Sudan University of Science and Technology

Collage of Engineering

Electronics Engineering Department

Designing and Implementation of Low Cost Embedded Oximiter

A Research Submitted in Partial Fulfillment for the Requirement Degree of the B.Sc. (Honors) in Electronic Engineering

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الآيـــة

قال تعالى:

(ولقد كرمنا بني آدم وحملناهم في البر والبحر ورزقناهم من الطيبات وفضلناهم على كثير ممن خلقنا تفضيلا)

صدق الله العظيم

سورة الإسراء
الآية(70)

Dedication

We dedicate this graduate project to our dear

mothers and fathers

to our sister and brothers

to our friends

to our supervisor

to everyone who taught us through our educational

level

to each of you, without your support, this

dream would not have come true.

Acknowledgment

Firstly, thanks to ALLAH almighty for giving the strength to complete this research.

Thanks expended to our supervisor Dr. Hisham AhmedAlifor his gaudiness, encouragement and spiritual support throughout this work.

We are grateful to the all the staff of electronics engineering department, college of engineering, Sudan University of Science and Technology for their help and useful advices.

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Abstract

This research covers the implementation of low-cost embedded oximeter. An oximeter is a non-invasive device capable of monitoring the blood's oxygen saturation. It has been widely used in the medical, fitness and clinical care worlds.

The used oximeter is expensive to be implemented and has large size which makes it hard to be carried everywhere. The goal of this project was to implement a low-cost embedded oximeter that cheap to build and easy to carry. The device consists of three main parts: an optical sensor that consists of optical transmitter and receiver for emitting the light and receiving it, microcontroller: which receives and processes the signal and liquid crystal display to display the results. The circuit was simulated, the hardware was implemented and the results have been tested comparing to a medical oximeter device.

المستخلص

هذا البحث يتناول تصميم جهازمقياس تأكسج مدمج وقليل التكلفة .مقياس التأكسج هو جهاز غيرغازي قادر على رصد نسبة تشبع الأكسجين في الدم. وقد تم استخدامه على نطاق واسع في الطب، واللياقة البدنية والرعايةالسريرية.

مقياس التأكسج المستخدم مكلف إضافة الى حجمه الكبير مما يجعله صعب الحمل.لذلك كان الهدف من هذا المشروع هوعمل جهاز مقياس تأكسج رخيص وسهل الحمل. يتكون الجهاز من ثلاثة أجزاء رئيسية: جهاز استشعارضوئي يتكون من جهاز إرسال واستقبال ضوئي لبعث الضوء وتلقيه، متحكم دقيق: يقومبإستقبال ومعاجةالإشارة وشاشة الكريستال السائل لعرض النتائج. تمت محاكاة الدائرة إلكترونيا،وتصميم الجهازمعإختبار النتائج وذلك بمقارنتها بجهاز قياس التأكسج الطبي

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Abbreviations

HB	Hemoglobin
SPO2	Amount of the Oxygenated bound to Hemoglobin Arterial blood
CO2	Light emitting Diode
LDR	Light Dependent Resister
SAO2	Amount of Oxygen bound to Hemoglobin in arterial blood

IDE	Integrated Development Environment
O2	Two oxygen atoms
ROP	Retinopathy of prematurity
SET	Signal Extraction technology
CCHO	Critical Congenital Heart disease
HRPO	High resolution pulse Oximetry
PVI	Plethvariability Index
LCD	Liquid crystal display
ADC	Analog to digital converter
OPT	Optional practical training
IR	Infrared Radiation

Chapter One

Introduction

Introduction

1.1preface:

Oxygen is one of the most important elements required to sustain life, it is the key for generating energy in cellular respiration. The lake of oxygen can cause chronic fatigue, depression, insomnia, frequent headache. The matter is that most of people do not know that the oxygen is low in their blood or tissues until they get sick. There is a device called oximeter, that measures the oxygen in blood and display the result as ratio to decide whether it normal or not. The oximetr is a simple, relatively cheap and non-invasive technique to monitor oxygenation. It monitors the percentage of hemoglobin that is oxygen-saturated. Oxygen saturation should always be above 95%, although in those with long-standing respiratory disease or cyanotic congenital heart disease, it may be lower, corresponding to disease severity. The oxy hemoglobin dissociation curve becomes sharply steep below about 90%, reflecting the more rapid de-saturation that occurs with diminishing oxygen partial pressure .[1]

An oximiter measures the oxygen saturation of hemoglobin in arterial blood – which is a measure of the average amount ofoxygen bound to each hemoglobin molecule. The percentage saturation is given as a digital readout.

An oximeter gives no information on the oxygen content of the blood, the amount of oxygen dissolved in the blood and the respiratory rate or tidal volume i.e. ventilation.

Oximeters also give no information about the level of CO2 and therefore have limitations in the assessmentof patients developing respiratory failure due to CO2 retention. On rare occasions oximeters may

develop faults and like all monitoring the reading should always be interpreted in association with the patient's clinical condition.

1.2Problem Statement:

An oximiter device faced the problem of high producing and acquiring cost, In addition to it is multi-componentand large size which makes it difficult and tiresome to carry it everywhere.

1.3Proposed Solution:

A new oximiter will be designed and implemented in an inexpensive way that makes it cheap to implement and purchase, while being compact to be easy to carry and use.

1.4Aims and Objectives:

The aim of this project is to design and implement a low cost embedded oximeter.

The objectives of this project are:

- Toaccurately read and track the state of true arterial circulation and monitor the functionality of human body organs.
- Toavoidhealthproblems caused by hypoxia by measuring and monitoring the oxygen saturation and the early detection of deficiency.

1.5 Methodology:

After studying and identifying the elements required for implementing the device, the circuit has been simulated with proteus and the microcontroller using integrated development environment (IDE) language and the code was loaded to the simulation circuit and the results were monitored while keeping changing the light intensity.

After validation the hardware circuit was implemented by connecting the electronic elements together and installing them on the bread board. The results were tested by comparing it with result of a medical pulse oximeter.

1.6 Thesis organization:

Chapter One: is explanations and introduction about the problem.

Chapter Two: is a theoretical background and related works in medical field.

Chapter Three: describes steps of hardware design the oximeter device and how to view it in a software application.

Chapter Four: discusses the results of simulation and implementation for the project.

Chapter Five: explain the conclusion and the future ideas that can be performed.

Chapter Two

Literature review

Chapter Two

Literature review

2.1Technical background:

2.1.1Light-Emitting Diodes

A light-emitting diode (LED) is a two-lead semiconductor light source .it is a p-n junction diode that emits light when activated .when suitable voltage is applied to the LED, electrons are able to recombine with electron holes within the device ,releasing energy in the form of photons .this effect is called electroluminescence ,and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.

LEDs are typically small (less than 1mm2) and integrated optical components may be used to shape the radiation pattern.[36]

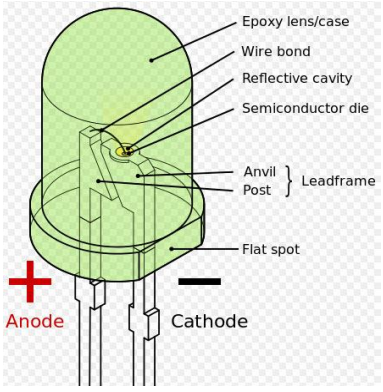

Figure2-1LED[36]

2.1.2Infrared light emitting diode:

An infrared light emitting diode (IR LED) is a special purpose LED emitting infrared rays ranging 700 nm to 1mm wavelength. Different IR LEDs may produce infrared light of different wavelengths; IR LEDs are usually made of gallium arsenide or aluminum gallium arsenide. In complement with IR receivers, these are commonly used as sensor. An IR sensor is used to detect infrared radiation falling on it.[36]

2.1.3Arduino Uno:

Arduino is an electronic development board based on material hardware and software easy to use and learn .it can be used by both professionals and beginners, and it uses everything you can think.

Arduino can communicate with the surrounding environment through a number of sensors, and can influence its surroundings by controlling motors or small lights and other electronic parts. The micro-controller on the board is programmed by easy to learn arduino programming language and by arduino's integrated development environment (Arduino IDE) too. Arduino's projects can be integrated –arduino is connected to its sensors and electronic part only-or the arduino is connected and communicates with programs on the computer, such as processing program and MATLAB[37]

Figure2-2[37]

2.1.4 Wire jumper:

Aword of wire in scientific circles means a physical path in which a signal or energy is transferred using a physical property.

There are two common sections of wires:

- Power or signal transmission wires.
- Wire for transmission of optical signal (fiber optical).[36]

2.1.5 Liquid crystal display (LCD):

Liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and 7-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.[36]

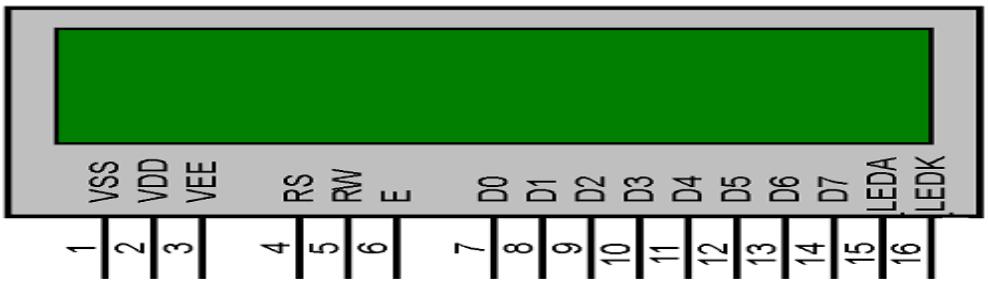

Figure2-3.LCD[36]

2.1.6 Potentiometer:

A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat.[36]

Figure 2-4. Potentiometer[36]

2.1.7Breadboard:

A breadboard is a construction base for prototyping of electronics. Originally it was literally a bread board, a polished piece of wood used for slicing bread. In the 1970s the solder less breadboard became available and nowadays the term "breadboard" is commonly used to refer to these.

Because the solder less breadboard does not require soldering, it is reusable. This makes it easy to use for creating temporary prototypes and experimenting with circuit design. For this reason, solder less breadboards are also extremely popular with students and in technological education. Now daysbreadboardare being used for small projects and all kinds of prototype electronic devices.[36]

2.2Related work:

In Karl Matthes developed the first 2-wavelength ear O_2 saturation meter with red and green filters (later switched to red and infrared filters). His meter was the first device to measure O_2 saturation.[2]

Pulse oximetry was developed by Takuo Aoyagi and MichioKishi, bioengineers, at Nihon Kohden using the ratio of red to infrared light absorption of pulsating components at the measuring site. Susumu Nakajima, a surgeon, and his associates first tested the device in patients, reporting it.[3]

The standard of care for the administration of a general anesthetic in the U.S. included pulse oximetry. From the operating room, the use of pulse oximetry rapidly spread throughout the hospital, first to the recovery room, and then into the various intensive care units. Pulse oximetry was of particular value in the neonatal unit where the patients do not thrive with inadequate oxygenation, but too much oxygen and fluctuations in oxygen concentration can lead to vision impairment or blindness from retinopathy of prematurity (ROP).

Furthermore, obtaining an arterial blood gas from a neonatal patient is painful to the patient and a major cause of neonatal anemia.[4]Motion artifact can be a significant limitation to pulse oximetry monitoring resulting in frequent false alarms and loss of data. The reason for this is that during motion and low peripheral perfusion, many pulse oximeters cannot distinguish between pulsating arterial blood and moving venous blood, leading to underestimation of oxygen saturation.

Early studies of pulse oximetry performance during subject motion made clear the vulnerabilities of conventional pulse oximetry technologies to motion artifact.[5][6]In 1995, Masimo introduced Signal Extraction

Technology (SET) that could measure accurately during patient motion and low perfusion by separating the arterial signal from the venous and other signals. Since then, pulse oximetry manufacturers have developed new algorithms to reduce some false alarms during motion[7] such as extending averaging times or freezing values on the screen, but they do not claim to measure changing conditions during motion and low perfusion. So, there are still important differences in performance of pulse oximeters during challenging conditions.[8]

Published papers have compared signal extraction technology to other pulse oximetry technologies and have demonstrated consistently favorable results for signal extraction technology.[9][10][11]

Signal extraction technology pulse oximetry performance has also been shown to translate into helping clinicians improve patient outcomes. In one study, retinopathy of prematurity (eye damage) was reduced by 58% in very low birth weight neonates at a center using signal extraction technology, while there was no decrease in retinopathy of prematurity at another center with the same clinicians using the same protocol but with non-signal extraction technology.[12]

Other studies have shown that signal extraction technology pulse oximetry results in fewer arterial blood gas measurements, faster oxygen weaning time, lower sensor utilization, and lower length of stay.[13]

The measure-through motion and low perfusion capabilities it has also allow it to be used in previously unmonitored areas such as the general floor, where false alarms have plagued conventional pulse oximetry. As evidence of this, a landmark study showed clinicians using signal extraction technology pulseoximetry on the general floor were able to decrease rapid response team activations, ICU transfers, and ICU days.[14]

An expert workgroup recommended newborn screening with pulse oximetry to increase the detection of critical congenital heart disease (CCHD).[15]

The CCHD workgroup cited the results of two large, prospective studies of 59,876 subjects that exclusively used signal extraction technology to increase the identification of CCHD with minimal false positives.[16][17]The CCHD workgroup recommended newborn screening be performed with motion tolerant pulse oximetry that has also been validated in low perfusion conditions.

The US Secretary of Health and Human Services added pulse oximetry to the recommend uniform screening panel.[18]

Before the evidence for screening using signal extraction technology, less than 1% of newborns in the United States were screened. Today, The Newborn Foundation has documented near universal screening in the United States and international screening is rapidly expanding.[19]

A third large study of 122, 738 newborns that also exclusively used signal extraction technology showed similar, positive results as the first two large studies.[20]

High resolution pulse oximetry (HRPO) has been developed for in-home sleep apnea screening and testing in patients for whom it is impractical to perform polysomnography.[21][22][23] It stores and records both pulse rate and SpO2 in 1 second intervals and has been shown in one study to help to detect sleep disordered breathing in surgical patients.[24]

Masimo introduced perfusion index, quantifying the amplitude of the peripheral plethysmograph waveform. Perfusion index has been shown to help clinicians predict illness severity and early adverse respiratory outcomes in neonates,[25][26][27] predict low superior vena cava flow in

very low birth weight infants,[28]provide an early indicator of sympathectomy after epidural anesthesia,[29]and improve detection of critical congenital heart disease in newborns.[30]

Masimo introduced the first measurement of the pleth variability index (PVI), which multiple clinical studies have shown provides a new method for automatic, noninvasive assessment of a patient's ability to respond to fluid administration.[31][32][33]

Appropriate fluid levels are vital to reducing postoperative risks and improving patient outcomes: fluid volumes that are too low (under-hydration) or too high (over-hydration) have been shown to decrease wound healing and increase the risk of infection or cardiac complications.[34]

Recently, the National Health Service in the United Kingdom and the French Anesthesia and Critical Care Society listed PVI monitoring as part of their suggested strategies for intra-operative fluid management.[35]

Chapter3
Design and Implementation of Oximeter

Chapter3
Design and Implementation of Oximeter

3.1Princible of work:

The core theory behind the oximeter is the variability of the absorption coefficient of photons going through human tissues at different wavelength. Since people are caring about the amount of oxygen in our blood, the specific wavelength region should be settled which is the most sensitive to the oxygen in our blood. In our blood, oxygenated hemoglobin (Hb) and deoxygenated hemoglobin (deoxy-Hb), which can be used to measure human blood oxygen level, have stronger absorbers of light with wavelength in the range of 650nm-1000nm (figure).In this wavelength range, other layers of human body, for instance water and fat, have a very low absorption coefficient comparing with that of oxygenated hemoglobin and deoxygenated hemoglobin. Also the good news is that the light absorption of Hb and deoxy-Hb at the two different wavelengths is different. When the light of around 650nm wavelength is emitted to our blood, deoxy-Hb absorbs more than oxy. And vice versa if the wavelength is around 1000nm, a majority portion of photons are absorbed by Hb.

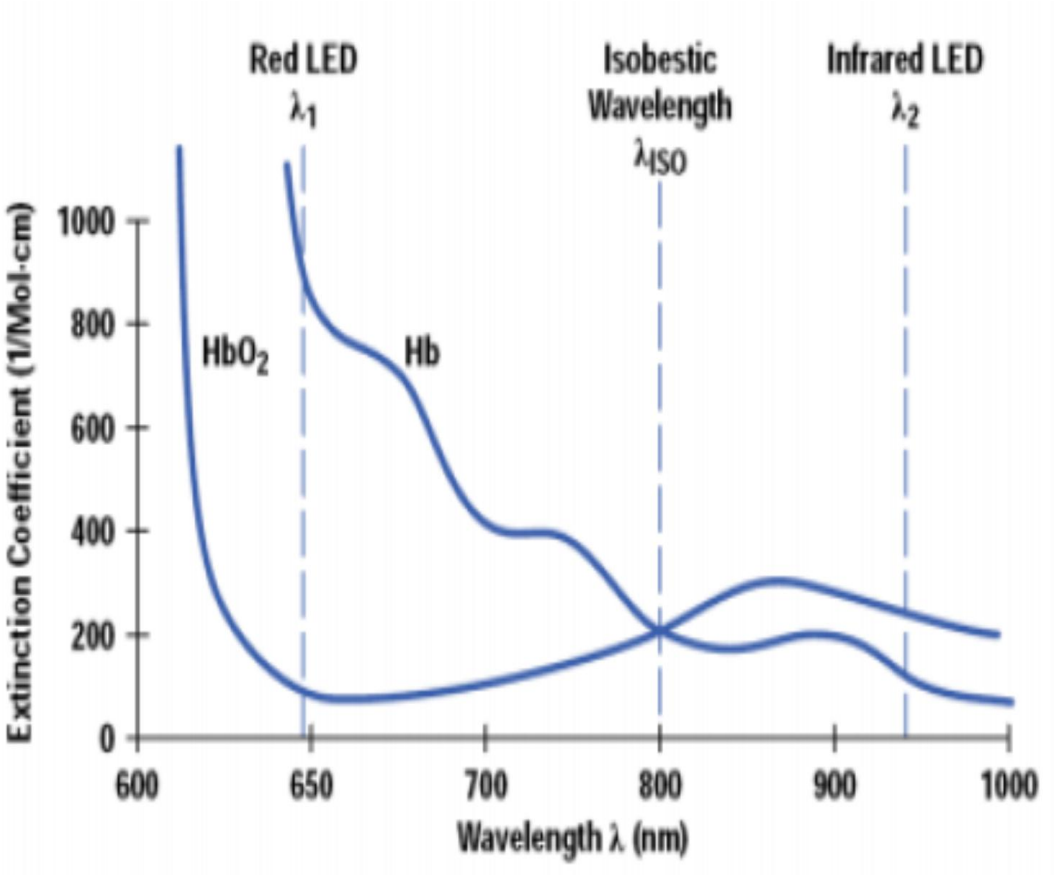

Figure3-1 Absorption Spectrum of Oxy and Deoxy Hemoglobin [35]

3.2 Methodology:

After studying and identifying the elements required for implementing the device, the circuit has been simulated with proteus and the microcontroller (Arduino Uno R3) using IDE language (Arduino 1.6.5) and the code was loaded to the simulation circuit and the results were monitored while keeping changing the light intensity.

After validation the hardware circuit was implemented by connecting the electronic elements together and installing them on the bread board.

The LEDS are initially installed in the bred board and connected to the microcontroller to be tested and ensured that they emit a wave between 900-1000.Then the IR receiver were placed to detect the light came from the finger. The internal resistance of IR light emitting diode well change because of the detected light and the voltage will change too.The IR sent this change an electrical signal to the microcontroller, the micro controller converted the electrical signal into a Digital signal using analog to digital convertor (ADC).

Then the liquid crystal display LCD (16*2) was installed in the bread board and connected to the microcontroller, and a variable resistance was connected to control the LCD illumination intensity.

The controller sends the digital wave to the LCD to be readout, this read is the percentage of oxygen saturation in the blood.

3.3The block diagram:

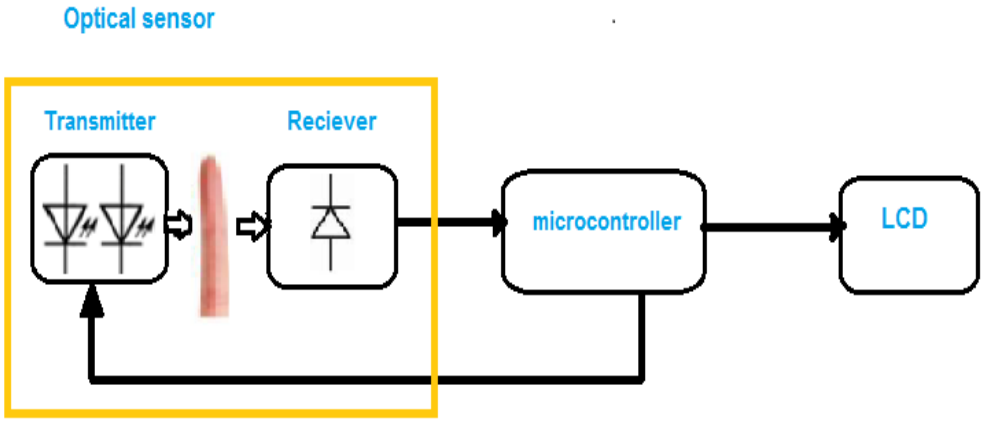

Figure.3-2the block diagram

3.3.1 Optical sensor:

Consist of:

- **Transmitter:**

Includes two light emitting diodes (LEDs) emit the light through the finger.

- **Receiver:**

Is an infrared photo detector is used to receive the light coming from the finger and convert the light signal into electrical signal to be processed by the microcontroller.

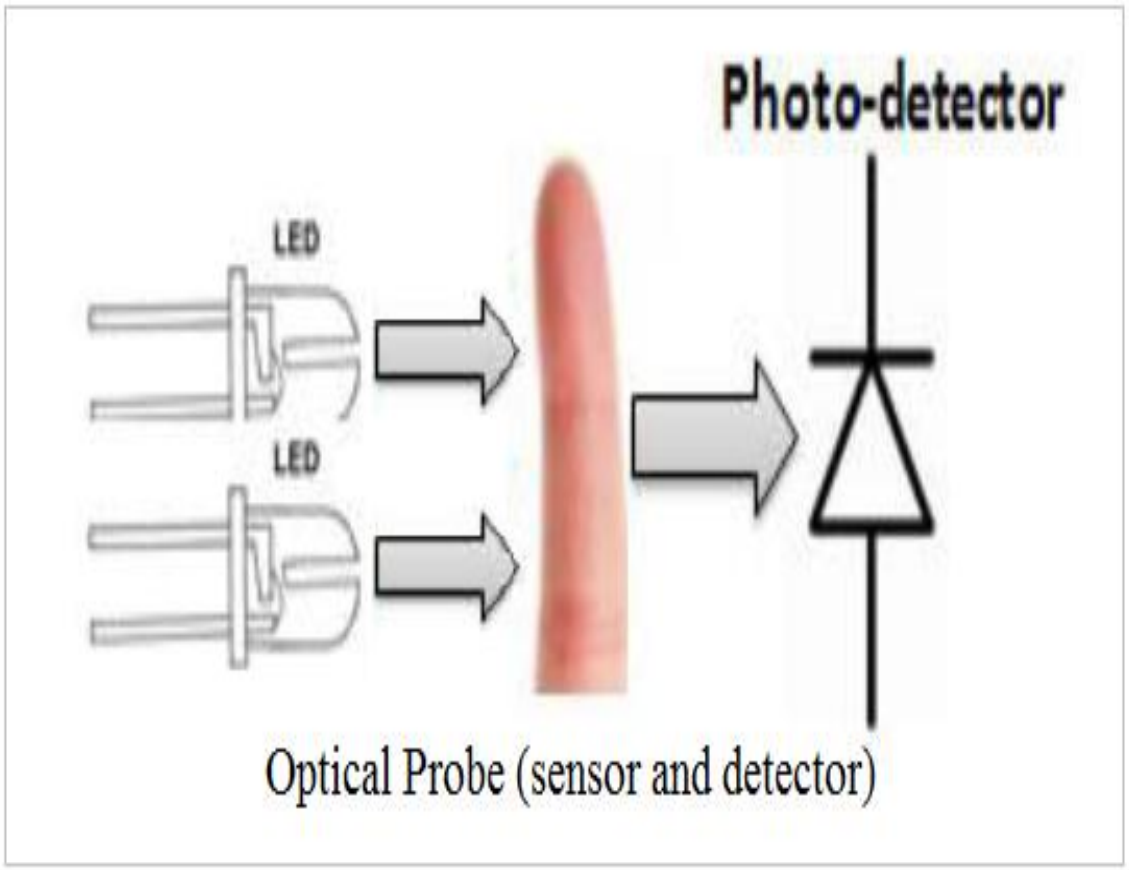

Figure 3-3 Optical Probe sensor

3.3.2Microcontroller (Arduino Uno):

Controls the two light emitting diodes (LEDs) .It sends two square waves to turn on and off the twolight emitting diodes(LEDs).

The microcontroller will be programmed to do the necessary calculations to measure the oxygen saturation level and control the LCD.

3.3.3Liquid crystal display (LCD): Todisplaythe results.

3.4Circuit diagram:

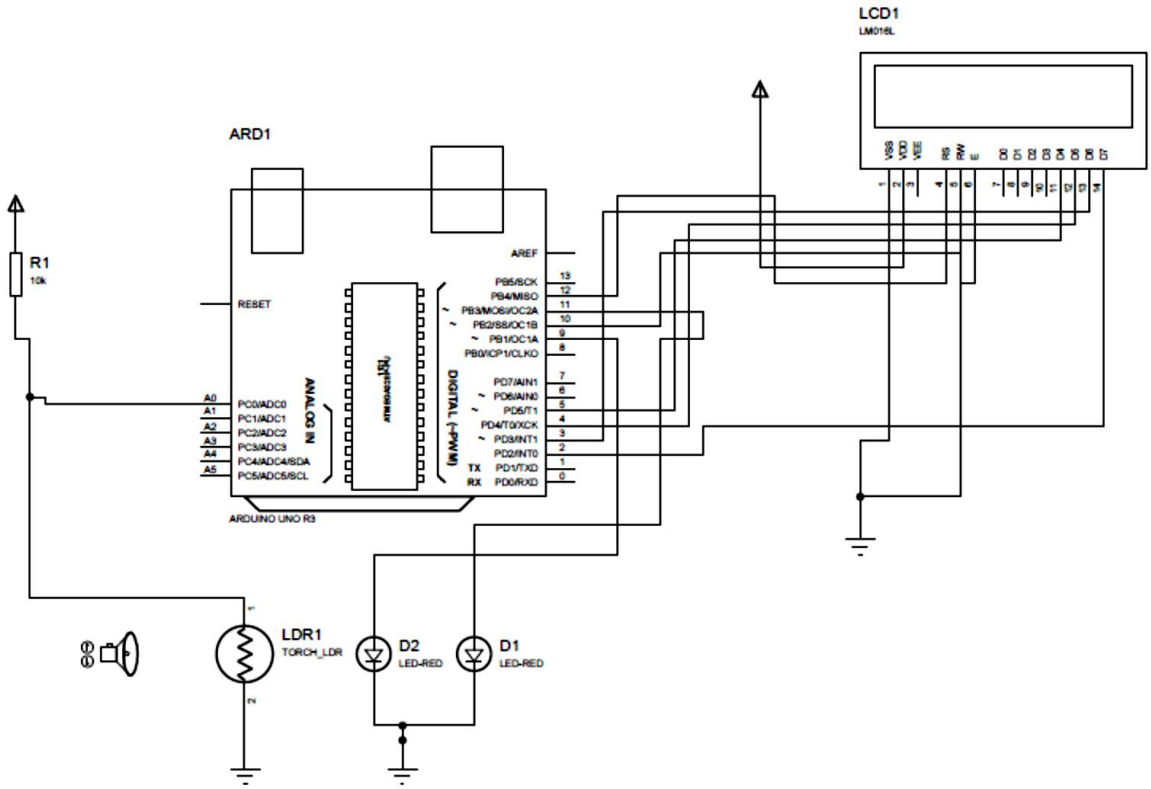

Figure3-4 *Circuit Diagram*

3.5Hardware implementation:

The two emitting diodes emit light with wavelength at the range of 900nm-1000, the range of infra red spectrum this light will be absorbed only by the oxygenated hemoglobin. The infrared photo detector on the other side will detect the light cross out the finger, as a result the internal resistance value of the infrared receiver will change which will change the voltage that inter the microcontroller .the microcontroller will convert the electrical signal into a digital signal using ADC, then it sends the digital data to the liquid crystal display to displayed.

First we connected the two light emitting diodes with arduino on bread board and tested them then we connect **the infra red light emitting diode to detect the light ,after that we connected the liquid crystal display with arduino after welding it on the bread board. Also we weld potentiometer resistance to control the light intensity of the LCD.last thing we upload the code to the cicuit**

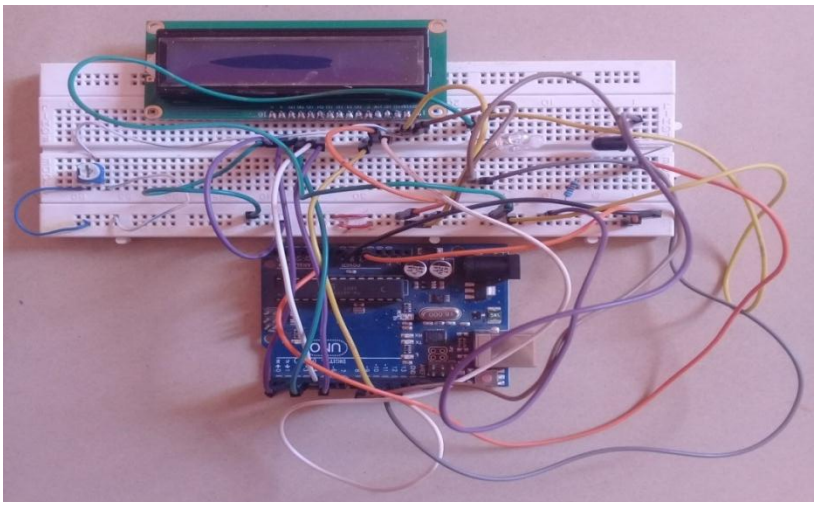

Figure 3-5 implemented circuit

3.6Oxygen Saturation calculation:

Oxygen saturation is a measurement of the percentage of oxygen binding sites that contain oxygen. If
all the oxygen binding sites contain oxygen, then the oxygen saturation is 100%. Oxygen saturation is defined as the ratio of oxy-hemoglobin to the total concentration of hemoglobin present in the blood
(i.e. Oxy-hemoglobin + reduced hemoglobin). When arterial oxy-hemoglobin saturation is measured by
an arterial blood gas it is called SaO2. When arterial oxy-hemoglobin saturation is measured noninvasively
by a finger pulse oximeter or handheld pulse oximeter, it is called SpO2.

Oxygen saturation formula:[38]

$$\text{Oxygen saturation} = \frac{C(HbO_2)}{C(HbO_2) + C(Hb)} \times 100\ (\%)$$

C (Hb) = Concentration of deoxygenated hemoglobin
C (HbO_2) = Concentration of oxygenated hemoglobin

SaO2 is defined as the oxy-hemoglobin (O2Hb) divided by the total hemoglobin (including all
hemoglobin species) in a sample and can be written as:

SaO2 = O2Hb / [O2Hb + Hb + MetHb + COHb]

Where O2Hb is oxy-hemoglobin, Hb is deoxy-hemoglobin, Met Hb is met-hemoglobin, and COHb is
Carboxy-hemoglobin.You multiply above fraction by 100 to get SaO2 in percentage.[38]

SpO2 is defined as the oxy-hemoglobin divided by all the functional hemoglobin in a sample and can bewritten as:

SpO2 = O2Hb/ [O2Hb + Hb]

It is determined by pulse oximetry.[38]

Calibration Adjustment:

A test pulse oximeter is first calibrated using human volunteers. the test pulse oximeter is attached to the volunteer and then the volunteer is asked to breathe lower and lower oxygen concentrations. at intervals, arterial blood samples are taken. as the volunteers' blood de-saturates, direct measurements made on the arterial blood are compared simultaneously with the readings shown by the test pulse oximeter. in this way, the errors due to the inability of applying beers and lamberts law strictly are noted and a correction calibration graph is made. however, in order to not harm the volunteers, the oxygen saturation is not allowed to drop below about 75 – 80 %. a copy of this correction calibration graph is available inside the pulse oximeters in clinical use. when doing its calculations, the computer refers to the calibration graph and corrects the final reading displayed. as mentioned before, the volunteer studies described before do not allow the saturation to go below about 75 – 80 %. for saturations below this, the calibration curve is mathematically estimated .therefore; pulse oximeters are typically less accurate below saturations of about 75 – 80 %.

The pulse oximeter uses empirical calibration curves developed from studies of healthy volunteers to calculate spo2. pulse oximeters use two light emitting diodes (leds) of specific and differing wavelength (typically 660 and 940 nm) to measure the combined absorption by a mixture of oxy-hemoglobin and deoxy-hemoglobin of red and infrared light measured using a photodiode. the photodiode measures the variation in the intensity of light falling upon it, and converts this into an electrical voltage. the ratio of the absorption at these two wavelengths is called the r value, and is compared with r values that are calibrated against direct measurements of arterial oxy-hemoglobin saturation (sao2) and arterial partial pressure of oxygen (pao2) for an individual model of pulse oximeter, using a volunteer population sample. volunteers breathe controlled hypoxic gas mixtures to create a range of sao2 values between 70% and 100% against which the spo2 of an individual pulse oximeter sensor may be calibrated. Pulse oximeters cannot determine the concentrations of oxy-hemoglobin or deoxy-hemoglobin; they provide an estimate of sao2 rather than a direct measurement. for each of the two wavelengths of light used in pulse oximeters, a ratio of the relative absorbance of oxy-hemoglobin and deoxy-hemoglobin is calculated. this

ratio is empirically related to sao2, as measured in experimental studies in human volunteers. since it is unethical to induce a degree of oxygen saturation below 70% in volunteers, pulse oximeter readings of approximately 70% represent the lowest limit of accurate output. it is recommended that readings lower than approximately 70% should be regarded as inaccurate since they represent extrapolation of the empirical data. thus, pulse oximeters do not measure sao2 but provide estimates. the accuracy of commercially available oximeters differs widely, probably due To the algorithm differences in signal processing.

The Pulse Amplitudes (Vpp) Of The Red And Infrared (Ir) Signals Are Measured And Converted To Vrms, In Order To Produce A Ratio Value: Ratio = (Red_Ac_Vrms/Red_Dc) / (Ir_Ac_Vrms/Ir_Dc). The Spo2 Can Be Determined Using The Ratio Value And A Look-Up Table That Is Made Up Of Empirical Formulas. The Pulse Rate Can Be Calculated Based On The Pulse Oximeter's Analog-To-Digital Converter (Adc) Sample Number And Sampling Rate. A Look-Up Table Is An Important Part Of A Pulse Oximeter. Look-Up Tables Are Specific To A Particular Oximeter Design And Are Usually Based On Calibration Curves Derived From, Among Other Things, A High Number Of Measurements From Subjects With Various Spo2 Levels. Figure Below Shows An Example Of A Calibration Curve.[39]

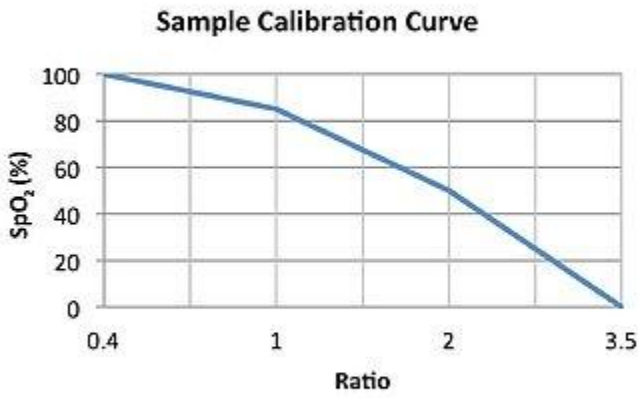

Figure3.6

The performance of each device is strictly related to the reliability and complexity of the algorithms used in signal processing and to the speed and quality of the microprocessor. There are numerous studies of the accuracy and precision of pulse oximeters in various adult and paediatric populations.

Most manufacturers claim mean differences (bias) of ≤2% with SDs (precision) of ≤4%. It should be noted, however, that these results have been reported in subjects with SaO2 levels that exceed 80%; the performance of pulse oximeters deteriorates remarkably when SaO2 decreases to <80%. 95% confidence limit for Pulse Oximetry is +/- 4% at SpO2 >70% (the error is higher at SpO2 <70%).

Correlation coefficients between pulse oximetry and direct blood oxygen saturation measurements are excellent, ranging from 0.77–0.99 when oxygen saturation is >70%.

Chapter Four
Result and Discussion

Chapter Four
Result and Discussion

Result and Discussion:

Proteus 7.7 professional program was used for simulating components and Arduino IDE for writing code.

The microcontroller sends two square waves to turn on and off the two LEDs. The turn on and off timing should be carefully designed because red LED and infrared LED cannot be turned on at the same time. The photo-detector receives the radiated light and converts the light signal into electrical signal which will be read and detected by the micro controller (Arduino Uno) and display the result on the liquid crystal display as in figure 4-1when the code is uploaded on proteus to the simulated circuit then the oxygen saturation ratio will be read.

When the slanted light on light depenent resistor (LDR) is decreased , the value of resistance to optical resistance increases and the voltage on it increases which will give high reads on liquid crystal display (LCD) as shown in the figure 4-2.

When the slanted light on light depenent resistor (LDR) is increased , the value of resistance to optical resistance dencreases and therefore the voltage dencreases which will give low reads on LCD as shown in [Figuer 4-3 , 4-4].

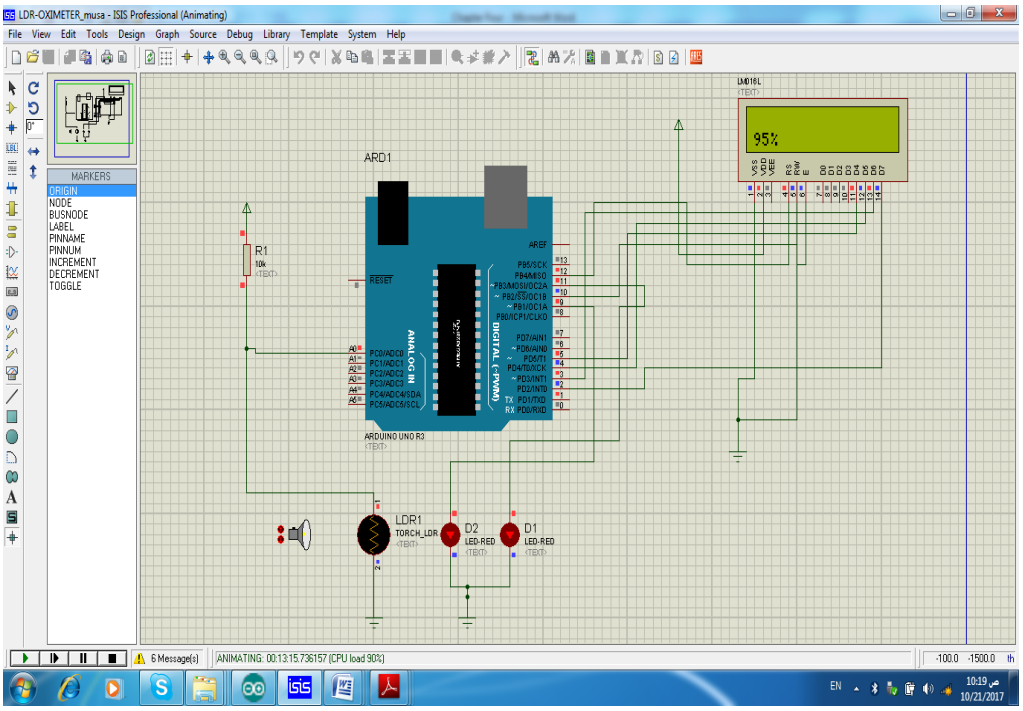

Figure 4-1 oxygen measurement

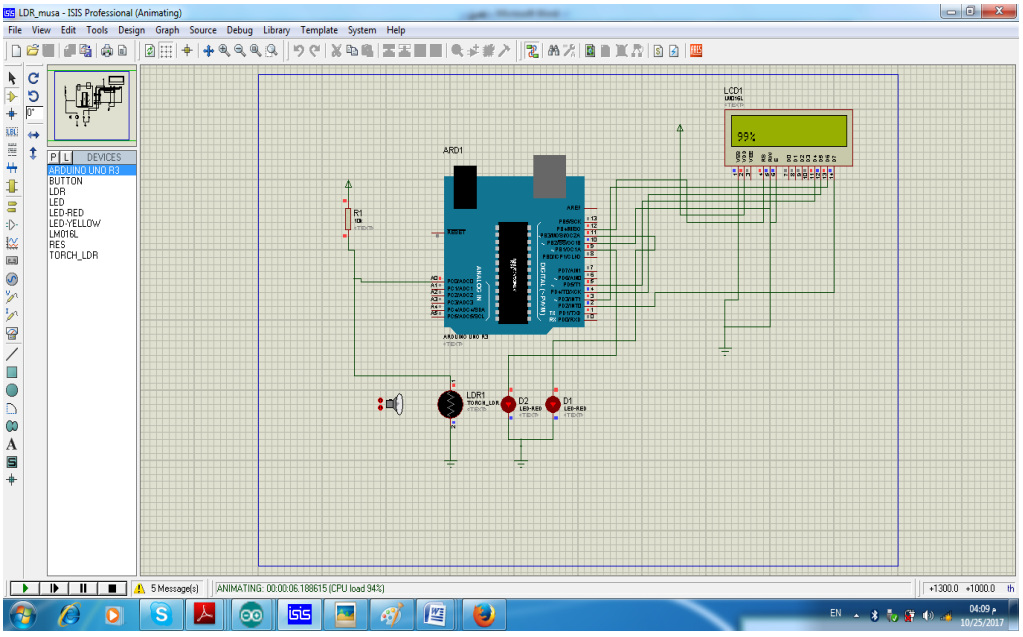

Figure4-2

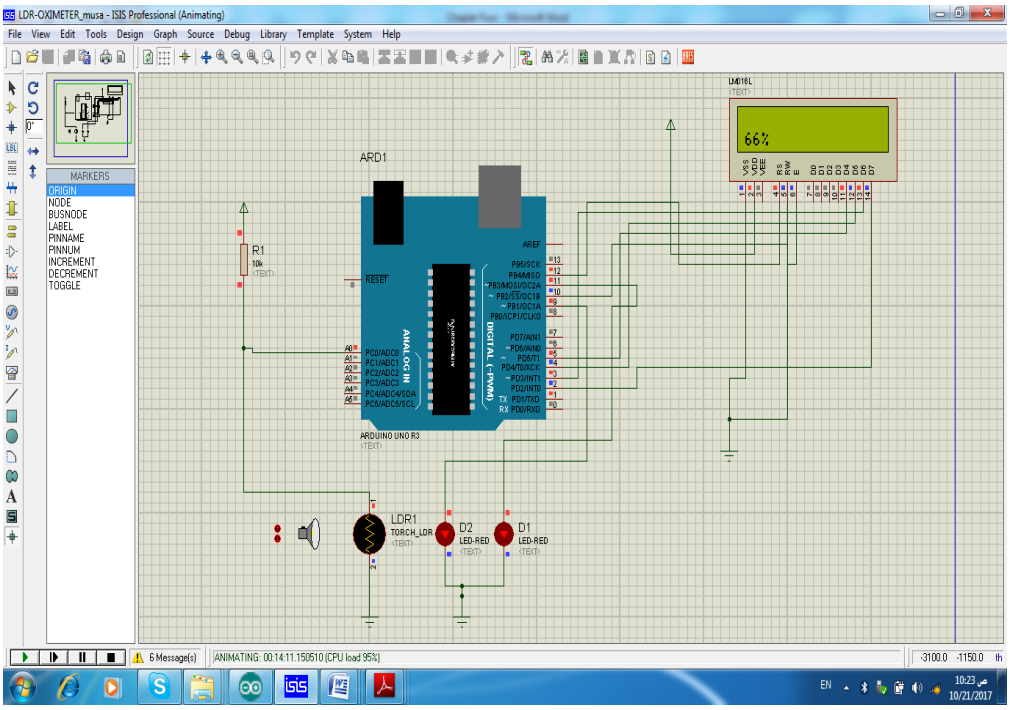

Figure4-3

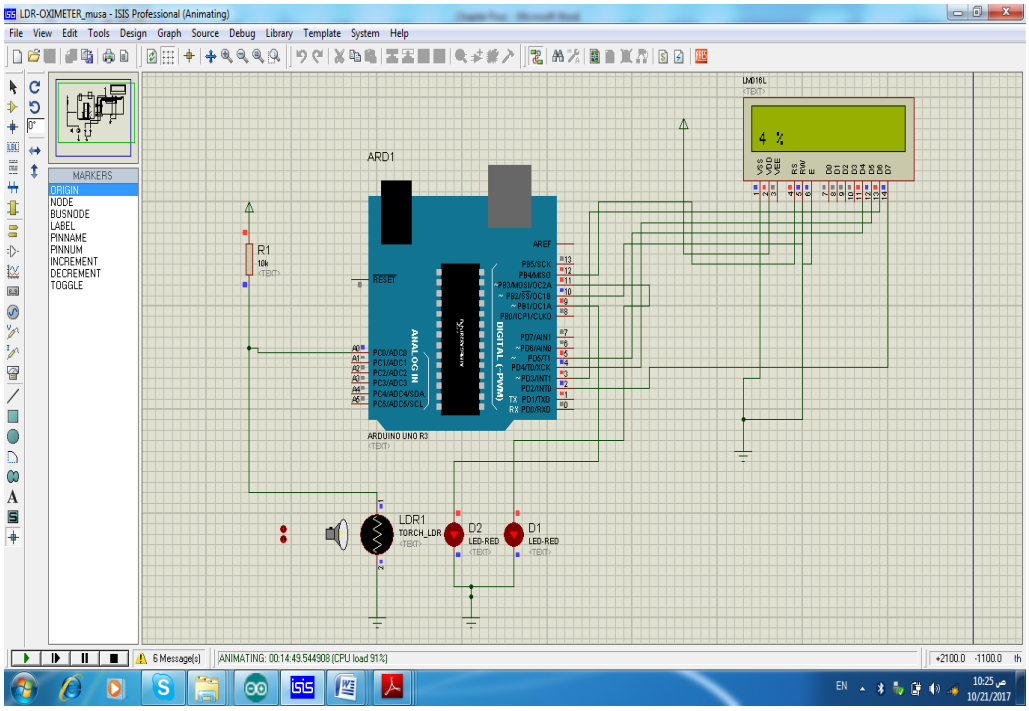

Figure4-4

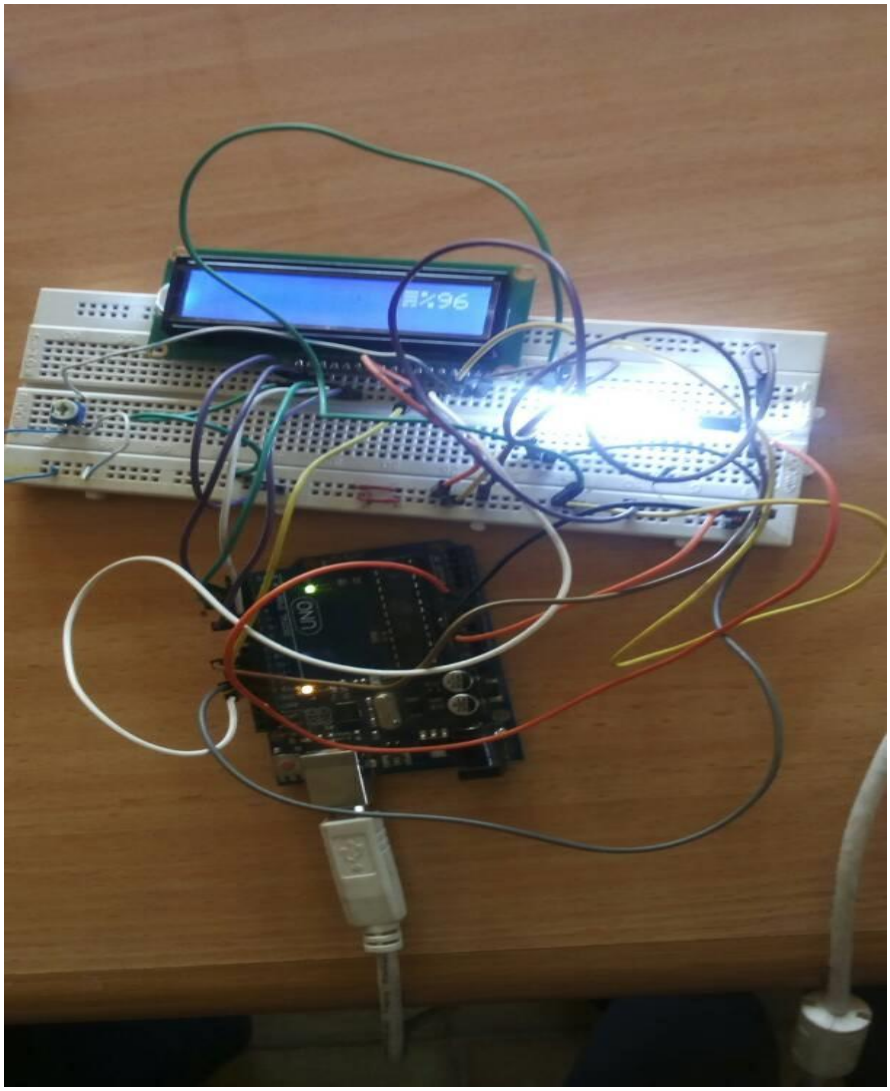

Figure4-5

The figure 4.5 show the hardware implementation of the device which includes the microcontroller (Arduino Uno), two light emetting diodes(LEDs), photodetector (infrared diode), liquid crystal display(LCD) and variable resistance to control the LCD light.

Chapter Five

Conclusion and Recommendation

Chapter Five

Conclusion and Recommendation

5.1Conclusion:

In this research a successful simulation as well as practical implementation of low cost embedded oximeter.

The proposed device has a complete hardware implementation consist of an optical sensor, microcontroller (Arduino Uno) and liquid crystal display (LCD).

The device was tested and worked well, also proteus simulation worked properly.
The sensed data was processed by the microcontroller and the results were displayed on the liquid crystal display.

The proposed device can be used in medical field in order to measure the oxygen ratio and the oxygen saturation in the blood, it well be useful in diagnosing, anesthesia and post anesthesia care units, critical care and in monitoring physiological parameters of the patients.

5.2Recommendations:

This project can be improved to more advanced projects more efficient and easy usage, we recommended to:

1.The device can be developed to be wearable.

2-The ability of downloading low cost oximiter in mobile phones as many application in real life.

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Appendix A

Appendix A

The Code

```
#include <LiquidCrystal.h>

#define redLED 9

#define iredLED 11

#define analogPin A0

volatileintmaxTemp,minTemp;    //shared variables between interrupts and loop

volatile  intlastcount,count;

intRmax, Rmin, IRmax, IRmin;

float R,Spo2;

int spo2_int;

intinterrupts_counter =0; //count the times of interrupts

void setup(){

  // put your setup code here, to run once:

  //initially switch on Red LED, after each interrupt will turn the other

pinMode(redLED,OUTPUT);

pinMode(analogPin,INPUT);

Serial.begin(9600);
```

```
 //initialize LCD
LiquidCrystallcd(12,10, 5, 4,  3, 2);
lcd.begin(16, 2);
init_interrupts();
attachInterrupt(max_min_num); //interrupt call max_min_num function
Rmax=0;
IRmax=0;
Rmin=0;
IRmin=0;
}
voidmax_min_num(){
lastcount =count;
count = analogRead(analogPin); //read signal
if(count>max Temp){
max Temp = count;}
else if(count<min Temp){
min Temp = cont;}
while(1){
digitalWrite(redLED,HIGH);
```

delay(2000); //let red led signal to be stable

//interrupts();

while(!((lastcount>average)&& (count<average))){ }

digitalWrite(redLED,HIGH);

init_interrupts();

while(!((lastcount>average)&& (count<average))){ }

noInterrupts(); // temporarily disabel interrupts, to be sure it will not change while we are reading

Rmax = max Temp;

Rmin = min Temp;

delay(100);

}

digitalWrite(redLED, LOW);

R = (Rmax -Rmin);

*Spo2 = (R-180)*0.01 +97.838;*

int Spo2_int = (int)Spo2; //float Spo2 to int Spo2_int

String Spo2_float = floatToString(buffer,Spo2,2);

LiquidCrystallcd(12,10, 5, 4, 3, 2);

lcd.begin(16, 2);

```
lcd.setCursor(0,1);
lcd.print("SPO2:");
lcd.setCursor(5,1);
lcd.print(Spo2_int);
delay(1000);
init_interrupts();
 }
```