PROJECT REPORT

Measurement and Instrumentation

Final Project · Part 1

MQ135 Gas Sensor for CO_2 and Ethanol Concentration Measurement

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ABSTRACT

This report presents the design and evaluation of a low-cost gas measurement system based on the MQ135 metal-oxide gas sensor and an Arduino Nano. After a 24-hour preheat and calibration of the sensor's reference resistance R_0, the Arduino converts the sensor output into concentration values in parts per million (ppm) and sends them to a custom Python interface that displays live readings and graphs.

Two experiments were carried out. In the first, carbon dioxide (CO_2) was measured at fifteen locations on campus with different ventilation and occupancy. Readings ranged from about 376 ppm in well-ventilated spaces to about 2,172 ppm in a crowded laboratory with limited ventilation, with an average of about 1,125 ppm, following the expected relationship between ventilation, occupancy and CO_2 accumulation. In the second, the sensor was exposed to ethanol vapour from hand sanitiser and perfume. It responded immediately and recovered after the source was removed, but most readings exceeded the sensor's specified detection range, so they are interpreted as a relative response rather than as absolute concentrations.

Keywords: MQ135, gas sensor, CO_2 measurement, air quality, ethanol detection, sensor calibration, Arduino

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1 Electronic System Design

1.1 Project Overview

The objective of this project is to design and implement an air-quality measurement system using the MQ135 gas sensor and an Arduino Nano microcontroller. The system detects variations in gas concentration and converts the sensor output into calibrated concentration values in parts per million (ppm). Two measurement scenarios were investigated: monitoring carbon dioxide (CO_2) in different real-world environments, and evaluating the sensor's response to ethanol vapour from perfume and hand sanitiser.

The MQ135 was selected because it is widely used for indoor air-quality monitoring and responds to several gases, including carbon dioxide, ammonia, alcohol vapour, benzene and smoke. Because the sensor produces an analog voltage that depends on gas concentration, calibration is required before meaningful measurements can be obtained.

1.2 System Block Diagram

Figure 1 shows the overall architecture. The MQ135 detects the surrounding gas and produces an analog voltage. The Arduino Nano reads this signal, applies the calibration parameters, converts the measurement to ppm and sends the result to the computer for visualisation.

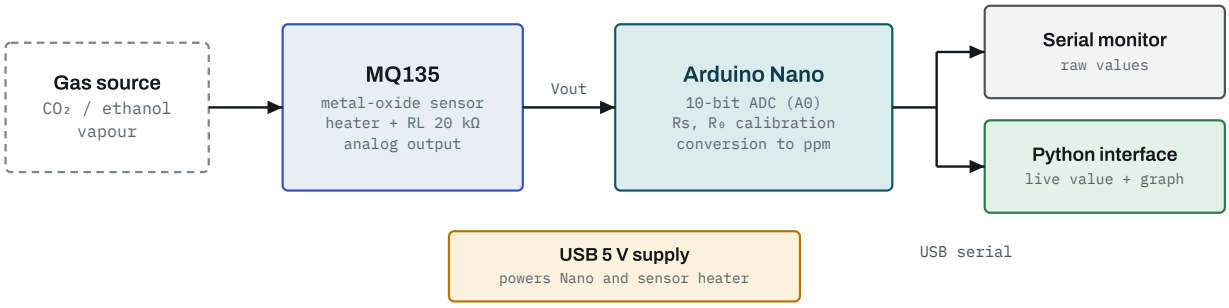


Figure 1. Block diagram of the MQ135 measurement system.

1.3 Measurement Principle

The MQ135 contains a heated tin-dioxide sensing layer whose resistance R_S falls as the concentration of reducing gases rises. The sensing element forms a voltage divider with the load resistor R_L, so the output voltage measured by the Arduino rises with gas concentration. The concentration is obtained from the ratio of R_S to the resistance R_0 measured in clean reference air, using the power-law characteristic curve of the sensor (Figure 2):

$$ppm = a \cdot (R_S / R_0)^b \tag{1}$$

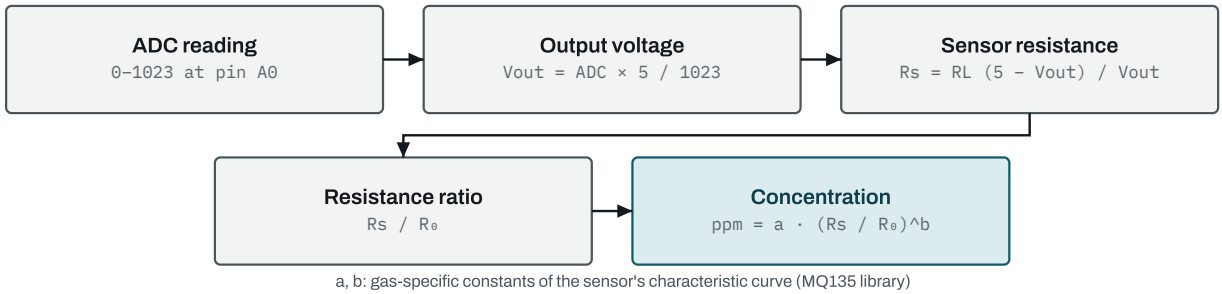


Figure 2. Conversion chain from the ADC reading to gas concentration.

1.4 Circuit Diagram

The MQ135 module is connected to the Arduino Nano with three connections: VCC, GND and the analog output (AO), which is connected to analog input A0 (Figure 3). The module's load resistor was replaced with a 20 kΩ resistor, as recommended by the project guideline.

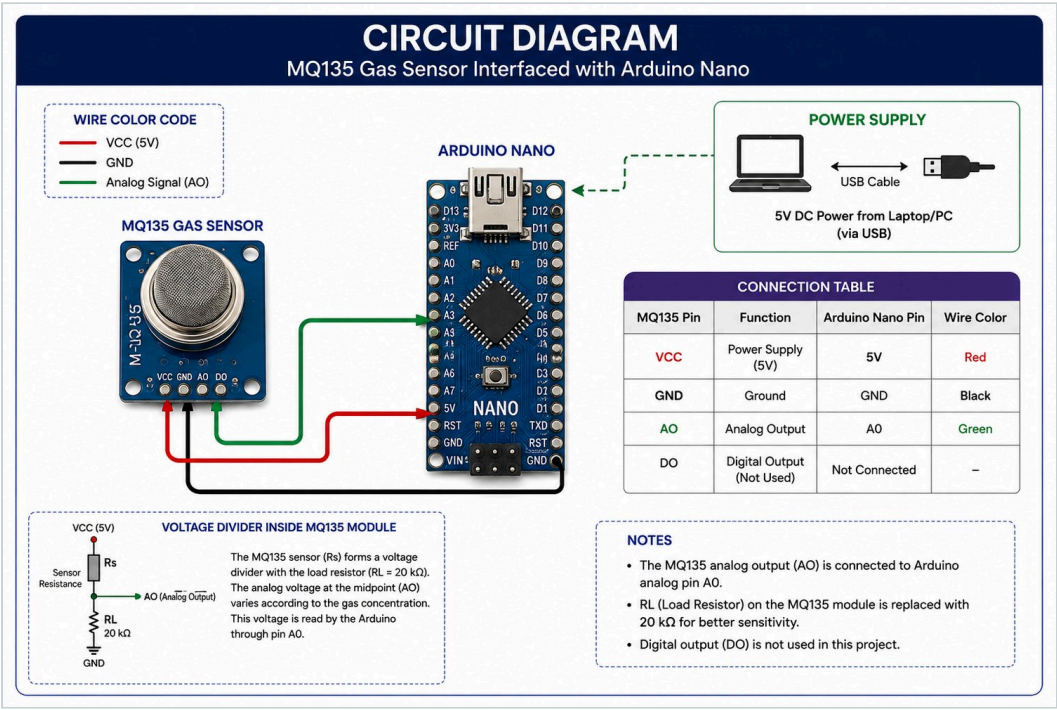


Figure 3. Circuit diagram of the MQ135 interfaced with the Arduino Nano.

1.5 Sensor Calibration

Before the sensor can report meaningful ppm values it must be calibrated to determine R_0, its resistance in clean reference air. The calibration followed the project guide and used the MQ135 Arduino library (Figure 4):

- the sensor was preheated continuously for 24 hours to stabilise its internal heating element;
- a 20 kΩ load resistor was used, matching the hardware configuration;
- the calibration sketch using `gasSensor.getRZero()` was uploaded, the sensor was allowed to stabilise, and several R_0 readings were taken and averaged;

- the resulting values were entered as the `RZERO` constant in `MQ135.h` before measurements were made.



Figure 4. Calibration procedure.

Table 1. Calibration results

Target gas	R_0
Carbon dioxide (CO_2)	221.30
Ethanol	144.46

After calibration, the measurement sketch using `gasSensor.getPPM()` was uploaded. The Arduino continuously reads the sensor, converts the measured resistance into concentration using the calibrated R_0 and sends the result over the serial port.

2 Experimental Results and Discussion

2.1 Experimental Set-up

The set-up consisted of the Arduino Nano, the MQ135 sensor on a breadboard, USB power and a laptop running the monitoring software. CO_2 measurements were collected in enclosed and open environments, and ethanol measurements were made by exposing the sensor to vapour from hand sanitiser and perfume. Before each measurement the sensor was allowed to stabilise.

2.2 Real-Time Display

Instead of relying only on the Arduino Serial Monitor, a custom monitoring interface was developed in Python (Figure 5). It receives the sensor data through the serial port, processes the incoming values and displays the concentration in real time, together with a dynamic graph and summary statistics, which made changes in CO_2 and ethanol concentration easier to observe during the experiments.

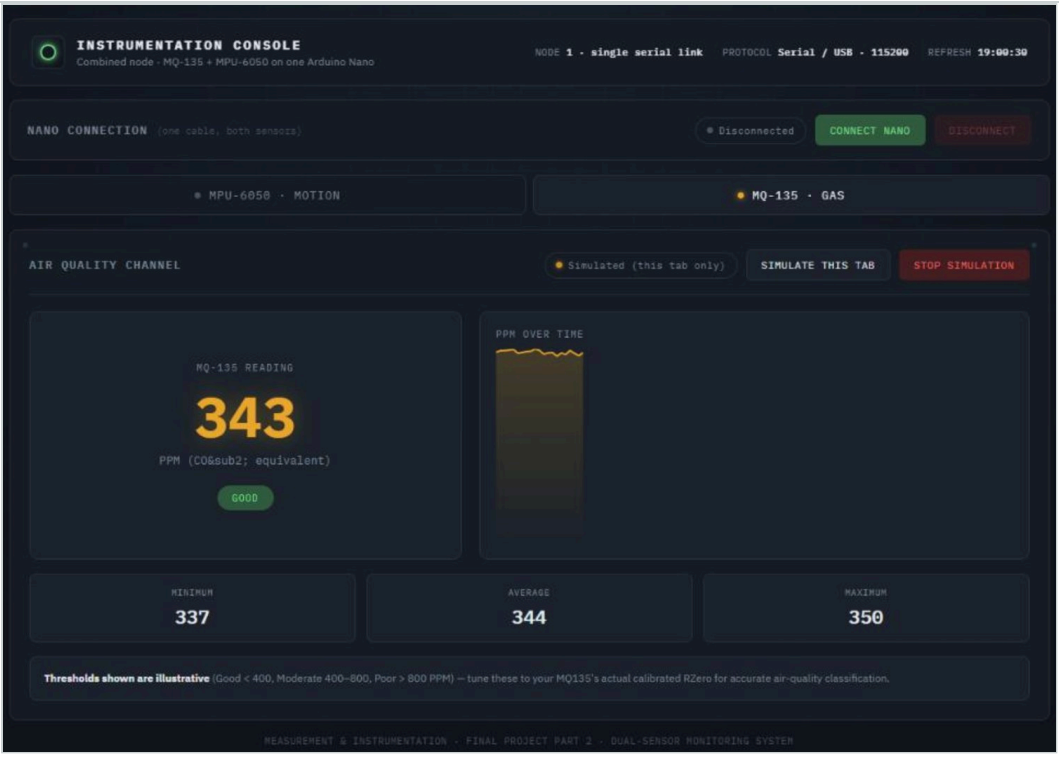


Figure 5. Real-time monitoring interface displaying live gas concentration.

2.3 Experiment 1: CO_2 Concentration

The first experiment evaluated whether the sensor detects variations in CO_2 concentration under different environmental conditions. Fifteen measurements were collected at locations with different ventilation, occupancy and air quality (Table 2, Figure 6).

Table 2. CO_2 concentration at each test location

No.	Location and condition	CO_2 (ppm)
1	Room with normal airflow, AC on, 4 people, no smoking	375.96
2	Near a window, close to the AC fan's hot air	693.19
3	Biomedical lab, AC off	469.35
4	Closed sound-isolated room	1,835.24
5	Practical lab room with 17 people	1,486.74
6	Laboratory building, 2nd floor open space	818.28
7	Inside an elevator with 4 people	1,191.71
8	Mechanical machines laboratory	2,171.76
9	Open-air futsal arena	721.16
10	Basement floor of the laboratory building	1,773.15
11	Manufacturing systems lab with a strong smell	1,332.92
12	Open rooftop	661.38

No.	Location and condition	CO_2 (ppm)
13	Open green area with trees next to FTI	552.94
14	Canteen smoking area, 8 students	1,460.21
15	Open parking area	1,332.97

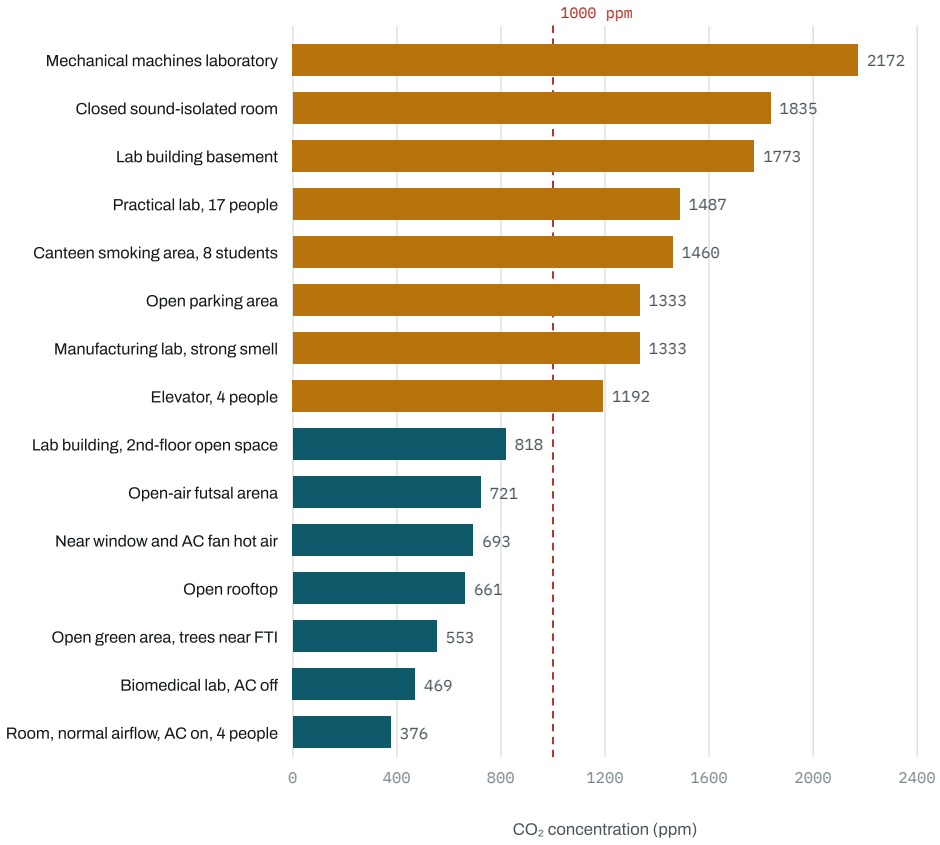


Figure 6. CO_2 concentration by location, sorted from highest to lowest. Orange bars exceed 1,000 ppm.

The results show a clear relationship between environmental conditions and CO_2 concentration. Well-ventilated locations consistently produced lower values, whereas enclosed areas with several occupants produced significantly higher ones. The lowest reading, about 376 ppm, was recorded in a room with normal airflow and is close to the normal atmospheric CO_2 level. The highest, about 2,172 ppm, was recorded in the mechanical machines laboratory, where ventilation was limited and several people were present. This increase is expected because human respiration continuously releases CO_2 into enclosed spaces.

The average of the fifteen measurements was about 1,125 ppm. Most locations had acceptable indoor air quality, although several exceeded 1,000 ppm, a level commonly used as a comfort guideline for indoor spaces. Throughout the experiment the sensor gave stable readings that followed the expected physical behaviour of CO_2 accumulation.

2.4 Experiment 2: Ethanol Response

The second experiment examined the sensor's response to ethanol vapour, using a commercial alcohol-based hand sanitiser and perfume. The source was placed at different distances from the sensor, or enclosed with it, while the output was monitored continuously (Figure 7, Table 3).



(a) Sanitiser on tissue near the sensor

(b) Perfume cap placed over the sensor

Figure 7. Ethanol exposure tests.

Table 3. Sensor output during ethanol exposure

No.	Condition	Library output (ppm)
1	Perfume cap covering the sensor	56,174,563.07
2	Perfume cap about 2 cm from the sensor	18,137.46
3	Hand sanitiser on tissue, about 2 cm	916,378.15
4	Hand sanitiser on tissue, about 5 cm	26,251.11
5	Hand sanitiser on tissue, about 10 cm	1,278.79
6	Hand sanitiser cap covering the sensor	372,764,011.09
7	Sanitiser sprayed close to the sensor	9,159.22
8	Weaker perfume about 5 cm away	5,559.23
9	Light perfume sprayed close to the sensor	60,342.69
10	Sensor sealed in a bag with sprayed sanitiser for about 1 min	510,093.42

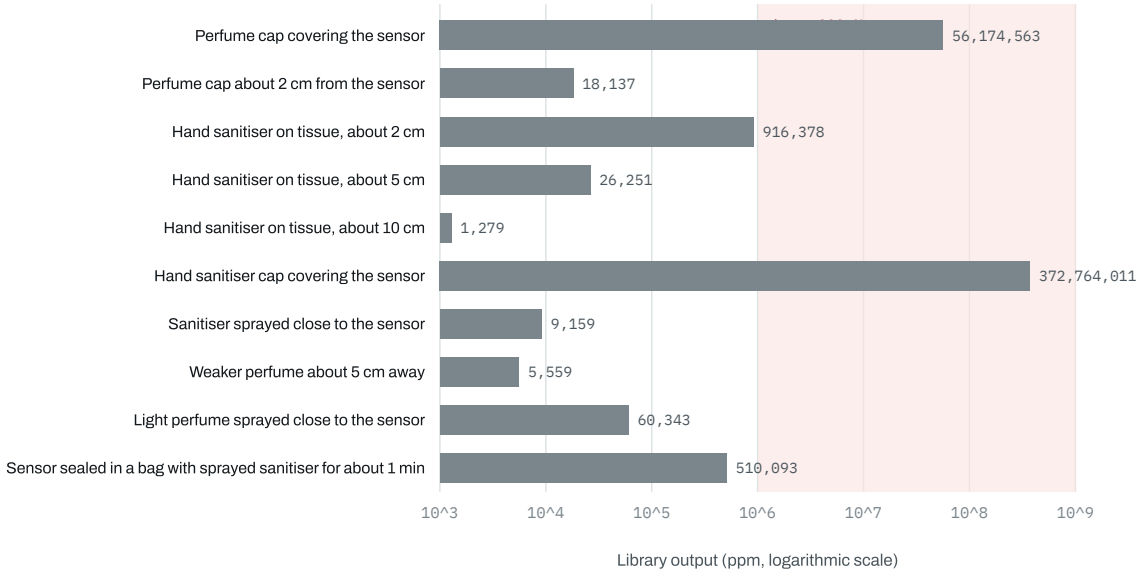


Figure 8. Ethanol test outputs on a logarithmic scale. The shaded region marks values above 1,000,000 ppm (100 %), which are physically impossible.

The sensor responded immediately when exposed to ethanol vapour. The output increased sharply as the source approached the sensing element, and the two largest outputs occurred when a cap was placed directly over the sensor (tests 1 and 6). After the source was removed, the readings gradually returned toward their initial values, showing that the sensing material recovered. The response was repeatable, which is consistent with the operating principle of metal-oxide semiconductor sensors, whose resistance falls in the presence of reducing gases.

The absolute values, however, cannot be taken as true concentrations. The MQ135 is specified for concentrations of roughly 10–1,000 ppm, and the conversion curve in Equation (1) is valid only within that range. At high exposure the sensor resistance becomes very small, and the power-law curve then produces extremely large numbers; two readings exceed 1,000,000 ppm, which would correspond to more than 100 % ethanol in air. The ethanol results are therefore best read as a relative indicator: they reflect the strength of exposure (a source placed directly over the sensor gives the largest output, and output falls with distance, as in tests 3, 4 and 5), but accurate ethanol measurement would require calibration against reference concentrations within the sensor's range.

3 Conclusion

This project implemented the MQ135 gas sensor as a low-cost environmental measurement device on the Arduino Nano platform, with a custom Python interface for real-time visualisation. In the CO_2 experiment, measurements at fifteen locations showed that enclosed and crowded spaces produce markedly higher concentrations than open or well-ventilated areas, confirming that the calibrated sensor detects changes in indoor air quality effectively.

In the ethanol experiment, the sensor responded quickly and repeatably to alcohol vapour and recovered after exposure, demonstrating its sensitivity to volatile organic compounds. Because most readings were outside the sensor's specified range, these results are qualitative and show the limit of applying a single characteristic curve beyond its intended concentration range.

The MQ135 does not provide laboratory-grade accuracy, but after calibration it is an economical and practical sensor for educational work and basic air-quality monitoring. Future work includes calibration against certified reference gases, temperature and humidity compensation, operation within the sensor's valid concentration range, wireless data transmission to an IoT platform, and monitoring several gases simultaneously.