# Heart rate sensor with IoT features

*Nurul 'Ain* Amirrudin[1], *Muhammad* Nazreen[1], *Mohd Amir* Syafiq[1], *Muhammad Hafiz* Irwan[1], *Fajar Aqhari* Bolang[1], *Achmad Tegar* Andika Putra[1], *Aizan* Ariffin[1], *Khairul Huda* Yusof[1], and *Norazliani* Md. Sapari[2*]

[1]Faculty of Information Science & Engineering, Management & Science University, Shah Alam, Selangor, Malaysia.
[2]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81300 Johor Bharu, Malaysia

**Abstract.** This paper describes the working of a heartbeat sensor project aimed at creating an internet-enabled heart rate monitoring device, combining the ESP32 microcontroller, MAX30102 pulse oximeter sensor, and OLED display. The device transmits real-time data to a webpage, allowing users to monitor their heart rate conveniently. Challenges included securing a stable internet connection and optimizing power consumption. Potential applications range from remote patient monitoring to fitness tracking, promoting healthier lifestyles. The project demonstrated the convergence of IoT and health monitoring technologies. Plans involve refining the device's capabilities and enhancing user experience.

## 1 Introduction

Heart rate monitoring plays a vital role in healthcare and fitness, providing valuable insights into cardiovascular health and physical performance. With the increasing interest in personal health tracking and the prevalence of lifestyle-related health issues, there is a growing demand for accessible and accurate heart rate monitoring devices. This project aims to develop a Heart Rate Sensor with IoT Features, offering an affordable and user-friendly solution for continuous heart rate monitoring.

Recent studies have demonstrated the significance of heart rate sensors in various applications. For instance, the author in [1] shows these sensors offer valuable insights into cardiovascular health and physical performance, enabling individuals to gain a better understanding of their heart rate and heart rate variability (HRV) patterns which is particularly valuable for assessing stress levels, physical exertion during exercise, and detecting potential cardiac abnormalities. Additionally, the author in [2] showcased that through diverse sensing modalities and signal processing methods, these sensors offer non-invasive and continuous monitoring of heart health. They empower healthcare professionals and individuals to gain valuable insights, track cardiovascular changes in real time, and potentially identify early signs of cardiac issues. The discussion of extramural applications and future developments underscores their versatility, making heart rate sensors invaluable tools for personalized health management and medical advancements. These findings underscore the importance of developing efficient and reliable heart rate monitoring devices, such as the proposed Heart Rate Sensor with IoT Features, to empower individuals in managing their cardiovascular health.

The primary aim of this project is to develop a comprehensive and user-friendly pulse oximetry system using the MAX30102 pulse oximeter sensor and microcontroller ESP32. The system's main goal is to enable real-time monitoring and analysis of the user's heart rate and blood oxygen saturation levels. The output will be displayed on an OLED screen for immediate feedback to the user. Additionally, the system will leverage IoT technology to connect to a client's PC or smartphone, facilitating remote monitoring and data visualization. By achieving this objective, the project seeks to empower individuals with a convenient and efficient tool for monitoring vital signs, promoting proactive health management, and potentially enabling early detection of health issues, leading to improved overall well-being.

ESP32, a widely used microcontroller board, has gained popularity for developing heart rate sensors due to its versatility, cost-effectiveness, and ease of implementation. ESP32-based heart rate sensors employ various measurement techniques, including photoplethysmography (PPG), electrocardiography (ECG), and pulse sensors. PPG sensors use light absorption to measure blood volume changes, while ECG sensors detect electrical signals produced by the heart. Pulse sensors measure heart rate from the fingertip or earlobe. Understanding the pros and cons of each technique is crucial for selecting the most suitable approach for specific applications [3, 5].

To obtain accurate heart rate readings, researchers have applied signal processing and filtering algorithms to ESP32 heart rate sensor data. Digital signal processing techniques, such as noise reduction, baseline wander removal, and peak detection, are commonly used to improve signal quality and reduce artefacts [6]. Comparative studies evaluating different algorithms' effectiveness would be valuable in optimizing sensor performance.

Moreover, ESP32's capability for wireless communication allows heart rate data to be transmitted to external devices, such as smartphones or computers. Researchers have explored various communication protocols like Bluetooth, Wi-Fi, and Zigbee for real-time

* Corresponding author: norazliani.ms@utm.my

monitoring and data logging. Moreover, visualization techniques have been employed to present heart rate data graphically, making it more accessible for users to interpret and track their health status [7].

Previous research made by Andreas Faulhaber, made a prototype low-cost pulse oximeter kit using an Arduino with an OLED for display. Andreas also uses the Arduino IDE line plot to output the pulse rate as output [8].

The accuracy of heart rate measurements is critical for both medical and fitness-related applications. Researchers have conducted studies to validate the accuracy of ESP32-based heart rate sensors against medical-grade devices. Calibration techniques have been proposed to improve accuracy and mitigate individual differences, providing reliable heart rate data [9].

ESP32 offers a flexible platform for heart rate sensors, enabling various measurement techniques and applications, including wearable monitoring and wireless data transmission. Researchers continue to improve the accuracy, energy efficiency, and usability of these sensors, paving the way for enhanced healthcare and fitness tracking solutions. The versatility and cost-effectiveness of ESP32 make it an attractive choice for developing heart rate sensors and advancing remote healthcare and fitness monitoring technologies.

## 2 Methodology

Fig. 1 illustrates the steps of a heart rate monitoring system using the MAX30102 sensor and ESP32 microcontroller.

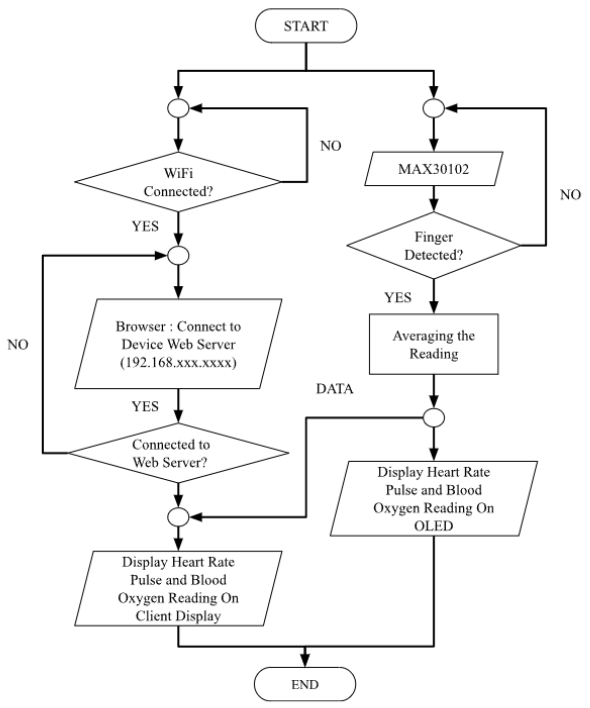


**Fig. 1.** Flowchart of The Proposed System

When the power is switched on, the system waits for the red light to indicate readiness. Once ready, the user places their finger on the sensor, allowing the MAX30102 to detect the heart rate reading. The sensor sends this data to the ESP32 microcontroller, which displays the reading on an OLED screen. Additionally, the ESP32 is connected to WiFi, enabling it to transmit data to a web browser via the http socket [9]. The heart rate data is then shown on the web browser, providing real-time heart rate monitoring and accessibility to the user or healthcare professionals for further analysis and tracking.

Fig. 2 represents a system designed for real-time pulse oximetry and data visualization. The MAX30102 pulse oximeter sensor serves as the input, capturing the user's heart rate and blood oxygen saturation levels. The microcontroller ESP32 processes the data received from the sensor, performing calculations and analysis. The output is displayed on an OLED screen, providing immediate feedback to the user. Additionally, the system is connected to a client PC or smartphone via WiFi, enabling remote monitoring and data visualization for healthcare professionals or the users themselves.

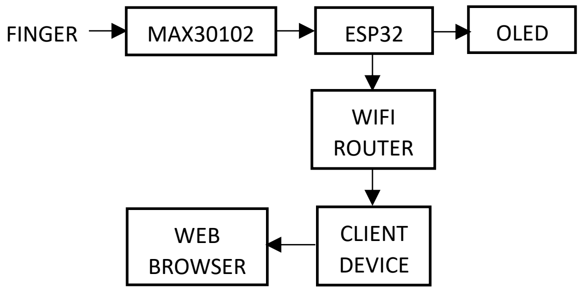


**Fig. 2.** Block Diagram of The System

Fig. 3 shows the circuit diagram of the heart rate monitoring system. The MAX30102 pulse oximeter sensor and OLED display are connected to ESP32. The heartbeat sensor and OLED have four wires. One each for the ground connection, the power connection, the SCL connection, and the SDA connection. The Serial Data (SDA) pin is used for data transmission and the Serial Clock (SCL) pin carries the clock signal. Table 1 below shows the components used to build the prototype.

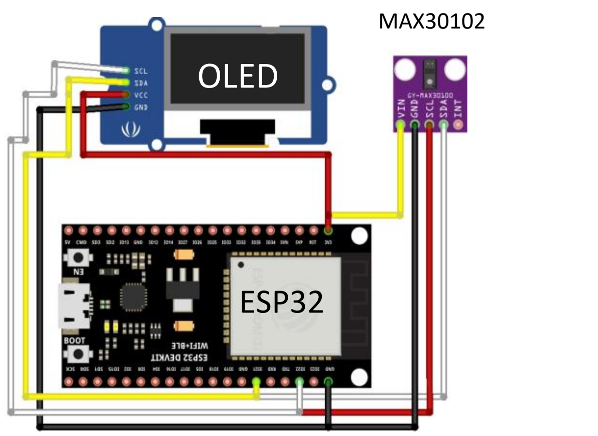


**Fig. 3.** The Circuit Diagram of The Heart Rate Monitoring System

**Table 1.** Prototype components

| ITEM NAME | QUANTITY |
|---|---|
| OLED | 1 |
| Heartbeat sensor (MAX30102) | 1 |
| Battery holder (4 x AA slots) | 1 |
| Battery AA 1.5 V | 4 |
| Glue gun kit | 1 |
| Soldering kit | 1 |
| ESP32 (microcontroller) | 1 |
| Project casing | 1 |
| 12 V AC - DC power supply | 1 |
| Female power jack | 1 |
| Buck converter step down dc to dc | 1 |

## 3 RESULT AND ANALYSIS

The heart rate sensor project with IoT features has been successfully implemented and is functioning as expected as shown in Fig.4. The use of the MAX30102 sensor has enabled accurate heart rate measurement. The project successfully determines the user's heart rate and displays it on an OLED screen, allowing for real-time monitoring. One of the significant achievements of the project is the incorporation of IoT capabilities, enabling users to access heart rate data remotely via a web page on both PCs and mobile devices. This feature enhances the project's usability and convenience, as users can monitor their heart rate data from anywhere with an internet connection. The integration of the OLED screen provides an additional visual display for users to see the waveforms of the heart rate measurement, offering a more comprehensive understanding of their heart rate patterns. During the testing phase, the project showed robust performance, producing consistent and reliable heart rate readings. The IoT feature was also evaluated to ensure data transmission security and privacy, and appropriate measures were taken to safeguard user information. Overall, the heart rate sensor project with IoT features has achieved its objectives and offers a practical and user-friendly solution for heart rate monitoring as illustrated in Fig. 5, 6 and 7. The successful implementation of this project opens possibilities for further enhancements and applications in the field of healthcare and wearable technology.

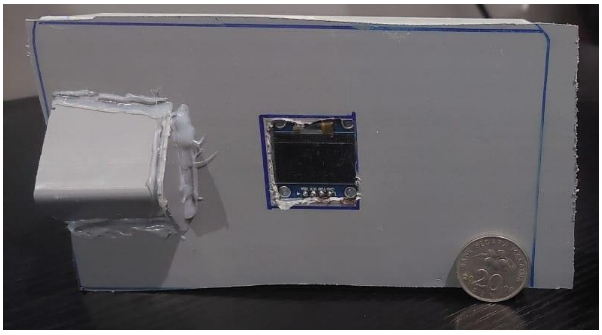

**Fig. 4.** Top View of The Developed Prototype

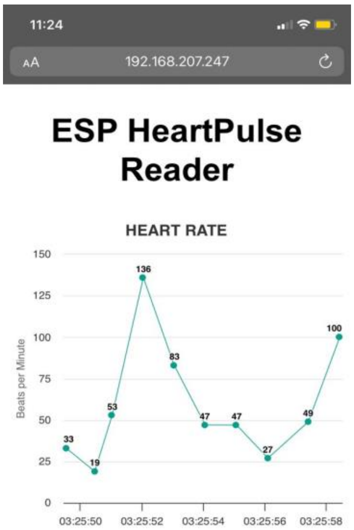


**Fig. 5.** Result of BPM from a web browser via smartphone

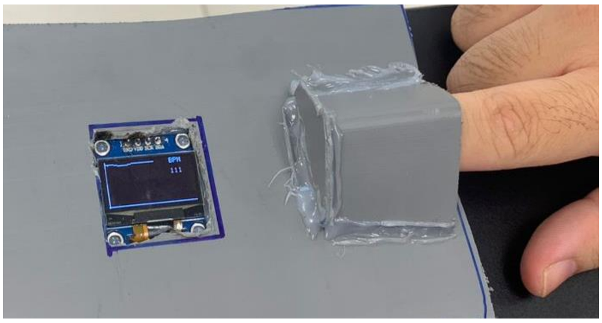

**Fig. 6.** Prototype reading pulse

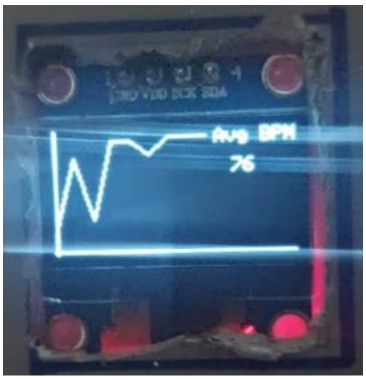


**Fig. 7.** Result of BPM on OLED

 https://doi.org/10.1051/e3sconf/202451605002

The MAX30102 and commercial oximeters are both devices used for measuring blood oxygen saturation levels (SpO2) and heart rate. While the commercial oximeter is a dedicated medical-grade device, the MAX30102 is a sensor module often integrated into wearable devices for fitness and health monitoring. Let's compare the two based on various aspects.

In Table 2, there are visible differences in component and feature availability. In Andreas' research, the IoT was not implemented but combined multiple components to become an oximeter sensor. To read the heart pulse rate, the sensor TAOS TSL230ARD is used with the LTE3371 LED [8]. Table 3 presents a difference between MAX30102 and commercial oximeter.

**Table 2.** Comparison between the current project and the previous paper

| | Project Prototype | Andreas Faulhaber project |
|---|---|---|
| **Microcontroller** | ESP32 | Arduino Mega |
| **Sensor** | MAX30102 | TAOS TSL230ARD with LTE3371 LED |
| **IoT** | Yes (WiFi-based) | No |
| **Display** | Yes (OLED + Web Browser + Arduino IDE) | Yes (OLED + Arduino IDE) |
| **Power Supply** | Battery and 5V USB-B input | Battery and 5V USB-B input |

**Table 3.** Comparison between MAX30102 and commercial oximeter

| | MAX30102 | Commercial Oximeters |
|---|---|---|
| **Accuracy and Precision** | MEDIUM | HIGH |
| **Application** | Can be implemented as wearable devices | Hospitals and clinics |
| **Data Presentation** | Raw data that can be interpreted however the user wants. | User-friendly interface |
| **Data Connectivity** | User choice of connectivity (many) | Bluetooth to smartphones, manually jot down the data, |
| **Power Consumption** | Low-powered due to its ability to integrate with microcontrollers | High-powered for hospital use, Low powered for consumer use |

Random Data Example:

Assuming a hypothetical scenario, let's consider the following random data readings for both devices:

Commercial Oximeter:
- SpO2: 97%
- Heart Rate: 78 bpm

MAX30102 (Wearable Device):
- Red Signal Value: 80 bpm (unstable)

Table 4 presents the differences between the proposed prototype and the commercial product. In the market product research and analysis, it has been determined that it has a few features. Those who have it can calculate the percentage of oxygen, percentage of PI (perfusion index) and pulse rate beat per minute. It can display these 3 and the waveform is displayed on the small display as well. It is not IOT-able.

**Table 4.** The difference of the prototype and commercial product

| | Prototype | Commercial |
|---|---|---|
| **How long it takes to measure** | 10-15 seconds | 10 seconds |
| **What does it display** | BPM line graph and value, Oximeter value, BPM and Oximeter on browser (IOT) | Percentage of Oxygen, Perfusion Index percentage, Pulse rate beat per minute and waveform |
| **IOT-able** | YES | No |
| **Battery** | 4* AA battery, 5V 1A to 3A USB-B PSU | AAA battery |

The project aim is to develop a heart rate monitoring device capable of sending real-time data to a webpage using WiFi. The components utilized in this system included the ESP32 microcontroller, the MAX30102 pulse oximeter sensor, and an OLED display. Through successful integration, the device can wirelessly transmit heart rate data to users' smartphones or PCs. The heart rate sensor prototype creates a signal by utilizing the MAX30102 sensor, which is a pulse oximeter and heart rate sensor integrated circuit. This sensor employs photoplethysmography (PPG) to detect changes in blood volume in tissues, specifically in the fingertip or earlobe in this case. The PPG sensor emits light into the skin, and the light is absorbed by blood vessels, depending on the blood volume changes due to the heart's pulsations. The reflected or transmitted light is then measured by the sensor, resulting in a waveform signal. This waveform signal represents the varying blood volume in the measured area, which correlates with the heart's beating and, therefore, provides heart rate information. By analyzing the PPG waveform, the heart rate can be accurately determined and displayed on the OLED screen or transmitted to the IoT-enabled webpage for remote monitoring.

## 4 Conclusion

In conclusion, health screening devices are having an increase in demand. This is because it evolves together with modern technology. This heart rate sensor comes with features that can detect the heartbeat rate of the user instantly with the use of a sensor and with the help of ESP32 which acts as the microcontroller in this system. This will help users to receive their heartbeat rate instantly and will prevent further troubles if the readings of the heartbeat rate show abnormality as immediate actions can be taken.

The wireless heart rate monitoring device, comprising the ESP32 microcontroller, MAX30102 pulse oximeter sensor, and OLED display, successfully achieved its goal of transmitting heart rate data to a webpage through WiFi. The device offers valuable applications in various fields, including healthcare, fitness, and wellness. The project demonstrated the potential of merging IoT and health monitoring technologies, fostering opportunities for further advancements in the field of remote health monitoring.

The authors would like to acknowledge the financial support of this research. This work was funded by Universiti Teknologi Malaysia (UTM) under UTM Fundamental Research (UTMFR), Vot number: Q.J130000.3851.21H87

## References

1. N. Alugubelli, H. Abuissa, and A. Roka, Wearable Devices for Remote Monitoring of Heart Rate and Heart Rate Variability—What We Know and What Is Coming. **22**, 8903–8903 (2022)
2. A. Galli, R.J.H. Montree, S. Que, E. Peri, and Rik Vullings, An Overview of the Sensors for Heart Rate Monitoring Used in Extramural Applications. **22**, 4035–4035 (2022)
3. A. Bueno, K. Nonaka, and S. Sales, Hybrid Interrogation System for Distributed Fiber Strain Sensors and Point Temperature Sensors Based on Pulse Correlation and FBGs (2009)
4. Q. Liu and X. Sun, Research of Web Real-Time Communication Based on Web Socket. International Journal of Communications. Network and System Sciences. **5**, 797-801 (2012)
5. Y. Yamagata, T. Kumagai, Y. Sai, Y. Uchida, and K. Imai, A sensor powered by pulsed light (for gas density of GIS) (2002)
6. G. Horak, V. Bilas, and D. Vasic, Noise Analysis of the Pulse-Width Modulator for Quasi-Digital Sensors (2008)
7. Md. Asaduzzaman Miah, Mir Hussain Kabir, S. Rahman, and M. A. H. Akhand, Continuous heart rate and body temperature monitoring system using Arduino UNO and Android device. (2015)
8. Faulhaber, Andreas. Design and implementation of a low cost pulse oximeter kit for research and educational purposes (2016) 10.13140/RG.2.2.20079.02727/1.
9. Bassett DR Jr, Rowlands A, Trost SG. Calibration and validation of wearable monitors. Med Sci Sports Exerc (2012)