

Executive Summary

This project develops an IoT-based Air Quality Monitoring System using a Raspberry Pi to measure and display environmental conditions in real time. Air quality sensors collect data such as particulate levels and other environmental readings, which are processed by the Raspberry Pi. The system uses a Python backend to gather and manage the sensor data and an HTML/JavaScript frontend to present the information through a web-based interface. This allows users to view current air quality readings and trends directly from the local system. The goal is to provide a low-cost and accessible solution for monitoring air quality and increasing environmental awareness.

Background

- **Project Mission:** "Smart Air. Healthy Campus."
- **Target Environment:** Designed for reliable, real-time air quality monitoring on a university campus.
- **Core Problem:** The need for accessible, low-cost hardware to track particulate matter (PM2.5, PM10), temperature, humidity, and gas levels.
- **Significance:** Provides immediate environmental feedback to improve health and campus awareness



Figure 1. AirIQ logo

Experimental Setup

Architecture:

- **Edge/Hardware Layer (Layer X):** Raspberry Pi acting as the main controller, interfacing with PMS5003 and BME680 sensors.
- **Frontend Layer (Layer Y):** A web dashboard that retrieves data via local APIs for real-time visualization.
- **Local Backend Layer (Layer Z):** A software-based pipeline using FastAPI to handle data ingestion, AQI computation, and SQLite for local persistence.

Detailed Technical Information (Engineering Design):

- **Local Data Flow:** Data flows from sensors to the Pi, is processed locally, and served directly to the UI without external cloud dependencies.
- **Communication Protocols:** Uses I2C, UART, and GPIO for hardware-to-Pi communication.
- **Data Structure:** Sensor readings are bundled into synchronized JSON payloads containing device IDs and timestamps.
- **Processing Logic:** Implements a Timed Sampling Loop and moving average smoothing to ensure stable, noise-free readings.

Experimental Test Plan

- **Sampling Loop:** Utilize a timed polling scheduler to read sensors every 1 to 5 seconds to generate synchronized records.
- **Data Fusion:** Assemble sensor values from different interfaces (UART/I2C/GPIO) into a single structured JSON payload.
- **Validation Protocols:** Apply range checking to ensure values like humidity stay within 0–100% and numeric types are correct.
- **Signal Refining:** Implement a 5-sample moving average window to reduce noise and spikes in particulate and gas sensor outputs

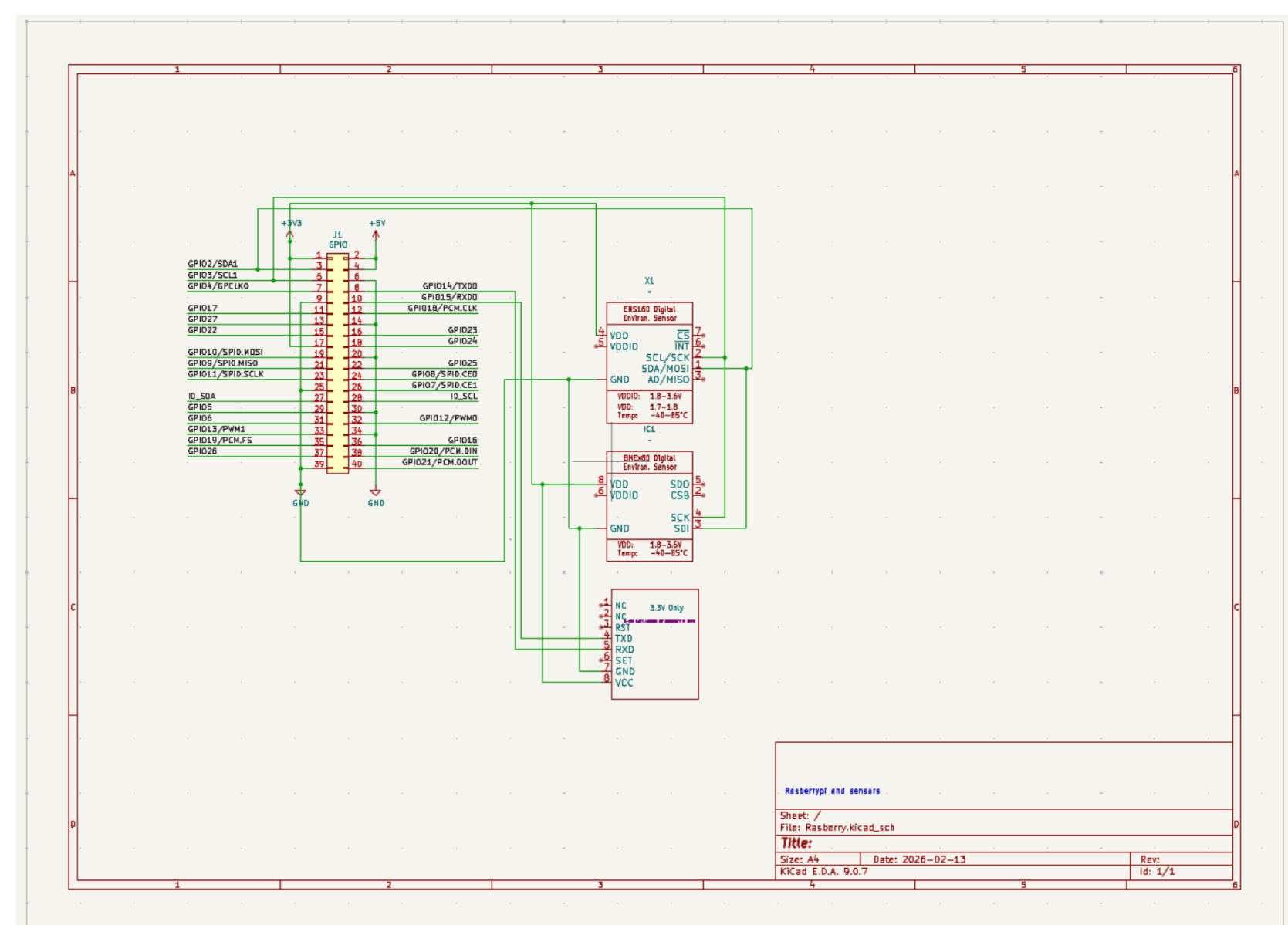


Figure 2. PCB Design

Experimental Results

- **AQI Accuracy:** Successfully mapped PM2.5 readings to U.S. EPA AQI categories (e.g., Good, Moderate, Unhealthy).
- **Data Integrity:** Validated that JSON payloads remained self-contained and extensible, allowing for the addition of new sensors without pipeline breaks.
- **Local Persistence:** Achieved atomic writes to the SQLite readings table, preventing partial data storage during system resets.
- **System Latency:** Confirmed near real-time responsiveness between the hardware sensors and the local web dashboard.

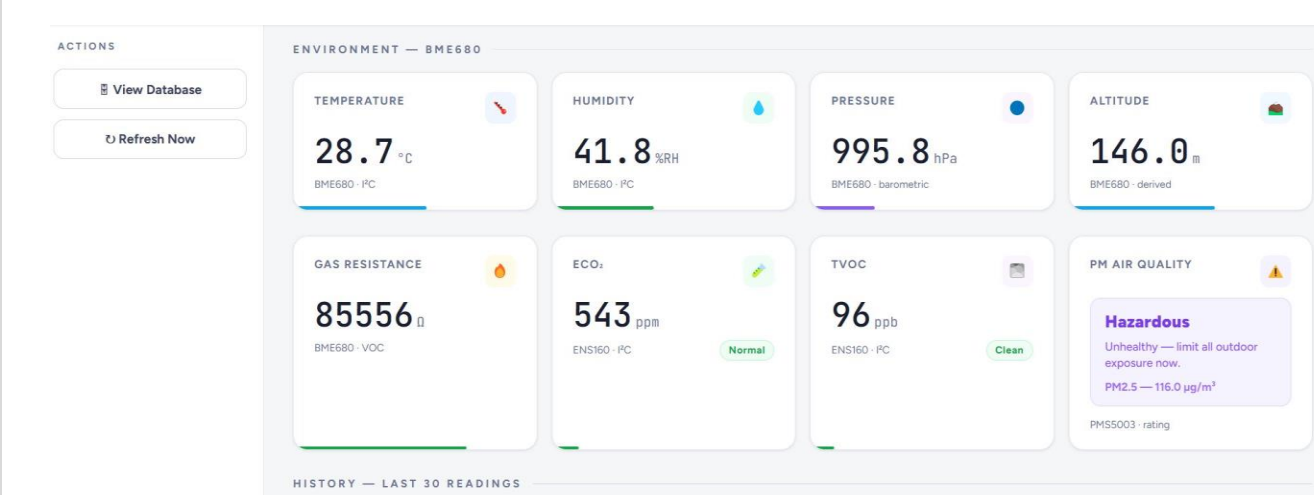


Figure 3. Web Dashboard (UI)

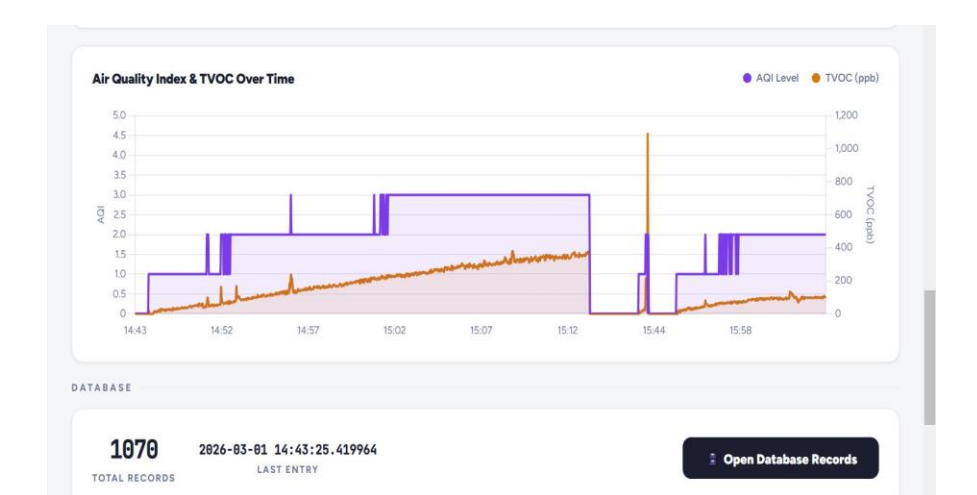


Figure 4. Web Dashboard (UI)

Conclusions

- **Goal Achievement:** Successfully created an end-to-end local pipeline from sensing to visualization without external cloud dependencies.
- **Hardware Efficiency:** Python provided simple, extensive library support for managing multiple IoT sensors on a single Raspberry Pi node.
- **Future Work:** Potential for distributed nodes and enhanced aggregation queries for longer-term historical trends.
- **Special Thanks To:** Chenxi Wang and Steve Mcdermott



Figure 5. Group Photo

References

- lady ada. PM2.5 Air Quality Sensor. Adafruit Industries, 3 June 2024, <https://cdn-learn.adafruit.com/downloads/pdf/pm25-air-quality-sensor.pdf>. Accessed 13 Feb. 2026.
- lady ada. Adafruit BME680 Humidity & Temperature Barometric Pressure & VOC Gas Sensor. Adafruit Industries, 2024, <http://cdn-learnadafruit.com/downloads/pdf/adafruit-bme680-humidity-temperature-barometric-pressure-voc-gas.pdf>. Accessed 13 Feb. 2026.
- lady ada. Adafruit ENS160 MOx Gas Sensor. Adafruit Industries, 2024, <http://cdn-learn.adafruit.com/downloads/pdf/adafruit-ens160-mox-gas-sensor.pdf>. Accessed 13 Feb. 2026.