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Pulse Rate and Oxygen Level Measurement Using Arduino

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Abstract: ***Use of technology in healthcare is growing importance as a result of the tendency to acquire chronic disease like heart attack and high blood pressure. Heart rate and blood oxygen saturation is a couple of such biometrics that is monitored in this project to provide information regarding the health of the body. By measuring the intensity change of light transmitted through tissue due to arterial blood, heart rate is measured. Furthermore, oxygenated blood has different light absorption characteristics than deoxygenated blood under red and infrared wavelengths. Comparing the absorptions produce an estimate of the oxygen saturation of blood. The purpose is to examine how heart rate and the oxygen saturation of subject is measured from finger and then processed and displayed. The design, is small in size, easy to use, allows a non- invasive, real time method to provide information regarding health. This enables an efficient and economical means for managing the health care. This document is intended to be used by engineers, medical equipment developers, anyone related to medical practice and interested in understanding the operation of pulse oximeter and heart rate monitoring system.***

Keywords: Beat per minute (BPM), Pulse oximetry, Oxygenated Hemoglobin (HBO_2), SPO_2, Photoplethysmography

I. INTRODUCTION

Measurement of heart rate and pulse oximetry are very important factors to access the condition of human cardiovascular system. Heart rate is formerly measured by placing the thumb over the arterial pulsation, and counting the pulses usually in a 30 second period. Heart rate is then found by multiplying the obtained number by 2. This method although simple, is not accurate and can give errors when the rate is high [1]. In clinical environment, heart rate is measured under controlled conditions like blood measurement, heart voice measurement, and Electrocardiogram (ECG). ECG is one of frequently used and accurate methods for measuring the heart rate. But ECG is not economical [2]. The heart rate of a healthy adult at rest is around 75(±15) (or greater for females) beats per minute (bpm). Athletes normally have lower heart rates than less active people. Babies have a much higher heart rate at around 120 bpm, while older children have heart rates at around 90 bpm. Heart rate varies significantly between individuals based on fitness, age and genetics [3].

On the other hand, the percentage of arterial blood saturated with oxygen helps to determine the effectiveness of a patients respiratory system. The technique by which blood oxygen saturation is determined is called Pulse Oximetry [4]. In earlier days, the common method used to measure blood oxygen saturation was arterial blood gas measurement. An Arterial Blood Gas is a blood test that involves puncturing an artery with a thin needle and syringe and drawing a small volume of blood [5]. This method was invasive, expensive, difficult, painful and potentially risky. So, Pulse Oximeter is introduced, operation of which is non-invasive and based on measuring the absorption of red and infrared light that passes through a patient's finger or ear lobe by using light sensors. Acceptable normal ranges for patients are from 95 to 100 percent, those with a hypoxic drive problem, would expect values to be between 88 to 92 percent. Due to its non-invasive nature, high precision, and reasonable cost, optical pulse oximetry and heart rate measurement system is widely adopted as a standard patient monitoring technique [6]. Diagnosis of heart disease can be achieved by correlating the pattern of measured value with a typical healthy signal, characterizing the measured value with basic logic decisions.

II. LITERATURE REVIEW

According to Handbook of Biomedical Instrumentation by R.S. Khandpur [7], techniques of measuring heart rate are:

A. Average Calculation

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

B. 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.

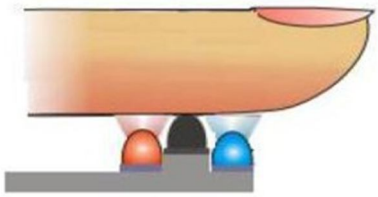


Fig. 1 Transmittance Method

Combination Of Beat-to-Beat Calculation with Averaging:

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

Pulse oximetry relies on measurement of physiological signal 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 Lamberti's law. According to Beer Lamberti's law transmittance of light through the tissue can be calculated using: $I_{out} = I_{in} e^{A}$ (1) 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[8]. According to Yousuf Jawahar, Pulse oximetry can be done by two methods [9]:

1) *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 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 body when there are obstacles such as bones or muscles.

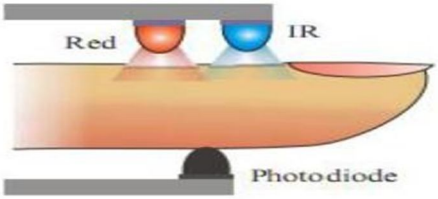


Fig. 2 Reflectance Method

2) *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. Based on all these reviews, there are two methods are chosen to calculate heart rate and blood oxygen saturation level.
3) *Heart Rate Calculation:* In this project is based on the beat-to-beat heart rate calculation process. In this process, 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:

Heart rate bpm (2) $= \frac{\text{No. Pulses for a given period T} \times 60}{T}$

4) *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:

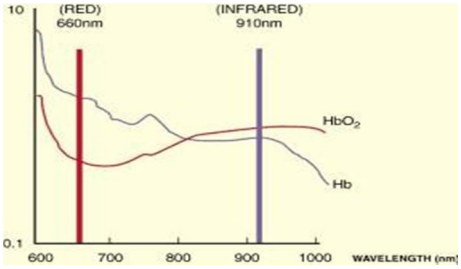


Fig. 3 Absorption Relationship Of Oxygen Levels In The Blood For The Red And Infrared Wavelengths

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 DC signal representing the residual arterial blood, venous blood, and bloodless tissue. A small portion will be an AC signal representing the arterial pulse. Because this is the only AC signal [10].

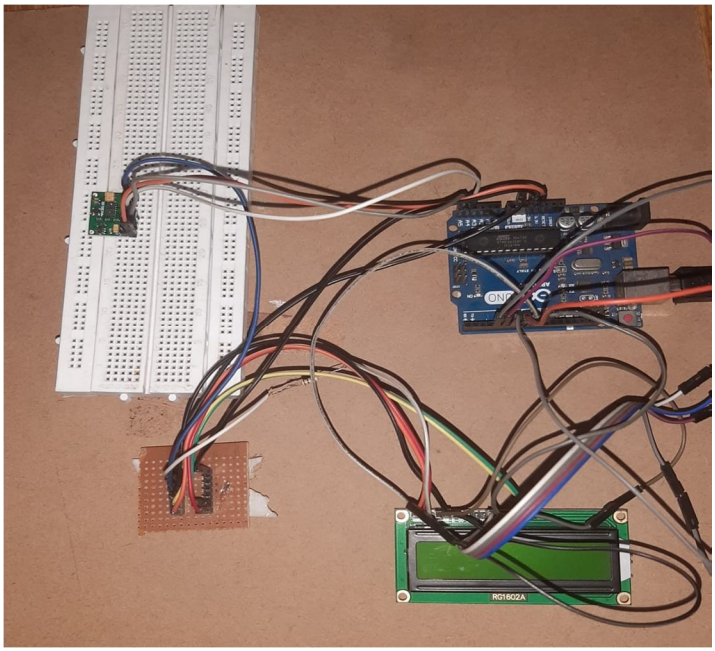


Fig. 4 Light Absorption By Tissue Type

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

SPO_2

3)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).

To find oxygen saturation, first calculate the ratio *R*

$$R = \frac{\frac{AC(red)}{DC(red)}}{\frac{AC(IR)}{DC(IR)}} = \frac{\frac{MAX(PPG)\ red}{MIN(PPG)\ red}}{\frac{MAX(PPG)\ IR}{MIN(PPG)\ IR}}$$

The maximum and minimum value will be used to calculate the ratio *R*. Using this value oxygen saturation level can be measured [5]. So, if we consider any linear equation then, the oxygen saturation level can be calculated as, $SPO_2 = a$ ñ bR

Where a and b can be considered as the calibrated values, which are constants.

III. SYSTEM OVERVIEW

A. *Sensor System*

The optical sensor is consisting of light emitter and detector and control circuit, which are discussed below:

B. *Max 30100 Sensor*

Pulse Oximetry is a test used to measure the oxygen level i.e., oxygen saturation of the blood. It is an easy, painless measure of how well oxygen is being sent to parts of your body furthest from your heart, such as the arms and legs.

No doubt the Max30100 Pulse Oximeter is an amazing sensor, still it has some disadvantages it may generate incorrect readings if the finger is not properly placed. The ambient light falling on the sensor can affect the final reading. While using the Max30100 Oximeter, make sure your finger is not moving because it can result in an incorrect reading. One more thing that you really need to take care of while using the Max30100 Sensor is that, never press the sensor too hard as this affects the blood flow and as a result you will get incorrect readings. Try to place your finger softly and make sure your finger does not move, this way you can get the most accurate reading.

This is my first getting started tutorial on the Max30100 pulse Oximeter which covers the extreme basics including:

1) Max30100 Pulse Oximeter technical specification

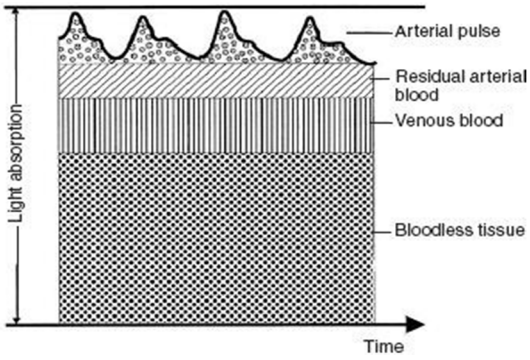
2) Max30100 sensor Pinout

3) $\frac{HbO_2}{Hb+HbO_2}$

4) Interfacing Max30100 Pulse Oximeter Sensor with Arduino

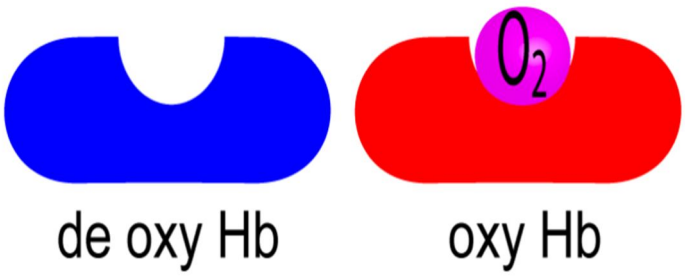
5) Programming and finally

6) Testing

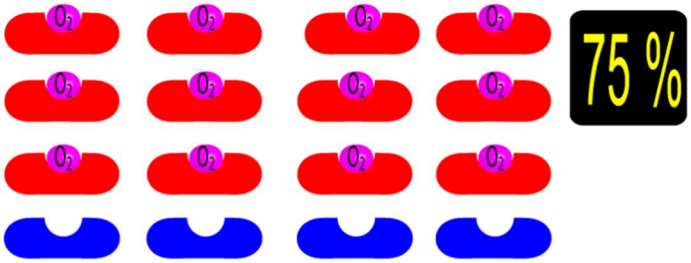


C. *Control Circuit*

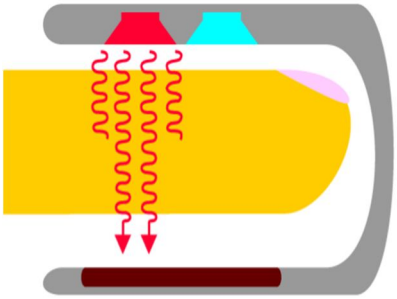
1) *Oxygen Saturation:* Pulse Oximeter measure oxygen saturation. Before we learn the principles of how pulse Oximeter work, we need to have an understanding of what oxygen saturation is. Oxygen enters the lungs and then is passed on into blood. The blood carries the oxygen to the various organs in our body. The main way oxygen is carried in our blood is by means of hemoglobin. The hemoglobin without oxygen we will call de oxygenated hemoglobin (deoxy Hb). The hemoglobin with oxygen, we will call oxygenated hemoglobin (oxy Hb).



Oxygen saturation simply refers to the percentage of the available hemoglobin that carries oxygen. Take the situations below. There are 16 hemoglobin units and none of the 16 have oxygen. The oxygen saturation is therefore 0 %.



And if all the blood cells carries the oxygen then of course it is going to be 100%.



The Oximeters comes in different shapes and sizes, but the overall working principle of the pulse Oximeters is exactly the same. Some are of the clip type like the one you can see in the picture above, while some works on the reflection technique, as the one I am using works on the reflection. So, when the light passes or reflects, we can measure the Oxygen concentration. enough to convert the weak pulsating signal into a TTL pulse [13].

D. Microcontroller

To implement the advanced signal processing algorithms on microcontroller in real-time for pulse oximeter and heart rate monitor, the computation involves ratio calculation and look up table implementation to calculate final SpO2 for display. The microcontroller (ARDUINO) is programmed to analog output of Max 30100 pulse oximeter to convert to Digital output and display at LCD screen of 16/2. The output signal of Max 30100 sensor will be supplied to the Microcontroller which will be converted from analog signal into digital signal through the built-in ADC. The microcontroller computes the received the analog output signal of the sensor and hence to derive SpO_2 value. At the same time it calculates the number of beats per minute.

E. Serial Transfer and Display

For the device to be user friendly, the output is displayed via LCD: SPO2 concentration in percentage and pulse rate in bpm. A 16x2 LCD display is very basic module and is preferred over seven segments and other multi segment LEDs.

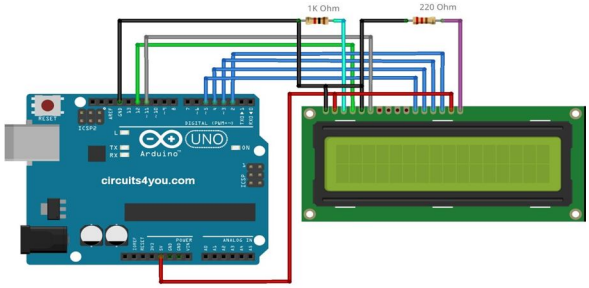


Fig. 8 Interface Arduino with LCD

F. Range

Preset values SPO_2 and heart rate are interpreted by the table I and II:

Table I 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
15years-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

IV. CONCLUSION

The Heart rate monitoring and pulse oximeter device available in 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 SpO2 level. Our designed device has the advantage that it can be used by non- professional people at home to measure the heart rate and SPO2 level easily and safely. At the same time abnormal condition can be detected easily and data can be sent to doctor from PC through email for further diagnosis.

V. ACKNOWLEDGMENT

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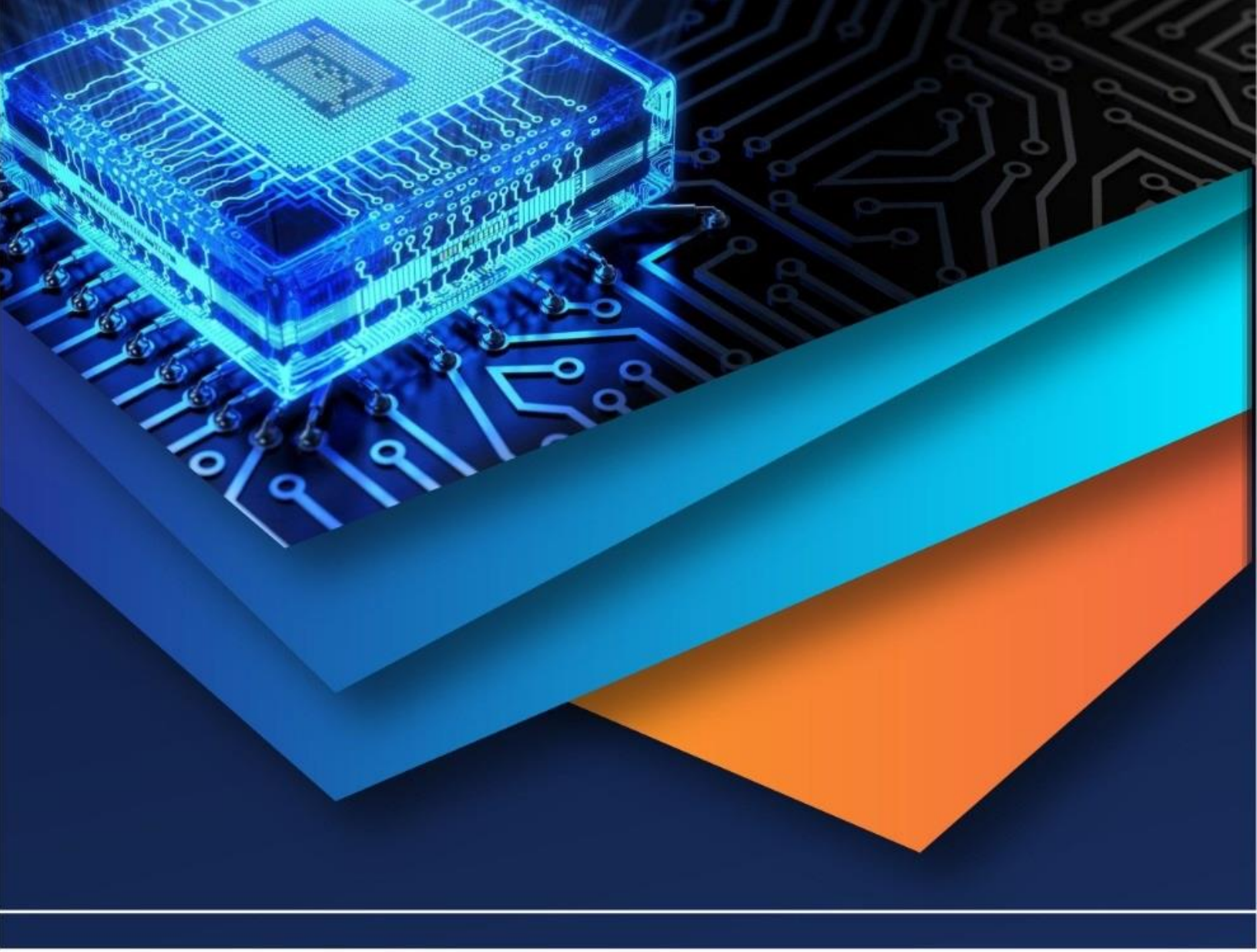

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