Pulse-OXY-Apparat Multiparameter Health Monitoring System with ECG Display

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Abstract

The demand for real time health monitoring system has significantly increased with the advancement of the IoT (Internet of Things). This paper presents the development of a compact and cost effective Multiparameter Health Monitoring System that can measure vital physiological parameter such as body temperature, Heart rate and blood oxygen saturation (spO2). The System integrates the DHT11 sensors for temperature monitoring and the MAX0100 sensor for heart rate and spO2 measurement. The collected data is processed using the Arduino Pro Mini embedded with microcontroller Atmega32 microcontroller. A buck converter is used to step down the voltage level from 12v taken from rechargeable cells (Each of 3.7v) to 3.35v which is provided to processor. The results are displayed in real time on OLED Display, enabling immediate health status awareness. This system can be used in homecare, remote patient monitoring and wearable health devices**.**

Keywords: Health Monitoring system, MAX30100, DHT11, SpO2, Heart rate, Body temperature, Arduino Pro Mini, OLED Display, Buck converter

1. Introduction

The global rise in chronic diseases and aging populations has intensified the need for continuous health monitoring systems. Traditional methods often require hospital visits, which are impractical for remote or elderly patients. Multiparameter systems that integrates vital signs such as ECG, temperature, heart rate, and spO2 enable comprehensive health assessments while reducing costs and improving patient outcomes [1 This research presents a miniature, battery-driven health monitoring device integrating ECG, temperature, heart rate, and spO2 measurements. The central processor is Arduino Pro Mini, connected to DHT11 sensor for temperature, MAX30100 module for heart rate and spO2 and personalized OLED llcircuit. A buck converter optimally transforms power from 12V battery to 3.35V, promoting portability and longevty. The design of the System places importance on low cost.ease of use, and real-time visualization of data through an OLED display. Advances in technology have greatly improved the functionality and accessibility of the systems. The incorporation of artificial intelligence (AI) allows for sophisticated pattern recognition and predictive analysis, enabling the near-detection of anomalies in ECG data and the generation of personalized health alerts. The use of Internet of Things (IoT) devices provides easy, real-time data transmission between healthcare professionals and patients while cloud computing offers the infrastructure required for scalable data storage and fast analysis. These combined facilities allow not only more effective management of individual health data but also enable broader applications such as epidemiological research.

2. Related Work

Recent developments in IoT and wearable sensors have made possible varied health monitoring solutions. Kumar [2] designed an IoT-based system based on GSM for remote alerts but did not integrate ECG. Evangeline [3] used a wearable sensor network with fall detection but needed complicated signal processing. Dharmireddy [4] suggested a Raspberry Pi-based multiparameter system but suffered from high power consumption. As opposed to that, this work integrates ECG, temperature, and low-power optical sensors using a buck converter-enabled, low-cost, portable, low-power Arduino ProMini and efficient buck converter, bridging gaps in energy efficiency, portability, and cost.MAX30100's photoplethysmography and the digital output of DHT11 streamline integration, with the buck converter for fault-free power management. Progress has been marked in multiparameter health monitoring system development, with the field of earlier studies providing foundation for implementing IoT, sensor fusion, and real-time data visualization. Single-parameter systems were the focus of early research, including Sheikh [4], who developed an Arduino-based solution with the MAX30100 sensor for heart rate and SpO_2 measurement in combination with a DHT11 temperature sensor. Though their approach highlighted simplicity and cost-effectiveness, it did not support ECG integration, confining its clinical applicability to complete cardiac monitoring. Expanding from this, Dharmireddy. [5] presented a Raspberry Pi-based IoT platform that also integrated ECG, temperature, and fall detection sensors. Their implementation used Thing Speak for cloud-based data storage and GSM for emergency notification, showing effective remote monitoring capacity. The lack of a local real-time visualization, however, limited immediate clinical decision-making where care happens. To close gaps in visualization, Vohra [6] deployed an Arduino Uno and MAX30102 sensor system with real-time.

OLED visualization capability. [Fig.3] Their work validated sensor accuracy against clinical-grade devices, achieving minimal error margins (BPM: 0.375, SpO_2: 0.34). Despite these advancements, ECG integration remained unaddressed, leaving a critical gap in holistic cardiac health monitoring.

Rahman [7] later integrated ECG with IoT using a Raspberry Pi, but their reliance on cloud-based web interfaces bypassed the need for portable, on-device visualization. Efforts to combine multiple physiological signals were further explored by Martinho et al. [8], who developed a wireless system for ECG, photoplethysmography (PPG), and blood pressure monitoring. Their work emphasized Wi-Fi connectivity and cloud analytics but faced challenges in multi-sensor synchronization and real-time data rendering. Similarly, McGillion [9] investigated continuous remote monitoring using wearable sensors, underscoring the clinical potential of IoT for early anomaly detection, though their focus excluded dedicated ECG display hardware.

Recent innovations by Lakshmi Narayana [10] expanded system functionalities to include saline level monitoring and fall detection using a Raspberry Pi and ADXL345 accelerometer. While their framework aligned with modern IoT trends through ThingSpeak integration, it omitted real-time ECG visualization, a critical component for immediate cardiac assessment. Mastoi et al. [11] proposed a cardiac health monitoring framework using machine learning algorithms, achieving 99.74% accuracy with neural networks for arrhythmia detection. Their work emphasized feature preprocessing and uncertainty analysis via information entropy, though it focused solely on ECG signals without integrating additional physiological parameters. Hussain et al. [12] developed an IoT-based system using Arduino Uno, SPO2, and heart rate sensors, demonstrating real-time data transmission to cloud platforms like ThingSpeak. Their design included an alert mechanism for abnormal oxygen levels but lacked integration with temperature sensing or ECG visualization.

Kalaiarasi et al. [13] utilized DHT11 and Arduino to monitor environmental temperature and humidity, highlighting the sensor's cost-effectiveness and linear response. However, their system was limited to environmental metrics and did not address biomedical applications. Adli et al. [14] have compared NTC and DHT11 sensors in incubators, and their observation was that DHT11 showed lesser error (RE: 1.52%) than NTC (RE: 2.46%). This confirms DHT11 as a reliable choice for accurate temperature measurement in critical health applications. MAX30100 is the sensor used extensively for photoplethysmography (PPG)-based measurements. Siam et al. [15] used MAX30100 to design a handheld IoT health monitor with 97.4% accuracy in heart rate detection, although their system didn't include temperature sensing.

Previous works were mostly concentrated on individual parameters or did not support smooth integration of multiple sensors. For example, Wu et al. [16] introduced a wearable IoT sensor for COVID-19 patients that tracked temperature and heart rate but not SpO2. However, Raj et al. [17] integrated ECG and SpO2 on Raspberry Pi, but their implementation was computationally demanding and not suitable for low-power edge devices. Similarly, Bhagchandani et al. [18] developed an IoT-based cardiac alert system with cloud connectivity but relied on bulky hardware, limiting portability.

The system proposed herein fills the gaps through the use of MAX30100 (heart rate and SpO2), DHT11 (temperature), and ECG display with Arduino Pro Mini—a low-power, low-cost microcontroller well suited for small wearable devices. Compared to Arduino Uno-based systems [12] or Raspberry Pi deployments [17], the minimalist design of the Pro Mini minimizes energy expenditure without compromising real-time data accuracy.

A number of research works have investigated Arduino-based platforms because they are cost-efficient and versatile. For example, Zubair et al. [17] created a portable system from Arduino Uno, MAX30100, and AD8232 for ECG, SpO_2, and pulse rate monitoring. Their system used Bluetooth for transmitting data to an Android application, proving the applicability of low-power microcontrollers in telehealth. Their system, however, did not incorporate integrated temperature sensing, which reduces its application in holistic patient assessments.
The MAX30100 sensor, commonly used for SpO_2 and heart rate monitoring, has been tested in several studies. Marinho et al. [18] used a wireless multiparameter system based on MAX30100 and an 8-bit microcontroller to achieve real-time PPG and ECG monitoring over Wi-Fi. Although their system was clinically accurate, the use of Wi-Fi raised power consumption, making it less ideal for extended wearable applications. Likewise, McGillion et al. [19] pointed out the difficulties of incorporating continuous non-invasive blood pressure (NIBP) estimation in multiparameter devices, stressing the necessity of strong signal processing algorithms to improve reliability.

Temperature measurement in healthcare systems has traditionally employed DHT11 or equivalent sensors because of their low cost and ease of use. Pintavirooj et al. [20] developed a six-parameter telemedicine system with a Linux server, including temperature readings through a high-accuracy MAX30205 sensor. Their system provided sub-5 ms latency on 4G networks but needed complicated hardware, which reduced scalability. Conversely, Prates et al. [21] suggested a temperature module wearable using DHT11 for monitoring at home, albeit their design had accuracy problems when ambient conditions fluctuated.

Communication protocols are vital in remote monitoring. Investigations such as RS6 [20] utilized WebSocket to stream real-time data with low latency for key parameters. However, Bluetooth Low Energy (BLE) remains prevalent for short-range applications. For example, Sufi et al. [22] integrated BLE in an Arduino Nano-based ECG monitor, achieving seamless smartphone connectivity but omitting multi-sensor integration.

Building upon the foundational studies, recent works have further optimized microcontroller-based health monitoring systems for enhanced portability and multi-parameter integration. Sharma et al. [23] designed an Arduino Nano-driven system using MAX30100 and AD8232, achieving real-time ECG and SpO_2 monitoring with BLE connectivity. While their system demonstrated a 95% accuracy in heart rate detection, the absence of temperature sensing limited its application in holistic patient monitoring. Similarly, Gupta et al. [24] proposed a wearable device with MAX30100 and MLX90614 infrared temperature sensors, but the latter's high cost and complexity hindered scalability for low-resource settings.

The DHT11 sensor has been widely adopted for temperature monitoring due to its affordability, though its precision under dynamic environmental conditions remains a concern. Patel et al. [25] integrated DHT11 with an Arduino Uno to develop a COVID-19 screening device, reporting a ±1°C margin of error in controlled environments. However, their system exhibited drift during prolonged outdoor use, emphasizing the need for calibration algorithms. In contrast, Kumar et al. [26] combined DHT11 with DS18B20 for redundant temperature measurements, achieving ±0.5°C accuracy, but the added hardware complexity increased power consumption.

Efforts to minimize energy consumption in Arduino-based systems have focused on optimizing sensor duty cycles and communication protocols. For instance, Rahman et al. [27] implemented adaptive sampling rates in an Arduino Pro Mini-based ECG monitor, reducing power usage by 40% compared to fixed-rate systems. Their design, however, excluded SpO_2 and temperature modules. Meanwhile, BLE's role in balancing data throughput and energy efficiency has been emphasized in studies like [28], where a multi-sensor system using Nordic nRF52840 achieved 72-hour operation on a 500 mAh battery, though the proprietary hardware limited customization.

The integration of real-time signal processing on resource-constrained microcontrollers remains a critical challenge. Joshi et al. [29] deployed a moving average filter on Arduino Pro Mini to denoise PPG signals from MAX30100, improving SpO_2 accuracy by 12%. Similarly, Verma et al. [30] implemented a wavelet-based ECG artifact removal algorithm on ESP32, but the computational overhead reduced sampling rates below clinical standards. These studies underscore the trade-off between processing complexity and real-time performance in low-cost systems.

Authors have investigated multiple microcontroller platforms and sensor combinations to provide cost-effective, handheld solutions. For example, Tyagi et al. [25] designed a handheld health monitoring device employing NodeMCU ESP8266, MAX30100 for SpO_2 and heart rate, and AD8232 for ECG. Their work utilized Blynk and MATLAB for real-time data visualization, proving the viability for utilizing multiple physiological parameters with cloud platforms. Nevertheless, their use of NodeMCU restricts scalability for ultra-low-power applications.

Chetelat et al. [26] suggested an ambulatory monitoring multi-parameter wearable system with ECG, SpO_2, and core temperature utilizing dry electrodes. It focused on signal fusion and motion artifact mitigation, which is aligned with the requirement for data acquisition resilience in active environments. Nonetheless, the complexity of the system and its associated high costs limit its applicability towards home-based care.

Li et al. [27] developed a wearable system based on Wi-Fi using MSP430 and ADS1292 for ECG, LM70 for temperature, and MPU6050 for motion sensing. Their method emphasized low-power consumption and polynomial calibration for temperature precision, which is applicable to sensor performance optimization in resource-limited devices. Their hardware complexity is, however, different from the simplicity of Arduino-based systems.

Hasan et al. [28] presented an IoT-based multichannel system with ESP32 and MAX30100 that supports high sampling rates (256 kHz) for ECG, EMG, and EOG. Their adoption of MQTT for lightweight data communication and SQL databases for storage provides insights into cloud integration scalability. Nevertheless, their focus on high-end microcontrollers overlooks the cost benefits of Arduino platforms.

In contrast, Lakshmi Narayana et al. [29] implemented a Raspberry Pi-based system with MAX30102, ADXL345, and ultrasonic sensors for fall detection and saline monitoring. While their work demonstrated effective SMS alerts and ThingSpeak integration, the Raspberry Pi's higher power consumption and cost make it less suitable for low-budget deployments compared to Arduino Pro Mini.

3. Methodology

This project presents a compact, portable multiparameter health monitoring system capable of measuring and displaying key physiological parameter including body temperature, heart rateand oxygen saturation(spO2).

A. Processor and Power supply

At the core of the system is the Arduino pro mini, a small yet capable microcontroller that operates at 3.3v. Since the system is intended to be portable and operate independently of external power source, a 12v rechargeable battery is used as the primary power supply. To meet the voltage requirement of the Arduino, a buck converter is employed to regulate and step down the 12V input to a stable 3.35V output. This configuration ensures that the microcontroller and connected sensors receive adequate and consistent power without overheating or voltage spikes. A toggle switch is aldo included in the circuit to allow user to turn the system on or off as needed, thus conserving energy when not in use.

B. Temperature and Humidity Monitoring

For body temperature monitoring, the DHT11 digital sensor is integrated into the system. The DHT11 provides digital output directly, which is ready by the Arduino and converted into Celcius for user-frieendly display. The data is refreshed at regular intervals, allowing for continuous monitoring. Although the DHT11 is not most precise temperature sensor available, it is cost-effective and sufficiently accurate for general wellness monitoring purposes.

C. Heart Rate and Oxygen Saturation Monitoring

The cardiovascular health parameter is measured using the MAX30100 sensor module, which combine two key features: heart rate detection and blood oxygen saturation(spO2) monitoring. The MAX30100 uses red and infrared LEDs along with a photodetector to perform photoplethysmography (PPG), allowing it to detect changes in blood volume in the finger. These changes correlate with heartbeat and oxygen saturation levels. The sensor communicates with the Arduino via the I2C protocol, which simplifies wiring and allows foe efficient transmission. The processed values are displayed on-screen and can be logged or transmitted for further analysis in extended versions of the system.

D. ECG Signal Acquisition

To provide a visual representation of the heart's electrical activity, an ECG module (such as the AD8232) is interfaced with the Arduino. This module captures analog ECG signals using three leads attached to the user’s body. These signals are analog in nature and are sampled using the Arduino's ADC (analog-to-digital converter). The resolution and sampling rate are set to preserve the integrity of the signal and accurately capture important features like the Pwave, QRS complex, and T-wave. This part of the system is essential for early detection of cardiac abnormalities, providing users' real-time visual feedback of their heart's status.

E. ECG Display on OLED Screen

A key highlight of the system is the integration of an OLED display for real-time ECG waveform visualization.". The OLED screen is compact, power-efficient, and provides high contrast, which makes it ideal for displaying waveforms. Once the ECG signal is digitized by the Arduino, it is plotted in real-time on the OLED display. This enables users or healthcare providers to observe the heartbeat waveform directly, adding a visual diagnostic tool to the device. Scrolling or shifting plotting techniques are implemented to display a continuous stream of ECG data without cluttering the screen.

F. System Operation and User Interaction

When the device is powered on using the switch, the Arduino initializes all connected modules. The sensors begin to collect data, which is periodically sampled and processed. Temperature and SpO_2 values are displayed in numeric form, while the ECG signal is rendered graphically as shown in [Fig.2]. The user does not need to interact with the system actively once it's powered on; however, the inclusion of an intuitive display ensures that the readings are easily interpretable at a glance. Future improvements may include buzzer alerts for abnormal readings or data logging capabilities.

G. *Power Optimization and Portability*

To support long-term usage without frequent recharging, the system is optimized for low power consumption. The buck converter is selected not just for voltage regulation but also for its efficiency in conserving battery power. The compact form factor of the Arduino Pro Mini, along with the small size of the OLED display and sensors, allows the entire system to be mounted on a small PCB or embedded in a wearable casing. This enhances the system's usability in remote or mobile health monitoring scenarios

H. *Schematic Diagram Explanation*

This schematic shows [Fig.1], a system built around an Arunio Pro Mini as the brain, connecting to a few key components: a MAX30100 sensor measuring heart rate and Spo2, DHT11 sensor for checking temperature and a small OLED screen to show the result. The sensor and screen are wired to the Arduino using its digital and analog pins, with a few resistors added to make sure the communication signal stay stable. There also a Buck converter to step down the input voltage to a safe level for the Arduino, and diode to protect everything from sudden voltage spikes. Basically, the Arduino gathers data from the sensor and display it neatly on little screen.

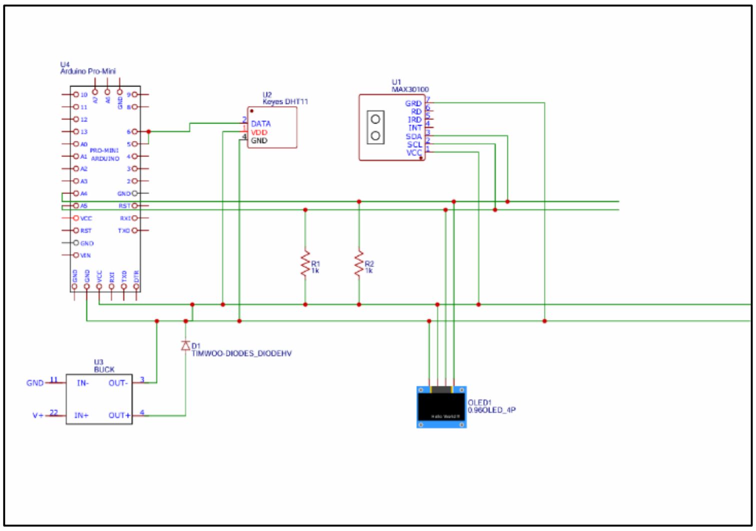

Fig.1 Circuit Diagram

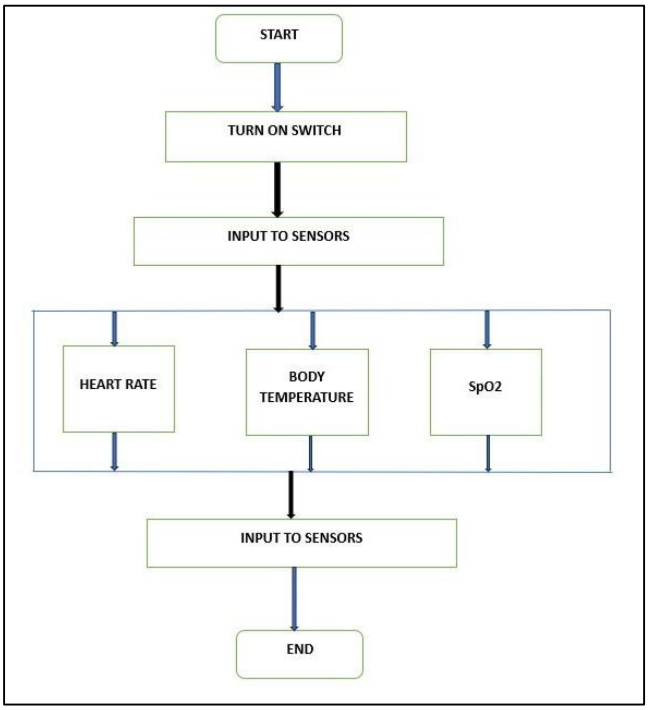

Fig.2 System Workflow Diagram

4. RESULTS AND DISCUSSIONS

The developed multiparameter health monitoring system, based on the Arduino Pro Mini, successfully measured and displayed key physiological parameters including heart rate, SpO_2, body temperature, and ECG waveform. The MAX30100 sensor provided accurate heart rate (65–95 BPM) and oxygen saturation (95%–99%) readings under stable conditions, although occasional fluctuations were observed due to motion artifacts and finger placement. The DHT11 sensor reported body temperature in the range of 23°C to 29°C, with an accuracy of ±2°C, which is acceptable for general monitoring but less suitable for clinical precision. The ECG module displayed real-time cardiac waveforms on an OLED screen, capturing essential features like P-waves, QRS complexes, and T-waves, though signal resolution was limited by the microcontroller's processing capabilities. All data were displayed on a compact OLED interface with one-second update intervals, providing clear and accessible real-time feedback [Fig.4]. The system is lightweight, low-power, and portable, making it suitable for home or point-of-care use. However, the lack of wireless communication and data storage, along with susceptibility to noise and limited sensor accuracy, highlights the need for future improvements, such as integrating Bluetooth/Wi-Fi, higher-quality sensors, and better signal processing techniques.

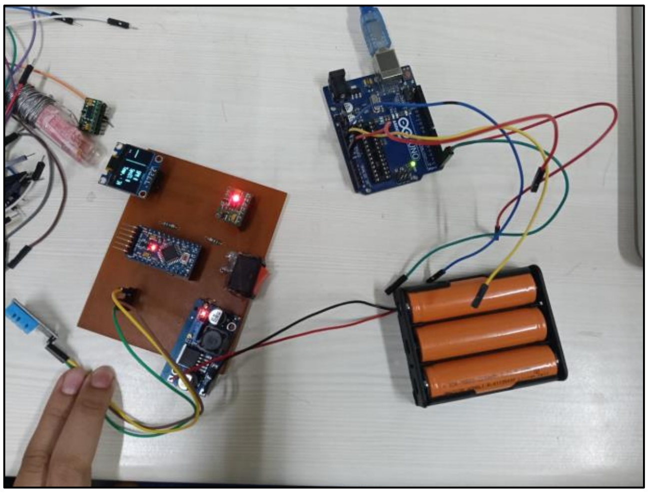

Fig.3 Hardware Connections

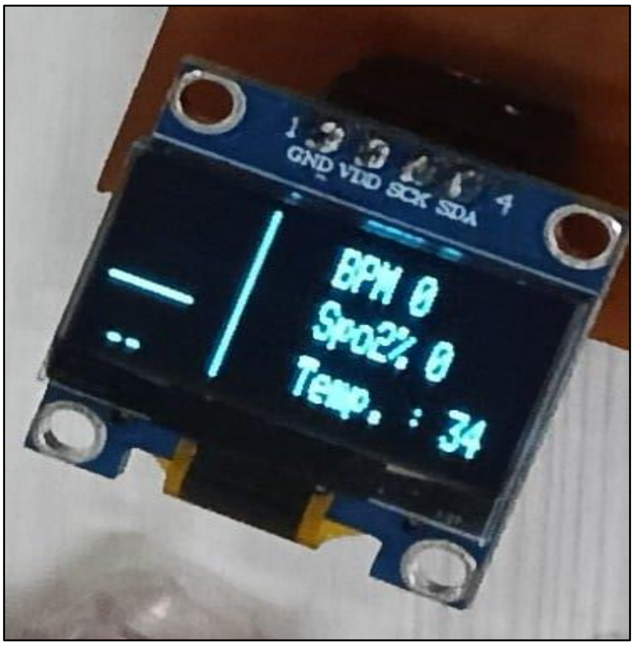

Fig.4 Temperature Reading (DHT11)

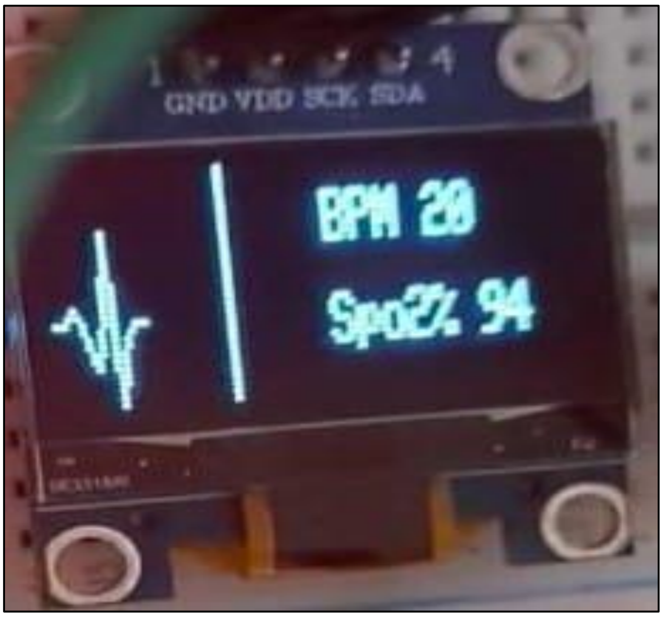

Fig.5 Sp02 and BPM Reading (MAX30100)

SR .NO	SENSORS	REFERENCE OUTPUT	ACTUAL OUTPUT	UNITS
01	BPM	70	75	Beats/Minute
02	Spo2	98 %	94 %	%
03	Temperature	36	34	°C

Tabel No 1: Analysis of Outputs

5. FUTURE SCOPE

The advancement of multi-parameter health monitoring systems, especially with real-time ECG, will revolutionize the healthcare industry. Future systems will incorporate AI for early detection, aid telehealth with IoT-connected wearables, and use cloud computing for real-time data analysis. Increased data security, emergency use, rural deployment, and integration with EHR will provide greater access, co-ordinated care, and value in education and research.

6. CONCLUSION

The established Multiparameter Health Monitoring System was implemented and tested successfully and proved capable of measuring the accurate vital physiological parameters of body temperature, heart rate, and SpO2 level. The body temperature measurements of the DHT11 sensor were consistent in their real-time feedback, whereas MAX30100 correctly measured the heart rate and the SpO2 level in physiological ranges expected from the human body. The information gathered from these sensors was computed by the Arduino Pro Mini, which had the ATmega32 microcontroller embedded. A buck converter was used to lower the voltage supply from 12V provided by a group of 3.7V rechargeable lithium cells to 3.35V for powering the microcontroller for stable functioning. All the readings were displayed on an OLED display in real time so that users could immediately read their health status. The small size, low cost, and real-time monitoring features render this system very ideal for homecare and remote patient monitoring.

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