Smart Gas Stove System

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***Abstract*—Kitchen safety in residential settings remains a major concern; leaks of LPG or malfunctions in the burner pose serious risks of fire, explosion, and toxic exposure. This work presents a Smart Gas Stove Safety System integrating gas- and flame-sensing for complete stove safety. The proposed safety system makes use of a gas sensor, MQ-6, for LPG detection, a multichannel infrared flame sensor to confirm whether ignition has occurred, and an ESP32-based microcontroller to create alerts in real time. In case the concentration of gas is abnormal or the burner is operating without ignition, audible and visual warnings will be raised. Less than 2 seconds are required for response times, while under empirical tests, accuracy of detection reached 100% within controlled environments. The proposed solution is cost-effective, reliable, and practical for kitchen appliances at home and in commercial businesses, hence filling a significant gap in the existing architectures concerned with the monitoring of gas concentration only without contextual verification of flame.**

***Index Terms*—Smart Stove System, Kitchen Safety, LPG Leak Detection, Flame Sensing, Real-Time Alert Mechanism, IoT Integration**

I. INTRODUCTION

Gas-related accidents in home kitchens are among the less- recognized public safety hazards. In India, there were over 1,869 such accidents from 2021 to 2024, where 473 deaths were caused by cooking gas cylinder explosions, and incident rates were far higher in developing regions. The conventional methods for ensuring kitchen safety rely on either passive detection or the manual vigilance of the operator; both of these are well short in the most threatening emergency situations. Homes not with automated context-aware gas-leak detection systems remain very vulnerable to these often-unnoticed leaks, such as when a burner fires without proper lighting—a com- mon hazard leading to immediate risks of explosion.

Although the use of semiconductor gas sensors and microcontroller-based alert mechanisms characterizes most existing gas-leak detection systems, few implementations con- sider the dual challenge of gas presence and burner mal- function. Identifying this research gap, the present paper puts forward a Smart Gas Stove Safety System that performs comprehensive stove-state awareness through gas and flame status sensing.

The key contributions of the proposed system are:

1) Dual-sensor Design: This paper presents a design that merges the MQ-6 gas sensor with a 5-channel IR flame sensor to concurrently monitor the presence of gas and the state of the burner.
2) Deterministic alert logic: Warnings are not only trig- gered when gas concentration surpasses safe thresholds but also critically when gas is present with an unlit flame.
3) Low-cost: ESP32-based design with easily available sen- sors ensures the design is low in cost and reproducible.
4) Real-time response: Latency in detection and raising an alert will be less than 2 seconds, suitable for emergency intervention
5) Scalability pathway: The design has to be modular, allowing future IoT integrations for remote monitoring and cloud logging. This work describes system architecture, implementation methodology, experimental validation results, and a roadmap toward IoT-enabled enhancements.

This paper presents the system architecture, implementation methodology, experimental validation results, and a roadmap for IoT-enabled enhancements. The remainder is organized as follows: Section II reviews related work and positions this contribution; Section III describes the system design and methodology; Section IV presents experimental results; Sec- tion V discusses future directions; and Section VI concludes.

II. LITERATURE REVIEW

With the increase in domestic and industrial accidents concerning LPG and other related flammable gases, there has been an urgent need for reliable gas-leak detection systems for some time. Human observation is not adequate since, in certain environments, gas leaks silently and spreads very fast. This challenge, among others, has inspired a section of researchers to investigate intelligent monitoring systems that could detect such leakages during the early stages.

One of the pioneering microcontroller-based solutions was put forward by Shahewaz and Prasad [1]. An Arduino Uno- based system was implemented using an MQ-2 sensor in- tegrated with a GSM module.The device can send SMS notifications and activate alarm systems in cases of leakage. Their system, though useful and at low cost, had no situational awareness-it could not tell whether the burners were on/off, if there was flame, or what the ambient conditions were. In this respect, it is incomplete regarding automated safety responses. Building on the above limitations, an improved IoT-enabled gas-monitoring system using Arduino and GSM communi- cation was proposed by Lavanya et al. [2].Their system incorporated LED indicators, a buzzer, and an automatic cutoff mechanism that is triggered at high LPG concentration. While this was quite responsive compared to earlier systems, it again totally relied on the threshold values of gas and would not be able to confirm whether the gas is actually intentionally released during cooking or there is accidental leakage due to flame failure.

Baballe and Bello [3] were able to provide a more preventive approach when they designed a system that incorporated the MQ-5 sensor, LCD display, and automated exhaust fan for the clearing of accumulated gas. This indeed shifts the emphasis from mere leak detection to active mitigation of the leaks.Their system also used fixed threshold logic, which may not hold accurately under natural conditions where temperature and ventilation, among other factors, change every now and then to affect gas density.

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As research went on, Babu et al. [4] proposed an IoT framework connected via the cloud with NodeMCU and MQ- 2 sensor. The proposed system was able to realize remote gas level monitoring through instant alerts on cloud dashboards. However, there is simply an indication for the presence of gas but flame and burner status are ignored, which may be the utmost necessary conditions to identify a safe or unsafe sce- nario.Meribout [5] investigated some high-precision industrial- grade technologies using infrared imaging, spectroscopy, and photoacoustic sensing. These indeed show excellent accuracy, such as long-distance detection, but are still unsuitable for regular household use due to cost, complexity, and power requirements.

Other research has used acoustics-based detection, where the sound generated by the escaping gas is processed with a filter or a machine-learning model [6]. While these systems are encouraging, they require highly sensitive microphones and constant calibration, which make them expensive and less practical to use in regular kitchens.

Specialized sensors have also contributed to safer sys- tems.The MQ-6 sensor used in [7] resulted in better sensitivity for propane and butane but suffered from different variations in its environment. Gupta et al. [8] used the combination of MQ- 135, MQ-2, and MQ-6 sensors with ESP8266 connectivity for a more comprehensive indoor air quality and gas monitoring system.Malik et al. [9] worked on faster IoT-based alerting mechanisms for improved reliability.Thamizhselvi et al. [10] extended the capabilities of the ICPECTS 2024 system to include mobile alerts and gas-usage estimation, thus making the entire system very safe and efficient. Bhattacharjee et al. [11] proposed a smart-home setting for detection and early warnings of several combustible gases. Imtiaz Anik et al. [12] presented a household safety system with modular implementation capable of handling both automated valve control and multilayer hazard prevention. Sharma et al. [13] recently developed an Arduino-based predictive approach able to detect leakage at a very incipient stage and to automatically take mitigation measures. Aggregated, these works establish a definite trend from simple threshold-based alarm systems to intelligent IoT-driven multi-sensor safety systems. Still, one important gap remains: most of the systems still do not combine flame sensing and burner-status analysis. Without those, it is impossible to reliably distinguish between safe combustion and dangerous unburned gas release. The proposed Smart Stove Safety System covers this deficiency by integrat- ing MQ-6 gas detection with flame sensing and automation through a microcontroller, making the approach even more intelligent and holistic toward ensuring real-time safety in kitchens related to both homes and commercial sectors.

III. SYSTEM DESIGN AND METHODOLOGY

A. Hardware Architecture

The system comprises five core components:

1) MQ-6 Gas Sensor: A semiconductor-type metal-oxide sensor (200-10000 ppm LPG sensitivity) that out- puts analog voltage proportional to gas concentration. Analog-to-Digital Conversion (ADC) maps sensor out- put to 0–4095 digital units on the ESP32.
2) 16x2 LCD Display: Provides with text alerts on the main unit for visual alerts and a red LED which turns on when a gas leak is detected.
3) Multi-Channel Flame Sensor: A 5-channel infrared flame detector operating at 700–1100 nm wavelength, capable of detecting flame presence at distances up to 150 cm. Outputs HIGH (5V) when flame detected, LOW (0V) otherwise.
4) ESP32 Microcontroller: Central processing unit exe- cuting real-time sensor polling, threshold comparison. Clock frequency: 240 MHz; Flash memory: 4MB.
5) ESP8266 or NodeMCU: Will be connected with the two 5-channel flame sensors and a relay to control the actuator to control the regulator knob.
6) Buzzer: 5V active buzzer (85 dB) providing audible alert stimulus.
7) Visual Indicators: LED (Red for gas leak) signaling system state.
8) Power Supply: 9V battery with buck converter (LM2596) and a voltage regulator(LM7805) providing stable 5V to all components.

B. System Operation Flow

1) At system startup, the ESP32 and ESP8266 are initial- ized and a bidirectional ESP-NOW link is established. The ESP8266 continuously monitors all four burners using two 5-channel infrared flame sensors, where four IR receivers per sensor are utilized for complete burner coverage. If a flame is detected on any burner, the system assumes normal stove operation and the gas leakage check is suppressed.
2) If no flame is detected, the ESP8266 transmits the burner status to the ESP32. The ESP32 then samples the MQ-6 gas sensor and compares the measured LPG concentration against a predefined threshold. When the value remains below the threshold, the system reverts to monitoring mode. However, upon exceeding the thresh- old, the ESP32 confirms a gas leakage event.
3) In the event of a confirmed leak, the ESP32 activates the buzzer and LED, and displays **"Gas Leak Detected"** on the 16×2 LCD. Simultaneously, it transmits a control command to the ESP8266, which triggers a relay to power a servo motor coupled to the regulator knob. The servo rotates the knob to the OFF position, thereby stopping the gas supply. The system then returns to continuous monitoring.

C. Circuit Configuration

1) Main Unit
- MQ-6 analog output connects to ESP32 Pin D34.
- Buzzer connects to Pin D27.
- Red LED connects to Pin D33
- SCL and SDA of the I2C module are connected to pins D22 and D21 respectively.
- All ground connections unified; 5V rail distributed.

2) Control Unit
- Flame Detector 1 connected to Pin D1 and Pin D2.
- Flame Detector 2 connected to Pin D3 and Pin D4.

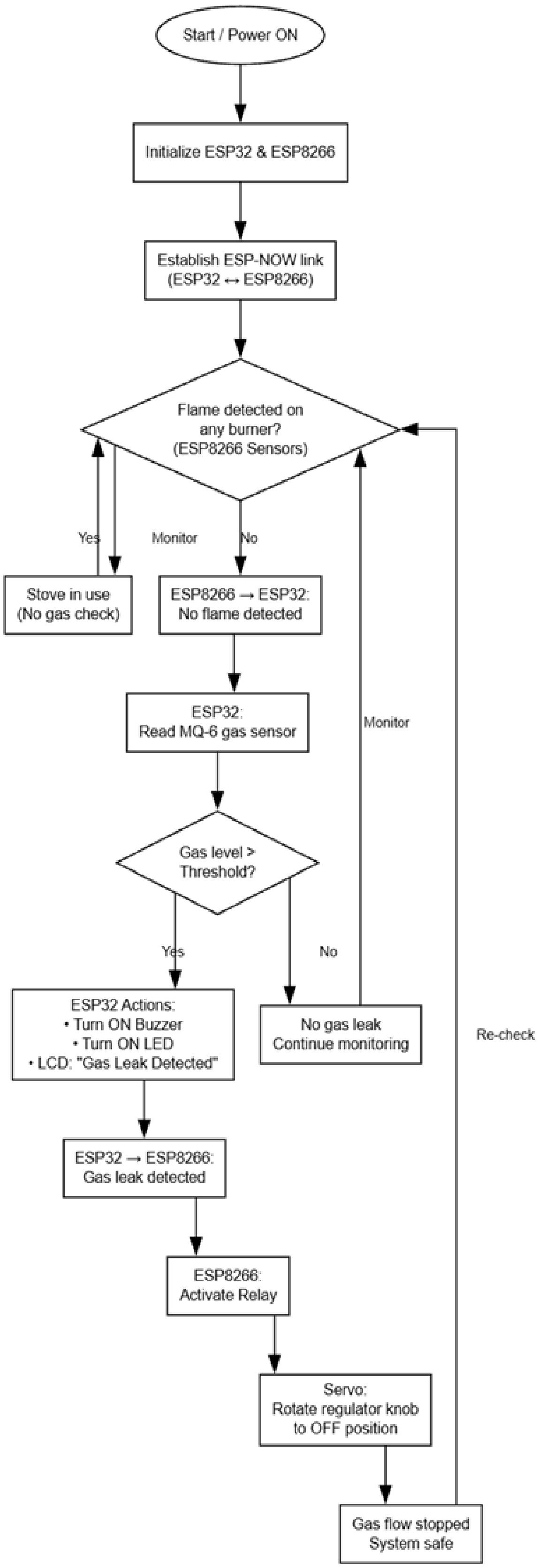

Fig. 1. Flowchart

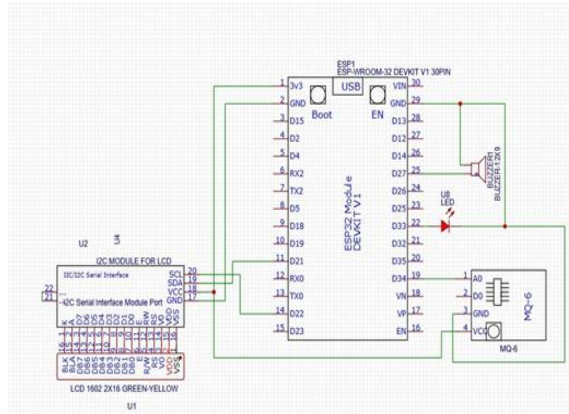

Fig. 2. Main Unit

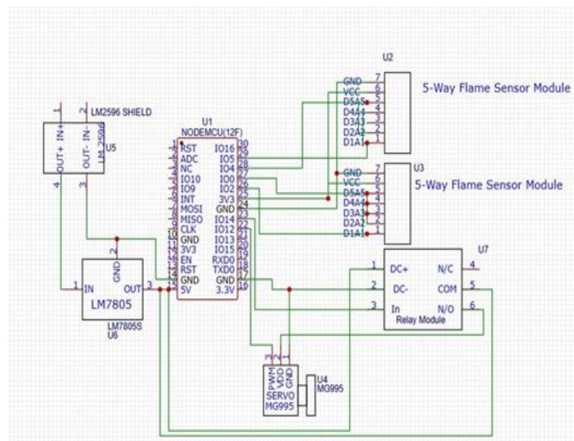

Fig. 3. Control Unit

- Relay Module connected to Pin D5.
- Servo Motor connected to Pin D6.

D. Firmware Implementation

Embedded C-based Arduino sketch implements: Interrupt-driven button input for manual test mode. Time-stamped event logging to EEPROM (non-volatile stor- age).

E. Mathematics

The MQ-6 gas sensor was interfaced with an ESP32 and powered using a 3.3 V supply with a 20 kΩ load resistance. The raw ADC output from the ESP32 (12-bit resolution, range 0–4095) was first converted into the sensor output voltage using:

$$V_{\text{out}} = 3.3 \cdot \frac{A}{4095} \quad (1)$$

Since the MQ-6 sensing element and load resistor form a voltage divider, the sensor resistance was calculated as:

$$R_s = R_L \quad \frac{V_s}{V_{\text{out}}} - 1 \tag{2}$$

To compensate for sensor variations, a reference resistance R_0 was determined under clean-air conditions, and all mea- surements were normalized using:

$$r = \frac{R_s}{R_0} \tag{3}$$

According to the MQ-6 sensitivity characteristics, the nor- malized resistance ratio and gas concentration follow a linear relationship in logarithmic scale:

$$\log_{10}(r) = a \cdot \log_{10}(C) + b \tag{4}$$

which gives the gas concentration in ppm as:

$$C = 10^{\frac{\log_{10}(r) - b}{a}} \tag{5}$$

By combining these expressions, the complete conversion chain from analog value to gas concentration is:

$$A \rightarrow V_{\text{out}} \rightarrow R_s \rightarrow \frac{R_s}{R_0} \rightarrow C \text{ ppm} \tag{6}$$

In this system, an analog threshold of A = 2300 was selected experimentally for gas-leak detection. This corresponds to an output voltage of approximately V_{out} =1.85 V. Using the divider equation with R_L=20 kΩ, this gives $R_s \approx 15.7k\Omega$
. For a typical calibrated value of R_0 (measured in clean air), this resistance ratio R_s/R_0 lies in the range where the MQ-6 datasheet crve corresponds approximately to 1800–2500 ppm of LPG, which is close to the commonly used alarm level of around 2000 ppm (10% LEL). Therefore, any ADC value above 2300 is treated as a gas leak condition, triggering the alarm and safety mechanisms in the proposed system.

IV. EXPERIMENTAL RESULTS AND VALIDATION

Controlled testing was conducted with LPG cylinder, regu- lator, and burner assembly. Test scenarios:

1) Gas Leak Detection: Controlled 1000-3000 ppm LPG release; measurement of sensor response time.
2) Flame Verification: Burner ignited and extinguished; measurement of flame sensor accuracy.
3) Dual-Condition Alert: Unlit burner with gas flow; mea- surement of hazard detection latency.
4) Environmental Robustness: Tests at 15°C, 25°C, 35°C; humidity 40–80%; assessment of sensor stability.

V. FUTURE WORK AND IOT INTEGRATION ROADMAP

The current prototype demonstrates proof-of-concept in controlled environments. Planned enhancements include:

A. IoT Cloud Connectivity

Integration of ESP8266 and ESP32 WiFi modules and Blynk platform for real-time remote alerts via smartphone notifications. Cloud logging enables analytics on gas concen- tration trends and predictive maintenance scheduling.

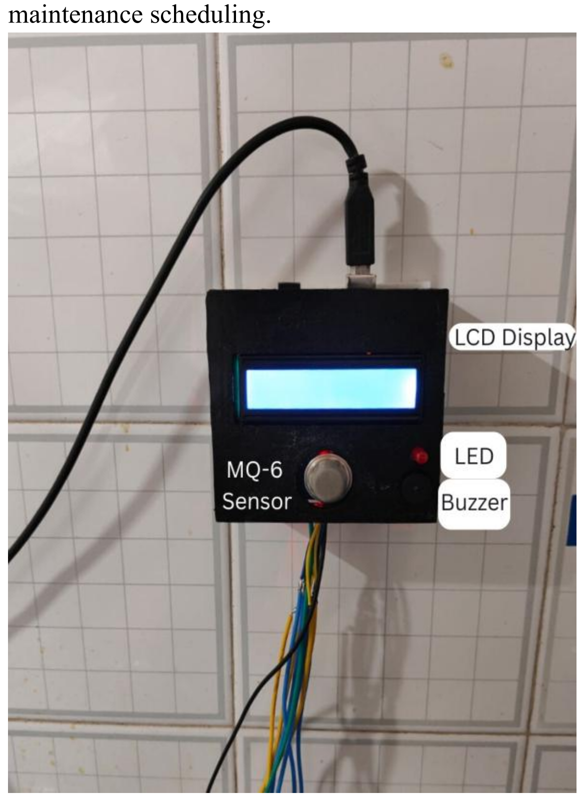

Fig. 4. Main Unit

Fig. 5. Gas Stove

B. Artificial Intelligence for Predictive Maintenance

Machine learning algorithms trained on historical sensor data to predict component degradation (sensor drift, flame detector aging) before failure. Implementation via Edge ML (TensorFlow Lite for microcontrollers).

C. Smart Home Integration

Protocol development for integration with existing home automation platforms (MQTT, HomeAssistant) enabling coor- dinated response (e.g., automatic exhaust fan activation, smart lock engagement).

V. CONCLUSION

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This paper introduced a Smart Gas Stove Safety System addressing a critical gap in existing kitchen safety architectures through integrated gas and flame sensing. The prototype successfully demonstrates:

Reliable dual-state monitoring: Simultaneous detection of gas presence and flame verification.

Fast response times: Sub-2-second alert latency suitable for emergency intervention.

Practical applicability: Tested and validated for residential and commercial kitchen environments.

The system's deterministic firmware and modular hardware design establish a foundation for future IoT enhancements, predictive maintenance algorithms, and integration with smart home ecosystems. By addressing the unlit-burner-with-gas scenario—a scenario overlooked in prior research—this work contributes a practical, immediately deployable safety solution for millions of households across developing regions.

Future research should explore sensor miniaturization, wire- less power transfer, and collaborative multi-unit networks for larger kitchen spaces. Additionally, standardization efforts should establish certification pathways for domestic gas safety devices, encouraging broader manufacturer adoption of dual-sensing architectures.

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