OXYGEN SATURATION MONITORING SYSTEM

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotation and summaries which have been duly acknowledged.

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ABSTRAK

Oksigen adalah salah satu unsur paling penting dalam kehidupan. Terutama bagi mereka yang mengalami risiko kegagalan pernafasan. Pemantauan kadar ketepuan oksigen adalah penting bagi memastikan kadar peredaran darah berpungsi dengan sempurna. Pulse Oximeter adalah salah satu alat yang digunakan dalam persekitaran klinikal bagi memantau kadar pengoksigenan darah dalam arteri. Walaubagaimanapun, sistem penjagaan kesihatan mengalami perubahan mengikut peredaran masa daripada pendekatan tradisional kepada pendekatan yang lebih moden. Pakar kesihatan memainkan peranan penting dalam pendekatan tradisional. Bagi pemeriksaan harian, pakar kesihatan memantau pesakit dengan bergerak secara fizikal dari seorang pesakit kepada pesakit yang lain di mana mereka tidak boleh memantau pesakit secara berterusan. Selain itu, pihak hospital tidak dapat mengesan sebarang kecemasan kecuali pada pemeriksaan kesihatan harian. Projek ini membentangkan satu inovasi peranti mengukur dan sistem pemantauan tahap ketepuan oksigen. Objektif utama projek ini adalah untuk membangunkan sistem pemantauan ketepu oksigen bagi memudahkan pakar kesihatan memantau pesakit menggunakan komputer, menentukan tahap ketepuan oksigen pesakit dan menganalisis kebolehpercayaan sistem ini. Kebolehpercayaan dan kesahihan projek ini telah dipastikan melalui ujian lapangan. Data analisis menunjukkan projek ini boleh menghasilkan bacaan yang tepat dan sama dengan alatan perubatan yang sedia ada di pasaran. Dengan menggunakan projek ini, pakar kesihatan boleh memantau kadar kesihatan pesakit mereka sepanjang masa daripada jarak jauh melalui komputer.

ABSTRACT

Oxygen is one of the most important elements in our life. Especially for those who has risk of respiratory failure. It is important to monitor the oxygen saturation level to ensure proper perfusion of blood in respiration system. Pulse oximeter has become the command used tools in the clinical environment for assessing arterial blood oxygenation. However, the healthcare system is undergoing changes according to the transformation of time from the traditional approach to a modern approach. In the traditional approach the professionals healthcare play the major role. For daily check-up, the professionals healthcare monitor their patient by move physically from one person to another where they not possible to monitor their patients continuously. Other than that, doctor and nurses cannot be detecting of any serious condition except they check the health of patients at the time. This project presents an innovation of measuring device and monitoring system for oxygen saturation level. The primary objective of this project is to develop oxygen saturation monitoring system for professional healthcare to monitor their patients easily from their computer, to determine the oxygen saturation level and to analyze the reliability of the system. The reliability and validity of this project have been ensured via field test. The data analyze shows that this project can produce accurate readings that are similar to the existing medical device. By using this project, professional healthcare can monitor their patients easily all the time from far via their computer.

Keywords – ***Respiratory Failure, Oxygen Saturation Level, Measuring Device, Monitoring System, Professionals Healthcare***

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

One of the most important elements needed to sustain life is oxygen (O_2) because it is used by cells to turn sugars into usable energy. Oxy-hemoglobin (HbO_2) is the protein hemoglobin, found in red blood cells, bounded to O_2 that delivers 98% of oxygen to cells. The measurement and calculation of the percentage of Hbo_2 in arterial blood is known as oxygen saturation (SpO_2)[1].

Pulse oximeter is a medical instrument that can detect heart-rate and oxygen saturation as signatures of our level of health condition. It can be implemented as a small device, and has been used widely in different applications[2]. Pulse oximeters gained rapid acceptance in a wide variety of medical applications, including surgical wards, intensive care units, general wards, ambulance and home care by providing early detection of decreases in the arterial oxygen supply, reducing the risk of accidental death and injury[3].

Based on article of pulse oximetry by Jubran A., pulse oximeter is usually used for monitoring oxygenation in the critical care setting. By forewarning the clinicians about the presence of hypoxemia, pulse oximeters may lead to a quicker treatment of serious hypoxemia and possibly circumvent serious complications. Hypoxemia is a sign of a problem related to breathing or circulation, and may result in various symptoms, such as shortness of breath repaid breathing and fast heart rate[4]. Current, pulse oximeters are using cable and need to reconnect each time the patient is move.

Oxygen Saturation Monitoring System has been developing to solve this problem. The purpose of this project is create oxygen saturation monitoring system where professional healthcare can monitor their patients by without moving physically from one to another and the data can be monitor from computer at nurses based station.

Human body requires and regulates a very precise and specific balance of oxygen in blood. Normal blood oxygen level in human are considered 95-100 percent. If the level is below 90 percent, it is considered low resulting in hypoxemia. Blood oxygen level below 80 percent may compromise organ function, such as the brain and heart, and should be promptly addressed. Continued low oxygen level may lead to respiratory arrest. Oxygen therapy may be used to assist in raising blood oxygen molecules (O_2) enter the tissues of the body.

In medical field, pulse oximeter is used to monitor oxygen saturation level of patients. But in hospitals they use manually method in recording patient data, some time when many patients at the same time they will lack of staff and this situation may lead error in recording of patient's data. To solve this problem this device is developed. Where by using this system, even many patients at a time they still can record the data by refer to the computer interface at computer at nurse based station and this system is user friendly.

1.2 PROBLEM STATEMENT

According to the transformation of time, the traditional method in recording and monitoring oxygen saturation level of patient does not suitable to use anymore. It is because the professionals healthcare need to monitor their patient by move physically from one person to another where they not possible to monitor their patients continuously. When many patients, hospital will lack of staff and the probability error in recording patient data is higher. Most of hospitals equipment is based on cable connections and it became hassle[6].

To solve this problem, the Oxygen Saturation monitoring systems are designed. This system provides continuously monitoring of SPO2 where nurse or doctor can monitor continuously monitor their patients from their computer as long as they have this system.

1.3 OBJECTIVE

The detail objective of this study is follow:

- To develop oxygen saturation monitoring system for healthcare professionals to monitor their patients easily from their computer.
- To determine and accurately measure vital parameter of patients which is SPO2.
- To analyze the reliability of the system.

1.4 SCOPE OF PROJECT

Scope of this project is to build oxygen saturation monitoring system for professional healthcare in monitor oxygen saturation level of patients without move physically from one patient to another. These projects consist of two parts which is hardware and software. The main part of this project is infrared sensor, LED and photo detector which use to measure the light that scatters though blood perfused tissues and converts the signal to an electrical signal.

Then continue by design an amplifier circuit to amplify the electrical signal. Next, Arduino Nano is use as open source electronic prototyping platform based on flexible, simple microcontroller board is chosen to connect with RF HC11. It is because this device is a small and non-invasive device. RF HC11 has been choosing as transmitter and receiver because it can reach to 300 Meter on Open Space. Then for software part it use Visual Basic software because it is user friendly.

1.5 SIGNIFICANT OF PROJECT

These projects are designed to facilitate work of doctor and nurse in monitoring SPO_2 of patients. The implementation of remote surveillance had improved the health management system in terms of accessibility of patient's health status in real time measurement. By using this system, allowed the person in charge at hospital monitoring SPO_2 of their patients without go to the patients regularly. Consequently, doctor and nurse can take an action as soon as possible if has an emergency is occur.

CHAPTER 2

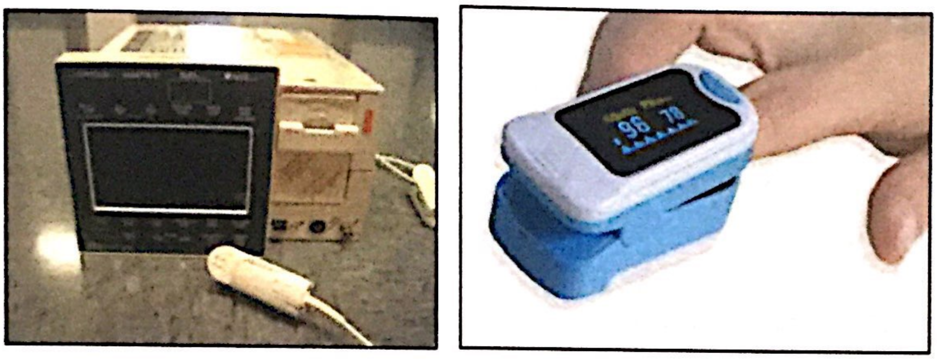
LITERATURE REVIEW

2.1 PULSE OXIMETER HISTORY

Pulse oximeter is a medical instrument that can use to detect heart rate and, oxygen saturation as signatures of our level of health condition[2]. Oximetry measurements can be traced to the early 1930's when German researcher used spectrophotometers (instruments that measure different wavelengths and intensities of light) to research light transmission through human skin. In 1934, one researcher reported measuring oxygen saturation in blood flowing through closed vessels in animals[7].

In 1939, German researchers reported use of an "ear oxygen meter" that used red and infrared light to compensate for changes in tissue thickness, blood content, light intensities and other variables. However, it was not until World War II that interest in oximetry took hold. At that time there was a need to evaluate oxygenation of high altitude pilots[7].

Between 1940 and 1942, a British researcher, Millikan, used two wavelengths of light to produce a practical, lightweight aviation ear oxygen meter for which he coined the word "oximeter". He noted that light transmitted through a red filter was oxygen-saturation-sensitive and light passing through a green filter was independent of oxygen saturation. It was later determined that oxygen insensitive-signals were not due to the green light filter but instead to infrared light[8].



Figures 2.1: The old version *vs* latest version of pulse oximeter

The system went through many modifications during the 1940's and 1950's and was eventually manufactured by the Waters Company. This system manually used in physiology, aviation and experimental study.

In 1964, a San Francisco surgeon developed a self-calibrating, 8-wavelength oximeter that was marketed by Hewlett Packard in the 1970's [9]. This system was used in clinical environments but was very large, weighing approximately 35 lbs. and had a bulky, clumsy earpiece. The unit was also very expensive (approximately $10,000.00). However, it did allow for continuous non-invasive monitoring of arterial oxygenation.

In the early 1970's, Takuo Aoyagi, a Japanese bioengineer, was trying to develop a non-invasive method to determine cardiac output using cardio green dye and measuring light passing through an earpiece. He found that light transmitted through the ear exhibited pulsatile variations that made it impossible to compute cardiac output. Fortunately, he was also interested in oximetry and was familiar with previous oximetry work. He recognized that he might be able to use the pulsating changes in the light transmission through the ear to measure arterial oxygen saturation. He then went on to develop a pulse oximeter and applied for a Japanese patent. At the same time, another Japanese researcher with Minolta was working on the same concept and applied for a patent a month later. This patent was denied in Japan but approved in the U.S.

In the late 1970's, the Biox Corporation in Colorado made significant advances in pulse oximetry, 2-wavelength measurements. They first introduced the use of Light Emitting Diodes (LED's) for the red and infrared light sources. They marketed their device directly to respiratory therapists and anesthesiologists who could see the benefit of continuous, real time, non-invasive oxygen saturation readings. Ohmeda Corporation purchased Biox, and in the 1980's, along with Nellcor (started by an anesthesiologist, Bill New) and Novametrix continued to make significant advances in size reduction, cost, and development of multiple site probes.

Today there are many manufacturers of pulse oximeters. All offer a variety of different oximeter boxes with SpO_2 (oxyhemoglobin) and pulse rate readings, waveform displays, alarms and etc. While the boxes and the displays may differ, they use a similar method of measuring oxyhemoglobin saturation by two wavelengths of light in the red and infrared range. But while the two-wavelength method is used to start the SpO_2 measurement process, the way the signals are processed after that point, play a major role on how accurate the readings will be, especially through motion and low perfusion. During the late 1990's and into the next decade, 'new generation' pulse oximeters have been introduced that have elevated the accuracy of pulse oximeter readings significantly[7][10][8].

2.2 THEORY OF PULSE OXIMETER

The most common used of a pulse oximeter is the determination of person's functional oxygen saturation. Pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated (Hbo_2) and deoxygenated hemoglobin (Hb). At 940nm, oxygenated hemoglobin (Hbo_2) absorbs more infrared light and allows more red lights to pass through. While at 660nm, deoxygenated hemoglobin (Hb) absorbs more red lights and allows more infrared light to pass through[5][11][12].

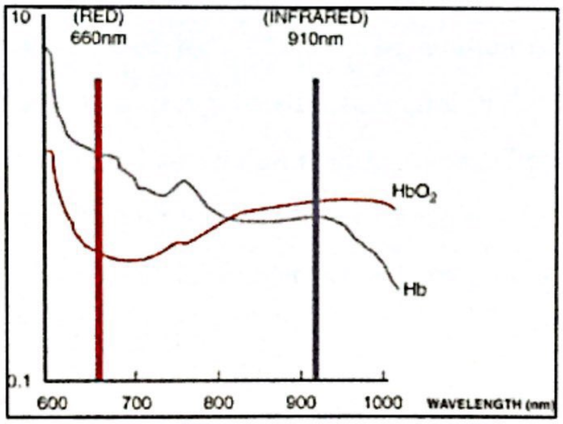


Figure 2.2: Light absorption characteristics of the two types of wavelength

A photo detector in the sensor perceives the non-absorbed light from the LEDs. At each wavelength, the light detected by the photodiode consists of a cardiac synchronous AC signal arising from arterial blood volume pulsations, superimposed on a DC level. The DC level depends on LED intensity, tissue absorption, path length, and detector sensitivity. The AC component represents the variable arterial blood (Figure 2.3) which is useful for calculation of oxygen saturation in blood[5].

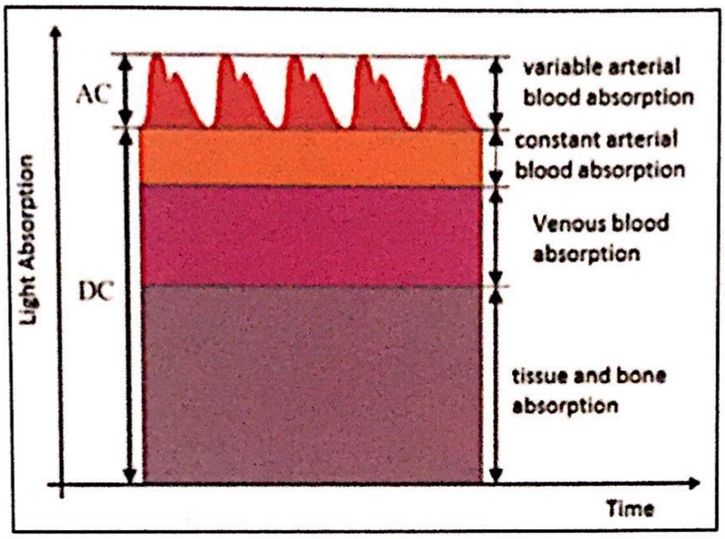


Figure 2.3: Light absorption diagram.

Pulse oximeters work by measuring the light absorption properties of haemoglobin using a red–infrared light source. The amount of light absorbed varies according to the proportion of oxygenated haemoglobin in the blood and this is analyzed to generate a numerical saturation reading. Normal physiological conditions arterial blood is between 87% and 97% saturated. Readings have an accuracy of +/– 2% although this varies with models. Finger probes are generally more accurate than ear probes[5][7].

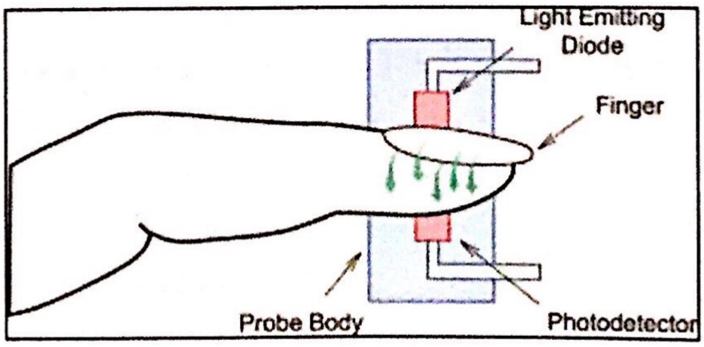


Figure 2.4: Illustration of the principle of a pulse oximeter

Oxygen transportation is performed through the circulatory system. Deoxygenated blood enters the heart where it is pumped to the lungs to be oxygenated. In the oxygenation process, blood passes through the pulmonary alveoli where gas exchange (diffusion) occurs (Figure 2.5). Carbon dioxide (CO) is released and the blood is oxygenated, afterwards the blood is pumped back to the aorta[13].

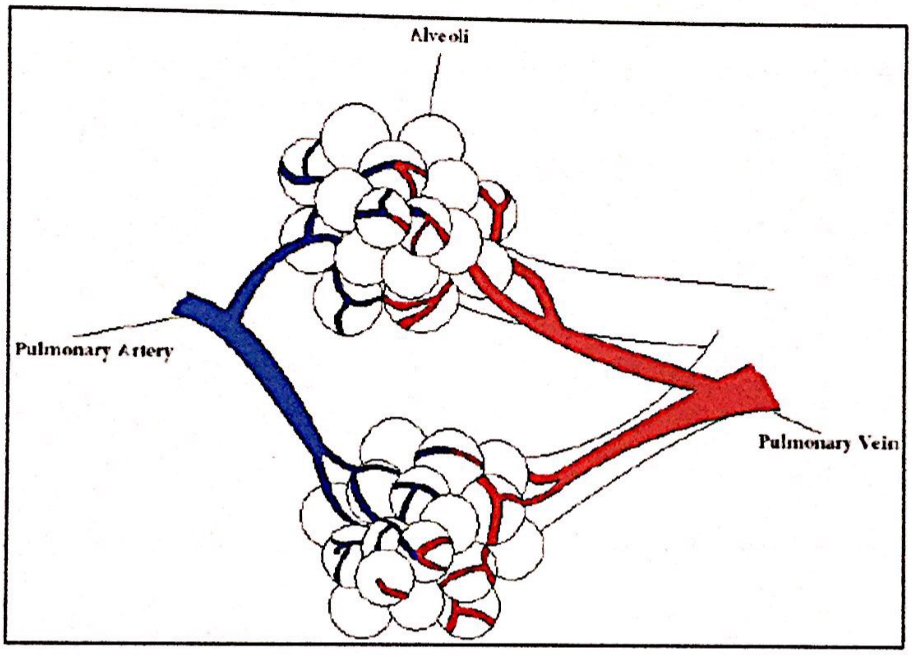


Figure 2.5: Pulmonary alveoli

2.3 PULSE OXIMETER PRINCIPLE

A pulse oximeter shines light of two wavelengths through a tissue bed such as the finger or earlobe and measures the transmitted light signal. The device operates on the following principles:

a) The light absorbance of oxygenated hemoglobin is different from absorption of deoxygenated haemoglobin and this system consist of sensor and two difference wavelengths, which include red and near infrared light.

b) The absorbance of both wavelengths has a pulsatile component, which is due to the fluctuations in the volume of arterial blood between the source and the detector [9][14][1][7][15][9].

Table 2.1: Reading of Pulse Oximeter

SPO_2 (%)	Oxygenation Status
95-100	Normal
91-94	Mild hypoxia
86-90	Moderate hypoxia
Less than 85	Severe hypoxia

Table 2.2: Patients Who Need Oxygen Regardless of Oxygen Saturation Measurement

1	Patients in cardiac or respiratory arrest
2	Patients with chest pain suspected to be of cardiac origin
3	Patients with multisystem trauma
4	Patients who are apneic or who require assisted ventilation
5	Patients with suspected or confirmed carbon monoxide poisoning or smoke inhalation
6	Neonatal patients in distress
7	Patients with suspected sickle cell crisis
8	Hypotensive patients (SBP < 80 mm Hg)

9	Near drowning patients

2.4 EXISTING PRODUCT

There are many models and brands of pulse oximeters. A sampling based on popularity and features was chosen. The models described cover the full gamut of possible feature sets from completely wired and stationary units to highly portable disaster-relief and triage models to Bluetooth-compatible wireless units.

2.4.1 PATIENT MONITOR

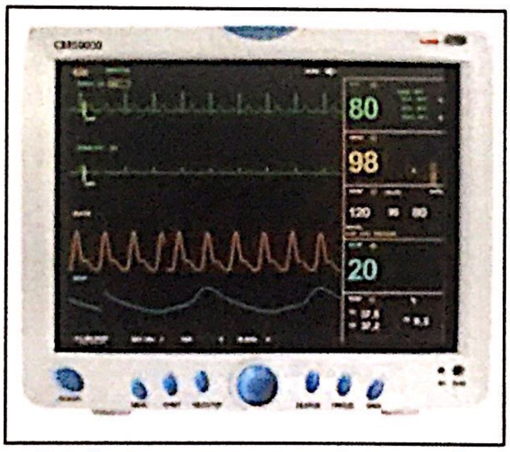


Figure 2.6: Patient Monitor

Patients monitor is one of the clinical equipment that can be used to measure blood oxygen saturation (SPO_2) level in hospital. This equipment has seven difference parameter that can be measure which are respiration, Invasive blood pressure (IBP), non-invensive blood pressure (NIBP), ECG 3/5/10 leas, duel parameter, end Tital Co2 and Pulse oximeter (SPO_2).

2.4.2 TRUSAT™ PULSE OXIMETER

Figure 2.7: TruSat™ Pulse Oximeter

The GE TruSat pulse oximeter is a durable model that displays oxygen saturation and pulse. The LCD display is backlit for easy viewing. It can either be powered by AC or battery power.

2.4.3 AVANT 9700

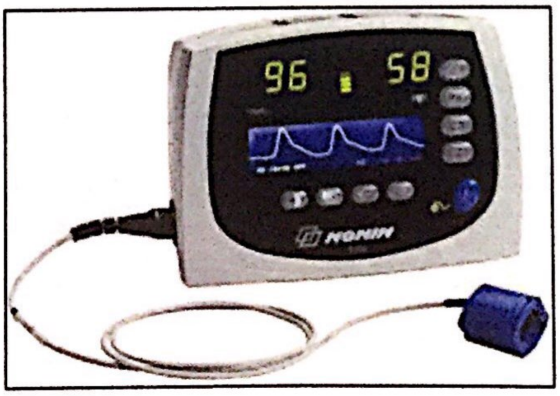


Figure 2.8: Avant 9700

The Avant 9700 is an industry leader pulse oximeter. The sensor is connected to the display via a wire. Oxygen saturation, pulse and plethysmograph are displayed in bright LED displays. The unit can be either AC powered or battery powered.

2.4.4 AVANT 4000

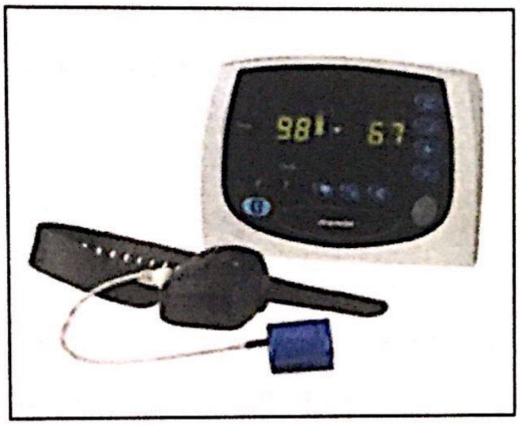


Figure 2.9: Avant 4000

The Avant 4000 system is the first Bluetooth pulse oximeter. The wireless communication is point to point, so this oximeter uses Bluetooth as a cable replacement. Oxygen saturation and pulse rate are displayed in bright LED displays.

2.4.5 WRISTOX AND SPO 7500

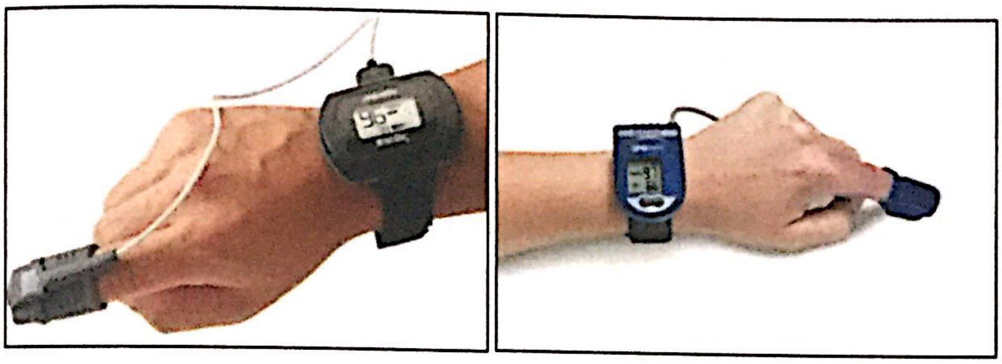


Figure 2.10: WristOx and SPO7500

Nonin's WristOx7 and SPO medical's SPO 75008 are both wrist worn devices that are intended for sleep and long term studies. They store periodic readings in memory that can be downloaded to a PC for viewing and analysis. Both display current data on a small LCD display attached to the wrist. The SPO 7500 is unique because it uses a reflectance sensor as opposed to transmission.

2.4.6 FINGERTIP PULSE OXIMETER

Figure 2.11: Fingertip Pulse Oximeter

Finger pulse oximeter is equipped with technology to rapidly detect changes in our blood oxygen level. It can help give us the knowledge that our need to take control of our condition. A finger pulse oximeter is easy to use. Just clip it on fingertip to get a blood oxygen reading.

2.5 DISEASE THAT EFFECTING OF BLOOD OXYGEN SATURATION (SPO_2) READING

Oxygen saturation is the body's ability or more specifically the ability of the haemoglobin on the red blood cells to carry oxygen. Oxygen level can be measured by using pulse oximeter, which uses to measures the saturation level of haemoglobin or SpO2. It can also be measured with a blood test called an arterial blood gas. There are several factors that affect reading of SPO_2 and can be below than 95 percent [9].

2.5.1 CHRONIC OBSTRUCTIVE PULMONARY DISEASE

Chronic obstructive pulmonary disease or COPD can have a profound effect on the oxygen saturation level in our body. People with COPD suffer from chronic oxygen deficiency because the air sacs or alveoli can no longer accommodate inhaled oxygen. The alveoli either have collapsed or are plugged with mucus. Individuals with this disorder often end up using supplemental oxygen as the body can no longer breathe in and maintain an adequate oxygen saturation level.

2.5.2 PULMONARY CIRCULATION

Several disorders can affect the circulation to and from our lungs, which affects our oxygen saturation level. A pulmonary embolism, which is a blockage or blood clot that has travelled to one or more sections of our pulmonary artery, can come from any part of our body due to a broken bone, surgery, disease, pulmonary hypertension or cor pulmonale. Heart disease or lung cancer also alters our pulmonary circulation, causing a decrease in our oxygen saturation level.

2.5.3 EMPHYSEMA

Emphysema permanently alters the structure of the air sacs in the lungs. The disease breaks down the walls of the alveoli, causing each one to merge with another, forming fewer and larger alveoli. This damage reduces the surface area available to absorb oxygen and release carbon dioxide. The disease process alters the oxygen saturation level. The drops in oxygen will causes and become short of breath because of breathe harder and deeper because the body tries to bring in enough oxygen to feed our cells. This condition also causes cor-pulmonale, an enlargement of the right side of the heart due to the increased work of breathing.

2.5.4 ASTHMA

Asthma is one of example disease that can affect our blood oxygen saturation level. Asthma is a chronic ongoing lung disease marked by cute flare-ups or attacks of difficult with breathing. It is a common disease that can happen at any age but more often occurs during childhood. Inflammation of the airway in the lung can cause asthma. For those suffer of asthma their bronchioles and alveoli become inflamed, irritated and swollen, blocking the flow of air into the lungs. This condition can cause a decreasing of our oxygen saturation level.

2.5.5 PERIPHERALLY VASOCONSTRICTED PATIENTS

In order to provide a reading, pulse oximeter probes require pulsatile blood flow through the structure to which it is attached. In patients who are peripherally vasoconstricted, either as a compensatory response to shock, or due to hypothermia or as a result of the administration of vasopressor agents (drugs used to cause constriction of the blood vessels) have poor peripheral blood flow through structures such as fingers, toes and ears. As a result, the pulse oximeter probe will likely fail to deliver a reading, or if it does, it is generally unreliable.

2.6 LIMITATION OF PULSE OXIMETER

Pulse oximeter work using absorption characteristics of oxygenated (Hbo_2) and deoxygenated hemoglobin (Hb) by red and infrared light LED's, however considerable differences exist in the way different manufacturers obtain and process data. This is occurs because the light-emitting diodes, sampling frequency, and microprocessor algorithms. Below are the several factors which affect accuracy of pulse oximeter[14].

Table 2.3: Factors That Affect Pulse Oximeter

Condition	Problem
SpO2 values < 80%	Pulse oximeters can overestimate oxygen saturation, particularly in those with darkly pigmented skin.
Poor perfusion (cold digits) due to hypotension, hypovolemic shock, cold environment, or cardiac failure	May result in the machine not providing a reading.
Anemia	Oxygen delivery to tissues is inadequate but SPO_2 is normal.
Carbon monoxide poisoning	Carbon monoxide binds to hemoglobin, resulting in inadequate oxygen transport despite normal pulse oximeter readings.
Certain antiretroviral medication	Affect oxygen's affinity for hemoglobin.
Movement, shivering patients, heart arrhytmias	Oximeter may not be able to identify an adequate pulse signal.
Nail polish, dirt, artificial nail	Can cause false low reading or no reading.
Bright artificial light (in operating room)	Can cause false reading.
Older patients	Normal oxygen saturation levels may be slightly lower than in younger people.
Sickle cell disease	Does not found SPO_2 result in adults, but may in children.

2.6.1 NAIL POLISH AND DIRT UNDER THE FINGER NAILS

Certain shades of nail polish (mainly hues of black, blue and green) have been shown to cause significantly lower oxygen saturation readings. Dirt under the finger nails has also been reported to cause difficulty in obtaining reliable readings. One of the ways that poor readings through nail polish can be overcome is to move the probe so that it transmits light from one side of the finger to the other, rather than through the nail bed. Alternatively, use another site such as an ear or toe.

2.6.2 BRIGHT EXTERNAL LIGHT SOURCE

Bright external light may overwhelm the light sensor in the oxygen saturation probe and give erratic or erroneous readings. This can be overcome by simply placing the patient's hand under a blanket or covering the probe with material, thereby blotting out external light. Failure to detect hypoventilation and hypercarbia (abnormally high level of $CO2$ in circulating blood) may occur without a decrease in haemoglobin oxygen saturation. This is especially true if the patient is receiving supplemental oxygen. A pulse oximeter should thus not be relied upon to assess the adequacy of ventilation, oxygen source disconnections or misplaced endotracheal tubes into the esophagus.

A combination pulse oximeter/ capnography provide a far better range of monitoring. A capnography measures $CO2$ in exhaled air and is thus the monitor of choice to pick up acute events such as a dislodged endotracheal tube. A pulse oximeter will only pick up the consequences of an acute event (hypoxia) and may result in significant time delay before healthcare providers may respond and correct the problem.

2.6.3 CARBON MONOXIDE POISONING

Once carbon monoxide has been absorbed it forms a strong bond with the iron atoms in the haemoglobin (called carbooxyhaemoglobin, or HbCO), which is the principle oxygen carrying component of blood. Carbon monoxide has a much higher (more than 200 times) affinity for haemoglobin than oxygen. It is therefore able to bond quicker and stronger with haemoglobin, thereby reducing haemoglobin oxygen transport.

Pulse oximetry only reads the percentage of bound haemoglobin; it cannot determine what gas has actually bonded to the haemoglobin. As such, a patient with carbon monoxide poisoning may exhibit normal pulse oximetry readings despite inadequate oxygen transport. This may significantly delay the recognition of hypoxemia in these patients. The events leading up to the emergency that is being treated becomes crucial information in interpreting the pulse oximetry results.

2.6.4 ANAEMIA

Anaemia, one of the most common blood disorders, it is a disease that characterised by a decrease in the number of red blood cells or a less than normal amount of haemoglobin. As mentioned earlier, pulse oximetry reads the percentage of bound haemoglobin. In anaemic patients, the less than normal available haemoglobin may indeed be saturated with oxygen, thus showing a normal pulse oximetry reading even though the patient has very poor tissue oxygen delivery.

2.6.5 SMOKE INHALATION

Firefighters and people who have been trapped in a fire can suffer airway and lung damage from smoke inhalation from burning wood that causes thick acidic smoke. This smoke burns and destroys lung tissue. As the water used to put out the fire turns to a fine mist, it picks up particles and chemicals from the burning debris and carries it into the lungs as the person struggles to breathe. As lung tissue deteriorates, the alveoli can no longer accept oxygen, causing a severe drop in oxygen saturation levels.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will cover the explanation of methodology that being used to make this project complete and working well. Methodology plays an important role in implementing oxygen saturation monitoring system. The detail explanations of the methodology are explained in this chapter such as the process of making the pulse Oximeter, hardware, interface and so on.

3.2 FLOW CHART

Flow Chart below will show that the whole process to implementing this project and it has been descriptive with detail explanation for every step of the process. Collecting data to find problem statement, design circuit, choosing suitable material and programming will be the first step of planning before produce this product.

Collecting data to find problem statement is most importance before produce a product. In collect the data, the interview and attribute questionnaire (APPEDIX A) to hospital staff how has been familiar with pulse oximeter have been done. By using the data we can find and create the problem statement.

Next step, after problems statement was created design circuit, choosing suitable material and programming to overcome the problem statement. For this project visual basic (VB) software has been choose to be one of the software for this project. It is because this software is easier to handle and user friendly.

After identify the problem statement, hardware and software material, this project are proceed by creating pulse oximeter which is more focus to measure blood oxygen saturation level in human body which is the electronic part of the device. This project using two types of sensors which are IR Led sensor (940nm) and Red Led sensor (660nm). This LED has been chose because at 940nm, oxygenated hemoglobin (Hbo_2) absorbs more infrared light and allows more red lights to pass through. While at 660nm, deoxygenated hemoglobin (Hb) absorbs more red lights and allows more infrared light to pass through. While during the process of making pulse oximeter, programming can be launch simultaneously. Arduino Nano used to store the programming, and control the devices. Besides that, to transfer and receive the data HC11-433Mhz is used.

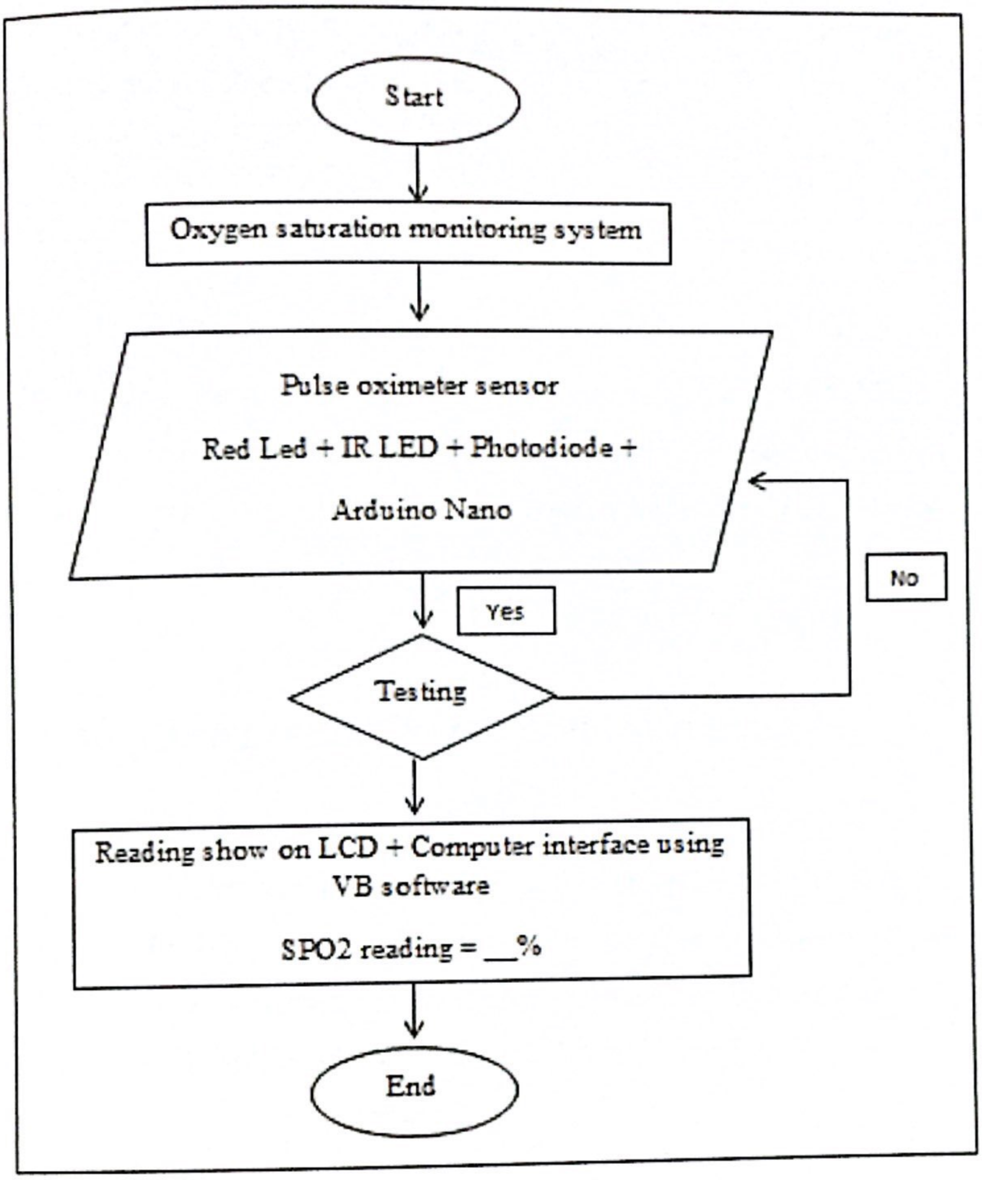


Figure 3.1: Flow Chart of Whole Project

According to this flow chart after hardware component is done, oxygen saturation monitoring system must be test. Test the device and system to ensure it is functioning and working in good and safe aspect. (If testing failed, return to the step before, redo the process, testing again the devices).

Last step of the whole project process is testing and collect data. Test the device to 30 subjects (students Politeknik Shah Alam) for the clinical testing and usability testing. Then, collect the data from and analysis the data by using Microsoft excel. Discuss and conclude the result that had analyzed.

3.3 HARDWARE

This project used hardware component to detect blood oxygen saturation as signatures of our level of health condition. The main component used in this project is pulse oximeter, Arduino Nano, Amplifier, HC11-433Mhz, and computer.

3.3.1 DESIGN AND IMPLEMENTATION PULSE OXIMETER

This section will explain the design and procedure used in forming of pulse oximeter. In this project, pulse oximeter is the one of importance part in this project. Pulse oximeter is used to detect oxygen saturation level and from the result we can justify our health condition. Then the data will display at 2 display which is LCD display and computer interface.

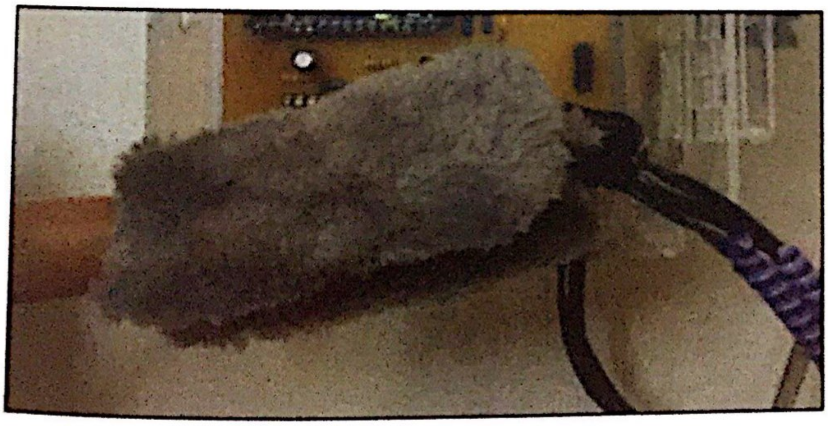


Figure 3.2: Pulse oximeter

3.3.1.1 PULSE CIRCUIT

The pulse circuit was implemented in order to give the continuous ON OFF voltage input to the Red and Infrared LED. The circuit operates using LM 358 and combine with the two resistor of 20 kΩ and capacitor of 100nF.

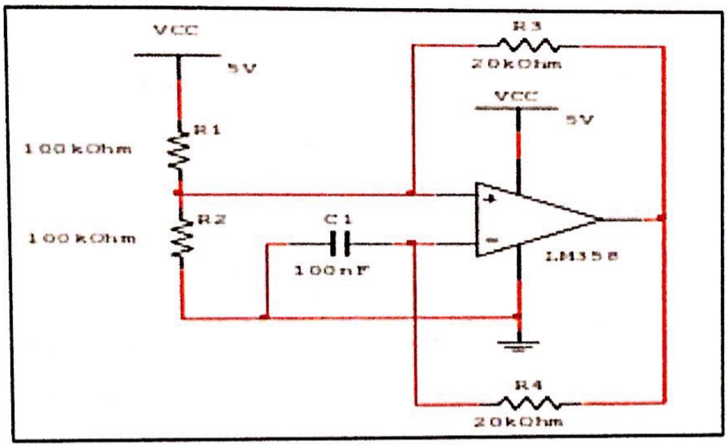


Figure 3.3: Pulse Circuit

3.3.1.2 LED CIRCUITS AND PHOTODIODE SELECTION

In order to verify the sensitivity of the photodiode in Red and Infrared spectrums, a Red LED and an Infrared LED were connected to the function generator producing a square wave pulse at the frequency of 1 kHz. The photodiode (BPW 34FS, peak sensitivity at 950 nm, 90% at 940nm) was directly linked to the positive and negative probes of the photodiode. Photodiode will produce the voltage signal by zoomed voltage level into the range 50mv/div.

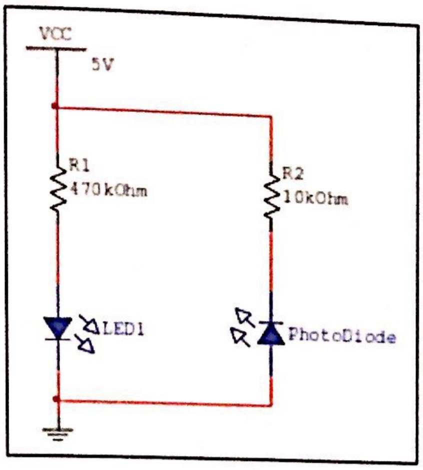


Figure 3.4: LED and Photodiode Testing

After such a setup, the photodiode was pointed at the LEDs individually to ensure that the square wave signal due to fast changing light intensity could be seen in the scope.

This test accomplished two things, first is to ensure that the photodiode was sensitive to both Red and Infrared light. Secondly is ensured that the slew rate (rate at which the photodiode is capable of changing between its extreme states) is enough to allow for capture of fast changing signals with good quality.

3.3.1.3 TRANS-IMPEDANCE AMPLIFIER (CURRENT TO VOLTAGE CONVERTER)

After photodiodes have been tested and deemed suitable for use in this project, the next step is to generate a voltage signal that is proportional to the intensity of light produced by the LED. Noting that the photodiode produces a current signal and voltage signal, current to voltage converter implemented.

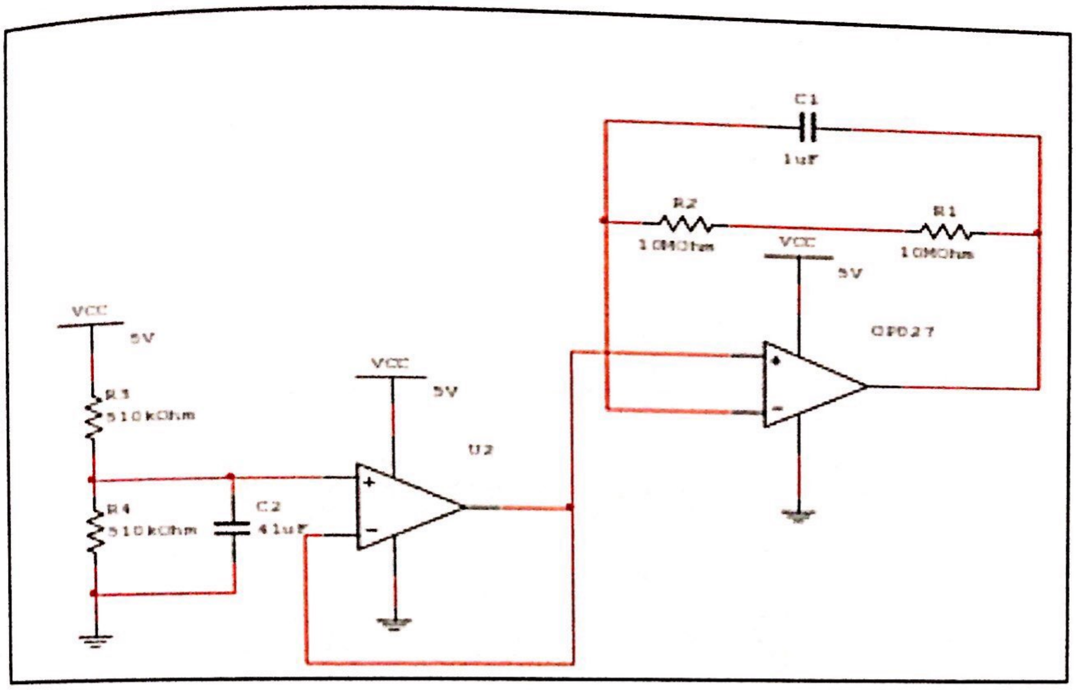


Figure 3.5: Trans-impedance Amplifier Circuit

According to the rules of the op-amp, it can be said that the current input to the negative terminal of the op-amp is zero. Therefore, any current generated due to the photodiode through a feedback resistor to the output. The operational amplifier used in this circuit is OP027. This is done to save space on the circuit board and keep things as close to each other as possible. In addition, this option ensures that the phase of working towards the same goal can be localized to a single IC, thus reducing the cross-board traffic and also ensure consistency and circuit parameters such as gain and bandwidth for that phase.

3.3.2 ARDUINO NANO

Arduino is an open-source electronics prototyping platform based on flexible, simple microcontroller board. The development hardware is easy to use with software writing in the board. For this project by taking an inputs signal from the sensors, it also can control a HC11-433MHz and LCD display. Referring to Figure

3.5, this project used Arduino Nano as a microcontroller to receive data and then display it through LCD display. Arduino Nano has small size, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x) or ATmega168 (Arduino Nano 2.x) with operate supply power at 5 volts.

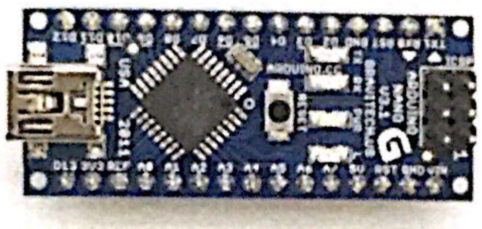


Figure 3.6: Arduino Nano

3.3.3 HC11-433MHZ

This wireless UART module is a new-generation multi-channel embedded wireless data transmission module. Its wireless working frequency band is 433.4-473.0 MHz, multiple channels can be set, with the stepping of 400 KHz, and there are 100 channels in total. The HC11 wireless communication frequency band is 434MHz in a high transparent FSK transceiver, high output power, high sensitivity and it reach to 150~300 Meter on Open Space compare to Bluetooth HC05/HC06.

In transparent transmission mode, the module act like normal receiving and sending serial port data, so it is convenient to use. The module adopts multiple serial port transparent transmission modes, and user could select them by AT command according to user's requirements. The average working current of three modes FU1, FU2 and FU3 in idle state is 80μa, 3.5mA an 22mA respectively, and the maximum working current is 100mA (in transmitting state).

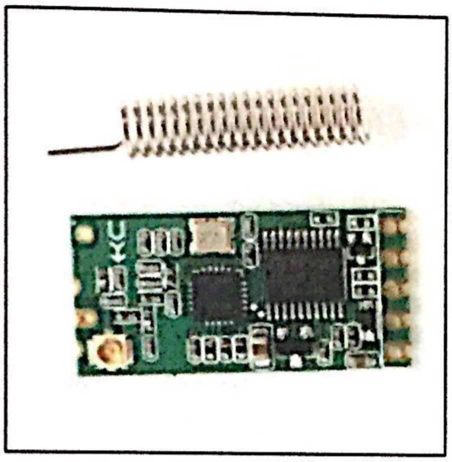


Figure 3.7: HC11-433MHz

3.3.4 LCD DISPLAY

Liquid Cystal Display is one of the display for this project. The output that will display is SPO2 reading for patients that using this device. In this project, the 16x2 LCD display has been used because of the amount character will display.

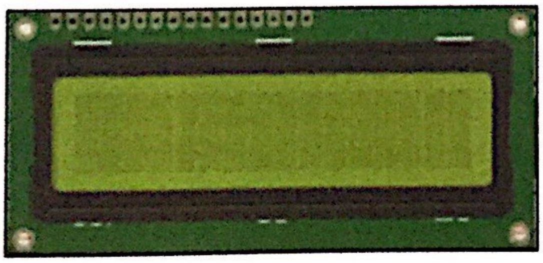


Figure 3.8: 16x2 LCD display

3.4 SOFTWARE

Visual Basic (VB) software is decide to as a software interface uses in this project, because it user friendly and easy to use. Besides that, this software also using a simple cording compares then C++ software. With this software, as long as hospital staffs have this software and distance from patients is not more than 300 meter in open area they can monitor their patients.

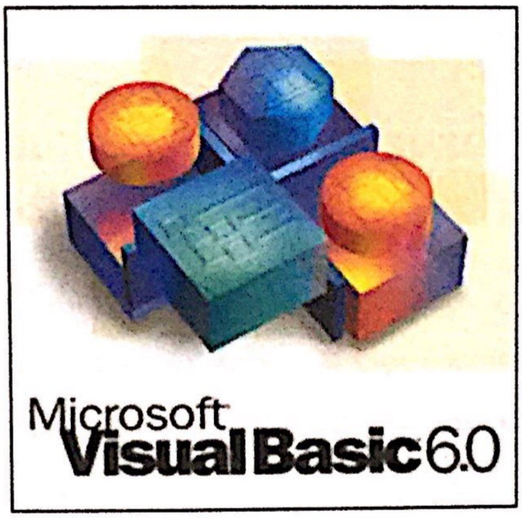


Figure 3.9: Visual basic software

3.5 BLOCK DIAGRAM

Oxygen saturation monitoring system is composed of several blocks of the network as show in Figure 3.10. Firstly, pulse oximeter which serves to detect oxygen saturation as signatures of our level of health condition. Then the signal is amplified by an amplifier. After that, Arduino Nano and HC11-433MHz module was used to program and transmit data. Finally, the data will display at two displays which is LCD display and computer interface at nurse based station.

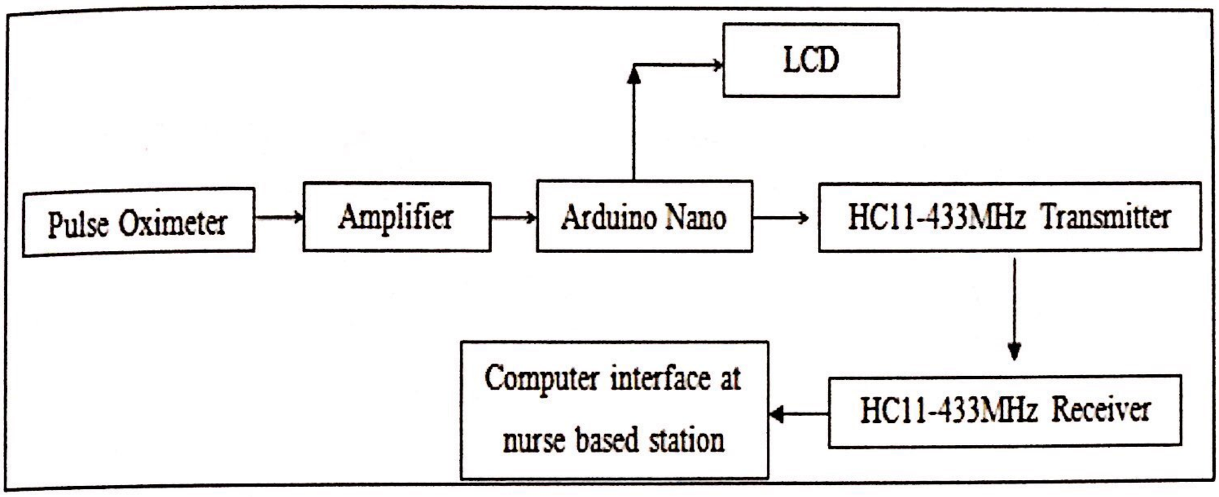
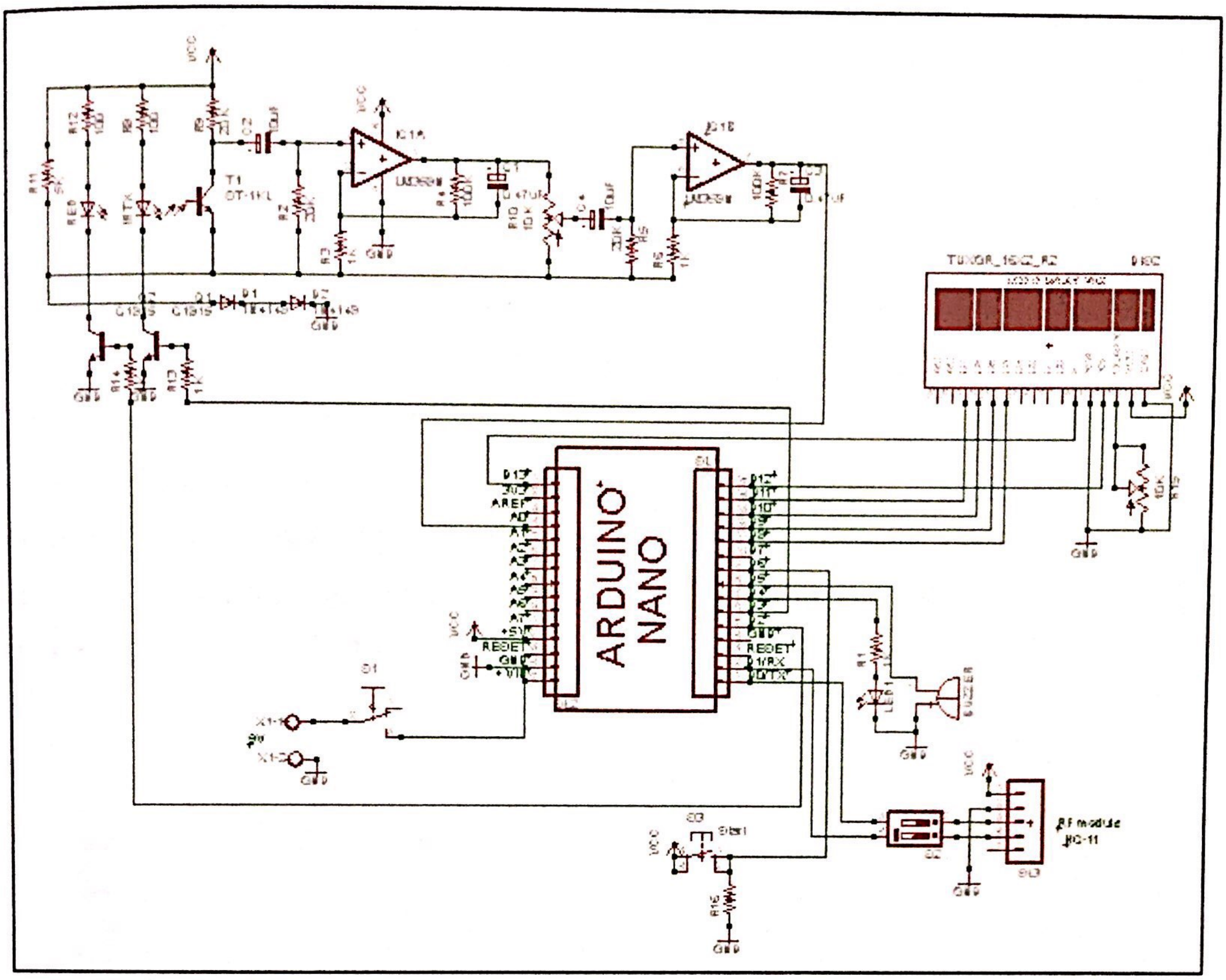


Figure 3.10: Block Diagram

3.6 SCHEMATIC CIRCUIT FOR HOLD PROJECT

Figure 3.11 shows schematic circuit that used to design the oxygen saturation monitoring system. This schematic circuit consists of a few circuits which are oximeter circuit, amplifier circuit, Rf transmitter circuit and power supply circuit.



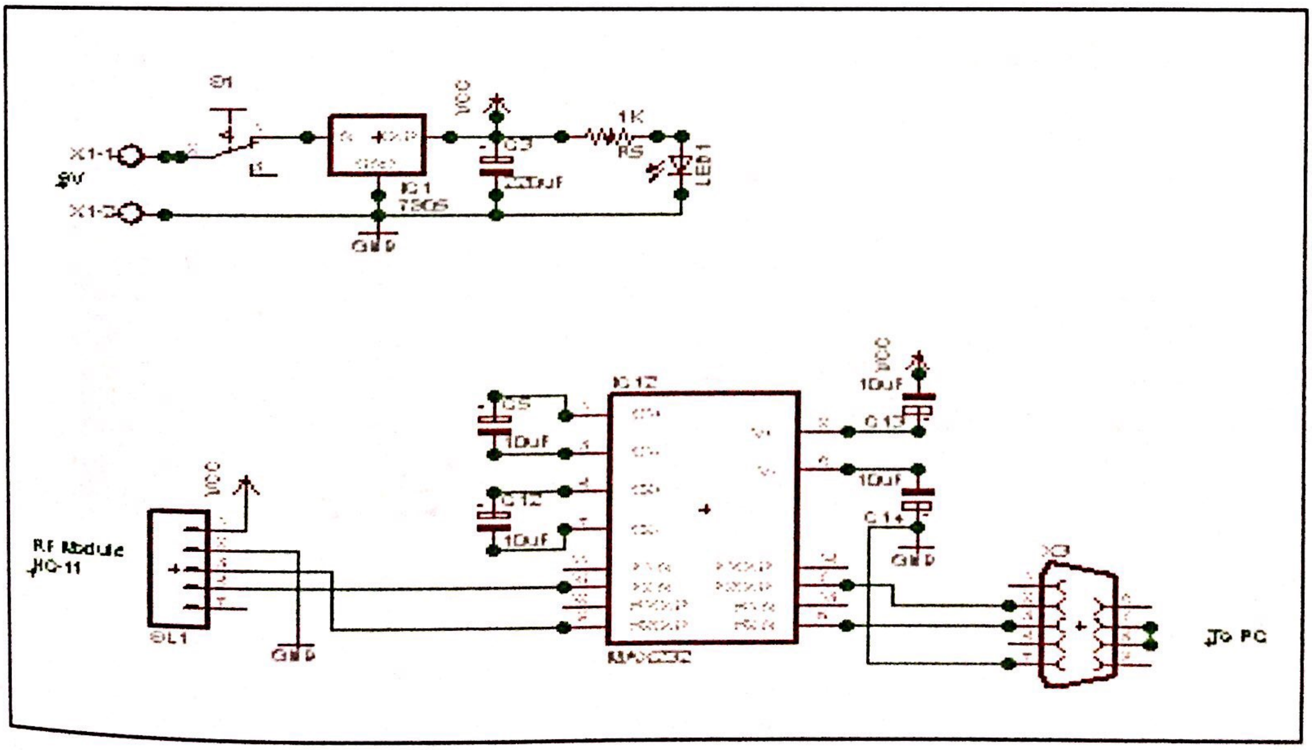
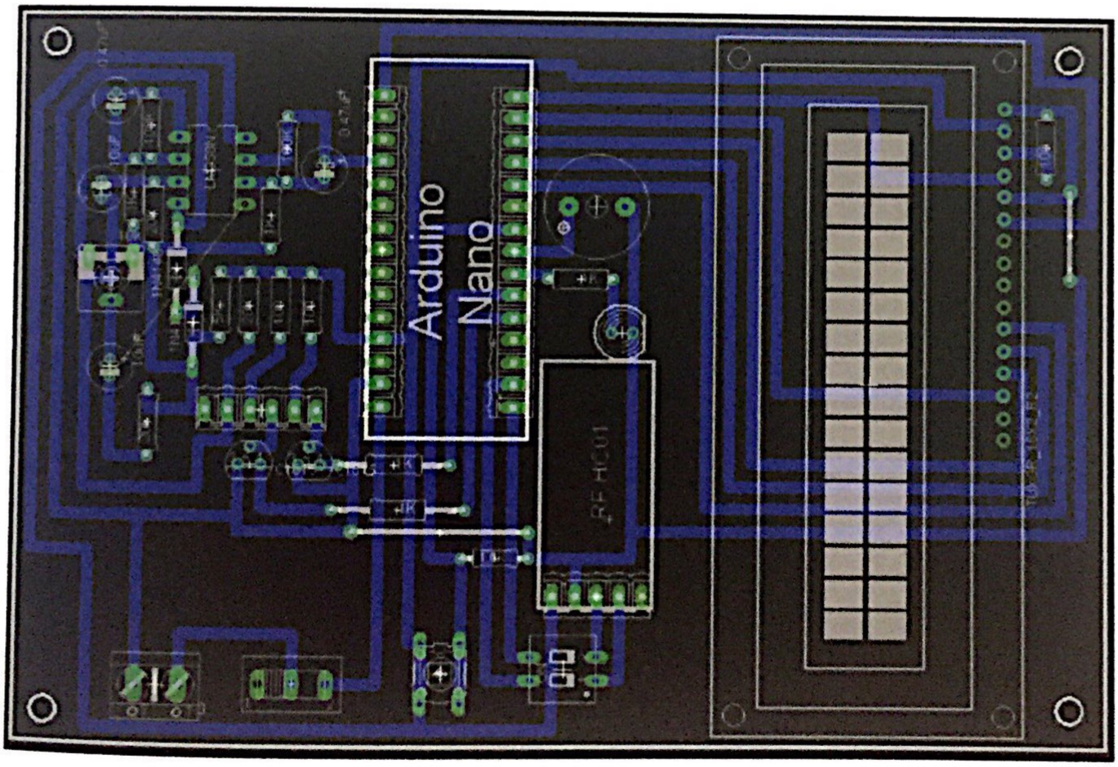


Figure 3.11: Schematic Circuit

3.7 PCB LAYOUT

Figure 3.12 shows the PCB layout for hold hardware device of oxygen saturation monitoring system by using software Eagle 6.0. PCB layout and schematic circuit has been draw by using same software. After finish drawing the schematic circuit the PCB layout can be load by click the file button, there's have "switch to board" button and click it. The schematic circuit display will change to PCB layout display. Once the layout had done, print the layout onto a glossy paper. After that, faced the printed sides of the glossy paper to the Board, then iron it until the PCB layout have transfer onto the Board. Proceed to the next step which is etching and drilling process to finish the PCB board.



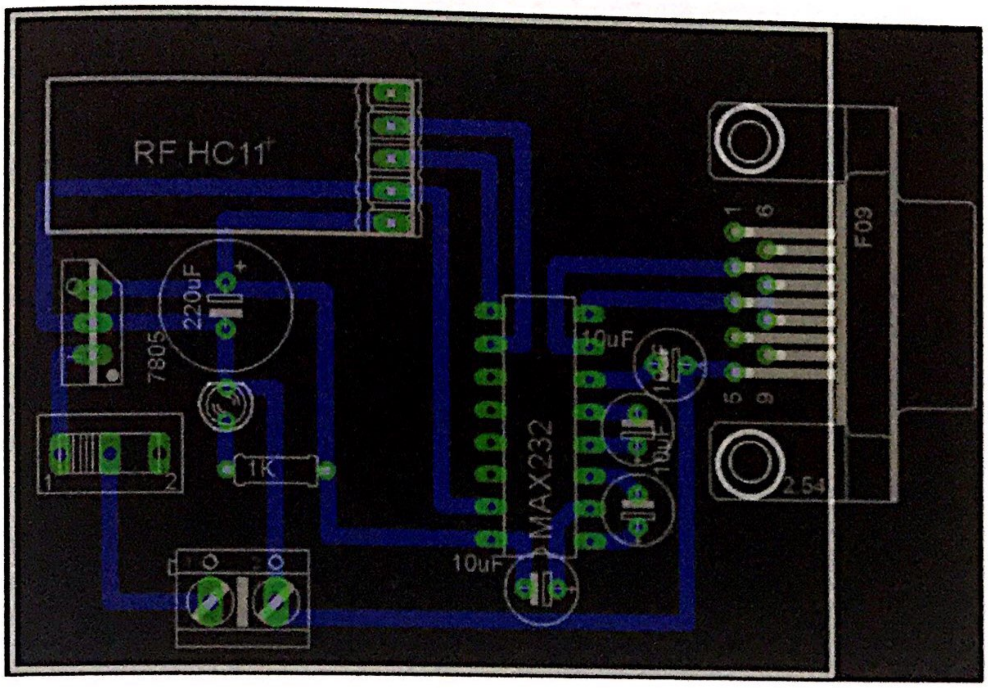


Figure 3.12: PCB Layout

CHAPTER 4

RESULT AND ANALYSIS

4.1 INTRODUCTION

This chapter will discuss about result and data analysis obtained by measuring oxygen saturation (SPO_2) using oxygen saturation monitoring system that have been compared with existing product which is fingertip pulse oximeter. As been mention before, the purpose of this project is to develop oxygen saturation monitoring system for healthcare professionals to monitor their patients easily from their computer. This product is design based on absorption of red and infrared, emitted by Light Emitting Diodes (LED) in the range of 660nm to 940nm.

Transmitted light through an area of skin on finger was detected by a photodiode. Therefore, the analysis throughout survey has been done to get a feedback about this project.

4.2 OXYGEN SATURATION MONITORING SYSTEM

The figure 4.1 below is the Oxygen Saturation (SPO_2) monitoring system that has developed. This device will monitor SPO_2 of patient continuously, reading will display at LCD display and computer interface. Data at LDC display will synchronic with computer interface. So as long as we have this software, we can monitor SPO_2 of patients from far.

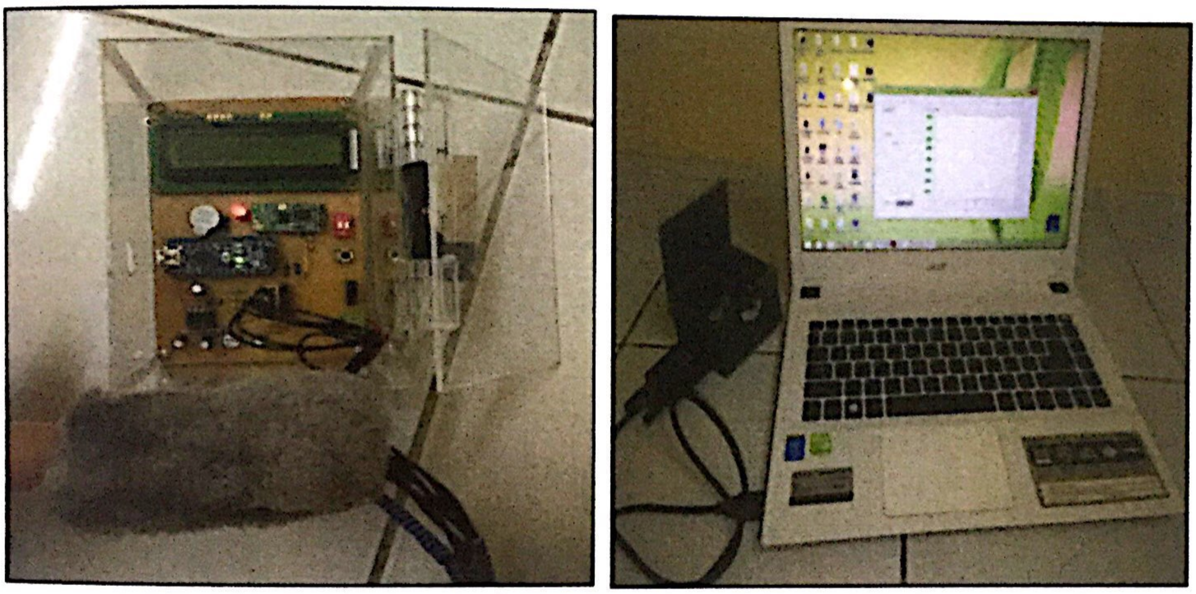


Figure 4.1: Oxygen Saturation monitoring system

Furthermore, this developed of Oxygen Saturation monitoring system is easy to handle and can be used to monitor patient without go physically to them. Compare with existing device, they need to go physically from one person to another. By using this system professional healthcare can choose either monitor their patient from their computer interface at nurse based station or move physically from one patient to another. But this system need to be run manually for each time they want to monitor of SPO_2 level of patient.

This developed of Oxygen Saturation (SPO_2) Monitoring System has 3 main parts, which are control panel, wireless communication and an interface. The control panel contain ON/OFF button, Arduino Nano, Amplifier circuit, sensor to detect blood oxygen saturation level, transmitter and LCD display. The second part of this system is communication part. Communication part consists of ON/OFF button, VGA connector and HC11-433MHz. And last part is computer interface. In this part it used only Visual Basic software. This Oxygen Saturation (SPO_2) monitoring system used two batteries to operate the hold system which is 9V batteries and a computer to display the interface.

4.2.1 STRUCTURE OF WIRELESS BLOOD OXYGEN SATURATION (SPO_2) MONITORING SYSTEM

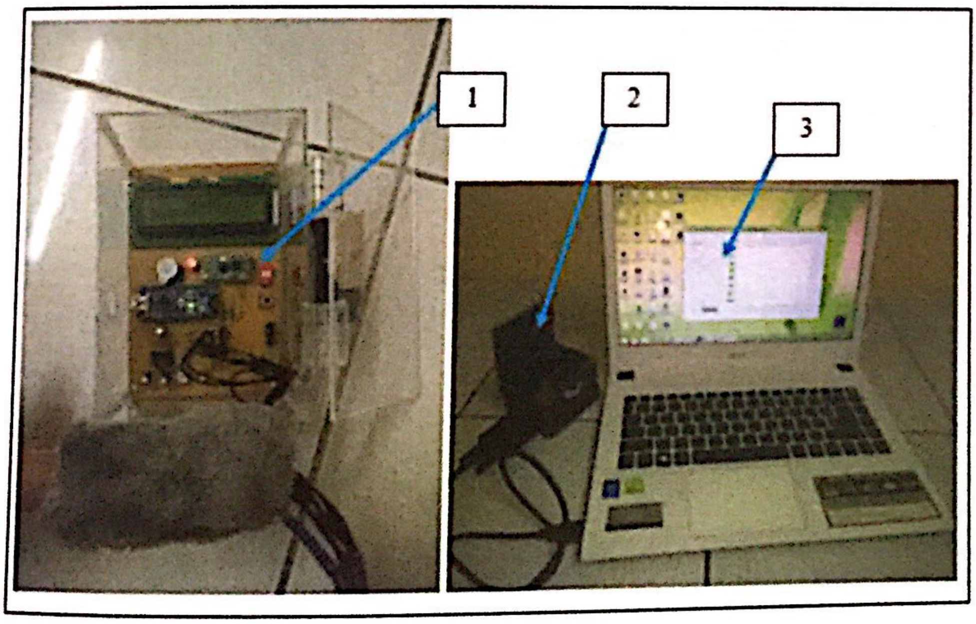


Figure 4.2: Oxygen Saturation Monitoring System (Top View)

Figures 4.2 had shown the top view of the Oxygen saturation (SPO_2) monitoring system, and the Table 4.1 shown the function of each part of the device.

Table 4.1: Shown the function of each part of the device.

NO	PARTS	FUNCTION
1	Control Panel	Setting and Control the Device
2	Receiver	Receive data before display to computer interface
3	Computer Interface	Display SPO_2 data continuously

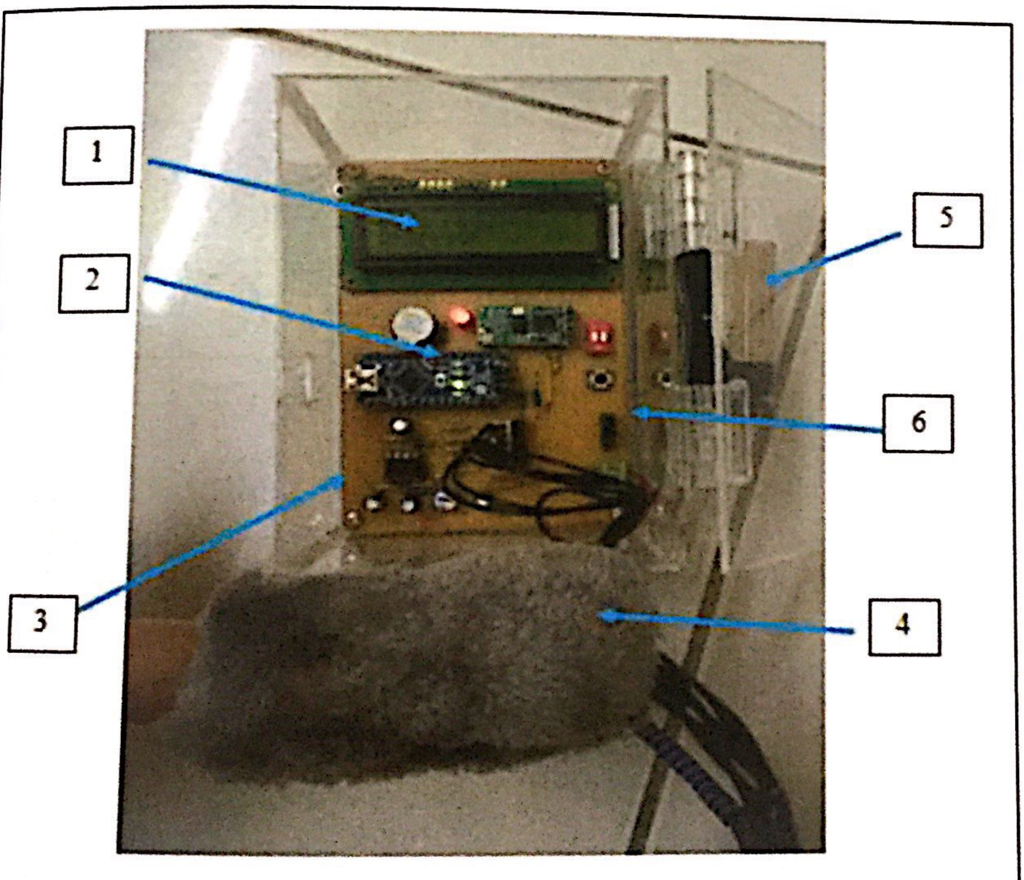


Figure 4.3: Control Panel (Top View)

Figure 4.3 had shown the top view of the control panel and table 4.2 had shown that the Function of each parts of control panel.

Table 4.2: Function of control panel

NO	PARTS	FUNCTION
1	LCD Displays	Display the result of SPO_2
2	Arduino NANO	Control of the device
3	Amplifier Circuit	To amplify waveform receive from sensor
4	Sensor of Pulse Oximeter	To absorb light in the range of 660nm and 940 nm through body tissues
5	9V Batteries Connector	Connect with the 9V batteries
6	Power Switch (ON/OFF)	ON and OFF the device

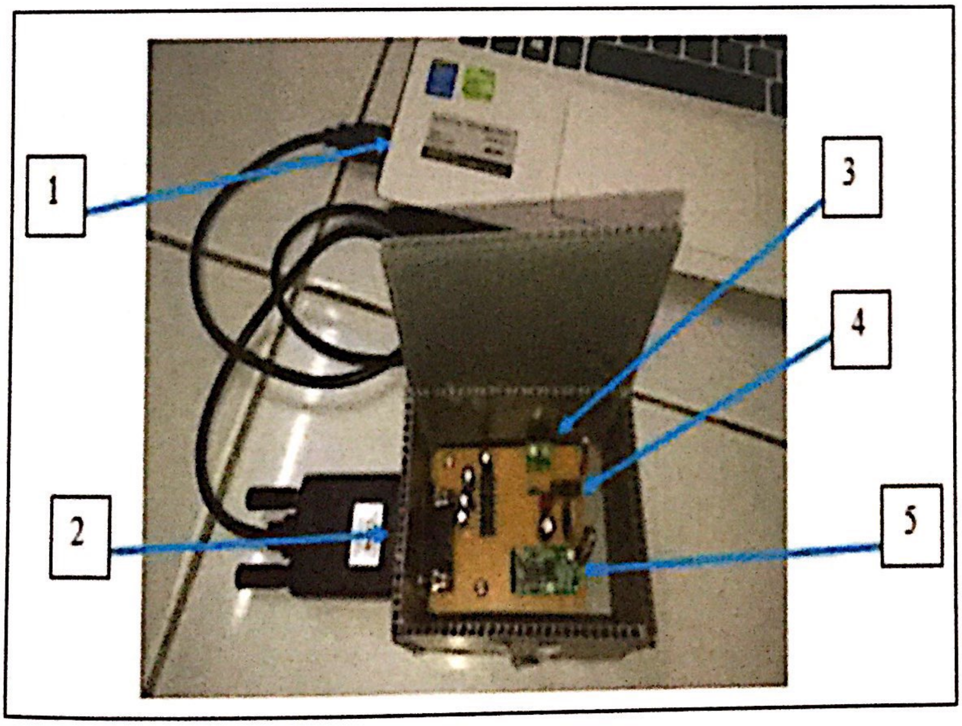


Figure 4.4: Receiver (Top View)

Figure 4.4 had shown the second part of this system which is the top view of the receiver panel and table 4.3 had shown that the Function of the Parts of receiver panel.

Table 4.3: Function of Receiver panel

NO	PARTS	FUNCTION
1	USB port	Display the number of count
2	VGA connector	Reset the Device's settings
3	9V batteries connector	Connect with the 9V batteries
4	ON/OFF button	ON and OFF the device
5	HC11-433MHz	To receive data before transmit to computer interface

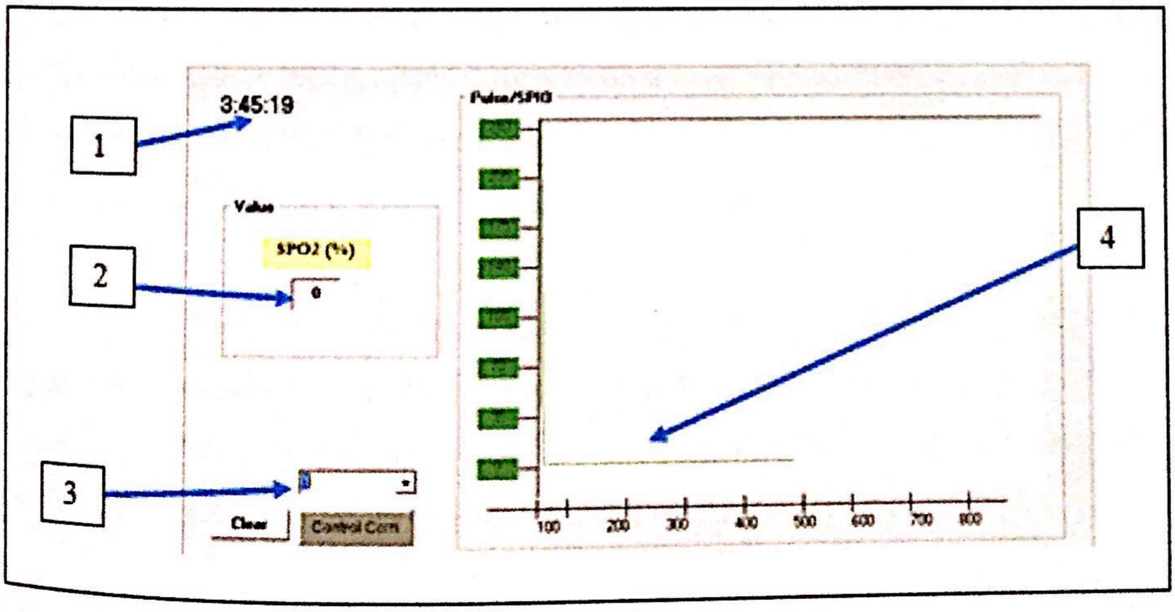


Figure 4.5: Blood oxygen saturation monitoring system interface

Figure 4.5 had shown the view of the computer interface that have been use in this project and table 4.4 had shown that the Function of the each part.

Table 4.4: Function of each part of computer interface

NO	PARTS	FUNCTION
1	Clock	Display real time
2	SPO_2 reading	Display the SPO_2 which is same with data at LCD display
3	Control com	Setting com that have been use by USB
4	Graph view	View graph depend on the SPO_2 reading

4.3 DATA ANALYSIS

Once the project is completed, test must be carried out on the product to find out whether this product is functioning well or not. Whereas, the purpose of this testing was identify whether the product works well executed as planned earlier.

From the analysis, graphs were produced showing the result of blood oxygen saturation (SPO_2) level of 30 subjects which each difference gender and range of age. Other than that the results have been compression between existing product and blood oxygen saturation (SO_2) monitoring system.

4.3.1 PRODUCT TEST

Table 4.5 : Product test

Gender	Oxygen Saturation monitoring system (%)
Female	97
	96
	98
	97
	98
	99
	95
	95
	97
	96
	94
	97
	94
	95
	96
Male	94
	97
	95
	94
	95
	96
	96
	95
	95

	99
	96
	99
	95
	97
	98

4.3.2 ACCURANCY TEST

The accurancy test for this product has been test by using comparing method. Result of this product has been compare with existing product which is fingertip pulse oximeter. 30 subject(15 male and 15 female) have been taken to test this product. Subject have been choose randomly from Polytechnic Shah Alam students.

Table 4.6: Comparison of female between new product and existing product

Gender	SPO2 reading (%)	
	Wireless SPO2 monitoring system	Fingertip pulse oximeter
Female	97	98
	96	97
	98	96
	97	96
	98	99
	99	98
	95	96
	95	97
	97	98

	96	97
	94	97
	97	97
	94	96
	95	97
	96	98

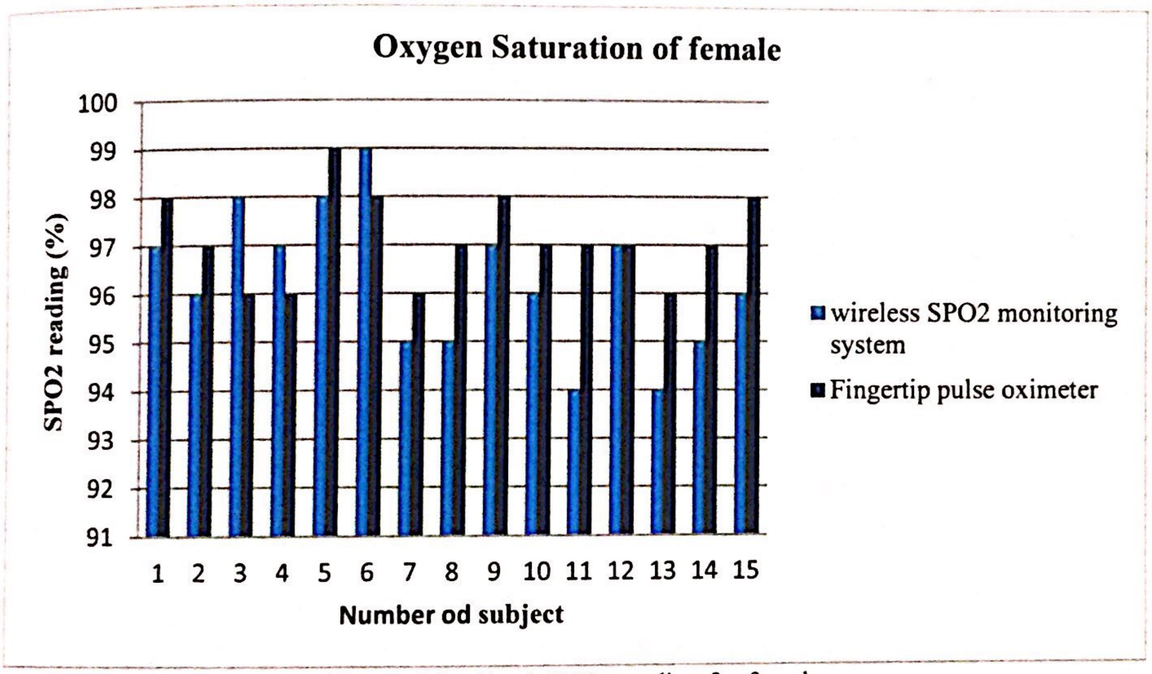


Figure 4.6 : Graph SPO_2 reading for female

Table 4.6 and figure 4.6 shows the reading amount 15 female student from polytechnic Shah Alam. Graph has been show only one subject which is respondent number 12 show the same reading when using both equipment. This is because this medical equipment is to sensitive. But usually reading of female oxygen saturation level is affected by a few factors such as movement, finger nail colour, disease and other. It is clearly show in the graph when the subject is using both equipment but the reading is difference.

Table 4.7: Comparison of male between new product and existing product

Gender	SPO2 reading (%)	
	Wireless SPO2 monitoring system	Fingertip pulse oximeter
Male	94	97
	97	98
	95	97
	94	97
	95	99
	96	98
	96	97
	95	97
	95	96
	99	98
	96	99
	99	98
	95	97
	97	98
	98	96

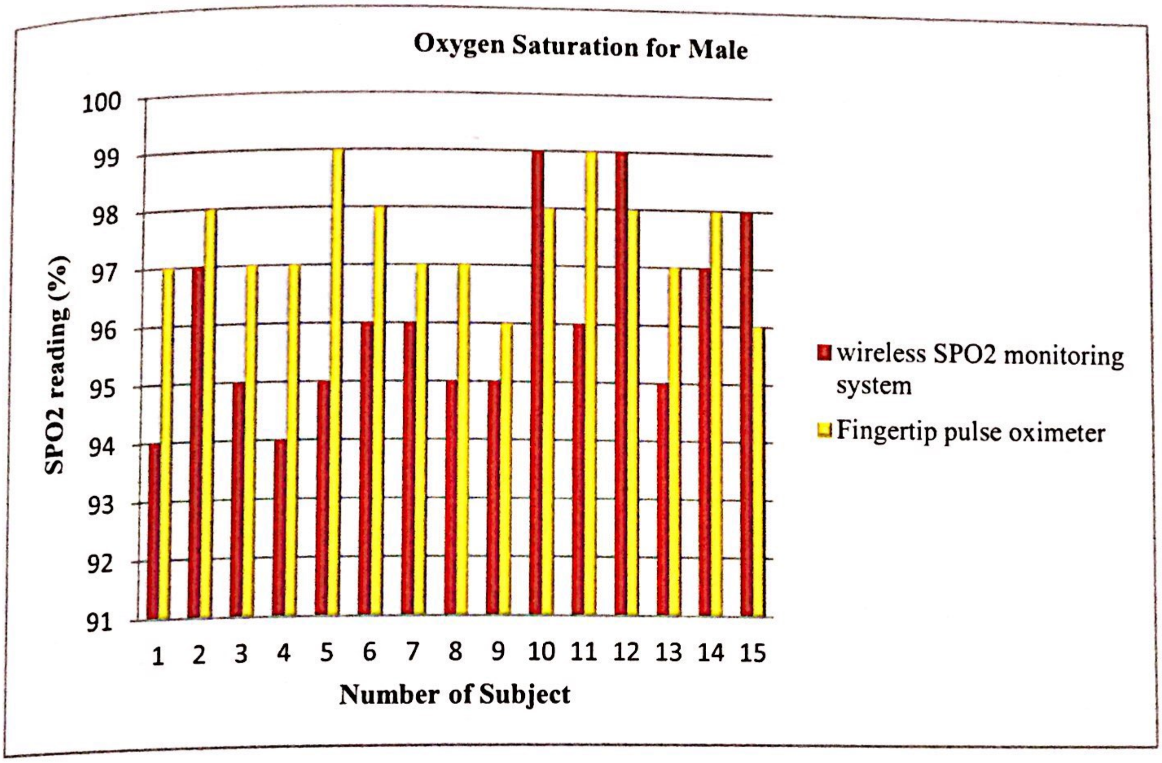


Figure 4.7 : Graph SPO_2 reading for male

Table 4.7 and figure 4.7 shows the reading amount 15 male student from polytechnic Shah Alam. Graph has been show there are no subject show the same reading when using both equipment. This is because this medical equipment is to sensitive. But usually reading of male oxygen saturation level is affected because of movement, smoking, disease and other. It is clearly show in the graph when the subject is using both equipment but show the difference reading.

Table 4.8: Acurrency test of product

Gender	SPO2 reading (%)		
	Wireless SPO2 monitoring system	Fingertip pulse oximeter	Percentage of accuracy (%)
Female	97	98	1.02
	96	97	1.03

	98	96	2.08
	97	96	1.04
	98	99	1.01
	99	98	1.02
	95	96	1.04
	95	97	2.06
	97	98	1.02
	96	97	1.03
	94	97	3.09
	97	97	0.00
	94	96	2.08
	95	97	2.06
	96	98	2.04
Male	94	97	3.09
	97	98	1.02
	95	97	2.06
	94	97	3.09
	95	99	4.04
	96	98	2.04
	96	97	1.03
	95	97	2.06
	95	96	1.04
	99	98	1.02
	96	99	3.03
	99	98	1.02
	95	97	2.06
	97	98	1.02
	98	96	2.08

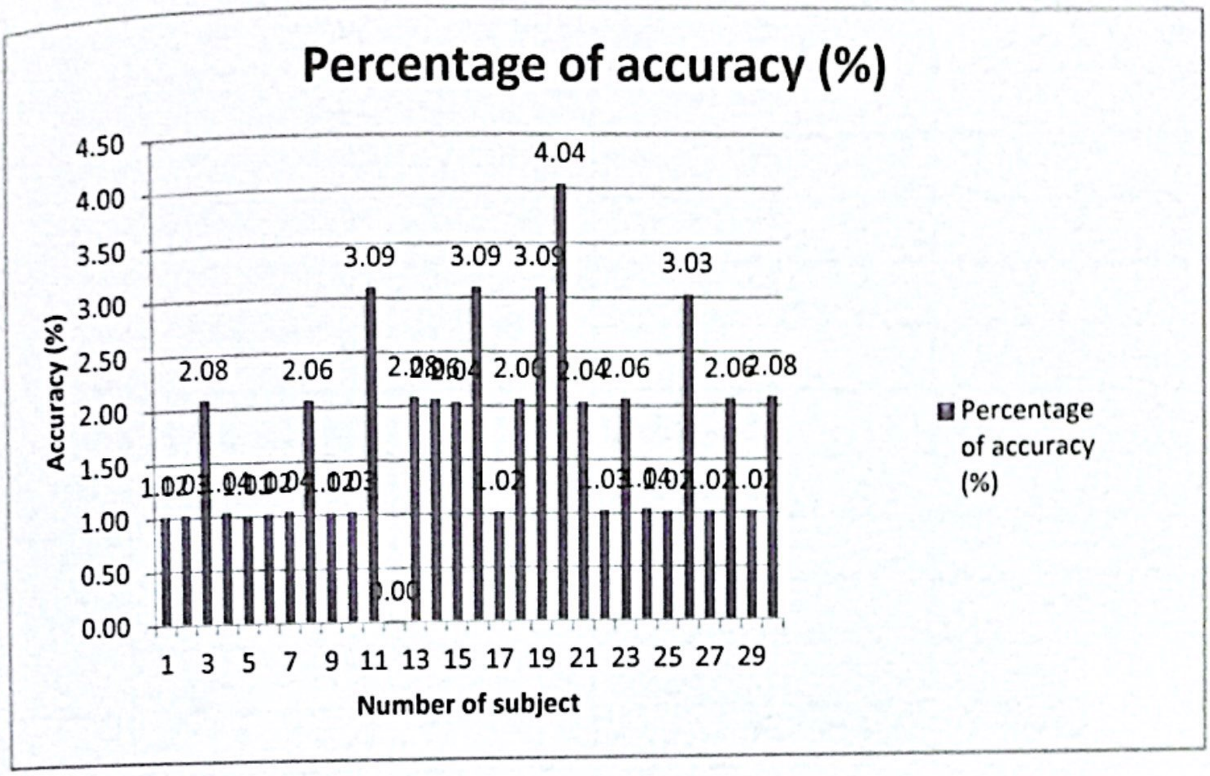


Figure 4.8: Graph of percentage of accurancy of new product vs existing product

Table 4.8 and table 4.8 shows percentace of accuracy and percentage of error of this product when compering with existing product. As we can see, the average of error of this when comparing with existing product is 0.1. Only subject number 12 which is female subject show zero percent of accurancy error.

Table 4.9: Percentage of error

Gender	SPO2 reading (%)		
	wireless SPO2 monitoring system	Fingertip pulse oximeter	Percentage of error (%)
Female	97	98	1
	96	97	1
	98	96	2
	97	96	1

	98	99	1
	99	98	1
	95	96	1
	95	97	2
	97	98	1
	96	97	1
	94	97	3
	97	97	0
	94	96	2
	95	97	2
	96	98	2
Male	94	97	3
	97	98	1
	95	97	2
	94	97	3
	95	99	4
	96	98	2
	96	97	1
	95	97	2
	95	96	1
	99	98	1
	96	99	3
	99	98	1
	95	97	2
	97	98	1
	98	96	2

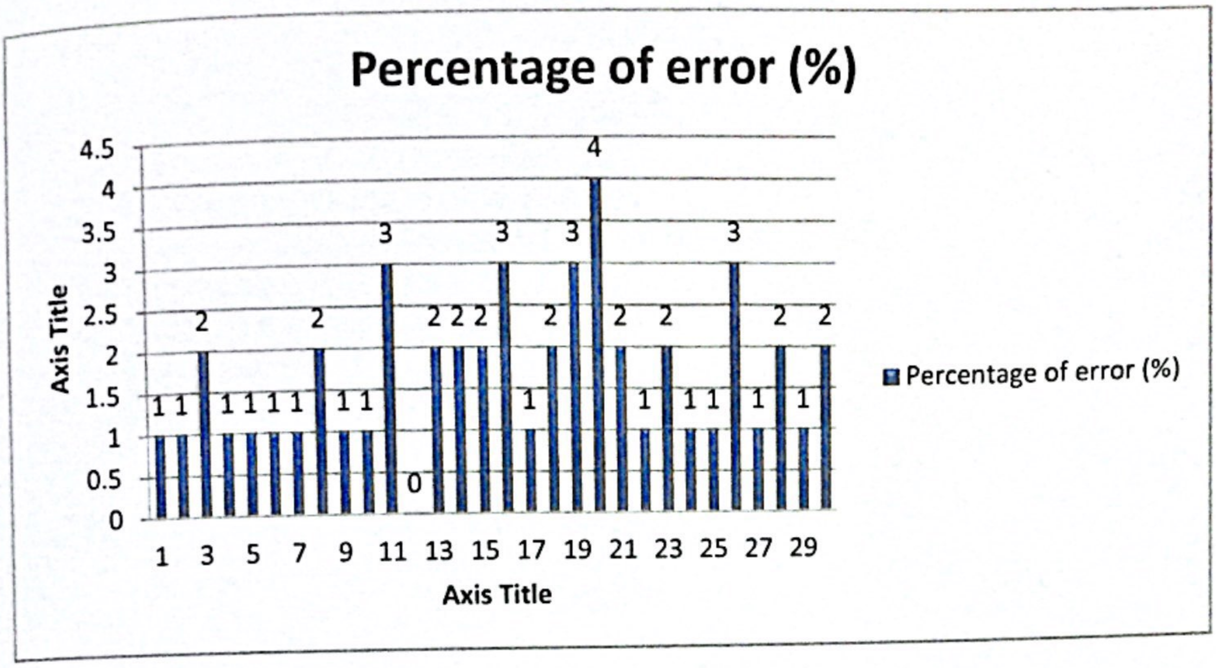


Figure 4.9: Percentage error of new product vs existing product

The accuracy of the calculation results of blood oxygen saturation level for these products experienced a slight error. As we have been discuss before, oxygen saturation level can be effected due to severel factor such as respiratory failure, carbon monoxide poisoning, nail polish, anemia, older patients and other. If subject is suffering diseases such as asthma, peripherally vasoconstricted patients and other it also will affect the blood oxygen saturation level and result can be mild hypoxia, Moderate hypoxia or sever hypoxia.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

In this chapter, the conclusion was divided to three subdivisions which are summary to discuss overall achievement of project, conclusion and recommendation of the future development.

5.2 SUMMARY

This project is to develop oxygen saturation monitoring system which is uses two wavelength of light for measurement of SPO_2. This level of oxygen saturation (SPO_2) is based on the red and infrared light absorption characteristics of oxygenated (Hbo2) and deoxygenated hemoglobin (Hb) in the range of 660nm to 940nm. Transmitted light through human tissues was detected by a photodiode.

The signal was amplified and acts as to Arduino NANO. LCD display will be display the SPO_2 level of programmable instruction. Then the data will be transmitting to HC11-433MHz which is work as a transmitted and will be display at computer interface. This equipment has been test to 30 subjects. Data are collected and data analysis was done to prove the accuracy of this device. The sensors assembled in this investigation are fully integrated into wearable finger clips.

Furthermore, objective of this project is to create a device and system with friendly user. This project is non-invasive device, where healthcare can easily monitor their reading. Moreover, healthcare can choose either want to monitor SPO_2 of their patients by physically go to them or monitor from their computer.

5.3 CONCLUSION

As a conclusion, the oxygen saturation monitoring system is developed and it have achieved the objective, which is to develop oxygen saturation monitoring system for healthcare professionals to monitor their patients from their computer. The second objective is to determine and accurately measure vital parameter of patients which is blood oxygen saturation (SPO_2) and the reliability of the system.

An accuracy test was done, 30 subjects has been choose to test this device and system. During this test, 30 students from Polytechnic Shah Alam have been choosing randomly, and the data was collected by compare the result with existing product. Once the testing was done, the data will be analysis by using Microsoft Excel. And the result finding that, the developed device is suitable and easy to be used. Healthcare can choose either want to monitor SPO_2 of their patients by moving physically to them or monitor from their computer interface.

5.4 RECOMMENDATION

Due to the lack of available sources, some improvement could be implemented. This recommendation is to enhance this project and bring it to the next level with better functions. This project is preliminary work towards a development of oxygen saturation monitoring system and several thing need to be improve especially at a part of sensor and the computer interface.

First of the important parts in this project is sensor, where the red and infrared sensor is used as transmitter and photodiode is receiver. Furthermore, for the next step of this project need to use a suitable photodiode sensor because the photodiode that have been use in this project is unstable and difficult to handle and other than that another parameter can be added. Second part is computer interface. In this project the interface only can monitor one patient at one time. Therefore, for the improvement of this project it should be build more than one device and added a few interfaces where user can store patient data and several patients can be monitor continuously at one time. Next improvement is added another parameter such as heart beat counting.

Besides that, more tests by comparing the oxygen saturation monitoring system and existing device should be done because it can make sure the accuracy of device is better. Therefore, study needs to be done in order to improve all the highlighted issues especially the results so that it can be brought to another level study.

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KEMENTERIAN PENDIDIKAN MALAYSIA

POLITEKNIK Sultan Salahuddin Abdul Aziz Shah

A Survey for Final Year Project

OXYGEN SATURATION MONITORING SYSTEM

Health Monitoring System is a device which measures the SPO2 of patient. After the vital parameters are measured it will transmit the data wirelessly to a PC base station. The objective of this project is to help the healthcare monitoring patients regularly and they no longer need to go to the patients to check their SPO2.

1. Occupation : Doctor ☐ Nurse ☐

2. Age : 21-30 ☐ 31-40 ☐
   41-50 ☐ 51-60 ☐

3. Gender : Male ☐ Female ☐

4. Do you know how to use a computer to record the patient data?

   Yes ☐ No ☐

5. How often you monitor your patient?

   3rd in day ☐

   5th in day ☐

Always ☐

6. Do you think this system will reduce your work?

Yes ☐ No ☐

7. Do you think this system can help to simplify the task of Intensive Care Unit?

Yes ☐ No ☐

8. How long do you retrieve patient data in existing method?

Slow ☐ Medium ☐ Fast ☐

9. What kind of method used in the current system?

Manual ☐ Computerized ☐

10. Which health care monitoring do you prefer?

Existing ☐ Innovation ☐

11. In your opinion, does this project will provide effectiveness in patients data monitoring system?

Yes ☐ No ☐

Prepared by, Verified by,

....

(Norfazeelah Mat Sidin) (Mdm Pushpa D/O Jegannathan)

Students Supervisor

APPENDIX B: PROJECT PROGRAMING

```
#define Led1 2
#define ir 3
#define Led 4
#define Buzzer 5
#define StartBut 6

#include <LiquidCrystal.h> //library lcd
#include <MsTimer2.h>

char msec, sec, minutes, hours;    //declare variables
unsigned char pulse;
char count, flag;
char txt[10];
int oxi;
char start_flag;
char sec_flag;
unsigned char ip1;

LiquidCrystal lcd(12, 13, 8, 9, 10, 11); // setup lcd pin

unsigned char oxinew = 0;
void flash()
{
 sec++;
 sec_flag = 1;
 if (sec >= 60)
 { //if sec>60 then min+1
  sec = 0;
  minutes++;
  if (minutes >= 60)
```

```
  { //if min > 60 then hour+1
    minutes = 0;
    hours++;
  }
 }
}

void beep()
{
 digitalWrite(Buzzer, HIGH);
 delay(100);
 digitalWrite(Buzzer, LOW);
 delay(100);
}
void setup() {
 MsTimer2::set(1000, flash); // 500ms period
 MsTimer2::start();
 pinMode(A0, INPUT);
 pinMode(StartBut, INPUT);
 pinMode(ir, OUTPUT);
 pinMode(Led, OUTPUT);
 pinMode(Led1, OUTPUT);
 pinMode(Buzzer, OUTPUT);
 Serial.begin(9600);  //rf comm setup
 lcd.begin(16, 2);    //16x2
 lcd.setCursor(0, 0);
 lcd.print("Health Monitor");   //start display
 delay(3000);              //1sec
 lcd.clear();
 sec = 0;                  //clear all register
 count = 0;
```

```
 pulse = 0;


}
//start program
void loop()
{
 //check timer every sec
 if (!start_flag)
 {
  //counter + 1 every sec
  if (sec_flag)
  {
   digitalWrite(ir, HIGH);
   lcd.setCursor(0, 0);
   lcd.print("SPO2 reading");
   sec_flag = 0;
   count = count + 1;
  }
  if (count >= 5)
  {
   pulse = pulse * 8 ;
   count = 0;
   start_flag = 0;
   Serial.write(pulse);
   if (pulse >= 60)
   {
    lcd.clear();
    lcd.begin(16, 2);   //16x2
    lcd.setCursor(0, 0);
    lcd.print("Still reading...");
    digitalWrite(ir, LOW);
```

```
    digitalWrite(Led1, HIGH);
    for (int i = 0; i < 300; i++) {
     oxi = analogRead(A0);
     oxi = map(oxi, 0, 760, 0, 100);
     lcd.setCursor(0, 1);
     lcd.print(oxi);
     if (oxi >= 40 && oxi <= 100)
       oxinew = map(oxi, 55, 100, 95, 100);
     if (oxi >= 0 && oxi <= 39)
       oxinew = 0;
    }
    lcd.clear();
    beep();
    lcd.begin(16, 2);    //16x2
    lcd.setCursor(0, 0);
    lcd.print("SPO2 result");

    lcd.setCursor(0, 1);
    lcd.print("SPO2:");
    lcd.print(oxinew);
    lcd.print("%");
    Serial.write(oxinew);
    delay(2000);
    count = 0;
    pulse = 0;
  }

}

ip1 = analogRead(A0) / 4;
if (ip1 >= 128)
```

```
 {
  digitalWrite(Led, HIGH);

  pulse = pulse + 1;
  while (1)
  {
   if (sec_flag)
   {
    sec_flag = 0;
    count = count + 1;
   }
   if (count > 5)
    break;
   ip1 = analogRead(A0) / 4;
   if (ip1 <= 45)
   {
    digitalWrite(Led, LOW);
    digitalWrite(Buzzer, LOW);
    break;
   }
  }
 }

 }
}
```

APPENDIX C: CONSENT FORM

Consent Form

Title of Study: Oxygen Saturation Monitoring System

I understand about the information of this study and received explanation from the investigator about the purpose of the investigation including benefits and risks

I am ________________________________. Matrix number ____________________. Phone number______________________. "Agree/Disagree to participate in the studies as described above.

Signature,

____________________,

Date:

Borang Kebenaran

Tajuk kajian: Oxygen Saturation Monitoring System

Saya memahami mengenai maklumat kajian ini serta mendapat penjelasan lanjut daripada penyelidik mengenai tujuan penyelidikan termasuk faedah dan risikonya.

Saya ________________________________. Kad Matrix ____________________. Nombor telefon ____________________. "Bersetuju / Tidak Bersetuju" untuk menyertai kajian yang dinyatakan seperti diatas.

Tandatangan.

____________________,

Tarikh: