DESIGN OF LOW COST BLOOD PRESSURE MONITOR FOR RURAL POPULATION

By

MOHAMAD SUFIAN BIN AYUB

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Universiti Teknologi Petronas

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

DESIGN OF LOW COST BLOOD PRESSURE MONITOR FOR RURAL POPULATION

by

Mohamad Sufian bin Ayub

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

____

Assoc. Prof Dr. Fawnizu Azmadi Hussin

Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June or December 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

MOHAMAD SUFIAN BIN AYUB

ABTRACT

In this modern area, oscillometric blood pressure monitor has been widely used in medical equipment, replacing the traditional manual sphygmomanometer, which using the detection of Korotkoff sound to measure blood pressure. The oscillometric blood pressure monitor has been applied being subject of many studies due to its simplicity of use and low price. Oscillometric method of measuring blood pressure is done through the record of cuff-pressure oscillation. The systolic blood pressure and diastolic blood pressure is determined through the value of maximum cuff-pressure oscillation (Amax), or also known as mean arterial pressure (MAP). This paper present the building of oscillometric blood pressure monitor with manual pumping mechanism. Firstly the signal is detected by pressure sensor MPX5050GP, and then filtered by OP amp LM324N. after that, the filtered and amplified signal will be sampled by the microcontroller PIC18F2321. The calculated blood pressure will dispayed in term of ‘pass’ and “fail’ through the lighting of LED.

ACKNOWLEDGEMENTS

First and foremost, I would like to extend my gratitude to ALLAH for His blessing and guidance in order for me to complete this Final Year Project entitled ‘Design of Low Cost Blood Pressure Monitor for Rural Population’ throughout this 8 months.

The completion of this project would not have been possible without the hard work and endless support for those who involved either directly or indirectly in this report. Firstly, I would like to thank my supervisor Assoc. Prof Dr. Fawnizu Azmadi Hussin for taking his time off his busy schedule to assist me in completing my final year project. Thank you also for his encouragement and valuable advices throughout period of conducting this project. All of his effort in providing me sufficient useful guidelines to ensure I can complete my project in the given time, were really appreciated by me.

Special thanks to my friend, Mr. Shafiq Ashraf for his help during the fabrication of this project and troubleshooting, as well as giving me the opportunity to learn new knowledge. Without his help, it would be really hard for me to complete this project.

Lastly, I would like to express my biggest thanks to my parent, who always pray for my best and always support me whenever I faced obstacles throughout completing of this final year project. I surely hopes that the outcome of this project may benefit to others as well.

Thank you.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 : INTRODUCTION

1.1 BACKGROUND STUDY

Our heart is an amazing organ in our body. It work reliably, and it has been safely pumping blood to each organ in our body for decades. The blood is transported throughout our body through blood vessels. If the heart is considered as pump, the blood vessels will be considered as pipes [1]. A blood pressure monitoring is a crucial way for us to check the performance of these pump and pipes.

Blood pressure is means by the pressure exerted on the wall of blood vessel by the blood circulation, due to the pumping action of the heart. The blood pressure may be varied between human and animal, and it is normally taken for two types of measurements. The two types of measurements are for the minimum pressure (diastolic) and maximum pressure (systolic) [1] . Different reading of blood pressure for both systolic and diastolic will determine the health condition of a person. Too low record of blood pressure will conclude that the person to suffer from hypotension and too high blood pressure record will be considered the person to suffer from hypertension.

It is important for us to monitor the blood pressure regularly; so that immediate action could be taken it early symptom of undesired blood pressure is detected. Nowadays, many blood pressure monitoring devices could be purchased in the market, but to have a cheap or low cost blood pressure monitor will be an issue. With the advancement of technology, the blood pressure monitor could be obtained from the concept of manual mechanism, to the automatic mechanism with the help of electronic devices.

1.2 PROBLEM STATEMENT

In the urban area, most of the people lived inside it are consist of people with education and career. Furthermore, the urban area is equipped with a lot of facilities, including hospital. For this kind of person, in case that they want to seek for medical checkup or advice from the doctor, they will go by themselves to the hospital by their own transport or by the public transports which can be easily get in the urban area. Plus, since they are consisting of careered person, most of them are affordable to pay for the medical expenses.

Unfortunately, in the scope of Malaysia, Malaysian citizen are also consisting of poor people who live alone, single mother, and old people, and they are live in the rural area. For all this poor people who live in this rural area, they might aware of their health condition, but they may be reluctant to seek for medical checkup in hospital, as they poor health condition prevent them to travel, or they do not have transport to go there, or they are not affordable to pay the medical expense. In addition, it might be difficult for them to obtained the public transport due to the population in rural area. As the government and non-government hospital aware about this matter, their management has put some effort in approaching the people in this rural area, but sometimes they might face some difficulties to entertain every villages in one rural area.

Due to this problem, the body of Corporate Social Responsibility of Universiti Teknologi PETRONAS (UTP-CSR) has been collaborated with the local hospital under the Malaysia Ministry of Health to held a social service with the local resident outside the university campus. The main target resident for this event is the folks of Kampung Aji, Bota, Perak. The majority folks living in the village were consist of old people, with some of them with poor health condition.

The duty of volunteer of UTP-CSR was to do the scheduled medical checkup on the residents, including doing the blood pressure monitoring. As to purchase the existing blood pressure monitor devices in the market is considered as costly, UTP-CSR has plan to invent our own blood pressure monitor device that is low cost, and easy to use. The design of the device will be done, in such way that it will be easy for the untrained volunteers to use it to measure blood pressure, without much expertise.

1.3 OBJECTIVES

1. To invent a low cost blood pressure monitor device
2. To create a blood pressure monitor that is easy to be used by the person who is untrained in measuring blood pressure.

1.4 SCOPE OF STUDY

There are two types of blood pressure monitors (or also known as sphygmomanometer) that widely used and available in the market nowadays. The type of blood pressure monitors are manual blood pressure monitor and automatic blood pressure monitor. For the manual blood pressure monitors, there are two common types of it, which is mercury sphygmomanometer and aneroid sphygmomanometer. For the automatic blood pressure monitor, the measurement of the blood pressure was done by two methods, which is automated auscultatory method and oscillometric method.

Most of blood pressure monitors available in the market nowadays are the one that provided with the hand cuff. The hand cuff is used to wrap the upper arm in order to apply pressure for the blood pressure measurement. However, there are also non-invasive blood pressure monitor that does not require the hand cuff for the blood pressure measurement. This non-invasive blood pressure monitor is normally consisting of small cuff that is used by placing it around the wrist or fingertip. The mechanism is the same with the one that is used in normal automatic oscillometric blood pressure monitor, but in term of accuracy, this type of blood pressure monitor has faced some issues.

Mercury blood pressure monitor is consisting of a high vertical column with mercury contained inside it, a hand cuff and also the bulb. The mercury-filled column is used as the pressure gauge. The bulb is used to manually pump air inside the hand cuff in as the hand cuff is placed around the upper arm. The measurement of the blood pressure is done by using auscultatory method. The blood pressure is determined by examining the height of the mercury inside the column, as response to the pressure applied to the hand cuff. For the aneroid blood pressure monitor, the mechanism and the method of measurement is the same with the one that is used in mercury blood pressure monitor, but the pressure gauge is replaced with barometer dial.

The electronic blood pressure monitor is consisting of some sensors and other electronic parts, depending on the method used in device. The pumping mechanism of the air inside the hand cuff is automatically done with the combination of the mechanical part electronic part of the blood pressure monitor. The blood pressure is determined through some electronic calculations. The reading of the blood pressure is displayed by using electronic display.

CHAPTER 2 : LITERATURE REVIEW

2.1 HISTORY OF BLOOD PRESSURE MONITOR

The history of blood pressure monitoring was started at 1733, when Reverend Stephen Hales started to explore his study in animal physiology, by measuring the blood pressure in several animal species. Most famously, he has inserted a long tube, which was made up from glass, upright into an incision in an artery of a horse. In this experiment, it has been realized that the pumping action of the horse’s heart generated a pressure force that causing the blood to flow and rise into the glass tube. In advance, Hales also took wax casts of the ventricle of the heart, and estimated how much blood has been pumped by the heart. This method has been correctly describing the function of mitral valve and aortic valve during systolic and diastolic, which later has been widely used in the medical world up until today. Nevertheless, these procedures were dangerous to be applied on humans, due to the risk of excessive blood loss and infections.

In 1854, a new discovery that contribute to the innovation of blood pressure monitoring was made when Karl von Vierordt, a German physician, create a mechanism called sphygmograph that was used to estimate blood pressure. The mechanism was consist of some weight and levers. Through this invention, he discover that a non-invasive blood pressure reading could only be taken of the pulse was stopped. This research has been followed up by Samuel Ritter von Basch, a doctor from Vienna. In 1881, he started to create a simple design of sphygmomanometer that consist of rubber bulb filled with water and a vertical column of glass filled with mercury; called mercury manometer. The rubber bulb was attached to the mercury manometer. The manometer was used to measure the pressure exerted by the fluid, which is equal to the amount of pressure to obviate the pulse. The recorded pressure required was known as the blood pressure reading.

The blood pressure monitoring begins to improvise when the Russian surgeon, Nikolai Sergeyevich Korotkov (romanised as Korotkoff) describes the ‘Korotkoff sound’ through the auscultatory technique. This technique was done by wrapping the air-filled cuff around the patient upper arm. As the cuff is inflated, it will constrain the blood arteries, thus preventing the blood from flowing through the arteries. As the cuff is deflated back, the arteries will be release and the blood will started to flow back. With the help of the stethoscope, the beginning of the blood flow could be heard as the cuff is deflating. This method has led to the increase of accuracy of blood pressure measurement. This auscultatory technique also has been widely used by the next generation of the clinician up until present days.

2.2 METHOD OF MEASURING BLOOD PRESSURE

Nowadays, the method of blood pressure monitoring has been evolved and enhanced from day to day. The method of the blood pressure measurement as explained above is known as auscultatory method. This method is depends to the ability of the human ear to detect and distinguish the Korotkoff sound with other sound sourced from the surrounding environment [2]. Thus, for the accurate result, measurement needed to be done in a quiet environment. This method may be advantage as it allows clinician or doctor to control the quality of the measurement. However, the hearing ability and acuity might be different between clinicians, hence the measurement might be varies.

For many years, mercury blood pressure monitor has been the standard instrument for measuring the blood pressure monitor in the National Health and Nutrition Examination Survey (NHANES)[3]. However, in recent years, the usage of the mercury has been issued by environmentalists. It is because of the increased environmental concerns about the disposal of mercury-contaminated medical waste and the risk of spills from mercury blood pressure monitor. Due to this matter, the clinical settings have begun phasing out the mercury devices.

From the traditional auscultatory method, the manual mechanism of blood pressure monitor has been evolved to the better solution, which is automatic mechanism of blood pressure monitor. In the automatic blood pressure monitor, the continuity of the auscultatory method is done through the automatic detection of Korotkoff sound. The audio signal will be detected by the microphone inside the cuff, which is then converted into electric signal before it is amplified and filtered by the band pass filter and the low pass filter[4]. The signal is then calculated by the electronic in the blood pressure monitor through some algorithms, before the final result of systolic and diastolic blood pressure is displayed on the screen. The pumping mechanism for inflation and deflation of the cuff is also electronically controlled.

The other method used in the automatic blood pressure measurement is oscillometric method. The oscillometric blood pressure monitor is composed of few electromechanical parts, a servomotor-based air pump, and electronic valve (with permanent leakage, only opened to deplete the cuff) and the inflatable cuff[5]. It has almost the same part compare to the electronic blood pressure monitor that use automated auscultatory method. This oscillometric method relies on the pressure oscillation in the hand cuff, and also with the help of algorithm to calculate the 'systolic' and 'diastolic' blood pressure. It does not require accurate placement on the cuff on the upper hand, nor expert clinician to take the measurement. Nevertheless, since it depends to the brachial artery oscillation and vessel stiffness, it may lead to inaccurate measurement for old people. In addition, there are much more hybrid devices used in the blood pressure monitoring such as aneroid sphygmomanometer and some other devices that use photoplethysmographic or tonometric technique.

2.3 THEORY

In this project, the target is to produce a blood pressure monitor that requires the lowest manufacturing cost. The initial proposal of this project was to build mercury blood pressure monitor, as the materials needed to build it were cheap, except the raw mercury. Unfortunately, the usage of mercury might lead to the hazardous chemical waste that will finally contribute to the pollution of the environment. In addition, the usage of mercury might expose us to the chemical contamination, due to the improper handling of the mercury during the development of the prototype. Hence, due to the stated problem, the best option to be chosen is to create a blood pressure monitor based on electronic mechanism.

The proposed design was to make an electronic blood pressure monitor, which is safer and less pollution to the environment. The prototype of this project will be built from scratch. The overall design of this prototype was inspired by the basic electronic blood pressure monitor design, as shown in figure 1, except that the pumping mechanism of the hand cuff is changed to the manual mechanism, instead of automated mechanism. As to meet the objective of this project, all of the components that will be used will be set to have as low cost as possible.

The electronic part in the blood pressure monitor is consisting of voltage regulator, pressure sensor, transducer, OP amp (which is later to be used to build band pass filter and low pass filter), signal conditioning and microcontroller. The pressure sensor will measure the pressure exerted by the cuff during the inflation and deflation of the cuff. The oscillation of pressure in the cuff measured by the pressure sensor is then converted into electrical signal by the transducer. The electrical signal produced by the transducer will be very small; hence it needed to be amplified by the amplifier contained in the signal conditioning. The amplified signal with go through the band pass filter and low pass filter to filter the unwanted noise. The signal of the recorded pressure from the pressure sensor will be sent to the microcontroller. The microcontroller will compute the blood pressure value before it is displayed.

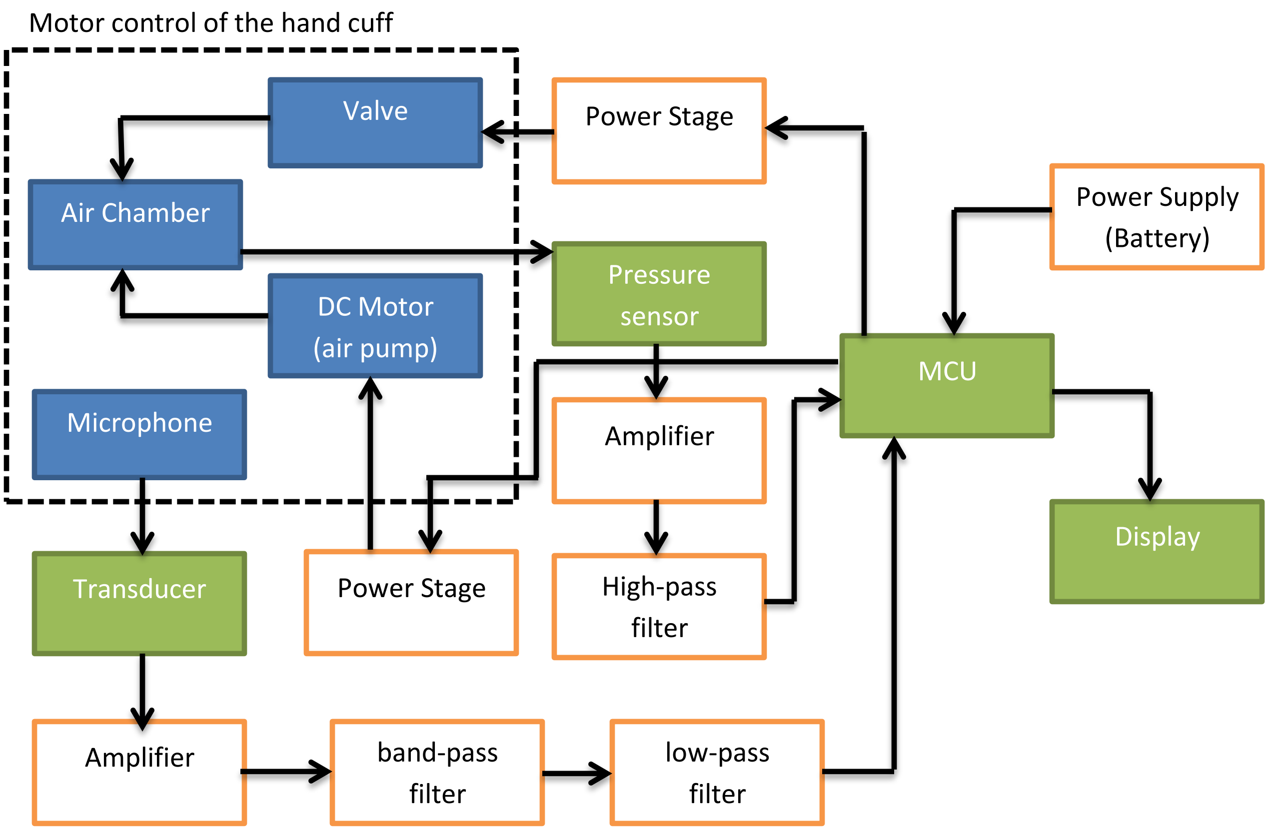


Figure 1: Basic electronic blood pressure monitor reference design block diagram. This design is created by referring to the *Freescale Medical Application. [6]*

In the process of blood pressure measurement, the system blocks brachial artery blood flow by inflating the cuff. When the hand cuff is deflating, the blood is resuming to flow, causing the wall of the artery to vibrate again. The vibration of the artery walls will be change from weak to strong and then become weak again[7]. Thus, the amplitude of the pulsatile oscillations increases to some degree and then decreases as blood flow to the limb normalized. In order to calculate the blood pressure using the oscillometric method, the value for the peak amplitude (Amax) need to be obtained[8]. According to the relationship of the blood pressure value and Amax, the systolic and diastolic blood pressure can be obtained.

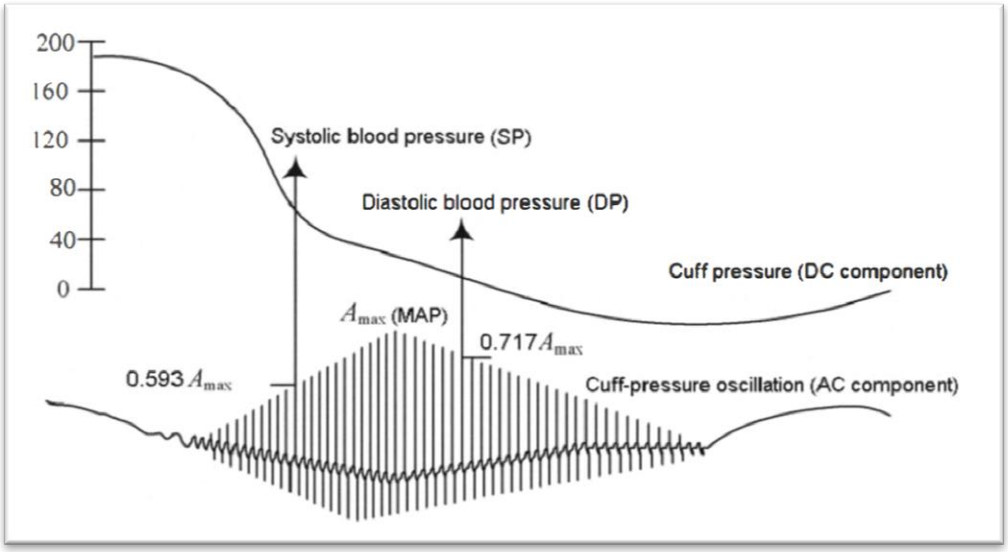


Figure 2 : Mark of systolic and diastolic blood pressure. The ratio taken in respect to Amax for both systolic and diastolic blood pressure may be varying between different manufacturers of blood pressure monitor.

At the same time, the voltage values of cuff pressure signal need to be converted to the corresponding blood pressure[7]. The blood pressure is then calculated by the electronic system in the blood pressure monitor. The measurement for a healthy person can be classified as the table 1 below.

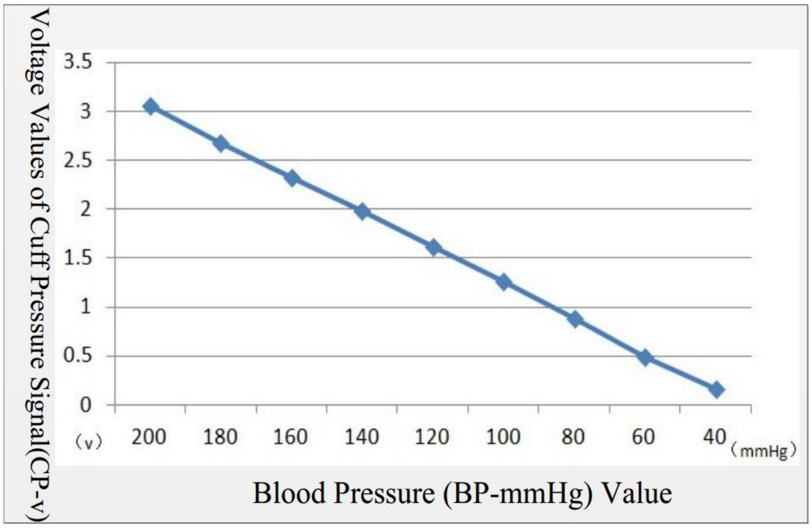


Figure 3: Proportional relationship of cuff pressure (CP) and blood pressure (BP) value

CATEGORY	SYSTOLIC (mmHg)	DIASTOLIC (mmHg)
Hypotension	< 90	< 60
Desired	90 – 119	60 – 79
Prehypertension	120 – 139	80 – 89
Hypertension – Stage 1	140 – 159	90 – 99
Hypertension – Stage 2	160 – 170	100 – 109
Hypertension Emergency	≥ 180	≥ 110

Table 1: Classification of blood pressure

CHAPTER 3 : METHODOLOGY

3.1 RESEARCH METHODOLOGY

For the final design of the prototype is decided, discussions has been done with the supervisor. The initial design was to design the mercury blood pressure monitor as the prototype, due to the concept of mercury blood pressure monitor that requires simple materials such as PVC, hand cuff with bulb, and also raw mercury, in order to fabricate the prototype. Unfortunately, after some discussion, it has been decided that the mercury blood pressure monitor could not be done as prototype, as the mercury may lead to the environmental pollution. It also may lead to the chemical contamination if the mercury was not carefully handled during fabrication.

Due to the stated reasons, discussion has been made with the supervisor, and the design of the prototype was changed to electronic blood pressure monitor. The proposed design was to purchase the existing electronic blood pressure monitor in the market, and integrating it with the android device, such as hand phone or tab. The electronic blood pressure monitor that to be purchased will be the one with the lowest possible price, as to minimum the cost of prototype fabrication. The purchased blood pressure monitor was *Automatic Blood Pressure Monitor BP 3BR1-1*, manufactured by *Microlife.* Some modifications needed to be done on the purchased blood pressure monitor. The proposed modification was to display the calculated value of the systolic and diastolic blood pressure on the android device. All the calculated values of systolic and diastolic will be transferred to the android device though Bluetooth. A Bluetooth chipset will be connected to the blood pressure monitor. A customized application will be programmed in the android device to display the received data. Unfortunately, after some discussion with the supervisor, it was found that the fabrication of the prototype will face some difficulties:

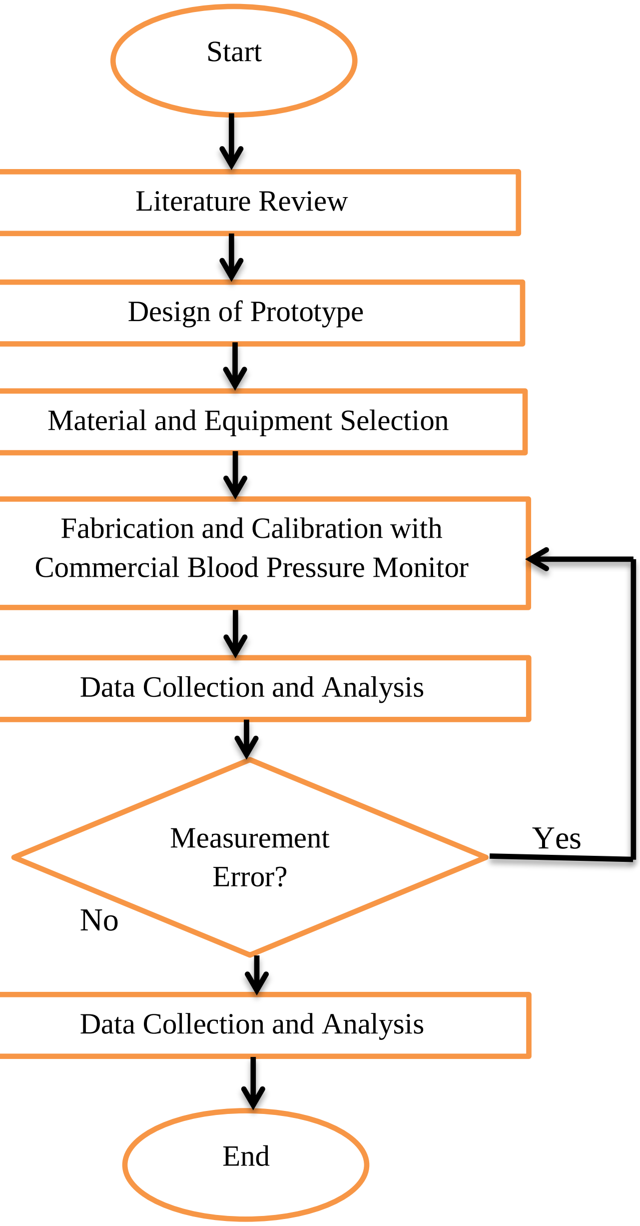
1. It was difficult to connect the Bluetooth chipset to the blood pressure monitor, as the data from the microcontroller unit was transferred to the LCD through parallel port. It was difficult to connect the Bluetooth chipset as the chipset requires serial port for the

connection. A separated circuit needed to be built to convert the parallel port into serial port, before it is connected to the Bluetooth.

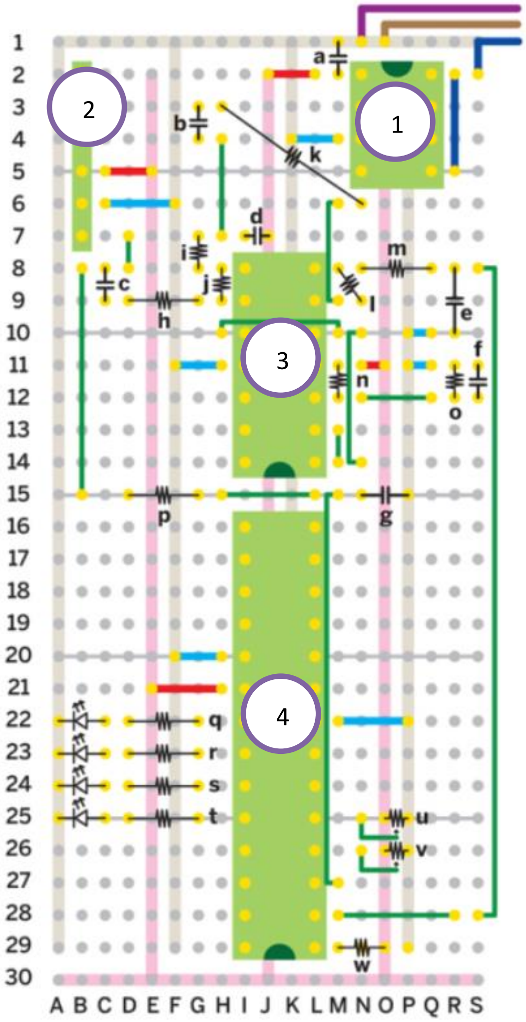
2. The transfer of the data to the android device could not be done without knowing the type if data interpret by the microcontroller and the type of data transferred to the LCD.

Due to the stated reason, the design was changed again, which was to build the prototype from scratch. The cost of the materials needed for the fabrication of the prototype were ensured to be as cheap as possible, as to achieve the target of this project, which is to create a low cost blood pressure monitor. The proposed design of this prototype will be explain in the next part of this report.

3.2 PROJECT FLOW CHART



3.3 PROTOTYPE DESIGN



Key	
Pink	+3.3V connection
Gray	Ground connection
Red	Wire to power source
Light blue	Wire to ground
Green	Wire
Purple	To battery ground
Brown	To crank ground
Dark blue	To switch
Label 1	Voltage regulator
Label 2	Pressure sensor
Label 3	Op-Amp IC
Label 4	Microcontroller

a	1µF	**m**	16kΩ
b	1µF	**n**	110kΩ
c	1µF	**o**	110kΩ
d	1µF	**p**	160kΩ
e	1µF	**q**	200kΩ
f	0.1µF	**r**	200kΩ
g	1µF	**s**	200kΩ
h	160kΩ	**t**	200kΩ
i	16kΩ	**u**	100kΩ
j	750kΩ	**v**	100kΩ
k	160kΩ	**w**	10kΩ
l	750kΩ		

Figure 4 : Connection of the components

Other materials needed :

AA batteries, battery holder, knobs, toggle switch, potentiometer, DIP socket, LEDs, circuit breadboard.

3.4 FABRICATION OF PROTOTYPE

1. Voltage regulator is inserted into the breadboard. The type if voltage regulator used in this project is L7805CV.

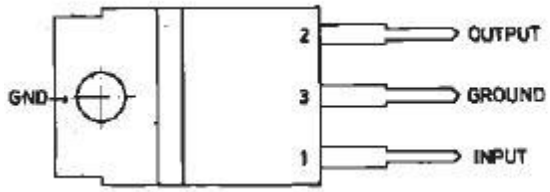


Figure 5: L7805CV voltage regulator

The ground pin is connected directly to the ground. 1µF capacitor is connected between output pin to the ground. The output pin is also connected to the 3.3V voltage source. 2 AA batteries is connected between input pin to the ground using battery holder.

2. LM324 chip is inserted into the board.

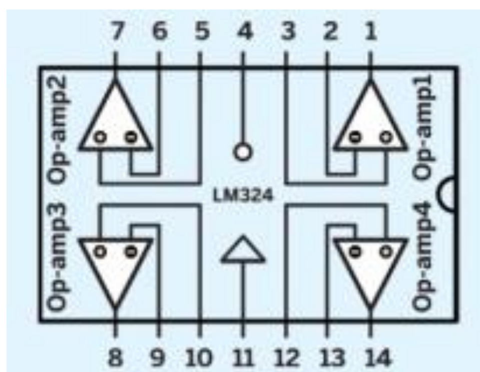


Figure 6: Op-amps position inside LM324 chip

Reference voltage of 1.65V is built by using op-amp 1. 0.1µF capacitor is connected between positive terminal of op-amp 1 to the ground. Two 110kΩ resistors are connected in parallel with the positive terminal. One 110kΩ resistor is connected between positive terminal to the ground, and the other one 110lΩ resistor s connected between positive terminal to the 3.3V voltage source. The output of op-amp 1 is connected to its own negative terminal.

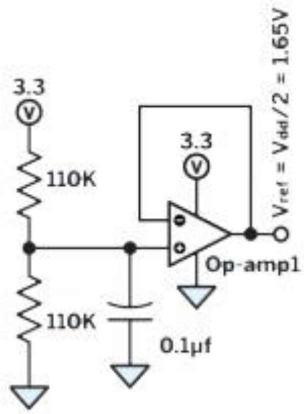


Figure 7: Connection on op-amp 1

3. Smoothing filters and frequency component is added into the prototype. The smoothing filter is consisting of a bandpass filter and a lowpass filter. The bandpass filter is constructed by cascading two highpass filter and two lowpass filter. The first highpass filter is done by connecting 1µF capacitor is series with 160kΩ resistor. The 160kΩ resistor is connected to the negative terminal of op-amp 3, and the cap of 1µF capacitor is connected to the output of pressure sensor. Gain is added to the op-amp 3 by connecting 750kΩ resistor between its negative terminal to its output.
4. For the lowpass filter, 16kΩ resistor is connected from the output of op-amp 3 to one hole on the breadboard, and 1µF capacitor is connected from this hole to the ground. The same connection of highpass and lowpass filter is created using op-amp 2, but the cap 1µF capacitor on the highpass filter side is connected to the hole at op-amp 3 just now.

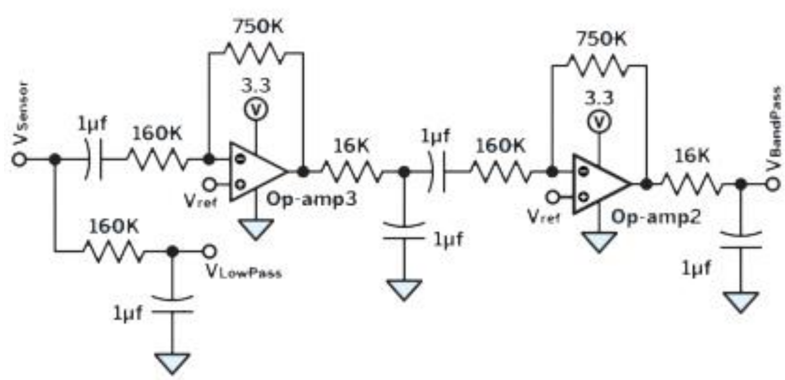


Figure 8: Connection of highpass filters and lowpass filters

5. The output of the second lowpass filter in op-amp 2 will be connected later with the microcontroller pin 2 (Vbandpass).
6. For the connection of the separate lowpass filter, 160kΩ is connected from the pressure sensor output (pin 1) to the one hole on the breadboard. From this hole, 1µF capacitor and microcontroller pin 3 (Vlowpass) are connected to it, as shown in the figure 8.
7. Pressure sensor is added into the circuit. The model of pressure sensor used is this prototype is MPX5050GP. Recall to the previous step (step 6), the output of the pressure sensor (pin 1) is connected to the 160kΩ resistor from the separate lowpass filter. The rest of the connection on the pressure sensor is doe as shown in the figure 9 below.

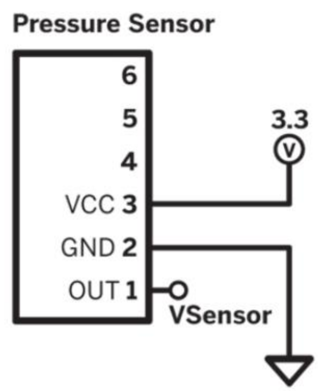


Figure 9: Connection on pressure sensor

8. Microcontroller chip is added into the circuit. The model of microcontroller used is PIC18F2321. The chip is installed first with program in the form of hex file, obtained from the website makezine.com. Power terminal is created on the microcontroller by connecting pin 8 and 9 to the ground, and pin 20 to the 3.3V voltage supply. Pin 1 of the chip is connected to the 3.3V power supply through 10kΩ resistor.
9. The output of the blood pressure taken will be displayed in term of PASS and FAIL. Hence, LED will be used to indicate both pass and fail result. 4 colors of LED which are clear (power), yellow (status), green (pass) and red (fail), will be connected on pin 21, 22, 23 and 24 respectively, through 200Ω resistor in each one of them.

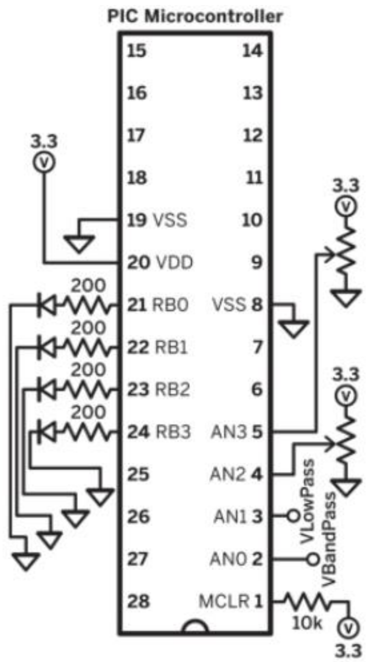


Figure 10: Connection on microcontroller chip

10. Two potentiometers are connected to the chip on pin 4 and 5 respectively, as shown in figure 10 above. The potentiometer is turned fully counterclockwise. The potentiometer connected on pin 5 is labeled as ‘Diastolic’ and the other potentiometer connected on pin 4 is labeled as ‘Systolic’.
11. The rubber hose of the hand cuff is connected to the pressure sensor.

3.5 PROTOTYPE TESTING

1. Before the prototype is used, the potentiometers need to be turned fully counterclockwise. The ideal reading for both diastolic and systolic blood pressure is 60-80mmHg and 100-120mmHg respectively. In order to calibrate the prototype, the ‘Diastolic’ potentiometer is marked as ‘60’ for the fully counterclockwise position, and for the maximum clockwise position, the “Diastolic’ potentiometer is marked as ‘110’. Hence, for the half position between ’60’ and ‘110’, the value should be ‘85’. (Note: All the units are in mmHg).
2. For the ‘Systolic’ potentiometer, the maximum counterclockwise position is marked as ‘100’, and the maximum clockwise position is marked as ‘180’.
3. The prototype is switched on. The power LED is observed to blink intermittently.
4. The person of the target group needed to sit down straight and calm. The hand cuff is attached to the person’s upper arm, just above the elbow.
5. The valve of the hand cuff is opened by turning the valve knob counterclockwise, in order to release air inside the cuff.
6. The valve is closed back by turning it fully clockwise, and the cuff is inflated using the hand pump. The cuff is pumped until the blood in restricted from flowing through the vein. It is approximately 7 times of pumping in order to completely block the blood from flowing through the vein below the hand cuff. The pumping is stopped as the status LED lighted up.
7. The valve is then gently opened a bit in order to allow the blood to flow. The air in the cuff is fully released until the cuff is fully deflated.
8. The pass and fail LED is observed. The pass LED (green LED) will light up if the blood pressure reading is within the chosen value. Otherwise, the fail LED (red LED) will light up if the pressure taken is above the chosen value.
9. Both of the pass and fail LED is lighted up when the cuff is deflating too fast. The measurement needed to be taken again until the desired output is obtained

3.6 GANTT CHART

Table ___shows the Gantt chart with the key milestone of the project for the FYP I and FYP II period.

		FYP 1														FYP 2													
No	**Task Name\Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Project Research and Study																												
	Literature Review		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Technical Specification			■	■	■	■	■	■																				
	Milstone: Completion of Extended Proposal								●																				
2	Design																												
	Conceptual Design								■	■	■																		
	Detailed Design										■	■	■																
	Milestone: Final Design of Product												●																
3	Material & Equipment Selection																												
	Material Selection										■	■	■	■	■														
	Sensors Identification										■	■	■	■	■														
	Milestone: Finalize Required Materials & Equipments														●														
4	Fabrication & Testing																												
	Fabrication of Product																■	■	■	■	■	■	■						
	Product Testing																		■	■	■	■	■	■					
	Milestone: Completion of Product Fabrication																							●					
5	Data Analysis																												
	Software Development																				■	■	■						
	Data Collection																		■	■	■	■	■						
	Data Intepretation																				■	■	■	■	■				
	Milestone: Achieve Functional Sensors and Reliable Data																								●				
6	Result & Finding																												
	Report Preparation																								■	■	■	■	■
	Milestone: Report Completion																												●

Table 2: Gantt chart of the project

3.7 KEY MILESTONE

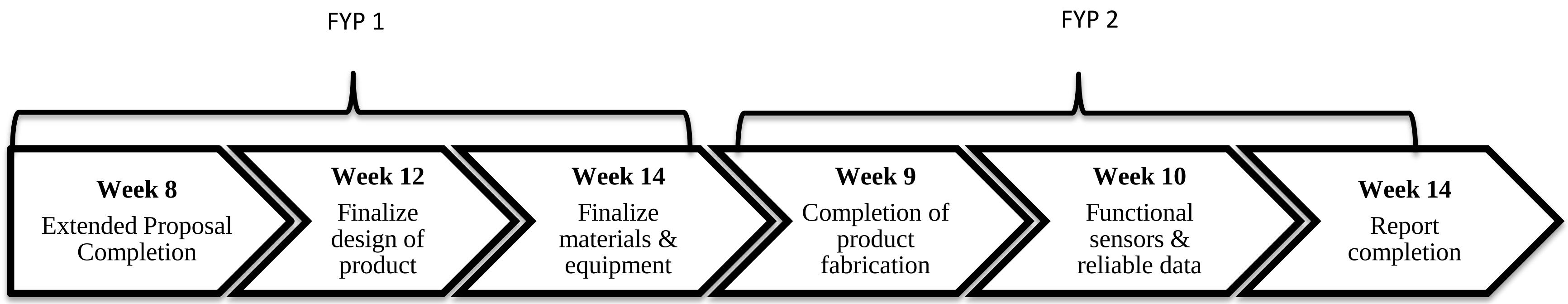


Figure shows the key milestone of the project for the period of FYP I and FYP II. During FYP I, the extended proposal was completed during week 8. Then, the final design of the product was completed during week 12, followed by the finalization of the materials and equipment selection on week 14.

During FYP II, the project will continue and the product fabrication is expected to be completed on week 9 with the sensors being functional with reliable data obtained to be achieved on week 10. Finally, report writing on the outcome of the project is to be completed on week 14.

CHAPTER 4 : RESULT AND DISCUSSION

4.1 EXPECTED RESULT

As for the expected result, after the potentiometer of for the calibration of systolic and diastolic value has been adjusted, the clear LED wil light ON when the power is switched ON.

After the measurement is done, if the reading of blood pressure monitor is on the normal condition, the green Led will turn ON. Otherwise, if the measured blood pressure is below or above normal value, red LED will turn ON.

4.2 DISCUSSION

4.2.1 Duration of Measurement.

The time taken for the complete the blood pressure measurement is 1.5 minutes. The time taken may be varying according to different individual. However, the time different is just within 10 seconds.

4.2.2 Accuracy

The measurement of blood pressure may be varying according to the person's behavior. The pressure sensor is very sensitive, as the reading of pressure calculated would be affected by a slight movement of the arm. The movement of the arm will cause the muscle of the arm to contract and exert pressure to me wall of the arteries. As the result, the blood pressure reading might be a little bit inaccurate.

Blood pressure measurement could not be taken to the person who is just finished their meals and to those who just finished doing vigorous activities. The stated situation may affect the measurement of blood pressure, as the heart rate is a little bit high from normal rate on that time.

4.2.3 Pressure Sensor

The pressure sensor used is this design in to sense the pressure in the arm cuff is MPX5050GP by Freescale Semiconductor. The specification if the pressure sensor is shown as below.

Parameters	**Minimum**	**Typical**	**Maximum**	**Units**
Pressure range	0	---	50	kPa
Supply Voltage	4.75	5.0	5.25	Vdc
Supply current	---	7.0	10	mAdc
Operating temperature	-40	---	+125	°C

Table 3 : Specification of pressure sensor

4.2.4 Smoothing filter

The smoothing filter is designed by cascading two badpass filter together. The two stages of filtering is done so that the overall bandpass stage could provide large gain to the system, and the frequency response of the filter would have harper cut off than using only single stage. By using this method, the signal-to-noise ratio can be improved.

By referring to figure 8, the lower frequency cutoff and higher frequency cutoff for both bandpass filter is the same. For the lower frequency cutoff, the value is calculated as follow:

$$f_{low} = \frac{1}{2\pi(1\mu F)(160k\Omega)} = 0.9947\ Hz$$

For the higher frequency cutoff, the value is calculated as follow:

$$f_{high} = \frac{1}{2\pi(1\mu F)(16k\Omega)} = 9.9472\ Hz$$

4.2.5 Usability

The design of the prototype should be usable for both adult and children. The comcept of the prototype is basically the same with regular blood pressure monitor sold in the market. The instruction of usage of this prototype is quite easy to be understand.

The size of the cuff used in this prototype is ideal for adult's arm size (9 – 13 inches in circumference). The downside of this prototype is that the output of the pressure measured is only in the form of LED lighting. There were no exact value of the blood pressure reading is shown as the prototype has no LCD to display it. The output is just in the form of PASS and FAIL. Hence, medical consultancy on hospitals or clinics is recommended for the accurate blood pressure reading.

CHAPTER 5 : CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

High blood pressure is one of the main health problems in the world. Hence, accurate blood pressure measurements are needed in order to diagnose the health condition, and to do the earlier prevention and treatment. As a conclusion, this project is important for the student to develop the knowledge and have a better understanding about the mechanism of the prototype. Although the university is equipped with the modern ans sophisticated facilities and infrastructure, it is the fact the outside of this university is surrounded by the poor villages with old folk. As the project might be a big success, it surely will give a lot of benefit to UTP-SRC and especially to the residents of Kampung Aji, Bota, Perak.

5.2 FUTURE PLAN

For the future plan, instead of manual pumping of the hand cuff, the automated inflation and deflation system of the cuff will be installed to the prototype. A Bluetooth will be installed to the prototype, so that it can be communicated with android devices. A customized application will be installed in the android device, so that the systolic and diastolic blood pressure value can be displayed on the android device. Prototype will be calibrated with the commercial blood pressure monitor in order to check the accuracy of the prototype.

CHAPTER 6 : REFERRENCE

[1] A. L. Rubin, *High Blood Pressure for Dummies*: Wiley, 2011.

[2] S. Daochai, W. Sroykham, Y. Kajornpredanon, and C. Apaiwongse, "Non-invasive blood pressure measurement: Auscultatory method versus oscillometric method," in *Biomedical Engineering International Conference (BMEiCON), 2011*, 2011, pp. 221-224.

[3] Y. Ostchhega, G. Zhang, P. Sorlie, J. P. Hughes, S. Debra, T. Nwankwo*, et al.*, "Blood Pressure Randomized Methodology Study Comparing Automatic Oscillometric and Mercury Sphygmomanometer Devices," October 5 2012.

[4] G. Gersak, K. Peterlin, and J. Drnovsek, "Virtual auscultatory non-invasive blood pressure monitor," in *Medical Measurements and Applications Proceedings (MeMeA), 2011 IEEE International Workshop on*, 2011, pp. 642-645.

[5] E. C. Pinheiro, "Oscillometric blood pressure monitor modeling," in *Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE*, 2008, pp. 303-306.

[6] "Freescale Medical Apllications User Guide," C. H. Alliance, Ed., ed, p. 27.

[7] J.-l. Zhang, Y. Liu, and J.-b. Wen, "Design of electronic blood pressure monitoring system based on mobile telemedicine system," in *Complex Medical Engineering (CME), 2013 ICME International Conference on*, 2013, pp. 145-149.

[8] Z. Pinwei and C. Linkai, "Design of automated oscillometric electronic sphygmomanometer based on MSP430F449," in *Future Information Technology and Management Engineering (FITME), 2010 International Conference on*, 2010, pp. 463-466.