DESIGN AND DEVELOPMENT OF A WEARABLE AIR QUALITY ENVIRONMENT MONITOR

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Air Quality Monitoring, Wearable Device, ESP32-S3, BME680 Sensor, Indoor Air Quality (IAQ), IoT-Based System, Embedded System, Environmental Monitoring, LVGL Interface, Portable Monitoring Device.

Introduction:

Indoor air quality has become an important concern due to its direct impact on human health, productivity, and overall comfort. People spend a significant amount of time in indoor environments such as homes, offices, and classrooms, where air quality can vary due to factors like ventilation, human activity, and the presence of pollutants. Traditional air quality monitoring systems are often bulky, expensive, and designed for fixed installations, making them less suitable for continuous personal monitoring.

With the advancement of embedded systems and IoT technologies, there is an increasing demand for compact and portable solutions that can monitor environmental conditions in real time. Wearable and portable monitoring devices offer the advantage of providing localized and user-specific air quality information, enabling better awareness and timely action.

This project focuses on the design and development of a compact, wearable air quality and environmental monitoring device using modern embedded technologies. The system utilizes the ESP32-S3 microcontroller and the Bosch BME680 environmental sensor to measure parameters such as temperature, humidity, pressure, and gas-based air quality indicators. The collected data is processed using the BSEC2 algorithm to generate reliable Indoor Air Quality (IAQ) values.

A custom enclosure is designed using CAD tools and fabricated using 3D printing to achieve portability and usability. The device displays real-time environmental information on an integrated screen, allowing standalone operation without continuous internet dependency. The developed system aims to provide a practical and accessible solution for monitoring indoor air quality in everyday environments.

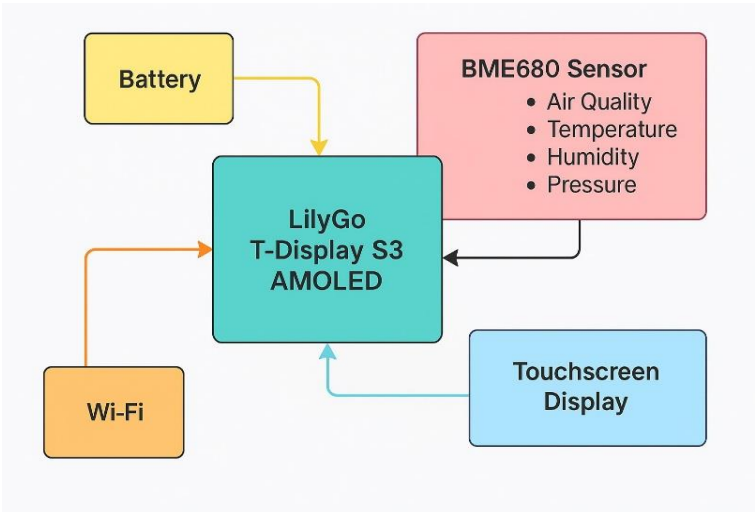

Figure 1: Block diagram of the device.

Objectives:

1. To design and develop a compact, wearable/portable air quality monitoring device.
2. To measure temperature, humidity, pressure, and indoor air quality (IAQ).
3. To implement the BSEC2 algorithm for accurate air quality estimation.
4. To provide real-time data visualization using an embedded display.
5. To design a custom 3D-printed enclosure for portability and protection.
6. To ensure standalone operation without continuous internet dependency.

Methodology:

1. The proposed system is developed as a compact, wearable air quality monitoring device using the ESP32-S3 microcontroller and BME680 environmental sensor. The sensor measures temperature, humidity, pressure, and gas-related parameters, which are continuously acquired by the microcontroller.
2. The raw sensor data is processed using the BSEC2 algorithm to generate accurate and stable Indoor Air Quality (IAQ) values. This improves reliability by compensating for environmental variations and sensor behaviour.
3. The processed data is displayed in real time on an AMOLED screen using a graphical interface developed with the LVGL framework. This enables clear and easy visualization of environmental parameters.
4. A custom enclosure is designed in Fusion 360 and fabricated using 3D printing to achieve a compact and portable form factor. The enclosure includes proper ventilation for accurate sensing and secure placement of components.
5. The firmware is developed using the Arduino IDE, integrating sensor data acquisition, processing, and display functions. The system operates as a standalone device and is tested under different indoor conditions to evaluate performance and stability.

Result and Conclusion:

1. The developed system successfully monitors environmental parameters such as temperature, humidity, pressure, and indoor air quality (IAQ) in real time. The BSEC2 algorithm provides stable and reliable IAQ values, improving the accuracy of air

quality estimation. The graphical interface displays the data clearly on the AMOLED screen, enabling easy interpretation by the user.

2. The device demonstrates consistent performance under different indoor conditions, responding appropriately to environmental changes. The compact and 3D-printed enclosure ensures portability and ease of use, making the system suitable for wearable or portable applications.
3. Overall, the project achieves its objective of developing a standalone air quality monitoring device with real-time visualization. The system is reliable, user-friendly, and effective for monitoring indoor environmental conditions, thereby validating the proposed design and implementation.

References:

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2. [2] Bosch Sensortec, *"BSEC Software Library Documentation,"* Bosch Sensortec GmbH, 2022.
3. [3] Espressif Systems, *"ESP32-S3 Technical Reference Manual,"* Espressif Systems, 2022.
4. [4] LVGL, *"Light and Versatile Graphics Library Documentation,"* 2023.
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Future Scope:

The future scope of this project includes:

1. Integration of additional sensors for detecting specific pollutants (e.g., PM2.5, CO_2).
2. Development of a mobile application for remote monitoring and alerts.
3. Implementation of cloud connectivity for long-term data storage and analysis.
4. Optimization of power consumption for extended wearable usage.
5. Enhancement of the graphical interface with advanced visualization features.
6. Improvement in enclosure design for better durability and ergonomics.
7. Expansion to outdoor air quality monitoring applications.
8. Integration with smart home or IoT systems for automated responses.