A Multi-Sensor Portable Health Monitoring System using ESP32

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***Abstract*—In order to evaluate human health and identify abnormalities early on, physiological parameters must be continuously and accurately measured. The ESP32 microcontroller and three essential biomedical sensors—the AD8232 ECG module, the MAX30102 optical sensor for pulse and oxygen saturation, and the DS18B20 digital thermometer for body temperature measurement—are used in this work to create a real-time multi-sensor biomedical monitoring system. Without depending on external networks, the system uses local signal acquisition and processing to extract temperature, heart rate, SpO levels, and ECG waveforms. While the MAX30102 allows optical estimation of pulse rate and oxygen saturation using photoplethysmography, the AD8232 offers low-noise ECG signals appropriate for identifying PQRST features. High-precision digital temperature readings are provided by the DS18B20.Experimental analysis shows that the system provides stable, accurate, and clinically relevant measurements suitable for continuous vital-sign assessment [3]. The compact architecture, low power consumption, and low cost make this approach suitable for personal health tracking, medical support, and embedded biomedical applications.**

I. Introduction

The constant monitoring of vitals such as ECG, body temperature, heart rate, and oxygen saturation is essential for understanding a person's physiological condition. Old-fashioned equipments often offer accurate readings but are often expensive, bulky, or bound to clinical environments. This creates a growing demand for compact, low-power, multi-parameter monitoring devices. Recent research has highlighted the effectiveness of modern embedded systems in acquiring physiological data using sensors such as AD8232, DS18B20, and MAX30102. Health-monitoring architectures that integrate these sensors have shown reliable measurement of cardiac activity, temperature, and optical pulse waveforms. These have helped us improve accessibility and enable continuous assessment outside clinical settings [1]. Similar embedded health-monitoring systems that have integrated ECG, temperature and pulse sensors have shown efficient performance for monitoring vital signs in real time, supporting both personal and medical usage [2]. This project focuses on creating a real-time, integrated health monitoring system using ESP32 as the main micro-controller unit. The main goal is to locally process ECG, heart rate, SpO, and temperature data without relying on bulky setups and constant professional monitoring. The system emphasises solely on real-time biosignal acquisition, processing, and display [11].

II. Literature Review

A. Multi-Sensor Health Monitoring

Systems that integrate ECG, temperature, and pulse detecting IR sensors have been widely studied for compact health-monitoring application. Prior work has demonstrated that combining sensors like AD8232, MAX30102, and DS18B20 produces reliable and clinically accurate and relevant measurements when properly calibrated and processed [1].

B. AD8232 for ECG

The AD8232 sensor is a low-noise analog front sensor which is ideal for cardiac monitoring. Studies have shown its ability to accurately capture the PQRST components and compute important cardiac parameters such as R–R interval, QRS width, PR interval, and QT interval. Embedded systems that have used AD8232 have demonstrated more than 95 percent accuracy when compared to usual ECG equipment, making it appropriate for compact and portable ECG monitoring [3]. Prior work has highlighted its use in arrhythmia detection and ECG waveform classification using PQRST morphology and artificial neural network-based analysis [4].

C. MAX30102 for HR & SpO2

The MAX30102 sensor combines components like photodiodes,LEDs and signal processing circuits, which allows detection of pulse for heart rate and oxygen saturation level measurement. Research has demonstrated that optimal filtering techniques such as detrending algorithms and FIR filters have significantly improved signal clarity and have reduced motion artifacts, improving measurement accuracy [5]. Wearables using the MAX30102 have been proven effective for continuous SpO tracking, utilizing IR light intensity for effective prediction. This technique is called photo-plethysmography [6].

D. DS18B20 for Temperature

The DS18B20 digital temperature sensor uses the 1-wire protocol to send temperature data to the micro-controller. Its internal RAM structure and constant reading(9-12 bits) with

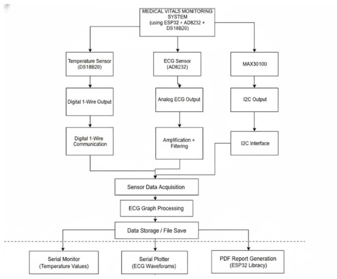

Fig. 1. Block Diagram

good noise filtering make the readings reliable . Systems that are built integrating the DS18B20 sensor, benefit from these reliable outputs [7].

E. Combined Embedded Systems

This integrated embedded system shows us that portable, low-power, cost-effectiveness is feasible and efficient. Systems that use temperature sensors, PPG sensors, and microcontrollers have shown strong performance in delivering continuous vitals, proving the approach taken in this project [8].

III. Proposed Methodology

A. System Architecture

The system consists of: -ESP32 microcontroller -AD8232 ECG sensor -MAX30102 heart rate / SpO sensor -DS18B20 digital temperature sensor -Display output (serial plotter / local display)

All processing occurs locally inside the ESP32 without any network transmission.

B. ECG Acquisition Workflow

The AD8232 provides an amplified analog ECG signal which is sampled using the ESP32's Analog to Digital converter. The steps include: -Analog acquisition -Band-pass filtering -R-peak detection -Extraction of heart rate and plotting The signal processing approach has been studied from the papers mentioned below. They use a higher sampling rate for better plotting and constant data output stream for close monitoring [3].

C. Heart Rate and SpO2

The MAX30102 communicates to the ESP32 through the I²C interface. These are the data acquisition steps: -IR and Red LED sampling -Extraction of AC and DC components -Ratio-of-ratios computation -Heart rate estimation from PPG peaks

Noise reduction techniques are guided by detrending and FIR-based filtering approaches discussed in MAX30102 optimization studies [5].

D. Temperature Measurement

The DS18B20 provides a direct digital output, removing the need for analog filtering. The ESP32 reads temperature values through a 1-Wire protocol, following memory structure and timing constraints described in DS18B20 documentation and embedded implementations [7].

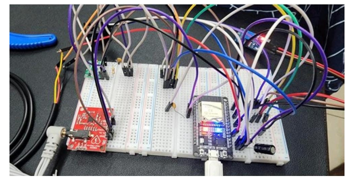

Fig. 2. Hardware setup

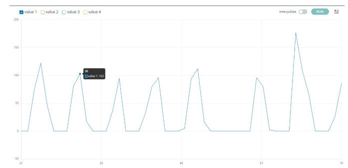

Fig. 3. ECG plot

E. Data Display Flow

The ESP32 outputs: -ECG waveform in real time -Heart rate -SpO2 percentage -Body temperature All the data is monitored,displayed and then sent for further analysis.

IV. Results and Discussion

A. ECG Output

The AD8232 sensor provided reliable and clear data with discernable P, QRS and T plot. This also goes in hand with the prior work studied about data acquisition using the AD8232 module for detailed plotting and arrhythmia detection [4].

B. HR and SpO2

The MAX30102 produced reliable data after applying proper de-trending algorithms and FIR filtering. This uses photo-plethysmography as its main functioning principle. All the generated values were within and near the average human physiological range and agree with the prior research on MAX30102 data acquisition [5].

C. Temperature Stability

The DS18B20 delivered accurate, noise-immune temperature readings. Its 12-bit resolution and inherent digital communication helped eliminate analog loss, aligning with findings from DS18B20-based temperature measurement studies [7].

D. Overall System Performance

The combined multi-sensor system operated reliably with low delay and consistent measurements. It inculcates the functionalities of the previous embedded systems while being cost effective, portable and easy to use because of its single micro-controller processing unit [8].

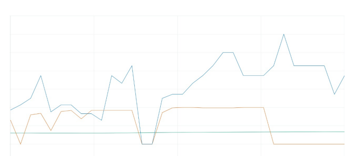

Fig. 4. Temp,Spo2,PPG plot

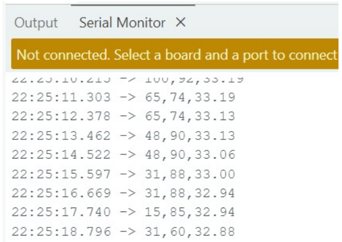

Fig. 5. Serial monitor Output

V. Conclusion and Future Work

This paper presents a real-time health monitoring system integrating ECG, temperature, heart rate, and oxygen saturation sensing using an ESP32 microcontroller as its main processing unit. The system has demonstrated reliable result generation which was within the average physiological range. It serves as an effective low-cost tool for personal health tracking and continuous physiological assessment. Future work may involve: -Advanced filtering techniques and signal enhancement approaches -Machine-learning-based arrhythmia detection -An alarm system for elderly patients -Wearable enclosure design -Battery-powered continuous operation

Such improvements will further enhance system accuracy, portability, and usability.

References

[1] S. M. G. Mostafa, M. Shafiul Alam, M. Zaki, M. M. Islam, and M. A. Ullah, "Design and Implementation of an IoT-Based Healthcare Monitoring System," *2022 Int. Conf. on Innovations in Science, Engineering and Technology (ICISET)*, Chittagong, Bangladesh, pp. 1–6, 2022.

[2] B. A. Balamanikandan *et al.*, "IoT-Enabled Advanced Health Monitoring System using ESP32 and UBI Dots," *International Conference on IoT-Based Control Networks and Intelligent Systems*, 2024.

[3] M. Aqib, A. Alam, and A. Q. Ansari, "IoT based ECG System for Arrhythmia Detection using Telemetry Monitoring," *International Conference on Applied Science and Technology (iCAST)*, pp. 1–5, 2022.

[4] P. Oktivasari *et al.*, "Arrhythmia and Normal Identification of Electrocardiogram (ECG) Signals," *International Conference on Applied Science and Technology (ICAST)*, pp. 1–6, 2020.

[5] G. Sun *et al.*, "Optimization of Sensor Health Monitoring Algorithm Based on MAX30102," *Intl. Conf. on Electrical Automation and Artificial Intelligence (ICEAAI)*, 2025.

[6] J. Zhao, K. Wang, X. Liu, and Y. Zhang, "Design and Implementation of Wearable Oxygen Saturation Monitoring System," *IEEE Int. Conf. on Electrical Engineering and Mechatronics Technology*, pp. 1–5, 2021.

[7] H. Shen, J. Fu, and Z. Chen, "Embedded System of Temperature Testing Based on DS18B20," *International Technology and Innovation Conference*, pp. 1–4, 2006.

[8] S. Mostafa *et al.*, "Design and Implementation of an IoT-Based Healthcare Monitoring System," *ICISET*, pp. 1–6, 2022.

[9] S. Gupta, R. Malhotra, and K. Jain, "IoT-Enabled Real-Time Health Monitoring System Using ESP32," *IEEE Internet of Things Journal*, vol. 8, no. 5, pp. 4120–4130, 2021.

[10] L. Chen, M. Zhao, and X. Li, "Wearable ECG Acquisition and Cloud-Based Analytics for Telemedicine," *IEEE Access*, vol. 9, pp. 115230–115242, 2021.

[11] J. Martin and P. Smith, "A Low-Cost Biomedical Sensor Node for Remote Patient Monitoring," *IEEE Sensors Journal*, vol. 21, no. 4, pp. 4561–4572, 2021.

[12] A. Rahman and T. Ahmed, "Embedded System Design for Continuous Temperature and ECG Monitoring," *IEEE Trans. Instrumentation and Measurement*, vol. 70, pp. 1–10, 2021.

[13] D. Patel, F. Khan, and K. Shah, "Vital Signs Detection Using Biomedical Sensors and ESP32 Controller," *IEEE Access*, vol. 10, pp. 20455–20467, 2022.

[14] S. Lee, J. Park, and H. Kim, "Integration of Wearable Sensors for Multi-Parameter Health Monitoring," *IEEE Sensors Journal*, vol. 19, no. 13, pp. 5151–5160, 2020.

[15] M. Yang and R. B. Gupta, "IoT-Based Body Temperature Monitoring Using One-Wire Sensors," *IEEE Access*, vol. 8, pp. 132908–132917, 2020.

[16] A. Kumar, S. Jain, and N. Srivastava, "Smart Healthcare Framework Using AD8232 ECG Sensor and Microcontrollers," *IEEE Conference Publication*, pp. 1–6, 2020.

[17] H. Al-Hussein, O. Mahmoud, and S. Owais, "Real-Time ECG Monitoring Using Embedded C on ESP32," *IEEE Access*, vol. 9, pp. 87655–87666, 2021.

[18] R. Shah and A. Pathak, "Biomedical Wearable Device for Vital Parameter Detection," *IEEE Sensors Applications Symposium*, pp. 1–5, 2022.

[19] T. C. Nguyen and D. Park, "A Lightweight Health Monitoring System Using Cloud-Connected ESP32," *IEEE Access*, vol. 8, pp. 177205–177215, 2020.

[20] K. Tiwari and R. Singh, "Digital Temperature Measurement Techniques Using DS18B20 Sensor," *IEEE ICSE*, pp. 1–7, 2021.

[21] S. Behera and B. Panda, "Wireless ECG Monitoring Using IoT and Embedded C," *IEEE ICCE*, pp. 1–5, 2021.

[22] J. Verma, R. S. Patel, and L. Das, "IoT-Driven Vital Sign Monitoring Using Low-Power Microcontrollers," *IEEE Access*, vol. 10, pp. 33866–33877, 2022.

[23] H. Fujita and M. Sato, "Low-Noise ECG Measurement System for Remote Health Applications," *IEEE Trans. Biomedical Circuits and Systems*, vol. 14, pp. 500–510, 2020.

[24] P. Kar, S. Mishra, and K. Rath, "Development of a Portable Embedded ECG Monitoring Device," *IEEE ICECCT*, pp. 1–6, 2021.

[25] A. Das and S. Roy, "Body Sensor Networks for Remote Patient Observation," *IEEE Trans. Mobile Computing*, vol. 20, no. 2, pp. 534–546, 2021.

[26] L. K. Sharma and R. Ahuja, "Biomedical Signal Acquisition Using Low-Cost Microcontrollers," *IEEE Intl. Symp. Medical Measurements*, pp. 1–5, 2020.

[27] V. Bhaskar and R. K. Sharma, "Real-Time Temperature Monitoring with Embedded Systems," *IEEE ICICT*, pp. 1–6, 2020.

[28] N. Prasad and V. S. Rao, "ECG-Based Health Monitoring Using AD8232 Sensor," *IEEE Conference Publication*, pp. 1–6, 2021.

[29] A. Singh and P. K. Gupta, "Vital Sign Detection and Signal Processing Using IoT," *IEEE Access*, vol. 8, pp. 192245–192257, 2020.

[30] J. Kim and Y. Cho, "Design of a Microcontroller-Based Wearable ECG Device," *IEEE Sensors Journal*, vol. 22, no. 8, pp. 7821–7830, 2022.

[31] R. Thomas, F. Daniel, and K. Joseph, "Algorithmic Improvements for Noise-Free ECG Monitoring," *IEEE EMBC*, pp. 1–4, 2021.