

# IoT-Based Gas Leakage Detection and Alert System Using MQ-2 Sensor and ESP32

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**Abstract**—Undetected gas leaks in homes, kitchens, laboratories and industrial sites can lead to fire, explosion and injury, and a local alarm alone cannot reach people who are away from the premises. This paper presents the design of a low-cost, IoT-oriented gas-leakage detection and alert prototype built around an MQ-2 gas sensor and an ESP32 microcontroller. The controller samples the sensor output and compares it with a configurable threshold. When the threshold is exceeded, it sounds a buzzer, sends a single SMS alert through a GSM module, and drives a servo to demonstrate a predefined mechanical response on a low-voltage model. An alert-state flag prevents repeated messages during one event and re-arms the system when the reading returns below the threshold. Because the decision is made locally on the ESP32, the audible alarm remains available when the cellular network is not. The paper describes the architecture, hardware interface considerations, calibration approach, control logic and safety considerations, and defines a validation protocol covering calibration, response time, SMS delivery and fault tests. The available project documentation does not include calibrated concentration data or repeated-trial measurements, so no accuracy or response-time claims are made. The system is a prototype and not a certified safety device.

**Index Terms**—Internet of Things (IoT); gas leakage detection; MQ-2 sensor; ESP32; GSM; SMS alert

## I. INTRODUCTION

### A. Background and motivation

Combustible gases such as liquefied petroleum gas (LPG), propane and methane are used in homes, commercial kitchens, laboratories and industrial plants. A leak becomes dangerous when gas accumulates and meets an ignition source. Such gases burn or explode only within a band of concentrations in air; the lower explosive limit is of the order of 2 % by volume for propane and 5 % for methane, so a warning raised while the concentration is still well below that limit gives occupants time to ventilate the

space and leave. Manual inspection is intermittent, and a standalone alarm is of little use when nobody is nearby to hear it. These limitations motivate compact systems that monitor a gas sensor continuously and also notify a responsible person remotely.

### B. Proposed approach

The Internet of Things (IoT) offers a practical framework for joining sensors, embedded controllers and communication modules. In the proposed design, an MQ-2 sensor produces a gas-sensitive electrical signal, an ESP32 evaluates that signal against a threshold, a buzzer warns people nearby, and a GSM module sends an SMS to a registered mobile number. A servo motor is included only as a demonstration actuator; it is not a certified mains-isolation or gas shut-off device.

### C. Objectives and organization

The objectives of this work are: (i) to define a clear, low-cost prototype architecture for gas sensing, local warning and remote notification; (ii) to specify the control logic, including a mechanism that prevents repeated SMS messages; (iii) to state the safety limits of the servo-based demonstration; and (iv) to propose a validation protocol so that performance can be measured and reported in future work. The available project documents contain no quantitative experimental measurements, so no accuracy or response-time claims are made.

The remainder of the paper is organized as follows. Section II reviews related work. Section III presents the system design, hardware interfaces, calibration approach, control logic and safety considerations. Section IV discusses the current evidence and the

proposed validation protocol. Section V states limitations and future work, and Section VI concludes.

## II. RELATED WORK

### A. IoT-based gas monitoring

Conventional gas alarms combine a gas-sensitive element with a local warning circuit. They are simple and inexpensive, but a local alarm cannot reach a user who is away from the monitored area. Microcontroller-based designs extend this pattern by evaluating the sensor signal in software and driving several outputs.

IoT-based gas monitoring has been studied from several angles. A review presented at ICISC 2020 discusses gas-leakage detection with integrated push notifications [1]. A 2023 review in E3S Web of Conferences surveys IoT and cloud technology for gas-leakage detection [2]. An ICEARS 2023 paper describes an IoT-based approach that cuts off electricity when an LPG leak is detected [3]. Together these works show that connected alerts and automated response are established design directions, while implementation safety and dependable detection remain open concerns.

### B. Sensing, platform and standards

The ESP32 provides embedded processing, analog inputs and several serial interfaces [4]. Microcontroller-based safety systems that combine sensor inputs with GSM SMS alerts have also been reported [5]. The MQ-2 is a semiconductor sensor that responds to several combustible gases and smoke, so its output does not identify a single gas [6]. Catalytic-bead and infrared sensors are commonly used in professional flammable-gas detectors and are generally more selective or stable, but they cost more; the MQ-2 trades selectivity for low price and easy availability, which suits a prototype. SMS delivery depends on the GSM module, SIM provisioning, network coverage and correct serial configuration. MQTT could support a future networked dashboard but is not needed for the GSM-SMS path described here [7].

Table I compares the main sensing technologies qualitatively. The comparison is general and is not drawn from measurements made in this work.

TABLE I Qualitative comparison of gas-sensing technologies.

| Technology           | Cost   | Selectivity                              | Typical use                        |
|----------------------|--------|------------------------------------------|------------------------------------|
| Semiconductor (MQ-2) | Low    | Low; responds to several gases and smoke | Prototypes, low-cost alarms        |
| Catalytic bead       | Medium | Moderate; responds to combustibles       | Industrial flammable-gas detectors |
| Infrared (NDIR)      | Higher | High for target gas                      | Fixed industrial detectors         |
| Electrochemical      | Medium | High for toxic gases                     | Toxic-gas and CO monitoring        |

Performance requirements for flammable-gas detectors are set out in standards such as IEC 60079-29-1 [8], and requirements for residential gas alarms appear in standards such as UL 1484 [9]. The prototype described here has not been assessed against either, and it should not be described as compliant with them.

### C. Positioning of this work

Beyond gas detection, IoT-based sensor monitoring has also been applied to induction-motor diagnosis using a convolutional neural network [10]. Embedded-controller designs have also been reported in other settings, such as a microcontroller-based automatic waste segregator for smart cities [11]. In the power-electronics domain, a matrix converter supported by a hybrid-vehicle system with perturb-and-observe control has been studied for vehicle-to-grid operation [12], and a multi-input DC–DC converter topology has been proposed for the utilization of renewable energy [13]. These related works address other applications and are cited for design context, not as performance baselines. Compared with cloud-dependent architectures, the proposed workflow makes its threshold decision locally on the ESP32, so the buzzer still sounds when the remote path is unavailable. The

contribution is not a new sensing principle but a bounded, reproducible integration of local detection, remote SMS notification and a clearly limited actuation demonstration.

### III. SYSTEM DESIGN AND METHODOLOGY

#### A. System architecture

Fig. 1 shows the architecture. The MQ-2 sensor supplies an analog signal to the ESP32. The ESP32 drives the buzzer through a digital output, the servo through a PWM output and the GSM module through a serial (UART) link. A regulated supply powers all modules. The hardware is listed in Table II and the signal interfaces in Table III.

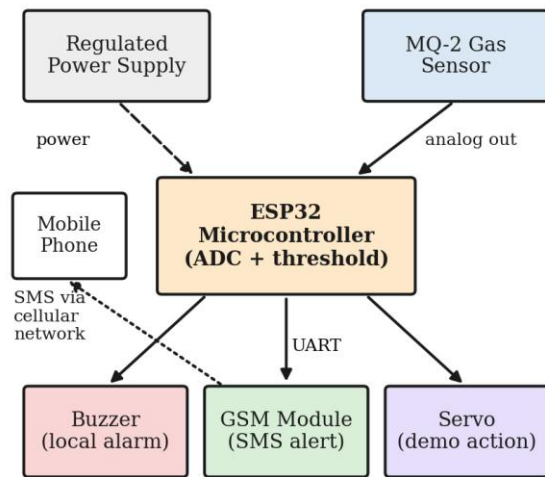


Fig. 1. Architecture of the proposed gas-leakage detection and alert system.

TABLE II Hardware components and their roles.

| Component             | Role in the system                                                            |
|-----------------------|-------------------------------------------------------------------------------|
| MQ-2 gas sensor       | Produces an output responsive to combustible gases and smoke.                 |
| ESP32 microcontroller | Samples the sensor, compares it with a threshold and coordinates all outputs. |
| Buzzer                | Gives an audible local warning when the threshold is exceeded.                |
| GSM module            | Sends an SMS alert to a configured mobile number.                             |
| Servo motor           | Demonstrates a programmed mechanical action on a low-voltage model.           |

| Component              | Role in the system                            |
|------------------------|-----------------------------------------------|
| Regulated power supply | Powers the controller and peripheral modules. |

TABLE III Signal interfaces.

| Module     | Signal type         | Connection to ESP32         |
|------------|---------------------|-----------------------------|
| MQ-2       | Analog voltage      | ADC input channel           |
| Buzzer     | On/off drive        | Digital output pin          |
| GSM module | Serial data         | UART (TX/RX, common ground) |
| Servo      | Pulse-width control | PWM output pin              |

Pin numbers are defined in the firmware. The exact GSM module and power-supply models should be stated in the final version for reproducibility.

#### B. Hardware interface considerations

Several practical points affect whether the interfaces in Table III work reliably. First, the ESP32 has two ADC groups, and the second group cannot be used while the Wi-Fi radio is active, so the sensor should be wired to a channel of the first group if wireless features are added later [4]. Second, the ESP32 uses 3.3 V logic; the logic levels of the GSM module must be checked, and a level shifter used where the module operates at a higher voltage. Third, GSM modules draw short, high current bursts during transmission, and servos draw high current when they move, so both should be fed from the regulated supply with adequate decoupling capacitance and a common ground, not from a microcontroller pin. Finally, the MQ-2 contains a heater that draws a steady current, which should be included when the supply is sized.

#### C. Sensing principle and threshold

The MQ-2 uses a tin-dioxide sensing layer whose electrical conductivity rises in the presence of combustible gases. A load resistor converts this change into a voltage that the ESP32 reads through its analog-to-digital converter (ADC), which has 12-bit resolution (0–4095 counts) by default. The sensor needs a warm-up period after power-on before readings are stable, and its output is affected by temperature, humidity, ageing and interfering gases [6]. If the sensor module is powered at 5 V, its analog

output must be checked against the ESP32's 3.3 V ADC input limit, and a voltage divider used if necessary.

The threshold in the project's example code is a raw ADC value of 2000. This is an uncalibrated configuration value, not a concentration or a universal safety limit. It must be calibrated for the sensor, supply voltage and installation environment before readings are interpreted as gas levels.

#### D. Calibration approach

The documentation does not describe a calibration procedure, so the following approach is proposed. After the warm-up period specified in the sensor manual [6], clean-air readings are recorded to establish a baseline. The sensor is then exposed, under supervised and ventilated laboratory conditions, to known concentrations of a target gas generated against a reference instrument, and the raw ADC counts are recorded for each level. The alarm threshold is chosen from this response curve so that it lies clearly above the baseline noise and clearly below a concentration regarded as hazardous. Readings should be averaged over several samples, and a small hysteresis band between the alarm-on and alarm-off levels can prevent the buzzer from chattering around the threshold.

#### E. Control logic

At start-up the ESP32 configures the sensor input and the output pins, opens the serial link to the GSM module, and sets the buzzer and servo to their normal states. It then samples the MQ-2 repeatedly (Fig. 2). If a reading exceeds the threshold, the controller switches the buzzer on, moves the servo to its demonstration position and requests one SMS alert. An alert-state flag records that the SMS has been sent, so the message is not repeated during the same event. When the reading falls back below the threshold, the buzzer is switched off, the servo returns to its normal position and the flag is cleared so a future event can trigger a new SMS (Fig. 3).

#### F. Firmware routine

The firmware can be summarised as the following sequence, which corresponds to Fig. 2.

- (1) Initialise the ADC input, the buzzer and servo outputs and the UART link to the GSM module; set the alert-state flag to false.

- (2) Wait for the sensor warm-up period before acting on readings.
- (3) Read the MQ-2 analog value and, if desired, average several samples to reduce noise.
- (4) If the value exceeds the threshold, switch on the buzzer and move the servo to its demonstration position.
- (5) If the alert-state flag is false, send one SMS through the GSM module and set the flag.
- (6) If the value is at or below the threshold, switch off the buzzer, return the servo and clear the flag.
- (7) Wait for the sampling interval and repeat from step (3).

Because the buzzer decision in step (4) precedes the SMS request in step (5), a slow or failed GSM response cannot delay the local alarm unless the SMS call blocks the loop. The firmware should therefore use a bounded wait for the GSM module's reply, or a non-blocking send, so that sensing continues while a message is pending. This is a recommended refinement rather than a documented feature.

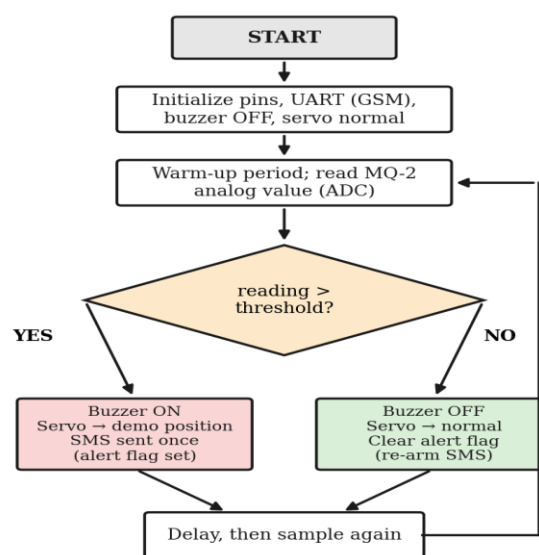


Fig. 2. Flowchart of the monitoring and alert routine.

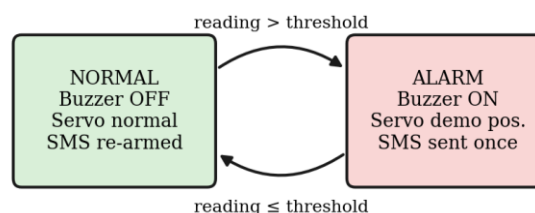


Fig. 3. Two-state behaviour: NORMAL and ALARM, with SMS re-arming on return to normal.

### G. Firmware parameters

Table IV lists the parameters that define the behaviour of the firmware. Only the threshold value is stated in the available documentation; the remaining values must be recorded when the prototype is documented for reproduction.

TABLE IV Configurable firmware parameters.

| Parameter         | Value or status                                                           |
|-------------------|---------------------------------------------------------------------------|
| Alarm threshold   | Raw ADC count of 2000 in the example code; uncalibrated.                  |
| Sampling interval | Not stated in the documentation.                                          |
| Warm-up period    | Not stated; to be set from the sensor manual [6].                         |
| SMS recipient     | One registered mobile number, set in the firmware.                        |
| Alert-state flag  | Set after the first SMS; cleared when the reading is below the threshold. |
| Servo positions   | Normal and demonstration angles, defined in the firmware.                 |

### H. Safety design considerations

- (1) No mains switching. A hobby servo must not be connected to household mains wiring or presented as a certified isolator. The servo is a low-voltage demonstration only.
- (2) Separate power paths. The GSM module and servo draw high peak current and should be supplied from the regulated supply, not from a microcontroller pin.
- (3) Local alarm first. The buzzer is driven directly by the threshold decision so that it works even if the SMS path fails.
- (4) Rated hardware for real use. Any real shut-off or electrical isolation must use certified equipment installed and validated by qualified professionals.

### I. Failure modes

A gas alarm can fail in two ways: it can stay silent during a leak, or it can sound when no gas is present. Missed detections can arise from an uncalibrated threshold, a sensor that has aged or been poisoned, poor placement relative to the gas (LPG is heavier than air and collects low, whereas methane is lighter and rises), loss of power, or firmware that has stopped running. False alarms can arise from smoke, cooking vapours, alcohol, humidity or temperature changes, since the MQ-2 is cross-sensitive [6]. The SMS path

adds its own failures: no network coverage, an exhausted SIM balance, or a module that has not registered on the network. The validation protocol in Section IV is designed to expose each of these.

## IV. RESULTS AND DISCUSSION

### A. Current evidence

The project documentation describes the intended behaviour: the MQ-2 provides input to the ESP32, a threshold crossing triggers the buzzer, the GSM module sends an SMS, and the servo demonstrates a predefined response. These functions show how sensing, embedded decision-making, local warning, remote notification and actuation can be integrated on low-cost hardware.

The documentation does not contain a test dataset, calibrated gas-concentration values, repeated-trial results, measured detection latency, SMS delivery rate, false-alarm rate or a comparison baseline. Quantitative performance therefore cannot be concluded, and none is claimed. Table V separates what the design supports from the evidence still needed.

TABLE V Design support and evidence still needed.

| Item            | Supported by design                                | Evidence needed                                                       |
|-----------------|----------------------------------------------------|-----------------------------------------------------------------------|
| Sensor response | MQ-2 readings are monitored and thresholded.       | Calibration method, test conditions, raw readings, repeat trials.     |
| Local alarm     | Buzzer activation is part of the response.         | Observed activation time and success/failure log.                     |
| SMS alert       | GSM-based SMS is in the workflow.                  | Delivery rate, latency, signal conditions, module and SIM details.    |
| Servo response  | Servo moves to a demonstration position.           | Measured movement, load, reset behaviour, safe mechanism description. |
| Reliability     | Depends on power, wiring, calibration and network. | Fault injection, power-interruption and long-duration tests.          |

### B. Proposed validation protocol

To turn the prototype into a measurable system, we propose the following metrics, to be measured under safely supervised conditions against a reference

instrument: detection latency,  $t_d = t_{\text{alarm}} - t_{\text{cross}}$ , where  $t_{\text{cross}}$  is the time the reading first exceeds the threshold and  $t_{\text{alarm}}$  is the time the buzzer turns on; SMS delivery rate, the number of SMS messages received divided by the number sent over repeated trials; and false-alarm rate, the number of alarms per hour with no gas present. Each should be reported as a distribution over repeated trials, not a single value.

Table VI outlines the tests that would produce this evidence. Each test should state its environment, the number of repetitions, the instruments used and the recorded outcome, so that another group can repeat it.

TABLE VI Proposed test plan.

| ID | Test                 | Purpose and record                                                                                         |
|----|----------------------|------------------------------------------------------------------------------------------------------------|
| T1 | Warm-up and baseline | Log clean-air readings from power-on until they stabilise.                                                 |
| T2 | Threshold crossing   | Under supervised conditions, log $t_{\text{cross}}$ and $t_{\text{alarm}}$ against a reference instrument. |
| T3 | SMS delivery         | Repeat alerts under stated signal conditions; count messages received and delay.                           |
| T4 | Re-arming            | Confirm one SMS per event and a new SMS after return below the threshold.                                  |
| T5 | Fault tests          | Power interruption, sensor disconnection, no network, SIM without balance.                                 |
| T6 | Long-duration run    | Log drift and false alarms over an extended period.                                                        |

### C. Discussion

The main benefit of the design is architectural. The local alarm remains useful if SMS fails, and SMS extends awareness beyond the installation area when the network is available. This dual path does not guarantee that an alert is received, and it does not show that a leak will be detected at a particular concentration. Calibration, sensor placement, warm-up, ageing and interfering substances all affect the MQ-2 output.

The design also has practical advantages for a teaching or prototyping setting: every module is inexpensive and widely available, the control logic is short enough to be read and checked line by line, and the alert-state flag keeps the message count bounded. These advantages concern ease of reproduction, not detection performance.

### D. Placement and use

Sensor placement strongly affects whether a leak is seen early. LPG is denser than air and tends to collect near the floor, whereas methane is lighter than air and tends to rise, so the sensor should be mounted at a height suited to the gas in use and away from direct airflow from fans or open windows, which can dilute the gas before it reaches the element. It should also be kept clear of cooking fumes where possible to limit false alarms. The sensor manual [6] should be consulted for the recommended replacement interval, because the sensing layer degrades with age. Plausible settings for the prototype are a domestic kitchen, a small laboratory or a teaching demonstration; in each case it should supplement, not replace, certified detectors and good ventilation practice.

### E. Security and privacy of the SMS path

The design as described only sends outgoing messages and does not accept commands by SMS, which keeps the attack surface small. The registered mobile number is stored in the firmware and should not be published with the source code. A messaging account with an exhausted balance or a lost network registration will fail silently unless the firmware checks the module's response, so the status of each send attempt should be logged. If remote commands or a network dashboard are added later, authentication and encrypted transport would become necessary.

In a real gas-leak event, people should avoid operating electrical switches, leave the area, and call the emergency service or gas supplier from a safe location.

## V. LIMITATIONS AND FUTURE WORK

The current work supports a prototype-level design description, not a validated safety product. The main limitations are the absence of calibrated sensor data and quantified test results, the dependence of SMS on GSM coverage, and the use of a servo as a demonstration actuator. The GSM module model, calibration procedure and electrical test conditions are also not specified.

Future work will include supervised testing, calibration against a reference instrument, repeated trials across defined conditions, and reporting of response-time distributions and false alarms. Reliability tests should cover power interruption, sensor disconnection, communication failure and

recovery after an alarm. A status indicator, backup power, fault diagnosis, event logging and an MQTT dashboard could be added. Any automated shut-off should use purpose-built, rated safety hardware assessed by qualified professionals.

## VI. CONCLUSION

This paper presented an IoT-oriented gas-leakage detection and alert design built around an MQ-2 sensor and an ESP32, with a buzzer for local warning, a GSM module for SMS notification and a servo for low-voltage demonstration of a response. The workflow is simple: sample the sensor, compare with a configured threshold, and raise the alerts once per event. The design shows how accessible components can improve awareness of a potential leak. No quantitative performance claim is justified by the available documentation. Calibration, reproducible testing, communication verification and professionally engineered safety components are essential before any real-world deployment.

## DECLARATION

A generative AI tool was used solely for grammar checking of the manuscript text. The authors reviewed all content and take full responsibility for the manuscript.

## REFERENCES

- [1]. "Gas Leakage Detection System using IoT with Integrated Notifications using Pushbullet—A Review," in Proc. 4th Int. Conf. Inventive Systems and Control (ICISC), 2020. [Online]. Available: <https://ieeexplore.ieee.org/abstract/document/9171093>
- [2]. "Gas Leakage Detection System Using IoT and Cloud Technology: A Review," E3S Web of Conferences, vol. 391, 2023, doi: 10.1051/e3sconf/202339101063.
- [3]. "IoT-Based Automatic Electricity Cut-Off Using LPG Gas Leakage Detection System," in Proc. 2nd Int. Conf. Electronics and Renewable Systems (ICEARS), 2023, doi: 10.1109/ICEARS56392.2023.10085217.
- [4]. Espressif Systems, "ESP32 Series Datasheet." [Online]. Available: [https://documentation.espressif.com/esp32\\_datasheet\\_en.html](https://documentation.espressif.com/esp32_datasheet_en.html)
- [5]. W. RajanBabu et al., "Arduino based women safety device: An experimental study," Premier Journal of Science, 2025, doi: 10.70389/PJS.100241.
- [6]. Zhengzhou Winsen Electronics Technology Co., Ltd., "Flammable Gas Sensor (Model MQ-2)," Technical Manual, v1.6, 2021. [Online]. Available: <https://www.winsen-sensor.com/d/files/manual/mq-2.pdf>
- [7]. OASIS, "MQTT Version 3.1.1," OASIS Standard. [Online]. Available: <https://docs.oasis-open.org/mqtt/mqtt/v3.1.1/os/mqtt-v3.1.1-os.html>
- [8]. International Electrotechnical Commission, "Explosive atmospheres—Part 29-1: Gas detectors—Performance requirements of detectors for flammable gases," IEC 60079-29-1.
- [9]. Underwriters Laboratories, "Standard for Residential Gas Detectors," UL 1484.
- [10]. L. Mubaraali, N. Kuppuswamy, and R. Muthukumar, "Internet of Things-based induction motor diagnosis using convolutional neural network," Electric Power Components and Systems, vol. 52, no. 2, pp. 265–276, 2024, doi: 10.1080/15325008.2023.2217434.
- [11]. "Automatic waste segregator for smart cities using micro controller," Journal of Xidian University, vol. 18, no. 1, pp. 772–775, Feb. 2024.
- [12]. S. Rasappan and K. I. Devi, "Matrix converter supported by hybrid vehicle system with perturb & observe algorithm for V2G operation," Int. J. Vehicle Structures & Systems, vol. 12, no. 3, pp. 251–255, 2020, doi: 10.4273/ijvss.12.3.05.
- [13]. "Resources using multi-input DC–DC converter topology for optimal utilization of a novel step-up interconnected enhanced technique renewable energy," Analog Integrated Circuits and Signal Processing, 2025, doi: 10.1007/s10470-025-02320-4.