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DIPLOMA IN ELECTRONIC ENGINEERING(MEDICAL)

DEE50102 PROJECT 2

FINAL YEAR REPORT

IOT BASED NON-INVASIVE BLOOD PRESSURE KIT FOR EDUCATION PURPOSE

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ABSTRACT

The paper presents design and development of a Non-invasive wireless blood pressure data acquisition instrument for remote monitoring based Micro-controller and Wifi transmission kit. The real-time blood pressure biomedical signal is measured using an optical measurement circuit based Plethysmography technique (PPG) continuously for a long period of time. The detected measured signal amplified using an operational amplifier circuit and interfaced with the Micro-controller. Blood pressure readings with help of developed algorithm has been calculated and transmitted via Bluetooth kit to the stationary computer. Numerical reading values of systolic and diastolic blood pressure remotely recorded and displayed with help of LCD as well stationary computer. Furthermore, the obtained results were compared with existing devices data like a Sphygmomanometer to verify the accuracy of the developed Instrument. Also, this product in shape of trainer kit that people will be able to learn more about Non-invasive blood pressure.

CHAPTER 1

1.1 INTRODUCTION

Blood pressure (BP) is a measurement of the force applied on the walls of artery vessels as heart pumps blood through the body. Moreover, blood pressure measurement is known as one of the vital signs and is widely used to monitor the physiological condition of human beings along with other vital signs such as heart rate, breathing rate, oxygen saturation and temperature [1]. Blood pressure can be seen as two variation systolic Blood pressures (SBP) and diastolic Blood pressure (DBP), and systolic is the peak or the maximum pressure on the walls of the arteries which happens when the ventricles of the heart are contacting. While, diastolic is the minimal pressure in the arteries, which happens near the end of the cardiac cycle when the ventricles are filled with blood. Typically, measured values for a healthy, resting adult are 115 millimeters of mercury (mmHg) (15 kilopascals [kPa]) systolic and 75 mmHg (10 kPa) diastolic [2]. Systolic and diastolic blood pressure measurements are not always static and Blood pressure does tend to change during the day. They also change in response to stress nutrition, drugs, and illness and exercise[3].

The measurements of BP are of a great importance because it is used for detection of hypertension (high blood pressure).Hypertension is a continuous, consistent, and independent risk factor for developing cardiovascular disease. 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 [4]. Blood pressure measurement is also important for particular disease patients, such as hemodialysis patients. Hence, in the daily life, blood pressure measurement and management is very useful for handling health situation and plays a preventive function.

Most non-invasive blood pressure monitors are based on either the auscultation or the oscillometric method [5]. Although both methods are generally accepted and widely used but they severely restrain patients' mobility, they require uncomfortable cuffs; they are not suitable for home-care and cannot be used for continuous long-term monitoring applications. Continuous measurement of BP for homecare requires an accurate and inexpensive method that is independent from patient movement and does not require continuous care by a practitioner. These requirements can be found in this monitoring system which will be designed using photoelectric plethysmography (PPG) technique.

PPG is a simple non-invasive method used to measure relative changes in pulse blood volume in the tissues. It utilizes the use of reflectance sensor that contains an infrared light source. The light source illuminates a part of the tissue (fingertip, toe, ear lope, etc.) and a photo-detector receives the returning light. The waveform obtained from this technique represents the blood volume pulse which can be used to measure blood pressure. PPG concept is shown in *fig. 1* where an Infra-red (IR) sensor is used as the source and a phototransistor is used as the detector. The sensor operates in reflection ('adjacent') mode where the source and the detector are place side by side. More to the point, a developed technique based on a noninvasive continuous blood pressure measurement using

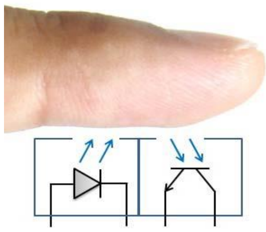


Figure 1

volume oscillometric method and photoplethysmograph technique has been investigated [6], and the study uses high intensity LED and a LDR (Light Dependent Resistor) and placed them at the edge of a finger. The concept is that the resistance of the LDR changes according to the light intensity received by the LDR. The change in resistance is proportional to the change of blood volume and as well as blood pressure in the finger. The result showed the systolic and diastolic blood pressure on a mini LCD.

In addition, a non-invasive blood pressure monitor was developed using photoplethysmograph method. Authors used infrared transmitter and receiver to estimate blood pressure in the fingertip. Authors were able to measure blood pressure and concluded that the results are in agreement with the standard blood pressure measurements [7].

On the other hand, a wireless digital measurement system was implemented and developed. In approach, piezoresistive transducer was used as the sensor and the device makes use of a microcontroller and a Sallen-Key active. The system transmits the collected data to a remote computer through a wireless device [8].

Moreover, blood pressure measuring system at the wrist based on the volume compensation method has been developed[9]. The authors used a method called volume-compensation in which cuff pressure (Pc) is gradually increased, and then the unloaded vascular volume (V0) is determined from the mean level of the DC component of the photo plethysmography (PG) signal (PGdc) at point of maximum amplitude of the pulsation signal of PG (PGac) [9].

1.2 PROBLEM STATEMENT

This project can help to check blood pressure from home and it is easier. Also, to design and implement a system that will measure blood pressure. Pulse oximeter will be designed to measure the volume changes in the blood. The PPG and ECG will then be combined to give a blood pressure reading. The accuracy of acquiring blood pressure using this method has to be determined. This project uses the PPG method to measure blood pressure as it gives a continuous and real time measurement. Beside that, this NIBP trainer kit can be used for anyone who want to learn more about how this nibp works, their measurement and etc.

1.3 OBJECTIVE

- ✓ Develop a hardware prototype for non-invasive blood pressure trainer kit.
- ✓ Develop a low cost, low power, reliable, non-intrusive, and non-invasive vital signs monitor.
- ✓ This data can then be obtained by a health care professional anytime via wireless network.
- ✓ Student be able to understand how the nibp works or how to get the values.

1.4 SCOPE OF PROJECT

Main of this project is to used for education, it is when the student can understand how the nibp works and can measured the values with manual using formula. At the same time, this device can used for individuals especially over the age of 50 years. This limitation is added to simplify our project and ensure it is achievable with the restricted time and resources available. Since the target subjects for this device are hospital, instituition and home. The most important feature of this device is that it must be easy to use.

1.5 IMPORTANT OF RESEARCH

- ➢ Monitoring of systolic and diastolic of blood pressure.
- ➢ To keep blood pressure under control.

CHAPTER 2

LITERATURE REVIEW

This chapter extend the literature reviews that cater the information in accordance with the objectives of this project. The relevant information and other extra features were gathered as shown below.

(Reliability and Validity of Non-invasive Blood Pressure Measurement System Using Three-Axis Tactile Force Sensor)

Blood pressure (BP) is a physiological parameter reflecting hemodynamic factors and is crucial in evaluating cardiovascular disease and its prognosis. In the present study, the reliability of a non-invasive and continuous BP measurement using a three-axis tactile force sensor was verified. All the data were collected every 2 min for the short-term experiment, and every 10 min for the long-term experiment. In addition, the effects on the BP measurement of external physical factors such as the tension to the radial artery on applying the device and wrist circumference were evaluated. A high correlation between the measured BP with the proposed system and with the cuff-based non-invasive blood pressure, and reproducibility, were demonstrated. All data satisfied the Association for the Advancement of Medical Instrumentation criteria. The external physical factors did not affect the measurement results. In addition to previous research indicating the high reliability of the arterial pulse waveforms, the present results have demonstrated the reliability of numerical BP values, and this implies that the three-axis force sensor can be used as a patient monitoring device.

In order to evaluate the reliability of BP values from the three-axis tactile force sensor, short- and long-term measurements were implemented after Institutional Review Board (IRB) approval (H-1809-113-974). In the short-term measurement, 30 volunteers without any cardiovascular problems attended (male: 19; female: 11; mean age: 30 years; range 22–59 years). According to the central limit theorem, the sample size of 30 in the short-term experiment was sufficient to form a Poisson distribution and transform to a normalized distribution for the statistical evaluation. After verifying the reliability of the short-term data, 10 of these volunteers also participated in the long-term measurement (male: 9; female: 1; mean age: 31.5 years; range 23–59 years). Because the general semiconductor sensors, including the tactile sensor, could maintain their characteristics continuously—under the assumptions of no environmental temperature or atmospheric pressure changes and no heat stack phenomenon from the USB 2.0 standard microcurrent (5V, 0.1A)—there was no need to retain all 30 volunteers to participate in the long-term experiment. Before conducting the experiments, all volunteers were well-informed about the experiments and agreed to participate.

Statistical analysis was performed using SPSS software (version 23, IBM, Armonk, NY, USA). To match the systolic and diastolic BP values with those of the oscillometric tonometer, the averages of the minimum and maximum values, respectively, from the tactile sensor data obtained during 10 s (approximately 13–15 pulse waveforms, varying according to the heart rate), were taken every time the oscillometric tonometer was used. The raw data were affected by the position of the sensor over the radial artery and by the tightness of the supporting wristband in each volunteer. The purpose of this study was the evaluation of the reproducible, continuous NIBP monitoring in the examinees, and the paired analysis between the baseline-corrected sensor data and the reference value was conducted first. After verifying the high correlation between them, linear regression was performed for both the short-term and long-term experiments to evaluate the correlation between the baseline-corrected 3D force sensor values and the cuff-based NIBP, and to obtain a linear equation for estimating BP from the baseline-corrected sensor value.

Even though the tightness of the wristband was carefully adjusted to maximize the amplitude of the arterial pulse wave (measured as the raw numerical value of the sensor), it inevitably varied from person to person, and the correlation between the amplitude of the arterial pulse wave and the NIBP might have been affected by the tightness of the wristband. Thus the difference between the calibrated BP from the sensor and the NIBP was evaluated against the raw numerical value of the sensor (which may reflect the tightness of the wristband) with correlation analysis, and against the wrist circumference in the same way.

To analyze the reproducibility, reliability, and degree of agreement between the two methods, a Bland–Altman analysis and an intraclass correlation coefficient (ICC) analysis were conducted [25,26,27,28,29,30,31,32].

Blood pressure measurement devices have become increasingly popular during the last decade as prices of these measurement devices have sunk to an appropriate level for ordinary consumers. The incorporation of automatic measurement features and ease of use have also contributed to the growing popularity of blood pressure measurement devices as a lifestyle device. However, such measurements devices are typically cuff based and based on indirect Blood Pressure (BP) measuring method using the detection of Korotkov-sounds. This method had been used for more than 100 years and has two major deficiencies. Firstly, the cuff grossly affects the measured parameter. Secondly, the method determines the blood pressure only at a single point of time. Oscillometric methods, applied in automatic home BP-meters, apart from the aforementioned inadequacies, have also a built-in uncertainty, where it empirically calculates the systolic and diastolic values from the measured mean pressure. In Tonometry the non-linear effect of the vascular wall decreases in bigger arteries. It is well known that good access to a "big" artery is at the wrist by palpating. Different mechanisms have been developed for the automatic noninvasive palpation on the arteria radialis. In order to obtain a stable blood pressure signal, the tonometric sensor must be protected against movement and other mechanical artifacts The Vascular unloading technique method is to unload the arterial wall in order to linearize this phenomenon with a counter pressure as high as the pressure inside the artery. Blood volume is kept constant by applying this corresponding pressure from the outside. The continuously changing outside pressure that is needed to keep the arterial blood volume constant directly corresponds to the arterial pressure. This is the basic principle of the so- called "Vascular Unloading Technique". For the realization, a cuff is placed over the finger. Inside the cuff, the blood volume in the finger arteries is measured using a light source and a light detector. The resulting light signal is kept constant by controlling the alterable cuff pressure. During systole, when blood volume increases in the finger, the control system increases cuff pressure, too, until the excess blood volume is squeezed out. On the other hand, during diastole, the blood volume in the finger is decreased; as a result, cuff pressure is lowered and again the overall blood volume remains constant. As blood volume and, thus, the light signal is held constant over time, intra- arterial pressure is equal to the cuff pressure. This pressure can easily be measured with a manometer.

Hydrostatic pressure refers to any pressure that a liquid exerts on its container. Blood hydrostatic pressure is the pressure that the volume of blood within our circulatory system exerts on the walls of the blood vessels that contain it. However, hydrostatic pressure is not the only pressure that is exerted on a blood vessel, osmotic pressure is also present and the cumulative pressure from inside is countered by the same two types of pressure exerted on the outside of the blood vessels by the tissues that surround them. The hydrostatic pressure exerted by our blood on our blood vessels is what we commonly refer to as our blood pressure and it can cause serious problems when upset. Blood pressure is not the same throughout, for example, the veins and capillaries in our feet have way more pressure inside them than the ones in our head, and gravity is responsible for this particular variation. When we get hypertensive, our blood vessels experience increased hydrostatic pressure on them due to increase of blood flow; it is at this point that arteriosclerosis occurs and as a result, the blood vessels become very hard in order to withstand the high blood pressure In this paper, a blood pressure monitoring device has been presented for real-time non-invasive blood pressure monitoring based on Android smart-phone. The monitoring device is consisted of three parts: two pieces of independent node modules for acquiring ECG and PPG signals and an Android smart-phone with our application. The acquired ECG and fingertip PPG data, which are measured simultaneously, are sent to user’s Android smart- phone by Bluetooth transmission module in real time and display on screen for monitoring. PTT can be computed from the interval between ECG and PPG. Finally, blood pressure can be estimate from the corresponding PTT.

(Designing Heart Rate, Blood Pressure and Body Temperature Sensors for Mobile On-Call System)

There has been an exponential increase in health care costs in the last decade. Seniors have to make frequent visits to their doctor to get their vital signs measured. There is a huge market for non-invasive methods of measurement of these vital signs. The objective of this project is to design and implement a reliable, cheap, low powered, non-intrusive, and accurate system that can be worn on a regular basis and monitors the vital signs and displays the output to the user's cell phone. This data is also easily accessible by the physician through wireless network. This project specifically deals with the signal conditioning and data acquisition of three vital signs: heart rate, blood pressure, and body temperature. Heart rate is measured through an Electrocardiogram that is obtained by attaching skin surface electrodes on the patient's wrists and legs. Blood pressure combines the methodologies of Electrocardiography and Photoplethysmography to continuously monitor the systolic and diastolic blood pressure. Body temperature is measured inside the ear with a thermistor.

Various ways of non-invasive blood pressure measurement were reviewed. The two main ways blood pressure can be measured are using an oscillometric arm-cuff method and using photoplethysmography (PPG). These methods are compared in Appendix B in Table 4. This project uses the PPG method to measure blood pressure as it gives a continuous and real time measurement.

Plethysmography measures the volume changes in an organ. Photoplethysmography is a plethysmograph obtained optically. PPG is obtained by a pulse oximeter. Light from a Light Emitting Diode (LED) is shone through the skin and changes in light absorption are measured through a photodiode.

There are two types of techniques that can be used:

i) Transmission, which is shining light through the skin with LEDs on one side of the body part and placing the photodiode on the other side to obtain the characteristics of the light transmitted through the skin. This technique would work on finger or ear;

ii) Reflection, which is shining light through the skin with LEDs on one side of the body part and placing the photodiode on the same side to obtain the characteristics of light reflected from the skin. This technique would work on forehead or chest.

(Automatic Noninvasive Measurement of Arterial Blood Pressure)

The measurement of the arterial blood pressure is of great clinical significance mainly for the detection and follow-up of hypertension which affects about one third of the adult popu-lation in the western world. An accurate and simple technique for the measurement of arterial blood pressure is essential for efficient diagnosis of hypertension and for its proper manage-ment. Because of the clinical significance of blood pressure measurements, a large market for blood pressure meters has been developed.

Automatic sphygmomanometry (automatic detection of Korotkoff sounds by microphone during the pressure cuff deflation) has been suggested for the measurement of systolic and diastolic blood pressure. The main problem with automatic sphygmomanometry is ambient noise and motion artifacts which are created by movements of the extremities or the whole body. Most of the commercial noninvasive automatic blood pressure monitors use either oscillometry (discussed below) or automatic detection of Korotkoff sounds or both [2]. Oscillometry is based on the measurement of the cardiac induced pressure oscillations in the cuff pressure during cuff deflation after inflating the cuff air pressure to above the sys-tolic blood pressure. These oscillations are due to the impact of the blood pressure pulse on the cuff and they appear even for cuff pressure above the systolic blood pressure value where the arteries under the cuff are closed, due to the impact of the pulsating arteries on the side of the cuff nearer to the heart. The oscillations increase when the cuff pressure decreases, reach a maximum, and then decrease, as Fig. 2 shows. It was found experimentally that the maximal oscillations occur for cuff pressure which is equal to the mean blood pressure. Systolic blood pressure is derived from the oscillometric pulse amplitudes versus the cuff pressure curve using empirical criteria [2], [3] such as a maximal derivative or some percentage of the maximal amplitude for cuff pressures above the one that corresponds to the maximal oscillations. Diastolic blood pressure is derived from the same curve for cuff pressures below the one that corresponds to maximal oscillations using similar empirical criteria. The algorithm for the determination of the systolic and the diastolic blood pressure from the oscillometric curve differ from manufacturer to manufacturer and might also differ between different types of devices of the same manufacturer. In Fig. 2, the criterion for systolic and diastolic blood pressure was an oscillometric wave with amplitudes of 0.6 and 0.8 of the maximal amplitude, respectively. These empirical criteria are probably the main source for the inaccuracy in blood pressure measurement by oscillometry. The amplitude ratio for systolic or diastolic blood pressure is probably not constant for different people and in different situations for the same person.

CHAPTER 3
METHODOLOGY

MICROCONTROLLER(ARDUINO UNO)

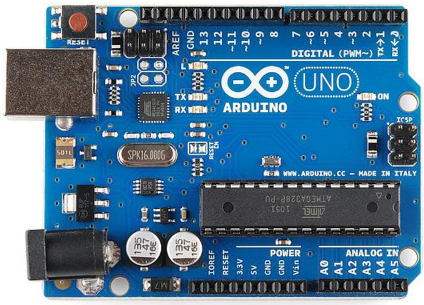


Figure 3.1

Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc.[2][3] The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.[1] The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable.[4] It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts.

WIFI(ESP8266)

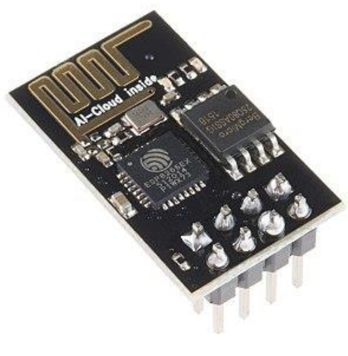


Figure 3.2

ESP8266 is a highly integrated chip designed for the needs of a new connected world. It offers a complete and self-contained WIFI networking solution, allowing it to either host the application or to offload all WI-FI networking functions from another application processor.

PULSE SENSOR

Figure 3.3

Pulse Sensor Amped is a plug-and-play heart-rate sensor for Arduino and Arduino compatibles. Pulse Sensor adds amplification and noise cancellation circuitry to the hardware. It's noticeably faster and easier to get reliable pulse readings. Pulse Sensor Amped works with either a 3V or 5V Arduino.

LCD

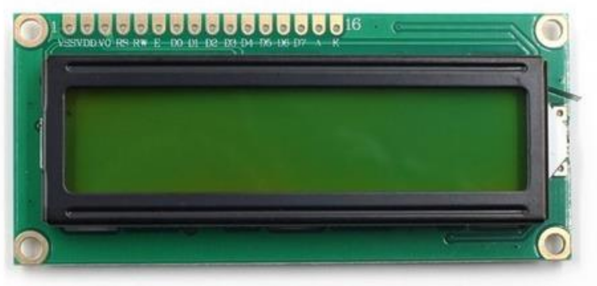


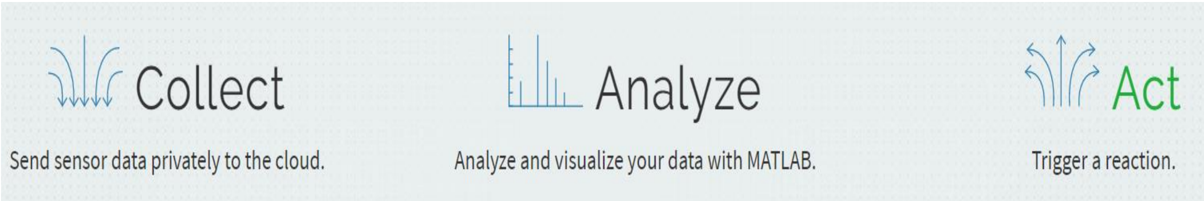
Figure 3.4

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome.

SOFTWARE

THINKSPEAK

Figure 3.5



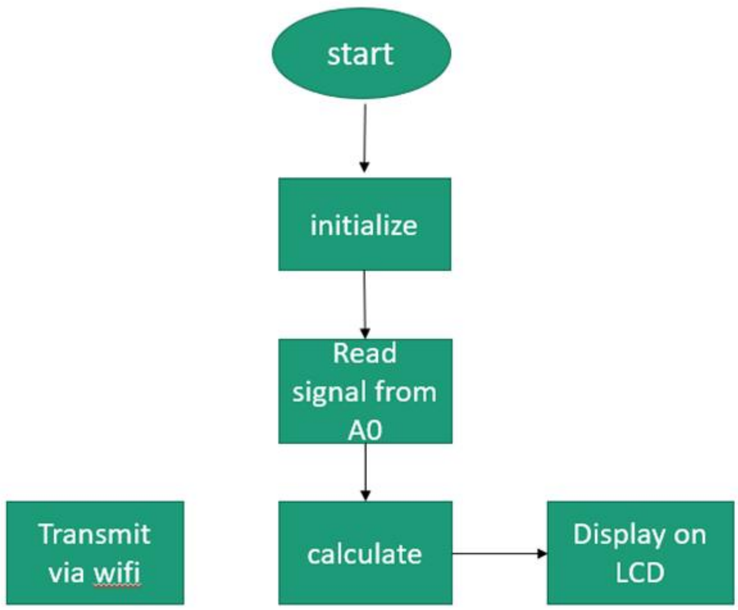
ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud. You can send data to ThingSpeak™ from your devices, create instant visualizations of live data, and send alerts using web services like Twitter® and Twilio®. ThingSpeak enables engineers and scientists to prototype and build IoT systems without setting up servers or developing web software.

Features:

- Collect data in private channels
- Share data with public channels
- RESTful and MQTT APIs
- MATLAB analytics
- Event scheduling
- Alerts
- App integrations

FLOWCHART

The program flowchart is shown in figure where the microcontroller is initialized and then set to read the analog signal form pin A0. The microcontroller then finds the highest peak of the signal and the lowest peak of the signal and then displays them as systolic and diastolic readings respectively in the LCD and Parallel serial terminal software via WIFI transmission kit.



BLOCK DIAGRAM

Proposed device consists of two main parts which are hardware and software. Hardware includes cuff, pressure sensor, microcontroller (Arduino Uno), Wifi module and smartphone. Fig. 3.6 shows the block diagram of the proposed system.

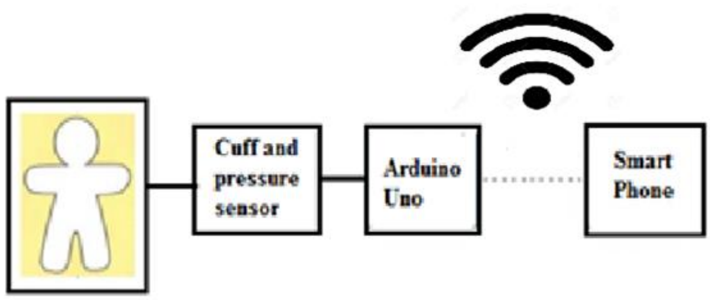


Figure 3.6

The digitized signal from microcontroller is sent to the smart phone through WIFI for simplicity of the system. The application software is designed in Virtuino. Student could view and save their measurement data through android phone. Furthermore, other people also can get the information if they download the apps.

CIRCUIT

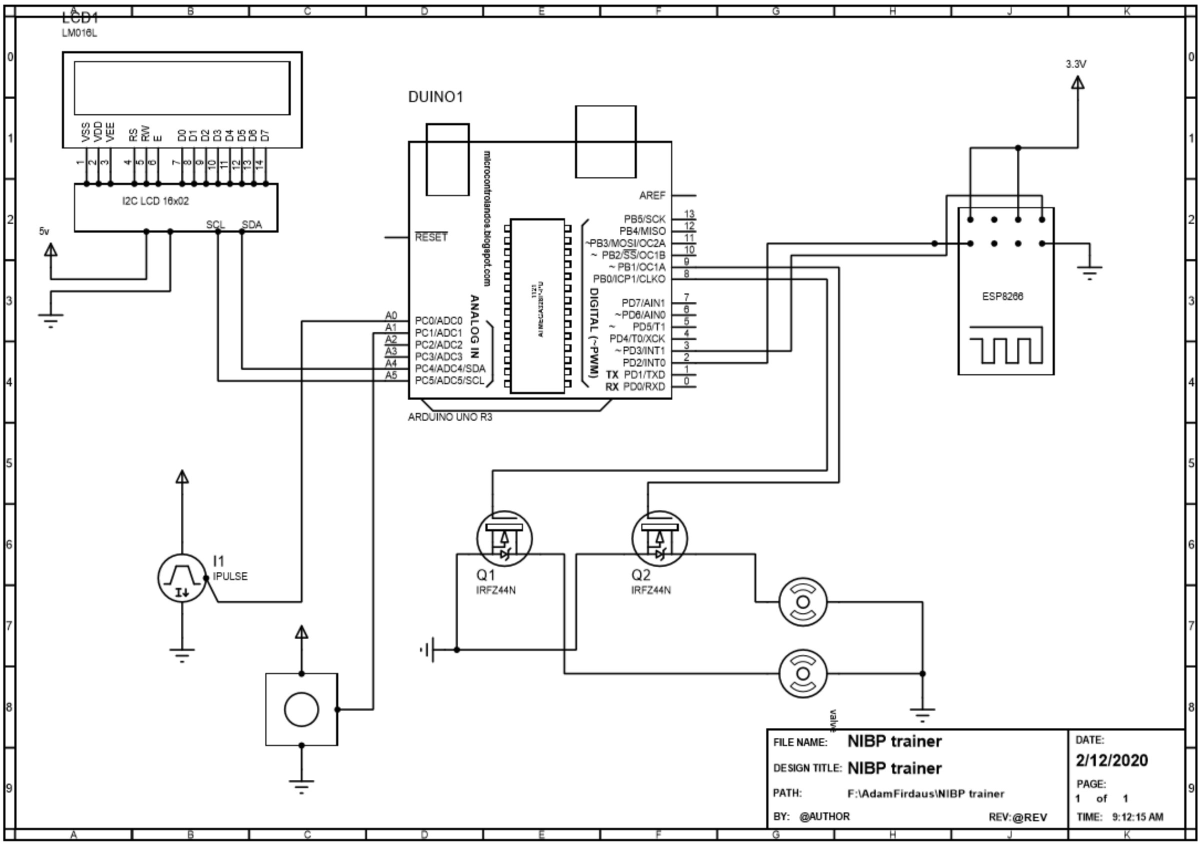


Figure 3.7

PCB LAYOUT

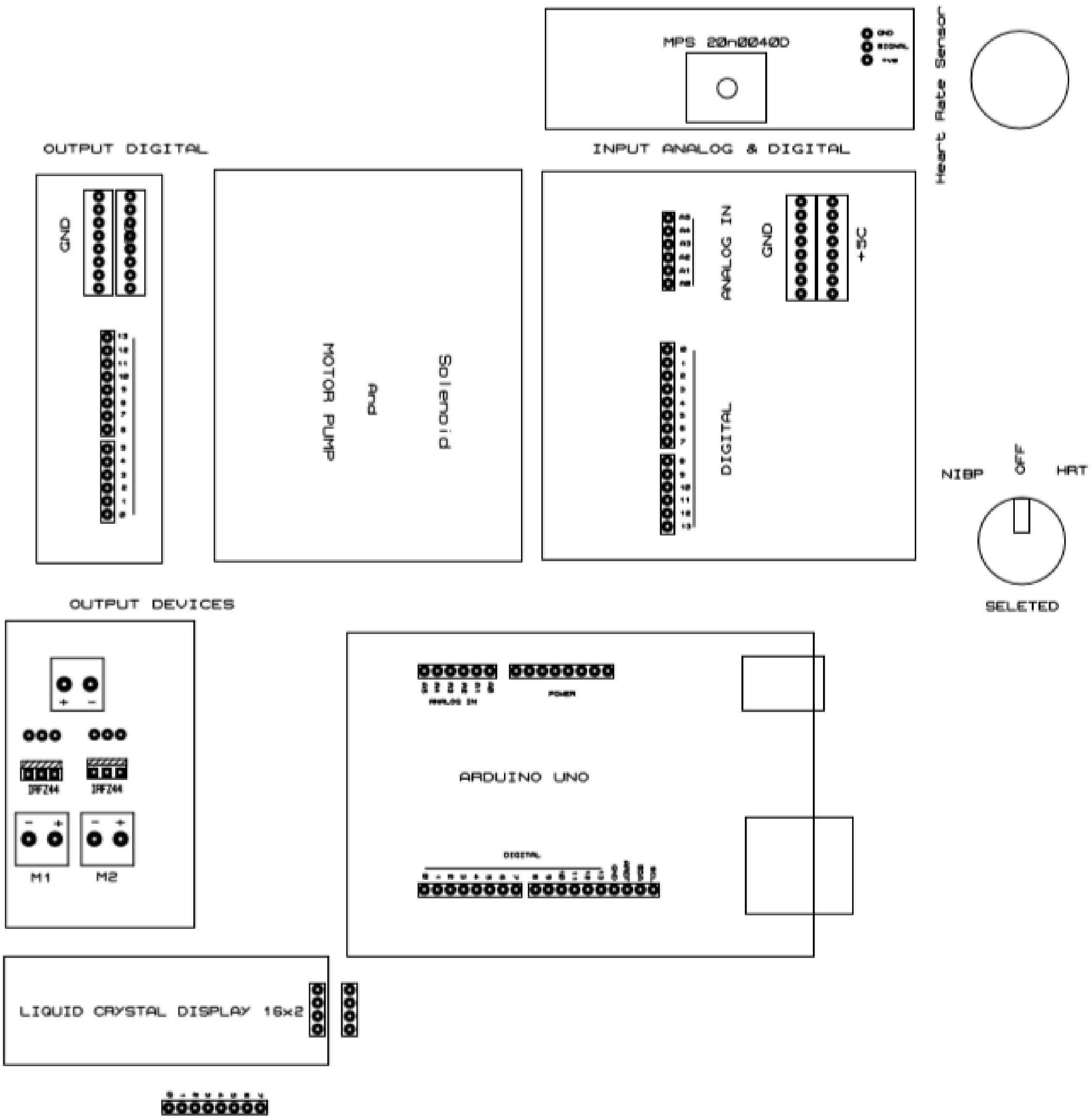


Figure 3.8

CHAPTER 4

RESULT

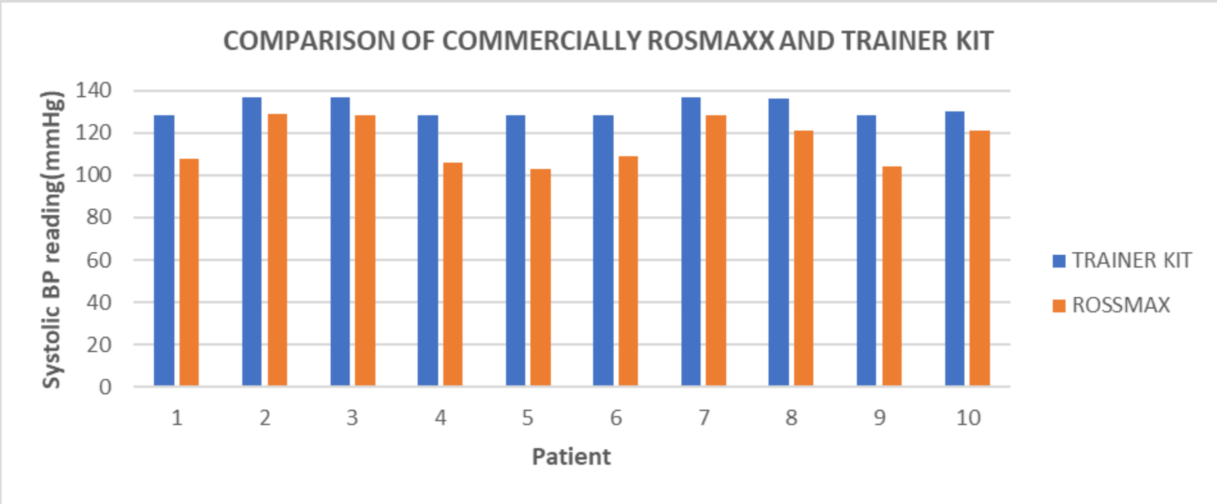


Figure 4.1

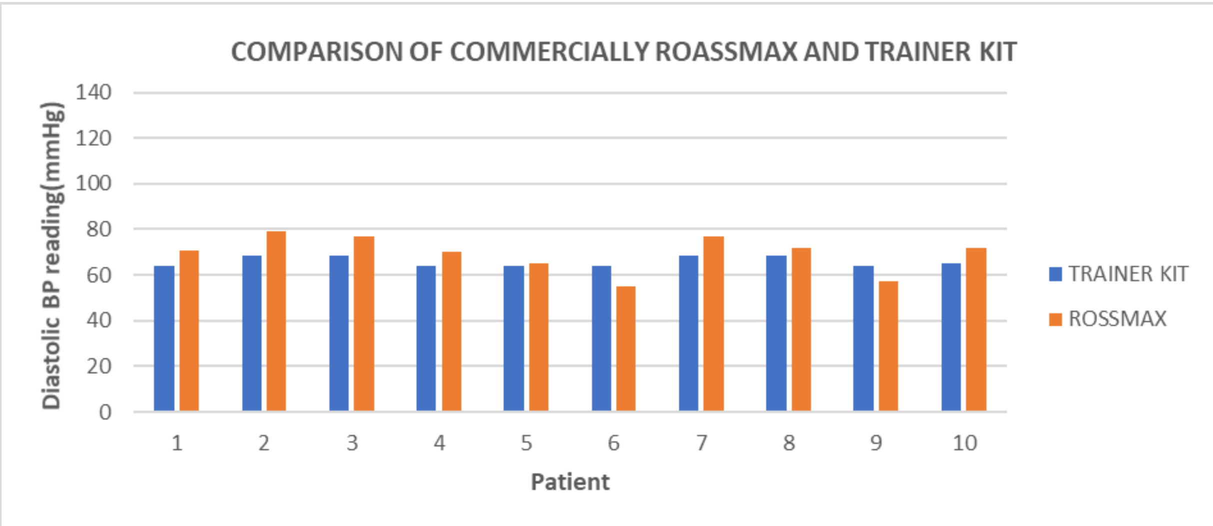


Figure 4.2

From the figure that has shown, we know that systolic blood pressure is the top number on the reading. It measures the force of blood against artery walls while ventricles, the lower two chambers of the heart squeeze, pushing blood out to the rest of the body. The diastolic blood pressure is the bottom number on the reading. It measures the force of blood against artery walls as heart relaxes and the ventricles are allowed to refill with blood. Diastole, this period of time when heart relaxes between beats is also the time that coronary artery is able to supply blood to the heart. To get the result, experiment was conducted to compare between commercially device rossmax and trainer kit. Based on the results, the device give different values at all time of measurement for systolic and diastolic. Result from device rossmax was show more accurate than trainer kit but it also reliable to use the result from the trainer kit. Furthermore, it is considerably acceptable since the readings values is in standard range. According to the J. Handler [10], the reading of systolic and diastolic discrepancy occurred due to some factors such as cuff over clothing, back unsupported, distended bladder and arm unsupported sitting or standing. The proposed device could be used for commercialization of BP measurement and future reference for technical students and researchers.

CHAPTER 5

CONCLUSION

This system of recording, measuring, and visualizing is a useful alternative for taking blood pressure. In the future it will allow for the constant monitoring blood pressure, on the part of the patient as well as medical centers. We developed Noninvasive Wireless Remote Monitoring Blood pressure Measurement instruement based Microcontroller. The blood pressure was measured continuously for a long period of time with help of developed algorithm the small embedded system and displayed the systolic and diastolic blood pressure on a mini LCD. The result were further compared with existing devices data like sphygmomanometer to verify the accuracy of the developed systems. Moreover, the developed systems can transmit can enabled device though wireless technology. This systems provide users an easy-to-use interface and simple BP management environment. The wifi interface provides a convenient and low-power consumption method for data transmission.

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SUPERVISOR

This report has been reviewed and validated as it fulfils the requirements if the final project design as set fourth

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Date :