

Microcontroller-Based Carbon Monoxide Detector

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Abstract

Carbon monoxide gas is a major source of environmental pollutant that emanates from fuel combustion with limited oxygen. The gas is lighter than the air and could be poisonous and dangerous if inhaled in high quantity by human beings. To prevent or reduce this poisoning and its effects, it is imperative to design and construct a detector that can assess the carbon monoxide levels in an environment and provide the concentrations level. The design involves assembling MQ-7 sensor and Atmega 328 microcontroller as the processor. Analogue input from carbon monoxide sources is converted to digital output and the result is displayed using Liquid Crystal Display (LCD). The output voltage of carbon monoxide emitted from vehicles, petrol and diesel generator, candle, etc. is determined. Decisions such as sending alerts to designated personnel or agency via short message service (SMS), phone call or by email, or sending commands to the actuators to turn on the environmental control devices.

Keywords: Microcontroller, carbon monoxide, detector, LCD, sensor, Atmega 328, buzzer.

1. Introduction

Carbon monoxide (CO), referred to as the silent killer gas, emanates from fuel combustion with limited oxygen. Once inhaled, the carbon monoxide inhibits oxygen's ability by replacing the oxygen in the red blood cells, and thereby preventing the supplied oxygen from reaching necessary organs in the human body. Carbon monoxide gas is a major source of air and environmental pollutant around the world especially in Nigeria where it accounts for a significant number of health fatalities (Ayres & Ayres, 2019). The toxicity of carbon monoxide is as a result of its affinity to react with transition metals, such as iron, that are found in the middle of a haemoglobin molecule. The absorption of carbon monoxide occurs through inhaling into the human blood system by interchange of gas in the lungs (Akinyemi & Usikalu, 2010; Roth et al., 2011). CO emission also contributes to the greenhouse effect causing climatic disturbances. To discourage the driving of vehicles with bad engines and exhaust pipes, law enforcement agencies need the CO detector to analyze the level of CO released by vehicles, burning of refuse and cooking in households using firewood and coal as fuel as the effective monitoring of CO released into the atmosphere is still a challenge to the ministry of environment and road safety officers.

The harmful effects of carbon monoxide can also be traced to binding with haemoglobin. As such, these dangerous effects to organisms that do not use this compound cannot be easily ascertained. For instance, Blumenthal (2001) reported that it does not affect photosynthesizing plants. Since it is easily absorbed through the lungs, inhaling carbon monoxide can cause nervous system damage, hypoxic injury, and even death in some serious cases. It has been reported (Prockop & Chichkova, 2017) that it is possible for different people and populations to have different levels of carbon monoxide tolerance. Suffices to note, however, that exposures at an average level of 100 PPM or greater is dangerous to human body and health. In the United States America, the Occupational Safety and Health Administration (OSHA) limits long-term workplace exposure levels of carbon monoxide to less than 50 PPM averaged over 8 hours. Furthermore, employees are advised to be evacuated from any closed or confined space if an upper limit ("ceiling") of 100 PPM is attained. Carbon monoxide exposure may lead to heart damage and thus causes a significantly shorter life span in human. The carbon monoxide tolerance level of people can be changed

by different factors, such as rate of ventilation, activity level, a pre-existing cardiovascular or cerebral disease, cardiac output, anaemia, sickle cell disease and other forms of hematological disorders, metabolic rate, and barometric pressure (Lipman, 2006).

In Table 1, the effects of carbon monoxide in relation to different concentration levels in the air are given. The concentration levels are given in parts per million. The table is given to further underscore the danger of exposure to carbon monoxide.

Table 1. Effects of carbon monoxide in relation to the concentration (in parts per million) in the air

Concentration	Symptoms
35 PPM (0.0035%), (0.035‰)	Dizziness and headache within 6 - 8 hours of continuous exposure
100 PPM (0.01%), (0.1‰)	Slight headache within 2 - 3 hours
200 PPM (0.02%), (0.2‰)	Slight headache within 2 - 3 hours; insensible
400 PPM (0.04%), (0.4‰)	Frontal headache within 1 - 2 hours
800 PPM (0.08%), (0.8‰)	Nausea and convulsions within 45 min; loss of judgment within 2 hours
1,600 PPM (0.16%), (1.6‰)	Headache, dizziness and increased heart rate within 20 mins; death within 2 hours
3,200 PPM (0.32%), (3.2‰)	Headache, nausea and dizziness in 5 - 10 mins; death within 30 mins.
6,400 PPM (0.64%), (6.4‰)	Dizziness and headache in 1 - 2 mins; convulsions, respiratory arrest, and death in less than 20 mins.
12,800 PPM (1.28%), (12.8‰)	Unconsciousness after 2 - 3 breaths; death in less than 3 mins.

Thus, there is need for carbon monoxide detection to protect and save lives. This constructed device acts as a metering system used to monitor the level of carbon monoxide concentration in air. It automatically sounds an alarm and displays on Liquid Crystal Display (LCD) if the carbon monoxide concentration level exceeds the set limit.

Aside the introduction section, the other sections of this paper have been organized as follows: Section Two provides information about past related works. In Section Three, the methodology, design and analysis of the detecting device are presented. Results are presented and discussed in Section Four. Finally, conclusion is given in Section Five.

2. Related Works

Poisoning from carbon monoxide typically occurs when it is breathed in at excessive levels (Guzman, 2012). The symptoms that come with it are often described as "flu-like" and commonly presents themselves in form of dizziness, headache, weakness, chest pain, vomiting, and convulsion. The excessive exposure can lead to unconsciousness, arrhythmias, seizures, or even death. While the classically described "cherry red skin" rarely occurs, the long-term complications also include tiredness, loss of memory, and numbness.

CO is a colourless and odourless gas, produced during an incomplete burning of organic matter, that is non-irritating at the initial stage (Bleecker, 2015). This process usually occurs in automobiles, generators, heaters, or cooking equipment that use carbon-based fuels. The process can also occur from exposure to methylene chloride. Carbon monoxide poisoning which can also occur accidentally, primarily causes adverse effects by combining with haemoglobin to form carboxyhemoglobin (HbCO). This combination prevents the blood from carrying oxygen to the required parts of the body (Bleecker, 2015). In addition, mitochondrial cytochrome oxidase and myoglobin are

affected. The diagnosis is based on a HbCO level greater than 10% among smokers and greater than 3% among nonsmokers (Schottke, 2016).

The death risk among people affected by carbon monoxide poisoning is between 1 and 30% (Guzman, 2012). Apart from proper venting of gas appliances, keeping exhaust systems of automobiles and generators in good repair, and keeping chimneys clean, other ways of preventing poisoning include carbon monoxide detectors. Generally, treating carbon monoxide poisoning consists of administering 100% oxygen and giving other forms of supportive care to the patient. This should be carried out continuously until symptoms are no longer present and the HbCO level reduces to less than 10%.

Carbon monoxide poisoning is the most common type of fatal poisoning in many countries. For instance, it is quite common in the United States of America, as it accounts for over 20,000 emergency cases in a year. Carbon monoxide poisoning cases is usually higher during the winter, due to occurrence particularly from the use of small-sized generators whenever there is outage of electricity supply. While the toxic effects of carbon monoxide have been known since ancient history, the discovery that haemoglobin is affected by carbon monoxide followed much later (Omaye, 2019). Other clinical related works on carbon monoxide are in Ferri, F. F. (2016) and NCEH (2020). Kao & Nanagas (2016) worked on toxicity associated with carbon monoxide.

Some of the recent carbon monoxide related works include Buckley, et. al. (2021) on hyperbaric oxygen for carbon monoxide poisoning, as well as Coulange, et. al. (2018) which has to do with reliability of new pulse CO-oximeter in victims of carbon monoxide poisoning. Dai, et. al. (2019) used mobile phone to detect drunk driving. Kousikan & Sundaraj (2016), Pintou (2014), Vaishnavi, et. al. (2016), Prashanth, et. al. (2018) and Lea, et. al. (2016) also worked on alcohol driving detection and prevention systems. Using GPS and GSM modules with intelligent devices, Musa, et. al. (2019) tracked vehicles to prevent drunk driving and accidents. The works in Musa & Adefisayo (2020) and Musa & Paul (2019) also involved intelligent sensing and detections. Some of the detection technology mentioned and more have been leveraged on to design the carbon monoxide detection system in this work.

Additional three related systems designed, constructed and implemented by Yen et al. (2021), Paruchuri & Rajesh (2018) and Gupta & Rakesh (2019) are also reviewed. An Arduino based CO detection in vehicles was implemented by Yen et al. (2020). The system measures the level of carbon monoxide in a vehicle cabin and a buzzer alarm is activated when there is a leak of carbon monoxide in the vehicle. However, monitoring is rather difficult with the system and it is unable to interact with the vehicle.

In Paruchuri & Rajesh (2018), toxic gas detection and alerting system for vehicles was designed. The level of CO present in the vehicle cabin is detected using microcontroller and sensor. An alarm circuit was designed to alert the user whenever the CO level reaches 30 PPM.

Using Raspberry Pi and gas sensor, a detector model was designed by Gupta & Rakesh (2019) to monitor the emission of CO in vehicles in real-time. The gas sensor communicates with the Raspberry Pi to detect the emitted CO. The values recorded in PPM are stored in the local database of Raspberry Pi and can be sent online to an email. Action could be taken in cases of vehicles emitting more than a threshold level. However, CO emitted from other vehicles may affect the accuracy of the value obtained using this system because it is installed at the exhaust.

3. Methodology

Carbon monoxide detector is assembled from the following components: a sensor, which measures the gaseous concentration and sends a signal when the carbon monoxide concentration is at a predetermined level; a microprocessor, which is capable of receiving an electrical signal from the sensor and able to send the signal to alarm horn and the control panel; a visual display, i.e. the LCD panel which communicates the level of carbon monoxide as well as other operating information; an alarm circuit, that can generate a very loud sound; a circuit board that serves as a base for the electronic components; and a power connection (either an AC or DC battery connection or both).

Figure 1 is a block diagram of the carbon monoxide detection system. In Figure 2, the circuit diagram of the carbon monoxide detector is shown. Some of the materials and devices in the circuit have been listed in Section 3.1. A brief description of some of the components including ATmega328, buzzer, LCD, LED, and other electronic devices have also been given.

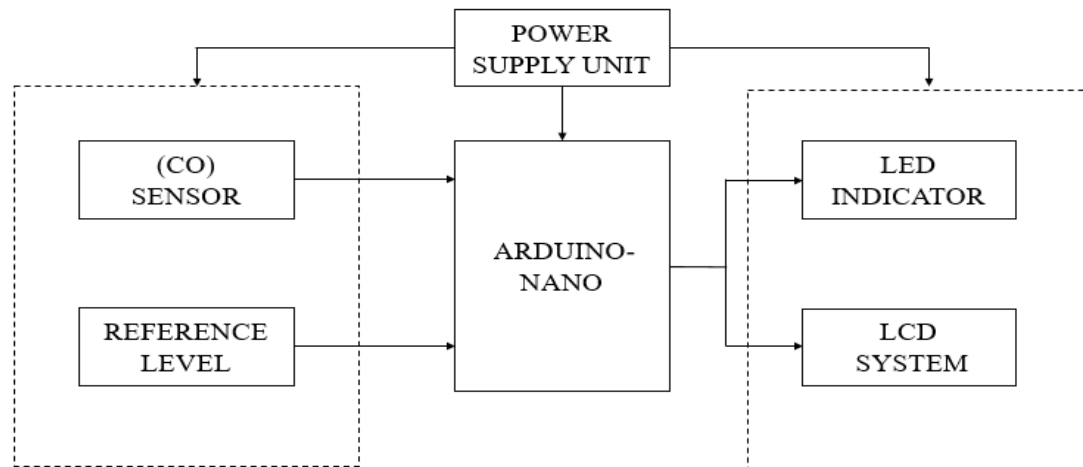


Figure 1. Block diagram of carbon monoxide detection system

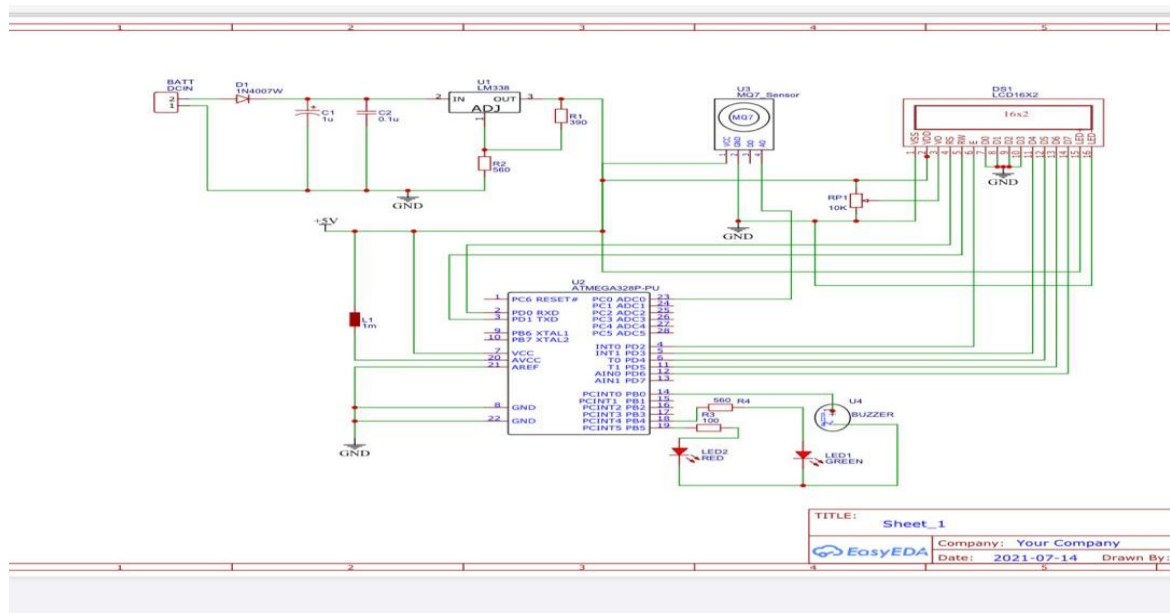


Figure 2. Circuit diagram of carbon monoxide detector

3.1 Materials

The materials used to construct the microcontroller-based carbon monoxide detector include the following:

- ATmega-328: It serves as the central processing unit of the system. The microcontroller receives signals and values from external modules and sensors and processes the information to give an appropriate output according to the code uploaded in the flash memory.

- ii. Liquid Crystal Display (LCD): LCD are used for displaying characters on the screen. The LCD used is a 20×4 display type.
- iii. Light Emitting Diode (LED): LEDs are used to show the current status/level of the energy unit available.
- iv. Rectifiers: Rectifiers are used to convert AC to DC voltages.
- v. Resistors: A resistor is an electronic component used for limiting the current that flows across it.
- vi. Capacitors: The capacitors have been used to remove noise in the DC voltage.
- vii. LM338T: The LM338T is used for producing a constant steady voltage (5V).
- viii. Diode: Diodes are electronic components that let current flow in only one direction (forward-biased).
- ix. Buzzer: The buzzer is used for alarm and to alert user that the energy unit is been exhausted.

3.2 System Hardware Construction

The system hardware design is the physical part of the system which is made up of the following circuit units: power unit, sensor unit and logic control unit. Figure 3 shows a part of the system hardware component.



Figure 3. System hardware component



Figure 4. Constructed detector undergoing test when the carbon monoxide concentration is above the set limit.

3.3 Software Programming

The software section is made up of programs that will control the microcontroller at the center of the system. The section presents the system flow charts, programming of Arduino, state the relevance of software in the system operation. The system flow chat is as presented in Figure 5.

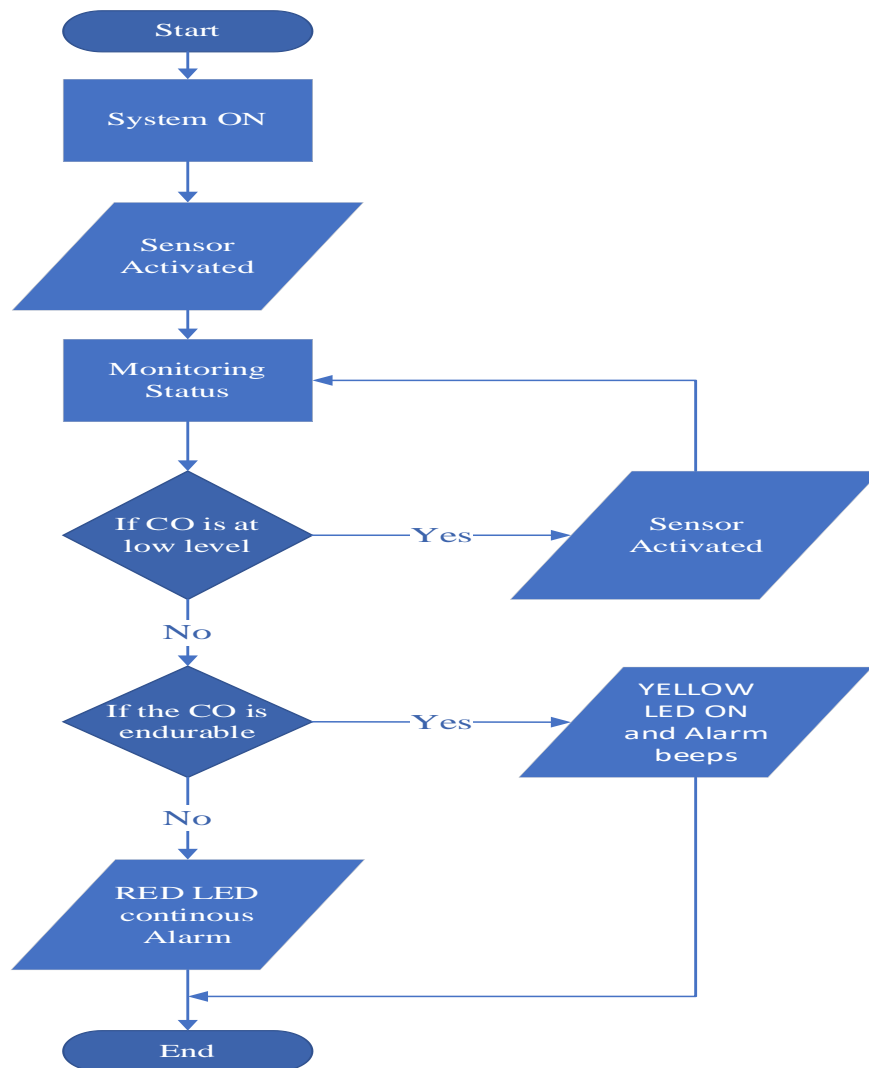


Figure 5. Flow chart showing the system operation

Figure 6 is the circuit diagram showing the complete simulation of the system which serves as the basis for the hardware construction.

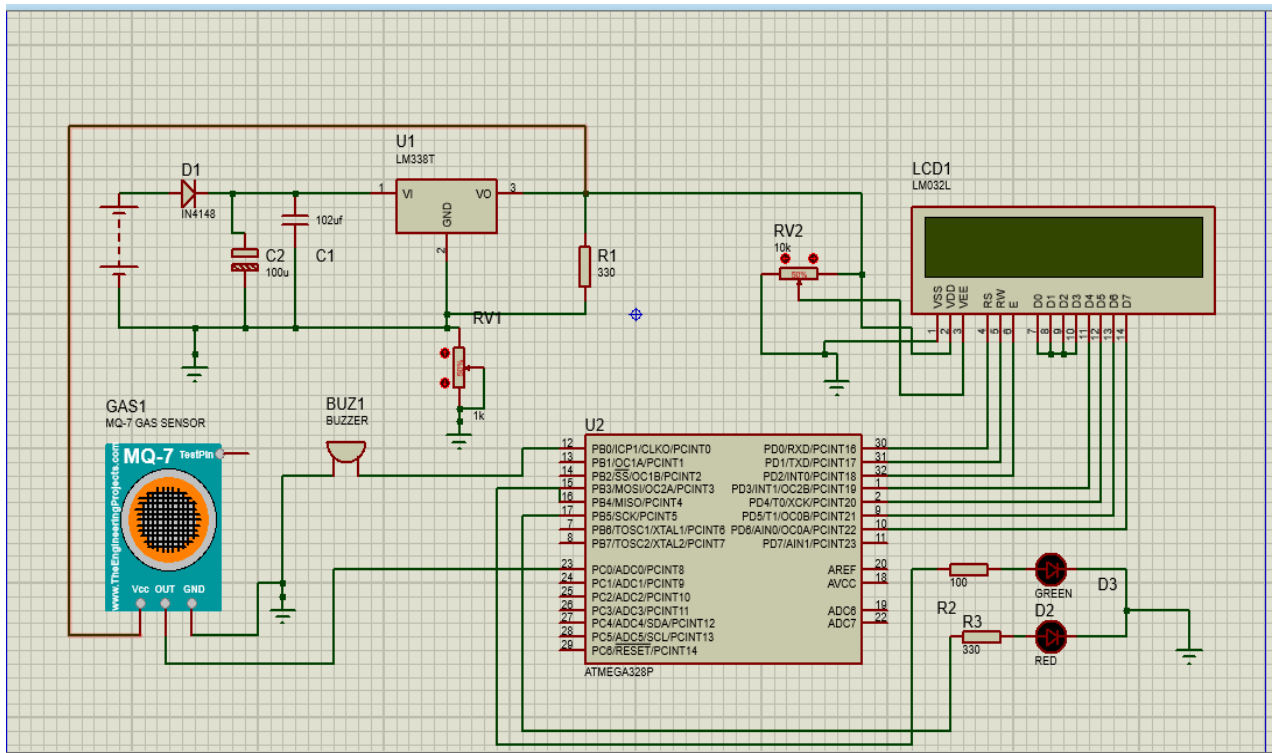


Figure 6. Complete simulation.

4. Results and Discussion

The sensor can detect the presence of carbon monoxide in the environment concerning the range of the sensitivity of the sensor. The respective analogue values of the concentration of the carbon monoxide detected have been taken at a different location and distance. Range of the sensitivity selected for this work is between 0 to 20 cm as shown in Table 2. The Table shows the results taken from the MQ-7 CO sensor placed in different locations. Their approximate analog values from the CO sensor at each environment were also recorded. It can be seen from the results that as the distance and location is varied and increased, the CO concentration detected and analog value decrease.

Table 2. CO concentration (%) and Distance (cm) with their approximate analog values

Distance (cm)	Analog value (0-1023)	CO Atmospheric (%) i.e. $[\text{Analog value} / \text{Total analog value}] \times 100$
0	500	48
5	400	40
10	300	30
15	200	20
20	100	10

Furthermore, the operation of the system when the carbon monoxide concentration detection is either in a high or low state is shown in Table 3. The Table shows how the system will operate when the CO concentration detected is either in high or low state.

Table 3. Operation of the system

Set Limit	32 PPM	1656 PPM
State/ Level	Low	High
Indicator	Green	Red
Buzzer	Off	On

5. Conclusion and Recommendations

As earlier emphasized, the environmental pollution caused by emission of carbon monoxide from vehicle and generator exhausts need to be reduced in order to save the environment from existential threats such as global warming, wildfires, food supply disruptions, etc. This work, compared to others, provides a cost-effective, easy-to-operate and easy-to-maintain system that can detect the concentration of carbon monoxide present in the atmosphere. If a relatively high level of carbon monoxide is detected, the device sounds an alarm and gives people the opportunity to properly ventilate the building or take other precautionary measures. Unlike smoke detectors, carbon monoxide detectors do not necessarily need to be positioned near ceiling levels. The developed carbon monoxide detector is recommended for use to reduce environmental pollution and increase vehicles life. It is also recommended for regulatory authorities to integrate the proposed system into automobiles and buildings for immediate detections and actions. If this is achieved, some serious public health issue challenges can be addressed and brought down to a minimum level.

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