

CAR CABIN AIR QUALITY MONITOR

ABSTRACT

Air inside a car often goes unnoticed, yet it can quickly become unhealthy due to trapped exhaust gases, carbon monoxide, or volatile organic compounds (VOCs). Poor cabin air can cause discomfort, headaches, or even serious health risks during long drives. To tackle this problem, we developed a smart car cabin air quality monitor that is affordable, portable, and easy to use.

The system combines an MQ-135 gas sensor with an ESP32 microcontroller to continuously monitor in-cabin air quality. A compact OLED display mounted on the dashboard shows real-time readings and indicates whether the air quality is “Good,” “Moderate,” or “Poor.” If poor air is detected, the system immediately triggers a buzzer for an audible alert, ensuring passengers are warned even without looking at the display. Additionally, the ESP32’s Bluetooth Low Energy (BLE) capability allows the device to send automatic notifications to a nearby smartphone without requiring an internet connection. For extended monitoring, the ESP32 can also send data to the cloud via Wi-Fi, where platforms like ThingSpeak or Adafruit IO log and visualize the readings. A containerized backend system using Docker with InfluxDB and Grafana provides long-term data storage, trend analysis, and intuitive dashboards.

By combining real-time sensing, audible and smartphone alerts, and cloud-based data insights, this project offers a practical and reliable way to ensure cleaner and safer air inside vehicles.

Components Used:

- **MQ-135 Gas Sensor** – Detects harmful gases and VOCs.
- **ESP32 Microcontroller** – Processes sensor data, drives display, handles Wi-Fi + BLE.
- **OLED Display (0.96" SSD1306, I²C)** – Shows air quality status in real-time.
- **Buzzer** – Provides audible alerts when air quality becomes poor.
- **USB Car Adapter (5V output)** – Powers the system from the car’s cigarette lighter socket.
- **Connecting Wires & Breadboard/PCB** – For assembling the circuit.
- **Optional Enclosure** – Protects the electronics inside the car.
- **Cloud Platform (ThingSpeak / Adafruit IO)** – For remote data logging and basic visualization.

- **Containerized Backend (Docker + InfluxDB + Grafana)** – For advanced analytics, dashboards, and long-term storage.

Working of the Car Cabin Air Quality Monitor

1. Power Supply

- The entire system is powered through a USB car adapter connected to the car's cigarette lighter socket.
- The adapter provides 5V, which powers the ESP32 and the MQ-135 sensor module.

2. Sensing Air Quality

- The MQ-135 gas sensor continuously samples the cabin air.
- It detects gases such as carbon monoxide, ammonia, benzene, smoke, and volatile organic compounds (VOCs).
- The sensor produces an analog voltage proportional to the concentration of pollutants in the air.
- This analog signal is read by the ADC pin of the ESP32.

3. Data Processing (ESP32)

- The ESP32 processes the raw sensor values, smooths them using averaging, and compares them with predefined thresholds.
- Based on the sensor reading, the ESP32 categorizes the air quality into Good, Moderate, or Poor.

4. Local Alerts

- **OLED Display:** Shows the live sensor reading and the air quality status (Good/Moderate/Poor). A simple bar indicator may also be shown for clarity.
- **Buzzer:** When air quality falls into the "Poor" range, the ESP32 triggers the buzzer, producing an audible alert so passengers are warned instantly.

5. Phone Alerts Without Internet (BLE)

- The ESP32 uses Bluetooth Low Energy (BLE) to connect with a nearby smartphone.
- If poor air quality is detected, the ESP32 automatically sends a notification to the user's phone (via a simple companion app or BLE notification service).
- This ensures that even if the car has no internet, the driver is alerted immediately.

6. Cloud Connectivity (Wi-Fi)

- When Wi-Fi or mobile hotspot is available, the ESP32 connects to the cloud platform (ThingSpeak or Adafruit IO) using MQTT/HTTP.
- Sensor readings are uploaded at fixed intervals for logging and remote monitoring.

7. Containerized Backend for Analytics

- A server running Docker hosts two containers:
 - InfluxDB: Stores the time-series sensor data.
 - Grafana: Provides interactive dashboards to visualize historical air quality trends, set alerts, and analyze patterns.
- This backend allows advanced analytics, such as identifying recurring poor air events or comparing pollution levels across different trips.