International Journal of Advanced Health Science and Technology
Multidisciplinary : Rapid Review : Open Access Journal
eISSN: 2808-6422

RESEARCH ARTICLE

OPEN ACCESS

Manuscript received September 10, 2021; revised October 3, 2021; accepted October 4, 2021; date of publication November 20, 2021;
Digital Object Identifier (DOI): https://doi.org/10.35882/ijahst.v1i1.1

Design of Reflectance Pulse Oximeter and BPM using the Max30100 Sensor in Early Detection of Hypoxemia in Patients with Cardiovascular Disorders

Chiu-Hua Huang and Jia-Wei Guo
Department of Electrical Engineering, National Central University, Taoyuan, China
Corresponding author: Chiu-Hua Huang (e-mail:huangchiu2002@gmail.com).

ABSTRACT **Blood oxygen saturation meter is a tool used to monitor the state of oxygen saturation in the blood and also the patient's heart rate (BPM) and to assist in the physical assessment of the patient without going through blood gas analysis. Oxygen saturation measuring devices usually use the difference in the wavelengths of red and infrared led light that will be captured by the photodiode. The purpose of this research is to make a pulse oximeter equipped with a display of SPO2, BPM values and an additional SP02 signal. The design of this measuring instrument uses the MAX30100 sensor, the minimum system circuit of Arduino ATmega328p and OLED (Organic Light-Emitting Diode). Data from the MAX30100 sensor enters the I2C pin on the minimum Arduino system, then the microcontroller is processed to produce the percentage of SPO2 value, BPM value, and SPO2 signal which is then displayed on the OLED. The test is done by comparing the module with standard measuring instruments which produces the largest % error of 0.81% for Spo2 and 0.87% for BPM. The error presentation is obtained from factor measurements, if there is finger movement it will cause a large error. From the results obtained, the tool is still feasible to use because in the "Guidelines for Testing and Calibrating Medical Devices" Ministry of Health RI 2001, the maximum limit in the pulse oximeter error tolerance is for Spo2 1% and BPM 5%.**

INDEX TERMS Pulse Oximeter, Saturasi Oksigen, BPM, OLED

I. INTRODUCTION

Drug Blood and heart are organs that are very vital and have a very important role in a person's life. Blood is the body's transportation system that provides essential substances needed by the body. Among the substances contained in the blood also have an important role in meeting oxygen in the body[1] Oxygen is the main ingredient for human life[2] Monitoring of arterial oxygen saturation is essential for detecting hypoxemia[3] it can also be if the human body lacks or excess oxygen it will cause disease and other body system disorders[1]. The human body maintains a very precise level of oxygen in the bloodstream. the usual range is between 95 - 100[4]. While the heart is the most important part in the human body[5]. Therefore, it is important to follow up and monitor his condition[6]. The heart functions to pump blood throughout the body[7] if the heart is not functioning properly, then a person cannot live normally. One way to know the heart rate can be checked on the arteries. Heart rate usually refers to the amount of time needed by the heart beats per unit time, commonly known as BPM (Beat Per Minute)[8].

The number of a person's heart rate, usually displayed per minute is called beats per minute (BPM). Normal heart rate for adults (17 years – 60 years) ranges from 60 – 100 BPM[9] and oxygen levels in the blood in a person's body with a normal value of oxygen saturation only around 95%. For SPO2 values, oxygenated hemoglobin absorbs more infrared light, while deoxygenated hemoglobin absorbs more red light. (How to Design Peripheral Oxygen Saturation (SpO2) and Optical Heart Rate, 2015 in[10]. Continuous measurement of arterial blood oxygen saturation level and pulse rate is a very important parameter for people[11].

A pulse oximeter is a medical device that indirectly monitors the patient's oxygen saturation level in the blood non-invasively and continuously[12] Such monitoring provides very useful diagnostic information diagnostic[13]. This non-invasive method is convenient for measuring signs of fatal disease[14]. The pulse oximeter analyzes the arteries and ignores other tissues around the blood[15]. The arteries are the only things that pulse on the fingers. So, the oximeter is one method of using a tool to monitor the state of oxygen saturation in the blood (arterials) and also to monitor a person's heart rate. To assist in the physical assessment of the patient, without having to go through a blood test analysis[16]. Pulse oximeters are also often used for long-term heart rate monitoring[17].

Based on the literature search, this research was made by Elita Kartini in 2016. In this study the author made a Fingertip Pulse Oximeter Show PC (BPM) but the device is not yet portable or still requires voltage from the PLN grid so it cannot be carried anywhere[10]. In 2017 this research was also made by Septi Kharunnisa, in this study the author made a Pulse Oximeter (SpO2) based on IoT (Internet of Things) but the tool made is also not equipped with heart rate parameters and is still not portable or still requires voltage from the PLN grid[18]. In 2018 this research was also made by Isabella Ratna Mustika Dewi, in this study the author made SPO2 Portable but the tool made was also not equipped with heart rate parameters (heart rate).[19]. In 2019 this research was also made by I Putu Anna Andika, in this study the author made a Portable Pulse Oximeter but the tool made was not yet equipped with a signal display[20]. Results Based on the above problems, therefore the purpose of this study is to develop a reflective pulse oximeter using the MAX30100 sensor for high accuracy reading. The development of the tool that the author will make is to display the results in the form of numbers and also the display of the Spo2 signal which will be displayed on the OLED (Organic Light Emitting Diode).

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

This study used five subjects aged 21 and 22 years. Subjects were taken randomly and data collection was repeated 5 times.

1) MATERIAL AND TOOL

This study uses the MAX30100 sensor to monitor blood oxygen saturation (SPO2), heart rate (BPM) and SPO2 signal. 2 resistors are used for pull ups before entering the microcontroller. Atmega328p microcontroller IC is used to process the data read by the MAX30100 sensor. OLED 0.96 as a display to display the SPO2, BPM and SPO2 signal values. Uses 1 battery as power supply. for measuring instruments used multimeter. For comparison, use a Finger Pulse Oximeter with the brand (JN Finger Clip Pulse Oximeter).

2) EXPERIMENT

In this study, researchers measured the spo2 value, heart rate and spo2 signal from randomly selected respondents and the results were compared with the standard.

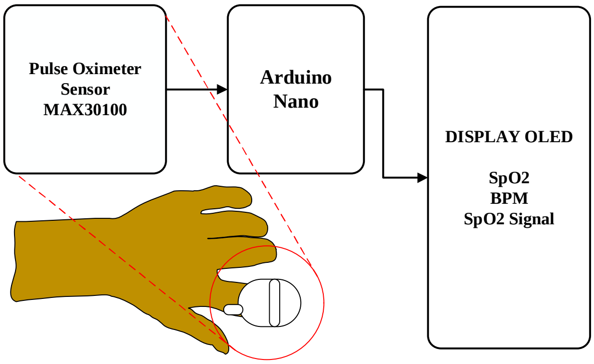

FIGURE 1. Diagram Block

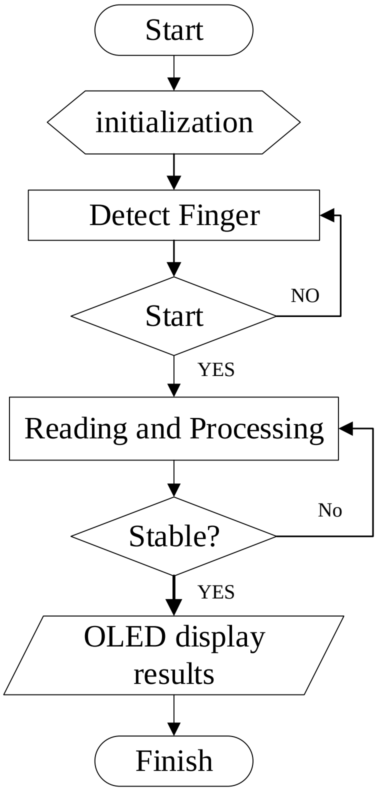

FIGURE 2. The Flowchart of Flowrate

B. THE DIAGRAM BLOCK

When the power button is pressed then all circuits will get a voltage including the sensor, if the sensor has received a voltage, it means the sensor is in a state of ready or standby. Place your index finger over the sensor. After that the sensor will start working and start processing data then processed by the microcontroller. The identified data in the form of oxygen saturation percentage and heart rate and Spo2 signal will be output or displayed on the OLED screen as shown in FIGURE 1.

C. THE FLOWCHART

First, when the device is started, it is ready, then the OLED will start initializing. Then place the index finger on the sensor then. Then the sensor will start reading and the data obtained is then processed in an Arduino circuit which then the results of the microcontroller processing will be displayed on the OLED in the form of numbers and also Spo2 signals. When finished press the reset button, then the tool will return to the initial state (**FIGURE 2**).

D. ANALOG CIRCUIT

FIGURE 3 This circuit consists of several important components, namely using the ATmega328 ic for the main control, then there is a reset circuit to reset it. and lastly there is a crystal circuit, because this crystal is important in a microcontroller circuit used for frequency generation.

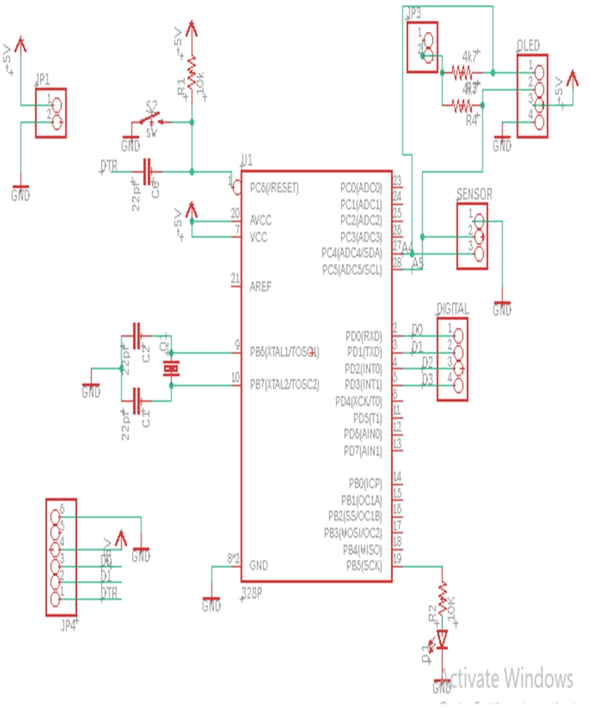

FIGURE 3. Circuit Of Microcontroler

The MAX30100 sensor has a digital value output. The value released is the ADC value that has been processed by the MAX30100 Sensor itself which is then processed by the microcontroller. before entering the microcontroller, the value of the sensor is given a pull-up resistor.

III. RESULT

In this study, the Oximeter was tested by comparing it with a standard measuring instrument. The results show that the value of the oximeter with the value of a standard measuring instrument is feasible to use (**FIGURE 4**).

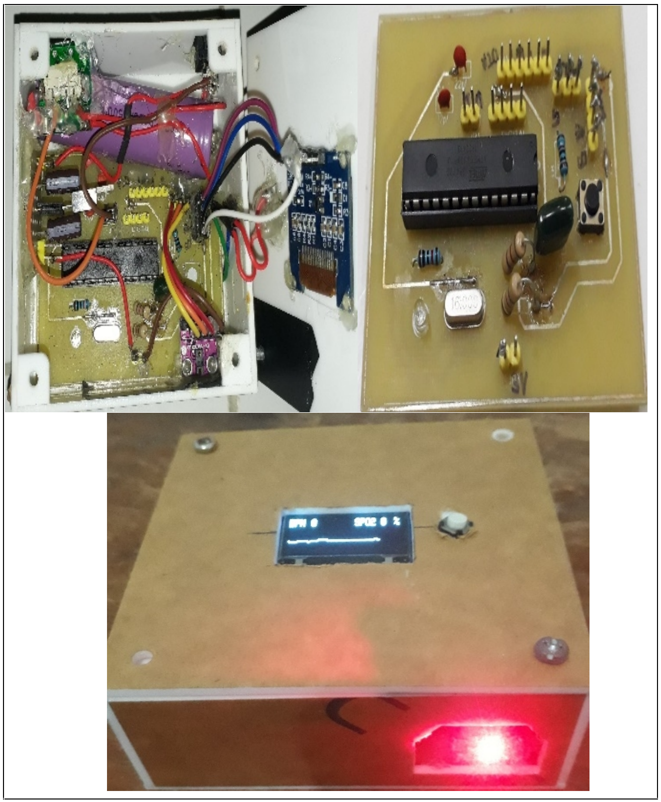

FIGURE 4. Result Of Microcontroler Circuit Design

The program below is a program for OLED and initialization of the MAX30100 sensor in order to communicate with the microcontroller. OLED with 115200 baudrate and sensor using 115200 baudrate, and also for sensor library.

Pseudocode: 1. Program Initialization.

```
SETUP (){
Serial.begin(115200);
if (!display.begin())
display.setTextSize(1);
display.setTextColor(WHITE);
display.setCursor(0, 0);
display.clearDisplay();

IF (!pox.begin()){
for(;;);
}
 IF (!sensor.begin()){
for(;;);
}
pox.setIRLedCurrent(MAX30100_LED_CURR_
7_6MA);
pox.setOnBeatDetectedCallback(onBeatDetected)
;
sensor.setMode(MAX30100_MODE_SPO2_HR)
;
```

```
sensor.setLedsCurrent(IR_LED_CURRENT,
RED_LED_CURRENT);
sensor.setLedsPulseWidth(PULSE_WIDTH);
sensor.setSamplingRate(SAMPLING_RATE);
sensor.setHighresModeEnabled(HIGHRES_MODE);
}
```

The program below is used to search for signal data taken from ir&red, then processed to find the upper and lower limits. And also to stabilize the signal.

Pseudocode: 2. Stable Data Function and Signal Difference.

```
LOOP () {
uint16_t ir, red;
pox.update();
sensor.update();
//=========Mencari batas atas dan bawah plotter=========//
IF(x>127) {
display.clearDisplay();
x=0;
lastx=x;}
IF (z > 30) {
z = 0;
lastMax = rollingMax;
lastMin = rollingMin;
rollingMin = 40000;
rollingMax = 60000;}

//=======Mencari update data plotter======
IF (sensor.getRawValues(&ir, &red)) {
Serial.print('\t');
Serial.println(red*30);
int y=40-(map(red*20, lastMin, lastMax, 20, 60));
display.drawLine(lastx,lasty,x,y,WHITE);
IF (red*10 > rollingMax){
rollingMax = red*20;}
 IF (red*10 < rollingMin){
rollingMin = red*20;}
lasty=y;
lastx=x;
}
```

.

The below program is enabled for stable data retrieval. Usually, the BPM value below 60 is still unstable and above 110. Likewise, when Spo2 is more than 100 it is unstable, then it is enabled to reset 0. Then the value will be displayed on the OLED.

Pseudocode: 3. stable data function for spo2 and bpm nilai values

```
//=======Mencari update data BPM======
IF (millis() - tsLastReport >
REPORTING_PERIOD_MS){
    BPM=round(pox.getHeartRate());
    IF ((BPM<60)|(BPM>110))
    Serial.print("spo2:");
     Serial.print(pox.getSpO2());
     Serial.println("\n");
     display.fillRect(0, 0, 128, 10 , BLACK);
     display.setCursor(25,0);
      display.println(BPM);
      Serial.println(BPM);

   //=======Mencari update data SPO2======
    spo2=(pox.getSpO2());
   delay(1);
   IF (spo2>100){
   spo2=0;}
   ELSE{
   spo=spo2;  }
     tsLastReport = millis(); }
```

This spo2 data was taken 5 times, measured using a module and also a comparison with the brand (FIGURE 5) (JN Finger Clip Pulse Oximeter).

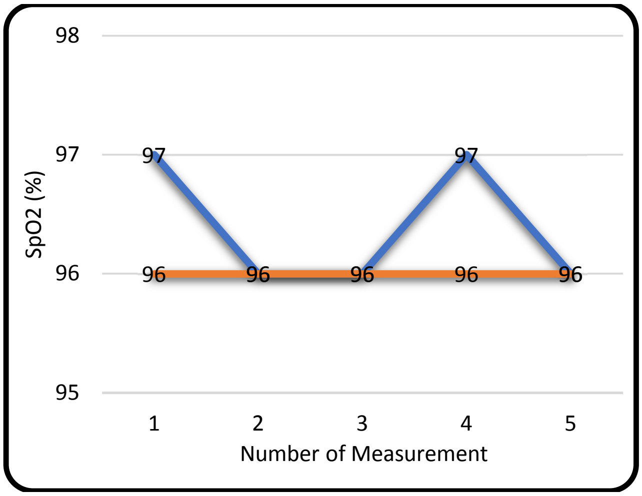

FIGURE 5. The result of the reading beetwen the comparison with the module (SPO2). Blue line and orange line are the SpO2 generated from design and calibrator, respectively.

This bpm data was taken 5 times, measured using a module and also a comparison with the brand (JN Finger Clip Pulse Oximeter) (FIGURE 6).

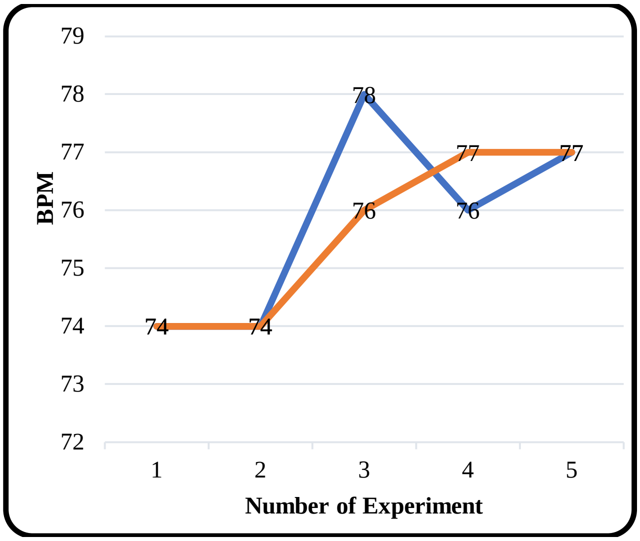

FIGURE 6. The result of the reading between the comparison with the module (BPM). Blue line and orange line are the BPM generated from design and calibrator, respectively.

TABLE 1.
The Error Of Measurement For The Spo2 Parameter Between The Design And Standard Unit (Pulse Oximetry).

No	Subject	Error (%)
1	P1	0,81
2	P2	0,41
3	P3	0,41
4	P4	0,62
5	P5	0,22

TABLE 2.
The Error Of Measurement For The Bpm Parameter Between The Design And Standard Unit (Pulse Oximetry).

No	Subject	Error (%)
1	P1	0,46
2	P2	0,87
3	P3	0,26
4	P4	0,22
5	P5	0,22

TABLE 1 and TABLE 2 show the error of measurement for SpO2 and BPM, respectively which is compare between design and standard.

IV. DISCUSSION

In this study, the researchers made a device consisting of a MAX30100 sensor, OLED, and also the minimum circuit of the ATmega328p system. In this circuit consists of several circuits, namely a series of pull up resistors, reset circuits, crystal circuits. For the measurement of SpO2 and heart rate values, 5 adult respondents were chosen randomly and the results were compared with standard calibrated measuring instruments. The spo2 parameter produces an error value of 0.81% and the beat per minute (BPM) parameter produces an error value of 0.87%. From the measurement results, this tool can work well and is feasible to use. However, the weakness of this module is when measuring if there is finger movement, it will cause a large error value.

V. CONCLUSION

After the Reflectance Pulse Oximeter module using the MAX30100 Sensor with a minimal system using ATmega328p displayed on the OLED. In testing the tool, the spo2 parameter error is 0.81% and the beat per minute (BPM) parameter produces an error value of 0.87%. From the results of the measurement tools that have been carried out, it can be said that when taking measurements if there is finger movement it will cause a large error value, and the use of good finger placement on the sensor to minimize finger movement corrects the error results.

REFERENCES

[1] U. Salamah and K. Oksigen, "Rancang Bangun Pulse Oximeter Menggunakan Arduino Sebagai Deteksi Kejenuhan Oksigen dalam Darah," vol. 06, no. 02, 2016.
[2] T. Guo, Z. Cao, Z. Zhang, D. Li, and M. Yu, "Reflective oxygen saturation monitoring at hypothenar and its validation by human hypoxia experiment," *Biomed. Eng. Online*, vol. 14, no. 1, pp. 1–19, 2015, doi: 10.1186/s12938-015-0071-z.
[3] F. Magadán Ferrera, F. J. Ferrero, C. Blanco, J. C. Viera, MGVega, and J. R. Blanco, "Design of a low-cost instrument for pulse oximetry," *Conf. Rec. - IEEE Instrum. Meas. Technol. Conf.*, no. April, pp. 573–577, 2006, doi: 10.1109/IMTC.2006.235185.
[4] P. M. Mohan, V. Nagarajan, and A. A. Nisha, "A frame work to estimate heart rate and arterial oxygen saturation (Spo2)," *Proc. 2017 IEEE Int. Conf. Commun. Signal Process. ICCSP 2017*, vol. 2018-Janua, pp. 1645–1648, 2018, doi: 10.1109/ICCSP.2017.8286669.
[5] M. A. Zaltum, M. S. Ahmad, A. Joret, and M. M. Abdul, "Design and Development of a portable Pulse Oximetry system," *Pulse*, vol. 05, no. 03, pp. 37–44, 2010.
[6] K. Kalyan, V. K. Chugh, and C. S. Anoop, "Non-invasive heart rate monitoring system using giant magneto resistance sensor," *Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS*, vol. 2016-Octob, pp. 4873–4876, 2016, doi: 10.1109/EMBC.2016.7591819.
[7] Y. Kong and K. Chon, "Heart Rate Estimation using PPG signal during Treadmill Exercise," *Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS*, pp. 3253–3256, 2019, doi: 10.1109/EMBC.2019.8857633.
[8] G. W. Wohingati and A. Subari, "Alat Pengukur Detak Jantung Menggunakan Pulsesensor Berbasis Arduino Uno R3 Yang Diintegrasikan Dengan Bluetooth," *J. Gema Teknol.*, vol. 17, no. 2, pp. 65–71, 2013.
[9] J. Hart, "Normal resting pulse rate ranges," *J. Nurs. Educ. Pract.*, vol. 5, no. 8, pp. 95–98, 2015, doi: 10.5430/jnep.v5n8p95.
[10] E. Kartini, H. Torib, and M. P. Assalim, "Fingerstip Pulse Oxymeter Tampil Pc (Bpm)," pp. 1–8, 2015.
[11] R. R, S. P, and S. P, "Design and Development of Miniaturized Pulse Oximeter for Continuous Spo2 and HR Monitoring with Wireless Technology," *Int. J. New Technol. Res.*, vol. 1, no. 1, p. 263706, 2015.
[12] B. Sangeeta and S. Laxmi, "A Real Time Analysis of PPG Signal for Measurement of SpO2 and Pulse Rate," *Int. J. Comput. Appl.*, vol. 36, no. 11, pp. 45–50, 2011.
[13] S. Sarkar, A. K. Bhoi, and G. Savita, "Fingertip Pulse Wave (PPG signal) Analysis and Heart Rate Detection Fingertip Pulse Wave (PPG signal) Analysis and Heart Rate Detection," no. February, 2015.

[14] D. Yang, J. Zhu, and P. Zhu, "SpO2 and heart rate measurement with wearable watch based on PPG," *IET Conf. Publ.*, vol. 2015, no. CP680, 2015, doi: 10.1049/cp.2015.0784.
[15] H. Kisch-Wedel, P. Bernreuter, G. Kemming, M. Albert, and B. Zwissler, "Does the estimation of light attenuation in tissue increase the accuracy of reflectance pulse oximetry at low oxygen saturations in vivo?," *IEEE Trans. Biomed. Eng.*, vol. 56, no. 9, pp. 2271–2279, 2009, doi: 10.1109/TBME.2009.2019629.
[16] Putra, A. A., Kemalasari, P. S., & Paulus, S. W., "Rancang Bangun Pulse Oximetry Digital Berbasis Mikrokontroller," Publikasi ilmiah 2006.
[17] Y. F. Chen, J. S. Shieh, S. Z. Fan, W. T. Chiang, M. F. Abbod, and Q. Liu, "Analyzing heart rate variability using a photoplethysmographic signal measuring system," *MESA 2016 - 12th IEEE/ASME Int. Conf. Mechatron. Embed. Syst. Appl. - Conf. Proc.*, pp. 1–6, 2016, doi: 10.1109/MESA.2016.7587195.
[18] S. Khairunnisa, I. D. Gede, H. Wisana, I. Priyambada, C. Nugraha, and J. T. Elektromedik, "Rancang Bangun Pulse Oximeter Berbasis Iot (Internet of Things)," p. 9, 2018..
[] I Putu Anna Andika, Triana Rahmawati, and M. Ridha Mak'ruf, "Pulse Oximeter Portable," *J. Electron. Electromed. Eng. Med. Informatics*, vol. 1, no. 1, pp. 28–32, 2019, doi: 10.35882/jeeemi.v1i1.6.

Link skematik dan program:

https://drive.google.com/drive/folders/1lUShcI6e5c3Zqiawx1TRpcmo977w5GJ1?usp=sharing