Carbon Monoxide (CO) ppm Density Measurement with High & Low Heating Cycles using MQ7 Discrete Semiconductor Sensor

Yash Vidyasagar
Student, M.Sc. I year,
Department of Electronics, Fergusson College Pune

S.M. Nagrale,
Department of Zoology,
Shri R.L.T. College of Science, Akola

Abstract

The CO equally affects healthy and unhealthy people. The breathing of CO can cause headache, vomiting, nausea and dizziness. If the level of CO is high enough, it a person may become unconscious or die. Exposure to moderate and high levels of CO over long periods of time has also been linked with increased risk of heart disease. If more amount of CO is taken in breathing, it may reduce the amount of oxygen carried by haemoglobin around the body in RBC. Due to this vital organs, such as brain, nervous tissues and the heart, do not receive enough oxygen for proper working of bodily functions. So to measure the density of CO in surrounding atmosphere we have used the reliable MQ7 sensor for precise measurements. The sensitive material of MQ-7 gas sensor is SnO2, which with lower conductivity in clean air. It make detection by method of cycle high and low temperature, and detect CO when low temperature (heated by 1.5V). We have designed simple Arduino UNO based system, to convert change of conductivity to correspond output signal of gas concentration. MQ-7 gas sensor has high sensitivity to Carbon Monoxide. The sensor could be used to detect different gases contains CO, it is with low cost and suitable for different application.

Nomenclature

R_s	Surface resistance of MQ7	s	surface
R_L	Series wound load resistance	L	load
V_c	Transistor collector voltage	c	collector
V_{RL}	Load voltage measured	RL	load resistor

Introduction

The system of CO density measurement uses the most reliable CO sensor, MQ7 for getting precise measurements. As per the data sheet of MQ7 carbon monoxide sensor, it is necessary that the MQ7 sensor must be activated through high and low heating cycles in order to get proper measurements. During low temperature phase, CO is absorbed on the plate of the sensor, producing accessible data. During high temperature phase of the sensor, the absorbed CO and other compounds by the sensor, evaporate from the sensor plate, cleaning it up for the next measurement, as give in the code of this project. *This project uses Arduino Nano ATMega328p microcontroller module with discrete MQ7, carbon monoxide sensor module with few other accessories*.

Mathematical Analysis

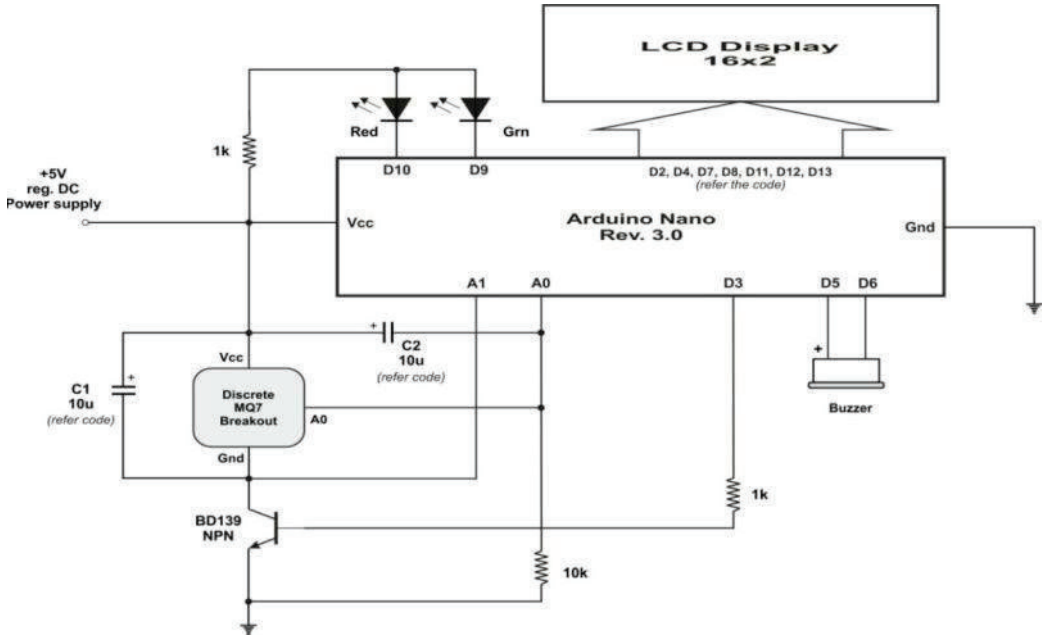
The surface resistance of the sensor Rs is obtained through effected voltage signal output of the load resistance RL which series-wound. The relationship between them is described:

$$\frac{R_s}{R_L} = \frac{(V_c - V_{RL})}{V_{RL}}$$

The output signal when the sensor is shifted from clean air to carbon monoxide (CO), is found to have abrupt changes. The output signal measurement is made within one or two complete heating period *(90 seconds from high voltage to 60 seconds for low voltage)*.

Sensitive layer of MQ7 gas sensitive components is made of SnO2 with stability, so it has excellent long term stability. Its service life can reach 5 years under using condition. The processed result is displayed on the Serial Monitor in Arduino software. There are three values under monitoring: Raw value, Heating time of MQ7 Sensor, CO ppm value. The circuit can be modified to display the results of 16x2 LCD display. The values measured in this circuit are compared with the Indian PUC standard values.

Block Diagram



Principle of Working

According to MQ-7 datasheets, this sensor has to run through high and low heating cycles in order to get proper measurements. During low temperature phase, CO is absorbed on the plate, producing meaningful data. During high temperature phase, absorbed CO and other compounds evaporate from the sensor plate, cleaning it for the next measurement. In general its operation can be understood step by step:

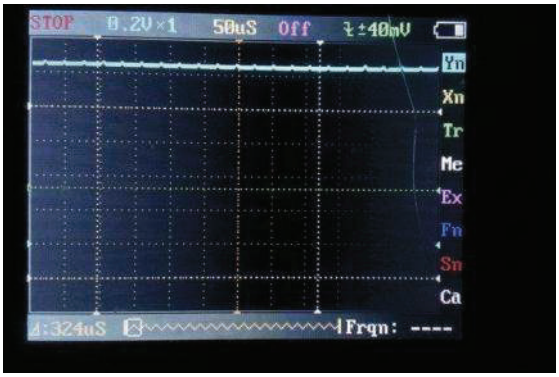
1. Apply 5V for 60 seconds; don't use these readings for CO measurement.
2. Apply 1.4V for 90 seconds; use these readings for CO measurement.
3. Go to step 1 again in the form of a loop i.e. **void loop()**

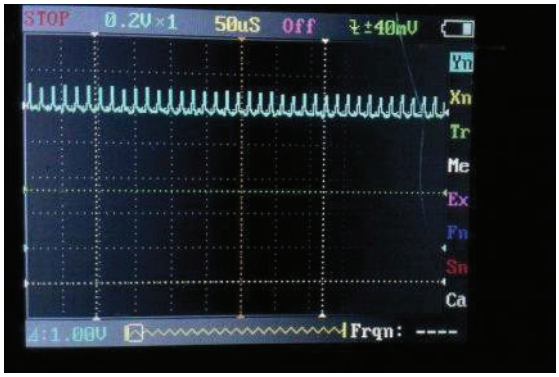
But Arduino can't provide enough power to run this sensor from its pins - sensor's heater requires 150 mA, while Arduino pin can provide only 40 mA, so if we attach it directly, Arduino will burn and sensor will not work.

The Arduino code is available on the 1st author's profile on www.github.com on request.

So we must use some kind of current amplifier that takes small input current to control large output current. Another problem is getting 1.4V. The only way to reliably get this value without introducing a lot of analog components is to use PWM *(Pulse Width Modulation)* approach with feedback that will control output voltage.

NPN transistor solves both problems: when it is constantly turned on, voltage across the sensor is 5V and it is heating for high-temperature phase. When we apply PWM to its input, current is pulsing, then it is smoothed by the capacitor, and the average voltage is kept constant. If we use high frequency PWM *(in the sketch it has frequency of 62.5 KHz)* and average a lot of analog readings *(in the sketch we average over ~1000 readings)*, then the result is quite reliable. We found that it is critical to connect capacitors. Images here illustrate difference in signal with and without C2 capacitor: without it, PWM ripple is clearly visible and it significantly distorts the readings, as shown below.





Practical Experimentation

We practical tested density of CO present in surrounding air at various places in Pune & Akola Ozone Day, 16 September 2019. We applied analytical and statistical methods for the measurement of CO in ppm, neglecting for other traces like nitrogen oxides *(NOx)*, sulphur dioxide *(SO2)* and suspended particulate matters *(SPM)*. The graphs of these readings will be explained in presentation. As per a case study done of *Assessment of Traffic Related Air Pollution and Ambient Air Quality of Metropolitan Cities, in Pune*, the air quality correlation also analyzed with the fuel types and it was observed that petrol vehicles contribute more pollution than diesel.

NAASQ Standardisation

The U.S. National Ambient Air Quality Standards (NAAQS) are standards for harmful pollutants. Established by the United States Environmental Protection Agency (EPA) under authority of the Clean Air Act (42 U.S.C. 7401 et seq.), NAAQS is applied for outdoor air throughout the country. The seven criteria of air pollution are: The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulphur dioxide. Criteria pollutants are the only air pollutants with national air quality standards that define allowable concentrations of these substances in ambient air.

References

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3. Reference of a working project of CO density measurement: http://www.instructable.com/ the_3d6 from Ultimate Robotics: reference for Arduino coding