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A Low Cost Method to Analyse Concentration of Carbon Monoxide (CO)

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Graphical abstract

Abstract

This paper presents the design and development of a Carbon Monoxide (CO) gas detector for vehicles. A gas sensor MQ7 was used to detect if there is any CO gas leakage in a vehicle. To develop a CO Smart Detector that operates systematically, Arduino Uno was used as a microcontroller to control the whole system. The gas detector would automatically alert the user inside the vehicles by triggering a warning using LED, buzzer and LCD display as indicators. An exhaust fan was also used to extract the polluted air from the vehicle. The colour, green, yellow or red would appear on the LED automatically when there is a certain level of CO concentration in the vehicle. Green LED is for safe condition and yellow LED and buzzer with beep sound will be turned on automatically in an alert condition. Finally, red LED with its continuous sound would come on when the MQ7 sensor detects a dangerous level of CO concentration in the vehicle. In addition to the buzzer with its continuous sound to alert users, a fan to extract the air from inside the vehicle could be turned on automatically or manually using a switch if the need arises.

Keywords: Carbon Monoxide (CO); gas detector; microcontroller

■1.0 INTRODUCTION

Nowadays, the issue of safety has become an important aspect in our life. For vehicles, a security system is necessary to protect the vehicle from being stolen or to protect its users from unexpected problems. Besides that, safety for vehicles can refer to saving of lives by detecting gas leakage. Thus, this project was designed to implement a gas detector alarm as a safety equipment to detect carbon monoxide (CO) gas leakage. Besides that, the proposed detector can also control the air inside a vehicle by extracting the polluted air from vehicle using an exhaust fan. The extraction process, can assist in overcoming the problem of gas leaks including carbon monoxide inside a vehicle. There was, a case involving the effects of prolonged exposure to carbon monoxide gas leak which had resulted in the loss of many lives. In another case published in the New Straits Times, it was about the death of a couple due to inhalation of carbon monoxide (CO) gas. In this incident, the existence of CO was caused by a leak in the exhaust system and it got into the car through the air conditioning system [1]. Another similar case of CO leakage reported involved a family with three children inside a car. These cases occurred because CO had leaked and got into the car ventilation system while the car was parked with the engine still in a running condition for 3 hours [2]. The idea is that prevention is better than cure in the context of CO leaks. Thus, a smart alarm gas detector in vehicle would be used to detect carbon monoxide (CO) gas and this could save lives. Besides that, the gas detector can also extract the air from inside a vehicle using an exhaust fan while alerting the people in the vehicle that the CO level is at a dangerous level.

■2.0 HARDWARE IMPLEMENTATION

This section will discuss the details of the materials and devices used in the hardware and software development CO detector. Besides that, the development of the sensing system and the output of the project will be presented.

2.1 Carbon Monoxide Sensor (MQ7)

In this project, MQ7 semiconductor sensor was used. The MQ7 gas sensor is made of tin dioxide (SnO2), a sensitive material, which has a low conductivity in clean air. This sensor can detect CO at high cycle and low temperature. At a low temperature, the output voltage is detected to have a low voltage. This voltage will give an output signal that the gas concentration is at low level and vice versa. The MQ7 gas sensor is sensitive to CO. In addition, the sensor is capable of detecting other gases that contain CO. MQ7 is a low cost sensor and suitable for applications such as domestic gas detector, industrial CO detector and portable gas detector. Figure 1 shows the basic structure and configuration of MQ7 gas sensor [3].

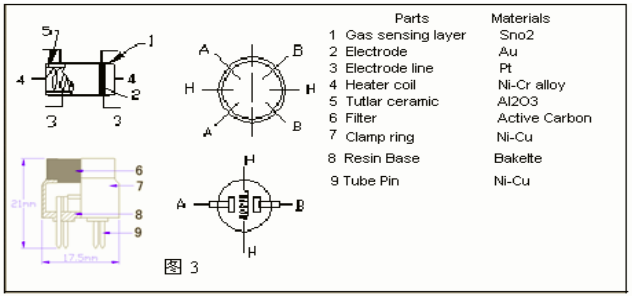

Figure 1 Basic structure of MQ7

2.2 Arduino Uno Board

Arduino Uno was used as microcontroller to control the whole system for this project. It is a single-board microcontroller that can be used for multidisciplinary electronics project. The software used for Arduino Uno is a standard programming language compiler and a boot loader that executes on the microcontroller. The microcontroller board consists of an Atmel 8-bit AVR microcontroller with a complete set for ease of use for programming and incorporation with other circuits. The microcontroller has 14 digital inputs and outputs. From the 14 digital input or output pins, 6 pins are used as PWM outputs. Besides that, it has six analog inputs with 16 MHz crystal oscillators. The Arduino Uno can be powered by USB connection or an external power supply [4]. The official board for Arduino Uno is shown in Figure 2.

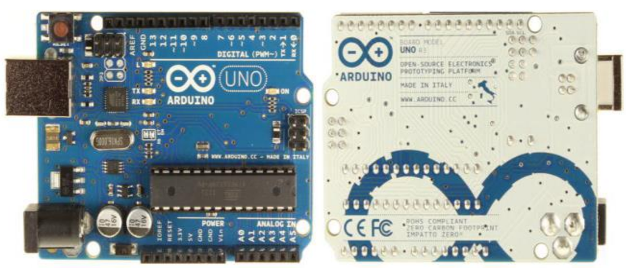

Figure 2 Arduino Uno Board

2.3 System Output

The system output for this project is important to ensure that it is capable of alerting the user when the concentration of carbon monoxide (CO) is at a dangerous level. It is also important to monitor the air inside a vehicle. For this project, the output system consists of four main parts:

1) Light Emitting Diode (LED)
2) Exhaust fan
3) Buzzer
4) Liquid Crystal Display (LCD)

3.0 METHODOLOGY

The project consisted of two main parts, namely hardware and software. 80% of the project focused on the development of the hardware and the remaining 20% was on the software. For the hardware development and implementation, the process included designing the circuit, PCB development and designing the casing for the detector. On the other hand, software development included the design of the flow chart and writing the programming for the Arduino Uno microcontroller. Upon completion of the software and hardware parts, the next processes were testing and debugging of the system [4].

3.1 Hardware Development

Figure 3 shows the block diagram for the project. DC power supply is supplied from the battery of a vehicle or from an external battery in the system. The output will trigger LED, LCD, fan and buzzer as programmed.

The power supply required to activate this device is at least 5V to 12 V i. The device must be connected to a power supply from the vehicle or battery. The potential difference generated by the sensors is sent to the analog and then to the digital converter (ADC) internal by Arduino Uno microcontroller. The analogue to digital converter will convert the analog signals from the sensors and convert the carbon monoxide reading into digital form to be processed and manipulated by the microcontroller. An output system will be determined by the microcontroller according to the program set by the program through the LED, LCD, fan and buzzer [5].

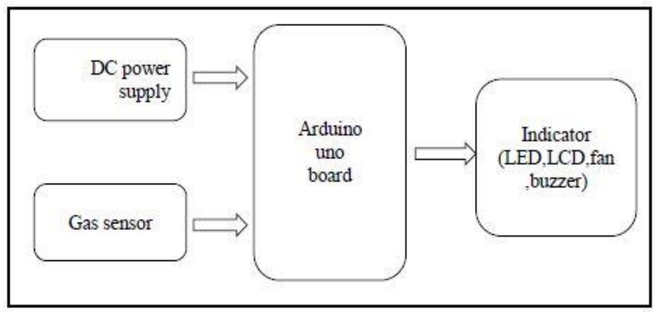

Figure 3 Block diagram of the system

3.2 Software Development (Arduino Uno Programming)

The Arduino Uno board is one of the main components used in this project. The whole system is controlled by a program in Arduino Uno board where it will receive the output from the gas sensor (MQ7) and interpret the data to trigger the system output which are LEDs, fan and buzzer. Figure 4 shows the flow chart for the whole programming of Arduino Uno microcontroller.

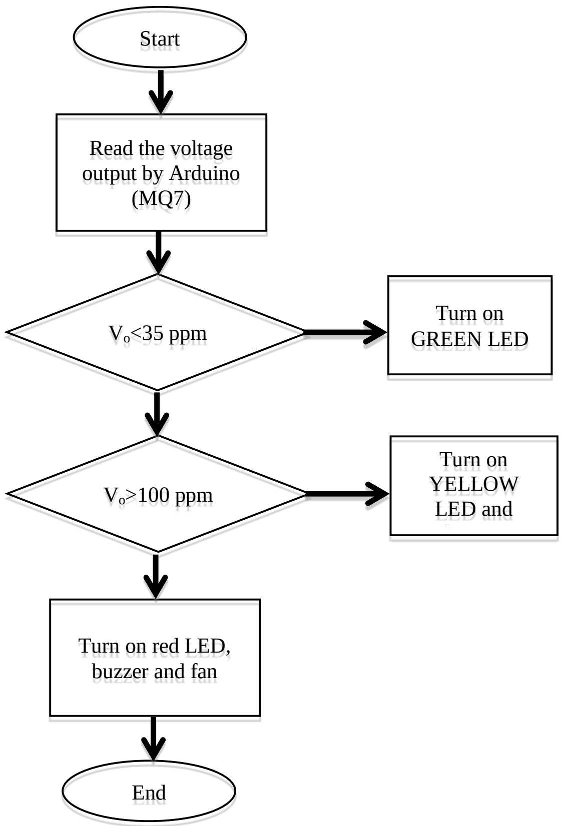

Figure 4 Flow chart for arduino programming

3.3 Calculation of CO Gas Concentration Process

The concentration of carbon monoxide is directly proportional to output voltage of MQ7. Figure 5 shows the graph concentration versus output voltage of MQ7. The input and output MQ7 configuration is shown in Table 1.

Table 1 Input and output voltage range for MQ7

Specification	Gas sensor (MQ7)
Input voltage range (volt)	DC Supply 5.0±0.1 V
Output voltage range (volt)	DC Supply 0-5.0 V

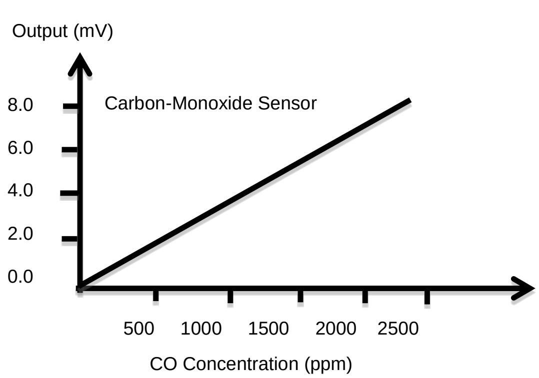

Figure 5 Graph output voltage versus concentration of CO

After the V_1 sampling process, the system will proceed with CO concentration calculation process. The value of CO concentration is obtained by calculating the value of the sensor resistance (R_s). The value of R_s is obtained from the following equation:

$$R_s = \frac{5 - V_1}{V_1} \quad \text{------------------ (1)}$$

Equation 1 is obtained from the MQ7 data sheet. The value of 5 is the positive reference voltage (Ref+) value of the system in volt. Figure 6 shows the graph of Sensor resistance ratio (R_s/R_o) versus CO Concentration in ppm. R_o is the sensor resistance (R_s) value at 100 ppm. Based on the graph, R_o is equal to 1.

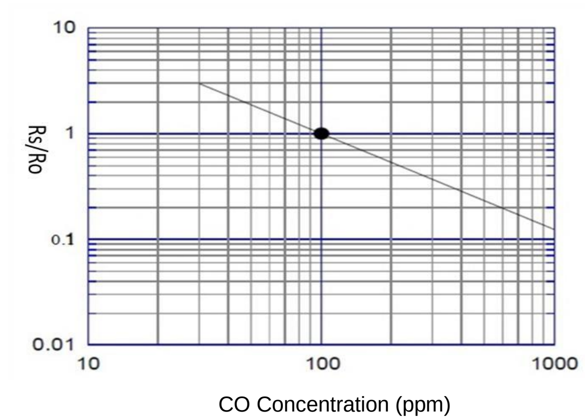

Figure 6 Graph Sensor resistance ratio (Rs/Ro) versus CO Concentration

From the log-log graph, the relationship between R_s and CO concentrations in ppm is obtained. Equation 2 shows the relationship between R_s and the CO concentration value. Alpha (α) is the graph slope value. When x-axis equals zero, the intersection value between the graph linear line and the y-axis equals 100.

$$C = 100 \times R_s^{\frac{1}{\alpha}} \quad \text{------------------ (2)}$$

The slope value is obtained using the following equation,

$$\alpha = \frac{\log X_1 - \log X_2}{\log Y_1 - \log Y_2} \quad \text{----------------- (3)}$$

By taking two points (first point at 100 ppm and second point at 1000 ppm) from the linear line graph, the slope can be calculated as

$$\alpha = \frac{\log 1 - \log 0.1}{\log 100 - \log 1000} \quad \text{---------------- (4)}$$

With the slope value equals -1, equation 2 can be simplified into

$$C = \frac{100}{R_s} \quad \text{---------------- (5)}$$

4.0 RESULTS AND DISCUSSION

This section describes the results of the project and discusses some of the problem solving methods during the process of completing this project. Several tests on the Smart Alarm Detector were conducted to determine whether the project is successful or if there is any problem in the hardware or software implementation. Data collection was performed under three different environment conditions. Then, the data were analyzed and compared with information obtained from references.

Upon completion of the development and implementation of the software and hardware, the CO Smart Detector was tested in three different situations. The situations with different amounts of CO concentrations are as follows:

1) Normal air.
2) Cigarette smoke
3) Car fumes

The test results were compared with the information obtained from several references. The results of the tests are shown in Table 2.

Table 2 Results of the r tests under three different conditions

Test condition	Result	Reference
Fresh air	-CO value: <35 ppm. -Green LED lights up.	In USA, the average concentration level of CO between 0.5-5.0 PPM [6].
Cigarette smoke	-CO value: 35-100 ppm. -Yellow LED lights up. -Buzzer automatically turns on with beep sound.	A room polluted with CO generated by cigarette is 25 PPM [7]. CO generated by cigarette smoke normally is 20 PPM and above [8].
Car fumes	-CO value: >100 ppm. -Red LED lights up. -Buzzer automatically turns on with continuous sound. -Fan automatically turns on.	CO value generated form car fumes in Mexico city area is between 100-200 PPM [9]

The results obtained from the project were compared with information obtained from several references because there was no proper equipment or available CO meter to check the correct values during the actual tests. The fresh air conditions were tested in a normal room condition without the presence of smoke or any source of incomplete combustion that can generate the CO. The output results for these conditions shown on the LCD were between 0.0 to 0.5 ppm and the green LED would light up to indicate a safe condition. Figure 7 shows the CO Smart Detector used in a test under normal air condition.

In another test, a cigarette smoke condition was tested by using a room with a number of people smoking cigarettes. The results showed on the LCD were between 35 ppm and 65 ppm. The yellow LED would light up and buzzer automatically turned on with beep sounds. The buzzer is used to indicate that the air condition in the test room was in a state of alert and precaution. Figure 8 shows the CO Smart Detector during the test in a room with cigarette smoke.

Figure 9 shows the CO Smart Detector test conducted on a car exhaust. The car smoke test was conducted in an open place and the sensor was placed directly in the exhaust of the car. The results shown on the LCD were between 100 ppm and 200 ppm. The red LED would light up and buzzer automatically turned on with a continuous sound. Besides that, the fan would also automatically turn on. The fan can also be manually turned on if it is necessary by turning on the fan switch.

Figure 7 CO smart detector during a test in normal air condition

Figure 8 CO smart detector during a test in a room filled with cigarette smoke

Figure 9 CO smart detector during a test using car fumes

5.0 CONCLUSION

With a growing awareness of Carbon Monoxide (CO) as a 'Silent Killer' and along with the rapid development of science and technology, many toxic gas alarm systems have been developed. This demonstrates the importance of having an effective alarm system to detect the presence of CO. This project was carried out using Arduino Uno as a microcontroller to control the whole system which acts as a gas emissions alarm system. It will detect CO in a vehicle. This device is capable of warning the user for emergency evacuation when the CO level exceeds 400 ppm [11]. In this system, the fan can be turned on manually using a switch or it will switch on automatically to reduce CO concentration if a dangerous level of CO concentration is detected.

There are many advantages in building a technology system that is based on Arduino Uno microcontroller. Some of the advantages are as follows:

1) Various sizes and peripheral selections
2) A wide selection of languages and tools
3) Robust hardware
4) Set of simple instructions

These advantages are the reasons why CO Smart Detector is easy to be programmed. The output system can be programmed to meet all the objectives of developing a toxic gas alarm system. Besides that, the signal used in the alarm system is simple and easy to understand.

As a conclusion, carbon monoxide (CO) is a very harmful gas to humans, and is very difficult to detect without the help of a machine [12]. Thus, this CO Smart Detector system is capable of detecting, measuring, alerting and assisting in the reduction of CO concentration. The developed system can be used for various applications such as inside vehicles, warehouse, public area (i.e bus stations), and in places with toxic gases. Finally, this Smart CO Detector has been designed, tested and proven to successfully detect and alert users of the presence of CO which will result in saving lives of those exposed to the gas.

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