Design of a Portable Carbon Monoxide (CO) Detection Device Utilizing MQ-7 Sensor for Health Monitoring in Care Rooms

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Abstract— Carbon monoxide (CO) is a colorless and odorless toxic gas that can be harmful to health if inhaled in high concentrations. This research aims to design and build a portable CO detection device utilizing an MQ-7 sensor with a measurement sensitivity range of 20 to 2000 ppm and an Arduino microcontroller. The system is programmed with a danger threshold of 25 ppm, which triggers a buzzer and LED alarm. The research method includes electronic circuit design, sensor testing on five different cigarette samples, and analysis of results. The test results indicate that this device can detect CO gas concentrations with high accuracy. The measurements showed that Sample 2 produced the highest average CO concentration at 44.6 ppm, while Sample 4 produced the lowest at 35.2 ppm. All tested samples successfully triggered the alarm system as they exceeded the pre-set safety threshold. This device serves as an effective mitigation tool for air quality monitoring in healthcare settings.

Keywords— Portable; Carbon Monoxide; Detector MQ-7.

I. Introduction

Carbon monoxide (CO) is a colorless, odorless, and tasteless poisonous gas generated from the incomplete combustion of carbonaceous materials, including tobacco, wood, and fossil fuels [1]. Nonetheless, when ingested in elevated doses, this gas is exceedingly lethal. Indoor carbon monoxide poses a significant threat to environmental health. This is particularly pertinent in healthcare environments, where superior air quality is essential to safeguard patients and medical personnel.

Rahma Desta Kusumawardani et al. [2], identify cigarette smoke as a primary cause of carbon monoxide in residential and public settings. The two primary categories of cigarette smoke are mainstream smoke, which is inhaled by active smokers, and sidestream smoke, which emanates from the burning tip of a cigarette. Due to the absence of filtering in sidestream smoke, its carbon monoxide concentration is significantly elevated. This elevates the risk of cardiovascular illness, respiratory ailments, and hypoxia in passive smokers, particularly among children and the elderly. Over 150 million individuals in Indonesia are subjected to cigarette smoke in domestic settings, public areas, and transportation [3]. This signifies that carbon monoxide exposure in confined areas persists in rising.

The synthesis of carboxyhemoglobin (COHb) results from the physiological affinity of carbon monoxide for hemoglobin, which is 200–250 times greater than that of oxygen. In such circumstances, the distribution of oxygen to bodily tissues is compromised, potentially resulting in systemic hypoxia [4]. If they impact the central nervous system, they may induce encephalopathy; if they influence the heart and blood arteries, they can result in cardiovascular complications. Consequently, a portable tool is required to swiftly and accurately monitor carbon monoxide levels to ensure the safety of the care environment [5]. Consequently, a portable, efficient, and precise tool is required to monitor carbon monoxide levels in order to ensure the safety of the care environment.

Prior studies have endeavored to develop carbon monoxide detectors utilizing microcontrollers. Arief Budi Laksono et al. [6] created a device utilizing ATmega328 for the measurement of carbon monoxide levels. The MQ-7 sensor is equipped with a buzzer that serves as a danger indicator. The findings indicate that the MQ-7 sensor exhibits high sensitivity to variations in carbon monoxide concentration. A demonstration of the creation of the Carbon Monoxide Pollution Detection and Monitoring System (CODS) [7], validating the efficacy of the MQ-7 sensor when included into an IoT-based quadcopter (drone). This system employs the MQ-7 sensor for gas detection and the u-blox NEO-6M GPS module for location identification, with data processed by a Raspberry Pi 3 Model B+. The information is subsequently transmitted to a web server and presented as an interactive map. Testing at three sites (Jakarta, Bekasi, and Depok) effectively validated the system's capacity for mobile monitoring in inaccessible regions, affirming the sensor's utility in dynamic environmental monitoring[7]. Evaluating the efficacy of the MQ-7 sensor in conjunction with the Blynk application through direct comparison with a conventional CO meter [8]. The research findings indicate that the MQ-7 sensor is effective in detecting and measuring CO levels, with results displayed on the Blynk application showing no significant discrepancies compared to the CO-meter. This integration is seen more efficient as it facilitates remote monitoring through the internet, enhancing safety for observers and proving more cost-effective than traditional CO meters [8]. Creation of a straightforward and economical carbon monoxide gas quality indicator device [9]. This apparatus employs a MQ-7 sensor as input for the ATMEGA16 microcontroller, which subsequently presents gas level indicators (such as "UNHEALTHY" or "DANGER") on the LED dot matrix display. Comprehensive system testing against the Stargas 898 calibration tool revealed minimal error rates, including 0.55% at 300 ppm readings. This study validates the efficacy of the MQ-7 sensor for economical static indication device applications [9]. The bulk of MQ-7 sensors continue to operate statically and have not been modified for application in portable medical settings, despite several studies demonstrating their efficacy.

This study aims to develop a portable carbon monoxide (CO) detection equipment for treatment rooms, utilizing the Arduino Uno microcontroller as the central control unit and the MQ-7 sensor. This system is designed to detect carbon monoxide levels between 25 and 100 ppm and present the findings on an OLED display. Furthermore, as an automated alarm system, it can issue alerts by a buzzer and LED. This design is beneficial due to its portability, energy-efficient internal battery, and user-friendliness for non-technical medical workers.

This research is theoretically founded on the operational basis of the MQ-7 sensor. This sensor use the alteration in resistance resulting from the chemical reaction between carbon dioxide gas and the SnO2 semiconductor layer. The analog voltage signal is transformed into numerical data expressed in ppm (parts per million). The OLED interface thereafter displays the ppm number to provide real-time information regarding the gas concentration in the room. Instruments employing this process can swiftly and precisely identify elevations in carbon dioxide levels. Consequently, this gadget may function as an early warning system in hospital care rooms and various public areas.

This project seeks to develop a practical, economical, and efficient prototype for carbon monoxide gas detection, exemplifying the application of biomedical science to enhance environmental health quality. This innovation will decrease the risk of exposure to harmful gases and will also become the professional obligation of future biomedical professionals to guarantee the safety of patients and medical staff in the environment.

II. Research Methodology

This study centers on the design and fabrication of a portable carbon monoxide (CO) detection apparatus utilizing Arduino Uno as the control hub. This apparatus is engineered to detect carbon monoxide from cigarette smoke in a treatment room with a MQ-7 sensor as input. Upon detection of CO gas, the Arduino Uno will analyze the data and exhibit the CO concentration on the LCD screen, concurrently triggering an alarm system that includes a buzzer and LED lights as a warning signal.

A. MQ-7 Sensor

The MQ-7 gas sensor has a high sensitivity for detecting and measuring the concentration of carbon monoxide (CO), with a measurement range of 20 to 2000 parts per million [9]. Tin Dioxide (SnO2) is the primary sensitive substance used in this six-pin sensor. The sensor's resistance will drop when CO gas is detected, according to its operating principle, which is based on the change in surface resistance (Rs) [9]. In order to transform the analog output into a digital signal, an ADC (Analog-to-Digital Converter) pin is needed [10]. This sensor needs a 5V AC/DC power source for the heater and a 5V DC power supply for the circuit in order to function [10]. This heating function is crucial because it purges the sensor of outside air impurities, ensuring steady and precise readings. The external load resistance (RL) needed for the MQ-7 sensor's application is suggested to be around 10 KΩ, and calibration is advised for best performance [11].

B. Block Diagram

The system is engineered to identify the presence of carbon monoxide gas in cigarette smoke and quantify the discovered gas concentration. The equipment design utilized in this study is illustrated in the figure below:

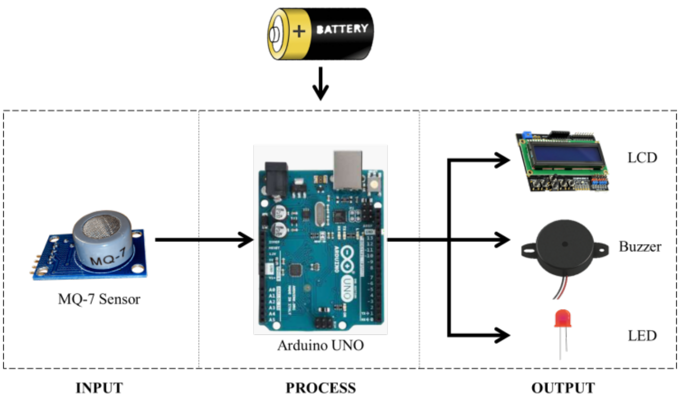

Figure 1. Block Diagram Design

The operational procedure of the system, depicted in the block diagram, commences with the Battery, which functions as the principal power source. This component delivers a reliable DC (direct current) voltage supply to initialize and run the complete electronic circuit, encompassing the microcontroller unit and all associated peripherals. The core of this system is the Arduino Nano, serving as the central processing unit (microcontroller). The Arduino Nano executes the embedded program, manages data reception (input), conducts data processing, and regulates output components. At the input stage, the MQ-7 sensor serves as the principal transducer, perpetually assessing ambient air quality to identify the presence of carbon monoxide (CO) gas. The interaction of CO gas molecules with the sensor's sensitive layer induces a modification in its internal resistance value. The alteration in resistance is transformed into an analog voltage signal that corresponds to the concentration of observed CO. The analog signal is subsequently transmitted to one of the ADC (Analog-to-Digital Converter) pins on the Arduino Nano. The microcontroller unit subsequently transforms this analog voltage signal into a discrete digital value. The digital value is subsequently processed and computed according to the sensor's characteristic curve to derive the actual CO concentration, usually expressed in parts per million (ppm). The Arduino Nano subsequently contrasts the computed concentration value with the pre-established safety threshold value within the application. Upon detecting CO levels surpassing the threshold, the Arduino Nano will concurrently activate three output components as a warning system. The LCD (Liquid Crystal Display) will present quantitative visual data, precisely denoting the observed CO gas concentration. Secondly, the buzzer will be engaged to provide a distinct audible warning as an indication of peril. Third, the LED (Light Emitting Diode) will illuminate, acting as a visual warning indicator to supplement the buzzer's signal, so assuring rapid user attention.

C. Flow Chart

This flowchart delineates the operational process of an early warning system for carbon monoxide (CO) gas. The procedure commences at the "Start" point, with the initial step being "Initialize LCD." This phase indicates that the system activates and readies the LCD panel for information presentation. Upon readiness of the screen, the system promptly engages its primary sensing element, "Sensor MQ-7 Mode On," which is explicitly engineered to quantify carbon monoxide levels. Upon activation of the sensor, the system initiates its basic program, which serves as a pivotal decision juncture: "Is carbon monoxide present?". The system will perpetually assess data from the sensor. If the response is "No," the process flow will revert to the same verification stage. This signifies that the equipment is in standby mode, persistently monitoring air conditions without cessation. Should the sensor identify carbon monoxide levels exceeding a specified threshold (the "Yes" path), the system will promptly initiate emergency measures. The findings will be presented on the LCD, indicating that the warning information or CO level will be displayed on the previously prepared screen. Concurrently, the system will activate dual alarms, specifically "Buzzer ON & LED ON," to deliver both an auditory alert (buzzer) and a visible signal (LED light) to the user. Upon the successful execution of all warning actions, the program flow in this figure is deemed complete ("End").

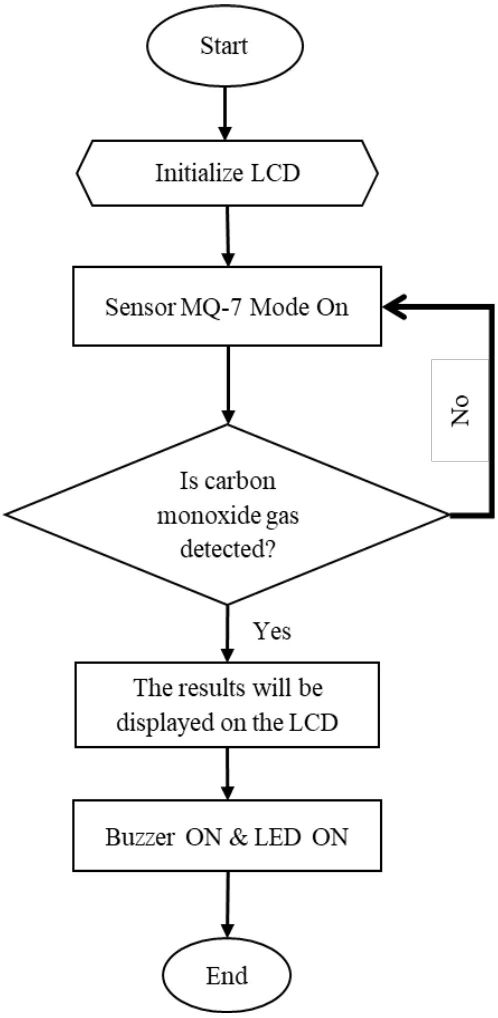

Figure 2. Flow Chart System Portable

III. Results and Discussion

A. System Design

This discourse will examine the circuit employed in "Design of a Portable Carbon Monoxide (CO) Detection Device Utilizing MQ-7 Sensor for Health Monitoring in Care Rooms." This is the complete circuit employed:

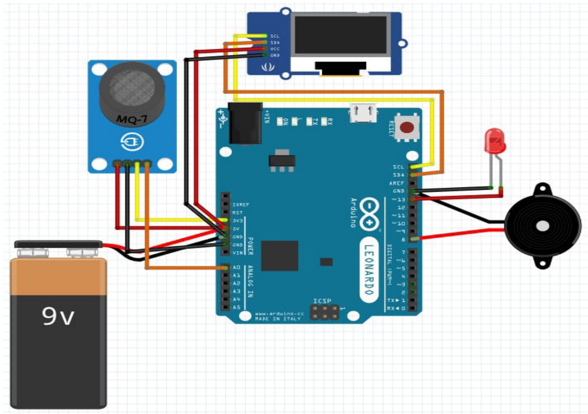

Figure 3. Overall Circuit Simulation

The circuit depicted has multiple circuit blocks that are essential components of the instrument I am constructing. The assembly comprises an LCD circuit, an OLED circuit, a gas sensor circuit, a buzzer, and an LED, which I shall elucidate sequentially as follows:

1. LCD OLED Circuit

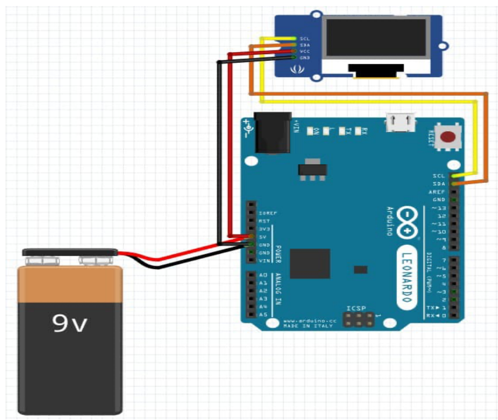

Figure 4. LCD OLED Circuit Simulation

The circuit simulation illustrates the link between the OLED LCD screen module and the Arduino UNO microcontroller based on Figure 4. Through its Vcc and GND pins, the OLED module receives 5V power from the Arduino UNO's 9V battery power source. The I2C protocol, which is used for data transfer between these two devices, is identified in its implementation at address 0x3C. The OLED SDA (Serial Data) and SCL (Serial Clock) pins are connected to the Arduino A4 and A5 pins, respectively, to create this I2C connection. The Adafruit_SSD1306 library and the Arduino IDE were used to create the software. The initialization function (setup()) first tries to establish a connection to the screen, as demonstrated in the program sample. An error message ("SSD1306 allocation failed") will be provided to the Serial Monitor for troubleshooting if the connection fails. A welcome message with the words "CO GAS DETECTOR," "Welcome," and "In My Program" will appear on the screen if it is successful. The program is prepared to move into the main loop to read and display the gas sensor values when this message is shown for five seconds before the screen is wiped. The whole software script utilized in this research can be found [Select one: 'in the online repository at [Insert URL]' or 'as Supplementary Material'].

2. MQ-7 Sensor Circuit

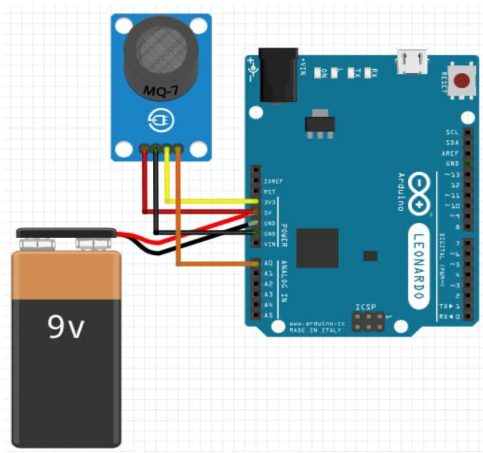

Figure 5. MQ-7 Sensor Circuit Simulation

Figure 5 illustrates the configuration of the MQ-7 gas sensor circuit, designed to detect carbon monoxide (CO) in treatment rooms, including emissions from cigarette smoke. This circuit is based on an Arduino UNO microcontroller, driven by a 9V battery through the Vin and GND pins. The MQ-7 sensor is powered by the Arduino, with its Vcc pin linked to the Arduino's 5V pin and its GND pin connected to the Arduino's GND port. The sensor module's analog output pin (A0) is linked to one of the Arduino's analog input pins, designated in the software as MQ7_PIN, for data acquisition. The provided example software elucidates the operational logic executed within the primary loop() function. During each cycle, the application acquires the raw data from MQ7_PIN, subsequently converts it to a voltage value (0-5V), and then computes the carbon monoxide concentration in parts per million (ppm) via a calibration method. The ppm value is shown on the OLED panel and transmitted to the Serial Monitor for debugging purposes. The program's central feature is the warning system: if the CO level over the threshold of 25 ppm, it will trigger visual (LED) and audio (Buzzer) warnings linked to LED_PIN and BUZZER_PIN, and present the status "DANGER" on the display. If the gas level stays beneath the threshold, the sirens remain dormant and the screen indicates the status "SAFE". The complete reading and verification process is reiterated every second (delay(1000)).

3. Buzzer Circuit

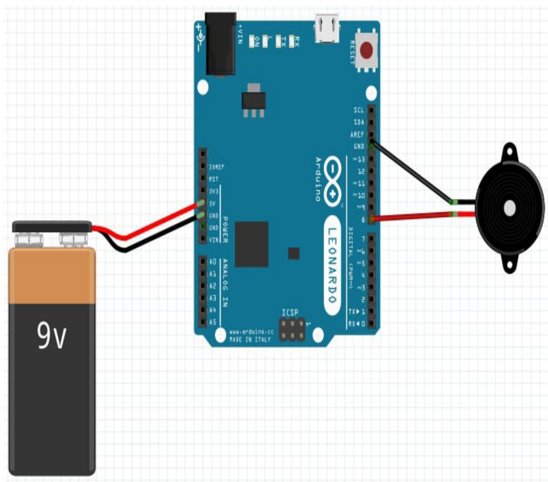

Figure 6. Buzzer Circuit Simulation

Figure 6 illustrates the buzzer circuit, which operates as a sound output actuator for the warning system. This circuit comprises an active buzzer and an Arduino UNO microcontroller, powered by a 9V battery via the Vin and GND pins. The diagram indicates that the buzzer's negative pin (black wire) is connected to a GND pin on the Arduino. The positive terminal of the buzzer (red wire) is linked to a digital I/O pin, which transmits a voltage signal to initiate the sound. The text and software example confirm that this buzzer will activate to issue a warning upon detection of carbon monoxide gas. The example program in the setup() section illustrates the essential initialization procedures for this function. The variable BUZZER_PIN is established as a constant corresponding to pin 5. The instruction pinMode(BUZZER_PIN, OUTPUT); is then executed.

This instruction designates pin 5 as an output pin, enabling it to transmit a HIGH (voltage) signal to activate the buzzer or a LOW signal to deactivate it, in accordance with the gas detection logic in the main loop.

4. LED Circuit

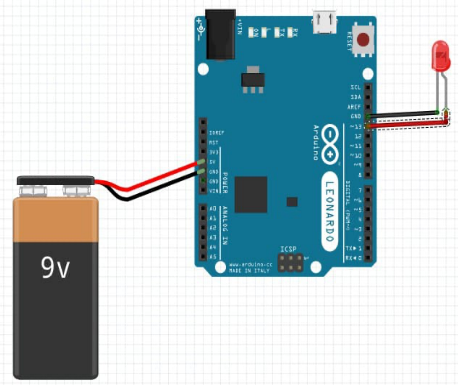

Figure 7.LED Circuit Simulation

Figure 7 illustrates the LED circuit, which functions as the visual alert output or indicator within the gas detection system. This circuit comprises a red LED linked to an Arduino UNO microcontroller, powered by a 9V battery. The physical connections indicate that the anode of the LED is linked to a digital I/O pin, whilst the cathode is connected to the GND pin. This LED will illuminate to issue a visual alert when the sensor identifies carbon monoxide gas at a hazardous level. The software configuration for this component is defined in the program samples. The constant variable LED_PIN is declared as 13, corresponding to digital pin 13 on the Arduino, as illustrated in the circuit diagram. Subsequently, within the setup() method, the command pinMode(LED_PIN, OUTPUT); is invoked. This command is crucial as it designates pin 13 as an output pin, enabling the microcontroller to emit a HIGH signal (voltage) to activate the LED or a LOW signal to deactivate it, contingent upon the gas detection logic within the main loop.

B. System Implementation

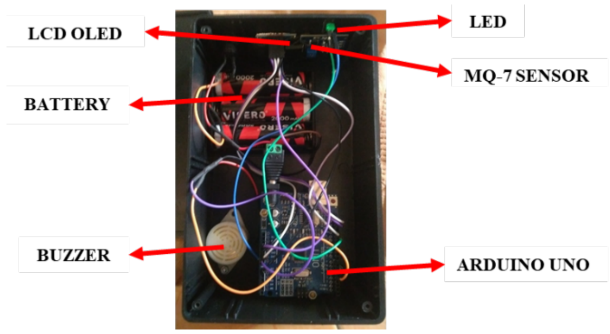

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Figure 8. Overall Circuit

The design and assembly of this carbon monoxide detection device commenced with the preparation of essential components, including an Arduino UNO, a MQ-7 sensor, an OLED LCD screen, jumper wires, a switch, and a housing enclosure. The implementation phase entailed building the sensor and LCD linked to the Arduino Uno, followed by downloading the program via a USB cable from a computer. Upon successful loading of the application, all components are systematically organized and assembled into the designated box to enhance the device's portability. The device was subsequently evaluated with cigarette smoke samples to confirm its operational efficacy. This system is designed to activate the alarm (buzzer and LED) and display a "dangerous" status on the LCD when the detected CO level surpasses the threshold of 25 ppm. The testing findings indicate that the gadget functions as intended: under standard air conditions, the sensor registers a value of 18 ppm, while exposure to cigarette smoke yields a maximum reading of 115 ppm. This tool has demonstrated efficacy and is beneficial for applications in healthcare settings, including rooms care, hospitals, health clinics, and school health units.

The results of the instrument were measured using a single cigarette sample. This experiment was conducted five times (n=5) to evaluate the instrument's dependability and precision. The mean, standard deviation, and standard error were derived from the five measurement data points to evaluate the sensor's performance.

Table 1. MQ-7 Sensor Test Result

Sampel (Cigarette)	Time (Min)	MQ-7 Sensor Trial (ppm)					Total	Avrg.
		1	2	3	4	5		
1	1	38	37	37	38	37	187	37,4
2	1	44	45	45	45	44	223	44,6
3	1	39	39	40	38	38	194	38,8
4	1	36	35	36	34	35	176	35,2
5	1	36	37	35	36	36	180	36

The graph above provides a comparative representation of the MQ-7 sensor testing findings. This graph delineates the average concentration of carbon monoxide (CO) gas in parts per million (ppm), represented on the vertical (Y) axis. The horizontal (X) axis denotes five distinct categories of cigarette samples (1, 2, 3, 4, and 5) utilized as sources of gas exposure. Each data point on this graph represents the mean value derived from five repetitions of the experiment (n=5) for each sample, with the smoke exposure period standardized to one minute. This line chart format is designed to clearly illustrate the fluctuations and direct comparisons of CO concentration levels recorded by the sensor for each sample, while also depicting the sensor's reaction trends to various gas sources.

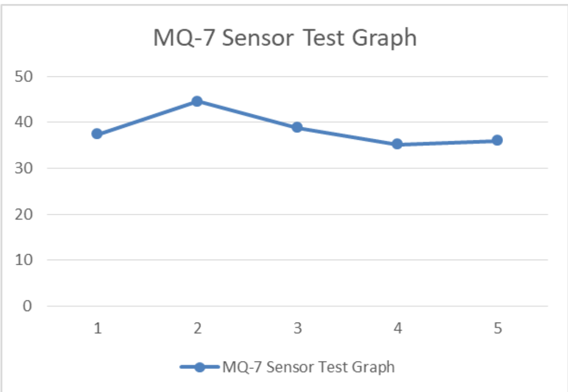

Figure 9. MQ-7 Sensor Test Graph

X-axis (Horizontal) : Cigarette Samples (1-5)
Y-axis (Vertical) : CO Concentration (ppm)

The five samples used in this test represent five different brands of commercial cigarettes. The differences in average CO concentrations (ranging from 35.2 ppm to 44.6 ppm) are due to differences in tobacco composition, paper material, and filter type for each brand. Sample 2 produced the highest CO emissions, indicating a greater degree of incomplete combustion compared to the other samples. The use of this sample variation aims to demonstrate the sensitivity of the MQ-7 sensor in responding to various CO gas sources at different concentrations.

The data analysis depicted in the graph indicates that the second cigarette sample yielded the greatest average CO concentration, peaking at 44.6 ppm. This result represents the maximum sensor response among the five samples evaluated. In contrast, the lowest average value was observed in the fourth cigarette sample, with a measured concentration of 35.2 ppm. The remaining three samples, specifically 1 (37.4 ppm), 3 (38.8 ppm), and 5 (36.0 ppm), exhibited values within these two extremes. The considerable disparity among these samples carries two crucial consequences. This suggests that each cigarette brand likely produces varying CO emissions when combusted under identical experimental settings. Secondly, and more importantly for this research, the data demonstrates that the MQ-7 sensor employed in the design of this device possesses sufficient sensitivity and responsiveness to identify and differentiate between varying levels of CO concentration, even with minor fluctuations, thereby confirming its efficacy as a detection instrument.

The test findings indicate that each cigarette sample yielded differing average quantities of carbon monoxide (ppm). The maximum average value documented was 44.6 ppm (Sample 2), while the minimum average value was 35.2 ppm (Sample 4). The crucial feature of this data is the tool's precision level, as outlined in the preceding paragraph. The findings from all five trials for each individual sample shown minimal variation. For instance, Sample 1 exhibits highly consistent readings (ranging from 37 to 38 ppm), while Sample 2 also demonstrates notable consistency (ranging from 44 to 45 ppm). The data's consistency demonstrates that the equipment possesses good reliability for repeated measurements.

The measurement accuracy of this device is ensured through a calibration process within the microcontroller firmware. The MQ-7 sensor is calibrated by determining the sensor's resistance in clean air (Ro) as a baseline reference. The analog data received is then converted into voltage (0-5V) and mapped into ppm units based on the sensor's characteristic curve (log-log scale of Rs/Ro). Based on five repeated tests for each sample, the device demonstrated high reading consistency with minimal deviation. This confirms that the applied calibration mechanism effectively maintains the stability and accuracy of the sensor in detecting real-time CO gas concentration fluctuations.

IV. Conclusion

From the study findings, implementation, testing, and discussions presented in the preceding chapters, two primary conclusions can be derived that pertain to the research problem statement as follows:

1. This research has effectively designed and constructed a completely operational prototype for a carbon monoxide (CO) gas detector in cigarette smoke. This system effectively incorporates the Arduino Uno microcontroller as the core processing unit, the MQ-7 gas sensor as the primary input component, and an OLED LCD screen for data visualization, along with alarm actuators, including an LED and buzzer for alerts. The success of this implementation encompasses not only hardware assembly but also the creation of software capable of real-time sensor data processing. The ultimate outcome is a detection system that functions as intended: it is portable, responsive, and proficient in delivering quantitative data and immediate alerts regarding the presence of CO gas, specifically catering to the requirement for monitoring instruments in settings such as treatment rooms.
2. The devised technology has been validated for performance and demonstrated sufficient sensitivity and reliability in detecting CO gas from cigarette smoke. This validation was performed utilizing a systematic testing methodology, using five distinct cigarette samples with five repetitions (n=5) over a period of one minute. The quantitative testing findings indicate that the MQ-7 sensor consistently detects and delivers distinct responses for each sample. This device specifically records a distinct detection range, with the minimum average value recorded at 35.2 ppm (4th cigarette sample) and the maximum average value reaching 44.6 ppm (2nd cigarette sample). All samples yielded readings significantly beyond the warning threshold (25 ppm) and exhibited consistent results across repeats, so demonstrating the sensor's functionality and affirming the device's precision and reliability for its primary use.

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