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Design and Preliminary Evaluation of an ESP32-Based Multi-Sensor Prototype for Baby Vital Sign and Movement Monitoring

Vani Paliwal

Student, Grade IX, Delhi World Public School, Ashta, Madhya Pradesh, India

ABSTRACT

Infants cannot verbally communicate discomfort or changes in their physical condition, making careful observation by parents and caregivers important. This paper describes the design of an educational prototype of a proposed Baby Vital Health Monitoring Band. The prototype integrates an ESP32 DevKit V1 microcontroller with a MAX30102 optical sensor, a DS18B20 digital temperature sensor and an MPU6050 accelerometer–gyroscope. The MAX30102 is used to obtain pulse-related optical signals and generate estimated pulse-rate and peripheral oxygen saturation (SpO_2) readings; the DS18B20 measures temperature at its probe; and the MPU6050 detects acceleration and rotational movement. The ESP32 collects the available sensor information and can transmit it wirelessly to a smartphone interface. A buzzer is included to demonstrate alerts triggered by programmed test conditions. The work follows a design-and-development approach and focuses on component integration and the proposed system architecture. No clinical testing, infant testing or quantitative accuracy evaluation is claimed. The prototype is an educational demonstration and is not a medical device. Further work must address infant-specific sensor placement, measurement validation, comfort, electrical and thermal safety, battery life, wireless reliability and data privacy before any real-world use is considered.

KEYWORDS: infant wearable technology; multi-sensor system; ESP32; MAX30102; SpO_2 estimation; DS18B20; MPU6050; Internet of Things; prototype development.

1. INTRODUCTION

Infant well-being is an important concern for parents and caregivers. Babies cannot verbally describe discomfort, pain or other changes in how they feel. Caregivers therefore rely on observation and, when necessary, appropriate medical equipment and professional advice. This has encouraged research into wearable technologies that may collect selected physiological or movement-related information in a convenient form.

Recent reviews describe developments in soft, wearable and wireless sensing systems for infants and neonates. They also identify specific design challenges, including fragile skin, device comfort, signal quality, miniaturisation and the need for clinical validation (Zhu et al., 2015; Zhou et al., 2024). Research into infant movement monitoring further shows that motion sensing is an active area of investigation, but that methods and interpretation require care (Peng et al., 2023).

This paper presents an educational prototype called the Baby Vital Health Monitoring Band. It explores how multiple electronic sensors can be connected to a common microcontroller and how available readings can be shared with a smartphone. The present work demonstrates a technical concept; it does not establish clinical usefulness or medical accuracy.

2. Aim, Objectives and Research Questions

2.1 Aim

To design and demonstrate an educational multi-sensor prototype that integrates optical, temperature and movement-sensing components with wireless data transmission.

2.2 Objectives

- To connect the MAX30102, DS18B20 and MPU6050 sensors to an ESP32 microcontroller.
- To demonstrate pulse-related optical signal acquisition and estimated SpO_2 output from the MAX30102 under a fingertip demonstration setup.

- To measure temperature at the DS18B20 probe.
- To detect acceleration and rotational movement using the MPU6050.
- To explore wireless transmission of available sensor readings to a smartphone display.
- To demonstrate a buzzer alert under programmed experimental conditions.
- To identify the additional engineering and safety work required before any infant-specific application.

2.3 Research questions

1. Can the selected sensors be integrated with an ESP32 in one educational prototype?
2. Can the ESP32 collect the available sensor information and transmit it to a smartphone?
3. What limitations must be addressed before the concept could be considered for infant-specific testing?

3. BACKGROUND AND RELATED WORK

Zhu et al. (2015) reviewed wearable sensor systems for infants and discussed the potential of wearable monitoring alongside design and implementation challenges. Zhou et al. (2024) reviewed skin-interfacing wearable biosensors for infants and neonates, highlighting the importance of soft materials, gentle interfaces, miniaturised electronics and reliable sensing. Peng et al. (2023) systematically reviewed technologies for continuous sensing and quantification of infant body motion. Together, these studies show that infant wearable monitoring is a multidisciplinary field involving electronics, materials, signal processing, clinical knowledge and safety assessment.

The present prototype is more limited than the systems described in clinical and engineering research. It uses readily available development-board components to demonstrate sensor integration and wireless communication. Its contribution is therefore an educational design demonstration, not a new clinically validated sensing method.

4. SYSTEM COMPONENTS

4.1 ESP32 DevKit V1

The ESP32 is the central controller. It receives digital information from the sensors, runs the programmed logic and supports wireless communication. The ESP32 family includes Wi-Fi and Bluetooth capabilities and common digital interfaces such as I²C (Espressif Systems, n.d.). The exact wireless mode used in the prototype should be stated in the final version.

4.2 MAX30102 optical sensor

The MAX30102 is an integrated optical sensor designed for pulse oximetry and heart-rate sensing applications. It uses red and infrared LEDs and a photodetector to measure changes in received light. Signal-processing algorithms can use these optical changes to estimate pulse rate and SpO_2. Readings can be affected by motion, placement, perfusion, ambient conditions and the measurement site. In the described demonstration, the sensor is placed on a fingertip; these readings must not be represented as validated infant measurements.

4.3 DS18B20 digital temperature sensor

The DS18B20 is a digital thermometer that communicates through a 1-Wire interface. It measures temperature at its sensing probe. A probe reading is not automatically equivalent to core body temperature, and the measurement location and contact conditions should be recorded.

4.4 MPU6050 accelerometer and gyroscope

The MPU6050 combines a three-axis accelerometer and a three-axis gyroscope. The accelerometer measures linear acceleration, while the gyroscope measures angular velocity. These outputs can be used to observe movement and changes in orientation. The sensor alone cannot identify sleep stages or diagnose a medical condition.

4.5 Supporting components

The prototype also uses a breadboard, jumper wires, a buzzer, a wearable-band demonstration material and a smartphone. The electronic circuit is described as being mounted separately from the soft demonstration band in the current presentation setup.

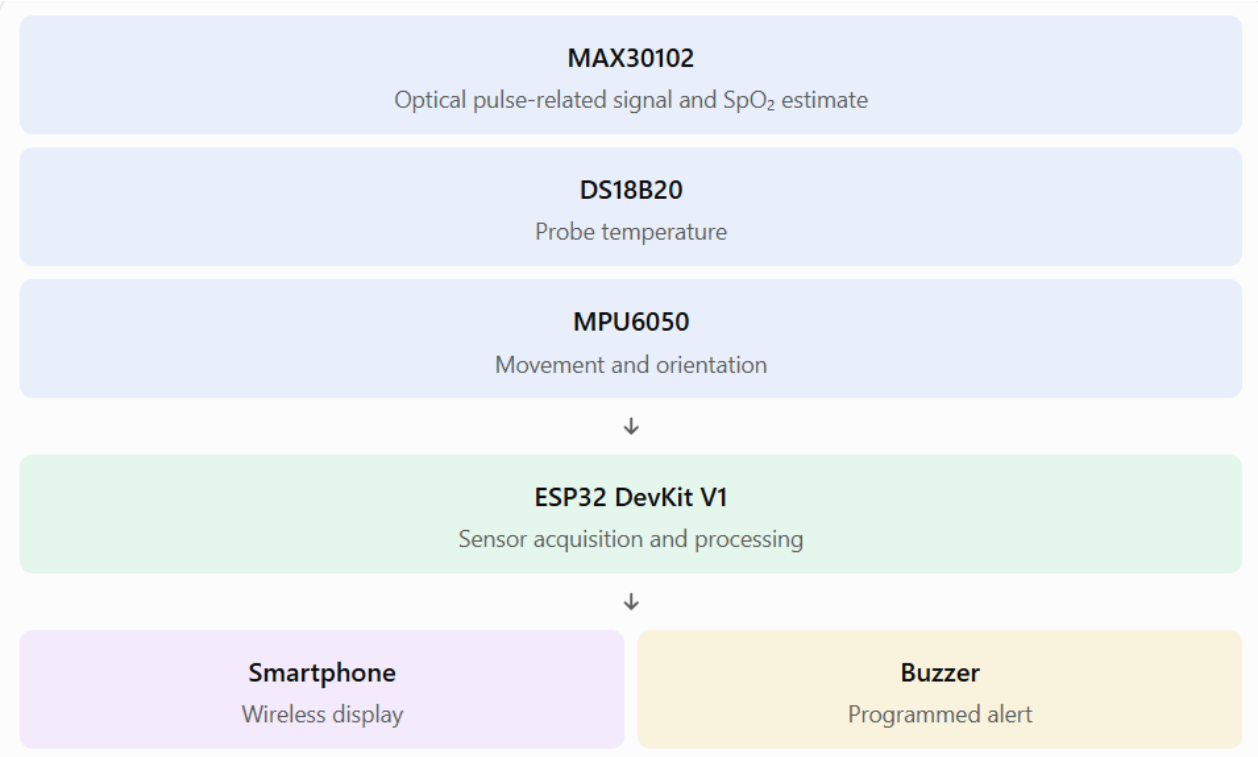

Figure 1: Proposed Flow of the Working of a Band

5. METHODOLOGY

5.1 Research design

This work uses a design-and-development approach. An educational electronic prototype is assembled to explore the connection of multiple sensors to one microcontroller and the transfer of available readings to a smartphone. The work is not a clinical study and does not involve testing on infants.

5.2 System architecture

The proposed architecture has five functional layers: (1) sensing layer – MAX30102, DS18B20 and MPU6050; (2) processing layer – ESP32 DevKit V1; (3) communication layer – Wi-Fi or Bluetooth, depending on the implemented configuration; (4) display layer – smartphone interface; and (5) alert layer – buzzer controlled by programmed conditions.

5.3 Sensor interfaces

The MAX30102 and MPU6050 commonly communicate using I²C. The DS18B20 uses the 1-Wire digital interface. The final submission should include the actual pin-to-pin wiring diagram, supply-voltage details, pull-up resistor arrangement where applicable, and the software libraries or firmware versions used. These details are necessary for reproducibility.

5.4 Data handling

The ESP32 reads the sensors and formats the available values for display. The smartphone interface is intended to show pulse-related output, estimated SpO_2, probe temperature, movement information and sensor-connection status. The final paper must identify the actual application or dashboard used and whether communication is through Wi-Fi or Bluetooth.

5.5 Alert demonstration

The buzzer can be activated when a programmed test condition is met, such as a demonstration threshold or a detected sensor-connection issue. Any thresholds used must be reported as software demonstration settings only. They must not be presented as clinical limits or medical advice.

6. PROTOTYPE DEMONSTRATION AND OBSERVATIONS

The project description indicates four demonstrations: (1) fingertip optical sensing using the MAX30102; (2) probe-temperature measurement using the DS18B20; (3) movement and orientation detection using the

MPU6050; and (4) transfer of available readings from the ESP32 to a smartphone, followed by a buzzer demonstration. These activities describe the planned demonstration sequence. They do not, by themselves, establish measurement accuracy, reliability or continuous operating capability.

No numerical dataset, repeated-trial results, reference-device comparison, response-time measurements, battery-life measurements or wireless-range measurements were supplied for this draft. Consequently, no averages, percentages, accuracy values or performance claims are reported. The following table must be completed from actual observations before submission.

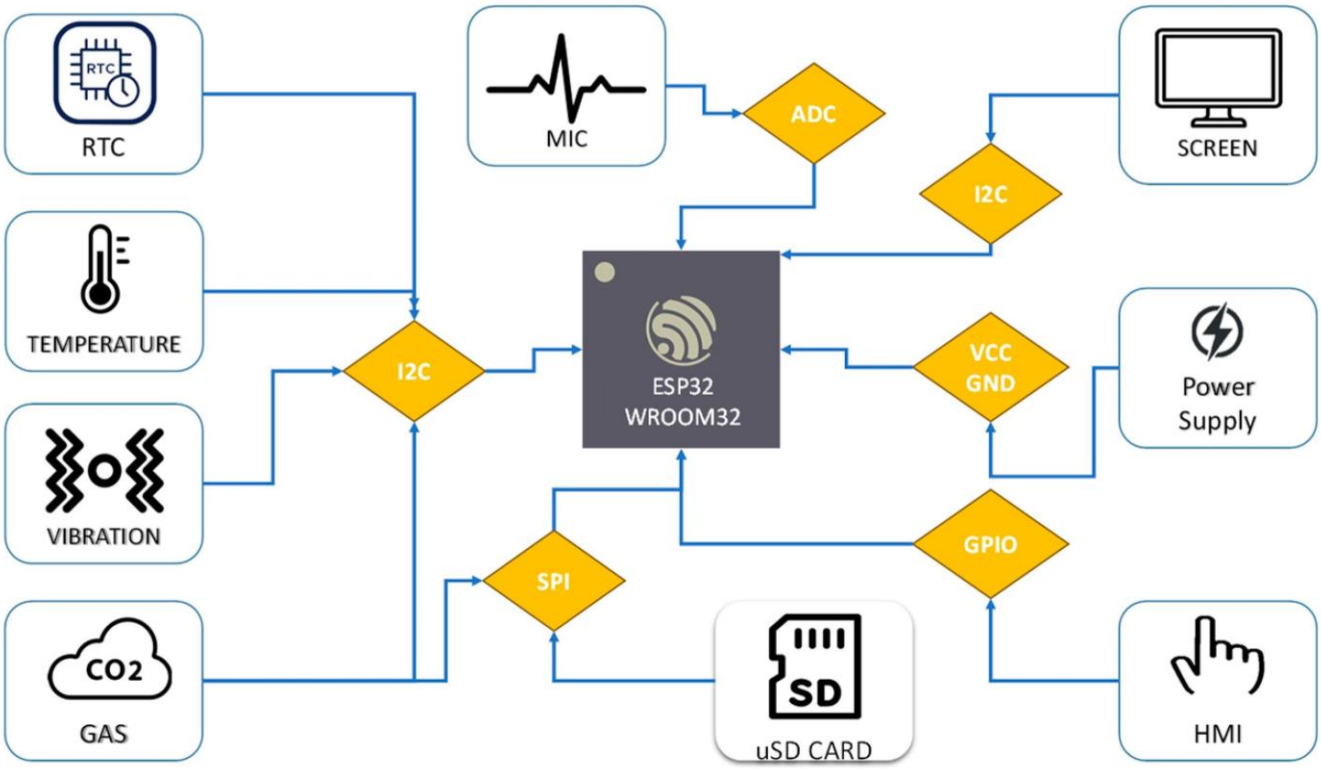

Figure 2: Proposed system Architecture

Table 1: Proposed Test

Test	What to record
MAX30102 fingertip demonstration	Raw/processed output, pulse-rate estimate, SpO_2 estimate, signal stability
DS18B20 probe measurement	Probe location, displayed temperature, comparison method if any
MPU6050 movement demonstration	Movement/orientation tested and corresponding sensor output
Smartphone communication	Connection method, successful updates, interruptions
Buzzer alert	Programmed test condition and whether buzzer activated

7. DISCUSSION

The prototype illustrates the educational value of combining different sensor types in a single embedded system. The ESP32 provides a common processing and communication platform, while the three sensors provide different kinds of information: optical signals, probe temperature and movement. A smartphone display can bring these outputs together in one interface.

However, integration does not automatically make the system suitable for infant monitoring. Optical measurements may be affected by motion and placement; a temperature probe measures its own contact environment; and an inertial sensor reports movement rather than a medical interpretation. Research on infant wearable systems stresses the need to address comfort, material safety, signal quality and validation for the intended population (Zhu et al., 2015; Zhou et al., 2024).

The most defensible conclusion at this stage is that a basic multi-sensor educational prototype can be assembled around an ESP32 and used to demonstrate sensor acquisition and wireless display, subject to verification of the actual test records. Further testing is needed to evaluate performance.

8. LIMITATIONS AND SAFETY CONSIDERATIONS

- The prototype has not been clinically validated and is not a medical device.
- MAX30102 fingertip readings have not been validated for infant use.
- DS18B20 probe temperature is not equivalent by default to core body temperature.
- MPU6050 movement data cannot independently identify sleep stages or diagnose illness.
- No documented accuracy, repeatability, response-time, battery-life or wireless-reliability dataset was supplied.
- Infant use would require assessment of choking and entanglement hazards, skin compatibility, pressure, heat, electrical safety, battery containment and secure attachment.
- Any future testing involving infants must be designed and supervised by qualified professionals, with appropriate institutional approval, parent/guardian consent and applicable ethical safeguards.

The prototype must not replace caregiver observation, professional medical advice or approved medical equipment. It should not be worn by an infant in its present form.

9. FUTURE SCOPE

- Develop a mechanically secure, lightweight design using materials assessed for skin contact and infant comfort.
- Evaluate suitable infant-specific sensing locations and sensor technologies with qualified clinical and engineering guidance.
- Compare sensor outputs against appropriate reference instruments under an approved test protocol.
- Measure repeatability, signal loss, motion artefacts, response time, wireless range and power consumption.
- Develop secure data handling, user authentication and privacy controls for the smartphone interface.
- Conduct formal electrical, thermal, mechanical and usability safety assessments before any human-use study.

10. CONCLUSION

The project presents the design and preliminary demonstration of an ESP32-based multi-sensor prototype integrating the MAX30102, DS18B20 and MPU6050 modules. The system provides an educational platform for exploring optical pulse-related sensing, probe-temperature measurement, movement detection and the integration of sensor outputs with wireless communication. The prototype demonstrates the engineering possibility of combining multiple sensor modules within a single embedded system. However, its current performance has not been established through clinical validation, and no conclusions can be drawn regarding its accuracy or suitability for infant monitoring. Further controlled testing, engineering refinement and safety assessment are necessary before any application involving infants can be considered. The project therefore represents an initial educational contribution to the study of wearable sensing technology.

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Ethics and Consent
No infants or human participants were involved in the work described in this draft. If any human-participant testing is later added, the relevant ethics approval and consent information must be reported accurately.

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Conflict of Interest
No Conflict of Interest

REFERENCES

1. Zhu, Z., Liu, T., Li, G., Li, T., & Inoue, Y. (2015). Wearable sensor systems for infants. *Sensors*, *15*(2), 3721–3749. https://doi.org/10.3390/s150203721
2. Chen, H., Xue, M., Mei, Z., Bambang Oetomo, S., & Chen, W. (2016). A review of wearable sensor systems for monitoring body movements of neonates. *Sensors*, *16*(12), Article 2134. https://doi.org/10.3390/s16122134
3. Peng, Z., Kommers, D., Liang, R.-H., Long, X., Cottaar, W., Niemarkt, H., Andriessen, P., & van Pul, C. (2023). Continuous sensing and quantification of body motion in infants: A systematic review. *Heliyon*, *9*(7), Article e18234. https://doi.org/10.1016/j.heliyon.2023.e18234
4. Zhou, L., Guess, M., Kim, K. R., & Yeo, W.-H. (2024). Skin-interfacing wearable biosensors for smart health monitoring of infants and neonates. *Communications Materials*, *5*, Article 72. https://doi.org/10.1038/s43246-024-00511-6
5. Hyun, A., Takashima, M., Hall, S., Lee, L., Dufficy, M., Ruppel, H., & Ullman, A. (2025). Wearable biosensors for pediatric hospitals: A scoping review. *Pediatric Research*, *98*(1), 90–99. https://doi.org/10.1038/s41390-024-03693-4
6. Allen, J. (2007). Photoplethysmography and its application in clinical physiological measurement. *Physiological Measurement*, *28*(3), R1–R39. https://doi.org/10.1088/0967-3334/28/3/R01
7. Tamura, T., Maeda, Y., Sekine, M., & Yoshida, M. (2014). Wearable photoplethysmographic sensors—Past and present. *Electronics*, *3*(2), 282–302. https://doi.org/10.3390/electronics3020282
8. Nitzan, M., Romem, A., & Koppel, R. (2014). Pulse oximetry: Fundamentals and technology update. *Medical Devices: Evidence and Research*, *7*, 231–239. https://doi.org/10.2147/MDER.S47319
9. Jubran, A. (2015). Pulse oximetry. *Critical Care*, *19*, Article 272. https://doi.org/10.1186/s13054-015-0984-8
10. Ray, D., Collins, T., Woolley, S., & Ponnapalli, P. (2023). A review of wearable multi-wavelength photoplethysmography. *IEEE Reviews in Biomedical Engineering*, *16*, 136–151. https://doi.org/10.1109/RBME.2021.3121476