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DESIGN AND IMPLEMENTATION OF AN LPG LEAKAGE DETECTION AND AUTOMATIC POWER SHUTDOWN SYSTEM

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Abstract

Liquefied Petroleum Gas (LPG) is widely used as a consumer gas to satisfy many consumer needs due to its affordability and availability. However, even a 10% (v/v) solution may ignite a spark. Finding LPG leaks is challenging because they are mostly colourless and odourless at low concentrations. To address this, a low-cost, reliable electronic system has been designed to detect LPG leaks and prevent ignition sources by shutting down power to the affected area using an MQ-2 gas sensor. Analog output from the MQ-2 sensor was received and processed by the ATmega13A-PU microcontroller, which compared the reading against a predefined threshold. Once the sensor threshold is reached, the microcontroller first activates a buzzer and a high-brightness red LED to alert occupants. After a 5-second delay, a 433 MHz RF transmitter sends a wireless signal to the receiver unit, which triggers a shunt-trip breaker via a solid-state relay. This action disconnects the main electrical supply, thereby eliminating the risk of sparks. The system was calibrated and tested under varying gas concentrations and distances, confirming accurate sensitivity and reliable operation. Once the power is shut down, occupants can safely ventilate the area by opening windows and doors. The system continues to operate in a loop until gas levels return to safe conditions. This approach ensures household safety, minimizes fire hazards, and provides a cost-effective solution suitable for residential and small commercial settings. Future enhancements include integrating Internet of Things (IoT) technology for remote notifications and automated ventilation controls, further improving safety and convenience.

Keywords: *LPG detection, MQ 2, Shunt trip barker, AtMega 13A-PU, 433MHz RF*

1. Introduction

Liquid petroleum gas (LPG) is one of the most commonly used energy resources in daily life, primarily for cooking, heating, manufacturing, and transportation [1,2]. It's widely accessible because of its reliability and efficiency[3]. However, LPG is also extremely dangerous because it is a highly flammable gas[4]. Even a small electrical or static spark can ignite leaked gas, causing severe explosions. According to studies, a significant number of LPG-related accidents have been reported [5]. Simply switching on a light bulb can produce a tiny spark at the switch contacts. If LPG has leaked and accumulated overnight, this spark can ignite the gas, resulting in explosions that may damage the kitchen, destroy the house, and cause serious injuries or fatalities[6]. To prevent such accidents, it is essential to detect combustible gases early and immediately remove ignition sources. The proposed system achieves this by monitoring the environment for LPG leakage and cutting off electrical power to prevent sparks. Once the system is triggered, occupants can safely open doors and windows to ventilate the area, locate the source of leakage, and repair it before restoring power. This method ensures a safer home environment while minimizing the risk of fire and explosion.

The system is designed to be low-cost and affordable, making it accessible for widespread domestic use. It employs an MQ-2 gas sensor to detect LPG concentrations and an ATTINY13A-PU microcontroller to process the data, as in Figure 2 [7,8]. A 433 MHz RF transmitter and receiver module provides wireless communication for remote breaker control [9]. A buzzer and red LED are used to alert occupants immediately when gas is detected, offering both audible and visual warnings. Finally, a shunt trip breaker is employed to shut down the entire power supply in the affected area. By integrating gas detection, early warning, and automatic power cut-off, this system provides a practical, reliable, and cost-effective safety solution to protect homes and lives from the dangers of LPG gas leakage.

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2. Materials and methods

The function of this system is straightforward. When LPG or any other combustible gas is present, the MQ-2 gas sensor detects it and produces an analog output signal. If this value exceeds the predefined threshold programmed into the microcontroller, the system immediately activates a buzzer and a 10 mm red LED to provide an early warning. After a 5-second delay, the microcontroller transmits an RF signal at 433 MHz to trigger the shunt trip breaker. Once the breaker trips, it disconnects the main power supply or a selected area of the power system, thereby reducing the risk of sparks or ignition. Following the power shutdown, occupants can safely open windows and doors to improve ventilation and allow the gas to dissipate, thereby reducing the risk of explosion and fire. Once proper ventilation has been achieved, the power can be manually restored. However, if the gas concentration remains above the safe limit, the system will automatically re-activate, sounding the alarm again, turning on the LED, and cutting off power. This process continues in a repetitive loop until the gas concentration returns to a safe range, as represented in Figure 2. By integrating gas detection, early warning, and automatic power cutoff, the system provides a reliable and effective way to prevent hazardous situations caused by LPG or other combustible gas leaks. Its design ensures enhanced safety, automation, and user intervention capability in domestic and industrial environments.

2.1. ATTINY 13a-pu microcontroller

The ATtiny13A-PU is a low-power, 8-bit microcontroller from Microchip's AVR family, designed for small-scale embedded applications where cost, size, and power consumption are critical. It comes in an 8-pin Dual In-line Package (DIP) as shown in Figures 2 and 3. The ATtiny13A is built on the enhanced RISC architecture, enabling most instructions to execute in a single clock cycle. This provides a processing performance of up to 20 MIPS at 20 MHz, which is impressive for such a small device. Despite its minimal pin count, the ATtiny13A offers useful features as follows:

i. 1 KB Flash memory for program storage
ii. 64 bytes SRAM for data
iii. 64 bytes EEPROM for non-volatile storage
iv. 6 programmable I/O pins
v. 4-channel, 10-bit ADC (Analog-to-Digital Converter)
vi. Timers with PWM (Pulse Width Modulation)
vii. Watchdog Timer for system reliability
viii. Operating voltage: 1.8V – 5.5V (supports both low-voltage and 5V systems)

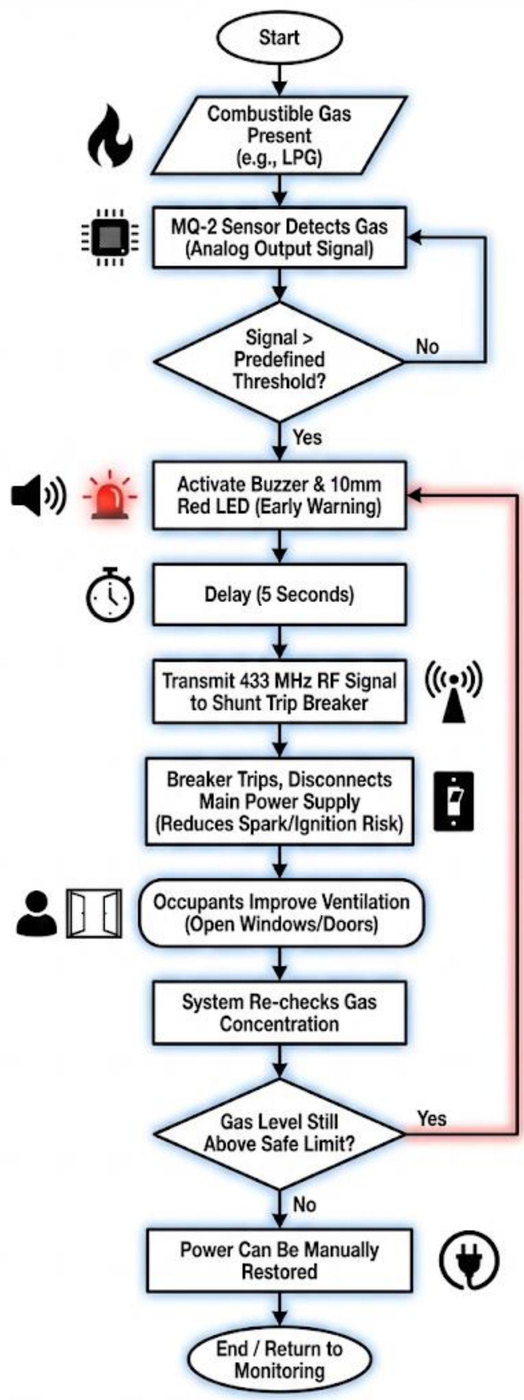

Fig. 1. Block diagram of the system

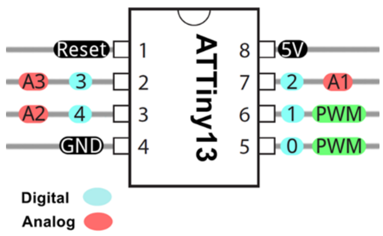

Fig. 2. ATTINY 13A-PU Pin out

Fig. 3. ATTINY 12A PU Microcontroller

2.2 MQ2 gas sensor

The MQ-2 gas sensor is a widely used chemiresistive gas detection device designed to sense combustible gases and smoke in the environment, as shown in Figure 4[8]. It is part of the MQ series of gas sensors, which are commonly used for gas leakage detection in safety, industrial, and domestic applications. The sensor is built with a sensitive material layer (SnO_2 – tin dioxide) whose electrical resistance changes when it comes in contact with gases. In clean air, the sensing layer's resistance is high. However, when combustible gases such as LPG, propane, methane, hydrogen, or smoke are present, the resistance decreases significantly, allowing the sensor to output a measurable signal. The MQ-2 operates on a 5V supply and provides both analog and digital outputs. The analog output provides a variable voltage proportional to gas concentration, while the digital output (via an onboard comparator) indicates whether the gas level has exceeded a set threshold.

Fig. 3. MQ – 2 Gas sensor

Key features include:

i. Detection range: 200 ppm – 10,000 ppm for LPG, propane, methane, and smoke
ii. Fast response and recovery time
iii. Long lifespan with low cost
iv. Simple interface with microcontrollers (e.g., Arduino, AVR, PIC, etc.)

2.3 Buzzer

A buzzer is an electromechanical or electronic sound-producing device that generates an audible alert or tone when an electrical signal is applied. Buzzers are widely used in alarm systems, indicators, and notification circuits to provide audio feedback in both industrial and domestic applications.

There are two main types of buzzers:

i. Electromechanical Buzzer (EMB):
ii. Contains a coil, diaphragm, and mechanical contacts.
iii. Produces sound by physically vibrating the diaphragm when current flows.
iv. Piezoelectric Buzzer (PZT):
v. Uses a piezoelectric ceramic element that vibrates when a voltage is applied.
vi. Typically smaller, consumes less power, and produces a sharper tone.

Key Features:

i. Voltage range: Typically 3–12 V DC for small buzzers
ii. Low power consumption (especially piezo buzzers)
iii. Audible output: Beeps, alarms, or continuous tones
iv. Compact size for easy integration in circuits

Fig. 4. Buzzer assembly

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2.4 433 Mhz Wireless RF Transmitter Receiver Module

The 433 MHz RF Transmitter and Receiver Module is a widely used pair of wireless communication devices designed for low-cost and short-range data transmission. Operating in the 433 MHz ISM (Industrial, Scientific, and Medical) frequency band, these modules are suitable for remote control, wireless monitoring, and simple data communication between two electronic systems, as represented in Figure 6. The RF Transmitter module encodes and transmits digital data as radio frequency (RF) signals, while the RF Receiver module captures and decodes the signals back into digital data. Since they use Amplitude Shift Keying (ASK) or On-Off Keying (OOK) modulation, they are simple, energy-efficient, and effective for low-data-rate applications.

Key Features:

i. Operating frequency: 433 MHz (ISM band, license-free in many countries)
ii. Range: Typically 50–100 meters (line-of-sight), extendable with better antennas
iii. Operating voltage: 3–12 V (transmitter), 5 V (receiver)
iv. Data rate: Up to 10 kbps (ideal for slow data transmission)
v. Compact size, low cost, and low power consumption

Fig. 5. 433 MHz Wireless RF Transmitter Receiver Module

2.5 Solid-state relay

A Solid State Relay (SSR) is an electronic switching device that performs the same function as an electromechanical relay (EMR) but without any moving parts, as represented in Figure 7[10]. Instead of using a physical contact mechanism, an SSR relies on semiconductor components such as thyristors, triacs, diodes, or transistors to switch electrical loads on and off. When a small control signal (voltage or current) is applied, the SSR activates its internal semiconductor switching circuit, enabling it to safely and efficiently control larger AC or DC loads. Because there are no mechanical contacts, SSRs are faster, quieter, and more durable compared to traditional relays.

Key Features:

i. Electrical isolation between control and load (using opto-couplers)
ii. Silent operation (no clicking sound like mechanical relays)
iii. Fast switching speed (in microseconds)
iv. Long lifespan due to absence of mechanical wear
v. Low electromagnetic interference (EMI)
vi. Available for both AC and DC load switching

Fig. 6. Solid-state relay

2.6 Shunt Trip Breaker

A Shunt Trip Breaker is a type of circuit breaker that can be remotely tripped (turned off) using an electrical signal, in addition to normal manual operation, as represented in Figure 8[11]. It is commonly used in safety and emergency shutdown systems to disconnect electrical power quickly in hazardous situations. Unlike standard circuit breakers, which rely solely on overcurrent or short-circuit conditions to trip, a shunt trip breaker includes a solenoid coil (the shunt trip mechanism) that, when energized, mechanically forces the breaker to open and interrupt the circuit.

Key Features:

i. Remote tripping capability via electrical control signal
ii. Can be integrated with safety sensors (gas detectors, fire alarms, etc.)

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iii. Provides fast and reliable power disconnection
iv. Maintains all the protective functions of a standard breaker (overcurrent, short-circuit).
v. Available in AC and DC versions depending on application

2.7 Main circuit

The electronic circuit was designed using Eagle 7.6.0 software and performs a specific safety function. The MQ-2 gas sensor detects the presence of combustible gases. The designed circuit is represented in Figure 9. It provides an analog output signal, which is directly fed into the ATTINY 13A-PU microcontroller. The microcontroller continuously monitors the sensor output and compares it with a pre-programmed threshold value. If the sensor reading exceeds this limit, it indicates the possibility of a gas leakage. In response, the system first activates a 10 mm red LED and a buzzer to provide a local visual and audible warning. After a 5-second delay, the microcontroller sends a control signal to initiate the main power shut-off process. This action disconnects electrical power to a pre-selected area, reducing the risk of ignition and preventing a possible explosion. This design ensures early detection, warning, and protective action, enhancing safety. The finalized circuit board is represented in Figure 11, and the printed circuit board is represented in Figure 12.

Fig. 8. Shunt Trip Breaker

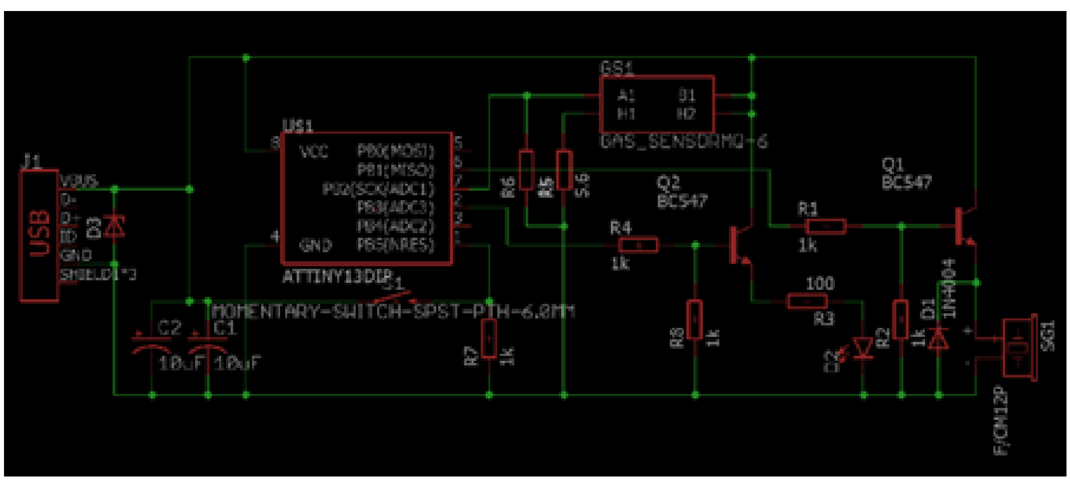

Fig. 9. Main Circuit Schematic diagram

Fig. 10. Printed circuit board

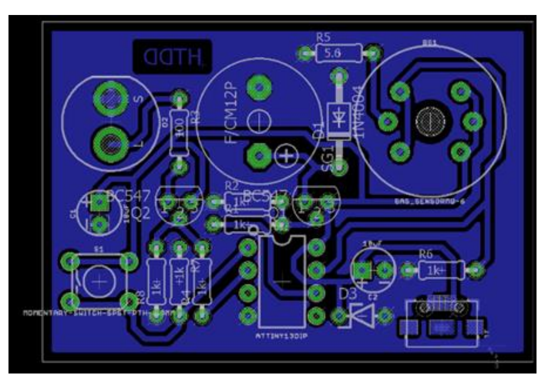

Fig. 11. Main Circuit PCB Diagram

3. Results and Discussion

After installing the system, it was tested and calibrated to ensure proper operation. The initial testing was carried out by releasing small amounts of LPG gas using a lighter, which contains the same type of combustible gas. The sensing circuit was attached as shown in Figure 14. Different gas concentrations were introduced at varying distances from the MQ-2 sensor to evaluate the system's sensitivity. During these trials, the system consistently detected the gas and triggered the LED, buzzer, and power cutoff sequence as programmed, as in Figures 12 and 15. If gas were not present in the chamber, no alarm would be shown, as in Figure 13. Calibration was then performed to adjust the microcontroller's threshold to ensure the system responded accurately under the intended environmental conditions. After fine-tuning, the system became capable of detecting even small concentrations of LPG. Each test confirmed that the circuit responded reliably, with timely alarm activation and power disconnection. This demonstrates that the system is both sensitive and effective for preventing LPG-related hazards.

Fig. 12. After LPG gas detection 10 mm LED turns on, and Buzzer active

Fig. 13. Sensor without LPG

Fig. 14. Indicating LPG gas leak

Fig. 15. Installing the device on the LPG gas tank

The system operated reliably during testing without failures and achieved the project's objectives using basic components. This demonstrates that a low-cost yet effective safety solution can be developed to prevent gas leakage. The project was successfully completed within its intended scope. For future development, the system can be enhanced by integrating IoT- based communication instead of the RF module. This would allow users to receive notifications from anywhere in the world without entering the premises. Additionally, IoT integration could enable automated ventilation, such as opening windows and activating fans, to ensure rapid gas removal.

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