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Stemming Alcohol-Based Industrial Fatalities Through Enhanced Breathalyser Sensitivity

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Abstract: The electronic breathalyser as an alcohol detection system is a semiconductor-based breath analysis device that detects the alcohol level in a person's blood system through the breath. Despite the high sensitivity of the MQ-3 alcohol sensor, the need to ensure enhanced sensitivity is paramount because of the fatal effects the alcoholic could cause at work place. Maintaining and enhancing sensitivity of alcohol detection system therefore requires a couple of precautions be taken. With hardware and software designs, MQ-3 calibrated to 0.4mg/L (about 200ppm) of alcohol concentration and Atmega 328P-PU microcontroller programmed with flowcode, Arduino Uno R3 and encoded with C, simulated on Proteus, and implemented on Veroboard, is mounted on the factory machine at a point very close to where the operator stands. When alcohol was detected, an analogue output to the microcontroller was used to calculate the percentage and displays it on the LCD. The LED comes on and the buzzer sounds an alarm to show the alcohol level exceeds the threshold. With 40% alcohol concentration there is a deviation of 1.021110507 in the response time of the alcohol sensor.

Keywords: Alcohol Detection, Flowcode, Sensitivity, Depressed Nervous System, Fatality.

I. INTRODUCTION

A good number of working people, particularly people working with machines in factories, workshops and at construction sites, consume alcohols and illicit drugs at a level that place them and those working around them at high risk of accident and injury. Such accident might lead to death when it becomes very fatal. Though the number of working people that use illicit drugs like cannabis and hemp is on the increase with time, the focus of this work is particularly on factory workers that consume alcohol before or while at work, and how to detect the level of alcohol in their bloodstream in what is known as blood alcohol concentration (BAC) level from their breath.

Alcohol has the capacity of depressing the central nervous system when taken to a certain level which differs from person to person. Consumption of alcohol and being under its influence result in such effects as impairment and loss of memory, concentration, mood, dexterity, observation, time to react to stimuli or events, relation to other people, sense of good judgement, and so on. Due to the sedative and hypnotic nature of alcohol, a factory worker under its influence therefore is of great danger to himself, other people around him and the company as a whole. He is at great risk of involving in or causing violence, absenteeism, accident and injury, resulting in embarrassments and loss of productivity, lives, equipment and jobs. Peter Anderson [1] wrote extensively about these work-related effects of alcohol consumption. In general, alcohol consumption is reported to be accountable for a great proportion of diseases, disabilities and about 3 million annual death records worldwide [2]. Craig Freudenrich [3] noted that of the 42,000 road accidents that happened in the year 1999 all over the United States of America (USA), 38 % of them were due to effects of alcohol consumption. Bezrutczyk [4] noted that about 3.2% of **all** deaths amounting to more than 5.2 million people all over the world die from alcohol-related hazards every year with the poorest countries accounting for 90% of the number.

When alcohol is consumed, it digests into the blood and diffuses into the air in the lungs as the blood circulates around the lungs. The quantity of alcohol in the breathed (exhaled) air reflects the quantity of alcohol in the blood system at the ratio of 1:2,100, that is, 2,100 ml of breathed air will contain the same quantity of alcohol as 1 ml of blood, which is the BAC [3]. The breathalyser works by analysing the breath in order to estimate the amount of ethanol digested into a person's blood by stating the BAC in grams/millilitre as conveyed by the person's breath. For example, the legal standard for drunkenness across the USA is 0.08 implies a 0.08 grams of alcohol exist in a 100 ml of blood, or given as 800 parts–per–million (ppm).

TABLE I: SHOWS THE PERCENTAGE OF ALCOHOL IN DIFFERENT BEVERAGES (Drug Free World 2019 [5])

Beverage	**Alcohol level**	**Beverage**	**Alcohol level**
Beer	2–6%	Brandy	40%
Cider	4–8%	Gin	40–47%
Wine	8–20%	Whiskey	40–50%
Tequila	40%	Vodka	40–50%
Rum	40%	Liqueurs	15–60%

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This work sets out to design and implement a very sensitive detection of alcohol consumption by factory workers and to alert the factory floor supervisors of the detection. It also examined causes of reduced sensitivity of the sensing material and how the sensitivity can be enhanced. Organisations must have programmes set out to test for alcohol and drugs at work place, both at scheduled and random, by surprise tests, in order to maintain safe and less accident prone workplace [6].

There are breathalyzers built to check the alcohol level of individuals through blood samples. Constraint with alcohol readings in blood samples is that food substances in the body contain alcohol that makes the readings inaccurate. Need for a faster, accurate and more efficient method necessitated the development of electronic breathalyzers that detect the level of BAC from the breath, and the improved versions that have been built over time. This is different from the chemical-based type that made use of acetaldehyde and trivet green chromium which creates coloration in the presence of ethyl alcohol. When the exhaled air of an alcoholic is passed into the tube containing these chemicals, it causes a coloration, the extent which is determined by the level of concentration of ethanol present in the exhaled air [7].

The effects of alcohol consumption are seen in all facets of life and work, from the home, to driving on the highway, to workers on the factory floor, among mining workers, everywhere. Very meaningful methods and efforts must always be deployed to detect the level of alcohol consumed by individuals and policies instituted to check those detected before it could lead to undesirable effects. Types of sensors used in breathalyser over time include: infrared spectroscopy mostly used in Intoxilysers, fuel cell used in Alcosensor III or IV where an electrode oxidises ethanol into acetaldehyde to cause colour changes based on the alcohol concentration, photovoltaic assay used in photoelectric Intoximeter, and semiconductor gas sensors [3].

Several research efforts at detecting those drunken with alcohol have led to the use of different techniques and materials at accomplishing this task, some of which are hereby reviewed. Nirosha et al [8] proposed the installing in vehicles an automatic MQ-3 sensor–based alcohol detector with the use of AT89S52 general-purpose microcontroller. It was designed to send alert message to the nearest police station through a GSM network, to raise a sound (buzzer) alarm and display alcohol level on an LCD, if the vehicle driver is detected to be drunk. They made use of Keil microVision software in C/C++ to programme the work. Gbenga et al [9] built an alcohol detector based on about the same principle and devices as by Nirosha et al, but used Arduino Uno ATmega328 as the microcontroller. In addition, they programmed it to disengage the ignition system of the vehicle when the driver is detected to be drunk. Al-Youif et al [10] built an alcohol detection vehicle lock for accident prevention that incorporated L293D Arduino-compatible shield to illustrate the functionality and ease of integration with a microcontroller unit. Kumar et al [11] did about the same thing with vehicle engine locking system as [8] and also made use of Arduino Uno ATmega328 microcontroller, but included an ultrasonic sensor for motor body area sensing so as to alert against motor body/object impacts. Sridhar et al [12] built into their prototype alcohol detection and a means of sensing that the seat belt is not used. The vehicle will just not start if the driver is drunk or refused to use the seat belt.

In many ways the air around us gets polluted with alcohol gas. In indoor homes, offices and factory floors, there are many air pollutants coming from cooking, sweeping, perfuming, painting, chemicals used in production processes, and so on, which make the quality of indoor air to be poor, unhealthy and uncomfortable due to inadequate ventilation and exchange of fresh and contaminated air. Rahman et al [13] built an optical sensor – based alcohol detector for use in detecting alcohol in beverages and in any liquid sample.

II. HARDWARE DESIGN

The general block diagram of the hardware design is shown in Figure 1. The hardware design consists of an ATmega 328P Microcontroller, a MQ-3 alcohol sensor, a Piezo-electric buzzer, 11.0592 MHZ Crystal oscillator, LED's, Resistors, Capacitors, a veroboard and a single pole switch. The hardware components are interfaced with each other, embedded with Arduino programme, used to manage the entire task and provide results in real time. In order to be portable a 9V battery connected to a 7805 voltage regulator to step it down to the required 5V is used to power the device. The supply voltage is cleaned up from noise using a 10pF electrolytic capacitor. The designs were conceived from both hardware and software perspectives. The detailed circuit diagram of the design is shown in Figure 2.

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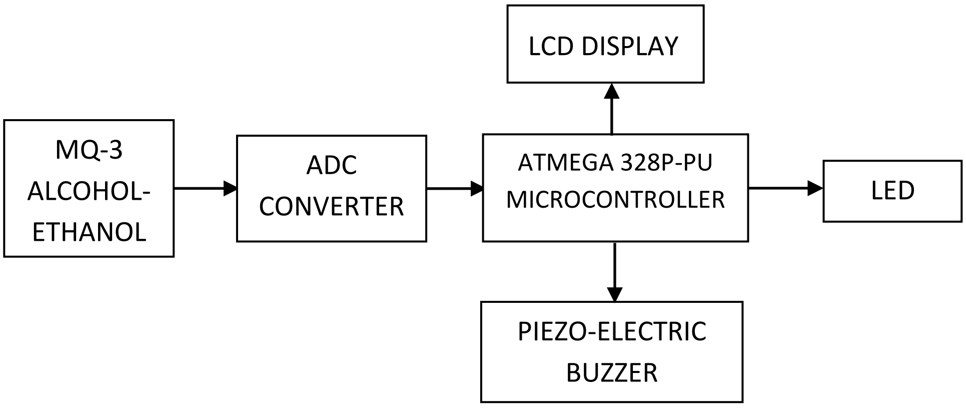

Fig 1: The Block Diagram of the Hardware Design

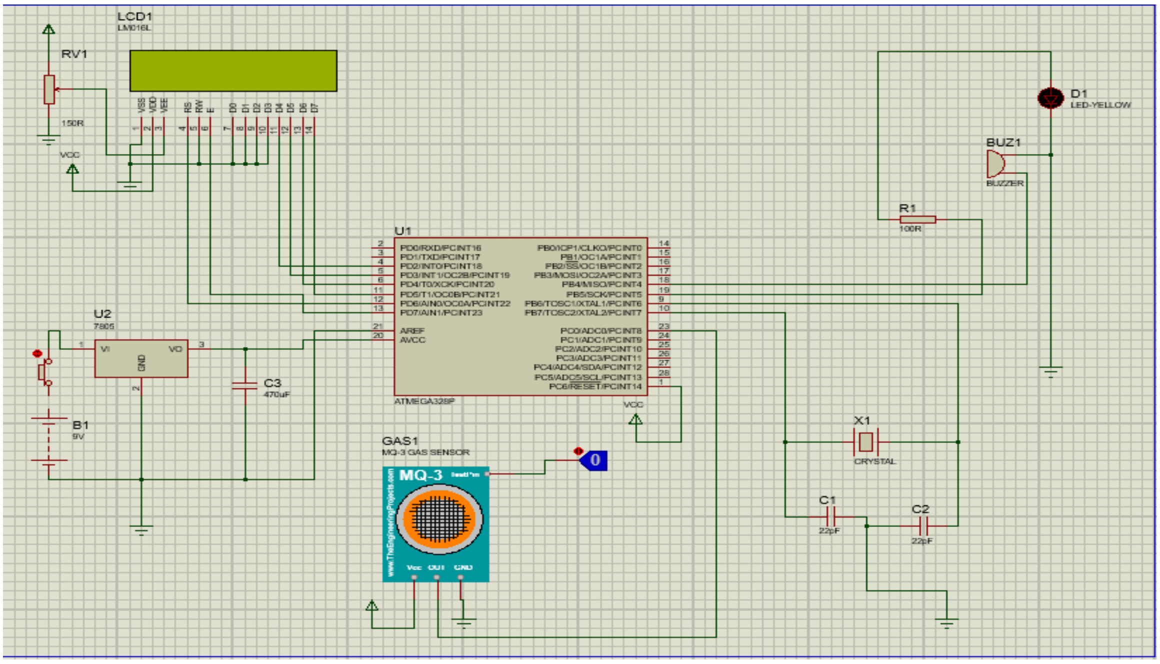

Fig 2: The Circuit Diagram of the Design.

III. SENSOR AND SENSITIVITY IMPROVEMENT

The MQ-3 sensor shown in Figure 3 is of the category of metal oxide semiconductor (MOS) sensors known as chemiresistors. Their sensing ability is based on change in the resistance of the sensing material. The sensing element of the MQ-3 sensor is made of Aluminium Oxide (Al2O3) coated with Tin Dioxide (SnO2) which is the actual sensing material. When heated up to a high temperature, oxygen is attracted to its surface, causing electron depletion to be formed in it. This results in higher resistivity to the flow of electric current in the sensing material. When alcohol is in the air around the surface of the heated SnO2, it reacts with it causing the density of absorbed oxygen to decrease and the potential barrier to flow of electrons also decreases and current begins to flow based on the concentration of the surrounding alcohol. The MQ-3 is highly sensitive to alcohol and detects 25 – 500 ppm of alcohol (ethane) and less sensitive to other gases like benzene, hexane, LPG, and air [14]. It has fast response and high sensitivity; works with 5V dc and consumes a power of 800mW; and provides both an indication of the presence of alcohol in air at the digital pinout (D0) and a representation of alcohol concentration in air at the analogue pinout (A0) [15]. Figure 4 shows the pin configuration and the on-board components of the sensor. Both the A0 and D0 outputs are connected to the appropriate analogue pin0 and digital pin8 respectively on Arduino for them to be read out.

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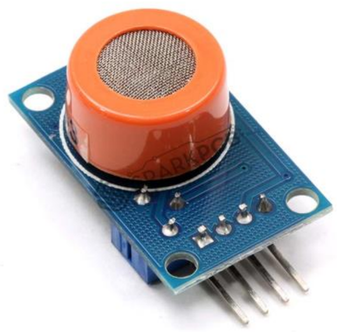

Fig 3: The MQ-3 Alcohol Sensor (Source: MQ-3 Datasheet [15])

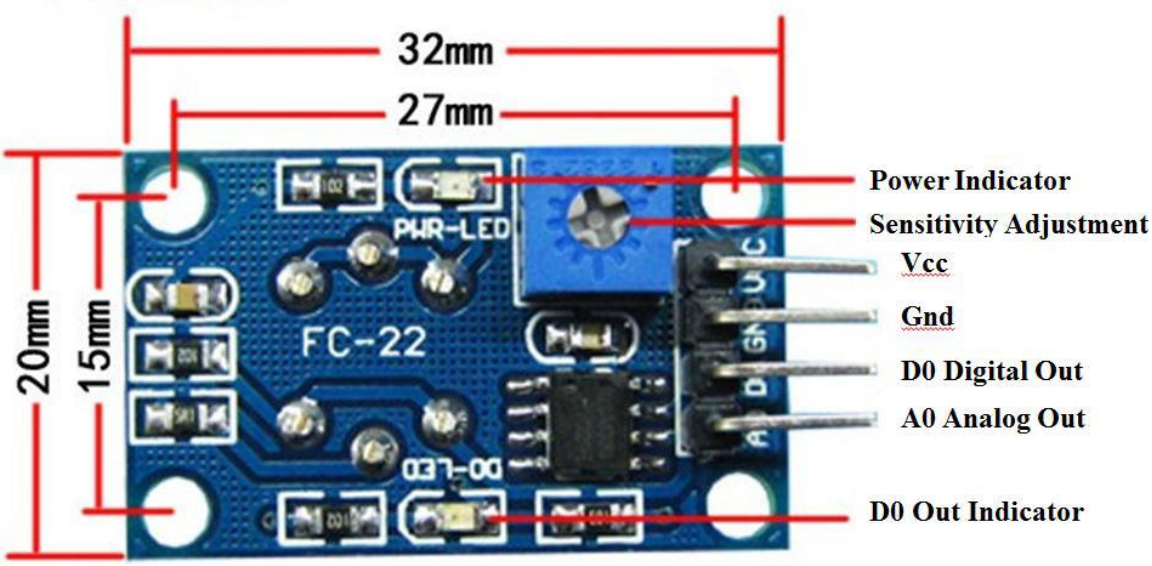

Fig 4: Pictorial Description of the MQ-3 Sensor Panel (Source: Handson Technology [16]).

The characteristic of this sensor is similar to those of other MQ gas sensors. So, sensitivity analysis for this category of sensors could be applied here also. In Table 2 we have the sensitivity characteristics of the sensor [15, 17]. These characteristics are manipulated to improve the sensitive of the sensor.
The sensor was calibrated for 0.4mg/L (approximately 200ppm) of alcohol concentration in air and use value of Load resistance (R_L) of about 200 KΩ (100KΩ to 470 KΩ). We calculated the relationship between the sensor resistance (R_S) for a particular gas to the sensor resistance (R_O) when only the nominal 0.4 mg/L of alcohol exists in air, from the expression:

$$R_S/R_O \quad (1)$$

The air around us can be very complex, so the sensor is noted to respond also to carbon dioxide (CO_2) and other volatile organic compounds (VOC) around us in different ways, particularly at different heater temperatures. Show in Figure 5 is a plot of the sensitivity of an alcohol sensor to three different VOCs as the operating temperature varies.

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TABLE II CHARACTERISTICS OF MQ-3.

Conditions	Parameter Name	Symbol	Technical Parameter	Remark
Sensing Resistance		R_S	1 to 8 MΩ (0.4/1 mg/L alcohol)	Detecting concentration slope: (0.4/1 – 10 mg/L alcohol)
Detection Range		25~500ppm alcohol		
Standard Circuit Conditions	Loop Voltage	V_C	≤ 24V DC	
	Heater Voltage	V_H	5.0 ±0.1V AC or DC	
	Load Resistance	R_L	Adjustable	
Sensing Characters under Standard Conditions	Output Voltage	V_S	2.5~4.0V(in 125ppm C_2H_5OH)	
	Sensitivity	S	R_O(in air)/R_S(125ppm C_2H_5OH) ≥ 5	
	Heater Resistance	R_H	29Ω ±1%	
	Concentration slope rate	α (0.4/1 mg/L)	≤ 0.6	
	Heater Consumption	P_H	≤ 900mW	
Standard detecting (testing) conditions	Temp Humidity V_C V_H	20℃±2℃ 65%±5% 5V±0.1 5V±0.1		
	Preheat time	24 – 48 Hours		

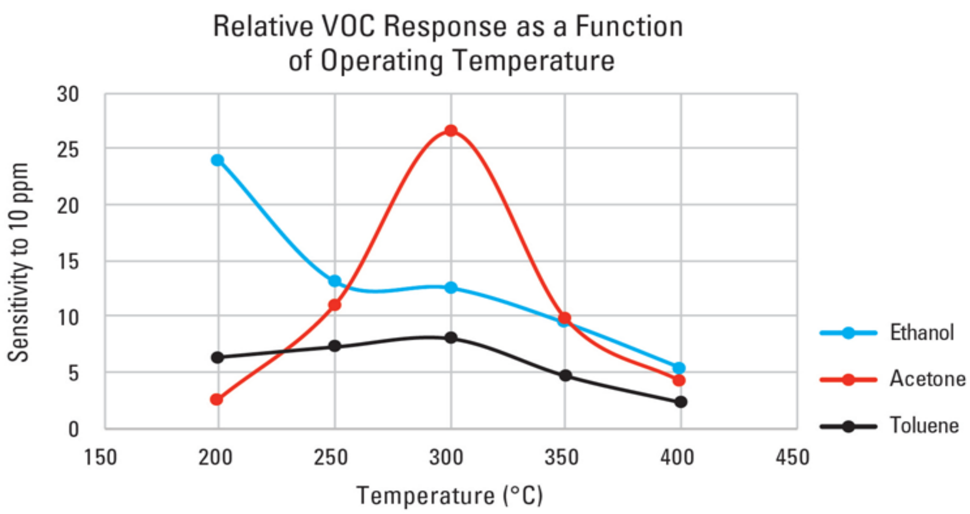

Fig 5: Effect of Temperature on Sensitivity of the MQ-3 Sensor to a Target Gas (Source: Handson Technology [16]).

The R_S varies according to the concentration of alcohol in the air as depicted by the voltage across it. This is the voltage across the point between the sensor and the load resistor. The relationship, R_S/R_O, is correlated with the BAC as shown in Figure 6 derived with load of 4.7kΩ, with the aid of the equation of a line log-log plot of the sensor load voltage against alcohol concentration shown in Figure 7 and given by [14]:

$$F(x) = F\left(\frac{x}{x_o}\right)^{\frac{log\left(F_1/F_o\right)}{log\left(x_1/x_o\right)}} \qquad (2)$$

where, F_o, x_o F_1 and x_1 are two points on the line in Figure 7, substituted to give yield:

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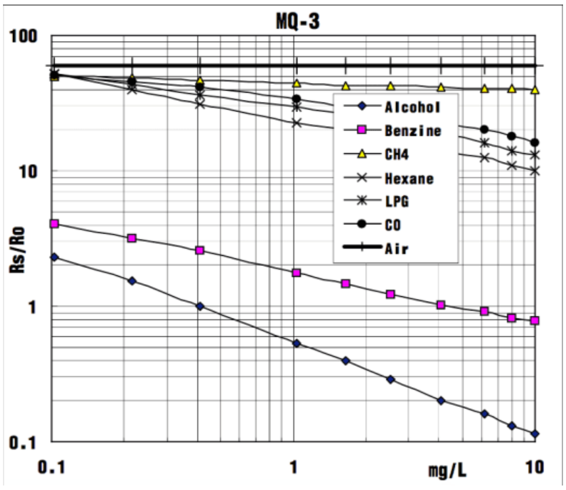

Fig 6: Sensitivity Characteristics of MQ-3

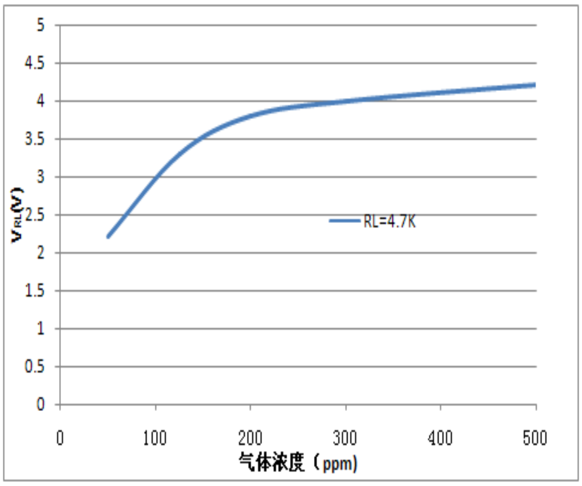

Fig 7: Voltage versus Alcohol Concentration.

$$F(x) = (1)\left(\frac{x}{0.4}\right)^{\frac{\log(0.2/1)}{\log(4/0.4)}} = 2.5x^{-0.699} \quad (3)$$

From this we obtain the relationship between R_S/R_O and BAC (mg/L) as:

$$\frac{R_S}{R_O} = 2.5mg/L^{-0.699} \quad (4)$$

Solving for BAC (mg/L) gave us:

$$mgL^{-1} = 0.4\left(\frac{R_S}{R_O}\right)^{1.431} \quad (5)$$

Since for maximum sensitivity, the sensor resistance was calibrated for BAC at 0.4mg/L for free air, given as R_O, playing around with the sensor resistance for a target gas, given as R_S, then the sensitivity of the sensor could be enhanced. This could be done by adding a variable resistor in parallel in the implementation design, along with the on-board resistor on the MQ-3 back board.

The following conditions will make the MQ-3 sensor lose its sensitivity [17]:

1. Exposure to organic silicon steam, silicon bond, fixture, silicon latex, putty or plastic contain silicon environment will make the sensing material lose sensitivity and never recover.
2. Exposure to high concentration corrosive gas (such as H2S, SOX, Cl2, HCl, and so on) will corrode the sensor structure and cause sensitivity attenuation.
3. Exposure to or spray with alkali, alkali metals salt such as brine, or to halogen such as fluorine will adversely change the sensor performance.
4. When spattered or dipped in water the Sensitivity will reduce.
5. Allowing the surface of the sensor to be iced breaks the sensing material and leads to loss in sensitivity
6. When voltage greater than the specified value is applied to the sensor the heater gets damaged, and the sensitivity of the sensor will become adversely affected.
7. When voltage is applied on the wrong pins the lead might get broken and the performance of the sensor gets negatively affected.
8. Storing sensor for long time before energising it electrically makes the sensor resistance drift in reverse order and thereby lose sensitivity.

IV. Software Design Using Flowcode

The flowcode programmed was written in Proteus for the implementation of this work and compiled to a HEX file which is the readable form of instruction for the microcontroller. Figure 8 shows the procedural steps of the flowcode programme that was written. The MQ-3 Alcohol-Ethanol Sensor input variables were declared and the proposed output statements for the LCD on active high and low and the proposed output level for the buzzer at active high and low were written.

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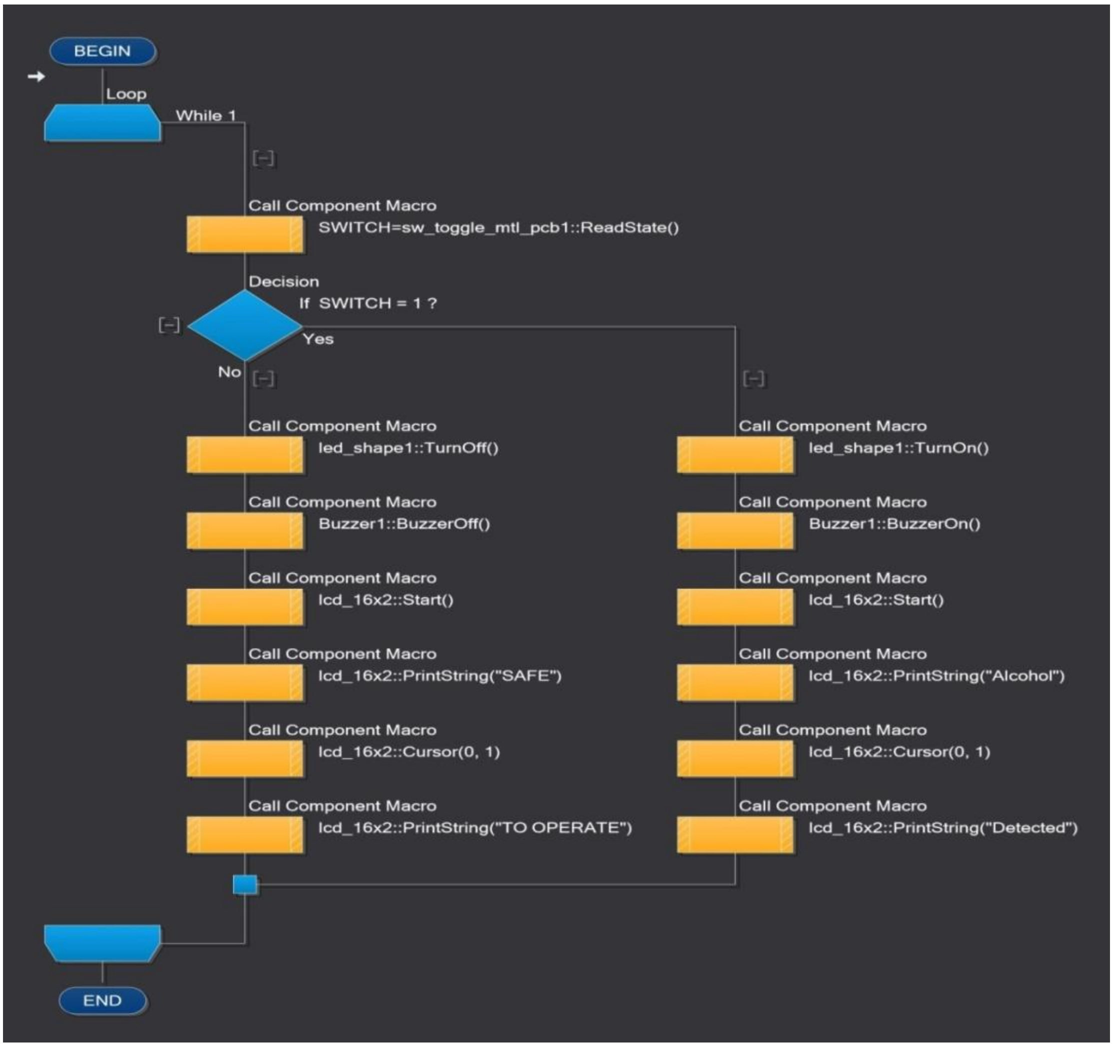

Fig 8: The Procedural Steps for the Flowcode Programme.

V. SIMULATION AND TESTING

The simulation was done on Proteus for both when there was no alcohol present in the vicinity of the sensor and when alcohol was present.

A. When Alcohol is not Detected in the System

The display on the LCD is as shown in Figure 9.

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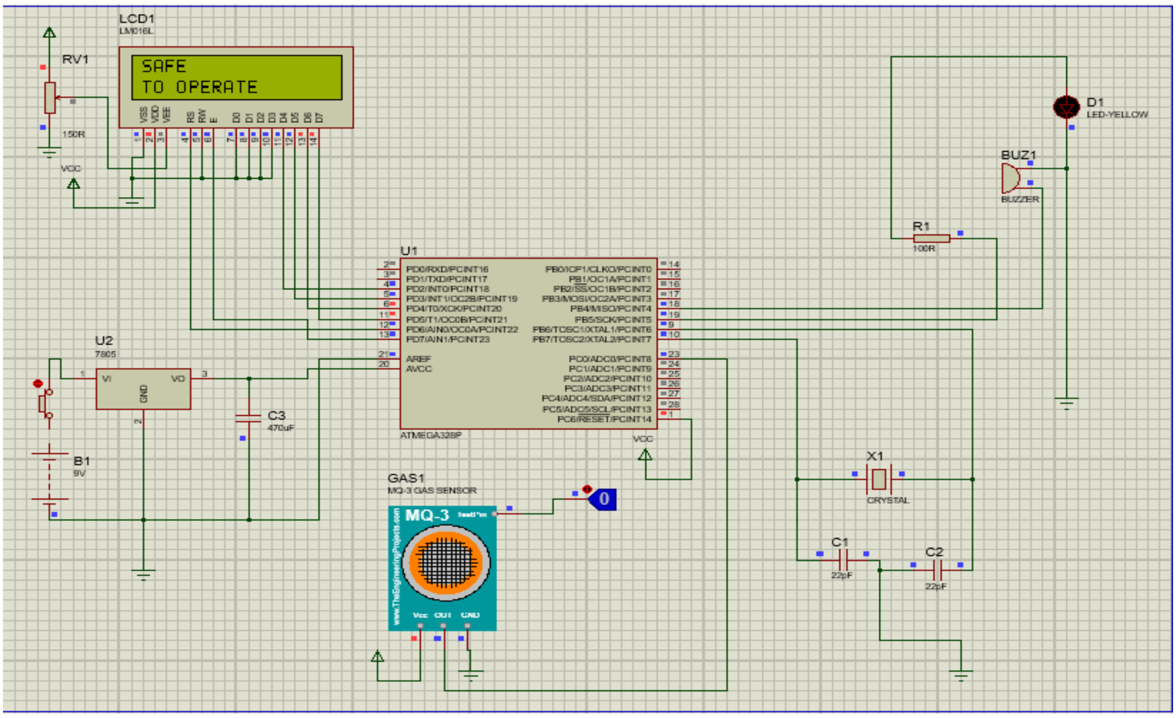

Fig 9: The Prototype Test When Alcohol is Not Present (Active Low)

B. When Alcohol is Detected in the System

The display on the LCD is as shown in Figure 10.

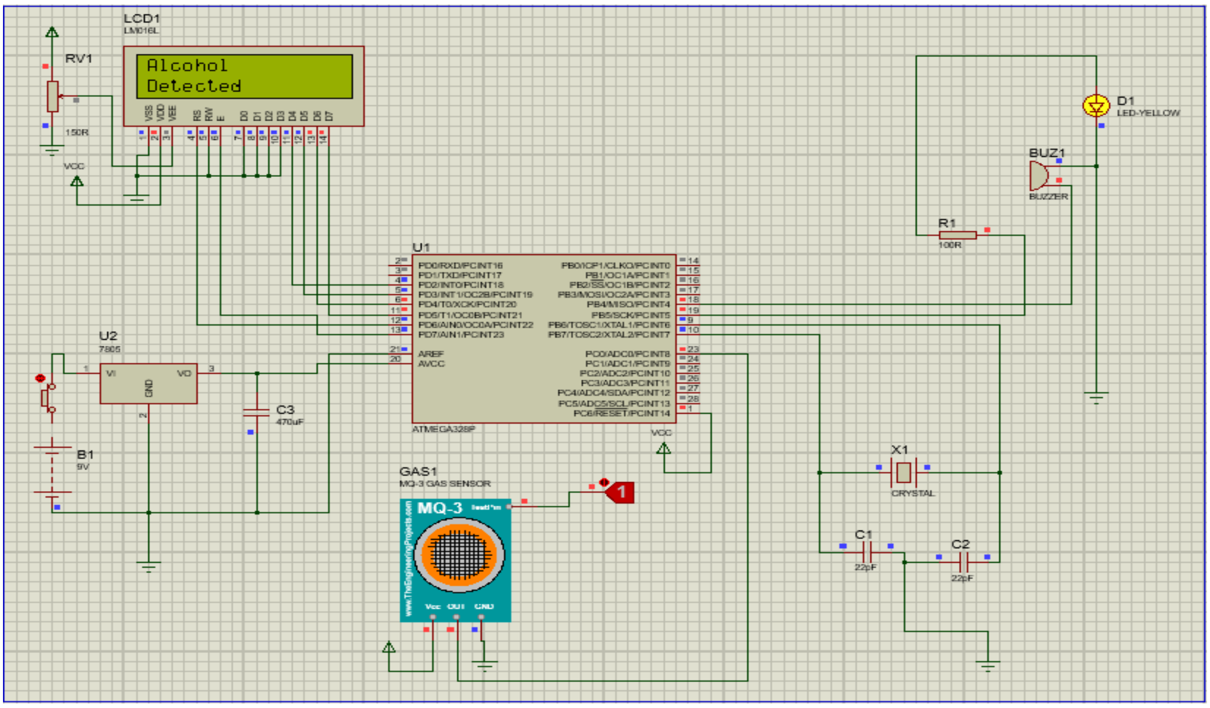

Fig 10: The Prototype Test When Alcohol is Present (Active High)

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C. Testing on Breadboard

The microcontroller and other components were installed on twin breadboard and the MQ-3 alcohol sensor was attached with project wire strands. The test was carried out both for when alcohol was not present and when it was present. Alcohol was made present around the sensor by dipping a cotton wool into an alcohol solution and bringing it to a close proximity to the alcohol sensor. Figures 11 and 12 showed the two scenarios and the LCD display displayed the two conditions with the alcohol levels in the air shown for each case.

It was observed that the breath based alcohol detection system when tested at several distance away from the alcohol source becomes less sensitive as it moves further away with the alcohol concentration reducing, and as the potentiometer of the alcohol sensor is regulated. This sensitivity is highest in clean air and varies with temperature at constant reference voltage. The heat up time of the alcohol sensor was importantly noted in the test. The minimum time of 15 minutes for heating up was initially observed for testing sake. The gas concentration has a direct relationship with the input voltage and the MQ-3 alcohol sensor has a very high sensitivity per time.

Figures 13 and 14 show the prototype with the components and microcontroller installed on a Vero board for both cases of alcohol not present and alcohol detection.

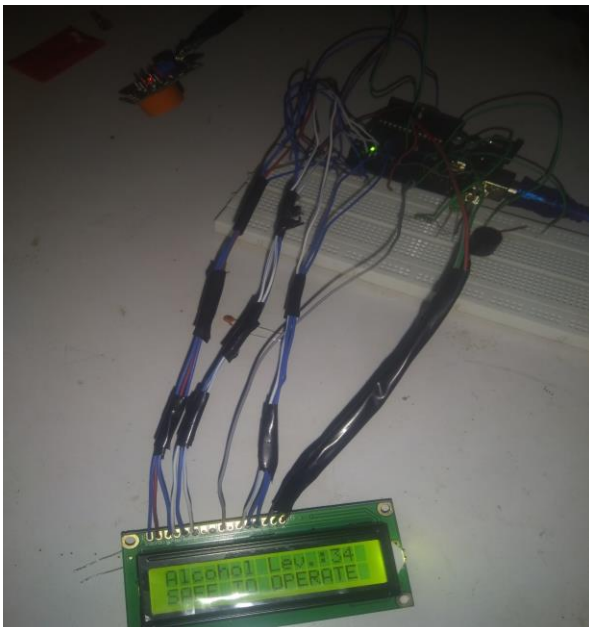

Fig 11: When Alcohol Is Not Detected

Fig 12: When Alcohol Is Detected

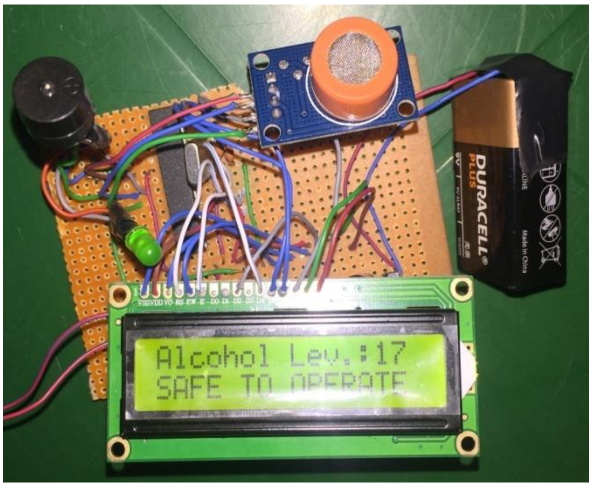

Fig 13: On Vero Board (No Alcohol)

Fig 14: On Vero Board (Alcohol Present)

VI. Results Analysis

The result of the test carried out as indicated in Table 3 shows that the alcohol system has a very fast sensitivity to the alcohol level in the surrounding. Once alcohol is detected in the system the LCD shows string characters of the alcohol percentage level as well as the alcohol state of the user, an LED and a buzzer is trigged active high. Once alcohol is no

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longer detected in the surrounding system the LCD shows string characters of the alcohol percentage level as well as the alcohol state of the user, the LED and buzzers triggers active low. The plot of sensitivity of the alcohol detection system measurement in time (in seconds) is shown in Figure 15.

TABLE III: TABLE OF OUTCOMES

Distance (cm)	Time (in Sec) For 40% Alcohol Conc.	Time (in Sec) For 15% Alcohol Conc.	Time (in Sec) For 4% Alcohol Conc.
1	0.4	0.7	1.2
2	0.6	1	1.5
3	0.8	1.3	1.8
4	0.9	1.7	2.2
5	1.3	2.1	2.5
6	1.7	2.3	2.8
7	2.2	2.5	3
8	2.5	2.7	3.3
9	2.9	3	3.7
10	3.3	3.2	3.9
Deviation	1.021111	0.851469	0.917061

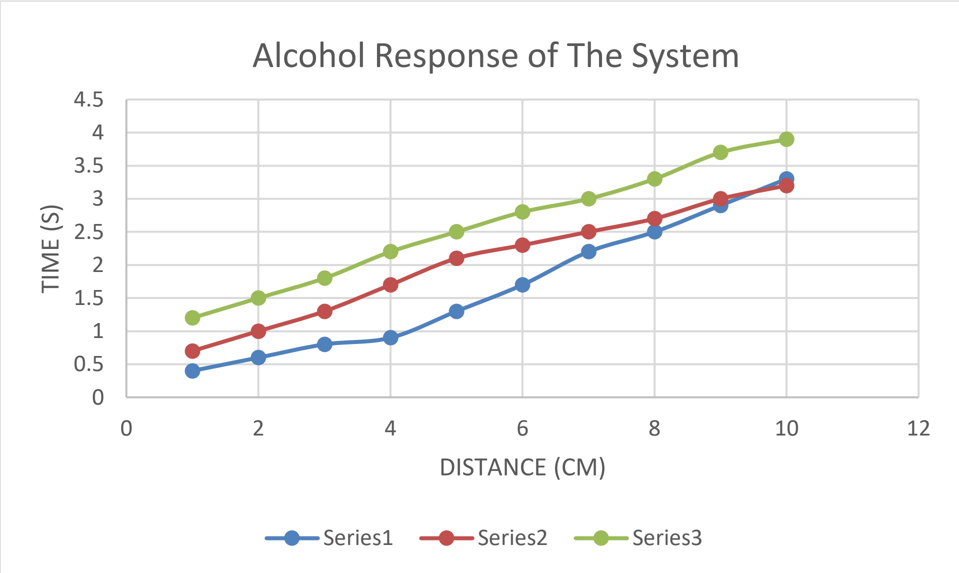

Fig 15: Plot of Alcohol Sensing Outcomes

VII. CONCLUSION

Alcohol-related embarrassments, injuries and death at workplace are on the increase. Methods and policies at detecting and prevent the consumption of alcohol would have positive effects at ensuring safety and reduce the hazards of the influence of alcohol consumption and the attendant cost of treatment and the loss of productivity and revenue. The MQ-3-based alcohol detector built in this work was well calibrated to ensure maximum sensitivity of the sensor. Ensuring the high sensitivity of the MQ-3 sensor is achieved through recommended measures is very important. This alcohol detection system meant to be mounted on the factory machines at very close range to where the machine operator sits or stands to operate the machine for the system to detect the level of alcohol in the operator's breath. Also, alcohol detecting systems could be installed at the entrance of the factory floor to stop those with high level of alcohol consumption from entering inside.

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