International Journal of Mechanical and Electrical Engineering
ISSN: 3005-9615 (Print), ISSN: 3005-7132 (Online) | Volume 5, Number 3, Year 2025
DOI: https://doi.org/10.62051/ijmee.v5n3.04
Journal homepage: https://wepub.org/index.php/IJMEE/index

STM32-Based Health Monitoring System

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ABSTRACT

With the intensifying trend of global population aging, the demand for health monitoring among the elderly is becoming increasingly urgent. This paper addresses the issues of bulkiness and complexity in traditional health monitoring devices by proposing a portable health monitoring system based on STM32 embedded technology. The system utilizes the MAX30102 photoplethysmography (PPG) sensor to achieve non-invasive heart rate and blood oxygen saturation (SpO_2) detection. An optimized signal processing algorithm effectively eliminates motion artifacts, while the STM32F103C8T6 microcontroller facilitates data acquisition and real-time analysis. Compared to conventional medical equipment, this system is compact, energy-efficient, and user-friendly, offering a reliable technological solution for daily health monitoring and chronic disease management in the elderly. It holds significant application value in the field of smart elderly care.

KEYWORDS

Intelligence; Health Monitoring; Heart Rate and Blood Oxygen Detection; Portable.

1. INTRODUCTION

With the groundbreaking advancements in artificial intelligence and the deep integration of Internet of Things (IoT) technologies, the field of intelligent health monitoring is undergoing a revolutionary transformation [1] [2]. Generative AI technologies, exemplified by ChatGPT and DeepSeek have not only expanded the boundaries of natural language processing but also provided novel intelligent solutions for health monitoring through their robust pattern recognition and data analysis capabilities. Concurrently, the persistent rise in global chronic disease incidence, as highlighted by World Health Organization (WHO) statistics indicating that cardiovascular diseases account for 17.9 million deaths annually, underscores the critical focus on developing wearable real-time health monitoring systems within both academia and industry.

Personalized services are becoming increasingly precise. Intelligent health monitoring systems tailor exclusive health management plans for users by leveraging big data and artificial intelligence, taking into account individual differences. The widespread adoption of voice and gesture controls facilitates accessibility for special groups. Systems now integrate emotion monitoring and environmental data to foster a healthy living environment[3]. Intelligent health monitoring systems are evolving beyond traditional models by focusing on the individual[4]. Currently, they employ natural interfaces, emotion recognition, and adaptive learning algorithms to lower usage barriers, provide proactive care, and establish personalized health baselines, all while ensuring privacy through local encryption and tiered authorization. At present, the core technical bottleneck of intelligent health monitoring systems lies in the fact that the accuracy of sensors is easily affected by the external environment [5]. Researchers like Linschmann Onno, Leonhardt Steffen, and Hoog Antink Christoph have developed an unscented Kalman filter to fuse multimodal cardiopulmonary sensor signals, reducing the average error in heart rate estimation. Additionally, the adaptability of these systems to various application scenarios is limited.

This study proposes an innovative design for a multi-parameter health monitoring system based on the STM32 microcontroller. The system employs the STM32F407 as the core processing unit and utilizes an improved I²C communication protocol to drive the MAX30102 biosensor, enabling simultaneous acquisition of heart rate and blood oxygen saturation (SpO_2) parameters. Real-time monitoring of these indicators aids users and their caregivers in promptly detecting physiological anomalies, thereby providing data support for early medical intervention.

2. SYSTEM DESIGN SCHEME

This paper presents a health monitoring system designed with a layered architecture, where the hardware platform comprises three main components: the core control unit, the multimodal biosensor module, and the display module, which work in concert. As illustrated in Figure 1, the system block diagram features an STM32 microcontroller as the system's core. It leverages its high-performance processing architecture to efficiently integrate multiple physiological signals. The sensing layer utilizes the MAX30102 biomedical sensor module, which connects to the main control unit via a configurable I²C interface. This sensor, based on a multi-wavelength photodetection mechanism (using red light at 660 nm and infrared light at 880 nm), can simultaneously capture photoplethysmography (PPG) signals. These signals, after being processed through adaptive filtering algorithms, provide calibrated waveform data for the parallel computation of heart rate and blood oxygen saturation.

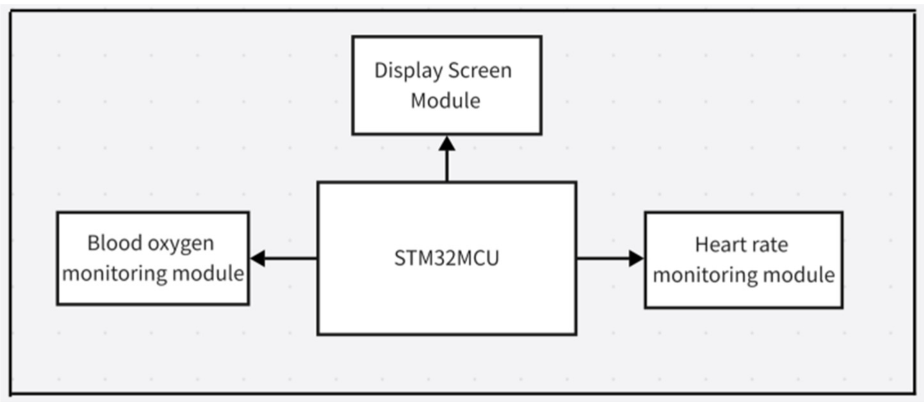

Figure 1. System structure block diagram

3. SOFTWARE DESIGN

3.1. Overall Program Flow The real-time heart Rate and Blood Oxygen Detection System

Based on the MAX30102 sensor follows a structured process. Initially, the system reads raw data from the sensor's red (RED) and infrared (IR) light using the I²C protocol. This data undergoes DC filtering to remove baseline drift, followed by noise suppression using a moving average filter and an eight-point moving average filter. The pre-processed signals are then subjected to Fast Fourier Transform (FFT) to determine heart rate from the spectral peak position. Concurrently, the ratio of the AC to DC components of the red and infrared light (R-value) is used to estimate blood oxygen saturation (SpO2). The results, including heart rate and SpO2 values, are displayed in real-time on an OLED screen, with additional debugging information output via a serial port. This process forms a comprehensive loop from data acquisition, signal processing, and algorithmic computation to result presentation. The system architecture includes key modules such as sensor interfacing, FFT spectral analysis, physiological parameter computation, and human-machine interaction. The core algorithms employ frequency domain analysis and empirical formulas to accurately calculate physiological parameters. The overall program flow is illustrated in Figure 2.

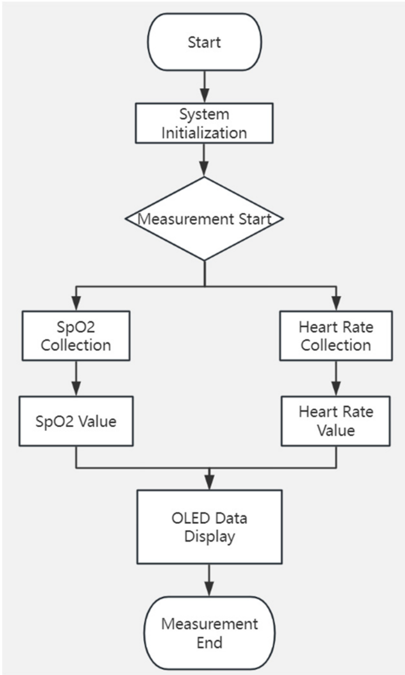

Figure 2. Overall Program Flowchart

3.2. Heart Rate and Blood Oxygen Detection Module

This module primarily facilitates the acquisition, processing, and display of data related to blood oxygen, serving to detect heart rate and blood oxygen levels. Initially, data is continuously read from the FIFO of the MAX30132 sensor. The subsequent process involves signal preprocessing, which includes calculating and removing the DC component, applying an eight-point moving average filter, performing a Fast Fourier Transform (FFT) on the filtered signal, calculating the amplitude spectrum, and summing the AC components. Peak detection is then conducted to derive heart rate and blood oxygen levels. The calculated blood oxygen value is checked, and if it exceeds 99.99%, it is capped at 99.99%. The heart rate and blood oxygen values are then output via a serial port and displayed on an OLED screen. The program flow for the heart rate and blood oxygen detection module is illustrated in Figure 3.

3.3. Display Screen Module

The system employs an OLED display to provide real-time visualization of heart rate and blood oxygen saturation data. Before writing command control words, it is necessary to check whether the LCD is in a busy state. If it is busy, the system must wait until the display signals that it has completed its current task before proceeding with writing control words and data. Prior to module operation,initialization isrequired, which involves configuring GPIOB Pin10 (SCL) and Pin11 (SDA) as open-drain outputs to simulate the I^2C communication protocol. This is achieved through software simulation of I^2C timing control (start/stop signals, byte transmission), including the initialization of the OLED, setting the display clock divide ratio (80h), configuring the multiplex ratio (64), adjusting contrast (0xCF), and setting pre-charge period parameters to activate the display and clear the screen.[6][7] The program flowchart for the OLED display is as follows fig 4:

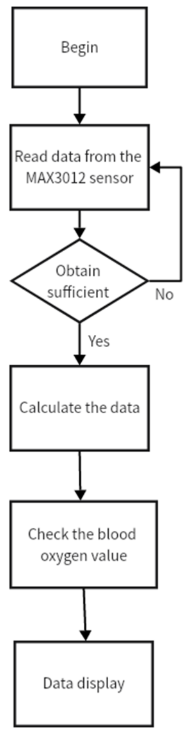

Figure 3. Heart Rate and Oxygen Saturation Module

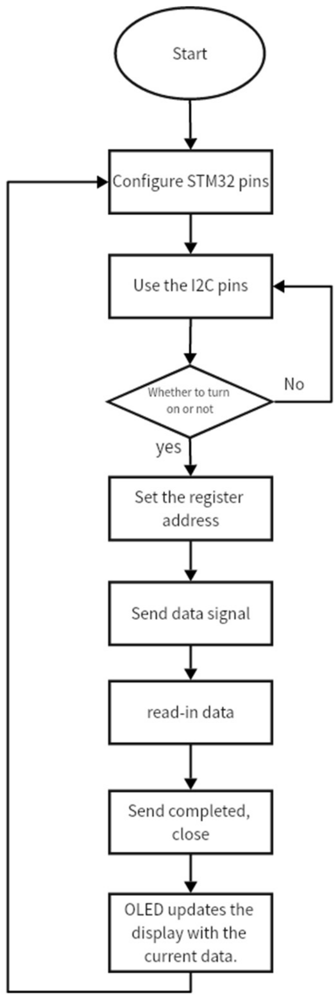

Figure 4. OLED Display Module

4. ANALYSIS OF THE ACTUAL MEASUREMENT RESULTS

In the measurement of heart rate and blood oxygen levels, it is crucial to ensure that the sensor is in close contact with the finger to maintain measurement accuracy and prevent significant errors due to insufficient skin contact. The temperature sensor displays ambient room temperature when not in contact with the skin and begins measuring body temperature upon contact. The OLED screen displays the physiological indicators of the subject: a heart rate of 66 beats per minute, an ambient room temperature of 17.6°C.and a blood oxygen saturation of 94%, all within the normal healthy range for humans. This health monitoring system is designed for ease of use and has garnered widespread support and acceptance. Its design allows for unrestricted use in terms of time and location, enabling individuals to monitor their health at any time and place. The system provides real-time monitoring of physiological parameters, including blood oxygen and heart rate, and issues alerts when data anomalies are detected, facilitating prompt intervention [8-10].

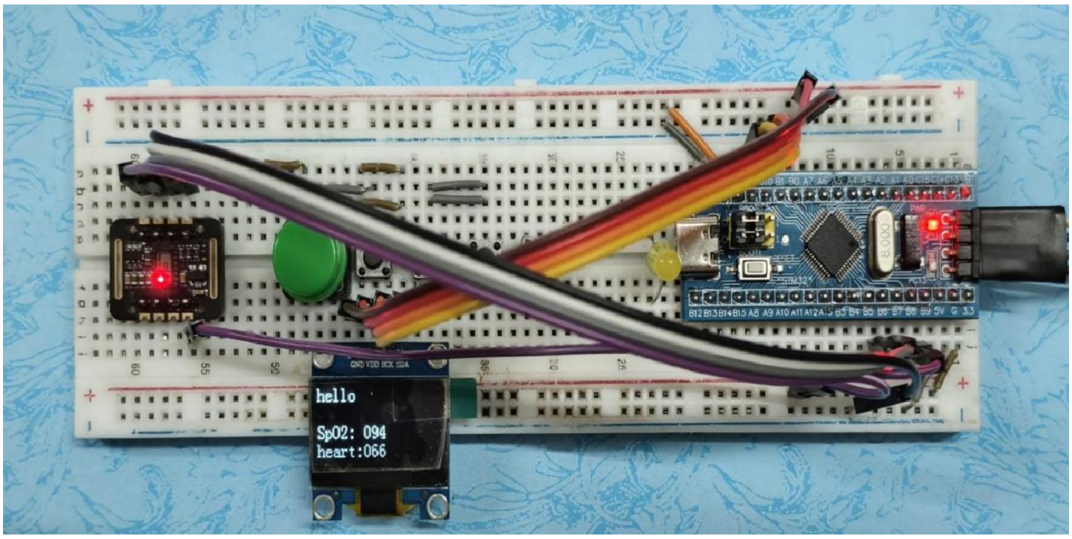

Figure 5. Test Results Figure

5. SUMMARY

This paper presents the design and implementation of a heart rate, blood oxygen, and body temperature monitoring system based on the STM32 microcontroller. By integrating the MAX30102 heart rate sensor and an OLED display, the system achieves real-time monitoring and display of heart rate and blood oxygen levels. The system is characterized by its simple structure, low cost, stable performance, and user-friendly operation, completing the entire process from data acquisition and processing to display. It accurately detects heart rate and blood oxygen information through various signal processing methods, such as DC component removal, average filtering, and fast Fourier transform, effectively extracting useful physiological parameter information. The display module reliably presents the detected data in real-time, and the system's functionality is comprehensive, meeting the basic requirements for heart rate and blood oxygen monitoring and display. The use of fast Fourier transform and other algorithms for frequency domain analysis of sensor data aligns with the principles of physiological signal processing, aiding in the accurate acquisition of heart rate information. The OLED display serves as the output device, offering advantages such as high contrast, self-illumination, and fast response, making it suitable for real-time display of critical information. Additionally, the system employs a simulated I2C communication protocol to interact with the OLED display, using GPIO software to simulate I2C timing control, which is a feasible and economical solution given limited hardware resources.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

ACKNOWLEDGMENTS

This work is supported by the Doctoral Scientic Research Foundation of Henan University of Science and Technology under Grant No. 400613480016, by the Key Science and Technology Program of Henan Province under Grant No. 232102241020, and by the Foundation of Henan Educational Committee under Grant No.23A520032.

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