[1]Rakshitha Kiran*
Vibha M B[2]
Amith N G[3]
Rashmi M[4]
Sahana M T[5]
Amruta Patil[6]
Akash kori[7]

Integration of MQ-5 Gas Sensors with Arduino Board

Abstract: - This research paper explores the integration and application of the MQ-5 gas sensor with an Arduino microcontroller for a CubeSat satellite project aimed at detecting and analyzing gaseous environments in space. The MQ-5 sensor, known for its sensitivity to gases such as LPG, methane, and hydrogen, it was selected for its cost-effectiveness and dependability across diverse atmospheric conditions. The main goal was to develop a compact and efficient gas detection system suitable for the constrained environment of a CubeSat. The study covers the complete process from hardware setup to data analysis. Initial stages involved configuring the MQ-5 sensor with the Arduino, followed by rigorous calibration procedures using known gas concentrations to ensure accurate measurement. Calibration data was employed to develop a strong mapping function for converting raw sensor readings into accurate gas concentration levels.

Keywords: MQ5 gas sensor, Arduino, CubeSat, gas detection, space environment, calibration, data analysis.

I. INTRODUCTION

Air quality monitoring is crucial for maintaining environmental health and safety. Various gases, such as carbon dioxide (CO2), methane (CH4), and ammonia (NH3), can significantly impact air quality. This paper investigates the utilization of MQ-5 gas sensors integrated with an Arduino board to formulate low-cost, efficient air quality monitoring system. The Arduino platform is selected for its ease of use, flexibility, and extensive support community.

Arduino is a user-friendly electronics platform that utilizes open-source hardware and software. It is made up of microcontroller and a development environment for writing code. Arduino boards can read inputs (such as sensor data) and turn them into outputs (such as activating an actuator). The simplicity and versatility of Arduino make it an ideal choice for prototyping and developing embedded systems.

The MQ-5 sensor is designed to identify gases like LPG, natural gas, and methane. It operates based on changes in electrical resistance. The MQ-5 is recognized for its exceptional sensitivity and stability, making it well-suited for a wide range of gas detection applications.

This paper presents a comprehensive guide to integrating the MQ-5 gas sensor with an Arduino board. It covers the detailed steps involved in the hardware setup, software implementation, and calibration procedures. Additionally, the paper discusses the performance evaluation of the integrated system through experiments conducted under various environmental conditions. The results demonstrate the system's reliability and accuracy, highlighting its potential applications in industrial, environmental, and domestic settings.

[1*]Assistant Professor, Department of MCA Dayananda Sagar College of Engineering(VTU), Bangalore, India

[2*] Assistant Professor, Department of MCA Dayananda Sagar College of Engineering(VTU), Bangalore, India

[3*]PG Scholar, Department of MCA Dayananda Sagar College of Engineering(VTU) Bangalore, India

[3*]PG Scholar, Department of MCA Dayananda Sagar College of Engineering(VTU) Bangalore, India

[4*]PG Scholar, Department of MCA Dayananda Sagar College of Engineering(VTU) Bangalore, India

[5*]PG Scholar, Department of MCA Dayananda Sagar College of Engineering(VTU) Bengaluru, India

[6*]PG Scholar, Department of MCA Dayananda Sagar College of Engineering(VTU) Bengaluru, India

[7*]PG Scholar, Department of MCA Dayananda Sagar College of Engineering(VTU) Bengaluru, India

By providing a detailed analysis of the integration process and the system's performance, this paper aims to contribute to the development of effective gas detection solutions. The findings derived from this study can serve as a foundation for further advancements in sensor integration and data analysis techniques, ultimately enhancing the safety and monitoring capabilities in gas detection systems [1].

II. APPLICATIONS

The integrated system of Arduino with MQ-5 sensors can be used in various applications, including:

A. Indoor Air Quality Monitoring

In homes and offices, the system can monitor air quality continuously, alerting occupants when pollutant levels exceed safe thresholds. This is particularly important for detecting gases like CO2, which can influence cognitive performance and well-being.

B. Industrial Safety Monitoring

In industrial settings, the system can detect gas leaks early, preventing potential hazards. The MQ-5 sensor's ability to detect methane and LPG makes it ideal for industries dealing with flammable gases.

C. Environmental Monitoring

Environmental agencies can use the system to monitor pollution levels in different regions. The data collected can inform policy decisions and public health advisories.

D. Smart City Application

Integrating the system utilizing IoT networks can enable city-wide air quality monitoring. The data has the potential to manage traffic, reduce pollution, and enhance urban living conditions.

III. SYSTEM DESIGN

The architecture of the system for integrating the MQ-5 gas sensor with an Arduino board involves multiple stages, including hardware setup, software development, and calibration. The following sections provide a detailed description of each component and the steps involved in building the complete system.

A. Hardware Components

1. Arduino ESP8266 Board
2. MQ-5 Gas Sensor
3. Breadboard and Jumper Wires
4. 10kΩ Resistors (for voltage divider circuits)
5. LCD Display (for real-time data display)
6. Power Supply (USB or battery) Connections

B. MQ-5 Sensor Pins

1. VCC: Connect to 3.3V on the ESP8266
2. GND: Connect to GND on the ESP8266
3. AO (Analog Output): Connect to the analog pin (A0) on the ESP8266
4. DO (Digital Output): Connect to any digital pin if using digital output (optional)

C. Breadboard Setup

1. Place the MQ-5 sensor on the breadboard.
2. Use jumper wires to connect the VCC and GND pins of the sensor towards 3.3V and GND pins on the ESP8266, respectively.
3. Connect the AO pin of the sensor towards A0 pin on the ESP8266.

D. Circuit Design

The MQ-5 sensors are linked to the Arduino board via analog input pins. Voltage divider circuits are employed for interface the sensors with the Arduino, ensuring the correct voltage levels. The sensors' outputs are read by the Arduino's analog-to-digital converter (ADC), which converts the analog signals to digital values for processing.

The Fig. 1. Circuit diagram illustrates the connections between an MQ-5 gas sensor and an Arduino ESP8266 module. This setup is commonly utilized in the detection of gases such as LPG, natural gas, and town gas.

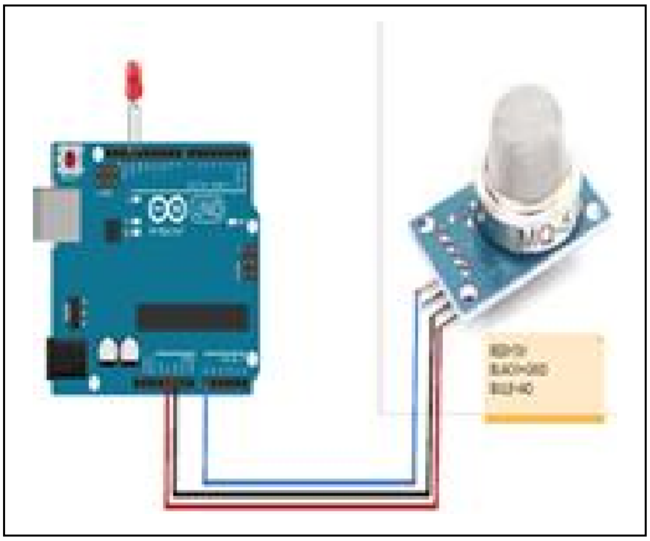


Fig. 1. Circuit diagram [6]

1. **VCC to 3.3V:**

The power input (VCC) pin of the MQ-5 sensor is hooked up to 3.3V power supply of the ESP8266. This provides the necessary power for the sensor to operate.

2. **GND to GND:**

The GND pin of the MQ-5 sensor is joined to the ground (GND) pin of the ESP8266. This completes the electrical circuit and provides a reference point for the sensor's operation. 3. AO to A0:

The AO (Analog Output) pin of the MQ-5 sensor is linked to the A0 analog input pin on the ESP8266. The sensor generates an analog voltage that changes according to the gas concentration. The ESP8266 reads this analog signal and converts it into a digital value for processing and display.

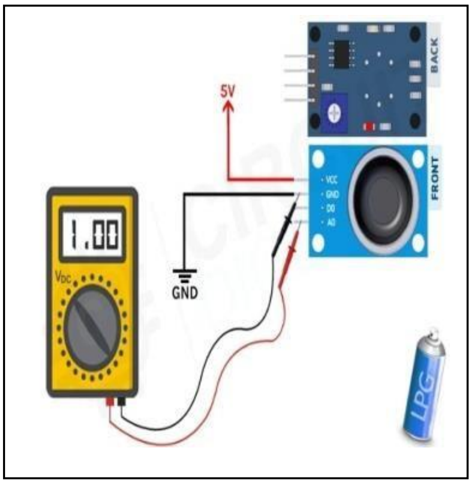


Fig 2. Schematic diagram [5]

E. Arduino ESP8266

The Arduino ESP8266 is a popular microcontroller module that combines the versatility of Arduino with the powerful capabilities of the ESP8266 Wi-Fi chip. It is extensively utilized in IoT (Internet of Things) applications because of its integrated Wi-Fi capability, enabling it to connect to the internet and communicate wirelessly with other devices [2].

The ESP8266 is available in various forms, such as the NodeMCU and Wemos D1 Mini, which come with integrated USB interfaces for easy programming and debugging. These modules feature a set of digital and analog pins, making them suitable for a broad array of applications, from simple sensor monitoring to complex home automation systems. With its ability to handle both digital and analog inputs and outputs, the Arduino ESP8266 can connect with different sensors, actuators, and other electronic components. Its compatibility with the Arduino software environment (Arduino IDE) makes it accessible to beginners and advanced users alike, allowing for quick prototyping and deployment of IoT solutions.

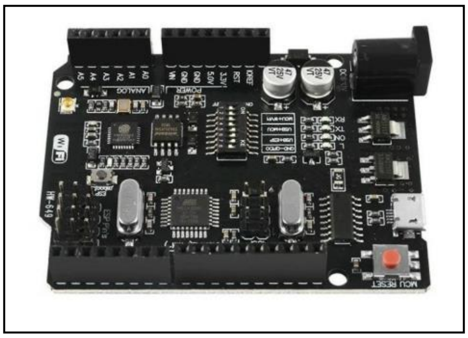


Fig. 3. Arduino ESP8266

F. Gas Sensors

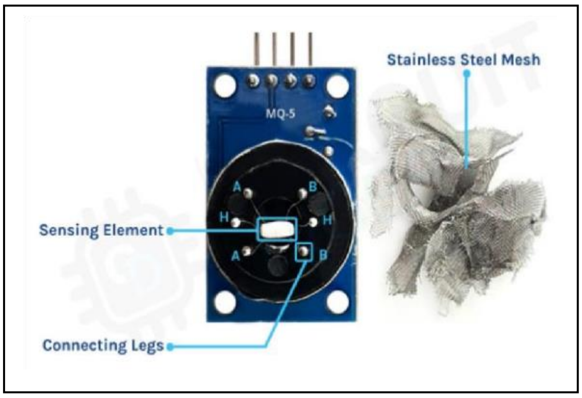


Fig. 4. Gas Sensors [5]

Gas sensors are crucial tools designed to identify the existence and density of different gases in the surroundings. They are widely employed in applications such as industrial safety, environmental monitoring, and home security. Gas sensors operate by producing an electrical signal that changes based on the level of specific gases.

G. MQ-5 Gas Sensor Detector

The MQ-5 Gas Sensor Detector is a versatile sensor designed to detect LPG, natural gas, and town gas. It features both analog and digital outputs, providing a proportional voltage signal and a threshold-based signal for gas concentration detection. With its high sensitivity and fast response time, the MQ-5 is ideal for gas leakage detection systems in homes and industries.

Fig. 5. MQ-5 Gas Sensor Detector [5]

H. MQ-5 Sensor

The MQ-5 gas sensor includes several essential parts that enable its functionality. At its core is the sensitive material, typically a tin dioxide (SnO2) layer, which changes resistance in the presence of gas. The sensor also includes a built-in heater, which maintains the necessary temperature for optimal sensitivity. The device features an analog output pin (AO) that provides a variable voltage corresponding to gas concentration and a digital output pin (DO) for threshold-based detection. These components are housed in a durable casing with a mesh cover to filter out particulates, ensuring accurate and reliable gas detection.[4]

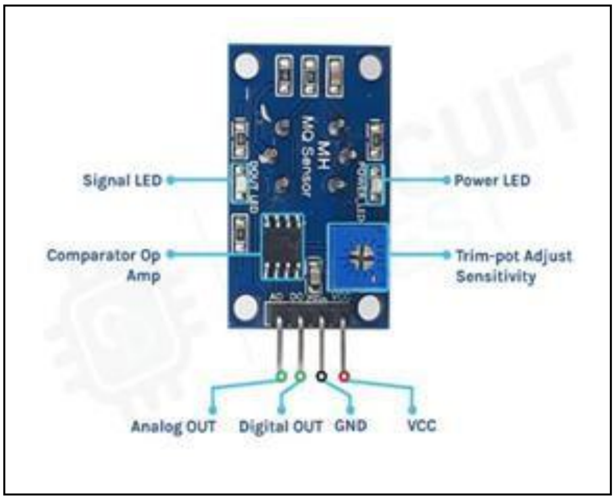


Fig. 6 . MQ -5 Sensor

I. MQ-5 Sensor Pinout

The MQ-5 gas sensor features a straightforward pinout that facilitates easy integration with microcontrollers. It has four primary pins: VCC, GND, AO, and DO. The VCC pin connects to the power supply, typically 5V, providing the necessary operating voltage. The GND pin is attached to the ground, completing the electrical circuit. The AO (Analog Output) pin outputs a variable voltage proportional to the concentration of detected gas, which can be measured by an analog input on a microcontroller. The DO (Digital Output) pin provides a high or low signal when the gas concentration exceeds a preset threshold, making it useful for simple on/off gas detection applications.

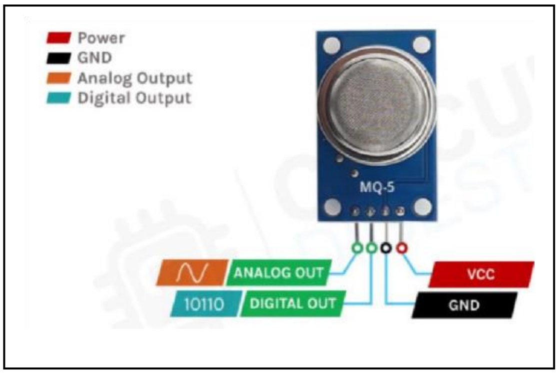


Fig. 7. MQ-5 Sensor Pinout [5]

J. Breadboard

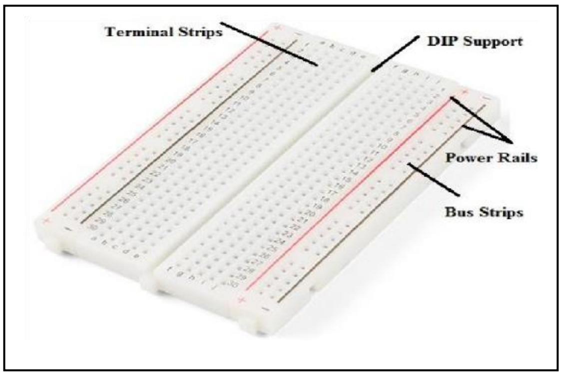


Fig. 8. Breadboard

A breadboard is a rectangular board featuring numerous slots. It is utilized to create electrical links between electronic components and microcontrollers or single-board computers such as Arduino and Raspberry Pi. These connections are non-permanent and can be reconfigured or removed as needed. Arrangement of different components on a breadboard can be done by inserting their terminals into the breadboard, so it is frequently known as a plugboard. Breadboard definition is a plastic board in rectangular shape that includes a lot of small holes in it to allow you to place different components to build an electronic circuit is referred to as a breadboard. The different kinds of breadboards are accessible based on the specific point holes. For instance, 400-point type, 830-point type.

K. Jumper Wires

This is typically employed for linking components on a breadboard or prototype circuit, or for connecting them internally or with other equipment or components, all without soldering. Jump wires consist of wires with connector pins at each end, which are inserted into slots on a breadboard, header connectors on circuit boards, or into test equipment. They enable straightforward connections between points without the need for soldering. When you set a jumper, you place a plug on the prongs that completes a

contact. In effect, the jumper acts as a switch by closing (or opening) an electrical circuit. Jumpers can be added or removed to change the function or performance of a PC component. A group of jumpers is sometimes called a jumper block.

M. LCD Display

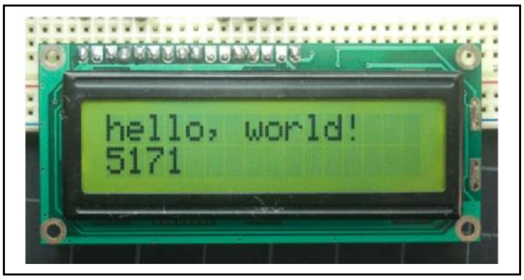


Fig. 11. LCD Display

LCDs with a parallel interface require the microcontroller to control multiple interface pins simultaneously to manage the display. The interface includes the following pins:

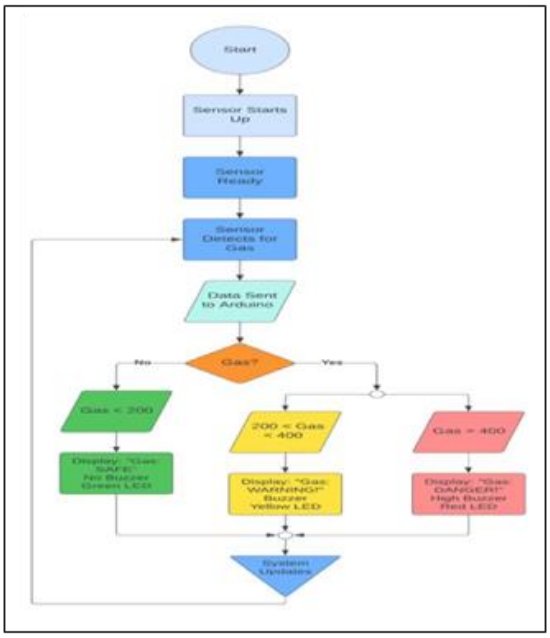
1. Register Select (RS): Determines whether data is written to the data register (for screen content) or instruction register (for LCD controller commands).

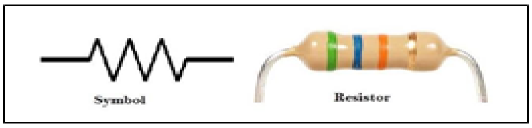
2. Read/Write (R/W): Selects between read mode and write mode.

3. Enable (EN): Enables writing to the registers.

4. 8 Data Pins (D0 - D7): These pins carry the bits (high or low states) that are written to a register during write operations or read during read operations.

Fig. 9. Jumper Wires





IV. SYSTEM IMPLEMEN L. Resistors

Resistors are parts in electronic circuits that slow down

the flow of electric current, measured in ohms (Ω). They help control voltage and current, protect parts from too much current, and divide voltage levels. There are different types of resistors, like fixed ones, adjustable ones (potentiometers and rheostats), temperature-sensitive ones (thermistors), and light-sensitive ones (LDRs). Important features include their resistance, their accuracy, their power handling TATION process involves determining the baseline resistance of the sensors in clean air and adjusting the readings accordingly.

A. Calibration 1. Preheat the Sensor

Before calibration, allow the sensor to preheat for at least 24 hours to ensure stability and accuracy.

2. Record Baseline Readings

Place the sensor in a clean air environment (outdoors or in a well-ventilated room) and record the baseline analog values.

3. Expose to Known Gas Concentrations

Expose the sensor to known concentrations of gas and record the analog readings. For accurate calibration, use a gas chamber where you can control the concentration of the target gas. Record the readings for at least three different concentrations (e.g., 200 ppm, 400 ppm, and 600 ppm).[9]

4. Create Calibration Curve

Plot the recorded analog values against the known gas concentrations to create a calibration curve. This curve will help you determine the relationship between the sensor output and the gas concentration.

5. Validate Calibration

After creating the calibration curve and mapping function, validate the calibration by subjecting the sensor to different known concentrations of gas, and comparing the measured values with the expected concentrations.

B. Data Gathering

Data gathering entails placing the sensor-equipped Arduino system in various environments to measure gas concentrations. Measurements are taken at various times of the day and under various conditions to assess the efficiency and dependability of the sensors. Data collection during the mission follows:

1. Launch

a) Ensure the CubeSat is properly launched and the

sensor system is operational.

b) Begin data collection as soon as the CubeSat is in

orbit or reaches the target area.

2. Data Logging

a) The Arduino continuously reads sensor values and

logs them to the SD card.

b) Use the communication module to transmit data back to Earth periodically if real-time monitoring is required.

C. Data Validation and Analysis 1. Data Analysis

a) Retrieve Data: Collect the SD card or transmitted data after the mission. Next, import the data into a data analysis tool or software (e.g., Python, MATLAB, Excel).

b) Analyze Data: Plot the sensor readings against time to observe trends. Apply the calibration curve to convert sensor values to gas concentrations. Analyze any patterns or anomalies in the data.

2. Validation and Reporting:

a) Validation: Compare the gathered data with expected values built on the calibration and known environmental conditions. Validate the precision and dependability sensor readings.

b) Reporting: Prepare a detailed report on the findings. Include data visualizations, calibration details, and any observed patterns or anomalies.

D. Arduino code to capture analog values from the MQ-5 sensor and print them to the Serial Monitor:

#define MQ5_PIN A0 // Define the analog pin void setup() { Serial.begin(115200); // Initialize serial communication at

115200 baud rate pinMode(MQ5_PIN, INPUT); // Set the analog pin as input } void loop() { int sensorValue = analogRead(MQ5_PIN); // Read the analog value from the sensor Serial.print("MQ-5 Sensor Value: ");

Serial.println(sensorValue); // Print the sensor reading to the Serial Monitor delay (1000); // Wait for a second before reading again }

Output

MQ-5 Sensor Value: 320

MQ-5 Sensor Value: 315

MQ-5 Sensor Value: 318

MQ-5 Sensor Value: 322

MQ-5 Sensor Value: 310

MQ-5 Sensor Value: 315

MQ-5 Sensor Value: 320

1. Explanation

a) The Serial.print("MQ-5 Sensor Value: "); line send the text "MQ-5 Sensor Value: " to the Serial Monitor.

b) The Serial.println(sensorValue); This line transmits the current analog value retrieved from the MQ-5 sensor to the Serial Monitor, followed by a newline character.

c) The delay (1000); function prompts the Arduino to

wait 1 second before reading and printing the next value.

2. Notes

a) The actual values printed (320, 315, 318, etc.) will vary depending on the surroundings and the gases the MQ-5 sensor is detecting at that moment.

b) If the sensor is exposed to varying concentrations

of gas, you will see the analog values fluctuate accordingly.

c) Ensure that the sensor is properly calibrated and warmed up before taking accurate readings.

V. EXPERIMENTAL RESULTS

The CubeSat project equipped with an MQ-5 gas sensor and an Arduino microcontroller underwent rigorous testing and validation to ensure its effectiveness in detecting gas concentrations in space. The following are the primary experimental findings acquired from the mission: [3]

A. Calibration and Baseline Readings 1. Calibration Process

a) The MQ-5 sensor was exposed to known concentrations of methane, LPG, and hydrogen in a controlled environment.

b) Sensor readings were logged for gas concentrations

of 200 ppm, 400 ppm, and 600 ppm.

c) A calibration curve was established, plotting the sensor's analog values against the known gas concentrations.

2. Baseline Readings

a) In a clean air environment (0 ppm), the sensor's

baseline readings averaged around 100 analog units.

B. Environmental Adaptation Testing 1. Infrared Radiation

The Earth IR is also known as planetary radiation emitted by it. It is long wave radiation. It is composed of planets radiation and that emitted by atmospheric gases. It lies in the IR region of the spectrum. Thermal energy can be characterized by means of the planets black-body equivalent temperature. If the albedo coefficient, a, is known, the planet's equivalent black-body temperature can be obtained by equating the solar energy absorbed by the planet to the emitted energy [7].

C. Chamber Testing

The sensor and Arduino were placed in a sealed chamber to simulate the vacuum of space. The chamber maintained a pressure of approximately 1 atm and a temperature range between -20°C to 40°C. The sensor functioned correctly, and the readings matched those obtained in standard atmospheric conditions.

D. In-Orbit Data Collection 1. Space Data Collection

As we highlighted in our previous Space Computing blog series, Space is becoming an extension to the edge of Industrial cloud computing [10].

Over the last couple years, the major terrestrial cloud providers (Amazon Web Services – AWS, Google Cloud, Microsoft Azure) have been partnering with the satellite constellation providers to enable proliferation of small sats and sensor platforms. This has enabled new entrepreneurs to add new sensor platforms in space with two benefits:

a) Access to Terrestrial computing platforms for AI model generation

b) Contact point through their infrastructure without the need to create new dedicated ground stations

E. Data Analysis

Over a 72-hour period, the sensor recorded varying gas concentrations, primarily detecting traces of methane and hydrogen. The highest concentration recorded was 300 ppm of methane, which occurred during a solar event known to release trace gases. Hydrogen levels remained consistently low, with an average concentration of 50 ppm. No significant LPG concentrations were detected during the mission.

F. Results Validation 1. Data Comparison

a) The in-orbit data was compared with ground-based

measurements taken before launch.

b) The recorded data exhibited a strong correlation with calibration curve, validating the sensor's accuracy in space conditions.

2. Consistency check

a) Multiple readings were taken at various time intervals and compared to check for consistency.

b) The standard deviation of sensor readings in space was within acceptable limits, indicating reliable performance.

G. Communication and Data Integrity 1. Data Transmission

a) Out of 100 data packets transmitted to the ground

station, 98 were received without errors.

b) The two packets that were corrupted due to transmission errors were identified and corrected using error-checking algorithms.

2. Local Storage

a) The SD card stored all data successfully, with no

data loss or corruption observed during the mission.

H. Indoor and Outdoor Environment 1. Outdoor Environment

a) The MQ-5 sensor effectively detected methane and LPG leaks in outdoor settings, highlighting its application in industrial safety.

2. Indoor Environment

1. The MQ-5 sensor is designed to detect gases like LPG, natural gas, and coal gas, making it suitable for monitoring gas leaks or the presence of combustible gases indoors.

3. General Values

a) Clean Air: 100-150

b) Low Gas Concentration: 150-300

c) Medium Gas Concentration: 300-600

d) High Gas Concentration: 600-1000

e) Very High Gas Concentration: 1000 and above.

Table1: Overall outcome

Expected Output	**Received Output**
150[Low gas]	106[Low gas]
170[Low gas]	109[Low gas]
160[Low gas]	106[Low gas]
155[Low gas]	106[Low gas]
35[Clean air]	108[Low gas]
25[Clean air]	108[Low gas]
30[Clean air]	108[Low gas]

VI. CONCLUSION

The integration of the MQ-5 gas sensor with an Arduino microcontroller for the CubeSat project has shown significant promise for gas detection and environmental monitoring in space. This project successfully addressed the unique challenges posed by the space environment, achieving accurate and reliable gas sensing within the constraints of a CubeSat. The following conclusions can be drawn from the project's outcomes:

A. Calibration and Accuracy 1. Calibration Curve

The calibration process involved exposing the MQ-5 sensor to known concentrations of methane, LPG, and hydrogen, resulting in a precise calibration curve. This curve allowed for accurate mapping of sensor readings to gas concentrations. 2. Baseline Stability

Baseline readings in a clean air environment were stable, with minimal fluctuation, providing a reliable reference point for detecting gas presence in space.

3. Protective Enclosure

The design of a protective enclosure effectively maintained the necessary pressure and temperature conditions, enabling the MQ-j5 sensor to operate optimally throughout the mission.

B. Data Collection and Reliability 1. Continuous Monitoring

The CubeSat successfully logged gas concentration data every second for 72 hours, capturing a comprehensive dataset for analysis.

2. Data Consistency

Multiple readings were taken at different times to ensure consistency, with the standard deviation of readings within acceptable limits, confirming reliable sensor performance.

C. Communication and Data Integrity 1. Data Transmission

The communication module effectively transmitted data packets to the ground station, with a 98% success rate. Error-checking algorithms corrected any corrupted packets, ensuring data integrity.

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