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BREATHALYZER ENABLED IGNITION INTERLOCK SYSTEM

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Abstract. A breath alcohol detector or better known as a breathalyzer plays a vital role in monitoring alcohol concentration in a person's bloodstream. This project involves the design and development of a breathalyzer device which controls an ignition switch. The hardware modules include the PIC16F877A microcontroller, alcohol sensor, LCD panel and ignition switch circuitry. The software component includes the programming and source code which is implemented via the PIC microcontroller. Upon assembly, the system is able to detect the alcohol concentration in a person's breath sample and displays the detected amount in terms of BAC (Blood Alcohol Concentration) percentage on the LCD panel. According to the amount, the system decides whether to enable or disable the ignition switch circuitry.

Keywords: Breathalyzer; blood alcohol concentration; ignition; alcohol; drunk

Abstrak. Pengesan alkohol atau lebih dikenali sebagai '*breathalyzer*' memainkan peranan penting dalam memantau kepekatan alkohol dalam aliran darah seseorang. Projek ini adalah merekebentuk dan membangunkan '*breathalyzer*' yang disambungkan ke suis pencucuhan (*ignition*). Modul perkakasan adalah termasuk mikrokontroler PIC16F877A, sensor alkohol, panel LCD dan litar suis pencucuhan. Komponen perisian adalah pengaturcaraan dan kod yang di programkan ke pengawal mikro PIC. Apabila diaktifkan, sistem ini mampu mengesan kepekatan alkohol didalam sampel nafas seseorang dan memaparkan jumlah yang dikesan dalam peratusan BAC (Blood Alcohol Concentration) pada panel LCD. Kemudian, dalam linkungan yang telah ditetapkan, sistem akan membuat pilihan samada menghidupkan atau mematikan litar suis pencucuhan.

Kata kunci: Pengesan alcohol; kepekatan alkohol dalam darah; pencucuhan; alcohol; mabuk

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1.0 INTRODUCTION

The breath alcohol tester is an electronic device that is used to measure and test the blood alcohol content in a person's blood stream. Commonly known as *'breathalyzer'* which means breath analyzer, the breath sample of a person is examined by the device through an alcohol sensor to check its alcohol content and displays its output in units of blood alcohol concentration (BAC). The detected amount is shown by means of BAC percentages through display components such as LCD display or seven segment decoder [1, 2, 10].

Initially, the breath alcohol detector's usages were quite limited and were only being utilized to detect and display blood alcohol concentration only. However, as the number of drunken driving cases has increased in recent years, extensive research and developments in applying these devices in vehicles to prevent individuals from driving vehicles after consuming an excessive amount of alcoholic beverages. Subsequently, in the United States of America, when the nation's drunk driving related accident cases reached a level worthy of concern, drunk driving or better known as DUI (Drive Under Influence) offenders were required to install an alcohol detection system in their vehicles. These detectors require the vehicle drivers to produce a breath sample to examine for excess alcohol presence before the engine is allowed to start [3, 4, 5].

In this project, a breath alcohol detector which controls the ignition switch using microcontroller was developed. Instead of just indicating and displaying the BAC percentage, the tester is programmed to control the ignition switch, as well as an alarm and a number LEDs. The fundamental components of this system are the MQ-3 alcohol sensor, PIC16F877A microcontroller unit, 2x16 characters LCD alphanumeric display and ignition switch circuit. In comparison to the already available detectors in the market, this system offers simplicity with extensive features at a minimal cost.

2.0 PROBLEM STATEMENT

A statistical study conducted by the Malaysian Ministry of Information over accident cases in recent years has shown that there is a steady growth in cases related to driving while under the influence of alcohol (DUI). Methods to curb the 'Section 44 APJ' [1] offenders from driving while intoxicated are still limited and non-extensive, apart from imposing hefty traffic summons, barring driving licenses and detention of those who are subjected to violation at numerous accounts. A more systematic and effective approach to prevent excessive alcohol consumers from taking the wheel is a definite necessity [9, 11, 12].

BULAN	2008	2009		
	JAN-FEB	JAN-FEB	PERBEZAAN	%
JUMLAH KES KEMALANGAN	60,083	59,643	-440	-0.7
JUMLAH KEMATIAN	1,065	1,082	17	1.6
JUMLAH KEMALANGAN MAUT	972	987	15	1.5
JUMLAH KEMALANGAN PARAH	1,236	1,126	-110	-8.9
JUMLAH CEDERA PARAH	1,533	1,388	-145	-9.5
JUMLAH KEMALANGAN RINGAN	2,367	2,052	-315	-13.3
JUMLAH CEDERA RINGAN	3,006	2,640	-366	-12.2
SUMBER: PDRM				ANALISIS: JKJR

Figure 1 Number of cases, deaths and accidents rates in Malaysia, 2008-2009 [9]

3.0 BREATH ALCOHOL IGNITION INTERLOCK DEVICE

A breath alcohol ignition interlock device (BIID or IID) is a mechanism which is installed in a vehicle's dashboard [7]. Before the vehicle can be started, the driver must breathe into the device. If the analysed result is over a programmed predetermined blood alcohol concentration, the vehicle will not start. This device keeps a record of the activity on the device and is interlocked with the vehicle's electrical system.

Authorities may require periodic review of the log. If violations are detected, then additional sanctions will be implemented [1]. This process is performed using either a pressurized alcohol/gas mixture at a known alcohol concentration, or with an alcohol wet bath arrangement that contains a known alcohol solution.

In some countries, it is mandatory that one needs to install this device if convicted of drunk driving. In the United States for instance, the court will impose an ignition interlock device requirement for up to a maximum of three years if the legal alcohol limit allowed for driving is exceeded [1].

Modern ignition interlock devices use an ethanol-specific fuel cell for a sensor. A fuel cell sensor is an electrochemical device in which alcohol undergoes a chemical oxidation reaction at a catalytic electrode surface (platinum) to generate an electrical current. This current is then measured and converted to an alcohol equivalent reading. Basically, a typical block diagram of an IID device operation is shown in the Figure 2.

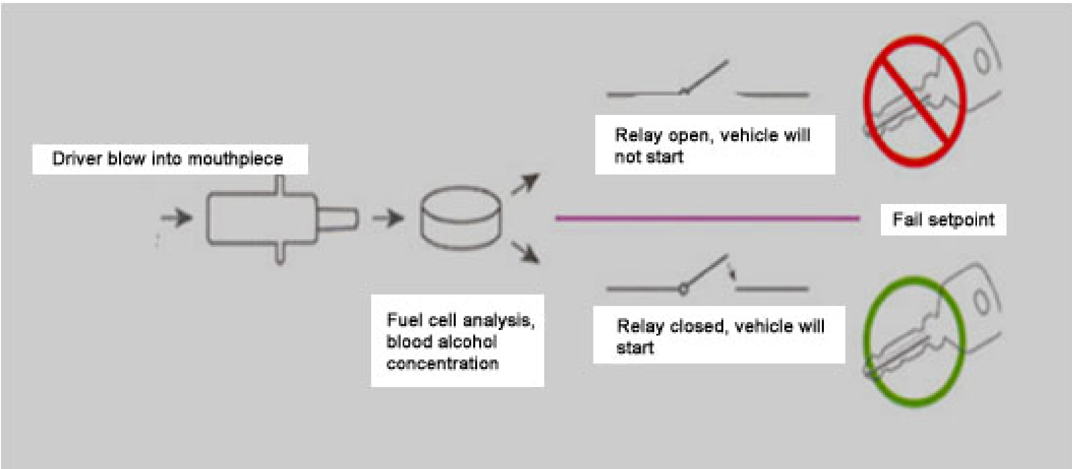

Figure 2 Block diagram of IID device operation

4.0 BLOOD ALCOHOL CONCENTRATION (BAC)

It is necessary to devise a method to create test gas concentrations to mimic various BAC's. The blood alcohol concentration is defined to be the percentage of alcohol, in grams, in 100mL of blood [8]. Therefore, 0.08% BAC is 80mg of alcohol within 100mL of blood. Since the sensor detects the presence of alcohol in air, not blood, a relatively constant ratio of 2100:1 was implemented to create these mock-solutions. This ratio comes from a scientifically agreed upon notion that the Breath Alcohol Concentration is defined as the amount of alcohol, in grams, in 210L of air [8].

Furthermore, ethanol has a specific gravity of 0.79. This means that 1mL of ethanol weighs about 0.79g (contrasting it to water, where 1g = 1mL). Calculations to find the amount of ethanol needed in each solution was done for the following concentration levels: 0.02, 0.04, 0.06, 0.08, 0.10, 0.12, and 0.20.

With these quantities now derived, it was then easy to create these concentrations by putting the amount of ethanol needed via a micropipette into a 1L flask. These flasks were then labelled and sealed in order to allow them to reach equilibrium. This typically took about an hour since the amount of ethanol was so low. Once they were created and ready, extensive calibration testing was then performed.

Table 1 Concentration of alcohol in breath and their corresponding BAC value

Concentration of Alcohol in Breath (grams/liter)	BAC (%)
0	0.00%
9.5×10^{-6}	0.02%
1.9×10^{-5}	0.04%
2.8×10^{-5}	0.06%
3.8×10^{-5}	0.08% (maximum legal limit in Malaysia)
4.7×10^{-5}	0.10%
5.7×10^{-5}	0.12%
9.5×10^{-5}	0.20%

5.0 METHODOLOGY

5.1 System Flowchart

The block diagram below shows the interconnection of the hardware of this system. An ac-dc adapter is used to supply 12 V to the voltage regulator circuit which will reduce this value to approximately 5 V. Power from this regulator circuit is then supplied to ignition switch circuitry, sensor, microcontroller and LCD display

The ignition switch consists of a switch, transistor and an LED. Once the port in the microcontroller turns high, current flows into the base terminal of the transistor and turns it on and subsequently closes the connection between the switch and the LED. At the same time, output in means of BAC percentages will be displayed on the 2 × 16 LCD. If high alcohol concentration is detected in the provided breath sample, port in the microcontroller will go high and turn on the buzzer.

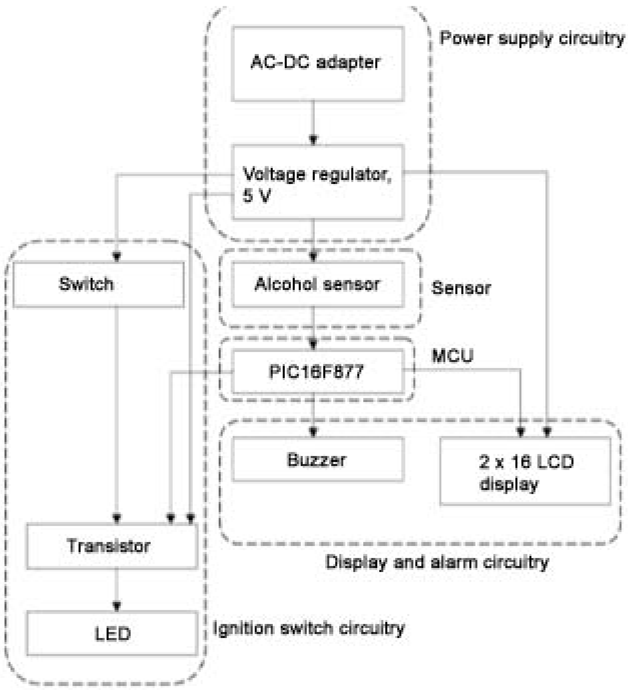

Figure 3 Block diagram of circuitry

5.2 Sensor

The model of alcohol sensor used is MQ-3 alcohol sensor manufactured by Hanwei Manufacturers [6]. This model is suitable to be used in developing devices such as alcohol checker or breathalyzers. It is highly sensitive to alcohol compound, stable, has fast response time and longer lifespan compared to other alcohol sensors [14].

This sensor operates as potentiometer. The higher alcohol substance is detected on its sensing layer, the higher to output voltage will be. Its input voltage is approximately 5 V. This sensor requires driver circuit in order to function.

The resistance of the MQ-3 varies with different types of gases at different concentration levels. Therefore, when using this component, calibration is necessary to determine its proper alarm point. The recommended value of the load resistance is about 200 kΩ (100 kΩ to 470 kΩ). Due to the fact that the sensor is a semiconductor device, it is highly affected by temperature and humidity.

Since the extensive testing of these two variables was beyond the scope of this project, it was assumed that the temperature and humidity in the lab room was nearly constant during any calibration processes. The sensor is also highly time dependent. While the resistance of the sensor reaches a fairly consistent steady-state value when exposed to ethanol gas concentrations, it still takes about a minute, on average, for that value to be attained.

It should also be noted that this sensor is sensitive to other organic compounds. Using pure ethanol and a well ventilated area helps to avoid any error by these detectable substances.

5.3 System Testing and Calibration

Proper testing of the voltage regulator is essential. The completed circuit of the voltage regulator was tested using LED as the load and the corresponding output voltage across the LED was measured using multimeter.

The input voltage that was fed into the microcontroller was not entirely linear over all concentrations of ethanol. Hence, careful attention had to be placed so that calibration was over the linear, or near-linear, region. Attention was also paid to the possibility of saturating or even damaging the sensor if too high a concentration was placed on the sensor. Each prepared ethanol concentration was placed against the sensor and the voltage level, V_{RL}, was viewed on the multimeter and recorded. An average value for each respective concentration was taken.

First, the completed circuit without the alcohol sensor was put through functional testing. The sensor voltage was replaced by a variable resistor. Once this calibration was done the sensor was connected to the rest of the circuit. The whole device was tested using the solutions that were prepared for the calibration of the sensor.

After fixing the sensor to the driver and connecting it to the motherboard, the output voltage from the sensor at normal room temperature was taken. This output voltage was set as the reference voltage for the calibration process. Then, human breath sample was blown at the sensor and the subsequent output voltage was taken. Finally, the sensor was then tested using alcohol substance and its output voltage was taken as well. The voltages set in the programming were readjusted according to the voltage measured during calibration and the hardware was again tested to verify the BAC percentage produced.

5.0 RESULTS AND ANALYSIS

The circuitry is divided into 3 sub-circuits which are the voltage regulator circuit, the motherboard which houses the microcontroller and the sensor driver. The sensor driver is connected to the motherboard which controls the whole system.

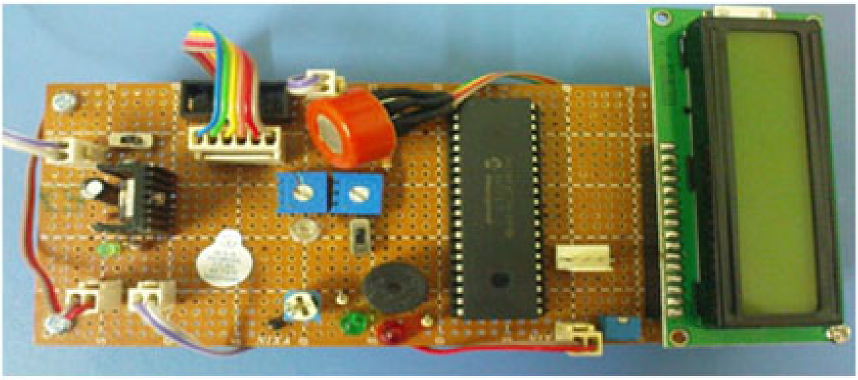

Figure 4 The circuitry of the project

When the system is switched on, the sensor takes time to stabilize its readings. The specification of the sensor of the system upon calibration is as in the Table 2.

Table 2 Specification of the sensor

Parameter	Values
Time taken for sensor to stabilize	15 to 20 seconds
Operating temperature	Room temperature = 29°C
Heater temperature	45°C to 60°C
Input voltage	5 V
Output voltage range	0 to 4.75 V
Saturated output voltage value	4.75 V
Normal atmosphere detected value	1.85 V to 2.5 V
Human's breath without alcohol detected value	0.50 V to 1.84 V
Detected BAC%	BAC = 0.00% to 0.06% - normal BAC = 0.08% to 0.20% - high
Lowest BAC%	0.00%
Lowest BAC%	0.00%
High BAC% starts from	0.08%
Highest BAC%	0.20%

The response of the sensor for different alcohol concentration and its corresponding voltage value is as in the Table 3.

Table 3 Voltage values and corresponding BAC values

Voltage(V)	BAC (%)
0	0.00
4.02	0.02
4.14	0.04
4.25	0.06
4.32	0.08
4.42	0.10
4.75	0.20

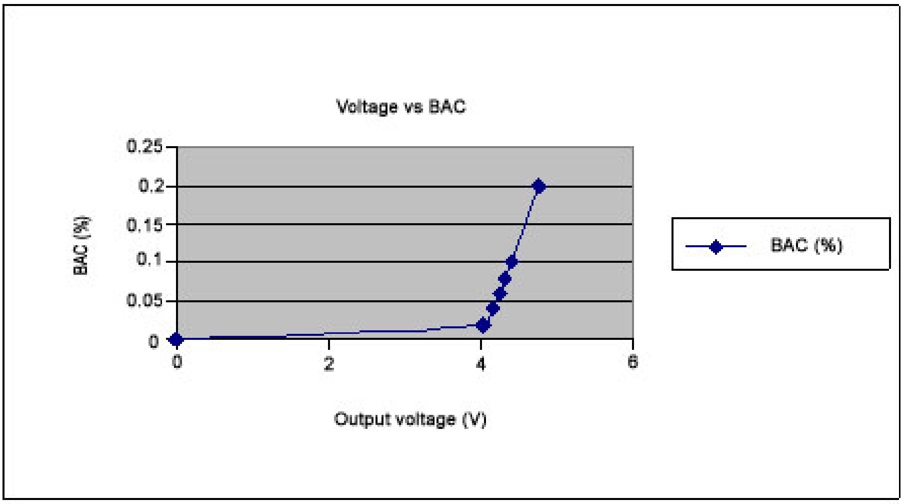

Figure 5 Response curve of BAC (%) via voltage values

For data analysis, a variable resistor was connected to the microcontroller as a replacement of the alcohol sensor. This input was varied its value accordingly in range of 5 V to match the corresponding BAC value.

The analogue input received was quantized into digital signal in the A/D converter. The signal was further processed by the microcontroller to yield its corresponding BAC value. This value was displayed on the LCD panel. Simultaneously, the buzzer and red LED were switched ‘ON’ depending on the input given.

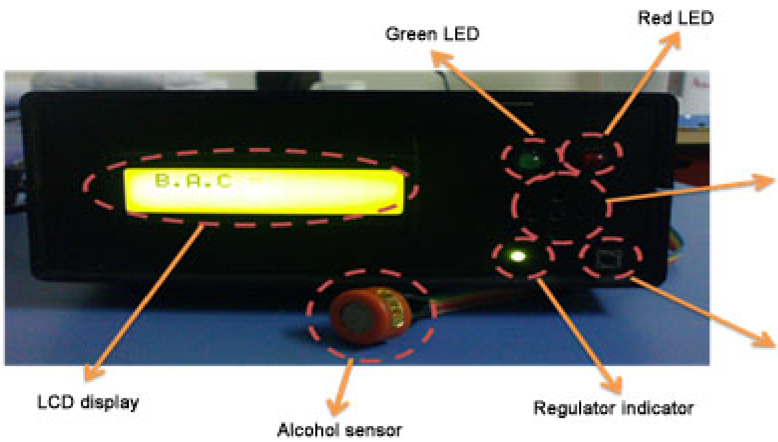

Figure 6 Overall view of the system

When the sensor detected the BAC from 0.00% until 0.06%, the LCD was displayed B.A.C = 0.00% – 0.06%, ENABLED which means the ignition switch was enabled because the BAC value was under the legal limit range. At the same time, green LED was turned ON and red LED and buzzer were turned OFF as in Figure 7.

Figure 7 Condition when BAC equal 0.00% to 0.06%

When the sensor detected the BAC from 0.08% until 0.20%, the LCD was displayed B.A.C = 0.08% – 0.20%, DISABLED, IGNITION LOCK which means the ignition switch was disabled and locked because the BAC value was on the illegal limit range. At the same time, green LED was turned OFF and red LED and buzzer was turned ON as in Figure 8.

Figure 8 Condition when BAC equal 0.08% to 0.20%

Hence, the result of the analysis was summarized as in the Table 4.

Table 4 Summary of the result

BAC (%)	GREEN LED	RED LED (%)	BUZZER	IGNITION SWITCH
0.00	ON	OFF	OFF	ENABLED
0.02	ON	OFF	OFF	ENABLED
0.04	ON	OFF	OFF	ENABLED
0.06	ON	OFF	OFF	ENABLED
0.08	OFF	ON	ON	DISABLED
0.10	OFF	ON	ON	DISABLED
0.20	OFF	ON	ON	DISABLED

6.0 RESULTS AND ANALYSIS

The proposed semiconductor breath alcohol detector is cheaper in cost and is as effective as other types of breath alcohol detector. Furthermore, the system can be easily interfaced to a microcontroller as the output yield is in voltages. However, it was found that the value of the concentration becomes saturated for BAC more than 0.20% even though the alcohol concentration used is more than that value. When power dissipation comes into concern, the semiconductor sensor model has very low power dissipation although it works with presence of heat because it only needs low voltage value in the range of 3.3 V to 5 V as its input. The sensitivity of the sensor is also relatively high compared to the other models. Although the sensor is capable of detecting other substances and misinterprets it as alcohol, the sensitivity towards alcohol is much higher and this makes it a very reliable alcohol detecting device.

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