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Design of a Carbon Monoxide Gas Measurement Tool Using Microcontroller-Based MQ-7 Gas Sensor in Households

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ABSTRACT

The increasing presence of carbon monoxide in residential environments poses a serious health risk due to its colorless, odorless, and tasteless nature. This study aims to develop and evaluate a carbon monoxide detection system using the MQ-7 sensor integrated with an Arduino microcontroller. The research employs an experimental design approach with a sequential development model, including system analysis, design, coding, and testing phases. The system is designed to detect carbon monoxide levels and provide early warnings using visual and auditory indicators. Testing results indicate that the system successfully detects varying concentrations of carbon monoxide with satisfactory accuracy and provides timely alerts. This study contributes significantly to household safety by offering a simple, effective, and affordable solution for carbon monoxide detection, thereby enhancing preventive measures against potential carbon monoxide exposure.
***Keywords**: Carbon Monoxide, MQ-7 Sensor, Arduino Microcontroller, Home Security.*

INTRODUCTION

Carbon monoxide (CO) is a toxic gas formed from the combustion of fossil fuels, such as wood, gas, and oil (Zlotnik & Chetverushkin, 2023). Carbon monoxide can be found in residential buildings, particularly from heaters, stoves, or combustion engines, posing serious health risks to humans. Because CO is colorless, odorless, and tasteless, it is difficult to detect without specialized equipment (Rizaldy & Witanto, 2016). High levels of CO exposure can cause fatal poisoning if not addressed promptly. Therefore, it is crucial to have a detection system that can provide early warnings of dangerous CO levels in the home.

Currently, although carbon monoxide detectors are available on the market, many are quite expensive and their complexity does not suit ordinary household needs. Therefore, a simpler, more effective, and affordable CO detection device for the general public is needed. In this regard, the use of MQ-7 gas sensor technology combined with a microcontroller can be an ideal solution for households. The MQ-7 sensor is well-known for its high sensitivity to carbon monoxide and can be integrated with a microcontroller to produce easily readable and processable output (Rosa et al., 2020).

This study makes a significant contribution to household safety, particularly concerning the risk of carbon monoxide exposure that often goes undetected in residential environments. The article presents an innovation in the form of an effective, simple, and affordable CO detection device, utilizing the MQ-7 gas sensor integrated with a microcontroller. This device is designed to provide early warnings to families so that they can take preventive action before CO levels reach dangerous thresholds. The novelty of this research lies in the development and testing of a CO detection device based on technology that can be easily and efficiently implemented in households.

This study aims to fill the gap in previous research that may not have offered affordable and easy-to-use solutions for CO detection in households. The authors build upon previous research emphasizing the importance of early CO detection, while also addressing and enhancing it by introducing a more practical and affordable solution for the general public. Thus, this research not only seeks to increase awareness of CO exposure risks but also to improve household safety through technology that can be accessed by a broader audience.

METHOD

Type of Research

This research is a quantitative study with an experimental approach. It aims to develop and evaluate a carbon monoxide detection system using the MQ-7 sensor integrated with an Arduino Uno.

Research Design

This study employs an experimental design to test the performance of the MQ-7 gas sensor system in detecting CO concentrations. The system development method used is the Waterfall model, which includes sequential phases in application development.

Research Approach

The research approach used is quantitative with an experimental method. Control variables are managed to analyze the outputs generated by the gas detection system.

Waterfall Model

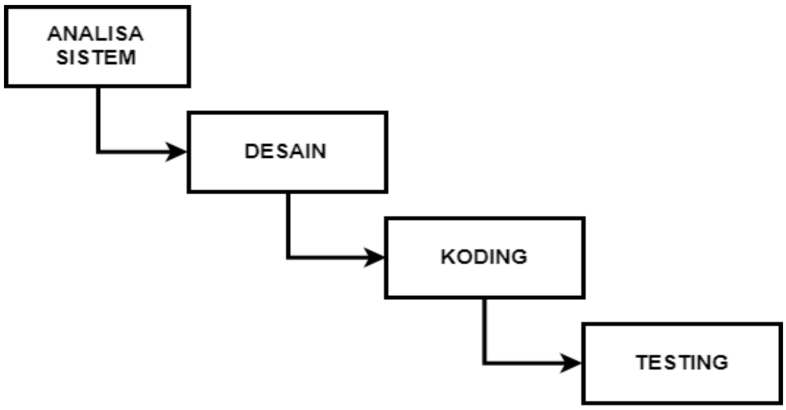

Figure 1. Waterfall Model

The Waterfall model is used as a sequential system development approach, consisting of the following phases:

1. **System Analysis Phase**
   - Objective
     To analyze system requirements through literature review and observation of existing systems.
   - Activities
     Identifying and documenting system needs, including required hardware and software components.
2. **Design Phase**
   - System Design
     Designing the system with a hardware model that includes the Arduino microcontroller and other supporting components (MQ-7 sensor, LED, buzzer, LCD Display).

Table 1. Component Connections

Arduino	Komponen
Pin 8	Green LED to GND
Pin 9	Yellow LED to GND
Pin 10	Red LED to GND
Pin 11	Positive Buzzer, Negative to GND
Pin A1	MQ-7 Gas Sensor
A4 (SDA)	SDA LCD I2C
A5 (SCL)	SCL LCD I2C
5V	VCC all components
GND	GND all components

- Circuit Diagram

  The circuit diagram (Figure 2) illustrates how the various components of the CO measurement device are connected. It includes the Arduino Uno microcontroller, MQ-7 gas sensor, LED indicators, buzzer, and LCD display. Each component is connected to the Arduino board through specific pins, ensuring proper signal flow and power distribution.

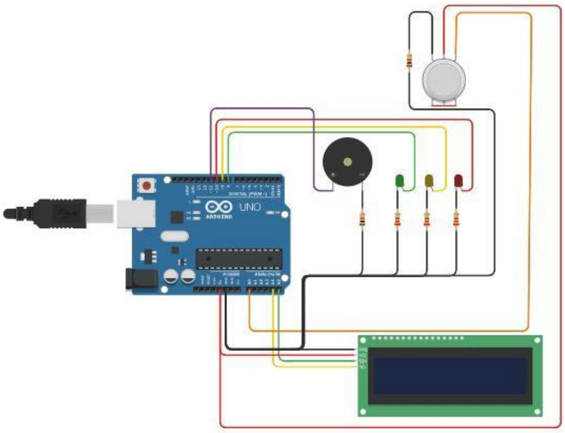

Figure 2. Circuit Diagram

- System Block Diagram

  The system block diagram (Figure 3) provides a high-level overview of the system's architecture. It shows the main components and their interactions.

  The MQ-7 gas sensor detects carbon monoxide (CO) levels and sends the analog signal to the Arduino Uno. The Arduino Uno processes this sensor data, performs necessary calculations, and controls the output devices. The LCD display shows the CO concentration readings to the user, while the LED indicators provide visual alerts based on the CO concentration levels. Additionally, the buzzer emits an audible alarm when CO levels exceed a predefined threshold.

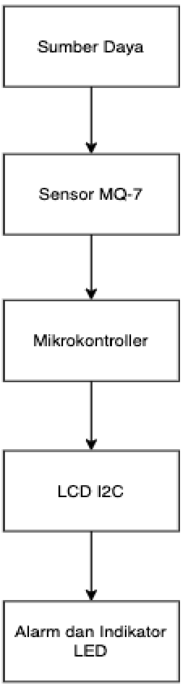

Figure 3. System Block Diagram

3. Coding Phase

- Program Development

  Writing code using the C programming language and Arduino IDE software.

- Implementation
  The implementation phase integrates the developed code with the hardware system. This involves connecting the MQ-7 sensor, LEDs, buzzer, and LCD display to the Arduino Uno as outlined in the hardware design. The code ensures that data from the sensor is read accurately and processed in real-time. The system flowchart, shown in Figure 4, illustrates the step-by-step process that the system follows:

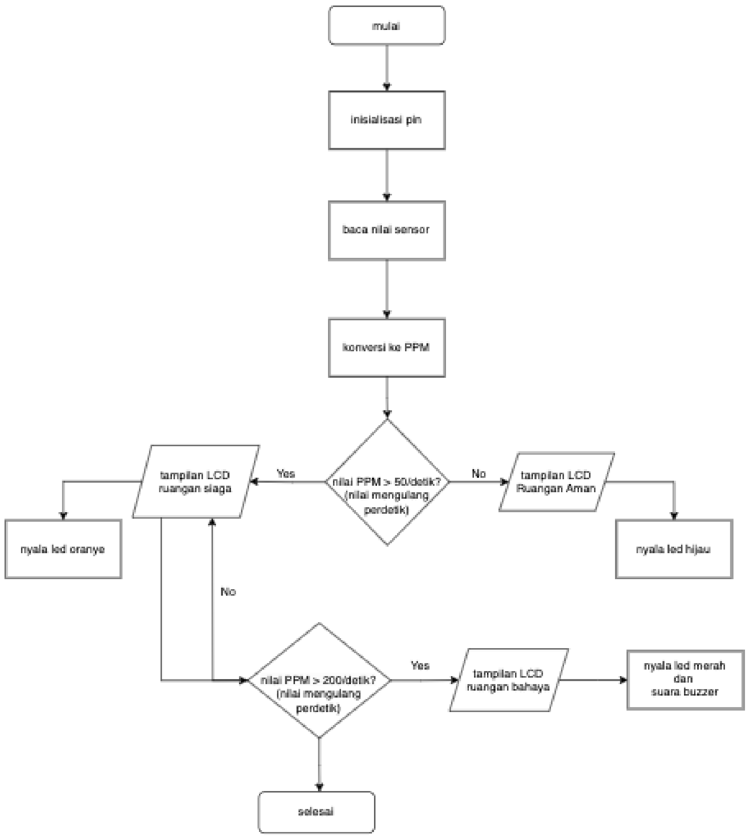

Figure 4. System Flowchart

Integrating the code with the hardware system to read sensor data, process data, and control outputs (LED, buzzer, LCD).

4. Testing Phase

- Testing
  Testing the system's functionality to ensure all components operate as planned.
- Evaluation
  We are measuring the accuracy of CO detection and the system's response to different CO concentrations.

Research Subjects

The research subjects are the carbon monoxide detection system involving the MQ-7 sensor, Arduino Uno microcontroller, and additional components such as LEDs, buzzers, and LCD Display.
Implementation Procedures

1. System Design:
   - Designing and assembling the carbon monoxide detection system.
   - Creating connection schematics and developing the code.
2. Sensor Calibration:
   - Calibrating the MQ-7 sensor to ensure accurate readings.
   - Using data from a reference instrument to establish the conversion equation from ADC to PPM.
3. System Testing:

- Testing the system with various CO concentrations.
- Checking the system's performance in providing appropriate warnings.

Tools, Materials, and Instruments Used

1. Tools:
   - Arduino Uno microcontroller
   - MQ-7 Gas Sensor
   - LCD Display with I2C Module
   - Buzzer
   - LEDs (Green, Yellow, Red)
   - Computer with Arduino IDE
2. Materials:
   - Connection Cables
   - Standard CO Gas Source (e.g., gas matches)
3. Instruments:
   - Air Quality Detector as a reference instrument

Data Collection and Analysis Techniques

1. Data Collection:
   Collecting data from sensor readings in ADC units and CO concentration measured with the reference instrument.
2. Data Analysis:
   Performing linear regression analysis to convert ADC data to PPM. Using the conversion formula to ensure reading accuracy, namely: PPM = (m × ADC value) + c.

RESULT AND DISCUSSION

This section describes the design of a carbon monoxide measurement device using an MQ-7 sensor based on a microcontroller. The MQ-7 sensor, which is sensitive to CO gas, is integrated with a microcontroller to process data and control the display and alert system. The MQ-7 sensor is connected to the microcontroller through electronic circuitry. The Arduino Uno is programmed in C to read the sensor values, convert them into voltage, and display them on an LCD and serial monitor. The program for the MQ-7 CO sensor is shown in Figure 5.

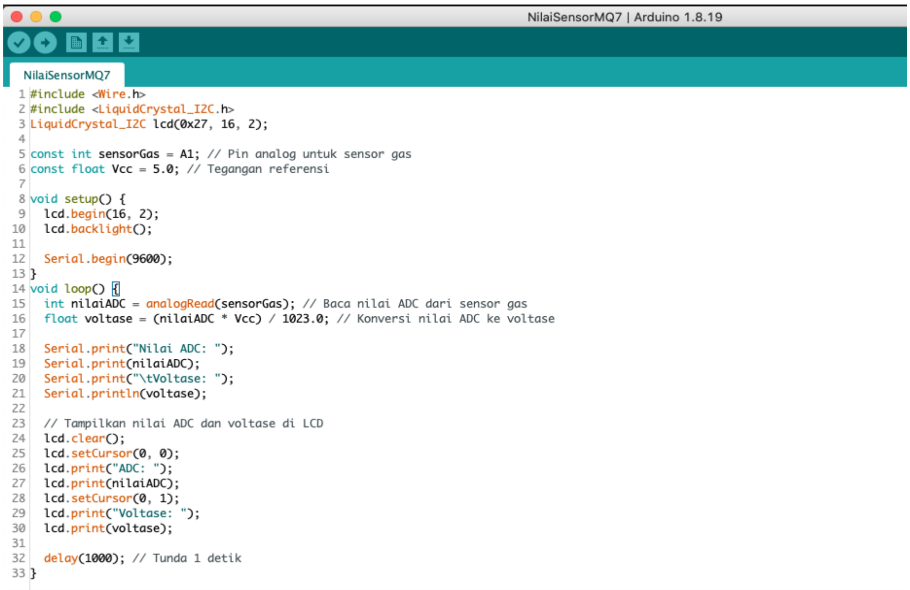

Figure 5. Program for the MQ-7 CO Sensor

The MQ-7 CO sensor has high sensitivity to carbon monoxide (Maharani & Kholis, 2020). However, before conducting direct tests in the kitchen, the MQ-7 sensor was calibrated using gas matches or benzene in the living room to verify the functionality of the sensor program. The concentration measurement results with gas matches or benzene using the Arduino gas sensor are shown in Figures 6 and 7.

Figure 6. Sensor Gas Values on LCD

Figure 7. CO Sensor Values on Serial Monitor

The concentration measurement results with gas matches or benzene are shown in Table 2. Below are the steps taken to test whether the sensor program functions properly.

Table 2. Measurement Results with CO Gas

No	Sensor CO MQ-7 Reading (ADC)	Voltage (Volt)
1	165	0.81
2	220	1.08
3	310	1.52
4	451	2.20
5	506	2.47
6	534	2.61
7	546	2.67

The MQ-7 sensor was calibrated with a CO gas measurement tool to determine its accuracy in detecting CO gas. As shown in Figure 8.

Figure 8. Air Quality Detector

Table 3 below shows the calibration results of the MQ-7 CO sensor with the Air Quality Detector shown in Figure 8.

Table 3. Calibration Results of CO Sensor with Air Quality Detector

No	MQ-7 Sensor CO Value (ADC)	CO Value on Air Quality Detector (PPM)
1	136	129
2	215	173
3	289	227
4	347	285
5	396	337
6	457	382
7	460	422

The MQ-7 sensor readings for detecting CO gas are still in ADC format, as shown in Table 3. Therefore, a conversion formula is needed to change the data from ADC to CO gas percentage. To obtain the conversion formula, ADC data was entered into Microsoft Excel. The slope and intercept formulas were then applied. To convert the ADC values from the MQ-7 sensor to PPM (Parts Per Million), the linear regression equation $y = 0.8761x - 8.5762$ obtained from the data in the table above was used. The calibration results show a slope of 0.8761 and an intercept of -8.5762 in the linear regression equation.

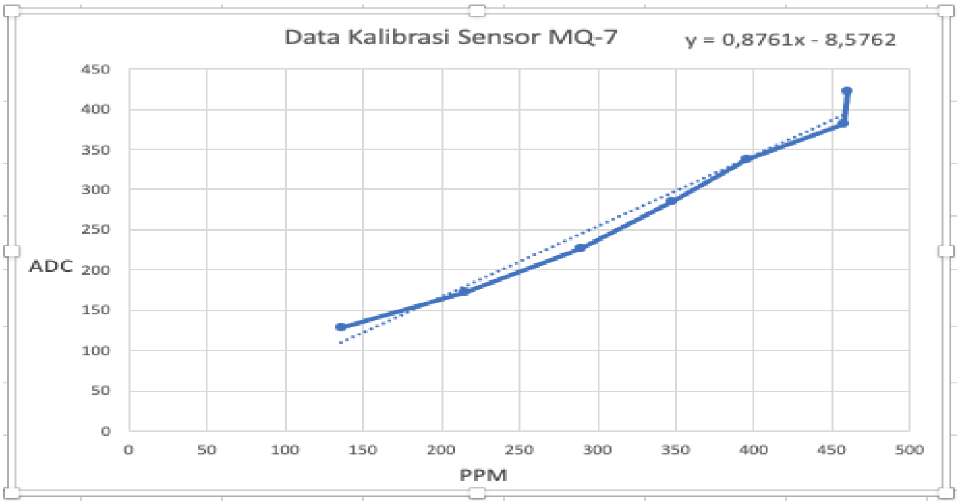

Figure 9. MQ-7 Sensor Calibration Results in Microsoft Excel

The data was then converted to parts per million (PPM) using the linear regression formula y = mx + c. In this case, the calculation is PPM = (0.8761 × ADC) - 8.5762. The results obtained after converting to PPM for the MQ-7 CO sensor values (ADC) are shown in Table 4.

Table 4. Conversion Results of CO Sensor Values to PPM

No	CO Value on Air Quality Detector (PPM)	MQ-7 Sensor CO Value (PPM)
1	129	111
2	173	180
3	227	245
4	285	295
5	337	338
6	382	392
7	422	394

For the results in Table 4, the calculations are as follows:

1. For ADC Value 136:
   PPM = (0.8761 × 136) − 8.5762
   PPM = 119.1496 − 8.5762
   PPM = 110.5734
2. For ADC Value 215:
   PPM = (0.8761 × 215) − 8.5762
   PPM = 188.3615 − 8.5762
   PPM = 179.7853
3. For ADC Value 289:
   PPM = (0.8761 × 289) − 8.5762
   PPM = 253.1929 − 8.5762
   PPM = 244.6167
4. For ADC Value 347:
   PPM = (0.8761 × 347) − 8.5762
   PPM = 304.0067 − 8.5762
   PPM = 295.4305
5. For ADC Value 396:
   PPM = (0.8761 × 396) − 8.5762
   PPM = 346.9356 − 8.5762
   PPM = 338.3594
6. For ADC Value 457:
   PPM = (0.8761 × 457) − 8.5762
   PPM = 400.3777 − 8.5762
   PPM = 391.8015
7. For ADC Value 460:
   PPM = (0.8761 × 460) − 8.5762
   PPM = 403.006 − 8.5762
   PPM = 394.4298

Testing Results

The performance of the MQ-7 gas sensor based on the microcontroller was tested at various locations in the house, including the living room, bedroom, and kitchen, to evaluate its performance and accuracy in detecting CO concentrations.

a. Testing in the Living Room

The testing was conducted to compare the carbon monoxide (CO) concentration values detected by the MQ-7 sensor with those from the Air Quality Detector. The tests were performed at three different times: morning, afternoon, and evening.

Table 5. CO Measurement Results for MQ-7 Sensor in the Living Room

Times	Testing		Error
	Air Quality Detector CO Value (PPM)	MQ-7 Sensor CO Value (PPM)	
Morning	0	0	0
	1	1	0
	2	1	1
Afternoon	0	0	0
	1	1	0
	2	1	1
Evening	0	0	0
	1	1	0
	2	3	1

From the testing results in the living room, as shown in the table above, the average absolute margin of error for the MQ-7 sensor was 0.33 PPM in the morning, afternoon, and evening. This margin of error is calculated as the absolute difference between the MQ-7 sensor measurement and the comparison tool measurement, expressed in the same units (PPM). The small margin of error indicates that the MQ-7 sensor provides fairly accurate readings.

b. Testing in the Bedroom

The testing was conducted to compare the carbon monoxide (CO) concentration values detected by the MQ-7 sensor with those from the Air Quality Detector. Similar to the testing in the living room, the tests in the bedroom were also performed at three different times: morning, afternoon, and evening.

Table 6. CO Measurement Results for MQ-7 Sensor in the Bedroom

Times	Testing		Error
	Air Quality Detector CO Value (PPM)	MQ-7 Sensor CO Value (PPM)	
Morning	0	0	0
	1	1	0
	2	1	1
Afternoon	0	0	0
	1	1	0
	1	1	0
Evening	0	0	0
	1	1	0
	2	2	0

From the testing results in the bedroom, as shown in the table above, the average absolute margin of error for the MQ-7 sensor was 0.33 PPM in the morning, and the margin of error was 0 PPM in the afternoon and evening. This margin of error is calculated as the absolute difference between the MQ-7 sensor measurement and the comparison tool measurement, expressed in the same units (PPM). The small margin of error indicates that the MQ-7 sensor provides fairly accurate readings in the bedroom.

c. Testing in the Kitchen

The testing compared the carbon monoxide (CO) concentration values detected by the MQ-7 sensor with those from the Air Quality Detector in the kitchen. Given that the kitchen is an area with a higher potential for CO emissions, the tests were performed at three different times: morning, afternoon, and evening.

Table 7. CO Measurement Results for MQ-7 Sensor in the Kitchen

Times	Conditions In The Test								
	Before Cooking			While Cooking			After Cooking		
	Air Quality Detector CO Value (PPM)	MQ-7 Sensor CO Value (PPM)	Error	Air Quality Detector CO Value (PPM)	MQ-7 Sensor CO Value (PPM)	Error	Air Quality Detector CO Value (PPM)	MQ-7 Sensor CO Value (PPM)	Error
Morning	0	0	0	124	160	36	1	1	0
	2	1	1	196	223	27	2	2	0
	3	1	2	284	304	20	4	2	2
Afternoon	0	0	0	140	163	23	1	0	1
	1	1	0	224	232	8	2	1	1
	3	2	1	294	311	17	2	1	1
Evening	1	0	1	135	145	10	1	0	1
	2	1	1	202	225	23	2	1	1
	3	1	2	301	311	10	3	1	2

The table above shows the measurement results of the MQ-7 sensor compared with the CO values detected by the Air Quality Detector at morning, afternoon, and evening times in the kitchen. The testing was conducted under conditions before, during, and after cooking using a gas stove (LPG). Below are the average absolute margin of error values for CO on the MQ-7 sensor based on the test results in the kitchen, derived from the data in the table above:

Table 8. Average Absolute Margin of Error for MQ-7 Sensor Based on Kitchen Testing Results

Times	Condition In The Test	Average Absolute Margin of Error (PPM)
Morning	Before Cooking	1
	While Cooking	27,67
	After Cooking	0,67
Afternoon	Before Cooking	0,33
	While Cooking	16
	After Cooking	1
Evening	Before Cooking	1,33
	While Cooking	14,33
	After Cooking	1,33

The margin of error is calculated as the absolute difference between the MQ-7 sensor measurement and the comparison tool measurement in PPM. A small margin of error indicates that the MQ-7 sensor provides fairly accurate readings in the kitchen, despite occasional fluctuations. Testing in the morning, afternoon, and evening before cooking showed alignment between the two devices with no detectable CO sources. During cooking, the margin of error increased, reflecting the difference in sensitivity of the devices to rapid changes in CO concentration due to gas stove combustion. After cooking, the margin of error varied due to differences in the devices' responses, although some margins of error showed alignment between the two devices.

Discussion

In the testing of the carbon monoxide measurement device using the MQ-7 sensor, the results analysis demonstrates the sensor's performance under various conditions and locations in the household as follows:

a. In the Living Room

The MQ-7 sensor exhibited very consistent and accurate results. The average absolute margin of error in the living room was 0.33 PPM in the morning, afternoon, and evening. This result indicates that the MQ-7 sensor provides accurate and stable readings, with minimal difference between the sensor readings and the CO detection tool used for comparison. In the evening, there was a slight difference where the MQ-7 sensor showed a slightly higher value compared to the comparison tool. However, this difference was not significant and suggests that the MQ-7 sensor remains effective in detecting CO concentrations in the living room. The study results show that the MQ-7 sensor provides consistent and accurate CO readings with an average absolute margin of error of 0.33 PPM. This is consistent with the research conducted by (Mahanijah Md Kamal et al., 2021), which also found that CO concentrations in the living room did not exceed the recommended standard levels. The highest CO value was recorded in the living room, influenced by outdoor air containing CO. Both studies indicate that the measured CO levels are within acceptable ranges and comply with ASHRAE standards and international recommendations.

b. In the Bedroom

Based on the testing results, the MQ-7 sensor demonstrated excellent performance in detecting carbon monoxide (CO) in the bedroom. The average absolute margin of error recorded was 0.33 PPM in the morning and 0 PPM in the afternoon and evening, indicating consistency and accuracy in the sensor's measurements. Although there was a small difference in the morning, where the Air Quality Detector showed a slightly higher CO value compared to the MQ-7 sensor, this difference remained within acceptable limits. Thus, the MQ-7 sensor has proven effective in monitoring CO concentrations in the bedroom with good accuracy. The low absolute margin of error indicates that the sensor can be relied upon to provide consistent results. The difference observed in the morning does not impact the overall sensor performance and can be considered within reasonable tolerance, making the MQ-7 sensor effectively usable for carbon monoxide detection applications with adequate accuracy. This result is consistent with research by (Kumar Sai et al., 2019), which also found CO values below 10 PPM and considered safe within the tested range. Both studies show that the MQ-7 sensor is effective for carbon monoxide detection in household environments, with good consistency and accuracy in detecting CO gas.

c. In the Kitchen

Testing in the kitchen showed more variable results. The absolute margin of error of the MQ-7 sensor varied significantly, with low values before cooking (0.33 PPM), a sharp increase immediately after cooking (27.67 PPM), and a decrease again after cooking (0.67 PPM). The large fluctuations in the margin of error during cooking reflect the sensor's response to rapid changes in CO concentration. Although the MQ-7 sensor is effective in detecting high CO concentrations during cooking activities, its response stability needs attention. The test results indicate that while the MQ-7 sensor is effective in detecting high CO concentrations during cooking, its response stability should be monitored. Nonetheless, these findings align with the results of the tool testing by (Revanolin & Dirgawati, 2022), which demonstrated that the MQ-7 sensor can be relied upon for CO detection, considering the response fluctuations during environmental condition changes.

Overall, the MQ-7 sensor shows good performance in detecting CO in the living room and bedroom with small margins of error and high result consistency. However, in the kitchen, the sensor is effective in detecting high CO concentrations but experiences fluctuations during rapid changes in CO levels.

CONCLUSIONS

The carbon monoxide (CO) detection device using the MQ-7 gas sensor based on a microcontroller has been successfully designed and built to enhance household safety from CO exposure risks. This device demonstrates good performance with consistent and accurate results across various areas of the home, including the living room, bedroom, and kitchen. It provides precise and stable readings and can be relied upon to detect CO presence in household environments.

The MQ-7 sensor exhibits high accuracy in detecting CO concentrations. In the living room and bedroom, the sensor shows an average absolute margin of error of 0.33 PPM, indicating good consistency and accuracy. In the kitchen, although there are significant fluctuations during cooking activities, the sensor remains effective in detecting high CO concentrations. Overall, the MQ-7 sensor proves to be accurate and consistent, in line with previous research affirming its reliability for carbon monoxide detection in household settings.

REFERENCES

Kumar Sai, K. B., Mukherjee, S., & Parveen Sultana, H. (2019). Low-Cost IoT-Based Air Quality Monitoring Setup Using Arduino and MQ Series Sensors with Dataset Analysis. *Procedia Computer Science*, *165*(2019), 322–327. https://doi.org/10.1016/j.procs.2020.01.043

Mahanijah Md Kamal, Ahmad Syahir Sazali, & Suzi Seroja Sarnin. (2021). Real-time indoor air quality monitoring association with humidity, temperature, and carbon monoxide levels in the residential environment. *Malaysian Journal of Chemical Engineering and Technology*, *4*(2), 107–113. https://doi.org/10.24191/mjcet.v4i2.14916

Maharani, S. H., & Kholis, N. (2020). Studi Literatur: Pengaruh Pengunaan Sensor Gas Terhadap Presentase Nilai Error Karbonmonoksida (CO) dan Hidrokarbon (HC) Pada Prototipe Vehicle Gas Detector (VGD). *Jurnal Teknik Elektro*, *09*(x), 569–578.

Revanolin, R., & Dirgawati, M. (2022). Karbon Monoksida (CO) dan Karbon Dioksida (CO2) di Dalam Ruangan Dari Aktivitas Memasak Rumah Tangga Dengan Jenis Bahan Bakar Berbeda : Literature Review. *FTSP Series*, 2021.

Rizaldy, A. N., & Witanto, A. P. (2016). *Alat Pendeteksi Bahaya Gas Beracun Pada Sumur Gali Menggunakan Mikrokontroler Dan Dimonitor Secara Wifi*. https://repository.its.ac.id/75455/%0Ahttps://repository.its.ac.id/75455/1/2213030037-089-Non_Degree_Thesis.pdf

Rosa, A. A., Simon, B. A., & Lieanto, K. S. (2020). Sistem Pendeteksi Pencemaran Udara Portabel Menggunakan Sensor MQ-7 dan MQ-135. *Ultima Computing : Jurnal Sistem Komputer*, *12*(1), 23–28. https://doi.org/10.31937/sk.v12i1.1611

Zlotnik, A. A., & Chetverushkin, B. N. (2023). Rancang Bangun Sistem Pengukur Gas Karbon Monoksida (Co) Menggunakan Sensor Mq-7 Berbasis Mikrokontroler Atmega 16A. *Математический Сборник*, *214*(4), 3–37. https://doi.org/10.4213/sm9800