

Detecting Potential Gas Hazards in Laboratory Environments with Arduino Uno and MQ Multigas Sensors

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ABSTRACT

The increasing use of various types of gases in laboratory activities carries significant safety risks, such as gas leaks, explosions, poisoning, and fires. Therefore, a reliable gas detection system is needed to prevent workplace accidents. This study aims to design and evaluate a gas detection system based on the ATmega328 microcontroller equipped with three types of gas sensors, namely MQ2, MQ3, and MQ135, each of which has a sensitivity to certain gases. This system was developed using an Arduino Uno board and is equipped with a buzzer and LED indicator as an early warning tool if gas concentrations exceed the safe threshold. MQ2 detects flammable gases such as LPG, methane, and hydrogen; MQ3 is sensitive to alcohol vapor; and MQ135 is used to detect air contaminants such as ammonia, benzene, and smoke. Through a series of trials in a laboratory environment, the performance of the sensors was tested based on their response speed, sensitivity, and reliability. The results show that this system is able to provide an effective early warning of potential gas leak hazards in the laboratory, and offers a practical, economical, and responsive solution to improve workplace safety in high-risk environments.

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1. INTRODUCTION

The use of various types of gases in laboratory activities is common, especially in experiments involving chemical compounds, combustion processes, or heating with certain gases such as LPG, methane, or alcohol. While their use is essential to support scientific activities, the risks posed by gas leaks are significant, ranging from fire and explosion hazards to exposure to toxic substances that endanger the health of laboratory users.

Therefore, early detection of gas leaks is critical to ensure workplace safety and prevent accidents.

According to research by Rahman et al. [1], a responsive gas leak detection system can reduce the risk of work accidents by up to 60% in industrial and laboratory environments, especially when combined with sound and visual early warning systems. Such systems function not only as detectors, but also as early mitigation tools that can save lives and prevent material losses. Advances in microcontroller technology have opened up opportunities to create cheaper and more flexible safety systems. Arduino Uno, an open-source microcontroller platform, is widely used in research and development of automation systems due to its ease of programming, extensive library availability, and compatibility with various sensors. One rapidly growing application is a gas detection system based on the MQ (Metal Oxide Semiconductor) series of sensors. The MQ2 sensor is known to be sensitive to flammable gases such as LPG, methane, and hydrogen; the MQ3 is used to detect alcohol vapors; while the MQ135 is capable of detecting air pollutants such as ammonia, benzene, and smoke. The combination of these three sensors enables the system to detect various types of hazardous gases commonly encountered in laboratory activities [2].

Several previous studies [3-6] also show that the use of Arduino in a gas detection system is able to produce fast response times and sufficient accuracy for small to medium scale environmental monitoring needs. With its low cost and high flexibility, this system is very suitable for application in educational and research laboratories. Based on this background, this study aims to design and implement a gas leak early detection system using Arduino Uno equipped with MQ2, MQ3, and MQ135 sensors. This system is also supported by a buzzer and LED as early warning indicators when hazardous gases are detected exceeding the safe threshold. It is hoped that this tool can improve work safety in the laboratory by providing a fast, effective, and economical warning system.

The research aims to design a simple and low-cost gas leak detection system based on Arduino Uno [7-8]. In addition, it also aims to integrate MQ2, MQ3, and MQ135 sensors in the system to detect various types of hazardous gases [9-11], and test the effectiveness and speed of the system in providing early warnings through buzzers and LED indicators [12]. This research is useful for adding scientific references related to the development of a microcontroller-based gas leak detection system, providing a theoretical basis for the development of a gas sensor-based environmental safety system, providing a practical, cost-effective gas detection solution that can be implemented in educational and research laboratories, and helping to improve work safety and prevent accidents due to gas leaks through an early warning system.

2. METHOD

This study uses a quantitative method to design and test a gas detection system based on the ATmega328 microcontroller [13] with three gas sensors, namely MQ2, MQ3, and MQ135. The MQ2 sensor is used to detect flammable gases such as LPG, propane, and

hydrogen with test samples in the form of gas lighter vapor. The MQ3 sensor is specifically for detecting alcohol and ethanol vapor, where in this study perfume is used as a test material. The MQ135 sensor functions to detect air pollutants such as ammonia, benzene, and smoke which are commonly found in laboratory activities.

The three sensors are connected to an Arduino Uno microcontroller that processes analog data from the sensors. The system does not use a concentration threshold, but rather measures the sensor's response time to the presence of gas. This response time is calculated as the time (in seconds) from the start of the sensor detecting gas until the buzzer and LED indicators are activated. The LED indicators consist of a green light that lights up when gas is not detected and a red light that lights up and a buzzer that sounds when gas is detected. Testing was conducted in a laboratory environment. Test samples were gas lighter vapor for the MQ2 and MQ135 sensors and perfume for the MQ3 sensor. Testing was carried out by exposing the sensor to gas/perfume vapor and recording the response time until the system issued a warning.

The collected data are in the form of sensor response time (seconds) and indicator status (green/red LED and active/inactive buzzer). The analysis was carried out to compare the response speed and sensitivity of the three sensors in detecting the tested gas. The components used include MQ2, MQ3, MQ135 sensors, Arduino Uno, buzzer, green and red indicator LEDs, breadboard, and connector cables. Programming and data processing were carried out using Arduino IDE.

Table 1. Testing Parameters

Parameter	MQ2	MQ3	MQ135
Gas source	Gas lighter vapor	Perfume (contains alcohol)	Gas lighter vapor
Detected gas	LPG, propane, hydrogen	Alcohol vapor, ethanol	Ammonia, benzene, smoke
Test environment	Closed space	Closed space	Closed space
Response time	About 4 seconds	About 3 seconds	About 2 seconds
Output indicator	Red LED + buzzer active when detected, green LED when safe	Red LED + buzzer active when detected, green LED when safe	Red LED + buzzer active when detected, green LED when safe
Metode analisis	Comparing sensor response time and indicator status as indicators of sensitivity and detection speed		

A fire detection system is needed that can detect the presence of leaking gas smoke or fire in the house. To detect gas leaks or fire smoke, a tool is needed to detect CO gas. Therefore, the author created a gas leak and fire smoke detection system using an Arduino Uno with an MQ-5 gas input as a sensor to detect fire smoke and an LED output and a 5V buzzer as a fire warning. This fire smoke detector, we use several hardware and software components.

2.1 Arduino Uno R3

Arduino is a microcontroller used to create programs that can control various electronic systems. Arduino is a board containing a microcontroller and input/output components, making it easier for users to create electronic system projects.

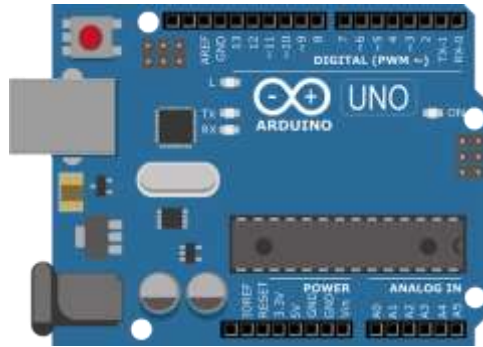


Figure 1. Arduino Uno

The Arduino used in this study is the Arduino Uno type R3. The Arduino Uno R3 itself is the third revision of the Arduino, released in 2011 and based on the Atmel Atmega328p chip. The Arduino R3 is an 8-bit microcontroller with 14 digital input/output pins. The Arduino R3 specifications can be seen in Table 2.

Table 2. Arduino Uno R3 specifications

Spesification
Microcontroller ATmega328p
Digital I/O 14 pin
Input Voltage 7-12v
Operating Voltage 5v
SRAM 2KB
Analog Input Pins 6
DC Current per I/O Pin 20 mA
DC Current for 3.3V Pin 50 mA
Flash memory 32 KB (Atmega328p)
PWM Digital I/O pins 6
EPROM 1KB
Clock Speed 16 MHz
LED_BULTIN 13
Length 68.6 mm
Weight 25g
Width 53.4 mm

2.2. MQ2 Gas Sensor

The MQ-2 sensor is a type of gas sensor used to detect flammable gases such as LPG (liquefied petroleum gas), propane, hydrogen, methane, and smoke. This sensor works based on the principle of changes in the resistance of semiconductor material (SnO_2) when exposed to certain gases. This change in resistance produces an analog signal that can then be read and processed by a microcontroller. The MQ-2 has high sensitivity to flammable gases with a detection range between 300 and 10,000 ppm. In this study, the MQ-2 sensor was used to detect the presence of gas from lighter vapor as a representation of potential gas leak conditions in the laboratory.



Figure 2. MQ2 Gas Sensor

2.3. MQ3 Gas Sensor

The MQ-3 sensor is a gas sensor with high sensitivity to alcohol and ethanol vapors. This sensor is commonly used in alcohol detection devices such as breathalyzers. Like other MQ sensors, the MQ-3 uses a heating element and a sensitive material that detects changes in resistance due to the presence of alcohol in the air. This sensor is capable of detecting alcohol in the range of 25 to 500 ppm. In this study, the MQ-3 was used to detect perfume vapor containing alcohol compounds, to simulate alcohol exposure in a laboratory environment.



Figure 3. MQ3 Gas Sensor

2.4. MQ135 Gas Sensor

The MQ-135 sensor is a gas sensor designed to detect various types of air pollutants, such as ammonia (NH₃), benzene, cigarette smoke, carbon monoxide (CO), and volatile organic compounds (VOCs). This sensor has the characteristics of a fast response and is sensitive to changes in air quality. Its working principle is similar to other MQ sensors, namely by detecting changes in resistance in the sensitive element when exposed to the target gas. The MQ-135 is used in this study to detect hazardous gas content using gas lighter vapor as a test sample, which aims to simulate air contaminants that may occur in laboratory activities.



Figure 4. MQ135 Gas Sensor

Table 3. Types of gas sensors

Sensor Type	Sensitive To
MQ-2	Butane, Cigarette Smoke, Methane
MQ-3	Ethanol, Alcohol, Cigarette Smoke
MQ-135	Benzene, Alcohol and Cigarette Smoke

2.5. Buzzer 5V

A buzzer is an electronic component that functions as an audio output device in the form of sound or voice as a warning or notification sign. In microcontroller-based systems, buzzers are often used as sound indicators that will be activated when certain conditions are met, for example when a dangerous gas is detected. A 5V buzzer is a type of buzzer that works at an operating voltage of 5 volts, which is generally compatible with the digital output of a microcontroller such as the Arduino Uno. There are two types of buzzers commonly used, namely active buzzers and passive buzzers. Active buzzers produce sound by only being given voltage, while passive buzzers require a frequency signal from the microcontroller to produce sound.

In this study, a 5V buzzer was used as an early warning indicator that would activate (sound) when the gas sensor detected a hazardous gas concentration. Activation of the buzzer indicated that the system had successfully detected a potential hazard and provided an audible alarm response to the user.



Figure 5. Buzzer 5V

2.6. Light Emitting Diode (LED)

A Light Emitting Diode (LED) is a semiconductor electronic component that emits light when an electric current flows through it. LEDs have advantages over conventional lamps due to their low power consumption, long lifespan, and small size. LEDs will only light up when installed with the correct polarity (anode to positive and cathode to negative), as they are components with a direct current direction (diode). In microcontroller-based gas detection systems, LEDs are used as visual indicators to provide information about the detection status. The use of LEDs as indicators aims to provide visual signals directly and easily understood by users, so that the system can be used practically and efficiently in a laboratory environment.

3. RESULTS AND DISCUSSION

Test results for the gas detection system show that each sensor has different response characteristics to the type of gas tested. The MQ-135 sensor, used to detect air pollutants such as ammonia, benzene, and smoke, demonstrated the fastest response time, approximately 1 second from the start of gas exposure. This indicates that the MQ-135 is highly sensitive to changes in air quality and is suitable for use as an early warning system in laboratory environments that potentially contain hazardous compounds.

The MQ-3 sensor, designed to detect alcohol vapor, showed a response time of around 3 seconds. While not as fast as the MQ-135, this sensor still showed good and consistent performance, especially when tested with perfume as a source of alcohol vapor. The MQ-2 sensor, which detects flammable gases such as LPG and hydrogen, had the slowest response time, at around 4 seconds. The MQ-2's slow response is likely due to the longer warm-up time required for its sensor element to function optimally.

This system does not use numerical thresholds or digital displays like LCDs, but instead relies on simple indicators such as LEDs and buzzers. A green LED illuminates when the environment is deemed safe, and a red LED and buzzer activate as a warning signal when the sensor detects gas. This approach is considered effective for a simple, inexpensive, and easily applicable rapid detection system in laboratory environments.

A comparison of the response times of these three sensors indicates that sensor selection should be tailored to specific detection needs in the field. This system is considered responsive and practical, and capable of providing reliable early warning under

controlled experimental conditions. However, for long-term use or in open environments, further testing is required to assess sensor stability, accuracy, and potential reading errors due to external factors such as temperature and humidity.

3.1. MQ2 Sensor Circuit

The MQ-2 sensor is used as the main component for detecting flammable gases such as LPG, propane, and hydrogen. This sensor is connected to the analog pin A0 on the Arduino Uno and receives a 5V voltage supply from the Arduino's output pin. In its implementation, the MQ-2 sensor produces an analog signal that changes depending on the concentration of the detected gas. This output is read by the Arduino and processed using simple programming logic to activate the indicator.

Tests were conducted using gas vapor from a lighter as a source of flammable gas. The tests were conducted in a sealed cardboard box to maintain a stable gas concentration around the sensor. The test results showed that the MQ-2 sensor responded within an average of 4 seconds after the gas vapor was released into the test chamber.

When gas is detected, the Arduino automatically activates a red LED as a visual indicator of danger, as well as a buzzer as an audio indicator. If no gas is detected, only the green LED lights up, indicating a safe condition. This MQ-2 sensor circuit demonstrates stable performance in detecting flammable gases. Although its response time is slower than other sensors used in this study, its accuracy in providing a warning signal is quite reliable. This is very important, especially in early detection systems for gas leaks in laboratory environments.

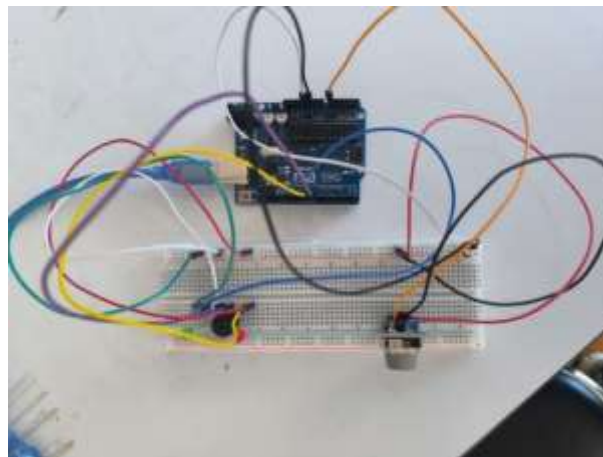


Figure 6. Arduino MQ2 Circuit

3.2. MQ3 Sensor Circuit

The MQ-3 sensor is used to detect the presence of alcohol and ethanol vapors. This component is highly sensitive to alcohol compounds, making it widely used in breathalyzers, or devices that measure alcohol concentration in breath. In this circuit, the MQ-3 is connected to analog pin A1 on an Arduino Uno and supplied with a 5V voltage.

The test was conducted using perfume as the test material because perfumes generally contain alcohol compounds such as ethanol. The test was conducted in a closed chamber (a shoe box) to prevent the perfume vapor concentration from dissipating quickly and to maintain its concentration around the sensor. When the perfume was sprayed into the chamber, the MQ-3 sensor showed a significant change in the analog signal.

The Arduino reads the signal from the sensor and responds within an average of 3 seconds. Upon detecting the presence of alcohol, the system activates a red LED and buzzer as a warning signal. If no alcohol vapor is detected, only the green LED lights up to indicate a safe environment.

Test results show that the MQ-3 sensor has a faster response time than the MQ-2, as well as high sensitivity to alcohol. This circuit is very effective for detecting the presence of alcohol vapor in a short time and is suitable for use in laboratory scenarios where alcohol-containing materials are frequently used.

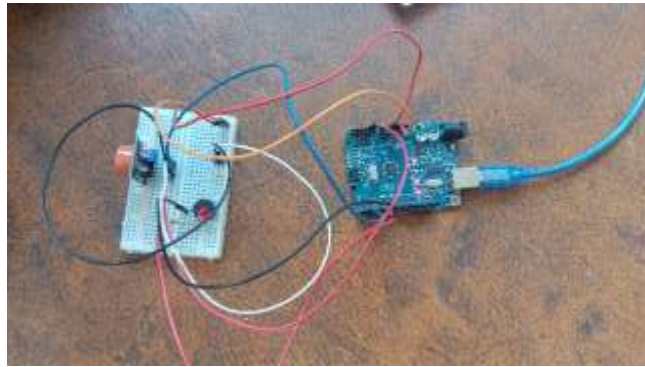


Figure 7. Arduino MQ3 Circuit

3.3. MQ135 Sensor Circuit

The MQ-135 sensor is used in this system to detect pollutant gases such as NH_3 , NH_2 , cigarette smoke, and other potentially toxic gases in a laboratory environment. The sensor is connected to analog pin A2 on the Arduino Uno and supplied with a 5V operating voltage.

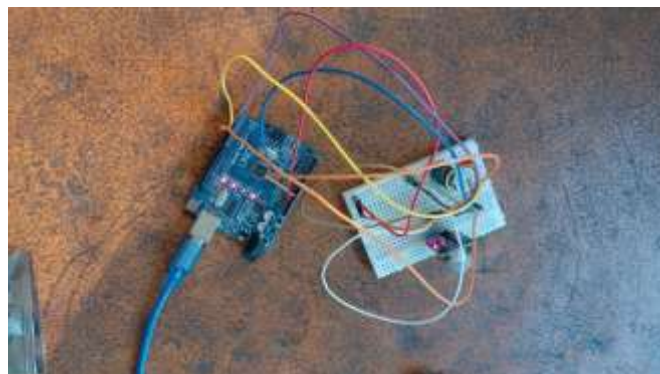


Figure 8. Arduino MQ135 Circuit

Tests were conducted using lighter vapor to simulate the presence of airborne pollutants. As with other tests, the sensor was placed in a closed chamber to maintain vapor concentration. The MQ-135 sensor demonstrated the fastest response compared to the other two sensors, with an average response time of only 1 second after gas exposure. When the sensor detects a pollutant, the Arduino automatically activates a red LED and buzzer to indicate an unsafe condition. If no gas is detected, the system remains lit with a green LED. The MQ-135 circuit exhibits high sensitivity and fast response time, making it an ideal component for an early air pollution detection system. This sensor is highly suitable for use in laboratory environmental monitoring applications that require rapid response to potentially hazardous contaminants.

3.4. Comparative Analysis

A comparison of the performance of the three gas sensors, the MQ-2, MQ-3, and MQ-135, was conducted based on test results covering response time, sensitivity, and reading stability. The analysis results showed that the MQ-135 sensor had the fastest response time, which was approximately 1 second from gas exposure, followed by the MQ-3 with an average time of 3 seconds, and the MQ-2 with a time of approximately 4 seconds. This response speed significantly influences the effectiveness of the system in providing early warnings, especially in critical situations in a laboratory environment.

Table 4. Sensor Performance Comparison Table

No.	Sensor	Type of Gas	Test Material	Response Time (s)	Indicator When Detected	Safe Time Indicator	Sensitivity	Reading Stability
1	MQ-2	Flammable gases (LPG, methane, hydrogen)	Gas lighter vapor	± 4	Red LED lights up, buzzer sounds	The green LED is on	Medium	Stable
2	MQ-3	Alcohol and ethanol vapor	Parfume	± 3	Red LED lights up, buzzer sounds	The green LED is on	High	Stable
3	MQ-135	Air pollutants (ammonia, smoke, benzene)	Gas lighter vapor	± 1	Red LED lights up, buzzer sounds	The green LED is on	Very High	Very Stable

In terms of sensitivity, the MQ-135 also ranks highest. This sensor responds very quickly to the presence of air pollutants such as ammonia and smoke, even at low concentrations. Meanwhile, the MQ-3 has high sensitivity to alcohol vapor, making it suitable for applications involving the detection of ethanol or other volatile alcohol

compounds. The MQ-2, although slightly slower, still has good sensitivity to flammable gases such as LPG and hydrogen, which is important for fire and explosion prevention.

In terms of reading stability, all three sensors demonstrated adequate performance during repeated testing. However, the MQ-135 achieved the highest stability, with consistent readings each time tested under similar conditions. The MQ-3 also demonstrated stable results against alcohol vapor from perfume. The MQ-2 was relatively more volatile, likely due to its longer preheating time before reaching optimal operating conditions.

The indicator mechanism used in this system facilitates quick and simple interpretation of results. When gas is detected, a red LED and buzzer activate to signal danger. Conversely, when no gas is present, a green LED illuminates to indicate a safe condition. This simple output makes the system easy to understand without requiring numerical reading, which is particularly useful in emergency situations. Overall, the performance of each sensor varies depending on the characteristics of the gas being detected. The MQ-135 excels in speed and sensitivity to pollutants, the MQ-3 is effective for alcohol vapors, and the MQ-2 remains relevant for combustible gases. These results provide important insight that sensor selection should consider the target gas type, required response time, and system stability over a specified period of use.

4. CONCLUSION

This research successfully designed and implemented a gas detection system based on an Arduino Uno microcontroller using three types of gas sensors: the MQ-2, MQ-3, and MQ-135. This system was designed to provide automatic early warnings through simple indicators such as LEDs and buzzers, without the use of digital displays such as LCDs.

Test results showed that each sensor performed differently in detecting specific gas types. The MQ-135 sensor had the fastest response time of approximately 1 second, making it highly effective for detecting air pollutants such as ammonia and smoke. The MQ-3 sensor demonstrated relatively fast performance in detecting alcohol vapors with an average response time of 3 seconds, while the MQ-2 sensor required approximately 4 seconds to detect flammable gases such as LPG and hydrogen.

The entire system was tested in a laboratory environment with a closed chamber to maintain stable gas concentrations. The indicators used performed well: a red LED and buzzer activated when gas was detected, and a green LED illuminated under normal conditions. The system demonstrated good responsiveness and reliability in repeated tests.

Overall, this system has proven to be effective, economical, and practical for use as an early warning tool for gas leaks or exposure to hazardous substances in laboratory environments. Although it does not use numerical thresholds or digital displays, the system is capable of providing real-time condition information through visual and audible indicators.

However, this study has limitations in quantitative accuracy because it does not measure gas levels in specific units. For further development, the system could be equipped with additional modules such as an LCD, IoT connectivity, or data logging features to allow for real-time monitoring and recording of detection results for further analysis.

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