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# GRAPHICAL METHOD FOR DETERMINATION OF MQ-SERIES GAS SENSOR CIRCUIT PARAMETERS FOR A STANDALONE GAS ALARM SYSTEM

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## ABSTRACT

MQ-series gas sensors belong to the metal oxide semiconductor (MOS) family of sensors that can sense the presence of many gases. These sensors find their application in gas alarm systems as key components. While necessary sensor circuit output voltage value for alarm point in a standalone gas alarm system is desirable, but what exact combination of the sensor circuit parameters is required? Hitherto, the determination of these circuit parameters has not been much attention in the research community. This study explores a structured graphical approach of determining MQ series gas sensor circuit parameters for a standalone gas alarm system that yields the desired sensor circuit output voltage value for the alarm point. Model equations were developed for the sensor dynamics, and based on these model equations, graphs for the determination of required sensor parameters were plotted for a case of MQ-4 gas sensor response to liquefied petroleum gas (LPG). A structured graphical approach for determining MQ-series gas sensor circuit parameters for alarm points in a standalone gas alarm system showed that using MQ-4 gas sensor and LPG as the target gas. For a sensor circuit output voltage of 2 V for alarm point at 1000 ppm of LPG, the corresponding value of $R_O$, $R_S$, and $R_L$ obtained were 20 kΩ, 30 kΩ, and 20 kΩ, respectively. Hence, the developed structured graphical approach is suitable for determining MQ series gas sensor circuit parameters for a standalone gas alarm system under the influence of its associated gases.

**Keywords**: *alarm point, base gas, calibration-concentration, gas concentration, gas sensor resistance*

## 1. INTRODUCTION

MQ-series gas sensors belong to the family of metal oxide semiconductor (MOS) gas sensors that can detect the presence of some volatile, oxidizable, or reducible gases in an oxygenated environment (Gómez, Pelegri-Sebastia and Lajara, 2020). MQ-series gas sensors are commonly used for gases detection owned to their high sensitivity, stability, and long-life characteristics in this regard (Örnek and Karlik, 2012). Furthermore, when connected as one of the basic components in the sensor circuit, a certain voltage that depends on the type and concentration of the gas can be measured at the circuit output (Nayyar, Puri, and Le, 2016; Ponzoni *et al*., 2017).

The MQ-series gas sensors form the major component in many gas alarm systems due to their cost and sensitivity advantages. Developed by (Ahmed *et al*., 2018) is a microcontroller-based gas alarm system that triggers a buzzer and LED indicator when the alarm set point for the MQ-9 gas sensor was 37,000 ppm of Methane gas. Designed by (Kumar and Kumari, 2019) is an Arduino-based system with MQ2, MQ4, and MQ135 gas sensors capable of monitoring the concentration of gases and giving an alarm when the concentration of the various types of gases in the atmosphere is above the threshold value. Also developed by (Ibrahim, 2018) is a microcontroller-based carbon monoxide and carbon dioxide detector using MQ-7 and MQ-135 for carbon monoxide and air quality sensing, respectively. The gas concentration was displayed in ppm on LCD. The alarm is triggered when the threshold for the safe gas concentration is reached. However, determining the sensor circuit parameters to achieve the required sensor circuit output voltage for a given alarm point has not been well researched. Therefore, this study presents a structured graphical method for determining the sensor circuit parameter that yielded the needed sensor circuit output voltage for the alarm point.

To achieve the aim of this study, the


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mathematical model equations that relate the: (i) sensor resistance ($R_S$) with the gas concentration ($x$) and the sensor resistance at standard calibration concentration of the sensor base gas in the clean air ($R_O$) and (ii) sensor circuit output voltage ($V_{RL}$), load resistance ($R_L$) and sensor resistance ($R_S$) were developed. The graphs that relate the parameters together were plotted based on these model equations.

Using these graphs for a particular case of an MQ-4 gas sensor under the influence of LPG, the parameters that yielded the desired sensor circuit output voltage of 2V for 1000 ppm of LPG alarm point were determined.

## 2. MATERIALS AND METHODS

The model Equations 1 and 2 were derived (Ajiboye *et al*., 2021a, b, c) to establish the relationship among the:

i. $R_S$, $x$ and $R_O$
ii. $V_{RL}$, $R_L$ and $R_S$

$$R_S = 10^{\wedge(mlog_{10}x+log_{10}c+log_{10}R_O)} \quad \text{(Eq.1)}$$

$$V_{RL} = \frac{R_L V_{CC}}{(10^{(mlog_{10}x+log_{10}c+log_{10}R_O)}+R_L)} \quad \text{(Eq. 2)}$$

These equations were used to plot the graphs to determine the circuit parameters value for a particular case of an MQ-4 gas sensor under the influence of LPG.

### 2.1. Determination of Ro

To determine $R_O$, the mesh plot of Figure 1 was carried out using Equation 1.

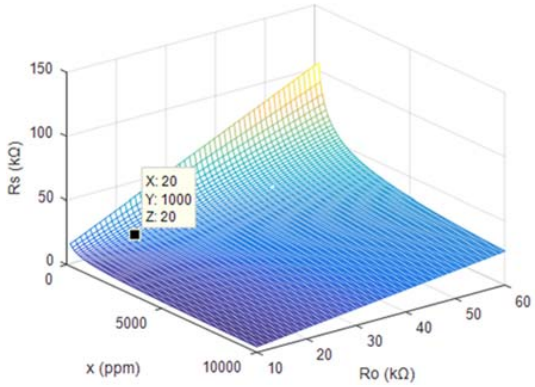



***Figure 1.*** *Mesh plot of $R_S$ versus $x$ and $R_O$ for MQ-4 gas sensor in the $CH_4$*

The value of $R_O$ was determined at 1000 ppm of $CH_4$, since $R_S$ = $R_O$ at this concentration and the value of $R_S$ under this condition is always given in the sensor data sheet (Ajiboye *et al*., 2021a)

### 2.2. Determination of Rs in the gas under investigation

To determine $R_S$ for the sensor in LPG, the mesh of Figure 2 was plotted using Equation 1.

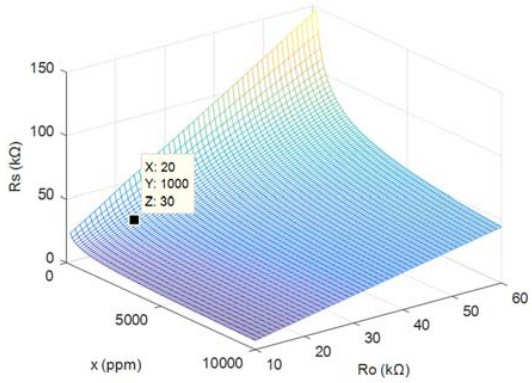



***Figure 2.*** *Mesh plot of $R_S$ versus $x$ and $R_o$ for MQ-4 gas sensor in LPG*

Using Figure 2, the value of $R_S$ can be determined for the given versus of x and $R_o$.

### 2.3. Determination of the sensor circuit R_L for alarm point determination of Ro

To determine the sensor circuit load resistance, $R_L$ for alarm point, the mesh plot of Figure 3 was plotted using Equation (2).

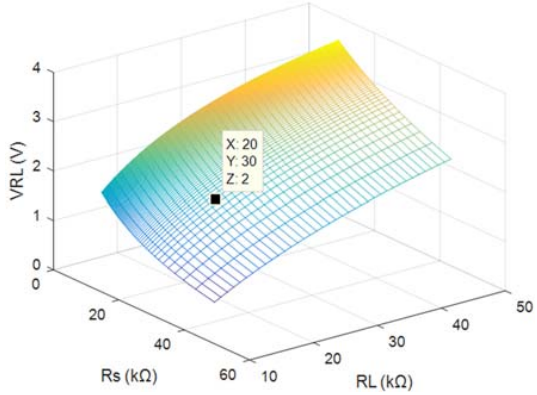



***Figure 3.*** *Mesh plot of $V_{RL}$ versus $R_S$ and $R_L$ for MQ-4 gas sensor in LPG*

Using Figure 3, the value of $R_L$ can be determined for known values of $V_{RL}$and $R_S$.

### 2.4. Experimental setup

The system was calibrated using simulation and emulation data. Simulation and emulation were achieved using Equation 3 and the experimental setup of Figure 4, respectively (Ajiboye *et al*., 2021b, c).

$$x = 10^{\left(\frac{log_{10}\left(\frac{R_L V_{CC}}{V_{RL}} - R_L\right) - log_{10} c - log_{10} R_O}{m}\right)} \quad \text{(Eq. 3)}$$

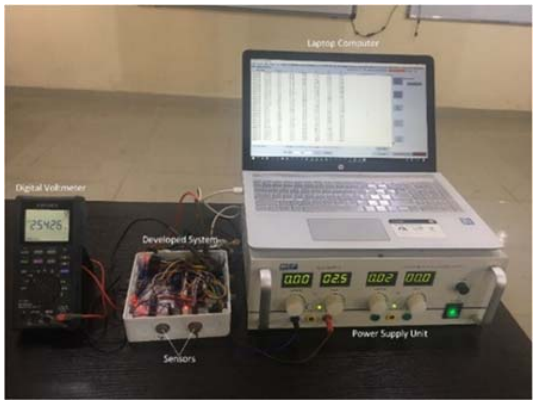



***Figure 4.*** *System emulation experimental setup* (Ajiboye *et al*., 2021b, c)

The experimental emulation setup of Figure 4 consists:

i. a digital multi-meter for monitoring the sensor circuit emulated voltage,

ii. the developed system,

iii. variable dc power supply unit for supplying of the sensor circuit emulated voltage and

iv. a laptop PC to monitor and store system output (emulated concentration).

To mimic the sensor circuit output voltage, the power supply was connected to the input pin of the microcontroller. Then the voltage from the power supply was varied within 1.545 V and 3.455 V. This is because the expected minimum and maximum sensor circuit output voltage range when LPG concentration was in the range of 200 to 10000 ppm is between 1.545 and 3.455 V. The system output (emulated LPG concentration level) was logged into the laptop PC. Finally, the simulated data were plotted against emulated data to obtain the system calibration graph.

## 3. RESULTS AND DISCUSSION:

From Figure 1, $\mathrm{R_O}$ and $\mathrm{R_S}$ was $20\ k\Omega$ each at calibration concentration of 1000 ppm for $\mathrm{CH_4}$ in clean air (Ajiboye *et al*., 2021a). When $\mathrm{R_O} = 20\ k\Omega$ with the sensor in 1000 ppm of LPG the corresponding value of $\mathrm{R_S}$ is $30\ k\Omega$ as can be seen in Figure 2. As revealed in Figure 3, for a required sensor circuit output voltage value of 2 V at an alarm point of 1000 ppm for LPG, the corresponding value of $\mathrm{R_L}$ is $20\ k\Omega$.

The system calibration graph of Figure 5 was obtained by plotting the simulated against emulated LPG concentration data.

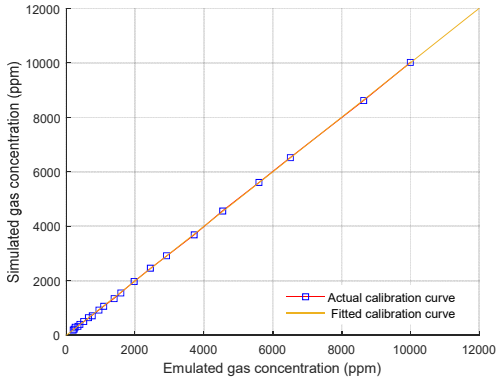



**Figure 5.** system calibration curve

Since the plot yielded a straight-line graph, the data were fitted linearly. The resulting system calibration equation is shown in Equation 4.

$$y = x + 8.6 \quad \text{(Eq. 4)}$$

where $y$ and $x$ are the predicted and emulated LPG concentration in ppm, respectively

## 4. CONCLUSIONS:

A structured graphical method was developed for determining MQ-series gas sensor circuit parameters for alarm points. The method was demonstrated using an MQ-4 gas sensor and LPG as the target gas. The developed method is concise, straightforward forward, and time-saving. The method is less prone to analytical errors since all that is required is the proper visual reading of the parameter value from the graph. For a particular case of expected sensor circuit output voltage of 2 V for alarm point at 1000 ppm of LPG, the corresponding value of $\mathrm{R_O}$ ,$\mathrm{R_S}$ and $\mathrm{R_L}$ obtained were $20\ k\Omega$, $30\ k\Omega$, and $20\ k\Omega$ respectively. Using simulation and emulation LPG concentration data, an Arduino-based standalone gas-alarm system was developed and calibrated.

The method can be applied to any type of MQ-series gas sensor under the influence of its associated gases.

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