ESP32 - Based Pulse Oximeter

Matúš Dikoš, Michal Kubaščík, Veronika Olešnaníková, Peter Ševčík

***Abstract*—**The project involved developing a device for monitoring pulse and blood oxygen levels using an ESP32 microcontroller and various sensors. The device measures these physiological parameters and transmits the collected data via Wi-Fi to a mobile device. This straightforward solution demonstrates the practical application of available technologies for creating a simple health-monitoring tool.

***Keywords*—**blood oxygen levels, ESP32, health monitoring, microcontroller-based systems, wireless data transmission

I. INTRODUCTION

The project aimed to develop a simple, compact and cost-effective device for monitoring pulse and blood oxygen levels. The design prioritized portability and ease of use, resulting in a small, wireless solution built using the ESP32-S2 Mini microcontroller and the MAX30102 sensor. This combination enabled real-time data collection and transmission via Wi-Fi to a mobile device, providing users with immediate access to health metrics in an intuitive way.

The project illustrates the versatility of modern microcontrollers and sensors in addressing everyday health-monitoring needs. By leveraging accessible and cost-effective components, the device demonstrates how basic biomedical measurements can be integrated into a lightweight and user-friendly tool. The ability to operate without reliance on external networks further enhances its functionality, making it suitable for a variety of applications, such as personal health tracking, educational demonstrations, or prototyping for more advanced medical devices.

This approach highlights the potential for such technologies to make health monitoring more accessible and practical in various contexts, from individual use at home to projects within academic settings. The simplicity of the design ensures that the device remains functional while still being easy to build, modify, and expand for future needs.

II. PURPOSE OF THE DEVICE

The design prioritized portability and ease of use, resulting in a small, wireless solution built using the ESP32-S2 Mini microcontroller and the MAX30102 sensor. This combination enabled real-time data collection and transmission via Wi-Fi to a mobile device, providing users with immediate access to health metrics in an intuitive way.

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III. Building and implementing the device

A. ESP32-S2 MINI

For this implementation, we used the ESP32-S2 Mini microcontroller as the central unit for both data collection and communication. The ESP32-S2 Mini is powered by a 32-bit single-core processor running at up to 240 MHz, and features integrated Wi-Fi capabilities, which are crucial for wireless data transmission. With 4 MB of flash memory, the microcontroller provides sufficient storage for handling and processing sensor data in real-time.

In this project, the ESP32-S2 Mini was responsible not only for transmitting pulse and blood oxygen level data over Wi-Fi but also for collecting and evaluating the data from the MAX30102 sensor. The microcontroller processes the raw sensor readings, applies necessary calculations, and prepares the data for transmission. This dual functionality - acting as both a data acquisition system and a communication hub-enabled the development of an efficient and compact health-monitoring device. The low power consumption and small form factor of the ESP32-S2 Mini made it an ideal choice for the portable device, allowing it to seamlessly collect, process, and transmit data in real-time.

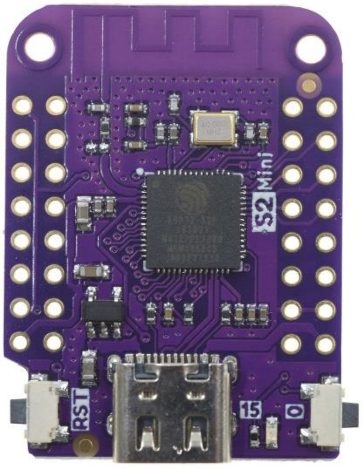

Fig. 1 Development board ESP32-S2FN4R2 developed by Wemos.

B. MAX30102

The sensor is made up of two light-emitting diodes (LEDs), one emitting monochromatic red light at a wavelength of 660 nm and the other emitting infrared light at 940 nm. These specific wavelengths are selected because oxygenated and deoxygenated hemoglobin have distinct absorption characteristics at these wavelengths. As demonstrated in the graph below, oxygenated hemoglobin (HbO2) and deoxygenated hemoglobin (Hb) exhibit noticeable differences in their absorption of red and infrared light.

The sensor consists of two main components: the emitting diodes and a photodetector. The LEDs emit light, which passes through the finger when placed steadily on the sensor. Oxygenated blood absorbs some of the light, while the rest is reflected through the finger and detected by the photodetector. The photodetector captures this reflected light, and the data is then processed and read by a microcontroller to determine the blood oxygen levels.

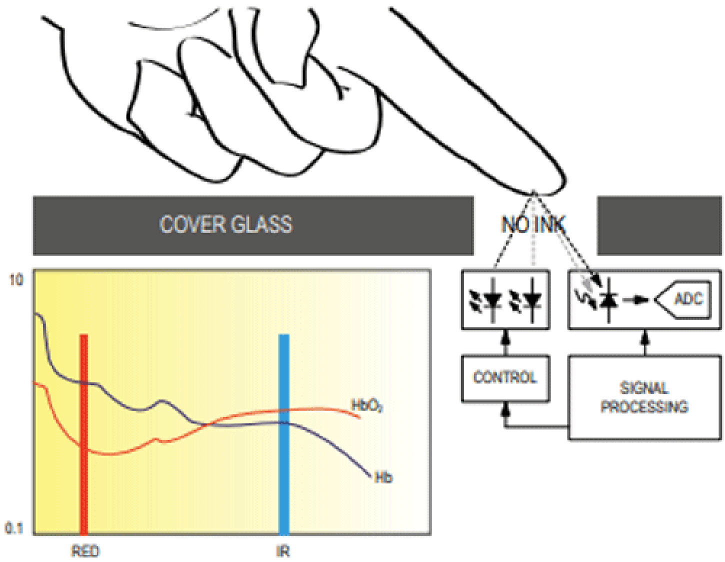

Fig. 2 MAX30102 sensor for pulse and blood oxygen level monitoring

C. *Communication*

In principle, the project aimed to develop a simple and compact device for monitoring pulse and blood oxygen levels. The design prioritized portability and ease of use, resulting in a small, wireless solution built using the ESP32-S2 Mini microcontroller and the MAX30102 sensor. This combination enabled real-time data collection and transmission via Wi-Fi to a mobile device, providing users with immediate access to health metrics in an intuitive way.

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D. *Heart rate*

To calculate the heart rate from the sensor data, the code first reads the infrared (IR) value from the MAX30102 sensor. It checks for a beat by using the checkForBeat() function, which detects the pulse. When a beat is detected, the time difference between the current reading and the last beat (delta) is calculated. This time difference is then used to calculate the beats per minute (BPM).

The calculated BPM is checked to ensure it falls within a valid range, typically between 40 and 220. If the BPM is valid, it is stored in an array for averaging over multiple readings. The average heart rate is then calculated by summing the most recent readings and dividing by the total number of readings to smooth out any fluctuations in the data.

E. *Blood oxygen*

The MAX30102 sensor is also capable of measuring blood oxygen levels (SpO2). Like the heart rate calculation, the sensor uses red and infrared LEDs to illuminate the blood vessels, and the reflection of this light is measured to estimate the amount of oxygen in the blood. The sensor calculates the ratio of the absorption of red and infrared light to determine the oxygen saturation level.

In this implementation, the sensor continuously collects this data, and the values are processed to calculate the SpO2 percentage. The code uses the MAX30102's built-in functions to retrieve the necessary raw data for this calculation. Once the values are processed, they are displayed on the OLED screen, alongside the heart rate, providing a simple yet effective way to monitor both metrics in real-time. The sensor's ability to manage both pulse and blood oxygen measurements makes it ideal for creating a compact, multi-functional health-monitoring device.

IV. FUTURE EXPECTATIONS

In future research will be device improved by external battery management system and ESP32-C3 development board, bringing up optimization size, power consumption and performance of device. Consequently, data will be transmitted over Wi-Fi to cloud storage with time series database, or via Bluetooth Low Energy to mobile application and further stored in cloud storage. Harvested data will be used for advanced medical analysis and health issues prediction, health management. The concept of the new device and health system is described in Fig. 3. Main purpose of the device is to match Health 4.0 standards.

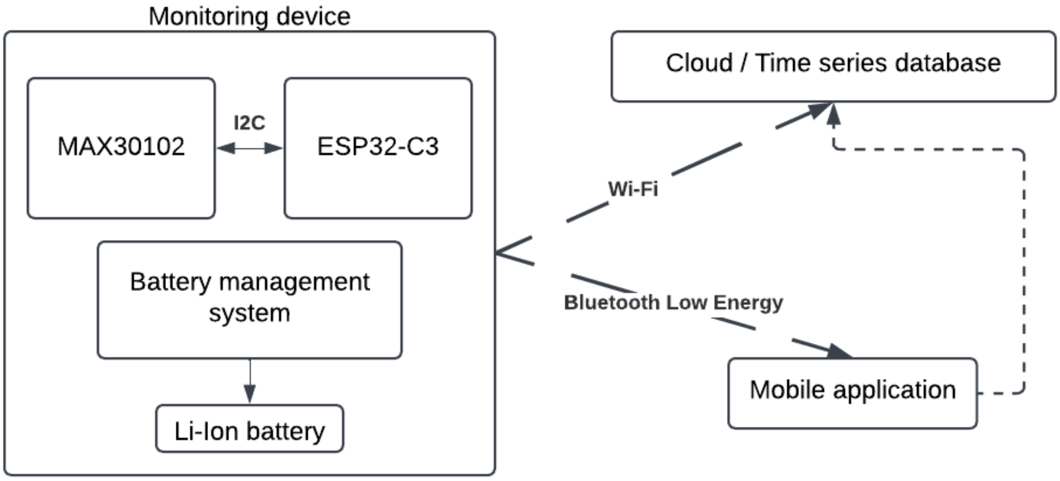

Fig. 3 Improved device design and health monitoring system

V. CONCLUSION

The creation of a compact, wireless health monitoring device capable of measuring heart rate and blood oxygen levels demonstrates the practical application of the ESP32-S2 Mini and MAX30102 sensor. The device successfully collects, processes, and transmits biomedical data in real-time, offering a simple and functional solution for basic health monitoring needs.

This project highlights how readily available components can be utilized to design systems that are both effective and easy to use. By combining reliable hardware with straightforward software implementation, I was able to create a device that meets its intended purpose without unnecessary complexity. The wireless communication and web-based interface further enhance the device's usability, making it accessible in a variety of scenarios.

Overall, this project reflects the potential of embedded systems in addressing practical challenges, while also serving as a valuable learning experience in hardware integration, software development, and system design.

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