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Design and Construction of a Microcontroller-Based Driver Alcohol Detection System (MDADS)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Vehicle accidents on most highways had caused a lot of losses. Many sustained injuries that marred them and left families helpless. Nigeria highways are not exempted. Drunk-driving increases tendency, severity and causality of crashes. Effects of auto crash damage to lives and properties necessitated the development of the Microcontroller-based Driver Alcohol Detection System (MDADS).

Study Design: The system employed ATMega328p microcontroller (CU) which coordinated operations of 7 units that made the MDADS. The units are: Sensor Unit (SU), Switch (S), Power Unit (PU); LCD Indicating Unit (LIU), Alarm Unit (AU), DC motor (Ignition) Unit (IU) and Liquid Crystal Display Unit (LCDU).

Place and Duration of Study: The study was conducted for 7 months in the Department of Computer Engineering, Federal Polytechnic Ile-Oluji (FEDPOLEL), Nigeria. It was conducted between October 2020 and July 2021.

Methodology: Once the MDADS is ON, it assesses presence of alcohol in the endogenous alcohol molecules from the driver with the help of the SU. The SU sends signal to CU to control and sends signal to trigger the IU, AU and the LCDU of the MDADS, if the Blood Alcohol Content (BAC) exceeds the stipulated threshold 0.29ml/l. 60s tolerance was given to driver to switch OFF the ignition. If driver refuses to comply by switching OFF the ignition, the CU sends a "SWITCH

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OFF" signal to the IU, the LCDU displays "Drunk" and the buzzer continuously sounds alarm. The designed system was tested and parameters for evaluation were taken. The parameters among other includes True Acceptance Rate (TAR), False Acceptance Rate (FAR), Unable to Accept Rate (UAR) and Detection Accuracy (DA),

Results: TAR were 0.81, 0.79, and 0.77 for man, alcoholic drinks and herbal mixture respectively. FAR were 0.03, 0.00, and 0.00 for man, alcoholic drinks and herbal mixture, respectively. For human being, Precision (*P*) and Recall concept (*R*) were 0.04 and 0.15 respectively while for P and R for others were negligible.

Conclusion: The results reveals that the system can be profitably employed for and improved safety on the highways through precise warning before "switching off" of car engine. A further design should be done to differentiate vividly between drunk drivers and presence of other alcoholic substances such as drugs that contain some alcoholic contents, petrol, methylated spirit and alcoholic drinks.

Keywords: Alcohol detection; blood alcohol content (BAC); false acceptance rate (FAR); true acceptance rate (TAR); microcontroller.

1. INTRODUCTION

Alcohol is one of man's most favorite recreational drugs and psychoactive substances. It sometimes causes impaired driving cases, sexual assaults, drug intoxication and even death [1]. Some of the factors that contributes to auto crashes on high ways include, fatigued driver, drunk-driving, bad roads etc [2,3,4,5]. Most of the early experiments on endogenous ethanol were hampered by technical difficulties, owing to the limited sensitivity and specificity of the analytical methods available. The possibility that ethanol or other volatiles might have been produced post-mortem or post-sampling could not be ruled out [6]. The overall public health and social burden attributable to alcohol consumption is unacceptably high. In 2016, 3 alcohol use resulted in some 3 million deaths (5.3% of all deaths) worldwide and 132.6 million Disability-adjusted Life Years or DALYS (5.1% of all dalys). Mortality from alcohol consumption is higher than from diseases such as tuberculosis, HIV/AIDS and diabetes. In 2016, an estimated 2.3 million deaths and 106.5 million DALYs among men globally were attributable to alcohol consumption. For women, the figures were 0.7 million and 26.1 million, respectively. Worldwide, in 2016, alcohol was responsible for 7.2% of all premature mortality (in persons aged 69 years or less). Younger people were disproportionately affected by alcohol; 13.5% of all deaths among 20–39-year-olds in 2016 were attributed to alcohol [7]. Federal Road Safety Corp's reported that (5-35 %) of road accident deaths are due to drunk-driving. Driving after drinking alcohol significantly increases the risk of a crash and the severity of crash [8].Researchers suggested that there should be an alert to call attention of the driver to the presence of alcohol in his body system, beyond permissible content [9]. Not only that, he also recommended that the system should be included into all bikes and tri-cycles.

1.1 Literature Review

Alcohol drank by a driver misses up with the body system and endogenous alcohol become released in every exhaled air from driver's body. A Driver Alcohol Detection System was developed using AMR 7 PIC microcontroller, GPS module, GSM module, MQ 135 alcohol gas sensor, which sends messages at intervals of 5 minutes to relative of the driver and GPS information of the driver. If accident occurs, it sends the information and the location of the incidence to the relative of the driver [10]. Dada et al., [11] designed alcohol detection system that employed MQ-3 sensor, ATMEGA 328 microcontroller. At percentage content of 40% BAC, the system would respond. Recognition accuracy arrived at was 97.25% and system sensitivity of 2.25% which was actually very low but 40% BAC was actually too high content in the body system of a driver. Oloyede et al. [9] developed a system that de-activate the fuel pump immediately alcohol is detected in the driver. He used MQ3 and ATMEGA 16 microcontroller in the design of the system. Text messages were also sent to next-of-kin of the driver, security post nearby. Kukre et al., [12] developed an alcohol detection system which was able to refuse to start the car ignition and also shut down the vehicle's ignition once the alcohol is detected. The alcohol sensor was attached to the steering or around the driver to sense the presence of alcohol. Once it stops, location of the vehicle is sent to the car owner through the GSM module.

Uzairue et al. employed IoT to detect Blood Alcohol Contents (BAC) of drivers in a smart city. The system was tested on the alcohol distance from the device and the threshold was 0.5 g/l and distance of 14cm from the developed device. This was a test on the alcohol and IoT was used. It shutted down the ignition before alarm was raised [4]. Shutting down the system before alerting the driver was an inappropriate sequence of action. Contactless method was developed using the iris (Navarro et al., 2016), without mouthpieces [13]. In order to reduce accidents of bike riders, SMART helmet was designed and developed by [14].

2. METHODOLOGY

2.1System Architecture

The Microcontroller-based Drivers' Alcohol Detection System (MDADS) was designed to operate at a 9volt. The microcontroller was programmed to receive signal from the MQ-3 sensor. Once it senses a presence of alcohol that is above 0.29mg/l from driver of the vehicle. The alert unit was activated by indicating red Light Emitting Diode (LED) and as well signals the alarm unit to sound a warning for 60seconds delay time to allow the driver to pack the vehicle. The system architecture consist of the following: ATmega 328P microcontroller, MQ-3 sensor, DC motor, LCD, LED, Battery (9volt), Crystal Oscillator, Resistor (10KΩ), Capacitor(25pf), Voltage regulator (LM7805) and the Buzzer. These components were architecturally designed to derive the seven (7) units of the MDADS: Power supply unit, Microcontroller unit, Display unit, Indicating unit, Alarm unit and the ignition unit/DC motor unit as shown in Fig. 1.

2.2 Input Units

The input unit of the MDADS consists of the power supply unit and the sensor.

2.2.1 Power supply unit

A stable source of voltage (between 2 to 5v) was used to drive the ATmega328P microcontroller. The required 5V was achieved through the use of an LM7805 voltage regulator. The power supply circuit is made of rectifier diodes configured in a bridge arrangement as shown in Fig. 2. This was necessary because integrated circuit as well as ATmega328P microcontroller can only run on D.C voltage as specified in datasheet. The 9v battery was used to supply the required minimum input voltage for the system. C3 is transient capacitor and its rating as stipulated in the 78xx voltage regulator's datasheet as 0.1uf [reference]. These capacitors were used for smoothening the output from the voltage regulators. Current limiting resistor calculation for the system is shown in equation 1:

$$\mathrm{R_4} = \frac{\mathrm{V_{out}} - \mathrm{V_D}}{\mathrm{I_D}} \tag{1}$$

$$V_{out} = Output\ voltage\ of\ regulator$$

$$V_D = Voltage\ drop\ across\ diode$$

$$I_D = Forward\ current\ of\ the\ LED$$

LED characteristics, resistor value was 330Ω. Forward current of LED = 10mA and voltage drop = 2v.

$$R_4 = \frac{5-2}{10\ x\ 10^{-3}} = 300\Omega$$

9V was stepped down by the circuit to deliver a secondary output of 5V, 1 A. The 9v battery output is rectified by a full-wave rectifier comprising diodes D1 through D2, filtered by capacitor C3 and C4 regulated by IC7805 (IC). Capacitor C3 bypasses the ripples present in the regulated supply as shown in Fig. 2.

2.3 Alcohol Detection Unit

The alcohol sensor unit was achieved with the help of MQ-3 sensor. It has four pins; test pin, V_{cc}, d_{out} and ground. The test pin was used to accept logic signals of 0 or 1 by using logic state pin. Two LED was used for the design (Red and Green). These LEDs were used to indicate when the when Blood Alcohol Content (BAC) was either below or above the set threshold These LEDs were used to indicate when the when Blood Alcohol Content (BAC) was either below or above the set threshold.

The green LED on automatically immediately the system is powered on, indicating that the system is on and the vehicle is moving. Red LED turns ON automatically when BAC exceeded the threshold (2.9g/l).

2.4 Processing Unit

Microcontroller unit: Control Unit of the system was developed using the ATMega 328P microcontroller coupled with Arduino UNO board and software controlled using Arduino.cc. Output Units: The output unit consists of the LED indicating unit, LCD display unit, alarm unit, engine deactivation units of the developed system.

2.4.1 LED indicating unit

This unit reflects conditions of the system. Two LED were used for the design (Red and Green). The Green LED is ON immediately the MDADS is powered on, indicating that car engine ON and that the vehicle is probably moving. Red LED turns ON automatically when alcohol is detected. This indicates that alcohol presence has exceeded the allowable threshold. The logic state is 1 the LED goes ON to indicate presence of alcohol and OFF to indicate the assumed normal condition. LCD Display Unit: A 16x4 characters Liquid Crystal Display (LCD) was used for display unit of the MDADS and it serves as part of output unit of the design. The LCD screen was equipped with I2C adapter. The I2C is a serial bus, which uses two bidirectional lines. The Serial Data Line (SDA) and Serial Clock Line (SCL). Both were connected via pulled-up resistors. The operating voltage of the LCD standard as 5V and 3.3V. The I2C adapter was soldered to the board to ease the wiring. Four (4) pins were used to hook up the LCD needed 5v required voltage. These are: V_cc, GND, SDA and SCL.

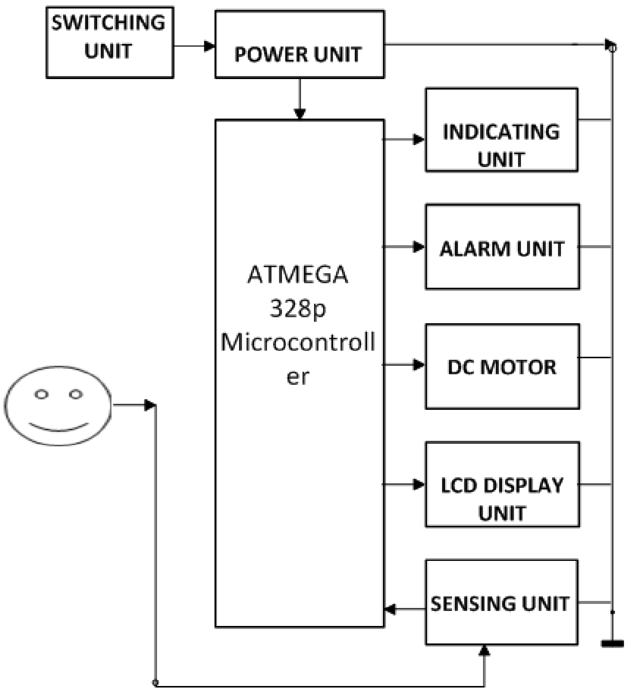

Fig. 1. Driver's breath alcohol detection system

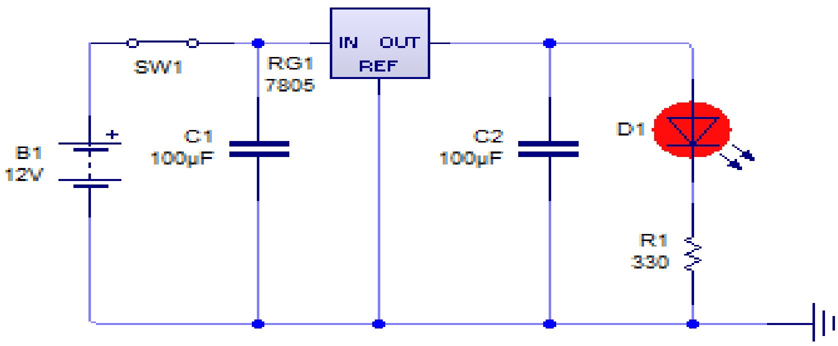

Fig. 2. Power supply unit

2.4.2 Alarm unit

The alarm unit used a buzzer which sounds to indicate that alcohol is detected. The buzzer used belongs to the PS series. The PS series are high-performance buzzers that employ Uni-morph piezoelectric elements and are designed for easy incorporation into various circuits. They have very low power consumption in comparison to electromagnetic units. It has a voltage requirement of 2V and is connected to pin 16 of the microcontroller. The purpose of the buzzer was to create awareness to passengers whenever alcohol is detected.

2.4.3 Engine deactivation/locking unit

The engine deactivation was represented by a DC motor. The DC motor operate based on a PRESET conditions. The DC motor starts working immediately after booting of the MDADS. Once the alcohol level exceeds the threshold (0.29 mg/l), the DC motor continuously moves for next 60seconds delay time for driver to park. If the driver refuses to park, the DC motor stops, causing the vehicle to stop moving. The DC motor was connected to pin-9 on the microcontroller and it operated with voltage range of (1.5~6.0) volts.

2.5 System Design and Analysis

The circuit diagram of the MDADS was designed using Proteus professional, version 7.9 software installed on PC which is running on a windows 10 Operating system. The Proteus circuit diagram design and the diagrammatical representation are shown in Fig. 3. The Vehicle alcohol detection system is powered on using 9volt DC battery, the 9volt DC battery was further stepdown to 5volt required by the microcontroller, sensor, and display and indicating unit. The ATmega328P microcontroller has already been designed to operate without the use of transformer. While other components like DC motor require 1.5V and the LEDs need 2V.

The Arduino board was designed locally in such a way that the microcontroller is able to interact with all the units present in the design of the MDADS. For adaptability, some pins configuration was change pins such as; SDA to 27, SCL to 28, RX to 3, AO to 23, 13 to 19, which is the LED connector, 9 to 15 which is the buzzer connector and 10 to 18 which is the motor connector, all the component were connected and they were able to interact with each other. The connection start from the source which is the DC battery to the LM8075 voltage regulator which regulated the 9volt Dc battery to 5volt, and it was connected to pin 7 and 5 on the microcontroller where other component takes instruction for execution. A 10KΩ resistor was used and connected to pin1 through pin 7 of microcontroller on port A. The two capacitors of each 22pF were connected to 12MHz crystal oscillator in parallel connection with the microcontroller on pin 9 through pin10 respectively. This was to synchronize operation of the microcontroller and other electronics on the board. In the design, one busser was used which was connected to pin15 and other pins was grounded. The DC motor to pin pin16 and the LED pin was connected to pin19, after which they were also grounded. The physical implementation of the design was carried out on the manufactured breadboards using mainly surface mounted components. The component was then soldered into the respective component slots using a 30W soldering iron.

2.5.1 Operation of Alcohol detection system using ATmega328P microprocessor

In the designed system, when the system is power on through the switch, signal will be send to the ATmega328P microcontroller immediately the LCD will display 'Digital Alcohol Analyzer' for few seconds before it started to analyze the Blood Alcohol Contents (BAC). The value for the Blood Alcohol Contents (BAC), usually fluctuate because of gas particle in air. During this interval, the Green LED indicator will be ON along with the DC motor and the LCD will display 'Normal' text. The Green LED is used to indicate that the system is working properly and the DC motor moving. The buzzer and the Red LED remain idle during this process, which implies that alcohol threshold is not yet exceeded. Immediately the MQ-3 alcohol sensor senses the presence of alcohol, and the concentration of the Blood Alcohol Contents (BAC) value is above 2.9 mg/l, the sensor sends a signal to the ATmeha328P microcontroller, then to the Buzzer will be activated along with the RED light. At this point, the Green LED will be ON and the DC motor will still be moving at its normal speed but, The LCD will display 'Drunk' text. This process helps to notify the driver of the vehicle that alcohol has being detected and the process will last for 60seconds delay of time for the driver to park. And if the driver fails to park for this interval of time, the dc motor will automatically stop moving, green LED will be off and the buzzer will be deactivated to stop alarming. The red LED will remain on and the LCD will still display drunk.

2.6 Flow Chart and Software

The flow chart of the system is shown in Fig. 4. The algorithm of the Alcohol detection system, it comprises of three main steps. First is to boot up the system, next is the measuring state, this stage measures the amount of alcohol level from the vehicle drivers. A prescribed set limit will be given as input to the microcontroller, once the alcohol level exceeds the limit the car will still continue to move for 60 seconds delay time for the driver to park else the vehicle will turn off automatically. The software design for this project was implemented using a C compiler for ATmega328p microchip. The code was dumped into the microcontrollers 'Arduino' programmer software. The system was tested on respondents, five minutes after the drivers had drank the drinks.

2.7 Parameters for Evaluation

Basic performance metrics for evaluation of the system are True Positive (TP): which is a correct detection of alcohol presence; False Positive (FP): which is an incorrect detection of presence of alcohol; False Negative (FN/UD): which is an undetected presence of alcohol. Others parameters are Precision *(P)* and Recall concept *(R)* shown in equations (2) and (3), respectively.

$$P = \frac{TP}{TP + FP} \quad (2)$$

$$R = \frac{TP}{TP + FN} \quad (3)$$

3. RESULTS AND DISCUSSION

Results of experimentation is shown in Appendix I. The results of the change in Blood Alcohol Content (ΔBAC) reveals that there is no significant difference in response of the device and gender.

3.1 Detection

The False Acceptance Rate (FAR) of the device were 0.03, 0.00 and 0.00 for man, alcoholic drinks and herbal mixture respectively. This implies that the device will mislead on 3 out of every 100 attempts/applications. The True Acceptance Rate (TAR) of the designed device were 0.81, 0.79 and 0.77 for man, alcoholic drink and herbal mixtures respectively. The Precision (*P*) was 0.04 while Recall Concept (*R*) was 0.15 for human being. *P* and *R* for all others were negligibly insignificant (0.00).

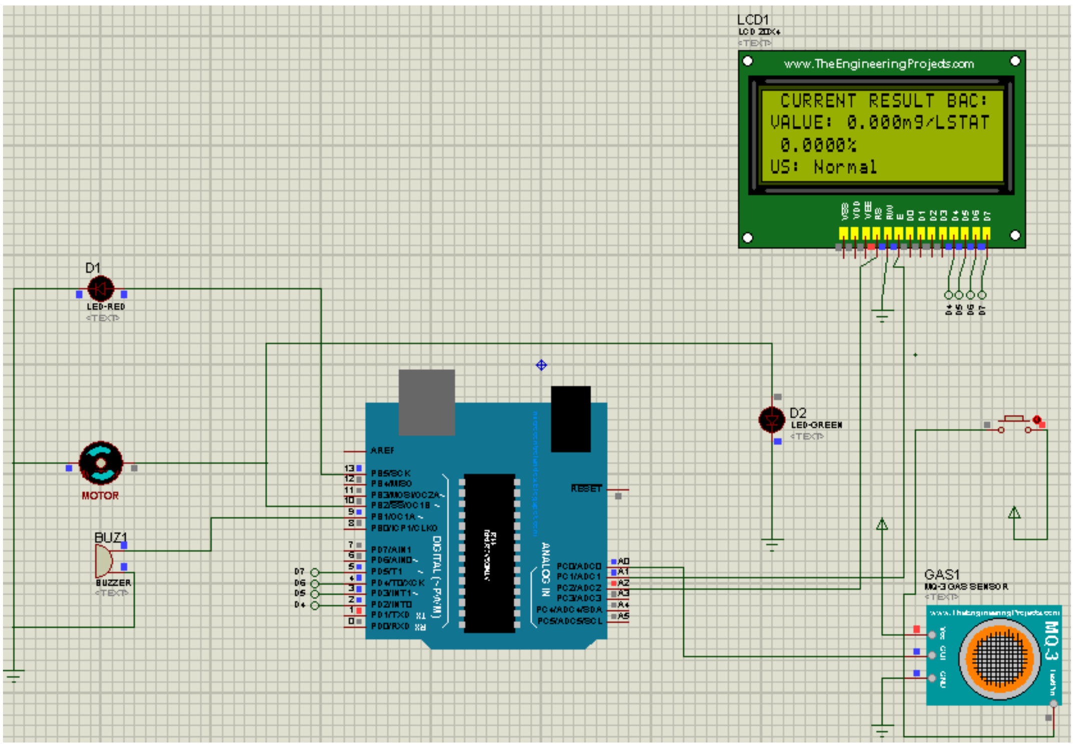

Fig. 3. Circuit diagram of the MDADS

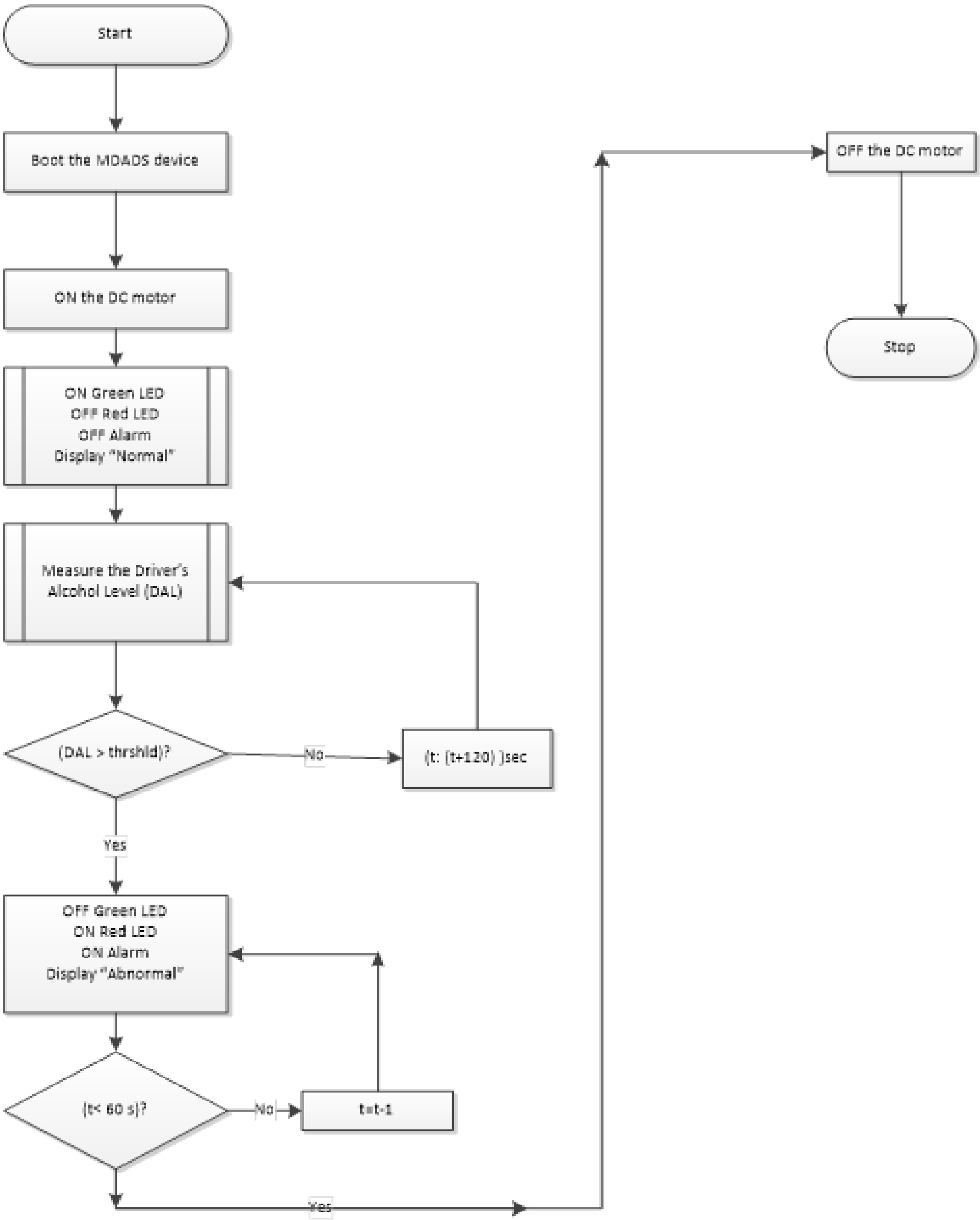

Fig. 4. Flowchart of the MDADS

Table. Confusion matrix of experimental results

	M & F	Alcoholic Drinks	Herbal	Total
FD	2	0	0	02
TD	47	19	8	74
FN/UD	11	5	4	20
Total	*58*	*36*	*12*	*96*
FAR	0.03	0.00	0.00	0.02
TAR	0.81	0.79	0.67	0.77
UDR	0.19	0.21	0.33	0.21
Total	*1.00*	*1.00*	*1.00*	*1.00*

4. CONCLUSION AND RECOMMENDATION

The Response Time (RT) of the device were neither gender nor period of the day sensitive. This means that the device can be used for both male and female. Also it suggest that the device can be used both during the day and night time. Results of the test on the designed revealed that MDADS was successfully designed and constructed for an improved highway safety. It can be employed. The Recognition Accuracy of the system for drunken driver was 97% for man, 100% for alcoholic drinks and herbal mixture. This recognition accuracy is highly encouraging.

As at 2017, South Africans Against Drunk Driving (SADD) insisted on 0.24 and 0.1 milligram per liter (ml/l) of BAC for private car owners and public drivers, respectively (Gumani, 2017). It is also noteworthy to mention at this juncture that the use of Electrocardiogram can produce a better recognition/accuracy results. Electrocardiagram should be tried and the result from it be compared with existing designs. Also, the device that will reduce the detection time can also be employed for enhanced performance.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

List 1. First respondent (Male, Day)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	
Δ_{BAC}	0.898	1.335	2.223	1.000	0.898	0.590	1.191	1.231	0.444	1.351	2.102	0.754	
Time	7.05	7.10	7:15	7:20	7:25	7:30	7:35	7:40	7:45	7:50	7:55	8:00	
FD	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TD	1	1	1	1	1	1	1	0	0	0	1	1	**9**
UD	0	0	0	0	0	0	0	1	1	1	0	0	**3**

List 2. Second respondent (Male, Day)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	
Δ_{BAC}	1.167	1.281	1.332	1.277	1.997	0.298	1.634	1.006	0.777	0.665	1.564	0.801	
Time	6.25	6.30	6.35	6.40	6.45	6.50	7.55	7.00	7.05	7.10	7.15	7.20	
FD	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TD	1	1	1	1	1	1	1	1	0	0	1	1	**10**
UD	0	0	0	0	0	0	0	0	1	1	0	0	**2**

List 3. Third respondent (Male, Day)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	
Δ_{BAC}	0.679	0.799	0.813	0.274	0.313	0.632	0.119	0.598	0.699	0.445	1.175	0.724	
Time	2.00	2.05	2:10	2:15	2:20	2:25	2:30	2:35	2:40	2:45	2:50	1:00	
FD	0	0	0	0	0	0	0	0	1	1	0	0	**2**
TD	0	0	0	0	0	0	0	0	0	0	0	0	**0**
UD	1	1	1	1	1	1	1	1	0	0	1	1	**10**

List 4. Fourth respondent (Male, Day)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	
Δ_{BAC}	0.967	1.331	1.132	0.997	2.037	0.292	1.654	0.416	1.007	0.965	1.464	0.98	
Time	7:25	7:30	7:35	7:40	7:45	7:50	7:55	8:00	8:05	8:10	9:15	8:20	
FD	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TD	1	1	1	1	1	1	1	0	0	0	1	1	**9**
UD	0	0	0	0	0	0	0	1	1	1	0	0	**3**

List 5. Third respondent (Female: Night)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	
Δ_{BAC}	1.882	1.6.45	1.810	0.529	0.746	0.532	0.579	1.280	0.566	1.101	0.402	0.931	
Time	3:08	3:13	3:18	3:23	3:28	3:33	3:38	3:43	3:48	3:53	3:58	4:03	
FD	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TD	1	1	1	1	1	1	1	0	0	0	1	1	**9**
UD	0	0	0	0	0	0	0	1	1	1	0	0	**3**

List 6. (Methylated Spirit; Day)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	
Δ_{BAC}	1.382	1.241	0.987	0.665	0.621	0.856	0.966	0.885	0.872	1.022	0.680	0.820	
Time	8:00	8:02	8:04	8:06	8:09	8:12	8:15	8:18	8:20	8:24	8:26	8:28	
FD	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TD	1	1	1	1	1	1	1	1	1	0	0	0	**9**
UD	0	0	0	0	0	0	0	0	0	1	1	1	**3**

List 7. (Seaman Schinapp (40% alcohol): Day)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	
Δ_{BAC}	1.006	0.595	0.618	0.942	0.961	0.788	0.508	0.978	0.836	1.080	1.080	0.220	
Time	9:10	9:12	9:15	9:17	9:20	9:22	9:24	9:26	9:28	9:30	9:32	9:35	
FD	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TD	1	1	1	1	1	1	1	1	1	1	0	0	**10**
UD	0	0	0	0	0	0	0	0	0	0	1	1	**2**

List 8. (Herbal Mixture (Monkey Tail): Day)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	
Δ_{BAC}	1.142	0.939	0.858	0.753	0.428	0.510	1.024	0.904	0.453	0.702	0.394	0.501	
Time	1.39	1:39	1:41	1:43	1:45	1:47	1:49	1:51	1:53	1:55	1:57	1:59	
FD	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TD	1	1	1	1	0	0	1	1	0	0	1	1	**8**
UD	0	0	0	0	1	1	0	0	1	1	0	0	**4**

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