Optical Sensor based measurement of SpO2 and Heart Beat

1Anushka Ghosh, 2Poushali Das, 3Dipak Mondal
1B.tech Final Year Student, 2,3Associate Professor
1, 2, 3 Electronics and Communication Engineering
1, 2, 3 Future Institute of Engineering and Management, Kolkata, India

Abstract— For measuring heartbeat, Infra-Red light has to be illuminated on the skin of the human body and an ordinary LED is used for measuring the oxygen content of the blood. This sensor works out the oxygen saturation by how much red light and Infra-Red light are absorbed inside the skin. With the help of our novel algorithm and proper optical signal processing, we have measured successfully the time between the increase and decrease of the oxygenated blood content of our body. We are able to detect body temperature, heartbeat, and oxygenated blood content from infants to aged people. It is a simple, reliable, and very much low-cost instrument.

Index Terms — MAX30100, Infra-Red, SpO2, Heartbeat, Oxygenated Blood

I. Introduction

In medical science, pulse oximeter has been used for several years. In many cases, like asthma, pneumonia, or during an operation, a patient’s oxygen level may not be stable and we need to monitor it. In this paper, we are trying to construct a pulse oximeter with some cheaper components, including a microcontroller. The pulse oximeter consists of two LEDs (Light Emitting Diode), one emits red light of wavelength 660nm and another one emits infrared light of wavelength 940nm. The pulse oximeter works out the oxygen saturation by how much red light and IR light is absorbed. This absorption of wavelengths of light is measured by a photo sensor. The pre-processing of LED and photodiode takes significant time. To avoid this, we use the Proto central MAX30100 sensor. It has the required circuits to acquire the desired signal. Our work does not contain much design comparison. Amplification and sampling should be done in the hardware part with analog signal as an input to get correct results. For calculation we need a device with good processing power and features that will look into the timing requirements. In our method, Node MCU is a correct match with low price and less amount of time. We generally place fingertip on the device’s red light. IR light is used for SpO2 measurement and both red light and IR light are used for heartbeat measurement. The output of the analog circuit is fed to a microcontroller, which calculates the heartbeat and SpO2 value and shows it on the OLED display.

II. Literature Survey

In earlier days, SpO2 is measured in a painful way called arterial blood gas and it used to take 20-30 minutes to obtain the result. But severe brain damage can happen in 5 minutes due to low oxygenation. So this process is not acceptable. According to several reports, each year 2000-10,000 people die due to undetected hypoxemia. Now, we briefly describe the development of this device. In 1935, German doctor Karl Mathes created the primary two-wavelength ear O2 saturation meter with red and green filters (afterward red and infrared filters), the primary gadget to measure oxygen saturation. In 1940, Glenn Allan Millikan made the original oximeter. In 1943, Earl Wood introduced a pressure capsule to press blood out of the ear so as to get an absolute O2 saturation value when blood was readmitted. This concept is the same as today’s new pulse oximeter. But it is troublesome to execute this concept because of unstable photocells and light sources, that’s why this strategy is not utilized clinically. In 1972 Japanese bioengineers, Takuo Aoyagi and Michio Kishi to begin with created the oximeter at Japanese medical electronic equipment producer Nihon Kohden. They utilized the concept of the proportion of red light to infrared light absorption of pulsation components. In 1975, Specialist Susumu Nakajima and his partners first tested the device in patients. In 1977, Japanese company Minolta first commercialized fingertip pulse oximeter OXIMET MET-1471. It was commercialized in the US in 1980 by Biox.

In 1995, Signal Extraction Technology (SET) was introduced by Masimo which was able to measure accurately during patient motion and low perfusion. After that, the producer of pulse oximetry refined a new algorithmic rule, an algorithmic program to decrease a few false alarms throughout motions, but these failed to calculate when conditions were changed continuously throughout motion and low perfusion. Some challenges to using a pulse oximeter are still present. Not only Signal Extraction Technology (SET) but also the perfusion index was introduced by Masimo in 1995. Perfusion index is used to help the medics foretell illness severity and low superior vena cava flow in less-weight infants, and so on. Many papers which were published have contrast signal extraction technology to other pulse oximeter technologies and the results of SET are better. It also helps medics in improving patient results. In 2011, pulse oximetry was added by the US Secretary of Health and Human Services to the screening panel. In 2014, one study showed that 122,738 newborns used signal extraction technology and the positive results. In 2020, one retrospective study revealed that using pulse oximeter over 10 years with signal extraction technology, the number of deaths was zero, and patients were not hurt by opioid-induced respiratory depression. High-resolution beat oximetry (HPRO) has been refined uncommonly for in-home rest apnea screening additionally makes a difference in testing patients whose polysomnography execution is illogical. It measures the pulse rate and SpO2 in less time at 1-second intervals. It helps the
surgical patients to measure sleep-disordered breathing. For the deployment of previous development of pulse oximeter, we are able to measure SpO2 and heartbeat of different aged people accurately with minimum error in all respect. We have discussed development of our pulse oximeter module in different section of this paper.

III. Working Principle
In fingertip pulse oximeter, when we place our finger on the sensor it passes red light and IR light through the finger to estimate the pulse rate and oxygen saturation level in blood. Oxygen saturation tells us about the amount of oxygen present in blood.

![Fig. 1: Demonstration of Pulse Oximeter](image)

In our body oxygen is specifically carried by hemoglobin in blood. Hemoglobin with oxygen is called oxygenated blood and hemoglobin without oxygen is called deoxygenated blood. Oxygen saturation means the percentage of available hemoglobin that carries oxygen. Our pulse oximeter module consists of two LED and a photo detector. The LED emits two types of light, one is red light (wavelength of 660nm) and another one is infrared light (wavelength of 950nm). When we place our finger on the MAX30100 pulse oximeter sensor, the light passes through finger. The finger consumed some portion of the light and rest of the light outreaches to the light detector. For measuring heart beat only IR light is required but for measuring oxygen saturation both red light and IR light is required. When heart pumps, the oxygenated blood is increased and when heart calms the amount of oxygenated blood decreases. By measuring the time between increment and decrement of the oxygenated blood we are able to determine heartbeat rate.

More IR light is consumed by the oxygenated blood and it passes more red light and deoxygenated blood consumes more red light and passes more IR light. Market available pulse oximeter works out on the oxygen saturation by how much red light and IR light is absorbed. It is depending on the oxyhemoglobin and deoxyhemoglobin present in our blood. The proportionality of absorbed IR light with respect to absorbed red light determines the oxygen saturation level. The whole process is the main function of pulse oximeter sensor. The sensor records the absorption level for both the light and reserves the record in the buffer. Here, NodeMCU works as an interface. NodeMCU's D1&D2 pin are connected with SCL(Serial Clock) & SDA(Serial Data). In our module, we have externally connected two 4.7kΩ resistors to active SCL & SDA pin of NodeMCU. Here, MAX30100 sensor and OLED display are working one by one. When clock is on of MAX30100 sensor, then it takes the data and display is off at that time. Then, the display is on and it shows the output and MAX30100 sensor is off at that time. The clock's on and off work at high frequency beyond 50Hz. So, human eyes are unable to perceive this. It seems that MAX30100 sensor and OLED display are working simultaneously. We have uploaded the code in NodeMCU through Arduino-IDE. MAX30100_PulseOximeter.h library function of Arduino-IDE calculates the SpO2 and heartbeat data. After signal processing, analyzed data will be shown by the OLED display correctly. There are some factors like temperature, nail-polish, movement which can make an impact on the accuracy of this device.

IV. Flowchart
According to the flowchart, we put our fingertip at the top of the LED of the SpO2 Sensor. Here Fig 2 indicates the entire process of SpO2 content measurement. MAX30100 sensor acts as SpO2 sensor. It has two LEDs (light emitting diodes), one emits infrared light at a wavelength around 940 nm and the other one emits red light at a wavelength around 660 nm. How much of this chosen wavelengths are passing through the finger is measured by the photodetector.
Fig 2: Flow Chart of Optical Sensor

The user’s pulse rate and blood oxygen percentage will be shown on the OLED display. If the value of SpO₂ is 90%-100%, then the oxygen saturation is good, otherwise, the patient needs to take oxygen separately. To get the correct value we need to place our finger properly.

V. Circuit Diagram

Here Fig. 3 depicts the entire circuit diagram for measurement of SpO₂ and heartbeat of people.

![Circuit Diagram](image)

Fig. 3: Circuit Diagram

SCL pin of MAX30100 and OLED display is connected to D1 of nodeMCU. SDA pin of MAX30100 sensor and OLED display is connected to D2 pin of nodeMCU. Two 4.7kΩ resistors are used. One terminal of both the resistors are connected to Vcc and another terminals of the resistors are connected to D1 an D2 pin of nodeMCU respectively.

VI. Experimental Results

We have observed data for SpO₂ and heart beat for ten different persons. Data are given in Table 1.
Experimental Observation

Graphs of Observation Table 1 are depicted in Fig-4 to Fig-7. In comparison with other available pulse oximeter modules at market, our device measures SpO2 of the blood and heartbeat accurately. Our device shows better reading in all respect with minimum errors.

<table>
<thead>
<tr>
<th>Sl no.</th>
<th>Age (years)</th>
<th>Measured Pulse Oximeter Data</th>
<th>Reference Pulse Oximeter Data</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Heart Beat(bpm)</td>
<td>SpO2(%)</td>
</tr>
<tr>
<td>1.</td>
<td>21</td>
<td>90</td>
<td>97</td>
</tr>
<tr>
<td>2.</td>
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</tr>
</tbody>
</table>

Fig 4: graph of SpO2 values
Fig 5: graph of % error of SpO2

Fig 5 shows that percentage error variation of SpO₂ of different people within -1 to +1 limit.

Fig 6: Heart Beat Measurement

Fig 7: Percentage error Calculation for Heart Beat
Fig 7 shows that percentage error variation of heartbeat of different people within -1.5 to +1 limit.

VII. Conclusion

The main purpose of the pulse oximeter is to measure the oxygen saturation of arterial blood. In this paper, we tried to make a pulse oximeter at a comparatively low price with high sensitivity and accuracy. Here, we have measured accurately $\text{SpO}_2$ and heartbeat of different people. We are facing lot of difficulties while measuring the fluctuating Heart Beats. As per our module, considerable oxygen saturation level varies from 95% to 100% for children and adult. Underneath 95% are considered as deteriorated. The people whose ages are above 70 years oxygen saturation level stays around 95 percent.

VIII. Future Work

Our further purpose is to plan a pulse oximeter that can be utilized for ceaseless checking of oxygen saturation and heartbeat of fetal during its birth and labor period. These days, the foremost utilized fetal pulse oximeter is Cardiotocography. It measures the heartbeat of fetal and mother’s uterine contraction utilizing two distinctive transducers which ought to be laid against the mother’s abdomen. One of the transducers, i.e. the ultrasound transducer measures fetal heartbeat, and another one, i.e. pressure sensitive transducer measure the quality and frequency of uterine withdrawals. The pressure sensitive transducer is additionally known as a tocodynamometer. After the water has broken, during internal monitoring a small sensor is connected to the baby’s head through a thin catheter to continuously monitor the pulse oximetry and heart rate of the fetal. After we place the sensor using a gold plated spiral needle, the catheter is removed. All this components use a wired communication device which gives the mother complete freedom of movement during her labor.

References