Low-Cost Multi-Parameter Vital Sign Monitoring Using Arduino and IoT Alerts

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DOI: https://doi.org/10.47772/IJRISS.2025.91200210

Received: 26 December 2025; Accepted: 31 December 2025; Published: 06 January 2026

ABSTRACT

Continuous monitoring of vital signs is essential for early detection of physiological abnormalities, yet conventional hospital-based systems are often costly and require intensive manual intervention. This study presents the design, implementation, and evaluation of a low-cost, Arduino-based multi-parameter health monitoring system capable of measuring heart rate, blood oxygen saturation (SpO_2), body temperature, and electrocardiogram (ECG) signals in real time. The proposed system integrates multiple biomedical sensors with an Arduino microcontroller, providing local visualization via an LCD interface and automated alerting through buzzer and LED indicators when predefined physiological thresholds are exceeded. To enable remote monitoring, the system transmits sensor data using a NodeMCU module to a cloud-based IoT platform (Ubidots) for visualization and logging. Experimental validation was conducted on 15 participants, with three repeated measurements collected per participant for heart rate, SpO_2, and body temperature. The results demonstrate stable real-time performance and reliable detection of abnormal conditions. A practical limitation identified is the reduced granularity of cloud-based graphs due to transmission rate constraints, despite accurate local monitoring. Overall, the findings confirm that low-cost, modular microcontroller-based systems can provide effective multi-vital monitoring and alerting, particularly in resource-constrained healthcare environments.

Keywords - Arduino; IoT healthcare; vital sign monitoring; heart rate; SpO_2; ECG; temperature sensing; alert systems

INTRODUCTION AND LITERATURE REVIEW

Continuous assessment of physiological parameters such as heart rate, blood oxygen saturation, body temperature, and cardiac electrical activity is fundamental to modern healthcare [1]. In many clinical environments, especially in developing regions, vital sign monitoring remains largely dependent on periodic manual measurements performed by healthcare personnel [2]. This approach is labor-intensive, susceptible to human error, and may delay the detection of critical physiological changes. Consequently, there is growing interest in automated, low-cost monitoring solutions that can provide continuous measurements and early warning alerts [3].

Recent advances in microcontroller platforms and biomedical sensors have enabled the development of compact and affordable health monitoring systems. Arduino-based platforms, in particular, have gained prominence due to their low cost, open-source ecosystem, and ease of integration with a wide range of sensors [4]. Studies have demonstrated the feasibility of using photoplethysmography (PPG) sensors for heart rate and SpO_2 estimation, temperature sensors such as LM35 for non-invasive body temperature measurement, and low-cost ECG modules for basic cardiac signal acquisition [5]. These systems are often further enhanced through Internet of Things (IoT) frameworks, allowing remote data transmission, storage, and visualization [6].

Existing literature highlights several advantages of IoT-enabled health monitoring, including real-time access to patient data, improved clinical decision-making, and reduced workload for healthcare staff [5]. However, many

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XII December 2025

reported systems focus on single-parameter monitoring or rely on relatively expensive wearable platforms [7]. Furthermore, while cloud dashboards are frequently used for visualization, limited attention is given to practical constraints such as data transmission rates, sampling mismatches, and their impact on signal representation [8].

The present study addresses these gaps by developing a multi-parameter monitoring system that integrates heart rate, SpO_2, body temperature, and ECG sensing within a single Arduino-based architecture [9]. Emphasis is placed on affordability, modularity, and real-time alerting, making the system suitable for routine monitoring in resource-limited settings [10]. In addition, the study provides an empirical discussion of cloud visualization limitations encountered during IoT deployment, an aspect often underreported in prototype-based research.

By combining multiple vital sign measurements with both local and remote alert mechanisms, this work contributes to the growing body of research on accessible digital health technologies. The following sections describe the system methodology, experimental validation, and discussion of results in detail.

METHODOLOGY

System Architecture

The proposed system is built around an Arduino microcontroller that serves as the central processing unit. Multiple biomedical sensors are interfaced with the Arduino to acquire physiological signals, including:

A pulse oximeter sensor for heart rate and SpO_2 measurement, an LM35 temperature sensor for body temperature, An ECG sensor module for cardiac signal acquisition.

Sensor outputs are processed in real time and displayed locally on a liquid crystal display (LCD). Threshold-based logic is implemented in the Arduino firmware to identify abnormal physiological conditions.

Alert and Notification Mechanism

Predefined threshold values are assigned to each physiological parameter based on standard clinical ranges. When sensor readings exceed or fall below these thresholds, the system activates visual (LED) and auditory (buzzer) alerts. This immediate feedback mechanism ensures rapid local awareness of potential health risks without reliance on network connectivity.

IoT Integration

For remote monitoring, the system integrates a NodeMCU module to transmit sensor data to a cloud-based IoT platform (Ubidots). Data are sent in JavaScript Object Notation (JSON) format. This allows clinicians or caregivers to remotely visualize patient data using a web dashboard. The transmission rate is configured to balance responsiveness and network constraints.

Experimental Procedure

The system was tested on 15 participants. For each participant, three consecutive readings were recorded for heart rate, SpO_2, and body temperature to assess consistency and repeatability. ECG signals were monitored continuously to verify signal presence and detect abnormal analog values indicative of noise or sensor disconnection.

Methodological Flow

The methodological workflow consists of sensor initialization, signal acquisition, filtering and smoothing (where applicable), threshold evaluation, local display and alerting, and optional cloud transmission. This modular flow allows easy expansion of the system with additional sensors in future work.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XII December 2025

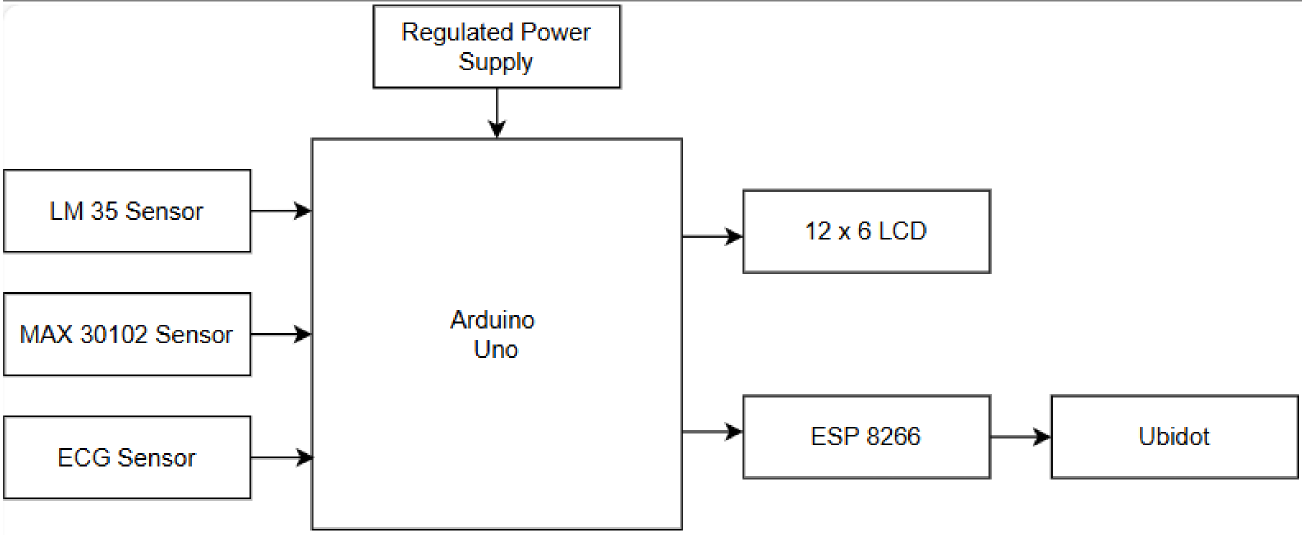

Figure 1. Block diagram of automatic health monitoring system using Arduino

RESULTS AND DISCUSSION

Heart Rate Measurement Results

Heart rate measurements were obtained from 15 participants, with three repeated readings recorded for each individual. The recorded values demonstrate a high degree of consistency across repeated trials, indicating stable sensor performance and reliable signal acquisition.

Table 1. Heart rate measurements across 15 participants with three repeated trials

Patient	First reading heart rate [BPM]	Second reading heart rate [BPM]	Third reading heart rate [BPM]
1	72	75	70
2	80	78	82
3	90	85	88
4	68	70	72
5	76	78	74
6	85	83	87
7	92	89	91
8	70	72	71
9	74	76	77
10	78	75	80
11	84	82	85
12	88	86	90

13	79	81	78
14	71	73	72
15	77	80	75

The numerical heart rate measurements are summarized in Table 1. To provide a clearer visual interpretation of inter-subject variability and intra-subject repeatability, a graphical representation of heart rate measurements across all participants is presented in Figure 2. As shown in the figure, the majority of heart rate values fall within the expected physiological range for resting individuals. Minor variations between repeated readings can be attributed to natural physiological fluctuations and minor changes in sensor placement during measurement.

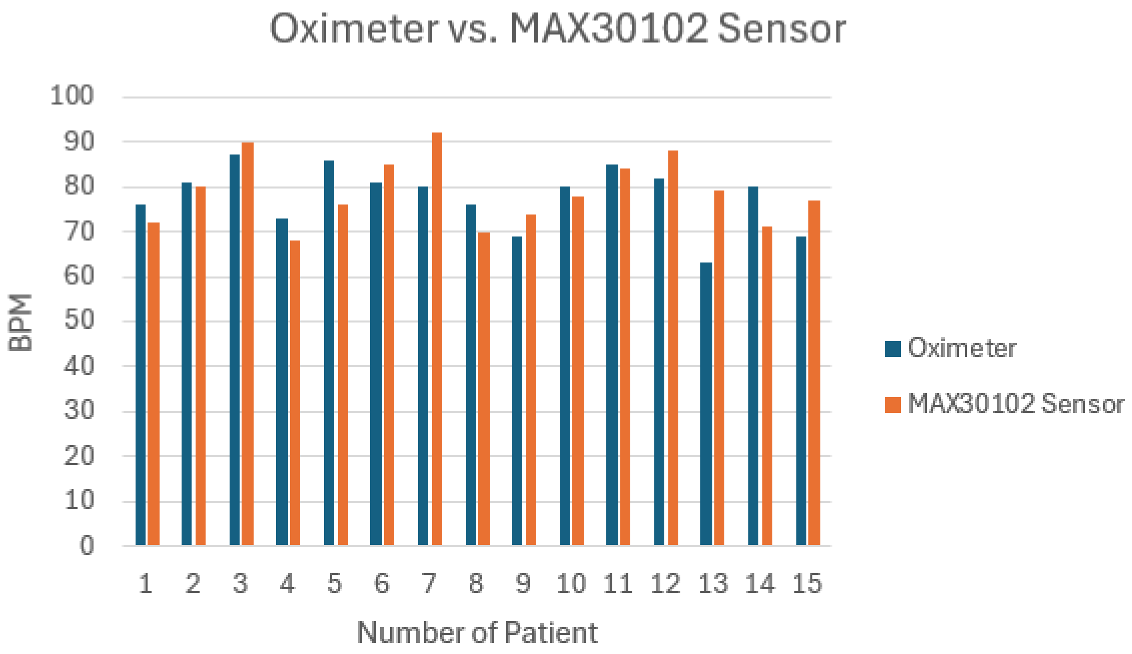

Figure 2. Heart Rate Measurements Across 15 Participants

SpO_2 Measurement Results

Blood oxygen saturation (SpO_2) levels were measured concurrently with heart rate using the integrated pulse oximeter sensor. The recorded SpO_2 values for all participants are presented in Table 2. The results indicate that SpO_2 levels remained largely within normal clinical limits, with minimal variation observed between repeated trials.

A graphical comparison of SpO_2 measurements is illustrated in Figure 3. The figure highlights the consistency of SpO_2 readings across participants, demonstrating the effectiveness of the photoplethysmography-based sensing approach implemented in the proposed system. The threshold-based alert mechanism was able to correctly detect low SpO_2 values when measurements dropped below the predefined limit.

Table 2. SpO_2 measurements across 15 participants with three repeated trials

Patient	First reading SpO_2 [%]	Second reading SpO_2 [%]	Third reading SpO_2 [%]
1	98	97	96
2	85	96	94

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XII December 2025

3	99	98	97
4	93	92	94
5	97	98	95
6	96	95	97
7	97	96	98
8	94	95	93
9	98	97	96
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14	93	94	91
15	98	97	96

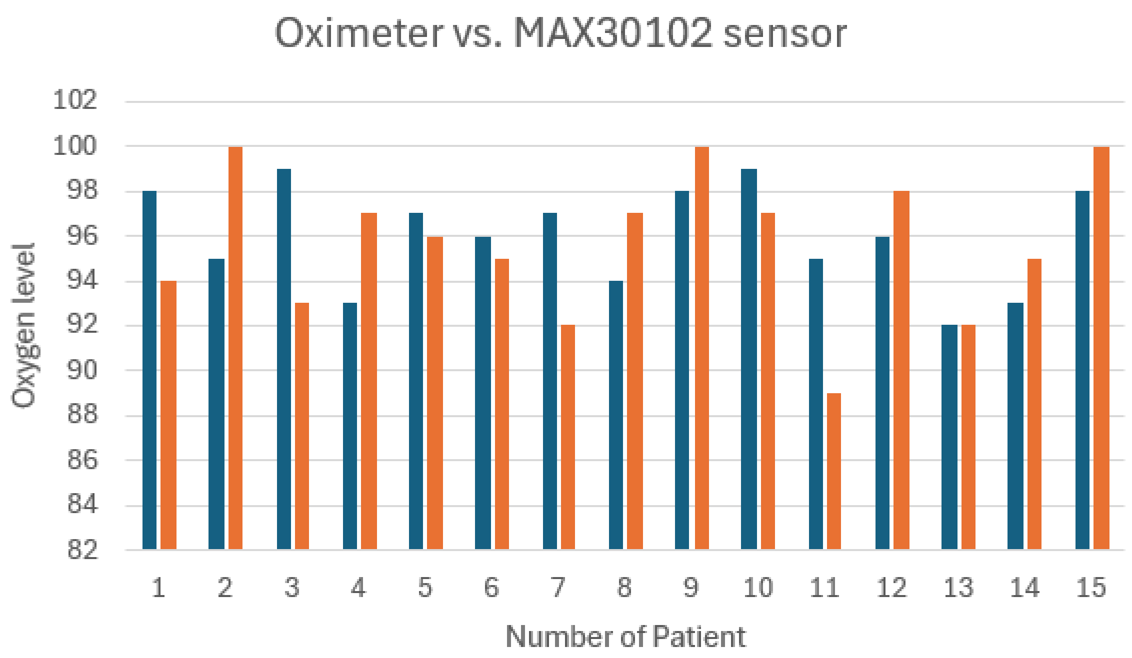

Figure 3. SpO_2 Measurements Across 15 Participants

Body Temperature Results

Body temperature measurements were obtained using the LM35 temperature sensor. The numerical temperature values recorded across three repeated trials for each participant are summarized in Table 3. The results show stable temperature readings with only minor deviations between measurements.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XII December 2025

For improved visualization, Figure 4 presents a graphical comparison of body temperature values across all participants. As shown in the figure, most recorded values fall within the normal physiological temperature range. The system successfully detected abnormal temperature conditions when values exceeded the predefined thresholds, activating both visual and auditory alerts accordingly.

Table 3. Body temperature measurements across 15 participants with three repeated trials

Patient	First reading body temperature [ºC]	Second reading body temperature [ºC]	Third reading body temperature [ºC]
1	36.5	36.7	36.4
2	37	36.8	37.1
3	36.8	37.0	36.9
4	36.3	36.5	36.6
5	36.9	37.0	36.7
6	37.2	37.3	37.1
7	36.7	36.9	37.0
8	36.6	36.8	36.5
9	37.1	37.2	37.0
10	36.5	36.7	36.6
11	37.3	37.4	37.2
12	36.8	37.0	36.9
13	36.4	36.6	36.5
14	36.7	36.8	36.5
15	37.0	37.1	36.9

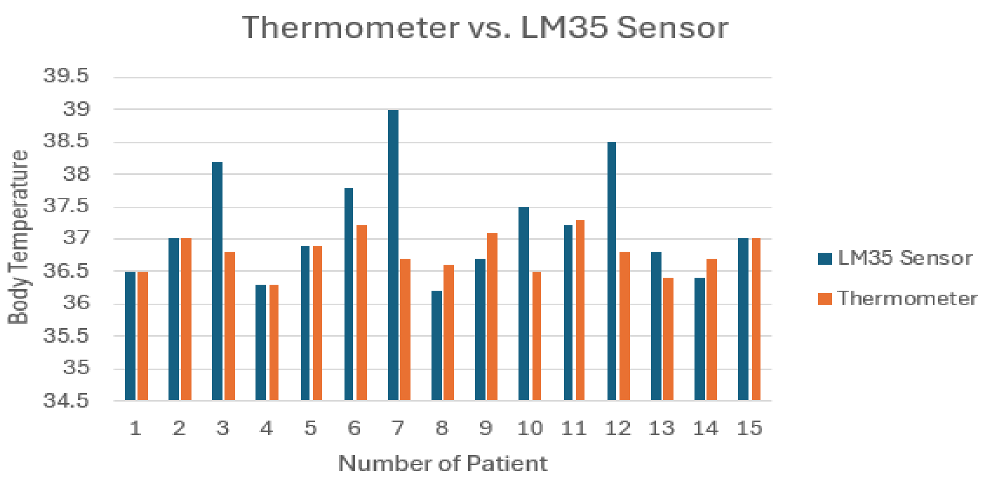

Figure 4. Body Temperature Measurements Across 15 Participants

ECG Signal Monitoring and IoT Visualization

The ECG sensor was used to monitor heart activity by measuring signal strength and displaying the ECG value in real time on the LCD. The system was programmed to trigger a warning whenever the ECG reading fell outside the acceptable range (below 100 or above 900). In addition, the system continuously checked the connection status of the ECG leads. If a lead became disconnected, the ECG value was shown as zero on the display, and a warning was activated through an LED indicator and a buzzer alert, ensuring that connection issues were clearly communicated to the user.

A mismatch was observed between the ECG values displayed on the Arduino and those shown on the Ubidots platform due to differences in data sampling and transmission rates. While the Arduino updates and displays ECG readings multiple times per second, Ubidots only allows one data point per second to be transmitted. As a result, only the most recent ECG value within each second is sent, while earlier readings are discarded. This limitation causes the Ubidots graph to appear less detailed, sometimes showing lag, gaps, or smoothed trends compared to the real-time fluctuations visible on the Arduino display, even though the ECG signal is being accurately captured by the system.

Overall, the results confirm that the proposed system achieves its design objectives. The combination of local alerting and remote monitoring enhances reliability and usability. Compared with related systems reported in the literature, the proposed approach offers comparable functionality at significantly lower cost, making it particularly suitable for low-resource environments.

CONCLUSION AND FUTURE WORK

This study presented a low-cost, Arduino-based multi-parameter vital sign monitoring system integrating heart rate, SpO_2, body temperature, and ECG sensing with real-time alerts and IoT-enabled remote visualization. Experimental evaluation involving 15 participants demonstrated stable measurements, effective threshold-based warning mechanisms, and reliable local display. The results confirm that the proposed system is suitable for routine, non-critical health monitoring, particularly in resource-constrained environments.

However, limitations were identified related to cloud data transmission rates, which reduce signal granularity and may hinder the remote detection of rapid physiological changes. Additional challenges include potential accuracy deviations of low-cost sensors compared to clinical-grade equipment, susceptibility to motion artifacts, power management constraints in multi-sensor operation, and reliability issues associated with low-cost microcontroller platforms. Furthermore, cybersecurity and data privacy concerns remain significant due to limited encryption and authentication capabilities in basic IoT implementations.

Future work will focus on improving data fidelity and system robustness through edge computing techniques such as adaptive sampling and local data caching. Hardware upgrades to more advanced, low-power microcontrollers and dedicated analog front-end circuits are recommended to enhance signal quality and energy efficiency. Strengthening data security through encrypted communication, secure authentication, and compliance with healthcare data protection standards is also essential. Finally, large-scale clinical validation and advanced signal processing techniques are required to improve accuracy, usability, and clinical relevance of the system.

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Teknikal Malaysia Melaka (UTeM) and the Centre for Research and Innovation Management (CRIM), UTeM for their research support.

REFERENCES

1. A. K. Khanna, M. Flick, and B. Saugel, “Continuous vital sign monitoring of patients recovering from surgery on general wards: a narrative review.,” Br. J. Anaesth., vol. 134, no. 2, pp. 501–509, Feb. 2025, doi: 10.1016/j.bja.2024.10.045.

2. B. van Zeist - de Jonge, J. de Man-Van Ginkel, M. Olvers, K. van den Berge, L. Kooij, and P. J. T. Rood, "Nurses' experiences with inhospital continuous monitoring of vital signs in general wards: A systematic review," PLOS Digit. Heal., vol. 4, no. 8 August, pp. 1–16, 2025, doi: 10.1371/journal.pdig.0000949.
3. H. H. J. van Noort, F. L. Becking-Verhaar, W. Bahlman-van Ooijen, M. Pel, H. van Goor, and G. Huisman-de Waal, "Three Years of Continuous Vital Signs Monitoring on the General Surgical Ward: Is It Sustainable? A Qualitative Study," J. Clin. Med., vol. 13, no. 2, 2024, doi: 10.3390/jcm13020439.
4. Y. P. Putra, W. K. Wibowo, and S. Prayogi, "Design and development of an Arduino-based oxygen saturation, heart rate variability, and blood glucose measurement device," IAES Int. J. Robot. Autom., vol. 14, no. 1, pp. 74–81, 2025, doi: 10.11591/ijra.v14i1.pp74-81.
5. S. Abdulmalek et al., "IoT-Based Healthcare-Monitoring System towards Improving Quality of Life: A Review," Healthc., vol. 10, no. 10, 2022, doi: 10.3390/healthcare10101993.
6. R. Raj, "Health Monitoring System using Arduino with SMS Alert and Remote Access," Int. J. Multidiscip. Res., vol. 7, no. 3, pp. 6–18, 2025, doi: 10.36948/ijfmr.2025.v07i03.43938.
7. H. Taherdoost, "Wearable Healthcare and Continuous Vital Sign Monitoring with IoT Integration," Comput. Mater. Contin., vol. 81, no. 1, pp. 79–104, 2024, doi: 10.32604/cmc.2024.054378.
8. S. Upadhyay et al., "Challenges and Limitation Analysis of an IoT-Dependent System for Deployment in Smart Healthcare Using Communication Standards Features," Sensors, vol. 23, no. 11, 2023, doi: 10.3390/s23115155.
9. I. Hussain, D. Deshalahre, Isha, and P. Thakur, "Assessing the Effectiveness of An IoT-Based Healthcare Monitoring and Alerting System with Arduino Integration," Rev. d'Intelligence Artif., vol. 38, no. 4, pp. 1211–1221, 2024, doi: 10.18280/ria.380415.
10. R. Sandeep, C. Science, and I. Technology, "Health Monitoring System Using Arduino and Esp8266," Int. Res. J. Mod. Eng. Technol. Sci., vol. 3, no. 3, pp. 364–367, 2023, doi: 10.56726/irjmets40094.