CUFFLESS AND CONTINUOUS BLOOD PRESSURE MEASUREMENT

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THIS REPORT IS SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF BACHELOR OF ELECTRONIC ENGINEERING TECHNOLOGY (MEDICAL ELECTRONIC) WITH HONOURS

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ENDORSEMENT

I hereby acknowledge that I have read this report and I find that its contents meet the requirements in terms of scope and quality for the award of the Bachelor of Electronic Engineering Technology (Medical Electronic) With Honours

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DECLARATION

I hereby declare that the final year project book is an authentic record of my own work carried out of one year Final Year Project for the award of Bachelor of Electronic Engineering Technology (Medical Electronic) with Honour, under the guidance of Puan Ida Maria Binti Mohd Yusoff.

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ABSTRACT

Nowadays, cardiovascular disease is one of the top killers of human life. People with cardiovascular disease or who are at high cardiovascular risk (due to the presence of one or more risk factors such as hypertension, or already established disease) need early detection. Blood pressure is also important parameter to early detection for cardiovascular diseases. This paper presents a cuff less and continuous blood pressure measurement. To complete this paper, a several method of blood pressure measurement are been studied. Cuff less and continuous blood pressure provides the continuous monitoring of blood pressure level to older person who are diagnosed with hypertension, as they need are frequent monitoring. The purpose of this project is an innovation of existing devices that portable and easy to operate by ordinary people and more users friendly. To develop this project, the photoplethysmography (PPG) sensor are be used as a main component. This sensor will operate with wavelength 640nm until 960nm. Matlab are used to analyze the signal transmitted from PPG sensor. In order to conduct the testing, 20 respondents were involved. During the testing, the reading of blood pressure will be appears on lcd and on the personal computer and will be recorded as a data collection. Comparison reading of blood pressure between existing device and prototype will be as a result in this project. Questionnaire will be distributed to get a comment or recommendation for this project. This device only used to measure one parameter of vital sign which is blood pressure.

Key word: Matlab, Blood Pressure, Non-Invasive, Photoplethymosgraphy, Wavelength

ABSTRAK

Pada masa kini, penyakit kardiavascular merupakan salah satu pembunuh senyap dalam kehidupan manusia. Pesakit yang berisiko untuk mendapat penyakit kardiovascular seperti risiko tekanan darah tinggi memerlukan pemeriksaan awal. Tekanan darah merupakan satu parameter penting dalam mengesan penyakit kardiovaskular. Projek ini direka cipta untuk pemeriksaan tekanan darah secara berterusan dan tiada Kaf. Untuk menyiapkan projek ini, beberapa kaedah pemeriksaan tekanan darah dikaji. Projek ini menyediakan pemantauan yang tekanan darah yang berterusan bagi mereka yang menghidap tekanan darah tinggi dan bagi mereka yang memerlukan pemantauan yang kerap. Tujuaan projek ini direka adalah merupakan satu inovasi daripada alatan yang sedia ada yang mudah alih serta memudahkan orang ramai yang bukan dari kalangan anggota perubatan menggunakannya serta lebih mesra pengguna. Untuk menjayakan projek ini photoplethysmographic (PPG) sensor digunakan sebagai komponen utama. Sensor ini menggunakan gelombang 640nm hingga 960nm sebagai komponen utama. Selain itu, Matlab digunakan untuk menganalisis isyarat yang dihantar dari PPG senor. Untuk mendapatkan data dalam projek ini, seramai 20 respondent telah terlibat dalam ujian tersebut. Semasa ujian, bacaan tekanan darah akan dipaparkan pada lcd dan akan direkodkan sebagai data analisis. Selain itu, perbandingan bacaan tekanan darah diantara alatan yang sedia ada dan prototype akan di analisa. Selain itu, soal selidik akan diedarkan untuk mendapatkan komen dan cadangan untuk penambah baikan projek ini. Projek ini direka hanya untuk mendapatkan satu parameter penting iaitu tekanan darah.

Kata kunci: Matlab. Tekanan Darah, Non Invasive, Gelombang Photopletyhmosgraphic,

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, cardiovascular disease is one of the top killers of human life. People with cardiovascular disease or who are at high cardiovascular risk (due to the presence of one or more risk factors such as hypertension, or already established disease) need early detection. Some factors that have motivated are the increasing percentage of aging population, and chronic diseases caused by lifestyle changes, leading to the need for constantly measuring the health status of individuals along their daily routine to avoid life threatening disorders.

Cardiovascular disease is the leading global cause of death, accounting for 17.3 Million deaths per year, a number that is expected to grow to more than 23.6 million by 2030. About 69 percent of people who have a first heart attack, 77 percent of people who have a first stroke and 74 percent who have congestive heart failure have blood pressure higher than 140/90 mm Hg. Nearly half of people with high blood pressure (46 percent) do not have it under control.[1]. According to the latest WHO data published in may 2014 Coronary Heart Disease Deaths in Malaysia reached 29,363 or 23.10% of total deaths. The age adjusted Death Rate is 150.11 per 100,000 of population ranks Malaysia 33 in the world[2].

In particular, blood pressure is one of the most important vital signs. Blood pressure is the pressure exerted by blood on blood vessel walls. The heart pumps blood into the arteries which carry the blood throughout the body. High blood pressure, also called hypertension, is dangerous because it makes the heart work harder to pump blood out to the body and contributes to hardening of the arteries, which further leads to several cardiac disorders. To measure blood pressure, it is necessary to obtain two pressures of the cardiac cycle which is the systolic pressure (the highest), and the diastolic pressure (the lowest).

1.2 Problem Statement

Blood pressure is very important to measure for the older persons who are diagnosed with Hypertension (high blood pressure), as they typically need frequent monitoring. Regarding the blood pressure monitoring, users would typically take a reading once a week to prevent the hypertension or any disease.

Besides that, traditional medical devices used in hospital are often bulky and expensive, only operated by specially trained nurses, and not suitable for self monitoring. Hence, there is a need of portable, low-cost devices that can be easily operated by ordinary people to detect physiological parameters like blood pressure for self-monitoring at home.

1.3 Objectives

The purpose of this project is:

1. To develop non invasive continuous blood pressure monitoring that portable and easy to operated by ordinary people.

2. To test the non invasive continuous blood pressure monitoring function and the accuracy of the device.
3. To compare the data between continuous reading and non continuous.

1.4 Scope of Project

The purpose of this project is to monitor the blood pressure. In this project, photoplethysmograpic (PPG) sensor place at finger used to estimate blood pressure. The non-invasive ausculatory and oscillometric measurements are simpler and quicker than invasive measurements, require less expertise, have virtually no complications, are less unpleasant and less painful for the patient [3]. This project focuses on the patient who that suffered with hypertension disease.

In this project the suggestion method that is a continuous blood pressure monitoring. . This project used the laptop as a main device, so the user can be used anytime, anywhere and anyone. This project consist 2 parts, which is hardware and software. For the hardware, photoplethysmograpic (PPG) sensor are use to estimate blood pressure. Besides that, for the software, arduino are using to displays the measured blood pressure information to laptop and transmits them through a wireless.

1.5 Significant Of Project

The significant of this project is to facilitate self monitoring for the patient who has the hypertension disease. The increase in blood pressure or hypertension is one of the factors that significantly raise the rate of morbidity and mortality in developed countries. Some factor to motivate this project is growing percentage of aging population, and chronic diseases caused by lifestyle changes, leading to the need for constantly measuring the health status of individuals.

It is an essential parameter for the diagnosis and treatment. Daily monitoring of blood pressure is also important to prevent the cardiovascular disease among normal people. Besides that, this project gives information to user for awareness of low blood pressure and high blood pressure.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews related literature from the existing research of the blood pressure, where the blood pressure measurement using a several method. Other than that, this chapter also covered the circulatory system, hypertension disease, whitecoat hypertension disease and hypotension.

2.2 The Circulatory System

The human heart pumps bloods through the arteries, which connect to smaller arterioles and then even smaller capillaries. The capillaries are thin walled vessels interconnect with the smallest arteries and smallest veins. Blood flow throughout the body begin its return to the heart when the capillaries return blood to the venules and then to the veins. The cardiovascular systems therefore consist of a closed circuit the heart, arteries, arterioles, capillaries, venules, and vein. It provides oxygen and nutrients to tissues while removing waste. The heart is located within mediastinum, resting on diaphagram. The heart divided into two artia and two ventricles. Blood low in oxygen and high in carbon dioxide enters the right side of the heart and is pumped into the pulmonary circulation. The left ventricle pumps blood out of the heart to the rest of the body. [4] The figure below show the Circulatory system.

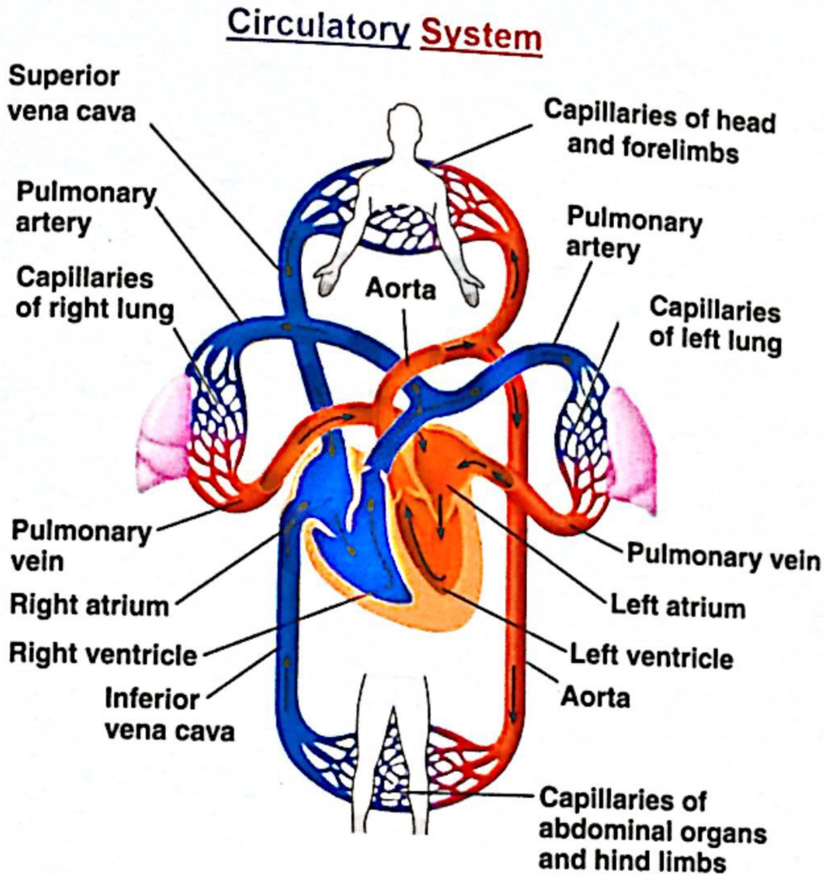

Figure 2.1: The Circulatory System

2.2.1 Blood Circulation

Blood enters the pulmonary circuit from the right ventricle though the pulmonary trunk, which extend upward posterior from the heart. It divides into right and left pulmonary arteries, which enter the right and left lungs, respectively. Repeated divisions connect to aarterioles and capillary network associated with the walls of the alveoli, where gas is exchanges between blood and air. The pulmonary capillaries lead to venules and then vein. Four pulmonary veins, two for each lung, return blood to the left atrium, completing the vascular loop of the pulmonary circuit.

The sysmetic circuit involves the movement of freshly oxygenated blood from the left atrium to left ventricle, then into the aorta and its branches, leading to all body tissues. Eventually it makes its way to the companion vein system that return blood to the right atrium[4].

2.2 2 The Cardiac Cycle

The cardiac cycle is the sequence of events in one heartbeat. In its simplest form, the cardiac cycle is the simultaneous contraction of both atria, followed a fraction of a second later by the simultaneous contraction of both ventricles. The heart consists of cardiac muscle cells that connect with each other (they are branched) and so when one contracts, they stimulate their neighbors and they all contract. The heart is an 'all-or nothing' muscle, getting its rest between beats. It can only respire aerobically[5].

The period between the start of one heartbeat and the beginning of the next is a single cardiac cycle. The cardiac cycle therefore includes alternate periods of contraction and relaxation. For any one chamber in the heart, the cardiac cycle can be divided into two phases. During contraction, or **systole** (SIS-to-le), a chamber ejects blood either into another heart chamber or ninto an arterial trunk. This occurs when the ventricles contract, closing the A-V valves and opening the Semi-Lunar valves to pump blood into the two major vessels leaving the heart. Systole is followed by the second phase, one of relaxation, or **diastole** (di-AS-to-le). During diastole a chamber fills with blood and prepares for the start of the next cardiac cycle[6]. This occurs when the ventricles relax, allowing the back pressure of the blood to close the semi-lunar valves and opening the A-V valves. The figure below show the cardiac cycle.

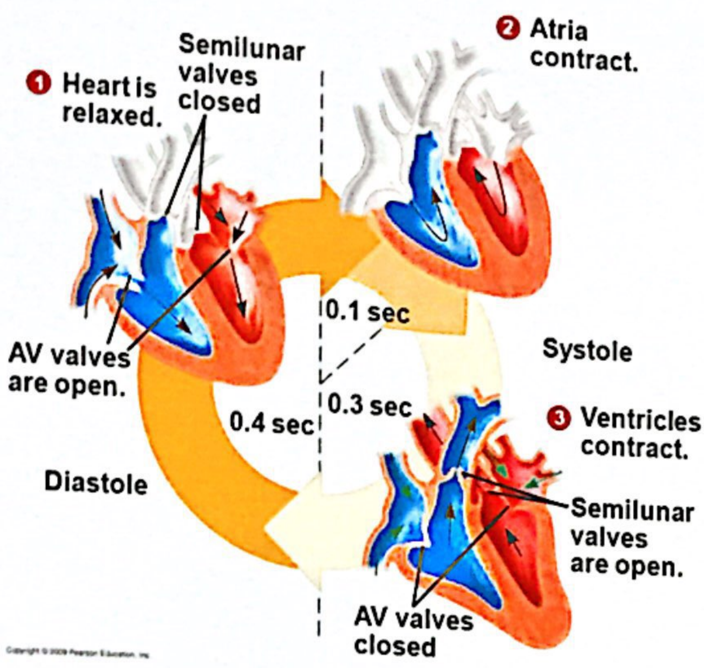

Figure 2.2: The Cardiac Cycle

2.2.3 Blood Pressure

Blood pressure, the amount of force applied on the walls of the arteries when the blood is forced throughout the body, depends on factors such as the amount of blood in the body, the pumping rate of the heart, the flexibility of the arterial walls, and the resistance to blood flow due to the size of the arteries. The blood pressure of a human varies continuously due to physical activity, medication, anxiety, and emotions. The body has unique mechanisms to regulate a person's blood flow; whenever a person's blood pressure drops, the heart rate increases to pump more blood and the arterial walls contract to increase the blood pressure[7]. The reading of blood pressure will effected by body position, temperature, surrounding, emotion and disease.

Blood pressure that is pathologically low is called hypotension, and pressure that is pathologically high is hypertension. Both have many causes and can range from mild to severe, with both acute and chronic forms.

Hypotension can cause the blood supply to the brain, heart and other tissues to be too low and hypertension is strongly correlated with higher risk for cerebral stroke and heart infarct.[3] Figure above show the blood pressure in the blood vessel

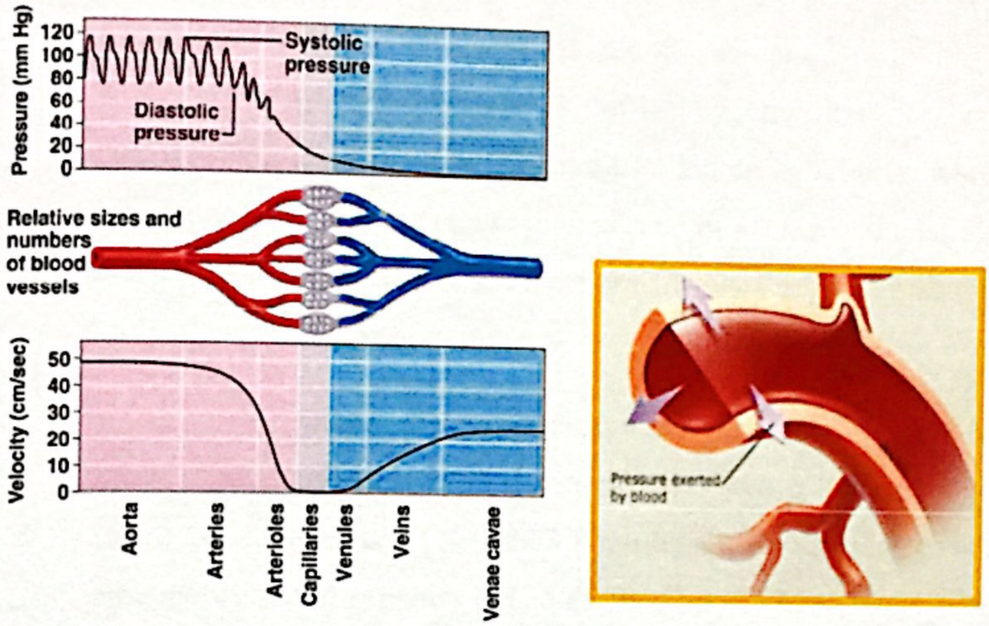

Figure 2.3: Blood Pressure and Velocity in the Blood Vessels

Normal resting systolic (diastolic) blood pressure in an adult is approximately 120 mmHg (80 mmHg), abbreviated "120/80 mmHg". Blood Pressure Measure = Systolic Pressure over Diastolic Pressure. The table below show the blood pressure stages.

Table 2.1: Blood Pressure Stages

Blood Pressure Category	Systolic mm Hg (upper #)		Diastolic mm Hg (lower #)
Low blood pressure (Hypotension)	less than 80	or	less than 60
Normal	80-120	and	60-80
Prehypertension	120-139	or	80-89
High Blood Pressure (Hypertension Stage 1)	140-159	or	90-99
High Blood Pressure (Hypertension Stage 2)	160 or higher	or	100 or higher
High Blood Pressure Crisis (Seek Emergency Care)	higher than 180	or	higher than 110

(Clinical Practice Guidelines, 2017)

2.2.3.1 White Coat Hypertension

Blood pressure measurements by a doctor a lesser extent by a nurse often lead the patient to experience an alerting reaction associated with an increases in blood pressure[8]. White coat hypertension (also referred to as 'office hypertension', or 'isolated clinical hypertension') is a term used to denote individuals who have blood pressures that are higher than normal in the medical environment, but whose blood pressures are normal when they are going about their daily activities[9].

White coat hypertension is a term used for persons not receivingantihypertensive medication who have a persistently high office blood pressure ($\geq$ 140/90 mmHg) together with a normal; ambulatory blood pressure (<135/85 mmHg) or home blood pressure. Muscle sympathetic nerve traffic inhibition coupled with a skin sympathetic nerve traffic excitation induced by measurement of blood pressure by a doctor has been reported to cause the increase in blood pressure. The prevalence of white coat hypertension in older persons is higher than in younger persons and has prevalence rates between 15% and 25% in the elderly. The magnitude of the white coat effect is increased by older age, female gender, and smoking[10].

2.2.3.2 Hypertension

High blood pressure is a common condition in which the long-term force of the blood against your artery walls is high enough that it may eventually cause health problems, such as heart disease. . Hypertension is a major risk factor for ischaemic and haemorrhagic stroke, myocardial infarction, heart failure, chronic kidney disease, cognitive decline and premature death. Untreated hypertension is usually associated with a progressive rise in blood pressure. The vascular and renal damage that this may cause can culminate in a treatment-resistant state[11].

High blood pressure is defined as a systolic blood pressure at or above 140 mmHg and/or a diastolic blood pressure at or above 90 mmHg. Systolic blood pressure is the maximum pressure in the arteries when the heart contracts. Diastolic blood pressure is the minimum pressure in the arteries between the heart's contractions. High blood pressure causes the heart to have to work harder to push blood throughout the body. This stresses the body's blood vessels, causing them to stiffen, clog or weaken[12].

2.2.3.3 Hypotension

Hypotension is therefore a BP that is much lower than usual and which may be causing symptoms such as dizziness or light-headedness. It is often defined as systolic BP less than 90 mm Hg or diastolic BP less than 60 mm Hg. A systolic BP below 100 mm Hg may be more appropriate if the patient normally has hypertension[13].

Fluctuation in blood pressure are a product of normal hemostatic mechanisms and we all experience period when our blood pressure is lower than what is normal for us as individual and that which is consistent with the term "normotensive" (typically 120/80mmhg)[14]

2.3 Method to Measure Blood Pressure

To get the reading of blood pressure there are several method which is invasive method, auscultatory method, oscillometric technique, ultrasound techniques and lastly volume clamping method of Penaz.

2.3.1 Invasive Method

Invasive (intra-arterial) blood pressure (IBP) monitoring is a commonly used technique in the Intensive Care Unit (ICU) and is also often used in the operating theatre. The technique involves the insertion of a catheter into a suitable artery and then displaying the measured pressure wave on a monitor. The most common reason for using intra-arterial blood pressure monitoring is to gain a 'beat-to-beat' record of a patient's blood pressure.

Continuous 'beat-to-beat' blood pressure monitoring is useful in patients who are likely to display sudden changes in blood pressure (e.g. vascular surgery), in whom close control of blood pressure is required (e.g. head injured patients), or in patients receiving drugs to maintain the blood pressure (e.g. patients receiving inotropes such as epinephrine). The technique allows accurate blood pressure readings at low pressures, for example in shocked patients[15]. Figure below show the invasive method of blood pressure.

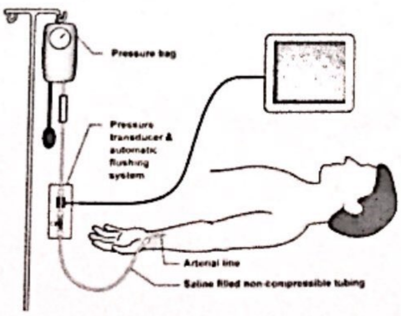

Figure 2.4 Invasive Method

2.3.2 The Auscultatory Method

Although the auscultatory method using mercury sphygmomanometer is regarded as the gold standard for office blood pressure measurement, widespread implementation of the ban in use of mercury sphygmomanometers continues to diminish the role of this technique.1 The situation is made worse by the fact that existing aneroid manometers, which use this technique, are less accurate and often need frequent calibration. New devices known as "hybrid" sphygmomanometers have been developed as replacement for mercury devices. Basically these devices combine the features of both electronic and auscultatory devices such that the mercury column is replaced by an electronic pressure gauge, similar to oscillometric devices, but the blood pressure is taken in the same manner as a mercury or aneroid device, by an observer using a stethoscope and listening for the Korotkoff sounds.[16] Figure below show the ausculatory method of non invasive blood pressure.

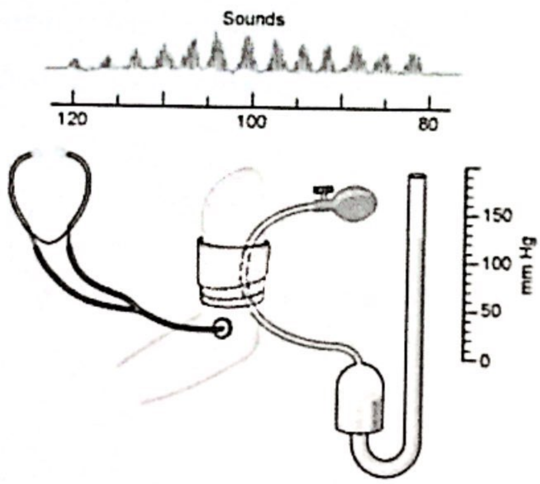

Figure 2.5: Ausculatory Method

2.3.3 Oscillometric Method

This was first demonstrated by Marey and it was subsequently shown that when the oscillations of pressure in a sphygmomanometer cuff are recorded during gradual deflation, the point of maximal oscillation corresponds to the mean intra-arterial pressure. The oscillations begin at approximately systolic pressure and continue below diastolic so that systolic and diastolic pressure can only be estimated indirectly according to some empirically derived algorithm. This method is advantageous in that no transducer need be placed over the brachial artery, and it is less susceptible to external noise (but not to low frequency mechanical vibration), and that the cuff can be removed and replaced by the patient during ambulatory monitoring, for example, to take a shower. The main disadvantage is that such recorders do not work well during physical activity when there may be considerable movement artifact. The oscillometric technique has been used successfully in ambulatory blood pressure monitors and home monitors. It should be pointed out that different brands of oscillometric recorders use different algorithms, and there is no generic oscillometric technique.[17] Figure below show the oscillometric method of non invasive blood pressure.

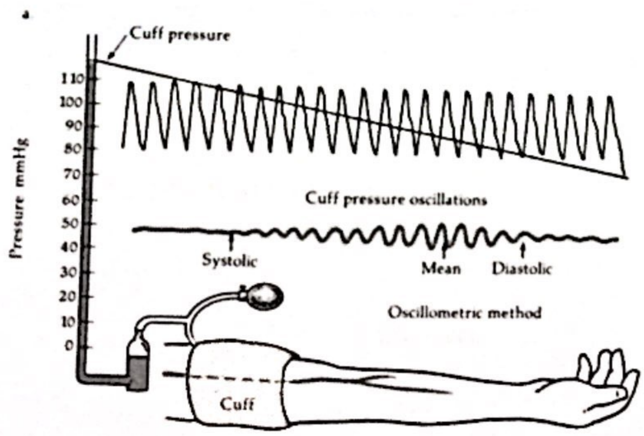

Figure 2.6: Oscillometric Method

2.3.4 The Finger Cuff Method of Penaz

This interesting method was first developed by Penaz and works on the principle of the "unloaded arterial wall." Arterial pulsation in a finger is detected by a photoplethysmograph under a pressure cuff. The output of the plethysmograph is used to drive a servo-loop, which rapidly changes the cuff pressure to keep the output constant, so that the artery is held in a partially opened state. The oscillations of pressure in the cuff are measured and have been found to resemble the intra-arterial pressure wave in most subjects. This method gives an accurate estimate of the changes of systolic and diastolic pressure when compared to brachial artery pressures the cuff can be kept inflated for up to 2 hours. It is now commercially available as the Finometer and Portapres recorders and has been validated in several studies against intra-arterial pressures[17]. Figure below show the finger cuff method.

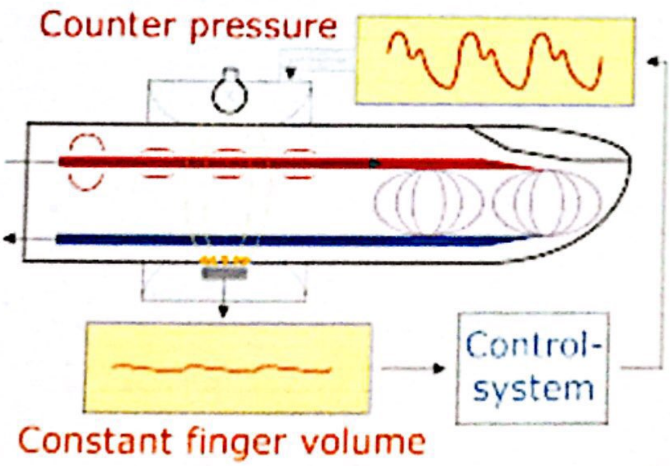

Figure 2.7: Finger Cuff Method

2.3.5 Tonometry Method

First presented by Pressman & Newgard in 1963, the arterial tonometer is a pressure Measurement method that can noninvasively and continuously record pressure alterations in a superficial artery with sufficient bony support, such as the radial artery. It uses a miniature transducer or a rigid sensor array or a flexible diaphragm, which is attached on the skin above the pulsating artery Skin and tissue located between the sensor and the array transfer pressure pulsations between them. When the pulsations reach their strongest level, the sensor is regarded as being correctly positioned. This can be facilitated by using a sensor array and selecting sensor elements with the strongest amplitude. This method requires that the sensors are closely alike in terms of sensitivity.

Next, the sensor or sensor array is pushed towards the vessel using, for example, air pressure. The vessel flattens when the pressure and, consequently, the force against the artery wall increases. Arterial pressure in the top of the flattened artery's center equals the supporting pressure, allowing the recording of an accurate blood pressure profile. If the pressure increases too much, the artery will occlude totally and the measurement will be erroneous. When the tonometer is attached on the skin over a superficial artery, such as the radial artery, blood pressure pulsations in it produce volume shifts inside the volume sensor resulting in an impedance change. The pressure inside the tonometer can be varied so that the strongest signal can be measured. This pressure corresponds to mean arterial pressure, MAP.[18] Figure below show the tonometry method of blood pressure method

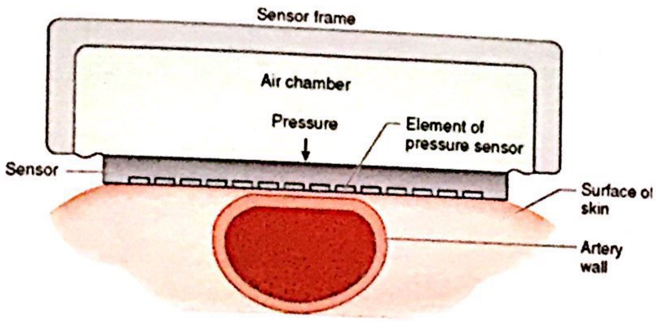

Figure 2.8: Tonometry Method

2.5 Existing Devices

Blood pressure reading can get using are several device such as, Finometer, Continuous Non Invasive Arterial Pressure (CNAP), Non Invasive Blood Pressure (NIBP) and Patient Monitor.

2.5.1 Finometer

These projects are innovating by using Finometer concept. There many parameters from this device which is reading of blood pressure, heart rate, inter beat interval, cardiac output, stroke volume, pulse rate, baroflex sensitivity, total peripheral resistance, maximum steepness of current upstroke, ascending aortic impedance, left ventricular ejection and lastly rate pressure. But on this project will focuses on blood pressure only. Finometer have many type and listed on the table below. The Finometer (FMS, Finapres Measurement Systems, Amsterdam) records the beat-to-beat finger pulse contour from which a number of cardiovascular parameters are derived, including systolic, mean and diastolic blood pressure, inter-beat-interval, and stroke volume (SV). The figure above shows the finometer device.

The noninvasive continuous blood pressure recordings provided by the Finometer have been recommended for 'research studies assessing short-term changes of blood pressure and its variability'.[19] The Finometer monitor has been shown to improve the accuracy of noninvasive measurement of absolute arterial pressure compared to the old Finapres device, measurement of blood pressure variability provides worse results in most spectral parameters and a better accuracy only in the HF band of systolic pressure. Hence, when autonomic assessment is based on the analysis of spontaneous blood pressure variability of pure cardiovascular origin, such as for instance in the measurement of baroreflex sensitivity by the transfer function method.[20] The image below show the image of Finometer device.

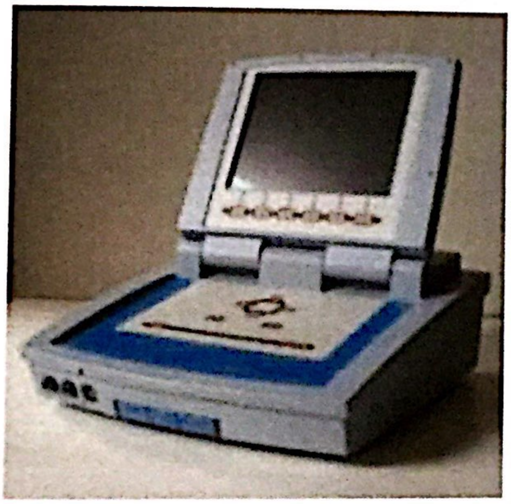

Figure 2.7 Finometer

2.5.2 Continuous noninvasive arterial pressure (CNAP)

The figure below show the Continuous and non-invasive blood pressure monitoring (CNaP). The CNAP system allows continuous noninvasive arterial pressure measurement based on the volume clamp method using a finger cuff. We aimed to evaluate the agreement between arterial pressure measurements noninvasively obtained using the CNAP device and arterial catheter-derived arterial pressure measurements in intensive care unit patients.[21]

These devices display real-time, continuous arterial pressure waveforms and allow noninvasive beat-to-beat arterial pressure measurement. The main advantage of these technologies is that they can bridge the gap between noninvasive but intermittent oscillometric techniques and continuous but invasive arterial pressure monitoring.[22]

The CNAP™ monitoring system consists of reusable finger cuffs, the cuff controller and the CNAP™ pod, which interfaces with the patient monitor. The finger cuffs are available in three sizes (i.e., small, medium and large), and consist of two semi-rigid cylinders covering two adjacent fingers, i.e. index and middle fingers. Inflatable cuffs, sensors and electronics are present inside the semi-rigid cylinders. The adequately sized finger cuff is connected to the cuff controller that contained the pneumatic control unit for the inflatable parts of the finger cuff. The finger cuff was applied contra lateral to the radial artery catheter. A 2.5-m-long cable leads from the cuff controller to the CNAP™ pod which contains hardware and software to drive sensor cuff function, interprets sensor signal and reports data to monitor. The continuously changing finger cuff pressure is measured with a pressure transducer. The analogue signal of the CNAP™ pod is displayed on another Drager Infinity Delta monitor that also controls a standard oscillometric upper-arm cuff for scaling purposes. CNAP™ is obtained by applying pressure via the finger cuffs such that the blood volume flowing through the finger arteries is held constant (i.e., volume-clamping).[23]

Figure 2.8: Continuous and non-invasive blood pressure monitoring (CNAP)

2.5.3 Non Invasive Blood Pressure (NIBP)

The term **NIBP**, for **Non-Invasive Blood Pressure**, is often used to describe oscillometric monitoring equipment. The equipment is functionally similar to that of the auscultatory method, but with an electronic pressure sensor (transducer) fitted in to detect blood flow, instead of using the stethoscope and the expert's ear. In practice, the pressure sensor is a calibrated electronic device with a numerical readout of blood pressure. To maintain accuracy, calibration must be checked periodically, unlike the inherently accurate mercury manometer. In most cases the cuff is inflated and released by an electrically operated pump and valve, which may be fitted on the wrist (elevated to heart height), although the upper arm is preferred. They vary widely in accuracy, and should be checked at specified intervals and if necessary recalibrated.

The cuff is inflated to a pressure initially in excess of the systolic arterial pressure, and then reduces to below diastolic pressure over a period of about 30 seconds. When blood flow is nil (cuff pressure exceeding systolic pressure) or unimpeded (cuff pressure below diastolic pressure), cuff pressure will be essentially constant. It is essential that the cuff size is correct: undersized cuffs may yield too high a pressure, whereas oversized cuffs yield too low a pressure. When blood flow is present, but restricted, the cuff pressure, which is monitored by the pressure sensor, will vary periodically in synchrony with the cyclic expansion and contraction of the brachial artery it will oscillate. Figure below show the images of non invasive blood pressure monitoring.

Figure 2.9: Non Invasive Blood Pressure

2.5.4 Patient Monitor

Continuous measurement of patient parameters such as heart rate and rhythm, respiratory rate, blood pressure, blood-oxygen saturation, and many other parameters has become a common feature of the care of critically ill patients. When accurate and immediate decision-making is crucial for effective patient care, electronic monitors frequently are used to collect and display physiological data. Increasingly, such data are collected using non-invasive sensors from less seriously ill patients in a hospital's medical-surgical units, labor and delivery suites, nursing homes, or patients' own homes to detect unexpected life-threatening conditions or to record routine but required data efficiently.

Patient monitoring can be rigorously defined as "repeated or continuous observations or measurements of the patient, his or her physiological function, and the function of life support equipment, for the purpose of guiding management decisions, including when to make therapeutic interventions, and assessment of those interventions"[24]. Figure below show the patient monitor device.

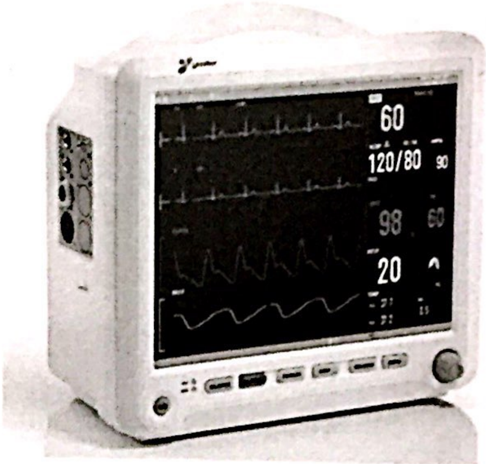

Figure 2.10: Patient Monitor Device

2.6 Sensor

The sensors are commonly used for blood pressure measurement pressure sensor. The pressure sensors are mostly used in all method of blood pressure measurement. The sensors are place with the cuff.

2.6.1 Pressure Sensor

Pressure sensors are commonly used in medical instrumentations to obtain information about the function and performance of an organ, group of organs, or system within the body. The complex nature of the organs being measured determines whether the sensor should be de- signed to be compatible with the organ geometry or whether measurement should be attempted extra corporally (i.e., outside the body). When designing sensors for medical instruments, factors such as anatomy, physiological function, and medical safety must be taken into consideration.

Pressure may be define as the force applied normal to a unit area. If the sensing area is known, a force sensor could be used to measure pressure provided the force is always applied over a constant area. In general, pressure sensor systems can be divided into three elements[25]:

1. The ''sensing element'' or ''transducer,'' which provides a physical interaction between the sensing material and the environment that alters its material properties.

2. The ''transduction mechanism'' inside the sensor structure, which converts the material property change into a useful signal that holds information about the environment-material interaction.

3. The display element where the output from the measuring system is displayed in an appropriate form

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will cover about the process and the method that used to make this project. Methodology plays an important role in executing the continuous blood pressure estimation. In this chapters, there will be covered to section which is software and hardware.

3.2 Design

This project will consist 2 parts which is hardware and software. This hardware consist Photoplethymograpic (PPG) sensor used to estimate the blood pressure from the subject, amplifier used to amplify the signal that gets from the PPG Sensor. Last part for hardware is used arduino to control the circuit and Espresso Lite used to transfer data from the circuit to the Laptop.

3.3 Hardware

In this project, the hardware has been used is PPG Sensor, amplifier, Bluetooth and lastly voltage regulator.

3.3.1 Photoplethymograpic (PPG) Sensor

The figure below show the Photoplethymosgraphy Sensor. Photoplethysmography (PPG) is a simple optical technique used to detect volumetric changes in blood in peripheral circulation. It is a low cost and noninvasive method that makes measurements at the surface of the skin. The technique provides valuable information related to our cardiovascular system. Recent advances in technology has revived interest in this technique, which is widely used in clinical physiological measurement and monitoring.

PPG makes uses of lowintensity infrared (IR) light. When light travels through biological tissues it is absorbed by bones, skin pigments and both venous and arterial blood. Since light is more strongly absorbed by blood than the surrounding tissues, the changes in blood flow can be detected by PPG sensors as changes in the intensity of light. The voltage signal from PPG is proportional to the quantity of blood flowing through the blood vessels.

Even small changes in blood volume can be detected using this method, though it cannot be used to quantify the amount of blood. A PPG signal has several components including volumetric changes in arterial blood which is associated with cardiac activity, variations in venous blood volume which modulates the PPG signal, a DC component showing the tissues' optical property and subtle energy changes in the body. Some major factors affecting the recordings from the PPG are site of measurement and the contact force between the site and the sensor. Blood flow variations mostly occur in the arteries and not in the veins[26].

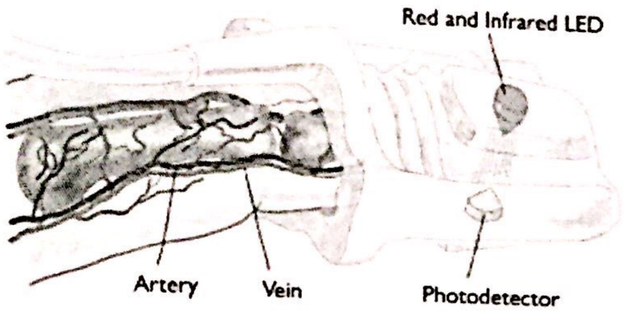

Figure 3.1 PPG Sensor

3.3.1.1 Light Wavelength PPG Sensor

The interaction of light with biological tissue can be quite complex and may involve scattering, absorption and/or reflection. Anderson and Parrish examined the optical characteristics and penetration depth of light in human skin within the visible region, the dominant absorption peak corresponded to the blue region of the spectrum, followed by the green-yellow region (between 500 and 600 nm) corresponding to red blood cells. The shorter wavelengths of light are strongly absorbed by melanin. Water absorbs light in the ultraviolet and longer IR regime; however, red and near-IR light pass easily. As a result, IR wavelengths have been used as a light source in PPG sensors. Blood absorbs more light than the surrounding tissue.

Therefore, a reduction in the amount of blood is detected as an increase in the intensity of the detected light. The wavelength and distance between the light source and photodetector (PD) determine the penetration depth of the light. Green light is suitable for the measurement of superficial blood flow in skin. Light with wavelengths between 500 and 600 nm (the green-yellow region of the visible spectrum) exhibits the largest modulation depth with pulsatile blood absorption. IR. IR or near-IR wavelengths are better for measurement of deep-tissue blood flow (e.g., blood flow in muscles).

Thus, IR light has been used in PPG devices for some time [6]. However, green-wavelength PPG devices are becoming increasingly popular due to the large intensity variations in modulation observed during the cardiac cycle for these wavelengths. A green LED has much greater absorptivity for both oxyhaemoglobin and deoxyhaemoglobin compared to infrared light. Therefore, the change in reflected green light is greater than that in reflected infrared light when blood pulses through the skin, resulting in a better signal-to-noise ratio for the green light source[26]. The figure below show the light wavelength PPG sensor.

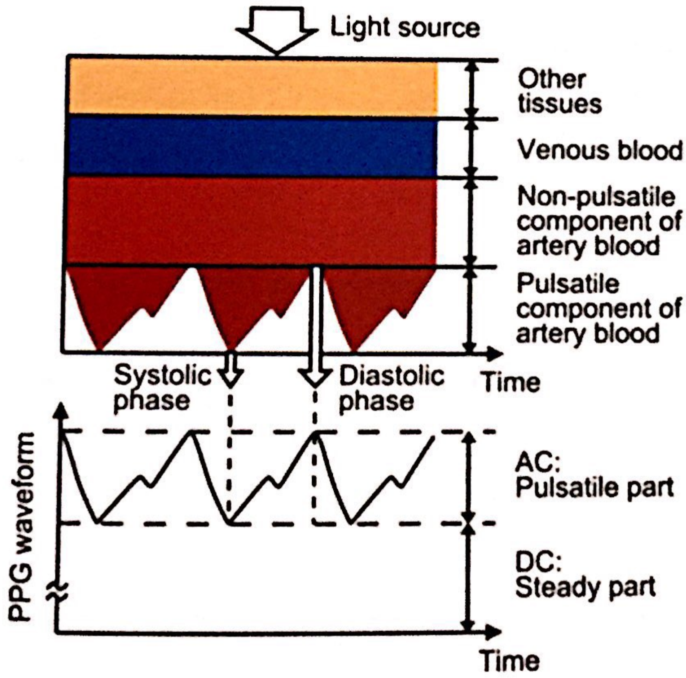

Figure 3.2: Light Wavelength PPG Sensor

3.3.2 Amplifier

The figure below shows the symbol of amplifier. An amplifier is used to increase the amplitude of a signal waveform, without changing other parameters of the waveform such as frequency or wave shape. They are one of the most commonly used circuits in electronics and perform a variety of functions in a great many electronic systems. They can be categorized as either *weak-signal amplifiers* or *power amplifiers*.

Weak-signal amplifiers are used primarily in wireless receivers. They are also employed in acoustic pickups, audio tape players, and compact disc players. A weak-signal amplifier is designed to deal with exceedingly small input signals, in some cases measuring only a few nanovolts (units of 10^{-9} volt). Such amplifiers must generate minimal internal noise while increasing the signal voltage by a large factor. The most effective device for this application is the field-effect transistor. The specification that denotes the effectiveness of a weak-signal amplifier is *sensitivity*, defined as the number of microvolt (units of 10^{-6} volt) of signal input that produce a certain ratio of signal output to noise output (usually 10 to 1).

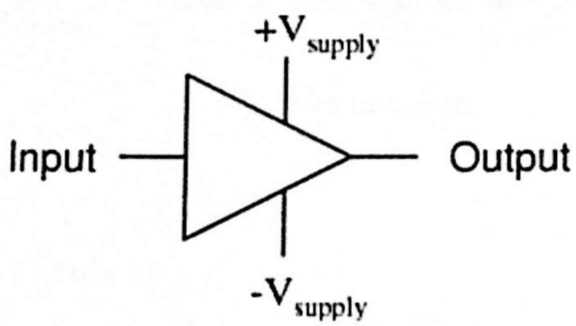

Figure 3.3 Symbol of Amplifier

3.3.3 Bluetooth

Figure below show the symbol of Bluetooth. Bluetooth is a standard used in links of radio of short scope, destined to replace wired connections between electronic devices like cellular telephones, Personal Digital Assistants (PDA), computers, and many other devices. Bluetooth technology can be used at home, in the office, in the car, etc. This technology allows to the users instantaneous connections of voice and information between several devices in real time. The way of transmission used assures protection against interferences and safety in the sending of information.

Between the principal characteristics, must be named the hardiness, low complexity, low consume and low cost. The Bluetooth is a small microchip that operates in a band of available frequency throughout the world. Communications can realize point to point and point multipoint.

Figure 3.4 Bluetooth

3.3.4 Voltage Regulator

Voltage regulator, any electrical or electronic device that maintains the voltage of a power source within acceptable limits. The voltage regulator is needed to keep voltages within the prescribed range that can be tolerated by the electrical equipment using that voltage[27]. Voltage regulators are a common feature in many circuits to ensure that a constant, stable voltage is supplied to sensitive electronics. How they operate is typical of many analog circuits, the judicious and elegant use of feedback to adjust theoutput to a desired level[28]. A voltage regulator is a voltage stabilizer that is designed to automatically stabilize a constant voltage level.

The figure below show the voltage regulator. A voltage regulator circuit is also used to change or stabilize the voltage level according to the necessity of the circuit. Thus, a voltage regulator is used for two reasons[29]:-

1. To regulate or vary the output voltage of the circuit.

2. To keep the output voltage constant at the desired value in spite of variation in the supply voltage or in load current.

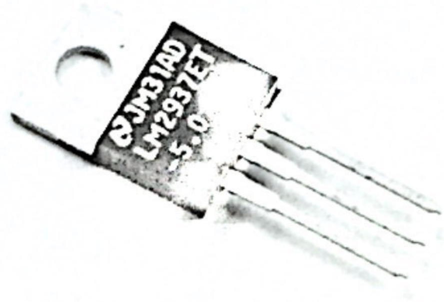

Figure 3.5: Voltage Regulator

3.3.5 Liquid Crystal Display (LCD)

LCD (liquid crystal display) is the technology used for displays in notebook and other smaller computers. Like light-emitting diode (LED) and gas-plasma technologies, LCDs allow displays to be much thinner than cathode ray tube (CRT) technology.

Liquid crystal display technology works by blocking light. Specifically, an LCD is made of two pieces of polarized glass (also called substrate) that contain a liquid crystal material between them. A backlight creates light that passes through the first substrate. At the same time, electrical currents cause the liquid crystal molecules to align to allow varying levels of light to pass through to the second substrate and create the colors and images that you see.

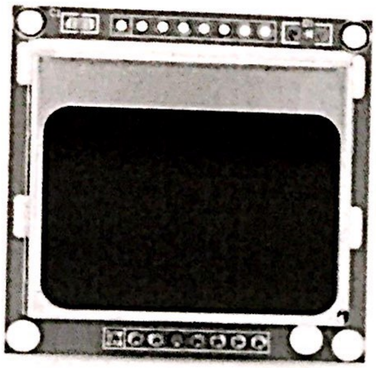

Figure 3.6: LCD

3.3.6 Design of Continuous Blood Pressure Measurement

This is a design of this project. This project can measure the blood pressure reading which is systolic, diastolic and heart rate. This project or focuses on systolic and diastolic. The figure below show the design of the project.

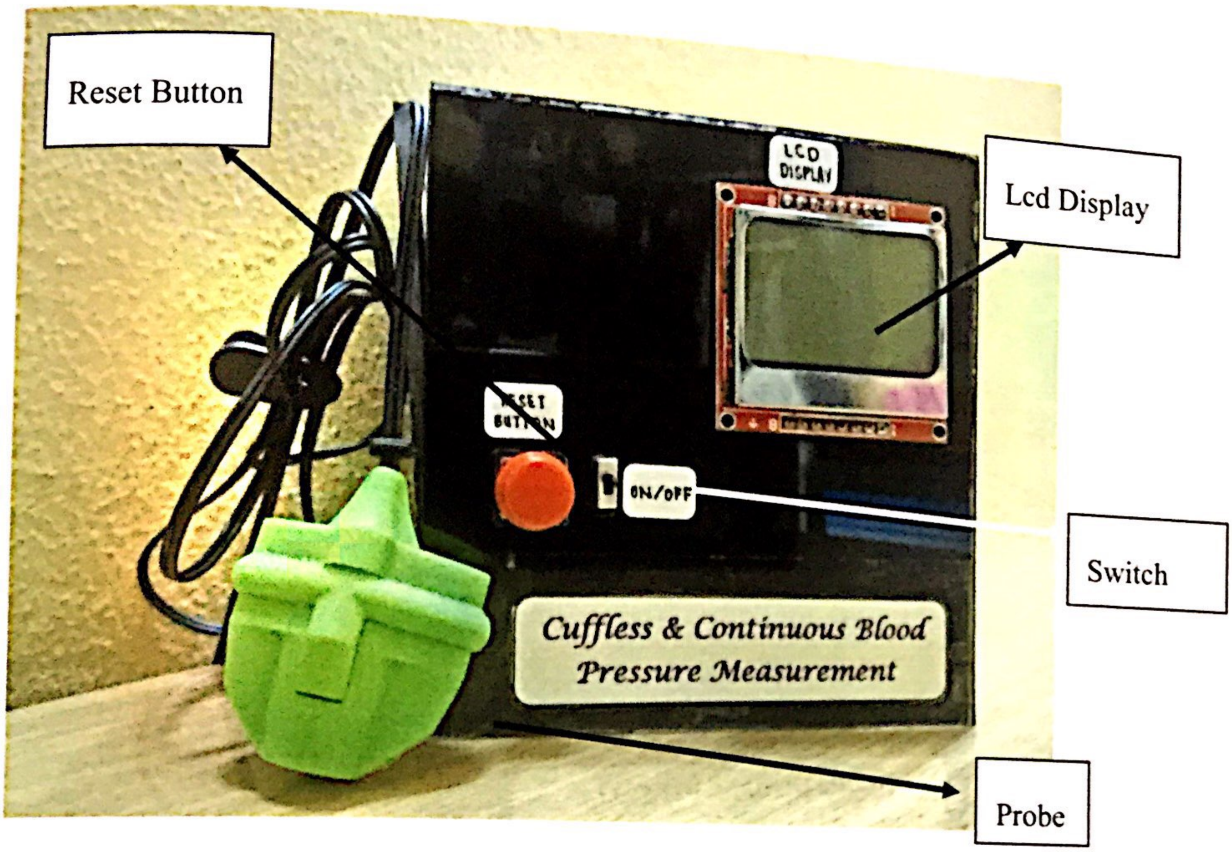

Figure 3.7: Design of the Project

3.4 Software

The software has been used in this project is matlab and arduino. This software is used to give instruction or to control the circuit and to get the reading while to display the output.

3.4.1 Arduino

Figure below show the symbol of arduino. Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board – 3 you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

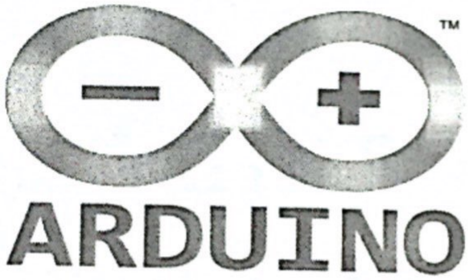

Figure 3.8 Arduino

3.4.2 Matlab

Figure below show the symbol of Matlab. The MATLAB platform is optimized for solving engineering and scientific problems. The matrix-based MATLAB language is the world's most natural way to express computational mathematics. Built-in graphics make it easy to visualize and gain insights from data. A vast library of prebuilt toolboxes lets you get started right away with algorithms essential to your domain. The desktop environment invites experimentation, exploration, and discovery. These MATLAB tools and capabilities are all rigorously tested and designed to work together.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

Figure 3.9 Matlab Software

3.5 Flow Chart

This project consist 2 flowcharts which is flow chart of overall project and the second is flow chart of continuous blood pressure. This flow chart will explain the flow or step during do this project.

3.5.1 Flow Chart of Overall Project

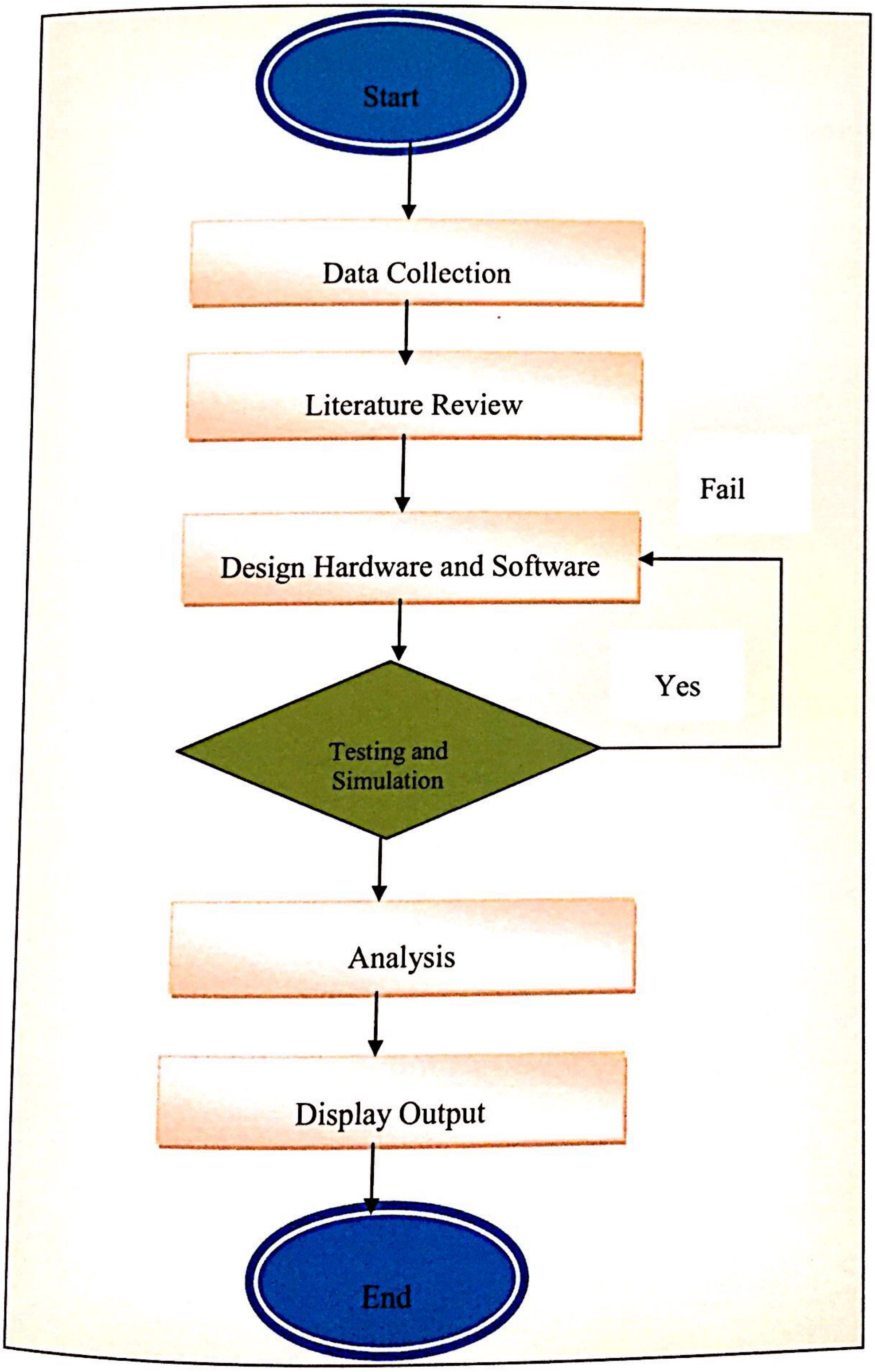

Figure 3.10 Flow Chart of Overall Project

Flow chart above show how these projects implement. At the first, data collection are collected to recognize the problem statement, objective, scope of project and significant of project. After identify the chapter 1, literature reviews are important to enhance the knowledge about this project. The sources for this literature review are from the journals and articles. After that, designation hardware and software should be discussed with supervisor. After get the endorsement about what a design should be to this project, the testing and simulation will be run to get a data. If fail, recheck back at the software and hardware, if success proceed to the data analysis and display the result.

3.5.2 Flow Chart Continuous Blood Pressure Estimation

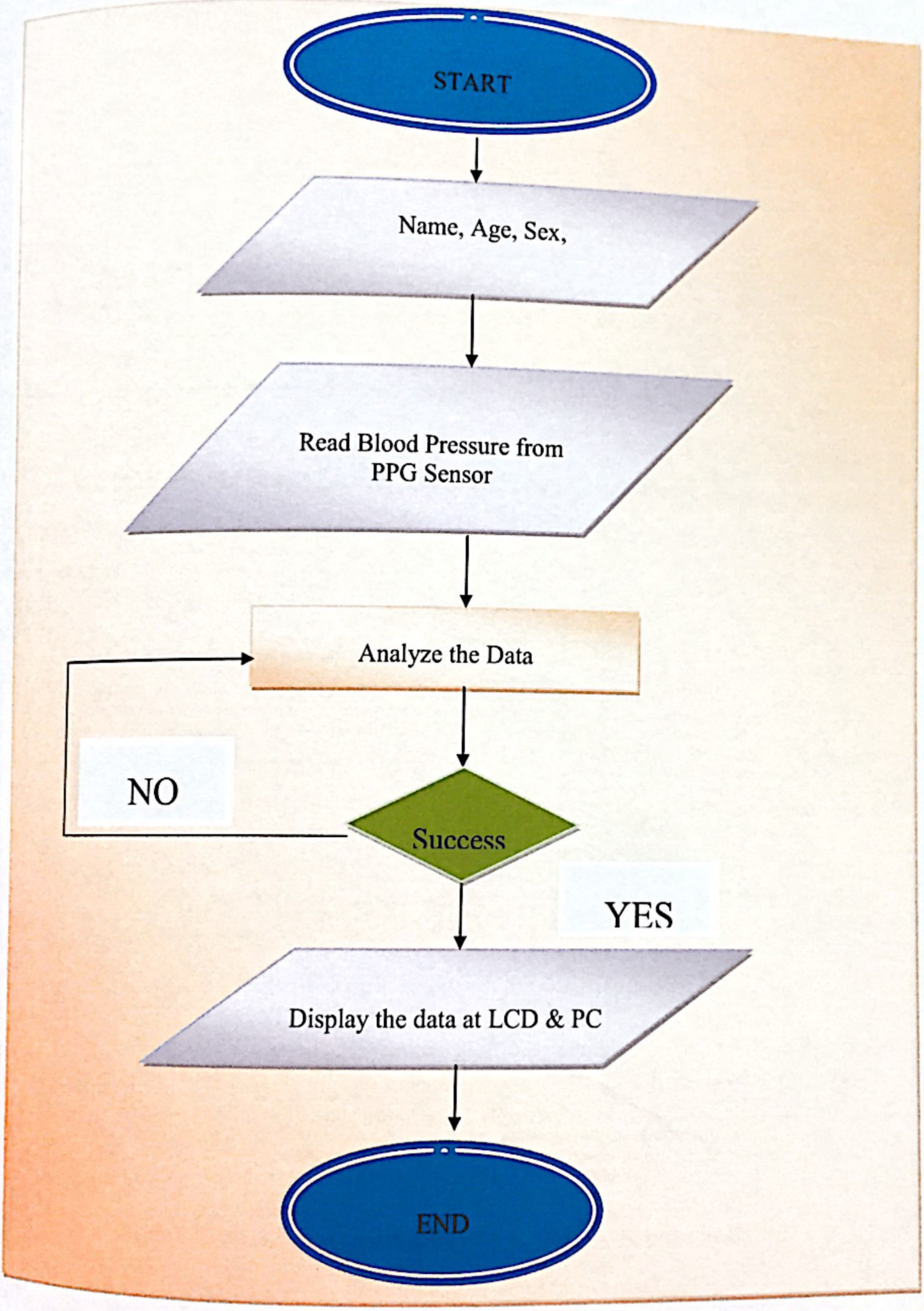

Figure 3.11 Flow Chart Continuous Blood Pressure Estimation

Flow chart above show how this continuous blood pressure works. First, the data of subject will insert to the laptop. After that, the PPG Sensor wills the read the continuous blood pressure from finger. After PPG read the continuous blood pressure from finger data will be analyze and display at the laptop.

3.6 Block Diagram

This project consists of block diagram. This block diagram is show the all component has been used in this project such as PPG Sensor, Voltage Regulator, Arduino, Bluetooth, LCD and Laptop. These components are selected because of their function.

3.6.1 Block diagram of project

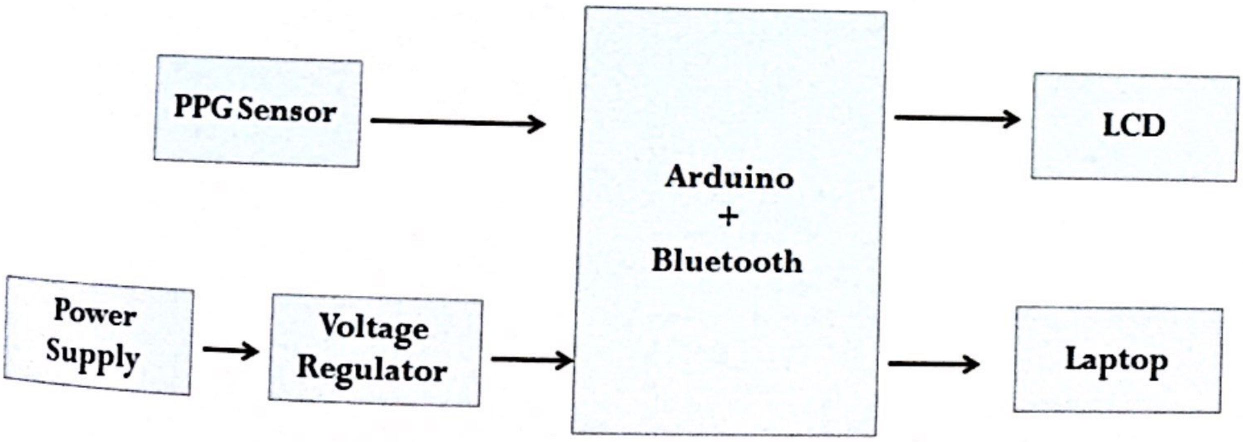

Figure 3.12 Block Diagram of Continuous Blood Pressure Estimation

Block diagram above will explain the scheme of this project. The important component that is used in this project is a Photoplethymograpic (PPG) Sensor. The detection of the blood pressure signal is based on using optical measurement technique called photoelectric plethysmography (PPG). This technique has the ability to detect the volume of blood pressures in the arteries. The PPG basic form utilizes two components: a light source to illuminates a part of the tissue (e.g. fingertip) and a photo detector to receive the light. Transparency of living tissue to light makes it possible for some part of the light from the source to pass through the tissue to the photo-detector. From the PPG signal pass to amplifier. After the sensor detected the changes in the volume of blood pressures, a low frequency and low magnitude biopotential signal is received by the photodiode. As the detected PPG signal is so weak, it must undergo some signal conditioning amplifying so that it can be used for further processing. Since the output voltage of the photo-detector has a large amount of dc component which requires a amplifier to suppress out the dc component The output of the signal conditioning stage is fed into a microcontroller where it is processed (sampling and quantizing). The Arduino microcontroller is used in this system. The microcontroller then displays the measured blood pressure information in Laptop and transmits them through a Bluetooth device to any stationary enabled computer device.

CHAPTER 4

RESULT AND DISCUSION

4.1 Introduction

This chapter showed the result from data collection such as questionnaire and data analyzed and generated graph and value by using Matlab. And then the result will be discussed in this chapter. Therefore the analysis will conducted through survey to get a feedback about this project. Beside that the data get will be compare the existing device.

Before develop this project, questionnaire is a one of method to data collection. Questionnaires are distributed to public and medical staff. Ten questionnaires are distributed to the public and twenty questionnaires are distributed to medicals staff. Medical staff included nurses, doctor and medical assistant. In this questionnaire, seven questions have been asked. Question are included are common knowledge, preferable checking, familiarize, simplifying tasking, improve health, and one additional question for medical staff which is implementing device.

4.2.1 Data analysis for Medical Staff

These surveys are distributed to medical staff. From the data obtain 19 staff or 95% prefer to check their blood pressure own self. Only 9 staff or 45% of them are known that blood pressure can get from heart sound. Third, 19 staff 0r 95% agree that the device can help to simply doctor's and nurse's job. Lastly, 19 staff or 95% also agree that the device can improve their health and lead to a better and 19 staff or 95% are needed to monitor continuous blood pressure.

Table 4.1 Result of Questionnaire (Medical Staff)

Question No.	Answer	
	YES	NO
3 (Preferable)	19	1
5 (Familiarize)	9	11
6 (Simplifying)	19	1

7 (Improve Health)	19	1
8 (Needed)	19	1

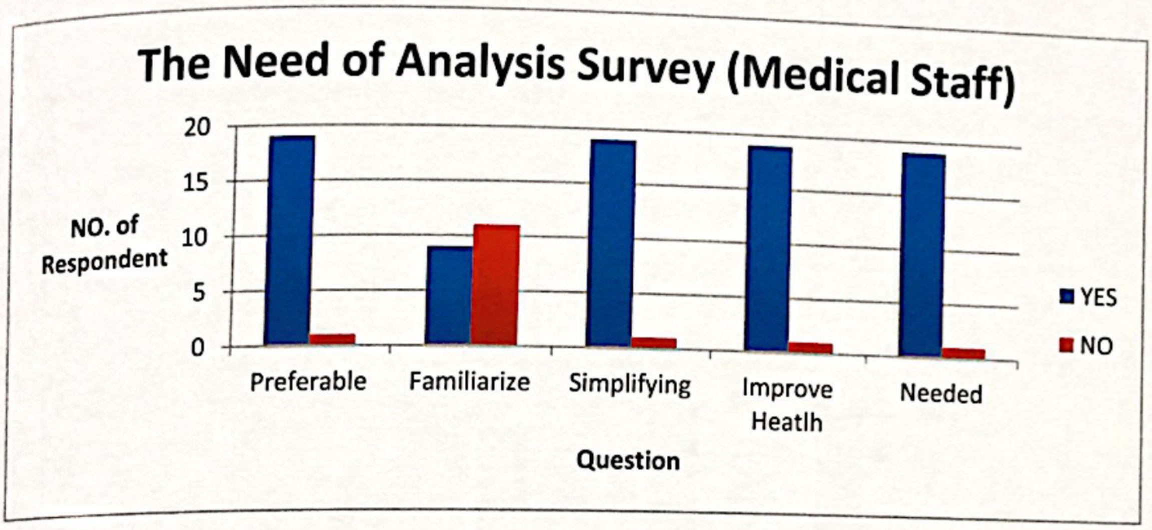

Figure 4.1 Graph the Need of Analysis Survey (Medical Survey)

4.2.2 Data analysis for Public

This survey was distributed to public. From the analysis based on table and graph, 7 respondent or 70% have knowledge about what is blood pressure. Second, 9 respondent or 90% are preferred to check the blood pressure by own self. Lastly, all respondent or 100% are agreed to the implementation a device to check blood pressure and all respondent or 100% agree this device can improve to health and lead to a better lifestyle.

Table 4.2 Result of Questionnaire (Public)

Question No.	Answer	
	YES	NO

4 (Knowledge)	7	3
7 (Preferable)	9	1
8 (Implementing Device)	10	0
7 (Improve Health)	10	0

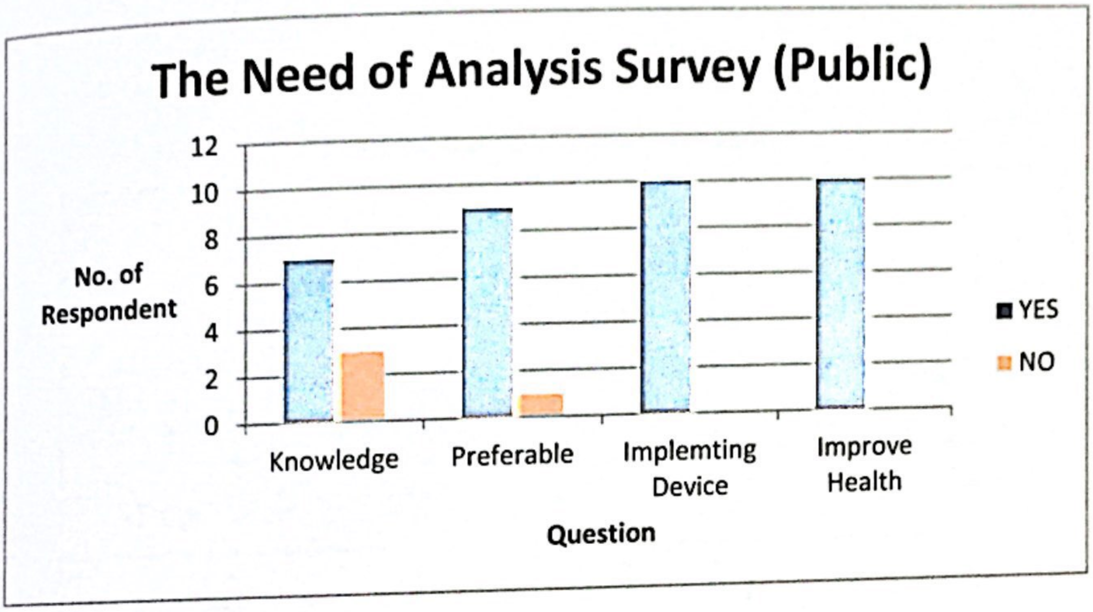

Figure 4.2 The Need of Analysis Survey (Public)

4.3 Post Survey

After these projects are finished, questionnaires are distributed to the respondents to get their feedback bout this project. Twenty questionnaires are distributed to public. This questionnaire consist three sections. Sections A consists are general question, sections B consists are evaluation and sections C consists are review question.

4.3.1 Data Analysis Section A

These surveys are distributed to the public. From the analysis based on graph, 17 people are agree that the device a suitable to use. Second, only 5 people are familiarizing with the devices, and all people understand the function of these devices. Next, 16 people are Preferable to buy this device own self. Lastly, 18 people agree this device is very helpful in improving their lifestyle.

Table 4.3 Data Analysis of Section A

Question No.	Answer	
	Yes	No
Suitable	17	3
Familiarize	5	15
Understanding	20	0
Preferable	16	4
Helpful	18	2

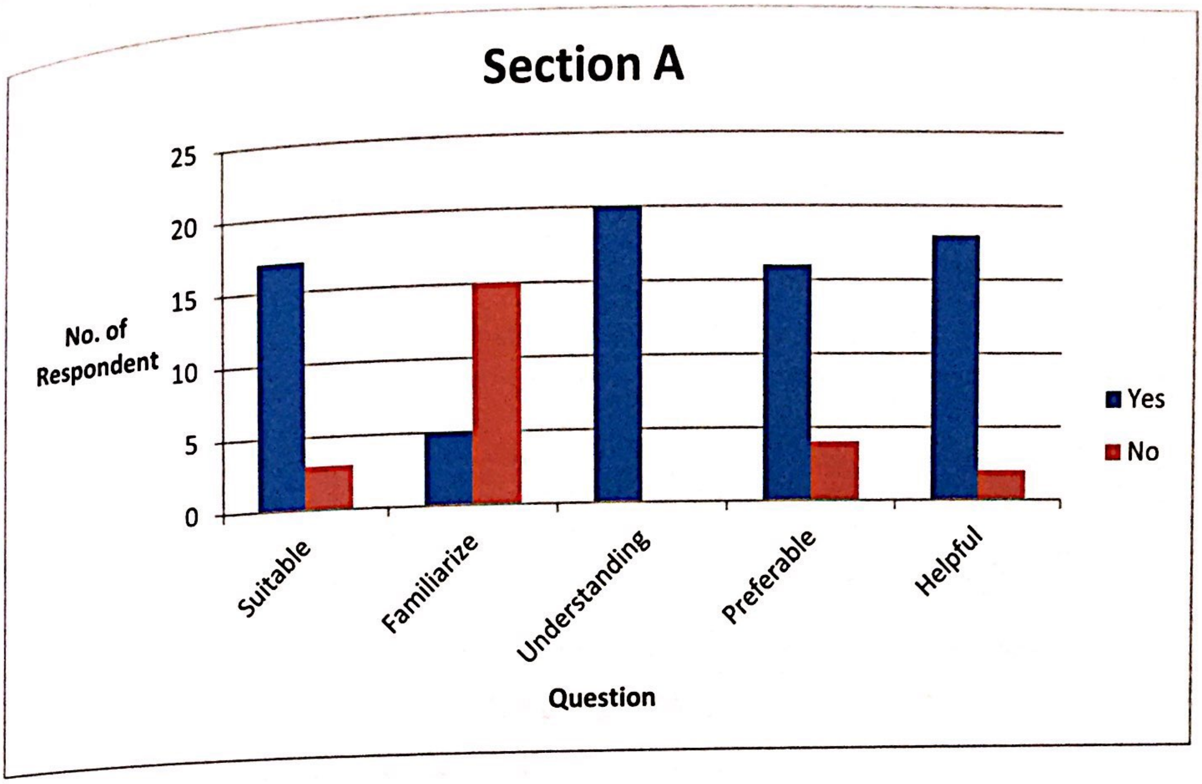

Figure 4.3 Graph Analyses for Section A

4.3.2 Data Analysis on Section B

These surveys are distributed to the public. From the analysis based on graph, 18 people are very satisfied and 2 people are somewhat satisfied that the device a convenient to used. Second, only 12 people somewhat satisfied and 8 people are neither satisfied with the reading. Next, all people are very satisfied that the device are safety to used. 10 people are very satisfied and 10 people somewhat satisfied if this device placed in our market. For minimize time the graph shows slightly same between somewhat satisfied and neither satisfied.

Table 4.4 Data Analysis Section B

Question No.	Scales				
	5	4	3	2	1

Convenient	18	2			
Accurate		12	8		
Safety	20				
Market	10	10			
Minimize time		10	10		

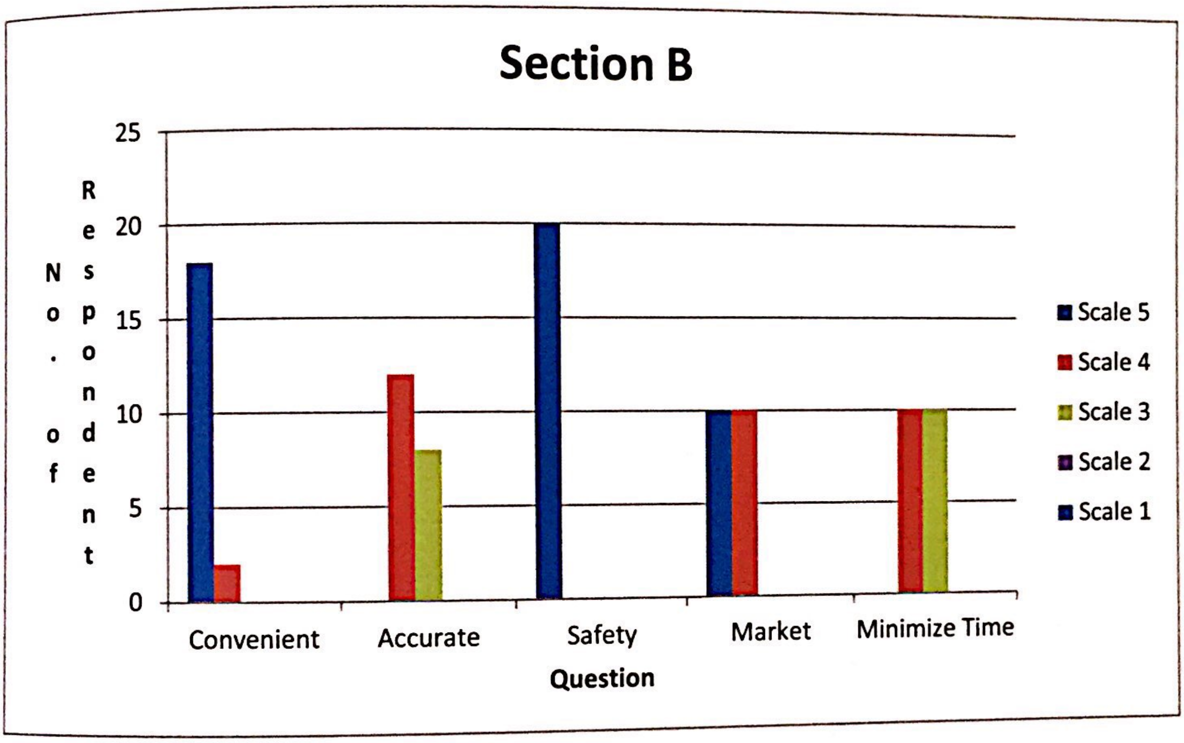

Figure 4.4 Graph Analyses on Section B

4.3.3 Data Analysis on Section C

These surveys are distributed to the public. From the analysis based on graph, 15 people are strongly agreed and 5 people are agreed that enjoy used the device. Second, only 13 people strongly agreed and 7 people agreed that the devices are safety to use. Next, 5 people strongly agree, 10 people are agreed and 5 people neutral about who want to purchase this device. Lastly, graph show the slightly increase for agreed that this device come more benefit to user.

Table 4.5 Data Analysis Section C

Question no.	Rate				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Enjoy				5	15
Safety				7	13
Purchase			5	10	5
Benefit				18	2

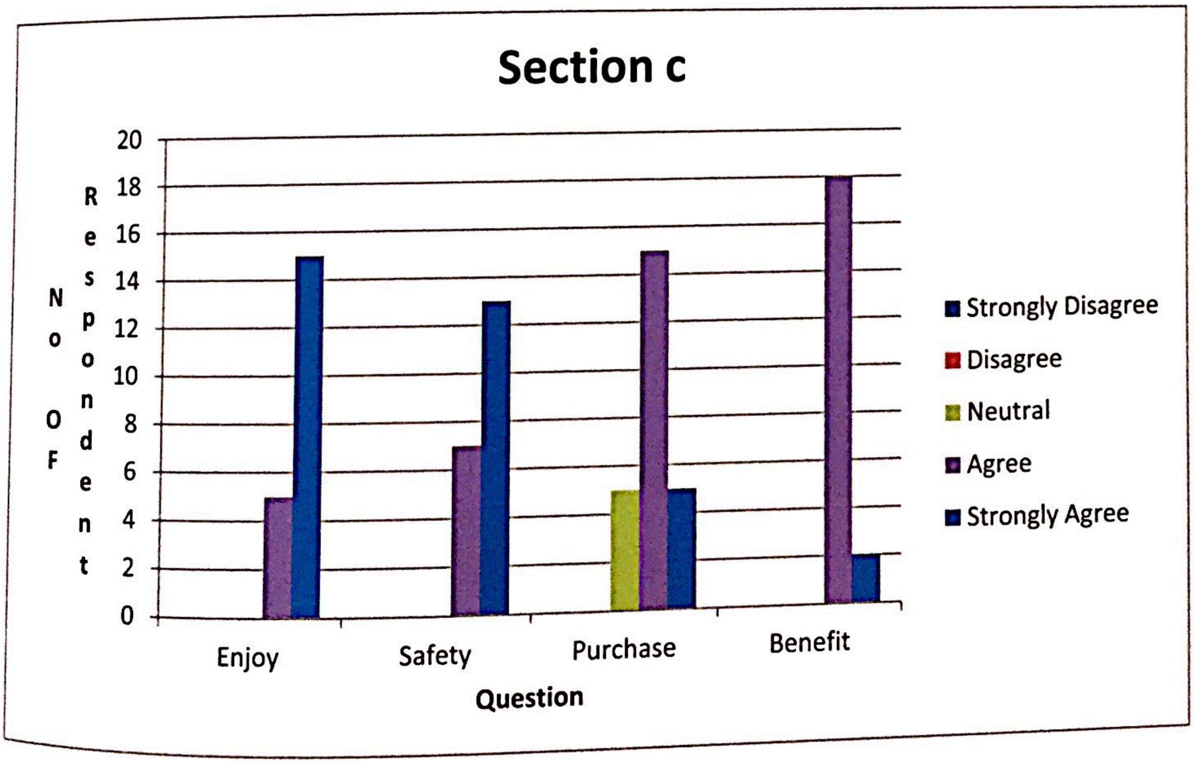

Figure 4.5 Graph Analysis Section C

4.3 Data Collection

Once the prototype is complete, the prototype must be test to carry out on the product to find out whether a product is built to function or not. Whereas, the purpose of this testing was identify whether the product work well executed as planned. The test will be conducted and the data will be compared with existing device.

4.3.1 Comparison between Existing Device and Continuous Blood Pressure Measurement (CBPM).

The data in the table below show the comparison between the existing device and the CBPM. Based on the table below, the graphs are develops to analyze the data. The reading have be taken at the index finger. In this data, the reading is higher is 130 for systolic and 87 for diastolic. The lower reading in this data is 99 for systolic and 74 for diastolic.

Table 4.6: Comparison of Existing and CBPM (Index Finger)

No. of respondent	Existing Device		CBPM	
	Blood Pressure Reading		Blood Pressure Reading Index Finger	
	Systolic	Diastolic	Systolic	Diastolic
1	124	77	119	78
2	101	79	101	79
3	120	82	125	85
4	109	70	110	72

5	112	80	112	80
6	126	70	120	71
7	124	79	119	80
8	99	62	100	65
9	120	81	125	81
10	127	86	130	90
11	111	76	120	85
12	100	73	99	74
13	125	81	128	84
14	110	72	117	78
15	124	84	127	85
16	121	82	123	83
17	119	78	120	80
18	119	83	118	84
19	123	87	130	87
20	106	67	108	67

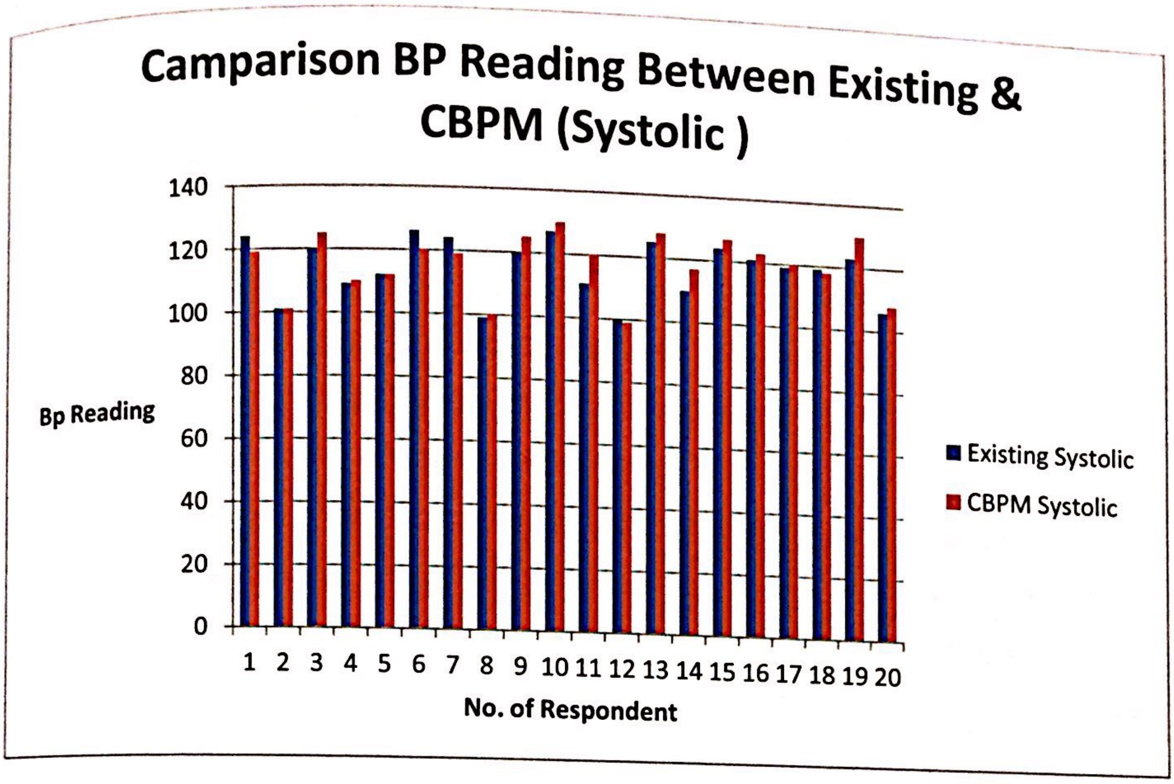

Figure 4.6: Comparison Bp Reading between Existing & CBPM (Systolic)

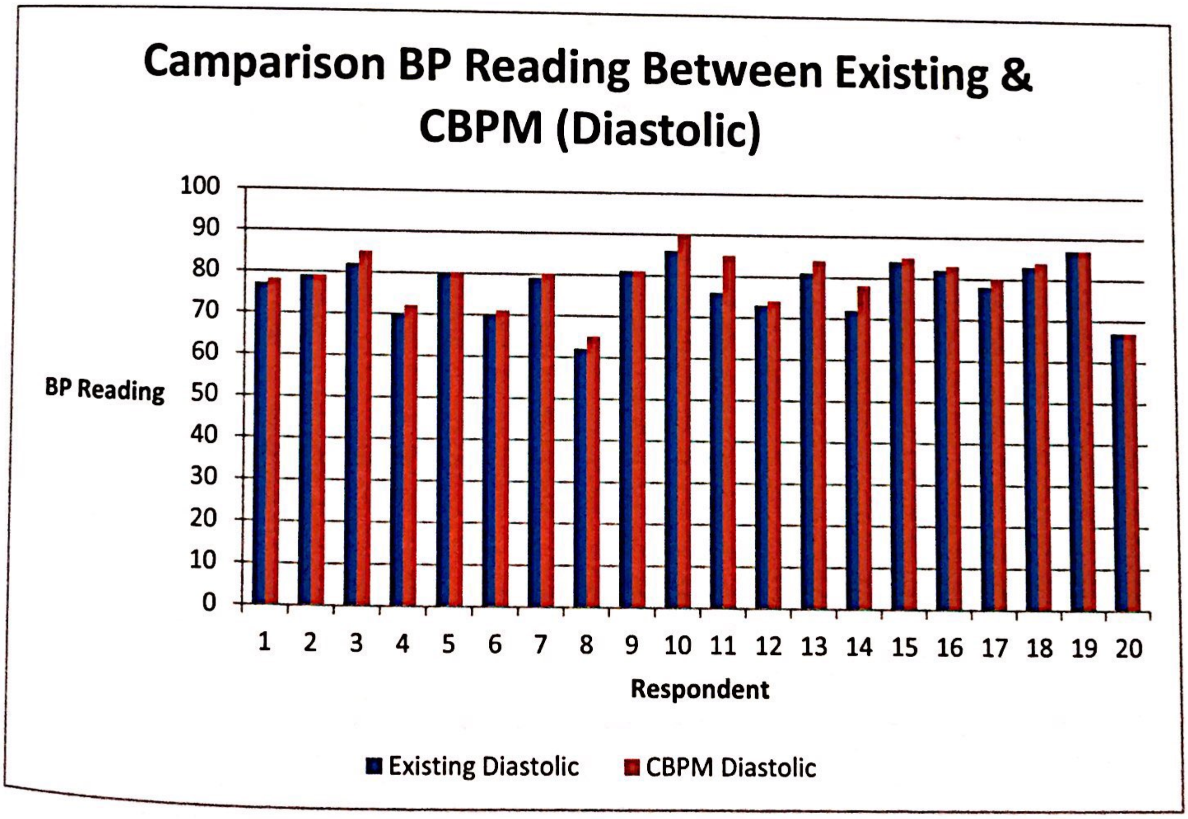

Figure 4.7: Comparison the Reading between Existing & CBPM (Index Finger)

4.3.1.1 Different Value Percentage Index Finger (Systolic & Diastolic)

The data below show the accuracy percentages of systolic. In this data, only 2 data is accurate compare to the other data. The accuracy of the data is affected by the environment factor and the position of respondent when the data it's collected. . In this data, 5 respondents get the accurate reading in the diastolic reading. As mention before, there are several factor affected the reading of blood pressure.

Table 4.7: Different Value percentage (systolic)

No.	Accuracy	
	Systolic	Diastolic
1	95.8	98.7
2	100.0	100.0
3	95.8	96.3
4	99.1	97.1
5	100.0	100.0
6	95.2	98.6
7	96.0	98.7
8	99.0	95.2
9	95.8	100.0

10	97.6	95.4
11	91.9	88.2
12	99.0	98.6
13	97.6	96.3
14	93.6	91.7
15	97.6	98.8
16	98.4	98.8
17	99.2	97.4
18	99.2	98.8
19	94.3	100.0
20	98.1	100.0

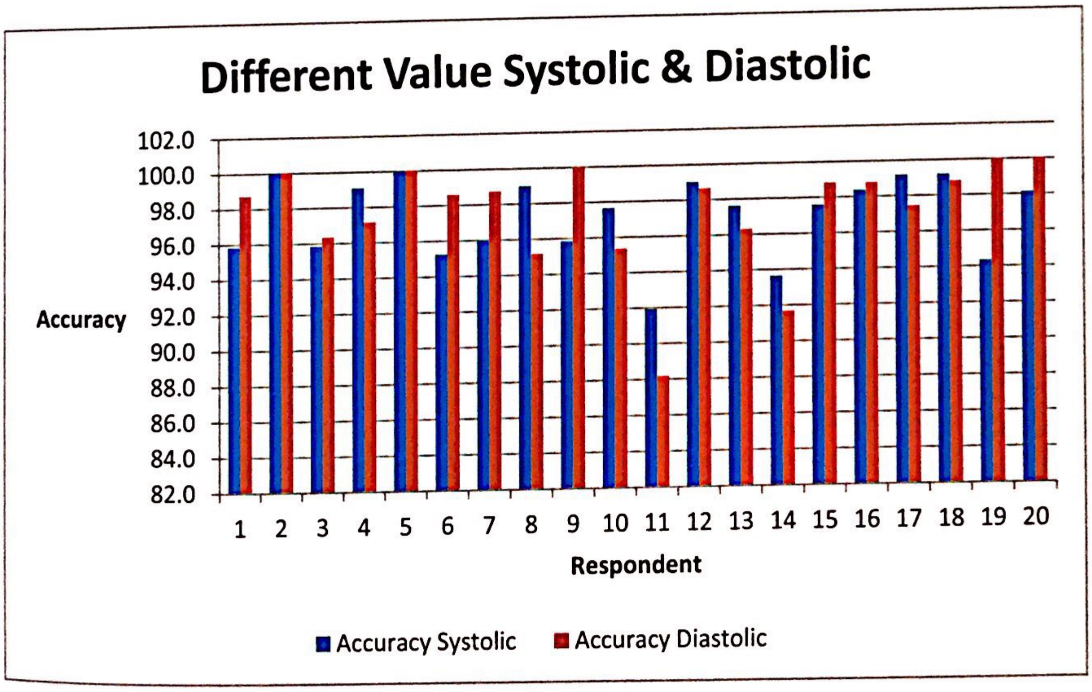

Figure 4.8: Different Value Systolic & Diastolic (CBPM)

4.3.2 Comparison between Existing Device and Continuous Blood Pressure Measurement (CBPM) at Thumb.

The data in the table below show the comparison between the existing device and the CBPM. Based on the table below, the graphs are develops to analyze the data. The reading have be taken at the thumb. In this data, the reading is higher is 127 for systolic and 62 for diastolic. The lower reading in this data is 99 for systolic and 74 for diastolic.

Table 4.8: Comparison between Existing Device and Continuous Blood Pressure Measurement (CBPM).

No.	Existing Device		Prototype	
	Blood Pressure Reading		Blood Pressure Reading Thumb	
	Systolic	Diastolic	Systolic	Diastolic
1	124	77	120	78
2	101	79	105	80
3	120	82	120	82
4	109	70	110	72
5	112	80	112	80
6	126	70	120	71
7	124	79	120	81
8	99	62	99	62

9	120	81	120	81
10	127	86	128	85
11	111	76	111	76
12	100	73	107	75
13	125	81	120	83
14	110	72	110	72
15	124	84	119	87
16	121	82	121	82
17	119	78	116	80
18	119	83	118	83
19	123	87	123	87
20	106	67	109	70

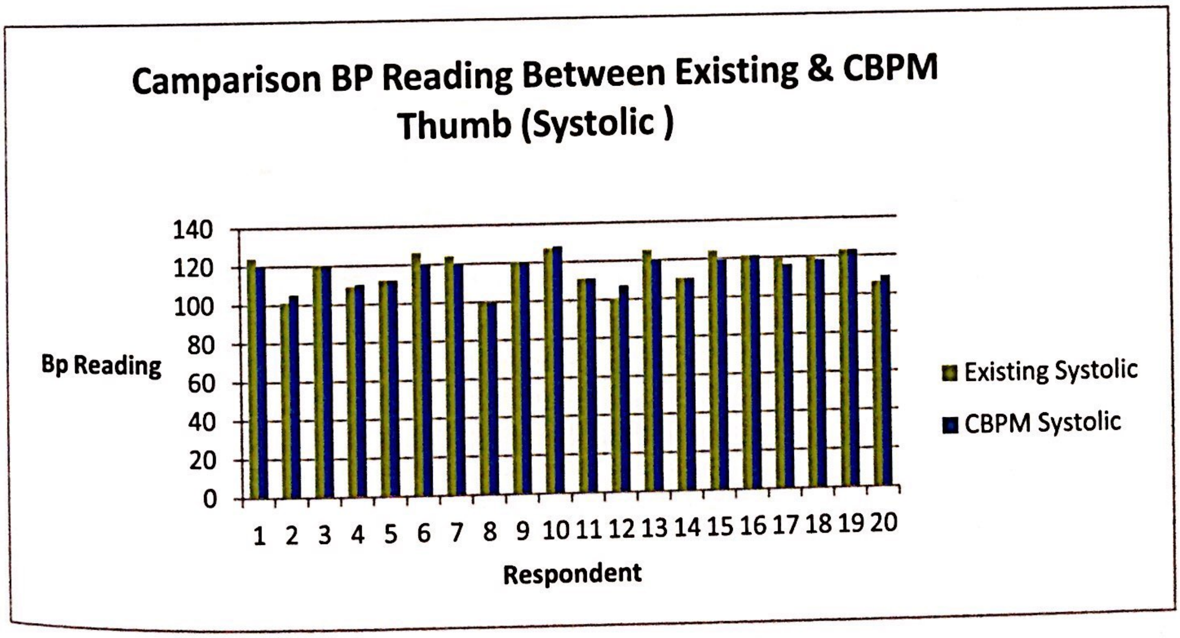

Figure 4.9: Comparison Bp Reading between existing & CBPM Thumb (Systolic)

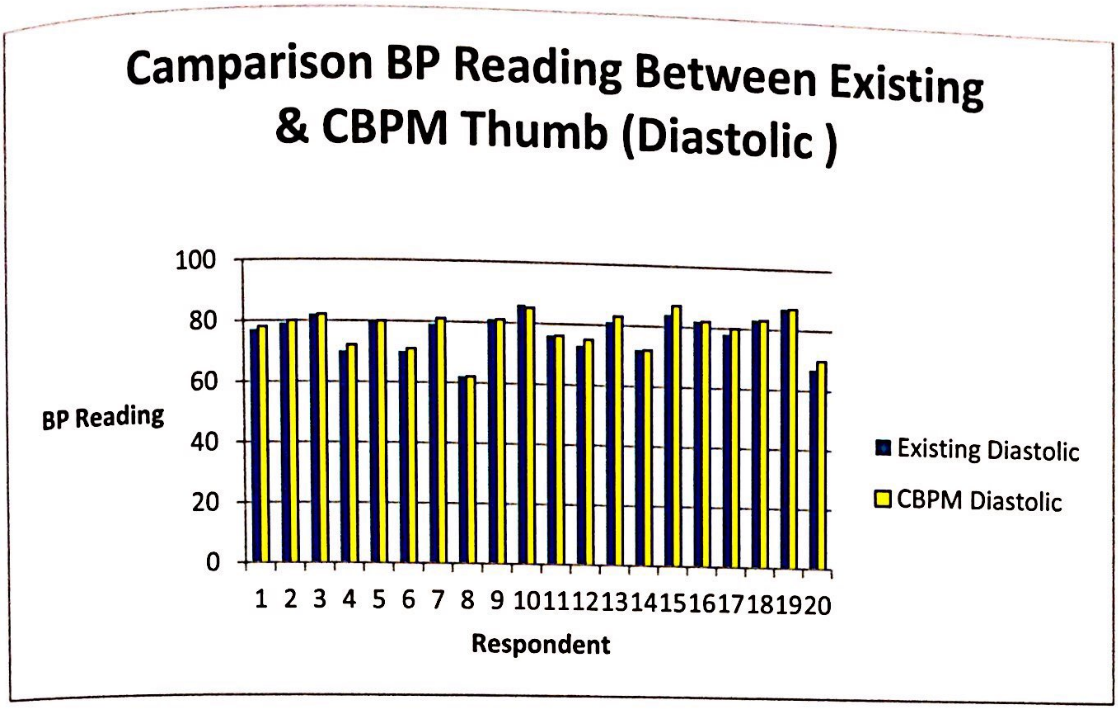

Figure 4.10: Comparison Bp Reading between existing & CBPM Thumb (Diastolic)

4.3.2.1 Different Value Percentage Index Finger (Systolic & Diastolic)

The data below show the accuracy percentages of systolic. In this data, only 6 respondents is accurate compare to the other data. The accuracy of the data is affected by the environment factor and the position of respondent when the data it's collected. . In this data, 6 respondents get the accurate reading in the diastolic reading. As mention before, there are several factor affected the reading of blood pressure.

Table 4.9: Accuracy Systolic & Diastolic (Thumb)

No.	Accuracy Systolic	Accuracy Diastolic
1	96.77	98.7
2	96.04	98.73
3	100	100
4	99.08	97.14
5	100	100
6	95.24	9857
7	96.77	97.47
8	100	100
9	100	100
10	99.21	98.84
11	100	100
12	93	97.26
13	96	97.53
14	100	100
15	95.97	96.43
16	100	100
17	97.48	97.44
18	99.16	100
19	100	100

20	97.17	95.52

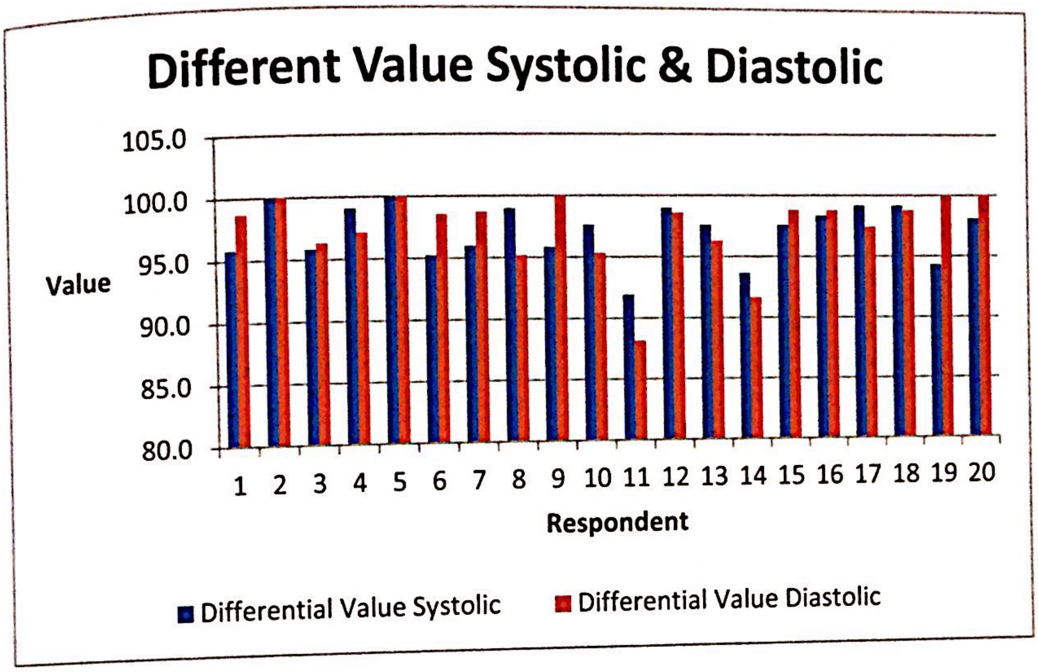

Figure 4.11: Different Value systolic (Thumb)

4.4 Comparison between Existing Device and CBPM

These projects have several different between existing devices. The different between this project (CBPM) and existing devices is the method uses, the sensor are used, the reading taking is continuous or not and the placement to get the reading. Refer the table below to see the differences between these devices.

Table 4.10: The differences between Existing device & CBPM

Existing		CBPM
Old Method	Method	New Method (Volume Clamp)
Pressure Sensor	Sensor	PPG Sensor
Not Continuous	Reading	Continuous
Arm	Place Take Reading	Finger

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter will cover the overall of this project. Besides that, this chapter will conclude all of this project and this project are achieved the objective or not. In this chapter also discusses about the future recommendation of project.

5.2 Conclusion

This project is developed an optical sensor system used to wavelength of light for the measure the relative change in pulse blood pressure volume in tissue. The non invasive optical measurement method is based on radiation of blue and near infrared light, emitted by Light Emitting Diode (LED) with range 650nm to 940nm. This sensor used reflectance sensor contain infrared light source. Light source illuminates a part of tissue and photodetactor receive the returning light.

The detection blood pressure signal based on optical measurement technique called photoelectric plethysmography (PPG). After sensor detect the change in volume of blood pressure, low frequency and low magnitude biopotential signal received by photo detector. PPG signal weak, it must undergo some signal conditioning (amplifier/filter) can be used for further processing.

The signal was amplified and acts to microcontroller. Personal Laptop will be display the value and graph of blood pressure. Data will be collected and data analysis will do to compare the accuracy of device. Signal acquisition by this is totally noninvasive. The sensor assemble in this investigation are fully integrated into wearable finger cuff.

Furthermore, in order of objective is to create a device with friendly user. This project is non –invasive device, where patient can easily monitor their reading. Moreover, the patient can easily bring this device because it is a portable. Lastly this project are achieved all objective in chapter 1.

5.2 Recommendation

After finished this project and the survey have been done, many comment and recommendation are suggested. It's because many people are not familiar with this device compare to existing devices. There is little recommendation for this project which is additional of indicator. Normally, ordinary people or who not in medical field not know their normal reading of blood pressure. It also will be an early warning to avoid any risk of disease. Besides that, existing device only display the reading of blood pressure and not display either it is high blood pressure or low blood pressure. Recommendation of this project is to combine three parameter which is heart rate, blood pressure and spo2. It's because this parameter used the same sensor and same wavelength.

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Appendix

Coding

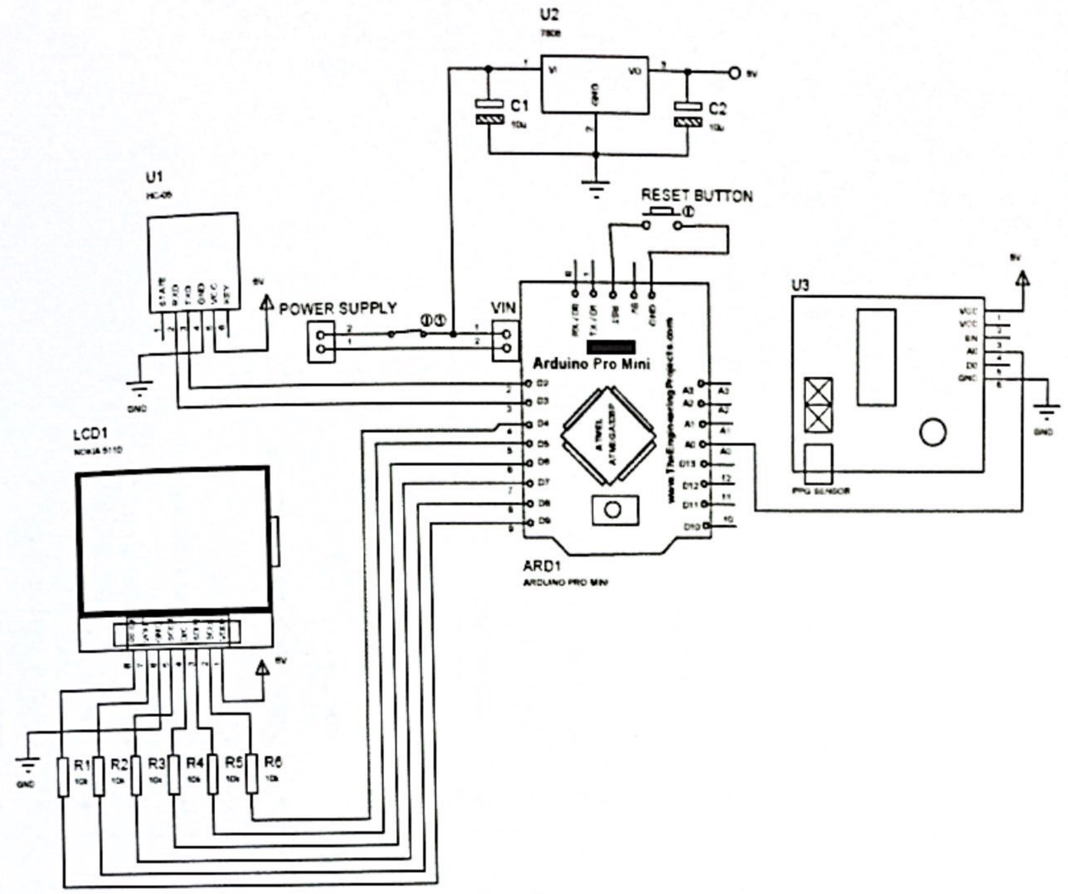
```
#include <SPI.h>

#include <Adafruit_GFX.h>

#include <Adafruit_PCD8544.h>

#include<SoftwareSerial.h>



SoftwareSerial bluetooth(3, 2);//rx,tx on arduino

Adafruit_PCD8544 display = Adafruit_PCD8544(4, 5, 6, 7, 8, 9);



#define INTERRUPT_PIN 2

#define LOGO16_GLCD_HEIGHT 16

#define LOGO16_GLCD_WIDTH  18



float sensorValue = 0;

int total = 0;

int averange = 0;

String reading;



void setup() {

  Serial.begin(115200);
```

```
bluetooth.begin(9600);
display.begin();
display.setContrast(50);
delay(500);
display.clearDisplay();
display.setRotation(2);
display.setTextSize(2);
display.setTextColor(BLACK);
display.setCursor(26, 8);
display.println("BPM");
display.setCursor(10, 27);
display.println("SYSTEM");
display.display();
delay(1000);
display.clearDisplay();


// while(1) {
// sensorValue = analogRead(A0);
// Serial.println(sensorValue);
// delay(500);
//}


}
```

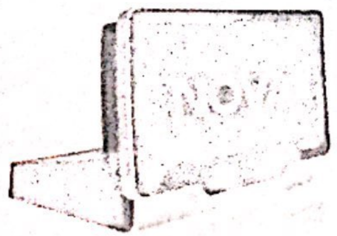
```
void loop() {
 for (int j = 0; j < 150; j++) {
  for (int i = 0; i < 20; i++)
  {
   sensorValue = analogRead(A0);
  }
  //     sensorValue += analogRead(A0);
  //     delay(2);
  //   }
  //   sensorValue = sensorValue / 20;
  //       if (sensorValue < 700) {
  //         sensorValue = 300;
  //       }
   Serial.println(sensorValue);
   bluetooth.println(sensorValue);
   reading = bluetooth.read();
  }
  display.setRotation(2);
  display.setTextSize(2);
  display.setTextColor(BLACK);
  display.setCursor(10, 10);
  display.println(reading);
```

```
display.display();

delay(2000);

display.clearDisplay();

}
```

Circuit Diagram



No.	Type	Description	Parameter	Advantages
1	 FINOMETER MIDI	• For hemodynamic trending in protocols when blood pressure changes are more important than absolute values. • Data can easily be stored on the laptop or network. Data can be transferred to patient files and other systems. • Export data to statistical programs and other database programs like Microsoft Excel easily	• Blood Pressure (BP) • Heart rate (HR) • Inter beat interval(IBI) • Cardiac output (CO) • Stroke volume(SV) • Baroreflex sensitivity (BRS) • Total peripheral resistance (TPR) • Max. steepness of current upstroke (dp/dt) • Left ventricle ejection (LVET)	
	 FINOMETER PRO	• Non-invasive, FINGER TIP, stationary blood measurement and beat-to-beat hemodynamic monitoring system. • captures the continuous blood pressure waveform	• Cardiac Output (CO), • Stroke Volume (SV), • Total Peripheral Resistance (TPR), • Pulse Rate Variability (PRV) • BaroReflex Sensitivity (BRS).	

	 **FINAPRESS NOVA**	• Presents a module for non-invasive accurate measurement of blood pressure and cardiac output values.	• Blood pressure (BP) • Heart rate (HR) • Inter beat interval (IBI)	
	 **PORTAPERS**	• offers standard ambulatory blood pressure monitoring (ABPM) and displays hemodynamic parameters	• Blood pressure (BP) • Heart rate (HR) • Inter beat interval (IBI) • Cardiac output (CO) • Stroke volume (SV) • Pulse rate variability (PRV) • Baroreflex sensitivity (BRV) • Total peripheral resistance (TPR) • Total arterial compliance (CwK) • Max. steepness of current upstroke (dp/dt) • Ascending aortic impedance (Zao) • Left ventricular ejection time (LVET) • Pate pressure product (PS*HR) •	

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A Survey of Final Year Project

This project is cuff less and continuous blood pressure monitoring which measure blood pressure. After the blood pressure is measured it transmits wirelessly to a phone. The significant of this project is an essential parameter for the diagnosis and treatment. Daily monitoring of blood pressure is also important to prevent the disease among normal people. Besides that, this project gives information to user for awareness of low blood pressure and high blood pressure.

Gender: (   ) Male   (   ) Female

Age: _____ Years

Occupation: _______________

1. Do you have any disease?

   (   ) Yes: _______________

   (   ) No

2. In general, how would you rate your overall health?

   (   ) Excellent   (   ) Very Good   (   ) Good

   (   ) Fair   (   ) Poor

3. How long have you been going to your doctor?

   (   ) Less than 6 months   (   ) At least 6 month

   (   ) At least 1 year   (   ) At least 3 years

   (   ) 5 years and more

4. Do you know what blood pressure is?

   (   ) Yes   (   ) No

5. Typically how often do you monitor your blood pressure?

( ) Once a week ( ) More than once a week

( ) Less than once a month ( ) don't know

6. How is your blood pressure reading

   ( ) Normal ( ) Lower ( ) Higher

7. As a user, do you prefer to check your blood pressure by yourself?

   ( ) Yes ( ) No

8. Are you agreed if a new device is implementing to monitor your blood pressure by yourself?

   ( ) Yes ( ) No

9. As a user, do you think this device can improve your healthcare and lead you to a better lifestyles?

   ( ) Yes ( ) No

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SURVEY QUESTIONNAIRE- CUFFLESS & CONTINUOUS BLOOD PRESSURE MONITORING

DISCLAIMER:

This survey is based on final year project of Bachelor of Electronic Engineering (Medical Electronic). The name of this device is Cuffless & Continuous Blood Pressure Monitoring. The aim of this survey is to understand the device after the pre-survey is done. It can be helpful to improve and to enhance the device in the future. All the data will be recorded and analyzed.

CONSENT:

I have read and understood all the information written above. My participation in this survey is voluntary and I am willing to share necessary information for this survey.

This survey is divided into three sections. Section A, B and C.

SECTION A

1. Are you found this device is suitable to use?
   ( ) Yes

   ( ) No

2. Are you familiar with this device?
   ( ) Yes

   ( ) No

3. Do you understand the function of this device?
   ( ) Yes

( ) No

4. If this device in market, do you prefer to have it?
   ( ) Yes

   ( ) No

5. Is this device is suitable to use and help in determine the high blood pressure
   ( ) Yes

   ( ) No

SECTION B

Directions: Please check and rate yourself honestly based on what you actually do given the statements using the following scales:

5 - Very satisfied 4 - Somewhat satisfied 3 - Neither satisfied 2 - Somewhat dissatisfied 1- very dissatisfied

NO	STATEMENTS	5	4	3	2	1
1	Is this device convenient to use?					
2	Is this device gives the accurate readings?					
3	Can this device is safe to use to user?					
4	Do you agree if this device placed in market of our country?					
5	Do you prefer if this device cam minimize the time taken?					

SECTION C

Please rate how strongly you agree or disagree with each of these statements.

Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I enjoy using this product.					
This product is safe to use.					
I would purchase this product.					
This product brings more benefit to user.					

Recommendation / Comments:

Signature,

Position: (Doctor / Nurse/ User)

Date: