EP 315 Project Report
Breath Analyzer using Arduino and MQ3 Sensor

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1 Introduction

A breathalyzer is a device used for estimating Blood Alcohol Content (BAC) from breath. An alcohol (gas) sensor is the main part of the device and its functions are carried out by a microcontroller. Chemical reactions occur inside the sensor when exposed to alcoholic vapours, and these alter a variable resistance inside the sensor. A voltage is recorded at the output, the magnitude of which depends on the concentration of alcohol in the sample.

The aim of our project was:

- To build a breathalyzer device that tests presence and concentration of rubbing alcohol in a vapour sample.
- To compare the measured concentration with a ”limit” value, and conclude whether the sample is from a drunk or sober individual.
- to build a car-control system that restricts driver from operating the car if he is declared drunk by the breathalyzer.

2 Apparatus Used

- Arduino Uno
- MQ3 alcohol sensor
- LCD Display (16*2)
- AC to 9V DC adapter
- IC 7805 Voltage Regulator
- AND Gate

3 Details about MQ3 sensor

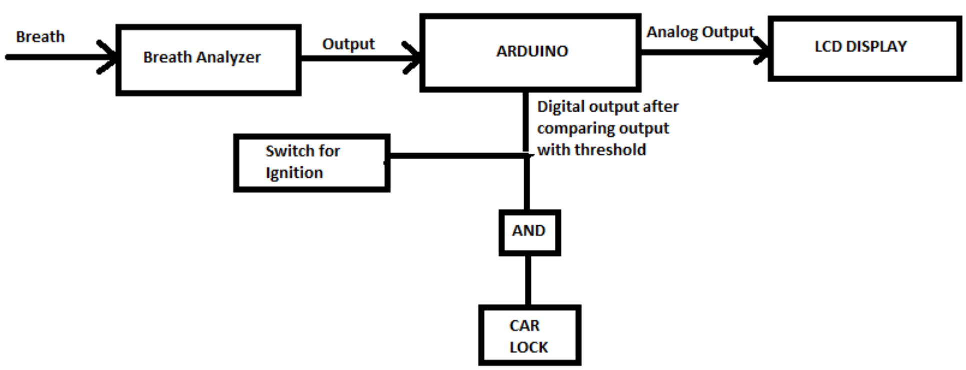
The MQ3 sensor has 4 pins - VCC, GND, AO(Analog Output) and DO(Digital Output). The sensor is made of Al_2O_3 ceramic tube and tin dioxide sensitive layer. The heater in the sensor draws a considerable amount of current and hence it is not recommended to use the Arduino as its power source.

The sensor resistance varies depending on the amount of alcohol in the air. Higher the amount of alcohol in the air, lower is the sensor resistance. The sensor resistance along with a load resistance forms a voltage divider. The MQ3 sensor gives the voltage across this load resistance as the output; this value increases with alcohol concentration in sample.

4 Setup

The output from a AC to 9V DC adapter is fed to a IC 7805 voltage regulator to produce a 5V output to power the MQ3 sensor and the LCD display.
The LCD display acts as the interface to the user and is initially in idle mode. The user needs to connect a Arduino input pin to 5V output and then disconnect it to prompt the Arduino to take readings from the sensor. From the time the input received by this pin switches from HIGH to LOW, 250 readings are taken and stored in a 10 second interval. The maximum value from these readings is taken and then converted into corresponding concentration value (See Calibration section for details). This output is displayed for a 10 second interval after which the setup again goes into idle mode and waits for a prompt to start taking readings.

4.1 Block Diagram



5 Calibration and testing

Due to unavailability of alcoholic beverages, all calibrations and tests have been done with surgical rubbing alcohol (70% by volume isopropyl alcohol solution).

The variable resistance inside the sensor is R_s, and the value of R_s upon exposure to atmosphere (no sample) is called R_o. The more alcohol, the lower the value of R_s. Instead of measuring this resistance directly, we measure the voltage level at the point between the sensor and a load resistor. The sensor and load resistor form a voltage divider; lower the sensor resistance, higher is the voltage reading across the load resistance. This value read by the analogRead function lies between 0 and 1024 and corresponds to a voltage range of 0 to 5 volts. Higher values of voltage mean higher concentration in sample.

The calibration method as suggested in the sensor's datasheet is to take a number of solutions with different, known concentrations and plot $\log(R_s/R_o)$ versus log C. This is an extremely hard approach for the following reasons :

- The sensor is sensitive to humidity and temperature of surroundings, and the value of R_o is not stable, especially during repeated measurements with samples of different concentrations.
- It is practically impossible to have a fixed concentration of highly volatile alcohol in vapours and determine the ratio R_s/R_o.
- The bigger issue with R_s/R_o approach, is that there is no solid data in the data sheet(there is a graph) that maps a certain ratio to a parts per million (ppm) measurement.

For these reasons, we devised our own method of calibrating the sensor. It is largely based on convenience of preparing solutions of different concentrations and it is as follows:

- We prepared rubbing alcohol solutions of different concentrations by volume (as shown in figure 1 below).
- We used a spraying bottle to spray solution three times onto a piece of cloth. Immediately after that, the cloth was held at a fixed distance of 1.3 cm from the face of the sensor for three seconds. These are optimal values of time, number of sprays and distance chosen after trials with different values.
- The Arduino receives continuous values of output voltage, and these values are plotted against time of measurement (discrete) on a graph. The peak value of voltage over a fixed interval of time, is considered as the output for that particular concentration. The peak value is chosen after it was noted to be an obvious measure that definitely depends on the concentration.
- The peak values were recorded multiple times for each concentration and their mean was considered. A scatter plot of log C vs log V (values in Figure 2) over the range of detection was made and the best linear fit for the data was obtained and extrapolated to other values of C. A linear fit (Figure 4) was decided since the plot of log (R_s/R_o) versus log C in the data sheet (Figure 3) was shown to be linear and we approximated the voltage V to be inversely proportional to R_s.
- The following best fit line was obtained:

  $$\log C = 3.23 \log V + 3.92 \tag{1}$$

  for the range $V \in (0.87, 3.63)$ Volts. This was used in the source code to calculate concentration of alcohol in a given sample.

1	% conc of rubbing alcohol	R1	R2	R3	R4	R5	R6		Average
2	5	296	322	365	0	0	0		327.666667
3	15	367	384	355	412	0	0		379.5
4	20	429	421	440	417	0	0		426.75
5	25	538	468	509	0	0	0		505
6	40	635	546	548	0	0	0		576.333333
7	50	660	626	680	643	518	542		611.5
8	60	616	691	590	656	0	0		638.25
9	75	669	695	710	0	0	0		691.333333
10	80	761	712	652	662	0	0		696.75

Figure 1: Sensor Readings for different concentrations of samples, '0' indicates no reading

1	% conc of rubbing alcohol	Average	Voltage(volts)	log V	w/v(mg/L)	log C
2	5	327.666667	1.599934896	0.204102311	27510	4.43949059
3	15	379.5	1.853027344	0.267881828	82530	4.916611845
4	20	426.75	2.083740234	0.318843577	110040	5.041550582
5	25	505	2.465820313	0.391961426	137550	5.138460595
6	40	576.333333	2.814127604	0.449343786	220080	5.342580577
7	50	611.5	2.985839844	0.475066509	275100	5.43949059
8	60	638.25	3.116455078	0.493660871	330120	5.518671836
9	75	691.333333	3.375651042	0.528357545	412650	5.615581849
10	80	696.75	3.402099609	0.531747025	440160	5.643610573

Figure 2: Data Table

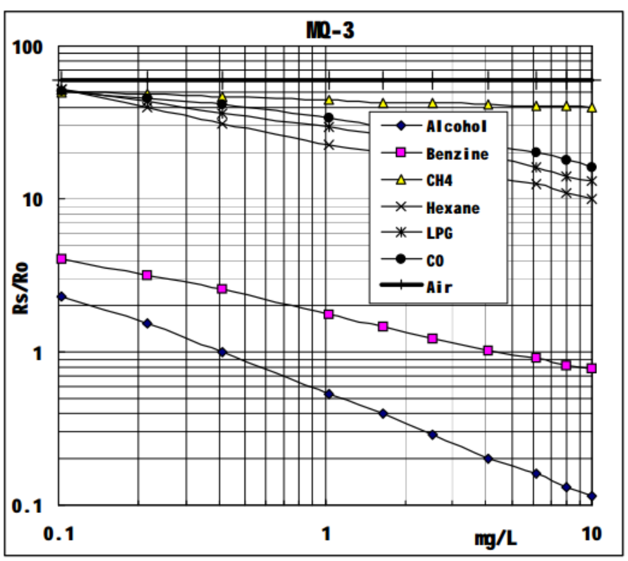


Figure 3: Sensitivity characteristics of MQ3 sensor from the data sheet

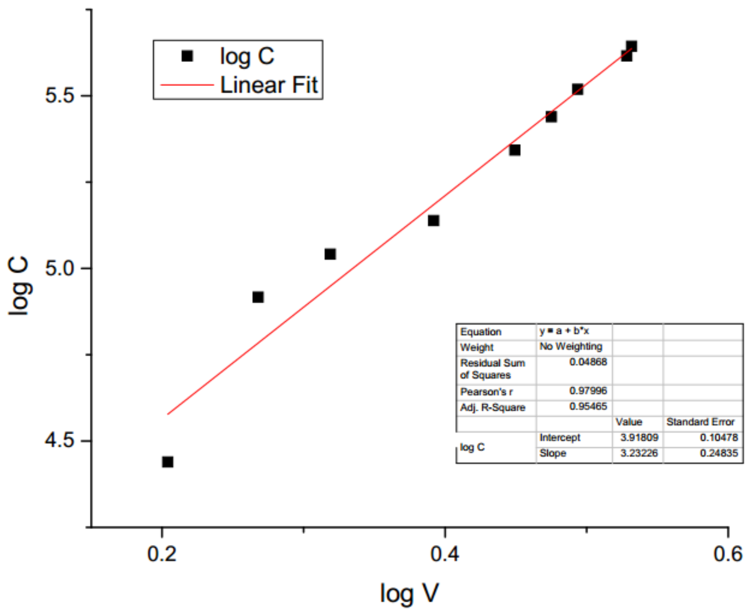


Figure 4: log C vs log V plot

This method of calibration was tested by making different concentrations of solutions (some of them different from those values used to arrive at the relationship between V and C). The concentration of alcohol in solution was determined and compared to the alarm point concentration and the two were displayed on an LCD. The focus was more on getting the drunk/not drunk status correct, than precisely determining the concentration in the sample. It was verified that the method gave fairly consistent results for very similar conditions of testing. The tests can be viewed categorically in videos present in :

`https://drive.google.com/open?id=1pzLyYQ1KRk5YbTXS3i4Cgta2qdA_VXQN`

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6 Sensitivity

The Arduino reads in values between 0 and 1024 for a 0-5 Volts range. Hence the least count is 0.0049 Volts. This can be used to determine the sensitivity of the instrument, i.e the change in concentration corresponding to this least count.

$$\log C = 3.23 \log V + 3.92 \tag{2}$$

Differentiating this equation, we get,

$$\Delta C = 3.23 * \frac{C}{V} * \Delta V \tag{3}$$

A plot of the sensitivity in concentration at different voltages and concentrations is plotted below. (Figures 5 and 6)

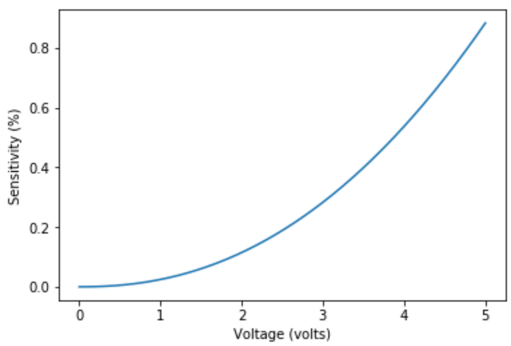

Figure 5: Sensitivity at different voltages

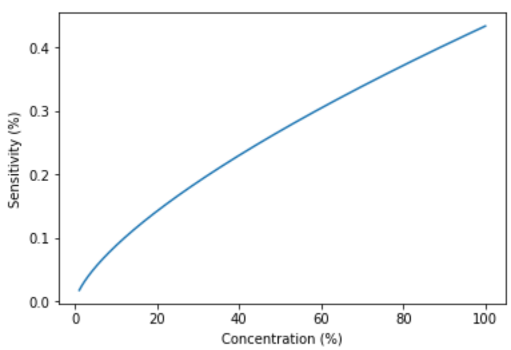

Figure 6: Sensitivity at different concentrations

The lower limit of detection should correspond to the reading when the sensor is kept in fresh air. This corresponds to about 1% concentration or equivalently about 0.87 Volts.
The upper limit of detection should correspond to the voltage at which concentration is 100%,

which is 3.63 Volts. However higher values outside this range are also observed sometimes due to errors (discussed in next section).

7 Sources of error

Calibration and subsequent tests are extremely tricky to execute with accuracy due to the following sources of errors:

- The amount of sample that comes out in 3 sprays vary.
- The distance at which sample is held from sensor actually has a huge effect on the output of the sensor, and it has been optimized to stay in voltage range of 100 to 800 for a large range of concentrations.
- The time for which the sample is kept in front of the sensor also varies slightly from trial to trial. The data sheet advises to avoid exposing sensor to vapours for a long time in the same trial.
- log C vs log V is not exactly a linear fit. Therefore, error in C determined may be considerable since sensitivity is seen to increase with C.