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Design and Implementation of an IoT-based Respiratory Motion Sensor

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INTRODUCTION & AIM

Respiratory rate is a key physiological indicator that reflects both physical health and emotional state, and its monitoring is critical for health tracking. In this work, we present the design and implementation of a device for real-time monitoring of respiratory system movements [1]. When breathing, the circumference of the abdomen and thorax changes; therefore, we used a Force Sensing Resistor (FSR) attached to the Printed Circuit Board (PCB) to measure this variation as the patient inhales and exhales. The mechanical strain this causes changes the FSR electrical resistance accordingly. Also, for streaming this variable resistance on an Internet of Things (IoT) platform, Bluetooth Low Energy (BLE) 5 is utilized due to the adequate throughput, high accessibility, and possibility of power consumption reduction.

In addition to the sensing mechanism, the device includes a compact, energy-efficient microcontroller and a 3-axis accelerometer that captures body movement [2]. Further benefits of incorporating FSR and accelerometer include accuracy, cost-effectiveness, and thinness [3]. Power is supplied by a rechargeable Lithium-ion Polymer (LiPo) battery, and energy usage is optimized using a buck converter. For comfort and usability, the enclosure was 3D printed using Stereolithography (SLA) technology to ensure a smooth, ergonomic shape. This setup allows the device to operate reliably over long periods without disturbing the user. Altogether, the design supports continuous respiratory tracking in both clinical and home settings, offering a practical, low-power, and portable solution.

METHOD

The proposed device captures respiratory motion through a Force Sensing Resistor (FSR) mounted on a custom PCB, which detects changes in abdominal and thoracic circumference. The ergonomic enclosure is fabricated via SLA 3D printing using durable ABS-like resin to ensure comfort and long-term usability.

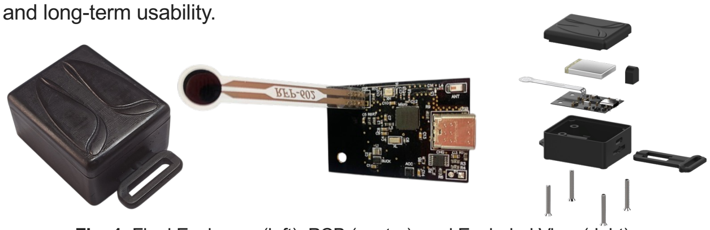

Fig. 1. Final Enclosure (left), PCB (center), and Exploded View (right).

The FSR operates in a voltage divider circuit and its resistance, sampled via an ADC, varies with applied pressure. The core of the system is a low-power nRF52832 microcontroller with integrated BLE 5 for real-time data transmission. A 3-axis accelerometer (LIS2DH12) records body motion at 50 Hz, providing context to the respiratory signal. Power is supplied by a 450 mAh rechargeable LiPo battery, regulated to 1.8 V using a high-efficiency buck converter (TPS62840). A USB Type-C port and charging IC (MCP73833T) support safe recharging, while the firmware handles BLE streaming, FSR and battery sensing, and accelerometer data collection.

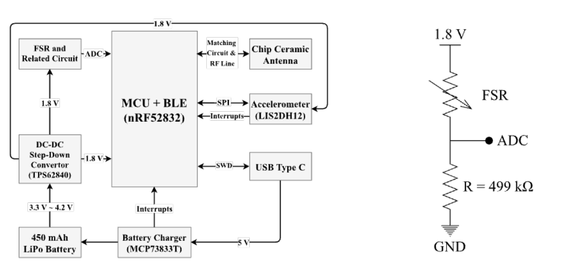

Fig. 2. System Block Diagram (left), Reading/measuring FSR resistance (right).

RESULTS & DISCUSSION

Table 1. Qualitative Comparison of Pressure Sensing Technologies

Sensor	Advantages	Limitations
FSR	Small, low-cost, flexible, durable	Hysteresis at high forces
Strain	Accurate, compact, temperature-stable	Noise-sensitive, higher power
Load Cell	High precision, excellent linearity	Bulky, expensive, power-hungry
Capacitive	Low power, sensitive, high resolution	Noise and temperature sensitive
Optical	High sensitivity, some flexible designs	Expensive, high power

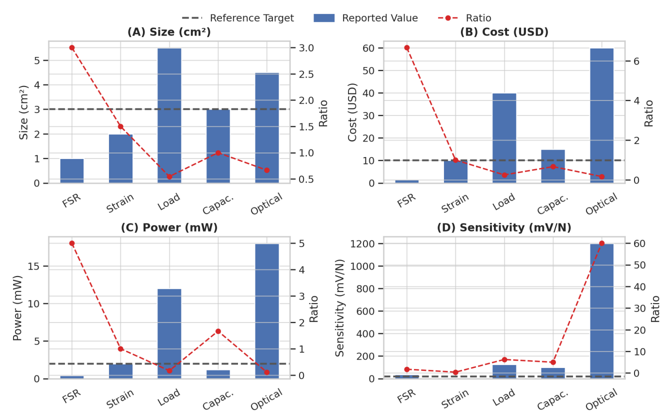

Fig. 3. Comparison of five sensor types (FSR, strain gauge, load cell, capacitive, optical) across four different metrics. Blue bars represent reported values. Black lines indicate reference targets suitable for wearable applications. Red lines show the ratio of reported to target values, where higher ratios imply better alignment with design goals.

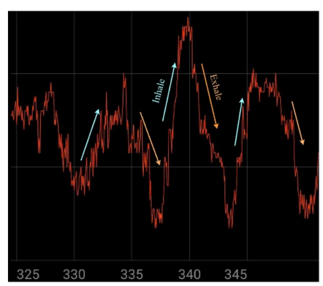

Fig. 4. Respiratory Signal Output

- FSRs, though less linear and prone to hysteresis, offered adequate accuracy for respiration tracking.
- Unlike load cells and optical sensors, our system is compact and low-power.
- Capacitive and optical types are more sensitive but less robust in noisy environments.
- Fig. 4 shows clean, real-time respiratory signals suitable for continuous monitoring.

CONCLUSION

The designed respiratory monitoring system introduces novel design elements and satisfies the desired functional requirements. The selection of proper elements, as well as innovative design approaches, ensure a high resolution of 12 bits for capturing respiratory signals and long battery life. Also, the size of the device makes it portable and convenient to use for patients. Moreover, it provides a system for sending notifications and communicating between the device and its user.

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