American Journal of Sensor Technology, 2023, Vol. 7, No. 1, 1-9
Available online at http://pubs.sciepub.com/ajst/7/1/1
Published by Science and Education Publishing
DOI:10.12691/ajst-7-1-1

Development and Comparison of Arduino Based MQ-2 and MQ-6 LPG Leak Sensors

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Received May 15, 2023; Revised June 24, 2023; Accepted July 2, 2023

Abstract LPG leakage is a significant cause of fire hazards and a substantial danger to human life and property. There are many commercially available LPG leak sensors, however they are very expensive. Hence alternative is needed. Using Arduino board added with gas sensor can be a great option. Gas sensors, specifically MQ-2 and MQ-6 gas sensors can explosive gases, including other volatile compounds and molecules in the air. They are popular in industrial, commercial, and residential settings for controlling atmospheric conditions, preventing leaks, fire, poisoning, and explosion hazards. This study compared and evaluated the capability of an Arduino-based MQ-2 and MQ-6 LPG sensor in terms of the response time, returned ppm values, and if there is a difference in the ability of the MQ-2 and MQ-6 gas sensor to detect particles of LPG; in terms of response time, and returned ppm values. The study was quantitatively designed, focusing on the experimental approach and a descriptive explanation. In testing the efficiency and capability of an Arduino-based LPG sensor using an MQ-2 and MQ-6 gas sensor, the paper gathered a fully filled 11-kilogram Pryce Gas LPG tank for the test. The testing of both MQ-2 and MQ-6 gas sensors revealed their capability and excellent efficiency in detecting LPG gas. From the obtained results from the response time it shows that both sensors have no significant difference in responding to LPG gas. However, the results from the ppm value shows that MQ-6 is more sensitive compared to MQ-2 gas sensor, demonstrating a significant difference in terms of returned ppm values. Additionally, the results from the data revealed that the optimal distance for the placement of both sensors is 20 cm to 40 cm from the source of the gas.

Keywords: *Arduino, efficiency, gas sensor, LPG, MQ-2, MQ-6*

Cite This Article: Sherwin Johanne D. Galceran, Florence John H. Villarico, John Jeffrey C. Omao, Leona Carla P. Estaniel, Ian Jay P. Saldo, Jhovel Roy D. Calo, and Mary Jade P. Dandoy, “Development and Comparison of Arduino Based MQ-2 and MQ-6 LPG Leak Sensors.” *American Journal of Sensor Technology*, vol. 7, no. 1 (2023): 1-9. doi: 10.12691/ajst-7-1-1.

1. Introduction

Arduino is an open-source computer platform that hobbyists can use to build their modules - that can be used to control experimental projects that involve smart devices. Arduino is highly flexible, reliable, and powerful for their compact size - making it a great tool for different applications, such as detecting smoke and gas leaks, and in agriculture and atmospheric sciences with great effect and accuracy [1,2,3,4,5]. There are many studies, such as the milk monitoring system [3], water quality monitor [6,7], air quality monitoring system [1], and soil moisture monitoring system [8] that incorporate Arduino boards into a sensor. A study claimed that the system is useful for industries, offices, and homes as it can detect both toxic and flammable gases like butane, LPG, methane, and carbon monoxide [9]. Gas sensors are electronic tools for detecting toxic and explosive gases, including other volatile compounds and molecules in the air. It is also designed to prevent fire, poisoning, and preventing gas leaks. Metal oxide semiconductors, specifically MQ-2 and MQ-6, are used for the detection of combustible gases because of their affordable price, reliability, simplicity, and availability - also because both have been used in similar studies with satisfactory results [10,11,12,13,14,15,16,17].

LPG is widely used in cooking for its efficiency, economic value, ease of storage, transportation, and low carbon footprint due to its clean burn [18]. LPG is a heavy gas and as such, when there is a leak, it accumulates in low areas like basements or sinks. This can result in a fire or suffocation risk. When LPG comes into contact with the skin, it can cause cold burns or act as an asphyxiant (inability to breathe) if present in high concentrations. Inhaling LPG can make a person sick [19]. In a case report, intentional inhalation of liquefied petroleum gas caused Ataxia with Parkinsonism and dystonia. According to the report, a low-neurotoxic gas mixture may have caused direct toxic damage to the brain via a mechanism of histotoxic hypoxia similar to that seen in CO intoxication. Constant inhalation of LPG fumes is bad for human health [20]. Furthermore, in a related study, they highlighted the rising risks and dangers of using LPGs and the need for an advance warning and preventative element that could have prevented further accidents [21].

While there are many commercially available LPG leak sensors, they are exuberantly expensive which cost one hundred thirty pounds (130), or around 8,517.846 Philippine Pesos [22]. There are many studies that use Arduino as an alternative to gas sensors. However, often, these studies use descriptive text to state that Arduino-based systems are effective but lack quantification and statistical analysis of test data to highlight the efficiency of said systems. Currently, almost no study compared the efficiency of an Arduino-based LPG leak sensor equipped with the MQ-2 and MQ-6 sensors back-to-back in field testing.

This study compared and evaluated the efficiency of an Arduino-based MQ-2 and MQ-6 LPG sensor in terms of the response time, returned ppm values, and if there is a difference in the ability of the MQ-2 and MQ-6 gas sensor to detect particles of LPG, in terms of response time, and returned ppm values. The main hypothesis is that there is no significant difference in the efficiency of the MQ-2 and MQ-6 in an Arduino-based LPG leak sensor based on their response time and returned ppm values.

2. Methodology Research Design

The study is of a quantitative design which utilized a descriptive explanation and an emphasis on the experimental method with statistical analysis. To test and compare the efficiency of the two Arduino-based LPG leak sensors, using the MQ-2 and MQ-6 gas sensors, the response time and ppm values with increasing distance from the LPG source were collected and analyzed in a controlled room.

2.1. Research Instruments

To create the Arduino based LPG leak detector system that were used to collect and conduct this study, the materials were assembled as follows: First, the MQ-2 and MQ-6 gas sensors to the A3-A6 pins should be connected to their respective breadboards using Dupont or jumper cables. Secondly, the A-4 pin, labeled GND, of the gas sensors should be connected to the grounding element of the breadboard. Thirdly, the A-2 pin, labeled VCC, needs to be connected to the positive side of the breadboard.

After, the 5-volt buzzers should then be connected to the B19-B22 pins of the breadboards. Then, the B22 pin, or the negative pin of the buzzers, should be connected to the ground of the breadboard. Next, the 3 LED bulbs (green, yellow, red) should be connected along the H pin slots of the two breadboards. Then, the anode (negative) pins of the LEDs should be connected to ground.

Next, the A0 of the Arduinos should be connected to A0 of the MQ-2 and MQ-6 gas sensors. Then, the positive of the 5-volt buzzer have to be connected to D08 slot of the Arduino, also the cathode (positive) needs to be connected of the LED's. The green cathode got to be connected to D2; the yellow cathode to D3; and, the red cathode to D4. Then, a 220 ohms resistor must be connected to the cathodes of the LED's and to the ground of the breadboard. Next, the positive and negative ends need to be connected to the breadboard, the ground of the breadboard should be connected to the GND slot of the Arduino, and positive should be connected to the 5V slot of the Arduino.

Then, the I2C LCD has to be connected with its corresponding pins; GND to the ground, the VCC to the positive, the SDA to the SDA slot of the Arduino, and the SCL to the corresponding slot of the Arduino. In addition, the Arduino must be connected to a computer via the USB port, and using the Arduino IDE create the code for the LPG leak sensors. The codes and libraries needed are open-source and technical advice can be readily given on the internet. Finally, the code and upload should be compiled to the Arduino.

In addition, this study employed Tinker-cad and Proteus 8, Computer Aided Design software, to virtually test the LPG leak sensors. The leak sensors were further tested in real-life – with input from a technician and computer programmer, as needed. Furthermore, the pictorial diagram was inspired from [28], and have been synthesized using Tinker-cad.

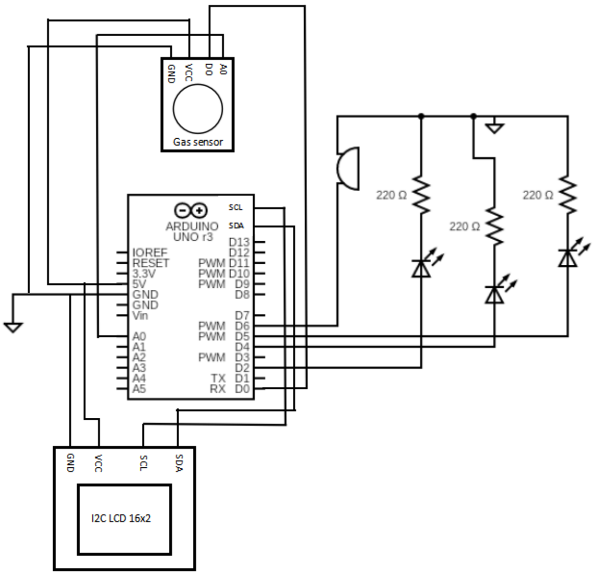

Figure 1. Circuit Diagram of Arduino-based Gas sensor

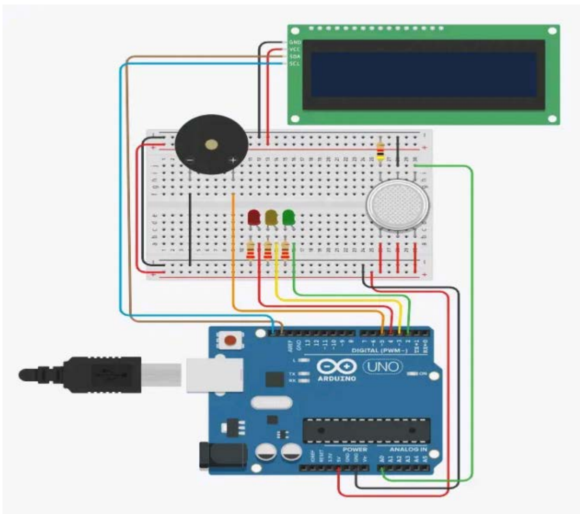

Figure 2. Pictorial Diagram of Arduino-based Gas sensor

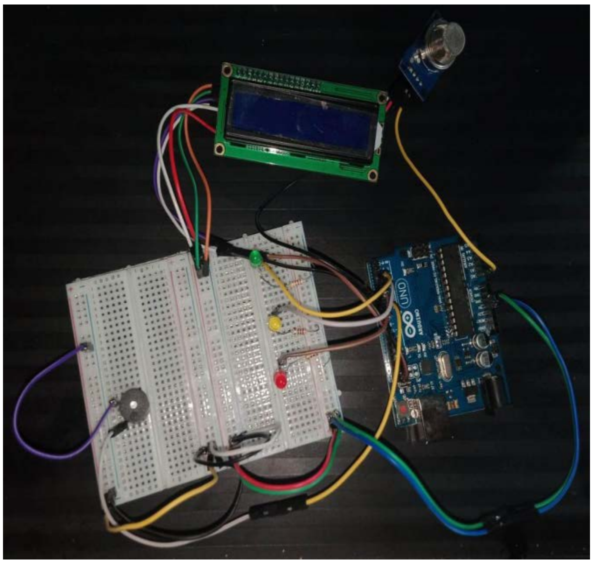

Figure 3. Actual Photo of the Sensor While Turned Off

2.1.1. Programming the Arduino Board

```
1  #include <MQ2.h>     // import libraries for the MQ-2 and LCD
2  #include <Wire.h>
3  #include <LiquidCrystal_I2C.h>
4  //I2C pins declaration
5  LiquidCrystal_I2C lcd(0x27, 16, 2);  // set the LCD address to 0x27 for a 16 chars and 2 line display
6
7  int redLed = 5;      // define which terminals of the Arduino are connected to what
8  int yellowLed = 4;
9  int greenLed = 2;
10 int buzzer = 6;
11 int Analog_Input = A0;
12 int lpg;
13
14 MQ2 mq2(Analog_Input);    // tells the Arduino to read for analog data from the MQ-2
15
16 void setup() {
17   pinMode(redLed, OUTPUT);  // define which is output and input
18   pinMode(greenLed, OUTPUT);
19   pinMode(buzzer, OUTPUT);
20   pinMode(Analog_Input, INPUT);
21   Serial.begin(9600);       // allows the Arduino to send signals to the LCD at 9600 bits per second
22   lcd.init();                   //Defining 16 columns and 2 rows of lcd display
23   lcd.backlight();               // turn on backlight
24   lcd.setCursor(0, 0);           // set cursor to first column, first row
25   lcd.print("LPG Gas Sensor");   // print on first line
26   lcd.setCursor(0, 1);           // set cursor to first column, second row
27   lcd.print("Initializing...");  // print on second line
28   delay(5000);                   // wait for 5 seconds
29   lcd.clear();                   // clear the LCD display
30   lcd.setCursor(1, 1);           // set cursor to first column, first row
31   lcd.print(" ");                // print on second line
32   lcd.setCursor(0, 0);           // set cursor to first column, second row
33   lcd.print("PPM: ");           // print on first line
34   mq2.begin();
35 }
36 void loop() {
37     int analogSensor = analogRead(Analog_Input);
38   float ppm = (float)analogSensor - 103; // calculate PPM value based on sensor value
39
40   if (analogSensor < 200) {  // no gas detected
41     digitalWrite(redLed, LOW);
42     digitalWrite(yellowLed, LOW);
43     digitalWrite(greenLed, HIGH);
44     noTone(buzzer);
45     lcd.setCursor(1, 1);
46     lcd.print("SAFE        ");
47     lcd.setCursor(0, 0);
48     lcd.print("PPM: ");
49     lcd.print(ppm);
50   }
51   if (analogSensor >= 200 && analogSensor < 400) {  // warning
52     digitalWrite(redLed, LOW);
53     digitalWrite(yellowLed, HIGH);
54     digitalWrite(greenLed, LOW);
55     tone(buzzer, 648, 500);
56     lcd.setCursor(1, 1);
57     lcd.print("WARNING!");
58     lcd.setCursor(0, 0);
59     lcd.print("PPM: ");
60     lcd.print(ppm);
61   }
62   if (analogSensor > 400) {  // evacuate
63     digitalWrite(redLed, HIGH);
64     digitalWrite(yellowLed, LOW);
65     digitalWrite(greenLed, LOW);
66     tone(buzzer, 1000);
67     lcd.setCursor(1, 1);
68     lcd.print("DANGER!    ");
69     lcd.setCursor(0, 0);
70     lcd.print("PPM: ");
71     lcd.print(ppm);
72   }
73   delay(1000);  // wait for 1 second before taking the next reading
74 }
```

Figure 4. Raw code for Arduino

The code, assembly, and flow diagram that used was created by synthesizing the code and insights from multiple authors online, namely, [2,23,28,29,34,36,37,38,40,44,51,52].

The code shown above allowed the Arduino board to function. At the top part, lines one and two specified to download, along with the main code, the library files for the LCD and the gas sensors, and initialized the LCD; it told the LCD it has 16 bits of horizontal and two vertical spaces to display text. The next set of lines initialized the system to know which data slots of the Arduino board are used to connect with another device. The next line called out the function that initializes the gas sensors. Below it is the void setup; it initializes the attached modules of the Arduino and tells it which one is an input node and which components are used for output; it also activates those components. Moreover, it instructed the Arduino to run at the normal time as indicated by Serial.begin (9600).

The main block of the code under the void loop first initialized the Arduino to receive data from the MQ gas sensors. It then gives it three conditions and three ways to react when received data meets the specified condition. First, if the data from the MQ sensors is below those 200, then the green LED lights up, and the LCD displays a safety message along with the ppm values. Then, if the analog data is greater than or equal to 300 but less than 400, the yellow LED lights up, the buzzer beeps at a low frequency and at broken beeps, and the LCD displays a warning message and the ppm values. Finally, when the MQ gas sensors emit data equal to or above the analog data of 400, the red LED lights up, the buzzer activates in a high-frequency continuous beep, and the LCD displays an evacuation notice - with the ppm values. It also tells the Arduino to refresh every second for new data updates and to keep track of the time.

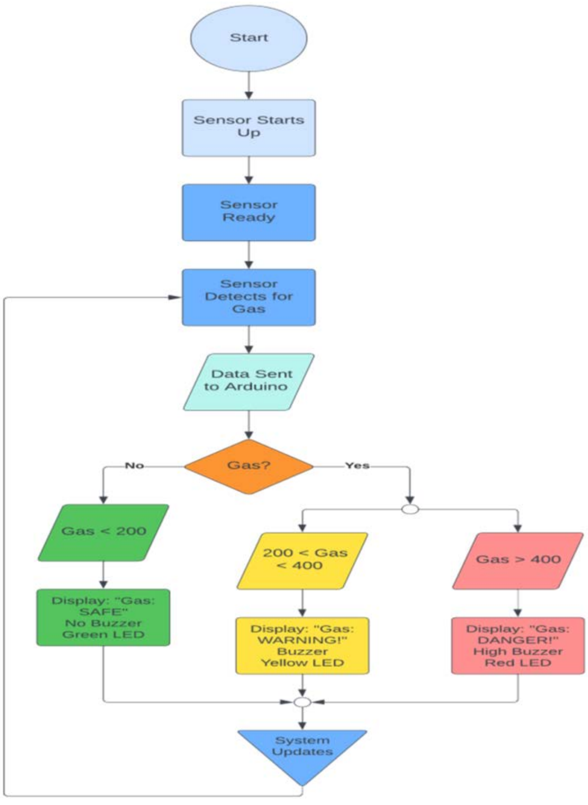

Figure 5. Flow Diagram of Gas Leak Sensor Process

2.2. Statistical Treatment of Data

The data collected from MQ-2 and MQ-6 equipped Arduino-based LPG leak sensors were analyzed using descriptive analysis, means, standard deviation, and Independent Samples Two-tailed T-tests, which will determine and compare the efficiency of both systems in detecting LPG.

2.3. Data Gathering Procedures

The study utilized the methods of [2,28,38,52], and the building regulations stated by [53] to develop and compare an Arduino-based LPG sensor using MQ-2 and MQ-6 gas sensors.

This study gathered a filled 11-kilogram Pryce Gas LPG tank for the test. There were a total of 5 replicates for each setup - for time interval and distance. The setups were then labeled as experiment MQ-2 and MQ-6. The 11-kilogram Pryce Gas LPG tank with the Lion LPG Regulator FB-727 was placed at the far end of the room, and the sensors were set up and prepared for the experiment.

The Arduino LPG leak sensors were placed in front of the gas exit hole of the LPG tank at a height of 47.5 cm off the ground, the same height as the LPG nozzle. This study was conducted during the course of 10 A.M. to 4 P.M. of one day to limit the differences in temperature (28.9 - 31.1°C), humidity (97-99%), and air pressure (29.7-29.9 in Hg). It also used only one room. Before the beginning of the test, a control experiment was conducted in which no LPG was released into the room while the systems were active. The control experiment covered a 0 to 100 cm distance with 20-centimeter increments. During the test proper, each setup was tested at a varying distance of 0, 20, 40, 60, 80, and 100 centimeters for the response time – which is determined via activation of either LED lights, LCD display, or buzzer warning – and returned ppm values of the two sensors via output from the LCD.

The test occurred in an enclosed room with a minimum dimension of 3.0 by 1.50 square meters with a ceiling height of 2.70 meters as dictated by Presidential Decree no. 1096 or the Revision to the National Building Code of the Philippines, with the actual dimension being 3 meters by 4.76 meters with a ceiling height of 2.78 meters. The room chosen had proper channels of ventilation, but it was closed off during the tests to limit uncontrolled variables; like wind; and potential hazards, like live wires, outlets, open flames, and smokers, from potentially interfering with the experiment results and causing fire and explosion hazards.

Data was then collected and monitored regarding the response time and the respective ppm values of the two prototypes in response to different distances from the source of LPG. The LPG tank was opened slightly to mimic a pipeline leak for 5 seconds when testing the sensors. The Arduino LPG leak sensors were activated, and ppm values were collected the moment the valve was turned on, then, 5, 10, and 15 seconds after the closing of the gas valve. The response time was collected with a stopwatch to find the delay interval after the LPG tank valve was opened. After closing the valve and conducting a trial, the Arduino LPG leak sensors were reset, and the room left opened in a controlled manner for 3-5 minutes to allow the safe dissipation of combustible gases and to reset the environment for the next set of tests. The process was then repeated until all data needed were recorded.

3. Results and Discussion

Table 1. Average Mean and Standard Deviation of the response time (seconds) of the MQ-2

MQ-2	Mean (in seconds)	SD
0 cm	1.126	±0.06
20 cm	0.570	±0.11
40 cm	0.948	±0.03
60 cm	1.340	±0.22
80 cm	1.488	±0.30
100 cm	1.294	±0.13

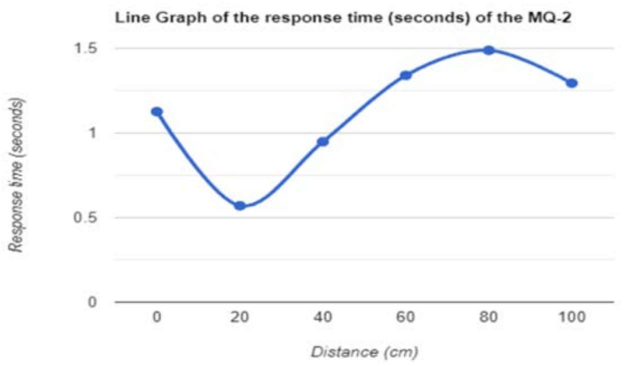

Figure 6. Line Graph Showing the Response time of the MQ-2

Table 1 presents the overall results of the Average Mean and Standard Deviation of the response time (seconds) of the MQ-2. The mean response times were 1.126 (SD = 0.06) for 0 cm, 0.57 (SD = 0.11) for 20 cm, 0.948 (SD = 0.3) for 40 cm, 1.34 (SD = 0.22) for 60 cm, 1.488 (SD = 0.30) for 80 cm, and 1.294 (SD = 0.13) for 100 cm of the MQ-2 gas sensor.

The table and graph show that the average response time of the MQ-2 sensor at 0 cm was 1 second in the beginning, then decreased to 0.5 seconds at 20 cm, and increased as the distance increased. However, at a distance of 100 cm, the response time decreased again.

Contrary to what was expected, the sensor did not react faster when the LPG gas was closer. The reason for this could be that the gas properly dissipated over a longer distance, allowing the sensor to detect it. The decrease in reading at 100 cm could be due to measurement error or remaining LPG gas residue from the previous test. Although the difference in response time between 0 cm and 20 cm was significant, the 0.194-millisecond difference at 100 cm was not considered important.

The research conducted by [28], confirms that there is a correlation between the response time of the MQ-2 sensor and the distance to the object being measured, with a slight increase observed as the distance increases. Additionally, another study highlights the impact of distance on response time in an air-tight room, similar to the one used in this experiment. The findings of their paper reveal that as the distance increases, there is a longer delay in response time. These results emphasized the importance of carefully considering the distance between the sensor and the object being measured to ensure accurate and dependable results [29].

Furthermore, reputable sources, confirms that LPG gas is stored at low temperatures and high pressures to maintain its liquid state within the tank. The boiling point of LPG is at a frigid -42°C, which necessitates its refrigeration to prevent vaporization. Once released from the tank, however, the liquid begins to vaporize as the temperature rises and pressure drops, naturally transitioning into a gaseous state. However, if the rate of vaporization exceeds the natural rate, the gas absorbs heat from the surrounding environment in an endothermic process to sustain the phase change [24,25,26]. Additionally, metal oxide semiconductor-type gas sensors, require heat and a heating element to function and detect gas. As LPG attempts to vaporize, it absorbs heat from the sensor's heating element, causing a slight delay in response time as the sensor requires additional time to heat up and properly detect and combust the LPG gas [16]. This concept is supported by [27], who found that LPG tanks' high flow rates made it more challenging for sensors to detect the gases at closer distances.

Table 2. Average Mean and Standard Deviation of the response time (seconds) of the MQ-6

MQ-6	Mean (in seconds)	SD
0 cm	0.942	±0.23
20 cm	1.012	±0.13
40 cm	1.33	±0.19
60 cm	1.298	±0.16
80 cm	1.134	±0.07
100 cm	1.31	±0.13

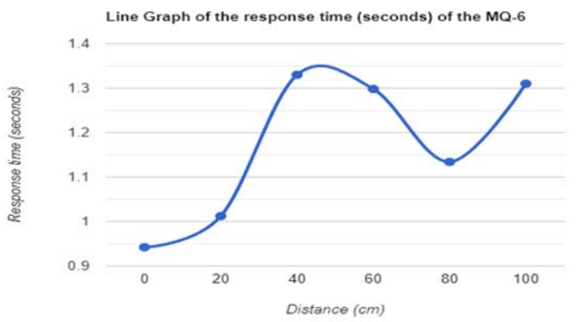

Figure 7. Line Graph Showing the Response time of the MQ-6

Table 2 presents the overall results of the Average Mean and Standard Deviation of the response time (seconds) of the MQ-6. The mean response times were 0.942 (SD = 0.23) for 0 cm, 1.012 (SD = 0.13) for 20 cm, 1.33 (SD = 0.19) for 40 cm, 1.298 (SD = 0.16) for 60 cm, 1.134 (SD = 0.07) for 80 cm, and 1.31 (SD = 0.13) for 100 cm of the MQ-6 gas sensor.

The table and graph show that the average response time of the MQ-6 sensor was steadily increasing as the distance increased from 0 to 40 cm. But after the 40 cm mark, the response time dropped very slightly. However, the response time increased again at a distance of 100 cm.

Table 1 and its graph show that the MQ-2 performs best at a distance of 20 cm, while in Table 2 and graph, the MQ-6 performs at its fastest when placed at 0 cm. This could be attributed to the MQ-6's higher sensitivity to LPG gases. However, the faster response times observed at the 60 and 80 cm marks may be considered anomalous, as gases are inherently unpredictable and energetic, with slight deviations having the potential to cause minor fluctuations in response times, yet the general trend still holds - distance increases response times.

The findings of [33], align with those presented in this paper. Their study examined the performance of the MQ-6 sensor within a range of 2-20 cm, with incremental increases of 2 cm. The outcomes revealed a progressive yet consistent rise in the response time of the leak sensor as the distance between the sensor and the source gradually increased.

In technical data sheets, the MQ-6 is more sensitive than the MQ-2 in detecting LPG gas, with a higher maximum ceiling value of 10000 ppm compared to 5000 ppm [30]. Recent studies by [31] [32], confirm this, showing that the MQ-2 has less sensitivity than the MQ-6. [32] found that the MQ-2 only provided high enough readings to trigger an alarm at a distance of 20 cm, and failed to do so at distances of 30-50 cm. [31] study demonstrated that the MQ-6 performed well at distances of up to 60 cm, but at 75 cm it only produced a dim light when detecting high enough LPG levels, and at 80 cm it failed to activate the gas sensor system. Therefore, it is clear that the MQ-6 is the more reliable and effective option for detecting LPG gas.

As indicated by the research of [38,39], the detection of gases is subject to numerous factors that can cause variations in data results. Even the configuration and operation of the sensor system can impact its performance, as [39] have pointed out. The positioning of the gas outlet in relation to the sensor, as well as temperature and concentration, can also affect sensitivity and reading values over time. These variables can produce results that are similar or dissimilar to those obtained by other researchers.

Table 3. Average Mean and Standard Deviation of the Returned ppm Values at Different Distance and Time Intervals After Closing of Gas Valve of the MQ-2

MQ-2	Mean (in ppm at 0 sec)	Mean (in ppm at 5 sec)	Mean (in ppm at 10 sec)	Mean (in ppm at 15 sec)
0 cm	618±47.27	89.6±12.38	37.6±3.21	26±3.32
20 cm	683.8±31.55	69.8±13.70	42.4±4.16	52.8±7.34
40 cm	584.8±91.12	36.4±5.03	28.6±4.34	35.6±5.28
60 cm	80.8±13.83	38.8±3.56	42.4±2.61	41±2.74
80 cm	58.6±6.69	35.6±1.14	34.4±3.51	39.2±4.32
100 cm	64.6±8.82	42±1.22	38±2.24	40.8±2.77

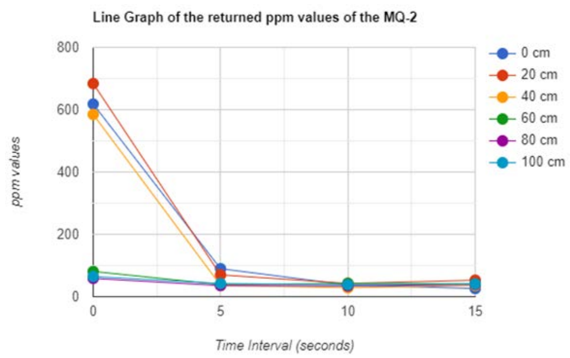

Figure 8. Line Graph Showing the ppm Values of the MQ-2 with Respects to Distance and Time Interval

Table 3 displays the outcomes for the average and standard deviation of the returned ppm values at different time intervals after shutting off the gas valve of the MQ-2. The mean values were highest at 0 cm distance intervals, with values of 618 (SD = 47.27), 89.6 (SD = 12.38), 37.6 (SD = 3.21), and 26 (SD = 3.32). The 0-cm mark was deemed the most important and was the only result discussed.

At the 0-second intervals of the 0, 20, and 40 cm marks the ppm were very high before decreasing rapidly upon the 60 cm mark that continued on with the rest of the distance intervals. The highest ppm value was taken at 0-second intervals in the 20-centimeter mark. At 5, 10, and 15-second intervals, the ppm values were significantly lower than in the 0-second intervals.

The table and graph above demonstrated a significant trend that highlights the impact of distance and time on the overall ppm values of the sensor. Once the gas valve is closed, the gases released tend to dissipate and mix with the surrounding atmosphere, leading to a reduction in the sensor's ppm values. Moreover, an increase in distance allows for greater dispersion of gas into the atmosphere, resulting in lower LPG gas detection at farther distances compared to closer distances to the LPG source.

A study on conducted for the MQ-2 gas sensor, showed a consistent decrease in ppm values as the sensor was placed farther from the source of LPG in a closed 4 by 4-meter room [35]. Their paper also suggested that the longer a gas leak occurs, the higher the resulting ppm values become, thus it stands to reason the opposite is also true - when the gas source is removed the ppm values become lower. [41,42] Both noted a similar trend of gradually decreasing ppm values as the sensors were placed further away. These studies support the idea that distance can impact the sensor's ability to detect LPG fumes. However, it is important to note that different testing circumstances can lead to varying results.

Table 4 displays the outcomes for the average and standard deviation of the returned ppm values at different time intervals after shutting off the gas valve of the MQ-6. The mean values were highest at 0 cm distance intervals, with values of 638.8 (SD = 41.92), 411.8 (SD = 31.42), 258.2 (SD = 21.11), and 211.4 (SD = 24.03). The 0-cm mark was deemed the most important and was the only result discussed.

Table 4. Average Mean and Standard Deviation of the Returned ppm Values at Different Distance and Time Intervals After Closing of Gas Valve of the MQ-6

MQ-6	Mean (in ppm at 0 sec)	Mean (in ppm at 5 sec)	Mean (in ppm at 10 sec)	Mean (in ppm at 15 sec)
0 cm	638.8 ±41.92	411.8 ±31.42	258.2 ±21.11	211.4 ±24.03
20 cm	899.2 ±8.26	428 ±7.07	470.8 ±30.87	495.4 ±28.75
40 cm	588.8 ±121.90	382.4 ±27.11	443.4 ±90.84	408.2 ±68.72
60 cm	496 ±18.64	384.6 ±23.39	353.6 ±23.24	346.8 ±11.88
80 cm	456.8 ±24.99	381.4 ±49.46	339.6 ±8.62	351.6 ±9.40
100 cm	481.8 ±6.10	378.4 ±13.74	352 ±15.52	329.4 ±15.98

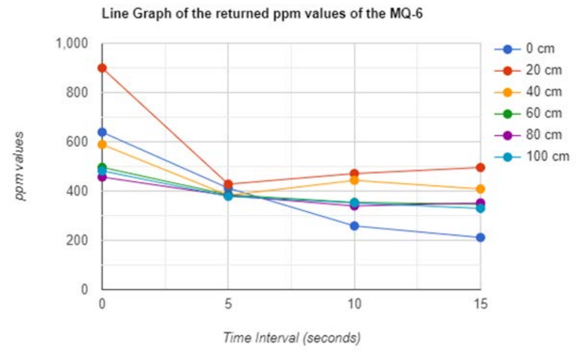

Figure 9. Line Graph Showing the ppm Values of the MQ-6 with Respects to Distance and Time Interval

At 0-second intervals, the ppm values of all distance intervals were above 400 (four hundred). However, the 20-centimeter mark took the highest value for returned ppm value, at 899.2. The ppm values at the 5-second intervals were closely similar, but the values either decreased or increased in the succeeding time intervals and distances.

It is noticeable that when compared to the previous table for the MQ-2, the values here are significantly higher even at the more extreme distances. In comparison to the returned ppm values of MQ-2 in Table 3, the returned ppm values of the above table and graph were significantly greater.

These findings are generally supported by [43] and all the other papers previously cited. The ppm values decrease with an increase in distance from the gas source. This finding has also been corroborated by the studies of [32,47], which both found that the ppm values decrease as the distance increases. The high returned ppm values of MQ-6 in the table were supported by the studies of [45,46].

Table 5. Independent Two-tailed T-Test for the Significant Difference of the response time (seconds) of the MQ-2 and MQ-6 (N=60)

Sensor	n	Mean	SD	t	df	P-value (2-tailed)	95% CI
MQ-2	30	1.128	± 0.337	-	-	-	1.008 - 1.252
MQ-6	30	1.171	± 0.210	-	-	-	1.095 - 1.245
Total	60	1.1493	± 0.28	- 0.5976	58	0.5592	-0.188 - 0.1017

Significant at 0.05 level

Table 5 presents the results of the independent two-tailed T-test for the significant difference of the response time (seconds) between the MQ-2 and MQ-6 at 0 to 100 centimeters. The population mean response time were 1.1277 (SD = 0.337, CI.95 = 1.008 - 1.252) for the MQ-2 gas sensor, 1.171 (SD = 0.2096, CI.95 = 1.095 - 1.245) for the MQ-6 gas sensor, and 1.1493 (SD = 0.28) for both sensors, $t(58) = -0.5976$, $p \geq 0.05$, CI.95 -0.188, 0.1017. Therefore, this paper accepted the null hypothesis that there was no significant difference between the response time of MQ-2 and MQ-6.

The data presented in Table 5 indicates that MQ-6 has a higher mean than MQ-2, but the very low mean difference between the MQ-2 and MQ-6 is otherwise insignificant to affect performance. There were also no significant differences in the response time as the MQ-2 and MQ-6 gas sensors used the exact same code to run their Arduino and tested under the same conditions and parameters. Minor differences observed could be attributed to minimal variations in gas molecule exit from the LPG tank, gas diffusion, electricity flow, and stopwatch accuracy. Thus, it is inaccurate to claim that one sensor is faster than the other in detecting LPG gas.

Upon careful examination of Tables 1, 2, 3, and 4, it has become evident that there exists a clear and direct association between gas concentration and response time. This signifies that as the level of gas concentration rises, the response time of the sensor will generally decrease. Furthermore, the sensor's efficacy is heavily reliant on the distance it is situated from the LPG tank.

The MQ-6 is vastly superior and boasts greater accuracy in gas detection as evidenced by the results by the research conducted by [45]. [45] Explains that the MQ-6 sensor is renowned for its exceptional sensitivity to gases and can identify them from distances of up to 30cm in as little as 0.16 seconds. Additionally, it exhibits a significant but limited sensitivity to alcohol and cigarette smoke. In comparison to the MQ-2 sensor, which has a shorter detection range of only 10 cm and a slower speed of 0.30 seconds. The research conducted by [50], demonstrated that the detection of gas levels was influenced by both proximity and concentration, with greater gas content being identified more rapidly. Subsequently, another study confirmed that the performance of MQ-6 gas sensors was impacted by differing environmental conditions [29].

Table 6. Independent Two-tailed T-Test for the Significant Difference of the returned ppm values of the MQ-2 and MQ-6 (N=240)

Sensor	n	Mean	SD	t	df	P-value (2-tailed)	95% CI
MQ-2	120	119.23	± 194.85	-	-	-	84.37 - 154.1
MQ-6	120	428.68	± 139.25	-	-	-	403.77 - 453.6
Total	240	273.96	± 29.02	- 14.1	238	<0.0001	-352.52 - -266.38

Significant at 0.05 level

Table 6 presents the results of the independent two-Tailed t-test for the significant difference of the returned ppm values between MQ-2 and MQ-6 at 0 to 100 centimeters. The population mean response time were 119.23 (SD = 194.85, CI.95 = 84.37 - 154.1) for the MQ-2 gas sensor, 428.68 (SD = 0.139.25, CI.95 = 403.77 - 453.6) for the MQ-6 gas sensor, and 273.96 (SD = 29.02) for both sensors, $t(238) = -14.1$, $p \leq 0.05$, CI.95 -352.52, -266.38. Therefore, this study rejected the null hypothesis that there was no significant difference between the response time of MQ-2 and MQ-6.

The significant difference was the result of the consistently higher values of the MQ-6 throughout the 0 to 100 cm test. It had high values during all the replicates during the 0, 5, 10, and 15-second intervals. Whereas, the MQ-2 always gets lower values in all the replicates of all time intervals and distances. The distance between the sensor and the LPG gas was also one of the factors affecting the significant difference in the mean values of ppm in both the MQ-2 and MQ-6.

From the previous Tables 3, and 4, the values of ppm for the MQ-2 vary greatly from MQ-6. The MQ-2 only manages to get high returned ppm values at every 0-second time interval of replicates and at the 0, 20, and 40 cm distances only. The rest of the returned ppm values were significantly lower than the MQ-6. The reason may lie in the detection scope of the gas sensors. The MQ-2 may also have taken too long to detect the LPG gas at distances of 5, 10, and 15 seconds because it needed a higher ppm concentration caused by its lesser sensitivity.

The concentration of LPG detected by the sensor decreases as the distance from the source increases, whereas closer proximity results in higher concentrations, as supported by research conducted by [42,48,49] have further demonstrated that the sensitivity of gas sensors can be improved by altering measurement conditions and system configurations, including reducing the distance from the sensor and changing the angle of the gas inlet.

The company manufacturer of the MQ-2 and MQ-6 gas sensor, has specified that MQ-2 and MQ-6 possess impressive detection capabilities. According to their product specifications, MQ-2 can detect LPG and propane with a concentration range of 300 ppm-5000 ppm, while MQ-6 can detect LPG, iso-butane, propane, and LNG with a concentration range of 200 ppm-10000 ppm. These impressive detection capabilities make MQ-2 and MQ-6 reliable and effective options for gas detection [30].

4. Conclusion

The obtained results from table one shows that the response of the MQ-2 gas sensor averages around 0.5 to 1.5 seconds throughout all distances of the test. While in the table two, it shows that the MQ-6 gas sensor averages around 0.9 to 1.33 seconds throughout all test distances. As shown in tables one and two, both gas sensors only took a few seconds to respond to the LPG gas for all distances, demonstrating their capabilities and sensitivities in responding to LPG gas.

The obtained results from table three shows that the ppm values of the MQ-2 gas sensor has a return ppm value range of 46.35 to 200.95 ppm throughout the test distances and time intervals. While in the table four, it shows that the MQ-6 has a return ppm value range of 382.35 to 573.35 ppm throughout the test distances and time intervals. With these values in mind, the results indicates that both gas sensors are sensitive and capable in detecting LPG and providing ppm values. However, the MQ-2 gas sensor consistently has a way lower mean average than MQ-6 gas sensor, which indicates that the MQ-2 is less sensitive in detecting the ppm of LPG gas. It can be deduced that the MQ-2 gas leak sensor is, therefore, less likely to trigger its alarm at distances longer than 40 cm, whereas the MQ-6 gas leak sensor is more sensitive and can still trigger the alarm even at distances of 100 cm. Therefore, in terms of ppm values, the MQ-2 gas sensor is less sensitive than the MQ-6 gas leak sensor. Additionally, in terms of detection capability, the MQ-6 is superior compared to the results of the MQ-2.

The results of p-value for response time was 0.5592. Since the p-value is greater than 0.05 this indicates that there was no significant difference between the response time of MQ-2 and MQ-6 gas sensor. They only had very inconsequential variations; their response times could be considered equal in all aspects. Therefore, it is safe to assume that regarding response time, the MQ-2 and MQ-6 are equal. However, the results from ppm value shows a p-value of 0.0001. Since the p-value is not greater than 0.05 this indicates that there is a significant difference between the ppm values of MQ-2 and MQ-6 gas sensor. Thus, it can be concluded that the MQ-6 is more sensitive at detecting LPG than the MQ-2 gas sensor.

Furthermore, based on all the data from all tables, it shows that the recommended distance for the placement of both sensors is 20-40 cm, which can detect a higher amount of gasses from the source of the LPG gas. The distance of 20-40 cm is also the most efficient in terms of response time which yielded the fastest results for the two Arduino-based LPG leak sensor systems. Regarding the results of this study, this paper recommends to further expand the knowledge for an Arduino Microcontroller as an LPG leak sensor through adding other modules primarily GSM modules for SMS messaging and a pneumatic valve switch to automatically shut of the LPG tank.

Acknowledgments

This paper would specifically like to acknowledge and express our immense gratitude for the financial support provided by Ms. Joje Mary Rodriguez, your aid was very crucial in making this publication a reality. Additionally, this paper would want to give its gratitude to our professors and teachers, namely, Ian Jay P. Saldo, Jhovel Roy Dael Calo, Mary Jade Peñafiel-Dandoy, Rolando Y. Casas, Rorei Marielle V. Asiñero, Vanie Y. Benben, Ace B. Cardeño, and Sherwin D. Camporedondo for the invaluable insights, suggestions, and guidance throughout the creation of this research. The same gratitude is also expressed to the Integrated Basic Education Department of San Isidro College for allowing the conduct of this work and for all the assistance provided for this research. Additionally, this paper would like to acknowledge all individuals, parties, and organizations that have contributed to this research, big and small. The help and support made this research possible.

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