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Carbon Dioxide and Carbon Monoxide Gas Detection System for Cars

Seow Mei Kee[1] and **Mohamed Sultan Mohamed Ali** [1*]

[1]School of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia.

[*]Corresponding author: sultan_ali@fke.utm.my, Tel: 607-5557165, Fax: 607- 5566272

Abstract: This paper report on a carbon dioxide and carbon monoxide gas detection system for cars. MQ7 and MQ135 are connected to ESP32 to detect carbon monoxide (CO) and carbon dioxide (CO2) respectively in this system. The numerical reading of the CO and CO2 are calculated in particles per million (ppm) and is displayed on a LCD. The real time result will also display on the Blynk mobile application. When the concentration of gases reaches a certain limit (1500ppm for CO2 and 35ppm for CO) the buzzer will on and an alert message will send to the mobile device informing the passenger on the danger. The aim of the system is to monitor the concentration of CO and CO2 in the car and enhanced the safety of the passenger in car.

Keywords: Carbon dioxide, Carbon monoxide, Gas sensor and IoT

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1. INTRODUCTION

People's lives are now closely connected to vehicles and other modes of transportation. Cars have almost become an indispensable means of transportation to humans as human often use car to drive from one location to another. Despite of enjoying a great comfort while driving the cars, there have been numerous cases where people died in car cabins due to suffocation or gas poisoning.

Carbon monoxide (CO) is a colorless and odorless gas that is extremely poisonous. CO is absorbed by the body in minutes, binds to hemoglobin, and thereby prevents the blood from transporting oxygen, causing the tissues without oxygen [1]. Vertigo, loss of consciousness, muscular impotence, and even coma and death (1 percent CO in the air kills in 15 minutes) are all symptoms of this CO poisoning [1].

On the other hand, Carbon dioxide (CO_2) is a colorless and odorless gas at low concentrations, but it has a sharp and acidic odor at sufficiently high concentrations. Headaches, dizziness, restlessness, tingling, dyspnea, sweating, tiredness, rapid heart rate, elevated blood pressure, coma, asphyxia, and convulsions are all possible side effects of a high CO2 level [2].

CO and CO_2 inhaled in excess can be harmful to humans' health and even lead to death. In United States, CO poisoning is a major cause of sickness and mortality which affecting about 50 000 people annually [3]. On 16 September 2020, three 21-year-old Malaysian girls died from alleged CO poisoning after falling asleep in their car in a petrol station parking lot [4]. CO_2 poisoning induces headaches and dizziness, making it difficult for the driver to concentrate on the road. When a driver is unable to maintain focus, an accident may occur.

Installing gas detection system in vehicle to warn the driver is a good solution of avoiding CO and CO_2 poisoning. There are many detectors had been developed to measure either only one gas (CO or CO_2) or both.

A standard IoT architecture for civil defense against the dangers of CO gas was proposed in 2019 [1]. The architecture was built on the MQTT communication protocol's publish-subscribe model. In 2019, Estrada et al. presented a low cost CO detector integrated with IoT system [5]. The system involved MQ-7 gas sensor (detect CO), ESP8266 integrated circuit, active buzzer and mobile application Blynk. Nest Protect is a smart smoke and CO alarm that used to detect smoke and CO in residential environment [6]. A CO monitoring and alert system for vehicles is created using MQ-7 CO sensor, power window, arduino, GSM modem and LCD screen [7].

For CO_2 detection, a real-time cognitive wireless sensor network system for CO_2 was proposed in 2016. This system used iAQ-2000 indoor air quality sensor to detect CO_2 concentration and radio module was used to performs the data exchange between the different nodes [8]. To produce, store, and visualize CO_2 concentrations, a monitoring architecture was developed [9]. The device combines the MQ135 and the ESP8266 to build a data collection wireless sensor network. Then, the information gathered was saved in a Firebase database and can be viewed using an Android app.

Kumar and Jasuja proposed an air quality monitoring system to monitor particulate matter 2.5 (PM 2.5), carbon monoxide, carbon dioxide, temperature, humidity and air pressure [10]. The data collected from the sensors can be viewed in the IBM Bluemix IoT platform anywhere when the device is connected to the internet. In 2018, Ibrahim proposed a CO and CO_2 level detector [11]. The system used MQ135 and MQ7 to detect CO and CO_2, a LCD display to display the level of gases in ppm, Arduino as microcontroller and buzzer as alarm when gas concentration is high.

The work done previously had successfully monitors the CO and CO_2 level individually or together. However, there are some gaps in the previous research works. The research works in [1],[5],[6] and [7] can be used to detect CO level in air but they cannot detect CO_2 concentration. Besides that the cost of device reported in [6] and [7] is high. In addition, the works in [8] and [9] can only be used to monitor the CO_2. In [10] and [11], both CO and CO_2 can be detected but they either does not contain alarm system or do not have an IoT platform to view the real-data of the sensor. The reading can only be view from the LCD on the device.

On the other hand, system reported in [9] and [10] does not contain alarm system to warn the user when the gas level is high. Besides that, most of the systems use only mobile phone or web to monitor the reading from the sensor and the gas level cannot be view directly from the device. This will be a problem when the user does not have any mobile phone with them.

This paper reports a low cost CO and CO_2 detection system for car that will help to reduce the risk of accident to be occurred. CO and CO_2 level in car is detect by using gas sensor and can be monitor using blynk mobile application as well as from the LCD display installed in the system. The alert message will be sent to the mobile phone and the buzzer will on when the gas concentration exceed its limit.

2. DESIGN AND WORKING PRINCIPLE

In this section, the overall concept of the system is being briefly described. The system architecture for our system is shown in Figure 1. The CO and CO_2 sensor are connected to the ESP32 microcontroller and is used to detect the CO and CO_2 level in the car cabin. The data collected by the sensors is continuously transmitted to the cloud database via ESP32 and Wi-Fi. The information gathered will be shown on the mobile app and LCD. The collected data will be compared to the threshold value set; if the data sensed by the sensor exceeds the threshold, the buzzer will buzz and a warning message will appear on the mobile app.

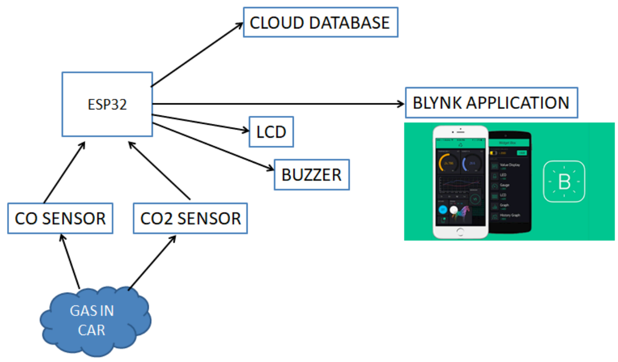

Figure 1. System architecture

One of the most important features in the proposed system is the selection of gas sensor. Metal Oxide Semiconductor (MOS), electrochemical, and optical sensors are the three types of gas sensors that are applicable for CO and CO_2 detection. Each type of gas sensor has its own set of characteristics, and the sensor selection is influenced by the system's overall power consumption, accuracy, lifespan, and cost.

Most of the gas sensors available in the market are belong to the MOS type. This is because they are small in size, have fast response times, are inexpensive, and have a long lifespan. They do, however, consume a lot of energy and have poor sensitivity, even though they are sensitive to environmental changes. Electrochemical sensors, on the other hand, are less susceptible to environmental changes and use less power, but they are more expensive and have a shorter lifespan. Optical sensors have a long life span and low energy consumption, but they are considerably more expensive, more difficult to incorporate into a device, and more easily damaged [12].

The sensor used in the system is MOS type as it is easy to get from the market, has fast response time, low cost and long lifespan. Since the system is to be implement in the vehicle and the environment change in the vehicles is very small so it should not be a big problem. The MOS type sensor used in this system is from MQ series and it is available as module. The analog output voltage provided by the sensor change in proportional to the concentration of smoke or gas.

3. ACTUAL SYSTEM

The hardware of the system includes a ESP32, a MQ-7 sensor, a MQ-135 sensor, a relay, a step-down converter, a I2C LCD, resistor (3.3kΩ and 1.7kΩ) and jumper wire. Figure 2 shows the circuit connection of the system.

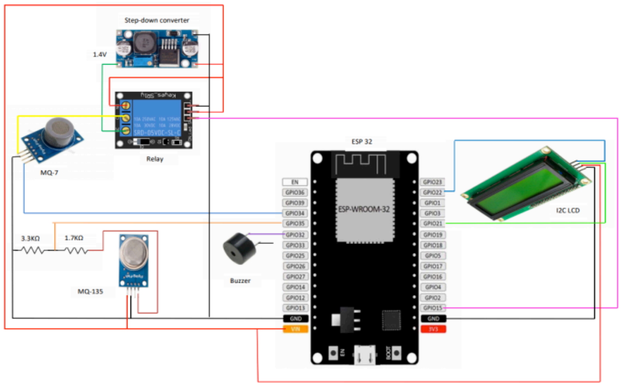

Figure 2. Circuit connection

ESP32 is the microcontroller used to control the overall system and it provides Wi-Fi functionality to the system. I2C LCD is a device that has a 16x2 LCD display screen with I2C interface and it is used in this system to display the level of CO and CO_2. The buzzer is used to add sound features to the system when the gas level in the car reaches the threshold set.

The gas sensor used are MQ-135 and MQ-7. MQ135 is used to detect the CO_2 in the car while MQ-7 is used to detect the CO. According to the MQ7 datasheet, the sensor detects by using a cycle high and low voltage process [13]. The sensor senses CO during the low temperature process (heating by 1.4V) and produces useful data. The gas absorbed on the sensor plate during the 1.4V period is evaporated (cleaning for the next measurement cycle) at high voltage (5V). A relay module and a step-down buck converter are used to accomplish this. The relay is used to cycle between 1.4V and 5V while the step-down converter is used to step down the 5V supply to 1.4V.

By referring to the sensitivity characteristics of the MQ-7 [13] and the MQ-135 [14] from the datasheet, the relationship between gas concentration in ppm and the sensor's resistance ratio RS/RO, where RS represents sensor resistance at different gas concentrations and RO represents sensor resistance at a known concentration without the presence of other gases, or in fresh air can be obtained. The ppm of the gas can be calculated using the "Equation (1)".

$$ppm = a \times \left(\frac{Rs}{Ro}\right)^{b} \tag{1}$$

The constant values of scaling factor (a) and exponent (b) for the gas we want to calculate can be obtained using the power regression.

The data collected by the sensor is send to blynk server and also firebase database via Wi-Fi connection through ESP32. A blynk mobile application is created to monitor the gas concentration in real time using a mobile phone. The display of the blynk application is show in Figure 3. The buzzer will buzz and the notification will be pop out on the mobile phone when the CO or CO_2 concentration reaches the limit set.

Figure 3. Blynk application

The Firebase real-time database is also created. The user can monitor the gas level in car using web without installing the blynk application.

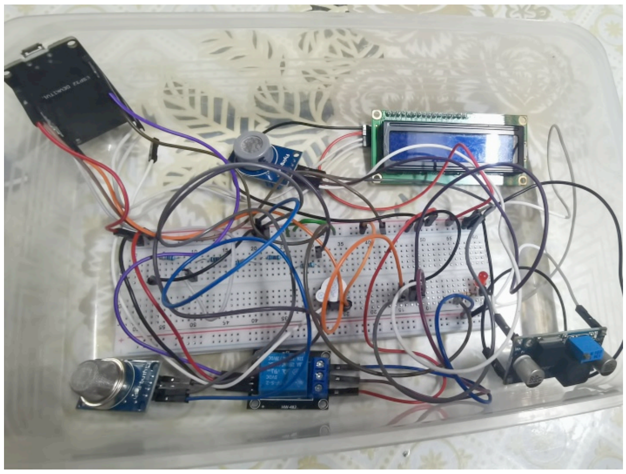

Figure 4. Assembled circuit

4. RESULTS AND DISCUSSION

The initial testing of the device was performed in a room with dimension of 7.5m x 4.8m x 3.05m for 2 hours. The test was performed without any one present in the room and the window in the room was opened. The measured result for the CO and CO_2 are shown in Figure 5 and Figure 6 respectively.

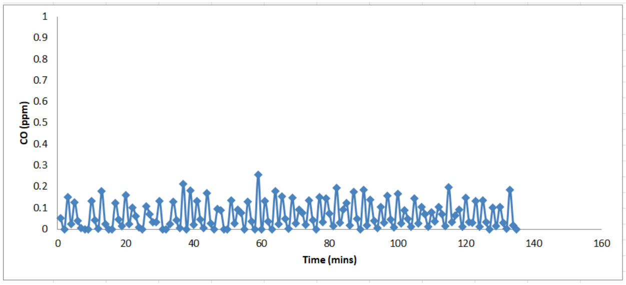

Figure 5. CO concentration in room

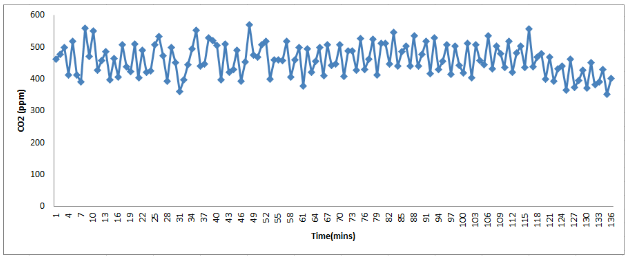

Figure 6. CO_2 concentration in room

The result collected show that the system is able to detect the CO and CO_2. Figure 5 shows the CO concentration is in the range of 0 to 0.3 ppm from the initial test. The 0ppm is due to the assumption that there is no CO reading during the heating cycle of MQ-7 (heating by 5V) as the gas absorbed is evaporated from the sensor plate. Figure 6 show that the CO_2 level in a room without anyone present is between 350ppm to 550ppm which is the normal indoor CO_2 level.

We also test the functionality of MQ-135 sensor by exhaling in front of the sensor. When we breathing near the sensor, the CO_2 is detected and the value of ppm increased. In order to test for the MQ-7 sensor, we collected the smoke of combustion in a jar with diameter 0.08m and height 0.115m (CO is produced by incomplete combustion). According to Figure 5, the CO level at normal condition is below 1 ppm. However, when the MQ-7 sensor is placed inside the jar as shown in Figure 7, the reading of the MQ-7 sensor increases to about 10ppm.

Figure 7. Functionality test on MQ-7

The system is then test in a static car with different amount of people and the air conditional in the car is on. The times taken for the gas to reach it safety limit 1500ppm for CO_2 and 35ppm for CO is observed and recorded. The experiment is stopped immediately after the gas exceed it limit for the safety purpose. The result is shown in Figure 8 and Figure 9.

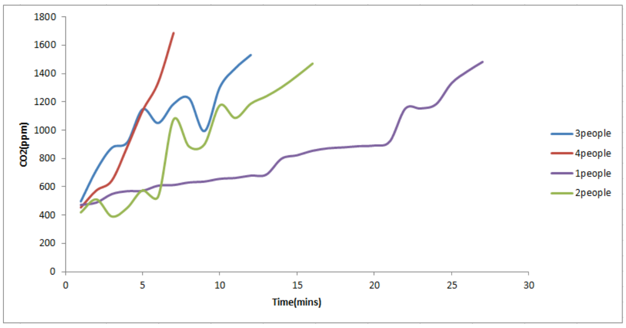

Figure 8. CO_2 level with different amount of people in car

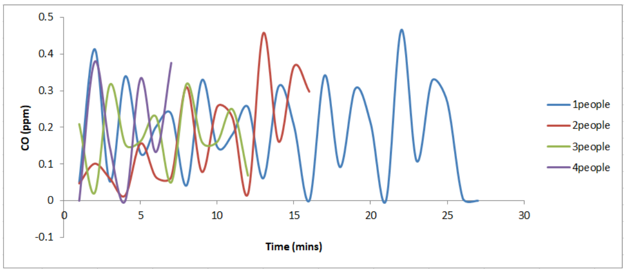

Figure 9. CO level with different amount of people in car

When the concentration of gas reach the limit set, the buzzer is on and the notification is send to the mobile phone.

Figure 10. Notification pop out on blynk application

The result in Figure 8 shows that the CO_2 level in the car increase with time. The result shows that with four passengers in a car, the CO_2 level reaches 1500 ppm in seven minutes, which is the fastest. With one passenger in car it reaches 1500ppm in 27 minutes, 16 minutes with two passengers and 12 minutes for three passengers. From Figure 9 we can observe that the CO level for different amount of passenger in car does not seen to have much different. This may due to increasing of people will cause the level of CO_2 exhaled increase but had not effect to the CO concentration.

5. CONCLUSION

In this paper, a low cost carbon dioxide and carbon monoxide gas detection system for cars is developed. The device will detect a rise in CO and CO_2 levels inside a car and alert the driver and passengers on the potential risk. An alert text message will be send and the alarm will rang if the CO concentration exceeds the normal amount. The concentration of the gas can be monitor using a mobile phone. The system is inexpensive and is portable, thus it can be installed in any car easily.

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