Integration of Heart Rate and SpO2 Monitoring in Wearable Health Technology

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Abstract:

The amalgamation of heart rate (HR) and peripheral capillary oxygen saturation (SpO2) monitoring into wearable health technology holds substantial promise for advancing preventive health care, chronic disease management, and enhancing the quality of life through continuous health insights. Continuous tracking allows for the identification of abnormal patterns, such as arrhythmias or hypoxemia, facilitating timely medical interventions. This abstract discusses the technological advancements, methodologies, and clinical implications of combining HR and SpO2 sensors in wearable devices. In this work, a low-cost wearable device integrated with HR and SpO2 monitoring system was developed. The results obtained from this new system is compared with conventional measuring system for validation and the result from new device is very promising.

Keywords: Heart Rate, Integration, Monitoring, Oxygen Saturation, Wearable Device

1. Introduction

Heart rate (HR) and oxygen saturation (SpO2) monitoring are crucial aspects of health management, offering significant benefits across various applications [**1, 2**]]. The main reason behind heart rate measurement includes early detection of cardiac diseases, assessment of physical fitness, stress and emotional monitoring. chronic disease management etc [**3**]. On the other hand, the significance of SpO2 measurement includes respiratory health monitoring, detection of hypoxemia, management of chronic respiratory conditions, COVID-19 and Other respiratory infections, fitness and high-altitude activities etc [**4**, **5]**.

Integrating heart rate and SpO2 monitoring in wearable devices provides a more comprehensive view of an individual's health, enabling better decision-making and personalized healthcare [**6,7**]. Wearable devices with HR and SpO2 monitoring make it convenient for users to continuously track their health metrics in real-time, promoting proactive health management [**8**]. These wearables facilitate remote monitoring by healthcare providers, allowing for continuous oversight of patients with chronic conditions and reducing the need for frequent hospital visits. Wearable devices can trigger alerts in case of abnormal heart rate or low SpO2 levels, ensuring timely medical attention and potentially saving lives [**9, 10**]. Continuous monitoring generates valuable data that can be analyzed to identify health trends, personalize treatments, and contribute to broader health research [**11**].

The primary objective of this study is to develop and evaluate an integrated system for heart rate (HR) and oxygen saturation (SpO2) monitoring within wearable health technology. The study aims to advance the field of wearable health technology, providing a robust, reliable, and user-friendly solution for continuous heart rate and SpO2 monitoring. This integrated system

has the potential to enhance personal health management, support clinical decision-making, and contribute to broader healthcare improvements.

2. Conventional Methods for HR and SpO2 Measurement:

Traditionally. Electrocardiography is considered as the gold standard for heart rate monitoring as ECG provides detailed insights into the electrical activity of the heart [**12**]. It is widely used in clinical settings for diagnosing and monitoring cardiac conditions. Pulse oximetry measures blood oxygen saturation using light absorption through a part of the body, usually a fingertip or earlobe [**13**]. This method is widely used in clinical settings for monitoring patients with respiratory or cardiac conditions

Nowadays, smartwatches have become popular tools for monitoring heart rate and oxygen saturation (SpO2) due to their convenience and advanced sensor technologies [**14**]. Some of the leading smartwatches known for their heart rate and SpO2 monitoring capabilities, along with key features and considerations includes Apple Watch Series 8, Fitbit Sense 2, Garmin Venu 2, Samsung Galaxy Watch 5 etc.

While current wearable technology for heart rate and SpO2 monitoring offers numerous benefits, several drawbacks and limitations still exist. Some of the key issues are

- Accuracy and Reliability
- Battery Life
- Comfort and Usability
- Data Privacy and Security
- Interoperability and Compatibility
- Cost
- Limited Clinical Validation
- User Compliance and Behavior

3. Design and development

The design and development of the combined heart rate (HR) and oxygen saturation (SpO2) monitoring in wearable device involved several key steps such as hardware selection, sensor integration, firmware development, and testing.

The methodology can be divided into the following phases:

a. Hardware Selection and Integration:

This process divided into two steps such as -

- Selection of components including heart rate sensor, SpO2 sensor, Wi-Fi module, microcontroller, display, and power source.
- Integration of hardware components on a breadboard to form the basic system architecture.

The hardware design of the heart rate monitoring watch includes the following components:

i. Heart Rate Sensor: They play a crucial role in helping individuals monitor and manage their cardiovascular health. A heart rate sensor is a device or component that measures a person's heart rate in beats per minute (BPM). It works by detecting and analyzing the electrical signals generated by the heart as it beats or by measuring changes in blood flow.

ii. SpO2 Sensor: An SpO2 sensor, also known as a pulse oximeter sensor, is a device that measures the oxygen saturation level in the blood, specifically the arterial blood, as well as pulse rate. They are integrated into wearable fitness trackers, smart watches, and home medical devices to provide continuous monitoring of SpO2 levels for individuals with respiratory conditions, sleep disorders, or those engaged in high-altitude activities. Monitoring SpO2 levels is crucial for assessing respiratory function, detecting hypoxemia (low oxygen levels), and guiding oxygen therapy interventions.

iii. Wi-Fi Module: a Wi-Fi module facilitates the transmission of heart rate data from the monitoring device to other devices or systems. By utilizing a Wi-Fi module, the heart rate monitoring system enables wireless connectivity, allowing users to monitor heart rate data remotely and access it from various devices or locations within the Wi-Fi network range. This

enhances the flexibility and convenience of heart rate monitoring, particularly in scenarios where mobility and real-time data access are critical, such as in healthcare settings or during physical activity monitoring.

b. Software Development:

This part involves the following steps such as

- Development of firmware for sensor data acquisition, processing, and display.
- Implementation of Wi-Fi connectivity for data transmission to external devices.
- Integration of algorithms for heart rate calculation and SpO2 measurement.
- Integration process of heart rate and SpO2 monitoring.

c. Protoype Development:

For prototype development, we use the following components and circuit was designed as per the circuit diagram shown in **Fig-1** and complete set up is depicted in **Fig- 2.**

i. NodeMCU is an open-source platform based on ESP8266 which can connect objects and let data transfer using the Wi-Fi protocol.

ii. The MAX30100 is an integrated pulse oximetry and heart-rate monitor sensor solution. It combines two LEDs, a photo-detector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals.

iii. The LED DISPLAY BOARD is used to display the output or the value results of the SpO2 or heart rate.

iv. Bread Board is used to set up the connection as a whole.

v. The male female wires are used to complete the connection of the components.

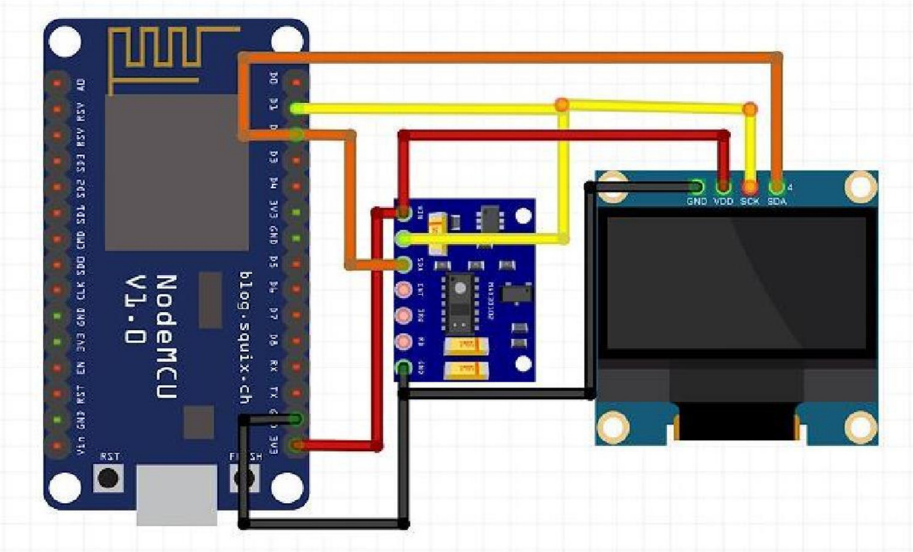

Fig-1: Circuit Diagram

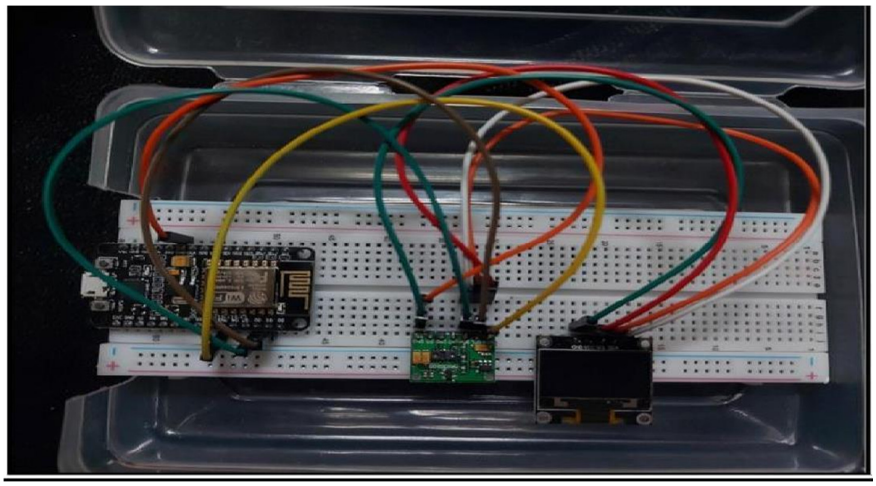

Fig-2: Circuit Design of Integrated HR and SpO2 Monitoring Device

d. Data collection, Testing and validation methods.

After development of integral circuit for monitoring HR and SpO2, we have collected data for 10 subjects of different age group using our newly developed circuit. Again, we have collected the data from same set of subjects from traditional way of measurement. After that this these two sets of data were compared for testing the effectiveness of the new device.

4. Results and Discussion

The data obtained from our newly developed device and from traditional devices were shown in **Table- 1**.

Table- 1: Heart Rate and SpO2 Measurement Data

Sl No.	Subject	Gender (M/F)	Age (Years	Using New Device		Using Traditional Device	
				Heart Rate (Per Min.)	SpO2 (%)	Heart Rate (Per Min.)	SpO2 (%)
1	S1	M	20	74	96	76	97
2	S2	F	21	71	97	70	97
3	S3	F	22	77	98	75	98
4	S4	M	22	75	98	74	97
5	S5	F	23	79	99	79	97
6	S6	M	34	82	97	80	96
7	S7	M	37	74	97	75	95
8	S8	M	45	83	96	81	95
9	S9	M	48	76	97	77	96
10	S10	F	50	80	95	79	97

From the above table, it is clear that the data obtained from both the devices were almost same for both heart rate and SpO2 measurement.

5. Conclusion

In this study we have designed a low cost wearble device integrated with HR and SpO2 monitoring system. The data obtained from this device was compared with the universally accepted measuring devices and it shows promising one. The integration of heart rate (HR) and blood oxygen saturation (SpO2) monitoring into wearable health technology represents a significant advancement in personal health management and medical care. These technologies, now commonplace in devices such as smartwatches and fitness trackers, offer a range of benefits that enhance user experience and health outcomes. The future of wearable health technology with integrated HR and SpO2 monitoring is promising. As technology evolves, we can anticipate more seamless and accurate health tracking, enhanced by the integration of additional physiological and environmental sensors. The convergence of wearable technology with telemedicine and electronic health records (EHR) will further revolutionize personal and public health systems, enabling a more connected and comprehensive approach to healthcare.

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