DIRECT PHOTOMETRY NON INVASIVE BILIRUBIN DEVICE

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ABSTRACT

The measurement of jaundice among neonates is important in determine the possible treatment to prevent any serious illness. The presence of enough bilirubin for the yellow pigment to be visible is called jaundice. Jaundice occurs in about 60% of healthy term infants and 80% of those born prematurely. Jaundice checked in hospitals by using invasive method which is blood test and urine test. Invasive blood sampling is stressful for the neonate, resulting in blood loss and an increased risk for infections at the site of sampling. Non Invasive Bilirubin Meter will overcome the issues happened. Direct photometric measurements are based on direct measurements of suitably solved serum at the wavelength of 455nm, which is the absorption maximum of bilirubin. Direct photometry can be used only in newborns. There was the knowledge of light transmission and absorption on a specific tissue compartment applied. The relevant skin photo diagnostics handle 575 nm (green) and 450 nm (blue monochromatic light). The device is use only one parameter which is reading of bilirubin in µmol/L. The output will appeared on the LCD based on the level of bilirubin. It appeared as Normal (Green Light), Moderate (Yellow Light) and Critical (Red Light and Buzzer).

ABSTRAK

Pengukuran jaundis di kalangan bayi adalah penting dalam menentukan rawatan yang mungkin untuk mengelakkan sebarang penyakit yang serius. Jaundis diperiksa di hospital dengan menggunakan kaedah invasif iaitu ujian darah dan ujian air kencing. Pensampelan darah secara invasif adalah memberi tekanan terhadap bayi, menyebabkan kehilangan darah dan peningkatan risiko untuk jangkitan di tapak persampelan. *Direct Photometry Non Invasive Bilirubin Device* akan mengatasi isu-isu yang berlaku. Ukuran fotometri secara terus berdasarkan serum secara terus sesuai dilakukan pada panjang gelombang 455nm, iaitu pada jumlah maksimum penyerapan bilirubin. Pengukuran cahaya secara terus hanya boleh digunakan pada bayi yang baru lahir. Terdapat sumber terhadap penghantaran cahaya dan penyerapan yang tertentu digunakan pada petak tisu. Diagnostik pada kulit secara fotometri berkaitan pengedalian 575 nm (hijau) dan 450 nm (cahaya monokromatik biru). Peranti ini menggunakan hanya satu parameter yang membaca bilirubin dalam μmol / L. Tahap keluaran akan muncul di LCD berdasarkan tahap bilirubin. Ia muncul sebagai Normal (Lampu Hijau), Sederhana (Lampu Kuning) dan kritikal (Lampu Merah dan Bunyi).

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LIST OF SYMBOLS

µmol / L	Unit of Bilirubin in micromol/L
Mg/dL	Milligram/ Decilliter (Unit of Bilirubin)
%	Percentage
nm	Nanometer. The Spectrum of LED

LIST OF ABBREVIATIONS

APDs	Avalanche Photodiode
DPNIBD	Direct Photometry Non Invasive Bilirubin Device
LED	Light Emitting Diode
LCD	Liquid Crystal Display
NICU	Neonatal Intensive Care Unit
PIC	Programmable Integrated Controlled
RBC	Red Blood Cell
SBR	Serum Bilirubin
TSB	Transcutaneous Serum Bilirubin
TcB	Transcutaneous Bilirubin

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The development of new technology which introduce new method and model detection of jaundice or hyperbilirubinemia by using non-invasive technique. The yellow discoloration is used to measure bilirubin concentration for determining the level of jaundice in infants[1]. Hyperbilirubinemia or Neonates Jaundice is commonly happened in the neonates or newborns due to rise in the amount of bilirubin concentration in the body. Non- invasive, transcutaneous, point of care measurement of transcutaneous bilirubin (TcB) pre-discharge by multi-wavelength spectral analysis, using a portable device is clinically equivalent to measurement of TSB in a diverse, multiracial term and near-term newborn population and predictive of subsequent hyperbilirubinemia[2]. Direct Photometry Non Invasive Bilirubin Device can overcome the problem when taking the blood from the neonates. It can be painless and user friendly to the user. Direct photometric measurements are based on direct measurements of suitably solved serum the wavelength of 455 nm which is the absorption maximum of bilirubin[3]. Direct photometry can be used only in newborns. In the case of most children and adults, the serum includes many other pigments of similar colors and reactions as bilirubin.

The proposed benefits of using this technology include non-invasive and accurate screening for clinically significant jaundice. Transcutaneous Bilirubin readings are instant and results can avoid delay with discharge and or indicate the need for formal SBR testing[4]. Based on biomedical engineer and hospital staff's, providing a non-invasive method in detecting hyperbilirubinemia or jaundice can overcome some problem that may occurs during taking neonates blood. And can overcome mistake in prick needle among neonates. However, this non-invasive method which is the Direct Photometry Non Invasive Bilirubin Device must be calibrated to avoid from false readings and wrong indicator.

1.2 Problem Statement

Hyperbilirubinemia or Neonates Jaundice is commonly happened in the neonates or newborns due to rise in the amount of bilirubin concentration in the body. Current detection techniques, however, require clinical tests with blood samples or other particular equipment. Hyperbilirubinemia commonly checked in hospitals by using invasive method which is blood test and urine test. This method is commonly can make parents become anxiety due to their baby being pricks with needle. It will reduce the need for invasive and painful blood sampling for determining bilirubin level. Then, the ready device to check jaundices are very expensive and commonly used in overseas. In Malaysia, the Invasive method is limited used only in certain private hospital.

There are limited numbers of device and consume more time to check jaundice among infants. Medical staffs such as doctors and nurses go through a difficult times and problems during blood test among infants. Due to this condition, nurses often make mistake mistakenly prick towards neonates. They need to wait for getting the result from laboratory. By using this non-invasive method, it can reduce the parental anxiety. Invasive method used total serum bilirubin cause heel puncture pain to the neonates. Non Invasive method diminishes the blood sample and heel puncture pain by not using any blood sample in determines the level of jaundice. It is able to reduce the need for invasive and painful blood test through the use of new generation of bilirubin meter.

Invasive blood sampling is stressful for the neonate, resulting in blood loss and an increased risk for infections at the site of sampling[5]. In addition, the method is laborious and time consuming, lacking the possibility for immediate diagnosis. In invasive detection methods the blood sample is taken from the vein puncture and the blood is collected for the laboratory test. In non-invasive detection methods blood samples are not required for detection process its functionality is based on the light, which is reflected by the skin. It measures the concentration of the bilirubin by spectral reflectance of the skin.

1.3 Objectives

This paper is focuses on the main objectives. There are the following objectives which are

a. To develop a new method of non-invasive technique to determine the bilirubin level.
b. To design a low cost product of bilirubin meter and affordable to user.
c. To reduce the need of invasive and painful blood test for newborn with hyperbilirubinemia disease.

1.4 Scope of Project

The scope of this project is divided into two parts which are simulation and hardware part. In simulation part, Arduino Software will be the main software that synchronized between hardware and software. From the simulation part, I should be able to study measure the signal strength of the component that will be implement in this project. For the hardware part, I will construct a hardware device. The PIC micro controller will also construct and programmed to integrate with the software part as to make sure that the connection between both parts is available where the input can communicate and program to the output application.

The main focusing respondent for Direct Photometry Non Invasive Bilirubin Device is on Pediatrics Unit in hospitals such doctors, nurse and also public people. Survey conducted for this project on ten newborns in Pediatrics Units in several hospitals. This project is analyzed for several features that can match with condition of neonates and user friendly to neonates and the Pediatric Units when used it.

Overall, for scope of project, I will implement hardware, software and questionnaire which is construct survey to completing my final year project's requirement. For the questionnaire part, I will distribute my survey at the hospitals to obtain the general approval from hospital's staffs and biomedical engineers. This will enhance my knowledge and skills in completing the Direct Photometry Non Invasive Bilirubin Device.

1.5 Significant of Project

Direct Photometry Non Invasive Bilirubin Device will overcome the issues that happened in Pediatrics Unit. For example, nurses often make mistakenly prick neonates during taking blood procedures. This device will make the neonates comfort with the user friendly features and feel painless. Direct Photometry Non Invasive Bilirubin Device can help Pediatrics Unit to get the faster result and accurate. This device also comes with affordable price than equipment in overseas. This new technology of product can enlighten the effort of Pediatrics Units. The impact of the device is painless, user friendly, and affordable.

Certain hospital's staffs such as doctors, medical health care and biomedical engineer does not agree with this development due to several aspects such accuracy of the Direct Photometry Non Invasive Bilirubin Device. From that, the judgments can be refutes with the evidences during testing this devices at the end of the projects. All the data can be analyzed and compared with the manual readings. It is easy for medical staff to make a comparison and judgments from the readings. The bilirubin device diminished blood sample and heel puncture pain by not using any blood sample from the neonates for jaundice detection. Transcutaneous bilirubinometry has the potential to reduce the number of blood samplings, thus reducing neonatal pain and discomfort, parental distress and medical care cost [6].

CHAPTER 2

LITERATURE REVIEW

2.1 Hyperbilirubinemia (Jaundice)

Hyperbilirubinemia is also known as jaundice among peoples nowadays. Hemoglobin, the red pigment in red blood cells, must undergo a succession of changes before the body can dispose of it [7]. Specific enzymes from our great processing center, the liver, carry out each step. Bilirubin, the yellow pigment responsible for jaundice, is a normal component in the breakdown of hemoglobin [8]. Adults often turn yellow when they have hepatitis because their livers aren't able to process the bilirubin. The presence of enough bilirubin for the yellow pigment to be visible is called jaundice. Jaundice occurs in about 60% of healthy term infants and 80% of those born prematurely [9].

If the bilirubin concentration rises to about 5 mg/dL, the face takes on a yellow appearance [10]. If the level reaches about 15 mg/dL, the yellow tint is visible from the head down to the mid abdomen. At a level of 20 mg/dL, even the soles of the feet are yellow. Higher readings of jaundice can lead the infants to a severe hyperbilirubinemia and can affect the health of the baby in a long period of time. They can be exposed to liver failure problems and cerebral palsy. Additional studies are needed on the relationship between central nervous system damage and the duration of hyperbilirubinemia, the binding of bilirubin to albumin, and changes seen in the brainstem auditory evoked response [11].

Figure 2.1: Comparison between healthy and severe jaundice.

2.1.1 Physiological Jaundice

The most common type of jaundice is called *physiologic jaundice*, the normal increased bilirubin in babies whose livers can't quite keep up with a slightly increased load of red blood cells[8]. This jaundice usually becomes visible on day 2 or 3 and peaks somewhere between days 2 and 4 as the liver gains control of the situation. The bilirubin levels usually fall substantially by day 7. Sometimes, they reach a level at which treatment is needed (>15 mg/dL before 48 hours old, >18 mg/dL before 72 hours old, > 20 mg/dL anytime–in otherwise healthy term babies).

2.1.2 Breast Milk Jaundice

Breast milk jaundice is far less common, occurring in about 2% of breast-fed term babies. Here the jaundice is often not visible until the baby is a week old and then reaches its peak during the second or third week. The exact mechanism by which breast milk causes jaundice is uncertain. Breast milk jaundice may be caused by enzymes in mom's milk that allow bilirubin to be reabsorbed into the blood from the intestines or by fatty acids in mom's milk that the baby processes as a priority over processing the bilirubin. Permanent damage or ill from breast milk jaundice is extremely rare. Phototherapy (lights used to lower bilirubin) may be used if the level of bilirubin is above 20 mg/dL. In breast milk jaundice, stopping breast milk for 1 to 2 days can help the bilirubin level drop rapidly.

2.1.3 Breast-feeding Jaundice

Breastfeeding jaundice is common and is a jaundice that may occur in the first week of life in breast-fed infants. The cause of breast-feeding jaundice is thought to be due to decreased milk intake leading to dehydration or low caloric intake. The incidence of breast-feeding jaundice may be reduced by increasing the frequency of feeding and refraining from using water to replace breast milk.

2.2 Bilirubin

Newborn jaundice occurs when a baby has a high level of bilirubin in the blood. Bilirubin is a yellow substance that the body creates when it replaces old red blood cells[12]. Jaundice occurs due to breakdown Red Blood Cells, the breakdown process is known as Hemolysis. If the cell breakdown rate occur at faster rate than the usual, it increased the level of bilirubin in the body and causes jaundice to the infants. Bilirubin concentration can be detected by using two different techniques which are invasive method and non-invasive method. Bilirubin is the yellowish pigment that is the byproduct of heme catabolism. Bilirubin is responsible for the yellow color of the urine[13]. When the cell is died hemoglobin is release from the cell, which is breakdown into heme and globin. Heme is finally converting into bilirubin, an orange-yellow pigment. Bilirubin is an endogenous anion derived from hemoglobin degradation from the Red Blood Cell[14].

Bilirubin is altered by exposure to light so serum and plasma samples must be kept in dark before measurements are made. When the liver function tests are abnormal and the serum bilirubin levels more than 17μmol/L suggest underlying liver disease. The formation of bilirubin in the body is around 250 mg to 35-mg. shunt bilirubin is the bilirubin form from the defective and immature cells[13]. As shown in Figure 2.2, the cells die after 120 days of life so that the formation of bilirubin takes place. The hemoglobin is releases from the dead cells. Heme is oxidizing to convert into bilverdine and globin is converting into the amino acids. The bilverdine is reductive to form bilirubin.

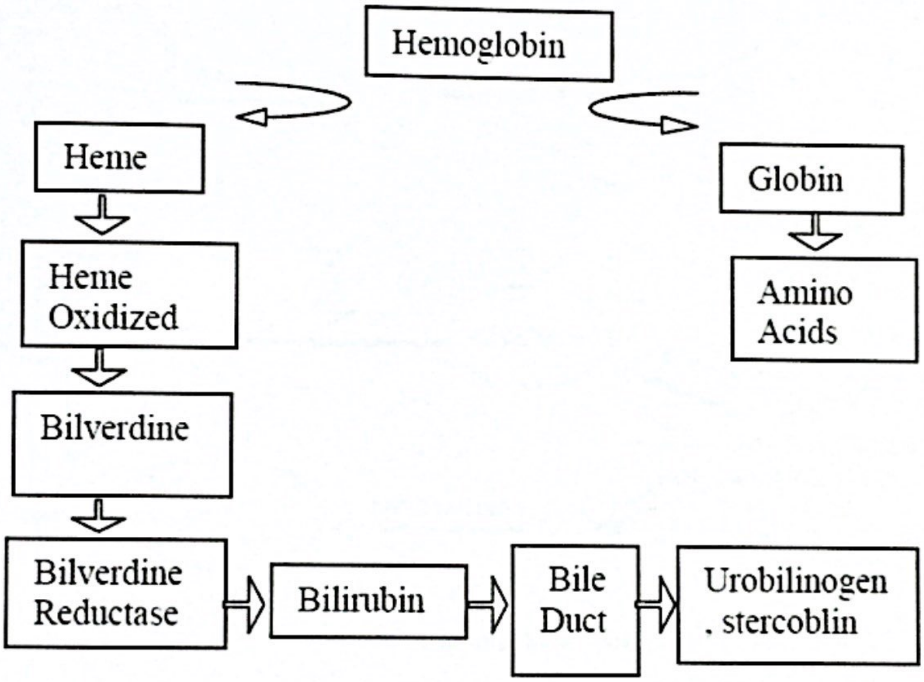

Figure 2.2: Process of Bilirubin Formation

Bilirubin is a product of heme catabolism. Red cell hemoglobin accounts for approximately 85% of all bilirubin. In newborns, the normal hemoglobin level is 15-18 mg/dl so the physiologic rate of RBC destruction is proportionately high. Excessive bruising from birth trauma or abnormal blood collections such as in a cephalohematoma may further add to the rate of RBC destruction and bilirubin formation. Heme is catabolized to unconjugated bilirubin in the reticuloendothelial system. Unconjugated bilirubin is bound to albumin in the plasma and transported bound to albumin to the liver and is conjugated with glucuronic acid in the hepatocytes; the conjugation is catalyzed by glucuronyl transferase. Conjugated bilirubin is secreted into the bile and enters the duodenum. In the small bowel, some of the bilirubin is hydrolyzed to yield unconjugated bilirubin and glucuronic acid. Most unconjugated bilirubin is excreted in the stool, but some is reabsorbed and returned to the liver for re-conjugation (enterohepatic circulation). The level of glucoroynl transferase is low in the newborn and any increase in the rate of bilirubin formation can overwhelm the capacity to conjugate.

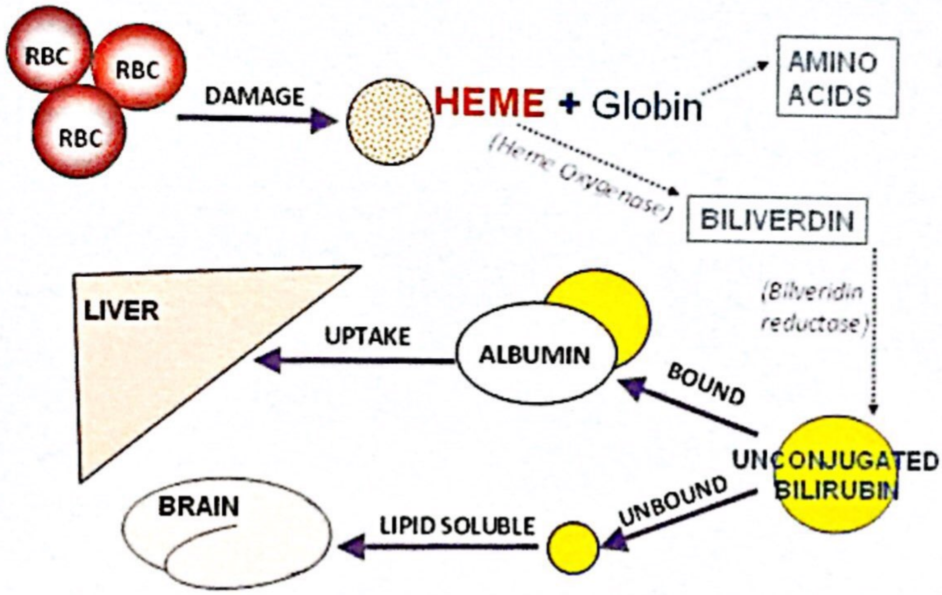

Figure 2.3: Bilirubin Metabolism

2.3 Types of Bilirubin

2.3.1 Total Bilirubin

This is measured as the amount, which reacts in 30 minutes after addition of alcohol. Normal range is 0.2-0.9 mg/dl (2-15μmol/L). It is slightly higher by 3-4 μmol/L in males as compared to females.

2.3.2 Direct or Conjugated Bilirubin

This is the water-soluble fraction. This is measured by the reaction with diazotized sulfanilic acid in 1 minute and this gives estimation of conjugated bilirubin. Normal range 0.3mg/dl(5.1μmol/L). Formed in the liver when sugars are attached (conjugated) to bilirubin. It enters the bile and passes from the liver to the small intestines and is eventually eliminated in the stool. Normally, no conjugated bilirubin is present in the blood.

2.3.3 Indirect of Unconjugated Bilirubin

This fraction is calculated by the difference of the total and direct bilirubin and is a measure of unconjugated fraction of bilirubin. This test measures the amount of bilirubin in your blood. Your body makes bilirubin when it breaks down hemoglobin. Hemoglobin is a protein in red blood cells. This breakdown is called hemolysis.

Table 2.1: Differences between Conjugated Bilirubin and Unconjugated Bilirubin.

No.	Unconjugated Bilirubin	Conjugated Bilirubin
1	Present normally in plasma.	Present normally in bile.
2	Attached non-covalently albumin.	Conjugated to glucuronic acid.
3	Has high molecular weight and cannot be filtered through the kidney.	Has small molecular weight and if present in plasma can be filtered through kidney.
4	Nonpolar, insoluble in plasma and can cross brain barrier in neonates causing brain damage.	Polar, soluble in plasma and cannot cross brain barrier.
5	Gives indirect Van den Bergh reaction.	Gives direct Van den Bergh.

2.4 Measuring Tools and Devices

Serum Bilirubin (TSB) is an invasive method to measure the amount of bilirubin directly from blood samples whereas Transcutaneous Bilirubinometer (TcB) is a noninvasive alternative that indirectly measures bilirubin. Both of these methods have their respective limitations [15]. Although invasive technique is the most accurate way but is painful for newborn babies and also cause delay in the treatment due to long procedures in laboratory. Transcutaneos Bilirubinometers which are non-invasive tools, cost thousands of dollars. Hence, this screening tool is unavailable in most clinics due to its high cost.

2.4.1 Blood Test

A small amount of your blood is needed to perform this test. The blood sample is obtained through venipuncture, where a needle is inserted into a vein through the skin in your arm or hand, and a small amount of blood comes out through the needle into tubing and is stored in a test tube. There are several aspects and preparations that must be followed before go through the blood test. In a newborn, higher bilirubin is normal due to the stress of birth. Normal bilirubin in a newborn would be under 5 mg/dL, but many newborns have some kind of jaundice and bilirubin levels above 5 mg/dL[16]. If the blood tests show abnormally high levels of bilirubin, doctor may order more tests to determine the underlying cause. Once the doctor has determined a cause of high bilirubin levels, it may take more bilirubin blood tests to monitor the effectiveness of the treatment.

In an older child or adult, normal values of direct bilirubin are from 0–0.4 milligrams per deciliter (mg/dL). Normal values of total bilirubin are from 0.3–1.0 mg/dL. The indirect bilirubin level in the bloodstream is the total bilirubin minus the direct bilirubin levels in the bloodstream. Additionally, normal reference ranges may vary from lab to lab. In a newborn, higher bilirubin is normal due to the stress of birth. Normal indirect bilirubin in a newborn would be under 5.2 mg/dL within the first 24 hours of birth, but many newborns have some kind of jaundice and bilirubin levels that rise above 5 mg/dL within the first few days after birth[17]. This is a blood test that measures the amount of a substance called bilirubin. This test is used to find out how well your liver is working. It is often given as part of a panel of tests that measure liver function. A small amount of bilirubin in the blood is normal, but a high level may be a sign of liver disease. The liver makes bile to help to digest food, and bile contains bilirubin. Most bilirubin comes from the body's normal process of breaking down old red blood cells. A healthy liver can normally get rid of bilirubin. But when you have liver problems, it can build up in the body to unhealthy levels.

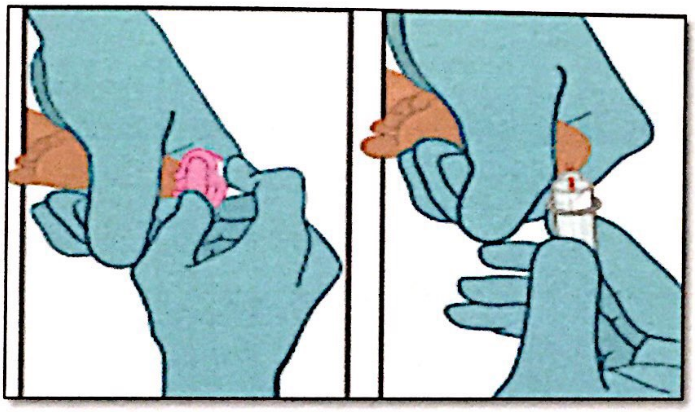

Figure 2.4: Blood Test

2.4.1.2 Risk of Blood Test

When the blood is collected, you may feel some moderate pain or a mild pinching sensation, though this is usually very short in duration and very slight[16]. After the needle is taken out, you may feel a throbbing sensation, and you will be instructed to apply pressure to the site where the needle entered for the rest of the day. There are some very rare risks to taking a blood sample:

a) Light headedness or fainting
b) Hematoma, a bruise where blood accumulates under the skin
c) Infection, usually prevented by the skin being cleaned before the needle is inserted
d) Excessive bleeding or bleeding for a long period afterward may indicate a more serious bleeding condition and should be reported to your doctor.

Since bilirubin is a strong antioxidant, mild hyperbilirubinemia may have a protective effect against ischemic cardiovascular disease and cancer[18]. In a recent study on a large population, the odds ratios for a history of colorectal cancer were reported to be reduced to 0.295 in men and 0.186 in women per 1 mg/dl increment in serum bilirubin levels. An inverse relationship between serum bilirubin levels and cancer mortality has also been reported. Such negative associations do not, however, conclusively establish a cause and effect relationship because of the presence of many potentially confounding variables.

2.4.2 Urine Test

The presence of urine bilirubin indicates hepatobiliary disease. Unconjugated bilirubin is tightly bound to albumin and not filtered by the glomerulus and thus not present in urine. The procedure is done by dipping the reagent strip into the urine sample and removing it immediately to avoid dissolving of the reagent pads. The color change on the reagent strip is compared to the corresponding color chart on the bottle label. However, the result from this measurement method is unreliable due to color interference and interpretation. Sample of urine should not be exposed to light since bilirubin is very sensitive to light and will lead to inaccurate test results. Bilirubin production in the body is normal and occurs when red blood cells break down in the liver. Red blood cells contain haemoglobin which is metabolised and produces bilirubin. Normally a small quantity of bilirubin is found in the blood serum. Total values of bilirubin found in the serum volume are 0.2-1 mg/dL (3.4-17.1 µmol/L). Two types of bilirubin found in the body.

a) Unconjugated which bind with other proteins
b) Conjugated which are free and passed in different parts of the body via the blood stream and ultimately accumulates in the liver.

Bilirubin in urine is also known as hyperbilirubinemia. Hyperbilirubinemia is the condition when the bilirubin is secreted via urine and dark yellow coloured urine is passed. Bilirubin is normally conjugated in the liver and become water soluble, un-conjugated bilirubin is unable to get soluble in the water. Unconjugated bilirubin is unable to filter in the kidney as it binds with albumin. The presence of bilirubin in the urine signifies the existence of conjugated hyperbilirubinemia. In case of biliary obstruction which occurs due to impairment of the passage of the bile into the large intestine or in case of hepatitis where reduction of bilirubin secretion into the bile cause conjugated hyperbilirubinemia. In case of septic shock bile production is increased as inflammatory cytokine production is high.

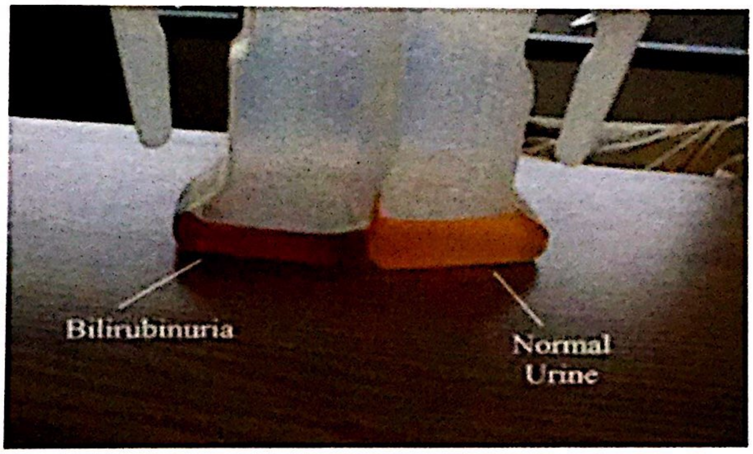

Figure 2.5: Bilirubin in Urine

Bilirubin is not present in the urine of normal, healthy individuals. It is a waste product that is produced by the liver from the hemoglobin of RBCs that are broken down and removed from circulation. It becomes a component of bile, a fluid that is released into the intestines to aid in food digestion. In certain liver diseases, such as biliary obstruction or hepatitis, excess bilirubin can build up in the blood and is eliminated in urine. The presence of bilirubin in urine is an early indicator of liver disease and can occur before clinical symptoms such as jaundice develop. The results of this test will be considered along with the result of urobilinogen . If positive, the healthcare practitioner will likely follow up with other laboratory tests, such as a liver panel, to help establish a diagnosis.

2.5 Readings of Jaundice Parameters

Table 2.2: Neonatal Jaundice Guideline of Management

Hours of Life	Total Serum Bilirubin levels mg/dL ($\mu mol/L$)					
	Low Risk ≥ 38 week and well		**Medium Risk ≥ 38 week + risk factors or 35 to < 38 week and well**		**High Risk 35 to <38 week + risk factors**	
	Intensive Phototherapy	**ET**	**Intensive Phototherapy**	**ET**	**Intensive Phototherapy**	**ET**
<24*						
24	12 (200)	19 (325)	10 (170)	17 (290)	8 (135)	15 (255)
48	15 (225)	22 (375)	13 (220)	19 (325)	11 (185)	17 (290)
72	18 (305)	24 (410)	15 (255)	21 (360)	13 (220)	18.5(315)
96	20 (340)	25 (425)	17 (290)	22.5 (380)	14 (240)	19 (325)
>96	21 (360)	25 (425)	18 (305)	22.5(380)	15 (255)	19 (325)

CHAPTER 3

METHODOLOGY

3.1 Preface

This section involves the methodology of this device. There are components that involved in this parts which are hardware and software which is simulation part. The main component that be used in this device is Arduino Software and a Spectrophotometer sensor. A Spectrophotometer measures the amount of light that a certain sample absorbs. A spectophotometer can be done by diffrating into two different wavelength of 455 nm and 575 nm. Basic principles of spectrophotometer consisting a beam of light passing through a diffraction grating. Out of the resulting spectrum, a certain range of wavelength gets selected by sending the light through a slit. Then, the light passes through the sample and hits a detector.

Designation of Direct Photometry Non Invasive Bilirubin Device based on research that has been made by using several journals, lectures, biomedical engineers and hospital's staffs in Neonatal Intensive Care Unit (NICU). A decision has been made during the discussion in obtaining the proper and accurate readings of hyperbilirubinemia. In this section will showed and explain about the design and flow of constructing the Direct Photometry Non Invasive Bilirubin Device. This section is one of the important parts in succession of the device. This section involves several flow chart, block diagram, processes, hardware and software part.

3.2 Design Direct Photometry Non Invasive Bilirubin Device

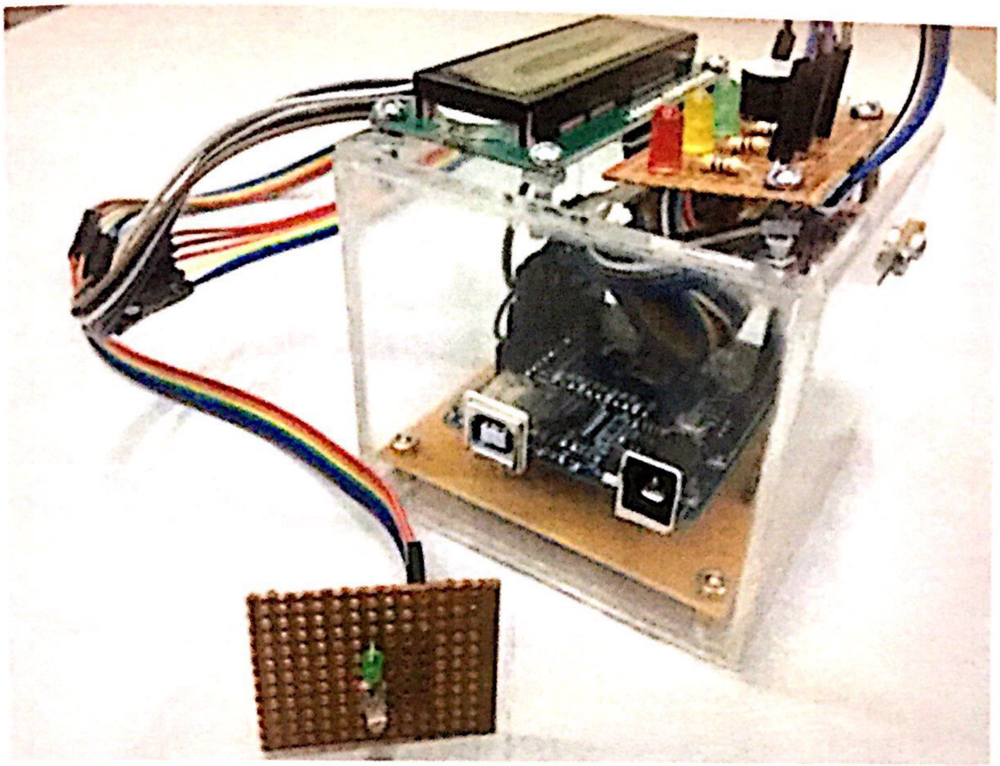

Figure 3.1: Prototype of Direct Photometry Non Invasive Bilirubin Device

3.2.1 Frontal View

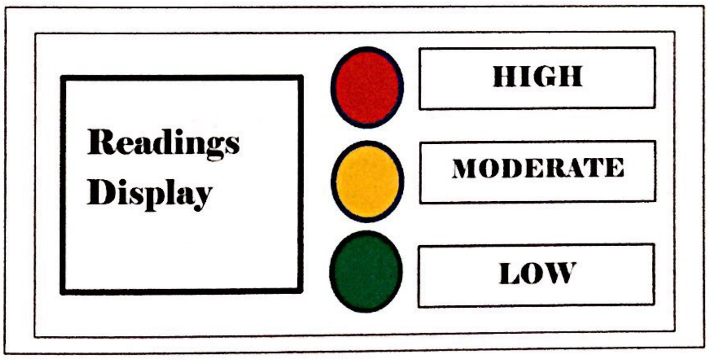

Figure 3.2: Frontal Part

According to the Figure 3.2, it is the design of frontal part of Direct Photometry Non Invasive Bilirubin Device. It is implemented by three different colors of LED as indicator of the jaundice's readings. Red LED will show the higher readings of 300 µmol/L. Orange-yellow LED will indicate the moderate readings at range of 85 up to300 µmol/L. Green LED will observe the low readings of jaundice at range of 0 to 85 µmol/L. The readings of jaundice will appear on the LCD Display.

3.2.2 Inner Part

In this section will discuss about inner part of the device. This section will implement hardware and software in obtaining the accurate and proper readings of jaundice. They are Spectrum Wavelength and Arduino UNO. The sensor circuit also wil combine with the Arduino and locate in the inner part.

3.2.3 Back View

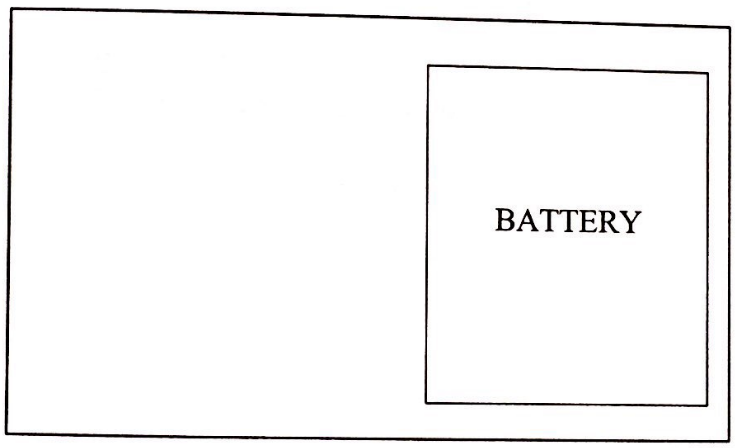

Figure 3.3: Back View

3.2.4 Side View

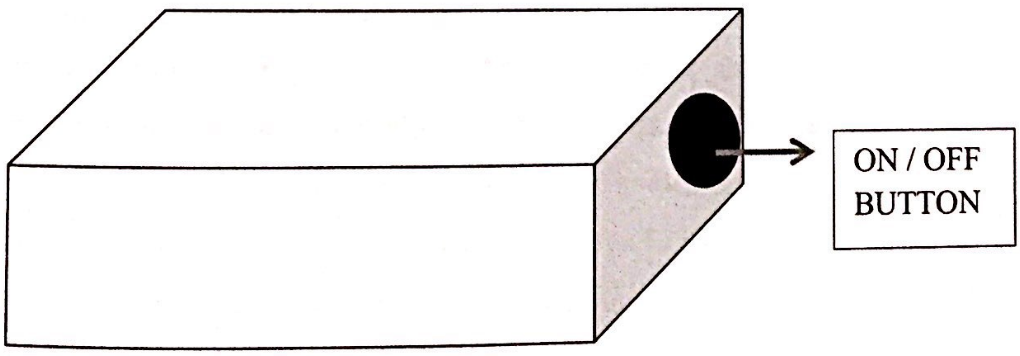

Figure 3.4: Side View

3.3 Hardware Section

A section which consist several parts and components that implemented in completing Direct Photometry Non Invasive Bilirubin Device.

3.4 Wavelength LED

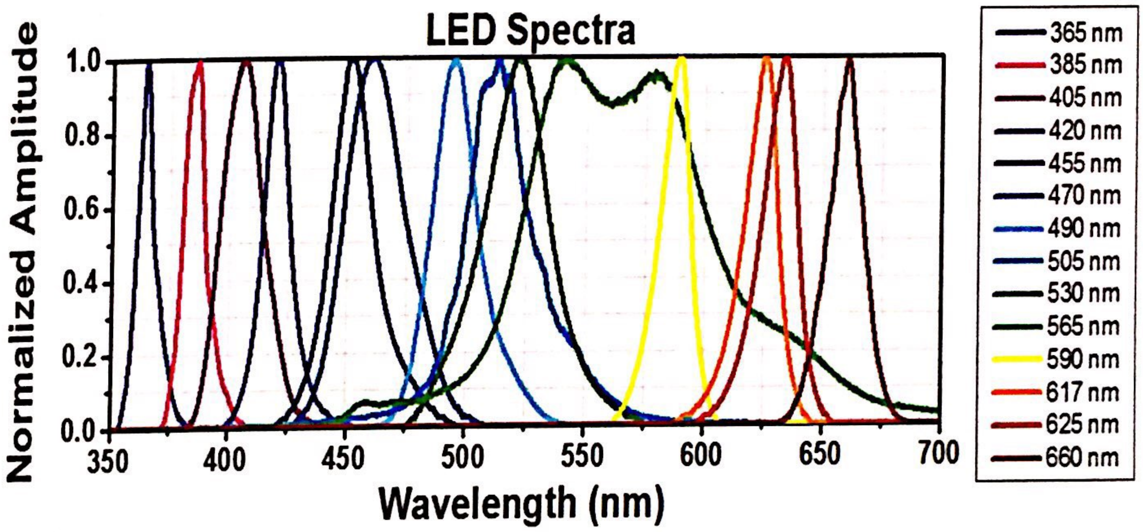

Figure 3.5: LED Spectra

The images below illustrate the effect of different LED colors used to illuminate printed package graphics containing a wide range of colors. Individual colors of print can be highlighted using the like color of light because colored LED lights contain a narrow band of wavelengths which reflect strongly when chosen to match the color of the surface[19]. White LED light contains all visible wavelengths and reflects a gray value from all colors according to their relative brightness. IR light reflects almost equally from each print color. But light waves can also have wavelengths lower or higher than the wavelengths in the visible spectrum, and many familiar types of radiation are just light waves with other wavelengths. Ultraviolet light and x-rays have wavelengths shorter than violet light, and infrared (heat) and radio waves have wavelengths longer than red light. The full range of wavelengths for light is called the "electromagnetic spectrum." The image and table below show which wavelength ranges in the electromagnetic spectrum correspond to which types of light.

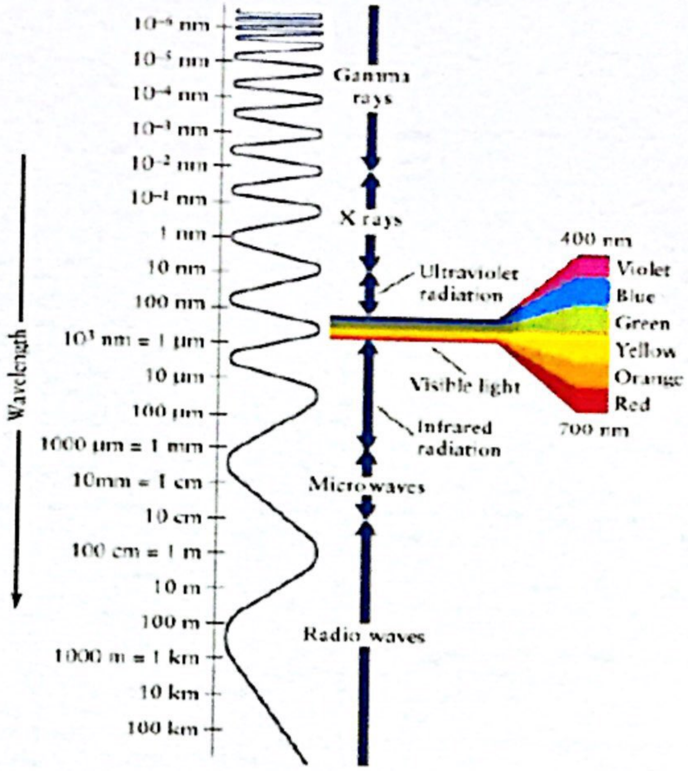

Figure 3.6: Electromagnetic Spectrum Correspond to Which Types of Light

3.4.1 Blue LED

Figure 3.7: 455 nm LED

A standard photometers using two wavelengths (455 nm and 575 nm). This instrument was calibrated with test solutions and has a technical error of ±1.3% for values up to 350 µmol/L. [20]. Blue LED is called as 455nm LED wavelength. It can absorbs light through direct photometric method. Direct photometric measurements are based on direct measurements of suitably solved serum at the wavelength of 455nm, which is the absorption maximum of bilirubin. Direct measurements may be also interfered by opalescence that results from the serum dilution or at the presence of oxy hemoglobin in the neonatal serum, which is often hemolytic and absorbs light at the wavelength of 455nm. In addition, there was controversial evidence to show that trancutaneous bilirubinometers can be used in dark skin coloured term neonates[21].

3.4.2 Green LED

Figure 3.8: 575 nm LED

These interferences might be suppressed by a proper adjustment of the working process, by measurements taken at two wavelengths of 455 and 575nm. The bilirubin concentrations are found from the absorbency differences. The first one corresponds mainly to the bilirubin content and the second one to the oxy hemoglobin content. A high quality device with a narrow definition of the monochromatic light must be used when measuring bilirubin by the direct spectral photometry. When calculating the concentration of bilirubin, we use the value of the molar bilirubin absorption coefficient. The molar absorption bilirubin coefficient ε is numerically equal to the bilirubin solution absorbency value having the concentration 1mol/L at a defined wavelength, temperature and layer width of 1cm.

3.5 Optical Detectors

Detectors perform the opposite function of light emitters. They convert optical signals back into electrical impulses that are used by the receiving end of the fiber optic data, video, or audio link. The most common detector is the semiconductor photodiode, which produces current in response to incident light. Detectors operate based on the principle of the p-n junction. An incident photon striking the diode gives an electron in the valence band sufficient energy to move to the conduction band, creating a free electron and a hole. If the creation of these carriers occurs in a depleted region, the carriers will quickly separate and create a current. As they reach the edge of the depleted area, the electrical forces diminish and current ceases. While the p-n diodes are insufficient detectors for fiber optic systems, both PIN photodiodes and avalanche photodiode (APDs) are designed to compensate for the drawbacks of the p-n diode.

3.5.1 Photodiode

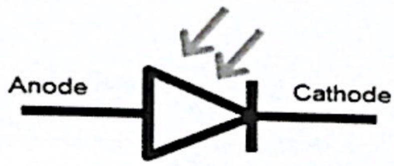

Figure 3.9 : Photodiode Symbol

A silicon photodiode is a solid-state device which converts incident light into an electric current. It consists of a shallow diffused p-n junction, normally a p-on-n configuration although "P-type" devices (n-on-p) are available for enhanced responsitivity in the 1μm region. Modern day silicon photodiodes are generally made by planar diffusion or ion-implantation methods. The silicon photodiode response is usually linear within a few tenths of a percent from the minimum detectable incident light power up to several milli Watts. Response linearity improves with increasing applied reverse bias and decreasing effective load resistance. Some photodiodes will look like a light emitting diode. They have two terminals coming from the end. The smaller end of the diode is the cathode terminal, while the longer end of the diode is the anode terminal. See the following schematic diagram for the anode and cathode side. Under forward bias condition, conventional current will flow from the anode to the cathode, following the arrow in the diode symbol. Photocurrent flows in the reverse direction.

When photons of energy greater than 1.1 eV hit the diode, electron-hole pairs are created. The intensity of photon absorption depends on the energy of photons – the lower the energy of photons, the deeper the absorption is. This process is known as the inner photoelectric effect. If the absorption occurs in the depletion region of the p-n junction, these hole pairs are swept from the junction - due to the built-in electric field of the depletion region. As a result, the holes move toward the anode and the electrons move toward the cathode, thereby producing photocurrent. The sum of photocurrents and dark currents, which flow with or without light, is the total current passing through the photodiode. The sensitivity of the device can be increased by minimizing the dark current.

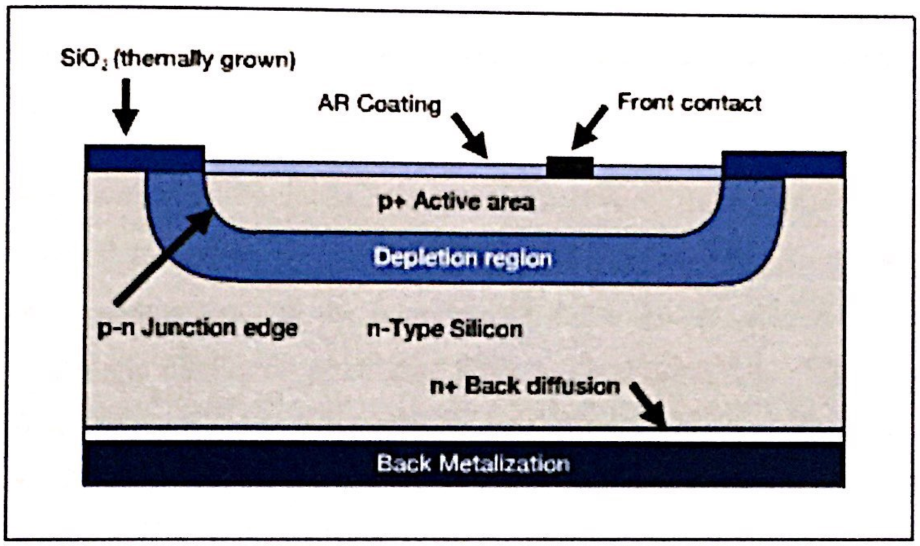

Figure 3.10: Photodiode Construction

3.6 Liquid Crystal Display

LCD (liquid crystal display) is the technology used for displays in notebook and other smaller computers. Like light-emitting diode (LED) and gas-plasma technologies, LCDs allow displays to be much thinner than cathode ray tube (CRT) technology. LCDs consume much less power than LED and gas-display displays because they work on the principle of blocking light rather than emitting it. An LCD is made with either a passive matrix or an active matrix display grid. The active matrix LCD is also known as a thin film transistor (TFT) display. The passive matrix LCD has a grid of conductors with pixels located at each intersection in the grid. A current is sent across two conductors on the grid to control the light for any pixel. An active matrix has a transistor located at each pixel intersection, requiring less current to control the luminance of a pixel.

For this reason, the current in an active matrix display can be switched on and off more frequently and improved the screen refresh time. Liquid crystal display is composed of several layers which include two polarized panel filters and electrodes. LCD technology is used for displaying the image in notebook or some other electronic devices like mini computers. Light is projected from a lens on a layer of liquid crystal. This combination of colored light with the grayscale image of the crystal (formed as electric current flows through the crystal) forms the colored image. This image is then displayed on the screen.

The principle behind the LCD's is that when an electrical current is applied to the liquid crystal molecule, the molecule tends to untwist. This causes the angle of light which is passing through the molecule of the polarized glass and also cause a change in the angle of the top polarizing filter. As a result a little light is allowed to pass the polarized glass through a particular area of the LCD. Thus that particular area will become dark compared to other. The LCD works on the principle of blocking light. While constructing the LCD's, a reflected mirror is arranged at the back. An electrode plane is made of indium-tin oxide which is kept on top and a polarized glass with a polarizing film is also added on the bottom of the device. The complete region of the LCD has to be enclosed by a common electrode and above it should be the liquid crystal matter.

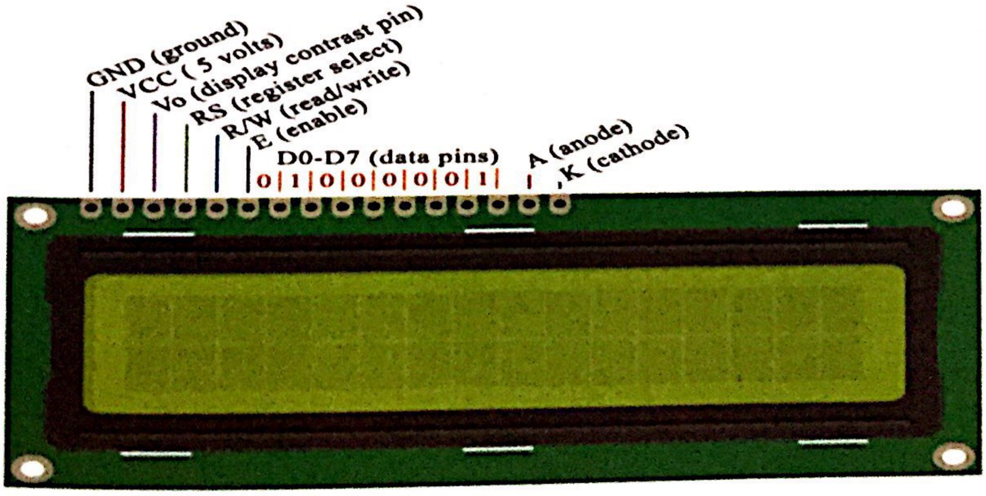

Figure 3.11: LCD pin

3.7 Schematic Circuit

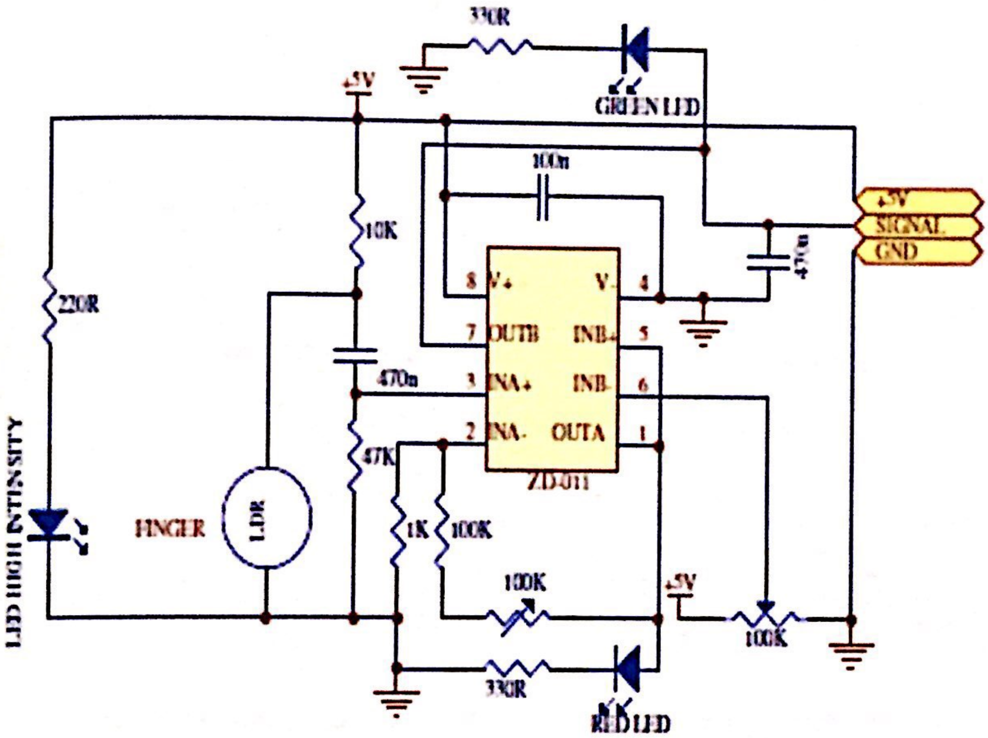

Figure 3.12: Schematic Design of Sensor Circuit

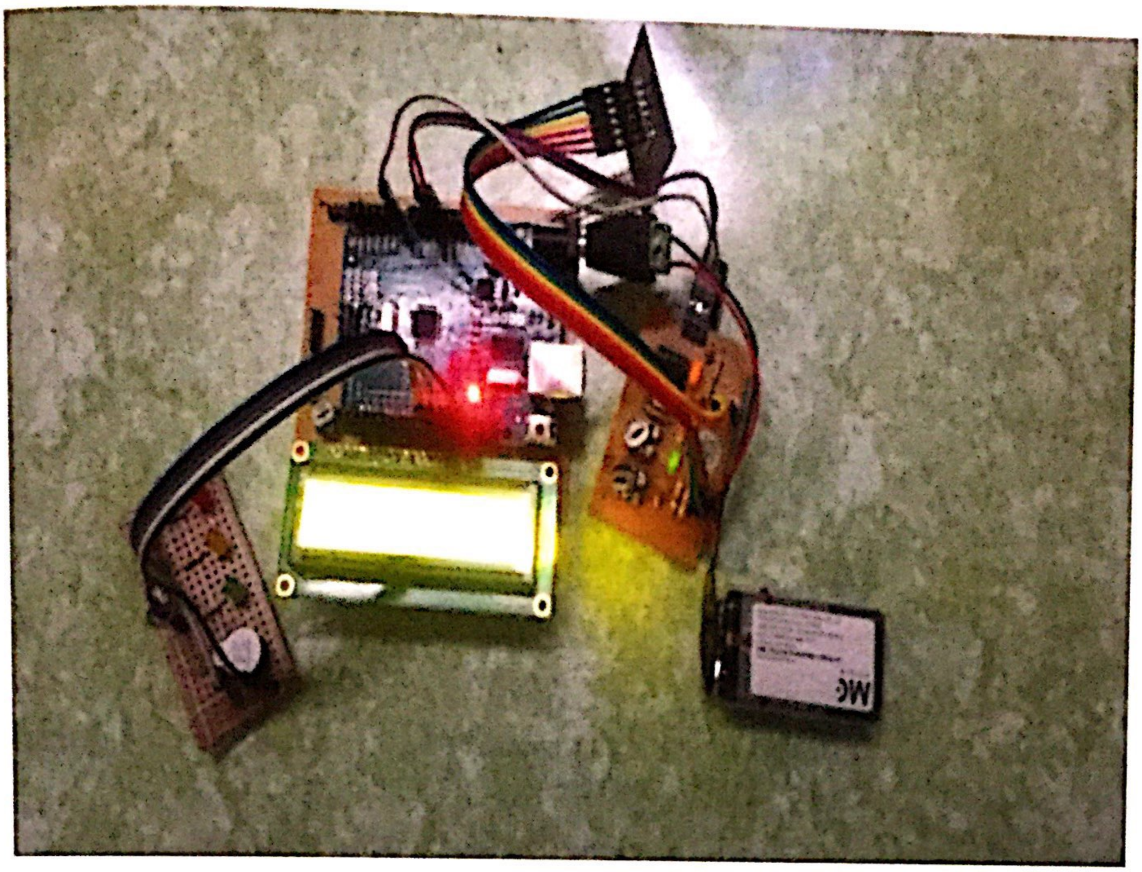

Figure 3.13: Hardware part of Direct Photometry Non Invasive Bilirubin Device

3.8 Software Section

A section which consist software part such as Arduino Software, and the programming code that implemented in completing Direct Photometry Non Invasive Bilirubin Device.

3.9 Arduino Software

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x) or ATmega168 (Arduino Nano). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. The Nano was designed and is being produced by Gravitech. The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teacher and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example. Arduino is a key tool to learn new things[22].

3.9.1 Arduino UNO

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button[23]. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards.

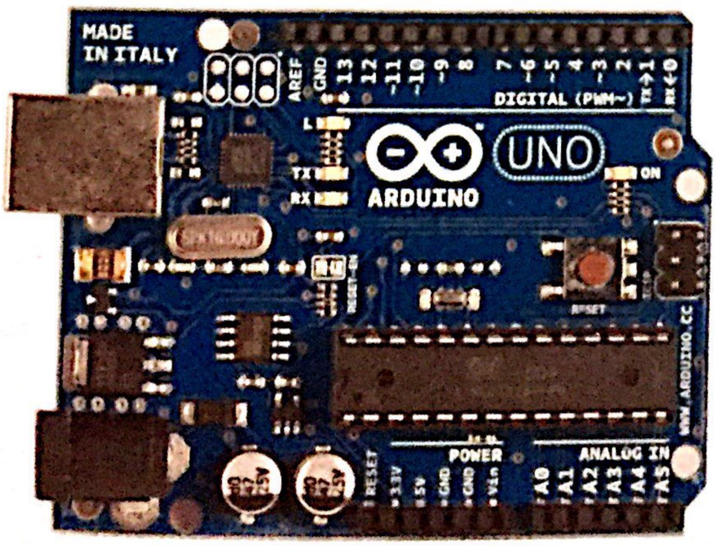

Figure 3.14 : Arduino UNO Board

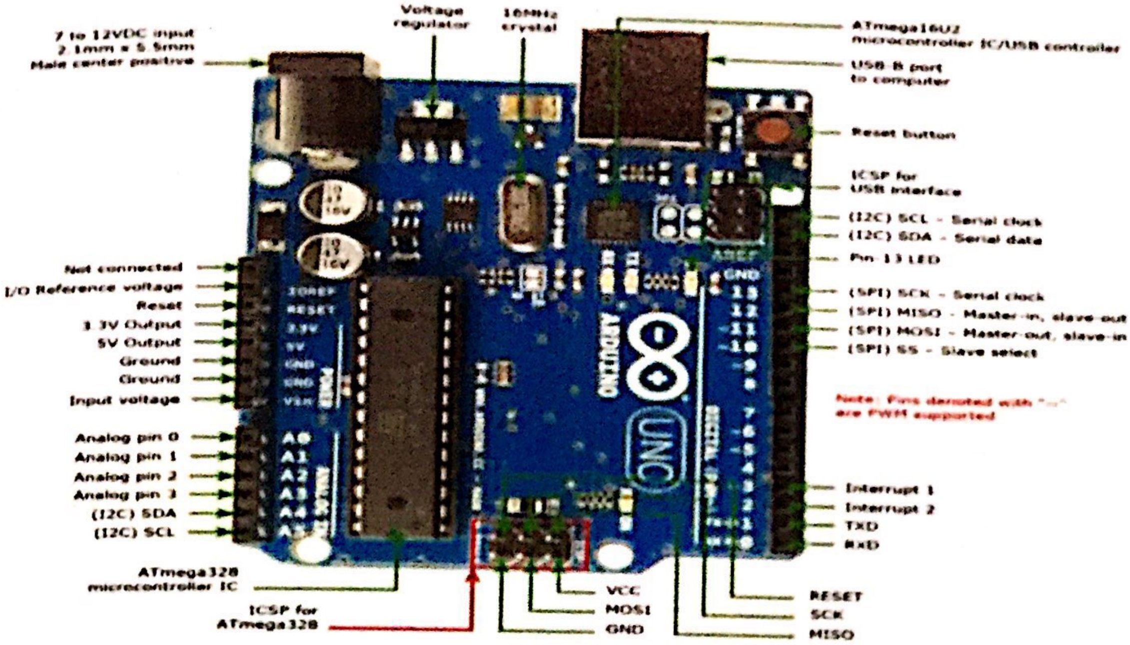

Figure 3.15: Pin Out of Arduino UNO

Table 3.1: Technical Specification

Microcontroller	ARmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12 V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

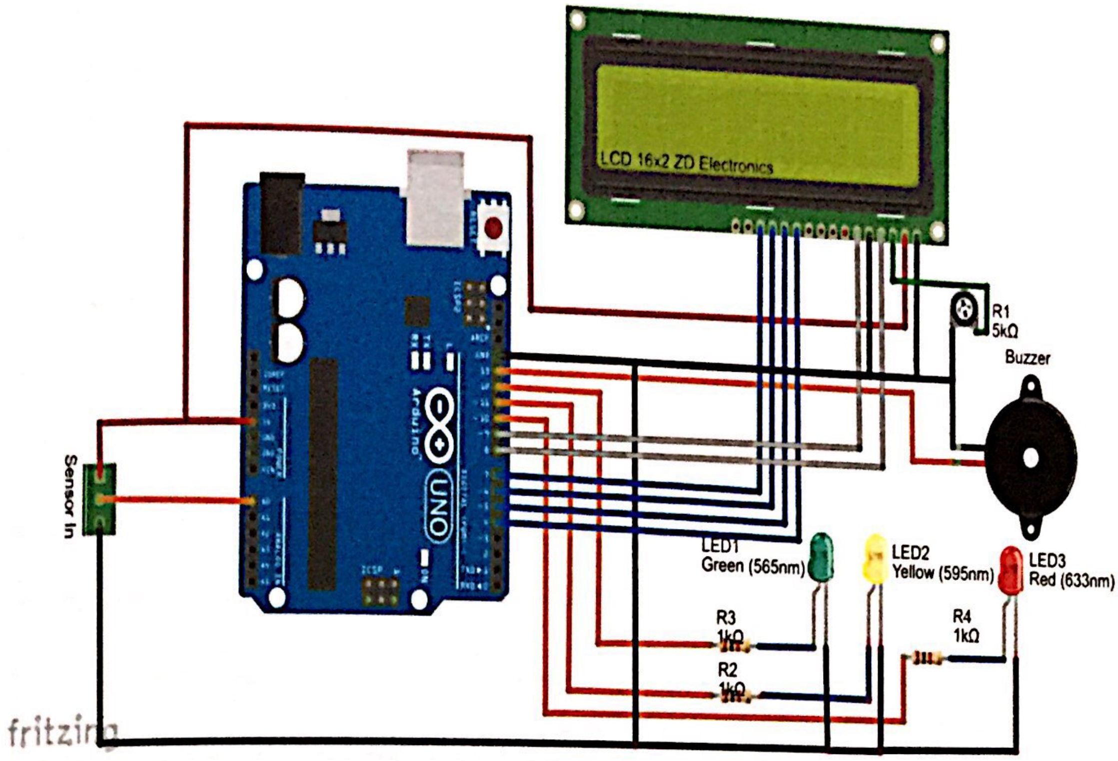

Figure 3.16: Arduino combine with sensor circuit

3.10 Programmed Code

```
#include <LiquidCrystal.h>

#include <SoftwareSerial.h>

LiquidCrystal lcd(8, 9, 4, 5, 6, 7);

SoftwareSerial ss(2, 3); //(RX,TX)

int Temp=A0;

int reading =0;

int suis;

int Bright;

int Rly1 =12;

int Rly2 =11;

int Rly3 =10;
```

```
int Buzz =13;
int SMSx=0;
int SMSy=0;
int SMSz=0;
void setup() {
Serial.begin(9600);
lcd.begin(16, 2);
 ss.begin(9600);
 lcd.begin(16, 2);
 lcd.setCursor(0, 0);
 lcd.print(" Direct Photometry Non Invasive ");
 lcd.setCursor(0, 1);
 lcd.print("Bilirubin Device");
 delay(1000);
 pinMode(Temp,INPUT);
  pinMode(Buzz,OUTPUT);
  pinMode(Rly1,OUTPUT);
  pinMode(Rly2,OUTPUT);
  pinMode(Rly3,OUTPUT);
reading = analogRead(Temp);
int Bright = reading/5;
 delay(100);
 lcd.clear();
 lcd.begin(16, 2);
     lcd.setCursor(0, 0);
     lcd.print("Reading: ");
```

```
        lcd.print(Bright, DEC);
delay(300);
{
 if (Bright>=323){
      lcd.setCursor(0, 1);
     lcd.print("Critical");
   digitalWrite(Buzz,HIGH);
   digitalWrite(Rly1,LOW);
   digitalWrite(Rly2,LOW);
   digitalWrite(Rly3,HIGH);
   delay(300);
  lcd.setCursor(0, 1);
  lcd.print("[ >20mg/dl]");
  delay(300);
      }
 else if (Bright >=10 && Bright <= 85 ){
  lcd.setCursor(0, 1);
   lcd.print("Normal ");
 digitalWrite(Buzz,LOW);
digitalWrite(Rly1,LOW);
digitalWrite(Rly2,LOW);
digitalWrite(Rly3,HIGH);
delay(300);
lcd.setCursor(0, 1);
lcd.print("[0-5mg/dl]");
delay(300);
```

```
else if (Bright >=85 && Bright <= 323 ){
  lcd.setCursor(0, 1);
    lcd.print("Moderate ");
  digitalWrite(Buzz,LOW);
  digitalWrite(Rly1,LOW);
  digitalWrite(Rly2,HIGH);
  digitalWrite(Rly3,LOW);
  delay(300);
  lcd.setCursor(0, 1);
  lcd.print("[6-19mg/dl]");
  delay(300);
}
else if (Bright <=323){
  lcd.setCursor(0, 1);
    lcd.print("Critical");
  digitalWrite(Buzz,HIGH);
  digitalWrite(Rly1,HIGH);
  digitalWrite(Rly2,LOW);
  digitalWrite(Rly3,LOW);
  delay(300);
  lcd.setCursor(0, 1);
  lcd.print("[ >20mg/dl]");
  delay(300);
    }
}
delay(100);
```

3.11 Process of Methodology

3.11.1 Flow chart of Project

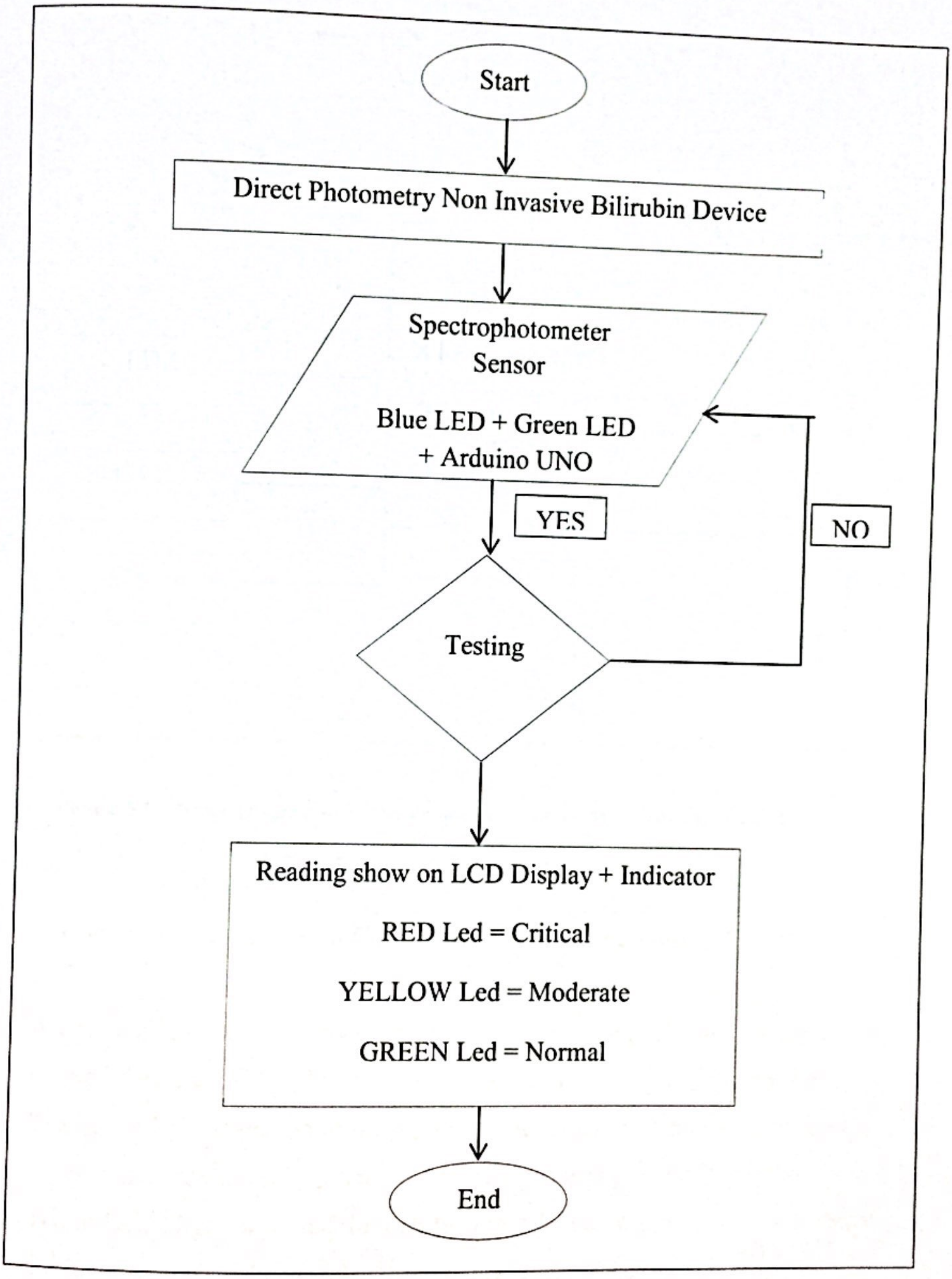

Figure 3.17: Flow Chart of Direct Photometry Non Invasive Bilirubin Device

3.11.2 Block diagram of Project

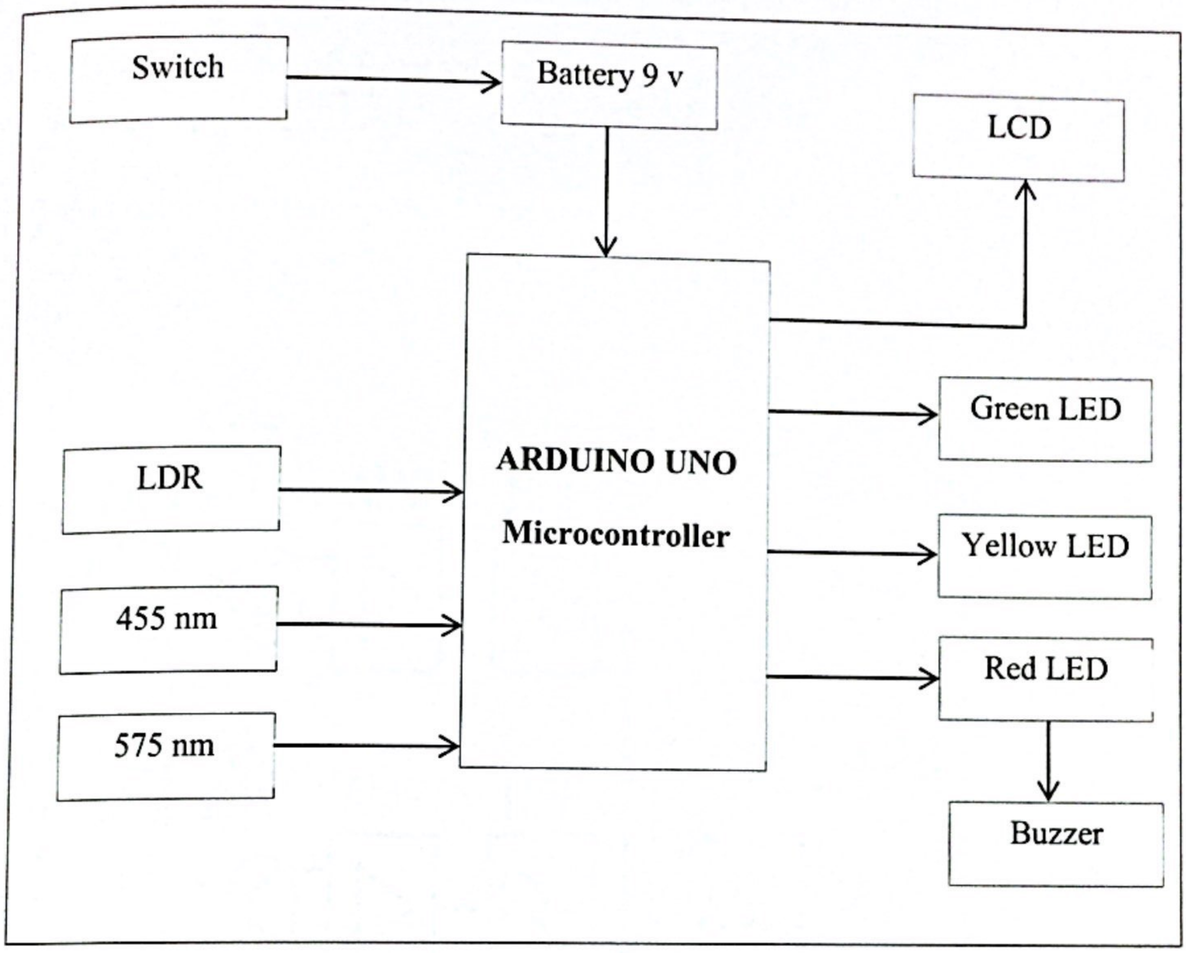

Figure 3.18: Block Diagram of Direct Photometry Non Invasive Bilirubin Device

3.12 Process to Detect Bilirubin Concentration Non-Invasively

a) A light is illuminate by activating a pressure sensitive probe, which is pressed on the infant's skin. A light generating tube illuminated a bright strobe light.

b) The bright light is passed to the skin to small distance to trans-illuminate the tissue underlying the skin where the pressure probe is pressed.

c) The reflected light is passed through the optical fiber to the spectrophotometer module to calculate the wavelength of the reflected light.

d) The dichromic mirror is established into the spectrophotometer module, which devices the reflected light into two spectra components.

e) One is passed through the green light filter with maximum absorption wavelength at 550 nm and second from blue light filter with maximum absorption wavelength at 460 nm.

f) The difference output is passed through the calibrating device to calibrate the intensity of yellow color by keeping the white light at zero.

Note: The variations of readings should not exceed to 5%.

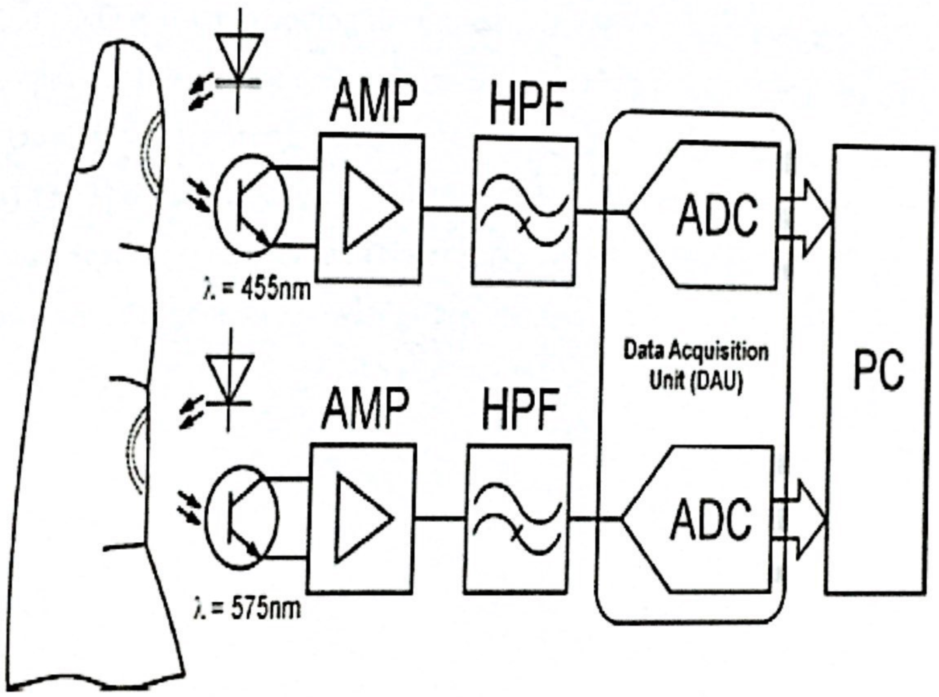

Figure 3.19: Principle of the electronic circuit of bilirubin measurements.

3.13 Microsoft Excel

Microsoft Excel is used to interpret my questionnaire or early survey in analysis my devices among hospital's staff and public. By using Microsoft Excel, graph is the suitable method to analyze and differentiate between each questions of my survey. This Microsoft is also to interpret the data that collected during testing the device. Excel is probably the most commonly used spreadsheet for PCs. Newly purchased computers often arrive with Excel already loaded. It is easily used to do a variety of calculations, includes a collection of statistical functions, and a Data Analysis Tool.

3.14 Summarize

Overall, methodology part implements the hardware, software and data analysis (Research). For hardware part, all the components will complete this scope such as Spectrophotometer Sensor, DC Motor, Buzzer and Amplifier. A part from that, Arduino UNO is used to coding the microcontroller and to control the possible output. The outputs of this device are readings of jaundice parameters will be showed on the LCD Display. Buzzer rang when the readings is on critical mode. The readings are also will be showed through the indicators which are Red (Critical readings), Yellow (Moderate readings) and Green (Normal readings). Questionnaire is also constructed to know about the general knowledge and the need of analysis survey.

CHAPTER 4

DATA ANALYSIS

4.1 Overview

In this part, it is implement analysis and collection of data. Through this data, it can compare between the accuracy and correlation between invasive techniques and non-invasive techniques. There are several parts that constructed in completing the Direct Photometry Non Invasive Bilirubin Device. For the first part, Pre-Survey is constructed to obtain the general information and general requirement for the title of Direct Photometry Non Invasive Bilirubin Device. All the data analysis that obtained is recorded in Chapter 4. In order to get the correct and accurate readings of Direct Photometry Non Invasive Bilirubin Device, the parameters and the results must be compared with the invasive techniques. The data can be obtained in several government hospitals. All the data is recorded in tabulated data and graph form.

4.2 Questionnaire

4.2.1 Pre – Survey Questionnaire

QUESTIONNAIRE

A SURVEY OF FINAL YEAR PROJECT "NON-INVASIVE BILIRUBIN METER"

1. Gender ☐ Male ☐ Female
2. Age ☐ Years
3. ☐ Hospital's Staffs
   ☐ Parents / Public
4. Have you heard about jaundice / hyperbilirubinemia ?
   ☐ Yes ☐ No
5. Which device do you prefer to measure jaundice on newborns?
   ☐ Taking baby's blood (INVASIVE)
   ☐ Placed against the forehead of the newborns.(NON-INVASIVE)
6. Do you agree if a new device is develops to check the jaundice without taking baby's blood?
   ☐ Yes ☐ No
7. Do you think this project can help to simplify the task of Pediatric Unit?
   ☐ Yes ☐ No
8. Which is more relevant for the newborns?
   ☐ Taking baby's blood (INVASIVE)
   ☐ Placed against the forehead of the newborns (NON-INVASIVE)
9. Is it taking a long time to obtain the result of jaundice when using the Invasive Method (Taking newborns's blood)?
   ☐ Yes ☐ No
10. Non-Invasive Bilirubin Meter is low cost and can give the correct reading of jaundice. Do you agree if this device is done?
    ☐ Yes ☐ No
11. What is your opinion about this device? Can you give your comment and suggestion.

____

____

____

Prepared by,	Verified by,
....	....
(NOOR SYAHIRAH BINTI MOHD LAZIM)	(MDM KU LEE CHIN)
08BEU15F3017	Supervisor

Figure 4.1: Pre-Survey Questionnaire

Through this part, the questionnaire is conducted among twenty hospital's staff and biomedical engineers at government hospital in Terengganu. A part from that, all the data in the survey form is tabulated in graph bar below. As overall, through the data collected from this questionnaire showed positive feedback in development of Direct Photometry Non Invasive Bilirubin Meter.

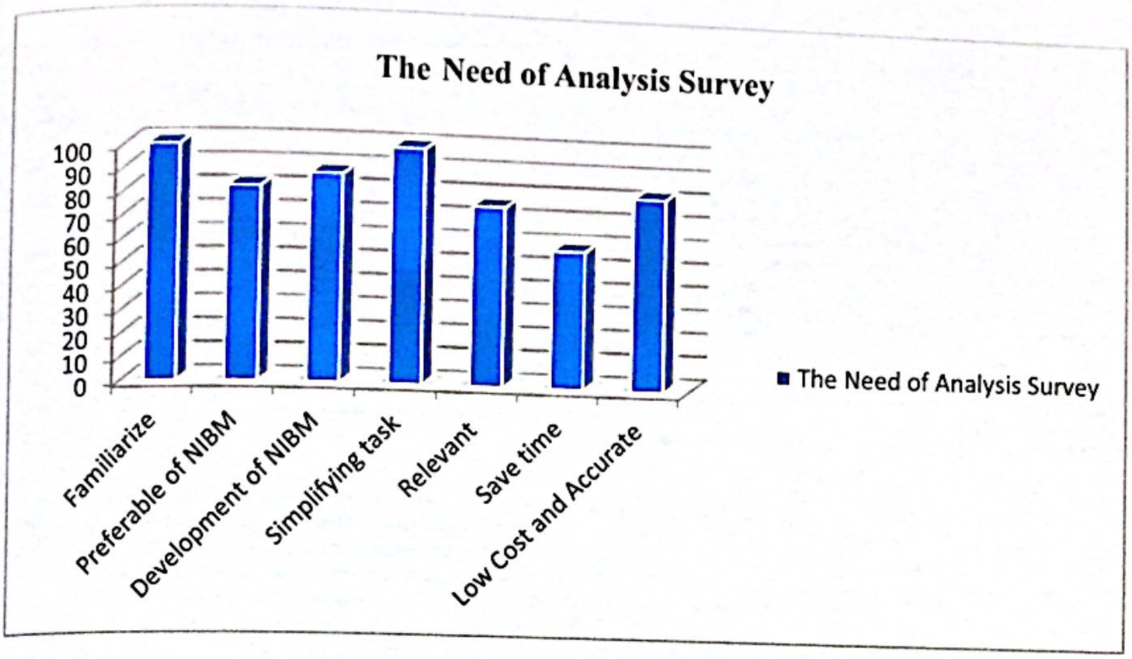

Figure 4.2: The Need of Analysis Survey

According to the Figure 4.2, in overall, all of my respondent are familiarize with the Direct Photometry Non Invasive Bilirubin Device i. It is about 82.4% shows that they are preferred to use the device in measuring jaundice. The graph shows 88.2% are agree if the development of Direct Photometry Non Invasive Bilirubin Device is continued. For overall of my respondent are agree that DPNIBD helps staffs and other users in simplifying task. About 76.5% shows that DPNIBD is more relevant to use to baby or neonates. 58.8% shows that invasive method is more time consuming. Lastly, about 82.4 % agree that DPNIBD can be a low cost product rather than device that used in oversea.

4.2.2 Post – Survey Questionnaire

POLITEKNIK
Sultan Salahuddin Abdul Aziz Shah
Jabatan Pengajian Politeknik

SURVEY QUESTIONNAIRE – NON INVASIVE BILIRUBIN METER

DISCLAIMER:

This survey is based on final year project of Bachelor of Electronic Engineering (Medical Electronic). The name of this device is Non Invasive Bilirubin Meter. The aim of this survey is to understand the device after the pre-survey is done. It can be helpful to improve and to enhance the device in future. It is also to analyze the device in getting the correct readings and measurement. Participation of this survey is completely voluntary and anonymous. You may choose to discontinue this survey at any time. No harm will befall to anyone of the participation. This device is focusing for below three months age. All the data will be recorded and analyzed.

CONSENT:

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

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

SECTION A

1. Are you find that this device is suitable to use?

☐ Yes

☐ No

2. Are you familiar with this device? Do you heard about similar device like this before?

☐ Yes

☐ No

3. Do you understand the function of this device?

☐ Yes

☐ No

4. If this device is in market, do you prefer to have it?

☐ Yes

☐ No

5. Which one of the method did you prefer to check the jaundice?

☐ Blood Test

☐ DPNIBD

6. Is this device is suitable to use and help in determining the jaundice?

☐ Yes

☐ No

SECTION B

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

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

NO	STATEMENTS	5	4	3	2	1
1	Is this device convenient to use?					
2	Is this device gives the accurate readings?					
3	Can this device is safe to use to neonatal babies?					
4	Do you agree if this device placed in market of our country?					
5	Do you prefer if this device cam minimize the time taken in obtaining results rather than blood test?					
6	Do you think this device is more secure to use to baby rather than pain method?					

SECTION C

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

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

Recommendation / Comments:

____

____

____

Signature,

____

Position: (Doctor / Nurse / Parent / User)

Date:

THANK YOU

Figure 4.3: Post – Survey Questionnaire

4.2.3 Effectiveness of Direct Photometry Non Invasive Bilirubin Device

Table 4.1: Effectiveness of Direct Photometry Non Invasive Bilirubin Device

NO.	QUESTIONS	PERCENTAGE
1	Suitable of used the device.	100
2	Familiarize of device.	52
3	Understanding the function of device.	92
4	Preferable device in market	89
5	Preferable device during checking hyperbilirubinemia.	84
6	Helpfulness	100
7	Convenient to Use	100
8	Accuracy	76
9	Safety	96
10	Market Device	96
11	Save Time	92
12	Secureness	92
13	Enjoy using the product	96
14	Safe to Use	92
15	Purchase Product	96
16	Beneficial	96

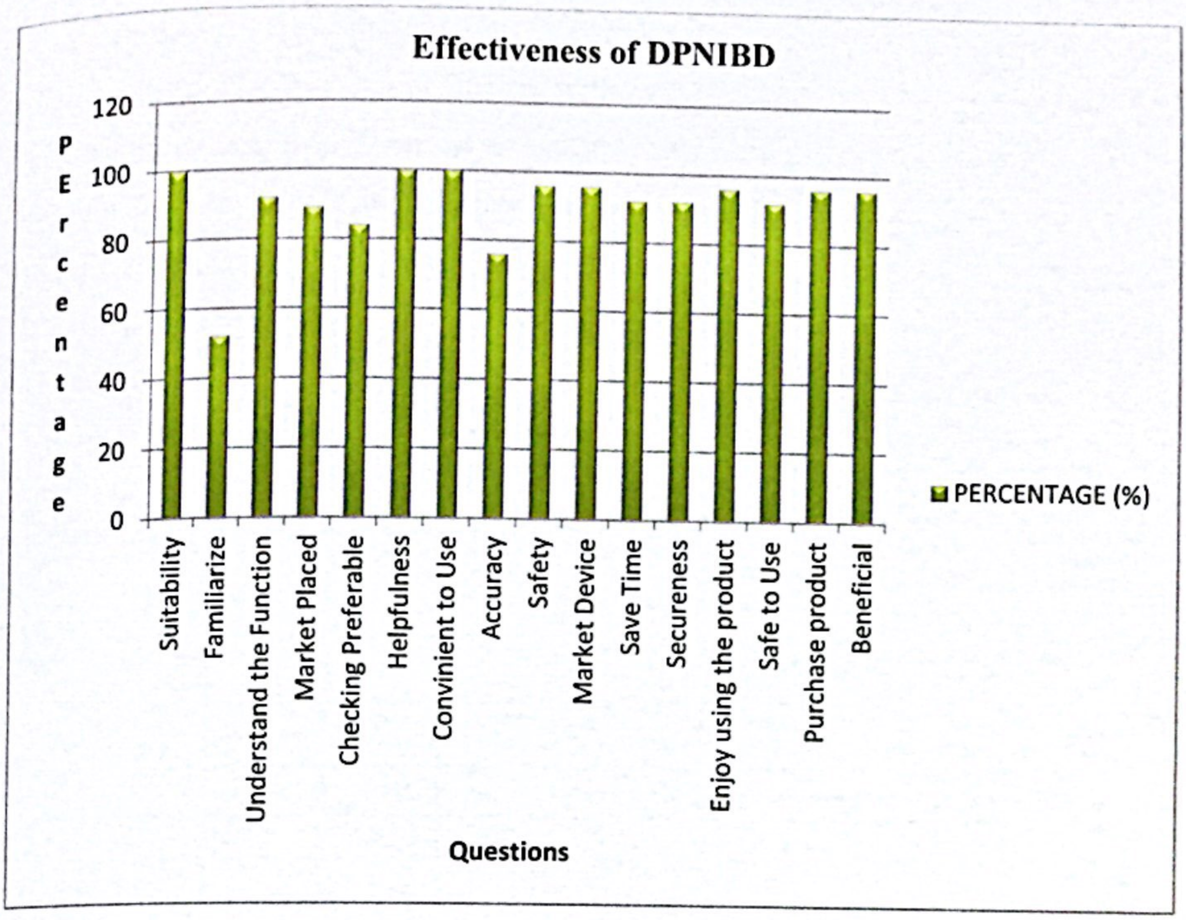

Figure 4.4: Effectiveness of DPNIBD on 30 subjects

4.3 Data Collection

Table 4.2: Range of Condition[24]

Condition	Serum Concentration (µmol/L)	Voltage Range
Normal	0 < thick < 85	4v - 6v
Mild	85<thick<323	2v – 4v
Critical	Thick > 359	0v – 2v

Table 4.2 shows the range of condition of the bilirubin level. Based on the readings, the device implements the bilirubin level in range form. The output for this device is in voltage (V). Then the value of voltage is used to determine the level of bilirubin. The level of critical, moderate and normal readings of bilirubin can be recorded based on the output voltage appeared during testing the device.

Table 4.3: Data Collection on Five Neonates.

Subject	DPNIBD (a)	Condition
1	195	Moderate
2	167	Moderate
3	145	Moderate
4	124	Moderate
5	66	Normal

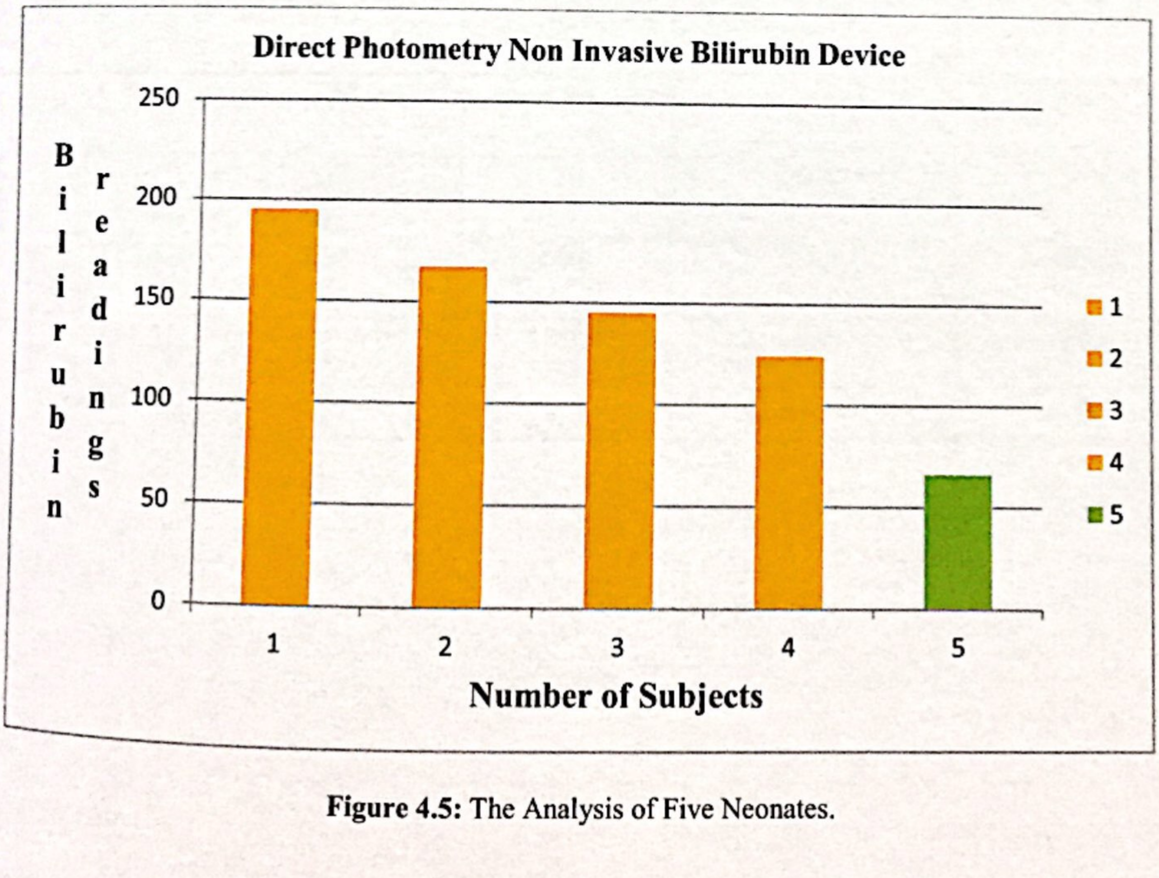

Figure 4.5: The Analysis of Five Neonates.

The range of condition was set according to normal, mild and critical as shown in Table 4.2, through the readings on Direct Photometry method (DPNIBD). Five samples have been taken to prove the concept as shown in Table 4.3. Orange-yellow LED indicated moderate or mild condition; Green LED showed normal healthy condition. As a result this method is capable to give reasonable result and also give advantages to study the non-invasive system for measurement of jaundice level.

Table 4.4: Comparison between Invasive and Non Invasive Readings

Subject	**DPNIBD (a)**	**SBr (b)**	**Percentage of Error (%) (b) - (a) / (b)**	**Percentage of Accuracy (%)**
1	195	200	2.5	97.5
2	167	160	4.4	95.6
3	145	149	2.7	97.3
4	124	120	3.3	96.7
5	67	70	4.3	95.7
TOTAL	698	699	17.2	428.8
TOTAL AVERAGE	139.6	139.8	3.4	96.6

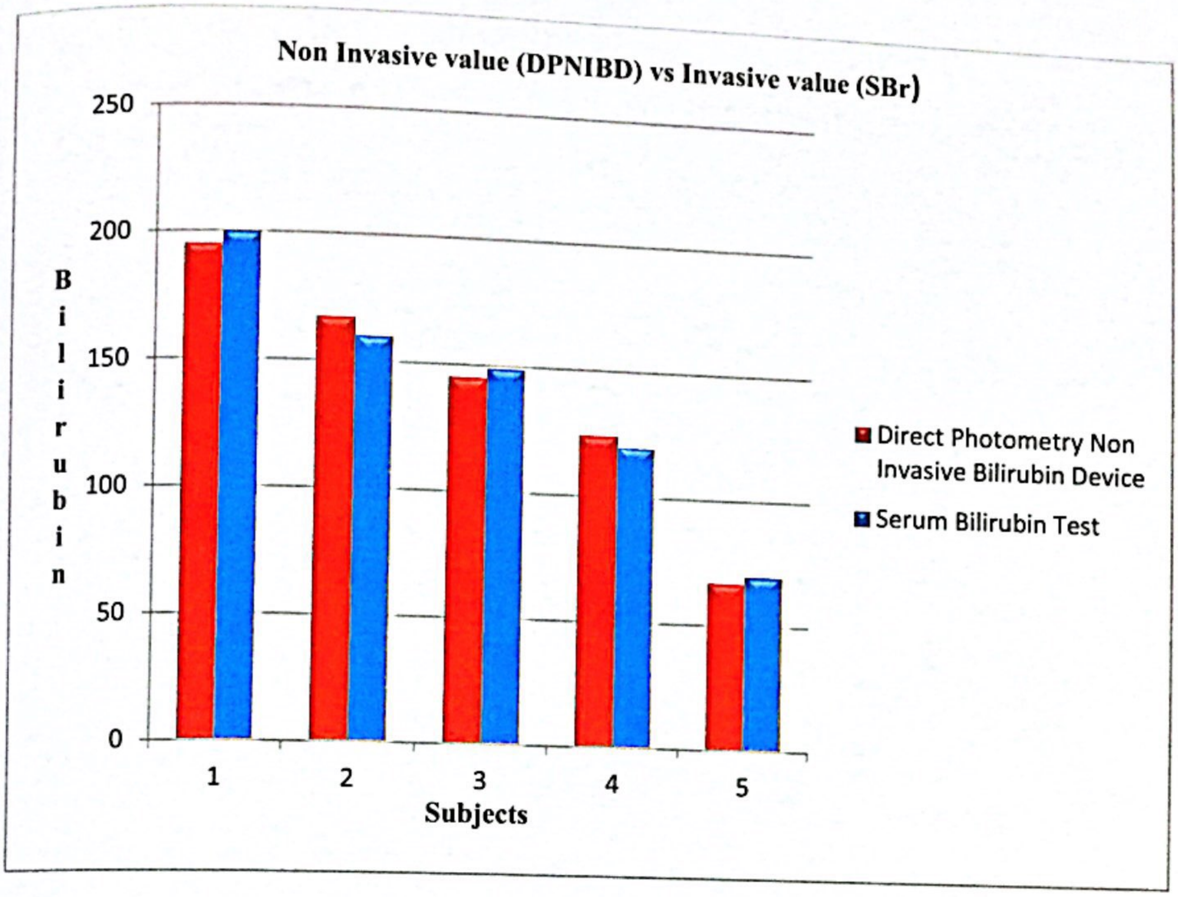

Figure 4.6: Non Invasive value versus Invasive Value.

The graph above show the percentage of readings of Direct Photometry Non Invasive Bilirubin Device compared to the Serum Bilirubin which is invasive method. Based on the graph, we can know the accuracy of the device that has been test on five subjects. The less percentage of error among five neonates in in subject-1, which is it only implement 2.5 percent or error following with Subject-3 that only consume 2.7 error. The others three implement 3.3, 4.3 and 4.4 percent of error. The less of error lead to accurate readings. This accuracy test is done in order to fulfill the requirement of and to show the effectiveness and accuracy of the Direct Photometry Non Invasive Bilirubin Device. Based on the graph, we can show the both percentage of accuracy and error of the device. This device only test on five neonates since it is quite difficult to get and done the test to newborn babies. That is because this device is focus on the physiological jaundice only. It is between babies two days until two weeks. Physiological jaundice occur among up to 24 hours and till 14 days. The babies with jaundice after 14 days will be positioned under the lamp.

$$\text{Percent Error} = \frac{\text{Invasive} - \text{Non Invasve}}{\text{Invasive}} \text{ X } 100$$

Figure 4.7: Calculation of Percentage of Error

Percent Accuracy = 100 - Error

Figure 4.8: Calculation of Percentage of Accuracy

CALCULATION FOR DPNIBD

Percentage of Error

$$\frac{139.8-139.6}{139.8} \text{ x } 100 = 3.4\ \%$$

Percentage of Accuracy

$$100 - 3.4 = 96.6\%$$

Figure 4.9: Calculation of Direct Photometry Non Invasive Bilirubin Device

Based on the calculation showed in the Figure 4.9, it is based on the formula given in the Figure 4.7 and Figure 4.8. It showed that Direct Photometry Non Invasive Bilirubin Device give 96.6 % of accuracy test. It is in the range of accuracy among 95 % and above. This device can be used and can be proved in order to achieve the bilirubin readings among neonates.

Table 4.5: Comparison of Invasive and Non-Invasive

No.	Title	Invasive	Non-Invasive
1	Blood Samples	Required	Not required
2	Pain and Distress	Occur	Not Occur
3	Spectral Reflectance	Not required	Required
4	Delay in Treatment	Occur	Not occur
5	Calibration	Subjective	Objective
6	Detection After Phototherapy	Can be applied	Cannot be applied
7	Factors Affects Detection	Melanin, oxyhemoglobin, deoxyhemoglobin, age, sex, dermal maturity is not affect the detection process.	Hemoglobin, deoxyhemoglobin, age, sex, dermal maturity is affect the detection.

The table above shows the comparison between non-invasive and invasive readings of jaundice. It is the results from the data collection and data analysis that have been interpreting between the non-invasive and invasive method. From this table, all the information are viewed to easier the user to compare the more convenient method. A part from that, users can make their own decision either to choose invasive or invasive method. Last but not least, this device already prove the effectiveness of this product in this chapter to open all the user's viewed about the latest technology in determining the hyperbilirubinemia or jaundice diseases.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Prologue

This is the last section in this writing. This section can lead to a conclusion, summarization and recommendation about Direct Photometry Non Invasive Bilirubin Device. Based on the preview chapter, there are a lot of knowledge and information and there is also data collection in order to prove the accuracy, correlation and learning process in designing Direct Photometry Non Invasive Bilirubin Device. These parts provide innovation ideas to those who interested in this device. By doing this recommendations, the device can be improve one to another time. A good device cannot be done in a short period. It must be done and research along the journey in completing it to become a perfect device. However, a lot of improvements and achievement could be done for future. Direct Photometry Non Invasive Bilirubin Device can be proceeds with a lot of new items and features. It can be a great device that are suitable and give a lot of advantages to all users. Besides, it can brings Malaysia's name to the higher level that compatible with others country. From this section, all the improvements and future achievement are stated to enhance this device. This device is one of the new technology that had in others country but the first device in Malaysia. A lot of effort must be done in order to bring this device to the next level.

5.2 Conclusion

Detection of jaundice in early stage can be predicted by using invasive method. Due to demand in our latest technology and without painful, a new device is designed in determined jaundice by using direct photometry non-invasive bilirubin device which is more preferable and painless for testing to the baby. By using this non-invasive bilirubin device, it can save time, user friendly, affordable, painless and can make a harmony situation without any pricking needle is needed to determine the level or readings of the jaundice among baby. A system is developed in designation of direct photometry sensor by building two different wavelengths which are 455 nm and 575 nm. The device can indicate the three conditions of jaundice; normal, mild and critical level with LED light with one parameter which is the unit of the bilirubin concentration is in µmol/dL. This new technology of product can enlighten the effort of users especially Pediatrics Units and parents. This device can be move to the higher level since our community does not aware enough about this device and the importance in determined jaundice among neonates. A workshop with the advice from NICU can be held in order to achieve the target. The device's target can be seen through the objectives that has been made in early process of the development of Direct Photometry Non Invasive Bilirubin Device.

The main parameter value (MPV) that can be seen in this device is non-trauma and painless. The competitor for this device is invasive technique which is traumatic and pain to subjects. The focuses on built this device can be anyone whether NICU units, Pediatrics Unit, Pharmacists, Medical Team or even a user such as parent. The main function in this device is non-trauma measure hyperbilirubinemia. Hyperbilirubinemia is known as jaundices. The main component that involves in this device is Direct Photometry sensor. It is the heart of this device. If it is failed, then all over of this device cannot function properly. As stated, the procedure in completing this device must be collaborate with Ministry of Health since it is illegal product if we continued this product without any endorsement or validation. This device of Direct Photometry Non Invasive Bilirubin Device is also got an endorsement from a hospital.

In future, this device can registered with National Pharmaceutical Regulatory Agency (NPRA) in order to achieve and testing to users.

5.3 Recommendation and Suggestions

During completing the device, there are many improvements and ideas that come from my mind. However, it is too late in improving this device according to time schedule in submitting and finishing the device is around the corner. A part from that, this section is the suitable recommendation in order to improve this design of Direct Photometry Non Invasive Bilirubin Device in future. First of all, safety precaution and safety button must be inserted and design in this product, since it is used to check newborn babies. Safety precaution can functions as protection and calibration test from biomedical engineer before test this device to the patient. Biomedical engineer can use the safety precaution or safety button as main item in validation this device. Safety precaution must have in every electronic device in order to keep the safety element before using it. Electrical Safety Test also can easier to do with the function from the safety button.

Second, the readings of bilirubin level must be calculated from a specified formula. The formula is not found until now. The try and error method is used in order to find the correct calculation. This device is implement range readings of jaundice. It is quite incorrect in determining the specified readings of bilirubin. The try and error method of the bilirubin calculation can be done by specific research about one year. This device cannot be done in that period. This is also the important part to maintain the accurate readings of this device.

Third, the casing can be done smaller than this device. This device can be more users friendly and easy going and easy to bring when the size is more small than usual. The casing can be more inconvenient. The new innovation that can be added in this device is the designation that similar to digital thermometer. New sensor also can be included. The sensor that also can be done in detecting the jaundice level is by using the photodiode that used in a digital thermometer. An app can be develop for smartphones so that jaundice can be detect at home at early stage without need to rush towards the laboratory to detect jaundice.

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APPENDIX A

LED ORDERING STATEMENT

08/11/2016

RS Components

Statement of conformity

This certificate confirms that the product detailed below complies with the specifications currently published by RS Components and has been subject to the quality conditions of our registration to the BS EN ISO9001:2008 management standard. Furthermore, where applicable, it provides assurance that all electrostatic discharge sensitive devices have been handled and packed under conditions that meet the administrative and technical requirements of the ANSI/ESD S20.20:2007 and the BS EN 61340-5-1:2007 electrostatic control standards.

RS Stock No.	247-1561
Description	Kingbright L-934MBD, Round Series Blue LED, 455 nm 3mm (T-1), Round Lens Through Hole package
Manufacturer/Brand:	Kingbright
Mfr. Part No.	L-934MBD

The foregoing information relates to product sold on, or after, the date shown below.

Martyn Green

Martyn Green

Quality Systems Manager

RS COMPONENTS

Date Nov 8, 2016

RS Components Ltd, Birchington Road, Corby, Northamptonshire, NN17 9RS, UK

PROGRAMMED CODE

```
#include <LiquidCrystal.h>
#include <SoftwareSerial.h>
LiquidCrystal lcd(8, 9, 4, 5, 6, 7);
SoftwareSerial ss(2, 3); //(RX,TX)
int Temp=A0;
int reading =0;
int suis;
int Bright;
int Rly1 =12;
int Rly2 =11;
int Rly3 =10;
int Buzz =13;
int SMSx=0;
int SMSy=0;
int SMSz=0;
void setup() {
Serial.begin(9600);
lcd.begin(16, 2);
/////////////////////////////////////////////////////////
ss.begin(9600);
lcd.begin(16, 2);
lcd.setCursor(0, 0);
lcd.print(" Direct Photometry Non Invasive ");
```

```
  lcd.setCursor(0, 1);
  lcd.print("Bilirubin Device");
  delay(1000);
  pinMode(Temp,INPUT);
   pinMode(Buzz,OUTPUT);
   pinMode(Rly1,OUTPUT);
   pinMode(Rly2,OUTPUT);
   pinMode(Rly3,OUTPUT);
}
void loop(){
{
///////////////////////////ADC LDR  ///////////////////////////////////
reading = analogRead(Temp);
 int Bright = reading/5;
    delay(100);
     lcd.clear();
////////////////////////////////////////////////////////////////
       lcd.begin(16, 2);
       lcd.setCursor(0, 0);
       lcd.print("Reading: ");
       lcd.print(Bright, DEC);
   //   lcd.print((char)223);
   //   lcd.print("%");
      Serial.println(" ");
```

```
delay(300);
{
if (Bright>=323){
lcd.setCursor(0, 1);
lcd.print("Critical");
digitalWrite(Buzz,HIGH);
digitalWrite(Rly1,LOW);
digitalWrite(Rly2,LOW);
digitalWrite(Rly3,HIGH);
delay(300);
lcd.setCursor(0, 1);
lcd.print("[ >20mg/dl]");
delay(300);
}
else if (Bright >=101 && Bright <= 109 ){
lcd.setCursor(0, 1);
lcd.print("Undetected");
digitalWrite(Buzz,LOW);
digitalWrite(Rly1,LOW);
digitalWrite(Rly2,LOW);
digitalWrite(Rly3,LOW);
delay(300);
}
else if (Bright >=10 && Bright <= 85 ){
lcd.setCursor(0, 1);
```

```
lcd.print("Normal ");
digitalWrite(Buzz,LOW);
digitalWrite(Rly1,LOW);
digitalWrite(Rly2,LOW);
digitalWrite(Rly3,HIGH);
delay(300);
lcd.setCursor(0, 1);
lcd.print("[0-5mg/dl]");
delay(300);
}
else if (Bright >=85 && Bright <= 323 ){
lcd.setCursor(0, 1);
lcd.print("Moderate ");
digitalWrite(Buzz,LOW);
digitalWrite(Rly1,LOW);
digitalWrite(Rly2,HIGH);
digitalWrite(Rly3,LOW);
delay(300);
lcd.setCursor(0, 1);
lcd.print("[6-19mg/dl]");
delay(300);
}
else if (Bright <=323){
lcd.setCursor(0, 1);
lcd.print("Critical");
digitalWrite(Buzz,HIGH);
```

```
        digitalWrite(Rly1,HIGH);
        digitalWrite(Rly2,LOW);
        digitalWrite(Rly3,LOW);
        delay(300);
        lcd.setCursor(0, 1);
        lcd.print("[ >20mg/dl]");
        delay(300);
          }
    }
    delay(100);
    }
    }
```

APPENDIX C

PRE-SURVEY QUESTIONNAIRE

QUESTIONNAIRE

<u>A SURVEY OF FINAL YEAR PROJECT "DIRECT PHOTOMETRY NON INVASIVE BILIRUBIN DEVICE"</u>

1. Gender ☐ Male ☐ Female

2. Age ☐ Years.

3. ☐ Hospital's Staffs
   ☐ Parents / Public

4. Have you heard about jaundice / hyperbilirubinemia ?
   ☐ Yes ☐ No

5. Which device do you prefer to measure jaundice on newborns?
   ☐ Taking baby's blood (INVASIVE)
   ☐ Placed against the forehead of the newborns.(NON-INVASIVE)

6. Do you agree if a new device is develops to check the jaundice without taking baby's blood?
   ☐ Yes ☐ No

7. Do you think this project can help to simplify the task of Pediatric Unit?
   ☐ Yes ☐ No

8. Which is more relevant for the newborns?
   ☐ Taking baby's blood (INVASIVE)
   ☐ Placed against the forehead of the newborns. (NON-INVASIVE)

9. Is it taking a long time to obtain the result of jaundice when using the Invasive Method (Taking newborns's blood)?
   ☐ Yes ☐ No

10. Non-Invasive Bilirubin Meter is low cost and can give the correct reading of jaundice. Do you agree if this device is done?
    ☐ Yes ☐ No

11. What is your opinion about this device? Can you give your comment and suggestion.

Prepared by,

Verified by,

……………………………..

…………………………

(NOOR SYAHIRAH

BINTI MOHD LAZIM)

08BEU15F3017

(MDM KU LEE CHIN)

Supervisor

POLITEKNIK SULTAN SALAHUDDIN ABDUL AZIZ SHAH

POLITEKNIK
Sultan Salahuddin Abdul Aziz Shah
Jabatan Pengajian Politeknik

SURVEY QUESTIONNAIRE – NON INVASIVE BILIRUBIN METER

DISCLAIMER:

This survey is based on final year project of Bachelor of Electronic Engineering (Medical Electronic). The name of this device is Non Invasive Bilirubin Meter. The aim of this survey is to understand the device after the pre-survey is done. It can be helpful to improve and to enhance the device in future. It is also to analyze the device in getting the correct readings and measurement. Participation of this survey is completely voluntary and anonymous. You may choose to discontinue this survey at any time. No harm will befall to anyone of the participation. This device is focusing for below three months age. All the data will be recorded and analyzed.

CONSENT:

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

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

SECTION A

1. Are you find that this device is suitable to use?

☐ Yes

☐ No

2. Are you familiar with this device? Do you heard about similar device like this before?

☐ Yes

☐ No

3. Do you understand the function of this device?

- [ ] Yes
- [ ] No

4. If this device is in market, do you prefer to have it?

- [ ] Yes
- [ ] No

5. Which one of the method did you prefer to check the jaundice?

- [ ] Blood Test
- [ ] Non Invasive Bilirubin Meter

6. Is this device is suitable to use and help in determining the jaundice?

- [ ] Yes
- [ ] No

SECTION B

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

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

NO	STATEMENTS	5	4	3	2	1
1	Is this device convenient to use?					
2	Is this device gives the accurate readings?					
3	Can this device is safe to use to neonatal babies?					
4	Do you agree if this device placed in market of our country?					
5	Do you prefer if this device cam minimize the time taken in obtaining results rather than blood test?					
6	Do you think this device is more secure to use to baby rather than pain method?					

SECTION C

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

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

Recommendation / Comments:

____

____

____

____

____

Signature,

____

Position: (Doctor / Nurse / Parent / User)

Date:

THANK YOU

Kingbright

T-1 (3mm) SOLID STATE LAMP

ATTENTION

OBSERVE PRECAUTIONS
FOR HANDLING
ELECTROSTATIC
DISCHARGE
SENSITIVE
DEVICES

L-934MBD BLUE

Features

- LOW POWER CONSUMPTION.
- POPULAR T-1 DIAMETER PACKAGE.
- GENERAL PURPOSE LEADS.
- RELIABLE AND RUGGED.
- LONG LIFE - SOLID STATE RELIABILITY.

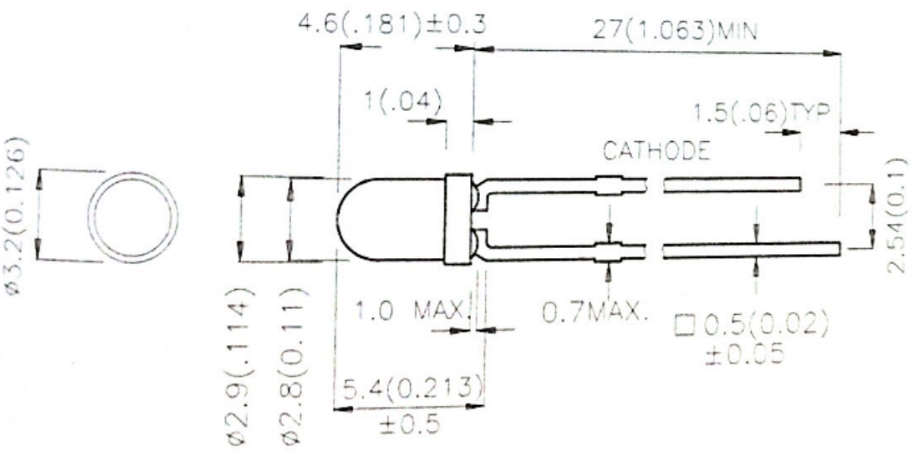
Description

The Blue source color devices are made with GaN on SiC Light Emitting Diode.

Static electricity and surge damage the LEDS. It is recommended to use a wrist band or anti-electrostatic glove when handling the LEDs.

All devices, equipment and machinery must be electrically grounded.

Package Dimensions



Notes:
1. All dimensions are in millimeters (inches).
2. Tolerance is ±0.25(0.01") unless otherwise noted.
3. Lead spacing is measured where the lead emerge package.
4. Specifications are subject to change without notice.

Selection Guide

Part No.	Dice	Lens Type	Iv (mcd) @ 20 mA		Viewing Angle
			Min.	Typ.	2θ1/2
L-934MBD	BLUE (GaN)	BLUE DIFFUSED	18	50	60°

Note:
1. θ1/2 is the angle from optical centerline where the luminous intensity is 1/2 the optical centerline value.

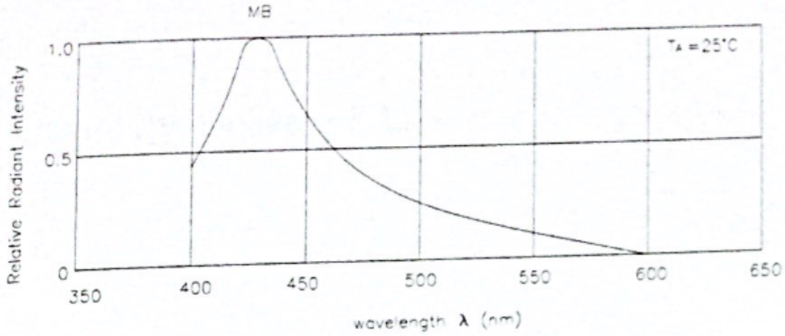
Electrical / Optical Characteristics at T_A=25°C

Symbol	Parameter	Device	Typ.	Max.	Units	Test Conditions
λpeak	Peak Wavelength	Blue	430		nm	I_F=20mA
λD	Dominate Wavelength	Blue	466		nm	I_F=20mA
Δλ1/2	Spectral Line Half-width	Blue	60		nm	I_F=20mA
C	Capacitance	Blue	100		pF	V_F=0V;f=1MHz
V_F	Forward Voltage	Blue	3.8	4.5	V	I_F=20mA
I_R	Reverse Current	Blue		10	uA	V_R = 5V

Absolute Maximum Ratings at T_A=25°C

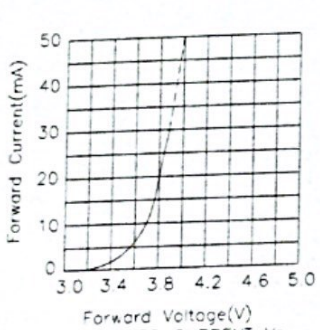
Parameter	Blue	Units
Power dissipation	105	mW
DC Forward Current	30	mA
Peak Forward Current [1]	150	mA
Reverse Voltage	5	V
Operating Temperature	-40°C To +85°C	
Storage Temperature	-40°C To +85°C	
Lead Solder Temperature [2]	260°C For 5 Seconds	

Notes:
1. 1/10 Duty Cycle, 0.1ms Pulse Width.
2. 2mm below package base.

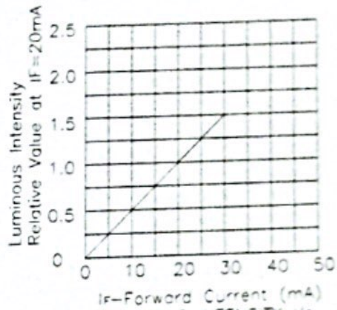


RELATIVE INTENSITY Vs. WAVELENGTH

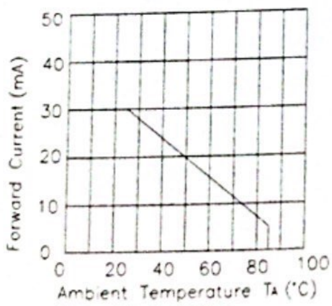
Blue **L-934MBD**



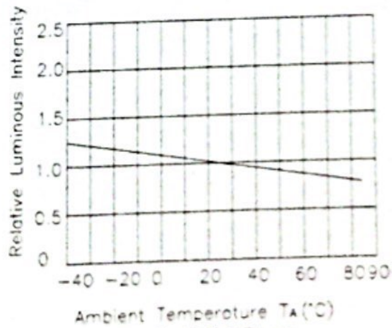
FORWARD CURRENT Vs
FORWARD VOLTAGE



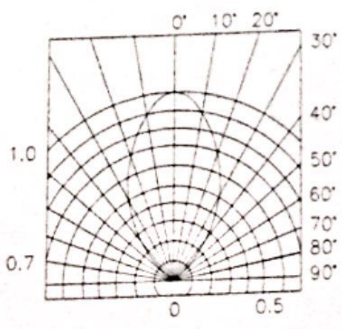
LUMINOUS INTENSITY Vs.
FORWARD CURRENT



FORWARD CURRENT
DERATING CURVE



LUMINOUS INTENSITY Vs
AMBIENT TEMPERATURE



SPATIAL DISTRIBUTION

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ngbright:

334MBD

Direct Photometry Non Invasive Bilirubin Device

L. C. Ku[1], N. S. M. Lazim[2]

Department of Electrical Engineering(Medical Electronic), Polytechnic Sultan Salahuddin Abdul Aziz Shah 40150, Shah Alam, Selangor, Malaysia

***

...stract - Measurement of jaundice among neonates is ...rtant in determine the possible treatment to prevent any ...us illness. Jaundice checked in hospitals by using invasive ...od is blood test and urine test. Invasive blood sampling is ...ful for the neonate, resulting in blood loss and an ...sed risk for infections at the site of sampling. Direct ...ometry Non Invasive Bilirubin Device will overcome the ...s happened. Direct photometric measurements are based ...irect measurements of suitably solved serum at the ...length of 455nm, which is the absorption maximum of ...bin. Direct photometry can be used only in newborns. ...e was the knowledge of light transmission and absorption ...specific tissue compartment applied. The relevant skin ...a diagnostics handle 575 nm (green) and 450 nm (blue ...chromatic light). The device is use only one parameter ...t is reading of bilirubin in μmol/L. The output will ...ared on the LCD based on the level of bilirubin. It ...ared as Normal (Green Light), Moderate (Yellow Light) ...Critical (Red Light and Buzzer).

...Words: *arduino, bilirubin, non-invasive, photometry, ...elength*

...TRODUCTION

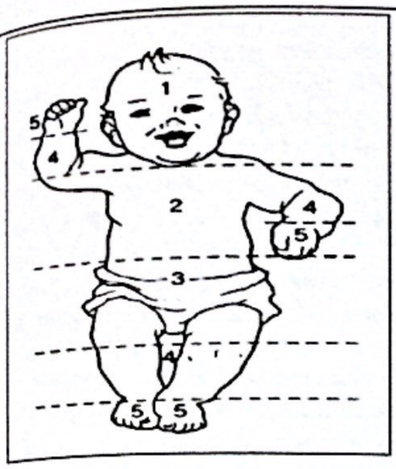
...development of new technology introduces the new ...el and method detection of jaundice or ...rbilirubinemia by using non-invasive method. The ...w discoloration is used to measure bilirubin ...ntration for determining the level of jaundice in ...s[1]. Hyperbilirubinemia or Neonates Jaundice is ...only happened in the neonates or newborns due to ...n the amount of bilirubin concentration in the body. ...nvasive, transcutaneous, point of care measurement of ...cutaneous bilirubin (TcB) pre-discharge by multi-...length spectral analysis, using a portable device is ...cally equivalent to measurement of TSB in a diverse, ...racial term and near-term newborn population and ...ctive of subsequent hyperbilirubinemia[2]. Non-...ive bilirubin meter can overcome the problem when ...g the blood from the neonates. It can be painless and ...friendly to the user.

Direct photometry can be used only in newborns. In the case of most children and adults, the serum includes many other pigments of similar colors and reactions as bilirubin. The proposed benefits of using this technology include non-invasive and accurate screening for clinically significant jaundice. Transcutaneous Bilirubin readings are instant and results can avoid delay with discharge and or indicate the need for formal SBR testing [3]. Based on biomedical engineer and hospital staff's, providing a non-invasive method in detecting hyperbilirubinemia or jaundice can overcome some problem that may occurs during taking neonates blood. And can overcome mistake in prick needle among neonates. However, this non-invasive method which is the Direct Photometry Non Invasive Bilirubin Device must be calibrating to avoid from false readings and wrong indicator.

1.1 Bilirubin

Bilirubin is the yellowish pigment that is the byproduct of heme catabolism. Bilirubin is responsible for the yellow color of the urine. When the cell is died hemoglobin is release from the cell, which is breakdown into heme and globin. Heme is finally converting into bilirubin, an orange-yellow pigment. Bilirubin is an endogenous anion derived from hemoglobin degradation from the Red Blood Cell [4]. Bilirubin is altered by exposure to light so serum and plasma samples must be kept in dark before measurements are made. When the liver function tests are abnormal and the serum bilirubin levels more than 17μmol/L suggest underlying liver disease.

In a newborn, higher bilirubin is normal due to the stress of birth. Normal bilirubin in a newborn would be under 5 mg/dL, but many newborns have some kind of jaundice and bilirubin levels above 5 mg/dL [5]. If the blood tests show abnormally high levels of bilirubin, doctor may order more tests to determine the underlying cause. Once the doctor has determined a cause of high bilirubin levels, it may take more bilirubin blood tests to monitor the effectiveness of the treatment.



Dermal Zone	Mean ± SD µmol/L
1	101 ± 5
2	152 ± 29
3	201 ± 31
4	257 ± 29
5	>257

e-1 : Correlation between icteric dermal zones (Kramer) and serum bilirubin values

Transcutaneous Bilirubinometry works by directing into the skin of neonate and measures the intensity of ific wavelength that is returned. The number of elengths, used is variable in different transcutaneous bilirubinometer. The meter analyzes the spectrum of optical l reflected from the neonates subcutaneous tissues. e optical signals are converted to electrical signal by a ocell. These are analyzed by a microprocessor to erate a serum bilirubin value. This is hand held, portable rechargable but expensive and sophisticated. When ure is applied to the photoprobe, a xenon tube rates a strobe light; and this light passes through the utaneous tissue. The reflected light returns through the d fiber optic bundle to the spectrophotometric module. ntensity of the yellow color in this light, after correcting he hemoglobin, is measured and instantly displayed in rary units. Bilirubin concentration is measured by ng the entire spectrum of visible light (380 to 760 nm) cted by the blood serum. This spectrum was received by ensor and sent to PIC microcontroller in voltage form. PIC analyzed accordingly as in Table 2 and the tions applied are normal, mild and critical jaundice[6].

2. METHODOLOGY

Designation Direct Photometry Non Invasive Bilirubin Device of based on research that has been made by using several journals, lectures, biomedical engineers and hospital's staffs in Neonatal Intensive Care Unit (NICU). A decision has been made during the discussion in obtaining the proper and accurate readings of hyperbilirubinemia. The designation of new method of non-invasive bilirubin meter involves several important parts which are determining the wavelength LED which are 455 nm and 575 nm. 455nm functioning as absorption of maximum bilirubin. It is also can absorbs light. It comes in a blue color of LED.

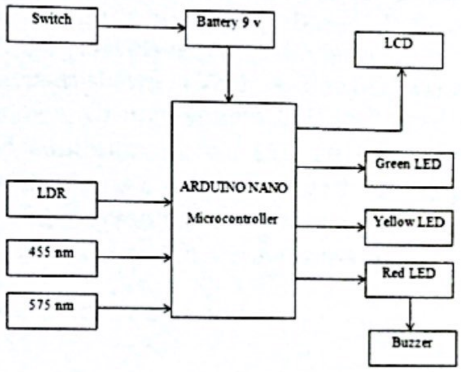
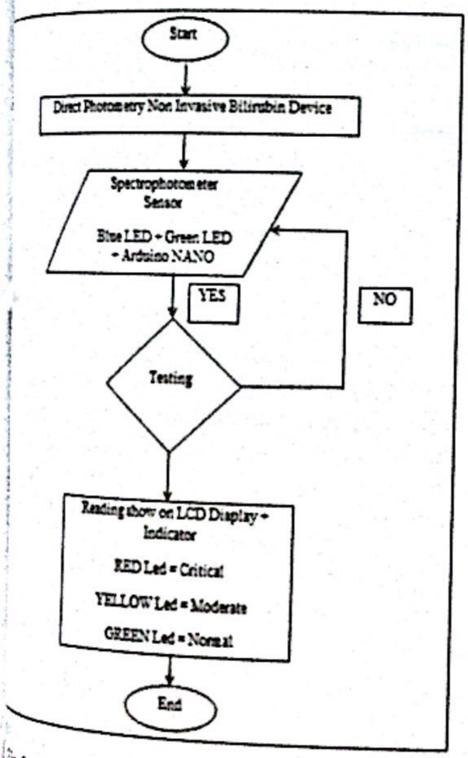


Fig -1: Block Diagram of Device

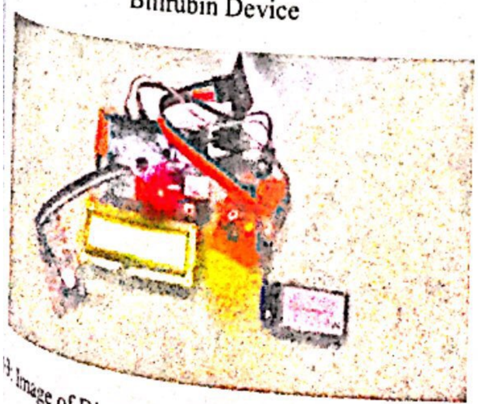
The other one LED that involves in wavelength LED is 575 nm. It is a monochromatic light. It is functioning as measuring bilirubin by detect spectral photometry. Based on the characteristics of this device, it must be suitable to detect the color of melanin which is the deep tissue in our body. Melanin means the pigment that gives human skin, hair and eyes their colors. Dark skinned people have more melanin in their skin than light skinned people have. Melanin is produced by cells called melanocytes. The project is divided into two parts which are hardware and software. The hardware part includes the circuit design for the spectrum LED to build the spectrophotometer sensor and the LCD display. While, the microcontroller had software part consists of the operational flow. The intensity of the yellow color in this light, after correcting for the hemoglobin, is measured and instantly displayed in arbitrary units.

This instrument was calibrated with test solutions and has a technical error of ±1.3% for values up to 350 µmol/L. Blue LED is called as 455 nm LED wavelength. It can absorb light through direct photometric method. Direct photometric measurements are based on direct measurements of suitably solved serum at the wavelength of 455nm, which is the absorption maximum of bilirubin. Direct measurements may be also interfered by opalescence that results from the serum dilution or at the presence of oxy hemoglobin in the neonatal serum, which is often hemolytic and absorbs light at the wavelength of 455nm.

...e interferences might be suppressed by a proper ...ment of the working process, by measurements taken ...wo wavelengths of 455 and 575nm. The bilirubin ...entrations are found from the absorbency differences. ...irst one corresponds mainly to the bilirubin content and ...econd one to the oxy hemoglobin content[7]. A high ...y device with a narrow definition of the ...chromatic light must be used when measuring ...bin by the direct spectral photometry[7]. When ...lating the concentration of bilirubin, we use the value of ...molar bilirubin absorption coefficient. The molar ...ption bilirubin coefficient ε is numerically equal to the ...bin solution absorbency value having the concentration ...L at a defined wavelength, temperature and layer ...of 1cm.



...g-2: Flow Chart of Direct Photometry Non Invasive Bilirubin Device



...-3: Image of Direct Photometry Non Invasive Bilirubin Device

According to the Figure, it was implemented by three different colors of LED as indicator of the jaundice's readings. Red LED will show the higher readings of 359 µmol/L. Orange-yellow LED will indicate the moderate readings at range of 85 up to323 µmol/L. Green LED will observe the low readings of jaundice at range of 0 to 85 µmol/L. The readings of jaundice will appear on the LCD Display.

3. RESULT AND DISCUSSION

This section discussed on the results. Data collection has been conducted to get the data non-invasive bilirubin device that has been produced. The range of condition was set according to normal, mild and critical as shown in Table-2 through the readings on Direct Photometry method (DPNIBD). Five samples have been taken to prove the concept as shown in Table-3. Red LED was shown critical condition; Orange-yellow LED indicated moderate or mild condition; Green LED showed normal healthy condition. As a result this method is capable to give reasonable result and also give advantages to study the non-invasive system for measurement of jaundice level.

Table -2: Range of Condition

Condition	Serum Concentration (µmol/L)	Voltage Range
Normal	0 < thick < 85	4v - 6v
Mild	85<thick<323	2v – 4v
Critical	Thick > 359	0v – 2v

Table -3: Data Collection on five subjects

SUBJECT	DPNIBD (umol/L)	Condition
1	334	Critical
2	328	Critical
3	167	Moderate
4	112	Moderate
5	84	Normal

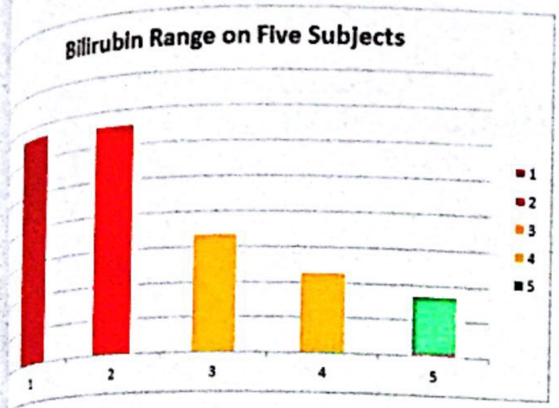


Chart -1: Bilirubin reading on Five Subjects

...per presented data collected from direct photometry ...vasive bilirubin device that has been produced using ...m LED. This innovation has created an alternative in ...painless bilirubin reading and reducing the usage of ...test and urine test. It can be concluded that the ...ment that has been developed is accurate and reliable ...suring non – invasively bilirubin.

...NCLUSIONS

...on of jaundice in early stage can be predicted by ...nvasive method. Due to demand in our latest ...ogy and without painful, a new device is designed to ...ne jaundice by using direct photometry non-invasive ...n device which is more preferable and painless for ... to the baby. By using this non-invasive bilirubin ... it can save time, user friendly, affordable, painless ... make a harmony situation without any pricking ...is needed to determine the level or readings of the ...e among baby. A system is developed in designation ...ctrophotometer sensor by building two different ...gths which are 455 nm and 575 nm. The device can ...s the three conditions of jaundice; normal, mild and ...evel with LED light. This new technology of product ...ghten the effort of Pediatrics Units.

...WLEDGEMENT

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...NCES

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BIOGRAPHIES

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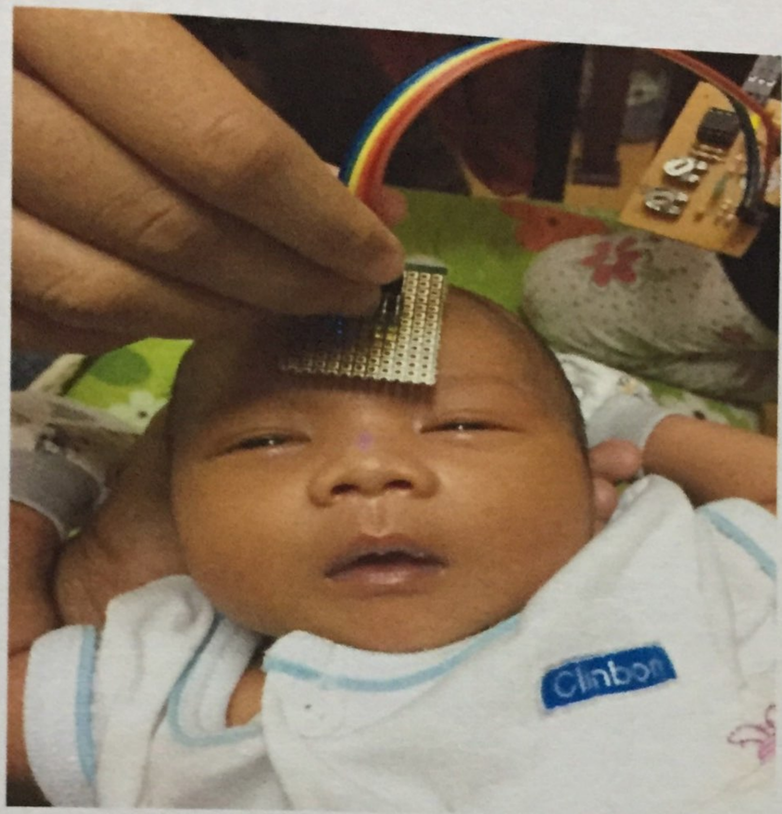
TESTING PROJECT ON BABY



APPENDIX B

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