HEARTRATE AND SPO2 MONITORING SYSTEM

A Report by

GROUP-6 OF SUBGROUP-1

Submitted by

TEAM MEMBERS	Roll No.
CHERUKURI TAPASWINI	21CS10018
TELU AMRUTHAVARSHINI	21CS30055
KOLATHURU VISHNU VARDHAN	21CE10031
THUMMALAPELLI JEEVAN KUMAR	21CH30034

Under the supervision of

Dr. M MANJUNATHA

Indian Institute of Technology Kharagpur

CONTENTS PAGE NO

ACKNOWLEDGEMENT

We express our sincere thanks to **Dr. M MANJUNATHA** for his novel association of ideas, encouragement, appreciation and intellectual zeal which motivated us to venture this project successfully. Without his help, stimulating suggestions and encouragement we would not have been able to finish the project. We are thankful for explaining the crucial aspect of topics related to the project.

We would also like to appreciate the crucial role of **PRAVIN VIDVA Sir,** for his constant guidance and willingness to share his vast knowledge.

Last but not the least we express our deep gratitude and affection to our parents who stood behind us in all our endeavors.

ABSTRACT

Heartbeat Sensor is an electronic device that is used to measure the heart rate i.e. speed of the heartbeat. Monitoring body temperature, heart rate and blood pressure are the basic things that we do in order to keep us healthy. In order to monitor the Arterial Pressure or Blood Pressure **Sphygmomanometer** is used. Pulse oximetry is used in this project to detect the heartbeat using fingers. When the heart expands (diastole) the volume of blood inside the fingertip increases and when the heart contracts (systole) the volume of blood inside the fingertip decreases.

For this an IR transmitter/receiver pair (LED) is placed in close contact with the fingertip. When the heart beats, the volume of blood cells under the sensor increases and this reflects more IR waves to the sensor and when there is no beat the intensity of the reflected beam decreases. The pulsating reflection is converted to a suitable current or voltage pulse by the sensor. The sensor output is processed by suitable electronic circuits to obtain a visible indication (digital display).

INTRODUCTION

Measurement of heart rate and pulse oximetry are very important factors to assess the condition of the human cardiovascular system. Heart rate is formerly measured by placing the thumb over the arterial pulsation.
Due to its non-invasive nature, high precision, and reasonable cost, optical pulse oximetry and heart rate measurement systems are widely adopted as a standard patient monitoring technique.

OBJECTIVE

The objective of this project is to build a system or a device that will measure the rate of heartbeat of the human body & detect heart attack. The device must be able to monitor all the heart rate in a continuous interval length of time. For the device to monitor all the heart rate in a continuous interval length of time, it is important for the device to be able to display the information regarding the heart rate to the patient on the LCD screen as well

GOAL OF THE WORK

Some severe diseases and disorders e.g. heart failure needs close and continual monitoring procedure after diagnosis, in order to prevent mortality or further damage as secondary to the mentioned diseases or disorders. Monitoring these types of patients, usually, occur at hospitals or healthcare centers. Heart and arrhythmias for instance, in many cases, need continual long-term monitoring.

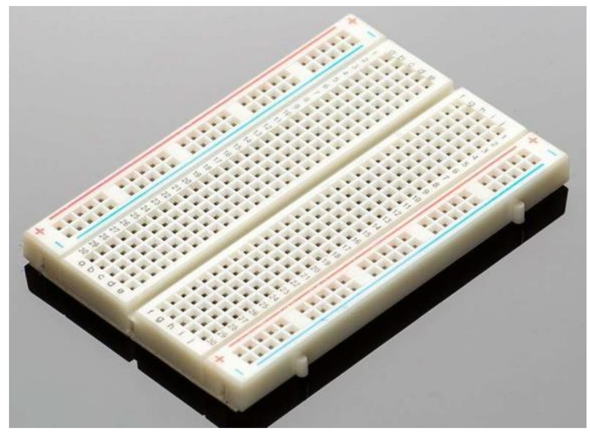
SCOPE OF THE WORK

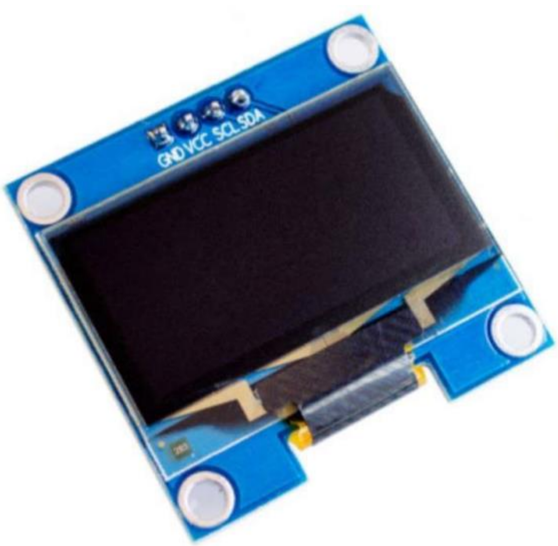
Long waiting time for hospitalization or ambulatory patient monitoring/treatment, are other well-known issues for both the healthcare institutions and the patients. This project provides healthcare authorities to maximize the quality and breadth of healthcare services by controlling costs. As the population increases and demand for services increases, the ability to maintain the quality and availability of care, while effectively managing financial and human resources, is achieved by this project.The use of modern communication technology in this context is the sole decisive factor that makes such a communication system successful.

COMPONENTS USED

ARDUINO UNO

BREADBOARD





LCD SCREEN

PULSE AND HEARTBEAT SENSOR

LITERATURE

Average Calculation:

An average rate is calculated by counting the number of pulses in a given time. This method does not show changes in time between beats and thus does not represent the true picture of heartfs response to exercise, stress and environment.

Beat To Beat Calculation:

This is done by measuring the time (T) in seconds, between two consecutive pulses, and converting the time into beats/min, using the formula beat/min = 60/T.

Combination Of Beat To Beat Calculation With Averaging:

This is based on four or six beats on average. The advantage of this technique over the averaging techniques is its similarity with the beat to beat monitoring system.

Pulse oximetry relies on measurement of physiological signals called photoplethysmography, which is an optical measurement of the change in blood volume in the arteries.

Pulse oximetry acquires PPG signals by irradiating two different wavelengths of light through the tissue, and compares the light absorption characteristics of blood under these wavelengths. These absorptions obey Beer Lambertfs law.

According to Beer Lambertfs law transmittance of light through the tissue can be calculated using:

$$I_{out} = I_{in}\, e^{A}$$

Where,

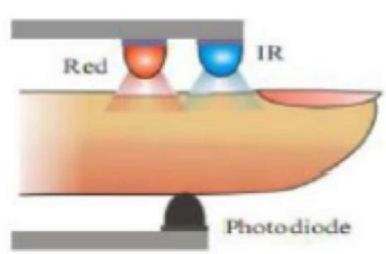
(I out) is the light intensity transmitted through fingertip tissue,

(I in) is the intensity of the light going into the fingertip tissue

and A is the absorption factor

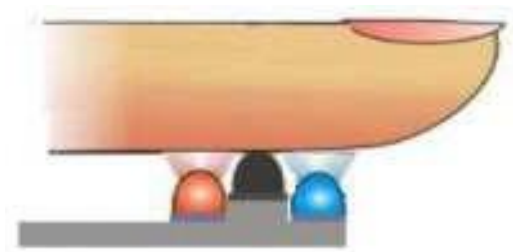
Pulse oximetry can be done by two methods

Transmittance Method: In this method, light is transmitted through tissue using the LED and is detected on the other end using a photo-detector. It is more suited to the areas of the body that lend themselves better to light transmittance through them, e.g. fingers or ear lobe. This Configuration Cannot be used in other areas of the body when there are obstacles such as bones or muscles.



Transmittance Method

Reflectance Method: In reflectance pulse oximetry it uses a photo detector on the same side as the LED to detect the light reflected by the tissue. This method is more useful where the vasculature is available close to the surface of skin e.g. forehead, wrist, forearm



Refiectance method

Based on all these reviews, there are two methods chosen to calculate heart rate and blood oxygen saturation level.

Heart rate calculation:

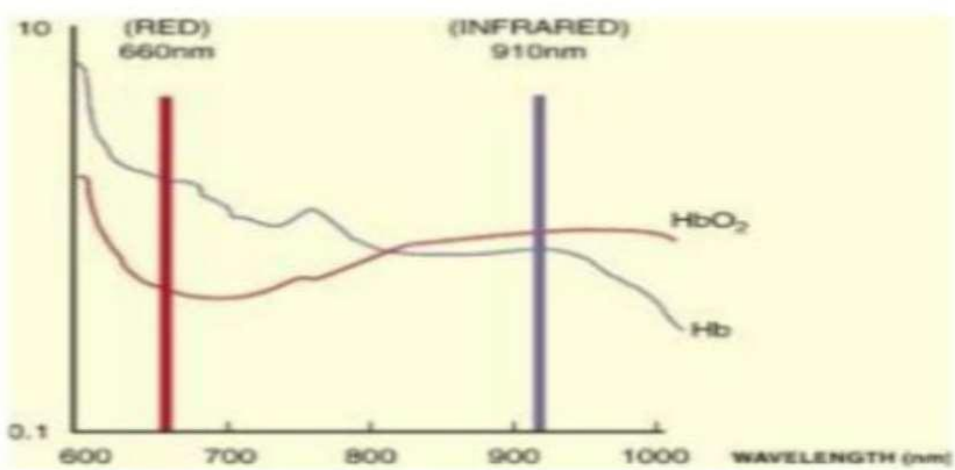
This project is based on the beat to beat heart rate calculation process. In this process, the number of pulses for a given period T is calculated and converted to bpm by multiplying with 60/T, that gives the instantaneous heart rate in bpm. So this can be expressed as:

$$\textit{Heart rate} = (\textit{No.of Pulses for a given period } T \times 60) / T \text{ bpm}$$

Calculation of blood oxygen saturation level:

The principle of pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin. Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through whereas deoxygenated hemoglobin absorbs more red light and allows more infrared light to pass through. Red light is in the 600-750 nm wavelength light band whereas infrared light is in the 850-1000 nm wavelength light band.

The absorption relationship is shown in following figure:



Absorption Relationship Of Oxygen Levels In The Blood For The Red And Infrared Wavelengths

Because the flow of blood is pulsatile in nature, the transmitted light changes with time. A normal finger has light absorbed from bloodless tissue, venous blood, and arterial blood. The volume of arterial blood changes with pulse, so the absorption of light also changes.The light detector will therefore see a large also changes.The light detector will therefore see a large CD signal representing the residual arterialblood, venous blood and bloodless tissue.

Now the basic formula to calculate oxygen saturation level can be stated as:

$$SPO_2 = \frac{HbO_2}{Hb+HbO_2}$$

Where, hemoglobin with oxygen molecules is considered as oxygenated hemoglobin (HbO_2). When it is carrying less oxygen molecules, then it is considered reduced (Hb).

DETAILS OF THE COMPONENTS

What is Arduino UNO?

Arduino UNO is a low-cost, flexible, and easy-to-use programmable open-source microcontroller board that can be integrated into a variety of electronic projects. This board can be interfaced with other Arduino boards, Arduino shields, Raspberry Pi boards and can control relays, LEDs, servos, and motors as an output.

Arduino UNO features AVR microcontroller Atmega328, 6 analogue input pins, and 14 digital 1/0 pins out of which 6 are used as PWM output.

How to Program Arduino UNO

Arduino UNO is easy to program and a person with little or no technical knowledge can get hands-on experience with this board. The Arduino UNO board is programmed using Arduino IDE software which is an official software introduced by Arduino.cc to program the board. The Arduino program is called a sketch which you need to unload into the board. The sketch is nothing but a set of instructions that allow the board to perform certain functions as per your requirements.

Each Arduino sketch comes with two main parts:

void setup() - this sets up the things that need to be done once and they don't happen again in the running program.

void loop() - this part comes with the instructions that get repeated again and again until the board is turned off.

OLED DISPLAY

OLEO, meaning Organic Light Emitting Diode is a relatively new technology with the potential to replace current LCD and LED televisions, monitors, and cell phone displays. It is structurally more complex than traditional LEDs and utilizes organic, carbon-based semiconductor materials for the emission region rather than silicon or germanium.

An OLEO module display is made up of many layers; first it is sealed on the top or bottom by a transparent material, usually glass or plastic. On each side is placed either an anode or a cathode, one of which must also be transparent for the light to be emitted effectively. Finally, within the anode and cathode are the organic LED compounds, called an emissive layer on the cathode side and conductive layer on the anode. When a positive voltage is placed on the anode, holes jump across the positive voltage is placed on the anode, holes jump across the emissive conductive barrier and join with electrons, which produces a photon of light.

An OLEO can be made far thinner than any known LCD technology, not only the material itself but the lack of any needed backlight, since LEDs emit their light while liquid crystals only manipulate the passage of light. The potential for flexible displays, less energy usage, higher contrast and refresh rates, and cheaper displays is driving many companies to make OLEDs mainstream. Read less

MAX30100

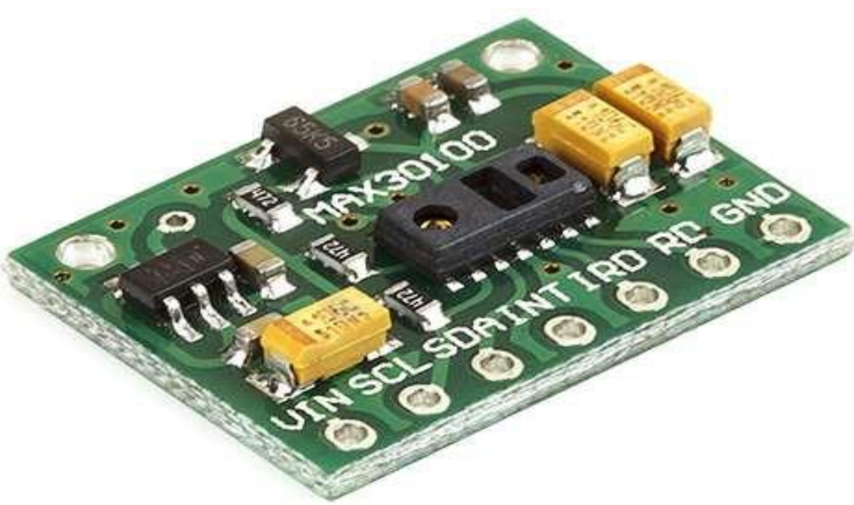
Pulse and Heartbeat Sensor

The MAX30100 is an integrated pulse oximeter and heart rate monitor sensor solution. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals.

The MAX30100 operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times.

Applications

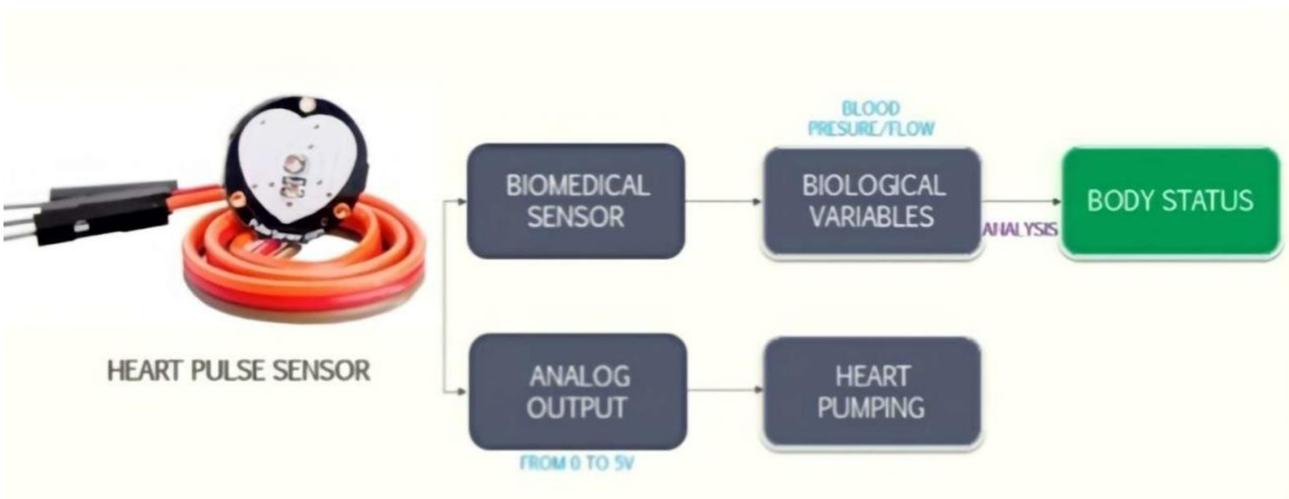
- Wearable Devices
- Fitness Assistant Devices
- Medical Monitoring Devices



WORKING OF HEART RATE SENSOR

The principle behind the working of Heart beat sensor is **PHOTOPLETHYSMOGRAPHY.** The Heart rate sensor uses an INFRARED LED (IR) and a PHOTOTRANSISTOR to detect the pulse of the finger and whenever a pulse is detected red LED flashes.

The sensor consists of a super bright red LED and light detector. The LED needs to be super bright as the maximum light must pass spread in finger and detected by detector. Now, when the heart pumps a pulse of blood through the blood vessels, the finger becomes slightly more opaque and so less light reaches the detector. With each heart pulse the detector signal varies. This variation is converted to an electrical pulse. This signal is amplified and triggered through an amplifier which outputs +SV logic.level signal. The output signal is also indicated by a LED which blinks on each heart beat

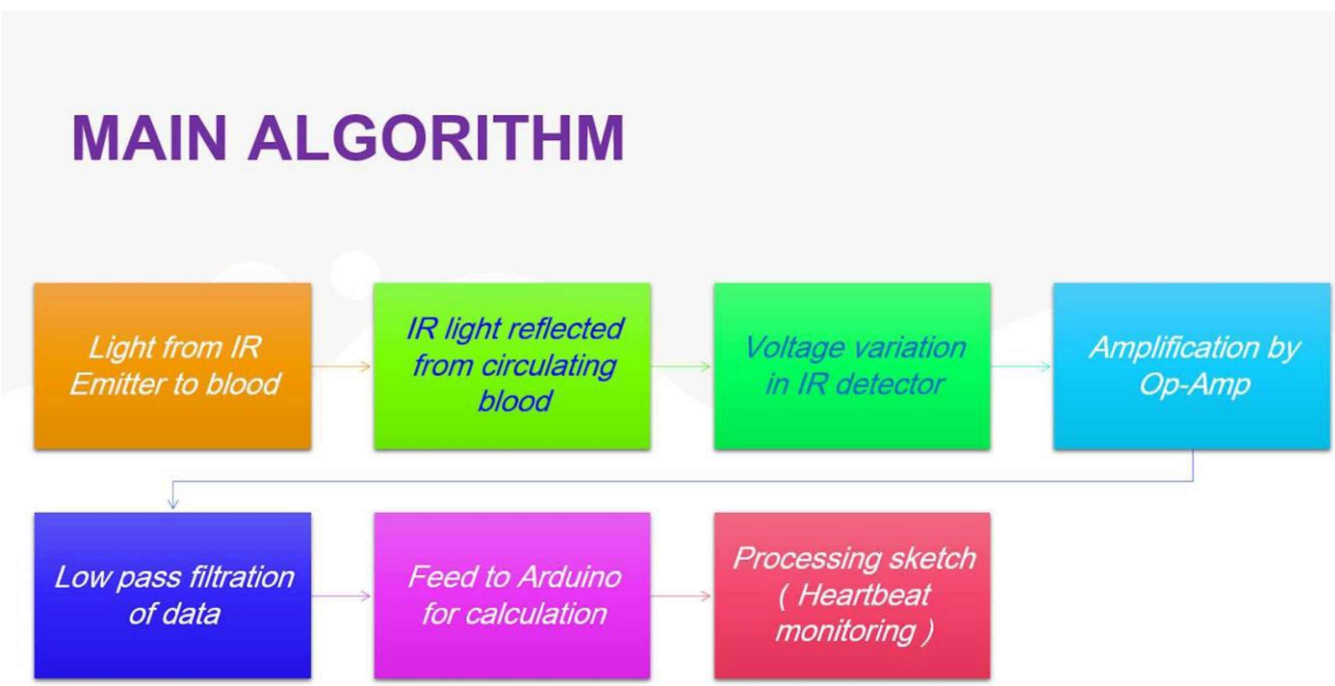


WORKING OF PULSE OXIMETER

A pulse oximeter measures the amount of oxygen in a patient's blood by sensing the amount of light absorbed by the blood in capillaries under skin.

Oximeters work by the principles of ***Spectrophotometry:*** *the relative absorption of red (absorbed by deoxygenated blood) and infrared (absorbed by oxygenated blood) light of the systolic component of the absorption waveform correlates to arterial blood oxygen saturations.*

- Pulse oximeter depends on the optical characteristics of hemoglobin,the blood protein that carries oxygen. when hemoglobin is more transmissive to red light and absorptive to infrared light.When hemoglobin contains little oxygen,it becomes relatively more transmissive to infrared and more absorptive to red light.



WORKING OF CIRCUIT

Upload the code to Arduino UNO and Power on the system. The Arduino asks us to place our finger in the sensor and press the switch.

Place any finger (except the Thumb) near Infrared Light ,Based on the data from the sensor, Arduino calculates the heart rate and displays the heartbeat in bpm.

While the sensor is collecting the data, sit down and relax and do not shake the wire as it might result in faulty values.

After the result is displayed on the LCD, if you want to perform another test, just push the reset button on the Arduino and start the procedure once again.

The pulse sensor notifies the changes to Arduino which then converts into BEATS PER MINUTE and collects the data in COM4 .The Arduino then plots the graphs between 8PM and Time using the data produced in Serial Plotter

SOFTWARE DESCRIPTION

PROTEUS SOFTWARE

Proteus is a simulation software used to simulate components and is capable of drawing desired circuits. It is being used for fast checkup of code you have written for microcontrollers.

- By using proteus you can make two-dimensional circuits designs as well.
- With the use of this engineering software, you can construct and simulate different electrical and electronic circuits on your personal computers or laptops.

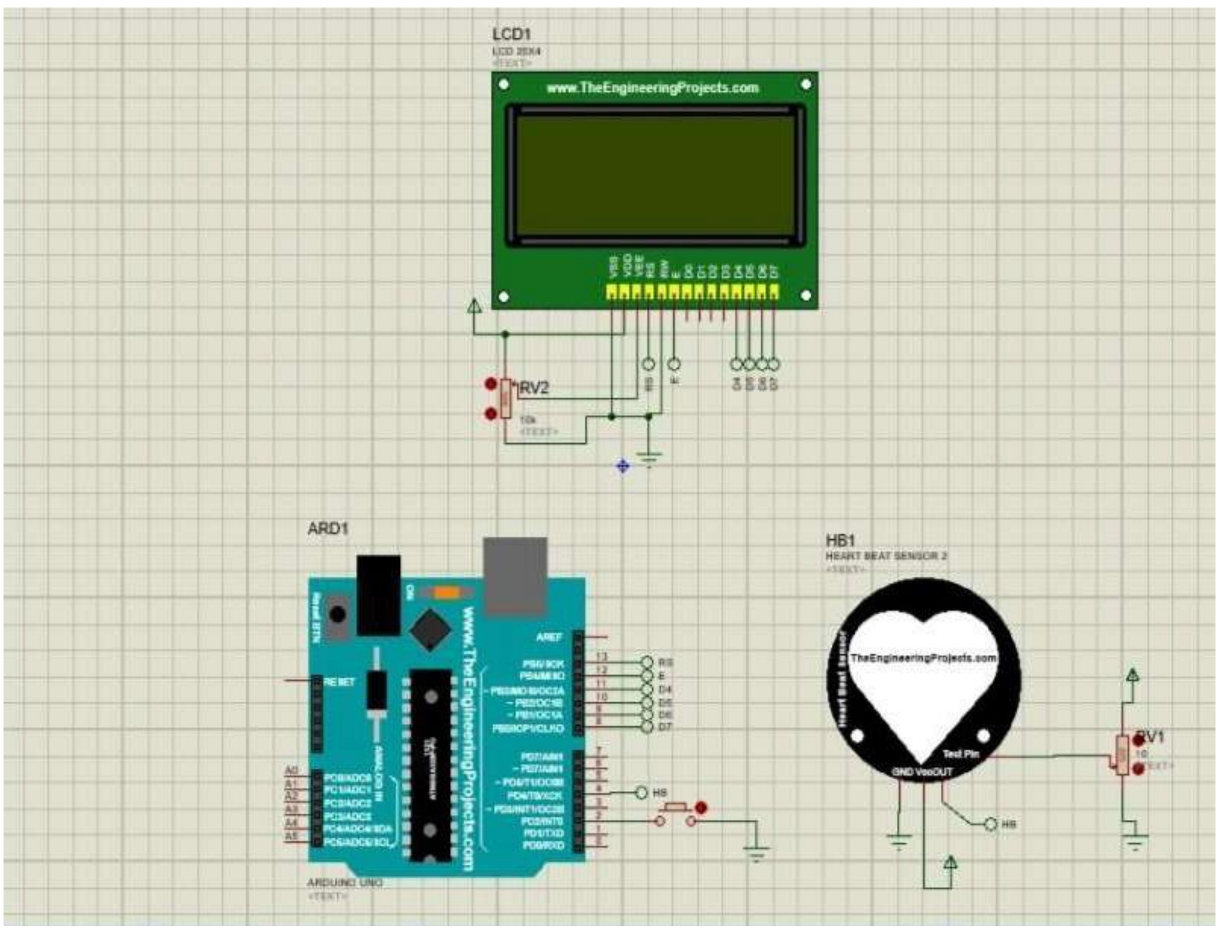
Designing of circuits on the proteus takes less time than practical construction of the circuit.

- The possibility of error is less in software simulation such as loose connection that takes a lot of time to find out connection problems in a practical circuit.
- Circuit simulations provide the main feature that some components of circuits are not practical then you can construct your circuit on proteus.
- There is zero possibility of burning and damaging any electronic component in proteus.
- The electronic tools that are very expensive can easily get in proteus such as an oscilloscope.
- Using proteus you can find different parents of circuits such as current, a voltage value of any component and resistance at any instant which is very difficult in a practical circuit.

EMBEDDED C

The C programming language is perhaps the most popular programming language for programming embedded systems. C remains a very popular language for microcontroller developers due to the code efficiency and reduced overhead and development time. C offers low-level control and is considered more readable than assembly. Many free C compilers are available for a wide variety of development platforms. The compilers are part of an IDEs with ICD support, breakpoints, single-stepping and an assembly window. The performance of C compilers has improved considerably in recent years, and they are claimed to be more or less as good as assembly, depending on who you ask. Most tools now offer options for customizing the compiler optimization. *A model of our assembly is prepared and simulated using* ***PROTEUS SOFTWARE.***

CIRCUIT DIAGRAM



PROGRAM USED IN PROTEUS SOFTWARE

```
#include <LiquidCrystal.h>

#include <TimerOne.h>

LiquidCrystal lcd(l3, 12, 11, 10, 9, 8);



int HBSensor = 4;

int HBCount = 0;

int HBCheck = 0;

int TimeinSec = 0;

int HBperMin = 0;

int HBStart = 2;

int HBStartCheck = 0;



void setup() {

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

  lcd.begin(20, 4);

  pinMode(HBSensor, INPUT);

  pinMode(HBStart , INPUT_PULLUP);

  Timerl .initialize(S00000);

  Timerl .attach Interrupt( timerIsr );

  led.clear();

  lcd.setCursor(0,0);

  lcd.print ("Current HB : ");

  lcd.setCursor(0,1);
```

```
  lcd.print("Time in Sec: ");

  lcd.setCursor(0,2);

  lcd.print("HB per Min  : 0.0");

}



void loop() {

  if(digitalRead(HBStart) == LOW){lcd.setCursor(0,3);lcd.print("HB Counting ..");HBStartCheck= 1;}

  if(HBStartCheck == 1)

  {

    if((digitalRead(HBSensor) == HIGH) && (HBCheck == 0))

    {

      HBCount = HBCount + 1;

      HBCheck= 1;

      lcd.setCursor(l 4,0);

      lcd.print(HBCount);

      led.print(" ");

    }

    if((digitalRead(HBSensor) == LOW) && (HBCheck == 1))

    {

      HBCheck = O;

    }

    if(TimeinSec == 10)

    {

        HBperMin = HBCount * 6;

        HBStartCheck = O;
```

```
        lcd.setCursor(14,2);
        lcd.print(HBperMin);
        led.print("");
        led.setCursor(0,3);
        lcd.print("Press Button again.");
        HBCount = 0;
        TimeinSec = 0;
    }
  }
}

void timerIsr()
{
  if(HBStartCheck == 1)
  {
      TimeinSec = TimeinSec + 1;
      lcd.setCursor(14,1);
      lcd.print(TimeinSec);
      led.print("");
  }
```

PROGRAM USED IN ARDUINO IDE

```
#include <Wire.h>
#include "MAX30100_PulseOximeter.h"
```

```
#include "Wire.h"

#include "Adafruit_GFX.h"

#include "OakOLED.h"

#define REPORTING_PERIOD_MS 1000

OakOLED oled;


PulseOximeter pox;


uint32_t tslastReport = 0;


canst unsigned char bitmap D PROGMEM=

{

0x00, 0x00, 0x00, 0x00, 0x01, 0x80, 0xl 8, 0x00, 0x0f, 0xe0, 0x7f, 0x00, 0x3f, 0xf9, 0xff, 0xc0,

0x7f, 0xf9, 0xff, 0xc0, 0x7f, 0xff, 0xff, 0xe0, 0x7f, 0xff, 0xff, 0xe0, 0xff, 0xff, 0xff, 0xfO,

0xff, 0xf7, 0xff, 0xfO, 0xff, 0xe7, 0xff, 0xfO, 0xff, 0xe7, 0xff, 0xfO, 0x7f, 0xdb, 0xff, 0xe0,

0x7f, 0x9b, 0xff, 0xe0, 0x00, 0x3b, 0xc0, 0x00, 0x3f, 0xf9, 0x9f, 0xc0, 0x3f, 0xfd, 0xbf, 0xc0,

0xl f, 0xfd, 0xbf, 0x80, 0x0f, 0xfd, 0x7f, 0x00, 0x07, 0xfe, 0x7e, 0x00, 0x03, 0xfe, 0xfc, 0x00,

0x01, 0xff, 0xf8, 0x00, 0x00, 0xff, 0xfO, 0x00, 0x00, 0x7f, 0xe0, 0x00, 0x00, 0x3f, 0xc0, 0x00,

0x00,0x0f,0x00,0x00,0x00,0x06,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00

};


void onBeatDetected()

{

Seriall.println("Beatl");

oled.drawBitmap( 60, 20, bitmap, 28, 28, 1);
```

```
oled.display();
}

void setup()
{
Serial.begin(9600);

oled.begin();
oled.clearDisplay();
oled.setTextSize(1);
oled.setTextColor(1);
oled.setCursor(O, O);

oled.println("Initializing pulse oximeter..");
oled.display();
Serial.print("Initializing pulse oximeter..");

if (!pox.begin()) {
Serial.println("FAILED");
oled.clearDisplay();
oled.setTextSize(1);
oled.setTextColor(1);
oled.setCursor(O, O);
oled.println("FAI LED");
oled.display();
```

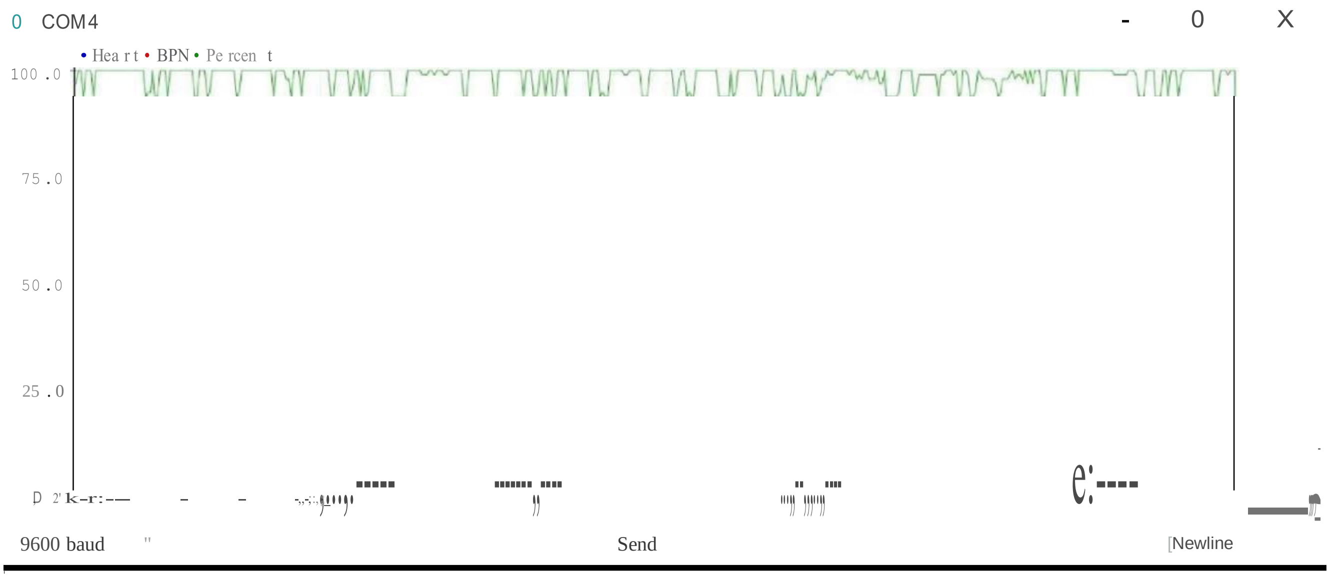
```
for(·,·,)·,

} else {

oled.clearDisplay();

oled.setTextSize(l );

oled.setTextColor(l);

oled.setCursor(0, 0);

oled.println("SUCCESS");

oled.display();

Serial.println("SUCCESS ");

}

pox.setOnBeatDetectedCallback(onBeatDetected);

}


void loop()

{

pox.update();


if (millis() - tslastReport > REPORTING_PERIOD_MS) {

Serial.print("Heart BPM:");

Serial.print(pox.getHeartRate());

Serial.print(" ---- ");

Serial.print("Oxygen Percent:");

Serial.print(pox.getSpO2());

Serial.println("\n");

oled.clearDisplay();
```

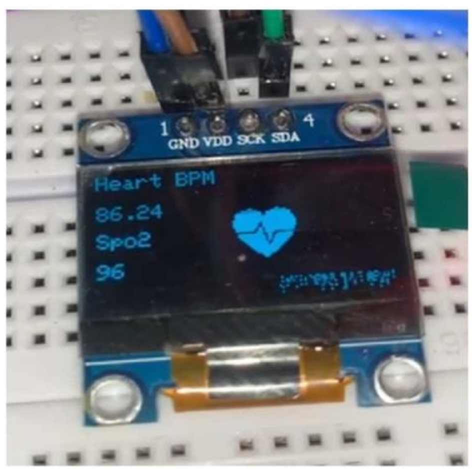
```
oled.setTextSize(l );

oled.setTextColor(l);

oled.setCursor(0,16);

oled.printl n(pox.getHeartRate());


oled.setTextSize(l );

oled.setTextColor(l );

oled.setCursor(0, 0);

oled.println("Heart BPM ");

oled.setTextSize(l );

oled.setTextColor(l );

oled.setCursor(0, 30);

oled.println("Spo2");

oled.setTextSize(l );

oled.setTextColor(l );

oled.setCursor(0,45);

oled.printl n(pox.getSpO2());

oled.display();

tslastReport = millis();

}

}
```

Using the instructions given in the code, Arduino /DE collects *the data frompulse* sensor *through Arduino board and reports the values in COM4 and plots the graph in Serial Plotter.*

OBSERVATION:-

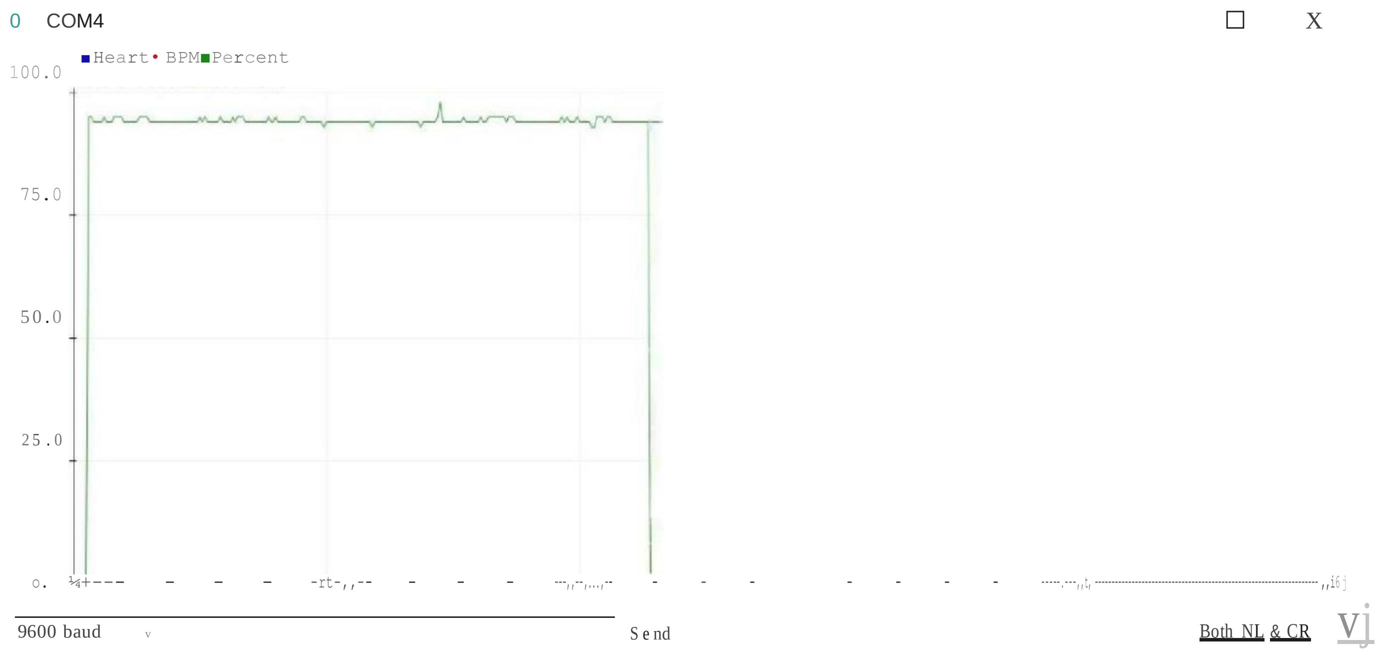
Heart rate plot of a person of 18 years age

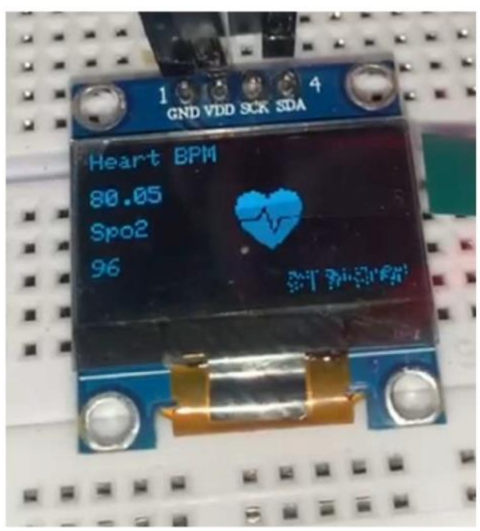




Average Heart rate is 86.24 8PM and SP02 value is 96

Heart rate plot of a person of 35 years age





Average Heart rate is 80.05 8PM and SP02 value is 96

PRECAUTIONS

During making of PCB circuit care should be taken so that in times of ironing the circuit is not shorted

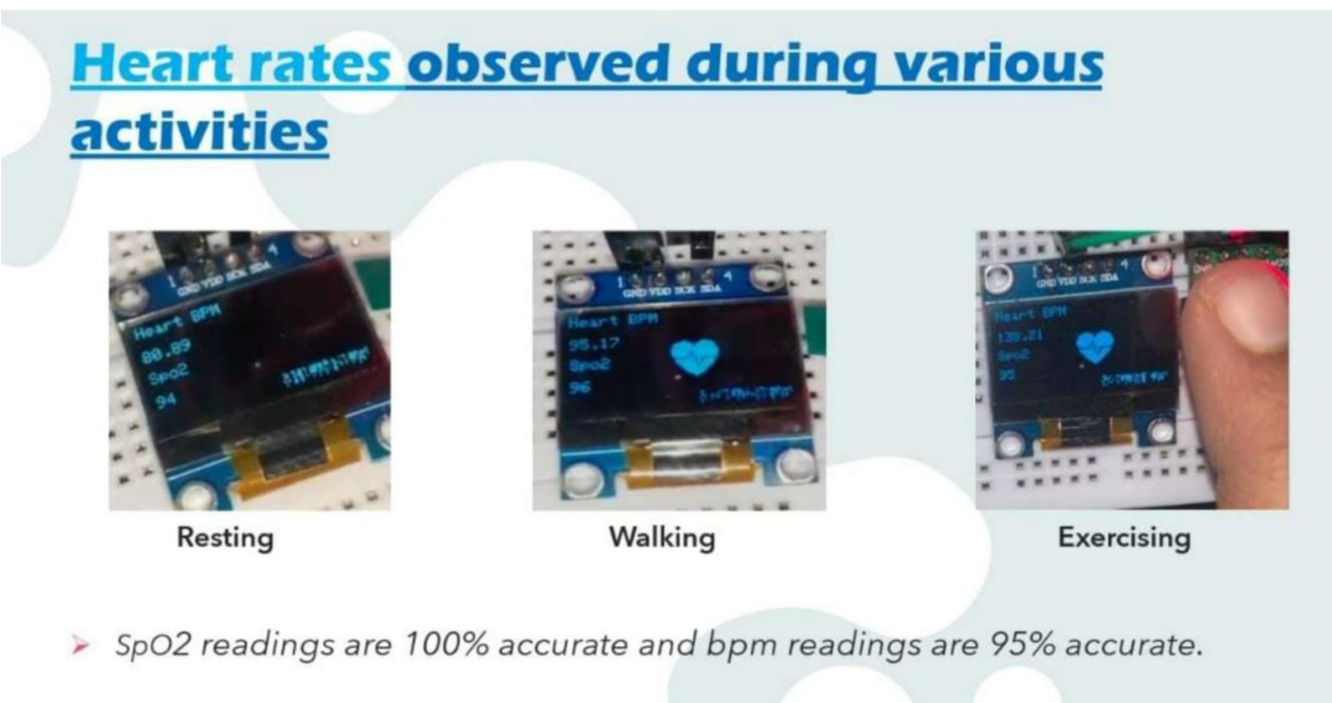
During placing the finger care should be taken so that it remains in the proper place of the finger.

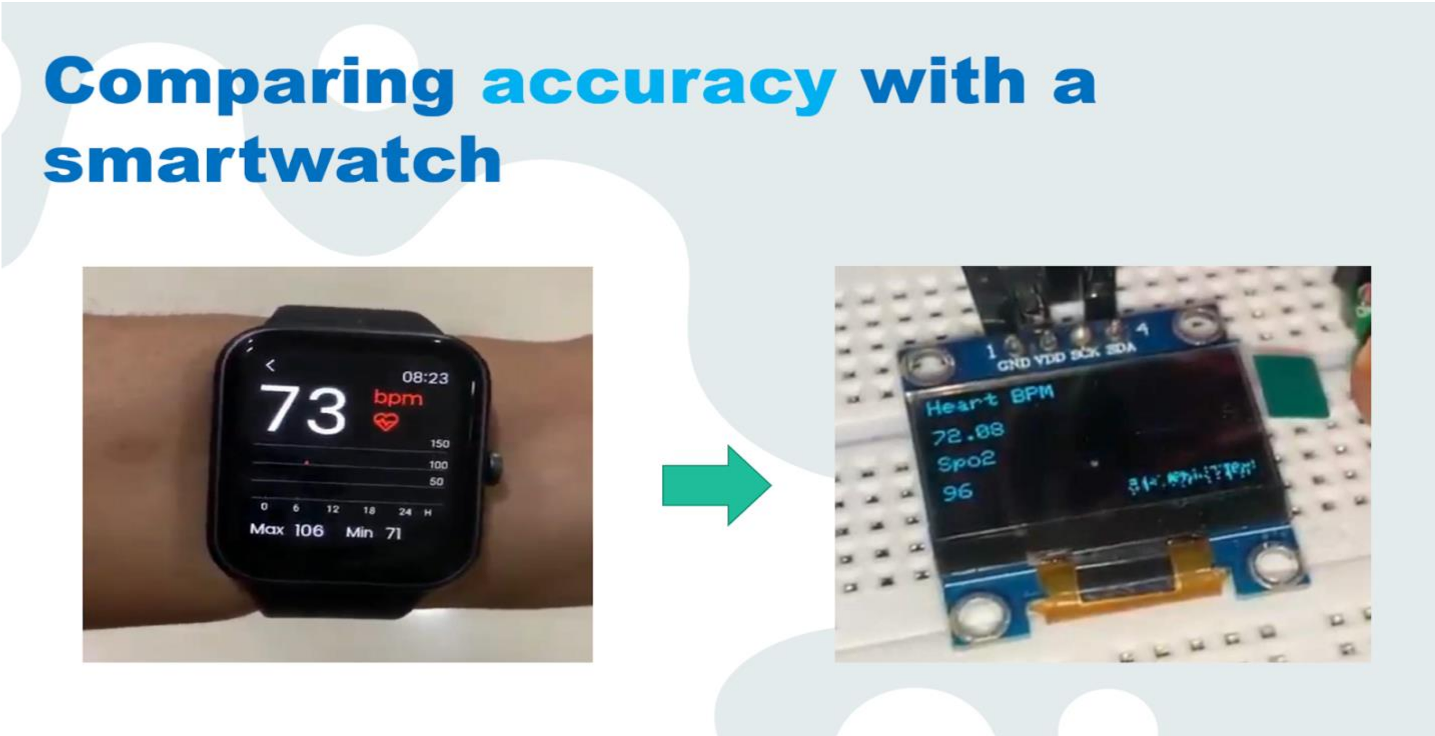
RESULTS

The Heart rate monitoring system was successfully made and worked fine.

- From the plots we can observe that the heart rate varies approximately from 80 to 1OD.Using a smart watch we found that our Heart rate measurement is of 95% accuracy and spo2 value is of 100% accuracy.

- **Tests have shown excellent agreement with actual heart beat rates**





Some of the errors might be observed as,

- Heart rate is taken by counting for 10 seconds, and multiplying by 6, there is an error of+/- 6 bpm built in the procedure.
- Miscounting could also be a factor.

The errors can be reduced by doing several trails of activity and finding an average heart rates.

PRESET VALUES OF SPO_2

SPO_2 Reading (%)	Interpretation
95-100	Normal
91-94	Mild Hypoxemia*
86-90	Moderate Hypoxemia*
<85	Severe Hypoxemia*

*Hypoxemia is defined as decreased partial pressure in blood and oxygen available to the body or an individual tissue or organ.

The output of heart rate is compared with the references representing bradycardia and tachycardia for adult or children. These referenced values were taken by statistical computation.

TABLE III PRESET VALUES OF HEART RATE

Age	Heart Rate (BPM)	Interpretation
15 years – adult	< 60	Bradycardia
1–2 days	> 159	Tachycardia
3–6 days	>166	Tachycardia
1–3 weeks	>182	Tachycardia
1–2 months	>179	Tachycardia
3–5 months	>186	Tachycardia
6–11 months	>169	Tachycardia
1–2 years	>151	Tachycardia
3–4 years	>137	Tachycardia
5–7 years	>133	Tachycardia
8–11 years	>130	Tachycardia
12–15 years	>119	Tachycardia
>15 years – adult	>100	Tachycardia

CONCLUSION

The Heart rate monitoring and pulse oximeter device available in the market are high pricing where the designed device is the cheapest one. The design proposes small size, light weight, low power consumption, standardized signal processing capabilities. This device is able to produce highly reliable test results for both heart rate and Sp02 level. Our designed device has the advantage that it can be used by non professional people at home to measure the heart rate and SP02 level easily and safely.

FUTURE ENHANCEMENTS

- This algorithm deals only with a single patient. This algorithm can be extended to multiple doctors and multiple patients..
- In future we can also design PC software to analyze this received signal and generate the report and this can be sent back to the doctor.
- Wit h the connection established between two ends we can also send the patient's body temperature, blood pressure to the doctor's side.
- Also a graphical LCD can be used to display a graph of the change of heart rate over time

PROBLEMS FACED DURING PROJECT

- Initially, the LCD screen showed O Bpm,as there are some issues with the components and wiring.
- **ESP-8266 WI-FI MODULE** did not get connected properly though code uploaded succesfully
- IOT Analyser and Thingspeak didn't take up any data read by ESP8266

Credit Author's Statement

Cherukuri Tapaswini- Hardware assembly *and information collection;*

Kolathuru Vishnu Vardhan- Making of PPT, Info on Sensors *and Lab report;*

Tummalapelli Jeevan Kumar- Proteus Simulation and Video editing;

Telu Amrutha Varshini - Coding and making of *Lab report.*

REFERENCES

1. Heart rate - Wikipedia

2) https://en.wikipedia.org/wiki/Pulse_oximetry

https://makersportal.com/blog/2019/6/24/arduino-heart-rate-monitor-using-max30102-and-pulse-oximetry

3) • Measure Heart Rate/BPM and SpO2 with MAX30102 + Arduino

4) Mohamed A. Zaltum, M. Shukri Ahmad, Ariffuddin Joret, and M. Mahadi Abdul Jamil, "Design and Development of a portable Pulse Oximetry system",

5) Yousuf Jawahar, Design Of An Infrared Based Blood Oxygen Saturation And Heart Rate Monitoring Device", pp 9-25, April 10, 2009.