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Developing Carbon Monoxide Gas Detectors In Vehicle Cabins

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ABSTRACT

A vehicle will produce carbon monoxide (CO) gas when an incomplete combustion occurs. CO is odourless and colourless. The MQ-9 sensor is installed on the vehicle to detect the presence of CO in the vehicle cabin. The detection of CO in the vehicle cabin involves the MQ-9 Sensor, Arduino Mega 2560, and Raspberry Pi. When the MQ-9 Sensor detects CO in the vehicle's cabin, it will send a voltage to the Arduino Mega 2560, and the Liquid Crystal Display (LCD) will display the existence of CO. It will also display the activity of the MQ-9 Sensor. This system will generate an alarm signal and activate the Power Window Motor to pull the vehicle window open 2 inches to increase the Oxygen content in the vehicle. The alarm will sound again when the MQ-9 sensor no longer detects the presence of CO in the vehicle cabin, and the Power Window Motor will raise the window again. At the same time, Raspberry Pi will send information about the presence of CO to the vehicle owner's mobile phone. Indirectly, this approach will help prevent deaths from CO poisoning in vehicles.

1.0 Introduction

CO consists of one element of carbon and one element of oxygen, which is a type of dangerous gas. According to C Reboul et. al (2017), among various air pollutants that occur, CO results from cigarettes, vehicle exhaust, and gas emissions from industry. CO is a type of gas that has no taste, smell, or color. Because of that, this gas is too difficult to detect by human senses. According to Miles et al. (2019), CO can prevent the blood from transporting oxygen when the human body absorbs it, and will cause tissues to lack oxygen. CO is very dangerous to humans when a person is exposed to this gas in high concentrations, which can cause blood disorders. If an individual is exposed to CO in high concentrations, it will cause dizziness, shortness of breath, headache, tiredness, sweating, high blood pressure, rapid heartbeat, coma, and seizures (Husen, 2021).

The MQ-9 sensor is a gas sensor suitable for use in equipment to detect CO in industrial areas and on a vehicle. Among the advantages of the MQ-9 Sensor is that it is high stable, fast response, and has high sensitivity to CO, Methane, and LPG (Arivalahan et al., 2021). The MQ-9 sensor uses a heater power supply: 5V AC/DC and uses a circuit power supply: 5V DC, measurement limit: 20 to 2000 ppm, to be able to measure CO. In the study of Estrada et al. (2019), a low-cost MQ-7 Sensor, a buzzer, and an ESP8266 integrated circuit were used to detect the concentration of CO in a room. The alarm will sound when the MQ-7 Sensor detects a concentration of CO above 25 parts per million and at the same time sends an alert to mobile devices informing people to leave the room. In the study, Mohammed et al. (2019) have used an MQ-7 Carbon Monoxide Sensor, Arduino, GSM modem, LCD screen, and alarm. SMS text messages will be sent to the user via modern GSM. The vehicle's Power Window will be activated to immediately operate the ventilation system to remove CO from the vehicle's cabin.

This study uses a second-generation Raspberry Pi. Raspberry Pi, which has 1 GB RAM and a quad-core 900MHz ARM Cortex-A7 CPU. According to Sabarwal (2020), Raspberry Pi is an education-oriented computer board, powerful, small size, a cheap price, and hackable. MQ-9 sensors are installed on the front of the driver and passenger seats and the inside of the roof of the vehicle for the rear seats. When the MQ-9 sensor detects the presence of CO in the vehicle cabin, this system will generate an alarm signal and activate the Power Window Motor to pull the vehicle window open by 2 inches, to increase the Oxygen content in the vehicle, where four Channel Relay Module units are connected to the power window for the front and rear mirrors and the Printed Circuit Board (PCB).

The Channel Relay Module will help to activate the lowering and raising of the vehicle's power window mirrors based on instructions from the Arduino Mega 2560, which acts as a Microcontroller when the MQ-9 Sensor detects the presence of CO in the vehicle's cabin. When the MQ-9 Sensor no longer detects the presence of CO, the alarm will sound again, and at the same time, the Power Window Motor will raise the window again. The Arduino Mega 2560 will display information on the existence of CO on the Liquid Crystal Display (LCD). The Arduino Mega 2560 will also send the output to the Raspberry Pi to be sent directly to the vehicle owner's mobile phone to notify the presence of CO in the vehicle cabin. According to Ismailov & Jo'rayev (2022), Arduino is very fast at reading analog input up to 10000 times per second.

2.0 Literature review

In a vehicle, CO results from burning fuel without enough oxygen to produce Carbon Dioxide. Incomplete combustion in a vehicle will produce very dangerous CO (Chenoweth et al., 2021). Engine warming is a method in which the vehicle engine is turned on, but the vehicle does not move. This usually happens when the driver stops at a traffic light, waits at a stop outside the house, or rests in the vehicle with the engine still running. The longer the vehicle is left in such a state, CO is produced due to the combustion of fuel in the combustion chamber. If the Vehicle Air Conditioning System has a problem, this CO will be drawn into the vehicle cabin.

For vehicles that use petrol or diesel as fuel, the combustion that takes place in the combustion chamber will produce many byproducts that are released as exhaust fumes. According to Sassykova et al. (2019), the main composition of vehicle exhaust consists of gases such as 200 toxic chemical compounds, Pb, CO, HC, and NOx. According to Amrullah et al. (2022), CO is the most common cause of poisoning for humans. It is doorless, colorless, and tasteless. Several factors, such as the formulation of Gasoline, the condition of the exhaust system, the state of compression in the engine, and the temperature of the engine, cause the release of CO. Motor vehicles' exhaust contributes to increased CO. A study conducted in Jinan, China, shows that motor vehicles are the main contributors to increased CO and NO2, Wang et al. (2022). When the vehicle is turned on, a good exhaust system will release harmful gases into the environment smoothly and safely. If the exhaust system has a problem or a leak, and it gets worse when the vehicle is

not moving, unknowingly, CO, which has no smell or taste, will enter the vehicle cabin and enter the respiratory tract and enter the bloodstream of the driver and passengers. CO is easily bound to Hemoglobin. Hemoglobin is the part of the Red Blood Cell that carries Oxygen, then forms Carboxyhemoglobin (COHb). CO binds to Hemoglobin with an affinity 200 times greater than oxygen, thus reducing the ability to carry Oxygen, Palmeri & Gupta (2023). The death of an individual can occur when the blood is no longer able to carry the oxygen that should be supplied to the body's tissues. According to Jevtic & Blagojevic (2019), CO is poisonous to the human body, and many modern processes in homes and vehicles will produce this deadly gas. The Air Conditioning System on a vehicle operates by taking and filtering air from the outside or air from the inside and distributing it into the vehicle cabin. It is better not to turn on the Air Conditioning System when a vehicle is stationary and at the same time it is at idle speed. In this situation, the vehicle's Air Conditioner can collect CO. Possible CO leakage situations in heating, ventilation, air conditioning (HVAC) in recirculation mode are shown in Figure 1, Galatsis (2021). In recirculation mode, and while the vehicle is in motion, cabin pressure is less than the rear of the vehicle. If any leaks exist in the exhaust system, exhaust gas mixed with external air will be drawn into the cabin.

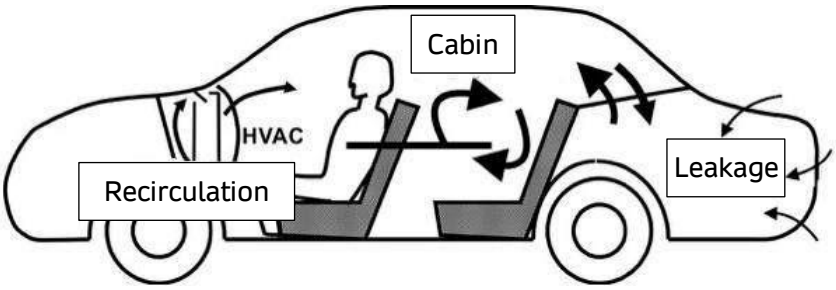


Figure 1: Possible CO entering with heating, ventilation, air conditioning (HVAC) in recirculation mode, Galatsis (2021)

3.0 Methodology

The development of a device to detect the presence of CO in the cabin of a vehicle involves an Arduino Mega 2560, which is the highest Microcontroller unit compared to most other similar boards. The Arduino Mega 2560 was chosen because it can handle large amounts of data based on a large enough RAM to control the driver program. This device is responsible for controlling hardware devices and implementing hardware specifications. Figure 2 shows the Schematic Printed Circuit Board (PCB), while Figure 3 shows the installation of the Arduino Mega 2560 on the Schematic PCB that has been developed. The flow of electric current that flows in the Schematic PCB to activate the MQ-9 Sensor and receive signals from the MQ-9 Sensor, and respond to the Arduino Mega 2560.

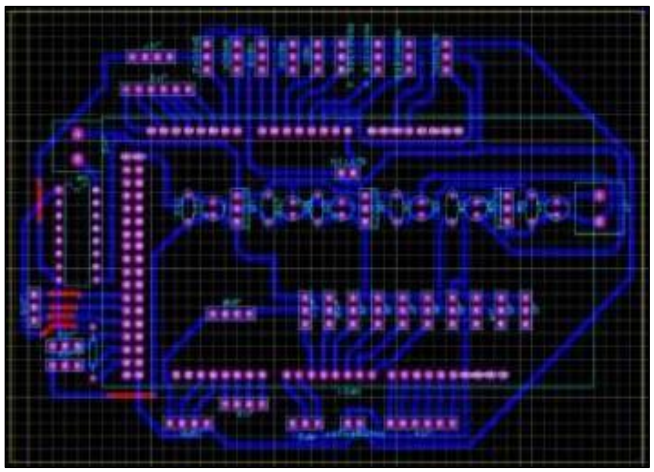


Figure 2: Schematic PCB

Figure 3: Installation of Arduino Mega 2560 on Schematic PCB

In this study, the Sensor Power Supply Circuit has been used to supply electricity to the PCB, which will activate the sensor, receive signals, and respond to the Arduino Mega 2560. A Liquid Crystal Display (LCD) is installed in the vehicle to inform the driver about the presence of CO in the vehicle cabin, which is very effective in electronic systems. LCD sends receiver data, 4-bit or 8-bit data from the processor device, then the data is processed and displayed in the form of dots that form letters.

Figure 4 shows the process flow that occurs in the system to detect the presence of CO in the cabin of the vehicle. When the MQ-9 Sensor detects CO in the vehicle's cabin, it will send a voltage to the Arduino Mega 2560, and the LCD will also display the activity of the MQ-9 Sensor. Next, this system will generate an alarm signal and activate the Power Window Motor to pull the vehicle's window glass open by 2 inches, to increase the Oxygen content in the vehicle. When the MQ-9 Sensor no longer detects the presence of CO, the alarm will sound again, and at the same time, the Power Window Motor will raise the window again.

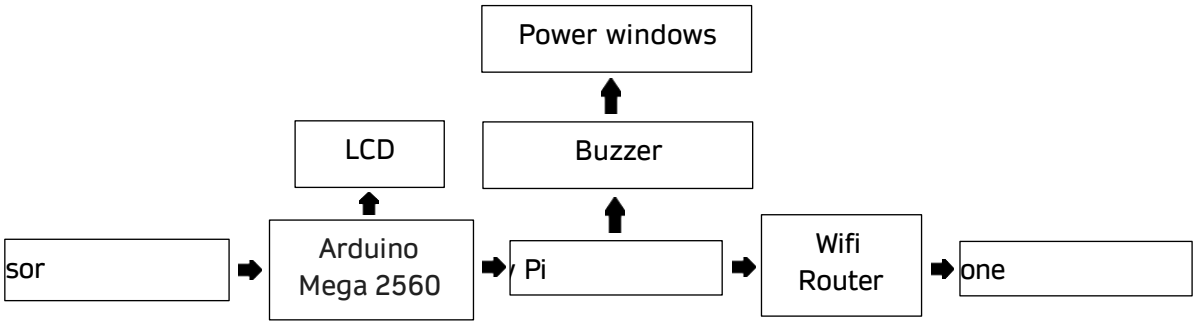


Figure 4: Process Flow That Occurs On The System To Detect The Presence Of CO In The Vehicle Cabin

Where two MQ-9 Sensor units are installed in the front part of the vehicle cabin, and another MQ-9 Sensor unit is placed on the inside of the roof of the vehicle for the back seat to detect the presence of CO. This system uses 4 4-channel relay Modules. The Front Power Window wire, located under the right side of the dashboard, that connects to the left and right Rear Power Window to control the down mirror is cut, and each is connected to the Relay on the COM 12-Volt Channel Relay Module pin and to the NC 12-Volt Channel Relay Module pin. At the same time, the NO pin on the Channel Relay Module is connected to the positive 12-volt from the battery. To control the Power Window Mirror up, the wire located under the Dashboard that connects to the left and right Rear Power Window to control the up mirror is cut, and respectively connected to the Relay on the COM 12-Volt Channel Relay Module pin and to the NC 12-Volt pin Channel Relay Module. In contrast, the NO pin on the Channel Relay Module is connected to the positive 12-volt from the

battery. All four DC+ pins on the Channel Relay Module are connected to the 12-Volt pins found on the PCB. The four DC pins on the Channel Relay Module are connected to the negative pin on the PCB. In comparison, the IN pin on all four Relays is connected to the pins on the PCB. In the study of Shahewaz & Prasad (2020), regarding gas leak detection and warning system using Arduino Uno, stated that the operating voltage is 5 volts.

Figure 5 shows the Power Distribution System connection produced by taking the 12V Positive Wire on the Front Power Socket Positive (D-06a) and the Negative Wire on the Front Power Socket Negative (D-06b). Power Supply converts 12-Volt to 5-Volt. Where each Positive Wire removed from the vehicle's original system will go through a 5A Fuse before being connected to the MQ-9 Sensor to detect the existence of CO in the vehicle's cabin.

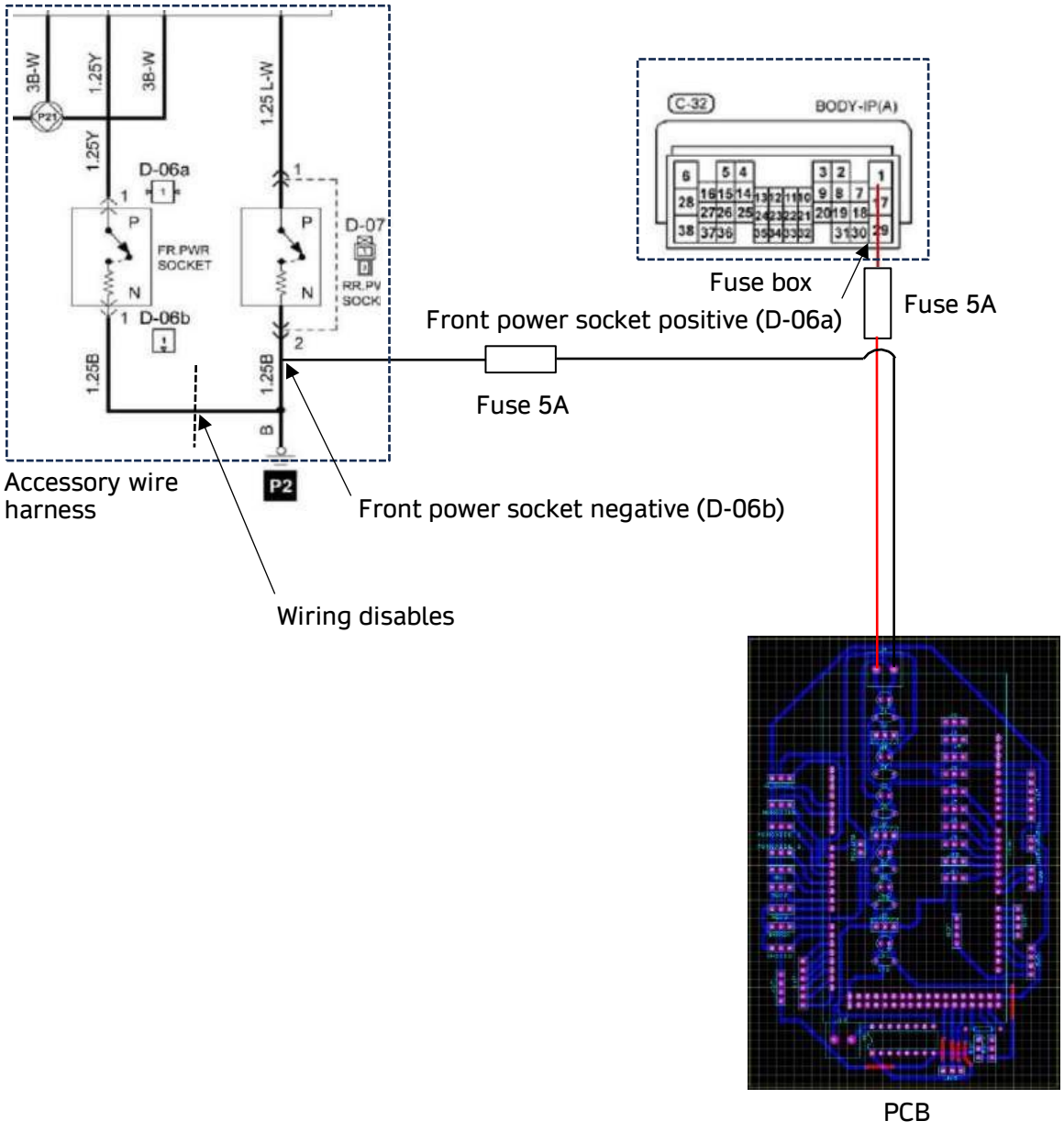
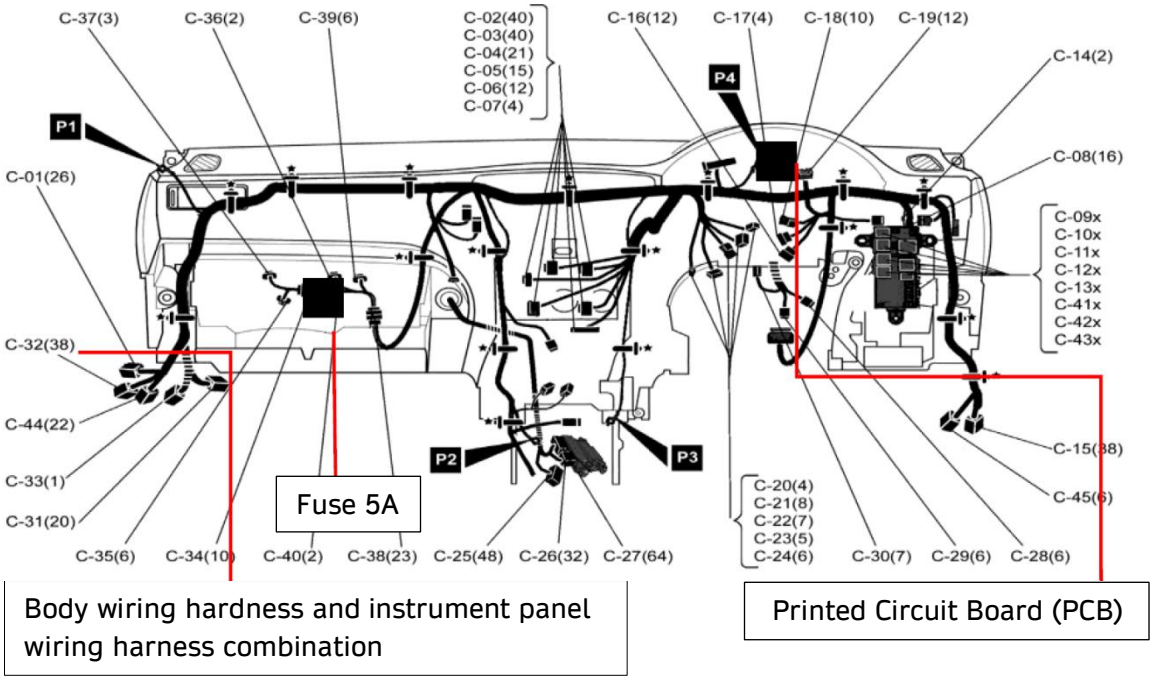


Figure 5: Power Distribution System

Next, the programming for the CO detection system in the vehicle cabin will be uploaded to the Arduino Mega 2560. The LED on pin 13 will blink, which shows that the Arduino Mega 2560 will work according to the program that has been built. Figure 6 is the Instrument panel wiring harness combination for the vehicle.



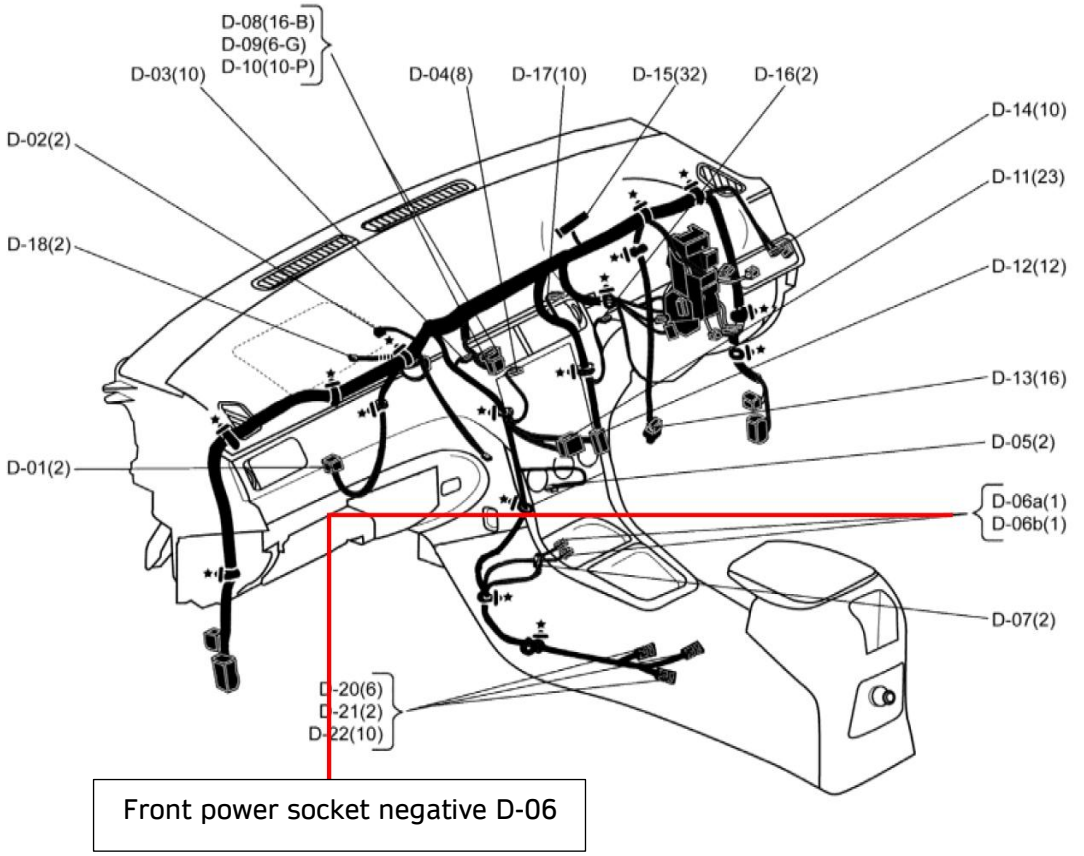


Figure 6: Connection of the developed system with the vehicle's original system

4.0 Discussion of analysis and findings

Table 1: Voltage value for MQ-9 Sensor

Measurement Point	Measure Value	True Value	Cause
Power Window Motor +Ve pin to ground	5-Volt	5-Volt	It is measured in standby mode
Pin -Ve Power Window Motor to ground	5-Volt	5-Volt	It is measured in standby mode
5V Positive Pin	5-Volt	5-Volt	5-Volt if there is no CO in the vehicle cabin
GND pin (negative)	5-Volt	5-Volt	5-Volt if there is no CO in the vehicle cabin
DOUT pin (output)	0-Volt	0-Volt	0-Volt due to the presence of CO in the vehicle cabin

Based on the tests carried out at a temperature of 27℃, it is confirmed that all installed MQ-9 sensor units are functioning properly. Each MQ-9 sensor is equipped with three pins: Positive Pin (5V), GND Pin (Ground), and DOUT Pin (Digital Output). Voltage measurements were taken using a multimeter at each pin. Under normal operating conditions, the MQ-9 sensors maintain a 5V output to the Arduino Mega 2560. However, when a sensor detects CO presence in the vehicle cabin, the DOUT Pin output becomes 0V. The Arduino Mega 2560 processes this voltage change and subsequently displays the information on an LCD screen. Additionally, the Arduino Mega 2560 transmits the output data to a Raspberry Pi, which then relays the information to the vehicle owner's mobile phone to alert them about CO detection. This setup is analogous to the system described by Juna et al. (2024), where an Arduino, integrated with GSM modules and sensors, sends an alert to a mobile phone in cases where children are left unattended in a vehicle.

5.0 Conclusion and Future Research

CO detectors in vehicle cabins have been successfully developed and tested. The application of the Arduino Mega 2560, Raspberry Pi, and the installation of the MQ-9 Sensor are highlighted as a medium to improve the safety level of drivers and passengers in the vehicle. When the MQ-9 Sensor detects CO in the vehicle's cabin, it will send a voltage to the Arduino Mega 2560, and the LCD will also display the activity of the MQ-9 Sensor. This system will generate an alarm signal and activate the Power Window Motor to pull the vehicle window open 2 inches, to increase the Oxygen content in the vehicle. The alarm will sound again when the MQ-9 sensor no longer detects the presence of CO in the vehicle cabin, and the Power Window Motor will raise the window again. The LCD in the vehicle will display the presence of CO. At the same time, Raspberry Pi will send information about the presence of CO to the vehicle owner's mobile phone. Indirectly, this approach will help avoid death due to CO poisoning in vehicles. For future development, it is proposed that the vehicle engine will be turned off automatically when the sensor detects the presence of CO in the vehicle cabin. This will be able to prevent death due to CO poisoning in vehicles.

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Author Contributions

Raja Hassan T. A.: Conceptualization, Methodology, Hardware, Software, Writing-Original Draft Preparation; **Wan Amiruddin Wan Mustapha**: Validation, Supervision- Hardware, Software, Testing; **Che Mod M. Z.**: Software, Validation, Writing-Reviewing and Editing; **Hakim M. I. N.:** Writing-Reviewing, discussion of analysis and findings.

Conflicts of Interest

The manuscript has not been published elsewhere and is not being considered by other journals. All authors have approved the review, agree with its Submission, and declare no conflict of interest in the manuscript.

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