into audible sound waves, allowing us to hear music, speech, and other audio content.</p>	<p>This speaker is used to hear voice while talking to a doctor</p>
<p>14</p>	<p>Mic sensor</p>  <p><i>Figure 15. Microphone sensor</i></p>	<p>Mic sensor is a device designed for transforming weak sound vibrations into tiny electrical pulses, which can be then amplified through a power amplifier over a loudspeaker for achieving a louder reproduction of the sound.</p>	<p>This sensor is used to record patient's voice while talking to a doctor</p>

In summary, the research methodology employed a combination of literature review, user research, technology assessment, and iterative design to guide the development of a health monitoring system that effectively meets the needs of chronic disease patients with hypertension and healthcare providers. The resulting system represents a significant advancement in remote healthcare delivery, facilitating improved management of chronic diseases and enhancing the quality of care for patients.

### 3.3.2 Software Design

The required software, development Healthy Monitoring System and libraries which are required to develop and test the proposed project are the following:

#### **SolidWorks**

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program. It provides better design visualization, design better products, faster design iterations, improved communication design, design with fewer errors, create more aesthetic design and products and also meets the client's/customer requirements. It was used to design a cover of our system [32].

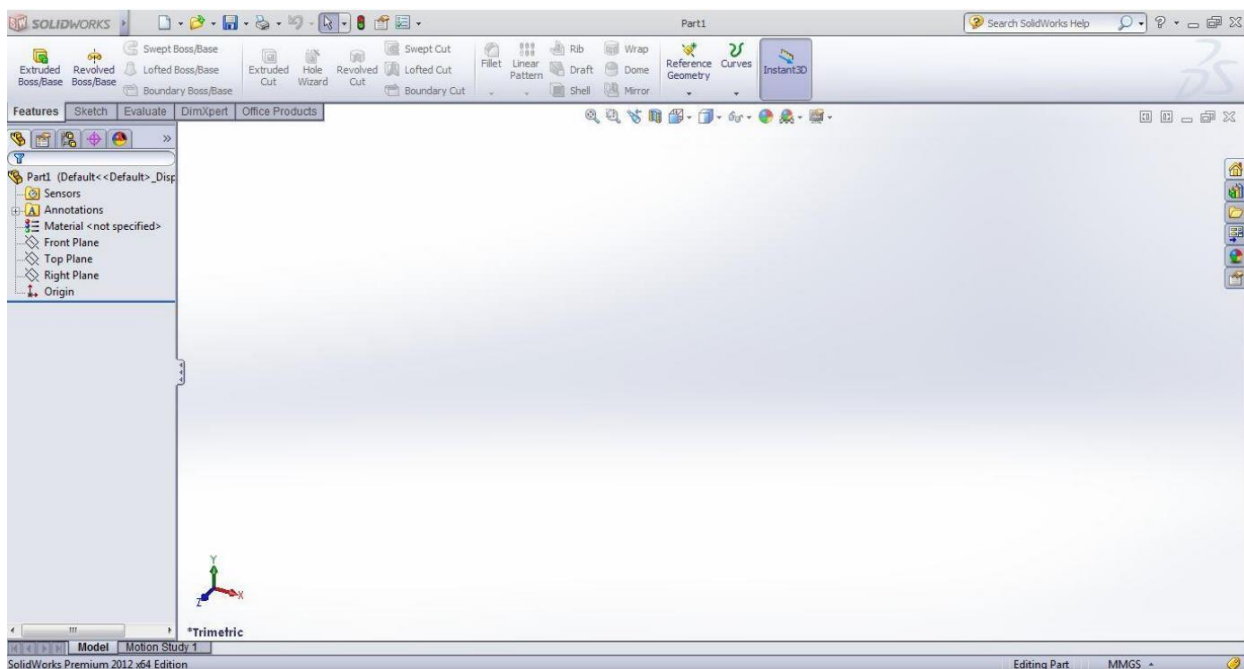


Figure 16. SolidWorks

#### **Arduino Software (IDE)**

The Arduino integrated development environment (IDE) is a cross-platform application written in Java, and is derived from the IDE for the Processing programming language and the Wiring projects. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. A program or code written for Arduino is called a "sketch" [10].

Arduino programs are written in C or C++. The Arduino IDE comes with a software library called "Wiring" from the original Wiring project, which makes many common

input/output operations much easier. Users only need define two functions to make a run able cyclic executive program:

**Setup ():** a function run once at the start of a program that can initialize settings

**Loop ():** a function called repeatedly until the board powers off.

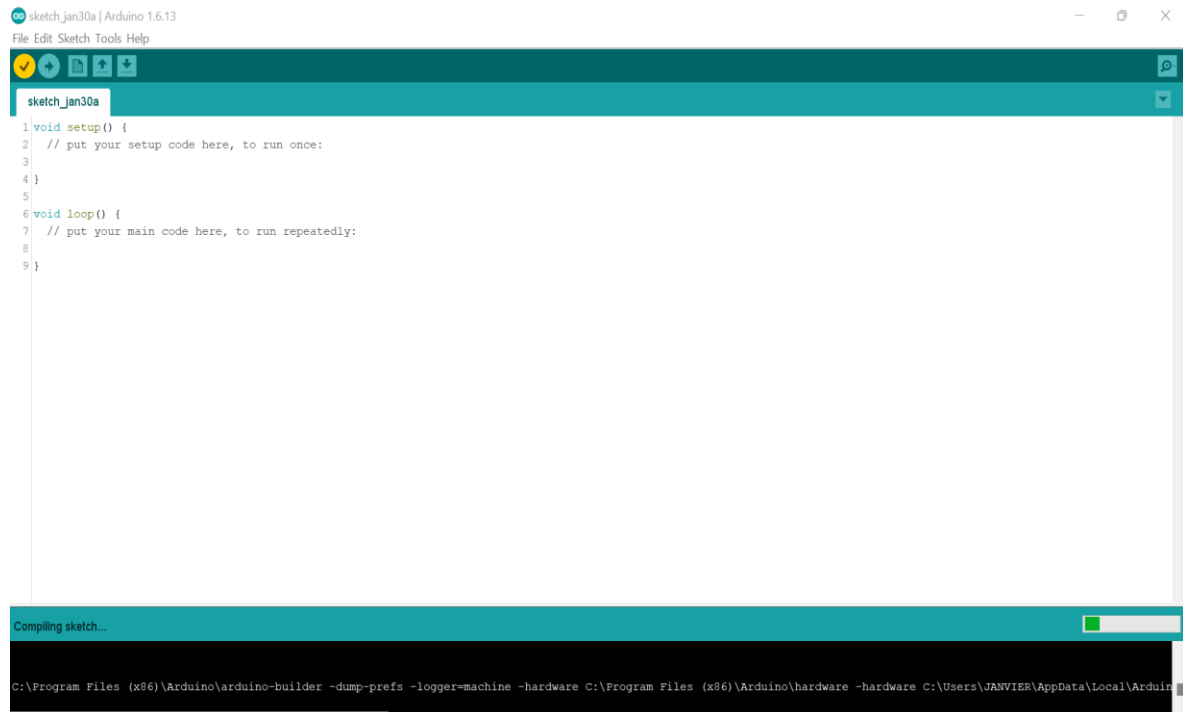


Figure 17.Arduino IDE

### 3.3.3 Tools used

#### laser cutting machine

A laser cutting machine is a type of equipment used to precisely cut materials using a focused laser beam. The process involves directing a high-powered laser beam onto the surface of the material, which melts, burns, or vaporizes the material along the predetermined cutting path[33]. This results in a clean, precise cut with minimal heat-affected zones and negligible material wastage. This laser printer was used to cut the model designed from SolidWorks in our project.



Figure 18.laser cutting machine

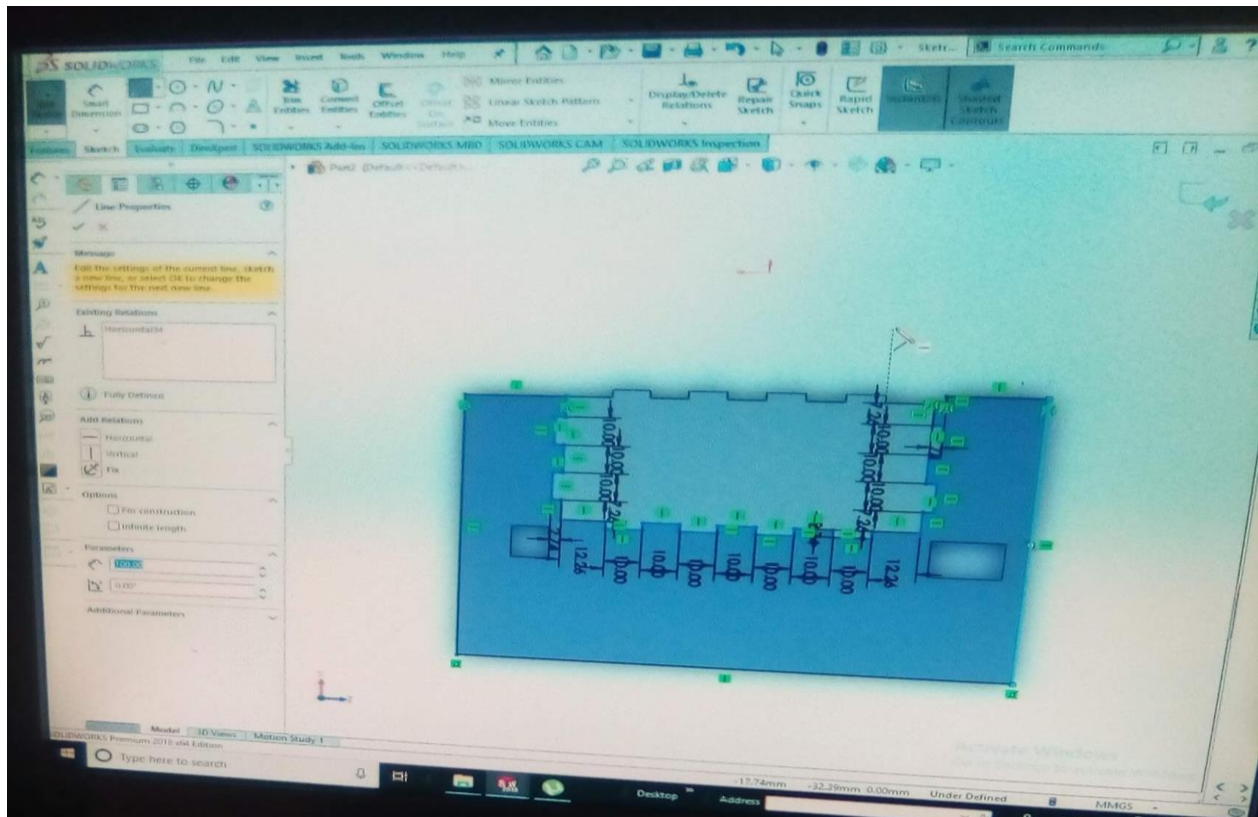


Figure 19. Solid works design for laser cutting machine

### 3.4 Conceptual design

The below flow chart explains the working and the decision flow of this framework.

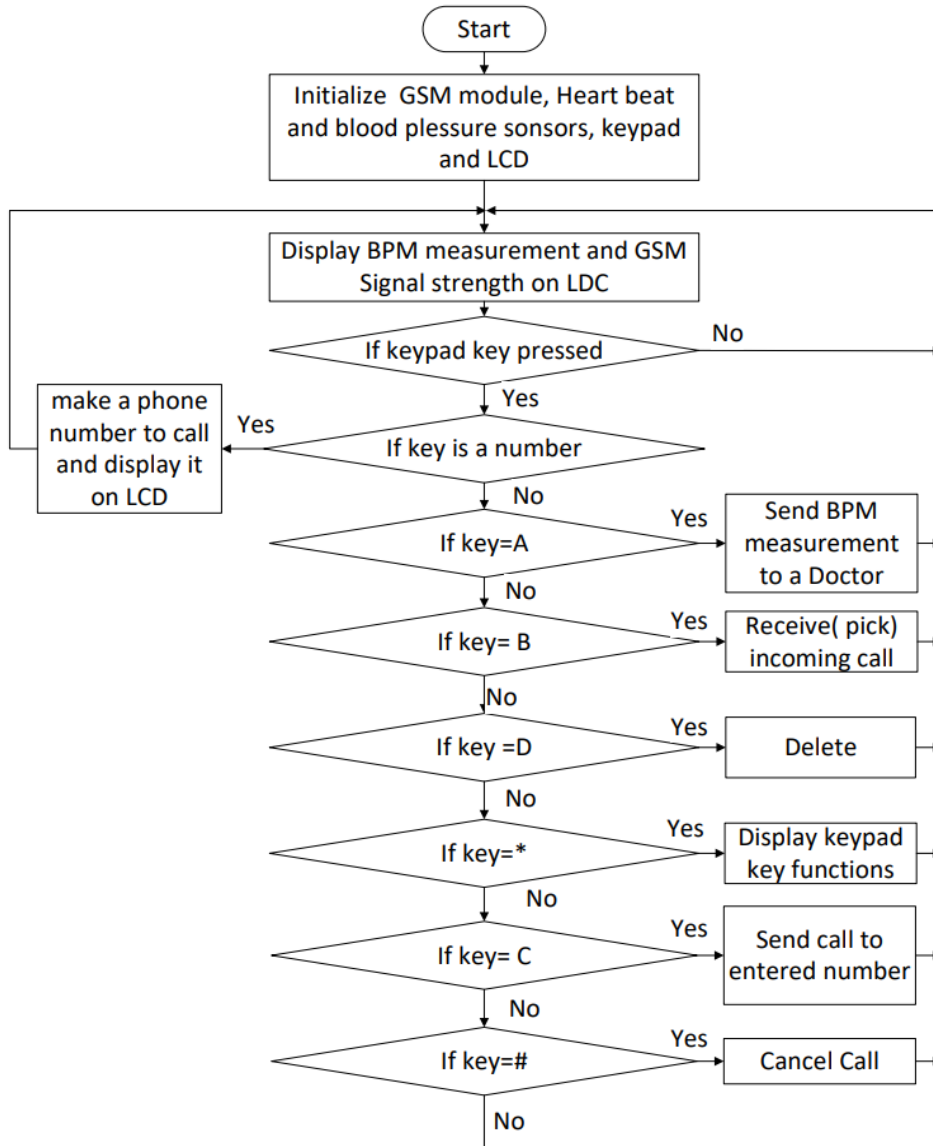


Figure 20. Flow chart of the system

## CHAPTER 4. THE PROJECT IMPLEMENTATION AND RESULTS

### 4.1 Hardware selection

In this section we design our project Real Time Health Monitoring System using Arduino and with the help of GSM and blood pressure sensor. The signals sensed from the patients is millivolt but the sensor volt is 5v. the sensors have the amplifiers, the sensed signals are amplified and it won't cause harm to human health. then the signals are sent to the Arduino. This signal is given to the Analog port (A0) of the Arduino UNO and Arduino UNO reads analog input and converts this analog voltage into digital bits form using inbuilt A to D converter It converts analog voltage level in any number between 0 to 1023. It uses 10 bits for processing. This is given to the ATmega328 microcontroller, it then processes the digital data into the respective measurements. Using GSM module, the results are sent to medical Doctor and the data are analyzed and immediate medical services will be provided if necessary.

#### 4.1.1 Block Diagram

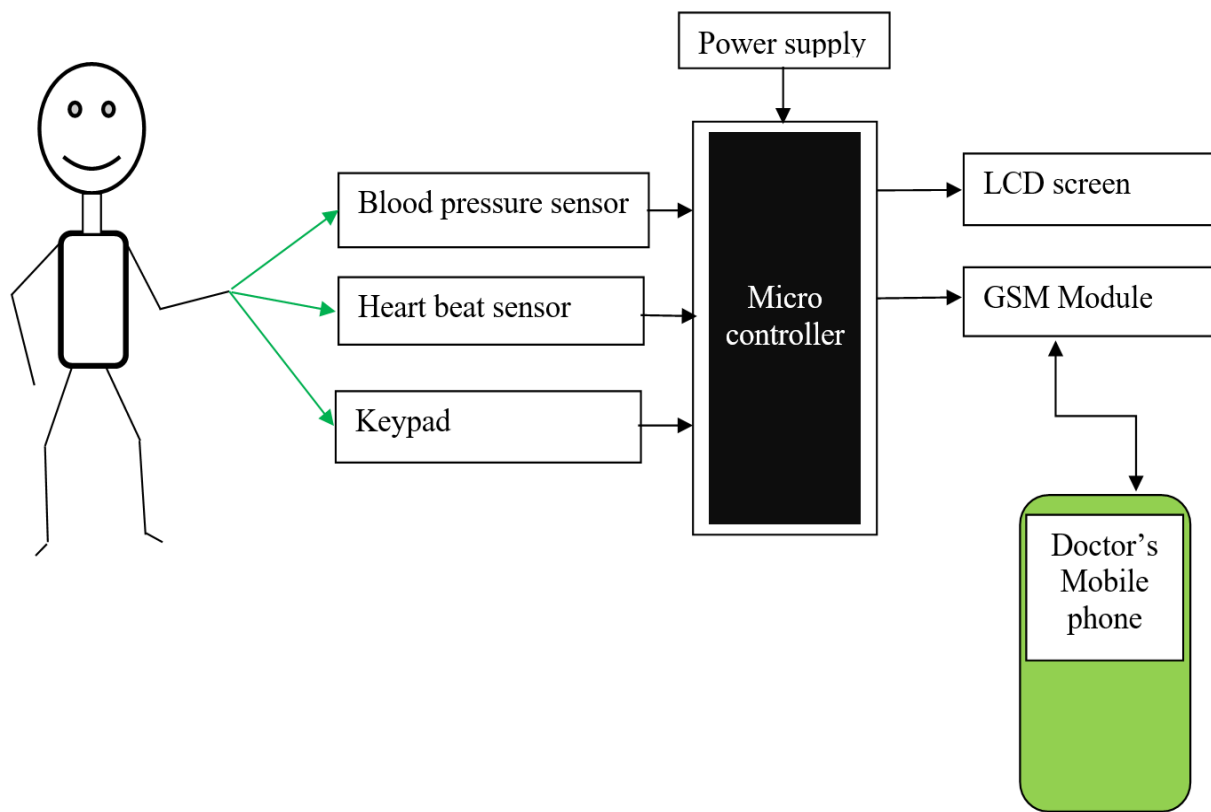


Figure 21. Block Diagram

## 4.2 SCHEMATIC DIAGRAM OF THE SYSTEM

Arduino program controls the all-interfaced devices as illustrated on the schematic diagram below. Blood pressure sensor takes patient blood pressure and heartbeat measurements and then send the data to the Arduino. Arduino receive the data from sensors, process the data and send the measurements to LCD to be displayed.

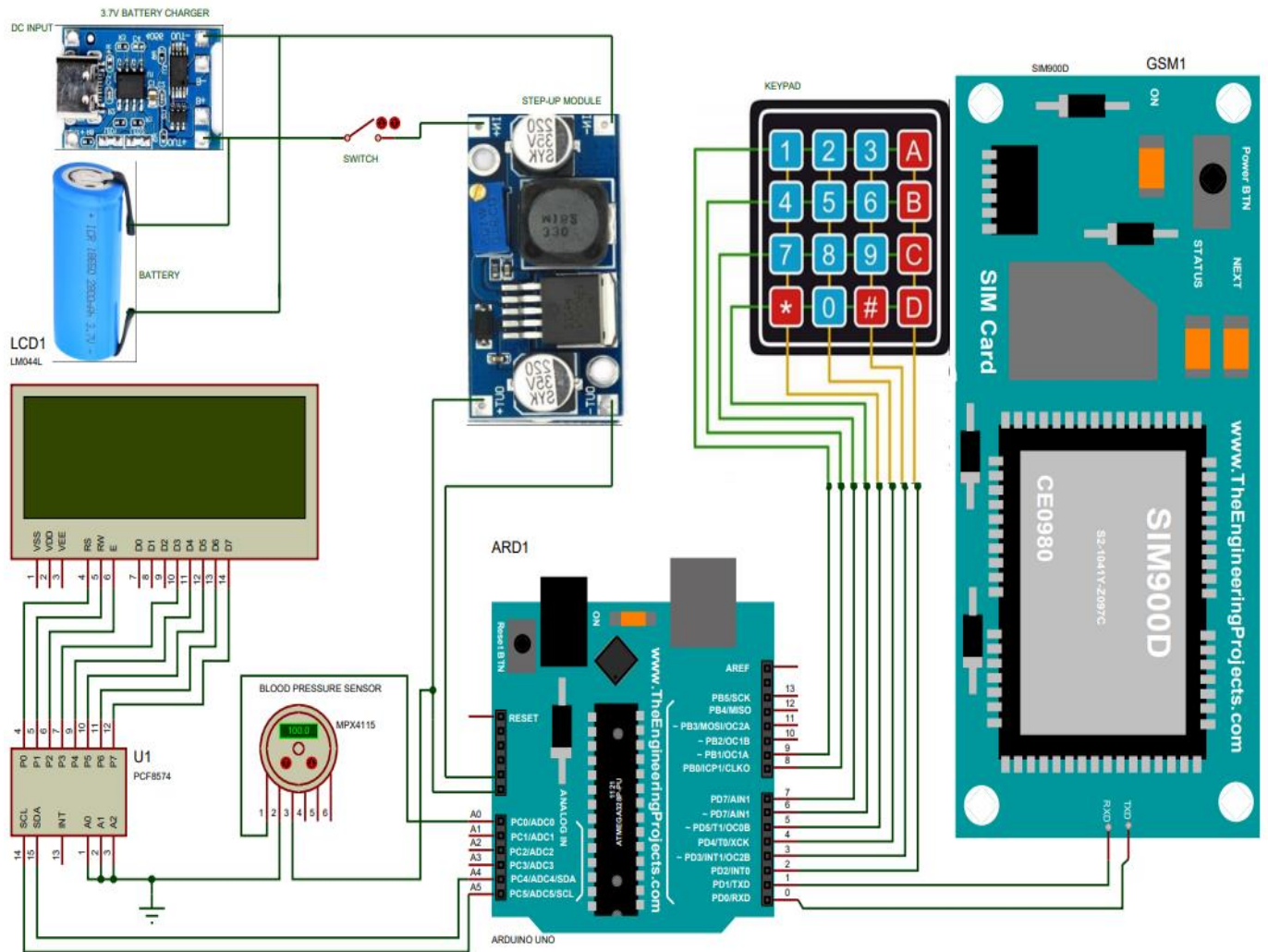


Figure 22. Schematic diagram of the system

The prototype of the project after assembling all the required components.



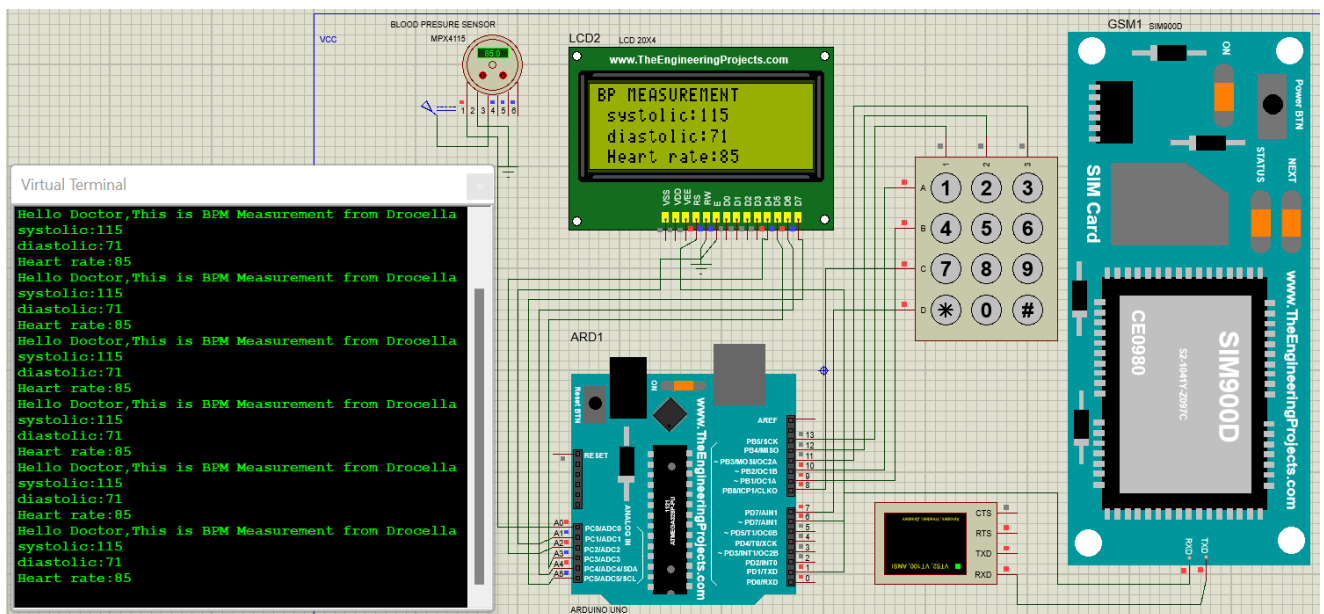
*Figure 23.prototype*

### 4.3 TEST AND RESULT ANALYSIS

Testing the overall system was accomplished by integrating all modules required in the design of this system. And then test if the system is working as it was designed to work. Following are test we did during the development of health monitoring system.

#### 1. Design test using proteus simulation software.

At the first we used proteus software to simulate the design of HMS and it run success full.



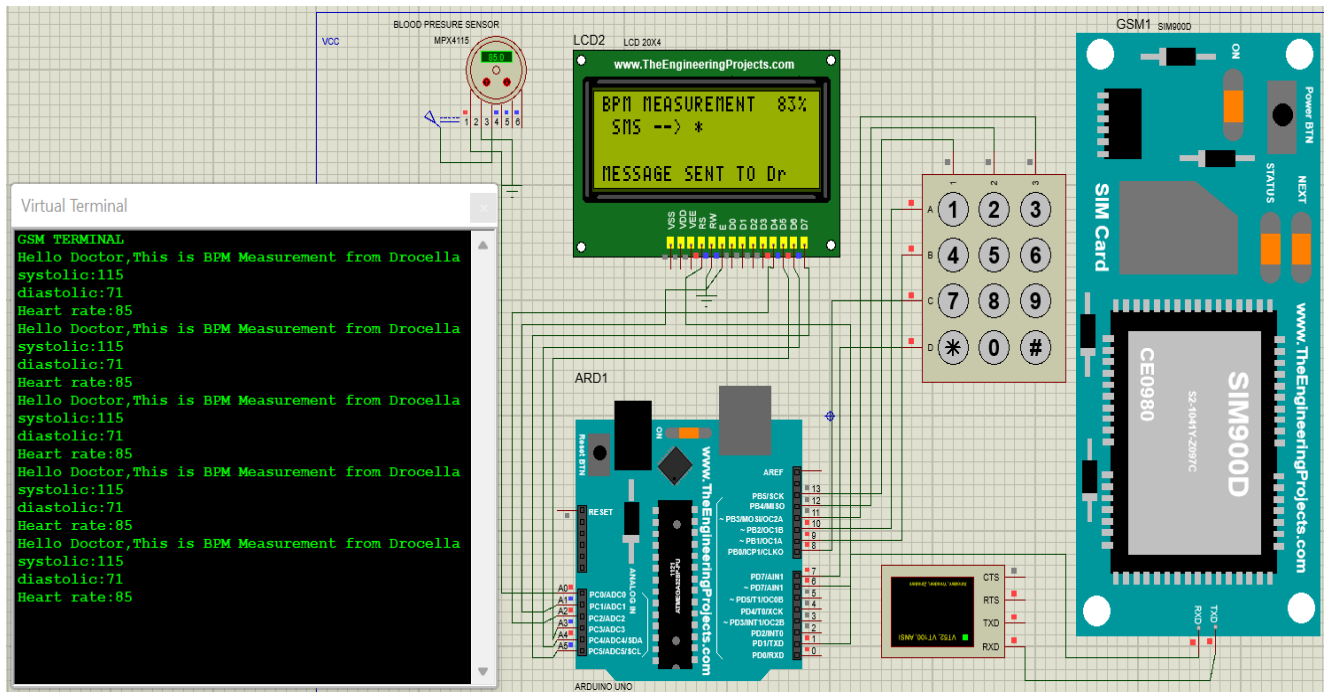


Figure 24. Simulation result

## 2. Testing communication Arduino with GSM Modem

Interface testing between Arduino with GSM module aimed to determine the successful call rate and delivery of a short message and to observe the length of waiting time (delay) delivery. A total of 20 samples was sent over a GSM modem by the microcontroller and calculated the delay. The average delay message delivery was 11.9 seconds average delay message delivery was 12.75 seconds

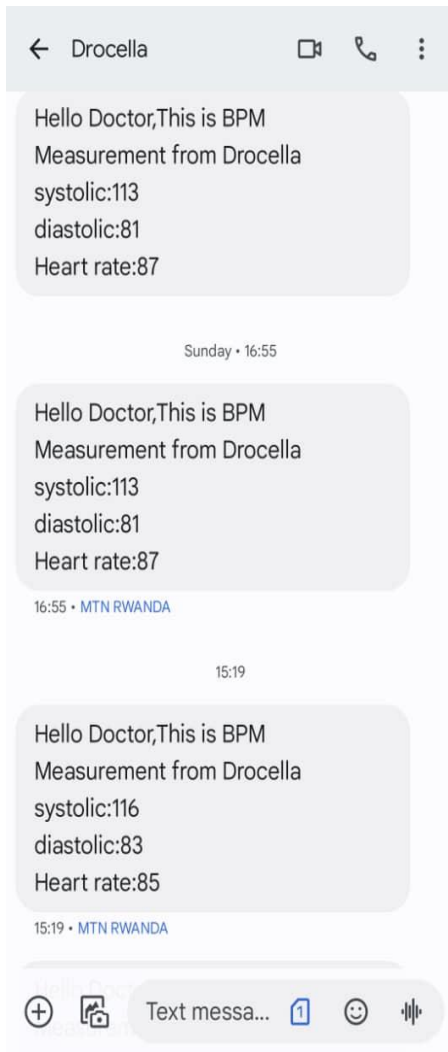
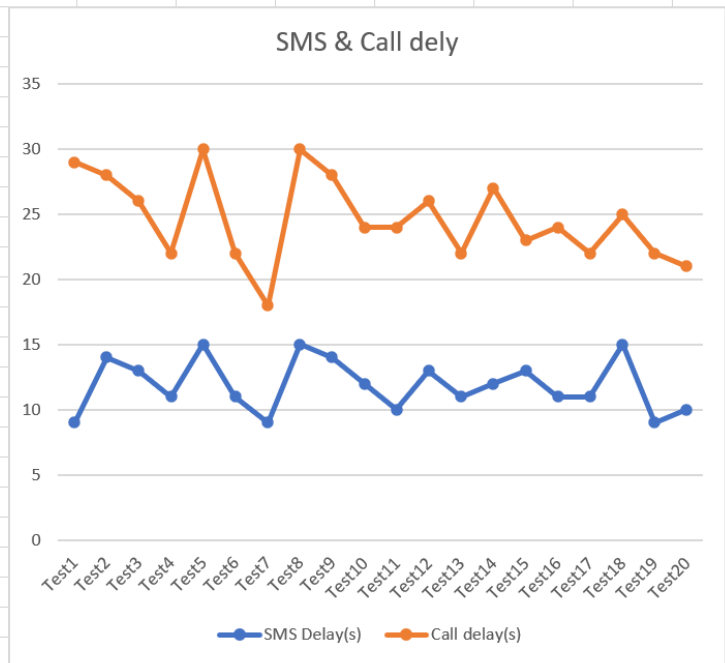


Figure 25. SMS and call test

Table 4. SMS and Call Test results

Test No	SMS Delay(s)	Call delay(s)
Test1	9	20
Test2	14	14
Test3	13	13
Test4	11	11
Test5	15	15
Test6	11	11
Test7	9	9
Test8	15	15
Test9	14	14
Test10	12	12
Test11	10	14
Test12	13	13
Test13	11	11
Test14	12	15
Test15	13	10
Test16	11	13
Test17	11	11
Test18	15	10
Test19	9	13
Test20	10	11
<b>Average</b>	<b>11.9</b>	<b>12.75</b>



From the test results shown above, it can be seen that the calls and health status measurements data were successfully sent to the doctor and when referring to the GSM communication the test results, delay between sending and receiving SMS ranges between 9 to 15 seconds, and the average was 11.9 seconds. This result was related to the relatively slower data processing in the microcontroller as the microcontroller must acquire data from sensors in advance before it processes the data into SMS format and sent the SMS to the doctor side.

### 3. Testing Blood Pressure Sensor



Figure 26..System test result

Table 5: Readings Comparison between BP Circuitry and OMRON BP Device

Test No	OMRON BP Device			BPM SYATEM		
	Systolic	Diastolic	Heart rate	Systolic	Diastolic	Heart rate
1	119	78	70	118	76	69
2	124	78	64	125	79	63
3	120	80	72	119	82	74
4	131	76	82	132	75	80
5	118	65	76	119	68	75
6	117	78	66	118	77	68
7	123	82	76	122	81	75
8	122	87	72	120	89	70
9	120	80	80	119	81	82
10	124	75	82	122	78	81

The data shown on Table 5 above is the comparison of blood pressure measured using our PB device with OMRON blood pressure device. The measurement process was done towards ten volunteer patients picked randomly without specific parameters such as gender, age, health condition etc. From these data readings, a simple analysis has been performed to check the accuracy of the readings from project circuitry

Table 6: Analysis of Systolic Pressure from Data on Table5

Test No	OMRON BP Device	BP Circuitry	%
	Systolic	Systolic	Percentage Error
1	119	118	0.8474
2	124	125	0.8
3	120	119	0.840
4	131	132	0.75
5	118	119	0.840
6	117	118	0.8474
7	123	122	0.819
8	122	120	1.6666
9	120	119	0.840
10	124	122	1.6393

Table 7: Analysis of Diastolic Pressure from Data on Table 5

Test No	OMRON BP Device	BP Circuitry	[%]
	Diastolic	Diastolic	Percentage Error
1	78	76	2.6315
2	78	79	1.2658
3	80	82	2.4390
4	76	75	1,3333
5	65	68	4.4117
6	78	77	1.2987
7	82	81	1.2345
8	87	89	2.2471
9	80	81	1.2345
10	75	78	3.8461

Table 8: Analysis of Heart rate from Data on Table 5

Test No	OMRON BP Device	BP Circuitry	[%]
	Heart rate	Heart rate	Percentage Error
1	70	69	1.4492
2	64	63	1.5873
3	72	74	2.7027
4	82	80	2.5
5	76	75	1.3333
6	66	68	2.9411
7	76	75	1.3333
8	72	70	2.8571
9	80	82	2.4390
10	82	81	1.2345

From Table 5 above, the percentage error of Systolic Pressure acquired from analysis comparison between data measured by using OMRON blood pressure device and data measured by using BP System are significantly stable with overall percentage error archived to be less than  $\pm 1\%$ . However, percentage error for Diastolic Pressure acquired from analysis still higher with stability of the readings fluctuated from one reading to the others. As well known in engineering society, there is no such a perfect device in real world application, there always a small amount of error especially in measurement device

## **4.4 LIMITATIONS**

### **4.4.1 Sensor Limitation**

Skin Contact Requirement, cuff size and positioning, or recent physical activity can affect readings.

### **4.4.2 Power Consumption**

Depending on the configuration of the developed Health Monitoring System which is sensors, GSM and Arduino-based system, it consumes significant power which make it difficult to last long in battery-operated mode. High power consumption limit battery life and necessitate frequent recharging.

In summary, the implementation of the health monitoring system involved a systematic and collaborative approach to bring the design vision to fruition, with a focus on functionality, usability, cost, and user satisfaction. Through careful planning, execution, and ongoing iteration, the system was successfully deployed to facilitate remote monitoring of chronic diseases and improve healthcare outcomes for patients and providers alike.

## **CHAPTER 5. CONCLUSION AND RECOMMENDATION**

### **5.1 Conclusion**

This study presented the Health Monitoring System to Link Chronic Disease Patients with Doctors at home. The system allows to monitor patient's blood pressure and heart rate from a farther area without requiring the physical contact with doctor. The framework is physically made and its execution has been tried and works effectively. Subsequently, this proposed system can be practically used for remote monitoring of the patient blood pressure, heart rate and body temperature. The developed system can be used reliably by people suffering from Hypertension. It is believed that, the different group of people such as aged, illiterate and Children greatly be benefited from this device. Future changes to the framework may incorporate; a genuine time clock so that the date and time of recording, GPS to track current patient's location can be sent alongside the information, a web GSM-based web information-based framework, portable application-based ECG signal and database system, oxygen sugar level and glucose monitoring with blood pressure and heart beat with self-assisting system and human language-based alarm to alert the patient when an abnormality is found.

### **5.2 Recommendations**

#### **To the research community**

Based on limitations encountered from this design, there is a need to enhance and integrate wearable healthcare devices to connect with other future technology trends, to solve the accuracy of data corrected and communication problems. Researchers need to ensure that any proposed systems are user-friendly, adaptable, and secure if they want to retain satisfied customers. Future expansion of this system should be made like adding GPS into the system which will help to track patient's location. Integration of IOT and AI should be made for storing data on cloud and data analysis

#### **To the end users**

This system was developed for research purpose, cannot be used in real life unless improved sensors are used for accurate data.

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## APPENDICES

### Appendix 1: Mode of Data Collection

In designing the health monitoring system for chronic disease management, various modes of data collection were employed to gather insights from stakeholders and users. The following outlines the methodologies utilized:

- **Surveys:** surveys were conducted to gather quantitative data on user preferences, needs, and technological literacy. Survey questions were designed to assess user demographics, current healthcare practices, and attitudes towards remote health monitoring. Surveys were distributed via email and social media platforms to reach a diverse sample of potential users.
- **Interviews:** In-depth interviews were conducted with chronic disease patients, caregivers, and healthcare professionals to gain qualitative insights into their experiences, challenges, and expectations regarding remote healthcare delivery. Semi-structured interview protocols were used to guide discussions on topics such as usability, privacy concerns, and desired features of the monitoring system.
- **Usability Testing:** Prototype versions of the health monitoring system were subjected to usability testing with representative users to evaluate the ease of use, functionality, and user experience. Participants were asked to perform specific tasks within the system while providing feedback on navigation, clarity of instructions, and overall satisfaction.
- **Literature Review:** A comprehensive review of existing research literature, academic publications, and industry reports was conducted to gather background information on remote health monitoring technologies, best practices, and emerging trends. The literature review informed the design process by identifying gaps in current knowledge and guiding decision-making on system features and functionalities.
- **Expert Consultation:** Input from experts in healthcare technology, telemedicine, and chronic disease management was sought throughout the design process to provide specialized knowledge and guidance. Experts were consulted through one-on-one meetings, advisory panels, and professional networks to validate design decisions and ensure alignment with industry standards and regulatory requirements.

By employing a combination of these data collection methods, a comprehensive understanding of user needs, preferences, and expectations was obtained, guiding the development of a health monitoring system tailored to the unique requirements of chronic disease management.

## Appendix 2: Some codes

```
#include <Keypad.h>
const byte ROWS = 4; //four rows
const byte COLS = 4; //four columns
char hexaKeys[ROWS][COLS] =
{
  {'1','2','3','A'},
  {'4','5','6','B'},
  {'7','8','9','C'},
  {'*','0','#','D'}
};
byte rowPins[ROWS] = {11, 10, 9, 8}; //connect to the row pinouts of the keypad
byte colPins[COLS] = {7, 6, 5, 3}; //connect to the column pinouts of the keypad
void send_data(String message)
{
  Serial1.println(message);
  delay(200);
}

void send_sms()
{
  Serial1.write(26);
}

void lcd_status()
{
  lcd.setCursor(2,1);
  lcd.print("Message Sent");
  delay (2000);
  //lcd.setCursor()
  //lcd.print("")
  //return;}
}
```